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CLOSE ARMING CONCEPTS FOR THE XW-5/REGULUS AND XW-5/MATADOR CONTACT-FUZED WEAPONS

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ABSTRACT

First estimates of the probabilities of defeat (unmodified by acquisition probabilities) are presented for the contact-fuzed Regulus and Matador weapons when they are fired upon on their down trajectories by conventional AA guns using proximity fuzed shells. The effect of the assumption of the altitude at which the weapons are assumed to be armed is examined relative to the probabilities of defeat. The conclusions of the study are that arming close to desired height of burst is highly desirable for both missiles and that an accurate arming device is highly desirable for both missiles, particularly the Matador.

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CLOSE ARMING CONCEPTS FOR THE XW-5/REGULUS AND XW-5/MATADOR CONTACT-FUZED WEAPONS

INTRODUCTION

A memorandum[1], dated January 3, 1955, from L. D. Smith, 1212, to W. D. Wood, 5132, requested that a study be made concerning the potential advantages to be gained in closer arming of the XW-5/Regulus and XW-5/Matador missiles. At the present time the Regulus and Matador weapons are armed at the nominal height of 20,000 feet, pressure-altitude.

In this memorandum the first estimates of the probabilities of defeat (unmodified by acquisition probabilities) are presented for the Regulus and Matador weapons when they are fired upon on their down trajectories by conventional AA guns using proximity fuzed shells. Comparative analyses of the effect of arming altitude on the probabilities of defeat are made, assuming both weapons to have contact fuzing capabilities provided by impact sensitive devices. On the basis of these analyses arming which is effected close to desired height of burst is shown to be significantly advantageous for both weapon systems.

DEFINITIONS AND ASSUMPTIONS

As applied to fission weapons, damage means that at least one fragment from an antiaircraft shell penetrates the HE sphere of the weapon or that the fragment fuzes the weapon by initiating the contact fuzing sequence. Defeat means the explosion of the HE (contained in the sphere) above an altitude of 6000 feet over the target. The HE explosion can give rise to premature full-scale yield or to reduced (including zero) nuclear yield.

There are no test data available that can directly yield the probability of defeating nuclear weapons by impact (and penetration into the weapon case) of antiaircraft shell fragments. Lack of knowledge of the vulnerability of the HE system to shell fragments prevents an exact statement as to the effects of fragment penetration of the weapon case. An attempt is made to estimate the probability of defeat of the weapon based on conjectures as to the effects of penetration which can be made from some few test data in existence. Consequently, the probability of defeating the weapon is expressed in this report as a fixed fraction of the probability of damaging the weapon, when damage is specified to mean that at least one shell fragment penetrates the weapon case. For the weapon with contact fuzing capability, this fraction is unity whenever the weapon is armed and the X-unit charged. The fraction is one third whenever the weapon is in the unarmed condition. However, neither the probability of penetration nor the probability of defeating the weapon can be calculated with confidence for any enemy firing scheme until the vulnerability of the weapon has been determined.

BOUNDS AND LIMITATIONS

The bounds of the problem considered in this memorandum do not include fire with antiaircraft shells that are not proximity-fuzed nor with air-to-air or ground-to-air guided or unguided missiles or rockets.

ENEMY COUNTERMEASURE ASSUMPTIONS

The only enemy countermeasure considered is the use of conventional antiaircraft guns firing proximity-fuzed shells directed by a modern fire-control system.

It is assumed that the most likely number of guns firing at the weapon at any one time is ten. It is assumed that the guns are always situated in optimum positions relative to the weapon trajectory. Each gun is assumed to fire independently; i.e., to have its own director system. The guns used are considered to be 90-mm antiaircraft guns (assumed comparable in performance to the Russian 85-mm guns). The rate of fire for each gun is taken to be 20 shots per minute without regard to tracking or prediction. Shots are assumed to be sufficiently separated in time to discount any salvo effect of the proximity-fuzed (VT) shells. The reliability of the VT fuze is taken to be 0.8. Wet weather effects on this type of shell are not taken into consideration. The shell trajectories are those for the NACA Standard Atmosphere. Each antiaircraft gun is assumed to be independently controlled by a director system equivalent to the SCR-584, M9 system (assumed to be comparable to the Russian capability now and in the near future). Any delay in opening fire is primarily contingent upon prediction difficulties of the fire-control director (later discussed in more detail). The probability that the weapon is acquired by the gun director system is noted only symbolically, since no numerical values are known. Note that the results of this study should properly be degraded by these acquisition probabilities. The dispersions assumed for the fire-control system are taken to be three times the dispersions specified for a proposed Naval device (the Mk 65 Gunfire Control System). The relations between the dispersions used and the slant range are shown in Fig. 1. The dispersions and the bias (systematic error) of the system are considered to be so related that the probability of damage can be maximized.

PROBABILITY OF DAMAGE AS RELATED TO PROBABILITY OF DEFEAT FOR FISSION WEAPONS

The fundamental assumption is that the HE sphere or the contact fuzing system provides those components which are of principal interest insofar as defeating the weapon is concerned. Although there is a nonzero probability that other fuzing or firing components could be damaged, it is the author's opinion that the locations of these other components and the geometry of the weapon are such that the associated probabilities of premature or dud operation are negligible, with the

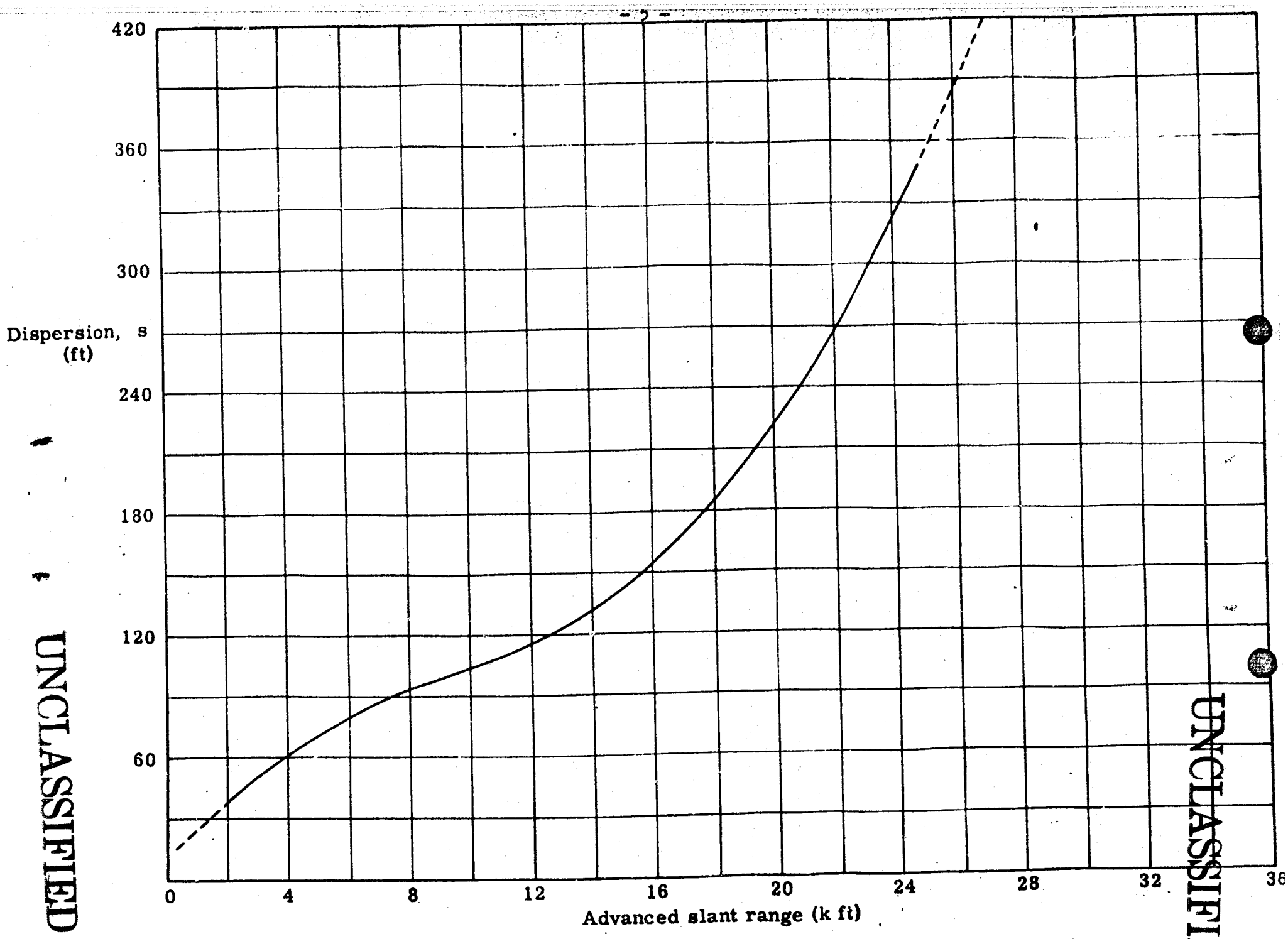

Fig. 1 -- Dispersion, s, versus advanced slant range, for the SCR-584, M9 System.

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possible exception of the probability of a dud resulting from a fragment penetrating the X-unit.

In addition, there exists a nonzero probability of damaging the weapon case in such a manner that the altered ballistics would interfere with fuzing at the desired burst height. This probability is not considered to contribute to the defeat of the weapon inasmuch as the probability is high that, at worst, contact of the weapon with the ground would provide the desired sequence of events so that a dud would not occur.

For each set of delivery parameters for which calculations were made, the probability of damage is accumulated to, but not below, a burst point having an altitude of 6000 feet above the target. No consideration is given to burst points less than 6000 feet above the target because it is assumed that, in view of the small dud probabilities and the wide-spread destructive effects of the weapon, damaging the weapon below an altitude of 6000 feet gains little or nothing as far as the defense is concerned.

The limited test data in existence permit only conjectures as to the outcome of penetration of the HE sphere by fragments from shells. From these data, it can be estimated that there is a one-third probability that an explosion occurs above an altitude of 6000 feet as a result of penetration of the weapon case; this probability is applicable to contact-fuzed atomic weapons in the unarmed condition only. Note that the latter probability may actually be closer to zero than it is to one-third; if so, the conclusions of this paper are strengthened. The existence of a contact fuzing system makes the probability high that an immediate (within 500 microseconds) detonation will occur whenever the weapon case is penetrated while the weapon is armed and the X-unit is charged. Consequently, whenever the weapon is armed the probability of damage is essentially the probability of defeat.

COMPUTATIONAL PROCEDURES

General

In the computational procedures a consistent attempt was made to choose those assumptions that will maximize the probability of defeat of the weapon. It must be emphasized that because (among other things) the vulnerability of the weapon to fragments, blast, etc., is not known, the results of the computations and the conclusions drawn therefrom can be accepted only in the restricted sense of first estimates.

The mathematical model for the problem is given in Reference 2 and will not be reproduced here.

WEAPON AND DELIVERY SYSTEM ASSUMPTIONS

The characteristics of Regulus and Matador which are pertinent to this study are as follows:

	Regulus	Matador
Cruising altitude, prior to dump (feet)	34,000	42,000
Cruising Mach number, prior to dump	0.9	0.9
Length (feet)	34	39.5
Max Dia (inches)	56.5	56.0
Speed, 20,000 ft to ground (approx. ft/sec)	1100	1100

The trajectory data for the Regulus and Matador(supplied by Division 1212) are reproduced in graphical form in Fig. 2.

The target is unspecified and no account is taken of the delivery errors due to ballistic or meteorological considerations.

RANGE OF ANTIAIRCRAFT SHELL BURSTS CONSIDERED

Difficulties involved in fire control when the time of flight of the antiaircraft shell exceeds 15 seconds result in such large inaccuracies in fire that the probability of damage to the weapon is assumed to be zero for all shots at weapon positions requiring more than 15 seconds time of flight of the shell.

CALCULATION OF THE ACCUMULATED PROBABILITY OF DEFEAT

The input data of the paragraph above and the methods and procedures of Reference 2 were used to calculate the probabilities of interest for assumed values of arming altitude above the target; namely, 6000, 7000, 8000, 9000, 10,000 15,000, and 20,000 feet. The lethal radius was assumed to be 15 feet for the unarmed weapon and 30 feet for the armed weapon. For those who are interested, the entire set of calculations is available in the files of 5131-1.

ACQUISITION PROBABILITIES

The results presented are unmodified by the acquisition probabilities, as noted earlier. However, it can be conjectured that these probabilities are close to unity for both the Regulus and M[redacted]s.

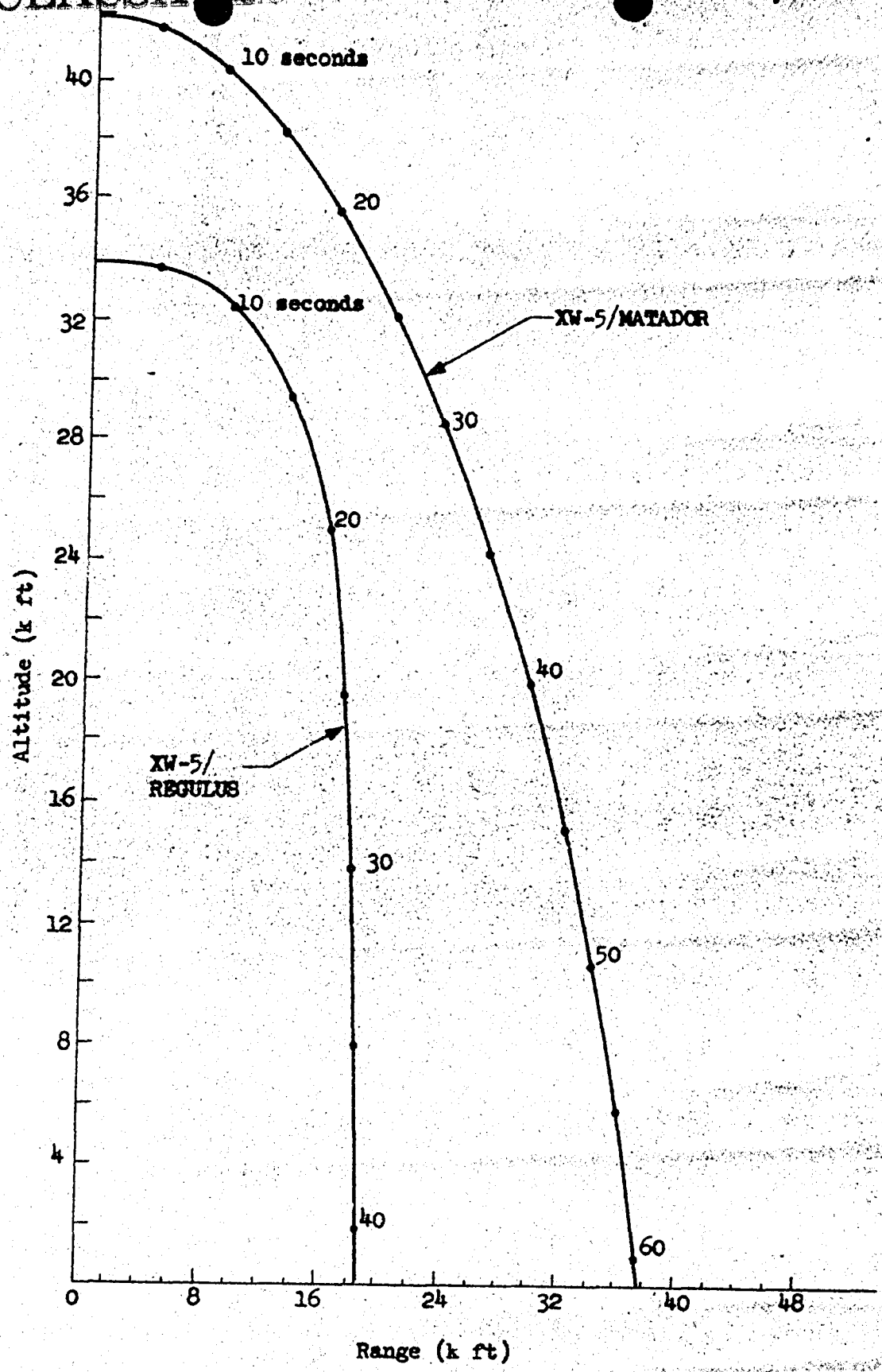

Fig. 2 -- Approximate down trajectories of the XW-5/REGULUS and XW-5/MATADOR missiles

RESULTS AND CONCLUSIONS

Figures 3 and 4 present the approximate effect of arming altitude on the probabilities of defeat (accumulated to an altitude of 6000 feet above the target) for the XW-5/Regulus and XW-5/Matador, respectively. The curves show directly the probability of defeat as a function of the altitude above the target at which the weapon is assumed to be armed and the X-unit charged. In addition, a scale along the left side of each figure gives the factor by which the probability of defeat is increased by arming at an altitude more than 6000 feet above the target; the unit base of both scales is the probability of defeat for the weapon armed at 6000 feet above the target.

Figures 3 and 4 show that, although the absolute probabilities differ between the Regulus and the Matador, the scale factors (as a function of arming altitude) are approximately the same for both weapons. Comparison of the probabilities of defeat of the XW-5/Regulus (Fig. 3) and the XW-5/Matador (Fig. 4) shows that, for arming below 10,000 feet, the sensitivity to arming altitude is greater for the Matador than for the Regulus. However, the probabilities of defeat for both weapons are significantly affected by the altitude at which they are assumed to be armed.

Note that zero error in arming altitude is assumed throughout. If there is a nonzero error, the gains which result from close arming may be nullified in some instances. Consequently, an accurate arming system is highly desirable if close arming is desirable.

The conclusions of this study are two-fold:

1. Arming close to the desired height of burst is highly desirable for both the Regulus and Matador missiles.

2. Then, if it is assumed that arming as close as possible to desired height of burst is desired, an accurate arming device is highly desirable for both missiles, particularly for the Matador.

C. R. McALLISTER - 5132

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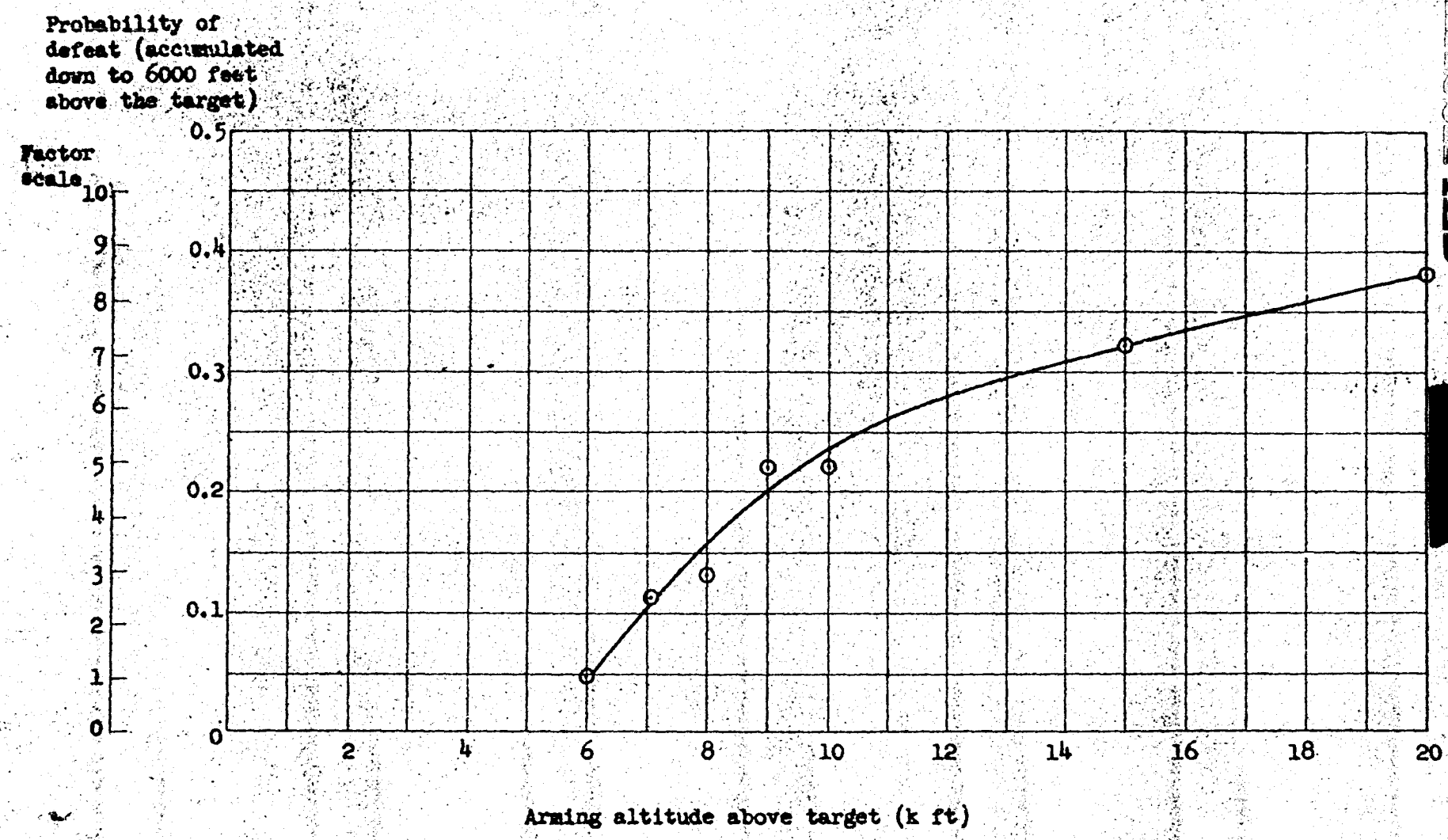

Fig. 3 -- Approximate effect of arming altitude on the accumulated probability of defeat of the XW-5/REGULUS

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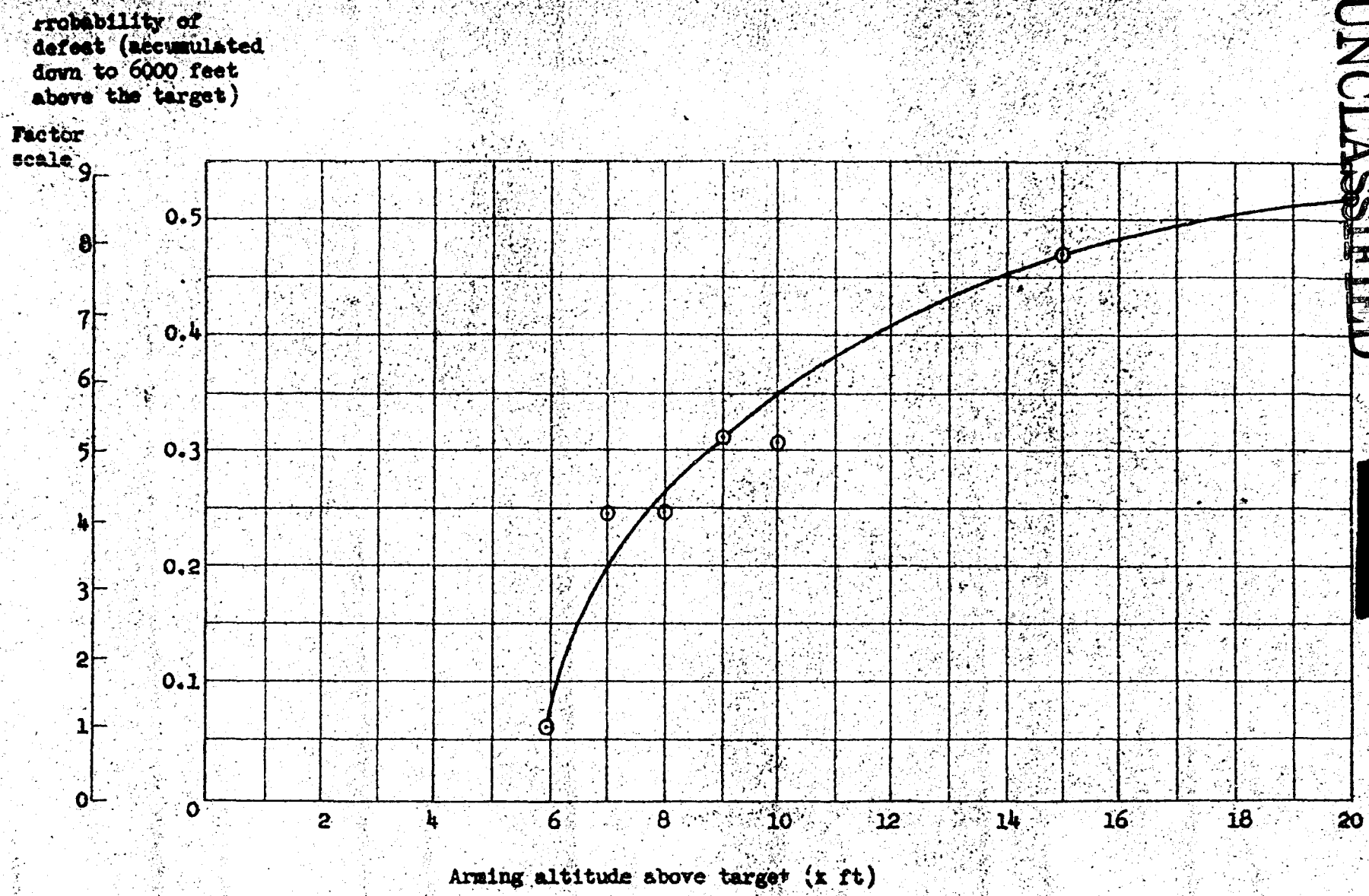

Fig. 4 -- Approximate effect of arming altitude on the accumulated probability of defeat of the XW-5/MATADOR

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REFERENCES

1. Memorandum, L. D. Smith, 1212, to W. D. Wood, 5132, Close Arming for the XW-5/Regulus and XW-5/Matador, January 3, 1955, Ref. Sym: 1212 (383).

2. Hildner, R. C., 5132, and McAllister, C. R., 5132, First Estimates of the Probabilities of Defeat for LABS Deliveries of the Mk 7 Mod 3 Bomb with the Mk 7 Mod 0 Fuze, Sandia Corporation, December 1, 1954, Technical Memorandum 235-54-51, Ref. Sym: 1923-(201), Q-44611.