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Report on
OPERATION "BACKFIRE"

VOLUME V

Recording and Analysis of the Trajectory

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Recording and Analysis of the Trajectory — SECTION 1

INTRODUCTION

1. SCRs 584, GLs II and a Type 14 Radar were deployed along the western coast of the Danish peninsula to track the rockets during flight and to determine their point of fall. In order to obtain more precise data of behaviour during the period of burning kine theodolites were used to produce a precise optical record of the initial part of the trajectory.

2. " X " Special Radar Battery and No. 2 AA (ATS) KT Detachment were made available to operate radars and kine theodolites, respectively, and a detachment of nine HAA recording vans to record the data obtained. By suitable tie-up between radar and optical results it was hoped to gain experience of the accuracy and the general behaviour of radars used in tracking long range rockets.

DEPLOYMENT

A.—Kine Theodolites (KTs)

3. Two German Askania kine theodolites were obtained to supplement the two brought from the United Kingdom by the KT Detachment. Four posts were established as follows :—

KA RR.61498911 KB RR.56608306	" British " Askania KTs (F600 lenses)
KC RR.63478400 KD RR.59957977	German Askania KTs (F300 lenses)

4. Kine Control was established beside KT site A in a HAA recording van. This site was also Radar Site R 5. A diagram of the deployment is at Plate 1. All four posts were connected to Kine Control by an omnibus speech circuit. Individual lines radiating from Kine Control to the four posts supplied the impulses for the cameras. These lines were for the most part in German underground telephone cables. By means of mechanical clock and the appropriate electrical circuits at Kine Control, all four KTs were pulsed simultaneously twice per second. In addition, an electrical counter was made to move with the pulses, and the counter was photographed 12 times/sec. beside a 1/100 sec. stopwatch (see later description of site R 5). After preliminary line troubles the system proved satisfactory. For details of the pulsing system see Appendix 1 to this Section.

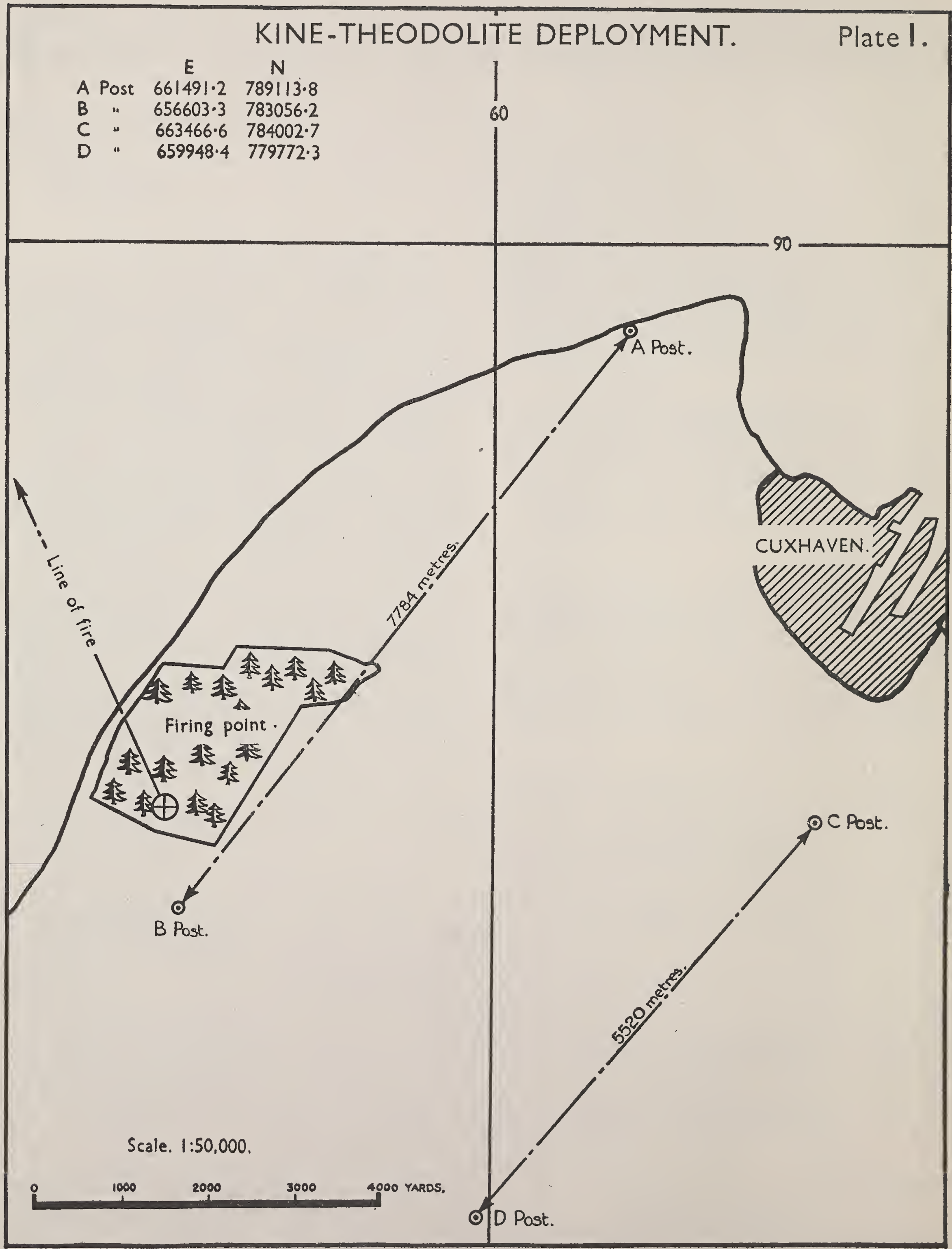
B.—Radar

5. Five sites were deployed with equipment as follows (see map at Plate 2) :—

All SCRs 584 except that at R 5 and all GLs II were fitted with long range modifications.

6. It was desirable to avoid sites to the east of the river ELBE as they were in the German Army concentration area " G." Site R 1 was therefore deployed south of the

SITE	LOCATION	EQUIPMENT	
R 1	BENDORF RN 090125 (later at TONNING RM.786361) (Nord de Guerre Zone Grid)	2 SCRs 584	2 HAA Recording Vans.
R 2	I of NORDSTRAND VB.8167 (North European Zone Grid)	1 SCR 584 (with 8 ft. paraboloid). 1 GL II. For Rocket 3 a second SCR 564 (with N^2 gate and auto-follow in range) was deployed	1 HAA Recording Van. A second van was deployed for rocket 3.
R 3	EMMELSBULL VW.763048 (North European Zone Grid).	1 SCR 584. 1 GL II.	1 HAA Recording Van.
R 4	RINGKOBING VR. 724502. (North European Zone Grid).	1 AMES Type 14. 1 GL II (modified). 1 LW (AA No. 4, Mk. III) (Rocket 3 only).	1 HAA Recording Van.
R 5	DOSE RR.615891 (Nord de Guerre Zone Grid)	1 SCR 584 (with cine camera on paraboloid).	1 HAA Recording Van (with Cine camera).


KINE-THEODOLITE DEPLOYMENT.
Plate I.
E N
A Post 661491·2 789113·8
B " 656603·3 783056·2
C " 663466·6 784002·7
D " 659948·4 779772·3
60
90
A Post.
Line of fire
7784 metres.
CUXHAVEN.
Firing point.
B Post.
C Post.
5520 metres.
Scale. 1:50,000.
0 1000 2000 3000 4000 YARDS.
D Post.

Kiel Canal. Originally the site was very similar to that at STEENBERGEN in HOLLAND, which had been used to observe rockets launched from the HAGUE area at LONDON. At a late date, however, the proposed line of fire was swung 4° further west, thus making aspect angles from this site less favourable. The equipments were sited on the highest ground in the area with a clear field of view in the direction of the launching point. The two SCRs 584 were deployed side by side. It was found that so sited, mutual interference due to unlocked pulses (running rabbits) was such as to make simultaneous operation of the sets impossible. When looking towards the launching site the dipoles of the radars were intervisible. Thus, for the first two launchings only one radar was in action at this site.

7. The results from R 5 on Rockets 1 and 2 had been unexpectedly good and actually of longer duration than from R 1. R 1 was therefore of little use in its first position. As Area " G " had been reduced in size it was decided to move R 1 further north to a position where it could be expected to obtain trajectory data beyond the end of the plot produced by R 5. Re-deployment was carried out in time for the third and final launch on Oct. 15. A site at TONNING (RM7836) recommended by A.O.R.G., was chosen in order that the maximum length of follow would be achieved, although it was realised that the head on aspects likely to be encountered might make following difficult at first. Recording of the equipment was done on a Westex Recorder modified to receive selsyn data transmission from two SCRs 584. An accurate 1/100 sec. stopwatch was used.

8. Site R 2 was also chosen to have a good field of view in the direction of the launching site. The SCR 584 here was fitted with an 8-ft. paraboloid with the aid of which it was hoped that the rocket would be followed from launch. This did not prove to be so, and it was found that a longer aerial spinner was necessary where an 8-ft. paraboloid was used. This had not been supplied with the paraboloid but was obtained in time for Rocket 3. For Rocket 3 a second SCR 584 with an N^2 gate, borrowed from the R.A.F., was deployed. This radar was modified for auto follow in range by means of a unit provided and fitted by IX Air Defence Command, United States Forces, European Theatre. A GL II with normal array was deployed with the intention of obtaining constant following to provide trajectory data and to assist the SCR 584 to pick up the target should it fail initially. The aerial heights were modified slightly to give optimum results, and provision was made for putting the SCR 584 on target by suitably marrying the magslip and selsyn transmissions (see Appendix 4). Recording was carried out in the normal manner using a 1/10 sec. stopwatch.

9. At R 3 both SCR 584 and GL II were sited with the intention of picking up and tracking rockets as they neared the vertex of the trajectory. As at R 2 the GL II was intended to do constant following and if necessary to put the SCR 584 on target. For this purpose data transmission was modified in the same way as at R 2. On account of the high angle of search siting was not critical. Recording was carried out in the normal manner using a 1/10 sec. stopwatch.

10. Equipment at R 4 was deployed with the intention of determining the fall of shot. The unmodified AMES Type 14 radar was sited on a suitable hummock some 20 ft. above the surrounding ground with a clear view in the direction of the target area. The GL II fitted with the normal BB modification was originally sited on the assumption that rockets would be fired at a range of 320 kms. (200 miles). The shorter range of 250 kms. (156 miles) made the expected aspect angle of rockets unfavourable, but it was nevertheless decided to retain the radar but with aerials set so as to lower the beam. By this means it was thought that air break-ups might be detected which would be missed by the Type 14. The GL II was sited normally on flat ground. An unmodified LW set (AA No. 4, Mk. III) was deployed to observe the fall of shot of Rocket 3 in order to test its suitability in this role. It was sited as for the Type 14. All recording at R 4 was done manually.

11. At R 5 an SCR 584 was sited on the sea wall roughly 8,000 yards from the firing point. A long follow was not expected due to aspect angle and range rate considerations, and the set was therefore not modified for following beyond 32,000 yards. Recording of the selsyn data on a Westex Recorder was done by means of a Filmo 70 DA Cine camera, running at 12 frames per second. Time was provided by a 1/100 second stopwatch. On the dial board of the recorder was situated an electric pulse counter which provided the means of tying up kine theodolite and radar records. The exact time of take-off of rockets was recorded by means of a light which was switched on automatically by the rocket as it lifted from the firing table (an external " Abhebekontakt "). On the paraboloid of the SCR 584 was fitted a Cine Kodak camera with a 6″ telephoto lens. This recorded at 16 frames per second a picture of the accuracy of follow of the radar.

12. At Appendix 3 will be found details of the " drill " carried out at each radar site together with the search data. Appendix 4 contains details of modifications carried out to SCRs 584 and GLs II. It was necessary to devise a special long range modification to the former sets on account of the unsuitability of the Westinghouse modification for fitting to sets made by the General Electric Company.

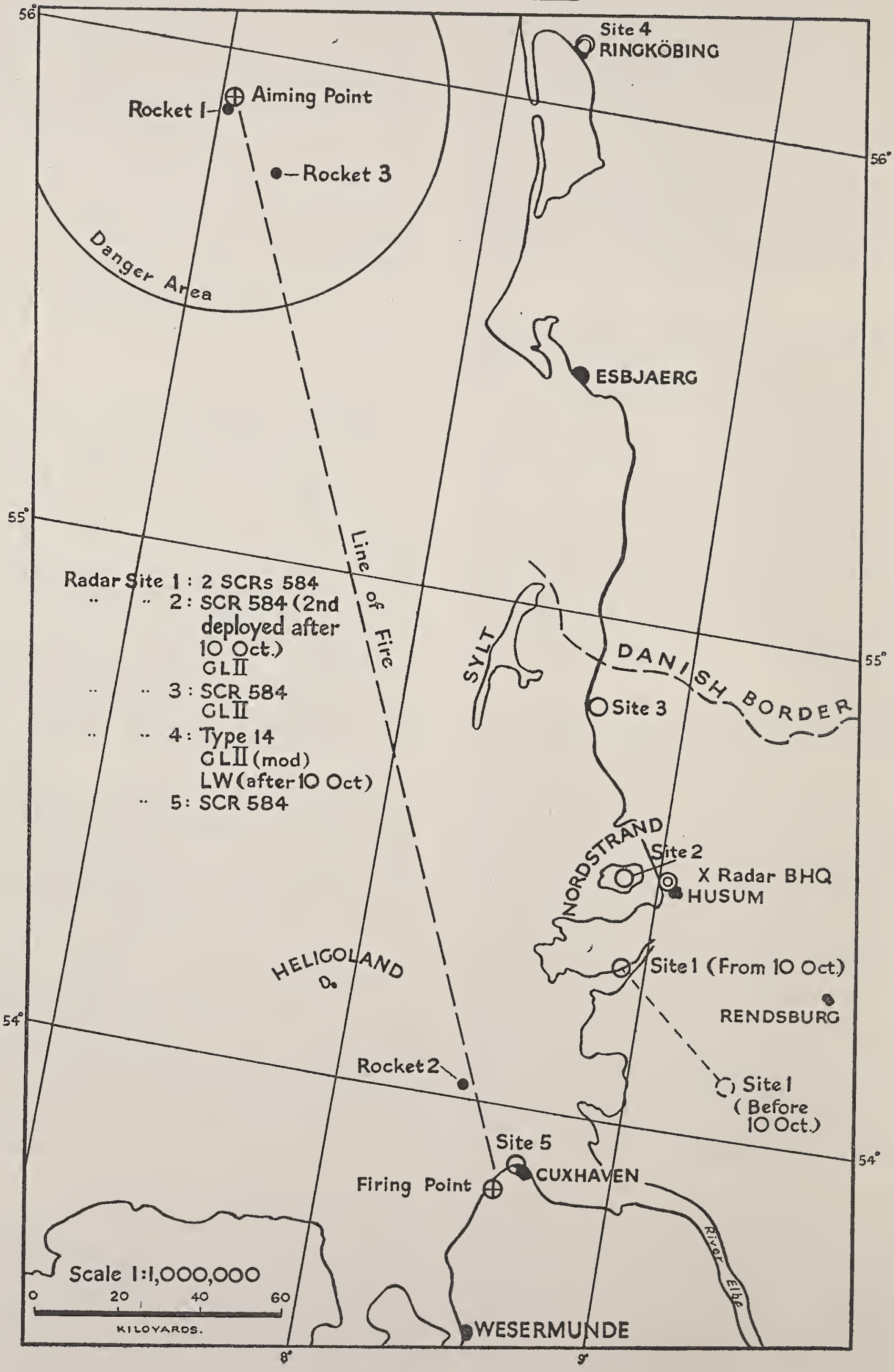
13. No special apparatus was installed to tie up in time data recorded at the various sites. A special BBC broadcast of the Greenwich time signal at half-hourly intervals between 1400 hrs. and 1600 hrs. each day was arranged. These signals were received by all recording vans. All stopwatches were started simultaneously at 1400 hrs. or on a later time signal if launching was delayed. They were all stopped simultaneously on the time signal immediately following the recordings.

SIGNALS COMMUNICATIONS

14. A Recording Control Point was established at RR615891, at the same place as Kine Control, KT Site A and Radar site R 5. Thus at RR615891 were one SCR 584, one kine theodolite, and two HAA recording vans. One of these vans housed kine control with its speech and impulse lines to all KT sites, and the second van the recording gear for the radar and the speech lines to all radar sites. Communication to the radar sites was by direct

DETAILS OF AIMING POINT, LINE OF FIRE & RADAR DEPLOYMENT.

Plate 2



line to HQ X Radar Battery (HUSUM) and thence by radiating pairs to sites R 1, R 2 and R 3. All recording vans used telerepeaters Mk. I, and by using one at the end of each line it proved possible to have all radar sites on the line at the same time. The recording vans at the recording control point had a line to the command post at the firing point. A second line was available as a standby.

15. It was originally intended that R 4 (in DENMARK) should be served with lines communications in the same way as R 1, R 2 and R 3, but delay in installation forced this station to rely on the alternative wireless net. This was provided by a Wireless Section equipped with No. 33 sets. One of these sets was deployed at each of sites R 1, R 2, R 3 and R 4, with two sets at the Recording Control Point (R 5). The sets were netted R 5 to R 4, and R 5 to R 1, R 2 and R 3, two nets being necessary to cover all the sites. The net R 5, R 1, R 2, R 3 was able to work RT.: that to R 4 only W.T. A diagram of the signals layout is given in Plate 3.

SURVEY

16. 20 Special Survey Det, RA, carried out the survey of the kine theodolite and radar sites. It was decided to construct a special grid system to co-ordinate the results of all recording sites. This was necessary because two grids (Nord de Guerre and North European Zone III) were involved in the area, and the Nord de Guerre grid was so far extended from its origin as to be insufficiently accurate for the purposes of recording. The "BACKFIRE" Grid was therefore constructed. It consisted of the North European Zone III extended southwards and swung about a point near to the launching site in order to have the same orientation as the Nord de Guerre zone grid. The co-ordinates of this point on the "BACKFIRE" grid were taken to the same as those on the Nord de Guerre Zone Grid.

17. Certain scale factors were applied in order that distances measured on the grid between latitude 53° 40′ N. and 55° 00′ would not differ from the true distance by more than 0·62 part in 1000. This margin of error held good for distances measured to points further north if measured from the launching point. All survey and computation of results was carried out using this grid system. Further details of the grid will be found in Appendix 5.

RESULTS

18. During the first phase of operations, Oct. 1-6, two rockets were successfully launched (Oct. 2 and 4). On Oct. 1 two unsuccessful attempts were made to launch the rocket which was eventually launched on Oct. 4 One further rocket was launched during a special demonstration on Oct. 15.

19. The Command Post Logs giving the sequence of events on these days is at Appendix 2. It will be observed that with the exception of the failures on Oct. 1 and delay in fuelling on Oct. 2, all other launches went according to plan with little or no delay.

20. It was decided before launching commenced that where the requirements of the field operation clashed with those of the flight recording, the field operation would have priority. Therefore, launchings were not delayed if radars or kine theodolites were out of action.

BEHAVIOUR OF THE ROCKETS

Rocket 1

21. Judging from the fall of shot this rocket behaved normally. Using a time switch to give fuel cut-off a 50 per cent. zone for range of ± 10 kms. should be expected of "normal" shots, since in the absence of an integrating accelerometer or radio fuel cut-off no allowance is made for variation in burner performance. The closeness of the fall of shot to the point of aim (1·9 km. short) is satisfactory evidence that the thrust unit behaved normally. It was unfortunately not possible to plot the exact position and time of fuel cut-off from the recorded results due to the unsteadiness of the velocity graph obtained from the kine theodolite records.

22. The velocity graph shows that the rocket had an initial acceleration of 0·89 g. rising to more than 3 g. in the region of fuel cut-off. The velocity at fuel cut-off must have been of the order of 1,410 m/sec. to give the observed range. The angle of inclination to the horizontal at fuel cut-off was 39°, and the observed time of flight 287 ± 5 secs. The vertex height above ground was 69·4 kms. The rocket fell 1·2 km. to the left of the line of fire, corresponding to an error in line of 0·28°.

Rocket 2

23. This rocket suffered fuel cut-off after 34½ secs., by which time it had achieved a velocity of 520 m/sec. and was at an inclination of 58° to the horizontal. The range to the fall of shot was 25·0 kms., the vertex height 17·4 kms. and the total time of flight 136 ± 1 secs. The rocket fell 0·99 km. to the left of the line of fire, corresponding to an error in line of 2·3°.

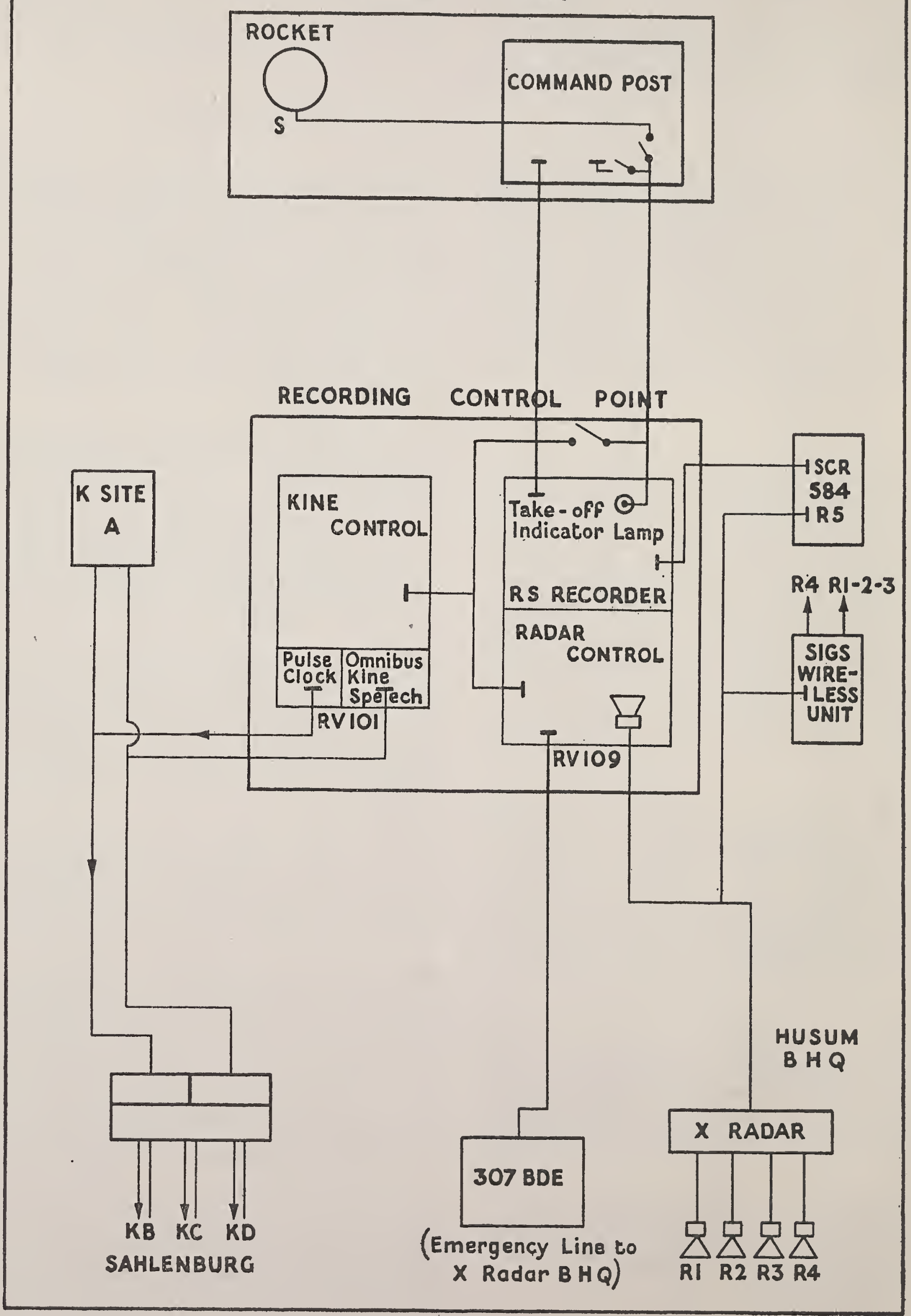
24. The initial acceleration of the rocket was 1·02 g. Thus the thrust of Rocket 2 was 10-15 per cent. greater than for Rocket 1, resulting in a greater acceleration than normal. This impression was also gained by experienced Germans who observed the take-off.

25. The reason for early fuel cut-off is not clear. It could not have been fuel cut-off due to overrunning of the turbine (schnellschluss) since the centrifugal switch which gives the cut-off signal for this is not energised until 40 secs. after take-off. It is certain that no physical break-up of the rocket occurred, neither did it burst into flames, since this would have been observed by the kine theodolite operators. From the theodolite films it would appear that flames were still being emitted from the venturi for some 6 secs. after the rocket ceased to accelerate.

Rocket 3

26. No visual results are available for the trajectory above 2,000 ft. The acceleration at take-off was 1·02 g., which is greater than the normal value. This is confirmed by the radar results which show that although the trajectory was

SIGNALS LAYOUT FOR RECORDING Plate 3



standard in space the rocket climbed more rapidly up its trajectory than it should have done. In spite of this, it fell 18·6 kms. short of the aiming point. This indicates either that the time switch operated several secs. sooner than it ought to have done, or that thrust deteriorated after 45 secs., or that fuel cut-off was given by overrunning of the turbine (schnellschluss).

27. Time of flight was 274 $\pm$ 3 secs. and the vertex height is estimated to have been approx. 64 kms. above ground. The rocket fell 5·3 kms. to the right of the line of fire, corresponding to an error of 1·3° in the line of fire.

PERFORMANCE OF KINE THEODOLITES

Rocket 1—Oct. 2

28. The weather was good, with an almost clear blue sky. All posts functioned correctly without hitch. " A " post lost target before the others due to a patch of cloud. Due to a fault in the cine camera in the R 5 recording van which caused the film to blur, thus making the pulse counter illegible, it was not possible to tie in these results with the radar results with any great accuracy. The exact time of take-off in relation to the theodolite records could, however, be obtained from the records of " B " post.

Rocket 2—Oct. 4

29. The weather was cloudless with slight high haze. Only two posts (A and B) functioned correctly, " C " post, due to line trouble, was only working locally, and " D " post was out of action with a faulty camera motor. " A " post lost target after approximately 50 secs. due to haze. " B " and " C " posts followed the projectile down to zero elevation at a distance of 25 kms. from the firing point.

Rocket 3—Oct. 15

30. Low cloud covered the area. The target was lost in cloud at 2,000 ft. All theodolites functioned correctly.

GENERAL

31. Computation of results revealed that synchrony of the four theodolites was not perfect. Results were worked out using pairs of bases, and it was found that CD base gave results which tended to lead those of AB. Photography of a spinning gramophone disc revealed only very slight errors of synchrony between instruments when they were working close together without long lines. The newer instruments acquired from the Germans were a little quicker to act than the older " British " instruments, but the greatest difference between instruments did not exceed 1/60 sec. The conclusion is that the source of the trouble was delays in pulse transmission through the long lines from the Kine Control Point to the KT sites.

32. Meaning the results of all available theodolites produced useful results for an appreciable distance beyond the fuel cut-off point. Velocity curves were rather unsteady in the region of fuel cut-off. This was because the rocket and flame became invisible on the film some time before cut-off, and in evaluating the film it had to be assumed that the rocket was in the centre of the field of view.

INDIVIDUAL PERFORMANCE OF RADARS

33. In addition to the breakdowns which caused certain equipments to be out of action during the firing, about 75 per cent. of the equipments had serious breakdowns at one time or another during the preparatory stages and in intervals between launches. The majority of troubles was due to failure of components such as transformers, motors, condensers and resistors. This is probably symptomatic of equipments which have been in storage for a fairly long period. The performance of the various sites is dealt with in detail below.

RADAR SITE R 1

34. Rocket 1.—Only one SCR 584 was in action. It followed the rocket for 33 secs. The initial signal/noise ratio was 6 : 1, and range of pick-up 65,000 yds. Aspect angle of target lost was approximately 100°. The second SCR 584 was out of action due to trouble with the long range modification.

Rocket 2.—One SCR 584 was in action. The signal appeared as before but was lost after 6 secs. when the radar locked down on to ground echoes. A fault was later discovered in the anti-lockdown modification. The second SCR 584 could not be used due to mutual interference.

Rocket 3.—New site at TONNING. Increased spacing between radars allowed both to operate simultaneously without interference. Both SCRs 584 saw the rocket with 5—1 signal strength and locked on. The signal faded rapidly after a few seconds. One radar attempted to lock on a second time when the rocket was some 20 kms. above ground (range 60,000 yds. and aspect 80°), but the radar did not track and the signal faded. The rocket probably went through the edge of the radar beam.

RADAR SITE R 2

35. Rocket 1.—The SCR 584 and the GL II failed to observe the rocket. It was later found that a longer spinner was necessary to work with the 8-ft. paraboloid and this had not been supplied. In the case of the GL II a fault was later discovered in the transmitter band pass filter which was causing loss of power.

Rocket 2.—Both radars were in action but failed for the same reason as given for Rocket 1.

Rocket 3.—The 2 SCRs 584 (one with an 8-ft. paraboloid and N^2 gate) saw the target for a few seconds only. Signal/noise ratio was $1\frac{1}{2}$: 1 at each. The signals faded immediately and no tracking was done. The rocket was not seen subsequently. The GL II followed in range only for 18 secs. The signal/noise ratio was 2 : 1, which was insufficient to allow constant following in bearing and angle.

RADAR SITE R 3

36. Rocket 1.—The SCR 584 did not observe the rocket probably due to the natural hazards of scanning the sky for a fast moving target. The GL II observed the target 1 min. 54 secs. after launch at a range of 79,200 yds., bearing 217·8°, A/S 45·7°. The target was lost after 21 secs. The radar track shows an apparent horizontal velocity of the rocket of 1/6 of the true value. The angle of sights was 9° too low and the bearing rate of change 6 times too small. The slant range was also approximately 10 per cent. too small. The initial signal/noise ratio was 3 : 1 falling to $1\frac{1}{2}$: 1.

ROCKET 2.—The SCR 584 was out of action and could in any case not have been observed since the rocket fell short. The GL II saw the target for 1 sec., 70 secs. after launch at a range of approximately 110,000 yds., bearing 214°. The break faded before it could be brought to the cross wire.

ROCKET 3.—The GL II was out of action with V^{T} 98 valve filament and transformer defects. The SCR 584 picked up the rocket unaided and tracked for approximately 15 secs. at a range of 83,000 yds.

RADAR SITE R 4

37. ROCKET 1.—The Type 14 PPI was out of action. The radar observed a saturation break at 85,000 yds. range (E 557550, N 1,011,500 Backfire Grid). Range and amplitude were steady for 30 secs. which the radar transmitter tripped. Estimated accuracy was $\pm$ 500 yds. in range and $\pm 1\frac{1}{2}°$ in bearing ($\pm$ 2,000 yds.)
GL II—no target seen.

ROCKET 2.—The rocket fell short, beyond the range of the radars.

ROCKET 3.—The Type 14 radar saw the fall of shot at 78,000 yds., bearing 240° (E 570100 N 998500). The signal was less strong than for Rocket 1 : signal/noise ratio was initially 5 : 1 becoming 4 : 1 almost immediately. The signal diminished to zero amplitude slowly. It was visible for 68 secs. The LW Radar (AA No. 4, Mk. III) saw the break for approximately 1 sec., 3 secs. earlier than the Type 14 at a range 79,200 yds. bearing 246° ($\pm$ 10°). GL II—no target seen.

RADAR SITE R 5.

38. ROCKET 1.—Immediate pick-up was obtained. The signal faded and the radar ceased accurate following at 15,000 yds. The radar operator tended to overrun in range by expecting a greater rate of increase of velocity than occurred. Film from paraboloid camera was useless due to over-exposure.

ROCKET 2.—The target was lost at 20,000 yds. due to fading signal. The camera on the paraboloid gave good results. Higher ratio gears were fitted to the range unit to allow higher range rates to be produced. These produced somewhat erratic operation due to imperfect fitting, but did not increase the range of tracking.

ROCKET 3.—The target was lost at 29,000 yds. The camera on the paraboloid was useless due to cloud.

RADAR GENERAL

SCR 584—VARIATION OF SIGNAL STRENGTH WITH ASPECT ANGLE AND ITS IMPLICATIONS

39. In the absence of special recording apparatus no actual measurements of signal strength could be made to relate signal strength to aspect angle. Some very strong impressions as to its effect were however gained. Site 1 in its initial position south of the KIEL CANAL was known to be poorly sited, and a long follow was not expected. Experience with such a site had already been gained with an SCR 584 deployed in HOLLAND observing launchings from the HAGUE and HOOK OF HOLLAND areas. When re-deployment was considered sites at HEIDE (RM 8723) and TONNING (RM 7736) were the alternatives. In order to achieve the maximum distance of follow the latter site was chosen. This site, however, produced no success for either of the SCR's 584, the signal being good initially but fading rapidly.

40. The situation at R2 was similar with the addition that the initial signal observed was a great deal weaker ($1\frac{1}{2}$: 1) even where the 8-ft. paraboloid was being used. The conclusion must be that for R 2 and the re-deployed R 1 the inclination of the rocket to the vertical was already sufficiently great at pick-up to reduce signal strength below that necessary to allow the radar to track at such ranges.

41. It is, however, worthy of note that although good following was not achieved from the site at TONNING the range and bearing data at pick-up would have been sufficient to obtain a rough pinpoint of the launching site had it been hostile. At R 2 it is doubtful if such information could have been deduced from the results since the signal was not visible for sufficiently long to enable a bearing to be determined. With the aid of a " side by side " presentation of the signals produced by the bearing split, the bearing of the launching position could probably have been deduced.

42. The actual values of aspect angles for the various sites were as follows :—
(zero aspect is directly head on, 180° directly tail on)

	ON TARGET		INITIAL SIG/NOISE RATIO	TARGET LOST	
	RANGE YDS.	ASPECT (°)		RANGE YDS.	ASPECT (°)
R 1 (first site)	65,300	90	6/1	66,500	100
(,, ,,)	65,200	90	6/1	65,200	91
(second site) ...	62,000	84	5/1	61,600	79
(,, ,,) ...	60,000	81	5/1	60,000	81
(,, ,,) ...	61,500	82	5/1	60,000	74
R 2 (assumed values—radar did not track)	(For rocket height 2,000 ft.) 77,000	82	$1\frac{1}{2}$/1	(For rocket height 5000 ft.) 77,000	75
R 5	—	—	—	15,200	151
		(abnormal trajectory)		20,100	120
				29,800	147

43. It would appear from these results that at a range of 60,000 yds. head on aspect angles of less than 80° cannot be tolerated if the radar is to track. Even at ranges of 15,000-20,000 yds. the sensitivity of signal strength to aspect is very marked, although the presence of the flame may also have affected the strength of signals received in this case. On the second rocket the radar followed for some time after the end of burning. This target was still lost at 20,000 yds. with an aspect of 120°.

FALL OF SHOT PLOTTING

44. The success achieved by the Type 14 was satisfactory proof that it can be used to plot fall of shot out to a range of at least 85,000 yds. and probably considerably more. On the first rocket a saturation signal was received from a range of 85,000 yds. It was visible for 30 secs. without diminution when the radar transmitter tripped and no further observations could be made. The third rocket was observed at 78,000 yds. but with a smaller signal (sig./noise 5 : 1). In each case the range to the target remained unchanged during the whole period for which the break was visible and the signal was steady. It would therefore appear that it was a fall of shot phenomenon and not the descending projectile which was seen by the radar.

45. The signal from Rocket 3 was visible for 68 secs. During this time the amplitude decreased to zero. Had the signal been due to the column of water one would expect it to grow slowly and diminish slowly. In fact the radar echo grew immediately to full strength, dropped almost immediately by about 1/5, and subsequently decayed slowly. A water spout 3,000 ft. high would collapse in about 14 secs. Had the signal been due to a column of water, the column must have been much greater than this.

46. It is notable that the Germans report observing the same phenomenon of sustained fall of shot echoes during their trial work done from Peenemunde. Here they observed fall of shot by radar (Freya) and reported unexpectedly good results. They reported large signals visible long after the physical waterspout had collapsed, but could offer no explanation.

47. The GL II at R 4 did not observe either of the falls of shot. The aspect angle of the falling projectile was unfavourable and observation of the rocket was not expected. The LW radar (AA No. 4, Mk. III) which observed Rocket 3 reported a break some 3 secs. before the Type 14, but the break did not remain visible for more than 1 sec. It seems probable that the echo was the rocket descending through the radar beam. The time discrepancy was probably caused by the dead time entailed in traversing the Type 14.

GL II

48. On only one occasion was any constant following attempted and the results were so poor as to be useless as track data. The ground speed of the projectile as given by the radar was 1/6 of its true value and the height 12 kms. low. There is also strong evidence that the slant range of 79,000 yds. was 10 per cent. too small. In spite of the slant range to the rocket being less than 79,000 in one case (R 2, Rocket 3) the signal strength was poorer and tracking was not possible. The cause of poorer signal strength would almost certainly be the head on aspects of as low as 75° which occurred, although a polarisation effect due to horizontal aerials may have reduced the signal strength. The rocket in this case was climbing whereas for R 3 it was more nearly horizontal.

49. The signal from Rocket 2 observed by the GL II at R 3 at a range of 110,000 yds. must be regarded with suspicion. It is said to have occurred 70 secs. after launch. At this time the rocket must have been at the top of its trajectory (ht. 17 km.) with zero inclination. Aspect angle would therefore be approximately 30° (head-on). This signal was only visible for a few seconds and disappeared before its range could be measured accurately. There can, therefore, be no certainty that it was in fact due to the rocket.

50. In the only case where the GL II is said to have tracked the rocket the bearing and angle data were not good enough to have put an SCR 584 on target. The inability of the GL II to produce sufficiently accurate bearing and angle data makes it for all practical purposes useless as a " putter on " for more accurate radars.

QUALITY OF THE SCR 584 DATA

51. Apart from the radar data from R 5, two other radars produced track data. The SCR 584 at Site 1 followed the first rocket from soon after launch up to a height of about 30,000 ft. The track produced can be seen on the trajectory diagram at Appendix 6. The second radar was that at R 3 which followed Rocket 3 at a range of 83,000 yds. just before it reached the vertex. Here again following was not good, but the range was extreme. The ground plan and vertical plots can be seen at Appendix 6. No smoothing has been done and, in fact, the track is of such poor quality as to make satisfactory smoothing impossible.

52. At R 5 it was possible to collect precise data as to the performance of the SCR 584 by comparison of theodolite and radar results. The average errors of following in bearing, angle and range are given in the table below:

ROCKET	AV. ERROR		BIAS		MEAN DEVIATION (bias removed)	CONSISTENCY		NO. OF READINGS
	Bg	A/S	Bg	A/S	A/S	Bg	A/S	
1	0·22°	0·27°	—·09°	—·23°	0·16°	·15°	·17°	74
2	0·22°	0·23°	—·20°	—·16°	0·16°	·16°	·10°	74

53. A negative bias in A/S of about 0·04° is to be expected due to a small displacement for which no correction has been made. Readings were made twice per second. Consistency is the average of the first differences of adjacent errors, and is a measure of the smoothness of the radar data. Further data will be available from the 16 mm. film taken from the camera on the paraboloid. The film cannot, however, be evaluated on the Continent and will in any event not produce results any more accurate than those in the table on page 13. Evaluation of the film will be carried out at A.O.R.G.

54. It was expected that the SCR 584 at R 5 would lose target due to the large range rate. In fact the signal was so poor at ranges greater than 20,000 yds. that it could not be held. This is shown by the results achieved on Rocket 2 where the rocket was followed for some time after it had ceased to accelerate. It was, nevertheless, lost at a range of 20,000 yds. Auto-range tracking would therefore not have increased the range of following, although it would undoubtedly have improved the quality of the data. It is interesting that the radar succeeded in holding Rocket 3 out to a greater range than the previous two. This was the only rocket to go to the right of the line of fire and as such would present a slightly more favourable aspect angle.

55. Graphs of the SCR 584 data can be seen at Appendix 6. These show visual and radar data against time. The aspect angle of the target is also shown.

TRAJECTORY DIAGRAMS

56. At Appendix 6 will be found the following diagrams of the initial part of the trajectory of each rocket:

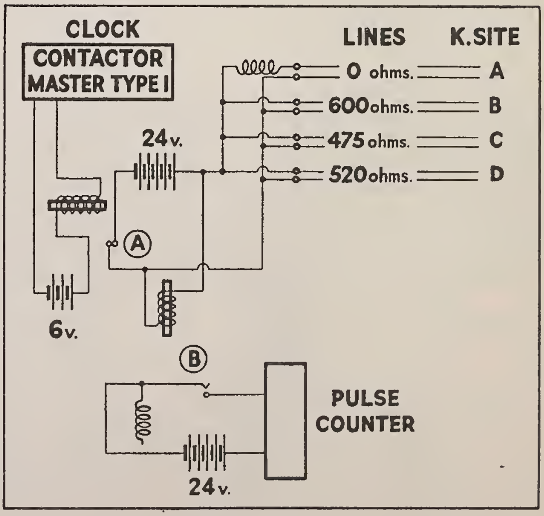
(1) Ground plan track
(2) Vertical plane plot
(3) Velocity
(4) Inclination

In the case of Rockets 1 and 2, kine theodolite data is available. SCR 584 data from R 5 is given in each case and SCR 584 data from R 1 in the case of Rocket 1. In each case the corresponding data for a "normal" rocket has been plotted. For Rocket 3 the SCR 584 track from R 3 is given in ground plane and the vertical plane. The extrapolated trajectory has been plotted on the graphs as accurately as is possible.

Details of System used to provide impulses for the Kine Theodolites . APPENDIX 1

The clock, a Contactor Master Type 1, closed relay (A) twice per second. This relay closed a circuit containing 24 volts from accumulators supplying the four kine theodolites in parallel with 25 m. amps.

In parallel with the lines to the kine theodolites was a second relay (B.) This relay opened a circuit containing an electrical counter which moved in consequence. At the end of each impulse the contact at (A) was opened and at (B) closed, thus arming the counter in preparation for the next pulse.



Log of Ops.—October 1, 1945 . . . APPENDIX 2

TIME	SEQUENCE OF EVENTS	TIME	SEQUENCE OF EVENTS
0930	Control point manned	1527	Fuel column left launching site
1043	Fuel column left KRUPPS	1527	Commander, 307 Inf. Bde. reported " All clear "
1045	Setting up of rocket completed	1541	Meilerwagen departed
1050	All kine sites manned	1542	Orienting completed
1108	All kine lines tested	1542	X-15 warning to recording sites
1209	All K.T's collimated	1546	Insertion of igniter
1330	R 1, R 2 and R 3 manned	1549	Steering tests completed
1400	Watches synchronised with B.B.C. time	1551	X-3 warning to recording sites
1411	Rocket tests completed	1552.5	Red Verey light fired
1412	Fuel column arrived at launching site	1554	*Attempt* to launch rocket
1425	Tanking begun	1751	X-15 warning to recording sites
1425	X-60 warning to recording sites	1752	All radars and kines ready for action
1433	All radars ready for action	1800	Watches checked with B.B.C.
1500	Time check	1810	X-3 warning to recording sites
1522	Fuelling completed	1812	Red Verey light fired
1523	X-30 warning to recording sites	1815	Attempt to launch rocket
		1815	Stand down

Log of Ops.—October 2, 1945

TIME	SEQUENCE OF EVENTS	TIME	SEQUENCE OF EVENTS
0930	Control point manned	1400	All recording vans synchronised time with B.B.C.
0950	Setting up of rocket completed	1406	Superfluous personnel leave launching site
1016	Fuel column leaves KRUPPS	1408	X-30 warning to recording sites
1050	Fuel column arrived special vehicle park	1408	Tanking completed. Departure of fuel column
1055	All kine sites manned	1410	All transport clear of temporary car park
1055	Main rocket tests completed	1415	Igniter inserted
1120	All Kine lines tested	1425	X-15 warning to recording sites
1200	Fuel column arrives launching site	1428	Orienting completed
1245	Tanking procedure commences	1430	Departure of Meilerwagen
1247	X-60 warning to recording sites	1432	Type 14 at R 4 ready for action with modified range tube
1249	All K.T. collimation completed	1436	All kine theodolites ready for action
1305	Radar R 2 reported out of action	1437	Test radar report
	Radar N at R 1, and Radar at R 5 reported ready for action	1437	Steering tests completed. Launching troop take cover
1337	Kine at site C out of action—impulse line not working	1437	K-3 warning to recording sites
1344	Comd. 307 Inf. Bde. reported " All clear "	1441.12.3 secs.	Rocket launched
1355	Type 14 at R 4 reported out of action		
1400	Watches synchronised		

Log of Ops.—October 4, 1945

TIME	SEQUENCE OF EVENTS	TIME	SEQUENCE OF EVENTS
0915	Setting up rocket completed	1345	Comd. 307 Inf. Bde. reported " All Clear "
1006	Control point named (delay due to transport breakdown)	1347	Tanking completed. Fuel column departed
1010	Fuel column leaves KRUPPS	1355	Superfluous personnel warned off site
1045	Fuel column arrives at special vehicle park	1356	All radars ready for action
1049	All kine sites manned	1400	Orienting completed
1130	Main rocket tests completed	1400	Time synchronised with B.B.C.
1225	Fuel column arrives at launching position	1401	X-15 warning to recording sites
1254	Tanking commences	1404	All transport clear of temporary car park
1254	X-60 warning to recording sites	1404	Igniter inserted
1255	Preliminary radar report	1406	Departure of Meilerwagen
	Only R 5 completely ready for action	1409	Steering tests completed. Launching troop take cover
1302	All kine lines tested. (Delay due to fault on impulse line at site B)	14010	Kine site C out of action
		1412	X-3 warning to recording sites
1302	K.T. collimation completed	1414	Red Verey light fired
1341	X-30 warning to recording sites	1415.55.09 secs.	Rocket launched

Log of Ops.—October 15, 1945

TIME	SEQUENCE OF EVENTS	TIME	SEQUENCE OF EVENTS
0900	Setting up of rocket completed. (Preliminary work had been done ahead of schedule)	1400	Recording vans synchronised time
		1430	Time check with B.B.C.
		1430	Comd. 307 Inf. Bde. reported " All Clear "
0920	Control point manned		
1030	All kine sites manned	1432	Tanking completed. Fuel column departed
1043	Fuel column left KRUPPS		
1047	Main rocket tests completed	1432	X-30 warning to recording sites
1120	All kine lines tested	1450	All transport clear of car park
1130	Fuel column arrives at special vehicle park	1452	Warning to clear launching site
		1454	All radars on the air and ready for action
1150	Radar report : R 1, R 2, R 4 and R 5—Ready for action. R 3—SCR 584 ready for action. GL II—High angle cams being fitted. Estimated to be ready for action at 1230 hrs	1455	Orienting completed
		1455	Igniter inserted
		1458	Meilerwagen departed
		1500	Steering tests completed. Launching troop takes cover
1302	Fuel column arrived at launching site	1502	X-3 warning to sites
1330	Tanking procedure begins	1504	Red Verey light fired
1331	X-60 warning to recording sites	1506.26.5	Rocket launched

To accommodate the distinguished visitors the normal time allowed for the procedure was extended by 45 minutes. This explains the gaps in time between various events. Though not necessarily following the normal sequence in time, the procedure for preparation was carried out without a hitch, although the tanking procedure did take longer than usual.

Radar Drills and Search Data . . APPENDIX 3

GL II STATIONS at R 2 AND R 3

1. Equipments were manned and operated as for normal aircraft engagements, and laid on the calculated crossing-point bearing. (The aspect at crossing-point is 90°). Ranges were set on the potentiometer scale corresponding to approximately 2,000 yds. in excess of the expected crossing-point range, to allow for pick-up shortly before crossing-point.

R 2	Search Range	70,000 yds.	Angle 30°.
R 3	,, ,,	84,000 ,,	Angle 45°.

2. The transmitter aerial switch was permanently left at "Follow" and "Follow" drill was ordered by GL I on receipt of the signal given from the command post at the firing point 3 minutes before launch. "Sig. Sel" was not used and bearing and angle operators used a continuous bright trace. This was useful in cutting out the effect of slight errors in time-base tracking.

GL II STATION at R 4 (Range only)

3. This equipment was operated as for a normal BB watch, with Operators 1 and 2, and recorder-timekeeper. (BB = Big Ben, and refers to the procedure used during Operation "CROSSBOW.")

GL RANGE CALIBRATION

4. Calibration pips were checked against Westex readings daily, and immediately after engagements.

SCR 584 EQUIPMENTS at R 1, R 1A AND R 2

5. A small search area approximately 3° each side of the surveyed bearing of the firing point was covered and a range approximately 1,000 yds. in excess of the surveyed range was set. It was thought necessary to carry out a small search to cover possible alignment errors and at the same time to "paint" the PPI. Angle setting 20 mils was employed. Normal operating drill was carried out. In the case of R 2 "2nd lay" was ordered by No. 1 if no pick-up was made within 30 seconds of "Shot," and range, bearing and angle figures corresponding to crossing-point were then set, with a search in angle of ± 100 mils.

Search data :—

	Bearing	*Angle*	*Range*
R1 ...	4,292 mils	20 mils	65,210 yds.
R1A ...	3,610 ,,	20 ,,	61,900 ,,
R2 ...	3,428 ,,	20 ,,	79,775 ,,

SCR 584 at R 3

6. This equipment was directed at the crossing-point bearing angle and range with an angle search of ± 100 mils carried out by an extra operator. On the report "Target," No. 3 set in a clockwise rate of change of bearing of approximately 1°/sec. This was necessary to hold the target in the beam for a sufficient length of time for strobing and switching to "Automatic."

Search data :—

	Bearing	*Angle*	*Range*
R 3 ...	3,965 mils	800-1,000 mils	82,000 yds.

SCR 584 at R 5

7. The equipment was directed at the fixed bearing and range of the firing point, and at a fixed angle of 5°. "Target" was reported by No. 2 when the signal was visible in strobe patch, and No. 3 switched to "Automatic." In the later stages of following it is necessary for No. 2 to follow using the "slew" hand wheel.

Search data :—

	Bearing	*Angle*	*Range*
R 5 ...	224°	5°	7,800 yds.

A M.E.S. TYPE 14 at R 4

8. This equipment was operated normally and traversed over an arc of ± 15° each side of the bearing to the target point, increased to + 15° and — 30° for Rocket 3. The average time of the complete double traverse for the 30° search arc was 8 secs., and for the 45° search arc 10 secs. The PPI was not employed and all readings were taken by obtaining a maximum break on the range tube by bracketing for bearing and subsequently reading the range and bearing scales.

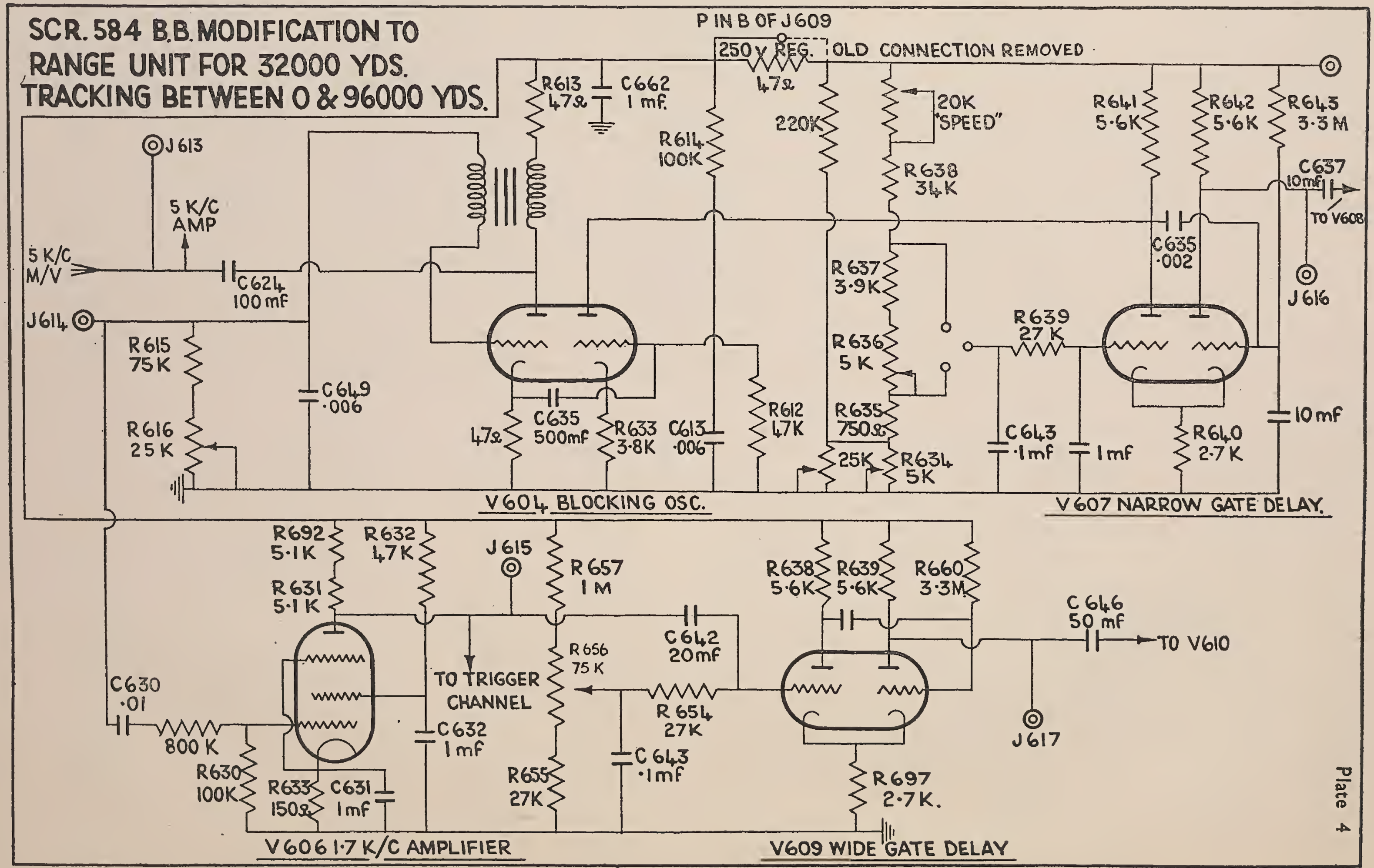
Search date :—

	Bearing	*Angle*	*Range*
R 4 ...	240°—270°	0°	70,000—100,000 yds.
Rocket 3 ...	225°—270°	0°	70,000—100,000 ,,

L W at R 4

9. This equipment was operated for Rocket 3 only. The serial array was in "low" position and drill normal. Search data as for Type 14, Rocket 3.

Plate 4



SCR. 584 B.B. MODIFICATION TO RANGE UNIT FOR 32000 YDS. TRACKING BETWEEN 0 & 96000 YDS.
PIN B OF J609
250 V REG.
OLD CONNECTION REMOVED
47Ω
220K
20K "SPEED"
R638 34K
R641 5·6K
R642 5·6K
R643 3·3 M
C637 10mf
TO V608
C635 ·002
J616
J613
5 K/C AMP
5 K/C M/V
C624 100 mF
J614
R615 75K
R616 25 K
C649 ·006
R613 47Ω
C662 1 mf.
R614 100K
R637 3·9K
R636 5 K
R635 750Ω
25K
R634 5K
R639 27 K
C643 ·1mf
1 mf
R640 2·7K
10 mf
47Ω
C635 500mf
R633 3·8K
C613 ·006
R612 47K
V604 BLOCKING OSC.
V607 NARROW GATE DELAY.
R692 5·1K
R632 47K
R631 5·1 K
J615
R657 1 M
R656 75 K
C642 20mf
R654 27K
C643 ·1mf
R655 27K
TO TRIGGER CHANNEL
C632 1 mf
C630 ·01
800 K
R630 100K
R633 150Ω
C631 1 mf
V606 1·7 K/C AMPLIFIER
R638 5·6K
R639 5·6K
R660 3·3M
C646 50 mf
TO V610
J617
R697 2·7K.
V609 WIDE GATE DELAY

Radar Modifications . . . . . APPENDIX 4

A.—MODIFICATIONS TO SCR 584 TO ENABLE THE EQUIPMENT TO TRACK OVER A RANGE ZONE OF 32,000 YDS. BETWEEN 0 AND 96,000 YDS.

1. General.—The standard extended range modification to the equipment was taken as a basis. Further components had to be added or existing components changed in value to ensure stability of operation of the range unit. Stable tracking was then possible in range over any desired range zone of 32,000 yds. between 0 and 96,000 yds. The standard modification includes an extensive modification to the gearing in the range indicator unit. This was not necessary using the method described below.

2.—Method.—The 1·7 kc. multivibrator, 1·7 kc. amplifier, narrow gate and wide gate circuits were modified as shown in attached circuit diagram (PLATE 4). The existing 20K narrow gate potentiometer in the range indicator unit was removed and replaced by a 20K Holial potentiometer. This was set so that a resistance value of 14K existed across pins A and C of the potentiometer when the range indicator was set at zero. The 20K potentiometer labelled " Speed " was mounted on the chassis for screwdriver control.

3. The 5 K.N.G. delay potentiometer was mounted on the chassis for screwdriver control and was replaced in its old location by a 25 K potentiometer to give the operator a less fierce control over the narrow gate delay.

4. Setting Up.—The range unit was set up as far as the 5 kc. multi-vibrator by the CRO method. The " 1·7 kc." was then adjusted to count down four times. The " Speed," N.H. delay and N.G. potentiometers were then adjusted to ensure range tracking in the range zone between 32,000 and 64,000 yds. It is then possible by movement of the narrow gate delay to bring the " narrow gate " (visible as a bright patch on the course range tube) to any range between 0 and 96,000 yds. and smooth strobe tracking over the selected range is possible.

5. Where a range zone selected does not lie between 0—32,000, 32,000—64,000 or 64,000—96,000 yds, it is advisable to mark the course range indicator with a line to which the N.G. Strobe is aligned when the operator is adjusting N.G. delay.

B. MODIFICATION TO GL II EQUIPMENT FOR LONG RANGE CONTINUOUS FOLLOWING

GL RECEIVER

6. Aerial System.—(*a*) At Site R 2 the elevation aerials were fixed at normal height for the frequency in use and the bearing and range aerials were all adjusted to $0{\cdot}5\lambda$.

(*b*) At Site R 3 the bearing and range aerials were dropped to $0{\cdot}4\lambda$ to increase the angle of the lobe, and in addition a high angle cam was fitted and the heights of the elevation aerials altered accordingly.

7. Time Base Modifications.—(*a*) To increase the length of time base scan two ·001 UF 5000V porcelain condensers were connected in parallel with the main time base condenser on both the range time base unit and the bearing and elevation time base unit. This was done by drilling two ¼-in. holes in the panels and screwing down the condensers on each panel. The tops of the condensers on the range time base panel were connected to terminal 23, whilst those on the bearing and elevation time base panel were connected to terminal 27.

(*b*) The resistors R32D to L on the range time base panel were removed and substituted by eight 220 K ohms 3 watt resisters.

8. Kipp Modifications.—(*a*) The Kipp was modified to give a longer negative pulse by connecting a ·002 UF 350V working condenser across C42A and a 0·1 UF 350V working condenser across C40A.

(*b*) A 0·1 UF 350V working condenser across C26A was fitted to increase brightness of " putter on " stroke (B.S.E.).

9. Calibrator Modifications.—To enable more pipe to be received on the C.R.T.S. the calibrator circuits were modified by

(*a*) Connecting a ·01 UF 350V working condenser across C12C and C26B.

(*b*) Inserting a 100 K ohm, 1/2 watt resister between terminal 3 and terminal 40.

10. IF Modifications.—(*a*) The video frequency amplifiers were removed and output stage and power pack converted to normal working. IF's were peaked to give 1 Mc bandwidth. Sensitivity as measured by 3/1 signal noise ratio method was less than 5 μV.

GL TRANSMITTER

11. Modulator.—The two output Pen 46 valves were replaced by ET 44 valves.

12. Oscillator.—Two ·001 UF 5000V condensers were connected across the grid condenser of the oscillator to give a wider transmitted pulse.

C. MODIFICATION TO PERMIT SCR 584 FOLLOWING OF GL II COARSE BEARING DATA

13. In order that the SCR 584 could follow the GL equipment in azimuth the remote selsyn on the position indicator unit was coupled to the coarse Bg magslip transmitter in the GL receiver. Existing leads to the magslip were disconnected and terminals 1, 2 and 3 connected to terminals 9, 10 and 11 of the terminal strip in the position indicator unit. These terminals are of course directly connected to S1, S2 and S3 of the remote selsyn. The rotor of the selsyn was energised from its usual 115V source of supply. A pair of leads was connected to terminals 14 and 15 (i.e., 115V supply to selsyn) on the position indicator unit and connected to the X and Y terminals on the magslip through a 200 ohm resistance. This produced 67V at terminals X and Y. A switch was incorporated in this circuit so that the power to the magslip could be switched off when not required to avoid overheating.

14. Tests were carried out and it was found that the remote selsyn followed the Bg magslip within $\pm$ 1/2 degree when variations of 5 degrees were made.

Explanation of " BACKFIRE " *Survey Grid* . . . . APPENDIX 5

OUTLINE OF PROBLEM

1. The requirements were (*a*) orientation and fixation in strict geodetic relationship of a number of points in the launching area, (*b*) orientation and fixation of radar stations along the Danish Peninsula, (*c*) the setting of a grid that would agree as nearly as possible with the map grid (Nord de Guerre) in the launching area and on which both (*a*) and (*b*) could be combined with reasonably true relationship.

SURVEY IN THE LAUNCHING AREA

2. A normal triangulation which included several trig. points was carried out and a mean azimuth and scale corrected distance for a baseline were obtained. Nord de Guerre co-ordinates using true distance values were computed for Station WOOD and co-ordinates were then computed for the remaining points.

SURVEY OF RADAR STATIONS

3. Nord de Guerre or European Zone III co-ordinates were obtained from 1/25,000 maps or trig. data and orientation from metro and/or trig. data. These values were then converted to the " BACKFIRE " grid by the methods outlined below.

THE " BACKFIRE " GRID

4. Owing to excessive scale factors involved the Nord de Guerre projection was not suitable for the area to be covered, and the North European Zone III projection was used. To agree with the condition laid down in para. 1 (*c*) the values obtained on this projection were then given a simple change of grid based on the Nord de Guerre and European Zone III values obtained for Station WOOD.

CONVERSION FORMULAS

5. Station WOOD.

" BACKFIRE " Co-ordinates :	656,147·0	783,450·0
Nord de Guerre do. :	Same as " BACKFIRE "	
European Zone III do. :	1,151,632·58	199,045·38

EUROPEAN ZONE III TO " BACKFIRE "

6. Let :

a = Bearing change in grids = 10° 16′ 20″ (to nearest second).

$\left.\begin{matrix} Ee \\ Ne \end{matrix}\right\}$ = Diff. E and N from WOOD in European Zone III values.

$\left.\begin{matrix} Eb \\ Nb \end{matrix}\right\}$ = Diff. E and N from WOOD in " BACKFIRE" values.

k = a scale factor = 0·999415

$\sin a = 0{\cdot}178324053$

$\cos a = 0{\cdot}983971803$

$m = k \sin a = 0{\cdot}17821973$

$n = k \cos a = 0{\cdot}98339618$

Then :

$Eb = Ee.n - Ne.m$

$Nb = Ne.n + Ee.m$

NORD DE GUERRE TO " BACKFIRE "

RIGOROUS METHOD

7. Using Lambert Projection Tables :
   (1) Convert Nord de Guerre to French Geographicals.
   (2) Convert these to Danish Geographicals.
   (3) Convert Danish Geographicals to European Zone III.
   (4) Convert to " BACKFIRE " by method outlined above.

SCALE FACTORS METHOD

8. Let A = a point for which both Nord de Guerre and " BACKFIRE " co-ordinates are known.
B = a point for which the " BACKFIRE " co-ordinates are required.
k = " BACKFIRE " scale factor = 0·999415.
k_1 = Scale factors from German Nord de Guerre charts for the Mid Point of the base AB.*
k_2 = Scale factor from North European Zone III. Tables for the mid latitude of the base AB.
C = Angle of conversion between " BACKFIRE " and Nord de Guerre grid for the mid point of the AB (see para. 9).

Then, distance AB on Nord de Guerre values X k. k_1. k_2 = distance AB in " BACKFIRE " values, and the bearing A to B in Nord de Guerre values plus or minus C = Bearing A to B in " BACKFIRE " value. The " BACKFIRE " co-ordinates of B can then be computed.

*k_1 must *not* be taken from Nord de Guerre Projection Tables. This method will be reasonably accurate provided that the point to be changed is not at too great a distance from P. When large distances, or areas where scale factors become inaccurate, are involved, the rigorous method should be used and the scale factors method only used as a rough computing check.

THE BEARING

9. The angle of conversion of North European Zone III and " BACKFIRE " grid is constant. For conversion of North European Zone III bearings to " BACKFIRE " bearings subtract 10° 16′ 20″. The angle of conversion in seconds between " BACKFIRE " and Nord de Guerre grid for a given point A is found by the following formulæ:

Diff. Longitude between point A and Station WOOD in seconds X 0·08299.

East of WOOD the Nord de Guerre bearings are the greater, west of WOOD the lesser.

DISTANCES

10. A scale factor K = 0·999415 has been introduced in the conversion from European Zone III to " BACKFIRE " in order that any distance measured on " BACKFIRE " grid between Latitudes 53° 40′ N and 55°00′ N will not differ from the true distance by more than 0·62 metre in 1,000. This margin of error also holds good for distances measured to points further north if measured from the launching area.

GEOGRAPHICAL COORDINATES

11. Nord de Guerre grid is based on French values.
European Zone III and Danish grids are based on Danish values.
1/25,000 maps of the G.S.G.S.4414 Germany series give German values.

The corrections are:
French to German Lat. + 1·30″ Long — 3·15″
German to Danish Lat. — 6·40″ Long + 1·20″

The Geographical values for Station WOOD are:
German values: Latitude 53°50′ 30·19″
: Longitudes 08°35′ 15·01″ East of Greenwich.

TABLES USED

12. The Lambert Projection Table for the Nord de Guerre and North European Zone III issued by the Office of the Chief Engineer, Washington, D.C., 1943, and the German scale factors chart issued in the SHAEF Survey Tech. Instr. No. 138, dated 10 March, 1945, were used.

LIST OF MAP REFERENCES ON THE " BACKFIRE" GRID

13. *Kine Theodolite Posts*	*Eastings*	*Northings*	*Ht.*
A	661491·2	789113·8	7·12
B	656603·3	783056·2	12·21
C	663466·6	784002·7	0·98
D	659948·4	779772·3	26·38
14. *Radar Equipments*			
R 1 SCR 584 North	708825·0	812575·0	36
SCR 584 South	708825·0	812550·0	36
E 1 (Redeployed)			
SCR 584 East	678701·0	836174·0	6
SCR 584 West	678523·0	836016·0	6
R 2 SCR 584	672652·0	855175·0	05
GL II	672698·0	855131·0	05
R 3 SCR 584	661296·0	891803·0	01
GL II	661374·0	891878·0	—
R 4 Type 14	631844·0	1,034152·9	—
GL II	631760·8	1,034204·8	—
R 5 SCR 584	661512·0	789116·0	7·1
15. *Launching Site and Aiming Point*			
Surveyed Point (Collimator)	656470·3	784040·3	13·67
Launching Point	656459·6	784043·9	13·67
Aiming Point	557930·0	1,013680·0	0·00

Bg of line of fire (uncorrected for rotation of earth) 336°46′ 35″ (" BACKFIRE " = Nord de Guerre) or 337° 25′ 25″ true.

Trajectory Diagrams . . . . . . APPENDIX 6

ATTACHED ARE THE FOLLOWING TRAJECTORY DATA DIAGRAMS:

1. GROUND PLAN TRACK	1″ = 1 km.	ROCKET 1
2. EXPANDED GROUND TRACK PLAN OF TAKE-OFF .	1 cm. = 2·5 metres	
3. VERTICAL TRAJECTORY DIAGRAM	1″ = 1 km.	
4. ROCKET VELOCITY—TIME GRAPH	1″ = 100 m/sec.	
	1″ = 4 secs.	
5. ROCKET INCLINATION—TIME GRAPH	1″ = 10 secs.	
	1″ = 4 secs.	

6, 7, 8, 9, 10—AS ABOVE FOR ROCKET 2.

11, 12, 13, 14, 15—AS ABOVE FOR ROCKET 3.

16. ROCKET 3—GROUND PLAN TRACK OF SCR 584 DATA FROM R 3.

17. ROCKET 3—VERTICAL TRAJECTORY DIAGRAM OF SCR 584 DATA FROM R 3.

18. ROCKET 1—GRAPH OF RANGE, BEARING, AND ANGLE OF SIGHT AGAINST TIMES FROM SCR 584 AT R 5 AND KINE THEODOLITE SITE "A."

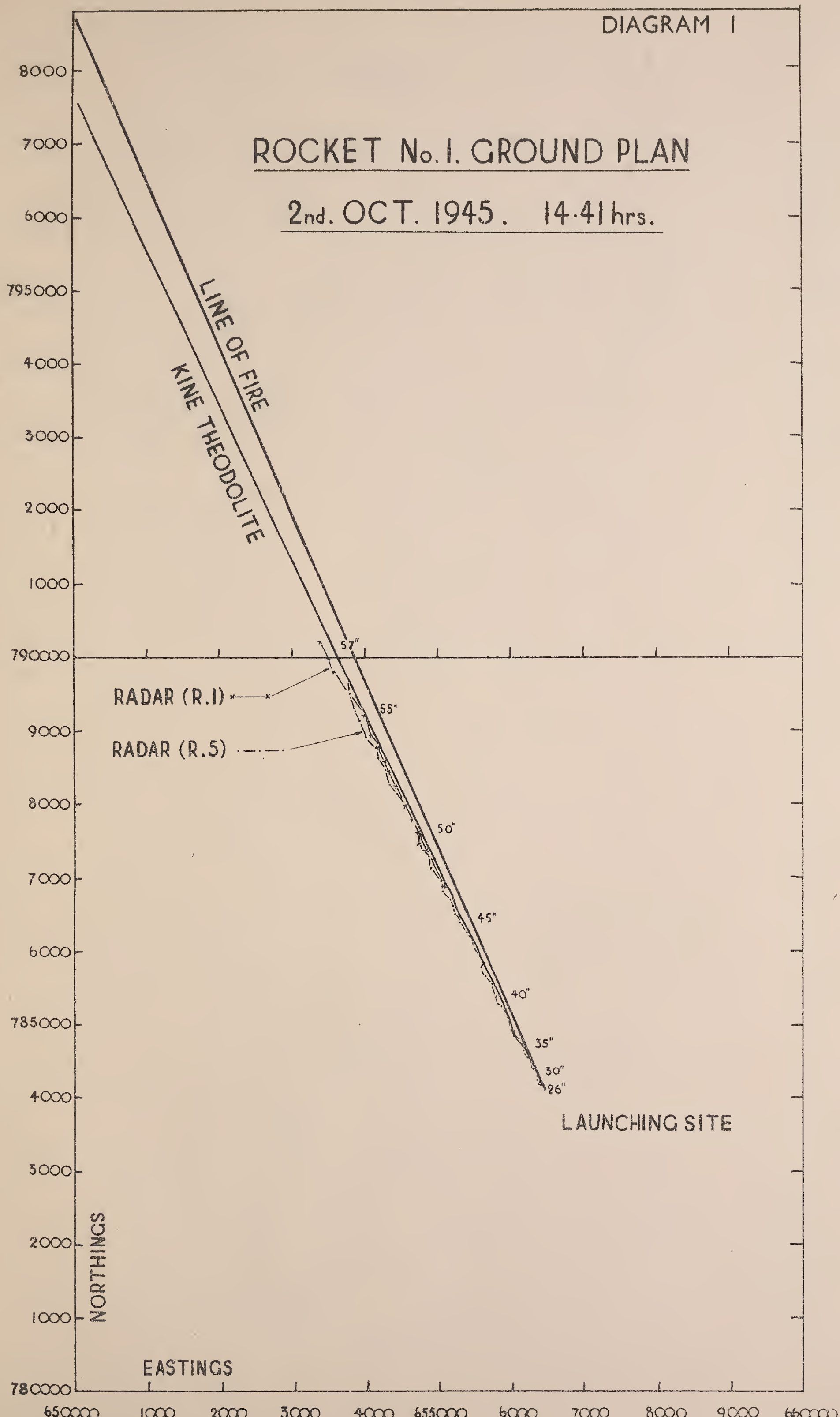


DIAGRAM 1
ROCKET No. 1. GROUND PLAN
2nd. OCT. 1945. 14·41 hrs.
LINE OF FIRE
KINE THEODOLITE
RADAR (R.1)
RADAR (R.5)
52"
55"
50"
45"
40"
35"
30"
26"
LAUNCHING SITE
NORTHINGS
EASTINGS
8000
7000
6000
795000
4000
3000
2000
1000
790000
9000
8000
7000
6000
785000
4000
3000
2000
1000
780000
650000
1000
2000
3000
4000
655000
6000
7000
8000
9000
660000

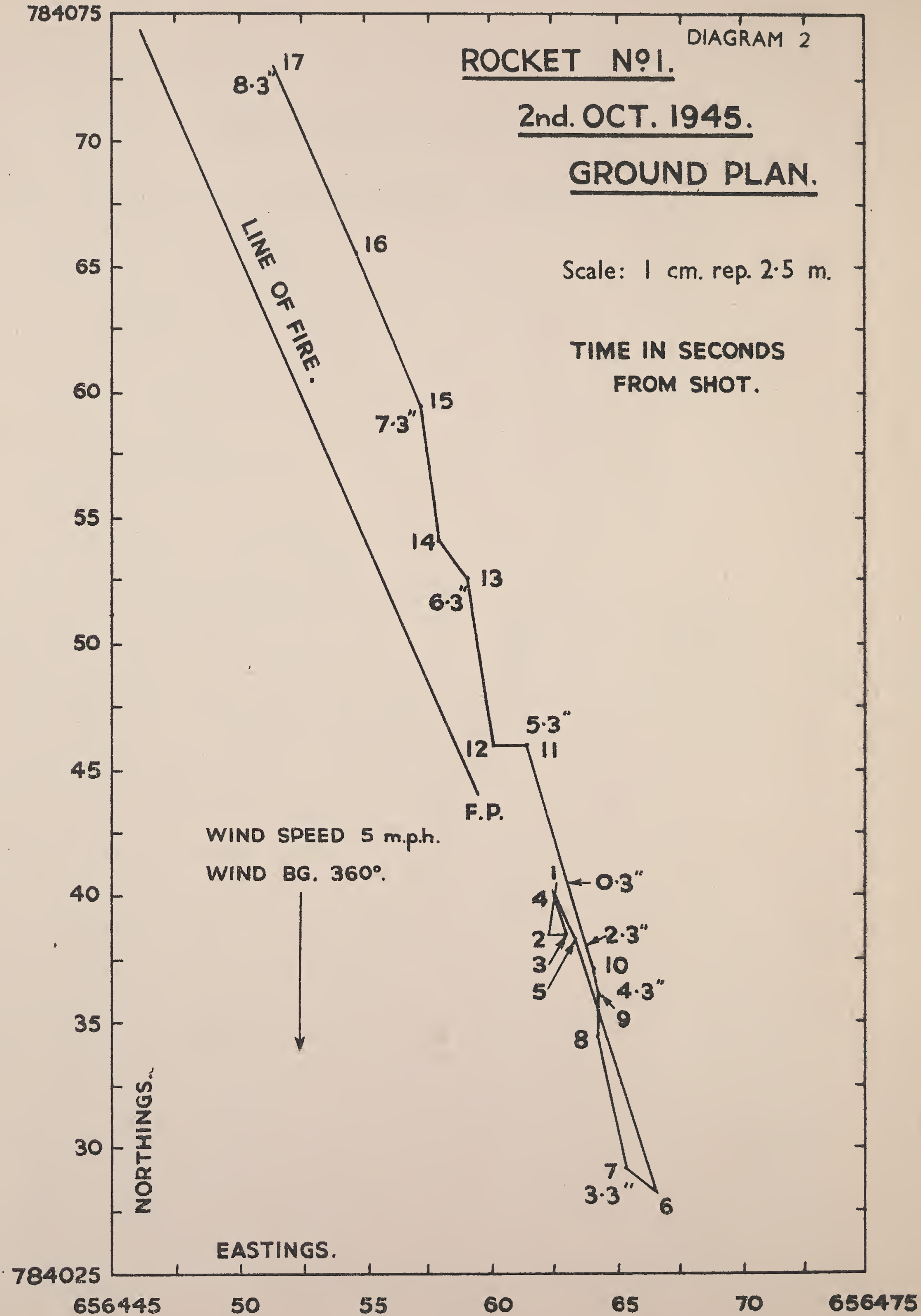


DIAGRAM 2
ROCKET Nº1.
2nd. OCT. 1945.
GROUND PLAN.
Scale: 1 cm. rep. 2·5 m.
TIME IN SECONDS FROM SHOT.
LINE OF FIRE.
F.P.
WIND SPEED 5 m.p.h.
WIND BG. 360°.
NORTHINGS.
EASTINGS.
784075
784025
656445
656475
8·3"
7·3"
6·3"
5·3"
4·3"
3·3"
2·3"
0·3"

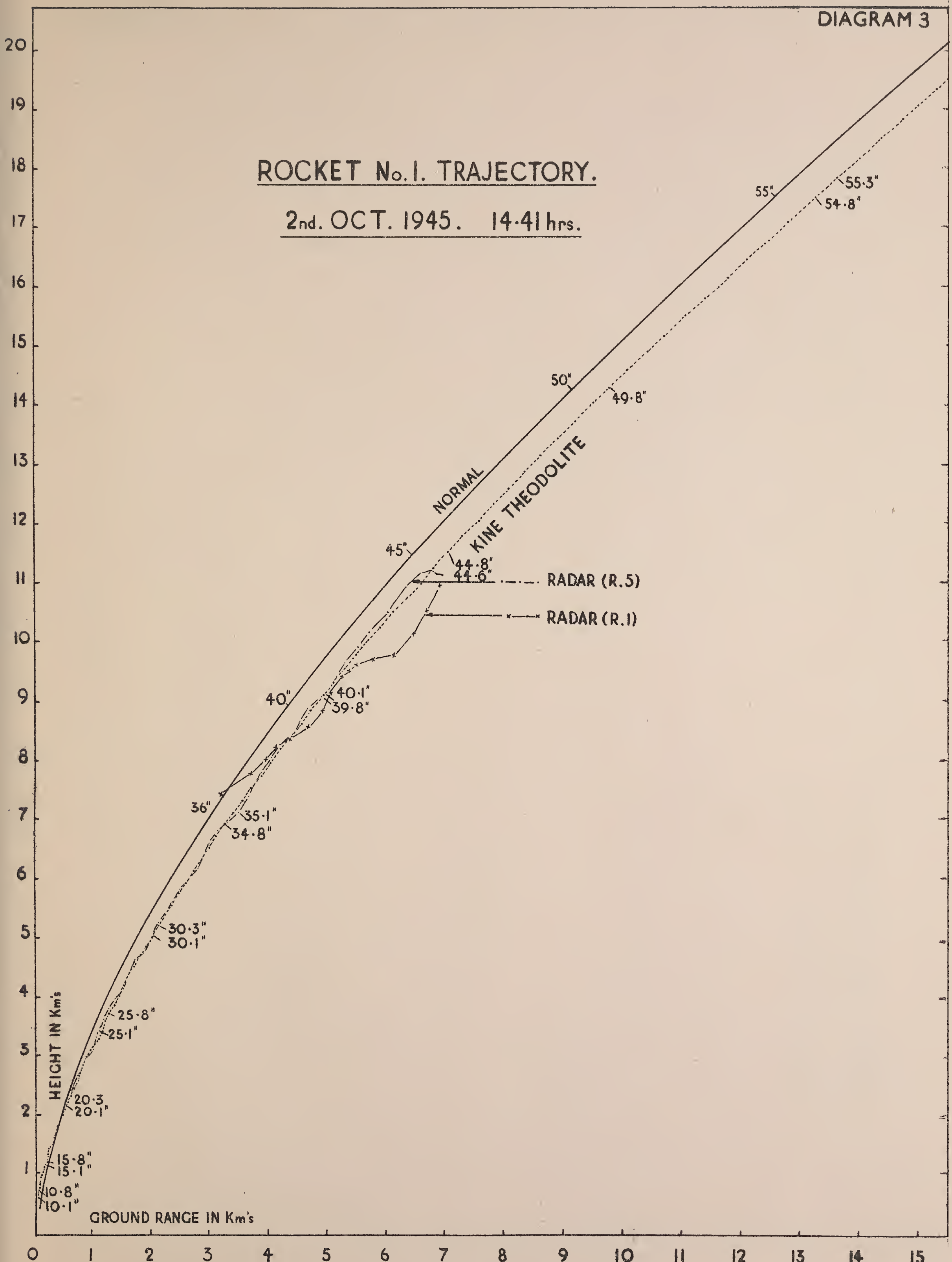


DIAGRAM 3
ROCKET No. I. TRAJECTORY.
2nd. OCT. 1945. 14·41 hrs.
HEIGHT IN Km's
GROUND RANGE IN Km's
NORMAL
KINE THEODOLITE
RADAR (R.5)
RADAR (R.1)
10·8"
10·1"
15·8"
15·1"
20·3
20·1"
25·8"
25·1"
30·3"
30·1"
35·1"
34·8"
36"
40"
40·1"
39·8"
45"
44·8"
44·6"
50"
49·8"
55"
55·3"
54·8"
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

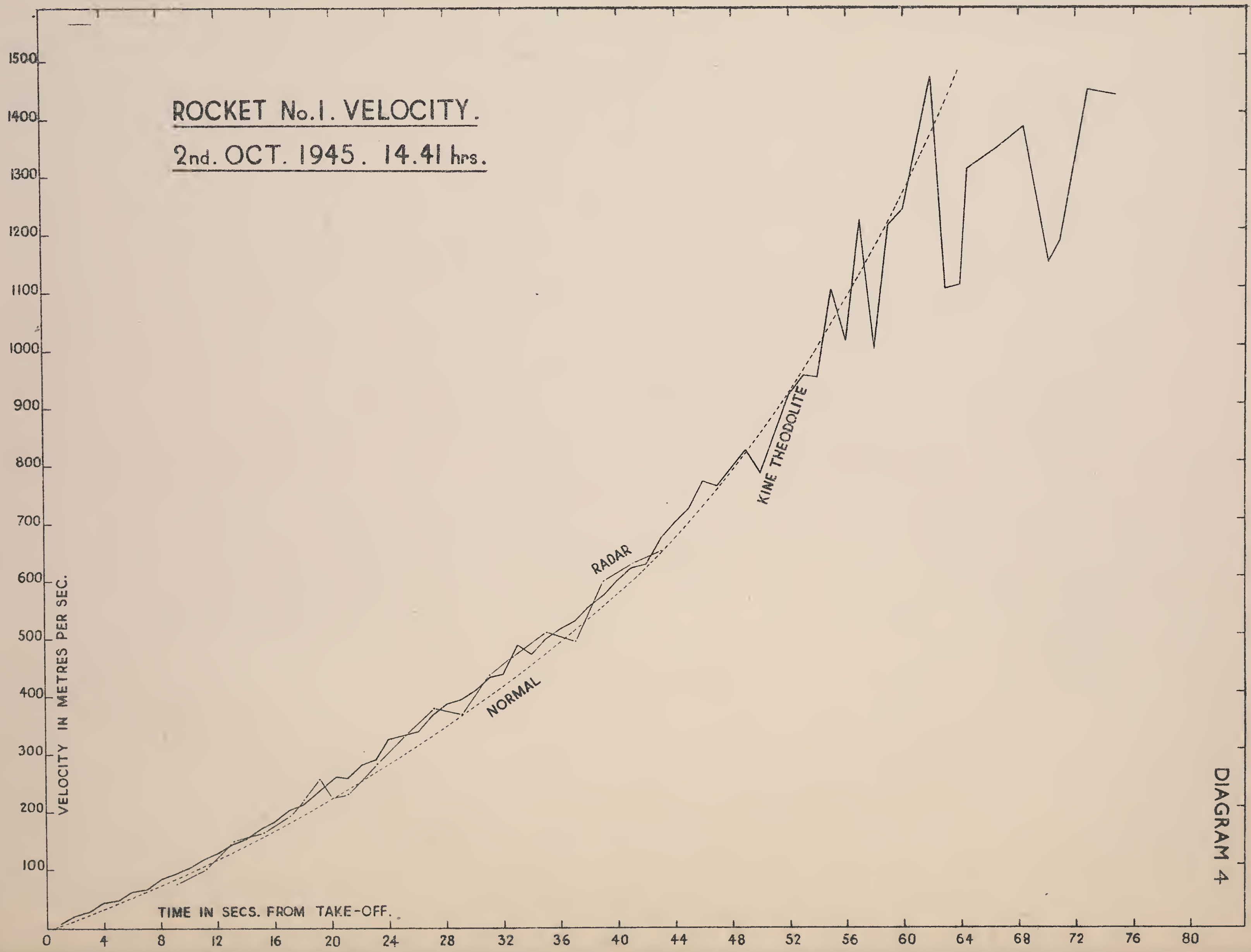
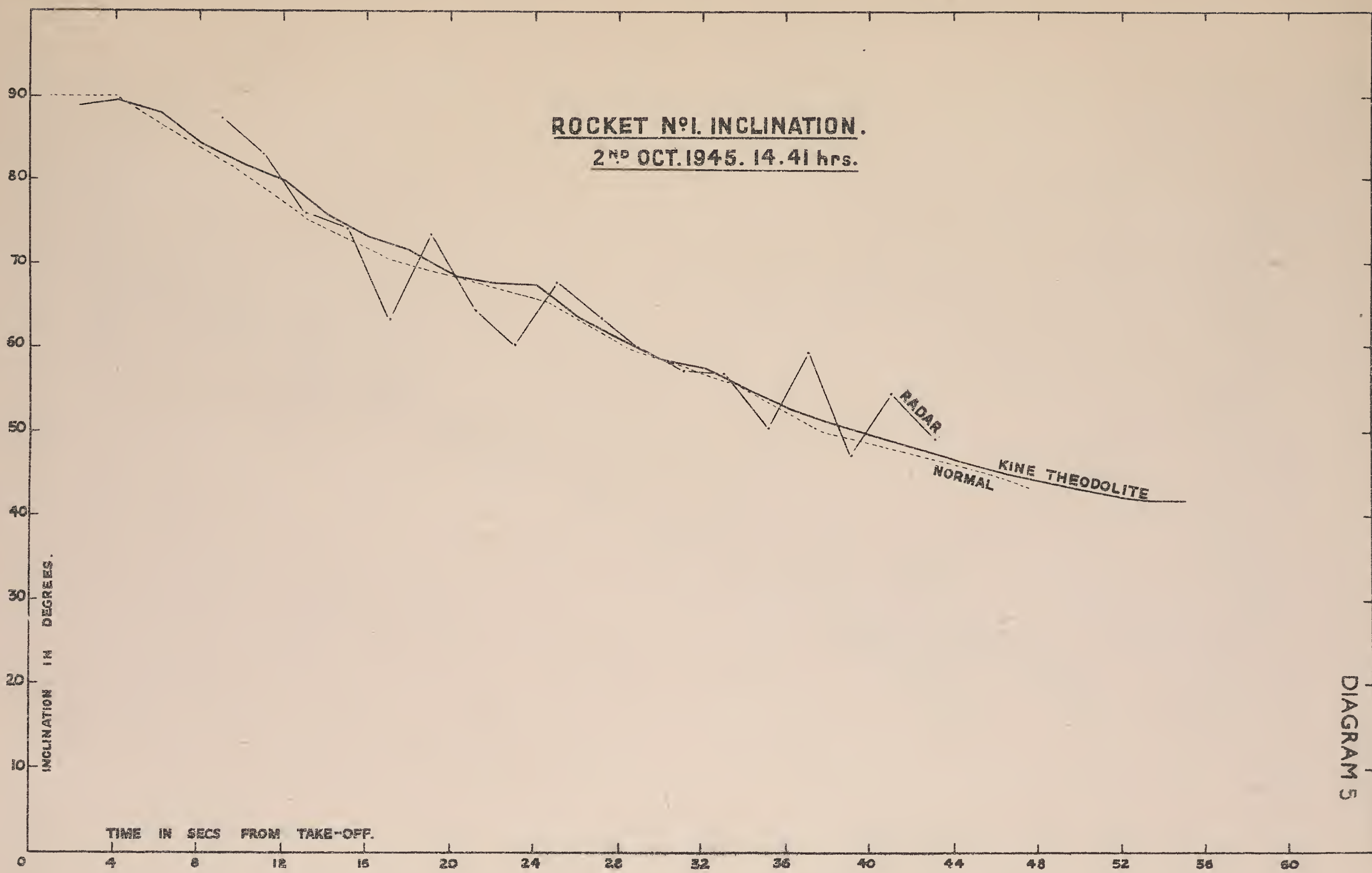


DIAGRAM 4
ROCKET No. 1. VELOCITY.
2nd. OCT. 1945. 14.41 hrs.
VELOCITY IN METRES PER SEC.
TIME IN SECS. FROM TAKE-OFF.
KINE THEODOLITE
RADAR
NORMAL
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80



ROCKET Nº1. INCLINATION.
2ND OCT. 1945. 14.41 hrs.
RADAR
NORMAL
KINE THEODOLITE
INCLINATION IN DEGREES.
90
80
70
60
50
40
30
20
10
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
TIME IN SECS FROM TAKE-OFF.

DIAGRAM 5

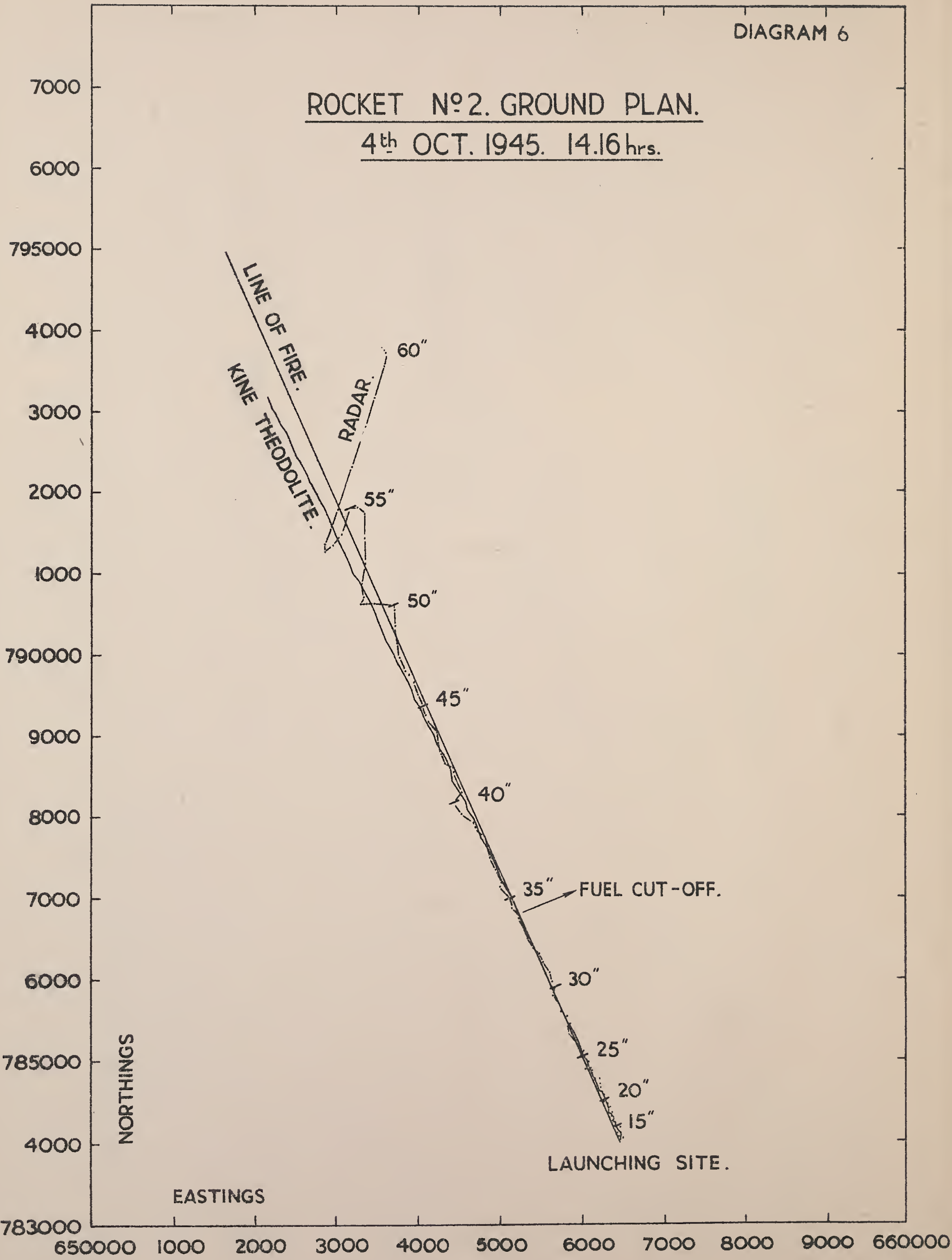


DIAGRAM 6
ROCKET Nº2. GROUND PLAN.
4th OCT. 1945. 14.16 hrs.
LINE OF FIRE.
KINE THEODOLITE.
RADAR.
60″
55″
50″
45″
40″
35″
FUEL CUT-OFF.
30″
25″
20″
15″
LAUNCHING SITE.
NORTHINGS
EASTINGS
7000
6000
795000
4000
3000
2000
1000
790000
9000
8000
7000
6000
785000
4000
783000
650000
1000
2000
3000
4000
5000
6000
7000
8000
9000
660000

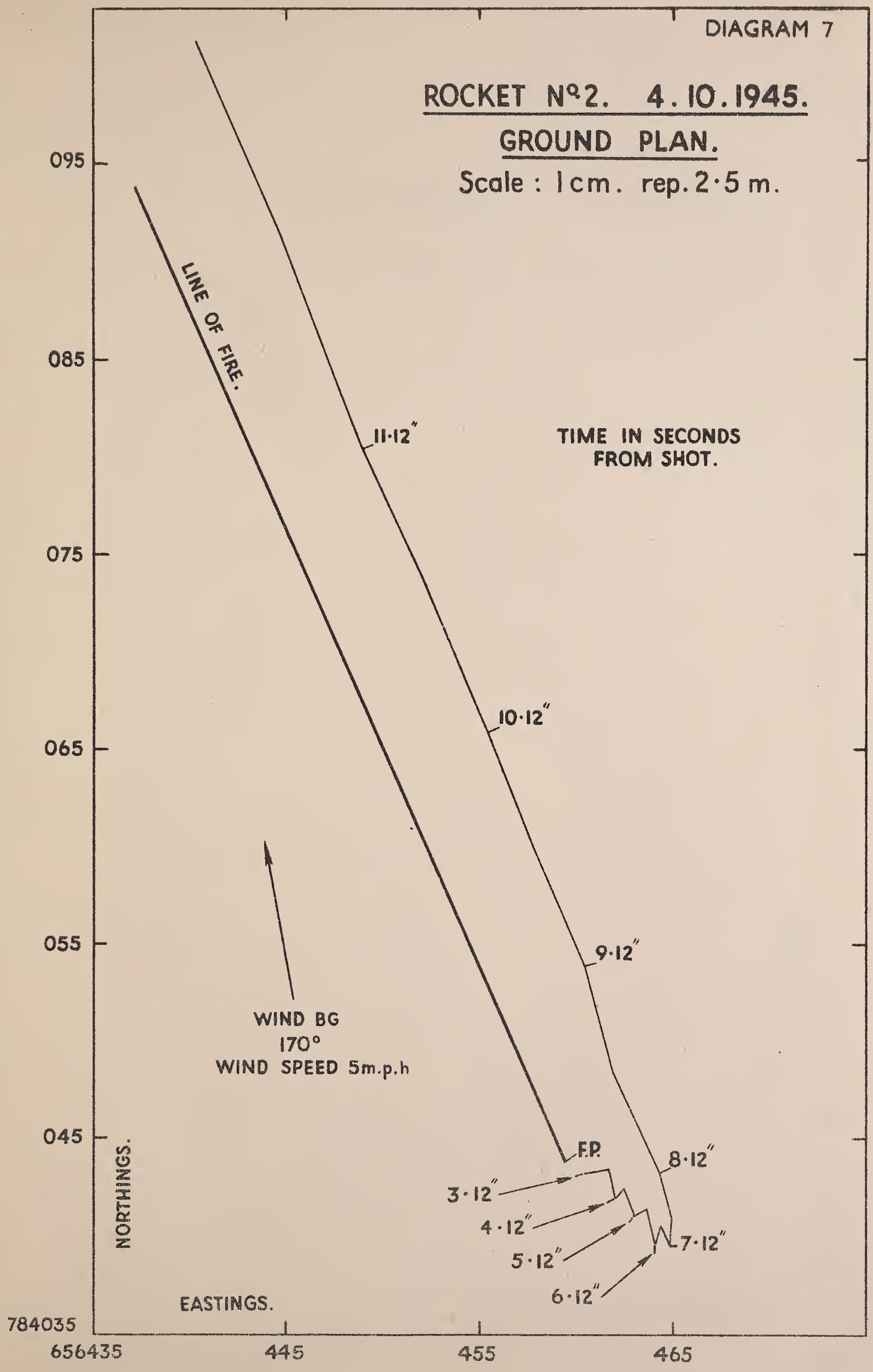


DIAGRAM 7
ROCKET Nº2. 4.10.1945.
GROUND PLAN.
Scale : 1cm. rep. 2·5 m.
095
085
075
065
055
045
784035
656435
445
455
465
LINE OF FIRE.
11·12″
10·12″
9·12″
8·12″
7·12″
6·12″
5·12″
4·12″
3·12″
F.P.
TIME IN SECONDS
FROM SHOT.
WIND BG
170°
WIND SPEED 5m.p.h
NORTHINGS.
EASTINGS.

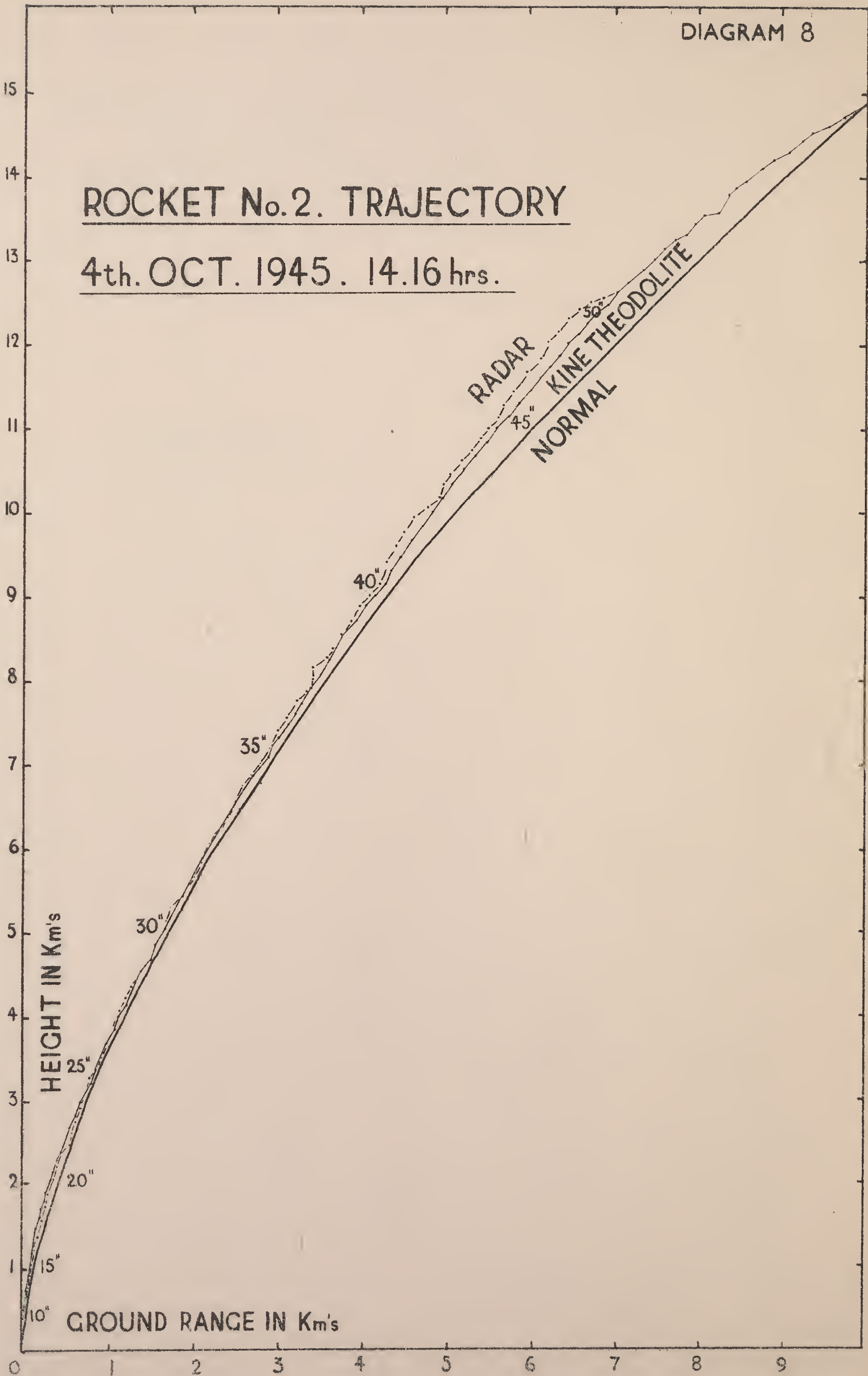
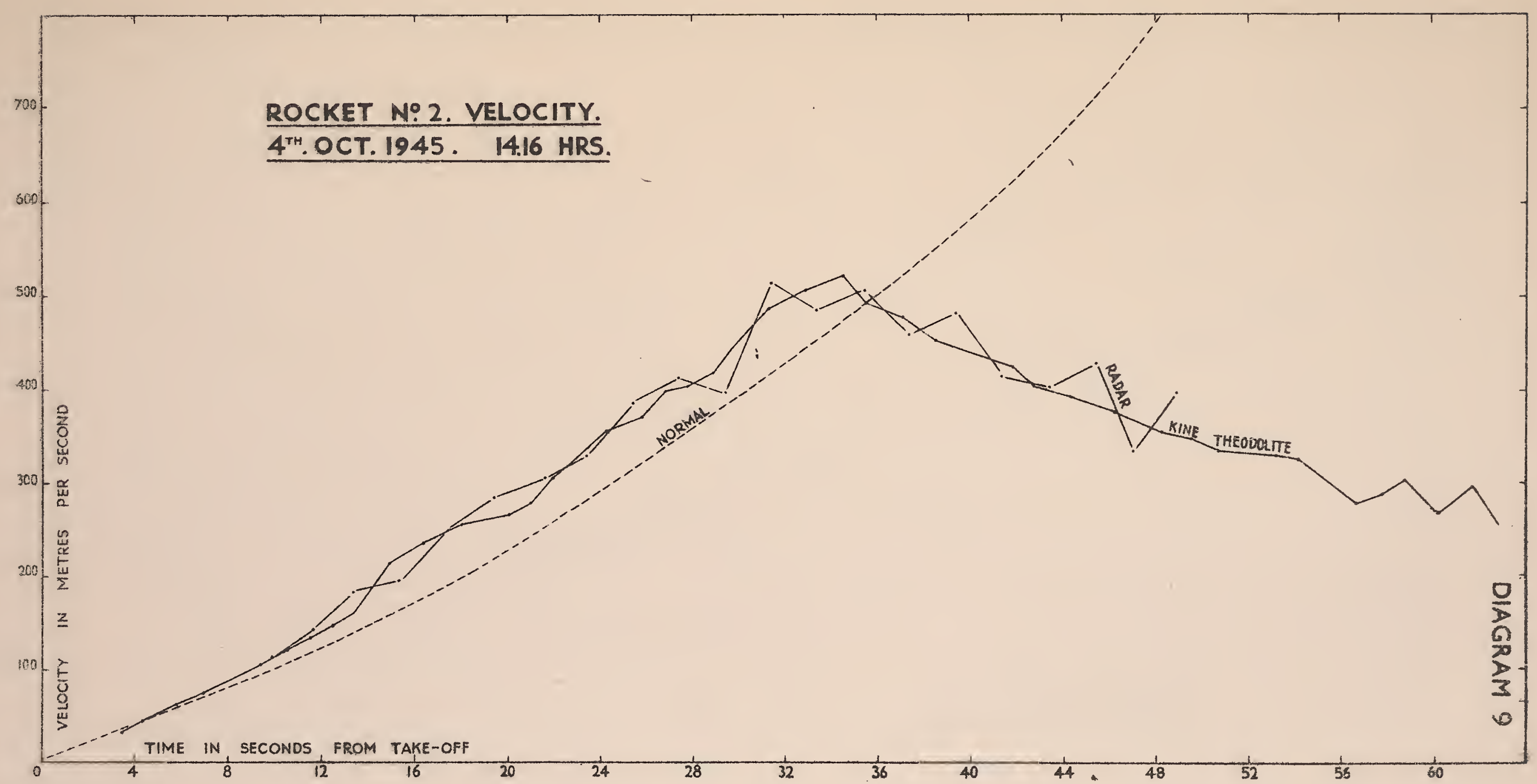


DIAGRAM 8
ROCKET No. 2. TRAJECTORY
4th. OCT. 1945. 14.16 hrs.
RADAR
KINE THEODOLITE
NORMAL
HEIGHT IN Km's
GROUND RANGE IN Km's
10"
15"
20"
25"
30"
35"
40"
45"
50"
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


ROCKET Nº 2. VELOCITY.
4TH. OCT. 1945. 14.16 HRS.
DIAGRAM 9
NORMAL
RADAR
KINE THEODOLITE
VELOCITY IN METRES PER SECOND
TIME IN SECONDS FROM TAKE-OFF
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
100
200
300
400
500
600
700

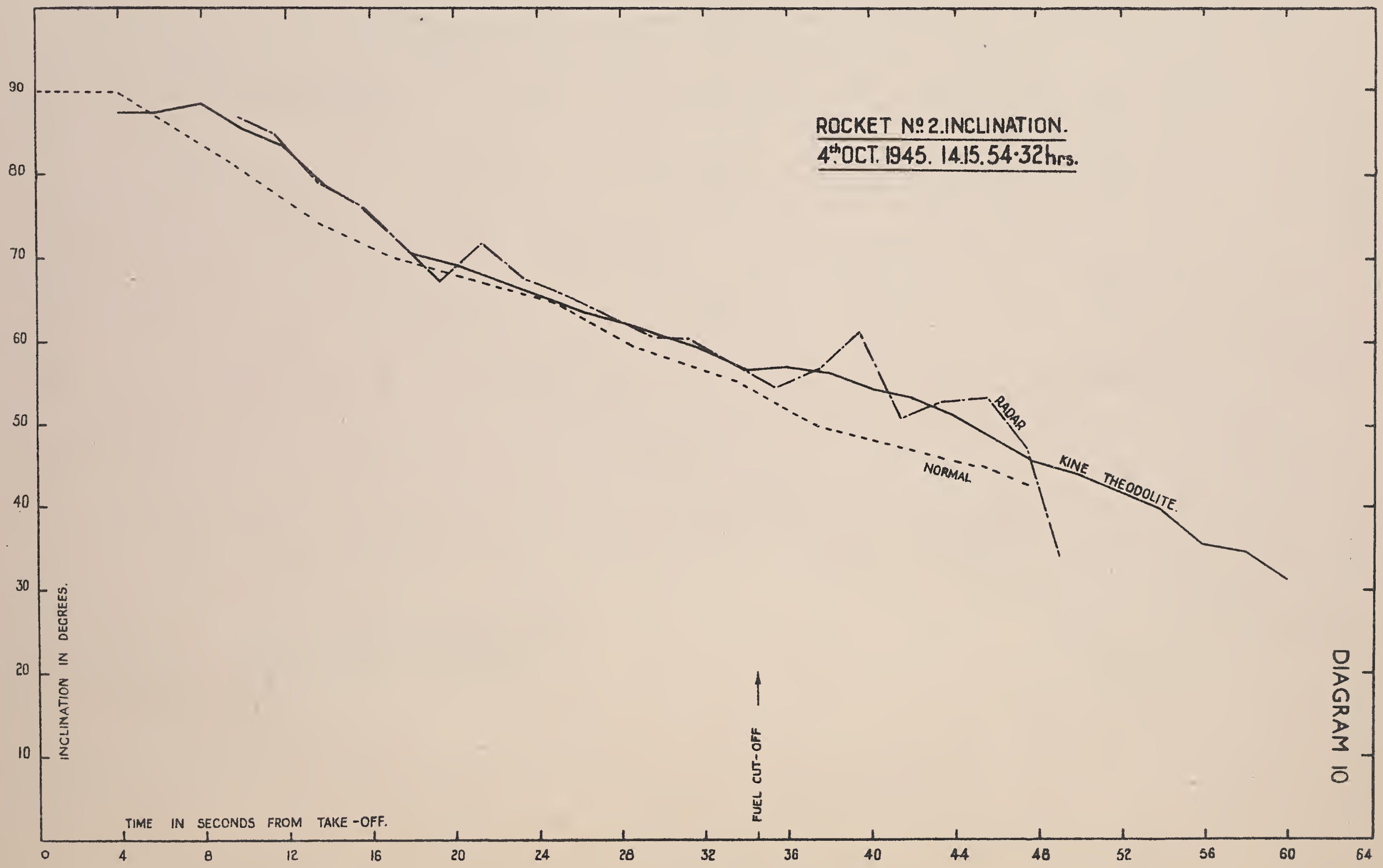


DIAGRAM 10
ROCKET No. 2. INCLINATION.
4th OCT. 1945. 14.15.54·32 hrs.
RADAR
KINE THEODOLITE.
NORMAL
FUEL CUT-OFF
INCLINATION IN DEGREES.
TIME IN SECONDS FROM TAKE-OFF.
90
80
70
60
50
40
30
20
10
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64

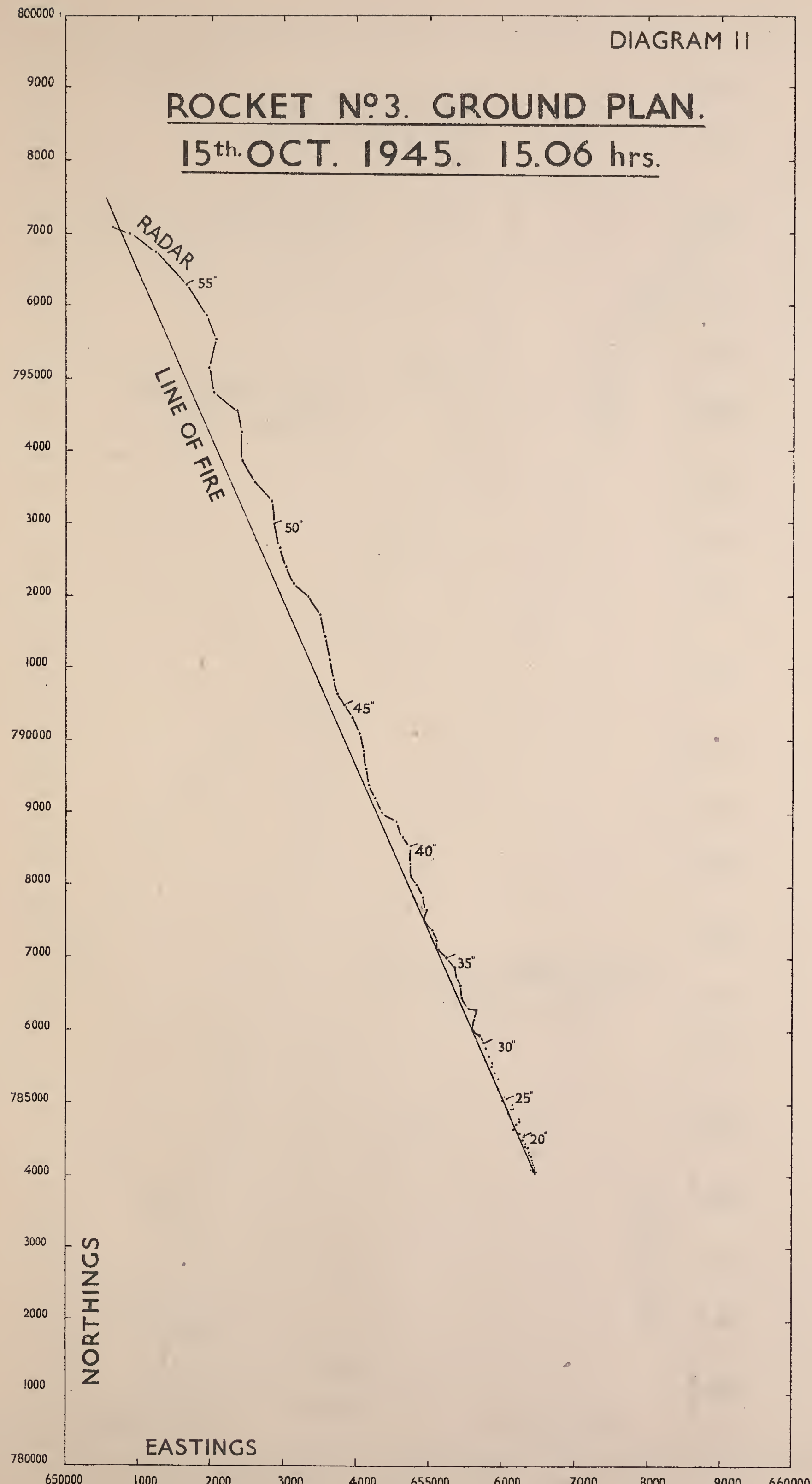


DIAGRAM 11
ROCKET Nº3. GROUND PLAN.
15th. OCT. 1945. 15.06 hrs.
RADAR
LINE OF FIRE
55"
50"
45"
40"
35"
30"
25"
20"
NORTHINGS
EASTINGS
800000
9000
8000
7000
6000
795000
4000
3000
2000
1000
790000
9000
8000
7000
6000
785000
4000
3000
2000
1000
780000
650000
1000
2000
3000
4000
655000
6000
7000
8000
9000
660000

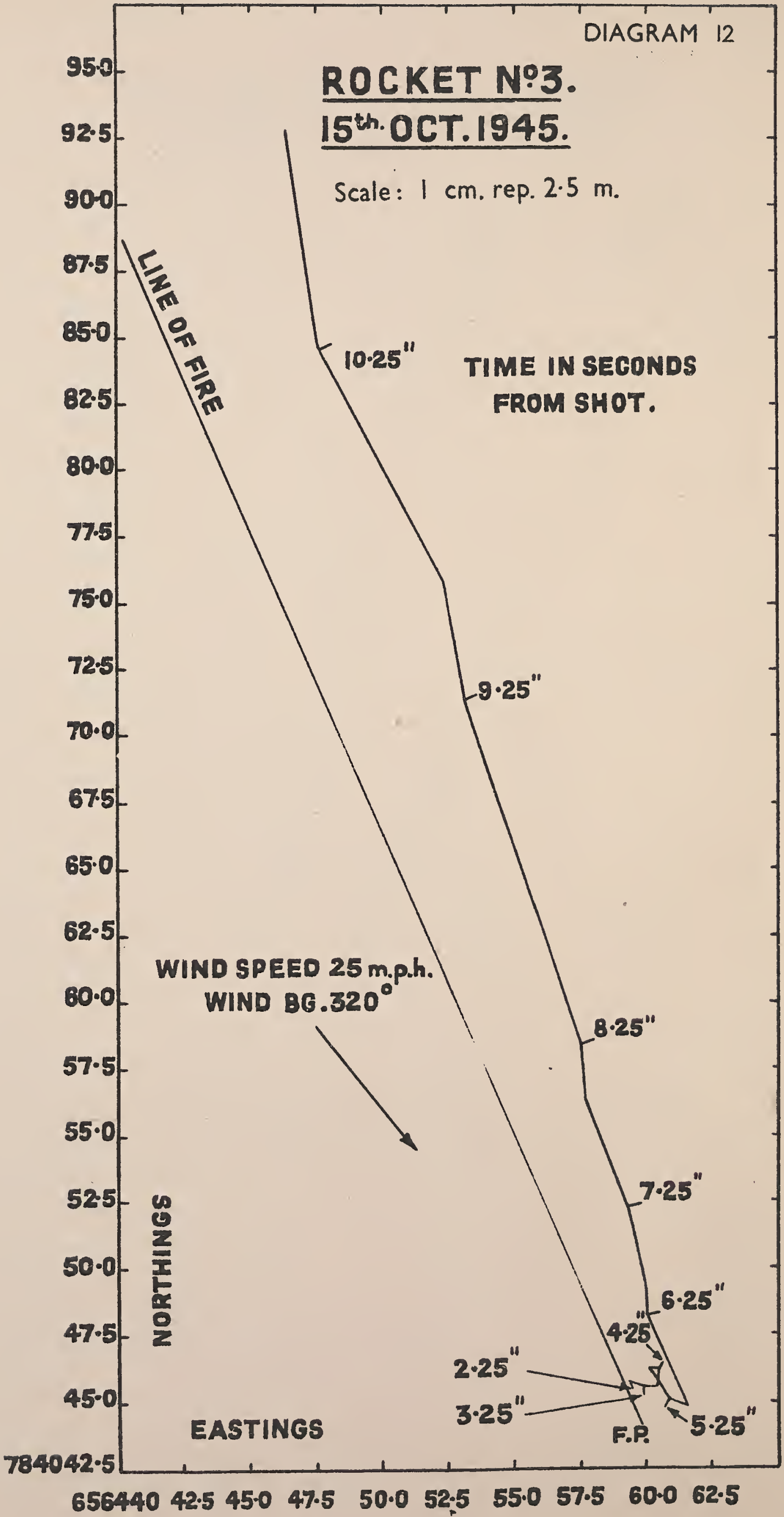


DIAGRAM 12
ROCKET Nº3.
15th. OCT. 1945.
Scale: 1 cm. rep. 2·5 m.
TIME IN SECONDS FROM SHOT.
LINE OF FIRE
10·25"
9·25"
8·25"
7·25"
6·25"
4·25"
2·25"
3·25"
5·25"
F.P.
WIND SPEED 25 m.p.h.
WIND BG.320°
NORTHINGS
EASTINGS
95·0
92·5
90·0
87·5
85·0
82·5
80·0
77·5
75·0
72·5
70·0
67·5
65·0
62·5
60·0
57·5
55·0
52·5
50·0
47·5
45·0
784042·5
656440
42·5
45·0
47·5
50·0
52·5
55·0
57·5
60·0
62·5

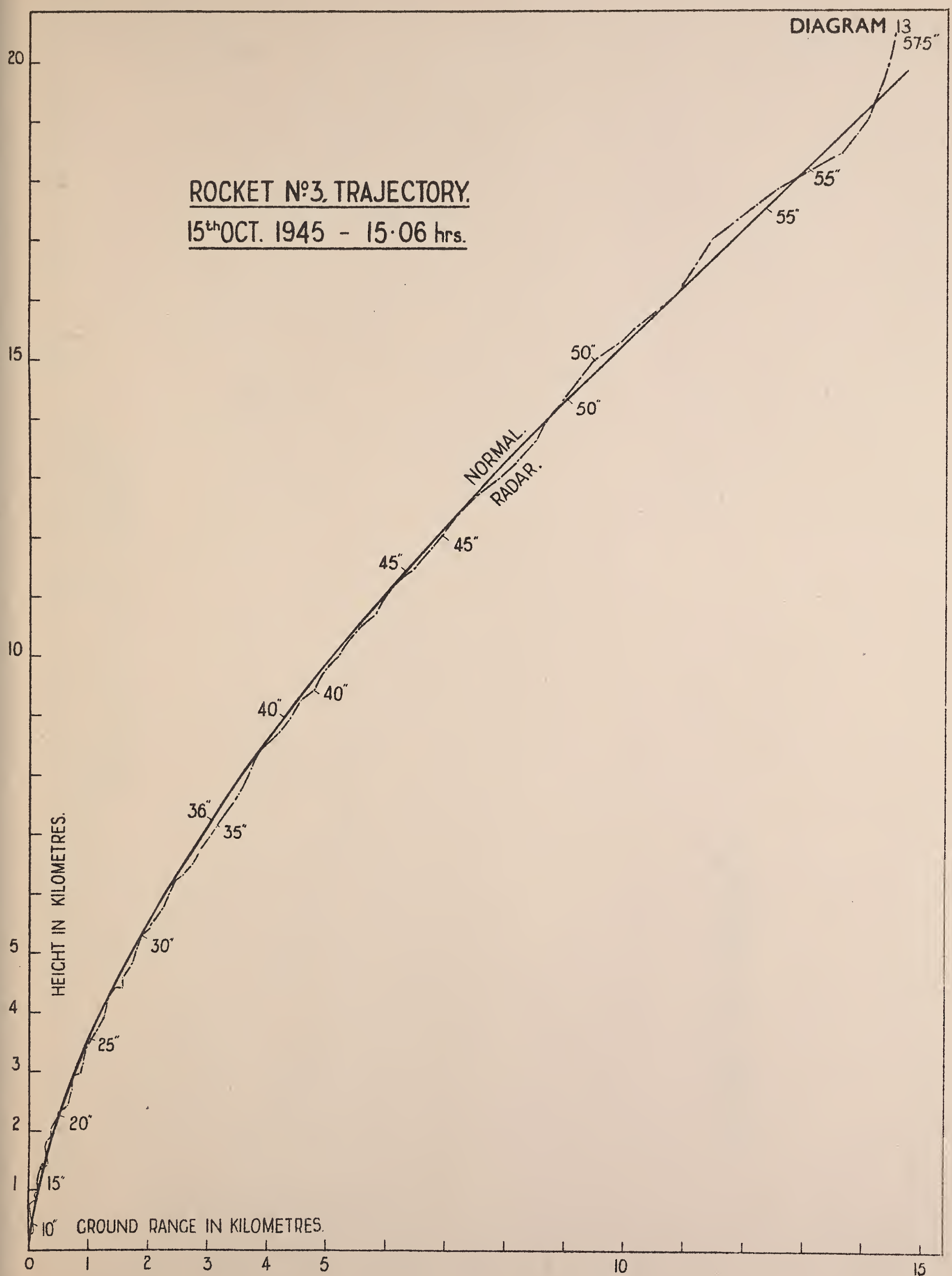
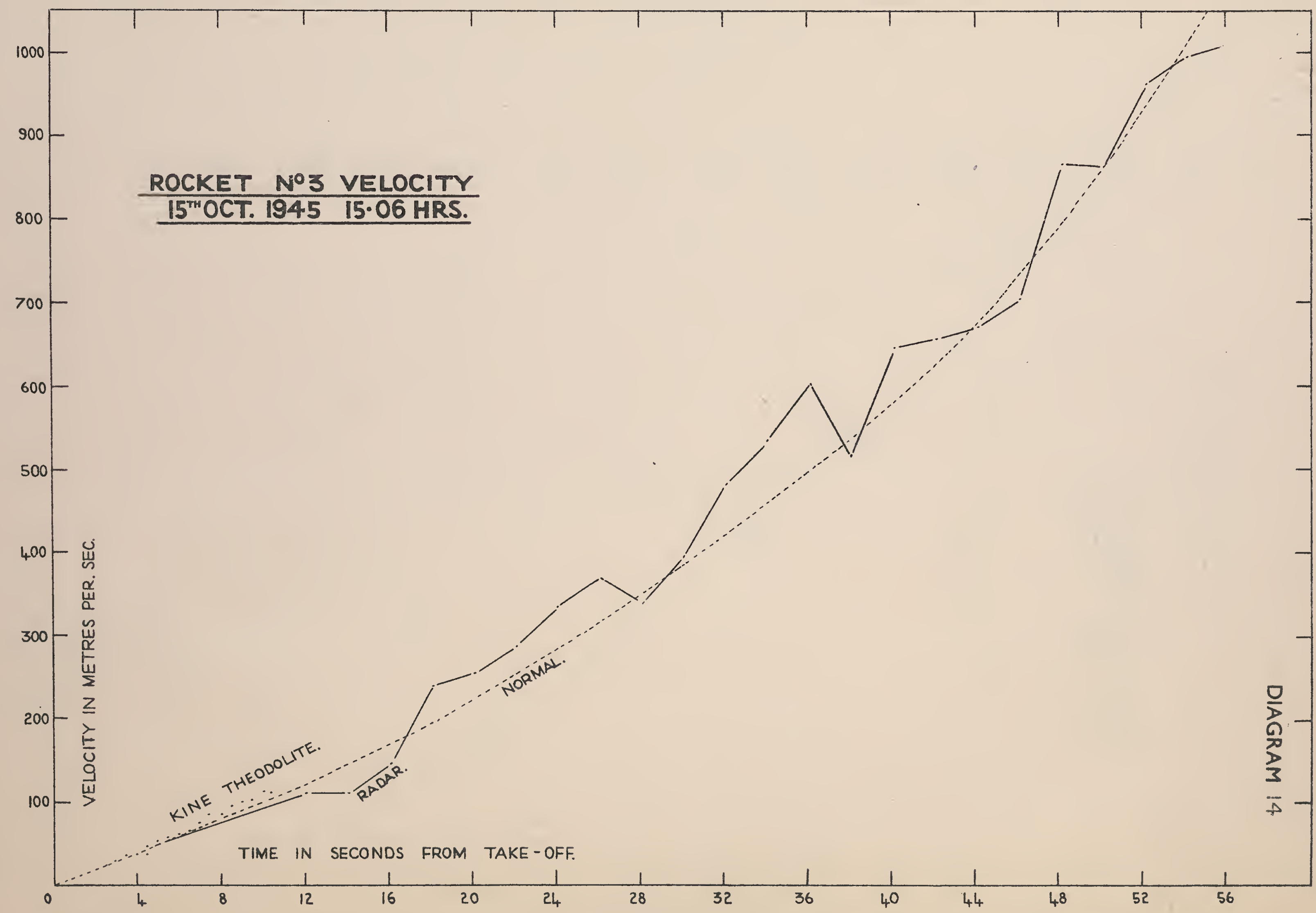
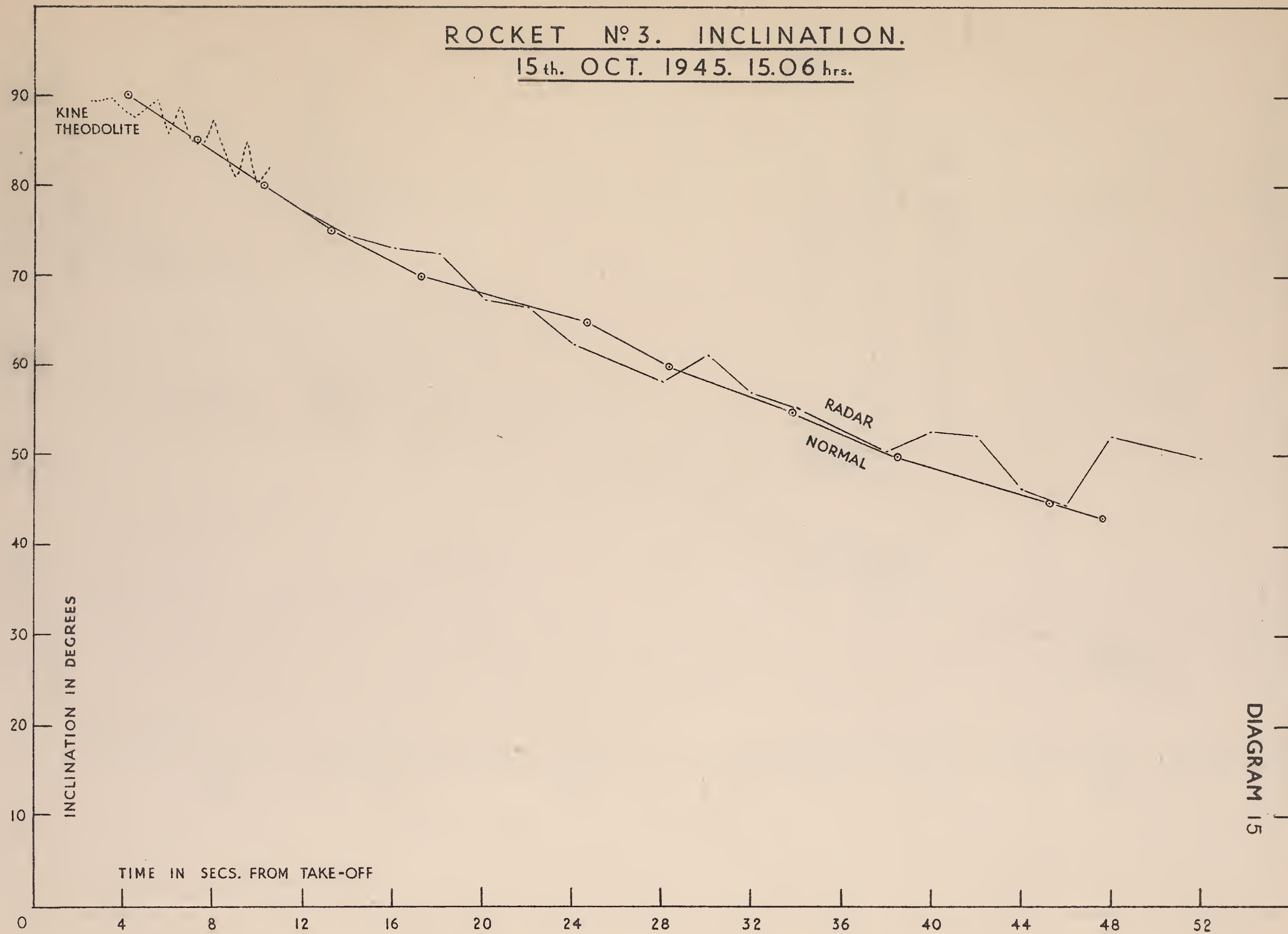


DIAGRAM 13
ROCKET No. 3. TRAJECTORY.
15th OCT. 1945 - 15·06 hrs.
NORMAL.
RADAR.
HEIGHT IN KILOMETRES.
GROUND RANGE IN KILOMETRES.
10"
15"
20"
25"
30"
35"
36"
40"
40"
45"
45"
50"
50"
55"
55"
57·5"
0
1
2
3
4
5
10
15
20


ROCKET N°3 VELOCITY
15TH OCT. 1945 15·06 HRS.
VELOCITY IN METRES PER. SEC.
TIME IN SECONDS FROM TAKE-OFF.
KINE THEODOLITE.
RADAR.
NORMAL.
DIAGRAM 14
1000
900
800
700
600
500
400
300
200
100
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56


ROCKET Nº 3. INCLINATION.
15th. OCT. 1945. 15.06 hrs.
KINE
THEODOLITE
RADAR
NORMAL
INCLINATION IN DEGREES
TIME IN SECS. FROM TAKE-OFF
90
80
70
60
50
40
30
20
10
0
4
8
12
16
20
24
28
32
36
40
44
48
52
DIAGRAM 15

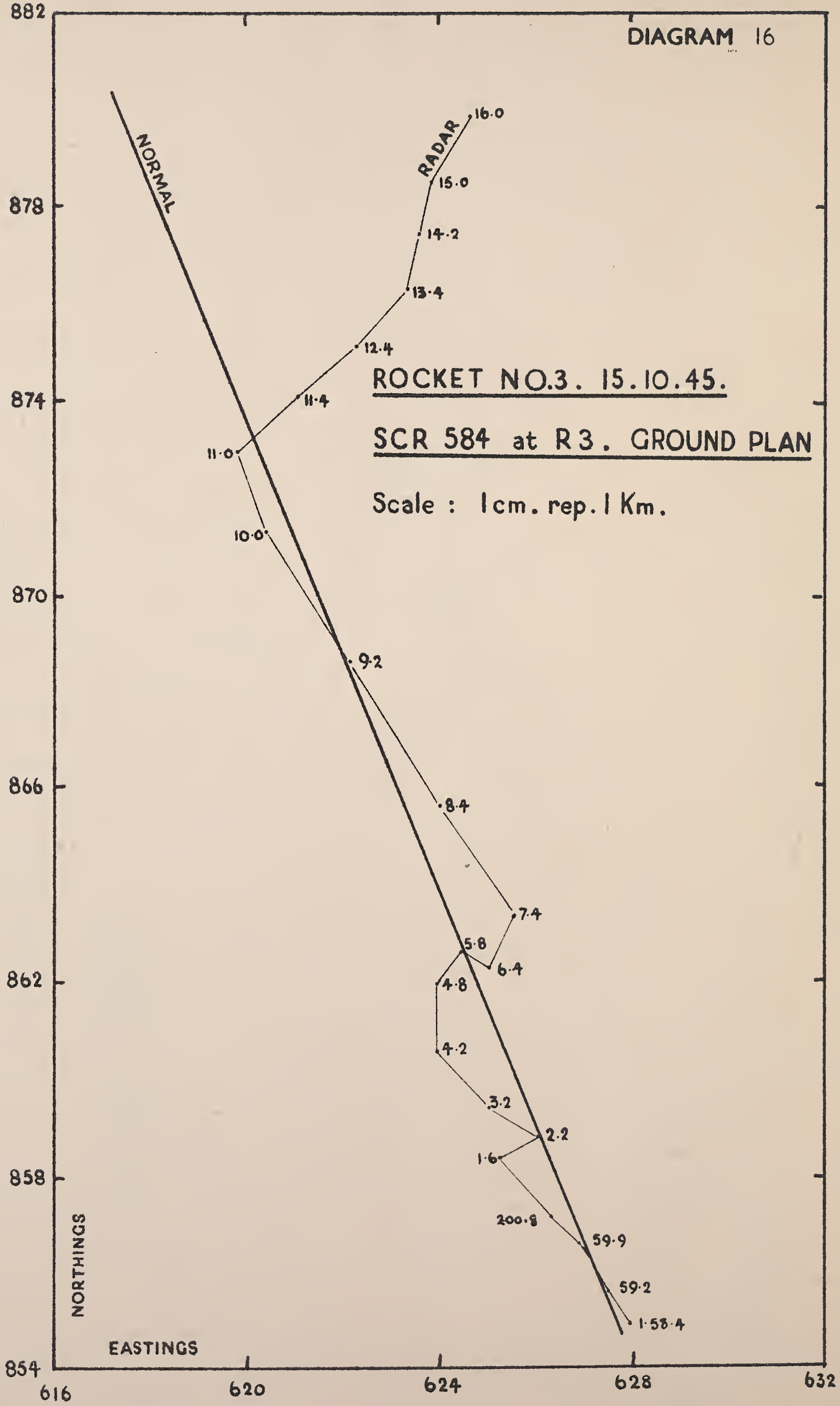


DIAGRAM 16
ROCKET NO.3. 15.10.45.
SCR 584 at R3. GROUND PLAN
Scale : 1cm. rep. 1 Km.
NORMAL
RADAR
16.0
15.0
14.2
13.4
12.4
11.4
11.0
10.0
9.2
8.4
7.4
5.8
6.4
4.8
4.2
3.2
2.2
1.6
200.8
59.9
59.2
1.58.4
882
878
874
870
866
862
858
854
616
620
624
628
632
NORTHINGS
EASTINGS

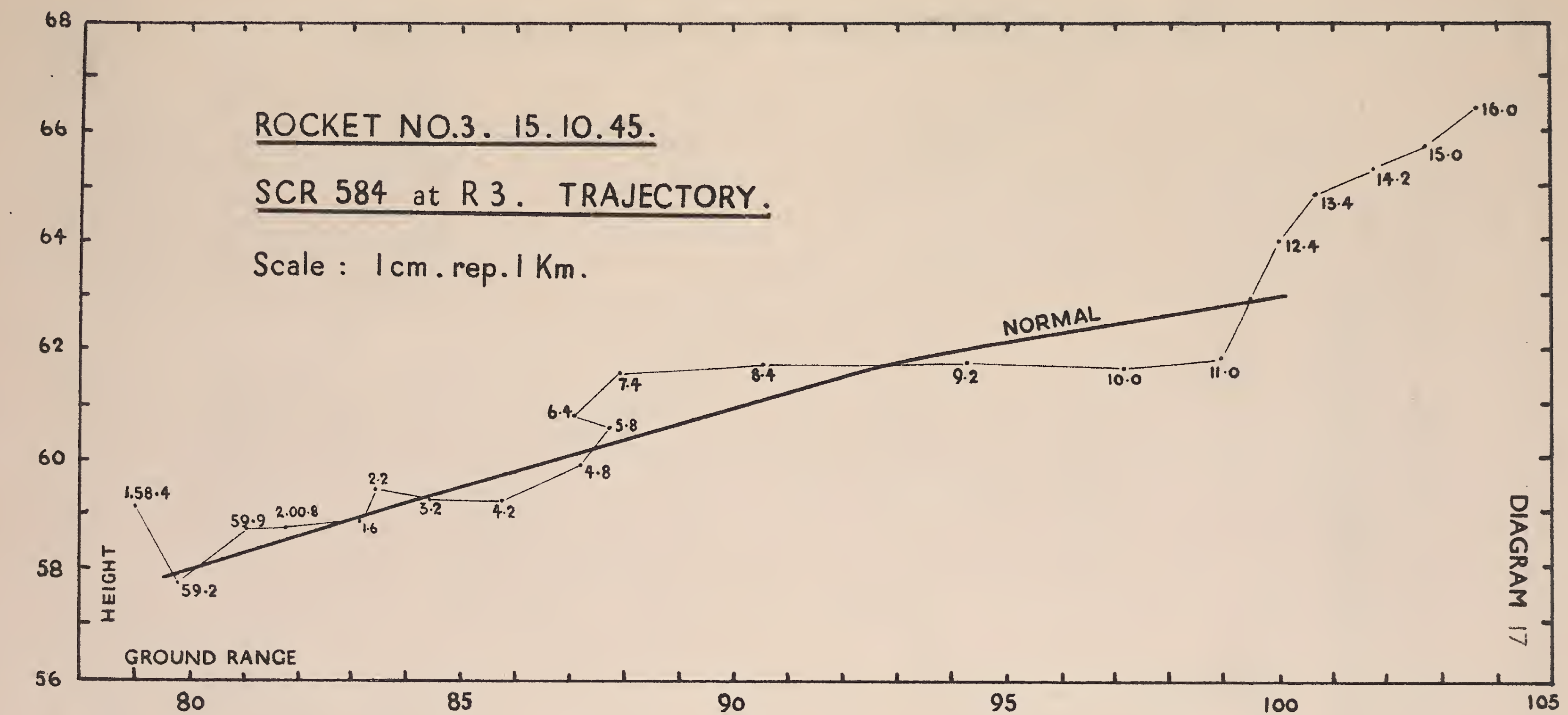


DIAGRAM 17
ROCKET NO.3. 15.10.45.
SCR 584 at R 3. TRAJECTORY.
Scale : 1 cm. rep. 1 Km.
NORMAL
HEIGHT
GROUND RANGE
68
66
64
62
60
58
56
80
85
90
95
100
105
1.58·4
59·2
59·9
2.00·8
1·6
2·2
3·2
4·2
4·8
5·8
6·4
7·4
8·4
9·2
10·0
11·0
12·4
13·4
14·2
15·0
16·0

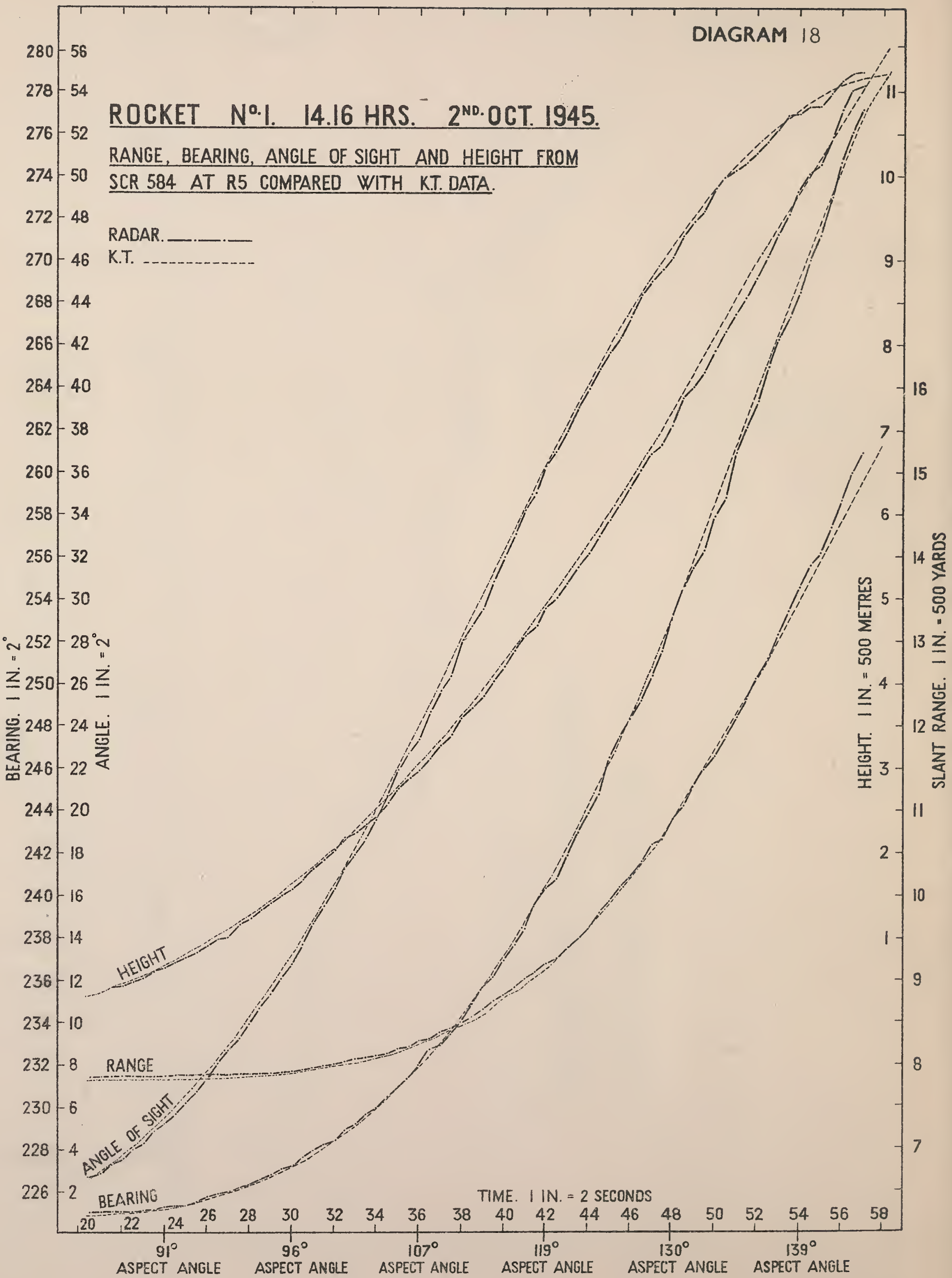


DIAGRAM 18
ROCKET No.1. 14.16 HRS. 2ND. OCT. 1945.
RANGE, BEARING, ANGLE OF SIGHT AND HEIGHT FROM
SCR 584 AT R5 COMPARED WITH K.T. DATA.
RADAR.
K.T.
HEIGHT
RANGE
ANGLE OF SIGHT
BEARING
BEARING. 1 IN. = 2°
ANGLE. 1 IN. = 2°
HEIGHT. 1 IN. = 500 METRES
SLANT RANGE. 1 IN. = 500 YARDS
TIME. 1 IN. = 2 SECONDS
91° ASPECT ANGLE
96° ASPECT ANGLE
107° ASPECT ANGLE
119° ASPECT ANGLE
130° ASPECT ANGLE
139° ASPECT ANGLE

STILL PHOTOGRAPHY

57. Photographs of the installations, equipments, procedures, and launchings were taken by the British Army Film Photographic Unit (A.F.P.U.) using a Zeiss Super Ikonta, 6 cm. × 6 cm., 2·8 Zeiss Tessar lens camera and by the U.S. Army Signal Corps Photographic Unit using a Kodak Speed Graphic 5-in × 4-in camera.

ACTION PHOTOGRAPHY

58. A detachment of the British Army Kinematograph Service was employed to take shots which will be used in the preparation of a training film. The object of the film is not to record operation "BACKFIRE" but to show how the A-4 works, its handling from railhead to firing point, and the process of launching. Shooting commenced on Sept. 12, 1945, and was completed on Oct. 22, 1945. All sequences were shot at KRUPPS or the firing site, with the exception of a few shots of German operational launching positions in The HAGUE area.

59. The equipment used was:

(*a*) Cameras

3 Newman cameras 1 Mitchell camera 3 Vinten cameras 1 Eyemo camera	with remote control gear for filming launchings.

(*b*) Searchlight equipment

3 × 5 kw lamps
6 × 2 kw lamps
3 × 500 kw lamps

60. For filming the launchings on Oct 2, Oct 4, and Oct 15, 1945, remotely controlled and manually operated cameras were used. The remote controlled cameras were positioned on two gun shields which were erected on the launching site (see Plate 5). The cameras were started from the command post.

61. Details of cameras used for the three launchings are as follows:

OCTOBER 2, 1945. First Launch.

(*a*) Remotely controlled cameras.

(i) Gunshield 1.

1 Vinten	40 mm. lens	32 f.p.s. fixed frame Ascent of rocket.

(ii) Gunshield 2.

1 Vinten	6 in. lens	32 f.p.s. fixed frame. Base of rocket.
1 Eyemo	2 in. lens	32 f.p.s. fixed frame. All rocket.

(*b*) Manually operated cameras.

Operated from lighthouse 2,000 yds. S.W. of firing point.

1 Mitchell	2 in. lens	192 f.p.s. fixed frame. Ascent of rocket.
1 Newman	12 in. lens	24 f.p.s. Following ascent of rocket.
1 Newman	6 in. lens	52 f.p.s. Following ascent of rocket.

OCTOBER 4, 1945. Second launch.

(*a*) Remotely controlled cameras.

(i) Gunshield 1.

1 Vinten	40 mm. lens	32 f.p.s. fixed frame. Ascent of rocket.

(ii) Gunshield 2.

1 Vinten	2 in. lens	96 f.p.s. fixed frame. All rocket.
1 Vinten	6 in. lens	32 f.p.s. fixed frame. Base of rocket.

(*b*) Manually operated cameras.

Situated 640 yds. in rear of Shelters 1 and 2.

1 Mitchell	12 in. lens	192 f.p.s.	All cameras covered ascent from take-off to smoke trail
1 Newman	12 in. lens	24 f.p.s.	
1 Newman	6 in. lens	32 f.p.s.	
1 Eyemo	3 in. lens	32 f.p.s.	

OCTOBER 15, 1945. Third Launch.

(*a*) Remotely controlled cameras.

As for second launch on October 4, 1945.

(*b*) Manually operated cameras.

Positioned in slit trenches S. of command post 60 yds. from the rocket.

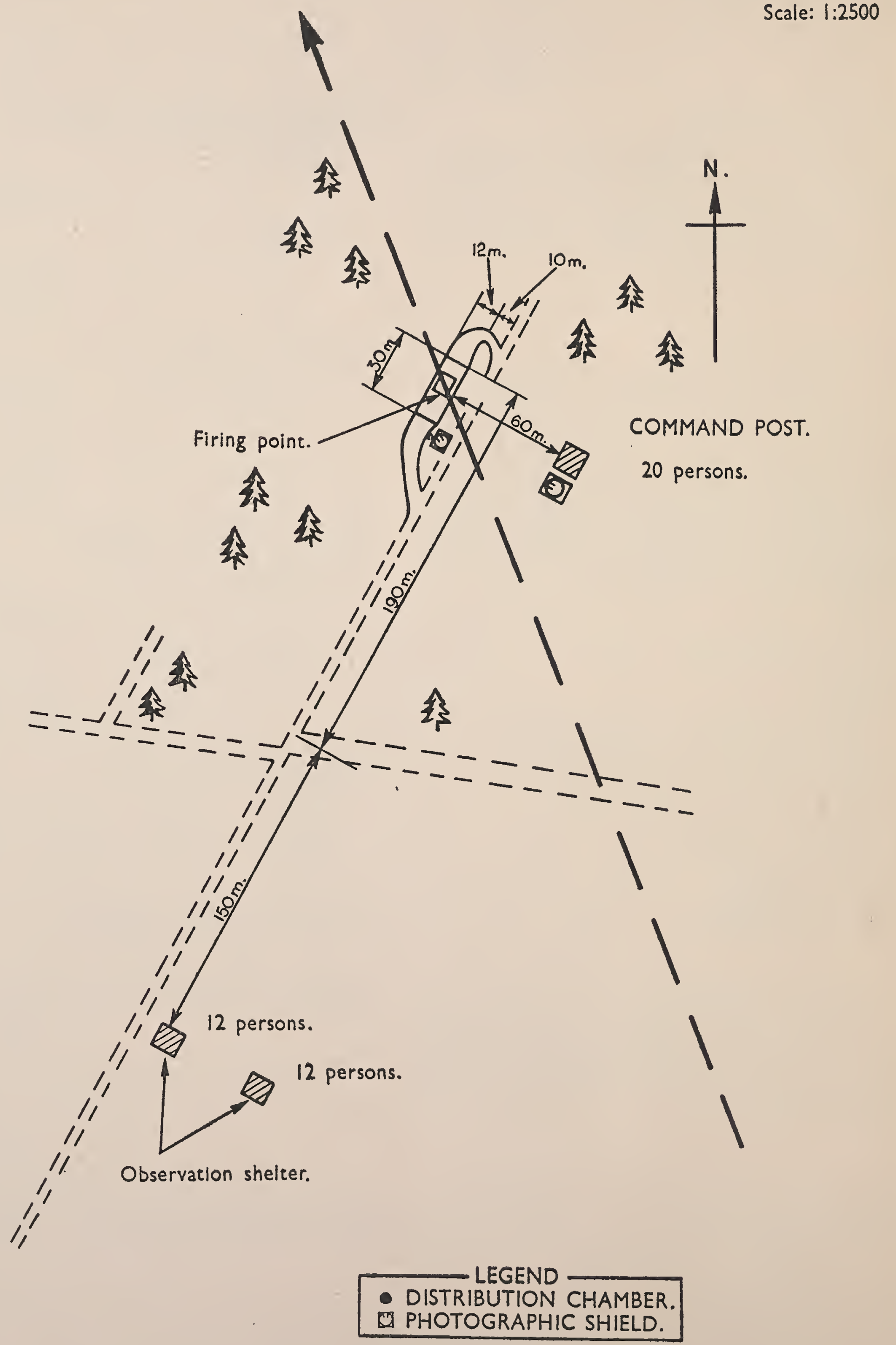
1 Newman	6 in. lens	32 f.p.s.	Covered ascent of rocket from take-off to disappearance cloud.
1 Mitchell	12 in. lens	192 f.p.s.	

62. On all launching days the cameras used infra red film except the 2 A.K.S. Vintens. Other sequences were shot with Kodak Plus X or Super XX.

DETAILS OF LAYOUT LAUNCHING SITE.

Plate 5.

Scale: 1:2500



Fuel Characteristics and Storage . . SECTION 3

LIQUID OXYGEN

63. Quantity required per rocket = 5,000 kg. (10,930 lb.)
Purity = 98 per cent.
Boiling temperature under atmospheric pressure = – 183° centigrade
Latent heat = 52 cal. per gram. (water = 560 cal. per gram)

64. When standing in the tanker, liquid oxygen has the interesting property that its purity actually improves, the gas which boils off carrying a large proportion of nitrogen. There is no need to include a purity test at the site as the factory material is above 99 per cent. oxygen.

65. Any particles of oil in the liquid oxygen, present by mischance, tend to float to the top when it is standing in the tanker. It is then a good practice to avoid completely emptying the tanker.

66. For the men engaged in transferring the oxygen from the rail tanker to the road tanker, and subsequently to the rocket, the Germans provided complete sets of asbestos clothing.

67. Storage and transport tanks are double-walled with the inner tank of copper or aluminium and the outer wall of steel plate. The inter-space is filled with insulating material of a non-combustible character in powder form.

68. When the external size is restricted as in rail or road transport sacrifice has to be made in the extent of the insulation provided. This is brought out in the following table for tanks which were used in the operation.

TANK	CAPACITY	THICKNESS OF INSULATION
FASSBURG STORAGE	56 tons	40 inches
RAIL	30 tons	12 inches
ROAD	6½ tons	9 inches

ALCOHOL

69. The standard material used was ethyl alcohol, as this gives an increase in range of about 30 kms. (260-290 kms.) over methyl alcohol.

Quantity required per rocket = 4 tons (8,150 lb. or 3700 kg. approx.), but varying according to range.
Concentration by weight = 75 per cent.
Specific gravity = ·8599 at 15° centigrade, and ·8556 at 20° centigrade.
Freezing temperature (100 per cent. material) = – 130° centigrade

70. The alcohol railway tank waggons used by the Germans are of a series of different types of up to 20 tons capacity. They have bottom connections for emptying through the portable alcohol pump.

HYDROGEN PEROXIDE

71. Quantity required per rocket = 126 litres (370 lb.).
Concentration by weight = 78-80 per cent.
Specific gravity (A-4 Fuel) = 1·34
Specific gravity (100 per cent. material) = 1·4633 at 0° centigrade.
Freezing temperature (100 per cent. material) = –1·9° centigrade (but undercools easily)

72. Hydrogen peroxide is stored in aluminium tanks whose capacity varies from 300 tons, as at Duneburg, to 20 tons, as at Kiel. Two types of rail tankers have been encountered, viz.—a large single tank of 20 tons capacity, and a smaller size with four separate cross-tanks each of 2½ ton capacity, making 10 tons in all. The small tanker was the one usually used for transporting hydrogen peroxide for the A-4 rockets to the railhead. Top connections alone are provided. The transfer of liquid to the road tanker is made by a pump whose suction hose is inserted through the top opening. Hoses used are made of Mipolam.

SODIUM PERMANGANATE

73. Quantity required per rocket = 11 litres (31 lb.)
Specific gravity = 1·26
Purity = 27 per cent. solution

74. This comes forward in sealed cans, each with a capacity of about two gallons. It is transferred into the rocket directly from one of these cans by the use of a tin funnel.