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THE EFFECT OF THE STEERING LOOP GAINS ON THE INTERCEPTION CAPABILITIES OF THE ARROW

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THE EFFECT OF THE STEERING LOOP GAINS ON THE INTERCEPTION CAPABILITIES OF THE ARROW

INTRODUCTION

This report extends the work of reference 1 on the gain of the steering loop of the Astra 1 fire control system in the Arrow when flying with an armament of Sparrow II missiles.

As stated therein, radome polarization errors appear to be causing instability in the automatic steering loop with the present gains. A reduction in the gains may be necessary to stabilize the system.

For the co-altitude attacks on which this study is based it is not necessary to simulate the steering loops in both roll and pitch channels. By assuming the interceptor holds the same height as the target the manoeuvre can be specified by the angle of bank alone. For this reason the simulation does not include the steering gain in the pitch plane.

In the Astra I system the gains of the two steering loops are chosen to give a level turn against a co-altitude target. Any variation or scheduling of the gain of the lateral steering loop in this simulation is thus assumed to be introduced similarly into the gain of the interceptor pitch steering loop in the actual system to preserve the same co-ordination.

In reference 1 attacks were made from tail, 90° beam, and head-on approach lanes against non-manoeuvring and weaving targets. Both aircraft started to manoeuvre at the initial positions shown in fig. 1, this assumes that the AI radar is locked-on at these ranges. The calculations were performed for a target Mach number of 1.2 and an interceptor Mach number of 1.5. Three gain systems were used, two constant values and one scheduled with range. In the present report a reduction to 2/3 of the original lock-on range, a target Mach number of 1.8 and an initial interceptor Mach number of 2.0 are also considered in combination with the earlier conditions. Altogether five constant values of the gain and three values scheduled with range are now used.

INTRODUCTION (Continued)

An attack is considered as successful if the interceptor is in the launch zone for Sparrow II missiles for a specified length of time, i.e. within the range limitations and the missile angular firing tolerance. A secondary consideration in evaluating the capability of a given gain system is the angular firing error at the mechanised firing time. At this time the interceptor is attempting to fly with zero firing error and this is the point at which the alternative armament of Genie rockets, with their smaller firing tolerance, is fired. Large values of 'g' at weapon release are also undesirable and provide a further basis for comparison of gain systems.

The probabilities of placement for successful conversion and the weighted mean values of firing error and normal acceleration are computed for each approach lane, assuming the midcourse guidance gives no heading errors. Weighting and combining these quantities s for several initial speeds, ranges and headings, as detailed in Table 1, overall values are then obtained.

The results of this study show that a constant azimuth gain of approximately .004 rad.sec./ft. gives the optimum values of overall conversion probability. The work on the scheduled gains suggests that it may be possible to use a smaller gain at longer ranges with virtually no loss of conversion probability, although a reduction to less than .003 at any point is not considered desirable.

METHOD

A digital computer program has been written for the I.B.M. 704 computer to simulate co-altitude lead collision attacks. The assumption is made that the interceptor always makes co-ordinated level turns and keeps the same height as the target, so that either the rolling or the pitching motion completely specifies the manoeuvre at any time. Assuming instantaneous response, the angle of bank demand, $\phi_D = \sin^{-1}\left[G_A . \frac{M_A}{T}\right]$, is taken to define the manoeuvre. In the above expression G_A is the gain of the azimuth steering loop, M_A is the calculated weapon miss distance in azimuth and T is the time-to-go to weapon impact. The simulation of this expression is further explained in reference 1. The azimuth and elevation planes are those normal to the gimbal axes of the Astra I seeker head.

The lead collision course is mechanised for release of Sparrow II missiles at 6 seconds to go to impact. Both aircraft are at 50,000 feet. An increase of 3 db in the gain at 20 seconds to go, presently included in the Astra I system, is not included in the simulation. The interceptor is always limited to a maximum speed equal to that at the start of the attack, the target being assumed to keep constant speed and altitude during any manoeuvre.

The Arrow performance data is taken from references 3 and 4.

ANALYSIS

A statistical analysis of the work is introduced in this report. It is assumed that the midcourse guidance gives a normal distribution of placement errors across a lane perpendicular to the direction of motion of the interceptor relative to the target, standard deviations of 3 and 6 nautical miles being considered. No heading errors are introduced. A specified time in the missile launch zone is taken as the criterion for the success of a conversion attempt; values of two and three seconds are used. For each region of an approach lane from which an attack is successful, the probability of placement in this region by the midcourse guidance gives a contribution to the conversion probability for that lane. Summing for all such regions gives the conversion probability for the lane.

Weighted mean values across each approach lane are computed for the missile firing error and the interceptor normal acceleration at the mechanised firing time. The weightings chosen are proportional to the probability of placement by the midcourse guidance at each position considered on the approach lane, only a standard deviation of 3 n.m. being used here. Where the attack fails over part of a lane due to interceptor "fall back" and cannot be continued to the mechanised firing time, a modified procedure is adopted. In this case, for initial placement regions from which no "fall back" occurs and the mechanised firing point is reached, the weightings from the normal probability distribution are increased pro rata to give a total probability of 100% placement to these regions.

The conversion probabilities and the mean firing errors and normal accelerations from each lane have been further weighted according to Table 1 to give overall values for the evaluation of the gain systems used. These weightings represent estimates of the relative likelihood of occurence of various initial conditions and their importance in choosing the gain system. The era of Arrow operation will obviously affect the weightings used, from considerations of expected target speeds and altitudes and the present Arrow speed limitation on the lowering of the missiles. Four weightings were therefore considered. Since the Arrow is vectored by the midcourse guidance for head-on and beam attacks, only a small weighting is given to the approaches made initially from the tail, to cover the use of this approach for re-attack.

In some cases, due to "fall back", there are no values for the firing error and normal acceleration for any part of the approach lane, e.g. no attack is possible when a Mach 1.8 target weaves away from a beam attack by a Mach 1.5 interceptor. Wherever this occurs the weightings of the contributions to the overall values of these quantities from the other approach lanes are increased pro rata so that the overall weightings for those values which exist total 100%.

ANALYSIS (Continued)

For evading targets the manoeuvre used throughout is a weave of alternate 90° turns to port and starboard at 1.5 'g', only the initial direction of turn being varied. The result is a variation in heading between ± 45° about a track at 45° to the original heading. Both "mean" and "minimum" conversion probabilities are evaluated against evading targets for each approach lane and also for the overall weighted results.

In estimating "mean" probabilities it is assumed that the target does not know the best evasive manoeuvre for the particular conditions and is therefore equally likely to turn initially towards or away from the interceptor. For "minimum" probabilities the target performs the evasive manoeuvre which allows the interceptor the smallest time in the missile launch zone. The minimum conversion probability derived in this way gives the probability of successful attack regardless of the initial direction of the target evasive manoeuvre.

For head-on and tail approaches a target weave to port represents a turn towards the interceptor for all cases on one side of the ideal approach, and a turn away for all cases on the other side. Thus the conversion probability for a symmetric lane is based on an equal proportion of targets turning away from and towards the interceptor and represents the mean conversion probability against a weaving target as defined above. By reversing the curves of time in the missile launch zone about the ideal approach lane we find the success regions against a target weaving to starboard. The minimum conversion probability against a manoeuvring target is then given by the total probability of placement by the midcourse guidance in success regions common to both initial directions of target manoeuvre.

For the port beam approach it is necessary to consider attacks from both sides of the ideal course (defined against a non-manoeuvring target) against both port and starboard weaving targets, since the same symmetry does not exist as for the head-on and tail approaches. The mean probability is now the mean of the conversion probabilities against port and starboard weaves. The minimum probability is again the probability of placement in success regions common to both target manoeuvres.

No values for mean normal acceleration and mean firing error are quoted for any of the cases where the target makes the best evasive manoeuvre. This is because the lanes from which successful attacks are possible in these cases are composed of some sectors in which the target turns towards the interceptor and others in which it turns away. To obtain mean values of normal acceleration and firing error therefore involves evaluating these quantities across the compound lanes. Except by use of very time-consuming graphical methods, it is not possible to give proper weight to the contributions for each of the manoeuvres, and this analysis has therefore been omitted.

RESULTS

In reference 1 attacks were made from tail, 90° port beam and head-on approach lanes against non-manoeuvring targets and targets which weaved to port. The initial conditions used were one set of ranges at which the aircraft manoeuvres commence (AI lock-on is assumed to have occurred at these ranges which are shown in fig. 1), with a target Mach number of 1.2 and an interceptor Mach number of 1.5. Three gains were used, the present value of .006, one quarter of this, .0015, and a gain scheduled with range, $.00036 + \frac{367}{R}$, with a limit of .012 and not .006 as stated in reference 1.

In the present report attacks are made from the same course differences or approach lanes against targets performing the same manoeuvres as before, with a target weave to starboard, i.e. away from the port beam attack, considered also. With the same aircraft speeds as before initial ranges equal to 2/3 those shown in fig. 1 are used. Both Mach 1.5 and Mach 2.0 interceptors are also considered against a Mach 1.8 target with the original initial ranges of fig. 1. The .006 and .0015 gains are again used. Three further constant values of the gain are considered against manoeuvring targets only, since the effect of gain is not so marked against non-manoeuvring targets. These are .0006, .003 and .012. Three gains scheduled with range are now used against both non-manoeuvring and evading targets, $.00036 + \frac{367}{R}$ with a limit of .012, $.00036 + \frac{367}{R}$ with a limit of .006, and $.0018 + \frac{183}{R}$ with a limit of .003. Fig. 13 plots these schedules to show the equivalent gain at any range. The total number of gain systems used in the present report is therefore eight.

Fig. 1 shows the initial attack positions considered in each approach lane for the full ranges used in reference 1. When considering attacks initiated at 2/3 of these ranges, 2/3 of the lane width and attack spacing has also been used. For this reason, no conversion probabilities have been quoted for a placement standard deviation of 6 n.m. where the attack was made from the 2/3 reduced range. For the same reason the overall results which include the reduced range cases, Tables 13 and 15, are not computed for $\sigma = 6$ n.m.

Figs. 2-12 are plots of the time in the missile launch zone against placement offset on the approach lane from which the success domains, and therefore the conversion probabilities, have been derived. Each figure shows attacks from one approach lane for one set of initial speeds and ranges, and covers all gain systems and target manoeuvres.

It may be seen that large and sudden variations of the time in the missile launch zone occur for small displacements across the approach lane against manoeuvring targets. A small displacement in the initial position of the interceptor will result in a significant difference in its path after flying against a manoeuvring target for some time under automatic steering. The time taken to fly to the missile launch zone will similarly vary and the target will have a different position and heading at missile launch, possibly having changed its direction of turn.

RESULTS (Continued)

Fig. 13, as already stated, shows the range variation of the scheduled gains considered.

Table 1 gives the weightings used in producing the tables of overall values of conversion probability, firing error and normal acceleration from the values for the various initial conditions. The first two weightings represent a fairly early era of Arrow operation and the expectation of a Mach 1.5 interceptor against a Mach 1.2 target is taken to be 70% for weighting 1 and 50% for weighting 2. Weightings 3 and 4 represent much less favourable conditions, in that both consider an 80% expectation of a Mach 1.8 target. Weightings 2 and 4 do not contain the cases with reduced range at lock-on. The restriction on the lane width explained above does not apply in this instance and overall probabilities for $\sigma = 6$ n.m. are derived for these two weightings. Table 1 also serves as an index to Tables and Figs. 2 to 12.

Each of the Tables 2 to 12 covers attacks from one approach lane for one set of initial speeds and ranges. The probabilities of successful conversion for each gain system and target manoeuvre are quoted for the two standard deviations of placement error and the two values for the time required in the missile launch zone. For each approach lane the weighted means of the firing errors and normal accelerations at the mechanized firing time are also quoted for each gain system and target manoeuvre, taking $\sigma = 3$ n.m.

Tables 13-16 present overall weighted values of conversion probability, firing error and normal acceleration for each gain, derived from Tables 2 to 12 using the weightings of Table 1.

Some of the results of Tables 13-16 are plotted in Figs. 14-16 for $\sigma = 3$ n.m. only. Fig. 14 shows the variation of the "mean" and "minimum" weighted conversion probabilities with gain for single-valued gain systems and manoeuvring targets, where the criterion for successful attack is two seconds in the missile launch zone. Fig. 15 shows the same conversion probabilities where three seconds is required. For the "mean" target manoeuvre only, Fig. 16 plots the overall means of the firing error and the normal acceleration for the single-valued gain systems.

DISCUSSION OF RESULTS

(i) Conversion Probability

For non-manoeuvring targets Tables 13-16 show that the conversion probabilities are generally high and little effect of gain may be noted for weightings 1 and 2. However for weightings 3 and 4 the constant gain of .0015 is better than either the gain of .0060 or the scheduled gains. This effect is produced entirely by the results of the beam attack on a speed superior target, i.e. a Mach 1.5 interceptor against a Mach 1.8 target, Table 12.

(i) Conversion Probability (Cont'd)

For evading targets, Figs. 14 and 15 both show that for constant gains the overall conversion probability increases as the value of the gain is reduced from .012. A maximum value is achieved between .0025 and .0045 and the probability then falls off very rapidly for further reductions in the gain.

It is clear that an increase in the time required in the missile launch zone for successful attack will cause some reduction in the conversion probability. Quite often, particularly where the conversion probability is high, the success domain may only be altered at large distances from the ideal course, where the probability of placement by the midcourse guidance is small. In such cases the variation in time in the launch zone has no apparent effect on the conversion probability.

In reference 2, it is shown that three seconds in the missile launch zone are required for firing a salvo of missiles. Figs. 14 and 15 show that only for a gain of .003 is the conversion probability appreciably reduced when three instead of two seconds are required, with weightings 3 and 4 showing larger reductions than weightings 1 and 2. Fig. 16 shows that for this gain the mean firing errors are of order 8 degrees for weightings 1 and 2 and 11 degrees for weightings 3 and 4. Since the missile angular firing tolerance is 11 degrees it is clear that whilst flying within the missile launch range limits the firing error is within the tolerance in many cases for only a short time. The conversion capability is therefore expected to be sensitive to the time required in the launch zone for this gain. Fig. 16 shows that a small increase in gain above the value of .003 results in a rapid fall in the firing errors, thereby eliminating this effect, as may be seen in figs. 14 and 15.

The conversion probabilities for three gains scheduled with range are given in Tables 13-16. Tables 14 and 16 show that for an increase in the standard deviation of the GCI placement errors from 3 to 6 n.m. the schedules show a much smaller loss in conversion probability than the constant gains. This however is not thought to be important as the GCI system is expected to achieve better accuracy than $\sigma = 6$ n.m.

The overall conversion probabilities for the schedule of $.00018 + \frac{183}{R}$ with a limit of .003 are seen to be quite inadequate. The schedule of $.00036 + \frac{367}{R}$ with a limit of .006 is as good as the constant gain of .006 except for weighting 1 which shows a small reduction in probability. The schedule of $.00036 + \frac{367}{R}$ with a limit of .012 represents a considerable improvement over the constant gain of .012 at all times against manoeuvring targets.

(ii) Firing Error and Normal Acceleration

A secondary consideration in evaluating the gain is the tactical capability of the aircraft when carrying Genie rockets, which have a much smaller firing tolerance than Sparrow. This tolerance is understood to be of order 1 degree. The overall mean firing errors given in Tables 13-16 are such as to make the use of an unguided rocket appear totally unacceptable, with any gain system. Fig. 16, for manoeuvring targets only, shows that with a

(ii) Firing Error and Normal Acceleration (Cont'd)

constant gain system the errors decrease monotonically with increasing gain. Stability studies have shown that the gain must always be less than .006 and may be limited to .004 even at short range. The overall firing errors lie in the range 3° to 4.5° for a gain of .006, and 5° to 7.5° for a gain of .004. The minimum value is seen to be always considerably greater than 1 degree. However, the higher speed of Genie means that, when released at 6 seconds-to-go (the time of flight mechanized for Sparrow in these calculations) it travels approximately twice the distance that the missile would travel. It may be shown from the form of the mechanization that the effect of this higher weapon speed is to reduce the firing errors. The results of fig. 16 must therefore be considered as qualitative only with regard to Genie. Nevertheless they cast some doubt on the ability of the Astra I system to complete successful attacks with Genie when operating in the automatic mode.

The firing errors for the constant gains and the gains scheduled with range may be compared from Tables 13-16 and fig. 16. These show that, for the schedules with limits of .006 and .003, the overall mean firing errors are virtually the same as those for constant gains set to the limiting values.

The overall mean values of normal acceleration at the mechanized firing point plotted in fig. 16 are thought to represent an acceptable level of 'g' for weapon release for all gains and flight conditions.

CONCLUSIONS

The conclusions of reference 1 with regard to the constant gain of .0015 are not confirmed by the work of considerably increased scope presented here. For a constant gain system against a manoeuvring target, fig. 15 shows that the peak values of conversion probability with Sparrow armament occur for gains between .0032 and .0045 for all weightings considered. A gain chosen from the band .0040 to .0045 gives conversion probabilities very close to the optima for all conditions.

The results for the non-manoeuvring speed superior target, Table 12, showing high conversion probability for the gain of .0015, are not considered here since this gain is unacceptable against a manoeuvring target and the recommended gain should give good capability for these conditions.

An increase in the recommended gain would be expected if interceptor response and computer lags were included in the study. A digital computer programme for three dimensional Astra I simulation, including an approximation for the system response, will soon be available, and a check of the present conclusions with this program and/or analogue computer studies may be desirable.

In addition to the factors included in the present study, noise and stability considerations will cause a reduction in capability of the system as the gain increases. Hence larger gains than .004, plus an allowance for the system lags, should not be used.

CONCLUSIONS (Cont'd)

By comparing figs. 14 and 15 with fig. 16 it will be observed that there is a rapid increase in the mean firing error corresponding to the rapid fall in conversion probability as the gain is reduced below the optimum value. In fact it has been shown that there is reason to expect some correlation between these quantities.

The results for the scheduled gains may be interpreted as showing that if the gain is increased up to a limit value as range decreases, the resulting conversion probability corresponds to a fixed gain whose value is less than the limit of the schedule. In general there is little change in the firing error from the value corresponding to the limiting gain. However, the schedules studied lie either wholly in the region of rapidly decreasing conversion probability or almost entirely above this region, and it is not possible to draw any definite conclusions concerning the suitability of schedules limited by the recommended constant gain. Nevertheless it appears probable that if it is necessary to introduce a schedule, the gain should not be allowed to fall below .003 at any range.

This study has given direct consideration only to Sparrow 2 armament and the results can only give qualitative indications of the performance with Genie. However, the magnitude of the firing errors obtained suggests that they may be unacceptably large for launch of this weapon. It is therefore considered that further study of the Astra I mechanisation will be necessary if carriage of Genie becomes an operational requirement.

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3. CF-105 Periodic Performance Report No. 9. Avro Report P/PERF/122.Dec. 1956.

4. CF-105 Longitudinal Control with L.E. Droop, Notch and Extension.Avro Report P/CONTROL/78. July 1955.

TABLE 1

WEIGHTINGS USED IN EVALUATING OVERALL VALUES OF CONVERSION PROBABILITY, NORMAL ACCELERATION AND FIRING ERROR.

Table and Figure No.		2	3	4	5	6	7	8	9	10	11	12
Initial (lock-on) range		Fig. 1 values			2/3 x Fig. 1 values			Fig. 1 values			Fig. 1 values	
Initial speeds	M_I	1.5			1.5			2.0			1.5	
	M_T	1.2			1.2			1.8			1.8	
Course difference (degrees) and lane of attack		0 Tail	180 Head-on	90 Beam	0 Tail	180 Head-on	90 Beam	0 Tail	180 Head-on	90 Beam	180 Head-on	90 Beam
Weighting of lanes (%)		10	50	40	10	50	40	10	50	40	50	50
Weighting 1 for initial conditions (%)		35			35			20			10	
Overall Weighting 1 (%)		3.5	17.5	14	3.5	17.5	14	2	10	8	5	5
Weighting 2 for initial conditions (%)		50			0			35			15	
Overall Weighting 2 (%)		5	25	20	0	0	0	3.5	17.5	14	7.5	7.5
Weighting 3 for initial conditions (%)		10			10			40			40	
Overall Weighting 3 (%)		1	5	4	1	5	4	4	20	16	20	20
Weighting 4 for initial conditions (%)		20			0			40			40	
Overall Weighting 4 (%)		2	10	8	0	0	0	4	20	16	20	20

TABLE 2 TAIL ATTACK

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges as Fig.1.

AZIMUTH GAIN (RAD.SEC/FT)	CONVERSION PROBABILITIES (%)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE	2	3	2	3		
STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	3	3	6	6	3	3
NO TARGET MANOEUVRE						
.0015	100	100	100	100	0.0	1.00
ORIGINAL VALUE .0060	100	100	100	100	0.0	1.00
.00036 + 367/R,LIMIT.0060	100	100	100	100	0.0	1.00
.00018 + 183/R,LIMIT.0030	100	100	100	100	0.0	1.00
.00036 + 367/R,LIMIT.0120	100	100	100	100	0.0	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS, i.e. MEAN TARGET MANOEUVRE						
.0006	100	100	100	100	11.8	1.06
.0015	100	100	100	100	10.6	1.61
.0030	100	100	100	100	5.6	1.37
ORIGINAL VALUE .0060	100	100	100	100	3.0	1.30
.0120	100	100	100	98	1.0	1.14
.00036 + 367/R,LIMIT.0060	100	100	100	100	2.9	1.31
.00018 + 183/R,LIMIT.0030	100	100	100	100	6.6	1.41
.00036 + 367/R,LIMIT.0120	100	100	100	100	1.3	1.18
BEST TARGET EVASIVE MANOEUVRE, i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET						
.0006	100	100	100	100		
.0015	100	100	100	100		
.0030	100	100	100	100		
ORIGINAL VALUE .0060	100	100	100	100		
.0120	100	99	100	95		
.00036 + 367/R,LIMIT.0060	100	100	100	100		
.00018 + 183/R,LIMIT.0030	100	100	100	100		
.00036 + 367/R,LIMIT.0120	100	100	100	100		

TABLE 3 HEAD-ON ATTACK

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges as Fig.1.

AZIMUTH GAIN (RAD.SEC/FT)	SECONDS IN THE MISSILE LAUNCH ZONE / STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M)	CONVERSION PROBABILITIES (°/o)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
	Seconds in launch zone	2	3	2	3		
	Standard deviation	3	3	6	6	3	3
NO TARGET MANOEUVRE							
	.0015	100	100	100	100	3.0	1.04
ORIGINAL VALUE	.0060	100	100	100	100	1.0	1.00
.00036 + 367/R, LIMIT	.0060	100	100	100	100	0.5	1.00
.00018 + 183/R, LIMIT	.0030	100	100	100	100	0.6	1.01
.00036 + 367/R, LIMIT	.0120	100	100	100	100	1.2	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS, i.e. MEAN TARGET MANOEUVRE							
	.0006	0	0	5	4	46.7	1.91
	.0015	100	100	100	100	6.0	1.05
	.0030	100	94	100	94	5.7	1.30
ORIGINAL VALUE	.0060	100	100	94	84	1.8	1.42
	.0120	100	99	94	84	0.0	1.26
.00036 + 367/R, LIMIT	.0060	100	100	100	100	2.5	1.43
.00018 + 183/R, LIMIT	.0030	100	97	100	88	6.6	1.25
.00036 + 367/R, LIMIT	.0120	100	100	100	100	1.0	1.26
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET							
	.0006	0	0	0	0		
	.0015	100	100	100	100		
	.0030	100	89	100	88		
ORIGINAL VALUE	.0060	100	100	88	67		
	.0120	99	98	88	68		
.00036 + 367/R, LIMIT	.0060	100	100	100	100		
.00018 + 183/R, LIMIT	.0030	100	93	100	75		
.00036 + 367/R, LIMIT	.0120	100	100	100	100		

TABLE 4 ATTACK FROM PORT BEAM

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Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2
Manoeuvre is Alternate 90° Turns at 1[illegible]
Initial Ranges as Fig.1.

SECONDS IN THE MISSILE LAUNCH ZONE → / AZIMUTH GAIN (RAD.SEC/FT.) ↓	CONVERSION PROBABILITIES (°/o) 2	3	2	3	MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	3	3	6	6	3	3
NO TARGET MANOEUVRE						
.0015	100	100	100	100	1.7	1.02
ORIGINAL VALUE .0060	100	100	100	100	1.0	1.00
.00036 + 367/R,LIMIT.0060	100	100	100	100	0.0	1.00
.00018 + 183/R,LIMIT.0030	100	100	100	100	0.5	1.00
.00036 + 367/R,LIMIT.0120	100	100	100	100	0.6	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS						
.0006	0	0	0	0	54.8	3.10
.0015	100	100	100	100	11.7	1.26
.0030	100	100	100	100	3.3	1.25
ORIGINAL VALUE .0060	100	100	100	100	1.5	1.43
.0120	100	100	100	100	1.0	1.14
.00036 + 367/R,LIMIT.0060	100	100	100	100	1.0	1.07
.00018 + 183/R,LIMIT.0030	100	100	100	100	2.9	1.26
.00036 + 367/R,LIMIT.0120	100	100	100	100	1.3	1.25
TARGET WEAVES TO STARBOARD FOR ALL ATTACKS						
.0006	98	96	84	82	6.9	1.02
.0015	100	100	100	100	12.1	1.05
.0030	100	100	100	100	1.3	1.32
ORIGINAL VALUE .0060	100	100	100	100	1.1	1.07
.0120	100	77	100	88	1.0	1.13
.00036 + 367/R,LIMIT.0060	100	100	100	100	1.7	1.43
.00018 + 183/R,LIMIT.0030	100	100	100	100	1.5	1.03
.00036 + 367/R,LIMIT.0120	100	100	100	100	1.0	1.06
MEAN TARGET MANOEUVRE						
.0006	49	48	42	41	30.8	2.06
.0015	100	100	100	100	11.9	1.16
.0030	100	100	100	100	2.3	1.29
ORIGINAL VALUE .0060	100	100	100	100	1.3	1.25
.0120	100	89	100	94	1.0	1.14
.00036 + 367/R,LIMIT.0060	100	100	100	100	1.4	1.25
.00018 + 183/R,LIMIT.0030	100	100	100	100	2.2	1.15
.00036 + 367/R,LIMIT.0120	100	100	100	100	1.2	1.16
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET						
.0006	0	0	0	0		
.0015	100	100	100	100		
.0030	100	100	100	100		
ORIGINAL VALUE .0060	100	100	100	100		
.0120	100	77	100	88		
.00036 + 367/R,LIMIT.0060	100	100	100	100		
.00018 + 183/R,LIMIT.0030	100	100	100	100		
.00036 + 367/R,LIMIT.0120	100	100	100	100		

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TABLE 5 TAIL ATTACK

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges = $^{2}/_{3}$ x Fig.1. Values

AZIMUTH GAIN (RAD.SEC/FT)		CONVERSION PROBABILITY (°/o)		MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE		2	3		
STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)		3	3	3	3
NO TARGET MANOEUVRE					
	.0015	100	100	0.0	1.00
ORIGINAL VALUE	.0060	100	100	0.0	1.00
.00036 + $^{367}/_{R}$,LIMIT	.0060	100	100	0.0	1.00
.00018 + $^{183}/_{R}$,LIMIT	.0030	100	100	0.0	1.00
.00036 + $^{367}/_{R}$,LIMIT	.0120	100	100	0.0	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS i.e. MEAN TARGET MANOEUVRE					
	.0006	97	94	6.8	1.08
	.0015	100	100	15.4	1.20
	.0030	100	100	4.9	1.20
ORIGINAL VALUE	.0060	100	100	2.7	1.40
	.0120	100	100	1.0	1.21
.00036 + $^{367}/_{R}$,LIMIT	.0060	100	100	2.5	1.39
.00018 + $^{183}/_{R}$,LIMIT	.0030	100	100	5.5	1.46
.00036 + $^{367}/_{R}$,LIMIT	.0120	100	100	1.0	1.23
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET					
	.0006	94	88		
	.0015	100	100		
	.0030	100	100		
ORIGINAL VALUE	.0060	100	100		
	.0120	100	100		
.00036 + $^{367}/_{R}$,LIMIT	.0060	100	100		
.00018 + $^{183}/_{R}$,LIMIT	.0030	100	100		
.00036 + $^{367}/_{R}$,LIMIT	.0120	100	100		

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TABLE 6 HEAD-ON ATTACK

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges = 2/3 x Fig. 1. Values

AZIMUTH GAIN (RAD.SEC/FT.)	STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	CONVERSION PROBABILITY (o/o)		MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE		2	3		
		3	3	3	3
NO TARGET MANOEUVRE					
	.0015	96	90	4.8	1.25
ORIGINAL VALUE	.0060	100	100	0.5	1.00
.00036 + 367/R,LIMIT	.0060	100	100	0.6	1.00
.00018 + 183/R,LIMIT	.0030	100	100	1.5	1.02
.00036 + 367/R,LIMIT	.0120	100	100	1.3	1.01
TARGET WEAVES TO PORT FOR ALL ATTACKS, i.e. MEAN TARGET MANOEUVRE					
	.0006	11	9	11.6	1.05
	.0015	11	9	19.9	1.80
	.0030	100	100	7.0	1.10
ORIGINAL VALUE	.0060	98	98	2.1	1.17
	.0120	92	85	2.0	1.10
.00036 + 367/R,LIMIT	.0060	96	92	1.7	1.18
.00018 + 183/R,LIMIT	.0030	99	99	6.0	1.40
.00036 + 367/R,LIMIT	.0120	99	99	1.5	1.13
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET					
	.0006	0	0		
	.0015	0	0		
	.0030	100	100		
ORIGINAL VALUE	.0060	97	97		
	.0120	83	79		
.00036 + 367/R,LIMIT	.0060	91	83		
.00018 + 183/R,LIMIT	.0030	99	98		
.00036 + 367/R,LIMIT	.0120	99	98		

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TABLE 7 ATTACK FROM PORT BEAM

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges = 2/3 x Fig.1. Values

AZIMUTH GAIN (RAD.SEC/FT)	STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	CONVERSION PROBABILITY (°/o)		MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE		2	3	3	3
		3	3	3	3
NO TARGET MANOEUVRE					
	.0015	100	100	3.3	1.05
ORIGINAL VALUE	.0060	100	100	0.5	1.00
.00036 + 367/R,LIMIT	.0060	100	100	0.0	1.00
.00018 + 183/R,LIMIT	.0030	100	100	0.5	1.00
.00036 + 367/R,LIMIT	.0120	100	100	0.0	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS					
	.0006	0	0	16.4	1.16
	.0015	0	0	25.0	2.50
	.0030	100	100	12.3	1.99
ORIGINAL VALUE	.0060	100	100	4.6	1.42
	.0120	100	100	2.0	1.19
.00036 + 367/R,LIMIT	.0060	100	100	4.7	1.42
.00018 + 183/R,LIMIT	.0030	100	100	12.4	2.01
.00036 + 367/R,LIMIT	.0120	100	100	6.0	1.20
TARGET WEAVES TO STARBOARD FOR ALL ATTACKS					
	.0006	84	83	7.1	1.07
	.0015	99	99	5.2	1.23
	.0030	95	85	4.7	1.30
ORIGINAL VALUE	.0060	100	100	2.6	1.17
	.0120	100	100	0.9	1.15
.00036 + 367/R,LIMIT	.0060	100	100	1.9	1.18
.00018 + 183/R,LIMIT	.0030	99	94	3.6	1.25
.00036 + 367/R,LIMIT	.0120	100	100	1.0	1.17
MEAN TARGET MANOEUVRE					
	.0006	42	42	11.8	1.12
	.0015	50	50	15.1	1.87
	.0030	98	84	8.5	1.65
ORIGINAL VALUE	.0060	100	100	3.6	1.29
	.0120	100	100	1.5	1.29
.00036 + 367/R,LIMIT	.0060	100	100	3.3	1.30
.00018 + 183/R,LIMIT	.0030	100	97	8.0	1.63
.00036 + 367/R,LIMIT	.0120	100	100	3.5	1.19
BEST TARGET EVASIVE MANOEUVRE, i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET					
	.0006	0	0		
	.0015	0	0		
	.0030	95	68		
ORIGINAL VALUE	.0060	100	100		
	.0120	100	100		
.00036 + 367/R,LIMIT	.0060	100	100		
.00018 + 183/R,LIMIT	.0030	99	94		
.00036 + 367/R,LIMIT	.0120	100	100		

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TABLE 8 TAIL ATTACK

Initial Interceptor Mach No. = 2.0
Target Mach No. = 1.8
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges as Fig.1.

AZIMUTH GAIN (RAD.SEC./FT.)	STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	CONVERSION PROBABILITY (°/o)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE		2	3	2	3		
		3	3	6	6	3	3
NO TARGET MANOEUVRE							
	.0015	100	100	100	100	0.0	1.00
ORIGINAL VALUE	.0060	100	100	100	100	0.0	1.00
.00036 + 367/R, LIMIT	.0060	100	100	100	100	0.0	1.00
.00018 + 183/R, LIMIT	.0030	100	100	100	100	0.0	1.00
.00036 + 367/R, LIMIT	.0120	100	100	100	100	0.0	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS, i.e. MEAN TARGET MANOEUVRE							
	.0006	14	12	18	18	2.3	1.30
	.0015	2	2	15	15	-	-
	.0030	100	100	100	95	11.1	1.30
ORIGINAL VALUE	.0060	100	100	100	100	3.0	1.47
	.0120	100	100	95	94	1.1	1.18
.00036 + 367/R, LIMIT	.0060	100	100	95	95	2.8	1.43
.00018 + 183/R, LIMIT	.0030	21	19	34	33	8.6	1.89
.00036 + 367/R, LIMIT	.0120	100	93	100	96	1.0	1.20
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET							
	.0006	0	0	0	0		
	.0015	0	0	0	0		
	.0030	100	100	100	90		
ORIGINAL VALUE	.0060	100	100	100	100		
	.0120	100	100	90	90		
.00036 + 367/R, LIMIT	.0060	100	100	90	90		
.00018 + 183/R, LIMIT	.0030	0	0	0	0		
.00036 + 367/R, LIMIT	.0120	100	86	100	91		

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TABLE 9 HEAD-ON ATTACK

Initial Interceptor Mach No. = 2.0
Target Mach No. = 1.8
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges as Fig.1.

AZIMUTH GAIN (RAD.SEC/FT.)		CONVERSION PROBABILITY (%)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE		2	3	2	3		
STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)		3	3	6	6	3	3
NO TARGET MANOEUVRE							
	.0015	97	90	72	59	7.4	1.28
ORIGINAL VALUE	.0060	100	100	100	100	2.5	1.00
.00036 + $^{367}/R$,LIMIT	.0060	100	100	100	100	1.3	1.00
.00018 + $^{183}/R$,LIMIT	.0030	100	100	100	100	1.7	1.05
.00036 + $^{367}/R$,LIMIT	.0120	100	100	100	100	1.6	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS i.e. MEAN TARGET MANOEUVRE							
	.0006	1	1	12	11	32.9	1.62
	.0015	20	18	41	36	29.6	2.45
	.0030	100	100	94	93	11.7	2.00
ORIGINAL VALUE	.0060	100	100	91	90	6.0	1.49
	.0120	99	99	78	78	5.0	1.21
.00036 + $^{367}/R$,LIMIT	.0060	100	100	92	91	5.8	1.46
.00018 + $^{183}/R$,LIMIT	.0030	99	99	89	89	11.1	2.15
.00036 + $^{367}/R$,LIMIT	.0120	100	100	92	91	4.9	1.23
BEST TARGET EVASIVE MANOEUVRE, i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET							
	.0006	0	0	0	0		
	.0015	0	0	15	0		
	.0030	100	100	87	86		
ORIGINAL VALUE	.0060	99	99	81	80		
	.0120	98	98	56	56		
.00036 + $^{367}/R$,LIMIT	.0060	99	99	84	82		
.00018 + $^{183}/R$,LIMIT	.0030	99	99	79	78		
.00036 + $^{367}/R$,LIMIT	.0120	99	99	83	81		

SECRET TABLE 10 ATTACK FROM PORT BEAM

Initial Interceptor Mach No. = 2.0
Target Mach No. = 1.8
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges as Fig.1.

	CONVERSION PROBABILITY (°/o)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE	2	3	2	3		
AZIMUTH GAIN (RAD.SEC/FT.) / STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	3	3	6	6	3	3
NO TARGET MANOEUVRE						
.0015	100	100	100	100	4.2	1.46
ORIGINAL VALUE .0060	100	100	97	97	1.7	1.00
$.00036 + 367/R$, LIMIT .0060	100	100	100	98	2.5	1.00
$.00018 + 183/R$, LIMIT .0030	96	95	81	79	2.1	1.01
$.00036 + 367/R$, LIMIT .0120	100	100	91	90	9.3	1.87
TARGET WEAVES TO PORT FOR ALL ATTACKS						
.0006	0	0	6	5	42.1	4.11
.0015	0	0	0	0	30.0	3.95
.0030	81	46	67	48	12.6	2.70
ORIGINAL VALUE .0060	100	100	100	100	4.4	1.64
.0120	100	100	100	100	1.8	1.23
$.00036 + 367/R$, LIMIT .0060	100	100	100	100	4.4	1.66
$.00018 + 183/R$, LIMIT .0030	15	11	30	27	13.7	2.86
$.00036 + 367/R$, LIMIT .0120	100	100	100	100	2.0	1.30
TARGET WEAVES TO STARBOARD FOR ALL ATTACKS						
.0006	39	37	44	43	15.6	1.13
.0015	7	6	23	22	1.7	1.10
.0030	100	43	94	62	4.8	1.33
ORIGINAL VALUE .0060	100	100	91	90	2.2	1.50
.0120	93	91	76	75	2.0	1.30
$.00036 + 367/R$, LIMIT .0060	100	98	98	82	1.4	1.31
$.00018 + 183/R$, LIMIT .0030	15	9	30	25	4.4	1.23
$.00036 + 367/R$, LIMIT .0120	100	100	95	94	1.0	1.21
MEAN TARGET MANOEUVRE						
.0006	20	19	25	24	28.9	2.62
.0015	4	3	12	11	15.9	2.53
.0030	91	45	81	55	8.7	2.15
ORIGINAL VALUE .0060	100	100	96	95	3.3	1.57
.0120	97	96	88	88	1.9	1.27
$.00036 + 367/R$, LIMIT .0060	100	99	99	91	2.9	1.48
$.00018 + 183/R$, LIMIT .0030	15	10	30	26	9.1	2.05
$.00036 + 367/R$, LIMIT .0120	100	100	98	97	1.5	1.26
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET						
.0006	0	0	0	0		
.0015	0	0	0	0		
.0030	81	29	67	32		
ORIGINAL VALUE .0060	100	100	91	90		
.0120	93	91	76	75		
$.00036 + 367/R$, LIMIT .0060	100	98	98	82		
$.00018 + 183/R$, LIMIT .0030	0	0	0	0		
$.00036 + 367/R$, LIMIT .0120	100	100	95	94		

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TABLE 11 HEAD-ON ATTACK

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.8
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges as Fig.1.

AZIMUTH GAIN (RAD.SEC/FT.)		CONVERSION PROBABILITY (°/o)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE		2	3	2	3		
STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)		3	3	6	6	3	3
NO TARGET MANOEUVRE							
	.0015	100	100	100	100	3.2	1.20
ORIGINAL VALUE	.0060	100	100	100	100	0.7	1.00
.00036 + 367/R,LIMIT	.0060	100	100	100	100	0.3	1.00
.00018 + 183/R,LIMIT	.0030	100	100	100	100	1.4	1.03
.00036 + 367/R,LIMIT	.0120	100	100	100	100	2.6	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS i.e. MEAN TARGET MANOEUVRE							
	.0006	0	0	0	0	29.5	1.32
	.0015	49	39	28	22	27.2	2.28
	.0030	89	78	67	65	14.6	2.17
ORIGINAL VALUE	.0060	43	41	47	46	6.5	1.39
	.0120	35	28	42	39	2.2	1.37
.00036 + 367/R,LIMIT	.0060	44	40	47	45	5.3	1.55
.00018 + 183/R,LIMIT	.0030	66	57	58	54	12.7	2.12
.00036 + 367/R,LIMIT	.0120	42	38	46	44	2.7	1.31
BEST TARGET EVASIVE MANOEUVRE, i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET							
	.0006	0	0	0	0		
	.0015	21	7	18	3		
	.0030	65	56	34	30		
ORIGINAL VALUE	.0060	0	0	0	0		
	.0120	0	0	0	0		
.00036 + 367/R,LIMIT	.0060	0	0	0	0		
.00018 + 183/R,LIMIT	.0030	33	14	17	7		
.00036 + 367/R,LIMIT	.0120	0	0	0	0		

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TABLE 12 ATTACK FROM PORT BEAM

Initial Interceptor Mach No = 1.5
Target Mach No. = 1.8
Manoeuvre is Alternate 90° Turns at 1.5 'g'
Initial Ranges as Fig.1.

AZIMUTH GAIN (RAD.SEC/FT.		CONVERSION PROBABILITIES (°/o)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE		2	3	2	3		
STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)		3	3	6	6	3	3
NO TARGET MANOEUVRE							
	.0015	90	89	74	73	4.0	1.05
ORIGINAL VALUE	.0060	63	56	57	53	0.7	1.00
.00036 + 367/R,LIMIT	.0060	46	43	48	46	0.2	1.00
.00018 + 183/R,LIMIT	.0030	46	43	43	41	1.6	1.01
.00036 + 367/R,LIMIT	.0120	46	43	48	42	0.8	1.00
TARGET WEAVES TO PORT FOR ALL ATTACKS							
	.0006	0	0	0	0	52.2	3.11
	.0015	0	0	0	0	35.0	3.05
	.0030	100	2	100	16	14.6	2.17
ORIGINAL VALUE	.0060	99	99	89	88	6.5	1.39
	.0120	100	100	100	100	4.1	1.15
.00036 + 367/R,LIMIT	.0060	100	100	100	100	6.2	1.41
.00018 + 183/R,LIMIT	.0030	0	0	1	0	14.9	1.17
.00036 + 367/R,LIMIT	.0120	100	100	100	100	4.3	1.17
TARGET WEAVES TO STARBOARD FOR ALL ATTACKS							
	.0006						
	.0015						
	.0030	INTERCEPTOR					
ORIGINAL VALUE	.0060	"FALLS BACK"					–
	.0120	– NO SUCCESS					
.00036 + 367/R,LIMIT	.0060						
.00018 + 183/R,LIMIT	.0030						
.00036 + 367/R,LIMIT	.0120						
MEAN TARGET MANOEUVRE							
	.0006	0	0	0	0		–
	.0015	0	0	0	0	–	–
	.0030	50	1	50	8		–
ORIGINAL VALUE	.0060	50	50	45	44		–
	.0120	50	50	50	50		–
.00036 + 367/R,LIMIT	.0060	50	50	50	50		–
.00018 + 183/R,LIMIT	.0030	0	0	1	0		–
.00036 + 367/R,LIMIT	.0120	50	50	50	50		–
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET							
	.0006						
	.0015						
	.0030	INTERCEPTOR					
ORIGINAL VALUE	.0060	"FALLS BACK"					
	.0120	– NO SUCCESS					
.00036 + 367/R,LIMIT	.0060						
.00018 + 183/R,LIMIT	.0030						
.00036 + 367/R,LIMIT	.0120						

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TABLE 13

OVERALL VALUES
WEIGHTING 1.

AZIMUTH GAIN (RAD.SEC/FT.)	STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	CONVERSION PROBABILITY (°/o)		MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE		2	3		
		3	3	3	3
NO TARGET MANOEUVRE					
	.0015	98	97	3.5	1.14
ORIGINAL VALUE	.0060	98	98	0.9	1.00
.00036 + 367/R, LIMIT	.0060	97	97	0.5	1.00
.00018 + 183/R, LIMIT	.0030	97	97	1.0	1.01
.00036 + 367/R, LIMIT	.0120	97	97	1.6	1.07
MEAN TARGET MANOEUVRE					
	.0006	23	23	26.5	1.66
	.0015	52	51	16.9	1.78
	.0030	96	88	7.5	1.52
ORIGINAL VALUE	.0060	94	94	3.1	1.35
	.0120	92	89	1.7	1.20
.00036 + 367/R, LIMIT	.0060	93	93	3.0	1.35
.00018 + 183/R, LIMIT	.0030	85	83	7.4	1.53
.00036 + 367/R, LIMIT	.0120	95	94	2.2	1.20
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET					
	.0006	7	7		
	.0015	44	42		
	.0030	91	83		
ORIGINAL VALUE	.0060	91	90		
	.0120	86	81		
.00036 + 367/R, LIMIT	.0060	87	86		
.00018 + 183/R, LIMIT	.0030	81	78		
.00036 + 367/R, LIMIT	.0120	90	89		

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TABLE 14

OVERALL VALUES
WEIGHTING 2.

AZIMUTH GAIN (RAD.SEC/FT.)	SECONDS IN THE MISSILE LAUNCH ZONE / STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	CONVERSION PROBABILITY (°/o)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
	SECONDS IN THE MISSILE LAUNCH ZONE	2	3	2	3		
	STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	3	3	6	6	3	3
NO TARGET MANOEUVRE							
	.0015	99	98	93	91	3.5	1.15
ORIGINAL VALUE	.0060	97	97	96	96	1.2	1.00
.00036 + 367/R, LIMIT	.0060	96	93	96	96	0.7	1.00
.00018 + 183/R, LIMIT	.0030	95	95	93	93	1.1	1.02
.00036 + 367/R, LIMIT	.0120	96	96	95	94	2.3	1.12
MEAN TARGET MANOEUVRE							
	.0006	18	18	20	18	34.4	1.97
	.0015	58	57	64	60	17.1	1.82
	.0030	93	83	88	81	7.8	1.65
ORIGINAL VALUE	.0060	92	92	88	85	3.3	1.42
	.0120	91	88	85	81	1.9	1.23
.00036 + 367/R, LIMIT	.0060	92	92	91	89	3.4	1.41
.00018 + 183/R, LIMIT	.0030	75	73	75	71	8.0	1.59
.00036 + 367/R, LIMIT	.0120	92	91	94	90	2.2	1.23
BEST TARGET EVASIVE MANOEUVRE i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET							
	.0006	5	5	5	5		
	.0015	52	51	54	50		
	.0030	87	76	81	72		
ORIGINAL VALUE	.0060	85	85	77	72		
	.0120	83	78	71	63		
.00036 + 367/R, LIMIT	.0060	85	85	82	79		
.00018 + 183/R, LIMIT	.0030	70	67	65	58		
.00036 + 367/R, LIMIT	.0120	85	84	81	81		

SECRET
UNCLASSIFIED

TABLE 15

OVERALL VALUES
WEIGHTING 3.

AZIMUTH GAIN (RAD.SEC/FT.)	SECONDS IN THE MISSILE LAUNCH ZONE / STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	CONVERSION PROBABILITY (°/o) 2	CONVERSION PROBABILITY (°/o) 3	MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
		3	3	3	3
NO TARGET MANOEUVRE					
	.0015	97	95	4.2	1.20
ORIGINAL VALUE	.0060	93	91	1.2	1.00
.00036 + 367/R, LIMIT	.0060	89	89	0.8	1.00
.00018 + 183/R, LIMIT	.0030	89	88	1.4	1.02
.00036 + 367/R, LIMIT	.0120	89	88	2.6	1.14
MEAN TARGET MANOEUVRE					
	.0006	10	10	32.4	1.98
	.0015	28	25	24.5	2.34
	.0030	85	67	10.8	1.88
ORIGINAL VALUE	.0060	78	78	4.5	1.45
	.0120	76	73	2.4	1.23
.00036 + 367/R, LIMIT	.0060	78	77	4.5	1.44
.00018 + 183/R, LIMIT	.0030	56	53	10.7	1.76
.00036 + 367/R, LIMIT	.0120	78	77	3.0	1.23
BEST TARGET EVASIVE MANOEUVRE, i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET					
	.0006	2	2		
	.0015	17	13		
	.0030	70	59		
ORIGINAL VALUE	.0060	60	60		
	.0120	58	56		
.00036 + 367/R, LIMIT	.0060	59	59		
.00018 + 183/R, LIMIT	.0030	46	42		
.00036 + 367/R, LIMIT	.0120	60	59		

TABLE 16

OVERALL VALUES
WEIGHTING 4

AZIMUTH GAIN (RAD.SEC/FT.) / SECONDS IN THE MISSILE LAUNCH ZONE / STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	CONVERSION PROBABILITY (°/o)				MEAN FIRING ERROR (DEGREES)	MEAN NORMAL ACCELERATION
SECONDS IN THE MISSILE LAUNCH ZONE	2	3	2	3		
STANDARD DEVIATION OF THE PLACEMENT ERROR (N.M.)	3	3	6	6	3	3
NO TARGET MANOEUVRE						
.0015	97	96	89	86	4.0	1.19
ORIGINAL VALUE .0060	93	91	91	90	1.2	1.00
.00036 + 367/R, LIMIT .0060	89	89	90	89	0.8	1.00
.00018 + 183/R, LIMIT .0030	89	88	86	85	1.3	1.02
.00036 + 367/R, LIMIT .0120	89	88	88	87	2.7	1.14
MEAN TARGET MANOEUVRE						
.0006	10	9	13	12	35.0	2.06
.0015	35	32	36	34	23.6	2.28
.0030	85	67	78	65	10.4	1.88
ORIGINAL VALUE .0060	79	78	76	73	4.4	1.46
.0120	76	74	71	69	2.7	1.24
.00036 + 367/R, LIMIT .0060	79	78	77	76	4.4	1.45
.00018 + 183/R, LIMIT .0030	56	53	56	53	10.5	1.74
.00036 + 367/R, LIMIT .0120	78	77	77	76	2.9	1.23
BEST TARGET EVASIVE MANOEUVRE, i.e. MINIMUM PROBABILITY AGAINST WEAVING TARGET						
.0006	2	2	2	2		
.0015	24	21	27	21		
.0030	70	59	59	51		
ORIGINAL VALUE .0060	60	60	54	51		
.0120	58	56	46	43		
.00036 + 367/R, LIMIT .0060	60	60	56	53		
.00018 + 183/R, LIMIT .0030	46	42	39	35		
.00036 + 367/R, LIMIT .0120	60	59	56	55		

INITIAL GEOMETRY WHEN BOTH AIRCRAFT START TO MANOEUVRE.

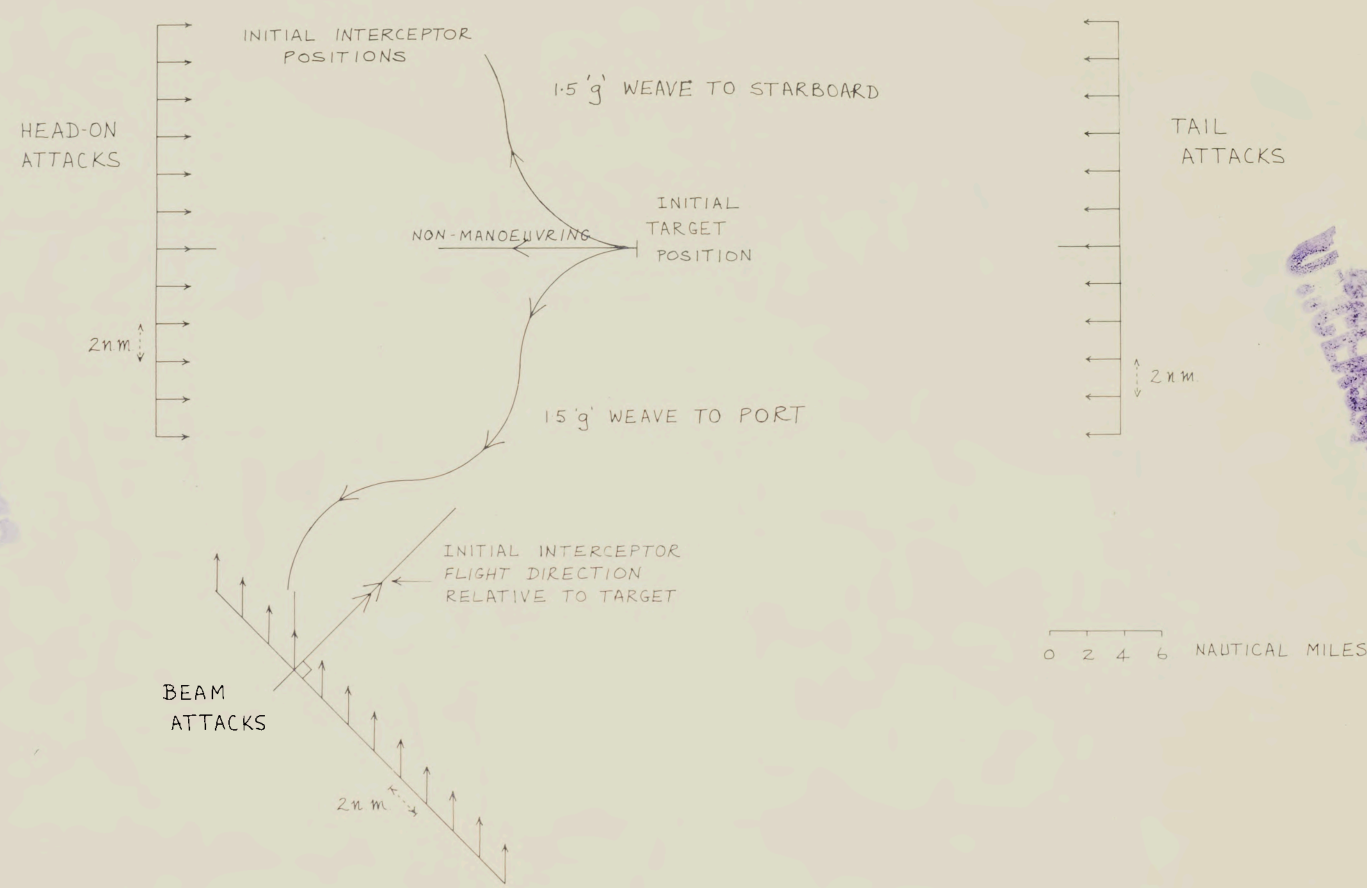
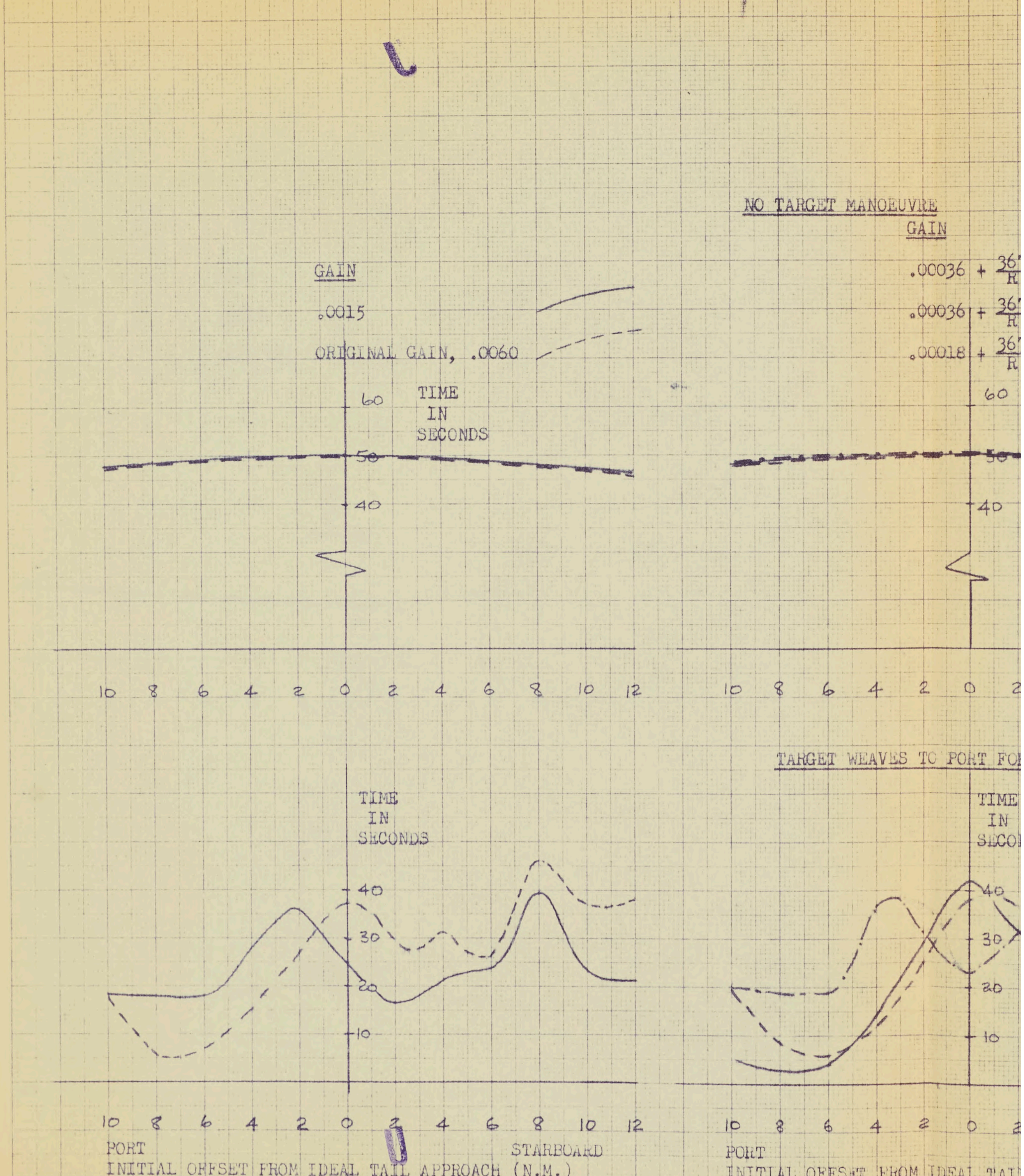


FIGURE 1

SECRET

TIME IN THE MISSILE LAUNCH Z



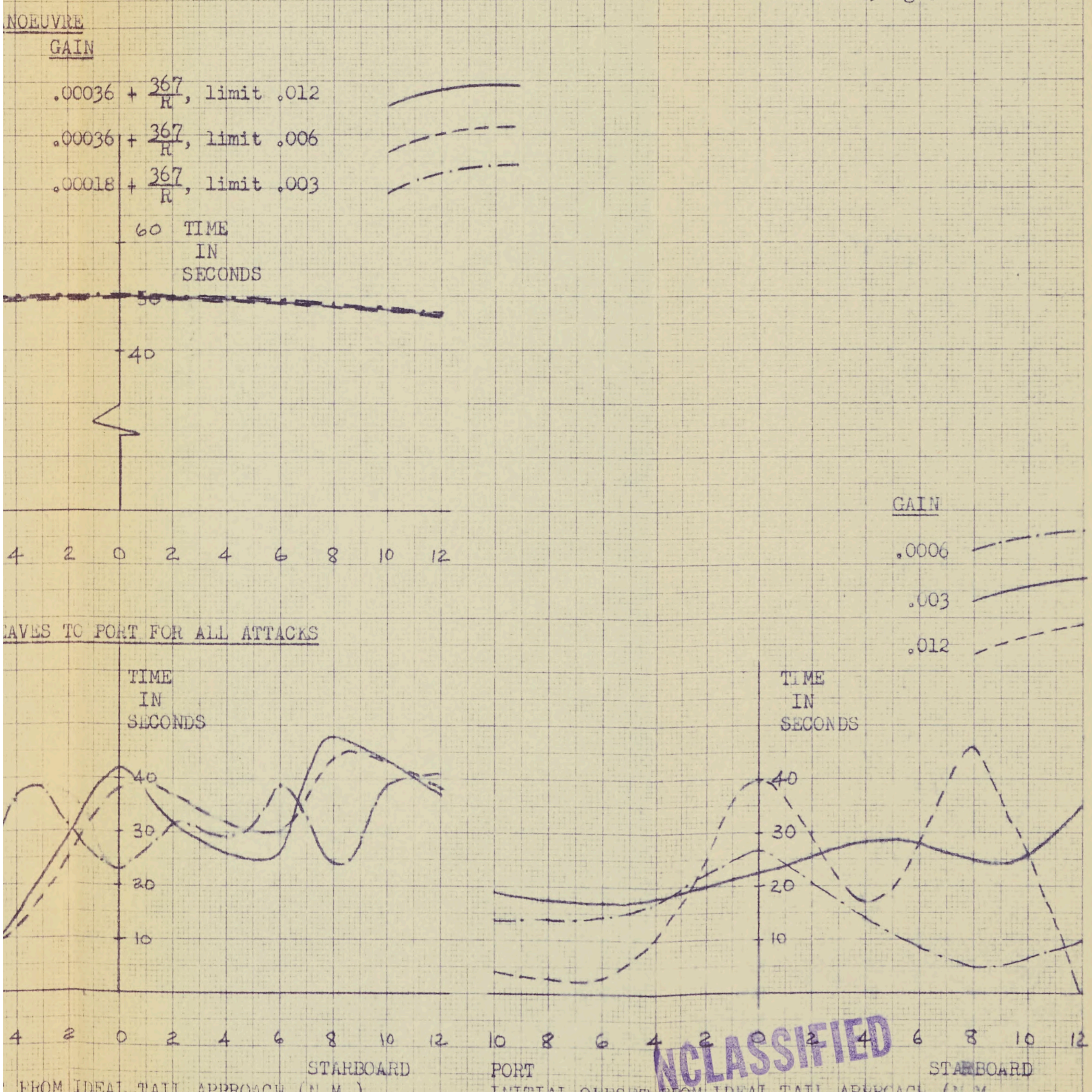
SECRET

...ISSILE LAUNCH ZONE VS INITIAL OFFSET

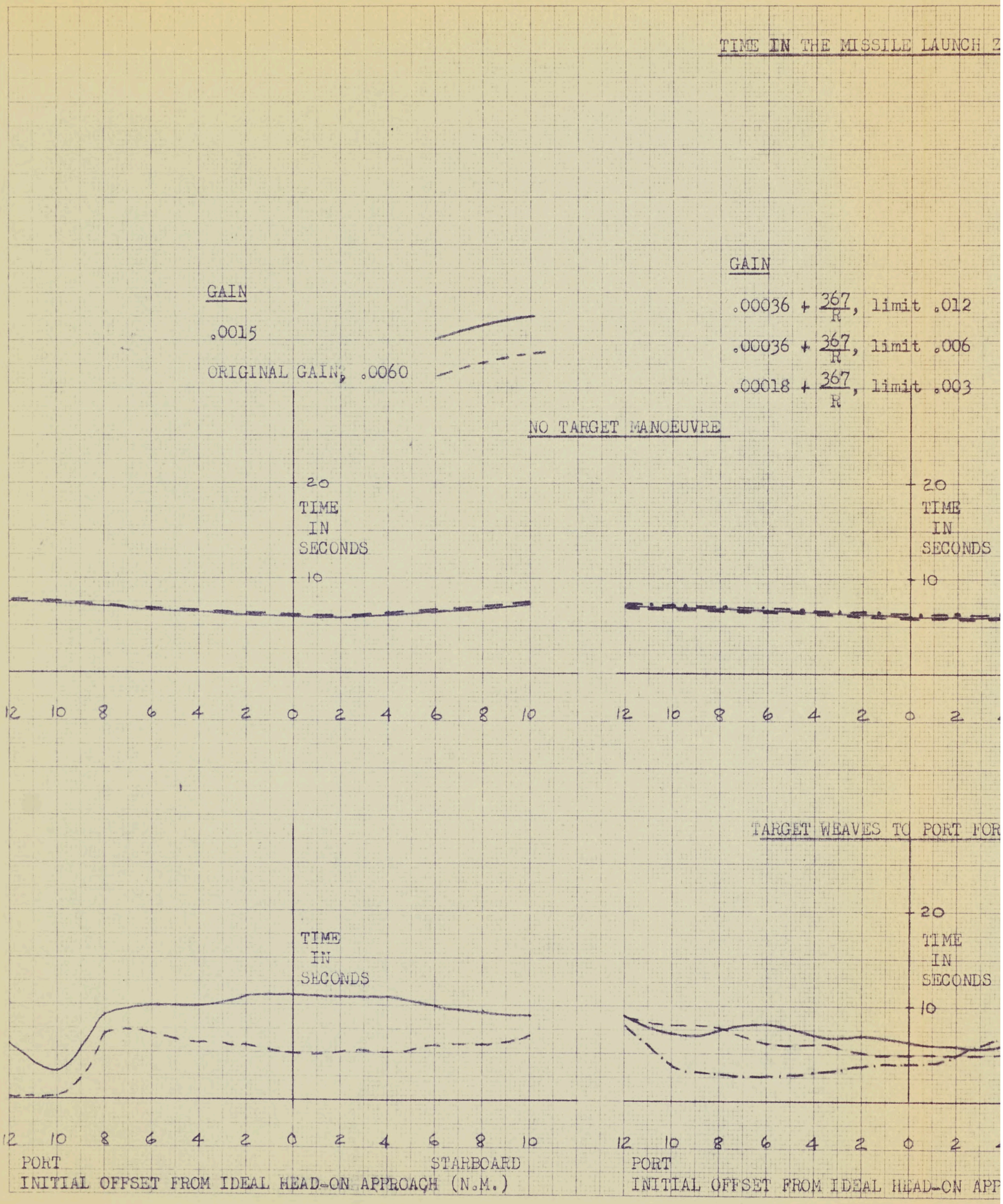
FIG. 2
...ATTACK

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2

Initial ranges as fig. 1
Manoeuvre is alternate 90° turns at 1.5 'g'.

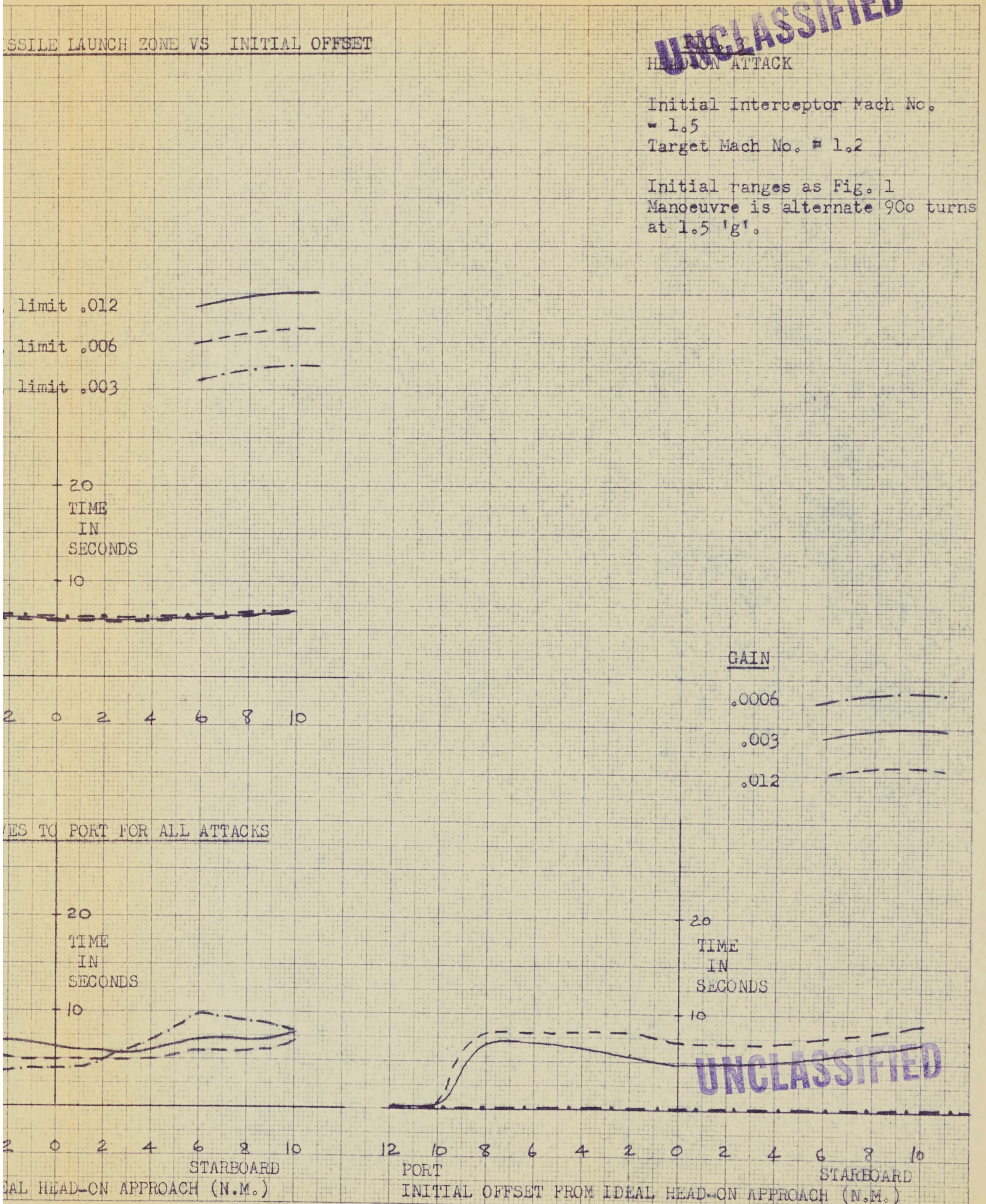


SECRET



SECRET

T

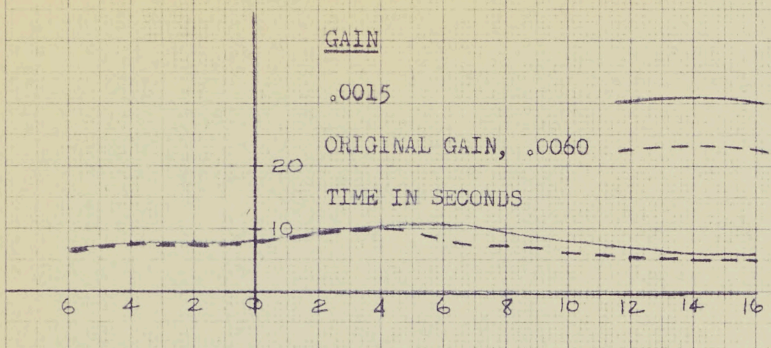


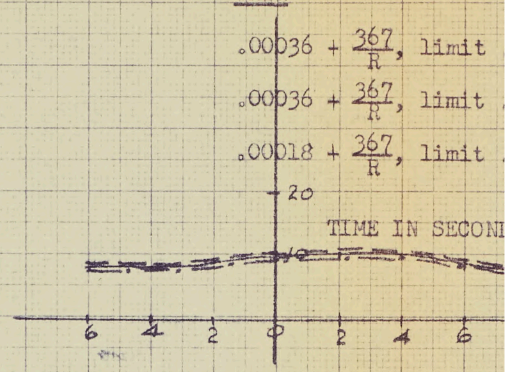
SSILE LAUNCH ZONE VS INITIAL OFFSET
HEAD-ON ATTACK
Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2
Initial ranges as Fig. 1
Manoeuvre is alternate 90o turns at 1.5 'g'.
limit .012
limit .006
limit .003
20
TIME IN SECONDS
10
2 0 2 4 6 8 10
GAIN
.0006
.003
.012
ES TO PORT FOR ALL ATTACKS
20
TIME IN SECONDS
10
2 0 2 4 6 8 10
STARBOARD
AL HEAD-ON APPROACH (N.M.)
20
TIME IN SECONDS
10
12 10 8 6 4 2 0 2 4 6 8 10
PORT
STARBOARD
INITIAL OFFSET FROM IDEAL HEAD-ON APPROACH (N.M.)

ET

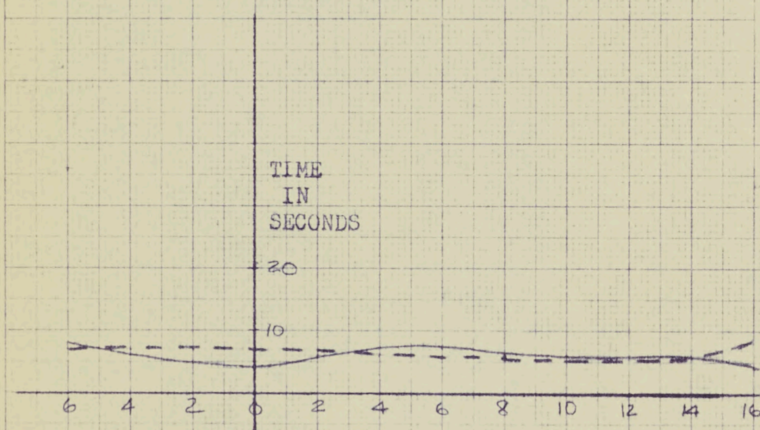
TIME IN THE MISSILE LAUNCH

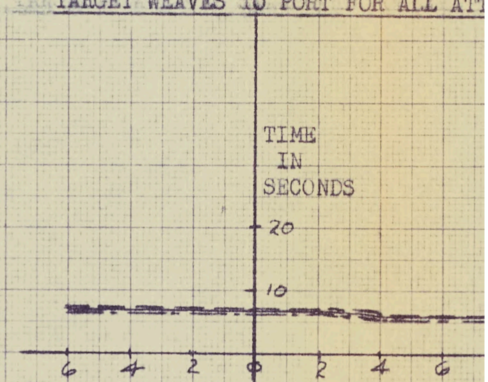
NO TARGET MANOEUVRE



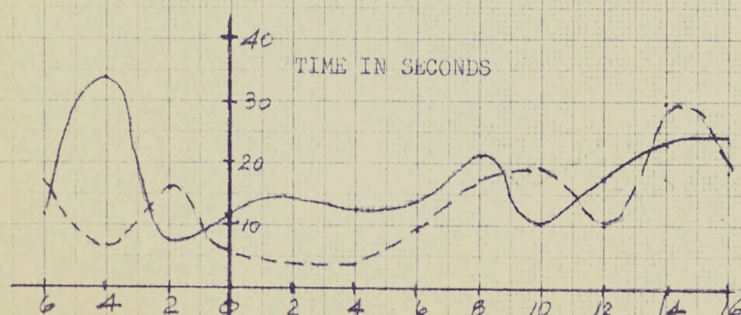


TARGET WEAVES TO PORT FOR ALL ATT

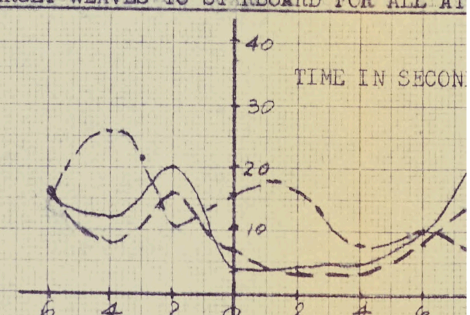




TARGET WEAVES TO ST RBOARD FOR ALL AT

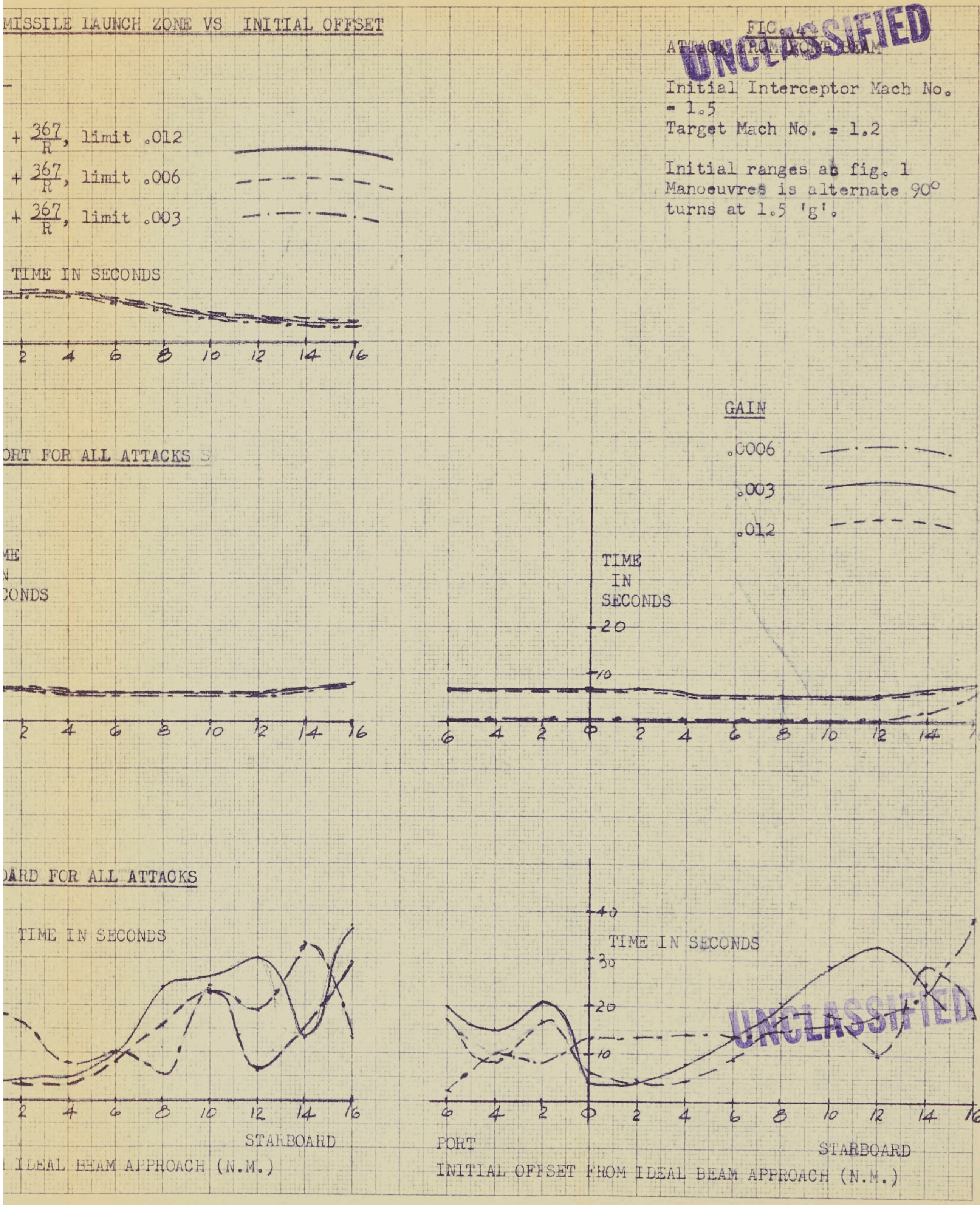


PORT STARBOARD
INITIAL OFFSET FROM IDEAL BEAM APPROACH (N.M.)



PORT
INITIAL OFFSET FROM IDEAL BEAM AP

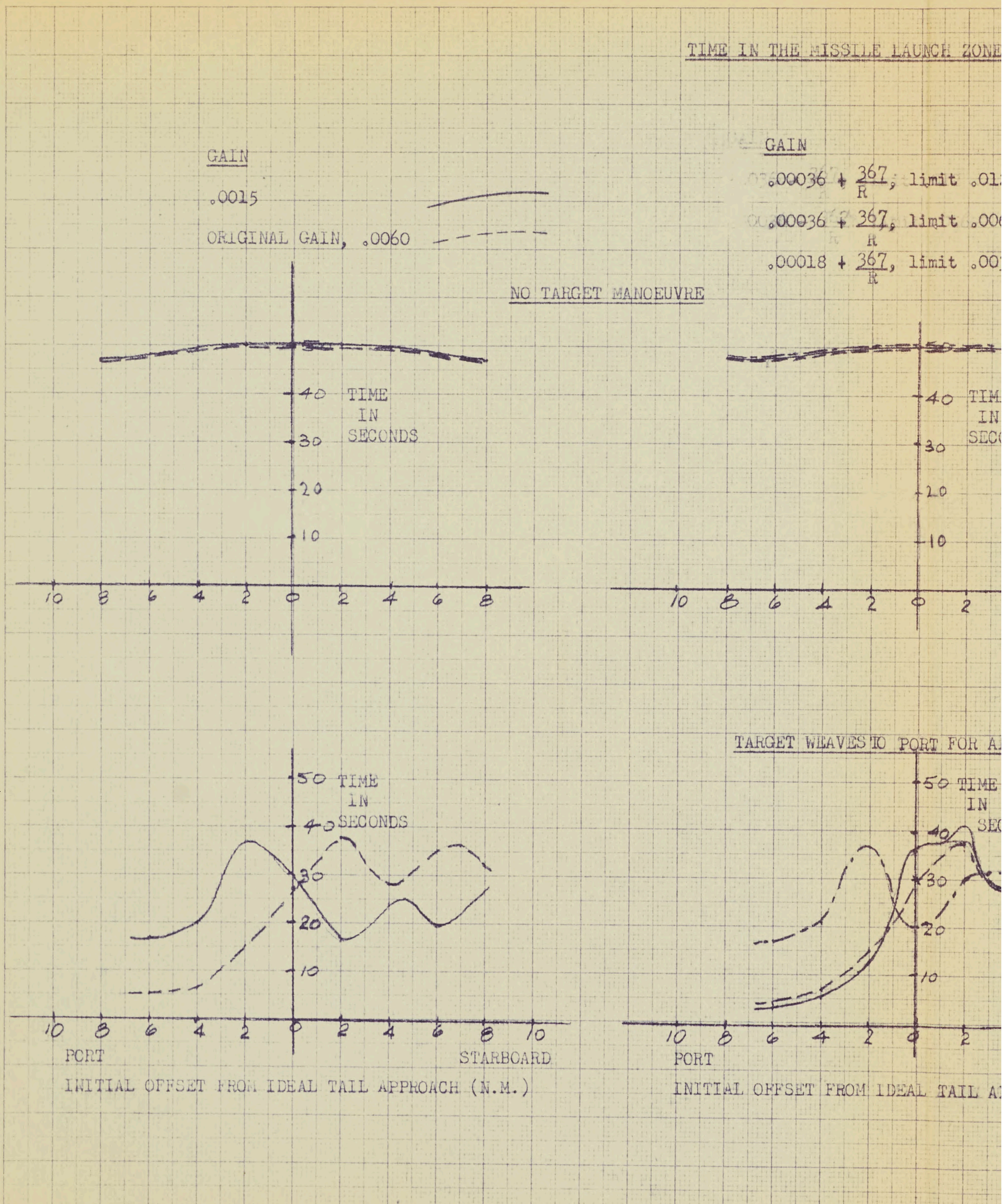
t



MISSILE LAUNCH ZONE VS INITIAL OFFSET
UNCLASSIFIED
Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2
Initial ranges at fig. 1
Manoeuvres is alternate 90° turns at 1.5 'g'.
+ 367/R, limit .012
+ 367/R, limit .006
+ 367/R, limit .003
TIME IN SECONDS
ORT FOR ALL ATTACKS
GAIN
.0006
.003
.012
TIME IN SECONDS
DARD FOR ALL ATTACKS
TIME IN SECONDS
TIME IN SECONDS
UNCLASSIFIED
STARBOARD
IDEAL BEAM APPROACH (N.M.)
PORT
STARBOARD
INITIAL OFFSET FROM IDEAL BEAM APPROACH (N.M.)

ET

SECRET



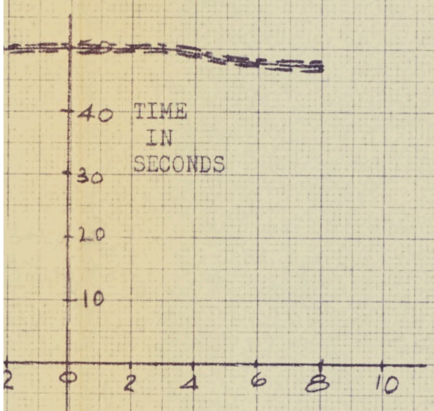
SECRET

E LAUNCH ZONE VS INITIAL OFFSET

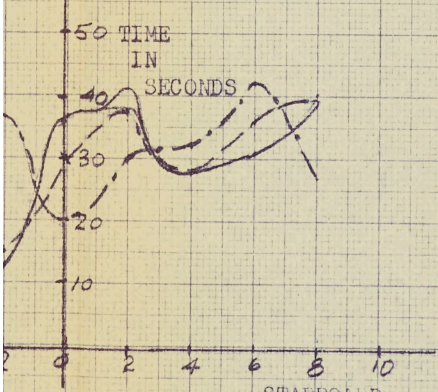
67, limit .012

67, limit .006

67, limit .003



O PORT FOR ALL ATTACKS



IDEAL TAIL APPROACH (N.M.)

FIG. 5

TAIL ATTACK

Initial Interceptor Mach No. = 1.5

Target Mach No. = 1.2

Initial ranges = 2/3 x fig. 1 values

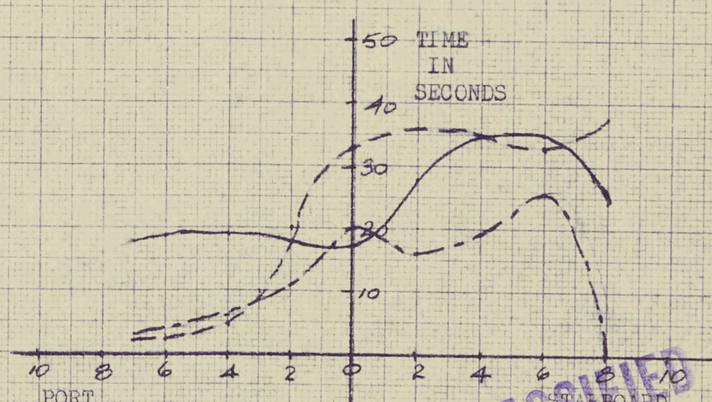
Manoeuvre is alternate 90° turns at 1.5 'g'.

GAIN

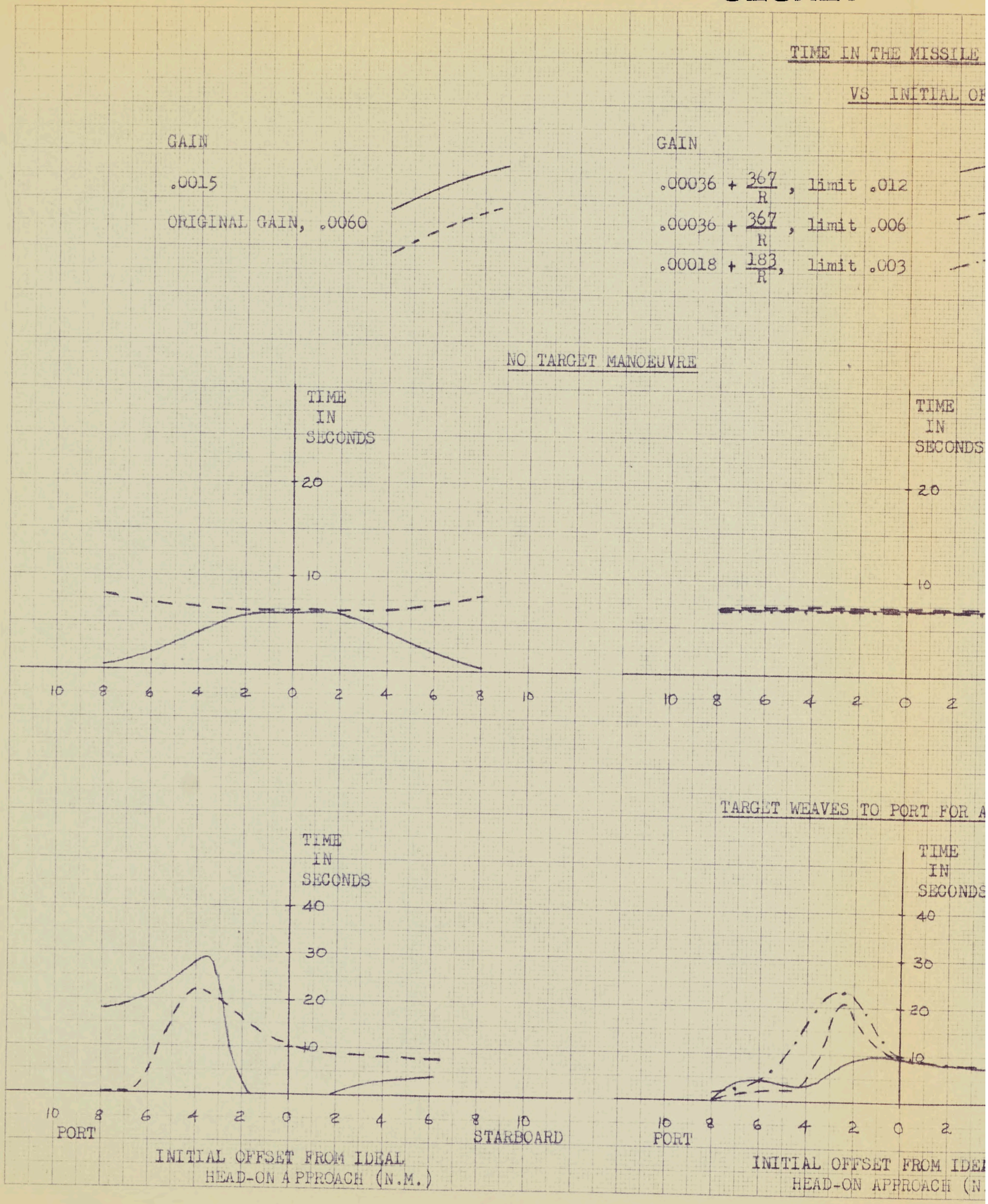
.0006

.003

.012



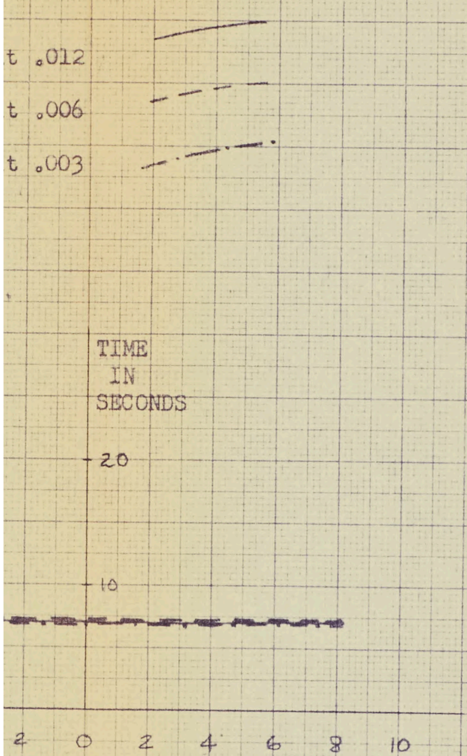
INITIAL OFFSET FROM IDEAL TAIL APPROACH (N.M.)


TIME IN THE MISSILE
VS INITIAL OF
GAIN
.0015
ORIGINAL GAIN, .0060
GAIN
.00036 + 367/R , limit .012
.00036 + 367/R , limit .006
.00018 + 183/R, limit .003
NO TARGET MANOEUVRE
TIME IN SECONDS
20
10
10 8 6 4 2 0 2 4 6 8 10
TARGET WEAVES TO PORT FOR A
40
30
PORT
STARBOARD
INITIAL OFFSET FROM IDEAL HEAD-ON APPROACH (N.M.)

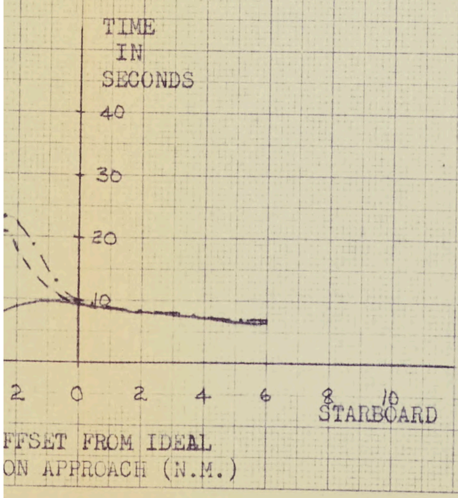
T

...N THE MISSILE LAUNCH ZONE

...VS INITIAL OFFSET



...S TO PORT FOR ALL ATTACKS



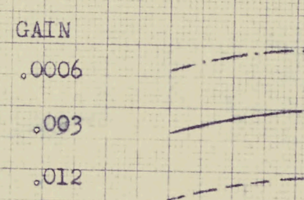
UNCLASSIFIED

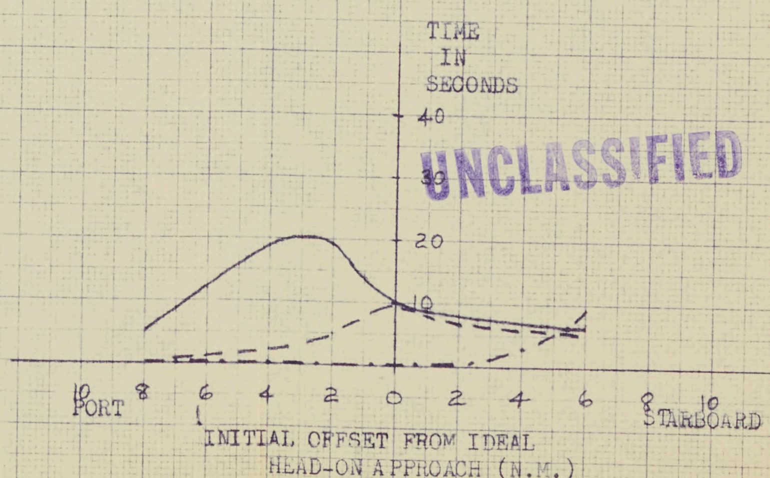
FIG. 6...

HEAD-ON ATTACK

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2

Initial ranges = 2/3 x fig. 1 values
Manoeuvre is alternate 90° turns at
1.5 'g'.

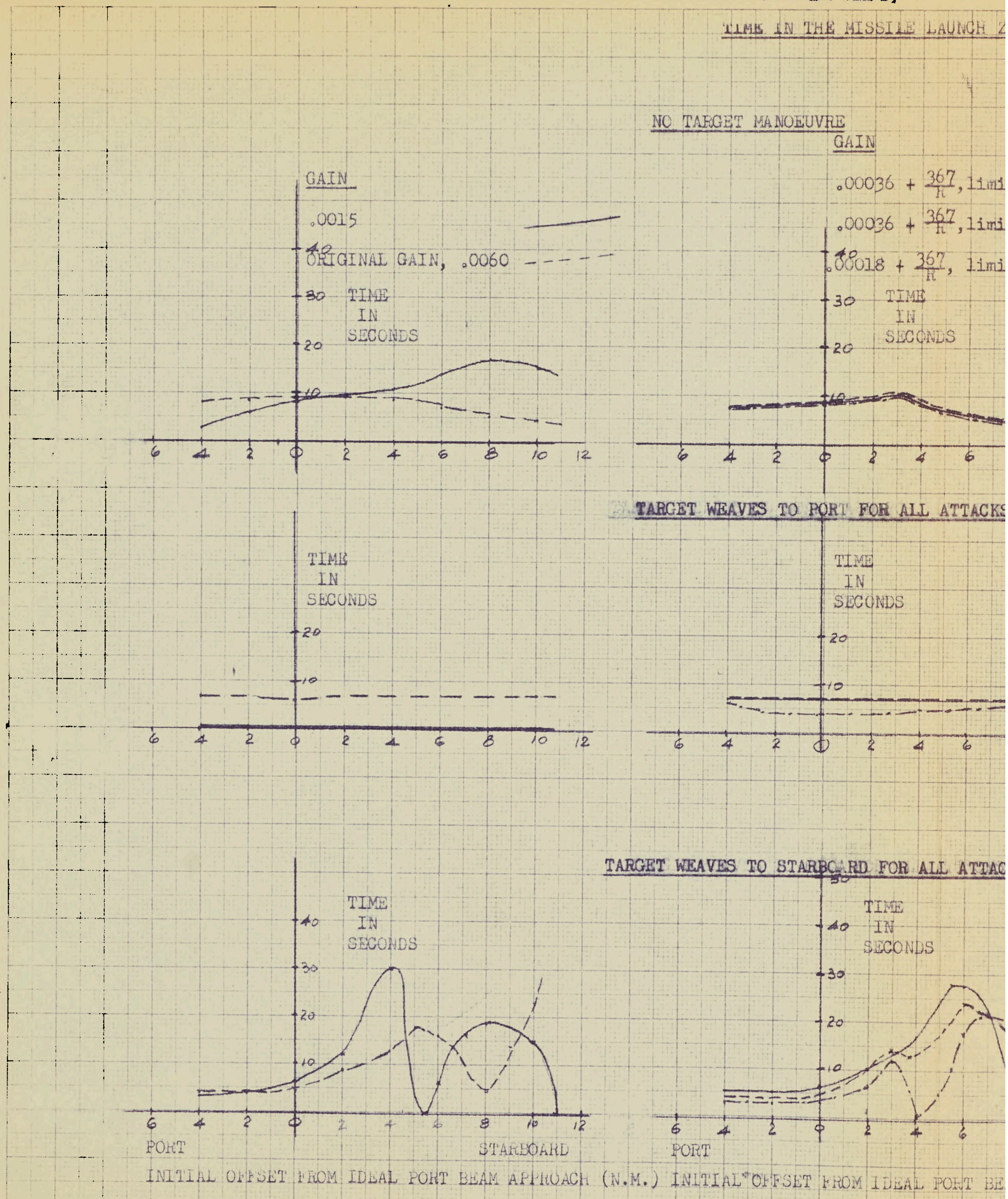




UNCLASSIFIED

ET

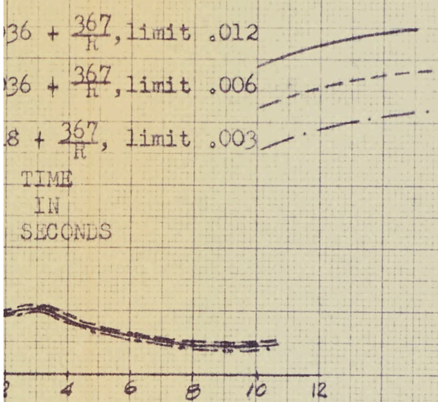
SECRET


TIME IN THE MISSILE LAUNCH Z
NO TARGET MANOEUVRE
GAIN
.0015
ORIGINAL GAIN, .0060
.00036 + 367/R, limi
.00036 + 367/R, limi
.00018 + 367/R, limi
TIME IN SECONDS
TARGET WEAVES TO PORT FOR ALL ATTACKS
TARGET WEAVES TO STARBOARD FOR ALL ATTAC
PORT
STARBOARD
INITIAL OFFSET FROM IDEAL PORT BEAM APPROACH (N.M.)
INITIAL OFFSET FROM IDEAL PORT BE

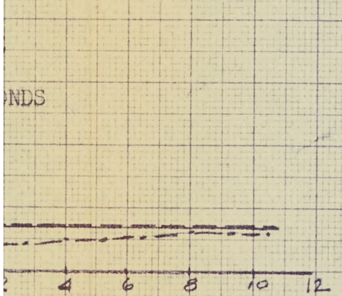
SECR

T

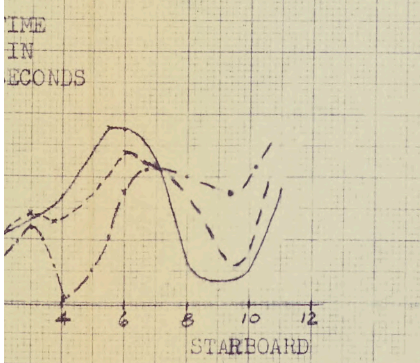
...SILE LAUNCH ZONE VS INITIAL OFFSET



...OR ALL ATTACKS



... FOR ALL ATTACKS



...IDEAL PORT BEAM APPROACH (N.M.)

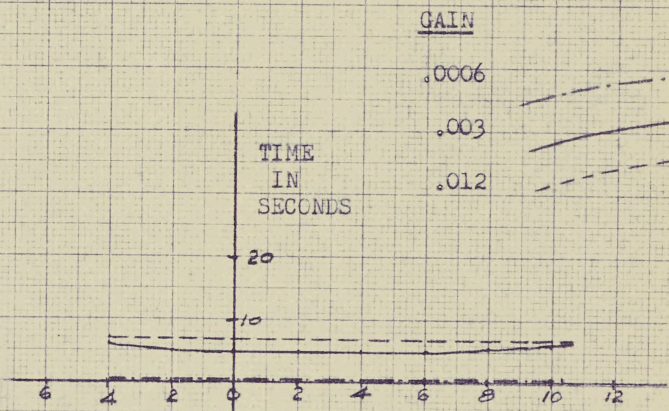
FIG. 7

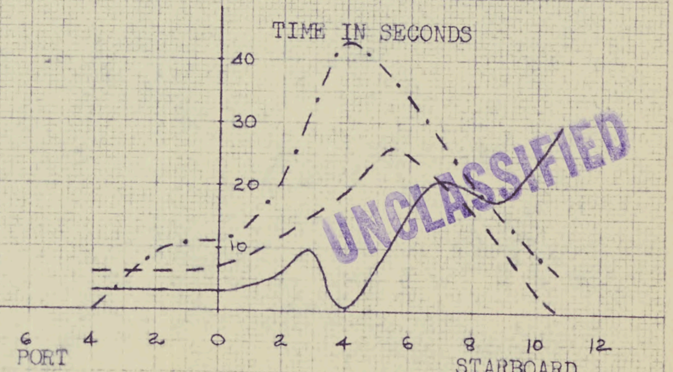
ATTACK FROM PORT BEAM

UNCLASSIFIED

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.2

Initial ranges = 2/3 x fig. 1 values
Manoeuvre is alternate 90° turns at 1.5 'g'.

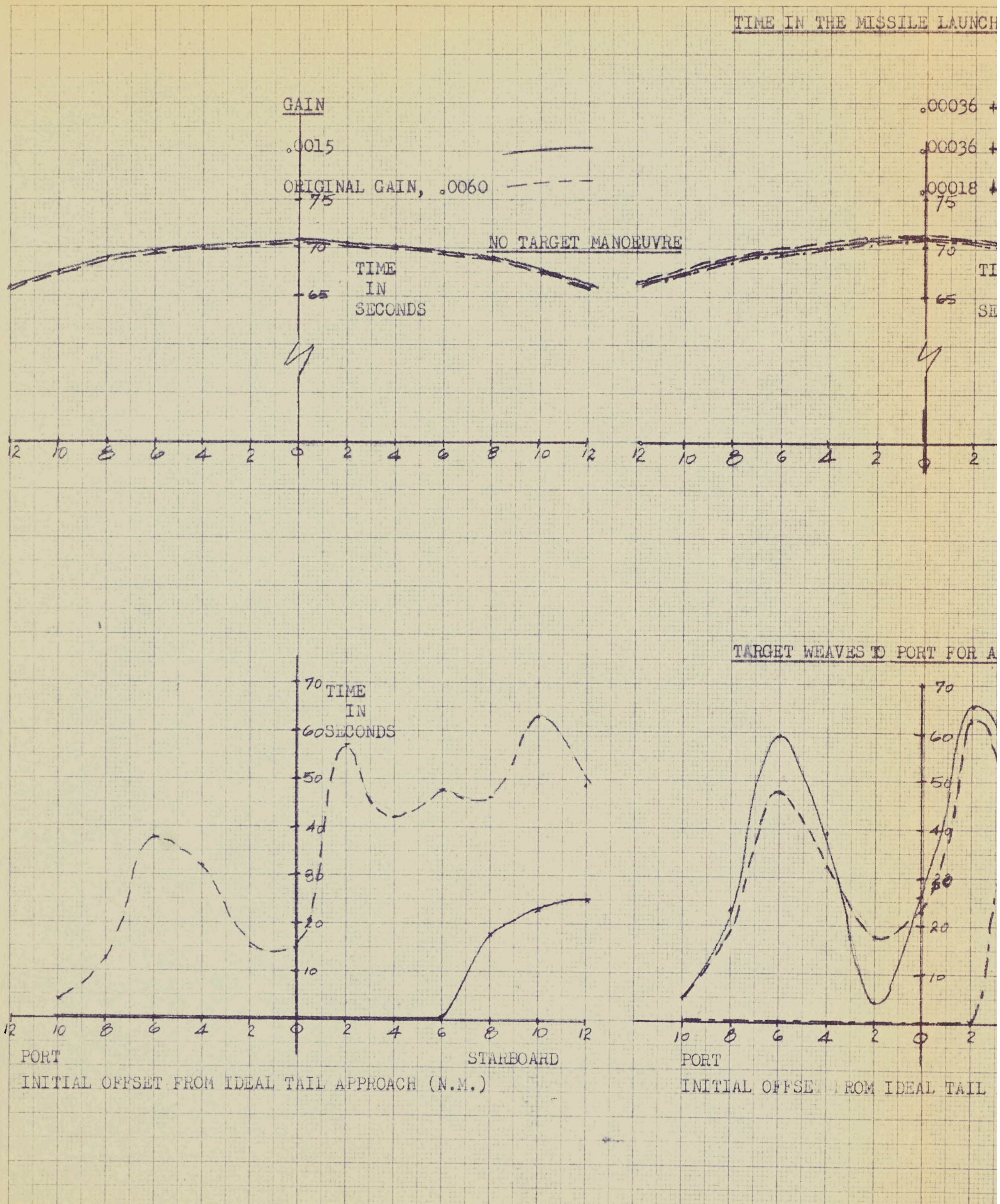




UNCLASSIFIED

INITIAL OFFSET FROM IDEAL PORT BEAM APPROACH (N.M)

SECRET


TIME IN THE MISSILE LAUNCH
GAIN
.0015
ORIGINAL GAIN, .0060
.00036
.00036
.00018
NO TARGET MANOEUVRE
TIME IN SECONDS
75
70
65
12 10 8 6 4 2 0 2 4 6 8 10 12
TARGET WEAVES TO PORT FOR A
70
60
50
40
30
20
10
PORT
STARBOARD
INITIAL OFFSET FROM IDEAL TAIL APPROACH (N.M.)
INITIAL OFFSE ROM IDEAL TAIL

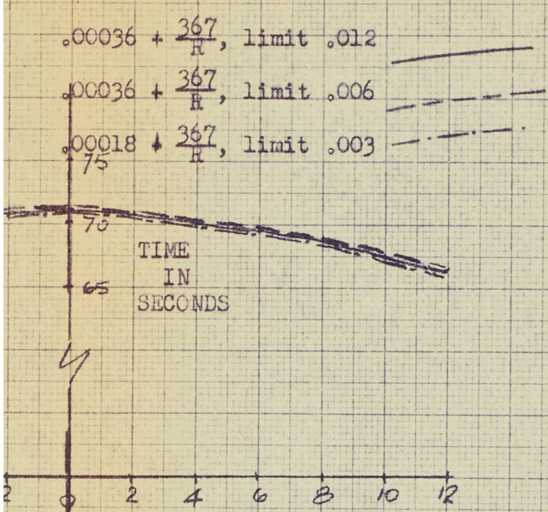
SSILE LAUNCH ZONE VS INITIAL OFFSET

FIG. 8

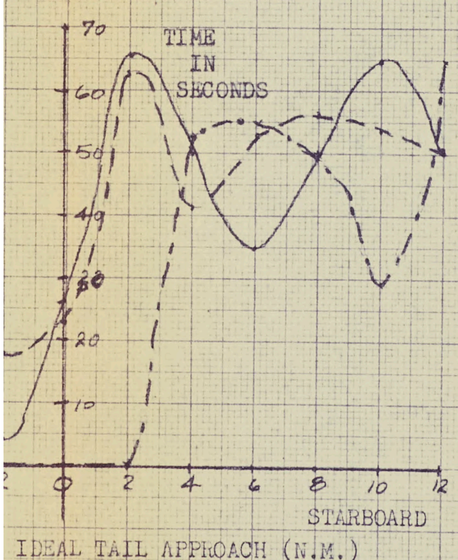
TAIL ATTACK

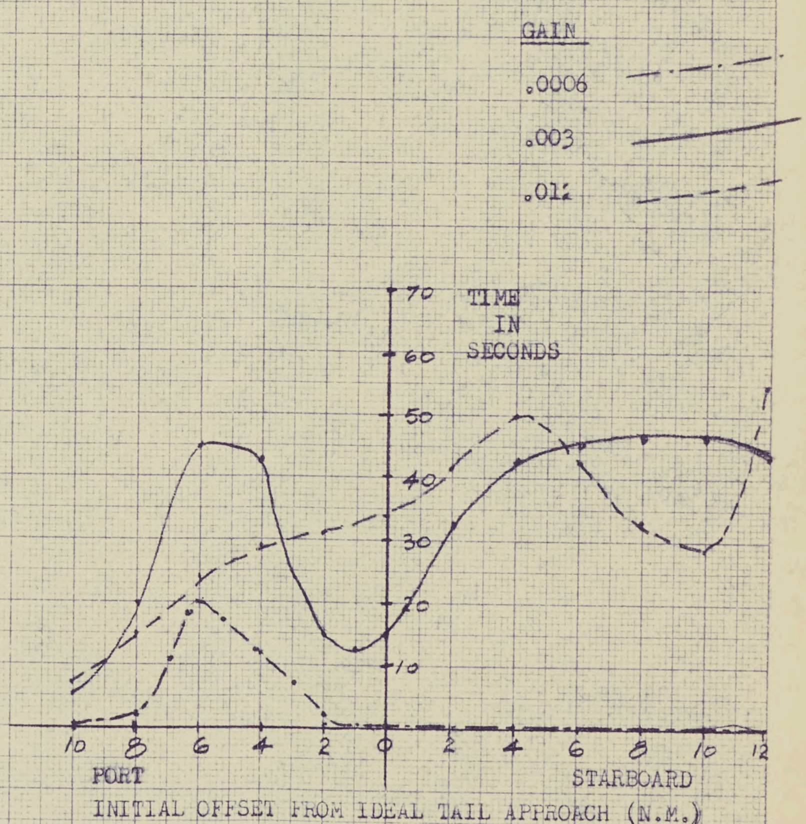
Initial Interceptor Mach No. = 2.0
Target Mach No. = 1.8

Initial ranges as fig. 1
Manoeuvre is alternate 90° turns at 1.5 'g'.



O PORT FOR ALL ATTACKS





ET

TIME IN THE MISSILE LAUNCH

GAIN

.0015

ORIGINAL GAIN, .0060

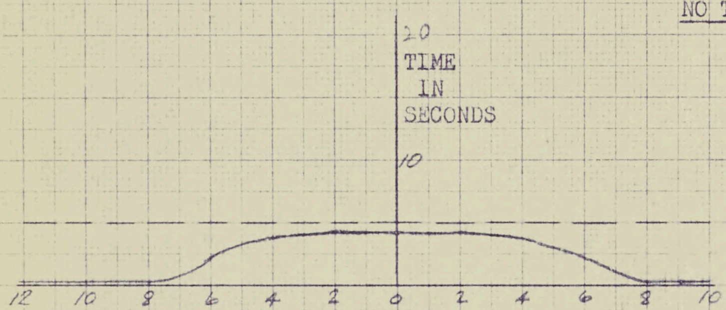
GAIN

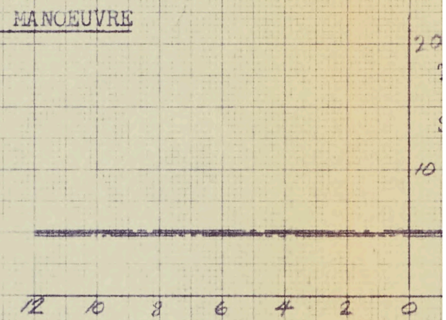
.00036 + $\frac{367}{R}$, limi

.00036 + $\frac{367}{R}$, limi

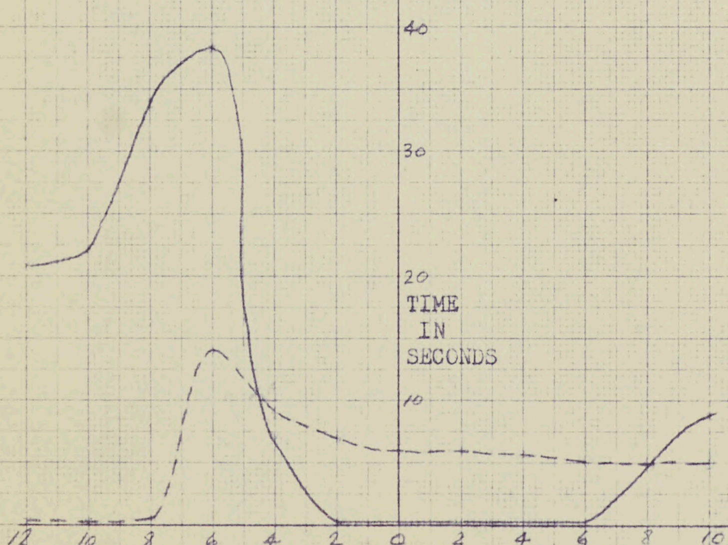
.00018 + $\frac{367}{R}$, limi

NO TARGET MANOEUVRE

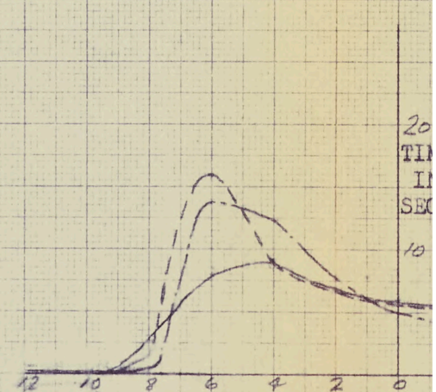




TARGET WEAVES TO PORT



INITIAL OFFSET FROM IDEAL HEAD-ON APPROACH (N.M.)



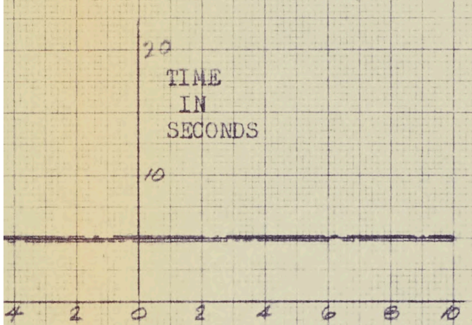
INITIAL OFFSET FROM IDEAL HEAD-

SSILE LAUNCH ZONE VS INITIAL OFFSET

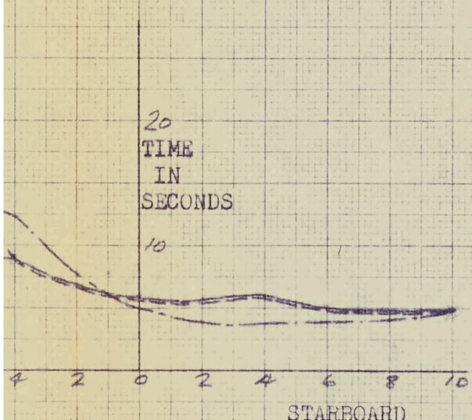
+ $\frac{367}{R}$, limit .012

+ $\frac{367}{R}$, limit .006

+ $\frac{367}{R}$, limit .003



AVES TO PORT FOR ALL ATTACKS



OM IDEAL HEAD-ON APPROACH (N.M.)

FIG. 9

HEAD-ON ATTACK

Initial Interceptor Mach No. = 1.0
Target Mach No. = 1.8

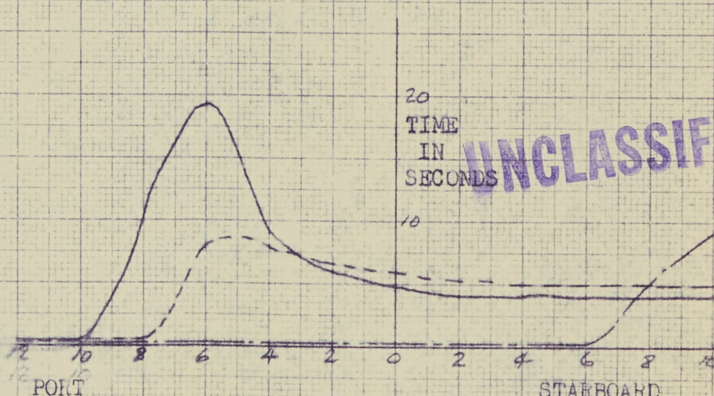
Initial ranges as Fig. 1
Manoeuvre is alternate 90° turns at 1.5 'g'.

GAIN

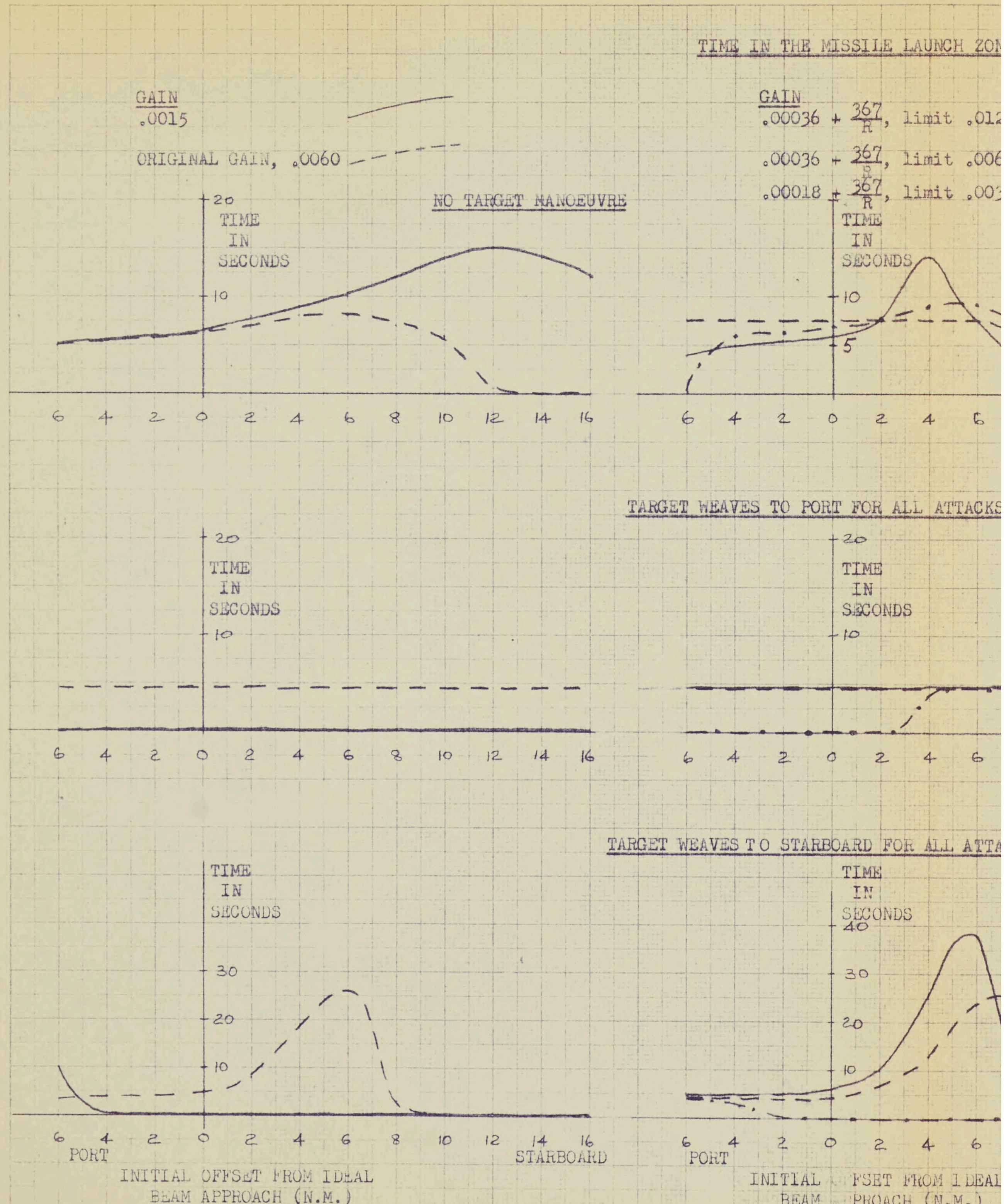
.0006

.003

.012

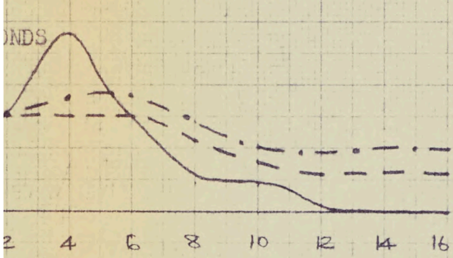


INITIAL OFFSET FROM IDEAL HEAD-ON APPROACH (N.M.)

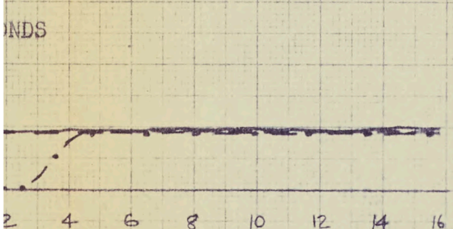

TIME IN THE MISSILE LAUNCH ZON
GAIN
.0015
ORIGINAL GAIN, .0060
NO TARGET MANOEUVRE
TIME IN SECONDS
GAIN
.00036 + 367/R, limit .012
.00036 + 367/R, limit .006
.00018 + 367/R, limit .003
TARGET WEAVES TO PORT FOR ALL ATTACKS
TARGET WEAVES TO STARBOARD FOR ALL ATTA
PORT
STARBOARD
INITIAL OFFSET FROM IDEAL BEAM APPROACH (N.M.)

E LAUNCH ZONE VS INITIAL OFFSET

', limit .012
', limit .006
', limit .003



ALL ATTACKS



FOR ALL ATTACKS

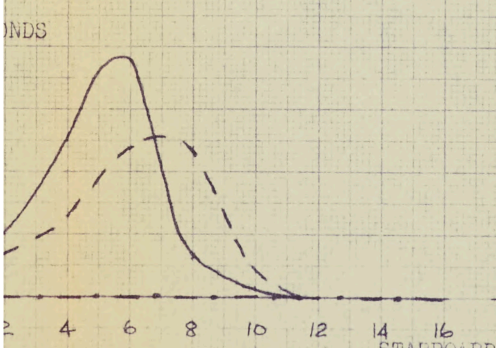


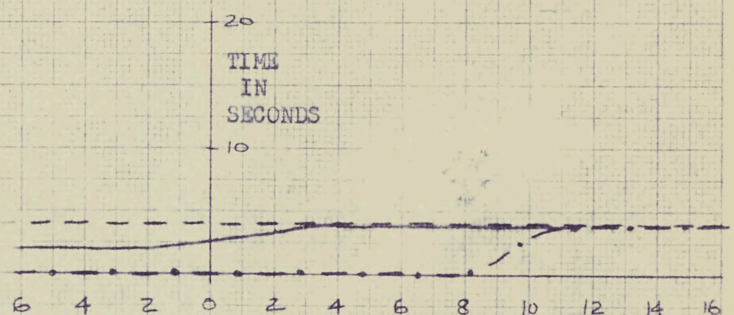
FIG. 10
ATTACK FROM PORT BEAM

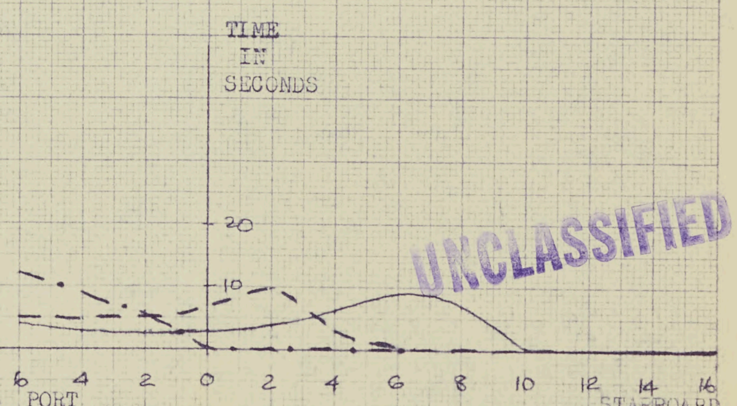
Initial Interceptor Mach No. = 2.0
Target Mach No. = 1.8

Initial ranges as fig. 1
Manoeuvre is alternate 90° turns at 1.5 'g'.

GAIN

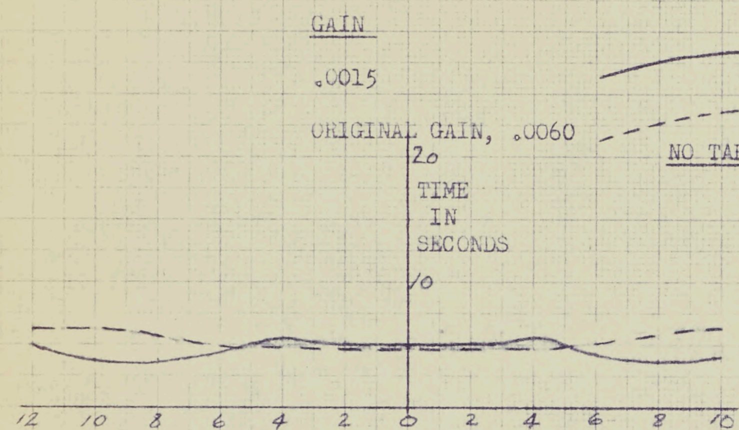
.0006
.003
.012



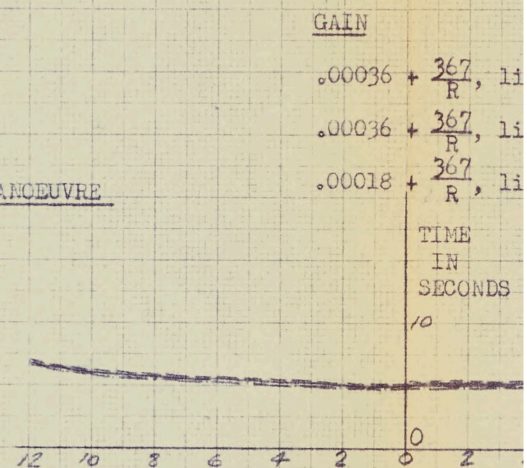


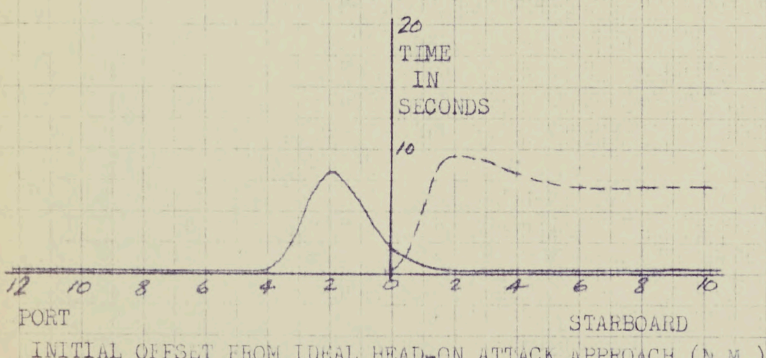
INITIAL OFFSET FROM IDEAL
BEAM APPROACH (N.M.)

TIME IN THE MISSILE L...NCH

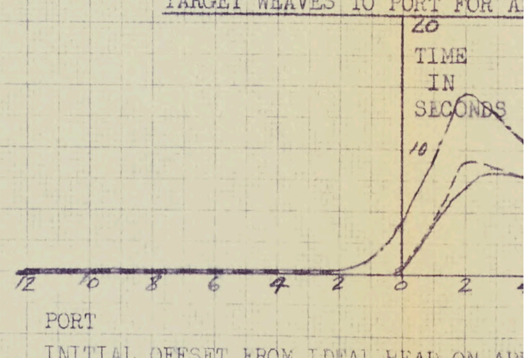


NO TARGET MANOEUVRE





TARGET WEAVES TO PORT FOR A

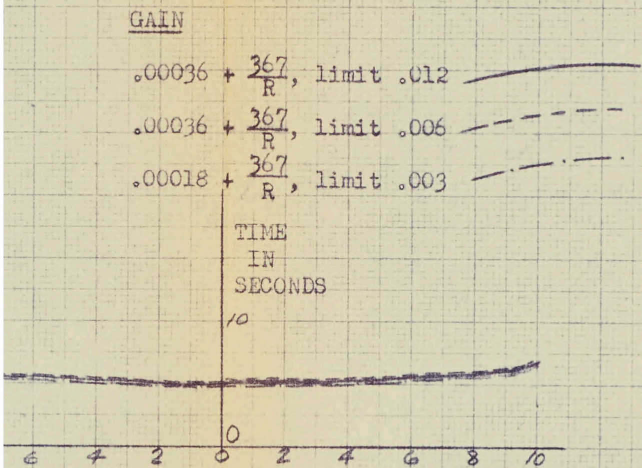


TIME IN THE MISSILE L..NCH ZONE VS INITIAL OFFSET

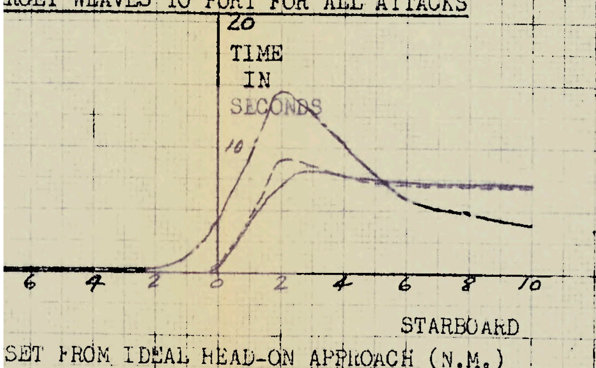
FIG. 11
HEAD-ON ATTACK

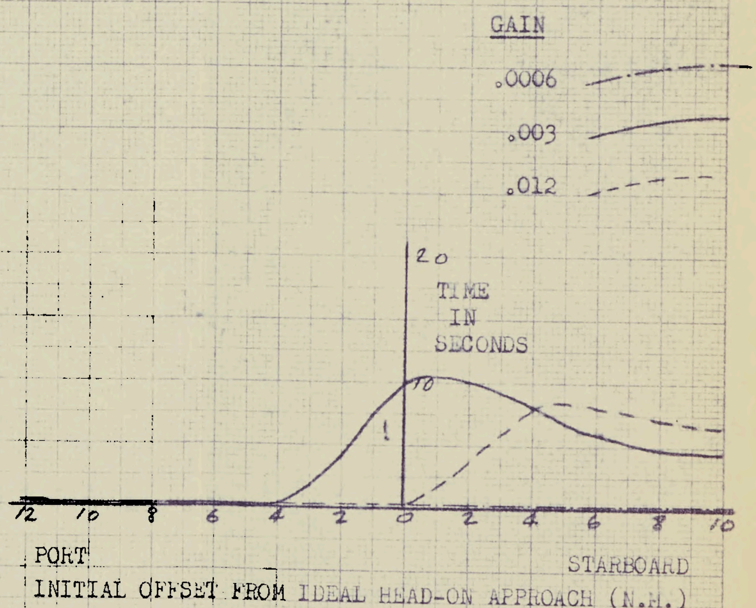
Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.8

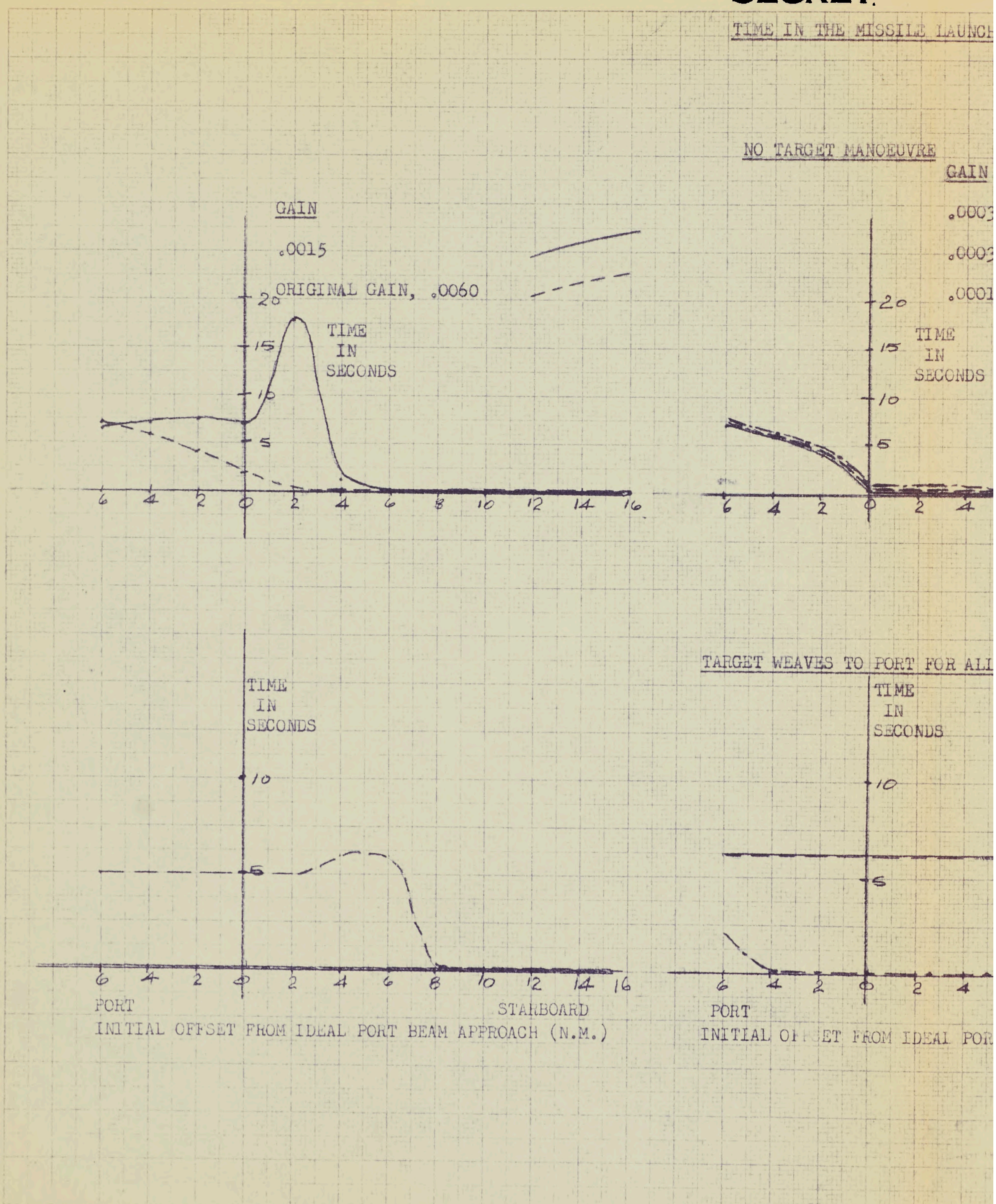
Initial ranges as fig. 1
Manoeuvre is alternate 90° turns at 1.5 'g'.



RGET WEAVES TO PORT FOR ALL ATTACKS





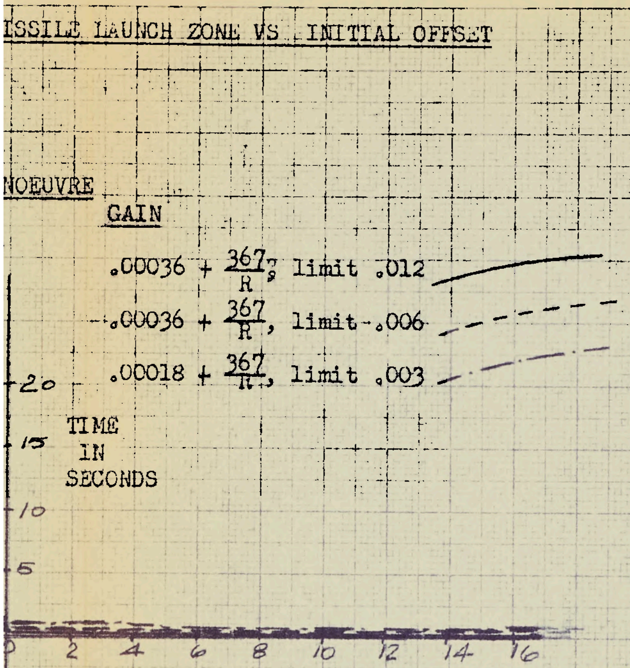


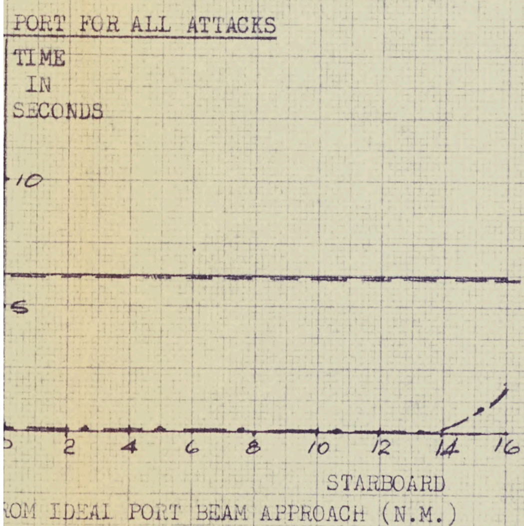
TIME IN THE MISSILE LAUNCH
NO TARGET MANOEUVRE
GAIN
.0015
ORIGINAL GAIN, .0060
TIME
IN
SECONDS
GAIN
.0003
.0003
.0001
TARGET WEAVES TO PORT FOR ALL
PORT
STARBOARD
INITIAL OFFSET FROM IDEAL PORT BEAM APPROACH (N.M.)

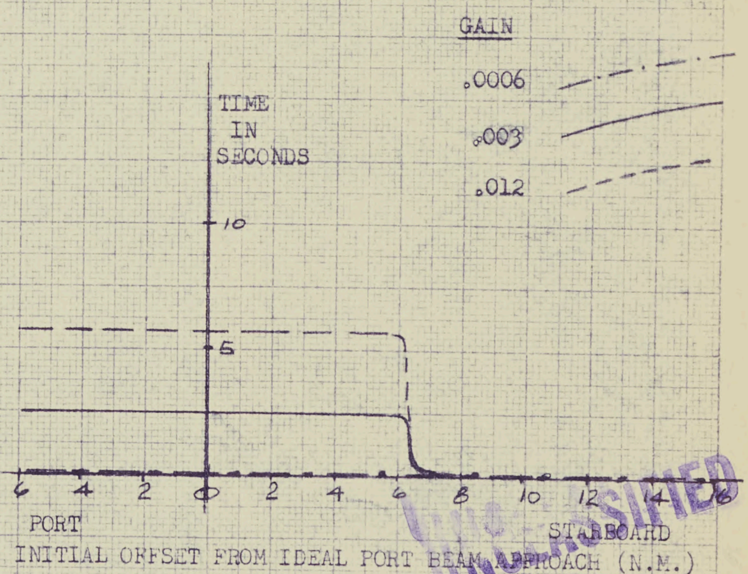
FIG. 12
ATTACK FROM PORT BEAM

Initial Interceptor Mach No. = 1.5
Target Mach No. = 1.8

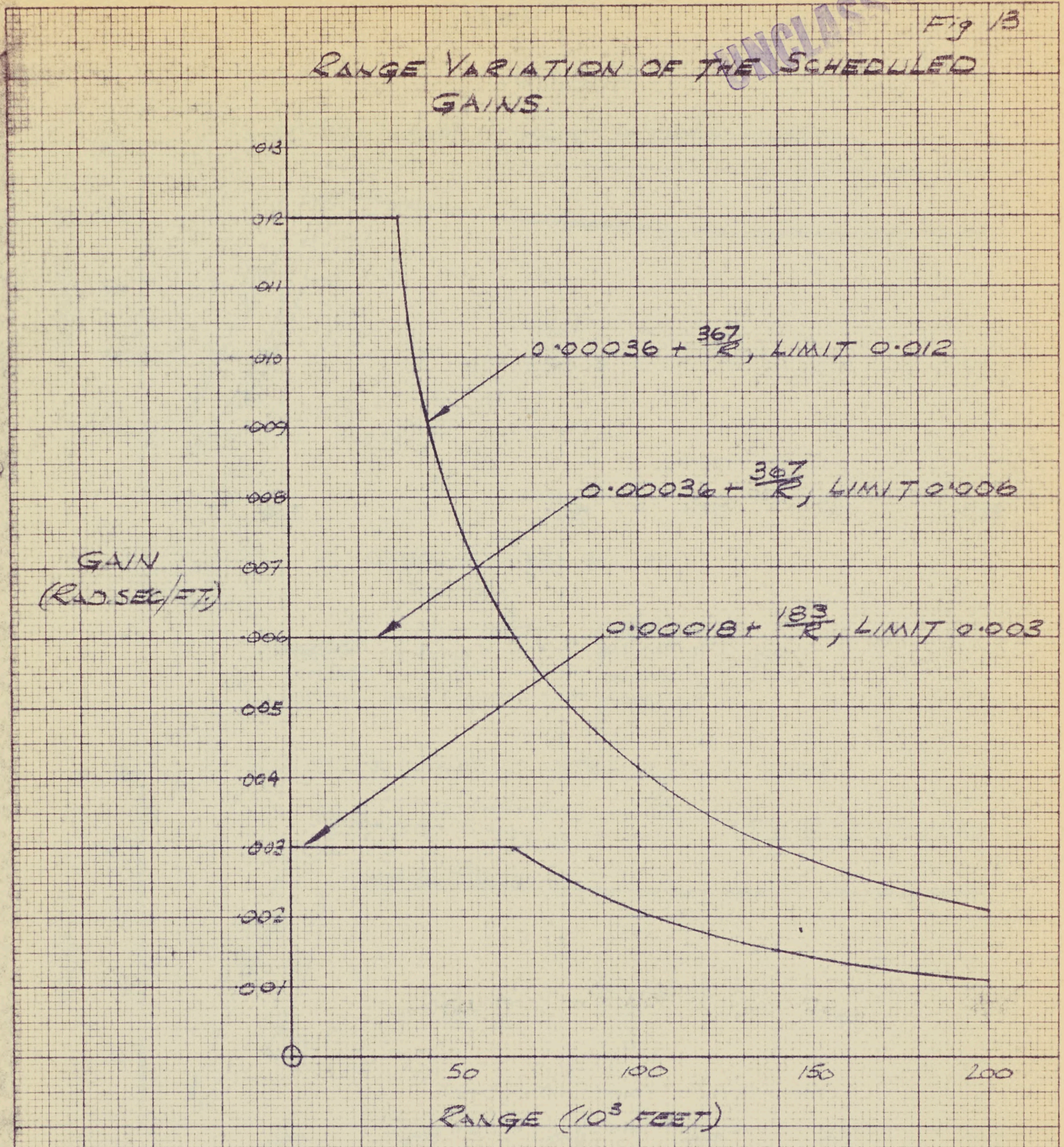
Initial ranges as fig. 1
Manoeuvre is alternate 90° turns at 1.5 'g'.







SECRET

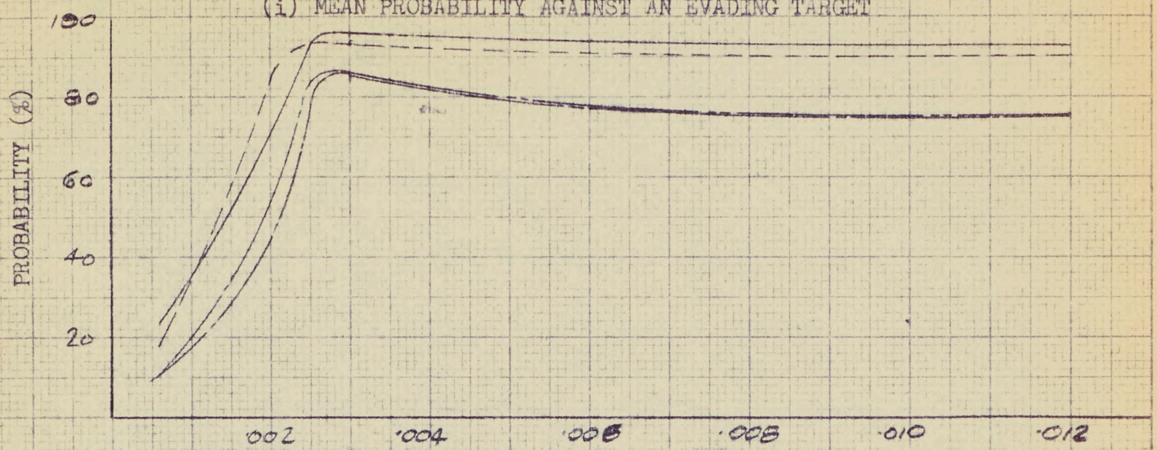


SECRET

UNCLASSIFIED
SECRET

FIG. 14

(i) MEAN PROBABILITY AGAINST AN EVADING TARGET

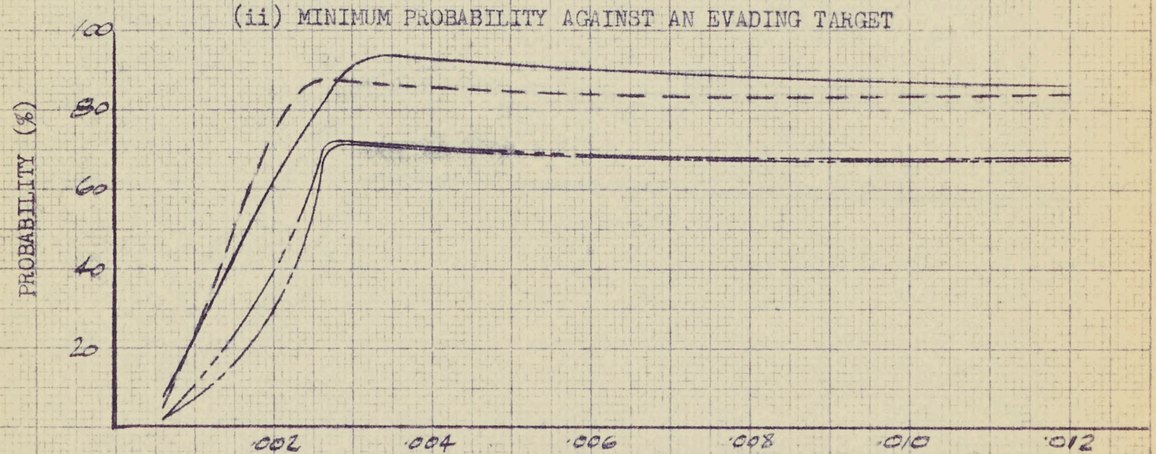


AZIMUTH GAIN (Rad. Sec./Ft.)

Legend for Both Curves

————————	Weighting 1)
– – – – – – – –	Weighting 2) See
—— – —— – ——	Weighting 3) Table 1
—— - - —— - - ——	Weighting 4)

(ii) MINIMUM PROBABILITY AGAINST AN EVADING TARGET



AZIMUTH GAIN (Rad. Sec./Ft.)

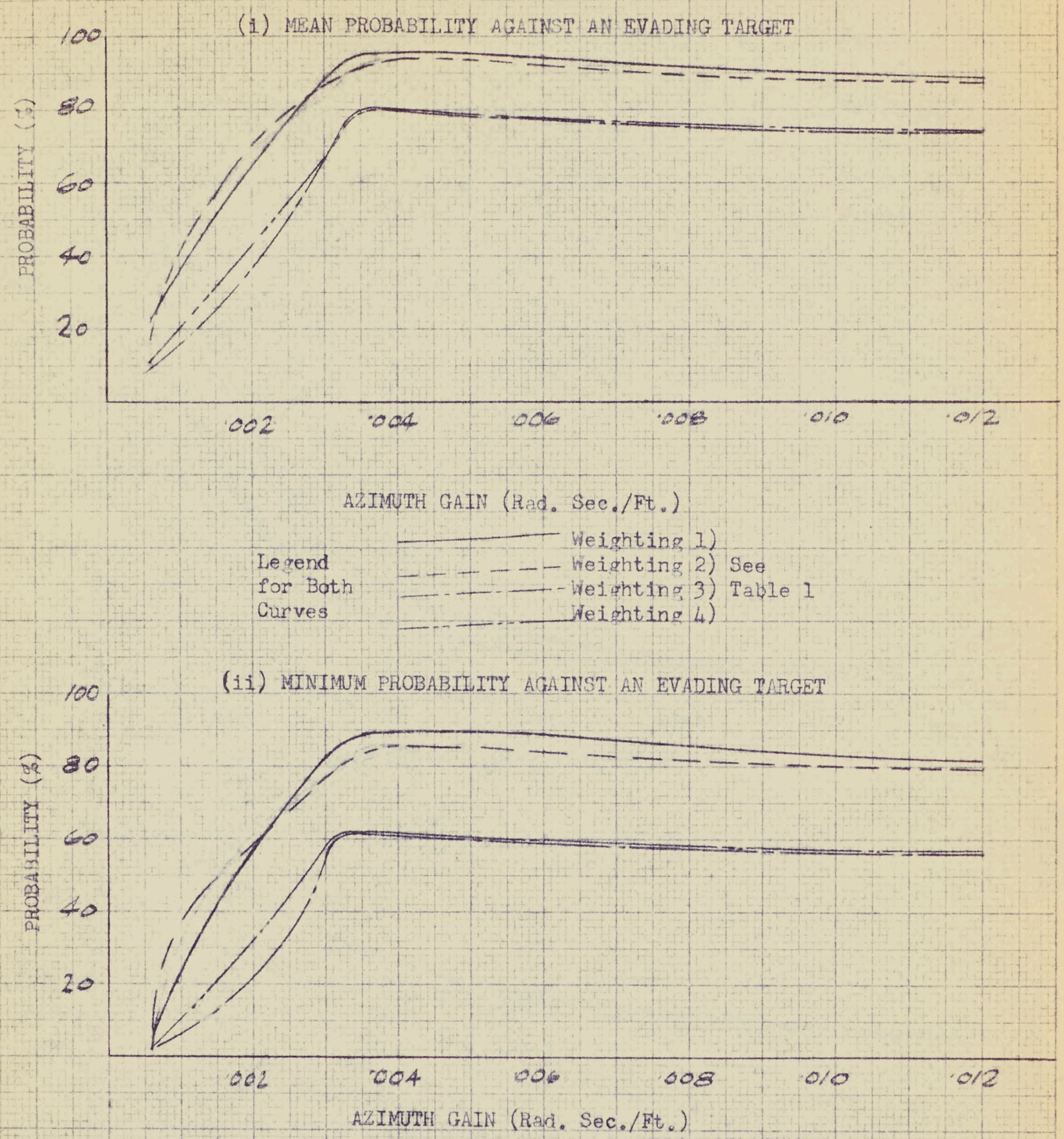
OVERALL CONVERSION PROBABILITIES FOR A CONSTANT GAIN SYSTEM

Standard Deviation of the Placement Error = 3 N.M.

Time Required in the Missile Launch Zone
For a Successful Attack = 2 Seconds

SECRET
UNCLASSIFIED

FIG. 15



OVERALL CONVERSION PROBABILITIES FOR A CONSTANT GAIN SYSTEM

Standard Deviation of the Placement Error = 3 N.M.

Time Required in the Missile Launch Zone
For a Successful Attack = 3 Seconds

FIG. 16

OVERALL MEAN VALUES OF THE FIRING ERROR AND NORMAL ACCELERATION

Standard deviation of the placement error = 3 n.m.