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A R T I L L E R Y T R A I N I N G

V O L U M E I V

P A R T I I - S E A R C H L I G H T S

P A M P H L E T No. 3

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ALLIED LAND FORCES IN SOUTH WEST PACIFIC AREA

LHQ.

SECRET
~~SECURITY~~
~~CONFIDENTIAL~~
C... H.Q. ... AFF. TAS. L. OF C. AREA
O. P / 8 / 32

SM20802.

HQ RAA	N.G. FORCE	30
	N.T. FORCE	30
	FIRST AUST ARMY	70
	SECOND AUST ARMY	55
	3 AUST CORPS	20
S.A. L of C		10
TAS. FORCE		10
SCHOOL OF SEARCHLIGHTS, RAA		50
" " A.A. ARTILLERY		10
SEARCHLIGHT TRAINING REGT, RAA		10.

ARTILLERY TRAINING VOL.IV - PART II - SEARCHLIGHTS - PAMPHLET No.3.

"OPERATIONAL PROCEDURE FOR SEARCHLIGHTS"

1. The attached is a draft copy of the above pamphlet which is being published in Great Britain.

2. This pamphlet supercedes the Manual of Anti-Aircraft Defence Vol.I, Part II Searchlights 1937, and is the basis upon which A.A.S.L. Drills 1940, Supplement No.4, was written.

3. Distribution allows for the following:-

H.Q. R.A.A.	1
A.A. GROUPS	2
A.A. OPS ROOMS Type A or B	2
H.Q. AAS/L BTYS	2
H.Q. AAS/L TROOPS	1.

Major General,
M.G.R.A., LHQ.

24 August 43.

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C O N T E N T

P A R T II

SEARCHLIGHT-AIDED FIGHTER INTERCEPTION

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G L O S S A R Y

A.A.L.M.G.	-	Anti-Aircraft Light Machine Gun.
A.D.G.B.	-	Air Defence of Great Britain
A.I.	-	Air Interception.
B.H.Q.	-	Battery Headquarters.
Catseye Aircraft	-	Aircraft not equipped with A.I.
G.C.I.	-	Ground Controlled Interception.
G.D.A.	-	Gun Defended Area.
G.L.	-	Gun Laying.
G.O.R.	-	Gun Operations Room.
H.A.A.	-	Heavy Anti-Aircraft Guns.
I.F.F.	-	Identification Friend or Foe.
Lt.A.A.	-	Light Anti-Aircraft Guns.
L.B.R.	-	Line of Bomb Release.
S.S.C.	-	Sector Searchlight Controller.
S.L.	-	Searchlight.
S.L.C.	-	Searchlight Control.
T.H.Q.	-	Troop Headquarters.
V.A.	-	Vulnerable Area.
V.H.F.	-	Very High Frequency.
V.P.	-	Vulnerable Point.

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SEARCHLIGHT-AIDED FIGHTER INTERCEPTION

CHAPTER I - OUTLINE OF THE SYSTEM

1. Outline of the System

1. The basis of all present systems of searchlight aided fighter interception is that a fighter aircraft, operating from a relatively fixed position in space, uses an intersection of searchlight beams to guide him to the bomber which he is to intercept. It is convenient to fix the fighter in space initially for example by making it orbit a vertical searchlight beam at a suitable radius. A fighter pilot, setting off from his orbit beacon to make an interception, directs his aircraft continuously at the intersection of searchlight beams engaging the bomber and in this way he describes a curve of pursuit which will ultimately bring him dead astern of the bomber. He can also to a limited extent adjust his height by observation of the intersection as he approaches it. Assuming that he has a command of speed over the bomber, he will eventually overtake it.

In the case of aircraft not equipped with A.I.(i.e. Catseye fighters) the fighter relies on the actual illumination of the bomber by the searchlights for the purpose of getting within range and firing. Where A.I. equipped aircraft are employed, the fighter may make use of the searchlight intersections to obtain an A.I. contact and then conclude the interception either in the dark or with the aid of the searchlight beams, according to the circumstances.

2. The principal merits of searchlight aided fighter interception are as follows:-

(a) It can be employed in large or small areas

(b) It is effective either in advance of or in the neighbourhood of the V.A.

(c) It can be employed without an elaborate system of ground communication or intricate apparatus. It may even be worked without an air raid reporting system.

(d) A number of fighters can be employed in making interceptions at one and the same time.

(e) Interception is quick

(f) Single engined and non A.I. fighters may be employed.

SEC. 2. BASIC REQUIREMENTS.

1. There are several different methods of operating the system but there are certain basic requirements common to them all. These requirements are:-

(a) An area of S.L's so placed that the raids will cross it.

(b) Night fighters suitably positioned and controlled.

(c) A control centre with access to an early system.

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CHAPTER II - THE INTERCEPTION AREA

3. Location of the Area.

1. It is desirable where possible to carry out interceptions in front of the area to be defended in order to destroy the bombers before they reach the V.A. and to avoid the danger of confusing the guns at the V.A. by the presence of fighters. To this end the interception area over which fighters are to operate will be laid out so as to form an obstacle through which the enemy bombers must pass in order to reach the V.A. In many cases the S.L's of the interception area will merge into the S.L. layout covering the V.A. itself - in others there may be a gap between the rearward edge of the interception area and the outer edge of the gun zone.

2. Where there is sufficient equipment, and the topography permits, the interception area should surround the V.A. in order to defend it against attack from any quarter. Where this is not possible it should be sited to cover the line of approach most favourable to the enemy; but it will be of little value if it is possible for the enemy to avoid it easily and without detriment to the success of his attack. Alternative forms of defence e.g. G.C.I./A.I. should be concentrated in areas, such as the sea approach to a port, where it is only possible to employ a S.L. aided interception on the landward side.

3. The interception area may be sited well forward so as to cover several G.D.A.s at the same time.

4. Shortage of S.L's or topographical considerations may preclude a sufficient depth of area to permit of interception in front of the objective. In such cases S.L's and fighters may be employed successfully in a "Combat Zone" immediately around and, in some cases, over the V.A. itself.

5. To summarize: the following factors must be taken into consideration when deciding upon the location of the interception area.

(a) Importance of intercepting bombers before they reach the V.A.
(b) Risk of fighters getting into the gun zones and causing restriction of fire (Sec. 10. 4).
(c) Possibility of the enemy being able to 'turn' the defence without much inconvenience.
(d) Likely lines of approach, taking into account the position of enemy aerodromes and likely navigational pinpoints.
(e) Proximity to each other of a number of V.A's., suggesting either one long interception area or several small local ones.
(f) Number of S.L's available.
(g) Distance of night fighter aerodrome from the orbit points (it is should be limited to 45 miles for twin engined fighters and 30 miles for single-engined).
(h) That in an interception area well forward, the raiding aircraft will probably be more dispersed than in the immediate approaches to the V.A. and that therefore the S.L's will be able to engage a greater number of aircraft in the forward area. (Sec. 10. 1).

(i) That a S.L. interception area can be moved with relative ease and speed. A S.L. detachment given roads reasonably free from traffic, can move about 50 miles and reconnoitre and occupy a new site between dawn and dusk on the same day.

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4. Dimensions of the Area and Positions of the Orbits.

I. For interception areas in advance of the V.A., the factors which have been taken into account in arriving at actual figures are as follows:--

(a) Total time taken for the interception.-It is of cardinal importance that interceptions should take as little time as possible. This is so firstly because long stern chases greatly reduce the number of interceptions that can be made by an aircraft within a given time. Secondly it is in all cases important, and in some essential, for the bomber to be destroyed before it has reached its objective. And thirdly where fighters not equipped with A.I. are being used, the interceptions must be concluded before the bomber has passed out of the illuminated area. The interception time depends only partly on the command of speed of fighter over bomber. This in any case will be relatively fixed for the fighters available and the bombers comm-only in use by the enemy. The two other factors affecting the problem of the time taken to intercept and return to orbit, are the positioning of the orbits, and the selection by each fighter only of those raids which he is in a better position than any of the others, to intercept.

(b) Visibility of searchlight beams. In most procedures for operating the system, the interception is begun as a result of an observer (who may be the pilot of the fighter aircraft or who may be a person on the ground near the orbit) seeing the intersections of beams at the front of the S.L. area. The furthest distance that the observer will be required to see must not therefore be greater than the range at which a searchlight beam is visible. This range varies enormously with atmospheric and weather conditions, but 15-20 miles can be taken as a figure applicable in average circumstances.

(c) Lateral spacing of fighter orbits. For two reasons it is important not to place fighter orbits too close together.
Firstly, a convenient radius of orbit for a twin-engined fighter is five miles. This of course is only a guide to the plot and cannot be adhered to at all exactly. If fighter orbits are made to overlap to any extent there is the danger of collision between aircraft at the same height. For this reason the distance between two adjacent orbits should be not less than 12 miles (and should be preferably greater).
Secondly, the closer the orbits are together, the more likelihood there is of two pilots on adjacent orbits setting off to intercept the same raid, since each will be able to see intersections in the other's sphere of operation. This is a complication which it is important to avoid as far as possible.
On the other hand, the further apart laterally the orbits can be placed, the easier it is to cover the whole of a broad front against attack from an unknown quarter when few fighters are available.

(d) Distance between the orbit and the outer edge of the S.L. layout.-If this distance is too great, some of the outer edge S.L's will be wasted since an intersection may have to travel some distance before the fighter sees it under normal conditions of visibility. A further factor in the determination of this distance is that it is unwise so to position the orbit beacon that the fighter while on orbit flies over the S.L. initiating sites i.e. the two outer edge rows of lights (Sec.10.3). Unless I.F.F. is being received by these S.L's, the fighter may be engaged by them.
It must be borne in mind that the closer the fighter is stationed to the front edge of the S.L. layout the less likely are his interceptions to be "head-on". With "head-on" interceptions the pilot may have to make a sharp turn through as much as 180° in order to get behind the bomber and it is not easy to maintain A.I. contact during this manoeuvre. On the other hand the further forward the orbits are placed, the longer the stern chases are likely to be for any given command of speed of fighter over bomber. The greater the command of speed, the further forward can the orbits be placed with safety.

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(e) Depth of S.L's behind the orbit.-Obviously the greater the depth here, the greater the possibility in cases of small command of speed, choice of unsuitable raid and low visibility of S.L. beams, etc. that the fighter will still have a chance of catching his target. This however involves the employment of many more S.L's over a large area and it may be necessary to risk the loss of some targets in this way in order to keep the number of S.L's required down. In any case, where A.I. fighters are used they can kill beyond the S.L. area if they have obtained contact while over it. Where the interception area forms part of or is just outside the S.L. layout of the V.A., this depth behind the orbit is fixed by the V.A. layout.
A further consideration is the possibility of intercepting outgoing raids. Where the interception area is in advance of the V.A. it is possible, when the ingoing raids have passed through, to move the fighters from the orbits placed for those raids (i.e. with the requisite depth in front and a smaller depth behind) to orbits having the requisite depth in the opposite direction for the interception of raids leaving the V.A. (Sec. 14.1(c)).

2. Empirical dimensions and orbit positions for interception areas in advance of the V.A. In order to intercept within the interception area every possible S.L. engaged raid, the overall depth of the area must be considerable (of the order of 30 miles). However, a high proportion of such raids can be intercepted using an area of more moderate dimensions. The following figures are suggested as a basis:-

(a) Lateral distance between orbit points - 12 to 14 miles.
(b) Distance between the orbit point and the forward edge of the S.L. layout 12 to 15 miles.
(c) Distance between the orbit point and the rearward edge of the S.L. layout - 6 to 10 miles.

If it is desired to vary these figures the following maxima and minima should be preserved for the reasons stated in para 1. The minimum lateral distance between orbit points must be 12 miles; the maximum is closely related to the overall depth of the S.L. layout. It should be not more than about two thirds of this distance and must be less if a high proportion of the raids is to be intercepted.
The minimum distance between the orbit and the forward edge of the S.L. layout is governed by the overall depth of the layout but should not be less than about 8 miles.
The overall depth of the layout should not be less than 18 miles for A.I. fighters and 23 miles for non-A.I. fighters, if it is desired to intercept at least 50% of the raids engaged by the S.Ls. The percentage of raids intercepted is largely determined by the overall depth of the layout (assuming of course than an adequate number of fighters is available).
For the theoretical considerations governing all these dimensions see further Artillery Training Volume IV Part III Pamphlet No.3.

3. Where the interception area is adjacent to or over the vulnerable area (Combat Zone). Where for reasons stated in Sec.3 it is not practicable to establish an interception area in advance of the V.A., interceptions with the aid of comparatively few S.L's can be obtained in the neighbourhood of the V.A. itself. The size of the S.L. area will depend on the resources available and the topography of the V.A. and may vary from a belt 8-9 miles deep round the V.A. (or covering certain approaches to it), to a small group of no more than 6 S.L's situate round the V.A. itself. It may even be profitable sometimes to deploy a few S.L's and a fighter on orbit to cover only a particular approach to the V.A. which is specially favoured by the enemy.
Where H.A.A. guns are deployed at the V.A. the fighters must orbit outside the G.D.A. to ensure that they do not come within range of the guns while on orbit. In order to operate successfully at a large V.A. they should have a minimum depth of 5 or 6 miles of S.L's in front of the orbit point. In certain cases a circular orbit will take them out over the front row of lights and therefore they must do instead a figure of eight behind the orbit or fly on a short patrol line near it. Where there are no H.A.A. guns at the V.A. the fighters may be stationed on an orbit located in the V.A. itself.

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The indications given by the S.L. beams will enable the fighters to make A.I. contact before the enemy aircraft has left the illuminated area in ir cases before it reaches the V.A. though its destruction may not be achieved until after the bombs have been dropped. Because of the narrow depth of SL's only A.I. fighters should be used in a combat zone.

The actual positioning of the orbits in Combat Zone does not present a serious problem since, unless the V.A. is very large indeed, every bomber intending to bomb the V.A. must approach sufficiently close to an orbit placed anywhere between the bombers and the V.A. However, depending on the direction from which the raid is approaching, certain positions for the orbits will be more suitable than others and it will usually be convenient to establish a number of alternative orbit points to be manned to meet the prevailing direction of attack. It should seldom be necessary, except in the case of a very large Combat Zone, to man more than two orbits at any one time and very often one orbit will be sufficient. There may, of course, be a number of fighters on each orbit manned.

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CHAPTER III. - THE FIGHTER

5. Types of Aircraft.

1. A.I. and Catseye aircraft. - Any fighter aircraft capable of operating by night can be used with S.Ls provided that its performance is such as to give it a command of speed over the bombers it must intercept. It is preferable for the aircraft to be equipped with A.I. since, not only can they operate in all conditions suitable for catseye fighters, but they also can be used in circumstances where catseye fighters would be useless. For example, in conditions of cloud where S.L. beams cannot penetrate sufficiently to provide illumination of bombers above the cloud, the A.I. fighters can obtain a contact with the aid of the patches of light formed by the S.Ls on top of the cloud and can then proceed without further reference to the S.Ls are able to provide intersections near the target but are unable to produce sufficiently consistent illumination for visual shooting by the fighter.

It has been found in practice that catseye fighters can operate with success when there is not more than about 4/10 cloud below or at the height at which they are operating. A.I. fighters can operate over as much as 10/10 cloud provided it is not so dense or so high that the illuminated patches produced by S.L. beams are too faint to provide assistance.

With a thin type of layout e.g. Combat Zone, the extent of the S.Ls may not be sufficient to permit of interception taking place within the illuminated area. In such cases it is sufficient if the A.I. aircraft can obtain contact with the aid of S.Ls and finish the interception by A.I. after the target has passed out of the S.L. area. When operating with A.I. aircraft it must be remembered that while the crew are using the inter-com system it is not possible for the ground control (or any other aircraft) to communicate with them by R/T. With most types of A.I. the inter-com is in use constantly while an A.I. chase is in progress and therefore no message can be passed to the aircraft once it has obtained A.I. contact. With certain types of A.I. the inter-com is not used and the above restrictions do not apply.

2. Single and twin-engined aircraft. - The twin-engined night fighter is best for working with S.Ls. It has better forward visibility than the single-engined fighter and usually more powerful armament. It has longer endurance in fuel and ammunition than the single-engined aircraft and this is a great advantage in night operations where raids are often so short that an aircraft has not time to re-arm and re-fuel during the raid and must make all its interceptions on one sortie.

On the other hand, the single-engined fighter is a perfectly suitable aircraft provided it can operate at night and conditions are suitable for S.L. illumination. There is no reason why suitable day fighters should not be used for this purpose where their other commitments allow and by this means both S.L. aided and G.C.I./A.I. interceptions can take place simultaneously even though there is only a limited number of night fighters available.

An advantage of single-engined aircraft over twin-engined is the greater speed with which the former can be got into the air. This is of particular importance where raids have developed without warning and there are no night fighters airborne. (Sec.14.I. (a)).

6. The Requirements of the Fighter.

1. Stationing the fighter. - The most usual method of stationing the fighter is to provide it with a vertical S.L. around which to orbit. It must be possible for the pilot to distinguish his orbit from others in the layout in order that he can locate it when first sent up or when returning from an interception. (sec. 8. 4 and Sec. 10.7).

An A.I. beacon can be used as an orbit beacon in place of a S.L. beam if A.I. equipped fighters only are operating. This is particularly useful in the case of Combat Zones where very few S.L.s may be available. (Sec. 4.3. and Sec. 18).

2. Command of speed - In view of the fact that there can be no

absolute command of speed of fighter over bomber, but only an average command, it is desirable artificially to increase the fighter's command of speed by stationing it initially at a greater height than the bomber it is to intercept - between 2.and 5,000 ft - according to the reliability of the information availiBility of the information available and the requirements of individual pilots.

3. The searchlight intersection. - The engagement of the bomber by S.Ls must be begun as soon as possible after it comes within range of the outer lights in order that the pilot may set off to intercept without any delay. Once the engagement has begun, it must be maintained continuously with a minimum of three beams on the target all the time. An optimum number is between 3 and 6. Any greater number tends to make the intersection unduly large and renders it difficult for the fighter to approach for the kill without himself being illuminated for some seconds before firing.

The majority of the beams on the target should come from sites forward of it. Beams exposed from the rear of the target create a lighted area behind it and make it more difficult for the fighter to approach unseen. Moreover, the harassing effect on the bomber crew is much greater if beams expose forward of the aircraft than if the bomber pilot receives the impression that he is flying away from the lights.

4. The engagement interval. - In order to enable the fighter to distinguish between one intersection and another, a definite minimum interval in miles must be preserved between S.L. engagements. On the other hand, the interval should not be exceeded unless low raid density makes this inevitable, otherwise the maximum number of engagements will not be obtained. The smallest interval at which pilots can discriminate will depend partly on weather conditions affecting the visibility of S.L. beams and partly on the experience of pilots. In any case the interval should not exceed 15 miles or be less than 8.

The interval must be preserved as far as possible as the targets fly through the area and if two engagements converge too close it may be necessary to abandon one of them. This should be avoided for as long as possible otherwise the system may be defeated by lateral evasive action on the part of the bombers or an interception may fail owing to the disappearance of an intersection already chosen by a fighter.

In normal circumstances engagements should only be initiated at the front edge of the illuminated area. Indiscriminate initiation within the area may confuse the fighters by causing them to attempt interceptions of targets which they are not able to overtake in the time and space available.

5. Dousing of searchlights by fighters - There may be occasions when a pilot requires the S.Ls to discontinue an engagement. These may occur either if the S.Ls are engaging the fighter by mistake or if a fighter equipped with A.I. has obtained a firm contact and desires to finish the interception in the dark. In such cases the fighter may signal to the S.Ls by pre-arranged code on his downward recognition light and in certain circumstances he may also be able to produce the required result by calling the Control Centre by R/T. The latter will only be possible where the particular S.L. engagement can be identified at the Control Centre and this will depend on the procedure in use (Sec.17.4.). Even in this case the downward recognition light should always be used as well as its effect is quicker; but the pilot must remember that it may not always be seen from the ground, particularly if the aircraft is not on an even keel.

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CHAPTER IV - THE SEARCHLIGHTS

7 - Layout and Siting of the Searchlights.

1. Spacing is determined by the number of beams required on each target and the numbers of targets it is required to engage in a given area. The two requirements laid down in Sec.6.3 and 6. 4, namely that a minimum of 3 beams and a maximum of 6 is required on each target and that there shall be a minimum distance of 8 miles between engaged targets, fix 6,000 yards as the spacing of the searchlights. At this spacing it is possible to engage targets 8-10 miles apart with 4-5 beams on each when these targets are at the height usually encountered, i.e.8-12,000 feet. If the spacing is more open, either fewer beams are available for each target if at the minimum interval of 8 miles or by preserving the requisite number of beams on each target, it will be impossible to engage raids closer than 12-15 miles and so the available fighters may not be continuously "fed". 6,000 yd spacing is therefore economical, meets the requirements, and ensures that the maximum number of raids can be engaged. This spacing fixes one light to 9 or 10 sq. miles.

2. It is shown in Sec.4 that the minimum overall depth of the S.L. area is 20 mile and that the width of the area required for each orbit point is 12 miles. The smallest "unit" area of S.Ls is therefore 240 sq. miles and a belt or zone is an area composed of a number of these units placed side by side. The Number of S.Ls required for the area is consequently the number per unit multiplied by the number of units used. On 6,000 yd. spacing there will be about 24 lights in a unit. Where it has been found necessary by reason of shortage of S.Ls to shorten the depth behind the orbit, calculation will give the number of S.Ls required or, alternatively the depth and width it is possible to produce with a given number of S.Ls.

3. After fixing on the map the boundaries of the S.L. area, the sites can be pinpointed at 6,000 yd. intervals in equilateral triangles. Where the map is divided into 10 km. squares, the pin points for a lay-out of straight rows are at 0050, 2500, 7500, 5050. It is immaterial however whether straight rows are adhered to or the rows are curved to suit the shape of the layout.

When the sites are chosen on the ground, it will usually be found that the exact pin points, for reasons stated in para. 4 below, cannot be adhered to. Tolerance up to 1,000 yds can be permitted provided the other sites are so chosen that the distance between any two sites is not greater than 7,000 yds. nor less than 5,000 yds.

It is permissible to omit odd sites for topographical or other reasons provided that no two adjacent sites are omitted and provided the neighbouring lights are "closed in" slightly to minimise the gap.

4. There are technical considerations affecting the siting of all types of S.L. locators and these are dealt with in A.A.S.L. Drills, 1940, and Supplements. In addition to these considerations there are two tactical requirements in the siting of equipment:-

(a) Sites on the outer edge of the layout and rearward edge of the interception area must be chosen so that long range detection is possible - e.g. in the case of S.L.C., free from ground breaks. This rule should apply to the 2 rows of lights forming the boundary of the area since it is these lights which must secure initial early pick up from whichever direction the enemy aircraft enters.

(b) Where possible, all inner lights should be so sited that detection is easy in the direction from which incoming targets may be expected.

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6. Signals from searchlight sites - During operations certain visual signals will be given to the orbiting fighters by a beam on the orbit site (Secs.16.1. (a) 16.2. (a). Sec. 17 1.). Where fighters are operating near G.D.As, it may be desirable for S.Ls on the perimeter of the G.D.A. to employ a distinctive method of engaging incoming targets in order to indicate to fighters that they are coming within range of the guns. (Sec. 18.4). This method may consist of certain sites engaging incoming targets with occulting beams. All S.L. sites should be prepared at any time to indicate with the beam the bearing of the base aerodrome in order to assist fighters who require homing.

7. Responsibilities of the pilot. - It will be seen (Sec.16.1) that the successful operation of the system depends to a high degree on the careful observance by the pilot of certain simple rules. The essence of any procedure employed in the interception by pilots only of those raids which they are suitably placed to take on. Unless pilots fully understand and observe the procedure under which they are operating, interceptions will frequently take much longer than they should or may fail altogether; while the risks to the fighters themselves will be unnecessarily increased.

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8 - Equipment.

1. Projectors. 90 cm projectors are perfectly suitable for this work. though 150 cm projectors have a slight advantage in producing a smaller area of light around the illuminated bomber. It must be borne in mind that two 90 cm. projectors are required on each orbitsite in addition to the operational light. (Sec.16.1(a), 16.1.(b),17.1) These may be dispensed with in an emergency, but with some loss of efficiency.

2. Locators. 80% to 100% S.L.C. is a virtual necessity unless A.1 fighters are used, in which case the number of S.L.C. Locators might fall to 50% without seriously affecting results. (There is no mutual interference between S.L.C. sets over 5,000 yds. apart).

3. Visual Control Pillars, should be used on all sites if sufficient numbers are available. If only a proportion of sites can be so equipped, they must be evenly distributed over the area, i.e. not grouped.

4. Disposition of Equipment. Where visual control pillars are in use, the available S.L.C. should be concentrated in the outer edge, particularly the outer edge over which incoming raids will pass, so as to ensure initial pick up, after which the inner visual control pillar sites should ensure that the target is never lost, provided atmospheric conditions are good. Where visual control pillars are not available, a certain proportion of the S.L.C. equipment should be on the inner sites, otherwise the target would be frequently lost. Sound locators must be used on sites where no S.L.C. is available or where S.L.C. is unworkable.

5. Occulting Shutters must be fitted to orbit beacon projectors and to any others required to give certain information to fighters. If they are not available, coloured screens to fit over the front glass of the operational light are required at each orbit beacon site. The colour of such screens must be different for any two adjacent orbits. In the absence of any of this equipment paraffin flares may be used. (Secs. 6.1., 6.6., 10.7.).

6. Site Computers are required on one site in three where line communications exist from these sites to some central control room and where it is intended to use S.L. plots in the interception process, (Sec.17).

9 - Communications

1. Where line communications can be installed between selected S.L.sites and a control centre, it will be possible to provide the Searchlight Sector Controller with plots of S.L. engaged raids whereby he can employ improved methods of control (Sec.17). These plots are computed from angles taken from the equipment at sites every 10,000 yds throughout the area i.e. from one site in every three on 6,000 yds spacing. The use of plotting sites at greater intervals would not produce continuous plotting. Lines are therefore required from 8 sites out of the 24 in each battery to the Battery H.Q. and from each Battery H.Q. to some central room (preferably near or in the Control Centre) where they can be collated and passed to the Control Centre for reproduction on the S.S.Cs map. (Sec.13.1). This calls for about 55 miles of line in each battery. These lines can also be used for the downward transmission of instructions, states of readiness, advance plots, and other information from the Control Centre to the sites on the lines.

2. Where there are no line communications between sites and battery H.Q. there will usually need to be R/T communications between B.H.Q., and one site in every six (the Troop H.Q.). This must be regarded as the absolute minimum of communications although it will be shown later (Sec.10) that the system can operate though with reduced efficiency, without any communication to S.Ls. whatsoever, other than line or R/T to the orbits. This minimum, however, is really required for early warning of approach of raids. Early warning can be passed by line or R/T from Control Centre to the B.H.Qs., thence by R/T again to the T.H.Qs., and thence by visual S.L. signals using the beam, to the remaining sites. It is essential that the orbit sites have line or R/T communication to them or that sites with communications are specially chosen as orbit sites.

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10 - Operation of the Searchlights
(See also A.A.S.L. Drills 1940 Supplement No.4(1943)

1. The actions of the S.Ls are settled by two important rulings laid down for night fighter interception (Secs.6.3 and 6.4).

(a) That there must be a minimum interval between S.L. engaged targets of about 8 miles.
(b) That there must be a minimum of three beams on each target and a maximum of six. (This requirement fits in with requirement (a), since, on 6,000 yd spacing it is impossible to engage targets closer than about 8 miles and still keep 4 or 5 beams on each).

It follows therefore that if incoming raids are closer to each other than about 8 miles, some will be engaged and others will have to be ignored by the S.Ls in order to preserve a continuous engagement with 4 or 5 beams of these targets which were initially selected as over 8 miles apart.

2. Rules must be given to S.L. Detachment Commanders both on the outer edge where engagements are initiated and inside where engagements are merely continued, which tell them which targets to engage, and also when to engage and when to disengage. If such rules are properly applied by the Detachment Commanders, the requirements as to S.L. engagements can be satisfied in the absence of any higher control or communications from above.

3. Selection of Target . The two outer edge sites all round the S.L. area must engage all hostile targets except where a new target, if engaged, would be closer to an engagement already initiated by neighbouring sites than the minimum interval prescribed. To achieve this all outer edge sites will search for hostile targets by facing outward from the layout. All the remaining inner sites will engage only those targets already being engaged by other beams.

These rules are sufficient in themselves to satisfy the requirements without the appointment of a higher controller; i.e. the Detachment Commander is here the sole tactical executive. It may prove advantageous however to have Troop Commanders at O.Ps. on the outer edge and in R/T communication with the other outer edge sites, to assist in preserving the initiation interval in high density raids by ordering Detachment Commanders to disengage a target too close to one already accepted. Where line communications exist from 8 sites in the Battery to Battery H.Q. and S.L. plots are being passed to B.H.Q., a S.L. controller there, seeing the plots of all engagements as soon as they are initiated, can order Detachment Commanders to disengage where necessary.

These rules further ensure that additional initiations will not occur inside the S.L. area, i.e. too close to the orbiting fighter (Sec.6.4). Engagements usually travel 2 or 3 miles before the intersection "hardens" and the target becomes steadily illuminated. Thus if attempted too close to the orbit, initiations inside the area will only confuse the fighters.

A further valuable result of these rules is that fighters will not be engaged by the S.Ls. provided they keep inside the outer edge of initiating sites, since the inner lights over which the fighters will be operating only engage targets already being engaged. This advantage is apparent where the fighters carry no I.F.F. or it is not being received, or Sound Locators are being used.

4. Engagement and Disengagement. There are two methods of ensuring a steady 4 or 5 beams on a target as it crosses the area and these two methods both answer the Detachment Commander's problem as to when to engage and when to disengage.

(a) By counting the number of beams already on the target and judging whether by exposing his beam he will be at a higher angle than the lowest beamalready on. This method is difficult to apply and is not recommended.

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(b) By exposing and dousing at fixed, predet rmined angles of elevation. This method is extremely easy to operate; its drawback is that different target heights will produce different numbers of beams on the target. In practice this is not a serious objection and it is found that on 6,000 yds spacing, exposing and dousing at 25° elevation will put 4 - 5 beams on targets which are at heights of 9,000 to 11,000 ft.

5. Termination of Engagment. There are occasions when it is necesssary to terminate an engagement.

(a) A fighter may want the beams doused. (Sec.6.5). Where they are communications from the Control Centre to all sites as e.g. line to Battery H.Qs., line thence to Troop H.Qs and R/T thence to sites, one method by which a fighter can get the beams doused is to ask the Control Centre by R/T. The S.S.C., if he can identify the engagement from S.L. plots, then passes the order to the S.Ls. Where these communications do not exist (and also where they do), the pilot must signal for douse on the Downward Recognition Light.

(b) When, in the case where S.L. plots are displayed before the S.S.C., he sees that two engaged targets are converging too close and decides to discontinue one of them. He will decide which engagement must be continued and pass the order to the S.Ls. to disengage the other. For reasons stated in Sec. 6.4., this termination of an engagement must be done as infrequently as possible.

(c) When, where S.L. plotting is not in force, a Detachment Commander or a Troop Commander at an O.P. sees two engaged targets converging too close. The decision as to which raid should be abandoned must be left to the Detachment Commander since, from observation of the time base (S.L.C.) he may be able to tell whether or not a fighter is approaching the raid he is engaging. Where there is evidenceof a fighter, he must continue that engagement to the exclusion of the other approaching target.

6. Specification of Raid Interval. To make certain that the S.Ls will meet the fighters' requirements in the matter of raid interval and numbers of beams on each target, the S.S.C. must lay down for them beforehand, the minimum raid interval at which engagements will be initiated at the outer edge. Where the interception area is close to the V.A. and raids are therefore likely to converge as they cross it, initiation should be limited to about 12 or 15 miles so that they will have converged to the minimum of 8 - 10 miles near the line of orbit, thus obviating the necessity for disengaging certain raids at this point - an uncertain procedure where S.L. plotting does not exist.

7. Signals from the Orbit Site. In order to enable the fighter pilot to locate his own orbit, the orbit beacon site must display a distinctive signal. This is done either by causing the orbit beacon itself to flash a morse characteristic with the aid of an occulting shutter or by exposing a coloured beam (in addition to the orbit beacon) produced by covering the operational projector with a coloured screen. The coloured beam by itself is not sufficient in average weather conditions. Where neither screen or shutter is available, the orbit beacon site can be rendered distinctive by the aid of a group of flares placed around the orbit beacon. In an emergency - and for a short time only - a morse characteristic can be flashed by exposing and dousing the orbit beacon itself. For tactical or other reasons any S.L. site with communications may be required at short notice to act as an orbit beacon site and must therefore be prepared to give the emergency signal described above. The second signal projector provided on each orbit beacon site is required for the purpose described in Secs.16.1. (a), 16.1 (b), and 17.1.

11. States or Readiness

1. Where no communications (either line or R/T) exist to any of the S.L. sites, detachments must rely on warning from an air sentry who detects or suspects hostile activity.

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2. It is possible to pass the Take Post or Stand Down signal from one site to about 5 other neighbouring sites by use of the S.L. beam as a Signal. Thus where Troop H.Qs. can receive messages from the Control Centre via Battery H.Qs. they can relay these to the rest of the troop by prearranged visual signals. The usual Take Post signal is to revolve the beam (at 70° elevation) at fast speed for 30 seconds in one direction then 30 seconds in the other direction, and to douse.

3. S.L. detachments need 3 to 5 minutes to get into action from being asleep undressed; and 1 minute from being asleep fully dressed. This indicates the degree of warning required from the Control Centre.

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CHAPTER V - CENTRAL CONTROL

12. - The Sector Searchlight Controller

The decision to use fighters on any given night; their allocation between SL and other forms of interception, and the decision where fighters will be operating near GDAs, on the relationship between the two forms of defence, will normally be made by the authority in command of the AA. Defence of the VA, who will issue a policy for the night. This policy will be implemented, so far as SL aided interceptions are concerned by an Officer called the Sector Searchlight Controller (SSC). The SSC may be either an RAF or an Army Officer. He must have a complete understanding of the procedure to be employed and of the capabilities and limitations of the system from the point of view of both fighters and SL's. In view of the extent of his duties in action he should have no responsibility during operations other than the conduct of SL aided interceptions.

In the direction and control of operations the SSC will have various functions to perform. Certain of these depend on whether or not the procedure in use employs plots obtained from SL's. Others are essential to the system and common to every procedure. (Sec. 14).

13. - The Control Centre.

1. The SSC will conduct operations from a Control Centre which may be either the RAF Fighter Operations Room or a GCI station. There are great advantages in using a GCI station, but if one is used, it is essential that its range should cover the whole of the interception area under the control of the SSC and that the equipment sweeps continuously over this area. It is highly desirable for the SSC to have a PPI tube at the GCI station for his exclusive use, but even if this is not feasible it may still be advantageous to use the station as the Control Centre.

The facilities required by the SSC at the Control Centre are :-

(a) Information - Information of the scale and direction of the attack must be continuously available to the SSC both before and during operations.

In the RAF Operations Room this will be available as plots on the information table, derived from RDF and other sources. It should include, where possible, the height of the raids.

At the GCI station it will be provided by the PPI tube and should be supplemented as to long range plots, identity and height by information from the operations room. Heights of specific raids can be found accurately at the GCI station.

(b) The SSC's Map - The SSC should be provided with a talc covered gridded map of the area he controls and on it should be marked the boundaries of the SI area and the positions and designations of the orbits. In the Operations room, or in a GCI station where he has not the exclusive use of a PPI tube, this should be of ½" scale. Where he has a PPI tube of his own the tube itself will be his map.

(c) R/T Communications and Fixing - V.H.F. communication to the fighters is essential and it may be desirable to have a R.A.F. Deputy Controller to receive and pass messages under the direction of the S.S.C. Whether the S.S.C. is able to conduct the R/T communications himself will depend on the nature of the raid and the number of fighters employed.

It must be possible to establish the positions of the fighters by voice fixing and these positions should be marked on the S.S.C's map when obtained This requirement applies to a Control Centre of either type, though when suitable I.F.F. equipment is fitted in the fighters it should normally be possible to identify individual fighters on the P.P.I. tube. It is most satisfactory for fighters to operate throughout on the frequency of the fixer stations. If possible this should be different from the G.C.I. frequency.

(d) Communications to Searchlights - These are used for the passing of orders and information from the S.S.C. to the S.Ls. and for the passing of S.L. plots, where available from the S.Ls. to the Control Centre. For the latter, communications must be by line, but R/T may be used for the former. S.L. plots arriving at the Control Centre will usually be marked on the S.S.C's map with chinagraph (Sec. 17).

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14. Essential Functions of the S.S.C.

1. The disposition of fighters. Once aircraft have been allotted to the S.S.C. in accordance with the policy for the night, it is his responsibility to get them on orbit in time to meet the raids, and positioned where they will be most effective. He must also change his dispositions during the battle if circumstances require, and, if necessary, withdraw fighters which may be of greater value at a later stage in the operations.

(a) Ordering off fighters. After a warning of hostile aircraft approaching the area he must take steps to get his fighters to orbit either by bringing them first to a higher state of readiness or by ordering them off immediately according to the length of warning received. In this connection he must have due regard to the time it will take before they are airborne (according to the type of aircraft, the state of the aerodrome and the other traffic there) and also the time it will take from being airborne to being on orbit at the required height. Since the total time may be as long as 35 minutes for a twin-engined fighter, there will undoubtedly be many occasions when such aircraft cannot be got to orbit in time to meet the first raids. In such cases the S.S.C. must consider the advantages of ordering off his single engined fighters first (Sec.5.2). Where adequate warning is not possible and raids are of short duration it may be desirable to maintain standing patrols of twin-engined night fighters so that they can immediately be sent to orbit on warning of a hostile raid, approaching the area.

(b) Choice of orbits. The primary concern of the S.S.C. must be to destroy as many bombers as possible before they have dropped their bombs. Since it is doubtful whether the destruction of a bomber by a night fighter has much deterrent effect upon the remainder of the bombers in the raid or whether night fighters can break up or disperse a raid as can day fighters or gunfire, it follows that there is no intrinsic merit in keeping reserves either on the ground or in the air. A fighter with its limited fuel and ammunition can only shoot down a certain number of bombers on a sortie. The sooner these can be shot down the greater the chance that he may rearm and refuel, and return to the battle. The S.S.C. must therefore concentrate as many fighters as he can control, and the raid density warrants, on orbits in front of the V.A .. It has been found in practice that as many as 6 or 7 fighters can be controlled simultaneously. Obviously there is no object in using this number of fighters if the raid is so small or so concentrated that only two or three raids can be engaged by searchlights.

But if six fighters can be fully employed they should be sent to orbit irrespective of any raids that may or may not be following.

Where possible, orbits should be manned so that a line joining them is at right angles to the direction of the attack. If the interception area is extensive and the enemy is attacking over a section of it only, fighters should be concentrated in the path of the raid rather than spread thinly over all the orbits. In order to achieve this result and yet have fighters on them at one or more waiting beacons (either actual orbits or specially designated S.L's behind the line of orbits) which are suitable points from which to deploy to any section of the area. As soon as the S.S.C. ascertains the trend of the raid the fighters can be switched to the appropriate orbits. It may even be profitable where there is a shortage of fighters to adopt this policy at the risk of fighters arriving on orbit after the first bombers have passed through the area.

To facilitate the manning of orbits and to deceive the enemy, all orbit beacons should be exposed whenever S.L's are to operate.

(c) Change of dispositions. As the battle develops it may become necessary to move fighters to different orbits to meet the changing direction of the raid. When the raids are leaving the target a stage will be reached when the S.S.C. may have to decide to move his fighters to orbits where they can intercept the outgoers (Sec.4.1 and 4.2). This move should not be delayed for the sake of the remnants of those still approaching the target otherwise four or five kills may be missed for the sake of one extra shot down before it can drop its bombs.

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In certain cases it may be profitable to land a fighter while a raid is in progress if by so doing the fighter can be rearmed and refuelled in time to meet a second wave. The only consideration which must govern such a decision is whether the fighter is likely to make more kills by meeting the new raid with a full supply of fuel and ammunition than he would by staying to deal with the raids at the moment over the area.

2. The Control of Fighters. This is exercised from the Control Centre by R/T. When ordered off, fighters should be able to find their orbits with the aid of a single vector (given to them if possible before they take off) and the distinguishing characteristic of the beacon (Sec.6.1). It may sometimes be necessary to assist tthem with further vectors where for example the weather is cloudy and the beacons are not easily visible. They may also require vectors to orbits at the end of an interception. These vectors will be determined with the aid of voice fixes or information from the P.P.I. tube and passed by R/T. Return to base is effected in a similar way. When on orbit fighters should be given information regarding the height of bombers and the direction from which they are to be expected. Care must be taken however not to jam the R/T. with messages which will interfere with operational instructions or reports; while fix transmissions and vectors must be kept to a minimum. The S.S.C. must also ensure that the fighters have the necessary command of height (Sec.5.2).

At all times the S.S.C. is responsible for the safety of the fighters under his control and must take every precaution to avoid unnecessary risks. He must therefore pay careful regard to the heights of his fighters on orbit and ensure that two fighters on the same orbit are never separated by less than 1,000 ft. He must also keep in mind their endurance, (particularly in the case of single engined fighters); the distance they must travel in order to reach base; and the possible delays that may occur before they can land.

The S.S.C. may also have certain important functions to perform in relation to the control of the actual interception. These vary with the procedure employed and are dealt with in Chapter VI.

3. Control of Searchlights. Where some form of communications exists to S.L's the S.S.C's functions are:-

(a) To order states of readiness
(b) To issue instructions to orbit beacon sites
(c) To specify the engagement interval and the number of beams required on targets.
(d) Where appropriate, to pass G.C.I. plots to the S.L's.
(e) To pass heights of raids when needed for S.L. plotting.
(f) To order the termination of an engagement when requested by the fighter or when two S.L. engagements have drawn too close to each other.

Where communications are few or non-existent, (a), (b) and (c) may be covered by the issue of standing instructions; (d); (e) and (f) will not apply.

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CHAPTER VI - INTERCEPTION PROCEDURE

15. Introduction.

1. The successful operation of the system depends on the degree to which it is possible to select the fighter best placed to intercept any given raid. Or, considering the matter from the point of view of an individual fighter, the problem is to select raids suitable for interception by him. The selection will depend on the course of the target relative to the fighter orbits and it is not possible to predict this with absolute certainty. Mathematically correct selection requires an elaborate procedure which is not practicable without a highly organised system of communications and is primarily designed for the defence of very large areas. (See Artillery Training Volume IV Part III Pamphlet No.3).

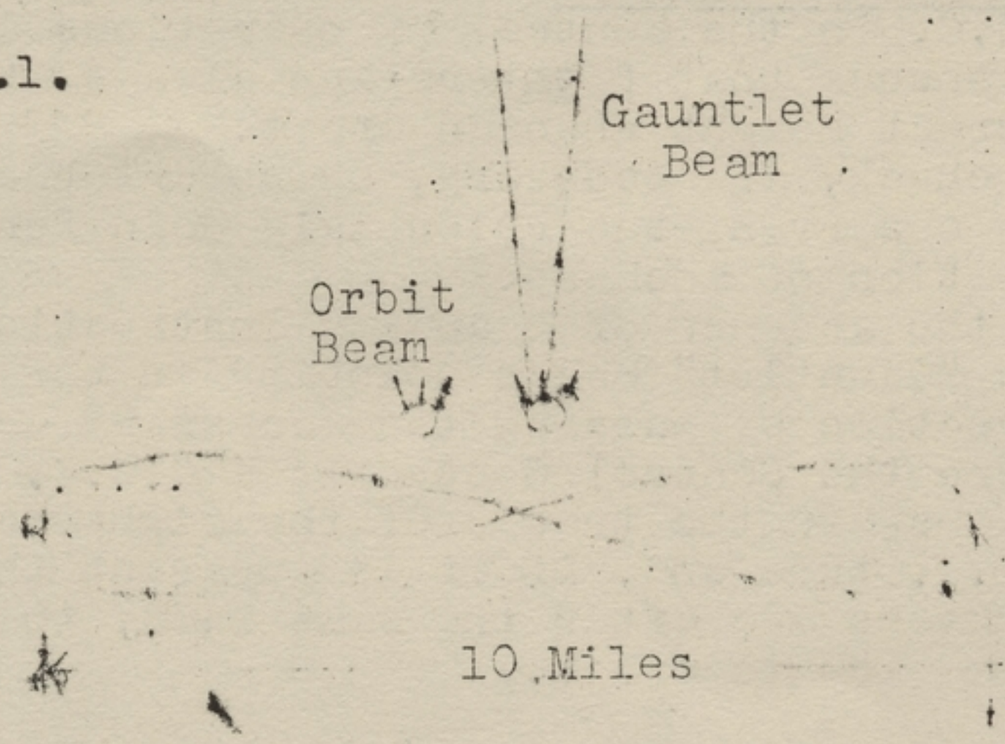
A practical approximation to the ideal can, however, be obtained by a number of procedures; and it will be remembered that even if the "correct" fighter is not selected, a fighter from an adjacent orbit will probably intercept though after a considerably longer chase. here it is possible to use S.L. plotting and to exercise control from a G.C.I. station, the system of selection thereby made possible can hardly be bettered. Since, however, S.L. plotting is likely to be the exception rather than the rule, it is convenient first to consider the procedures to be employed where it is not available. There are two alternatives; in the one case selection is exercised largely by the pilot himself and in the other by an officer stationed at each orbit beacon site. Where S.L. plotting is available, selection is exercised by the pilot subject to the overriding direction and control of the S.S.C. In all cases the control Centre may be either at the operations room or the G.C.I. station.

16. Procedure without Searchlight Plotting.

1. Selection by the fighter himself.

(a) Arrangements. This procedure is generally known as "Gauntlet". On the warning of hostile raids, the fighters are sent to their orbits and given a height at which to fly (Sec.6.2). They are told, either before setting off or by R/T when on orbit, the direction in relation to their orbits from which raids are expected. At the same time the second signal S.L. on the orbit beacon site (Sec.81) is exposed horizontally in this direction as a permanent guide to the pilot. The bearing of the beam may be defined in Standing Instructions but it is preferably detailed by the S.S.C. before or during operations. This beam is called the "Gauntlet" beam. When this beam is exposed, it is convenient for the pilot to cease doing a circular orbit and to fly a figure eight course (length about 10 miles) on the side of the beam is pointing. The sharp turns should be towards the direction in which the beam is pointing (See fig.1).

Fig.1.



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In this way he can maintain an almost continuous lookout for S.L. beams in the direction from which raids are approaching.

(b) Selection of the target. A pilot should confine his attention to an arc of a specified number of degrees on either side on the "Gauntlet" beam. This arc will depend on the depth of the belt in front of the orbit and will be arranged so that the arcs of adjacent orbits meet on the front line of S.Ls. Thus for a depth of 15 miles and orbits 12 miles apart the arc of each fighter will be approximately 35° on either side of the "Gauntlet" beam. This arc may be defined by earlier S.Ls on the front row of lights instead of by a "Gauntlet" beam.

If the pilot observes an intersection within his arc, he sets off to intercept and reports his departure by R/T to the S.S.C. giving the bearing and the estimated distance of the intercection from the orbit. He may, if he prefers, report the position of the intersection by means of the clock code, treating the "Gauntlet" beam as 12 O'clock. When a pilot has made a kill or has decided to abandon chase, he will inform the S.S.C. by R/T and, where necessary, will obtain from him a vector for return to orbit or base as the case may be.

If this procedure is followed, raids should be intercepted by the fighters best placed to do so provided that the "Gauntlet" beams are correctly oriented and the bombers are not making extensive changes of course.

(c) Economy of effort. Since all aircraft will be working on the same R/T frequency, all pilots will hear the reports of each other. By this means a pilot should know when another fighter from the same orbit has set off to intercept a particular raid and, in such case; the pilot on orbit should make no attempt to intercept the same raid. If desired, one of the pilots on orbit may be detailed to exercise a veto and to regulate the operation of the procedure.

There can be, however, no absolute certainty that two fighters either from the same or different orbits have not gone after the same raid and, therefore, a fighter must not open fire until he has recognised his target as hostile. With A.I. fighters a contact should be made within four minutes from leaving the orbit. After this time, if no contact is obtained, the pilot should re-orbit. In the case of Catseye fighters, a time limit should be fixed at the end of which, if the kill is not imminent, the pilot should re-orbit. In all cases fighters should obtain from the S.S.C. by R/T the height at which they are to return to orbit.

(d) Functions of the S.S.C. Under "Gauntlet" the function of the S.S.C. in the control of operations are :-

(i) To ensure that fighters are always at the correct height when on orbit.

(ii) To check, if necessary, using R/T that pilots are observing the rules laid down for the duration of a chase.

(iii) In the absence of Standing Instructions, to keep the "Gauntlet" beams pointing in the required direction by passing the necessary orders to S.Ls.

(iv) Where the Control Centre is a G.C.I. station, to observe the tracks of the fighters on the P.P.I. tube and, if it is apparent that two fighters are after the same raid, to send one of them back to orbit.

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2. Control from the orbit beacon site.

(a) Arrangements. This procedure requires a sub-control officer (the orbit officer) for each orbit point, who is stationed either at the orbit site or preferably on a hill or rising ground in the immediate neighbourhood. It is important that he should have good all-round visibility so that he can see intersections of S.L. beams in the distance. If he is stationed elsewhere than on the orbit site, he must have communication to it.

As in the case of "Gauntlet", each orbit has an arc of operation. This is not defined with reference to a "Gauntlet" beam but by angles of bearing from the orbit site. The arc is specified by the S.S.C. either in Standing Instructions or immediately prior to operations. The S.S.C. may change the arc during operations if the direction of the raid stream changes.

The fighters are disposed on their orbits by the S.S.C. and told the direction of approach of the raid. If there is more than one on an orbit, they will be given by R/T an order in which to intercept according to their priority in height on the orbit, the top one being given first turn. On being told that he is next to intercept, a pilot will commence a figure of eight "behind" the orbit as in "Gauntlet" (though in this case there will be no "Gauntlet" beam) and will wait for a visual signal from the ground. The S.L. projector used in "Gauntlet" to provide the "Gauntlet" beam is here used for the visual signal to the fighter and its beam is called the "Smack" beam.

(b) Selection of the Target. This is done by the orbit officer who, from his observation post, watches for the appearance of intersections within the arc of operation. As soon as he has selected a suitable intersection, he orders the smack beam to signal it to the fighter. The smack beam is exposed vertically for a few seconds and then depressed horizontally in the direction of the selected intersection. On seeing the smack beam expose, the fighter flies in to the orbit and, when it depresses, he flies along it towards the intersection which should already be visible to him. The smack beam is kept continuously pointing towards the intersection until it is apparent that the fighter has set off and it is then doused. When he leaves the orbit, the fighter informs the S.S.C. by R/T. The latter is thus able to change the heights of the remaining fighters if necessary and warn the fighter whose turn is next.

(c) Economy of effort. It is the duty of the orbit officer to ensure that only one fighter from his orbit sets off for any one intersection. The same rules as in "Gauntlet" apply to the duration of the chase.

(d) Functions of the S.S.C. The functions of the S.S.C. in the control of operations are:-

(i) To ensure that fighters are always at the correct heights when on orbit.

(ii) To check, if necessary, using R/T that pilots are observing the rules laid down for the duration of a chase.

(iii) In the absence of Standing Instructions to define to the orbit officers the arc of operation of each orbit site.

(iv) To d tail to the fighters on orbit their turn to intercept.

(v) Where the Control Centre is a G.C.I. station, to observe the tracksof the fighters on the P.P.I. tube and, if it is apparent that two fighters are after the same raid, to send one of them back to orbit.

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3. Relative merits of the two procedures. Interceptions should begin earlier with "Gauntlet" because the pilot will usually see intersections before the orbit officer and he sets off before waiting for any visual signal. On the other hand, since the position of the orbit officer is stable, he is better able to judge whether an intersection is within the arc of operation than a pilot who is moving very fast and is seldom exactly at the orbit point. The orbit officer can also be certain that he does not send two fighters after the same raid.

With control from an orbit site, the procedure is on the whole simpler for the pilot because, although he has to watch for and obey the signal of the smack beam, he is relieved of the responsibility of choosing his intersections and of checking those he sees against the reports of the other pilots. On the other hand, problems of personnel, communications and topography may make the system impracticable.

IV. Procedure Using Searchlight Plotting

1. Where S.Ls. are able to pass plots of engaged raids to the Control Centre, these will be marked on the S.S.C's map and used by him as a guide to the selection of targets for interception. The basis of the procedure is "Gauntlet" with the S.S.C. exercising an overriding control as between fighters on different orbits. In certain cases he will actually detail fighters to intercept. The procedure is the same whether Control is exercised from the operations room or a G.C.I. station but, as will be seen, the ability of the S.S.C. in the latter case to keep continuous track of his fighters, makes the exercise of his functions much simpler and more accurate. Arrangements at the orbit site are the same as for "Gauntlet" and, in the absence of other orders from the S.S.C., the procedure followed by the pilot is also the same. He sets off for intersections appearing within his arc of operation reporting by R/T their bearing and estimated distance from the orbit. The S.S.C. has the bearings of the "Gauntlet" beam marked on his map and, by comparing the report of the pilot with the plots of S.L. raids, he should be able to determine which raid the fighter is intercepting. By this means, he can decide immediately, or after another plot, whether the pilot has chosen a raid whose course makes it favourable for interception or whether it is unsuitable for the pilot reporting. In the former case, the message is merely acknowledged and the interception proceeds. In the latter, the S.S.C. may decide to call off the interception and, if so, he orders the pilot to return to orbit.

2. If because of poor visibility, pilots cannot see intersections until they have passed well into the area, the S.S.C. (who receives the plots of engagements from the moment they begin) may himself make the initial selection of targets and send a fighter off to intercept by giving him a "smack" vector from his orbit in the direction of the latest plot on the selected target. The pilot, on receipt of the vector, flies over his orbit and sets off in the specified direction. After a short time he should see the S.L. beams. The same procedure can be applied when a crossing target is approaching an orbit from outside the arc of operation and the fighter from the adjacent orbit has either been called off or has not attempted to intercept. In this case, a smack vector can be given to the pilot best placed to intercept.

By keeping a tally of raids which are being intercepted by fighters, the S.S.C. can see at a glance whether a fighter is proposing to intercept a raid on which another is already engaged. He must, however, take care to pass any order to abandon chase before the fighter (if A.I.) has made contact. (Sec.5.1).

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3. When he operates from a G.C.I. station, the S.S.C. is in the best possible position because, not only can he watch the progress of the engaged raids, but he can also observe the tracks of the fighters themselves. There is, however, always the possibility of error and therefore the pilot cannot be relieved of the responsibility of recognising a target as hostile before firing or keeping careful lookout for rriendly fighters in the vicinity.

4. Observation of the S.L. plots will show the S.S.C. whether engagements are converging too close and his tally will show him which may be abandoned and which must be continued - or whether both must be continued as long as possible. When a request for dousing is passed by a fighter, the S.S.C. should be able immediately to identify the S.L. raid in question and to transmit the message to the appropriate S.Ls.

5. When operating from a G.C.I. station with a P.P.I. tube of his own, the S.S.C. will have the S.L. plots marked on the face of the tube. As soon as it is possible to marry a line of S.L. plots with any aircraft shown on the tube, S.L. plotting on that raid can be discontinued and the raid tracked from the signals on the tube. Check plots may be called for at intervalsor when any doubt arises. At the same time, fighters will be tracked by a separate plotter - and thus the S.S.C. will have in front of him a complete picture of his own forces and the raids available for interception. If raid density and the number of fighters are sufficiently low for the fighters to be identified while on orbit, it is even possible for the S.S.C. to have regard to their exact position in relation to a raid when selecting or approving raids for interception.

6. It is clear that, where no separate P.P.I. tube is available for the S.S.C. and he can only share one which may also be employed for G.C.I. interception, his use of the tube will be limited to observing general raid trends for the purpose of disposing his fighters on orbit. Under favourable conditions he may also be able to check the positions of the fighters from time to time while they are engaged on interceptions. He must, however, operate primarily from his separate map as in an operation room.

18. Procedure In A Combat Zone.

1. Speed is the essence of Combat Zone procedure since by definition the S.L. area available for interception is small. Only A.I. aircraft can be used because the kill will often take place outside the illuminated area. The function of the S.Ls is to enable the fighter to make A.I. contact quickly after which the fighter can finish off the interception in its own time.

2. Since the orbits will be close to the V.A., most of the S.L. engagements of targets entering the area will be visible to all pilots on orbit and, generally speaking, every pilot will be suitably placed to intercept. Theproblem is therefore not one of selecting the best placed fighter but of arranging the order in which pilots are to intercept. In view of the importance of the time factor, individual control by the S.S.C. is out of the question. The fighter must set off immediately he sees even a single S.L. beam exposed. There are two alternative methods of producing the desired result. In the first, pilots are given a number indicating the order in which theywill set off to intercept and will remain on orbit until it is their turn even if they see an intersection of beams beforehand. On setting off, a pilot reports his turn number and the bearing of the beams he is after for the benefit of the other pilots. On returning to orbit, a pilot will report by R/T to the S.S.C. who will give him the number of his turn for the next interception. In the second method, control is left to one of the pilots on orbit. If two pilots are obviously setting off for the same intersection, the controlling pilot calls oneof them back. The function of the S.S.C. is to ensure that one of the pilots on orbit is always detailed to control.

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3. It is particularly important under this system to give the fighters an adequate command of height. During operations contacts are obtained very quickly - sometimes in well under a minute - but inevitably a large number of them will be head-on. To hold such contacts successfully requires good technique on the part of pilots and their crews, especially as the fighter will in most cases be diving towards the target. It is sometimes found convenient for S.L.C. S.Ls to douse when fighter and bomber breaks merge (for not only in order to be certain to avoid illuminating the fighter but also in order to free S.Ls for the engagement of fresh targets. The S.L. crews must be trained to distinguish where possible between the merging of breaks while the head-on part of the interception is in progress and the merging of breaks when the fighter has come behind the target and is in firm A.I. contact. S.Ls will not be doused where the merging is clearly the result of fighter and bomber converging head on.

4. Where a Combat Zone or other interception area is adjacent to a G.D.A., the question of defining the spheres of operation of fighters and guns is a matter of A.A. policy. Where it is desirable to limit the height to which the guns may fire, and to allow fighters to operate freely above this level, it must be borne in mind that there can be no question of getting S.Ls to engage targets either specifically for guns or specifically for fighters as they are unable to make such careful discrimination as to height.

Fighters should be warned not to enter the G.D.A. where there is no height restriction unless a kill is imminent and then they must usually do so at their own risk. It may be possible to indicate the boundary of the G.D.A. to them by using special S.L. signals (Sec.6.6.). It should also be possible for the gun G.Ls to distinguish raids with which fighters are in contact. If the procedure for dousing S.Ls when breaks merge is employed, a considerable proportion of the targets engaged by S.Ls within the G.D.A. will have no fighters after them and this should facilitate visual shooting by the guns. The G.D.A. lights should therefore be instructed not to initiate engagements on targets where they see merging breaks (especially if one is showing I.F.F.) and where possible to co-operate in the disengagement of targets on which the Combat Zone lights douse.

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PART II

THE EMPLOYMENT OF SEARCHLIGHTS OTHER THAN WITH FIGHTER AIRCRAFT

CHAPTER VII

INTRODUCTION

19 - Roles of searchlights

1. The roles of searchlights, other than those in which they are employed with fighter aircraft, may be summarised as follows.

(a) Co-operation with A.A. guns. To assist H.A.A. and Lt. A.A. guns either -

(i) to destroy the enemy aircraft, and/or
(ii) to prevent accurate bombing, mine laying, or machine gunning.

This necessitates direct illumination of the target.

(b) Dazzle. By dazzling the pilot and bomb aimer of the enemy aircraft, to prevent accurate bombing, mine laying, and machine gunning. This also necessitates direct illumination of the target

(c) Coast Artillery Role To operate as Coast Artillery Searchlights.

(d) Deception

(i) to deceive enemy aircraft as to their position in relation to the ground and
(ii) to prevent accurate bombing or mine-laying

CHAPTER VIII

THE EMPLOYMENT OF SEARCHLIGHTS WITH H.A.A. GUNS

20 - Requirements for visual shooting

1. Time of illumination To enable H.A.A. guns to shoot visually at night it is necessary that the target shall be continuously illuminated during

(a) the time required for the production of gun data,
(b) the flight of shell and
(c) the period of bombardment.

2. This total time is of the order of 30 seconds where target height is being provided from G.L. data. The time may be as much as 75 seconds if height is determined by visual height finder.

3. The requirement is, therefore, that the target shall remain continuously illuminated from the moment that the guns engage for a period of 30 seconds where G.L. data is available or 75 seconds where it is not.

4. Degree of illumination. The degree of illumination of the target must be sufficient to enable the predictor and identification telescope crews to lay accurately and identify immediately. The maximum height at which this can be accomplished and the number of beams required in its accomplishment depends on many critical factors, including the atmospheric conditions.

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5. Given good weather without haze, searchlights deployed in a G.D.A. should be able to illuminate night-doped bomber aircraft so that they can be clearly seen from the gun position at any height up to 15,000 ft., and on occasions even higher.

6. The illumination required for accurate predictor and identification telescope laying does not normally exceed that provided by four or five beams on the target. If the visual height finder is being used a higher degree of illumination is required, and six to eight beams may be needed. The more beams on the target, the easier it is to hold the target; but more than eight beams gives rise to unnecessary glare which may spoil the engagement.

21 - Layout of the searchlights

1. Spacing of searchlights in the illuminated area. 3,500 yards is the standard spacing generally employed for co-operation with H.A.A. guns.

2. To ensure that an early pick-up is obtained, searchlights should certainly not be spaced at more than 3,500 yards apart for the first two rows.

3. Once a target has been picked up it can usually be held by searchlights spaced up to 4,500 yards apart, even when taking violent evasive action. At this spacing as many as 10 beams can be exposed on target at normal heights and targets as low as 2,500 feet can be successfully followed. If a number of targets are to be engaged at the same time, however, the searchlight density inside the lighted area needs to be increased to spacing of 3,500 yards or less.

4. In cases where the number of searchlights is limited, it is preferable to reduce the size of the illuminated area, for example along unlikely lines of approach, rather than decrease the density of the spacing. A layout containing too few searchlights may often provide a navigational guide for the enemy without being of real assistance to the guns.

5. With S.L.C. equipment suitably sited, the illumination of the target is certain and continuous up to the ceiling imposed by atmospheric conditions, providing the spacing and density of the searchlights allows a sufficient number of beams to be put on the target.

6. Size of the illuminated area. It is desirable that the full period of bombardment should take place before the bomber reaches the "line of bomb release" (L.B.R.) round the V.A. to be defended; because not only is there then the opportunity of destroying the bomber before the bombs are dropped, but also the bomber will then normally be flying on an even course and this will assist the predictor control of the guns. It is desirable, therefore, to provide for illumination of the target for 30 seconds before it reaches the L.B.R. where G.L. is used or 75 seconds where it is not.

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7. If a suitable spacing of searchlights is provided, it can be assumed that the target will be sufficiently illuminated when it crosses the first row of searchlights for the gun drill to start. To provide the ideal defence, therefore, the outer edge of the searchlight layout must be at a distance from the line of bomb release equivalent to 75 seconds of flight of the aircraft (assuming G.L. data not available). The distance in yards of the "line of illumination" (the outer edge of the layout) from the edge of the V.A. is provided by the formula:-

$$D = V (75 + T)$$

where D is the distance required, V is the speed of aircraft in yards per second and T is the time of flight of bomb in seconds. Where H is the height of the target in feet:-

$$T = \frac{1}{4}\sqrt{H}$$

Table A gives figures for the distance D for different speeds of aircraft at varying heights.

TABLE A

Height of aircraft in ft. Level flight	Speed of aircraft in miles per hr. 200	250	300	350	400	
6,000	9,400	11,800	14,100	16,500	18,800	
10,000	10,000	12,500	15,500	17,500	20,000	Distance of L.O.I from edge of V.A. in yards
14,000	10,400	13,100	15,600	18,200	20,800	
10,000	10,800	13,600	16,200	18,900	21,600	
22,000	11,200	14,000	16,800	19,600	22,400	

8. Table B shows the number of searchlights required to cover circular layouts of various radii at 3,500 yards spacing.

TABLE B

Radius of illuminated area in yards.	No. of searchlights required at 3,500 yards spacing
9,000	27
13,000	48
15,000	75
18,000	106
21,000	148

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9. From tables A and B, it is possible to calculate the number of searchlights at 3,500 yards spacing required and the radius of the layout for the all round ideal defence of a V.A. For example, with the target speed 300 m.p.h. at a height of 10,000 ft, if the V.A. is 3½ miles in diameter, the number of searchlights required at 3,500 yards spacing is approximately 106 and the radius of the illuminated area will be 11 miles.

10. It will be seen from these tables that the minimum number of searchlights necessary for the ideal defence of a small V.A. against slow targets at comparatively low heights is approximately 50. If a large V.A. is to be defended against high, fast, targets, it is necessary to employ more than 150 searchlights.

11. Owing to limitations of men and equipment it may not always be possible to provide a sufficient number of searchlights to provide for such complete defence of a V.A. In this case, it is normally preferable to reduce the size of the illuminated area rather than increase the spacing.

12. The more the illuminated area is reduced, the closer the L.O.I. approaches to the L.B.R. Where the L.O.I. is approximately coincident with the L.B.R., the guns will not be able to shoot visually before the target reaches the L.B.R., but the target will be illuminated as it passes over the V.A., and beams may be exposing in the eyes of the bomb-aimer at the moment of bomb release. Thus the bomb aimer may be dazzled at a critical moment and his accuracy materially reduced.

13. Reduction of the size of the illuminated area while lessening the effectiveness of the defences, affords considerable saving of men and equipment. As a rough guide, 24 searchlights at 3,500 yards spacing should be able to illuminate the target on or just before the L.B.R., providing the V.A. is a small one.

14. If the size of the illuminated area is so reduced that the target will be engaged only after it has passed the L.B.R., the value of the searchlights will be greatly lessened. As explained above, the results of dazzle may alone prevent accurate bombing, but if the target is not engaged until after the bombs are released this advantage is entirely lost.

15. When the L.O.I. chosen is close in to the L.B.R. sentry lights may be employed in order to give early warning and to assist in obtaining an early pick-up. These lights should be sited 8 to 10 miles from the edge of the illuminated area in commanding positions along most likely lines of aproach.

16. <u>Shapes of the illuminated area</u>. A circular layout will not always be desirable or practical. When deciding the position of the L.O.I (i.e. the shape of the illuminated area), the following factors must be considered:-

(a) The shape of the V.A.
(b) The probable line or lines of attack (See Artillery Training Vol 1, Pam No 11- The ex-M.A.A.D. Vol. 2 Pamphlet I Sec 5 (Subsection 8).
(c) The estimated height and speed of the attack.
(d) The searchlight equipment available and the spacing to be adopted.
(e) The position of the H.A.A. guns.
(f) Topographical features of the area.

(If the V.A. is on the coast, the layout will be approximately semi-circle).

17. The shape of the layout employed will seldom be the ideal layout, but some modification of it made necessary by local circumstances. The plan eventually decided upon, even though short of the ideal must contrive to make the best possible use of the equipment available.

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I8. From time to time it may be necessary to alter the shape of the layout, to counter fresh enemy tactics, or if the enemy isusing it for navigational purposes.

I9. Laying out an illuminated area. The layout of an illuminated area, large or small, may be developed as follows:-

(a) Diagrammatic layout. Having decided the shape and spacing of the illuminated area, a diagrammatic layout, such as the one shown in Plate II, will be made out. It will be convenient, as a rule, to prepare this on a piece of tracing paper and subsequently to prick through the positions of searchlight stations on to a one-inch map.

(b) Approximate positions. If the map available is detailed and accurate, it should be possible, from a careful study of it, to modify the diagrammatic layout and to fix positions for individual sites sufficiently well for the majority of the sites to be finally sited within 200 or 300 yards of those approximate positions. In doing this the regular spacing of the sites must be retained as far as possible, to avoid leaving any gaps in the lighted area. Searchlight sites should be located as far away as possible from the gun positions.

At this stage it is convenient to split up the layout into batteries and troops.

When only a proportion of the stations are equipped with S.L.C. the sites which they are to occupy should next be marked on the map. Priority arcs for each S.L.C. set to cover all approaches must be worked out and noted.

Except in fixed defences, the choosing of the approximate positions will be the duty of the searchlight commander of the particular defended area.

(c) Personal reconnaissance. The final choice of the site for a searchlight is generally made by the troop commander, though every detachment commander should be capable of siting his station correctly in case of need, given the map reference of the approximate position. Should a site have to be placed more than 300 yards from the approximate position, the fact must be reported as soon as possible to the battery commander, since this may entail a modification of the position of other lights in order to maintain a correct general spacing.

22 - Searchlight Equipment.

I. While it is desirable to have all beams directed by S.L.C., mutual interference may occur if sets are closer than 5,000 yards. Where, for this reason, certain searchlights are not directed by sound-locators. Hand-control is preferable where a searchlight is within 4,500 yards of one or more S.L.C. equipped lights. Generally sound-locators are found to be of little use once the guns engage.

2. In an evenly spaced 3,500 yards layout, a suitable distribution of S.L.C. equipment is one third S.L.C. and two thirds hand controlled stations. The S.L.C. stations should be spaced in equilateral triangles 6,000 yards apart as shown in Plate III.

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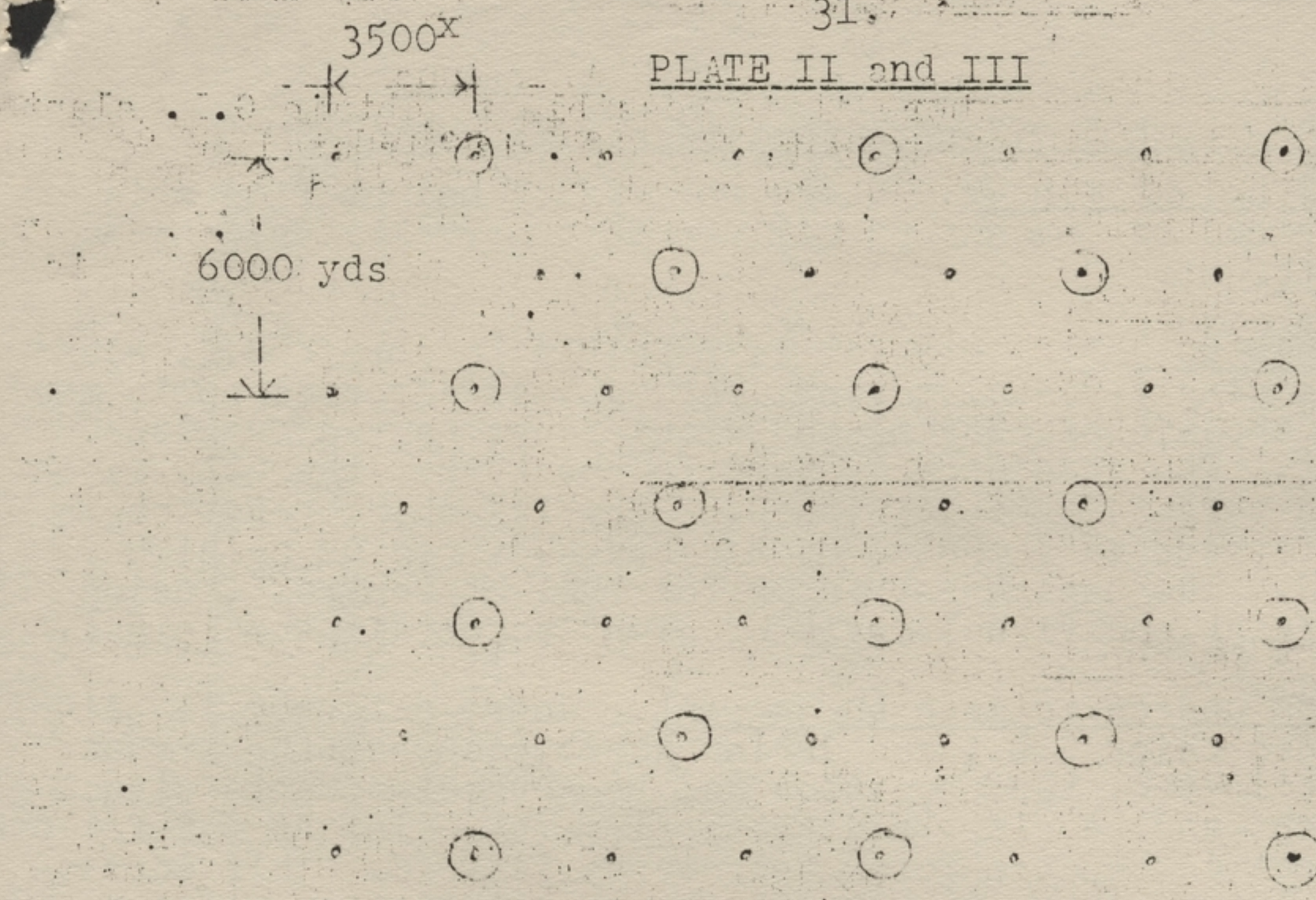
PLATE II and III



1 in 3 DISTRIBUTION OF S.L.C. IN A 3500 YARD LAYOUT

Key
o - Hand Controlled Stations
(o) - Stations equipped with S.L.C.

3. Of the two sizes of searchlights in service (90 cm. and 150 cm) the 150 cm. projectors will provide the greater degree of illumination, and the greater range. Satisfactory results may be obtained with layouts where only S.L.C. controlled projectors ("masters") are 150 cm., the hand-controlled stations ("satellites") being equipped with 90 cm. projectors. (From the projector controller's point of view, it is easier to hold the target with a 90 cm projector than with a 150 cm projector).

4. If control pillars are available, they should be sited primarily on hand-controlled stations. Where they are not available for all stations, control pillars should be evenly distributed over area.

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23 - Method of engagement by H.A.A. guns

1. Using visual height finder. Where the visual height finder is used, the method of engagement will be that normally used by day viz. "Height Control".

2. Data to obtain height. Where it is possible to obtain G.L. slant range in engaging a visual target, the G.L. is directed on to the target with the aid of bearing and slant range passed from the Command Post. The predictor is used to check that the G.L. is on the selected target. Except with G.L. Mk. III this operation is difficult if there is a choice of targets e.g. medium or high density raid. The engagement is as for "Height Control", using G.L. slant range and visual angle of sight to obtain the height.

3. Changing from unseen to seen engagement. Where a target is being engaged unseen using G.L., and during the engagement the target becomes illuminated, the predictor can be corrected on to visual angle of sight and bearing by disregarding the pointers and following the target in the predictor telescopes instead. This correction may be large enough to warrant the calculation of a fresh height (using G.L. slant range). The choice of a fresh height curve should not take more than a few seconds, after which the engagement is continued by visual following with the predictor. In general it is not advisable to change from an unseen to a seen engagement.

4. Employment of G.C.I. Where G.C.I. information is available, it is desirable to have plots passed to perimeter guns and searchlights. Such plots are valuable for early warning and for information of the general position and trend of the raids. It will usually be impracticable to select individual targets for engagement and to attempt to identify them to both searchlights and G.L's by means of downward plotting. It is preferable for guns and searchlights having received the initial information of the position of the approaching raiders, independently to select their own targets.

24 - Method of operation of the searchlights.

1. Rules for engagement. All S.L.C. equipped stations within effective range should engage incoming targets. All hand-controlled stations within effective range should conduct a limited search on the intersection of the S.L.C. beams. Once the target has been picked up only the minimum number of beams required to give adequate illumination should remain exposed. Other stations should then hold themselves in readiness to engage fresh targets. Once a target is illuminated and is engaged by the guns, every endeavour must be made to continue the illumination until either the target is destroyed or passes out of range.

2. In cases where there is a choice of targets it is necessary to select one for engagement. Where one target is illuminated and the other is not the engagement of the illuminated target must be continued in preference to the fresh target. Where the choice is between two (or more) illuminated targets, or two (or more) unilluminated targets the target chosen should be:

   (i) the most dangerous,
   (ii) the nearest,
   (iii) incoming rather than the outgoing,
   (iv) the largest
   (v) targets below rather than above 15,000 ft.

3. It is preferable to have one target well illuminated by 6 beams rather than two targets badly illuminated by 3 each. At the same time it is better to have two targets well illuminated by 5 beams on each than one with 10 beams.

4. It is important that S.L.C. equipped stations should disengage as soon as the target commences to recede and is held by a sufficient number of beams, so that fresh targets may be engaged without delay. Each perimeter S.L.C. locator will have a priority arc and will normally observe through it when not actually engaging a target.

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5. Any plotting to or from searchlight stations will be secondary to the engagement of fresh targets. In general there should be no attempt to control the engagement of targets from a central operations room.

25 - Communications.

1. Communications to the searchlight stations in a G.D.A. are by no means an essential part of the system of defence. Where they do exist, however, they may be usefully employed for giving early warning and passing positions of targets to and from the stations. For the purpose of passing early warning messages, R/T or visual searchlight signals may be used in the absence of line communications.

2. Providing the communications are satisfactory and the plotting equipment is available, it is possible for searchlights in a G.D.A. to send upward plots to Gun or Bty. operations room. Where the G.D.A. is used as part of fighter interception area, upward plotting may be necessary, but when the G.D.A. is isolated, the value of the plots is by no means essential.

3. Information of the approach of hostile aircraft will usually be available from one of the R.D.F. equipments in a G.D.A. Where no such early warning information is available, the use of Sentry Lights becomes important for both guns and searchlights. If the G.D.A. is surrounded by another searchlight layout e.g. an interception area, warning will be automatically given when these beams expose.

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CHAPTER IX - THE USE OF SEARCHLIGHTS WITH LT A.A. GUNS

26 - Requirements of the guns and searchlights.

1. Time of illumination. In order to enable Lt. A.A. guns to shoot visually it is necessary that the target shall be continuously illuminated in range of the guns for a period of time which is the sum of

   (a) the drill time,
   (b) time of flight of shell and
   (c) the duration of bombardment

   Whatever the method of fire control in use, the drill time and flight of shell is seldom more than 8 seconds. A further 10 seconds is required for an effective bombardment.

2. The requirement is, therefore, that the target shall remain continuously illuminated from the moment that the guns engage for a period of 18 seconds.

3. Degree of illumination. The degree of illumination of the target must be sufficient to enable the gun layers (and predictor layers if used) to see the target clearly. Normally, with targets flying at heights of 4,000 ft. and below, one well-directed beam can illuminate the target to the required degree. In practice it is necessary to keep at least three beams on one target to ensure that the target is continuously illuminated. The requirements is, therefore, that the target shall be illuminated by a minimum of three beams while being engaged by the guns.

27 - Layout of the Searchlights

1. Spacing of searchlights in the illuminated area. The standard spacing searchlights co-operating with Lt. A.A. guns in the defence of a V.A. is 1,500 yards.

2. As explained above, it is necessary to maintain an illumination by at least three beams. The spacing of searchlights required to do this will be directly related to the height at which the targets fly; the lower the targets, the closer is the spacing required. In order to ensure at least three beams on a target with a minimum angle of elevation of any projector at five degrees, the maximum spacing needed is:-

for	targets	at	100 ft	spacing	380	yards.
"	"	"	300 ft	"	1150	"
"	"	"	500 ft	"	1900	"
"	"	"	1000 ft	"	3800	"

3. Low level attack by night may well be made from heights as low as 500 ft. If targets at 500 ft are to be illuminated, the spacing should not be more than 1,900 yards, but if more than one target is to engaged, the spacing should be reduced accordingly.

4. According to the local circumstances, a wider or closer spacing than the standard 1,500 yards may be required. Where an illuminated area is of large diameter and targets are unlikely to fly below 1,000 ft., a spacing of 2,000 yards in the centre of the area may suffice. Where the V.P. is small and the enemy has adopted "hedge-hopping", cannon fire, and dive bombing tactics by night, the spacing may have to be reduced to 500 yards.

5. At the edge of the illuminated area it is found that searchlights at 1,500 yards spacing pick up and hold any target at 500 ft. and above. Where targets are lower than this, the spacing may have to be reduced.

6. Size of the illuminated area. As in the case of co-operation with H.A.A., it is desirable that the full period of bombardment should

take place before the target reaches the L.B.R. To provide the ideal defence, therefore, the target must be illuminated at a distance from the L.B.R. equivalent to 18 seconds of flight. With suitable spacing it can be assumed that the target will be illuminated by the time it reaches the outer row of lights.

7. The distance from the centre of the edge of the illuminated area, (and therefore the radius of the L.O.I.), required to illuminate the target for 18 seconds before it reaches the L.B.R., depends on the height and speed of the target. Table A shows the radius of the L.O.I. required for various speeds and target. Table A shows the radius of the L.O.I. required for various speeds and heights of aircraft. The calculations are based on the formula D = V (18 + T).

TABLE A.

Height of aircraft in ft. level flight	Speed aircraft in Miles per hour					
	200	250	300	350	400	
100	2000	2600	3100	3600	4100	Radius of L.O.I. to illuminate 18 seconds before target reaches L.B.R layout. V.P. in centre.
250	2200	2700	3200	3800	4300	
500	2400	3000	3500	4100	4700	
1000	2600	3200	3700	4500	5200	
1500	2800	3500	4200	4900	5500	
2000	2900	3700	4400	5100	5800	
4000	3400	4200	5100	5900	6800	

8. To find the radius of the L.O.I. when defending a V.A. of appreciable dimensions, half the width of the V.A. must be added to the figures shown in Table A.

9. Table B shows the approximate number of searchlights necessary to fill an illuminated area of various radii with even spacing of 1,500 yards.

TABLE B.

Radius of illuminated area in yards	No of searchlights required
2000	11
3000	18
4000	30
5000	45
6000	70

10. From tables A and B above, it will be seen that some 70 searchlights at 1,500 yards spacing are needed to provide the ideal searchlight defence against all types of attack from 500 ft. to 4,000 ft., when the objective is literally a V.P. If the objective is of any appreciable size, more searchlights will be required.

11. The men and equipment available will often not allow of an ideal illuminated area. When the total number of searchlights available is less than the ideal requirement, the size and shape of the layout decided upon must be carefully arranged to make the best possible use of available equipment. The considerations

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governing the reduction of size of the illuminated area are similar to those already discussed in connection with the employment of searchlights with H.A.A. guns.

12. In the case of a large V.A. it may be possible only to provide defence with searchlights for certain selected V.Ps within the V.A.

13. As with H.A.A., Sentry lights may usefully be used to give early warning.

14. Anti-dive-bombing layout. Searchlights employed to combat dive bombing must all be within a few hundred yards of the V.P. which, if the enemy is forced to adopt dive bombing tactics, is likely to be very small, e.g. a small bridge, a defile etc. Even 3 or 4 searchlights will prove effective for this purpose, providing the raid density is not high.

15. Searchlight stations employed in a low-flying defence role may need to be withdrawn from sites by day for camouflage purposes, and redeployed at dusk to different sites. The A.A.L.M.Gs. may remain deployed by day if required. If the same sites are in use for any length of time, the enemy will soon learn the shape of the layout and use it to help locate his objective. Where a mobile reserve exists, it may be used to alter the shape of the layout, or thicken up one side of the area.

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28. - Searchlight equipment.

1. Projectors. Either 90 cm. or 150 cm. projectors are effective against low flying aircraft. Owing to its lighter weight, however, the 90 cm. projector is easier to control and for that reason is more suitable in this role for it is very important that the projector should be capable of smooth and quick traverse.
2. Projectors must be sited to obtain the best possible field of view, particularly in the direction away from the V.A. This usually implies siting on a forward slope or on the top of rising ground.
3. S.L.C. equipment. S.L.C. equipment used against low flying aircraft should be mounted on the projector (00 F.S. or 150 F.S.); if it is desired to use three or more S.L.C. sets in this one layout, a test should be made to ensure that they do not cause mutual interference great enough to prevent pick up at the ranges required. If the interference is too great, the remedy is either to change the location of the S.L.C. equipment, or to reduce the number of sets in use.
4. In some circumstances "line-locking" of S.L.C. sets may be adopted to avoid mutual interference. The chief disadvantage of this method is that sets which are line-locked can engage only the same target.
5. Generators. The noise of the generator must be carefully screened otherwise it may interfere with the picking up of the target. Generators should be sited where possible away from the expected direction of attack viz. between the projector and the V.P.
6. Spotters. Spotting chairs and binoculars are usually not necessary. With low flyingtargets, the best vantage point for the spotter normally changes with the direction of the beam; the spotter should be free to move during the engagement.
7. Sound-locators. Sound-locators are not effective against fast aircraft unless the target is over 3,000 ft. Below this height, the angular rate of change is too great for efficient operation. For aircraft above this height, however, the sound-locator may be used effectively. Up to 3,000 or 4,000 ft the target can easily be picked up by the trained projector controller with unaided ear, thus rendering the use of sound locators unnecessary at these heights.

29. - Method of operation of the searchlight.

1. Picking up the target. The method used to pick up a low flying target should vary with the weather, number of searchlights in use, and other conditions. The following is an example of a method suitable for use in average visibility.

   As the target approaches the edge of the searchlight layout, the two nearest stations engage with dispersed beams. These beams are directed either by the projector controller judging the position of the target by sound, or by the S.L.C. crew, where the station is equipped with S:L.C. As soon as the first two dispersed beams are exposed, the four stations nearest to them expose in focus and search on sound in the neighbourhood of the dispersed beams. When not engaging a target, the S.L.C. equipped station will usually observe through a priority arc facing outwards from the centre of the layout. As soon as a target is picked up, all beams engaging should normally be in focus.
2. Speed of pick-up is absolutely essential. Drill orders should be cut to the minimum; beams must expose exactly when required; and flickovers should be followed immediately by illuminations.
3. Holding the target. Once the target is illuminated, all beams exposed should follow in focus, unless the detachment commander on a station considers that by so doing the target will be lost, (i.e. the angular rate of change of his projector is too great to follow with the beam in focus). The control of the projector is invariably manual at this stage.

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4. Stations inside the layout expose and illuminate all approaching targets as soon as they are in effective range. The detachment commander's primary object must be to engage all targets which come within his range. Greatest care is necessary when holding a target to see that the beam does not merely follow the intersection without actually illuminating the target. This may "blanket" the view of other detachments and even cause the target to be lost.

5. Dousing. Detachments break off the engagement as soon as the target is :-

(a) Receding, AND
(b) Is held by three other beams.

Immediately each beam is doused, the projector should be turned round to face away from the V.A. and be prepared to engage fresh targets. S.L.C. crews immediately recommence observing through the priority arc.

6. It is important that the beams do not illuminate objects on the ground which may provide the enemy with a navigational aid, e.g. the V.P. itself, tall buildings, or bridges. To prevent this it may sometimes be necessary to allot "dead arcs" to certain stations below specified angles of elevation.

7. Medium and high density raids. The maximum height of targets which can be engaged by Lt AA guns is approximately 5,000 ft. The searchlights deployed to co-operate with these guns can, however, engage targets at any height.

8. Where the Lt AA layout is located in a H.A.A. G.D.A. with searchlights at 3,500 yards spacing (e.g. to defend a V.P. inside a larger V.A.), some or all of the spaced searchlights may have a dual role and operate as part of the H.A.A.

9. Where there is no H.A.A. gun defence and an attack at heights out of range of that Lt AA guns develops, a decision must be made whether or not to allow the closed spaced searchlights to engage. If they do not engage, the dazzle, deterrent and harassing effects will be lost; if they do engage, the location of the enemy's objective is given away.

As a general rule, the searchlights should be allowed to engage when the ground objective is easy to find, or when fires have been started. While there is still hope that the enemy may fail to locate his objective, the searchlights should usually remain blacked out.

30 - Communications.

1. Except in the case of airfield canopies (Sec. 31), rigid control of detachments is seldom a requirement, and the main use of the communications is to provide early warning of approach of targets and to douse beams when necessary. As the searchlights are all at close spacing, R/T communications within the troop are satisfactory and, therefore, line communication to individual stations is rarely required.

31 - Airfield canopies.

1. Owing to the size of modern airfields, it is seldom practicable to provide an ideal defence against the bombing of dispersal points, workshops, hangars, watersupplies, runways etc. The defence, therefore, relies on the dazzle and deterrent effect of the searchlights and guns, and the destruction of hostile aircraft venturing a sufficient distance across the airfield.

2. Layout and equipment. The layout is arranged to give the maximum concentration of beams on the target before it reaches the airfield, and may take the following forms:

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(a) The grouping of stations in twos or threes.
(b) Even spacing around the perimeter.
(c) Combination of single and grouped stations

3. The siting of lights singly gives an all round L.O.I. further out than that of a grouped arrangement and therefore usually gives an earlier pick-up.

4. It may, however, be advisable to use a grouped arrangement from the point of view of ease of communications, administration or protection.

5. The spacing of the stations depends largely on the topographical features of the area but, in general, the sites should be 1,000 to 2,000 yards apart. One or two of the searchlights may have to be specially sited to illuminate a runway if required. Where stations are in groups, each site should be not less than 200 yards from its neighbour. Stations should be at least 150 yards from Lt. A.A. guns.

6. For a small airfield 6 searchlights may prove satisfactory, but for large airfields, 9 should be used. 3 S.L.C. sets are normally sufficient and should be sited to give the best results in their own priority arc. Where groups are used, each should include one S.L.C. equipment. If more than 3 or 4 sets are in operation at the same time, it may be necessary to employ line-locking, otherwise mutual interference may be so great as to prevent any of them working efficiently.

7. Operational control. The Anti-Aircraft Defence Commander (A.A.D.C.) of the airfield is in charge of the operation of both searchlights and guns. The duty of the .A.A.D.C. is to ensure that the defences under his command are used to the best advantage in protecting the airfield. He must, therefore, decide the best moment at which to expose the searchlights so that they illuminate the aircraft sufficiently early to allow the guns to concentrate an effective fire, but not so early that the target will alter its course and avoid being picked up.

8. The method of engagement has been dealt with in Sec. 29.

9. The A.A.D.C. will exercise strict control over beams exposed and doused and guns engaging, both to obtain the maximum effective use of his searchlights and guns, and to ensure that friendly aircraft are not engaged.

10. Defence against intruder aircraft. An intruder aircraft usually attacks by following and machine-gunning a friendly aircraft in the process of landing at night. Special methods of operation are necessary to deal with this type of attack. The procedure will depend largely on the local conditions at each airfield but the following is an example:

Immediately a friendly aircraft crosses the edge of the airfield to land on the runway, a "blanket" of dispersed searchlight beams is set up across the beginning of that runway. If an intruder intends to attack the landing aircraft, it must fly through the blanket and be observed and engaged in the ordinary way by guns and searchlights. The blanket also has the effect of hiding the landing aircraft by interposing glare between the two aircraft. The blanket is obtained by laying the beams from suitably placed stations on predetermined angles of bearing and elevation.

11. Communications. The communications needed to control the defences must be reliable. The best arrangement is a Control Post for the A.A.D.C., with line communication to all guns and searchlights on an omnibus circuit. A line from the control post to the Air Force Flying Control Officer will also be required or, better still, the A.A.D.C. should be with the Flying Control Officer.

12. Since the enemy may be expected to make maximum use of the element of surprise in his attack, the best early warning system possible must be made available for the defences, and some quick

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means devised of communicating the alarm to the guns and searchlights.

13. Equipment. The searchlight equipment required is the same as described in Section 28, S.L.C. equipped stations may be used to provide early warning and information to the A.A.D.C.

32 - Anti-minelaying

1. The searchlight role. The anti-minelaying role may be summarised as follows:-

(a) To illuminate enemy minelaying aircraft for Lt. AA and H.A.A. guns.
(b) To deter the pilot by dazzle.
(c) To indicate the location of the mines in the water and so assist subsequent minesweeping operations.

2. Layout and siting. Minelaying aircraft normally fly at low altitudes. Sites must be chosen having a clear field of view over the sea through a large arc, and should be placed as low and close to the water as possible. The possibility of shallow penetrations inland has also to be borne in mind when choosing sites. Close spacing - in the region of 1,000 yards - is desirable as defences in depth is seldom possible. The number of stations required will depend on the length of the channel to be protected. In some cases the anti-minelaying stations may form part of another searchlight layout e.g. defence of a V.A.

3. Equipment and operation. It is essential that all equipment can be operated at or below zero degrees elevation. It is often not possible to obtain early warning of targets approaching low over the sea from outside sources and, therefore, a certain proportion of stations should be equipped with S.L.C. These should be sited so as to give the best possible pick-up free of interference from ground breaks along the likely lines of approach. S.L.C. must be directly mounted and capable of rapid traverse. The remainder of the equipment will normally be hand-controlled.

4. The procedure for engaging minelaying aircraft is basically the same as already described for searchlights in co-operation with Lt. A.A. guns in the defence of a V.A.

5. Anti-minelaying searchlights may assist in locating the position of mines dropped by enemy aircraft by two or more stations illuminating the mine and following it down until it strikes water. The bearing angles are noted for each station, and from these the mine is accurately pinpointed in the channel. This duty may on occasions be considered more important than, and take precedence over, continuing the illumination of the aircraft after the mine has been dropped.

6. Owing to the extremely short warning of approach, detachments should be permitted to expose on all targets, unless specific orders to the contrary have been received.

7. Communication to sites is necessary in order that warning of approaching raiders may be given, and in addition, information concerning the presence of friendly aircraft or shipping. R/T is usually found to be adequate.

CHAPTER X.

THE EMPLOYMENT OF SEARCHLIGHTS FOR DECEPTION AND AS A DETERRENT.

33 - Deception

1. The searchlight role. Searchlights may be employed to deceive the the enemy as to the true position of his ground objective, the coastline and the location of A.A. defences. This deception may prevent him from locating his ground objective, or cause him to bomb inaccurately. Deception normally takes one of the following forms:-

(a) Total or partial blackout
(b) False layouts
(c) Creation of false coastlines
(d) Dark lanes
(e) Glare effect
(f) Combinations of the above

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2. The effectiveness of any of these forms of deception is increased if atmospheric conditions prevent the enemy from seeing the ground.

The operation of searchlights in each of the above roles is briefly considered below:-

(a) Total or partial blackout. Blacking out part or all of the searchlights in an illuminated area surrounding or adjacent to a V.A. may mislead the enemy as to the true position of his objective.

(b) False layouts. Searchlights deployed adjacent to an existing searchlight layout alter the shape of the original layout as seen from the air, and therefore, the apparent position of the objective. The effect will be increased if, at the same time, an equivalent number of searchlights are blacked out on the opposite side of the illuminated area. This form of deception may be effective if the enemy is using the shape of the illuminated area to estimate the position of his objective. The use of searchlights in their fully mobile role will facilitate the creation of these false areas. Concentrations of beams over an area outside but near the target area, may mislead the enemy as to the whereabouts of his objective. This is most likely to be successful if the dummy V.A. can be arranged on ground which in some way resembles the true V.A. as seen from the air. False fires, dummy aerodrome landing lights, A.A fire at the intersections, and other deceptive measures may usefully be employed in conjunction with the searchlights.

(c) Creation of false coastline. The enemy's night navigation is considerably assisted if he can pinpoint when crossing the coastline. The exact position of the coastline is often indicated by searchlight beams at the edge of an illuminated area known to coincide with the coast. On nights of poor visability, the blacking out of searchlights in a belt a few miles deep, contiguous with the coast; may cause the enemy to be uncertain of his exact land fall.

(d) Dark lanes. A lane through an illuminated area in which searchlights are blacked out will often be chosen by an enemy pilot as the route to his objective. A.A. barrage may be arranged in these dark lanes.

(e) Glare effect. In conditions of poor visibility it may be possible to obscure the objective from the enemy aircraft by traversing dispersed beams in confusing patterns at low angles of elevation.

4. Only by continuous alteration of the locations and methods of deception will maximum results be obtained. The keynote of the use of searchlights for deception is mobility combined with imagination and initiative. For example, a dark lane, once successful, will lose its value unless moved to a different area.

34 - Dazzle defence

1. Object. Searchlight may be employed to dazzle:-
(a) the bomb aimer and thereby interfere with his accuracy, and
(b) the pilot, by preventing him from seeing the ground or even his instruments.

This form of defence is operated either by a special "dazzle layout" or automatically when the target is illuminated by any type of searchlight layout normally used with active weapons of defence.

2. Requirements for dazzle. During the bombing run-up, the bomb aimer is obliged to look in the direction of his objective for 20 to 30 seconds. If a searchlight placed within a few hundred yards of his objective is exposed exactly on the aircraft, the bomb aimer will be unable to see the ground within about 1,000 yards of the searchlight. In addition, if he looks at the searchlight, which he must do during the run-up, he will be blinded for 5 to 10 seconds.

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3. Merely by exposing a searchlight beam exactly on the aircraft as it approaches the L.B.R., therefore, accurate bombing can be prevented and a second run-up may even be necessary. The sooner the searchlight beam exposes, the greater is the effect. The bomb aimer's judgment will be more impaired if the tiring and irritating effect of the dazzle lasts for any length of time. The pilot will be hampered and have difficulty in reading his instruments when dazzled, but this is not serious unless the aircraft is flying low. The pilot of the low flying aircraft, if suddenly dazzled, may lose control and cause the aircraft to dive and crash.

4. The first requirement from searchlights to bring about this dazzle effect is that at least one searchlight near the bomber's objective is exposed and held exactly on the aircraft. If the accuracy of the bombing is to be affected, the bomb-aimer must be dazzled as early as possible before, and up to the moment the bombs are released. The second requirement is that several beams must engage at the same time to ensure that at least one is accurately and effectively causing dazzle. The dazzle effect of one beam is substantially lost if it is even 1° off the target.

5. Once the bombs have been dropped, the effectiveness of this type of defence is reduced, and it is, therefore, stressed that, to obtain the best results, the crew of the bomber must be dazzled before the bombs are dropped.

6. It will be realised that the effects of dazzle on the bombing accuracy will not be so marked if the V.A. is large, or if pattern bombing tactics are being employed. Dazzle is most effective where the V.A. is small and where very accurate bombing is required to do damage.

7. Layout and equipment. With searchlights employed to assist Heavy and Lt A.A. guns as described in this pamphlet, the dazzle will automatically occur if the searchlights fulfil their role and illuminate the target.

8. Where a V.A. is defended by a searchlight layout designed for use with Lt. A.A. only, the searchlights form an effective "Dazzle layout" against a high level attack out of range of the Lt. A.A. guns. Even if there is no H, A.A. gun defence available, effective dazzling of the high flying raiders will minimise the accuracy of the bombing. For this reason, a proportion of the searchlight stations in a close spaced layout should include S.L.C. equipment.

9. Accurate dive bombing at night may be effectively countered by means of a special dazzle layout consisting of three to six searchlights placed 200 or 300 yards apart round a V.P. (if S.L.C. locators are to be used to direct these searchlights they may have to be line-locked to avoid mutual interference.) If required, a dazzle layout may be deployed inside an existing layout, or some of the stations of a normal illuminated area specially sited near V.Ps so as to form a dazzle layout. Dazzle sites should not be arranged geometrically around a V.P., or they will provide an aiming mark for the bomb-aimer. The siting of these positions may be combined with the principles of deception.

10. Where a dazzle layout is employed, it is essential that the position of the stations are moved at frequent intervals, otherwise the enemy may quickly use it to his own advantage in finding and bombing his objective.

CHAPTER XI.

MISCELLANEOUS USES.

35 - A.A. Searchlights in a Coast Artillery role.

1. The searchlight role. Searchlights may be employed in close support of Coast Artillery guns against such targets as enemy M.T.Bs., landing craft and submarines operating in coastal waters.

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The tactical roles are broadly as follows:-

(a) Observation lights. To detect the approach of hostile craft and to give early warning.

(b) Fighting lights. To illuminate individual targets for the particular guns to which they are allotted.

(c) Illuminated area lights. To illuminate areas through which hostile craft cannot pass without being detected.

2. Layout and siting. Siting will depend on the gun layout ordered by the Defence Commander, but in general, searchlights will usually be sited in groups of not less than two, so that continuous action can be maintained during carbon changingor breakdown.

3. Individual searchlights must be sited as close to high water level as possible to give:-

(a) the greatest area of surface illumination and greatest range at the minimum depression of the projector, and,

(b) uninterrupted search over the entire are without masking by rooks etc.

4. Equipment. The standard A.A. 90 cm projector is used and is either hand controlled, or fitted with control gear for remote control.

5. Operation. On warning of the approach of hostile craft, the observation lights will expose. These have two roles:-

(a) as sentry beams exposed on a fixed bearing, through which the craft must pass, or

(b) as search beams searching the channel or area inland of the sentry beam.

Observation lights are given arcs of search which will overlap to ensure that the whole area is covered.

As soon as a target is picked up, the fighting lights will illuminate and follow it for sufficient time for it to be engaged by the guns. Fighting lights, normally allotted one to each gun, may be exposed either in focus to give maximum illumination and range, or dispersed in the case of a close target moving at speed.

6. Illuminated area lights will expose on a fixed bearing with dispersed beeams, thus permanently illuminating large areas through which hostile craft must pass. This reduces the possibility of targets being lost by fighting lights after the initial pick-up owing to evasive action, low visibility or high speed.

7. Communications. Each group has a Searchlight Directing Station with which it is in communication, and from which orders to expose or douse are given, and information and warning of approach are passed. Remotely controlled projectors are controlled from this station.. Each directing station is under the control of the main Command Post which will receive warning of expected attacks and any other information available from higher command.

36 - Homing beacons.

1. Object. The object of "Homing beacons" is to direct friendly aircraft to their own or other airfields by means of searchlight beams when, for any reason, they are unable to find an airfield in the normal manner.

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2. Friendly bombers returning after action over enemy territory with their radio equipment damaged often require the assistance of homing beacons.

3. The searchlight role. The standard signal given by searchlights to home distressed aircraft is as follows:-

(a) the beam is exposed as nearly horizontal as possible for a period of 30 seconds in the direction of the selected airfield;

(b) the beam is then elevated to 45° and depressed again three times, as fast as possible;

(c) it is then left exposed for another 30 seconds as nearly horizontal as possible;

(d) the procedure is continued until the aircraft is flying in the direction and the beam remain exposed until the sound of the aircraft had died away, or for a period of 2 minutes, whichever is the longer.

4. Calling for homing beacons. A distressed aircraft may call for homing beacons either "directly" or "indirectly".

(a) "Indirect" or "Normal" calls for homing. The Air Force Control Liaison Officer or equivalent may call for homing beacons on receipt of information that an aircraft is in distress and requires to be homed. The order will be passed to searchlight stations through the normal channels of communication.

(b) "Direct" calls for homing. In order to obtain homing beacons, the pilot will:-

(i) cause his aircraft to circle for at least two minutes, AND

(ii) switch on his navigation and downward recognition lights, or fire the combination of coloured lights of the period, or use a combination of both these signals.

37 - Intersecting cones to indicate airfields.

1. Object: Searchlights may be called upon to supply an intersection of beams directly over an airfield to indicate the position to aircraft.

2. This procedure is used to assist in landing aircraft under conditions of poor visibility.

When the intersection is required, the searchlights merely expose on predetermined angles of bearing and elevation to form a cone over the airfield, and maintain it for as long as may be required.

38 - Balloon barrage warning.

Searchlights near the edge of a balloon barrage may be called upon to provide a warning to a friendly aircraft of the exact position of the barrage. This is accomplished by predetermined searchlights exposing on, and illuminating the balloons.

39. - Bomber rondezvous beacons.

1. The use of searchlight beacons will materially assist the concentration of bomber aircraft into a small area over a selected point on their outward track.

2. When such beacons are required, they are provided by one or more searchlights. These "bomber rondezvous beacons" will be exposed either vertically or intersecting. Beams may flash a code in order to identify themselves to approaching bombers.

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G L O S S A R Y

A.A.L.M.G.	-	Anti-Aircraft Light Machine Gun.
A.D.G.B.	-	Air Defence of Great Britain
A.I.	-	Air Interception.
B.H.Q.	-	Battery Headquarters.
Catseye Aircraft	-	Aircraft not equipped with A.I.
G.C.I.	-	Ground Controlled Interception.
G.D.A.	-	Gun Defended Area.
G.L.	-	Gun Laying.
G.O.R.	-	Gun Operations Room.
H.A.A.	-	Heavy Anti-Aircraft Guns.
I.F.F.	-	Identification Friend or Foe.
Lt.A.A.	-	Light Anti-Aircraft Guns.
L.B.R.	-	Line of Bomb Release.
S.S.C.	-	Sector Searchlight Controller.
S.L.	-	Searchlight.
S.L.C.	-	Searchlight Control.
T.H.Q.	-	Troop Headquarters.
V.A.	-	Vulnerable Area.
V.H.F.	-	Very High Frequency.
V.P.	-	Vulnerable Point.

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SEARCHLIGHT-AIDED FIGHTER INTERCEPTION

CHAPTER I - OUTLINE OF THE SYSTEM

1. Outline of the System

1. The basis of all present systems of searchlight aided fighter interception is that a fighter aircraft, operating from a relatively fixed position in space, uses an intersection of searchlight beams to guide him to the bomber which he is to intercept. It is convenient to fix the fighter in space initially for example by making it orbit a vertical searchlight beam at a suitable radius. A fighter pilot, setting off from his orbit beacon to make an interception, directs his aircraft continuously at the intersection of searchlight beams engaging the bomber and in this way he describes a curve of pursuit which will ultimately bring him dead astern of the bomber. He can also to a limited extent adjust his height by observation of the intersection as he approaches it. Assuming that he has a command of speed over the bomber, he will eventually overtake it.

In the case of aircraft not equipped with A.I. (i.e. Catseye fighters) the fighter relies on the actual illumination of the bomber by the searchlights for the purpose of getting within range and firing. Where A.I. equipped aircraft are employed, the fighter may make use of the searchlight intersections to obtain an A.I. contact and then conclude the interception either in the dark or with the aid of the searchlight beams, according to the circumstances.

2. The principal merits of searchlight aided fighter interception are as follows:-

(a) It can be employed in large or small areas

(b) It is effective either in advance of or in the neighbourhood of the V.A.

(c) It can be employed without an elaborate system of ground communication or intricate apparatus. It may even be worked without an air raid reporting system.

(d) A number of fighters can be employed in making interceptions at one and the same time.

(e) Interception is quick

(f) Single engined and non A.I. fighters may be employed.

SEC. 2. BASIC REQUIREMENTS.

1. There are several different methods of operating the system but there are certain basic requirements common to them all. These requirements are:-

(a) An area of S.L's so placed that the raids will cross it.

(b) Night fighters suitably positioned and controlled.

(c) A control centre with access to an early system.

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CHAPTER II - THE INTERCEPTION AREA

3. Location of the Area.

1. It is desirable where possible to carry out interceptions in front of the area to be defended in order to destroy the bombers before they reach the V.A. and to avoid the danger of confusing the guns at the V.A. by the presence of fighters. To this end the interception area over which fighters are to operate will be laid out so as to form an obstacle through which the enemy bombers must pass in order to reach the V.A. In many cases the S.L's of the interception area will merge into the S.L. layout covering the V.A. itself - in others there may be a gap between the rearward edge of the interception area and the outer edge of the gun zone.

2. Where there is sufficient equipment, and the topography permits, the interception area should surround the V.A. in order to defend it against attack from any quarter. Where this is not possible it should be sited to cover the line of approach most favourable to the enemy; but it will be of little value if it is possible for the enemy to avoid it easily and without detriment to the success of his attack. Alternative forms of defence e.g. G.C.I./A.I. should be concentrated in areas, such as the sea approach to a port, where it is only possible to employ a S.L. aided interception on the landward side.

3. The interception area may be sited well forward so as to cover several G.D.A.s at the same time.

4. Shortage of S.L's or topographical considerations may preclude a sufficient depth of area to permit of interception in front of the objective. In such cases S.L's and fighters may be employed successfully in a "Combat Zone" immediately around and, in some cases, over the V.A. itself.

5. To summarize: the following factors must be taken into consideration when deciding upon the location of the interception area.

(a) Importance of intercepting bombers before they reach the V.A.
(b) Risk of fighters getting into the gun zones and causing restriction of fire (Sec. 10. 4).
(c) Possibility of the enemy being able to 'turn' the defence without much inconvenience.
(d) Likely lines of approach, taking into account the position of enemy aerodromes and likely navigational pinpoints.
(e) Proximity to each other of a number of V.A's., suggesting either one long interception area or several small local ones.
(f) Number of S.L's available.
(g) Distance of night fighter aerodrome from the orbit points (it is should be limited to 45 miles for twin engined fighters and 30 miles for single-engined).
(h) That in an interception area well forward, the raiding aircraft will probably be more dispersed than in the immediate approaches to the V.A. and that therefore the S.L's will be able to engage a greater number of aircraft in the forward area. (Sec. 10. 1).

(i) That a S.L. interception area can be moved with relative ease and speed. A S.L. detachment given roads reasonably free from traffic, can move about 50 miles and reconnoitre and occupy a new site between dawn and dusk on the same day.

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4. Dimensions of the Area and Positions of the Orbits.

I. For interception areas in advance of the V.A., the factors which have been taken into account in arriving at actual figures are as follows:--

(a) Total time taken for the interception.-It is of cardinal importance that interceptions should take as little time as possible. This is so firstly because long stern chases greatly reduce the number of interceptions that can be made by an aircraft within a given time. Secondly it is in all cases important, and in some essential, for the bomber to be destroyed before it has reached its objective. And thirdly where fighters not equipped with A.I. are being used, the interceptions must be concluded before the bomber has passed out of the illuminated area. The interception time depends only partly on the command of speed of fighter over bomber. This in any case will be relatively fixed for the fighters available and the bombers commonly in use by the enemy. The two other factors affecting the problem of the time taken to intercept and return to orbit, are the positioning of the orbits, and the selection by each fighter only of those raids which he is in a better position than any of the others, to intercept.

(b) Visibility of searchlight beams. In most procedures for operating the system, the interception is begun as a result of an observer (who may be the pilot of the fighter aircraft or who may be a person on the ground near the orbit) seeing the intersections of beams at the front of the S.L. area. The furthest distance that the observer will be required to see must not therefore be greater than the range at which a searchlight beam is visible. This range varies enormously with atmospheric and weather conditions, but 15-20 miles can be taken as a figure applicable in average circumstances.

(c) Lateral spacing of fighter orbits. For two reasons it is important not to place fighter orbits too close together.
Firstly, a convenient radius of orbit for a twin-engined fighter is five miles. This of course is only a guide to the plot and cannot be adhered to at all exactly. If fighter orbits are made to overlap to any extent there is the danger of collision between aircraft at the same height. For this reason the distance between two adjacent orbits should be not less than 12 miles (and should be preferably greater).
Secondly, the closer the orbits are together, the more likelihood there is of two pilots on adjacent orbits setting off to intercept the same raid, since each will be able to see intersections in the other's sphere of operation. This is a complication which it is important to avoid as far as possible.
On the other hand, the further apart laterally the orbits can be placed, the easier it is to cover the whole of a broad front against attack from an unknown quarter when few fighters are available.

(d) Distance between the orbit and the outer edge of the S.L. layout.-If this distance is too great, some of the outer edge S.L's will be wasted since an intersection may have to travel some distance before the fighter sees it under normal conditions of visibility. A further factor in the determination of this distance is that it is unwise so to position the orbit beacon that the fighter while on orbit flies over the S.L. initiating sites i.e. the two outer edge rows of lights (Sec.10.3). Unless I.F.F. is being received by these S.L's, the fighter may be engaged by them.
It must be borne in mind that the closer the fighter is stationed to the front edge of the S.L. layout the less likely are his interceptions to be "head-on". With "head-on" interceptions the pilot may have to make a sharp turn through as much as 180° in order to get behind the bomber and it is not easy to maintain A.I. contact during this manoeuvre. On the other hand the further forward the orbits are placed, the longer the stern chases are likely to be for any given command of speed of fighter over bomber. The greater the command of speed, the further forward can the orbits be placed with safety.

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(e) Depth of S.L's behind the orbit.-Obviously the greater the depth here, the greater the possibility in cases of small command of speed, choice of unsuitable raid and low visibility of S.L. beams, etc. that the fighter will still have a chance of catching his target. This however involves the employment of many more S.L's over a large area and it may be necessary to risk the loss of some targets in this way in order to keep the number of S.L's required down. In any case, where A.I. fighters are used they can kill beyond the S.L. area if they have obtained contact while over it. Where the interception area forms part of or is just outside the S.L. layout of the V.A., this depth behind the orbit is fixed by the V.A. layout.
A further consideration is the possibility of intercepting outgoing raids. Where the interception area is in advance of the V.A. it is possible when the ingoing raids have passed through, to move the fighters from the orbits placed for those raids (i.e. with the requisite depth in front and a smaller depth behind) to orbits having the requisite depth in the opposite direction for the interception of raids leaving the V.A. (Sec. 14.1(c)).

2. Empirical dimensions and orbit positions for interception areas in advance of the V.A. In order to intercept within the interception area every possible S.L. engaged raid, the overall depth of the area must be considerable (of the order of 30 miles). However, a high proportion of such raids can be intercepted using an area of more moderate dimensions. The following figures are suggested as a basis:-

(a) Lateral distance between orbit points - 12 to 14 miles.
(b) Distance between the orbit point and the forward edge of the S.L. layout 12 to 15 miles.
(c) Distance between the orbit point and the rearward edge of the S.L. layout - 6 to 10 miles.

If it is desired to vary these figures the following maxima and minima should be preserved for the reasons stated in para 1. The minimum lateral distance between orbit points must be 12 miles; the maximum is closely related to the overall depth of the S.L. layout. It should be not more than about two thirds of this distance and must be less if a high proportion of the raids is to be intercepted.
The minimum distance between the orbit and the forward edge of the S.L. layout is governed by the overall depth of the layout but should not be less than about 8 miles.
The overall depth of the layout should not be less than 18 miles for A.I. fighters and 23 miles for non-A.I. fighters, if it is desired to intercept at least 50% of the raids engaged by the S.Ls. The percentage of raids intercepted is largely determined by the overall depth of the layout (assuming of course than an adequate number of fighters is available).
For the theoretical considerations governing all these dimensions see further Artillery Training Volume IV Part III Pamphlet No.3.

3. Where the interception area is adjacent to or over the vulnerable area (Combat Zone).- Where for reasons stated in Sec.3 it is not practicable to establish an interception area in advance of the V.A., interceptions with the aid of comparatively few S.L's can be obtained in the neighbourhood of the V.A. itself. The size of the S.L. area will depend on the resources available and the topography of the V.A. and may vary from a belt 8-9 miles deep round the V.A. (or covering certain approaches to it), to a small group of no more than 6 S.L's situate round the V.A. itself. It may even be profitable sometimes to deploy a few S.L's and a fighter on orbit to cover only a particular approach to the V.A which is specially favoured by the enemy.
Where H.A.A. guns are deployed at the V.A. the fighters must orbit outside the G.D.A. to ensure that they do not come within range of the guns while on orbit. In order to operate successfully at a large V.A. they should have a minimum depth of 5 or 6 miles of S.L's in front of the orbit point. In certain cases a circular orbit will take them out over the front row of lights and therefore they must do instead a figure of eight behind the orbit or fly on a short patrol line near it. Where there are no H.A.A. guns at the V.A. the fighters may be stationed on an orbit located in the V.A. itself.

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The indications given by the S.L. beams will enable the fighters to make A.I. contact before the enemy aircraft has left the illuminated area in in cases before it reaches the V.A. though its destruction may not be achieved until after the bombs have been dropped. Because of the narrow depth of SL's only A.I. fighters should be used in a combat zone.

The actual positioning of the orbits in Combat Zone does not present a serious problem since, unless the V.A. is very large indeed, every bomber intending to bomb the V.A. must approach sufficiently close to an orbit placed anywhere between the bombers and the V.A. However, depending on the direction from which the raid is approaching, certain positions for the orbits will be more suitable than others and it will usually be convenient to establish a number of alternative orbit points to be manned to meet the prevailing direction of attack. It should seldom be necessary, except in the case of a very large Combat Zone, to man more than two orbits at any one time and very often one orbit will be sufficient. There may, of course, be a number of fighters on each orbit manned.

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CHAPTER III. - THE FIGHTER

5. Types of Aircraft.

1. A.I. and Catseye aircraft. - Any fighter aircraft capable of operating by night can be used with S.Ls provided that its performance is such as to give it a command of speed over the bombers it must intercept. It is preferable for the aircraft to be equipped with A.I. since, not only can they operate in all conditions suitable for catseye fighters, but they also can be used in circumstances where catseye fighters would be useless. For example, in conditions of cloud where S.L. beams cannot penetrate sufficiently to provide illumination of bombers above the cloud, the A.I. fighters can obtain a contact with the aid of the patches of light formed by the S.Ls on top of the cloud and can then proceed without further reference to the S.Ls are able to provide intersections near the target but are unable to produce sufficiently consistent illumination for visual shooting by the fighter.

It has been found in practice that catseye fighters can operate with success when there is not more than about 4/10 cloud below or at the height at which they are operating. A.I. fighters can operate over as much as 10/10 cloud provided it is not so dense or so high that the illuminated patches produced by S.L. beams are too faint to provide assistance.

With a 'thin' type of layout e.g. Combat Zone, the extent of the S.Ls may not be sufficient to permit of interception taking place within the illuminated area. In such cases it is sufficient if the A.I. aircraft can obtain contact with the aid of S.Ls and finish the interception by A.I. after the target has passed out of the S.L. area. When operating with A.I. aircraft it must be remembered that while the crew are using the inter-com system it is not possible for the ground control (or any other aircraft) to communicate with them by R/T. With most types of A.I. the inter-com is in use constantly while an A.I. chase is in progress and therefore no message can be passed to the aircraft once it has obtained A.I. contact. With certain types of A.I. the inter-com is not used and the above restrictions do not apply.

2. Single and twin-engined aircraft. - The twin-engined night fighter is best for working with S.Ls. It has better forward visibility than the single-engined fighter and usually more powerful armament. It has longer endurance in fuel and ammunition than the single-engined aircraft and this is a great advantage in night operations where raids are often so short that an aircraft has not time to re-arm and re-fuel during the raid and must make all its interceptions on one sortie.

On the other hand, the single-engined fighter is a perfectly suitable aircraft provided it can operate at night and conditions are suitable for S.L. illumination. There is no reason why suitable day fighters should not be used for this purpose where their other commitments allow and by this means both S.L. aided and G.C.I./A.I. interceptions can take place simultaneously even though there is only a limited number of night fighters available.

An advantage of single-engined aircraft over twin-engined is the greater speed with which the former can be got into the air. This is of particular importance where raids have developed without warning and there are no night fighters airborne. (Sec.14.I. (a)).

6. The Requirements of the Fighter.

1. Stationing the fighter. - The most usual method of stationing the fighter is to provide it with a vertical S.L. around which to orbit. It must be possible for the pilot to distinguish his orbit from others in the layout in order that he can locate it when first sent up or when returning from an interception. (sec. 8. 4 and Sec. 10.7).

An A.I. beacon can be used as an orbit beacon in place of a S.L. beam if A.I. equipped fighters only are operating This is particularly useful in the case of Combat Zones where very few S.L.s may be available. (Sec. 4.3. and Sec. 18).

2. Command of speed - In view of the fact that there can be no

absolute command of speed of fighter over bomber, but only an average command, it is desirable artificially to increase the fighter's command of speed by stationing it initially at a greater height than the bomber it is to intercept - between 2 and 5,000 ft - according to the reliability of the information availibility of the information available and the requirements of individual pilots.

3. The searchlight intersection. - The engagement of the bomber by S.Ls must be begun as soon as possible after it comes within range of the outer lights in order that the pilot may set off to intercept without any delay. Once the engagement has begun, it must be maintained continuously with a minimum of three beams on the target all the time. An optimum number is between 3 and 6. Any greater number tends to make the intersection unduly large and renders it difficult for the fighter to approach for the kill without himself being illuminated for some seconds before firing.

The majority of the beams on the target should come from sites forward of it. Beams exposed from the rear of the target create a lighted area behind it and make it more difficult for the fighter to approach unseen. Moreover, the harassing effect on the bomber crew is much greater if beams expose forward of the aircraft than if the bomber pilot receives the impression that he is flying away from the lights.

4. The engagement interval. - In order to enable the fighter to distinguish between one intersection and another, a definite minimum interval in miles must be preserved between S.L. engagements. On the other hand, the interval should not be exceeded unless low raid density makes this inevitable, otherwise the maximum number of engagements will not be obtained. The smallest interval at which pilots can discriminate will depend partly on weather conditions affecting the visibility of S.L. beams and partly on the experience of pilots. In any case the interval should not exceed 15 miles or be less than 8.

The interval must be preserved as far as possible as the targets fly through the area and if two engagements converge too close it may be necessary to abandon one of them. This should be avoided for as long as possible otherwise the system may be defeated by lateral evasive action on the part of the bombers or an interception may fail owing to the disappearance of an intersection already chosen by a fighter.

In normal circumstances engagements should only be initiated at the front edge of the illuminated area. Indiscriminate initiation within the area may confuse the fighters by causing them to attempt interceptions of targets which they are not able to overtake in the time and space available.

5. Dousing of searchlights by fighters - There may be occasions when a pilot requires the S.Ls to discontinue an engagement. These may occur either if the S.Ls are engaging the fighter by mistake or if a fighter equipped with A.I. has obtained a firm contact and desires to finish the interception in the dark. In such cases the fighter may signal to the S.Ls by pre-arranged code on his downward recognition light and in certain circumstances he may also be able to produce the required result by calling the Control Centre by R/T. The latter will only be possible where the particular S.L. engagement can be identified at the Control Centre and this will depend on the procedure in use (Sec.17.4.). Even in this case the downward recognition light should always be used as well as its effect is quicker; but the pilot must remember that it may not always be seen from the ground, particularly if the aircraft is not on an even keel.

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CHAPTER IV - THE SEARCHLIGHTS

7 - Layout and Siting of the Searchlights.

1. Spacing is determined by the number of beams required on each target and the numbers of targets it is required to engage in a given area. The two requirements laid down in Sec.6.3 and 6. 4, namely that a minimum of 3 beams and a maximum of 6 is required on each target and that there shall be a minimum distance of 8 miles between engaged targets, fix 6,000 yards as the spacing of the searchlights. At this spacing it is possible to engage targets 8-10 miles apart with 4-5 beams on each when these targets are at the height usually encountered, i.e.8-12,000 feet. If the spacing is more open, either fewer beams are available for each target if at the minimum interval of 8 miles or by preserving the requisite number of beams on each target, it will be impossible to engage raids closer than 12-15 miles and so the available fighters may not be continuously "fed". 6,000 yd spacing is therefore economical, meets the requirements, and ensures that the maximum number of raids can be engaged. This spacing fixes one light to 9 or 10 sq. miles.

2. It is shown in Sec.4 that the minimum overall depth of the S.L. area is 20 mile and that the width of the area required for each orbit point is 12 miles. The smallest "unit" area of S.Ls is therefore 240 sq. miles and a belt or zone is an area composed of a number of these units placed side by side. The Number of S.Ls required for the area is consequently the number per unit multiplied by the number of units used. On 6,000 yd. spacing there will be about 24 lights in a unit. Where it has been found necessary by reason of shortage of S.Ls to shorten the depth behind the orbit, calculation will give the number of S.Ls required or, alternatively the depth and width it is possible to produce with a given number of S.Ls.

3. After fixing on the map the boundaries of the S.L. area, the sites can be pinpointed at 6,000 yd. intervals in equilateral triangles. Where the map is divided into 10 km. squares, the pin points for a lay-out of straight rows are at 0050, 2500, 7500, 5050. It is immaterial however whether straight rows are adhered to or the rows are curved to suit the shape of the layout.

When the sites are chosen on the ground, it will usually be found that the exact pin points, for reasons stated in para. 4 below, cannot be adhered to. Tolerance up to 1,000 yds can be permitted provided the other sites are so chosen that the distance between any two sites is not greater than 7,000 yds. nor less than 5,000 yds.

It is permissible to omit odd sites for topographical or other reasons provided that no two adjacent sites are omitted and provided the neighbouring lights are "closed in" slightly to minimise the gap.

4. There are technical considerations affecting the siting of all types of S.L. locators and these are dealt with in A.A.S.I. Drills, 1940, and Supplements. In addition to these considerations there are two tactical requirements in the siting of equipment:-

(a) Sites on the outer edge of the layout and rearward edge of the interception area must be chosen so that long range detection is possible - e.g, in the case of S.L.C., free from ground breaks. This rule should apply to the 2 rows of lights forming the boundary of the area since it is these lights which must secure initial early pick up from whichever direction the enemy aircraft enters.
(b) Where possible, all inner lights should be so sited that detection is easy in the direction from which incoming targets may be expected.

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6. Signals from searchlight sites - During operations certain visual signals will be given to the orbiting fighters by a beam on the orbit site (Secs.16.1. (a) 16.2. (a). Sec. 17 1.). Where fighters are operating near G.D.As, it may be desirable for S.Ls on the perimeter of the G.D.A. to employ a distinctive method of engaging incoming targets in order to indicate to fighters that they are coming within range of the guns. (Sec. 18.4). This method may consist of certain sites engaging incoming targets with occulting beams. All S.L. sites should be prepared at any time to indicate with the beam the bearing of the base aerodrome in order to assist fighters who require homing.

7. Responsibilities of the pilot. - It will be seen (Sec.16.1) that the successful operation of the system depends to a high degree on the careful observance by the pilot of certain simple rules. The essence of any procedure employed in the interception by pilots only of those raids which they are suitably placed to take on. Unless pilots fully understand and observe the procedure under which they are operating, interceptions will frequently take much longer than they should or may fail altogether; while the risks to the fighters themselves will be unnecessarily increased.

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8 - Equipment.

1. Projectors. 90 cm projectors are perfectly suitable for this work, though 150 cm projectors have a slight advantage in producing a smaller area of light around the illuminated bomber. It must be borne in mind that two 90 cm. projectors are required on each orbit site in addition to the operational light. (Sec.16.1(a), 16.1.(b),17.1) These may be dispensed with in an emergency, but with some loss of efficiency.

2. Locators. 80% to 100% S.L.C. is a virtual necessity unless A.1 fighters are used, in which case the number of S.L.C. Locators might fall to 50% without seriously affecting results. (There is no mutual interference between S.L.C. sets over 5,000 yds. apart).

3. Visual Control Pillars, should be used on all sites if sufficient numbers are available. If only a proportion of sites can be so equipped, they must be evenly distributed over the area, i.e. not grouped.

4. Disposition of Equipment. Where visual control pillars are in use, the available S.L.C. should be concentrated in the outer edge, particularly the outer edge over which incoming raids will pass, so as to ensure initial pick up, after which the inner visual control pillar sites should ensure that the target is never lost, provided atmospheric conditions are good. Where visual control pillars are not available, a certain proportion of the S.L.C. equipment should be on the inner sites, otherwise the target would be frequently lost. Sound locators must be used on sites where no S.L.C. is available or where S.L.C. is unworkable.

5. Occulting Shutters must be fitted to orbit beacon projectors and to any others required to give certain information to fighters. If they are not available, coloured screens to fit over the front glass of the operational light are required at each orbit beacon site. The colour of such screens must be different for any two adjacent orbits. In the absence of any of this equipment paraffin flares may be used. (Secs. 6.1., 6.6., 10.7.).

6. Site Computers are required on one site in three where line communications exist from these sites to some central control room and where it is intended to use S.L. plots in the interception process, (Sec.17).

9 - Communications

1. Where line communications can be installed between selected S.L.sites and a control centre, it will be possible to provide the Searchlight Sector Controller with plots of S.L. engaged raids whereby he can employ improved methods of control (Sec.17). These plots are computed from angles taken from the equipment at sites every 10,000 yds throughout the area i.e. from one site in every three on 6,000 yds spacing. The use of plotting sites at greater intervals would not produce continuous plotting. Lines are therefore required from 8 sites out of the 24 in each battery to the Battery H.Q. and from each Battery H.Q. to some central room (preferably near or in the Control Centre) where they can be collated and passed to the Control Centre for reproduction on the S.S.Cs map. (Sec.13.1). This calls for about 55 miles of line in each battery. These lines can also be used for the downward transmission of instructions, states of readiness, advance plots, and other information from the Control Centre to the sites on the lines.

2. Where there are no line communications between sites and battery H.Q. there will usually need to be R/T communications between B.H.Q., and one site in every six (the Troop H.Q.). This must be regarded as the absolute minimum of communications although it will be shown later (Sec.10) that the system can operate though with reduced efficiency, without any communication to S.Ls. whatsoever, other than line or R/T to the orbits. This minimum, however, is really required for early warning of approach of raids. Early warning can be passed by line or R/T from Control Centre to the B.H.Qs., thence by R/T again to the T.H.Qs., and thence by visual S.L. signals using the beam, to the remaining sites. It is essential that the orbit sites have line or R/T communication to them or that sites with communications are specially chosen as orbit sites.

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10 - Operation of the Searchlights
(See also A.A.S.L. Drills 1940 Supplement No.4(1943)

1. The actions of the S.Ls are settled by two important rulings laid down for night fighter interception (Secs.6.3 and 6.4).

(a) That there must be a minimum interval between S.L. engaged targets of about 8 miles.
(b) That there must be a minimum of three beams on each target and a maximum of six. (This requirement fits in with requirement (a), since, on 6,000 yd spacing it is impossible to engage targets closer than about 8 miles and still keep 4 or 5 beams on each).

It follows therefore that if incoming raids are closer to each other than about 8 miles, some will be engaged and others will have to be ignored by the S.Ls in order to preserve a continuous engagement with 4 or 5 beams of these targets which were initially selected as over 8 miles apart.

2. Rules must be given to S.L. Detachment Commanders both on the outer edge where engagements are initiated and inside where engagements are merely continued, which tell them which targets to engage, and also when to engage and when to disengage. If such rules are properly applied by the Detachment Commanders, the requirements as to S.L. engagements can be satisfied in the absence of any higher control or communications from above.

3. Selection of Target . The two outer edge sites all round the S.L. area must engage all hostile targets except where a new target, if engaged, would be closer to an engagement already initiated by neighbouring sites than the minimum interval prescribed. To achieve this all outer edge sites will search for hostile targets by facing outward from the layout. All the remaining inner sites will engage only those targets already being engaged by other beams.

These rules are sufficient in themselves to satisfy the requirements without the appointment of a higher controller; i.e. the Detachment Commander is here the sole tactical executive. It may prove advantageous however to have Troop Commanders at O.Ps. on the outer edge and in R/T communication with the other outer edge sites, to assist in preserving the initiation interval in high density raids by ordering Detachment Commanders to disengage a target too close to one already accepted. Where line communications exist from 8 sites in the Battery to Battery H.Q. and S.L. plots are being passed to B.H.Q., a S.L. controller there, seeing the plots of all engagements as soon as they are initiated, can order Detachment Commanders to disengage where necessary.

These rules further ensure that additional initiations will not occur inside the S.L. area, i.e. too close to the orbiting fighter (Sec.6.4). Engagements usually travel 2 or 3 miles before the intersection "hardens" and the target becomes steadily illuminated. Thus if attempted too close to the orbit, initiations inside the area will only confuse the fighters.

A further valuable result of these rules is that fighters will not be engaged by the S.Ls. provided they keep inside the outer edge of initiating sites, since the inner lights over which the fighters will be operating only engage targets already being engaged. This advantage is apparent where the fighters carry no I.F.F. or it is not being received, or Sound Locators are being used.

4. Engagement and Disengagement. There are two methods of ensuring a steady 4 or 5 beams on a target as it crosses the area and these two methods both answer the Detachment Commander's problem as to when to engage and when to disengage.

(a) By counting the number of beams already on the target and judging whether by exposing his beam he will be at a higher angle than the lowest beamalready on. This method is difficult to apply and is not recommended.

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(b) By exposing and dousing at fixed, predet rmined angles of elevation. This method is extremely easy to operate; its drawback is that different target heights will produce different numbers of beams on the target. In practice this is not a serious objection and it is found that on 6,000 yds spacing, exposing and dousing at 25° elevation will put 4 - 5 beams on targets which are at heights of 9,000 to 11,000 ft.

5. Termination of Engagment. There are occasions when it is necesssary to terminate an engagement.

(a) A fighter may want the beams doused. (Sec.6.5). Where they are communications from the Control Centre to all sites as e.g. line to Battery H.Qs., line thence to Troop H.Qs and R/T thence to sites, one method by which a fighter can get the beams doused is to ask the Control Centre by R/T. The S.S.C., if he can identify the engagement from S.L. plots, then passes the order to the S.Ls. Where these communications do not exist (and also where they do), the pilot must signal for douse on the Downward Recognition Light.

(b) When, in the case where S.L. plots are displayed before the S.S.C., he sees that two engaged targets are converging too close and decides to discontinue one of them. He will decide which engagement must be continued and pass the order to the S.Ls. to disengage the other. For reasons stated in Sec. 6.4., this termination of an engagement must be done as infrequently as possible.

(c) When, where S.L. plotting is not in force, a Detachment Commander or a Troop Commander at an O.P. sees two engaged targets converging too close. The decision as to which raid should be abandoned must be left to the Detachment Commander since, from observation of the time base (S.L.C.) he may be able to tell whether or not a fighter is approaching the raid he is engaging. Where there is evidenceof a fighter, he must continue that engagement to the exclusion of the other approaching target.

6. Specification of Raid Interval. To make certain that the S.Ls will meet the fighters' requirements in the matter of raid interval and numbers of beams on each target, the S.S.C. must lay down for them beforehand, the minimum raid interval at which engagements will be initiated at the outer edge. Where the interception area is close to the V.A. and raids are therefore likely to converge as they cross it, initiation should be limited to about 12 or 15 miles so that they will have converged to the minimum of 8 - 10 miles near the line of orbit, thus obviating the necessity for disengaging certain raids at this point - an uncertain procedure where S.L. plotting does not exist.

7. Signals from the Orbit Site. In order to enable the fighter pilot to locate his own orbit, the orbit beacon site must display a distinctive signal. This is done either by causing the orbit beacon itself to flash a morse characteristic with the aid of an occulting shutter or by exposing a coloured beam (in addition to the orbit beacon) produced by covering the operational projector with a coloured screen. The coloured beam by itself is not sufficient in average weather conditions. Where neither screen or shutter is available, the orbit beacon site can be rendered distinctive by the aid of a group of flares placed around the orbit beacon. In an emergency - and for a short time only - a morse characteristic can be flashed by exposing and dousing the orbit beacon itself. For tactical or other reasons any S.L. site with communications may be required at short notice to act as an orbit beacon site and must therefore be prepared to give the emergency signal described above. The second signal projector provided on each orbit beacon site is required for the purpose described in Secs.16.1. (a), 16.1 (b), and 17.1.

11. States or Readiness

1. Where no communications (either line or R/T) exist to any of the S.L. sites, detachments must rely on warning from an air sentry who detects or suspects hostile activity.

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2. It is possible to pass the Take Post or Stand Down signal from one site to about 5 other neighbouring sites by use of the S.L. beam as a Signal. Thus where Troop H.Qs. can receive messages from the Control Centre via Battery H.Qs. they can relay these to the rest of the troop by prearranged visual signals. The usual Take Post signal is to revolve the beam (at 70° elevation) at fast speed for 30 seconds in one direction then 30 seconds in the other direction, and to douse.

3. S.L. detachments need 3 to 5 minutes to get into action from being asleep undressed; and 1 minute from being asleep fully dressed. This indicates the degree of warning required from the Control Centre.

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CHAPTER V - CENTRAL CONTROL

12. - The Sector Searchlight Controller

The decision to use fighters on any given night; their allocation between SL and other forms of interception, and the decision where fighters will be operating near GDAs, on the relationship between the two forms of defence, will normally be made by the authority in command of the AA. Defence of the VA, who will issue a policy for the night. This policy will be implemented, so far as SL aided interceptions are concerned by an Officer called the Sector Searchlight Controller (SSC). The SSC may be either an RAF or an Army Officer. He must have a complete understanding of the procedure to be employed and of the capabilities and limitations of the system from the point of view of both fighters and SL's. In view of the extent of his duties in action he should have no responsibility during operations other than the conduct of SL aided interceptions.

In the direction and control of operations the SSC will have various functions to perform. Certain of these depend on whether or not the procedure in use employs plots obtained from SL's. Others are essential to the system and common to every procedure. (Sec. 14).

13. - The Control Centre.

1. The SSC will conduct operations from a Control Centre which may be either the RAF Fighter Operations Room or a GCI station. There are great advantages in using a GCI station, but if one is used, it is essential that its range should cover the whole of the interception area under the control of the SSC and that the equipment sweeps continuously over this area. It is highly desirable for the SSC to have a PPI tube at the GCI station for his exclusive use, but even if this is not feasible it may still be advantageous to use the station as the Control Centre.

The facilities required by the SSC at the Control Centre are :-

(a) Information - Information of the scale and direction of the attack must be continuously available to the SSC both before and during operations.

In the RAF Operations Room this will be available as plots on the information table, derived from RDF and other sources. It should include, where possible, the height of the raids.

At the GCI station it will be provided by the PPI tube and should be supplemented as to long range plots, identity and height by information from the operations room. Heights of specific raids can be found accurately at the GCI station.

(b) The SSC's Map - The SSC should be provided with a talc covered gridded map of the area he controls and on it should be marked the boundaries of the SI area and the positions and designations of the orbits. In the Operations room, or in a GCI station where he has not the exclusive use of a PPI tube, this should be of ½" scale. Where he has a PPI tube of his own the tube itself will be his map.

(c) R/T Communications and Fixing - V.H.R. communication to the fighters is essential and it may be desirable to have a R.A.F. Deputy Controller to receive and pass messages under the direction of the S.S.C. Whether the S.S.C. is able to conduct the R/T communications himself will depend on the nature of the raid and the number of fighters employed.

It must be possible to establish the positions of the fighters by voice fixing and these positions should be marked on the S.S.C's map when obtained This requirement applies to a Control Centre of either type; though when suitable I.F.R. equipment is fitted in the fighters it should normally be possible to identify individual fighters on the P.P.I. tube. It is most satisfactory for fighters to operate throughout on the frequency of the fixer stations. If possible this should be different from the G.C.I. frequency.

(d) Communications to Searchlights - These are used for the passing of orders and information from the S.S.C. to the S.Ls. and for the passing of S.L. plots, where available from the S.Ls. to the Control Centre. For the latter, communications must be by line, but R/T may be used for the former. S.L. plots arriving at the Control Centre will usually be marked on the S.S.C's map with chinagraph. (Sec. 17).

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14. Essential Functions of the S.S.C.

1. The disposition of fighters. Once aircraft have been allotted to the S.S.C. in accordance with the policy for the night, it is his responsibility to get them on orbit in time to meet the raids, and positioned where they will be most effective. He must also change his dispositions during the battle if circumstances require, and, if necessary, withdraw fighters which may be of greater value at a later stage in the operations.

(a) Ordering off fighters. After a warning of hostile aircraft approaching the area he must take steps to get his fighters to orbit either by bringing them first to a higher state of readiness or by ordering them off immediately according to the length of warning received. In this connection he must have due regard to the time it will take before they are airborne (according to the type of aircraft, the state of the aerodrome and the other traffic there) and also the time it will take from being airborne to being on orbit at the required height. Since the total time may be as long as 35 minutes for a twin-engined fighter, there will undoubtedly be many occasions when such aircraft cannot be got to orbit in time to meet the first raids. In such cases the S.S.C. must consider the advantages of ordering off his single engined fighters first (Sec.5.2). Where adequate warning is not possible and raids are of short duration it may be desirable to maintain standing patrols of twin-engined night fighters so that they can immediately be sent to orbit on warning of a hostile raid, approaching the area.

(b) Choice of orbits. The primary concern of the S.S.C. must be to destroy as many bombers as possible before they have dropped their bombs. Since it is doubtful whether the destruction of a bomber by a night fighter has much deterrent effect upon the remainder of the bombers in the raid or whether night fighters can break up or disperse a raid as can day fighters or gunfire, it follows that there is no intrinsic merit in keeping reserves either on the ground or in the air. A fighter with its limited fuel and ammunition can only shoot down a certain number of bombers on a sortie. The sooner these can be shot down the greater the chance that he may rearm and refuel, and return to the battle. The S.S.C. must therefore concentrate as many fighters as he can control, and the raid density warrants, on orbits in front of the V.A .. It has been found in practice that as many as 6 or 7 fighters can be controlled simultaneously. Obviously there is no object in using this number of fighters if the raid is so small or so concentrated that only two or three raids can be engaged by searchlights.

But if six fighters can be fully employed they should be sent to orbit irrespective of any raids that may or may not be following.

Where possible, orbits should be manned so that a line joining them is at right angles to the direction of the attack. If the interception area is extensive and the enemy is attacking over a section of it only, fighters should be concentrated in the path of the raid rather than spread thinly over all the orbits. In order to achieve this result and yet have fighters on them at one or more waiting beacons (either actual orbits or specially designated S.L's behind the line of orbits which are suitable points from which to deploy to any section of the area. As soon as the S.S.C. ascertains the trend of the raid the fighters can be switched to the appropriate orbits. It may even be profitable where there is a shortage of fighters to adopt this policy at the risk of fighters arriving on orbit after the first bombers have passed through the area.

To facilitate the manning of orbits and to deceive the enemy, all orbit beacons should be exposed whenever S.L's are to operate.

(c) Change of dispositions. As the battle develops it may become necessary to move fighters to different orbits to meet the changing direction of the raid. When the raids are leaving the target a stage will be reached when the S.S.C. may have to decide to move his fighters to orbits where they can intercept the outgoers (Sec.4.1 and 4.2). This move should not be delayed for the sake of the remnants of those still approaching the target otherwise four or five kills may be missed for the sake of one extra shot down before it can drop its bombs.

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In certain cases it may be profitable to land a fighter while a raid is in progress if by so doing the fighter can be rearmed and refuelled in time to meet a second wave. The only consideration which must govern such a decision is whether the fighter is likely to make more kills by meeting the new raid with a full supply of fuel and ammunition than he would by staying to deal with the raids at the moment over the area.

2. The Control of Fighters. This is exercised from the Control Centre by R/T. When ordered off, fighters should be able to find their orbits with the aid of a single vector (given to them if possible before they take off) and the distinguishing characteristic of the beacon (Sec.6.1). It may sometimes be necessary to assist tthem with further vectors where for example the weather is cloudy and the beacons are not easily visible. They may also require vectors to orbits at the end of an interception. These vectors will be determined with the aid of voice fixes or information from the P.P.I, tube and passed by R/T. Return to base is effected in a similar way. When on orbit fighters should be given information regarding the height of bombers and the direction from which they are to be expected. Care must be taken however not to jam the R/T. with messages which will interfere with operational instructions or reports; while fix transmissions and vectors must be kept to a minimum. The S.S.C. must also ensure that the fighters have the necessary command of height (Sec.5.2).

At all times the S.S.C. is responsible for the safety of the fighters under his control and must take every precaution to avoid unnecessary risks. He must therefore pay careful regard to the heights of his fighters on orbit and ensure that two fighters on the same orbit are never separated by less than 1,000 ft. He must also keep in mind their endurance, (particularly in the case of single engined fighters); the distance they must travel in order to reach base; and the possible delays that may occur before they can land.

The S.S.C. may also have certain important functions to perform in relation to the control of the actual interception. These vary with the procedure employed and are dealt with in Chapter VI.

3. Control of Searchlights. Where some form of communications exists to S.L's the S.S.C's functions are:-

(a) To order states of readiness
(b) To issue instructions to orbit beacon sites
(c) To specify the engagement interval and the number of beams required on targets.
(d) Where appropriate, to pass G.C.I. plots to the S.L's.
(e) To pass heights of raids when needed for S.L. plotting.
(f) To order the termination of an engagement when requested by the fighter or when two S.L. engagements have drawn too close to each other.

Where communications are few or non-existent, (a), (b) and (c) may be covered by the issue of standing instructions; (d); (e) and (f) will not apply.

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CHAPTER VI - INTERCEPTION PROCEDURE

15. Introduction.

1. The successful operation of the system depends on the degree to which it is possible to select the fighter best placed to intercept any given raid. Or, considering the matter from the point of view of an individual fighter, the problem is to select raids suitable for interception by him. The selection will depend on the course of the target relative to the fighter orbits and it is not possible to predict this with absolute certainty. Mathematically correct selection requires an elaborate procedure which is not practicable without a highly organised system of communications and is primarily designed for the defence of very large areas. (See Artillery Training Volume IV Part III Pamphlet No.3).

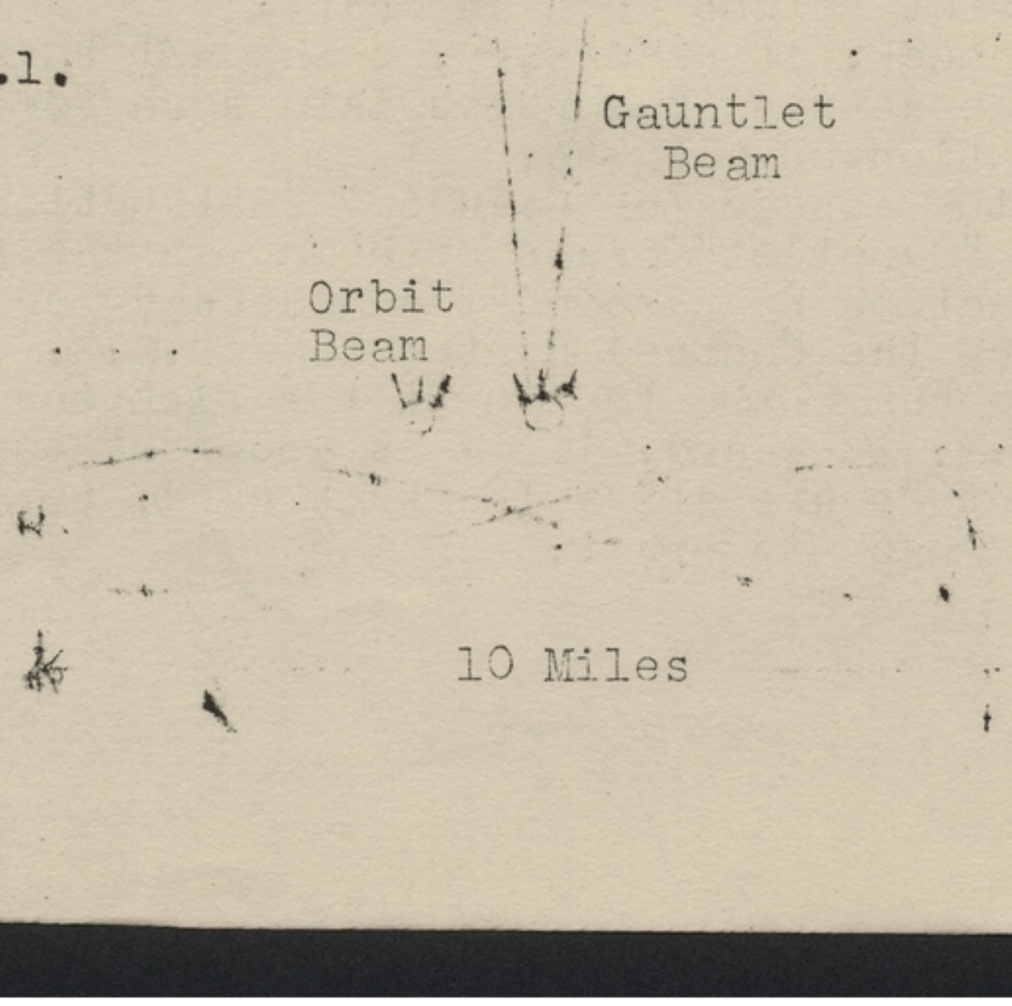
A practical approximation to the ideal can, however, be obtained by a number of procedures; and it will be remembered that even if the "correct" fighter is not selected, a fighter from an adjacent orbit will probably intercept though after a considerably longer chase. here it is possible to use S.L. plotting and to exercise control from a G.C.I. station, the system of selection thereby made possible can hardly be bettered. Since, however, S.L. plotting is likely to be the exception rather than the rule, it is convenient first to consider the procedures to be employed where it is not available. There are two alternatives; in the one case selection is exercised largely by the pilot himself and in the other by an officer stationed at each orbit beacon site. Where S.L. plotting is available, selection is exercised by the pilot subject to the overriding direction and control of the S.S.C. In all cases the control Centre may be either at the operations room or the G.C.I. station.

16. Procedure without Searchlight Plotting.

1. Selection by the fighter himself.

(a) Arrangements. This procedure is generally known as "Gauntlet". On the warning of hostile raids, the fighters are sent to their orbits and given a height at which to fly (Sec.6.2). They are told, either before setting off or by R/T when on orbit, the direction in relation to their orbits from which raids are expected. At the same time the second signal S.L. on the orbit beacon site (Sec.81) is exposed horizontally in this direction as a permanent guide to the pilot. The bearing of the beam may be defined in Standing Instructions but it is preferably detailed by the S.S.C. before or during operations. This beam is called the "Gauntlet" beam. When this beam is exposed, it is convenient for the pilot to cease doing a circular orbit and to fly a figure eight course (length about 10 miles) on the side of the beam is pointing. The sharp turns should be towards the direction in which the beam is pointing (See fig.1).

Fig.1.



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In this way he can maintain an almost continuous lookout for S.L. beams in the direction from which raids are approaching.

(b) Selection of the target. A pilot should confine his attention to an arc of a specified number of degrees on either side on the "Gauntlet" beam. This arc will depend on the depth of the belt in front of the orbit and will be arranged so that the arcs of adjacent orbits meet on the front line of S.Ls. Thus for a depth of 15 miles and orbits 12 miles apart the arc of each fighter will be approximately 35° on either side of the "Gauntlet" beam. This arc may be defined by earlier S.Ls on the front row of lights instead of by a "Gauntlet" beam.

If the pilot observes an intersection within his arc, he sets off to intercept and reports his departure by R/T to the S.S.C. giving the bearing and the estimated distance of the intercection from the orbit. He may, if he prefers, report the position of the intersection by means of the clock code, treating the "Gauntlet" beam as 12 O'clock. When a pilot has made a kill or has decided to abandon chase, he will inform the S.S.C. by R/T and, where necessary, will obtain from him a vector for return to orbit or base as the case may be.

If this procedure is followed, raids should be intercepted by the fighters best placed to do so provided that the "Gauntlet" beams are correctly oriented and the bombers are not making extensive changes of course.

(c) Economy of effort. Since all aircraft will be working on the same R/T frequency, all pilots will hear the reports of each other. By this means a pilot should know when another fighter from the same orbit has set off to intercept a particular raid and, in such case, the pilot on orbit should make no attempt to intercept the same raid. If desired, one of the pilots on orbit may be detailed to exercise a veto and to regulate the operation of the procedure.

There can be, however, no absolute certainty that two fighters either from the same or different orbits have not gone after the same raid and, therefore, a fighter must not open fire until he has recognised his target as hostile. With A.I. fighters a contact should be made within four minutes from leaving the orbit. After this time, if no contact is obtained, the pilot should re-orbit. In the case of Catseye fighters, a time limit should be fixed at the end of which, if the kill is not imminent, the pilot should re-orbit. In all cases fighters should obtain from the S.S.C. by R/T the height at which they are to return to orbit.

(d) Functions of the S.S.C. Under "Gauntlet" the function of the S.S.C. in the control of operations are :-

(i) To ensure that fighters are always at the correct height when on orbit.

(ii) To check, if necessary, using R/T that pilots are observing the rules laid down for the duration of a chase.

(iii) In the absence of Standing Instructions, to keep the "Gauntlet" beams pointing in the required direction by passing the necessary orders to S.Ls.

(iv) Where the Control Centre is a G.C.I. station, to observe the tracks of the fighters on the P.P.I. tube and, if it is apparent that two fighters are after the same raid, to send one of them back to orbit.

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2. Control from the orbit beacon site.

(a) Arrangements. This procedure requires a sub-control officer (the orbit officer) for each orbit point, who is stationed either at the orbit site or preferably on a hill or rising ground in the immediate neighbourhood. It is important that he should have good all-round visibility so that he can see intersections of S.L. beams in the distance. If he is stationed elsewhere than on the orbit site, he must have communication to it.

As in the case of "Gauntlet", each orbit has an arc of operation. This is not defined with reference to a "Gauntlet" beam but by angles of bearing from the orbit site. The arc is specified by the S.S.C. either in Standing Instructions or immediately prior to operations. The S.S.C. may change the arc during operations if the direction of the raid stream changes.

The fighters are disposed on their orbits by the S.S.C. and told the direction of approach of the raid. If there is more than one on an orbit, they will be given by R/T an order in which to intercept according to their priority in height on the orbit, the top one being given first turn. On being told that he is next to intercept, a pilot will commence a figure of eight "behind" the orbit as in "Gauntlet" (though in this case there will be no "Gauntlet" beam) and will wait for a visual signal from the ground. The S.L. projector used in "Gauntlet" to provide the "Gauntlet" beam is here used for the visual signal to the fighter and its beam is called the "Smack" beam.

(b) Selection of the Target. This is done by the orbit officer who, from his observation post, watches for the appearance of intersections within the arc of operation. As soon as he has selected a suitable intersection, he orders the smack beam to signal it to the fighter. The smack beam is exposed vertically for a few seconds and then depressed horizontally in the direction of the selected intersection. On seeing the smack beam expose, the fighter flies in to the orbit and, when it depresses, he flies along it towards the intersection which should already be visible to him. The smack beam is kept continuously pointing towards the intersection until it is apparent that the fighter has set off and it is then doused. When he leaves the orbit, the fighter informs the S.S.C. by R/T. The latter is thus able to change the heights of the remaining fighters if necessary and warn the fighter whose turn is next.

(c) Economy of effort. It is the duty of the orbit officer to ensure that only one fighter from his orbit sets off for any one intersection. The same rules as in "Gauntlet" apply to the duration of the chase.

(d) Functions of the S.S.C. The functions of the S.S.C. in the control of operations are:-

(i) To ensure that fighters are always at the correct heights when on orbit.

(ii) To check, if necessary, using R/T that pilots are observing the rules laid down for the duration of a chase.

(iii) In the absence of Standing Instructions to define to the orbit officers the arc of operation of each orbit site.

(iv) To detail to the fighters on orbit their turn to intercept.

(v) Where the Control Centre is a G.C.I. station, to observe the tracksof the fighters on the P.P.I. tube and, if it is apparent that two fighters are after the same raid, to send one of them back to orbit.

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3. Relative merits of the two procedures. Interceptions should begin earlier with "Gauntlet" because the pilot will usually see intersections before the orbit officer and he sets off before waiting for any visual signal. On the other hand, since the position of the orbit officer is stable, he is better able to judge whether an intersection is within the arc of operation than a pilot who is moving very fast and is seldom exactly at the orbit point. The orbit officer can also be certain that he does not send two fighters after the same raid.

With control from an orbit site, the procedure is on the whole simpler for the pilot because, although he has to watch for and obey the signal of the smack beam, he is relieved of the responsibility of choosing his intersections and of checking those he sees against the reports of the other pilots. On the other hand, problems of personnel, communications and topography may make the system impracticable.

17. Procedure Using Searchlight Plotting

1. Where S.Ls. are able to pass plots of engaged raids to the Control Centre, these will be marked on the S.S.C's map and used by him as a guide to the selection of targets for interception. The basis of the procedure is "Gauntlet" with the S.S.C. exercising an overriding control as between fighters on different orbits. In certain cases he will actually detail fighters to intercept. The procedure is the same whether Control is exercised from the operations room or a G.C.I. station but, as will be seen, the ability of the S.S.C. in the latter case to keep continuous track of his fighters, makes the exercise of his functions much simpler and more accurate. Arrangements at the orbit site are the same as for "Gauntlet" and, in the absence of other orders from the S.S.C., the procedure followed by the pilot is also the same. He sets off for intersections appearing within his arc of operation reporting by R/T their bearing and estimated distance from the orbit. The S.S.C. has the bearings of the "Gauntlet" beam marked on his map and, by comparing the report of the pilot with the plots of S.L. raids, he should be able to determine which raid the fighter is intercepting. By this means, he can decide immediately, or after another plot, whether the pilot has chosen a raid whose course makes it favourable for interception or whether it is unsuitable for the pilot reporting. In the former case, the message is merely acknowledged and the interception proceeds. In the latter, the S.S.C. may decide to call off the interception and, if so, he orders the pilot to return to orbit.

2. If because of poor visibility, pilots cannot see intersections until they have passed well into the area, the S.S.C. (who receives the plots of engagements from the moment they begin) may himself make the initial selection of targets and send a fighter off to intercept by giving him a "smack" vector from his orbit in the direction of the latest plot on the selected target. The pilot, on receipt of the vector, flies over his orbit and sets off in the specified direction. After a short time he should see the S.L. beams. The same procedure can be applied when a crossing target is approaching an orbit from outside the arc of operation and the fighter from the adjacent orbit has either been called off or has not attempted to intercept. In this case, a smack vector can be given to the pilot best placed to intercept.

By keeping a tally of raids which are being intercepted by fighters, the S.S.C. can see at a glance whether a fighter is proposing to intercept a raid on which another is already engaged. He must, however, take care to pass any order to abandon chase before the fighter (if A.I.) has made contact. (Sec. 5.1).

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3. When he operates from a G.C.I. station, the S.S.C. is in the best possible position because, not only can he watch the progress of the engaged raids, but he can also observe the tracks of the fighters themselves. There is, however, always the possibility of error and therefore the pilot cannot be relieved of the responsibility of recognising a target as hostile before firing or keeping careful lookout for friendly fighters in the vicinity.

4. Observation of the S.L. plots will show the S.S.C. whether engagements are converging too close and his tally will show him which may be abandoned and which must be continued - or whether both must be continued as long as possible. When a request for dousing is passed by a fighter, the S.S.C. should be able immediately to identify the S.L. raid in question and to transmit the message to the appropriate S.Ls.

5. When operating from a G.C.I. station with a P.P.I. tube of his own, the S.S.C. will have the S.L. plots marked on the face of the tube. As soon as it is possible to marry a line of S.L. plots with any aircraft shown on the tube, S.L. plotting on that raid can be discontinued and the raid tracked from the signals on the tube. Check plots may be called for at intervals or when any doubt arises. At the same time, fighters will be tracked by a separate plotter - and thus the S.S.C. will have in front of him a complete picture of his own forces and the raids available for interception. If raid density and the number of fighters are sufficiently low for the fighters to be identified while on orbit, it is even possible for the S.S.C. to have regard to their exact position in relation to a raid when selecting or approving raids for interception.

6. It is clear that, where no separate P.P.I. tube is available for the S.S.C. and he can only share one which may also be employed for G.C.I. interception, his use of the tube will be limited to observing general raid trends for the purpose of disposing his fighters on orbit. Under favourable conditions he may also be able to check the positions of the fighters from time to time while they are engaged on interceptions. He must, however, operate primarily from his separate map as in an operation room.

18. Procedure In A Combat Zone.

1. Speed is the essence of Combat Zone procedure since by definition the S.L. area available for interception is small. Only A.I. aircraft can be used because the kill will often take place outside the illuminated area. The function of the S.Ls is to enable the fighter to make A.I. contact quickly after which the fighter can finish off the interception in its own time.

2. Since the orbits will be close to the V.A., most of the S.L. engagements of targets entering the area will be visible to all pilots on orbit and, generally speaking, every pilot will be suitably placed to intercept. Theproblem is therefore not one of selecting the best placed fighter but of arranging the order in which pilots are to intercept. In view of the importance of the time factor, individual control by the S.S.C. is out of the question. The fighter must set off immediately he sees even a single S.L. beam exposed. There are two alternative methods of producing the desired result. In the first, pilots are given a number indicating the order in which theywill set off to intercept and will remain on orbit until it is their turn even if they see an intersection of beams beforehand. On setting off, a pilot reports his turn number and the bearing of the beams he is after for the benefit of the other pilots, On returning to orbit, a pilot will report by R/T to the S.S.C. who will give him the number of his turn for the next interception. In the second method, control is left to one of the pilots on orbit. If two pilots are obviously setting off for the same intersection, the controlling pilot calls oneof them back. The function of the S.S.C. is to ensure that one of the pilots on orbit is always detailed to control.

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3. It is particularly important under this system to give the fighters an adequate command of height. During operations contacts are obtained very quickly - sometimes in well under a minute - but inevitably a large number of them will be head-on. To hold such contacts successfully requires good technique on the part of pilots and their crews, especially as the fighter will in most cases be diving towards the target. It is sometimes found convenient for S.L.C. S.Ls to douse when fighter and bomber breaks merge (for not only in order to be certain to avoid illuminating the fighter but also in order to free S.Ls for the engagement of fresh targets. The S.L. crews must be trained to distinguish where possible between the merging of breaks while the head-on part of the interception is in progress and the merging of breaks when the fighter has come bahind the target and is in firm A.I. contact. S.Ls will not be doused where the merging is clearly the result of fighter and bomber converging head on.

4. Where a Combat Zone or other interception area is adjacent to a G.D.A., the question of defining the spheres of operation of fighters and guns is a matter of A.A. policy. Where it is desirable to limit the height to which the guns may fire, and to allow fighters to operate freely above this level, it must be borne in mind that there can be no question of getting S.Ls to engage targets either specifically for guns or specifically for fighters as they are unable to make such careful discrimination as to height.

Fighters should be warned not to enter the G.D.A. where there is no height restriction unless a kill is imminent and then they must usually do so at their own risk. It may be possible to indicate the boundary of the G.D.A. to them by using special S.L. signals (Sec.6.6.). It should also be possible for the gun G.Ls to distinguish raids with which fighters are in contact. If the procedure for dousing S.Ls when breaks merge is employed, a considerable proportion of the targets engaged by S.Ls within the G.D.A. will have no fighters after them and this should facilitate visual shooting by the guns. The G.D.A. lights should therefore be instructed not to initiate engagements on targets where they see merging breaks (especially if one is showing I.F.F.) and where possible to co-operate in the disengagement of targets on which the Combat Zone lights douse.

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PART II

THE EMPLOYMENT OF SEARCHLIGHTS OTHER THAN WITH FIGHTER AIRCRAFT

CHAPTER VII

INTRODUCTION

19 - Roles of searchlights

1. The roles of searchlights, other than those in which they are employed with fighter aircraft, may be summarised as follows

(a) Co-operation with A.A. guns. To assist H.A.A. and Lt. A.A. guns either -

(i) to destroy the enemy aircraft, and/or
(ii) to prevent accurate bombing, mine laying, or machine gunning.

This necessitates direct illumination of the target.

(b) Dazzle. By dazzling the pilot and bomb aimer of the enemy aircraft, to prevent accurate bombing, mine laying, and machine gunning. This also necessitates direct illumination of the target

(c) Coast Artillery Role To operate as Coast Artillery Searchlights.

(d) Deception

(i) to deceive enemy aircraft as to their position in relation to the ground and
(ii) to prevent accurate bombing or mine-laying

CHAPTER VIII

THE EMPLOYMENT OF SEARCHLIGHTS WITH H.A.A. GUNS

20 - Requirements for visual shooting

1. Time of illumination To enable H.A.A. guns to shoot visually at night it is necessary that the target shall be continuously illuminated during

(a) the time required for the production of gun data,
(b) the flight of shell and
(c) the period of bombardment.

2. This total time is of the order of 30 seconds where target height is being provided from G.L. data The time may be as much as 75 seconds if height is determined by visual height finder.

3. The requirement is, therefore, that the target shall remain continuously illuminated from the moment that the guns engage for a period of 30 seconds where G.L data is available or 75 seconds where it is not.

4. Degree of illumination. The degree of illumination of the target must be sufficient to enable the predictor and identification telescope crews to lay accurately and identify immediately. The maximum height at which this can be accomplished and the number of beams required in its accomplishment depends on many critical factors, including the atmospheric conditions.

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5. Given good weather without haze, searchlights deployed in a G.D.A. should be able to illuminate night-doped bomber aircraft so that they can be clearly seen from the gun position at any height up to 15,000 ft., and on occasions even higher.

6. The illumination required for accurate predictor and identification telescope laying does not normally exceed that provided by four or five beams on the target. If the visual height finder is being used a higher degree of illumination is required, and six to eight beams may be needed. The more beams on the target, the easier it is to hold the target; but more than eight beams gives rise to unnecessary glare which may spoil the engagement.

21 - Layout of the searchlights

1. Spacing of searchlights in the illuminated area. 3,500 yards is the standard spacing generally employed for co-operation with H.A.A. guns.

2. To ensure that an early pick-up is obtained, searchlights should certainly not be spaced at more than 3,500 yards apart for the first two rows.

3. Once a target has been picked up it can usually be held by searchlights spaced up to 4,500 yards apart, even when taking violent evasive action. At this spacing as many as 10 beams can be exposed on target at normal heights and targets as low as 2,500 feet can be successfully followed. If a number of targets are to be engaged at the same time, however, the searchlight density inside the lighted area needs to be increased to spacing of 3,500 yards or less.

4. In cases where the number of searchlights is limited, it is preferable to reduce the size of the illuminated area, for example along unlikely lines of approach, rather than decrease the density of the spacing. A layout containing too few searchlights may often provide a navigational guide for the enemy without being of real assistance to the guns.

5. With S.L.C. equipment suitably sited, the illumination of the target is certain and continuous up to the ceiling imposed by atmospheric conditions, providing the spacing and density of the searchlights allows a sufficient number of beams to be put on the target.

6. Size of the illuminated area. It is desirable that the full period of bombardment should take place before the bomber reaches the "line of bomb release" (L.B.R.) round the V.A. to be defended; because not only is there then the opportunity of destroying the bomber before the bombs are dropped, but also the bomber will then normally be flying on an even course and this will assist the predictor control of the guns. It is desirable, therefore, to provide for illumination of the target for 30 seconds before it reaches the L.B.R. where G.L. is used or 75 seconds where it is not.

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7. If a suitable spacing of searchlights is provided, it can be assumed that the target will be sufficiently illuminated when it crosses the first row of searchlights for the gun drill to start. To provide the ideal defence, therefore, the outer edge of the searchlight layout must be at a distance from the line of bomb release equivalent to 75 seconds of flight of the aircraft (assuming G.L. data not available). The distance in yards of the "line of illumination" (the outer edge of the layout) from the edge of the V.A. is provided by the formula:-

$$D = V (75 + T)$$

where D is the distance required, V is the speed of aircraft in yards per second and T is the time of flight of bomb in seconds. Where H is the height of the target in feet:-

$$T = \frac{1}{4}\sqrt{H}$$

Table A gives figures for the distance D for different speeds of aircraft at varying heights.

TABLE A

Height of aircraft in ft. Level flight	Speed of aircraft in miles per hr. 200	250	300	350	400	
6,000	9,400	11,800	14,100	16,500	18,800	
10,000	10,000	12,500	15,500	17,500	20,000	Distance of L.O.I from edge of V.A. in yards
14,000	10,400	13,100	15,600	18,200	20,800	
10,000	10,800	13,600	16,200	18,900	21,600	
22,000	11,200	14,000	16,800	19,600	22,400	

8. Table B shows the number of searchlights required to cover circular layouts of various radii at 3,500 yards spacing.

TABLE B

Radius of illuminated area in yards.	No. of searchlights required at 3,500 yards spacing
9,000	27
13,000	48
15,000	75
18,000	106
21,000	148

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9. From tables A and B, it is possible to calculate the number of searchlights at 3,500 yards spacing required and the radius of the layout for the all round ideal defence of a V.A. For example, with the target speed 300 m.p.h. at a height of 10,000 ft, if the V.A. is 3½ miles in diameter, the number of searchlights required at 3,500 yards spacing is approximately 106 and the radius of the illuminated area will be 11 miles.

10. It will be seen from these tables that the minimum number of searchlights necessary for the ideal defence of a small V.A. against slow targets at comparatively low heights is approximately 50. If a large V.A. is to be defended against high, fast, targets, it is necessary to employ more than 150 searchlights.

11. Owing to limitations of men and equipment it may not always be possible to provide a sufficient number of searchlights to provide for such complete defence of a V.A. In this case, it is normally preferable to reduce the size of the illuminated area rather than increase the spacing.

12. The more the illuminated area is reduced, the closer the L.O.I. approaches to the L.B.R. Where the L.O.I. is approximately coincident with the L.B.R., the guns will not be able to shoot visually before the target reaches the L.B.R., but the target will be illuminated as it passes over the V.A., and beams may be exposing in the eyes of the bomb-aimer at the moment of bomb release. Thus the bomb aimer may be dazzled at a critical moment and his accuracy materially reduced.

13. Reduction of the size of the illuminated area while lessening the effectiveness of the defences, affords considerable saving of men and equipment. As a rough guide, 24 searchlights at 3,500 yards spacing should be able to illuminate the target on or just before the L.B.R., providing the V.A. is a small one.

14. If the size of the illuminated area is so reduced that the target will be engaged only after it has passed the L.B.R., the value of the searchlights will be greatly lessened. As explained above, the results of dazzle may alone prevent accurate bombing, but if the target is not engaged until after the bombs are released this advantage is entirely lost.

15. When the L.O.I. chosen is close in to the L.B.R. sentry lights may be employed in order to give early warning and to assist in obtaining an early pick-up. These lights should be sited 8 to 10 miles from the edge of the illuminated area in commanding positions along most likely lines of approach.

16. <u>Shapes of the illuminated area</u>. A circular layout will not always be desirable or practical. When deciding the position of the L.O.I (i.e. the shape of the illuminated area), the following factors must be considered:-

(a) The shape of the V.A.
(b) The probable line or lines of attack (See Artillery Training Vol 1, Pam No 11- The ex-M.A.A.D. Vol. 2 Pamphlet 1 Sec 5 (Subsection 8).
(c) The estimated height and speed of the attack.
(d) The searchlight equipment available and the spacing to be adopted.
(e) The position of the H.A.A. guns.
(f) Topographical features of the area.

(If the V.A. is on the coast, the layout will be approximately semi-circle).

17. The shape of the layout employed will seldom be the ideal layout, but some modification of it made necessary by local circumstances. The plan eventually decided upon, even though short of the ideal must contrive to make the best possible use of the equipment available.

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I8. From time to time it may be necessary to alter the shape of the layout, to counter fresh enemy tactics, or if the enemy is using it for navigational purposes.

I9. Laying out an illuminated area. The layout of an illuminated area, large or small, may be developed as follows:-

(a) Diagrammatic layout. Having decided the shape and spacing of the illuminated area, a diagrammatic layout, such as the one shown in Plate II, will be made out. It will be convenient, as a rule, to prepare this on a piece of tracing paper and subsequently to prick through the positions of searchlight stations on to a one-inch map.

(b) Approximate positions. If the map available is detailed and accurate, it should be possible, from a careful study of it, to modify the diagrammatic layout and to fix positions for individual sites sufficiently well for the majority of the sites to be finally sited within 200 or 300 yards of those approximate positions. In doing this the regular spacing of the sites must be retained as far as possible, to avoid leaving any gaps in the lighted area. Searchlight sites should be located as far away as possible from the gun positions.

At this stage it is convenient to split up the layout into batteries and troops.

When only a proportion of the stations are equipped with S.L.C. the sites which they are to occupy should next be marked on the map. Priority arcs for each S.L.C. set to cover all approaches must be worked out and noted.

Except in fixed defences, the choosing of the approximate positions will be the duty of the searchlight commander of the particular defended area.

(c) Personal reconnaissance. The final choice of the site for a searchlight is generally made by the troop commander, though every detachment commander should be capable of siting his station correctly in case of need, given the map reference of the approximate position. Should a site have to be placed more than 300 yards from the approximate position, the fact must be reported as soon as possible to the battery commander, since this may entail a modification of the position of other lights in order to maintain a correct general spacing.

22 - Searchlight Equipment.

I. While it is desirable to have all beams directed by S.L.C., mutual interference may occur if sets are closer than 5,000 yards. Where, for this reason, certain searchlights are not directed by sound-locators. Hand-control is preferable where a searchlight is within 4,500 yards of one or more S.L.C. equipped lights. Generally sound-locators are found to be of little use once the guns engage.

2. In an evenly spaced 3,500 yards layout, a suitable distribution of S.L.C. equipment is one third S.L.C. and two thirds hand controlled stations. The S.L.C. stations should be spaced in equilateral triangles 6,000 yards apart as shown in Plate III.

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PLATE II and III

1 in 3 DISTRIBUTION OF S.L.C. IN A 3500 YARD LAYOUT

Key
- ○ - Hand Controlled Stations
- ⊙ - Stations equipped with S.L.C.

3. Of the two sizes of searchlights in service (90 cm. and 150 cm). the 150 cm. projectors will provide the greater degree of illumination, and the greater range. Satisfactory results may be obtained with layouts where only S.L.C. controlled projectors ("masters") are 150 cm., the hand-controlled stations ("satellites") being equipped with 90 cm. projectors. (From the projector controller's point of view, it is easier to hold the target with a 90 cm projector than with a 150 cm projector).

4. If control pillars are available, they should be sited primarily on hand-controlled stations. Where they are not available for all stations, control pillars should be evenly distributed over area.

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23 - Method of engagement by H.A.A. guns

1. Using visual height finder. Where the visual height finder is used, the method of engagement will be that normally used by day viz. "Height Control".

2. Data to obtain height. Where it is possible to obtain G.L. slant range in engaging a visual target, the G.L. is directed on to the target with the aid of bearing and slant range passed from the Command Post. The predictor is used to check that the G.L. is on the selected target. Except with G.L. Mk. III this operation is difficult if there is a choice of targets e.g. medium or high density raid. The engagement is as for "Height Control", using G.L. slant range and visual angle of sight to obtain the height.

3. Changing from unseen to seen engagement. Where a target is being engaged unseen using G.L., and during the engagement the target becomes illuminated, the predictor can be corrected on to visual angle of sight and bearing by disregarding the pointers and following the target in the predictor telescopes instead. This correction may be large enough to warrant the calculation of a fresh height (using G.L. slant range). The choice of a fresh height curve should not take more than a few seconds, after which the engagement is continued by visual following with the predictor. In general it is not advisable to change from an unseen to a seen engagement.

4. Employment of G.C.I. Where G.C.I. information is available, it is desirable to have plots passed to perimeter guns and searchlights. Such plots are valuable for early warning and for information of the general position and trend of the raids. It will usually be impracticable to select individual targets for engagement and to attempt to identify them to both searchlights and G.L's by means of downward plotting. It is preferable for guns and searchlights having received the initial information of the position of the approaching raiders, independently to select their own targets.

24 - Method of operation of the searchlights.

1. Rules for engagement. All S.L.C. equipped stations within effective range should engage incoming targets. All hand-controlled stations within effective range should conduct a limited search on the intersection of the S.L.C. beams. Once the target has been picked up only the minimum number of beams required to give adequate illumination should remain exposed. Other stations should then hold themselves in readiness to engage fresh targets. Once a target is illuminated and is engaged by the guns, every endeavour must be made to continue the illumination until either the target is destroyed or passes out of range.

2. In cases where there is a choice of targets it is necessary to select one for engagement. Where one target is illuminated and the other is not the engagement of the illuminated target must be continued in preference to the fresh target. Where the choice is between two (or more) illuminated targets, or two (or more) unilluminated targets the target chosen should be:

   (i) the most dangerous,
   (ii) the nearest,
   (iii) incoming rather than the outgoing,
   (iv) the largest
   (v) targets below rather than above 15,000 ft.

3. It is preferable to have one target well illuminated by 6 beams rather than two targets badly illuminated by 3 each. At the same time it is better to have two targets well illuminated by 5 beams on each than one with 10 beams.

4. It is important that S.L.C. equipped stations should disengage as soon as the target commences to recede and is held by a sufficient number of beams, so that fresh targets may be engaged without delay. Each perimeter S.L.C. locator will have a priority arc and will normally observe through it when not actually engaging a target.

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5. Any plotting to or from searchlight stations will be secondary to the engagement of fresh targets. In general there should be no attempt to control the engagement of targets from a central operations room.

25 - Communications.

1. Communications to the searchlight stations in a G.D.A. are by no means an essential part of the system of defence. Where they do exist, however, they may be usefully employed for giving early warning and passing positions of targets to and from the stations. For the purpose of passing early warning messages, R/T or visual searchlight signals may be used in the absence of line communications.

2. Providing the communications are satisfactory and the plotting equipment is available, it is possible for searchlights in a G.D.A. to send upward plots to Gun or Bty. operations room. Where the G.D.A. is used as part of fighter interception area, upward plotting may be necessary, but when the G.D.A. is isolated, the value of the plots is by no means essential.

3. Information of the approach of hostile aircraft will usually be available from one of the R.D.F. equipments in a G.D.A. Where no such early warning information is available, the use of Sentry Lights becomes important for both guns and searchlights. If the G.D.A. is surrounded by another searchlight layout e.g. an interception area, warning will be automatically given when these beams expose.

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CHAPTER IX - THE USE OF SEARCHLIGHTS WITH LT A.A. GUNS

26 - Requirements of the guns and searchlights.

1. Time of illumination. In order to enable Lt. A.A. guns to shoot visually it is necessary that the target shall be continuously illuminated in range of the guns for a period of time which is the sum of

   (a) the drill time,
   (b) time of flight of shell and
   (c) the duration of bombardment

   Whatever the method of fire control in use, the drill time and flight of shell is seldom more than 8 seconds. A further 10 seconds is required for an effective bombardment.

2. The requirement is, therefore, that the target shall remain continuously illuminated from the moment that the guns engage for a period of 18 seconds.

3. Degree of illumination. The degree of illumination of the target must be sufficient to enable the gun layers (and predictor layers if used) to see the target clearly. Normally, with targets flying at heights of 4,000 ft. and below, one well-directed beam can illuminate the target to the required degree. In practice it is necessary to keep at least three beams on one target to ensure that the target is continuously illuminated. The requirements is, therefore, that the target shall be illuminated by a minimum of three beams while being engaged by the guns.

27 - Layout of the Searchlights

1. Spacing of searchlights in the illuminated area. The standard spacing searchlights co-operating with Lt. A.A. guns in the defence of a V.A. is 1,500 yards.

2. As explained above, it is necessary to maintain an illumination by at least three beams. The spacing of searchlights required to do this will be directly related to the height at which the targets fly; the lower the targets, the closer is the spacing required. In order to ensure at least three beams on a target with a minimum angle of elevation of any projector at five degrees, the maximum spacing needed is:-

for targets at	100 ft	spacing	380	yards.
" " "	300 ft	"	1150	"
" " "	500 ft	"	1900	"
" " "	1000 ft	"	3800	"

3. Low level attack by night may well be made from heights as low as 500 ft. If targets at 500 ft are to be illuminated, the spacing should not be more than 1,900 yards. but if more than one target is to engaged, the spacing should be reduced accordingly.

4. According to the local circumstances, a wider or closer spacing than the standard 1,500 yards may be required. Where an illuminated area is of large diameter and targets are unlikely to fly below 1,000 ft., a spacing of 2,000 yards in the centre of the area may suffice. Where the V.P. is small and the enemy has adopted "hedge-hopping", cannon fire, and dive bombing tactics by night, the spacing may have to be reduced to 500 yards.

5. At the edge of the illuminated area it is found that searchlights at 1,500 yards spacing pick up and hold any target at 500 ft. and above. Where targets are lower than this, the spacing may have to be reduced.

6. Size of the illuminated area. As in the case of co-operation with H.A.A., it is desirable that the full period of bombardment should

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take place before the target reaches the L.B.R. To provide the ideal defence, therefore, the target must be illuminated at a distance from the L.B.R. equivalent to 18 seconds of flight. With suitable spacing it can be assumed that the target will be illuminated by the time it reaches the outer row of lights.

7. The distance from the centre of the edge of the illuminated area, (and therefore the radius of the L.O.I.), required to illuminate the target for 18 seconds before it reaches the L.B.R., depends on the height and speed of the target. Table A shows the radius of the L.O.I. required for various speeds and target. Table A shows the radius of the L.O.I. required for various speeds and heights of aircraft. The calculations are based on the formula D = V (18 + T).

TABLE A.

Height of aircraft in ft. level flight	Speed aircraft in Miles per hour					
	200	250	300	350	400	
100	2000	2600	3100	3600	4100	)
250	2200	2700	3200	3800	4300	)
500	2400	3000	3500	4100	4700	) Radius of
1000	2600	3200	3900	4500	5200	) L.O.I. to
1500	2800	3500	4200	4900	5500	) illuminate
2000	2900	3700	4400	5100	5800	) 18 seconds.
4000	3400	4200	5100	5900	6800	) before target reaches L.B.R layout. V.P. in centre.

8. To find the radius of the L.O.I. when defending a V.A. of appreciable dimensions, half the width of the V.A. must be added to the figures shown in Table A.

9. Table B shows the approximate number of searchlights necessary to fill an illuminated area of various radii with even spacing of 1,500 yards.

TABLE B.

Radius of illuminated area in yards	No of searchlights required
2000	11
3000	18
4000	30
5000	45
6000	70

10. From tables A and B above, it will be seen that some 70 searchlights at 1,500 yards spacing are needed to provide the ideal searchlight defence against all types of attack from 500 ft. to 4,000 ft., when the objective is literally a V.P. If the objective is of any appreciable size, more searchlights will be required.

11. The men and equipment available will often not allow of an ideal illuminated area. When the total number of searchlights available is less than the ideal requirement, the size and shape of the layout decided upon must be carefully arranged to make the best possible use of available equipment. The considerations

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governing the reduction of size of the illuminated area are similar to those already discussed in connection with the employment of searchlights with H.A.A. guns.

12. In the case of a large V.A. it may be possible only to provide defence with searchlights for certain selected V.Ps within the V.A.

13. As with H.A.A., Sentry lights may usefully be used to give early warning.

14. Anti-dive-bombing layout. Searchlights employed to combat dive bombing must all be within a few hundred yards of the V.P. which, if the enemy is forced to adopt dive bombing tactics, is likely to be very small, e.g. a small bridge, a defile etc. Even 3 or 4 searchlights will prove effective for this purpose, providing the raid density is not high.

15. Searchlight stations employed in a low-flying defence role may need to be withdrawn from sites by day for camouflage purposes, and redeployed at dusk to different sites. The A.A.L.M.Gs. may remain deployed by day if required. If the same sites are in use for any length of time, the enemy will soon learn the shape of the layout and use it to help locate his objective. Where a mobile reserve exists, it may be used to alter the shape of the layout, or thicken up one side of the area.

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28. - Searchlight equipment.

1. Projectors. Either 90 cm. or 150 cm. projectors are effective against low flying aircraft. Owing to its lighter weight, however, the 90 cm. projector is easier to control and for that reason is more suitable in this role for it is very important that the projector should be capable of smooth and quick traverse.
2. . Projectors must be sited to obtain the best possible field of view, particularly in the direction away from the V.A. This usually implies siting on a forward slope or on the top of rising ground.
3. S.L.C. equipment. S.L.C. equipment used against low flying aircraft should be mounted on the projector (90 F.S. or 150 F.S.); if it is desired to use three or more S.L.C. sets in this one layout, a test should be made to ensure that they do not cause mutual interference great enough to prevent pick up at the ranges required. If the interference is too great, the remedy is either to change the location of the S.L.C. equipment, or to reduce the number of sets in use.
4. In some circumstances "line-locking" of S.L.C. sets may be adopted to avoid mutual interference. The chief disadvantage of this method is that sets which are line-locked can engage only the same target.
5. Generators. The noise of the generator must be carefully screened otherwise it may interfere with the picking up of the target. Generators should be sited where possible away from the expected direction of attack viz. between the projector and the V.P.
6. Spotters. Spotting chairs and binoculars are usually not necessary. With low flyingtargets, the best vantage point for the spotter normally changes with the direction of the beam; the spotter should be free to move during the engagement.
7. Sound-locators. Sound-locators are not effective against fast aircraft unless the target is over 3,000 ft. Below this height, the angular rate of change is too great for efficient operation. For aircraft above this height, however, the sound-locator may be used effectively. Up to 3,000 or 4,000 ft the target can easily be picked up by the trained projector controller with unaided ear, thus rendering the use of sound locators unnecessary at these heights.

29. - Method of operation of the searchlight.

1. Picking up the target. The method used to pick up a low flying target should vary with the weather, number of searchlights in use, and other conditions. The following is an example of a method suitable for use in average visibility.

   As the target approaches the edge of the searchlight layout, the two nearest stations engage with dispersed beams. These beams are directed either by the projector controller judging the position of the target by sound, or by the S.L.C. crew, where the station is equipped with S.L.C. As soon as the first two dispersed beams are exposed, the four stations nearest to them expose in focus and search on sound in the neighbourhood of the dispersed beams. When not engaging a target, the S.L.C. equipped station will usually observe through a priority arc facing outwards from the centre of the layout. As soon as a target is picked up, all beams engaging should normally be in focus.
2. Speed of pick-up is absolutely essential. Drill orders should be cut to the minimum; beams must expose exactly when required; and flickovers should be followed immediately by illuminations.
3. Holding the target. Once the target is illuminated, all beams exposed should follow in focus, unless the detachment commander on a station considers that by so doing the target will be lost, (i.e. the angular rate of change of his projector is too great to follow with the beam in focus). The control of the projector is invariably manual at this stage.

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4. Stations inside the layout expose and illuminate all approaching targets as soon as they are in effective range. The detachment commander's primary object must be to engage all targets which come within his range. Greatest care is necessary when holding a target to see that the beam does not merely follow the intersection without actually illuminating the target. This may "blanket" the view of other detachments and even cause the target to be lost.

5. Dousing. Detachments break off the engagement as soon as the target is :-

(a) Receding, AND
(b) Is held by three other beams.

Immediately each beam is doused, the projector should be turned round to face away from the V.A. and be prepared to engage fresh targets. S.L.C. crews immediately recommence observing through the priority arc.

6. It is important that the beams do not illuminate objects on the ground which may provide the enemy with a navigational aid, e.g. the V.P. itself, tall buildings, or bridges. To prevent this it may sometimes be necessary to allot "dead arcs" to certain stations below specified angles of elevation.

7. Medium and high density raids. The maximum height of targets which can be engaged by Lt AA guns is approximately 5,000 ft. The searchlights deployed to co-operate with these guns can, however, engage targets at any height.

8. Where the Lt AA layout is located in a H.A.A. G.D.A. with searchlights at 3,500 yards spacing (e.g. to defend a V.P. inside a larger V.A.), some or all of the spaced searchlights may have a dual role and operate as part of the H.A.A.

9. Where there is no H.A.A. gun defence and an attack at heights out of range of that Lt AA guns develops, a decision must be made whether or not to allow the closed spaced searchlights to engage. If they do not engage, the dazzle, deterrent and harassing effects will be lost; if they do engage, the location of the enemy's objective is given away.

As a general rule, the searchlights should be allowed to engage when the ground objective is easy to find, or when fires have been started. While there is still hope that the enemy may fail to locate his objective, the searchlights should usually remain blacked out.

30 - Communications.

1. Except in the case of airfield canopies (Sec. 31), rigid control of detachments is seldom a requirement, and the main use of the communications is to provide early warning of approach of targets and to douse beams when necessary. As the searchlights are all at close spacing, R/T communications within the troop are satisfactory and, therefore, line communication to individual stations is rarely required.

31 - Airfield canopies.

1. Owing to the size of modern airfields, it is seldom practicable to provide an ideal defence against the bombing of dispersal points, workshops, hangars, watersupplies, runways etc. The defence, therefore, relies on the dazzle and deterrent effect of the searchlights and guns, and the destruction of hostile aircraft venturing a sufficient distance across the airfield.

2. Layout and equipment. The layout is arranged to give the maximum concentration of beams on the target before it reaches the airfield, and may take the following forms:

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(a) The grouping of stations in twos or threes.
(b) Even spacing around the perimeter.
(c) Combination of single and grouped stations

3. The siting of lights singly gives an all round L.O.I. further out than that of a grouped arrangement and therefore usually gives an earlier pick-up.

4. It may, however, be advisable to use a grouped arrangement from the point of view of ease of communications, administration or protection.

5. The spacing of the stations depends largely on the topographical features of the area but, in general, the sites should be 1,000 to 2,000 yards apart. One or two of the searchlights may have to be specially sited to illuminate a runway if required. Where stations are in groups, each site should be not less than 200 yards from its neighbour. Stations should be at least 150 yards from Lt. A.A. guns.

6. For a small airfield 6 searchlights may prove satisfactory, but for large airfields, 9 should be used. 3 S.L.C. sets are normally sufficient and should be sited to give the best results in their own priority arc. Where groups are used, each should include one S.L.C. equipment. If more than 3 or 4 sets are in operation at the same time, it may be necessary to employ line-locking, otherwise mutual interference may be so great as to prevent any of them working efficiently.

7. Operational control. The Anti-Aircraft Defence Commander (A.A.D.C.) of the airfield is in charge of the operation of both searchlights and guns. The duty of the .A.A.D.C. is to ensure that the defences under his command are used to the best advantage in protecting the airfield. He must, therefore, decide the best moment at which to expose the searchlights so that they illuminate the aircraft sufficiently early to allow the guns to concentrate an effective fire, but not so early that the target will alter its course and avoid being picked up.

8. The method of engagement has been dealt with in Sec. 29.

9. The A.A.D.C. will exercise strict control over beams exposed and doused and guns engaging, both to obtain the maximum effective use of his searchlights and guns, and to ensure that friendly aircraft are not engaged.

10. Defence against intruder aircraft. An intruder aircraft usually attacks by following and machine-gunning a friendly aircraft in the process of landing at night. Special methods of operation are necessary to deal with this type of attack. The procedure will depend largely on the local conditions at each airfield but the following is an example:

Immediately a friendly aircraft crosses the edge of the airfield to land on the runway, a "blanket" of dispersed searchlight beams is set up across the beginning of that runway. If an intruder intends to attack the landing aircraft, it must fly through the blanket and be observed and engaged in the ordinary way by guns and searchlights. The blanket also has the effect of hiding the landing aircraft by interposing glare between the two aircraft. The blanket is obtained by laying the beams from suitably placed stations on predetermined angles of bearing and elevation.

11. Communications. The communications needed to control the defences must be reliable. The best arrangement is a Control Post for the A.A.D.C., with line communication to all guns and searchlights on an omnibus circuit. A line from the control post to the Air Force Flying Control Officer will also be required or, better still, the A.A.D.C. should be with the Flying Control Officer.

12. Since the enemy may be expected to make maximum use of the element of surprise in his attack, the best early warning system possible must be made available for the defences, and some quick

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means devised of communicating the alarm to the guns and searchlights.

13. Equipment. The searchlight equipment required is the same as described in Section 28, S.L.C. equipped stations may be used to provide early warning and information to the A.A.D.C.

32 - Anti-minelaying

1. The searchlight role. The anti-minelaying role may be summarised as follows:-

(a) To illuminate enemy minelaying aircraft for Lt. AA and H.A.A. guns.
(b) To deter the pilot by dazzle.
(c) To indicate the location of the mines in the water and so assist subsequent minesweeping operations.

2. Layout and siting. Minelaying aircraft normally fly at low altitudes. Sites must be chosen having a clear field of view over the sea through a large arc, and should be placed as low and close to the water as possible. The possibility of shallow penetrations inland has also to be borne in mind when choosing sites. Close spacing - in the region of 1,000 yards - is desirable as defences in depth is seldom possible. The number of stations required will depend on the length of the channel to be protected. In some cases the anti-minelaying stations may form part of another searchlight layout e.g. defence of a V.A.

3. Equipment and operation. It is essential that all equipment can be operated at or below zero degrees elevation. It is often not possible to obtain early warning of targets approaching low over the sea from outside sources and, therefore, a certain proportion of stations should be equipped with S.L.C. These should be sited so as to give the best possible pick-up free of interference from ground breaks along the likely lines of approach. S.L.C. must be directly mounted and capable of rapid traverse. The remainder of the equipment will normally be hand-controlled.

4. The procedure for engaging minelaying aircraft is basically the same as already described for searchlights in co-operation with Lt. A.A. guns in the defence of a V.A.

5. Anti-minelaying searchlights may assist in locating the position of mines dropped by enemy aircraft by two or more stations illuminating the mine and following it down until it strikes water. The bearing angles are noted for each station, and from these the mine is accurately pinpointed in the channel. This duty may on occasions be considered more important than, and take precedence over, continuing the illumination of the aircraft after the mine has been dropped.

6. Owing to the extremely short warning of approach, detachments should be permitted to expose on all targets, unless specific orders to the contrary have been received.

7. Communication to sites is necessary in order that warning of approaching raiders may be given, and in addition, information concerning the presence of friendly aircraft or shipping. R/T is usually found to be adequate.

CHAPTER X.

THE EMPLOYMENT OF SEARCHLIGHTS FOR DECEPTION AND AS A DETERRENT.

33 - Deception

1. The searchlight role. Searchlights may be employed to deceive the the enemy as to the true position of his ground objective, the coastline and the location of A.A. defences. This deception may prevent him from locating his ground objective, or cause him to bomb inaccurately. Deception normally takes one of the following forms:-

(a) Total or partial blackout
(b) False layouts
(c) Creation of false coastlines
(d) Dark lanes
(e) Glare effect
(f) Combinations of the above

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2. The effectiveness of any of these forms of deception is increased if atmospheric conditions prevent the enemy from seeing the ground.

The operation of searchlights in each of the above roles is briefly considered below:-

(a) Total or partial blackout. Blacking out part or all of the searchlights in an illuminated area surrounding or adjacent to a V.A. may mislead the enemy as to the true position of his objective.

(b) False layouts. Searchlights deployed adjacent to an existing searchlight layout alter the shape of the original layout as seen from the air, and therefore, the apparent position of the objective. The effect will be increased if, at the same time, an equivalent number of searchlights are blacked out on the opposite side of the illuminated area. This form of deception may be effective if the enemy is using the shape of the illuminated area to estimate the position of his objective. The use of searchlights in their fully mobile role will facilitate the creation of these false areas. Concentrations of beams over an area outside but near the target area, may mislead the enemy as to the whereabouts of his objective. This is most likely to be successful if the dummy V.A. can be arranged on ground which in some way resembles the true V.A. as seen from the air. False fires, dummy aerodrome landing lights, A.A. fire at the intersections, and other deceptive measures may usefully be employed in conjunction with the searchlights.

(c) Creation of false coastline. The enemy's night navigation is considerably assisted if he can pinpoint when crossing the coastline. The exact position of the coastline is often indicated by searchlight beams at the edge of an illuminated area known to coincide with the coast. On nights of poor visability, the blacking out of searchlights in a belt a few miles deep, contiguous with the coast; may cause the enemy to be uncertain of his exact land fall.

(d) Dark lanes. A lane through an illuminated area in which searchlights are blacked out will often be chosen by an enemy pilot as the route to his objective. A.A. barrage may be arranged in these dark lanes.

(e) Glare effect. In conditions of poor visibility it may be possible to obscure the objective from the enemy aircraft by traversing dispersed beams in confusing patterns at low angles of elevation.

4. Only by continuous alteration of the locations and methods of deception will maximum results be obtained. The keynote of the use of searchlights for deception is mobility combined with imagination and initiative. For example, a dark lane, once successful, will lose its value unless moved to a different area.

34 - Dazzle defence

1. Object. Searchlight may be employed to dazzle:-
(a) the bomb aimer and thereby interfere with his accuracy, and
(b) the pilot, by preventing him from seeing the ground or even his instruments.

This form of defence is operated either by a special "dazzle layout" or automatically when the target is illuminated by any type of searchlight layout normally used with active weapons of defence.

2. Requirements for dazzle. During the bombing run-up, the bomb aimer is obliged to look in the direction of his objective for 20 to 30 seconds. If a searchlight placed within a few hundred yards of his objective is exposed exactly on the aircraft, the bomb aimer will be unable to see the ground within about 1,000 yards of the searchlight. In addition, if he looks at the searchlight, which he must do during the run-up, he will be blinded for 5 to 10 seconds.

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3. Merely by exposing a searchlight beam exactly on the aircraft as it approaches the L.B.R., therefore, accurate bombing can be prevented and a second run-up may even be necessary. The sooner the searchlight beam exposes, the greater is the effect. The bomb aimer's judgment will be more impaired if the tiring and irritating effect of the dazzle lasts for any length of time. The pilot will be hampered and have difficulty in reading his instruments when dazzled, but this is not serious unless the aircraft is flying low. The pilot of the low flying aircraft, if suddenly dazzled, may lose control and cause the aircraft to dive and crash.

4. The first requirement from searchlights to bring about this dazzle effect is that at least one searchlight near the bomber's objective is exposed and held exactly on the aircraft. If the accuracy of the bombing is to be affected, the bomb-aimer must be dazzled as early as possible before, and up to the moment the bombs are released. The second requirement is that several beams must engage at the same time to ensure that at least one is accurately and effectively causing dazzle. The dazzle effect of one beam is substantially lost if it is even 1° off the target.

5. Once the bombs have been dropped, the effectiveness of this type of defence is reduced, and it is, therefore, stressed that, to obtain the best results, the crew of the bomber must be dazzled before the bombs are dropped.

6. It will be realised that the effects of dazzle on the bombing accuracy will not be so marked if the V.A. is large, or if pattern bombing tactics are being employed. Dazzle is most effective where the V.A. is small and where very accurate bombing is required to do damage.

7. Layout and equipment. With searchlights employed to assist Heavy and Lt A.A. guns as described in this pamphlet, the dazzle will automatically occur if the searchlights fulfil their role and illuminate the target.

8. Where a V.A. is defended by a searchlight layout designed for use with Lt. A.A. only, the searchlights form an effective "Dazzle layout" against a high level attack out of range of the Lt. A.A. guns. Even if there is no H, A.A. gun defence available, effective dazzling of the high flying raiders will minimise the accuracy of the bombing. For this reason, a proportion of the searchlight stations in a close spaced layout should include S.L.C. equipment.

9. Accurate dive bombing at night may be effectively countered by means of a special dazzle layout consisting of three to six searchlights placed 200 or 300 yards apart round a V.P. (if S.L.C. locators are to be used to direct these searchlights they may have to be line-locked to avoid mutual interference.) If required, a dazzle layout may be deployed inside an existing layout, or some of the stations of a normal illuminated area specially sited near V.Ps so as to form a dazzle layout. Dazzle sites should not be arranged geometrically around a V.P., or they will provide an aiming mark for the bomb-aimer. The siting of these positions may be combined with the principles of deception.

10. Where a dazzle layout is employed, it is essential that the position of the stations are moved at frequent intervals, otherwise the enemy may quickly use it to his own advantage in finding and bombing his objective.

CHAPTER XI.

MISCELLANEOUS USES.

35 - A.A. Searchlights in a Coast Artillery role.

1. The searchlight role. Searchlights may be employed in close support of Coast Artillery guns against such targets as enemy M.T.Bs., landing craft and submarines operating in coastal waters.

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The tactical roles are broadly as follows:-

(a) Observation lights. To detect the approach of hostile craft and to give early warning.

(b) Fighting lights. To illuminate individual targets for the particular guns to which they are allotted.

(c) Illuminated area lights. To illuminate areas through which hostile craft cannot pass without being detected.

2. Layout and siting. Siting will depend on the gun layout ordered by the Defence Commander, but in general, searchlights will usually be sited in groups of not less than two, so that continuous action can be maintained during carbon changingor breakdown.

3. Individual searchlights must be sited as close to high water level as possible to give:-

(a) the greatest area of surface illumination and greatest range at the minimum depression of the projector, and,

(b) uninterrupted search over the entire are without masking by rooks etc.

4. Equipment. The standard A.A. 90 cm projector is used and is either hand controlled, or fitted with control gear for remote control.

5. Operation. On warning of the approach of hostile craft, the observation lights will expose. These have two roles:-

(a) as sentry beams exposed on a fixed bearing, through which the craft must pass, or

(b) as search beams searching the channel or area inland of the sentry beam.

Observation lights are given arcs of search which will overlap to ensure that the whole area is covered.

As soon as a target is picked up, the fighting lights will illuminate and follow it for sufficient time for it to be engaged by the guns. Fighting lights, normally allotted one to each gun, may be exposed either in focus to give maximum illumination and range, or dispersed in the case of a close target moving at speed.

6. Illuminated area lights will expose on a fixed bearing with dispersed beeams, thus permanently illuminating large areas through which hostile craft must pass. This reduces the possibility of targets being lost by fighting lights after the initial pick-up owing to evasive action, low visibility or high speed.

7. Communications. Each group has a Searchlight Directing Station with which it is in communication, and from which orders to expose or douse are given, and information and warning of approach are passed. Remotely controlled projectors are controlled from this station. Each directing station is under the control of the main Command Post which will receive warning of expected attacks and any other information available from higher command.

36 - Homing beacons.

1. Object. The object of "Homing beacons" is to direct friendly aircraft to their own or other airfields by means of searchlight beams when, for any reason, they are unable to find an airfield in the normal manner.

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2. Friendly bombers returning after action over enemy territory with their radio equipment damaged often require the assistance of homing beacons.

3. The searchlight role. The standard signal given by searchlights to home distressed aircraft is as follows:-

(a) the beam is exposed as nearly horizontal as possible for a period of 30 seconds in the direction of the selected airfield;

(b) the beam is then elevated to 45° and depressed again three times, as fast as possible;

(c) it is then left exposed for another 30 seconds as nearly horizontal as possible;

(d) the procedure is continued until the aircraft is flying in the direction and the beam remain exposed until the sound of the aircraft had died away, or for a period of 2 minutes, whichever is the longer.

4. Calling for homing beacons. A distressed aircraft may call for homing beacons either "directly" or "indirectly".

(a) "Indirect" or "Normal" calls for homing. The Air Force Control Liaison Officer or equivalent may call for homing beacons on receipt of information that an aircraft is in distress and requires to be homed. The order will be passed to searchlight stations through the normal channels of communication.

(b) "Direct" calls for homing. In order to obtain homing beacons, the pilot will:-

(i) cause his aircraft to circle for at least two minutes, AND

(ii) switch on his navigation and downward recognition lights, or fire the combination of coloured lights of the period, or use a combination of both these signals.

37 - Intersecting cones to indicate airfields.

1. Object: Searchlights may be called upon to supply an intersection of beams directly over an airfield to indicate the position to aircraft.

2. This procedure is used to assist in landing aircraft under conditions of poor visibility.

When the intersection is required, the searchlights merely expose on predetermined angles of bearing and elevation to form a cone over the airfield, and maintain it for as long as may be required.

38 - Balloon barrage warning.

Searchlights near the edge of a balloon barrage may be called upon to provide a warning to a friendly aircraft of the exact position of the barrage. This is accomplished by predetermined searchlights exposing on, and illuminating the balloons.

39. - Bomber rondezvous beacons.

1. The use of searchlight beacons will materially assist the concentration of bomber aircraft into a small area over a selected point on their outward track.

2. When such beacons are required, they are provided by one or more searchlights. These "bomber rondezvous beacons" will be exposed either vertically or intersecting. Beams may flash a code in order to identify themselves to approaching bombers.

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OPERATION OF FIGHTER SECTOR AND FIGHTER AIRCRAFT IN CO-OPERATION WITH SEARCHLIGHTS.

1. INITIATION OF ACTION.

The decision of the Sector Controller as to whe whether fighters will be ordered into the air on a warning of the approach of enemy aircraft will be based on;

(a) Weather conditions - mainly cloud density and cloud base. Reports on this will be received by the Sector Controller from the Search light Control Officer at 30 minute intervals during the hours of darkness.

(b) Advice from the Searchlight Control Officer as to the degree of probality of Searchlights illuminating the enemy due to cloud condition.

(c) Length of warning received - sufficient warning will be necessary to ensure that the defending Fighters can gain altitude before the enemy reach the Outer Line of Illumination. (O.L.I.)

2. ORBITING.

Fighters will be sent up to orbit the searchlight beacon, on orders from the Sector Controller.These beacons will normally be situated in the following position.
In the centre of the defended area- forming a "Spiders Web " defence

3. The fighter pilot on reaching his orbit point will report "In Position" to his parent Sector Controller, indicating that he is "On Orbit" at the ordered altitude.

4. Fighters will carry out a left hand orbit of the beacon at not more than 4 miles radius from it.

5. When more than one fighter is to be employed, aircraft will be layered at heights of not less than 2000 feet apart. Normally the fighter at the maximum altitude will be detailed to intercept.

6. PERLIMINARY WARNING.

A fighter on orbit who is likely to be detailed will be given the following information.

(a) Height of approaching raid

(b) General direction of the raider from the orbit beacon, and approximate distance.

7. ACTION BY FIGHTER ORDERED TO INTERCEIPT.

When the Controller decides to detail a fighter to a selected raid, he will give the code word "SMACK" accompanied by an indication of the direction (N - S - E - W) from which the enemy is approaching the orbit beacon (this direction may have changed since the preliminary general warning given in accordance with paragraph 6 (b) above).

The code word "SMACK" will constitute the order to the Fighter to cease orbiting and proceed in the direction indicated by the orbit beacon which will depress to an anble of 20degrees above the horizontal, and on the bearing of the approaching raid.

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8. BEACONS AS INDICATORS OR POINTERS.

The searchlight detachment manning the orbit beacon should now hear the fighter in the close vicinity of the beam. On receiving the code word "SMACK" they will immediately depress the orbit beacon to an angle of 20 degress above the horizontal and on the bearing of the approaching raid. The Fighter meanwhile should be on the look-out for this signal. He will follow the pointer from its source and in the distance, should see one or more searchlights engaging (not necessarily illuminating) the enemy aircraft which has been selected for him. The orbit beacon will be doused at the end of ONE minute, or if one or more fighters are still orbiting, it will be elevated to the vertical again to act as a beacon for remaining fighters.

N.B. (i) This system of making use of the orbit beacon as a pointer is a safeguard against a fighter leaving his orbit point in an attempt ab effect an interception on a raider not intended for him.

(ii) In condition of low cloud, the pilot may find difficulty is seeing the visual pointer when it is depressed to 20 degress elevation. Under such conditions it may be necessary for the controller to give the pilot an initial vector after the code word "SMACK".

9. EFFECTING CONTACT.

The fighter will then fly towards the enemy aircraft by constantly directing his aricraft towards the intersection of the searchlight beams.

10. TERMINATION OF INTERCEPTION.

The fighter having destroyed, lost or broken-off from a raid will inform his parent Sector and ask for a vector back to his orbit beacon if required.

If one or more additional fighters are on orbit the fighter who has given up his chase may be ordered to return to base, or if he is sent back to orbit the Controller will order the height at which he is to orbit.

11. ACTION IN THE EVENT OF FAILURE OF COMMUNICATIONS.

Should land communications fail, the normal procedure will be for the Controller to inform the fighter and to give the code word "CRACKERS". On regeipt of this code word the orbit beacon will depress to 50° on bearing 360° and elevate to 90° and depress to 50° again three times quickly, and remain so exposed until further orders. The fighters will take this as a signal to attack any enemy aircraft illuminated by S/L beams within the area, having informed the Fighter Sector Controller of the direction of hostile raid from the orbit.

The fighter may or may not be given the appropriate visual signal, depending on the location of the break in the communications. Discretionary powers will remain, however, with the Company Control Officer (CCO) at the Company Operations Room (COR) controlling the orbit Beacon site to give the normal intercept signal if communications be satisfactory to the forward searchlight and GL stations, and the said COR is in a posit on correctly to time the "SMACK" signal.

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8. INTERSECTING CONES TO INDICATE AERODROMES.

Intersecting searchlight beams to form a cone over an aerodrome to indicate its position may be ordered by the Sector Controller and formed by searchlights in the vicinity if necessary. If a pilot requires these searchlights to douse he will fire a RED Verey Light or flick his navigation lights on and off several times. Searchlights will immediately douse.

9. DANGER AREAS.

(a) Should there be prohibited areas , danger areas such as wireless masts etc. between the aircraft and the aerodrome to which it is being "Homed" the aircraft wherever possible will be routed by a "dog-leg" arrangement of searchlight beams to keep the aircraft clear of danger areas. The S.C.O. will plan this "Dog Leg" Route and inform the C.C.O's concerned.

(b) In order to indicate to the pilot of the aircraft that he is being "dog legged" searchlight stations selected to form this "dog leg" will expose vertically, and will not give the standard homing signal until the aircraft is heard approaching their station.

C.C.Os. will order the bearings on which the standard homing signal will be given by the searchlights concerned.

10. OPERATIONS TO HAVE PRIORITY OVER HOMING.

Searchlights engaging or about to engage the enemy are not to be ordered to give homing signals. A "Homing Call" in these circumstances cannot be answered but the information that one has been made will be reported immediately to the Sector Controller via the S.C.O. The Sector Controller may then at his discretion , order the Standard Homing Signal.

From R.A.A.F.C. 24/5/43.

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EC 4351 (5)

SECRET

ALLIED LAND FORCES IN S.W. PACIFIC AREA

EC 1202

E in C,
L H Q

CE First Aust Army (4)
CE N.G. Force (5)
CE N.T. Force (3)
1 Aust CE Works QLD L of C Area (10)
2 " " NSW " " (10)
3 " " VIC " " (5)
8 Aust CRE Works TAS Force (2)
9 " " S.A.L of C Area (3)
10 " " WWA. " " (4)
GI SME (Frt) (3)
RAE Trg Centre, WAGGA (3)
D/M in C Adv LHQ (for information) (1)

Copies : M G R A (14)

AAS/L INFORMATION - ABBREVIATIONS USED

1. From time to time abbreviations and code words have appeared in AASL Documents from Gt Britain and have not been clearly understood in Australia.

2. Further information has come to hand on this matter and the following "glossary of terms" is set out.

3. This should be read in conjunction with EC 4351 "REPORT OF THE CONGRESS OF INSTRUCTORS IN SEARCHLIGHTS", and EC 436 "OPERATIONAL ROLES OF SEARCHLIGHTS IN MODERN AIR DEFENCE".

"BOXES"

In Gt Britain there are S/L Belts which are comprised of two "Indicator Zones" with a Killer Zone between them. The depth of the "Indicator Zone" is 12 mile and the Killer Zone 20 mile.

This belt is sub-divided into "Boxes" or areas over which one or more night fighters operate. The width of each "Box" is 1¼ miles. One "box" is therefore 44 miles deep by 1¼ miles wide. At the centre of each "Box", that is on a line through the centre of the Killer Zone at intervals of 1¼ miles, there are Orbit Beacon Stations.

ORBIT BEACONS - These consist of a normal 150 cm operational projector fitted with a removable coloured screen and an additional 90 cm projector for signalling purposes. Over the beacons one or more fighters orbit. If there is more than one fighter they are "layered" 1000 ft apart onheight. Adjacent "Boxes" have different coloured screens for fitting to the operational projector at their Orbit Beacon Station to identify them to the fighters.

"BULLS EYE" RAIDS AND "DARK" RAIDS

Two forms of night interception are carried on in Gt Britain.

(a) G.C.I./Al
(b) Searchlight aided

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The number of G.C.I./Al interceptions that can be carried on at one time over an area is very limited owing to

the presence of a large number of aircraft cluttering up the P.P.I. screen and the controller has difficulty in allotting fighters to raids. Searchlight aided interceptions are therefore carried on at the same time as GCI/Al interceptions, and it is therefore necessary to distinguish, on the night interception table at the Sector Operations Room, where the GCI/Al fighters are, so that Searchlights will not engage them. For the purposes of plotting and reference a fighter is regarded as a satellite of its raid and when a raid is to be intercepted by a searchlight aided fighter the raid is known as a "BULLS EYE" Raid and when by GCI/Al interception a "DANK" Raid. Appropriate plaques are then placed on the Night Interception and Main tables at the Fighter Sectors.

"CRACKERS"

When the density of targets becomes so great or communications fail to such an extent that the Sector Controller is unable to obtain sufficient information about the tracks of the raids being engaged by searchlights to enable him to order fighters to intercept, he passes the code word "CRACKERS" to the fighters and the searchlights.

The Orbit beacons depress to 50° elevation pointing to the front of their "Box", and searchlights engage targets entering the "Boxes" at intervals of five minutes.

The fighters move forward to the edge of the Killer Zone and intercept all targets illuminated by searchlights entering the Killer Zone from the Indicator Zone.

"SMACK"

When a raid has been located by searchlights and the controller considers that it is in a favourable position in relation to the fighter for interception, he passes the code word "SMACK" to the fighter and to searchlights.

On receipt of this code word the Orbit Beacon depresses to 20° in the direction of the selected raid and the fighter takes this signal as his order to move forward and intercept. When the fighter receives the order "SMACK", he ceases to orbit and positions himself behind the orbit beacon awaiting the beam signal to move forward and intercept the SELECTED raid.

4. Ack. 3/1/43 Melbourne 3/1/43

31 Jan 43

for Major General
Engineer in Chief

Major

59 AA Bde

Copy to OC

SECRET

ALLIED LAND FORCES IN S.W. PACIFIC AREA

EC 6025

E in C,

L H Q

ENGINEER SERVICES BRANCH
6TH DISTRICT S.W.P.
62 | 2 | 32

C E	N G Force		(4)
C E	N T Force		(3)
1 Aust	CE Works	Q'LD L of C Area	(7)
2	" "	NSW " "	(10)
3	" "	VIC " "	(5)
8	" CRE "	TAS Force	(2)
9	" CRE "	S.A. L of C Area	(3)
10	" CRE "	W.A. " "	(4)
CI	SME (Frt)		(2)
RAE Trg Centre, WAGGA			(2)
D/E in C, Adv LHQ (information)			(1)

REPORT ON SEARCHLIGHT 'FAN' TRIALS

... 1. The attached copies of above report are circulated for information of all concerned.

2. Distribution is down to AA S/L Coys in your Area with a copy for retention by your HQ.

27 Nov 42

E Wright Lt
for Major General
Engineer in Chief

59 S.L. Coy

AUSTRALIAN WAR MEMORIAL
AWM2018.8.1110

EC 6025

SECRET

REPORT ON SEARCHLIGHT 'FAN' TRIALS

GENERAL

A flight was carried out from Valley aerodrome on the night of 16th August, 1942, to try and observe the effectiveness of the present 21 beam 'fan' under various conditions. Unfortunately the 'target' aircraft proved to be U.S., and therefore no direct evidence was obtainable.

The weather was slightly hazy - the haze extending to above 10,000' - and thin cloud was approx 3/10 at 5,000'. All runs occurred between 2230 hrs and 2359 hrs. No moon was visible. The aircraft used was a Mk VI Beaufighter.

DESCRIPTION OF RUNS

Run (a) Elevation of centre beam of fan .. 30°
Height of Aircraft .. 10,000'
Fan Beams .. In focus
Course .. Straight run in towards fan from approx 18 miles to 4 miles distance from fan.

Run (b) As for run (a), but with Fan Beams dispersed.

Remarks On run (a) beams extended well above aircraft at 12 miles, but gaps between beams were fairly large, giving an inconsistent background brightness. At no time could more than 12 separate beams be counted, possibly indicating faulty direction of the fan beams.

At 4-5 miles distance from the fan slight dazzle was experienced. It was very noticeable that some 2 miles of the coast line were fairly clearly illuminated in front of the fan.

On run (b) an even background of reduced brightness was obtained, but the extreme 'shortness' of the dispersed beam meant that any attack by a fighter would have to be made from well above the E/s - thus exposing the fighter to serious risk of being shot down.

Run (c) As for run (a), but with elevation of Fan Beams reduced by 10%.

Remarks Unsatisfactory owing to apparent reduction of height of fan, and the fact that dazzle was experienced at considerable range from the fan - first being noticeable at some 12 miles distance.

Run (d) As for run (a) but with fan elevated so that centre beam was at 60° elevation.

Run (e) As for run (d) but with beams dispersed.

Remarks In my view run (d) was the most promising one of the night - though more beams would be desirable both to increase the size of the fan and to fill in gaps between existing beams.

Wing Commander WOOLFE who was piloting the machine preferred the evenly illuminated background obtained in (e), but agreed that the upward extent of the fan was too small. (See remarks on run (b)).

Run (f) All Fan Beams elevated to 90° and dispersed.

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Remarks The effect was naturally that of one large dispersed beam of increased brightness. The size of the illuminated background was too small to be of any practical use.

Run (g) As for run (a), but with aircraft at 4,000'.

Run (h) As for run (b), but with aircraft at 4,000'.

Remarks As for (a) and (b) with the exception that more promise was offered by the dispersed beams in this case - as compared with run (b) - due to the reduced beight of the aircraft.

CONCLUSIONS

1. Much more experimental work is required.

2. It appears that for normal operational heights beams 'in focus' are likely to give better results than dispersed beams, due to increased 'beam brightness' and beam length, though the reverse may be found to be true for heights below 5,000'.

3. A careful check of the optimum disposition and directing of the beams is required to avoid risk of unnecessary overlap.

4. Consideration must be given to the risk of illuminating a target area in front of the fan.

5. The most satisfactory elevation for the fan may prove to depend on the height of the target, and, if so, should be capable of speedy change according to advance information on raid heights.

6. It may be found that the disadvantage of reduced beam brightness occasioned by the use of the fan at higher angles of elevation than 30° is more than outweighed by the reduced risk of dazzling the fighter pilot, together with the advantage of the increased height of the fan enabling an attack to be carried out from below the E/a, and the reduced risk of illuminating the V.A.

7. In view of the possibility of attacks on a V.A. from more than one direction, the layout of the fan should, if possible, be such as to allow it to be turned through 360° so as to meet any possible line of attack where this can be done without the risk of illuminating the V.A.

8. The optimum number of beams required can only be found by further experiments - in any case it is likely to prove to be a very large figure. It appears that the use of 'Fans' must be extravagant in the use of projectors though the number of personnel required to man them would be relatively small since no locating equipment is required.

AUSTRALIAN WAR MEMORIAL AWM2018.8.1110

File with previous "Fan" trials reports 6/5/43

(3)

SECRET

ALLIED LAND FORCES IN S.W PACIFIC AREA

EC 6623

E in C,

L H Q

C E	N G Force	(4)
C E	N T Force	(3)
1 Aust CE	Works Q'LD L of C Area	(7)
2 " "	" N S W " "	(10)
3 " "	" VIC " "	(5)
8 " CRE	" TAS Force	(2)
9 " CRE	" S.A L of C Area	(3)
10 " CRE	" W.A " "	(4)
CI SME (Frt)		(2)
D/E in C, Adv LHQ (information)		(1)

REPORT ON SEARCHLIGHT 'FAN' TRIALS

1. Further to EC 6025 of 27 Nov. 42, following additional remarks are circulated.

2. The trials detailed in the Report were carried out in the U.K with the object of providing a background of light against which enemy aircraft may be silhouetted in order to facilitate engagement by Fighters.

3. For the purpose of these trials up to 21 S/L's have been deployed ~~dixpixxxx~~ in a "fan" layout. Further experimental work is going on, and considerable investigation is required in regard to the angle of elevation of the "fan", the disposition of the S/L's, the degree of brightness of the beams and other matters.

4. As an immediate result of the experiment carried out, an additional 42 projectors ~~hxvexbxxxxxprxjxxtxxrx~~ have been deployed in the trial area. Further reports will be forwarded as investigations proceed.

5. S/L "fans" are designed to assist Fighters only. They have no application to A A Guns.

6. Distribution of this additional information is precisely the same as that set out in E C 6025.

E W Coates Major
for Major General
Engineer in Chief.

AUSTRALIAN WAR MEMORIAL AWM2018.8.1110

-4 FEB 1943
59 A.A.Coy., R.A.E.

8 Aust. C.R.E. (Works).
62/2/40

File

SECRET

ALLIED LAND FORCES IN SOUTH WEST PACIFIC AREA.

EC 959.

E in C, LHQ.

CE	First Aust Army	(4)
CE	NG Force	(5)
CE	NT Force	(4)
1 Aust CE (Works)	Q'land L of C Area	(10)
2 " " "	NSW " "	(10)
3 " " "	VIC " "	(5)
8 Aust CRE (Works)	Tas Force	(2)
9 " " "	SA L of C Area	(3)
10 " " "	WA L of C Area	(4)
CI SME (Frt)		(3)
RAE Trg Centre, WAGGA		(3)
D/E in C, Adv LHQ		(2)

Copies for information to:-

MGRA	(2)

REPORT ON AAS/L DAZZLE TRIALS.

1. Attached report emanates from tests carried out in AUSTRALIA, and contains much useful information. Similar trials should be arranged where possible by local Commanders to check the views expressed in this present report, and results forwarded to this Directorate.

AAS/L ENGAGEMENT OVER ENEMY TERRITORY.

2. The "Extract from information bulletin received via RAAF" also attached refers to operations over EUROPE, and from the attackers point of view reveals the FRUSTRATIVE effect of AASL's (see EC 436, "D").

3. Sufficient copies of this circular are provided to permit distribution down to AAS/L Coys in your Area.

4. Ack. 3/2/43 Message Hand 11/2/43

for Major General
Engineer in Chief.

26 Jan 43.

59 AAS/L

AUSTRALIAN WAR MEMORIAL
AWM2018.8.1110

REPORT ON SEARCH LIGHT ILLUMINATION FOR DEFENCE AGAINST GROUND ATTACK BY AIRCRAFT.

The following report has been compiled as a result of the exercises carried out in November 1942. The report is written from the airman's point of view, and deals with the following aspects of the problem.

(a) The dazzle effect of masses searchlights on pilots in low and medium level attacks.

(b) The target illumination afforded by searchlight beams exposed at low angles.

(c) The effect on map reading and target location.

(d) The effect on bomb sighting.

DAZZLE EFFECT OF MASSED SEARCHLIGHTS ON PILOT'S VISION IN LOW AND MEDIUM LEVEL ATTACKS.

Low level attack may be carried out at any height below 4,000 feet. At such an altitude, searchlight beams may engage the aircraft at a low angle. When engaged from ahead, the pilot is very effectively blinded, and must withdraw into his cockpit and fly entirely by instruments. He is thus prevented from carrying out any violent evasive manoeuvres due to the limitations of his flight instruments. Low angle beams engaging from abeam are effectively broken by the main planes and engine nacelles, and therefore cause the pilot less discomfort. Beams engaging from the rear quarter may, dependent upon the construction of the aircraft shine through the side windows of the pilot's cabin, and cause such reflections as to make instrument flying essential. Beams exposed on an aircraft when it is vertically above the source of the light, have very little effect, as they are effectively broken by the fuselage and the main planes.

TARGET ILLUMINATION AFFORDED BY SEARCHLIGHT BEAMS EXPOSED AT LOW ANGLES.

The bomb aimer was most effectively blinded by the lights, and consequently no illumination was noticed. There is little possibility of low angle beams ahead of the aircraft illuminating the target as they effectively blind the bomb aimer from this angle. As the aircraft passes the lights, however, and the beams shine from astern, the blinding effect is practically eliminated and the danger of target illumination becomes great, particularly if the aircraft is held by the searchlights to maximum range.

EFFECT ON MAP READING AND TARGET LOCATION.

While the aircraft was surrounded by beams, the ground was not visible at all, making accurate target location impossible.

The bomb aimer tried fixing his position when some distance from the target and immediately the lights were exposed, noting the position of each group on his map. He subsequently fixed his position by the positions of the lights relative to the target. By this method it was possible to guide the pilot over the target with sufficient accuracy for area bombing.

EFFECT ON BOMB SIGHTING.

With searchlights shining from ahead of the aircraft, accurate bomb sighting is impossible. Lights behind the aircraft caused practically no inconvenience. Any ground illumination

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practically eliminates the effect of the lights. As an illustration of this, a bush fire on the out-skirts of the target area was visible the whole time. Using the method outlined under the heading "Effect on Map Reading and Target Location", it may be possible for one aircraft to locate the target and illuminate it by incendiary bombs. The remaining aircraft could then make an effective bombing run.

2. It must be remembered in considering this report that only one aircraft was employed, and naturally suffered intense illumination from the searchlights which were free to concentrate. With large numbers of aircraft this would not be so, and it is considered that aircraft which are not held in the searchlights could make an effective bombing run.

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EXTRACT FROM INFORMATION BULLETIN RECEIVED VIA RAAF.

"Most German cities, within effective bombing range of England, are protected by 80 to 100 instrument-controlled searchlights. These searchlight systems are better than anything the British have at present. The masses of searchlights are confusing to bombers. One night over Essen so many searchlights came on the attacking planes, that the crews couldn't see a thing. The British find that when a pilot gets into one of these searchlight areas, he must keep his head down and fly by instruments, so as not to allow the dazzling light to blind and confuse him. It is impossible for the bomber to throw the searchlights off its trail, and it must protect itself by evasive action."

"Turning south, we pinpointed on the south shore and set course at 1500 feet for Schiphol - map reading in. When within about five miles of the aerodrome, 20-25 searchlights lit just ahead of us and came immediately on to the aircraft. The Pilot tried to break through but was so blinded by the lights that we had to turn back to the Zuider Zee. In attempting to get out of the lights our height varied from 1600 to 200 feet. Light tracer was about us as soon as the searchlights came near and stopped when we lost them. In the Zuider Zee we held comference and decided to try from the south at a height of 3500-400 feet. Once more we set course for a landfall - a lake to the S.S.E. of the target and reached it without trouble. As we turned on the run, however, searchlights again uncovered all/around us and both light and heavy flak appeared uncomfortably close. The Wop/A.G. reported he had been hit but he did not consider it dangerous. Once more pilot had to turn back because of the lights and, so, not knowing the extent of the gunner's wound, the Captain decided to abandon the task and we returned to base with bomb load intact."

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Dist B

SECRET

ALLIED LAND FORCES IN SOUTH WEST PACIFIC AREA

EC 156

E in C,
L H Q

1	Aust CE (Works)	Qld L of C Area	(10)
2	" " "	NSW " "	(10)
3	" " "	Vic " "	(4)
9	Aust CRE "	SA " "	(3)
10	" " "	WA " "	(3)
	CE Tas Force		(3)
	CE NG Force		(5)
	CE NT Force (12 Aust Div)		(3)
	CE 1 Aust Army		(2)

Copies for information to:-

SME (Frt)	(5)
RAE Trg Centre	(5)
D/E in C, Adv LHQ	

VISIBILITY OF AIRCRAFT ILLUMINATED BY

SEARCHLIGHT BEAMS

1. Herewith copies of report on experiments carried out in UK on the above subject for the Ministry of Supply.

2. Enough copies are provided to allow one copy for your HQ and one copy for each CRE, AA Def HQ, AASL Bn and AASL Coy in your Formation or Area.

for Major General,
Engineer in Chief.

6 Jan 43

Sgl typed
Secret when filled

54 BPS/1

Copies sent
Secret

S E C R E T

VISIBILITY OF AIRCRAFT ILLUMINATED BY SEARCHLIGHT BEAMS

1. PURPOSE OF THE REPORT

The purpose of this report is to estimate the maximum ranges at which aircraft illuminated by searchlight beams are visible, both from the ground and from the air. The report is an abbreviated version of a longer one, which gives details of the calculations and experiments on which the results stated here depend. The report is divided into two Parts :

A. Visibility of aircraft from the ground, in particular a discussion is given of the ranges at which visual control of searchlights is possible.

B. Visibility of illuminated aircraft from the air, an estimate is given of the illumination required to make a bomber visible to a fighter pilot.

A. VISIBILITY OF AIRCRAFT FROM THE GROUND

2. FACTORS AFFECTING THE RANGE

The range at which illuminated aircraft can be seen from a searchlight site will depend on the following factors :

a) Weather conditions, since there is small chance of seeing an aircraft even through thin cloud or ground mist, we confine our investigation to haze. It will be shown that with equipment which will give a range of 20,000 ft on a clear night, only 10,000 ft may be obtained on a very hazy night. The effect of conditions likely to occur in industrial districts is also discussed.

b) Position of observer, the relative ranges at which an aircraft can be seen by the man on the long arm, a man working a control pillar and a more distant spotter are calculated. The increase of range obtainable with binoculars is also discussed. With a control pillar, it is found that the range is nearly twice that from the long arm.

(c) Night-camouflage; it is shown that the maximum range at which a night-camouflaged aircraft can be seen is of the order of 2/3 of that for an uncamouflaged machine.

(d) Size and aspect of aircraft. The range for aircraft seen end on may be as much as 20% less than in plan view.

(e) Number of beams illuminating the aircraft; a beam from one other site may increase the range up to which visual control is possible by 10 to 15%, a "cone" of lights by, say 50%.

(f) Type of projector and arc current. With the 150 cm projector it should be possible to see about 20% further than with the 90 cm projector, depending on the weather conditions.

Information of the type calculated in this report should be of value both on account of the fairly accurate comparison that it gives of the ranges obtainable with different types of equipment, and the somewhat less accurate absolute values of the ranges. For instance, it is useful to know how much improvement in the ranges at which visual control is possible will be gained by the use of a control pillar, and to compare it with the effect of a more powerful projector. Our figures for the absolute values of the ranges at which the target can be seen depend on such factors as the eyesight of the operators, and may well be in error by as much as 20%. Further, the range at which a target can be picked

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up will not be the same as the range up to which it can be held. The ranges depend, however, so sensitively on the weather conditions that more accurate values would be of no practical value. Our values will at any rate tell us whether a given system of visual control, e.g. one visual light in three on the 6000 yards spacing, is likely to give results on most cloudless nights, or only on particularly clear ones.

It might at first be thought that the differences between operators, and such factors as the time available for spotting the target aircraft, would affect the maximum range obtainable by much more than 20%. Actually, however, when the target aircraft is at nearly the maximum visible range, a decrease of 10% in the range will nearly double the light entering the observers eye; the apparent brightness increases very rapidly as the aircraft approaches the observer. Thus our estimated uncertainty of 20% corresponds to a range of brightnesses of about 1 to 10 as seen from the ground. In one set of experiments on the visibility of small light sources seen against a dark background, a source was said to be visible if, in a long series of experiments, the observer had a 50% chance of spotting the source, from a given distance, in 10 seconds. The brightnesses required by three different observers varied between 1 and 1.5 only. If the source was doubled in brightness, the chance of spotting it went up to about 95%, if it were halved, the chance went down to less than 10%. Thus a variation in brightness by about four to allow for the available time seems not unreasonable, and we hope that it is not too optimistic to assume that a factor 10 will cover the whole range of conditions occurring in practice.

3. ATMOSPHERIC CONDITIONS

We are interested in atmospheric haze for two reasons :

(a) because the absorption and scattering by the atmosphere and by the aerosols (water droplets, ice and smoke particles suspended in it) cut down the intensity of the light on its way to and from the target aircraft.

(b) because the scattering of the light by the atmosphere and aerosols makes the searchlight beam visible.

It is interesting that even in pure air the molecules of air themselves scatter enough light to make a searchlight beam visible on a dark night, however, according to the information at present available, over England even at 20,000 ft the impurities in the atmosphere will normally contribute more than four times as much as the molecules to the brightness of the beam observed from the side.

Natural haze is believed to consist of small water droplets of diameter about 1/2 to 1/4 of the wavelength of light. Industrial haze consists mainly of solid carbon particles of about the same size. The way in which such particles will scatter light can be calculated theoretically. In both cases, according to the size of the particle, from 5 to 20 times more light is scattered in the forward direction, i.e. in directions making an angle of less than 40° to the beam, than is scattered sideways and backwards. This is the reason why a searchlight beam appears brighter when depressed towards an observer. The carbon particles, unlike the water droplets, absorb light as well as scattering it, both theory and experiment show that carbon particles of this size will absorb about three times as much light from a beam as they scatter out of it. Thus a searchlight beam passing through a natural haze that cuts its intensity down to one-half in a given distance will appear much brighter than the same beam passing through an indistrial haze which cuts it down by the same amount.

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Some of the results obtained are as follows :-

a) The range at which a bright patch can be seen depends, except in extreme cases, only on its area and not on its shape; this holds for elliptical patches with the ratio of length to breadth as great as 20 to 1. This is confirmed by an RAE report for dark patches against a brighter background, but here a falling off of visibility is recorded if the ratio of length to breadth exceeds 12.

b) For small patches subtending much less than 0.25° at the eye (e.g. an aircraft at 10,000 ft seen without binoculars), the visibility for a constant background brightness depends only on the product of the area and of the excess brightness over the background, i.e. on the total excess illumination which reaches the eye. For patches much bigger than this the visibility depends on the product of the excess brightness and the linear dimensions of the patch.

c) A small bright patch or point source will be visible against a dark background which will be invisible against a brighter one. A point source must be about five times as bright to be visible against a searchlight beam seen from a point 200 ft from the projector as against the night sky. The effect of background on large patches (i.e. aircraft seen from the air from ½ mile away, or from the ground through binoculars) is larger still.

d) Finally, we must remember in all visibility work that no object, however large, will be visible if its contrast with the background drops below 0.02. This does not affect us much in searchlight work, where the contrasts even for night-camouflaged aircraft at extreme range are more often of the order 0.1.

The fact, mentioned in paragraphs c) and d) above, that a luminous background reduces the range at which an illuminated object can be seen, is responsible for the impression that it is impossible to see an aircraft "through" a beam, especially from the end of a long arm. Actually, it is not any difficulty in seeing <u>through</u> a beam that is responsible; if a beam is viewed at right angles, an illuminated object will be <u>more</u> visible if on its far side than on the near side. The reason for this is as follows : Let us consider, in fig 1, an observer at O viewing two targets at A and B. These are supposed to be at equal distances from the axis of the beam, so the illumination is the same for one as for the other. Moreover, they are viewed against the same background, namely the brightness. But whereas the apparent brightness of a target at A is that due to its illumination by the beam together with the brightness of the beam (i.e. of the illuminated haze particles) superimposed on it, that of a target at B is mainly due to its illumination alone, since very little of the beam is in front of it. Thus A will appear brighter than B.

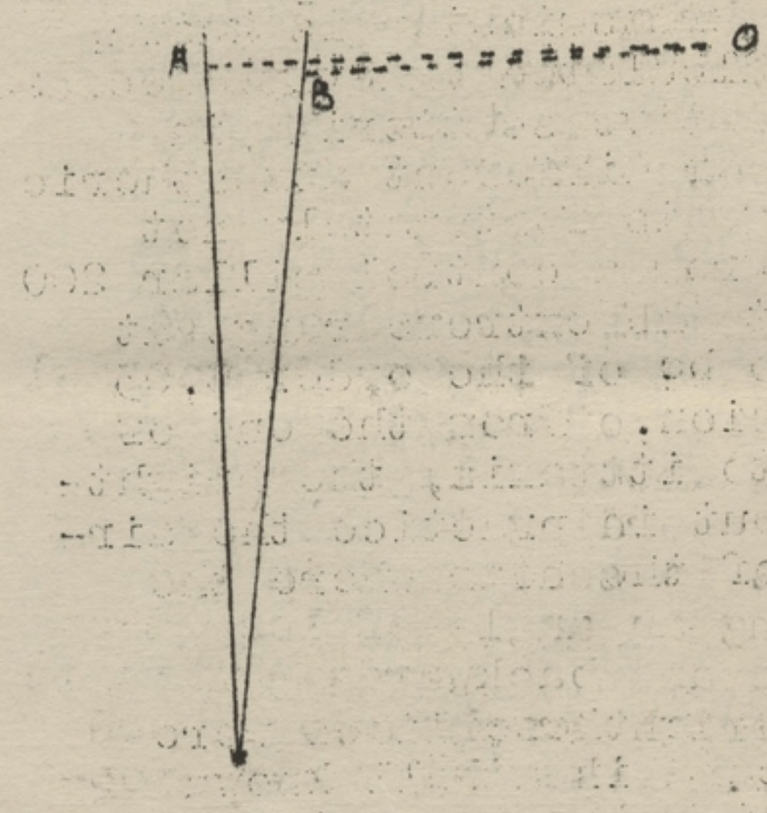

Fig 1

There is one position of B, near to the edge of the beam, for which the light reflected from the target to the observer is just equal to the light from the illuminated haze which the target hides. If the side of the target exposed to the observer is uniformly illuminated it will then be invisible. If it is still further to the right of the beam, it will appear as a dark silhouette against it.

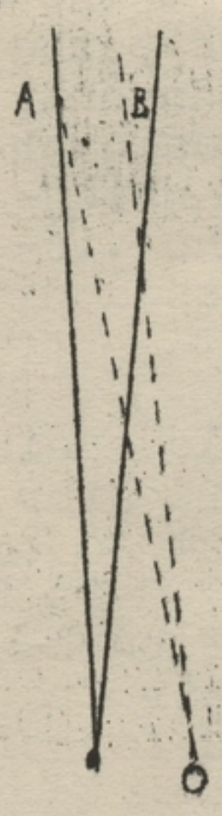

Fig 2

To an observer at a point near to the projector the situation is different, since the line of sight OA in fig 2 enters the beam nearer to the projector than OB, and thus passes through a region where the haze particles are more birghtly illuminated. Thus the beam brightness against which the target is seen is greater when it is at A than when it is at B. This is the reason why it may be visible at B but not at A.

Actually we find on carrying out the calculations that when the observer is as near to the projector as the man controlling the long arm, the target will be visible at the greatest range if held on the near side of the beam where the illumination is about a quarter of the value on the axis; the necessity for holding the target on the near side is confirmed by common experience. Only if the target is brightly illuminated by a considerable number of other beams will it be possible to see it when near the axis.

From observation points 200 ft away the A.D.E.E. trials and calculations show that the position of maximum visibility is quite near to the axis of the beam; also the range at which the aircraft can be seen is relatively insensitive to the position in the beam, decreasing only very near the edge.

In order to calculate searchlight ranges, then, we require to know the beam brightness as seen by the observer looking towards the aircraft. This will of course depend on the amount of haze in the atmosphere, and thus on the atmospheric transmission. Even when the atmospheric transmission is known, however, the beam brightness cannot be calculated exactly, because the polar curve, which determines the relative scattering in different directions, is not constant under different atmospheric conditions. However, the calculated range is fortunately not very sensitive to the beam brightness. From a control pillar 200 ft from the projector the beam as seen at the extreme range at which an aircraft is visible turns out to be of the order 0.03 c.f.c. whatever the atmospheric transmission. From the end of the long arm, viewing the beam parallel to its axis, the brightness is of the order 0.6 to 1.2 c.f.c., but in practice the aircraft will probably be held in the edge of the beam where the brightness is much less.

Calculations of searchlight ranges on these lines were first made by the French investigator Rocard in a well known series of papers. The calculations on which this report are based extend his in the following respects.

1) More recent experimental data on visibility are used.

2) The calculations are extended to apply to objects of low reflecting power, such as night-camouflaged aircraft.

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3) The calculations are carried out for points very near to the projector (end of long arm).

In general our results are in fair agreement with Rocard's for the cases which were calculated by him.

Using the experimental results on the visibility of light patches mentioned above, we have worked out the ranges at which an aircraft directly overhead can be seen in the light of a single beam from various positions near the projector, in the case of the observer on the end of the long arm, it is supposed that he is directing the beam to obtain maximum visibility for himself. The ranges are all "pick-up" ranges; that is to say they are calculated on the assumption that an observer who knows roughly where to look can spot the target with certainty in 2 or 3 seconds. Ranges up to which the target can be held by a searchlight are believed to be 15 to 20% greater, The ranges are calculated in weather of the following types :

I. A clear night, with transmission 0.9 per 1000 yards both on the ground and up to the aircraft. The daylight visibility under these conditions would be 17½ miles.

II. A slight haze, with the transmission co-efficient of 0.7 per 1000 yards. This is assumed to extend up to the aircraft, which is unlikely if the aircraft is higher than 8000 ft. The visibility in daylight would be 7 miles.

III. A thick haze, transmission 0.5 per 1000 yards, visibility in daylight 3 miles. Again the haze extends up to the aircraft.

IV. Thick haze on the ground reaching to 3000 ft only, cutting down light by 50%. Above the haze top, transmission 0.9 per 1000 yards. This is probably typical for haze nights.

V. Thick smoke haze, cutting down light to 25%; above that, transmission 0.9 per 1000 yards.

For the searchlight we take a 150 cm prijector.

For the aircraft a plan area of 700 sq ft and diffuse reflection factor

0.3 uncamouflaged
0.03 camouflaged

For the binoculars we take a magnification 6 and a loss of 50% of light in transmission.

RANGES IN FEET
UNCAMOUFLAGED

Weather	I	II	III	IV	V
From long arm	20,000	13,000	9,000	16,300	12,000
From 200 ft	25,500	15,000	10,000	20,000	15,000
From 200 ft with binoculars	38,000	20,000	13,500	28,500	22,500
From distant point (naked eye)	28,500	16,500	11,000	22,500	17,500

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CAMOUFLAGED

Weather	I	II	III	IV	V
From longarm	13,500	9,500	7,000	10,000	7,000
From 200 ft	17,000	11,500	8,000	11,700	9,500
From 200 ft with binoculars	25,000	15,000	10,000	19,000	14,000
From distant point (naked eye)	19,500	12,500	8,500	13,500	11,000

Ranges with 90 cm projector, from 20% less in clear weather, to 15% in hazy weather, increase of range with the 200 cm projector about 5%.

Ranges increased by 10% to 15% if two beams are on the target, more if control is from the long arm.

By a distant point is meant a point about 1/4 of a mile away; from more distant points the ranges may be greater by 10 to 20%.

It must be emphasised that these ranges are all for an aircraft directly overhead. For other cases the ranges are less because -

a) The aircraft is illuminated obliquely.

b) The area of silhouette is less.

c) In cases IV and V the light has further to gonthrough the ground haze.

For comparison we give the ranges obtainable with control pillar and binoculars on a camouflaged aircraft directly overhead and at 45° to the vertical.

Weather	I	II	IV	V
Directly overhead	25,000	14,700	19,000	14,000
45° to vertical	22,000	13,200	14,000	10,000

The most important conclusions to be drawn from these calculations are :

a) That aircraft can be followed with a control pillar to nearly twice the ranges possible with long arm control.

b) Negligible increase of range by using a larger projector than the 150 cm, ranges 15 to 20% less with 90 cm projector than with 150 cm.

c) Night-camouflage cuts down the ranges to two-thirds of those on uncamouflaged aircraft.

d) With the control pillar ranges between 20,000 and 30,000 ft are possible on camouflaged aircraft on ordinary clear nights.

e) A thick smoke haze may nearly halve these ranges.

5. COMPARISON WITH EXPERIMENT

The fact that an aircraft at 20,000 ft has been seen with the naked eye is compatible with our theory if the weather was clear.

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The Biggin Hill trials on night-camouflage give ratios between the ranges with and without night-camouflage in fair agreement with out theoretical values. The short ranges obtained suggest that there was considerable industrial haze.

The Portland-Chesil beach trials give ranges about 20% greater than ours. The discrepancy can be accounted for on various grounds, one of which is the fixed target with an indefinite time for the observer to pick it up. We consider our values more applicable to A.A. work, for the ranges at which aircraft can be picked up. It is probable that they can be held up to greater ranges, possibly 20% more, but we have not the experimental evidence to make an exact estimate. As regards the relative effect of change of atmospheric absorption, type of projector used and distance of observer from the projector, the Chesil beach results on white targets are in excellent agreement with ours, except that the effect of nearness to the projector in cutting down the range was rather greater for the larger projectors than our theory predicts.

Recently ADRDE have made trials on the ranges up to which aircraft could be held with binocular remote control and with the long arm. The results were as follows :

Target	Height	Weather	Ranges (feet) Control pillar	Long arm
Hudson, uncamouflaged	7,000	Clear	27,000	14,800
Whitley, camouflaged	8,000	Haze to 5000 ft	21,500	9,650

The increase in range with the control pillar is of the order given by our calculations.

B. VISIBILITY OF AIRCRAFT FROM THE AIR

The ranges at which illuminated aircraft are visible from the air are far harder to estimate than the ranges from the ground.

The only source of information available is an experiment with model aircraft recently carried out by RAE Farnsborough. A model painted with night-camouflage was hung up against a faintly illuminated screen, which could be varied to represent the beam brightness or that of the night sky. The model was then illuminated and the range at which it was visible determined.

RAE have considerable experience of determining the ranges at which dark aircraft are visible in silhouettes against a night sky; they find that the ranges obtained in the dark room with models are usually about half those obtained in operation - e.g. with AI fighters. We have made the rather arbitrary assumption that the same factor must be used in interpreting the laboratory experiments on illuminated aircraft.

In the experiments the following effects were noticeable, before the model was illuminated, it was visible from sufficiently near in silhouette against the background. As the illumination increased, then to an observer behind and slightly underneath, there came a point when the brightness was equal to that of the background and the aircraft was invisible. For brighter illumination the aircraft appeared silver from below; from above it appeared black with bright edges.

Thus weak illumination, though perceptible to an observer in the illuminated aircraft, may be worse than useless to the fighter pilot.

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In order to appreciate the results obtained, we give a few figures to fix our orders of magnitude :

At a slant range of 20,000 ft, in clear weather, the illumination in the centre of a 150 cm beam is about 0.5 ft candles, equal to that in a room with poor artificial light. At the edge of the conventional beam the illumination is one-tenth of this, and outside the edge the illumination drops rapidly to about 0.005 to 0.001 (mmonlight). The cone in which the illumination is comparable with moonlight extends over at least 6°, compared with $1\frac{1}{2}$° of the true beam of the 150 cm projector.

The brightness of a night-camouflaged aircraft with reflection coefficient 0.03 (believed normal for aircraft in service) illuminated normally by a single beam will thus be :

In centre of beam	0.015 e.f.c.
At edge	0.0015 "
In fringe	0.00015 "

In hazy weather these values should be halved.

We contrast these values with the backgrounds against which the aircraft must be seen :

Starlit sky (no moon)	0.0001 e.f.c.
Beam from 150 cm projector at 20,000 ft, viewed at right angles	0.00005 to 0.0002 e.f.c.
The same, viewed at 20° to axis, looking towards the projector	0.001 e.f.c.

We see that the moonlight type of illumination is likely to be worse than useless, as it will scarcely bring the brightness of the aircraft up to that of the background; but that illumination with any part of a single true beam gives an ample contrast, unless the fighter pilot is looking almost down a beam.

In the experiments, the following values of the illumination were required to make an aircraft visible from half a mile or a mile away, and 30° below :

Background (e.f.c.)	Illumination (f.c) $\frac{1}{2}$ mile	1 mile
0.0001 (night sky)	0.024	0.04
0.0012 (intersection of many beams, or beam viewed obliquely)	0.16	0.20

The reflection coefficient is taken to be 0.03.

We see, therefore, that illumination with any part of the true beam will be sufficient if the background is not too bright, and illumination from near the centre will make the aircraft visible against any background of beams likely to be encountered.

The ranges at which aircraft can be seen in silhouette against the beams can also be determined from RAE model experiments. Against a starlit sky Al fighters establish visual contact at 6 - 700 ft; an aircraft is visible in plan view against the same background at 1000 to 1100 ft. Even if the background is increased to 0,001 these ranges are only increased by about 50%.

In conclusion, it may be stressed that with RDF-controlled searchlights there is very little to be said for using a large projector. In cloudless weather the illumination at the centre of a 90 cm beam will normally be ample. In cloudy weather, unless the cloud is very thin, no projector will give enough light to illuminate the aircraft. Under normal weather conditions when searchlight work is possible, it is probable that the 90 cm gives <u>enough</u> light over a wider cone, and will therefore illuminate the aircraft sufficiently for a greater percentage of the time. The advantage of the 150 cm beam is in extending the range to which visual control is possible.

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