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Submitted in partial fulfillment of
the requirements for the degree of

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BY A SUBMARINE LAUNCHED MISSILE

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This work is accepted as fulfilling

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ABSTRACT

The advent of the missile firing submarine has added yet another dimension to the problem of defending convoys and task groups during ocean transit. The specific situation wherein the submarine must surface to fire a relatively short range missile against a convoy of ships is considered. The model developed considers several different problem parameters. It enables the calculation of probability of detection of the submarine, probability of killing the submarine before a particular missile is fired, and the expected number of missiles that the submarine will fire. Selected results from randomly selected parameter values are also presented.

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TABLE OF SYMBOLS

δ	Ratio of radar search angle to 360 degrees
R	Assured radar detection range (miles)
T1	Time interval from submarine surfacing to firing of the first missile (minutes)
T2	Time interval between the firing of each additional missile after the first one (minutes)
n	Total number of missiles to be launched
V_c	Cruise velocity of the search aircraft (knots)
β	Total area searched by one aircraft during some time interval ($\beta \leq \alpha$)
A	Total area to be searched by the searching force (square miles)
α	Area searched by one aircraft during complete surfaced interval of one submarine ($\beta \leq \alpha$)
N	Number of search aircraft
X	The number of a particular missile launch ($X \leq n$)
V_d	Attack velocity of the aircraft (knots)
Q	$\sin(\delta\pi)$ if $0 < \delta \leq 0.5$; 1 if $0.5 \leq \delta \leq 1.0$
$\cap$	Intersection of two events
$\cup$	Union of two events
P(A)	Probability of event A occurring
P(A | B)	Probability of event A occurring, given that event B has occurred (Conditional probability)
P(D)	Probability of detection
$P_K(X)$	Probability of kill before missile number X is fired
$P_F(i)$	Probability exactly i missiles are fired
E(X)	Expected number of missiles fired by the submarine during one surfaced period
$f_X(x)$	Probability density function

TABLE OF SYMBOLS (Con't)

$F_X(x)$ Cumulative distribution function for the random variable X

Note: Units of measurement in parenthesis indicate mode of entry for Appendix C.

CHAPTER I

INTRODUCTION

1.1 Objective.

The constantly evolving process of measure and countermeasure have, in recent years, added yet another weapon to the submarine arsenal. The ability of the submarine to surface and launch an anti-shipping missile allows the attacking submarine to stand off many miles from its intended target and launch its attack. This same type of attack is also very possible against either strategic or tactical land based targets that are close to shore lines.

In order to assist operational forces in gaining an insight into the problem, and to make guidelines available that will assist in the selection of numbers of aircraft, altitudes to fly, etc., a mathematical model is presented in this paper. This same model can be used with equal facility by prospective developers of future search systems. The model presented is an adaptation, through set and probability theory, of search theory techniques developed by P. A. Morse, G. E. Kimball, and B. O. Koopman. [2,1]

Included in this paper, besides the model, are probabilities of detection and kill, and expected numbers of missiles fired for randomly selected values of the various necessary parameters.

CHAPTER II

MODEL DEVELOPMENT

2.1 Assumptions.

Several assumptions are basic to the development of this model. Some are made in light of the author's operational experience, and others are assumptions of necessity in order to release the model from human factor encumberances that cannot be readily expressed mathematically. A slightly different developmental path for the same model is presented in Appendix I, including the assumptions made and its mathematics.

The basic scenario is described as follows. Consider a convoy (task group) at sea. It is known that enemy submarines present a threat, but the presence of one or more of these submarines in the immediate area is not an established fact. Among the offensive threats that the enemy submarine force has, is the ability to surface and launch anti-shipping missiles. An airborne radar search is to be conducted about the convoy as a defensive measure.

The launching of a missile requires the submarine to remain on the surface for some finite length of time. The position of the submarine within the area described about the convoy by the missile flight radius is unknown. It is assumed that this position is equally likely to be at any point in the launching area. Factors affecting the missile launch radius, hence the area to be searched, are discussed later in the paper.

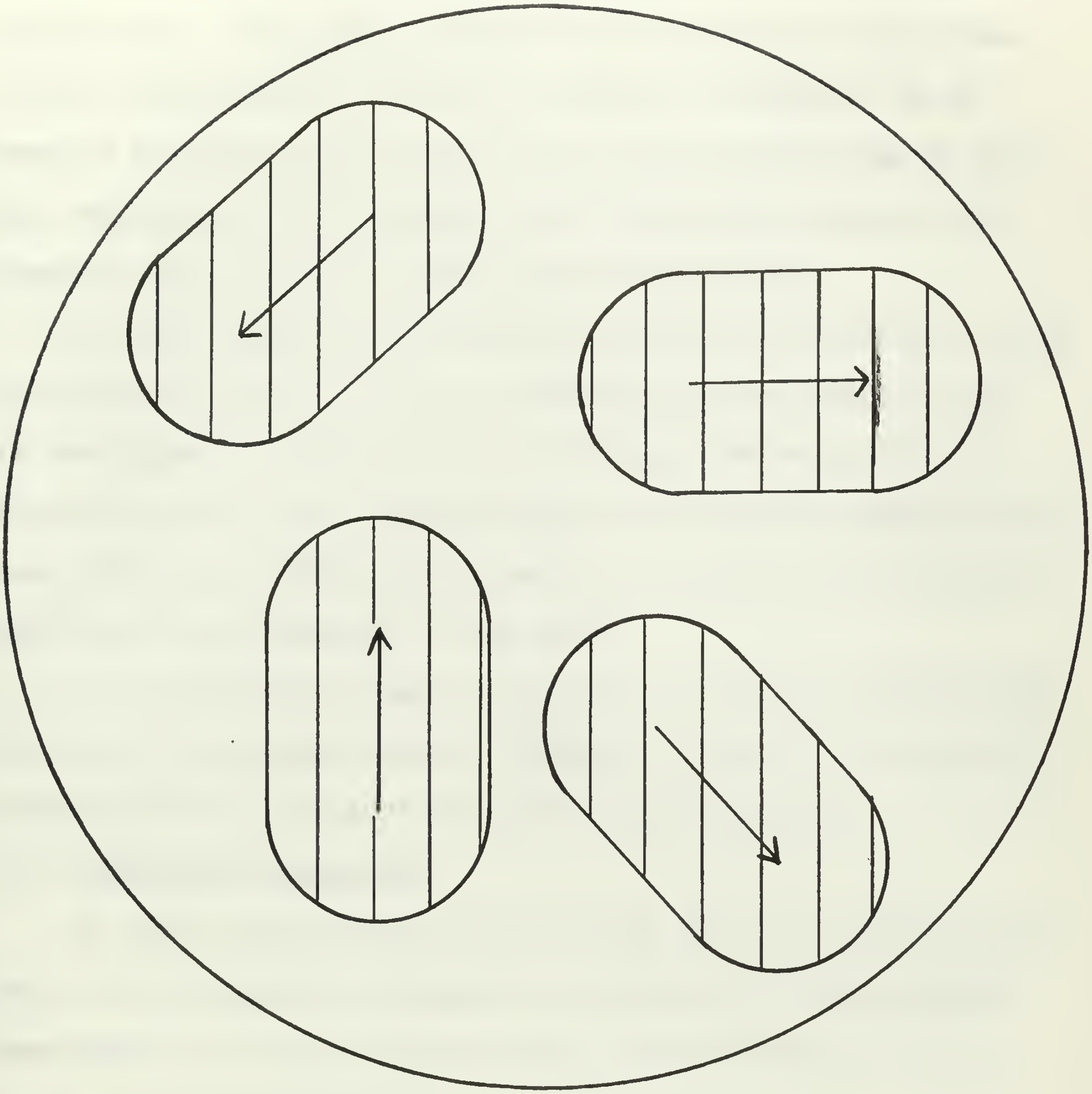
Two further assumptions about the submarine are made. First, it is

assumed that the submarine has no information as to the whereabouts of the search aircraft at the instant that he decides to surface. Second, the number of missiles to be fired is decided upon before surfacing, thereby fixing the length of the firing cycle before the actual time of surfacing. This latter restriction is not extremely unreasonable in the case where the submarine has orders to shoot at a specific time (i. e., the start of a surprise attack leading to open hostilities).

The only search weapon considered in this model is the aircraft search radar. Further, it is assumed that the paths flown by the aircraft are random within the search area. A study of Figure (1) will show this to be a reasonable assumption, even when each aircraft is assigned a search sector within the search area. Note that search sector lines could be drawn in the figure, but without them drawn the randomness becomes quite clear.

A parameter called the "Assured Radar Detection Range" is used throughout the model. This quantity is defined as the range at which the number of targets missed at lesser ranges equals the number of targets contacted at greater ranges. This has been called the "Cookie Cutter" detection range. From this definition, the probability of detecting a target passing within this range of an aircraft is one. Care in selection of the "Assured Radar Detection Range" for a particular situation is to be emphasized. This subject will be discussed later in the paper.

Once the submarine has been detected it is assumed that the only possible attack vehicle is the detecting aircraft. If any other aircraft



Scale: 1 inch = 50 miles
Search Parameters: 20 minutes at 150 knots, with 30 mile radar.

Random Search Assignment Diagram

Figure 1

were closer, this would imply that that aircraft would have made detection first. The latter assumption must be modified to some extent if more than one type of aircraft is present. In addition, the assumption is made that the firing of one or more missiles does not give away the position of the submarine, even though the presence of the submarine somewhere in the area is then obviously known.

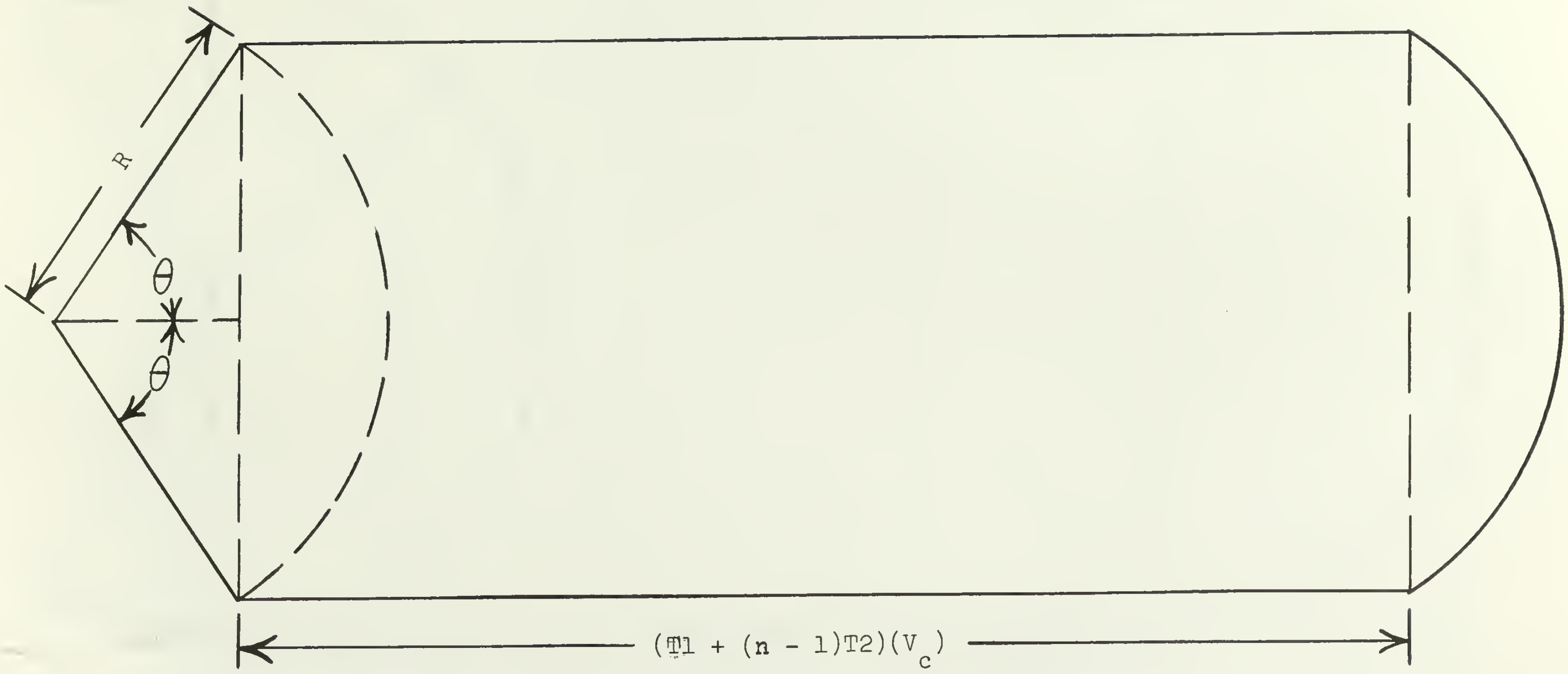
The delay involved in speed build up during the initial part of the attack phase, when the aircraft is transitioning from cruise to dash (attack) speed, is assumed offset by the ability of the aircraft to attack using short range standoff weapons such as air to surface rockets. Also, arriving in attack position implies a successful kill with probability one for the purposes of this model.

All other parameters used in this model are fairly straightforward. Either they are standard aircraft parameters, or they will have to be estimated, as in the case of the enemy submarine parameters.

2.2 Probability of detection.

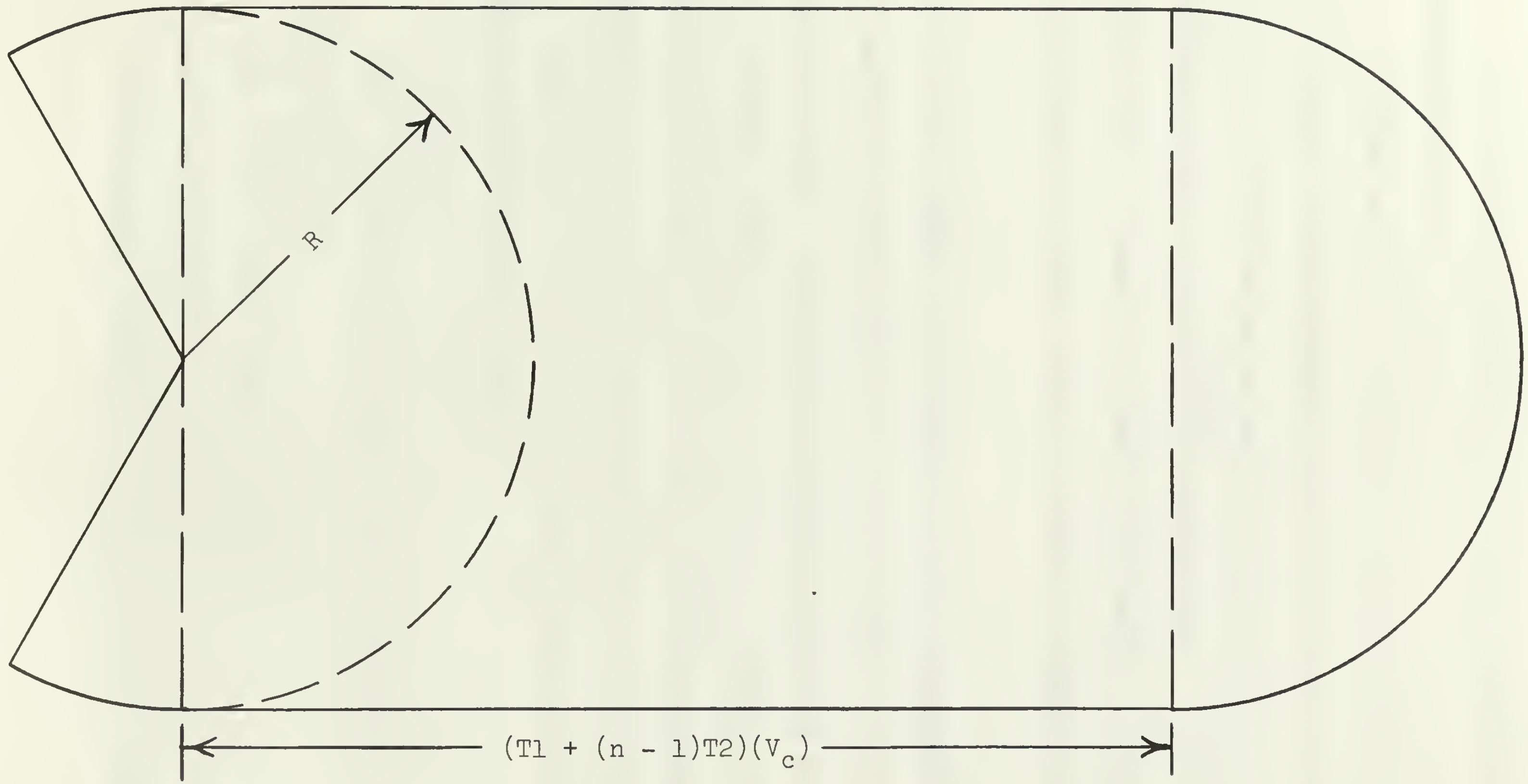
The total area searched by each aircraft while the submarine is on the surface is depicted in Figure (2) or Figure (3), depending on the sweep angle of the search radar in use. The calculation of the area involved is developed using:

a. The area searched out immediately after the submarine surfaces is approximately equal to the area covered by one sweep of the radar. This is some portion of the area of a circle, and is computed as $\delta \pi R^2$. Where δ is the fraction of a 360 degree circle covered by the search radar,



Individual Aircraft Search Area $(0 < \delta \leq 0.5)$

Figure 2



Individual Aircraft Search Area $(0.5 \leq \delta \leq 1.0)$

Figure 3

and R is the assured radar detection range.

b. In addition to the above the area covered while the submarine is on the surface is:

(time on surface) X (aircraft cruise speed) X (twice the search radius measured perpendicular to the flight path)

c. If $\delta \leq 0.5$ the search width (radius measured perpendicular to the flight path) is R sin $(\delta\pi)$, noting that $\delta\pi = \theta$. This result can easily be seen by a study of the geometry of Figure (2). If $\delta \geq 0.5$ then the search radius, as shown in Figure (3), is simply R.

d. The time spent on the surface by the submarine will be dependent upon the time it takes to fire each missile, and the number of missiles to be fired. This time is computed using the formula (T1 + (n - 1)T2). Where T1 is the time from surfacing to launching of the first missile, and T2 is the interval between successive launches. The quantity n is the total number of missiles to be fired.

e. Combining the above subparagraphs together the total area searched by each aircraft is then:

$0 < \delta \leq 0.5$

$$\alpha = \delta\pi R^2 + (T1 + (n - 1)T2)V_c R2\sin(\delta\pi) \quad (1)$$

$0.5 \leq \delta \leq 1.0$

$$\alpha = \delta\pi R^2 + (T1 + (n - 1)T2)V_c 2R \quad (2)$$

To obtain the probability of detection of a submarine by N search aircraft the development used by P. A. Morse and G. E. Kimball is

followed. [2] In this development the random search postulated previously is essential. In addition any overlap of search effort is assumed to occur in a random manner.

Consider the instant when the total area searched since the submarine is surfaced is β. The probability that the submarine is not detected prior to this instant is denoted by $P(0,\beta)$. Next, increase the area searched by $d\beta$. This increase being positioned at random within A, the total area to be searched. The probability that the submarine will not be detected in $d\beta$ is $1 - d\beta/A$. The probability that no contact is made while $\beta + d\beta$ is being searched is then denoted by $P(0,\beta + d\beta)$. Then:

$$P(0,\beta + d\beta) = \left(1 - \frac{d\beta}{A}\right) P(0,\beta)$$

$$\frac{P(0,\beta + d\beta) - P(0,\beta)}{P(0,\beta)} = -\frac{d\beta}{A}$$

$$\frac{d\,P(0,\beta)}{P(0,\beta)} = -\frac{d\beta}{A}$$

Yielding the differential equation:

$$d\,P(0,\beta) = -\frac{d\beta}{A} P(0,\beta) \qquad (3)$$

Solving this differential equation, with the boundry condition $P(0,0) = 1$, results in:

$$P(0,\beta) = e^{-\beta/A} \qquad (4)$$

Therefore, since the total area searched in the actual problem is denoted $N\alpha$, the probability of detection of a submarine during its total on surface period is:

$$P(D) = 1.0 - e^{-\frac{N\alpha}{A}} \qquad (5)$$

2.3 Probability of detection of at least one submarine in a group.

There are three possible surfacing situations for the multiple submarine problem. First, consider the case where two (or more) submarines surface simultaneously. As will be further elaborated on later, this would seem to be the most likely of the three cases. The probability of detection of at least one of M submarines is:

P(detection of at least one of M) =

$$= 1.0 - \binom{M}{0}\left(1.0 - e^{-\frac{N\alpha}{A}}\right)^{0}\left(e^{-\frac{N\alpha}{A}}\right)^{M}$$

$$= 1.0 - \left(e^{-\frac{N\alpha}{A}}\right)^{M}$$

$$= 1.0 - e^{-\frac{NM\alpha}{A}} \qquad (6)$$

The second case to be considered is the situation where the submarines surface at disjoint intervals (no two or more on the surface at the same time). This is clearly the original problem stated and may be handled with the theory initially developed.

The last case involves different surfacing times and overlapping surfaced intervals. Probabilities for this situation are calculable only for each individual case. In addition, this situation does not seem as operationally appealing as the previous cases. In this case the detection of one submarine would only serve to alert the convoy as to the presence of submarines in the area, hence making succeeding

attacks by succeeding submarines more risky to those submarines.

2.4 Probability of kill before the X^{th} missile is fired.

Now that the probability of detecting a surfaced submarine is calcuable, the next logical question concerns what can be done about the detected submarine. Especially, what can be done before the submarine can fire his missile(s).

In order to develop this part of the model a digression is necessary for background purposes. This development uses the methods demonstrated by E. Parzen. [3]

Consider four events A, B, C, and D.

$$
\begin{aligned}
P(A\cap(B\cup C)\cap D) &= P\left\{\left[(A\cap B)\cup(A\cap C)\right]\cap D\right\} \\
&= P\left[(A\cap B\cap D)\cup(A\cap C\cap D)\right] \\
&= P(A\cap B\cap D) + P(A\cap C\cap D) - P(A\cap B\cap D\cap A\cap C\cap D) \\
&= P(A\cap B\cap D) + P(A\cap C\cap D) - P(A\cap B\cap C\cap D) \qquad (7)
\end{aligned}
$$

Next let:

A = The event the submarine is in some searched area β, designated detection in the following.

B = The event that the submarine is in the initial sweep of some aircraft's radar upon surfacing, designated $\odot$ in the following.

C = The event that the submarine is in the balance of a particular area of size β, designated $\boxdot$ in the following.

D = The event the submarine is killed, designated kill in the following.

Using the above definitions the following results are to be noted.

a. $B \cup C = \odot + \boxdot = \beta$

b. $B \cap C = \phi$ (empty set)

Using result (b), term number three of equation (7) can be handled thusly:

$$P(A \cap B \cap C \cap D) = P(A \cap \phi \cap D) = P(\phi) = 0 \tag{8}$$

Using the above definitions and the result shown in equation (8), equation (7) can be rewritten in the form:

$$P\left[\text{detection} \cap (\text{detection in } \odot \cup \text{detection in } \boxdot\,) \cap \text{kill}\right]$$

$$= P(\text{detection} \cap \text{detection in } \odot \cap \text{kill}) +$$

$$P(\text{detection} \cap \text{detection in } \boxdot \cap \text{kill})$$

$$= P(\text{detection}) \cdot P(\text{detection in } \odot \mid \text{detection}) \cdot P(\text{kill} \mid \text{detection} \cap \text{detection in } \odot) + P(\text{detection}) \cdot P(\text{detection in } \boxdot \mid \text{detection}) \cdot P(\text{kill} \mid \text{detection} \cap \text{detection in } \boxdot) \tag{9}$$

The following results concerning equation (9) follow directly from the previous definitions.

a. detection $\cap$ detection in $\odot$ = detection in $\odot$

b. detection $\cap$ detection in $\boxdot$ = detection in $\boxdot$

c. detection $\cap$(detection in $\odot \cup$ detection in $\boxdot$) = detection

Using these results, equation (9) can then be rewritten in the form:

$$P(\text{detection} \cap \text{kill}) = P(\text{detection}) \cdot Z \tag{10}$$

Where:

$$Z = P(\text{detection in } \odot \mid \text{detection}) \cdot P(\text{kill} \mid \text{detection in } \odot) + P(\text{detection in } \boxdot \mid \text{detection}) \cdot P(\text{kill} \mid \text{detection in } \boxdot) \tag{11}$$

Since:

$$P(\text{kill} \cap \text{detection}) = P(\text{kill} \mid \text{detection}) \cdot P(\text{detection}) \tag{12}$$

from the laws of probability, equation (11) or Z is actually the

$P(\text{kill} \mid \text{detection})$.

In order to uncondition equation (11) we again turn to probability theory. Consider the two events F and G.

$$P(F) = P(F \cap G) + P(F \cap G^c)$$
$$= P(F \mid G) \cdot P(G) + P(F \mid G^c) \cdot P(G^c) \quad (13)$$

Where G^c is defined as G complement. Next we make the following definitions.

F = The event the submarine is killed, designated kill in the following.

G = The event the submarine is in a searched area, designated detection in the following.

We then arrive at:

$$P(\text{kill}) = P(\text{detection}) \cdot P(\text{kill} \mid \text{detection}) + P(\text{no detection}) \cdot P(\text{kill} \mid \text{no detection}) \quad (14)$$

From a practical standpoint the $P(\text{kill} \mid \text{no detection})$ must be equal to zero. Therefore:

$$P_K(X) = P(\text{kill before the } X^{th} \text{ missile is fired})$$
$$= P(\text{detection before the } X^{th} \text{ missile is fired}) \cdot Z \quad (15)$$

Where Z is as defined in equation (11).

The next step in the development is to explicitly define all of the terms of equation (15) in terms of the measureable parameters. The probability of detection term is similar to that expressed in equation (5), with the only change being the substitution of the X^{th} missile for n in equation (1) or equation (2), whichever is appropriate.

Examining equation (11) we find the first term of Z to be P(detection in $\odot$ | detection). This is equivalent to the event that the surfacing submarine is within range R of an aircraft when it (the submarine) reaches the surface, given the fact that the submarine is in one of the searched areas β. (See Figure (2) or Figure (3), whichever is appropriate.) Since the submarine is equally likely to be in any part of β (see initial assumptions), this term can be represented as:

$$P(\text{detection in } \odot \mid \text{detection}) = \frac{\text{area in } \odot}{\text{total area in } \beta}$$

$$= \begin{cases} \dfrac{\delta \pi R^2}{\delta \pi R^2 + 2RV_c \sin(\delta \pi)(T1 + (X - 1)T2)} & 0 < \delta \leq 0.5 \\ \\ \dfrac{\delta \pi R^2}{\delta \pi R^2 + 2RV_c (T1 + (X - 1)T2)} & 0.5 \leq \delta \leq 1.0 \end{cases} \tag{16}$$

The next term to be considered is P(detection in $\boxdot$ | detection). This is clearly 1.0 - (the applicable portion of equation (16)).

The third term to be considered is the P(kill | detection in $\odot$). The given event in this probability statement implies that the submarine is detected as it surfaces, and will have a period of time equal to (T1 +(X - 1)T2) remaining on the surface before the X^{th} missile is fired. The distance that the aircraft can travel in this period is then (T1 + (X - 1)T2) V_d. If this distance is greater than or equal to R the aircraft will always be able to get to attack position. Therefore, P(kill | detection in $\odot$) will be one in this situation.

If the distance the aircraft can travel is less than R there will

be some percentage of contacts that, even though detected, will not come under attack. Again using the assumption of uniform distribution of contacts, the circular uniform distribution applies within the circle, and is of the form:

$$f_r(r') = \frac{2\delta\pi \ r\,dr}{\delta\pi R^2} = \frac{(2r)dr}{R^2} \tag{17}$$

$$F_r((T1 + (X - 1)T2)V_d) = \int_0^{(T1 + (X - 1)T2)V_d} \frac{(2r)\,dr}{R^2}$$

$$= \left(\frac{(T1 + (X - 1)T2)V_d}{R}\right)^2 \tag{17a}$$

Combining the information from the preceding two paragraphs:

$$P(\text{kill} \mid \text{detection in } \odot) = \begin{cases} \left(\frac{(T1 + (X - 1)T2)V_d}{R}\right)^2 & (T1+(X-1)T2)V_d \leq R \\ 1 & (T1 + (X - 1)T2)V_d \geq R \end{cases} \tag{18}$$

The last term needed is P(kill | detection in ⊡). Detection in the square itself implies two restrictions. First, detection will be made at range R, and second, detection is made after some period of time has elapsed since the submarine surfaced. If $(T1 + (X - 1)T2)V_d$ is less than R the aircraft will never be able to attack the submarine before missile X is fired. Therefore, the P(kill | detection in ⊡) is zero for this case.

If $(T1 + (X - 1)T2)V_d$ is greater than or equal to R, then there will

be some period after the time of initial surfacing that the aircraft will be able to get into attack position. Again under the assumption of equally likely submarine position in the square, there exists equally likely detection times given the fact that detection will be made. Defining T_t as the elapsed time the submarine has been on the surface when detected (a uniform random variable), we have:

$$f_{T_t}(t') = \frac{1}{(T1 + (X - 1)T2)} \qquad 0 \le t' \le (T1 + (X - 1)T2) \tag{19}$$

Examination of the physical situation indicates that an attack will be possible only when the total on surface time minus the elapsed time on the surface when detected is greater than the time needed to get to the target for attack. This is formulated as:

$$\left[(T1 + (X - 1)T2) - T_t\right] V_d \geq R \tag{20}$$

$$(T1 + (X - 1)T2)V_d - R \geq T_t V_d \tag{20a}$$

$$0 < T_t \leq \frac{V_d(T1 + (X - 1)T2) - R}{V_d} \tag{20b}$$

The period between the upper and lower bounds on T_t expressed in relation (20b) could be called the useful time for detection. Using relations (19) and (20b):

$$P\left[T_t \leq \frac{V_d(T1 + (X - 1)T2) - R}{V_d}\right] = F_{T_t}\left(\frac{V_d(T1 + (X - 1)T2) - R}{V_d}\right)$$

$$= \int_0^{\frac{V_d(T1 + (X - 1)T2) - R}{V_d}} \frac{1}{(T1 + (X - 1)T2)}\, dT_t = 1.0 - \frac{R}{(T1 + (X - 1)T2)V_d} \tag{21}$$

Multiplying and combining terms, and defining:

$$Q = \begin{cases} \sin(\delta\pi) & 0 < \delta \leq 0.5 \\ 1 & 0.5 \leq \delta \leq 1.0 \end{cases} \tag{22}$$

this development shows the probability of kill before missile X is fired to be:

$$P_K(X) = \begin{cases} \left[1 - e^{-\frac{N}{A}(\delta\pi R^2 + 2RV_c(T1 + (X - 1)T2)Q)}\right] \cdot \left[\dfrac{\delta\pi(T1 + (X - 1)T2)^2 V_d^{\,2}}{\delta\pi R^2 + 2RV_c(T1 + (X - 1)T2)Q}\right] & \text{(23a)} \\ \left[1 - e^{-\frac{N}{A}(\delta\pi R^2 + 2RV_c(T1 + (X - 1)T2)Q)}\right] \cdot \left[1 - \dfrac{2RV_cQ}{(\delta\pi R + 2V_c(T1 + (X - 1)T2)Q)V_d}\right] & \text{(23b)} \end{cases}$$

Equation (23a) is used when $(T1 + (X - 1)T2)V_d \leq R$, and equation (23b) is used when $(T1 + (X - 1)T2)V_d > R$.

2.5 <u>Expected number of missiles fired</u>.

In order to be able to make this calculation the probabilities of the submarine firing exactly one missile, exactly two missiles, ... , through exactly n missiles are needed. At the present stage the model has yielded the probability of killing the submarine <u>before</u> missile X is fired. The event that exactly one missile is fired is disjoint from any other firing event, as is the event that exactly two missiles are fired disjoint from any other firing event, etc. With these considerations in mind we proceed as follows:

$P_K(0)$ = P(0 missiles are fired)

$P_K(1)$ = P(0 missiles are fired, or one missile is fired)

. (24)

.

$P_K(n)$ = P(0 or 1 or 2 or . . . . . or n-1 missiles are fired)

Then using the set of equation (24):

$P_K(2) - P_K(1)$ = P(one missile is fired)

$P_K(3) - P_K(2)$ = P(two missiles are fired)

. (25)

.

$P_K(n) - P_K(n-1)$ = P(n - 1 missiles are fired)

The set of equations (25) can be written in the general form:

$$P_F(i) = P_K(i + 1) - P_K(i) \qquad i = 1, 2, \ldots, n - 1 \tag{25a}$$

The probability of the submarine firing exactly n missiles can then be computed by summing the (n - 1) equation (25a)'s and subtracting the result from one.

$$P_F(n) = 1 - \sum_{i=1}^{n-1} P_F(i) = 1 - P_K(n) \tag{26}$$

The expected number of missiles fired may now be formulated in the normal way for discrete probabilities.

$$\begin{aligned} E(X) &= 0\, P_F(0) + 1\, P_F(1) + 2\, P_F(2) + \ldots\ldots + n\, P_F(n) \\ &= 0\, P_K(1) + 1\, (P_K(2) - P_K(1)) + \ldots + n\, (1 - P_K(n)) \\ &= n - P_K(1) - P_K(2) - \ldots\ldots - P_K(n) \\ &= n - \sum_{i=1}^{n} P_K(i) \end{aligned} \tag{27}$$

CHAPTER III

CONCLUSIONS

3.1 General results.

Representative values of probabilities of detection, probabitities of kill, and expected numbers of missiles fired are presented in Appendix B. The parameters used in this appendix were chosen at random from the many combinations of numbers used during development of the model. All computations were done using a digital computer.

The manner in which the probability tables are presented in the appendix clearly shows two very interesting results of the model. The first of these is evident when, for a given set of fixed heading parameters (aircraft and submarine capabilities, and area to be searched), any range R is picked. Following across the line that was chosen in the tables it is evident that the return per added aircraft, in terms of increased probabilities, diminishes as the number of aircraft is increased. This of course is a characteristic of exponential curves, and is to be expected here in view of the development.

A study of the $P_K(X)$'s, for X equal one and two especially, illustrates the second of the above results. Again using fixed heading parameters, but this time holding N constant and changing R, this study reveals that in some cases the probabilities of kill start to increase with increasing R, reach a maximum, and from there on will diminish.

In order to explain this phenomenon, consider the circular shaped

area that the search aircraft's radar sweeps out during each sweep. When R is increased, the area searched is increased as a function of R squared, hence significantly increasing the total area searched. This also increases the probability of detection. If the aircraft could reach, and attack, all of the targets it detects before the missile of interest can be fired, this would imply a steadily increasing $P_K(X)$. This is in fact the case for reasonable, tactically interesting sets of parameters. On the other hand, if R is extended past the distance of possible travel by the aircraft before the missile of interest is launched, two events take place. First, the probability of reaching all targets detected in the initial sweep of the radar after the submarine surfaces is now less than one. Second, the aircraft will be unable to reach any targets detected after the surfacing time in order to stop the missile launch of interest. Thus, considering the rate of increase in searched area with an increase in R, there exists a higher and higher probability that a submarine detected will be outside attack range. The above facts then give an intuitive reason why the $P_K(X)$'s do reach maximum values. After testing many sets of parameters that could be tactically interesting, the author found that the maximum occurred at the point where $R = (T1 + (X-1)T2)V_d$.

A partial proof of the above will be sketched through a combination of numerical and analytical techniques as follows:

a. Proof that equations (23a) and (23b) are in fact equal at $R = (T1 + (X - 1)T2)V_d$, thus establishing continuity at this point.

b. Proof that equation (23a) is monotone decreasing for:

$$(T1 + (X - 1)T2)V_d \le R < \infty. \qquad (28)$$

c. Statement of a result about the form of equation (23b), that was observed from many numerical results, for:

$$0 < R \leq (T1 + (X - 1)T2)V_d. \tag{29}$$

At this point, in order to simplify the notation, the quantity T will be used to refer to (T1 + (X - 1)T2).

A comparison of the two parts of equation (23) shows that step (a) above requires that:

$$\left[\frac{\delta \pi T^2 V_d^{\,2}}{\delta \pi R^2 + 2RV_c TQ}\right] = \left[1 - \frac{2RV_c Q}{(\delta \pi R + 2V_c TQ)V_d}\right]$$

at the point where $R = TV_d$. Therefore, upon substitution we get:

$$\left[\frac{\delta \pi R^2}{\delta \pi R^2 + 2RV_c TQ}\right] = \left[\frac{(\delta \pi R + 2V_c TQ)\frac{R}{T} - 2RV_c TQ}{(\delta \pi R + 2V_c TQ)\frac{R}{T}}\right]$$

$$\frac{\delta \pi R^2}{\delta \pi R^2 + 2RV_c TQ} = \frac{\delta \pi R^2}{\delta \pi R^2 + 2RV_c TQ} \tag{30}$$

The proof of step (b) is effected by examination of the first partial derivative of equation (23a) with respect to R. After some algebraic manipulation this is:

$$\frac{\partial P_K(X)}{\partial R} = K\left[1 + \frac{N}{A}(\delta \pi R^2 + 2RV_c TQ) - e^{\frac{N}{A}(\delta \pi R^2 + 2RV_c TQ)}\right] \tag{31}$$

Where:

$$K = \frac{e^{\frac{N}{A}(\delta \pi R^2 + 2RV_c TQ)}\,(2\delta \pi R + 2V_c TQ)(\delta \pi T^2 V_d^{\,2})}{(\delta \pi R^2 + 2RV_c TQ)^2} \tag{31a}$$

This derivative must be less than zero for all values of R greater

than TV_d in order for the slope of the $P_K(X)$ curve to be negative in this range. Examination of the constant term K shows that this is always a positive constant. Therefore, the term in the brackets in equation (31) must be negative for this proof to work. A series expansion of the exponential term yields:

$$e^{\frac{N}{A}(\delta \pi R^2 + 2RV_c TQ)} = 1 + \frac{N}{A}(\delta \pi R^2 + 2RV_c TQ) + \frac{\frac{N}{A}(\delta \pi R^2 + 2RV_c TQ)^2}{2\,!} + \ldots \qquad (32)$$

Substituting equation (32) into equation (31) and performing the subtraction leaves:

$$\frac{\partial P_K(X)}{\partial R} = K \left\{ - \left[\frac{\left(\frac{N}{A}(\delta \pi R^2 + 2RV_c TQ)\right)^2}{2\,!} + \frac{\left(\frac{N}{A}(\delta \pi R^2 + 2RV_c TQ)\right)^3}{3\,!} + \ldots \right] \right\} \qquad (33)$$

Equation (33) is clearly negative for all allowable values of R under consideration, thus completing the proof of this step.

Lastly step (c) is somewhat more difficult. Again a study of the first partial derivative of equation (23b) would seem to be the desired path of approach. The idea being to prove this derivative positive for the desired range of R. This derivative is (again after some manipulation):

$$\frac{\partial P_K(X)}{\partial R} = \left\{ \frac{2}{(\delta \pi R + 2V_c TQ)V_d \, e^{\frac{N}{A}(\delta \pi R^2 + 2RV_c TQ)}} \right\} \cdot$$

$$\left\{ \frac{N}{A}(\delta\pi R + V_c TQ)(\delta\pi R V_d + 2V_c Q(TV_d - R)) + \left(1 - e^{\frac{N}{A}(\delta\pi R^2 + 2V_c RTQ)}\right)\left(\frac{2T(V_c Q)^2}{\delta\pi R + 2V_c TQ}\right)\right\} \qquad (34)$$

Equation (34) is quite complicated, and any definitive analytical results are very hard to obtain. The equation will break down in many forms, some parts of which are clearly positive, other parts clearly negative, but in no case found were any of the terms found sufficiently alike so that a statement about their relative magnitudes could be made. In view of this difficulty many computer calculations were made. Many widely varying combinations of parameters were used in these calculations. All computations showed that equation (23b) did reach a maximum, and then start decreasing. In all cases where tactically interesting sets of parameters were used this maximum was found to be at ranges greater than TV_d, so that when the maximum was reached this equation did not apply to the problem.

The considerations involved in selecting "tactically interesting" parameter combinations were avoidance of unreasonably long on surface times for the submarine, use of so many aircraft and such large R's that $N\alpha$ was many times larger than A, etc.

The desired conclusion then is that by using reasonable sets of parameters the maximum $P_K(X)$'s will be at ranges equal to TV_d. If unusual aircraft parameters are to be used care must be exercised in the selection of areas to be searched, etc., in order to derive meaningful

results from the model.

3.2 Parameter relationships.

Following up on the discussion in the latter part of the previous section, one of the most striking parameter relationships occurs in the $P_K(X)$ equations. Of particular note is the fact, that when the killing of the submarine by the detecting aircraft is desired, there is no benefit in increasing R above the range equal to $(T1 + (X - 1)T2)(V_d)$. In fact, ground is lost when R is greater than this limit. This has an affect on search altitude selections, and radar scope range settings, since these factors directly affect R. Furthermore, the designer of future aircraft has a handle on the relationship between R and V_d for this type of problem.

The area to be searched, when circular in shape, has a tendency to become very large, even with seemingly small increases in circle radius. Again, the area is a function of the radius squared. An unnecessary increase in the area to be searched can drastically reduce the effectiveness of the total search.

Noting that the increase in the area actually searched by each aircraft is a function of both R and R squared, it becomes apparent that for a plain search problem the more range the better. An increase of just five miles, say from 20 to 25 miles, makes a 56% increase in the area covered by one sweep of the radar.

3.3 Tactical implications.

While this model enables the calculation of probabilities of detection and kill, and the expected numbers of missiles fired by the

submarine for specific sets of parameters, this is clearly not the whole picture.

As an example, the selection of the size of the area to be searched is quite important. Should the radius of the circle in question be equal to the maximum missile travel distance? This author submits that the answer to this question is no. Besides this maximum launch range the planner should take into account possible range maximums at which the submarine might detect the convoy, disposition of the ships in the convoy, estimates of the reliability of the enemy missile (if available), possible other methods of attacking a detected submarine, among other factors, By making rational estimates of the above factors the search probability can probably be raised, as might be the kill probabilities.

The "Assured Radar Detection Range" is a key quantity in this model, hence a good understanding of how values for it are arrived at is necessary. Many variables are involved. These include sea state, operator training and proficiency, proximity of other small non-submarine targets, flight altitude, meteorological conditions, and type of radar installed in the aircraft. It is stressed that this quantity is the range at which the total number of targets missed at lesser ranges equals the total number of targets detected at greater ranges. Care should be exercised in order to avoid overestimating this parameter.

3.4 Model extensions to similar situations.

Two situations that bear directly on this problem were not considered in this development due to their necessary introduction of some human factors variables. The first is the case where the submarine delays

surfacing due to his ECM detecting a search aircraft's radar. The other is the case where the submarine surfaces, fires part of his desired launch of missiles, and then decides to submerge for the same reason enumerated immediately above. Both of these cases are very real possibilities, and consideration should be given them in the planning phase of a search operation. Since the ECM detection range of a radar is greater than the detection range on the submarine by the aircraft radar, these cases have some interesting ramifications. Among these is the calculation of the area covered by electronic emmissions that are of such strength as to dissuade the submarine from surfacing for some given period of time. This type of situation could delay missile launches, hence causing problems in the fire control solution. Also, using a random search will cause the submarine to be more cautious, even after the present aircraft passes (assuming an ECM detection), since the submarine does not know when that aircraft may turn and recover some given position, or even another aircraft might pass through the same area. Detailed extensions in these areas would be of great value, but are beyond the scope of this paper.

Another obvious extension of this model is to the case of a search for a missile launching submarine on station off a coast line. Justification would be very difficult for the assumption of a uniform distribution of targets along an entire coast. This problem can be resolved by selecting areas with high probabilities of containing submarine missile launch stations, and then assuming a uniform distribution of targets throughout each individual area.

Applications of the basic probability of detection model presented can be extended to the search for trawlers, Search and Rescue operations, or for any situation that meets the assumptions made in the development of the model. When considering targets that are continuously on the surface, α then becomes the total area searched by each aircraft while on station.

Last to be considered is the case of multiple types of aircraft involved in the same search. In this case an α must be calculated for each aircraft, based on its parameters. These α's are then summed. The probability of detection computations are then straight forward. Some problems are encountered in the probability of kill computations. There exists the chance that an aircraft with a long range radar might detect the target, and there is an aircraft with a shorter range radar closer to the target than the detecting aircraft. In this situation the possibility of mutual assistance must be considered. The various factors involved in equations (23a) and (23b) will also have to be weighted for the different types of aircraft. This could be done by using the circle and square technique of section 2.4. This latter path is necessitated by the possible differing dash speeds of the aircraft involved.

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APPENDIX A

COMPARISON OF TWO RANDOM SEARCH MODELS

Another approach to the search phase of this problem is presented by B. O. Koopman. [1] This development will be outlined in this appendix, and some interesting comparisons pointed out.

Three assumptions are made in this development. They are:

a. The target's position is uniformly distributed in the area to be searched.

b. The observer's path(s) is (are) random in A, in the sense that it (they) can be thought of as having its (their) different (not too near) portions placed independently of one another in A.

c. On any portion of path which is small relative to the total length of path, but decidedly larger than the range of possible detection, the observer always detects the target within the lateral range R, and never beyond.

All parenthetical expressions in the foregoing, except for "not too near", have been inserted by this author for the purpose of clarifying analogies that will be drawn later.

The model development itself proceeds by dividing the total path length (call it L) into m equal segments. The probability of failing to detect the submarine, during its entire on surface period, is then the product of the detection failure probabilities for each segment.

$$P(\text{fail to detect the submarine}) = (1.0 - \frac{\alpha}{A})^m \qquad (A1)$$

$$P(\text{detection}) = 1.0 - (1.0 - \frac{\alpha}{A})^m \qquad \text{(A2)}$$

As m increases equation (A2) can be approximated by:

$$P(\text{detection}) = 1.0 - e^{-\frac{m\alpha}{A}} \qquad \text{(A3)}$$

for large m. It is immediately noted that equation (A3) is precisely the result obtained in the previous formulation of the problem.

It would seem intuitively appealing to let the number of segments m, be equal to N, the number of search aircraft in the problem. The desire being to tie m, in some simple manner, to some parameter in the previous formulation. One also desires that the turns necessary for each individual aircraft be kept to a minimum so that the probability of detection on each leg is as close to α/A as possible.

A problem arises with assumption (c) when large (40 mile plus) radar detection ranges are used. For example, if the submarine is on the surface for 20 minutes, and the aircraft flies 50 miles during this time, it is clear that assumption (c) is not fulfilled.

A comparison between the results of the exponential and equation (A2) formulations was made using a digital computer for the computations. A selected portion of these results is displayed as Table A1.

A few words of explanation about the selection of the particular values presented in Table A1 follow. Many combinations of parameters were run through the computer, from which the results presented in the table are representative. It was discovered that all parameter combinations yielded the same general trends, which can be noted from the entries in

TABLE 1A

Constant Parameters:

$\delta = 1.0$ V_c = 150 knots T1 = T2 = 5.0 minutes n = 4 missiles

All areas are circles with radii = 50 (50) 200 miles

First row is exponential result. Second row is $1 - (1 - \frac{\alpha}{A})^N$ result.

R \ N	1	2	3	4	5	6	7	8	9	10
	A = 7850 square miles									
10	.154 .167	.285 .307	.395 .423	.488 .520	.567 .600	.634 .667	.690 .723	.738 .769	.778 .808	.813 .840
20	.340 .415	.564 .658	.712 .800	.810 .883	.874 .931	.917 .960	.945 .977			
30	.524 .742	.773 .934	.892 .983							
40	.683 ****									
50	.806					**** α/A > 1.0				
60	.890 ****									
	A = 31,400 square miles									
10	.041 .042	.080 .082	.118 .120	.154 .157	.189 .193	.222 .226	.254 .259	.285 .290	.314 .319	.342 .348
20	.099 .104	.187 .197	.267 .280	.340 .355	.405 .422	.463 .482	.516 .535	.564 .584	.607 .627	.646 .665
30	.169 .186	.310 .337	.427 .460	.524 .560	.605 .642	.672 .708	.727 .762	.773 .807	.812 .842	.844 .872
40	.250 .288	.437 .492	.578 .638	.683 .742	.762 .816	.822 .869	.866 .907			
50	.336 .409	.559 .651	.707 .794	.806 .878						
60	.424 .551	.668 .799	.809 .910							

TABLE 1A (Con't)

R \ N	1	2	3	4	5	6	7	8	9	10
A = 70,650 square miles										
10	.018	.037	.054	.072	.089	.106	.122	.138	.154	.170
	.019	.037	.055	.072	.090	.107	.123	.140	.156	.171
20	.045	.088	.129	.168	.206	.242	.276	.308	.340	.369
	.046	.090	.132	.172	.210	.247	.281	.314	.346	.376
30	.079	.152	.219	.281	.338	.390	.439	.483	.524	.562
	.083	.158	.228	.291	.350	.403	.453	.498	.539	.577
40	.120	.226	.318	.400	.472	.535	.591	.640	.683	.721
	.128	.239	.336	.421	.495	.560	.616	.665	.708	.745
50	.166	.305	.421	.517	.597	.664	.720	.767	.806	.838
	.182	.331	.453	.552	.634	.700	.755	.799	.836	.866
60	.217	.387	.521	.625	.706	.770	.820			
	.245	.430	.570	.675	.755	.815	.860			
A = 125,600 square miles										
10	.010	.021	.031	.041	.051	.061	.071	.080	.090	.099
	.011	.021	.031	.041	.051	.061	.071	.081	.090	.100
20	.026	.051	.075	.099	.122	.144	.166	.187	.208	.228
	.026	.051	.076	.100	.123	.146	.168	.190	.211	.231
30	.045	.089	.130	.169	.207	.243	.277	.310	.341	.371
	.046	.091	.133	.173	.211	.248	.283	.316	.348	.378
40	.069	.134	.194	.250	.302	.350	.395	.437	.476	.513
	.072	.139	.201	.258	.311	.361	.407	.449	.489	.526
50	.097	.185	.264	.336	.401	.459	.512	.559	.602	.641
	.102	.194	.277	.351	.417	.477	.530	.578	.622	.660
60	.129	.241	.339	.424	.498	.563	.619	.668	.711	.748
	.138	.257	.359	.447	.524	.589	.646	.695	.737	.773

the table. Where no entry appears in the table, that particular situation was considered to be tactically uninteresting. This event occurred when the total area searched by all aircraft was considerably larger than the total area to be searched. In all cases though, at least the values for N equal one are given.

Three definite trends are evident from the tabled results.

a. Given A and N fixed, the P(D)'s differ by greater and greater amounts as R is increased.

b. If R and N are fixed, the difference in the P(D)'s decreases as A increases.

c. Varying A and R will produce convergence, divergence, or some combination of the two for the range of N that is tactically interesting. It should be kept in mind that the differences referred to above are between the two different methods of formulating the problem.

Next some of the causes for these trends are explored. In the process a metric will be developed for when to use which form of the P(D) equation.

The reason behind trend (a) is related to assumption (c). Note that as R increases this assumption fits the actual situation less and less. In fact, rather than the high probability of a straight course that is desired for each aircraft, as R increases the probability that an aircraft will have to turn increases. A study of Figure (1) illustrates this point.

Trend (b) can also be explained by the lessened probability of turn for each aircraft as A increases. When an aircraft turns there must be

some overlap (i. e., less total area searched), hence the probability of detection on each non straight leg is less than α/A.

The convergence/divergence problem in trend (c) is a function of the relative sizes of α/A and N. The major point to note is that in no case, considering the range of N that is tactically feasible, is a clear cut case of close convergence established.

From all of the foregoing two important points should be retained. First, each time assumption (c) fails to hold a lesser probability of detection is implied. Secondly, the exponential formulation always provides this lesser probability. In the case of large A and relatively small N (i.e., turns by each individual aircraft are less likely), the agreement between the two formulations is very close.

All of the above points to the exponential formulation for probability of detection calculations. It is to be noted that the two developments ended up in essentially the same place, but that the latter method deviates somewhat from its assumptions, thus making the method somewhat questionable.

APPENDIX B

SAMPLE RESULTS

Selected results using randomly picked parameter values are presented. The first eight pages contain the results of P(D) calculations, and the latter pages give $P_K(X)$ and E(X) results.

PROBABILITY OF DETECTION

SEARCH AREA 7850 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 5.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.15	.28	.39	.48	.56	.62	.68	.73	.77	.80
20	0	.33	.56	.70	.80	.87	.91	.94	0	0	0
30	0	.52	.77	.89	0	0	0	0	0	0	0
40	0	.68	0	0	0	0	0	0	0	0	0
50	0	.80	0	0	0	0	0	0	0	0	0
60	0	.89	0	0	0	0	0	0	0	0	0

SEARCH AREA 7850 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.18	.32	.44	.54	.62	.69	.74	.79	.83	.86
20	0	.37	.61	.75	.85	.90	.94	.96	0	0	0
30	0	.56	.81	.92	0	0	0	0	0	0	0
40	0	.72	0	0	0	0	0	0	0	0	0
50	0	.83	0	0	0	0	0	0	0	0	0
60	0	.91	0	0	0	0	0	0	0	0	0

SEARCH AREA 7850 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 10.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.25	.44	.58	.68	.76	.82	.87	.90	.92	.94
20	0	.48	.73	.86	.93	.96	.98	.99	0	0	0
30	0	.67	.89	.96	0	0	0	0	0	0	0
40	0	.80	0	0	0	0	0	0	0	0	0
50	0	.89	0	0	0	0	0	0	0	0	0
60	0	.95	0	0	0	0	0	0	0	0	0

PROBABILTIY OF DETECTION

SEARCH AREA 7850 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 5.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.21	.37	.50	.60	.69	.75	.80	.84	.88	.90
20	0	.42	.66	.80	.89	.93	.96	.98	0	0	0
30	0	.61	.85	.94	0	0	0	0	0	0	0
40	0	.75	0	0	0	0	0	0	0	0	0
50	0	.86	0	0	0	0	0	0	0	0	0
60	0	.92	0	0	0	0	0	0	0	0	0

SEARCH AREA 7850 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.24	.43	.57	.67	.75	.81	.86	.89	.92	.94
20	0	.47	.72	.85	.92	.96	.98	.99	0	0	0
30	0	.66	.88	.96	0	0	0	0	0	0	0
40	0	.80	0	0	0	0	0	0	0	0	0
50	0	.89	0	0	0	0	0	0	0	0	0
60	0	.94	0	0	0	0	0	0	0	0	0

SEARCH AREA 7850 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 10.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.34	.57	.72	.82	.88	.92	.95	.97	.98	.99
20	0	.60	.84	.94	.98	.99	1.00	1.00	0	0	0
30	0	.78	.95	.99	0	0	0	0	0	0	0
40	0	.89	0	0	0	0	0	0	0	0	0
50	0	.95	0	0	0	0	0	0	0	0	0
60	0	.98	0	0	0	0	0	0	0	0	0

PROBABILTIY OF DETECTION

SEARCH AREA 31400 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 5.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.04	.08	.12	.15	.18	.22	.25	.28	.31	.33
20	C	.10	.18	.26	.33	.40	.46	.51	.56	.60	.64
30	0	.17	.31	.42	.52	.60	.67	.72	.77	.31	.84
40	0	.25	.43	.57	.68	.76	.82	.86	0	0	0
50	C	.33	.55	.70	.80	0	0	0	0	0	C
60	0	.42	.66	.80	0	0	0	0	0	0	0

SEARCH AREA 31400 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	0	.05	.09	.14	.18	.22	.25	.29	.32	.35	.38
20	C	.11	.21	.30	.37	.44	.50	.56	.61	.65	.69
30	C	.19	.34	.46	.56	.64	.71	.76	.81	.84	.87
40	0	.27	.47	.61	.72	.79	.85	.89	0	0	0
50	0	.36	.59	.73	.83	0	0	0	0	0	0
60	C	.45	.69	.83	0	0	0	0	0	0	0

SEARCH AREA 31400 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 10.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	0	.07	.13	.19	.25	.30	.35	.39	.44	.47	.51
20	C	.15	.28	.39	.48	.56	.62	.68	.73	.77	.8C
30	C	.24	.42	.56	.67	.75	.81	.85	.89	.92	.94
40	0	.33	.56	.70	.80	.87	.91	.94	0	0	0
50	0	.43	.67	.81	.89	0	0	0	0	0	0
60	C	.52	.77	.89	0	0	0	0	C	0	0

PROBABILTIY OF DETECTION

SEARCH AREA 31400 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 5.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 5.C MIN.

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	0	.06	.11	.16	.21	.25	.29	.33	.37	.41	.44
20	C	.13	.24	.33	.42	.49	.56	.61	.66	.70	.74
30	C	.21	.37	.50	.61	.69	.75	.80	.85	.88	.9C
40	C	.3C	.50	.65	.75	.83	.88	.91	C	0	C
50	C	.39	.62	.77	.86	0	0	0	0	0	0
60	C	.48	.73	.86	0	0	0	0	0	0	0

SEARCH AREA 31400 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 5.C MIN.

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.07	.13	.19	.24	.29	.34	.39	.43	.47	.50
20	0	.15	.27	.38	.47	.55	.62	.67	.72	.76	.80
30	C	.24	.42	.55	.66	.74	.8C	.85	.88	.91	.93
40	C	.33	.55	.70	.80	.86	.91	.94	C	0	C
50	0	.42	.67	.81	.89	0	0	0	0	0	0
60	C	.51	.76	.88	0	0	C	0	C	0	0

SEARCH AREA 31400 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 1C.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES CN SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 10.C MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	C	.10	.19	.27	.34	.41	.47	.52	.57	.61	.65
20	C	.21	.37	.50	.60	.69	.75	.80	.84	.88	.90
30	C	.31	.53	.68	.78	.85	.90	.93	.95	.97	.98
40	C	.42	.66	.80	.89	.93	.96	.98	0	0	C
50	0	.52	.77	.89	.95	C	0	0	C	0	0
6C	0	.61	.85	.94	0	0	0	0	0	0	0

PROBABILTIY OF DETECTION

SEARCH AREA 70650 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 5.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.04	.05	.07	.09	.10	.12	.14	.15	.17
20	0	.04	.09	.13	.17	.20	.24	.27	.30	.33	.36
30	0	.08	.15	.22	.28	.33	.39	.43	.48	.52	.56
40	C	.12	.22	.31	.40	.47	.53	.59	.63	.68	.72
50	C	.16	.30	.42	.51	.59	.66	.72	.76	.80	.83
60	0	.22	.38	.52	.62	.70	.77	.82	0	0	0

SEARCH AREA 70650 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.02	.04	.06	.08	.10	.12	.14	.16	.18	.19
20	C	.05	.10	.14	.19	.23	.27	.31	.34	.37	.41
30	0	.09	.17	.24	.31	.37	.42	.47	.52	.56	.60
40	C	.13	.24	.34	.43	.50	.57	.62	.67	.72	.75
50	C	.18	.33	.45	.54	.63	.69	.75	.79	.83	.86
60	0	.23	.41	.55	.65	.73	.79	.84	C	0	0

SEARCH AREA 70650 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 10.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	0	.03	.06	.09	.12	.15	.17	.20	.22	.25	.27
20	C	.07	.14	.20	.25	.30	.35	.40	.44	.48	.52
30	0	.11	.22	.31	.39	.46	.52	.57	.62	.67	.71
40	0	.17	.30	.42	.51	.59	.66	.72	.76	.80	.84
50	C	.22	.39	.52	.63	.71	.77	.82	.86	.89	.92
60	0	.28	.48	.62	.73	.80	.86	.90	0	0	0

PROBABILTIY OF DETECTICN

SEARCH AREA 70650 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 5.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER CF MISSILES CN SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 5.C MIN.

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.03	.05	.07	.10	.12	.14	.16	.19	.21	.23
20	C	.06	.11	.17	.21	.26	.30	.34	.38	.42	.45
30	C	.10	.19	.27	.34	.4C	.46	.52	.56	.61	.65
40	C	.14	.27	.37	.46	.54	.61	.66	.71	.75	.79
50	C	.20	.35	.48	.58	.66	.73	.78	.82	.86	.89
60	C	.25	.44	.58	.68	.76	.82	.87	0	0	C

SEARCH AREA 70650 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER CF MISSILES CN SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 5.0 MIN.

NO. CF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.03	.06	.09	.12	.14	.17	.19	.22	.24	.27
20	C	.07	.13	.19	.25	.30	.35	.39	.43	.47	.51
30	C	.11	.21	.30	.38	.45	.51	.57	.62	.66	.7C
4C	C	.16	.30	.41	.51	.59	.65	.71	.76	.80	.83
50	C	.22	.39	.52	.62	.70	.77	.82	.86	.89	.91
60	C	.27	.47	.62	.72	.80	.85	.89	C	0	C

SEARCH AREA 70650 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 1C.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES CN SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 10.C MIN.

NO. CF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.05	.09	.13	.17	.21	.25	.28	.31	.34	.37
20	C	.10	.19	.27	.34	.40	.46	.51	.56	.60	.64
30	C	.15	.28	.39	.49	.57	.63	.69	.74	.78	.81
40	C	.21	.38	.51	.62	.7C	.76	.81	.85	.89	.91
50	C	.28	.48	.62	.73	.8C	.86	.90	.92	.95	.96
60	C	.34	.56	.71	.81	.87	.92	.95	0	0	0

PROBABILTIY OF DETECTION

SEARCH AREA 125600 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 5.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES CN SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 5.C MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10
20	0	.03	.05	.07	.10	.12	.14	.16	.18	.20	.22
30	C	.04	.09	.13	.17	.20	.24	.27	.31	.34	.37
40	C	.07	.13	.19	.25	.30	.35	.39	.43	.47	.51
50	0	.10	.18	.26	.33	.40	.45	.51	.55	.60	.64
60	0	.13	.24	.34	.42	.49	.56	.61	.66	.71	.74

SEARCH AREA 125600 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES CN SUBMARINE IS 4
TIME TO FIRE EACH ADDITICNAL MISSILE 5.C MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.02	.04	.05	.06	.07	.08	.09	.10	.11
20	0	.03	.06	.08	.11	.14	.16	.19	.21	.23	.25
30	C	.05	.1C	.14	.19	.23	.27	.30	.34	.37	.40
40	C	.08	.15	.21	.27	.32	.38	.42	.47	.51	.54
50	0	.1C	.20	.28	.36	.42	.49	.54	.59	.63	.67
60	0	.14	.26	.36	.45	.52	.59	.64	.69	.74	.77

SEARCH AREA 125600 SQUARE MILES
CRUISE VELOCITY 145 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES CN SUBMARINE IS 4
TIME TO FIRE EACH ACCITICNAL MISSILE 10.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	C	.02	.04	.05	.07	.09	.10	.12	.13	.15	.16
20	0	.04	.08	.12	.15	.18	.22	.25	.28	.31	.33
30	0	.07	.13	.19	.24	.29	.34	.38	.42	.46	.50
40	C	.10	.18	.26	.33	.40	.46	.51	.56	.60	.64
50	C	.13	.24	.34	.43	.50	.57	.62	.67	.72	.75
60	0	.17	.31	.42	.52	.60	.67	.72	.77	.81	.84

PROBABILTIY OF DETECTION

SEARCH AREA 125600 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 5.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.03	.04	.06	.07	.08	.10	.11	.12	.13
20	0	.03	.07	.10	.13	.16	.18	.21	.24	.26	.29
30	0	.06	.11	.16	.21	.25	.30	.34	.37	.41	.44
40	0	.08	.16	.23	.30	.36	.41	.46	.50	.55	.58
50	0	.12	.22	.31	.39	.46	.52	.58	.62	.67	.71
60	0	.15	.28	.38	.48	.55	.62	.68	.73	.77	.80

SEARCH AREA 125600 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 5.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.03	.05	.07	.08	.10	.11	.13	.15	.16
20	0	.04	.08	.11	.15	.18	.21	.24	.27	.30	.33
30	0	.07	.13	.18	.24	.29	.33	.38	.42	.45	.49
40	0	.09	.18	.26	.33	.39	.45	.50	.55	.59	.63
50	0	.13	.24	.34	.42	.50	.56	.62	.67	.71	.75
60	0	.16	.30	.42	.51	.59	.66	.72	.76	.80	.83

SEARCH AREA 125600 SQUARE MILES
CRUISE VELOCITY 225 KNOTS
TIME TO FIRE FIRST MISSILE 10.0 MIN.

RADAR SEARCH ANGLE 360 DEGREES
NUMBER OF MISSILES ON SUBMARINE IS 4
TIME TO FIRE EACH ADDITIONAL MISSILE 10.0 MIN.

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.03	.05	.08	.10	.12	.15	.17	.19	.21	.23
20	0	.06	.11	.16	.21	.25	.29	.33	.37	.41	.44
30	0	.09	.17	.25	.31	.38	.43	.48	.53	.57	.61
40	0	.13	.24	.33	.42	.49	.56	.61	.66	.70	.74
50	0	.17	.31	.42	.52	.60	.66	.72	.77	.81	.84
60	0	.21	.37	.50	.61	.69	.75	.80	.85	.88	.90

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIREC

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 7850 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELOCITY =, 19C KTS.
TIME TO FIRE FIRST MISSILE = 5.0 MIN. TIME TO FIRE EACH ADDITICNAL MISSILE = 5.0 MIN.

X = 1

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
20	C	.09	.16	.22	.27	.30	.33	.36	0	0	0
30	C	.08	.13	.16	0	0	0	0	0	0	C
40	C	.07	0	0	0	C	0	0	0	0	C
50	C	.06	0	0	0	0	0	0	0	0	0
60	C	.05	C	C	0	0	0	0	C	0	C

X = 2

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.08	.15	.21	.27	.32	.37	.41	.45	.48	.52
20	C	.18	.31	.42	.49	.55	.59	.63	0	0	C
30	C	.29	.45	.55	0	0	0	0	0	0	C
40	C	.27	0	0	0	C	0	0	0	0	0
50	C	.22	C	0	0	C	0	0	C	C	0
60	C	.19	0	0	0	C	0	0	C	0	C

X = 3

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.11	.20	.28	.35	.41	.47	.52	.56	.59	.63
20	0	.23	.39	.50	.58	.64	.68	.71	0	0	0
30	C	.34	.52	.62	0	0	0	0	0	0	0
40	C	.44	C	0	0	0	0	0	C	0	C
50	0	.47	0	0	0	C	0	0	0	0	C
60	0	.39	0	0	0	0	0	0	0	0	0

X = 4 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.13	.25	.34	.42	.49	.55	.60	.64	.68	.71
20	0	.27	.45	.57	.65	.70	.74	.76	0	0	0
30	0	.39	.58	.67	0	0	0	0	0	0	0
40	0	.49	0	0	0	0	0	0	0	0	0
50	0	.56	0	0	0	0	0	0	0	0	0
60	0	.60	0	0	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.634	3.312	3.028	2.778	2.557	2.362	2.190	2.037	1.902	1.731
20	4	3.235	2.689	2.296	2.013	1.809	1.660	1.551	0	0	0
30	4	2.899	2.311	1.996	0	0	0	0	0	0	0
40	4	2.732	0	0	0	0	0	0	0	0	0
50	4	2.682	0	0	0	0	0	0	0	0	0
60	4	2.772	0	0	0	0	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 7850 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELOCITY =, 19C KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.C MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	1C
10	C	.08	.15	.21	.27	.32	.37	.41	.45	.48	.52
20	C	.18	.31	.42	.49	.55	.59	.63	0	0	0
30	C	.29	.45	.55	0	C	0	0	0	0	C
40	C	.27	0	0	0	C	0	0	C	0	C
50	C	.22	0	0	0	C	0	0	0	0	C
60	0	.19	0	0	0	0	0	0	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.11	.20	.28	.35	.41	.47	.52	.56	.59	.63
20	C	.23	.39	.50	.58	.64	.68	.71	C	0	0
30	C	.34	.52	.62	0	0	0	0	C	0	C
40	0	.44	0	0	0	C	0	0	0	0	0
50	0	.47	0	0	0	0	0	0	0	0	0
60	C	.39	C	0	0	0	0	0	C	0	C

X = 3 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.13	.25	.34	.42	.49	.55	.60	.64	.68	.71
20	0	.27	.45	.57	.65	.7C	.74	.76	0	0	C
30	0	.39	.58	.67	0	C	0	0	0	0	0
40	C	.49	C	0	0	0	0	0	C	0	C
50	C	.56	0	0	0	0	0	0	0	0	0
60	C	.60	0	0	0	C	0	0	C	0	C

X = 4

NO. OF A/C / RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.16	.29	.40	.49	.56	.62	.67	.71	.74	.77
20	C	.31	.51	.63	.71	.75	.78	.80	0	0	C
30	C	.44	.64	.72	0	0	0	0	0	0	0
40	C	.54	0	0	0	0	0	0	0	0	0
50	C	.60	0	0	0	C	0	0	0	0	C
60	C	.64	0	0	0	C	0	0	C	C	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C / RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.525	3.118	2.770	2.471	2.215	1.995	1.805	1.642	1.501	1.379
20	4	3.014	2.344	1.887	1.574	1.358	1.209	1.106	C	0	C
30	4	2.538	1.808	1.440	0	C	0	0	0	0	C
4C	4	2.264	0	0	0	C	0	0	0	0	0
50	4	2.140	C	0	0	0	0	0	C	0	0
60	4	2.184	C	0	0	0	0	0	0	0	C

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 7850 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELCCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE =10.C MIN.

X = 1

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	0	.08	.15	.21	.27	.32	.37	.41	.45	.48	.52
20	C	.18	.31	.42	.49	.55	.59	.63	0	0	C
30	C	.29	.45	.55	0	0	0	0	0	0	0
40	C	.27	0	0	0	0	0	0	C	0	C
50	C	.22	0	0	0	C	0	0	0	0	C
60	0	.19	0	C	0	C	0	0	0	0	0

X = 2

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	0	.13	.25	.34	.42	.49	.55	.60	.64	.66	.71
20	C	.27	.45	.57	.65	.70	.74	.76	0	0	0
30	C	.39	.58	.67	0	0	C	0	0	0	C
40	C	.49	0	0	0	0	0	0	0	0	C
50	0	.56	0	0	0	0	0	0	0	0	0
60	C	.60	0	0	0	0	0	0	0	0	0

X = 3

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.18	.33	.45	.54	.62	.68	.72	.76	.79	.82
20	C	.35	.56	.68	.75	.79	.82	.83	0	0	0
30	C	.48	.68	.76	0	0	0	0	C	0	C
40	C	.58	0	0	0	0	0	0	0	0	0
50	C	.64	0	0	0	0	0	0	0	0	0
60	C	.67	C	0	0	C	0	0	0	0	C

X = 4

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	0	.23	.41	.54	.64	.71	.76	.81	.84	.86	.88
20	C	.42	.64	.76	.82	.85	.86	.87	C	0	C
30	0	.56	.75	.81	0	0	0	0	0	0	0
40	0	.65	0	0	0	0	0	0	0	0	0
50	C	.70	0	0	0	0	0	0	0	0	C
60	C	.72	0	0	0	C	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.373	2.869	2.461	2.131	1.861	1.640	1.458	1.308	1.184	1.080
20	4	2.778	2.037	1.580	1.292	1.108	.988	.909	C	0	0
30	4	2.276	1.540	1.212	0	C	0	0	C	0	C
40	4	2.C13	0	0	0	C	0	0	0	0	0
50	4	1.879	0	0	0	0	0	0	0	0	0
60	4	1.825	C	0	0	0	0	0	0	0	C

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 7850 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELCCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE = 5.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1

NO. OF A/C / RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
20	0	.17	.31	.41	.49	.56	.60	.64	0	0	0
30	0	.29	.47	.57	0	0	0	0	0	0	0
40	0	.29	0	0	0	0	0	0	0	0	0
50	0	.24	0	0	0	0	0	0	0	0	0
60	0	.20	0	0	0	0	0	0	0	0	0

X = 2

NO. OF A/C / RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.11	.21	.30	.37	.44	.50	.55	.59	.63	.66
20	0	.25	.42	.54	.63	.69	.73	.76	0	0	0
30	0	.38	.58	.68	0	0	0	0	0	0	0
40	0	.49	0	0	0	0	0	0	0	0	0
50	0	.58	0	0	0	0	0	0	0	0	0
60	0	.64	0	0	0	0	0	0	0	0	0

X = 3

NO. OF A/C / RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.15	.28	.39	.48	.55	.61	.66	.71	.74	.77
20	0	.31	.51	.64	.72	.78	.81	.83	0	0	0
30	0	.45	.66	.75	0	0	0	0	0	0	0
40	0	.57	0	0	0	0	0	0	0	0	0
50	0	.64	0	0	0	0	0	0	0	0	0
60	0	.69	0	0	0	0	0	0	0	0	0

X = 4 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	0	.19	.35	.47	.56	.64	.70	.75	.79	.82	.84
20	0	.37	.59	.72	.79	.83	.86	.87	0	0	0
30	C	.52	.73	.81	0	0	0	0	C	0	0
40	0	.63	0	0	0	0	0	0	C	0	C
50	0	.7C	0	0	0	C	0	0	0	0	0
60	0	.74	0	0	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.470	3.025	2.652	2.337	2.072	1.847	1.656	1.493	1.354	1.235
20	4	2.894	2.169	1.688	1.366	1.148	.999	.895	C	0	C
30	4	2.354	1.568	1.183	0	0	0	0	0	0	0
40	4	2.025	0	0	0	0	0	0	0	0	0
50	4	1.836	C	0	0	C	0	0	0	0	0
60	4	1.731	0	0	0	C	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 7850 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELOCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.11	.21	.30	.37	.44	.50	.55	.59	.63	.66
20	0	.25	.42	.54	.63	.69	.73	.76	0	0	0
30	0	.38	.58	.68	0	0	0	0	0	0	0
40	0	.49	0	0	0	0	0	0	0	0	0
50	0	.58	0	0	0	0	0	0	0	0	0
60	0	.64	0	0	0	0	0	0	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.15	.28	.39	.48	.55	.61	.66	.71	.74	.77
20	0	.31	.51	.64	.72	.78	.81	.83	0	0	0
30	0	.45	.66	.75	0	0	0	0	0	0	0
40	0	.57	0	0	0	0	0	0	0	0	0
50	0	.64	0	0	0	0	0	0	0	0	0
60	0	.69	0	0	0	0	0	0	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.19	.35	.47	.56	.64	.70	.75	.79	.82	.84
20	0	.37	.59	.72	.79	.83	.86	.87	0	0	0
30	0	.52	.73	.81	0	0	0	0	0	0	0
40	0	.63	0	0	0	0	0	0	0	0	0
50	0	.70	0	0	0	0	0	0	0	0	0
60	0	.74	0	0	0	0	0	0	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.23	.40	.54	.64	.71	.77	.81	.85	.87	.89
20	0	.43	.65	.77	.84	.87	.89	.90	0	0	0
30	0	.58	.78	.84	0	0	0	0	0	0	0
40	0	.68	0	0	0	0	0	0	0	0	0
50	0	.74	0	0	0	0	0	0	0	0	0
60	0	.77	0	0	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.309	2.754	2.308	1.947	1.655	1.418	1.225	1.068	.939	.833
20	4	2.639	1.822	1.327	1.022	.833	.715	.639	0	0	0
30	4	2.067	1.261	.915	0	0	0	0	0	0	0
40	4	1.632	0	0	0	0	0	0	0	0	0
50	4	1.338	0	0	0	0	0	0	0	0	0
60	4	1.163	0	0	0	0	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 — RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 7850 SQ. MILES — CRUISE VELOCITY = 225 KTS. — DASHVELOCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. — TIME TO FIRE EACH ADDITIONAL MISSILE =10.0 MIN.

X = 1

NO. OF A/C / RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.11	.21	.30	.37	.44	.50	.55	.59	.63	.66
20	0	.25	.42	.54	.63	.69	.73	.76	0	0	0
30	0	.38	.58	.68	0	0	0	0	0	0	0
40	0	.49	0	0	0	0	0	0	0	0	0
50	0	.58	0	0	0	0	0	0	0	0	0
60	0	.64	0	0	0	0	0	0	0	0	0

X = 2

NO. OF A/C / RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.19	.35	.47	.56	.64	.70	.75	.79	.82	.84
20	0	.37	.59	.72	.79	.83	.86	.87	0	0	0
30	0	.52	.73	.81	0	0	0	0	0	0	0
40	0	.63	0	0	0	0	0	0	0	0	0
50	0	.70	0	0	0	0	0	0	0	0	0
60	0	.74	0	0	0	0	0	0	0	0	0

X = 3

NO. OF A/C / RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.27	.46	.60	.70	.77	.82	.86	.88	.90	.92
20	0	.48	.71	.82	.87	.90	.91	.91	0	0	0
30	0	.63	.81	.87	0	0	0	0	0	0	0
40	0	.72	0	0	0	0	0	0	0	0	0
50	0	.77	0	0	0	0	0	0	0	0	0
60	0	.80	0	0	0	0	0	0	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.33	.55	.69	.79	.85	.89	.91	.93	.94	.95
20	C	.56	.79	.88	.91	.93	.93	.93	0	0	0
30	C	.71	.87	.90	0	C	0	0	0	0	0
40	C	.79	C	0	0	0	0	0	0	0	0
50	C	.83	0	0	0	0	0	0	0	0	0
60	C	.84	0	0	0	C	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.095	2.433	1.944	1.579	1.303	1.092	.930	.804	.704	.625
20	4	2.337	1.493	1.046	.798	.655	.570	.518	C	0	0
30	4	1.762	1.016	.742	0	0	0	0	C	0	C
40	4	1.366	0	C	0	C	0	0	0	0	0
50	4	1.122	0	0	0	0	0	0	0	0	0
60	4	.990	0	0	0	0	0	0	C	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4   RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 31400 SQ. MILES   CRUISE VELOCITY = 145 KTS.   DASHVELOCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE = 5.0 MIN.   TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.03	.04	.05	.06	.07	.08	.10	.11	.12
20	0	.02	.05	.07	.09	.11	.13	.15	.16	.18	.19
30	0	.02	.04	.06	.08	.10	.11	.12	.13	.14	.15
40	0	.02	.04	.06	.07	.08	.09	.10	0	0	0
50	0	.02	.04	.05	.06	0	0	0	0	0	0
60	0	.02	.03	.04	0	0	0	0	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.04	.06	.08	.10	.11	.13	.15	.17	.18
20	0	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
30	0	.09	.16	.23	.29	.34	.38	.42	.45	.48	.51
40	0	.09	.16	.22	.27	.30	.33	.36	0	0	0
50	0	.09	.15	.19	.22	0	0	0	0	0	0
60	0	.08	.13	.16	0	0	0	0	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.03	.05	.08	.11	.13	.15	.18	.20	.22	.24
20	0	.06	.12	.18	.23	.27	.31	.35	.39	.42	.45
30	0	.11	.20	.28	.34	.40	.45	.49	.52	.55	.58
40	0	.15	.27	.37	.44	.50	.54	.57	0	0	0
50	0	.19	.32	.41	.47	0	0	0	0	0	0
60	0	.18	.29	.35	0	0	0	0	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.04	.07	.10	.13	.16	.19	.22	.25	.27	.30
20	0	.08	.15	.21	.27	.32	.37	.41	.45	.48	.52
30	0	.13	.23	.32	.39	.45	.51	.55	.58	.61	.64
40	0	.18	.31	.42	.49	.55	.59	.63	0	0	0
50	0	.23	.39	.49	.56	0	0	0	0	0	0
60	0	.29	.45	.55	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.904	3.811	3.721	3.634	3.550	3.468	3.389	3.312	3.238	3.166
20	4	3.784	3.585	3.403	3.235	3.081	2.939	2.809	2.689	2.578	2.476
30	4	3.656	3.363	3.112	2.899	2.716	2.559	2.426	2.311	2.213	2.129
40	4	3.554	3.208	2.940	2.732	2.571	2.445	2.347	0	0	0
50	4	3.471	3.107	2.855	2.682	0	0	0	0	0	0
60	4	3.436	3.097	2.894	0	0	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIREC

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 31400 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELCCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITICNAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	0	.02	.04	.06	.08	.10	.11	.13	.15	.17	.18
20	C	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
30	0	.09	.16	.23	.29	.34	.38	.42	.45	.48	.51
40	0	.09	.16	.22	.27	.30	.33	.36	0	0	0
50	0	.09	.15	.19	.22	0	0	0	0	0	0
60	C	.08	.13	.16	0	0	0	0	0	0	0

X = 2 NO. CF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.03	.05	.08	.11	.13	.15	.18	.20	.22	.24
20	C	.06	.12	.18	.23	.27	.31	.35	.39	.42	.45
30	C	.11	.20	.28	.34	.40	.45	.49	.52	.55	.58
40	C	.15	.27	.37	.44	.50	.54	.57	0	0	0
50	C	.19	.32	.41	.47	0	0	0	0	0	0
60	C	.18	.29	.35	0	C	0	0	C	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.04	.07	.10	.13	.16	.19	.22	.25	.27	.30
20	0	.08	.15	.21	.27	.32	.37	.41	.45	.48	.52
30	C	.13	.23	.32	.39	.45	.51	.55	.58	.61	.64
40	C	.18	.31	.42	.49	.55	.59	.63	0	0	0
50	0	.23	.39	.49	.56	C	0	0	0	0	0
60	0	.29	.45	.55	0	0	0	0	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.04	.08	.12	.16	.19	.23	.26	.29	.32	.35
20	0	.09	.17	.25	.31	.37	.42	.47	.51	.54	.57
30	0	.15	.27	.36	.44	.51	.56	.60	.64	.66	.69
40	0	.20	.35	.46	.54	.60	.64	.67	0	0	0
50	0	.26	.43	.53	.60	0	0	0	0	0	0
60	0	.31	.49	.58	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.874	3.753	3.637	3.525	3.417	3.314	3.214	3.118	3.026	2.938
20	4	3.716	3.459	3.225	3.014	2.821	2.647	2.488	2.344	2.213	2.094
30	4	3.534	3.143	2.814	2.538	2.306	2.111	1.947	1.808	1.692	1.593
40	4	3.374	2.899	2.538	2.264	2.056	1.897	1.775	0	0	0
50	4	3.234	2.719	2.373	2.140	0	0	0	0	0	0
60	4	3.142	2.644	2.353	0	0	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 31400 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELOCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE =10.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.04	.06	.08	.10	.11	.13	.15	.17	.18
20	0	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
30	0	.09	.16	.23	.29	.34	.38	.42	.45	.48	.51
40	0	.09	.16	.22	.27	.30	.33	.36	0	0	0
50	0	.09	.15	.19	.22	0	0	0	0	0	0
60	0	.08	.13	.16	0	0	0	0	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.04	.07	.10	.13	.16	.19	.22	.25	.27	.30
20	0	.08	.15	.21	.27	.32	.37	.41	.45	.48	.52
30	0	.13	.23	.32	.39	.45	.51	.55	.58	.61	.64
40	0	.18	.31	.42	.49	.55	.59	.63	0	0	0
50	0	.23	.39	.49	.56	0	0	0	0	0	0
60	0	.29	.45	.55	0	0	0	0	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.05	.10	.14	.18	.22	.26	.30	.33	.36	.39
20	0	.11	.20	.28	.35	.41	.47	.52	.56	.59	.63
30	0	.17	.30	.40	.48	.55	.60	.65	.68	.71	.73
40	0	.23	.39	.50	.58	.64	.68	.71	0	0	0
50	0	.29	.46	.57	.64	0	0	0	0	0	0
60	0	.34	.52	.62	0	0	0	0	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.06	.12	.18	.23	.28	.33	.37	.41	.44	.48
20	0	.13	.25	.34	.42	.49	.55	.60	.64	.68	.71
30	0	.20	.36	.47	.56	.63	.68	.72	.75	.77	.79
40	0	.27	.45	.57	.65	.70	.74	.76	0	0	0
50	0	.33	.53	.64	.70	0	0	0	0	0	0
60	0	.39	.58	.67	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.830	3.670	3.517	3.373	3.237	3.108	2.985	2.869	2.759	2.654
20	4	3.634	3.312	3.028	2.778	2.557	2.362	2.190	2.037	1.902	1.781
30	4	3.420	2.954	2.579	2.276	2.031	1.833	1.671	1.540	1.432	1.344
40	4	3.235	2.689	2.296	2.013	1.809	1.660	1.551	0	0	0
50	4	3.062	2.477	2.111	1.379	0	0	0	0	0	0
60	4	2.899	2.311	1.996	0	0	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 31400 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELCCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE = 5.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.02	.04	.05	.07	.09	.10	.12	.13	.15	.16
20	0	.05	.09	.13	.17	.21	.25	.28	.31	.34	.36
30	0	.09	.16	.23	.29	.34	.39	.43	.47	.50	.53
40	0	.10	.17	.24	.29	.33	.36	.39	0	0	0
50	C	.09	.16	.21	.24	0	0	0	0	0	C
60	C	.09	.14	.18	0	C	0	0	0	0	C

X = 2 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	0	.03	.06	.09	.11	.14	.16	.19	.21	.23	.26
20	0	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
30	C	.12	.22	.31	.38	.44	.49	.54	.58	.61	.64
40	C	.17	.31	.41	.49	.56	.60	.64	0	0	C
50	C	.23	.39	.50	.58	0	C	0	C	0	C
60	0	.29	.47	.57	0	0	0	0	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.04	.08	.12	.15	.19	.22	.25	.28	.31	.34
20	C	.09	.17	.25	.31	.37	.42	.47	.51	.55	.58
30	C	.15	.27	.37	.45	.52	.58	.62	.66	.69	.72
40	C	.21	.37	.48	.57	.63	.68	.71	0	0	0
50	C	.27	.45	.57	.64	0	0	0	0	0	C
60	C	.34	.53	.63	0	0	C	0	C	0	C

X = 4

NO. OF A/C / RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.05	.10	.15	.19	.23	.27	.31	.35	.38	.41
20	0	.11	.21	.30	.37	.44	.50	.55	.59	.63	.66
30	0	.18	.32	.43	.52	.59	.65	.69	.73	.75	.78
40	0	.25	.42	.54	.63	.69	.73	.76	0	0	0
50	0	.31	.51	.62	.70	0	0	0	0	0	0
60	0	.38	.58	.68	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C / RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.858	3.723	3.594	3.470	3.351	3.238	3.129	3.025	2.926	2.831
20	4	3.678	3.388	3.128	2.894	2.683	2.494	2.323	2.169	2.030	1.904
30	4	3.466	3.024	2.658	2.354	2.101	1.890	1.715	1.568	1.445	1.342
40	4	3.273	2.732	2.328	2.025	1.798	1.627	1.498	0	0	0
50	4	3.089	2.490	2.096	1.836	0	0	0	0	0	0
60	4	2.907	2.287	1.934	0	0	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIREC

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 31400 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELCCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITICNAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.03	.06	.09	.11	.14	.16	.19	.21	.23	.26
20	C	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
30	0	.12	.22	.31	.38	.44	.49	.54	.58	.61	.64
40	0	.17	.31	.41	.49	.56	.60	.64	0	0	0
50	C	.23	.39	.50	.58	C	0	0	C	0	0
60	C	.29	.47	.57	0	C	0	0	0	0	C

X = 2 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.04	.08	.12	.15	.19	.22	.25	.28	.31	.34
20	0	.09	.17	.25	.31	.37	.42	.47	.51	.55	.58
30	C	.15	.27	.37	.45	.52	.58	.62	.66	.69	.72
40	0	.21	.37	.48	.57	.63	.68	.71	0	0	0
50	0	.27	.45	.57	.64	0	0	0	C	0	C
60	0	.34	.53	.63	0	C	0	0	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	C	.05	.10	.15	.19	.23	.27	.31	.35	.38	.41
20	C	.11	.21	.30	.37	.44	.50	.55	.59	.63	.66
30	C	.18	.32	.43	.52	.59	.65	.69	.73	.75	.78
40	0	.25	.42	.54	.63	.69	.73	.76	0	0	0
50	0	.31	.51	.62	.70	C	0	C	0	0	C
60	C	.38	.58	.68	0	0	0	0	C	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	0	.06	.12	.18	.23	.28	.32	.37	.40	.44	.48
20	0	.13	.25	.35	.43	.50	.56	.61	.65	.69	.72
30	0	.21	.37	.49	.58	.65	.70	.74	.78	.80	.82
40	0	.28	.47	.59	.68	.74	.77	.80	0	0	0
50	0	.35	.55	.67	.74	0	0	0	0	0	0
60	0	.42	.62	.72	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.813	3.636	3.468	3.309	3.159	3.017	2.882	2.754	2.634	2.519
20	4	3.591	3.233	2.917	2.639	2.395	2.180	1.990	1.822	1.675	1.544
30	4	3.346	2.823	2.404	2.067	1.797	1.579	1.403	1.261	1.146	1.053
40	4	3.088	2.436	1.969	1.632	1.390	1.214	1.087	0	0	0
50	4	2.828	2.093	1.631	1.338	0	0	0	0	0	0
60	4	2.575	1.807	1.390	0	0	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 31400 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELCCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE =10.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.03	.06	.09	.11	.14	.16	.19	.21	.23	.26
20	0	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
30	0	.12	.22	.31	.38	.44	.49	.54	.58	.61	.64
40	0	.17	.31	.41	.49	.56	.60	.64	0	0	0
50	0	.23	.39	.50	.58	0	0	0	0	0	0
60	0	.29	.47	.57	0	0	0	0	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.05	.10	.15	.19	.23	.27	.31	.35	.38	.41
20	0	.11	.21	.30	.37	.44	.50	.55	.59	.63	.66
30	0	.18	.32	.43	.52	.59	.65	.69	.73	.75	.78
40	0	.25	.42	.54	.63	.69	.73	.76	0	0	0
50	0	.31	.51	.62	.70	0	0	0	0	0	0
60	0	.38	.58	.68	0	0	0	0	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.07	.14	.21	.27	.32	.37	.42	.46	.50	.53
20	0	.15	.28	.39	.48	.55	.61	.66	.71	.74	.77
30	0	.23	.41	.53	.63	.70	.75	.79	.81	.83	.85
40	0	.31	.51	.64	.72	.78	.81	.83	0	0	0
50	0	.39	.60	.71	.77	0	0	0	0	0	0
60	0	.45	.66	.75	0	0	0	0	0	0	0

X = 4 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.10	.18	.26	.33	.40	.45	.50	.55	.59	.63
20	0	.19	.35	.47	.56	.64	.70	.75	.79	.82	.84
30	0	.29	.48	.62	.71	.77	.82	.85	.87	.88	.89
40	0	.37	.59	.72	.79	.83	.86	.87	0	0	0
50	0	.45	.67	.78	.83	0	0	0	0	0	0
60	0	.52	.73	.81	0	0	0	0	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.746	3.512	3.295	3.095	2.910	2.739	2.580	2.433	2.297	2.171
20	4	3.470	3.025	2.652	2.337	2.072	1.847	1.656	1.493	1.354	1.235
30	4	3.182	2.570	2.110	1.762	1.497	1.294	1.137	1.016	.921	.847
40	4	2.894	2.169	1.688	1.366	1.148	.999	.895	0	0	0
50	4	2.615	1.833	1.384	1.122	0	0	0	0	0	0
60	4	2.354	1.568	1.183	0	0	0	0	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 70650 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELOCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE = 5.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.01	.02	.02	.03	.03	.04	.04	.05	.05
20	0	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10
30	0	.01	.02	.03	.04	.05	.06	.07	.07	.08	.09
40	0	.01	.02	.03	.04	.05	.05	.06	.06	.07	.08
50	0	.01	.02	.03	.03	.04	.05	.05	.06	.06	.06
60	0	.01	.02	.03	.03	.04	.04	.04	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.02	.03	.04	.04	.05	.06	.07	.08	.09
20	0	.02	.04	.07	.09	.11	.12	.14	.16	.18	.20
30	0	.04	.08	.11	.15	.18	.21	.23	.26	.29	.31
40	0	.04	.08	.12	.15	.18	.20	.23	.25	.27	.28
50	0	.04	.08	.11	.14	.16	.18	.20	.21	.22	.24
60	0	.04	.07	.10	.12	.14	.16	.17	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.02	.04	.05	.06	.07	.08	.09	.11	.12
20	0	.03	.06	.08	.11	.14	.16	.18	.20	.23	.25
30	0	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
40	0	.07	.14	.20	.25	.30	.34	.38	.41	.44	.47
50	0	.09	.17	.24	.30	.34	.38	.42	.45	.47	.50
60	0	.09	.16	.22	.27	.30	.33	.36	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.03	.05	.06	.08	.09	.10	.12	.13	.15
20	0	.04	.07	.10	.13	.16	.19	.22	.25	.27	.29
30	0	.06	.11	.16	.21	.25	.29	.33	.36	.39	.42
40	0	.09	.16	.23	.29	.34	.38	.42	.46	.49	.52
50	0	.11	.21	.29	.36	.41	.46	.50	.53	.56	.58
60	0	.15	.26	.35	.42	.48	.52	.55	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.957	3.915	3.873	3.831	3.791	3.751	3.711	3.672	3.634	3.596
20	4	3.902	3.807	3.716	3.628	3.544	3.462	3.384	3.308	3.235	3.165
30	4	3.840	3.692	3.553	3.424	3.304	3.192	3.087	2.990	2.899	2.814
40	4	3.788	3.598	3.429	3.278	3.143	3.022	2.914	2.818	2.732	2.655
50	4	3.740	3.521	3.334	3.176	3.043	2.929	2.833	2.751	2.682	2.623
60	4	3.713	3.485	3.303	3.158	3.043	2.951	2.877	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 70650 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELCCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.C MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.01	.02	.03	.04	.04	.05	.06	.07	.08	.09
20	0	.02	.04	.07	.09	.11	.12	.14	.16	.18	.20
30	0	.04	.08	.11	.15	.18	.21	.23	.26	.29	.31
40	C	.04	.08	.12	.15	.18	.20	.23	.25	.27	.28
50	0	.04	.08	.11	.14	.16	.18	.20	.21	.22	.24
60	0	.04	.07	.10	.12	.14	.16	.17	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	1C
10	0	.01	.02	.04	.05	.06	.07	.08	.09	.11	.12
20	C	.03	.06	.08	.11	.14	.16	.18	.20	.23	.25
30	C	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
40	0	.07	.14	.20	.25	.30	.34	.38	.41	.44	.47
50	0	.09	.17	.24	.30	.34	.38	.42	.45	.47	.50
60	C	.09	.16	.22	.27	.30	.33	.36	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.02	.03	.05	.06	.08	.09	.10	.12	.13	.15
20	C	.04	.07	.10	.13	.16	.19	.22	.25	.27	.29
30	0	.06	.11	.16	.21	.25	.29	.33	.36	.39	.42
40	0	.09	.16	.23	.29	.34	.38	.42	.46	.49	.52
50	C	.11	.21	.29	.36	.41	.46	.50	.53	.56	.58
60	C	.15	.26	.35	.42	.48	.52	.55	0	0	C

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	C	.02	.04	.06	.07	.09	.11	.13	.14	.16	.17
20	C	.04	.08	.12	.16	.19	.22	.25	.28	.31	.34
30	C	.07	.13	.19	.24	.29	.33	.37	.41	.44	.47
40	C	.10	.18	.26	.32	.38	.43	.47	.51	.54	.57
50	C	.13	.24	.32	.40	.45	.50	.54	.58	.60	.62
60	0	.16	.29	.38	.46	.51	.56	.59	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.943	3.888	3.833	3.780	3.727	3.675	3.624	3.574	3.525	3.477
20	4	3.870	3.746	3.628	3.514	3.405	3.301	3.201	3.105	3.014	2.926
30	4	3.783	3.582	3.396	3.224	3.065	2.917	2.781	2.655	2.538	2.43C
40	4	3.700	3.435	3.2C1	2.994	2.81C	2.648	2.504	2.377	2.264	2.164
50	4	3.621	3.304	3.039	2.816	2.630	2.473	2.342	2.232	2.140	2.062
60	4	3.561	3.216	2.945	2.732	2.565	2.433	2.330	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 70650 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELOCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE =10.0 MIN.

X = 1

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.02	.03	.04	.04	.05	.06	.07	.08	.09
20	0	.02	.04	.07	.09	.11	.12	.14	.16	.18	.20
30	0	.04	.08	.11	.15	.18	.21	.23	.26	.29	.31
40	0	.04	.08	.12	.15	.18	.20	.23	.25	.27	.28
50	0	.04	.08	.11	.14	.16	.18	.20	.21	.22	.24
60	0	.04	.07	.10	.12	.14	.16	.17	0	0	0

X = 2

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.03	.05	.06	.08	.09	.10	.12	.13	.15
20	0	.04	.07	.10	.13	.16	.19	.22	.25	.27	.29
30	0	.06	.11	.16	.21	.25	.29	.33	.36	.39	.42
40	0	.09	.16	.23	.29	.34	.38	.42	.46	.49	.52
50	0	.11	.21	.29	.36	.41	.46	.50	.53	.56	.58
60	0	.15	.26	.35	.42	.48	.52	.55	0	0	0

X = 3

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.04	.07	.09	.11	.13	.15	.17	.18	.20
20	0	.05	.09	.14	.18	.22	.25	.29	.32	.35	.38
30	0	.08	.15	.21	.27	.32	.37	.41	.45	.48	.52
40	0	.11	.20	.29	.35	.41	.47	.51	.55	.58	.61
50	0	.14	.26	.35	.43	.49	.54	.58	.61	.64	.66
60	0	.18	.31	.42	.49	.55	.59	.63	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	C	.03	.06	.08	.11	.14	.16	.19	.21	.23	.25
20	C	.06	.12	.17	.22	.27	.31	.35	.39	.42	.45
30	0	.10	.18	.26	.32	.38	.44	.48	.52	.56	.59
40	0	.13	.25	.34	.42	.48	.54	.58	.62	.65	.68
50	C	.17	.31	.41	.49	.56	.61	.64	.67	.70	.72
60	C	.21	.36	.47	.55	.61	.65	.68	0	0	C

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.923	3.849	3.776	3.704	3.635	3.567	3.501	3.436	3.373	3.312
20	4	3.831	3.672	3.522	3.380	3.246	3.119	2.999	2.885	2.778	2.677
30	4	3.726	3.478	3.253	3.049	2.863	2.695	2.542	2.403	2.276	2.161
40	4	3.628	3.308	3.032	2.795	2.590	2.413	2.260	2.128	2.013	1.914
50	4	3.528	3.146	2.836	2.585	2.351	2.215	2.079	1.969	1.879	1.806
60	4	3.424	2.990	2.661	2.412	2.224	2.080	1.971	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 70650 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELOCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE = 5.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.01	.02	.02	.03	.04	.05	.05	.06	.07	.08
20	C	.02	.04	.06	.08	.10	.12	.14	.16	.17	.19
30	C	.04	.08	.11	.15	.18	.21	.24	.27	.29	.32
40	C	.04	.09	.12	.16	.19	.22	.24	.27	.29	.31
50	C	.04	.08	.12	.14	.17	.19	.21	.23	.24	.26
60	0	.04	.08	.11	.13	.15	.17	.18	C	0	0

X = 2

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	1C
10	C	.01	.03	.04	.05	.06	.08	.09	.10	.11	.12
20	C	.03	.06	.09	.12	.15	.17	.20	.22	.25	.27
30	0	.06	.11	.15	.20	.24	.28	.31	.35	.38	.41
40	0	.08	.16	.22	.28	.33	.38	.42	.46	.49	.52
50	0	.11	.21	.29	.36	.42	.47	.51	.55	.58	.61
60	C	.15	.27	.36	.44	.50	.54	.58	0	0	C

X = 3

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.02	.04	.05	.07	.09	.11	.12	.14	.15	.17
20	0	.04	.08	.12	.16	.19	.22	.25	.28	.31	.34
30	0	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
40	C	.10	.19	.27	.34	.40	.45	.49	.53	.57	.60
50	C	.14	.25	.34	.42	.48	.54	.58	.62	.64	.67
60	0	.17	.31	.41	.49	.56	.60	.64	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.05	.07	.09	.11	.13	.15	.17	.19	.21
20	0	.05	.10	.15	.19	.23	.27	.31	.34	.37	.40
30	0	.08	.16	.23	.29	.35	.40	.44	.48	.52	.55
40	0	.12	.22	.31	.39	.45	.51	.55	.59	.63	.66
50	0	.16	.29	.39	.47	.54	.59	.63	.67	.70	.72
60	0	.20	.35	.46	.54	.61	.65	.69	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.936	3.874	3.813	3.753	3.694	3.636	3.580	3.524	3.470	3.416
20	4	3.852	3.712	3.578	3.450	3.328	3.211	3.101	2.995	2.894	2.797
30	4	3.750	3.521	3.310	3.115	2.937	2.773	2.621	2.432	2.354	2.236
40	4	3.650	3.344	3.075	2.839	2.632	2.450	2.290	2.149	2.025	1.916
50	4	3.547	3.172	2.861	2.602	2.388	2.210	2.062	1.938	1.836	1.750
60	4	3.437	3.000	2.660	2.396	2.191	2.030	1.905	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 70650 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELOCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.03	.04	.05	.06	.08	.09	.10	.11	.12
20	0	.03	.06	.09	.12	.15	.17	.20	.22	.25	.27
30	0	.06	.11	.15	.20	.24	.28	.31	.35	.38	.41
40	0	.08	.16	.22	.28	.33	.38	.42	.46	.49	.52
50	0	.11	.21	.29	.36	.42	.47	.51	.55	.58	.61
60	0	.15	.27	.36	.44	.50	.54	.58	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.04	.05	.07	.09	.11	.12	.14	.15	.17
20	0	.04	.08	.12	.16	.19	.22	.25	.28	.31	.34
30	0	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
40	0	.10	.19	.27	.34	.40	.45	.49	.53	.57	.60
50	0	.14	.25	.34	.42	.48	.54	.58	.62	.64	.67
60	0	.17	.31	.41	.49	.56	.60	.64	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.05	.07	.09	.11	.13	.15	.17	.19	.21
20	0	.05	.10	.15	.19	.23	.27	.31	.34	.37	.40
30	0	.08	.16	.23	.29	.35	.40	.44	.48	.52	.55
40	0	.12	.22	.31	.39	.45	.51	.55	.59	.63	.66
50	0	.16	.29	.39	.47	.54	.59	.63	.67	.70	.72
60	0	.20	.35	.46	.54	.61	.65	.69	0	0	0

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.03	.06	.08	.11	.14	.16	.18	.21	.23	.25
20	0	.06	.12	.17	.22	.27	.31	.36	.39	.43	.46
30	0	.10	.19	.26	.33	.39	.45	.50	.54	.58	.61
40	0	.14	.25	.35	.43	.50	.56	.61	.65	.68	.71
50	0	.18	.32	.43	.52	.59	.64	.68	.71	.74	.76
60	0	.22	.39	.50	.59	.65	.70	.73	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.915	3.833	3.753	3.674	3.597	3.523	3.450	3.379	3.309	3.241
20	4	3.812	3.634	3.467	3.308	3.159	3.018	2.884	2.758	2.639	2.527
30	4	3.691	3.412	3.159	2.930	2.722	2.534	2.363	2.208	2.067	1.940
40	4	3.557	3.175	2.846	2.563	2.319	2.108	1.926	1.768	1.632	1.515
50	4	3.411	2.933	2.544	2.228	1.971	1.762	1.591	1.452	1.338	1.245
60	4	3.257	2.693	2.265	1.939	1.691	1.502	1.358	0	0	0

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 70650 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELOCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE =10.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.03	.04	.05	.06	.08	.09	.10	.11	.12
20	0	.03	.06	.09	.12	.15	.17	.20	.22	.25	.27
30	0	.06	.11	.15	.20	.24	.28	.31	.35	.38	.41
40	0	.08	.16	.22	.28	.33	.38	.42	.46	.49	.52
50	0	.11	.21	.29	.36	.42	.47	.51	.55	.58	.61
60	0	.15	.27	.36	.44	.50	.54	.58	0	0	0

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.05	.07	.09	.11	.13	.15	.17	.19	.21
20	0	.05	.10	.15	.19	.23	.27	.31	.34	.37	.40
30	0	.08	.16	.23	.29	.35	.40	.44	.48	.52	.55
40	0	.12	.22	.31	.39	.45	.51	.55	.59	.63	.66
50	0	.16	.29	.39	.47	.54	.59	.63	.67	.70	.72
60	0	.20	.35	.46	.54	.61	.65	.69	0	0	0

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.03	.07	.10	.13	.16	.19	.21	.24	.27	.29
20	0	.07	.14	.20	.26	.31	.36	.40	.44	.48	.51
30	0	.11	.21	.30	.37	.44	.50	.55	.59	.63	.66
40	0	.16	.28	.39	.48	.55	.60	.65	.69	.72	.75
50	0	.20	.35	.47	.56	.63	.68	.72	.75	.77	.79
60	0	.25	.42	.54	.63	.69	.73	.76	0	0	0

X = 4 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.04	.09	.13	.17	.20	.24	.27	.30	.33	.36
20	0	.09	.17	.25	.32	.38	.43	.48	.52	.56	.60
30	0	.14	.26	.36	.45	.52	.58	.63	.67	.71	.74
40	0	.19	.34	.46	.55	.62	.68	.73	.76	.79	.81
50	0	.24	.42	.54	.63	.70	.75	.78	.81	.83	.84
60	0	.29	.48	.61	.69	.75	.79	.81	0	0	0

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.885	3.773	3.666	3.562	3.462	3.366	3.272	3.182	3.095	3.011
20	4	3.753	3.524	3.313	3.117	2.937	2.769	2.614	2.471	2.337	2.214
30	4	3.607	3.261	2.958	2.691	2.456	2.249	2.067	1.905	1.762	1.635
40	4	3.450	2.995	2.618	2.305	2.044	1.827	1.646	1.494	1.366	1.259
50	4	3.285	2.732	2.304	1.971	1.711	1.508	1.348	1.222	1.122	1.043
60	4	3.115	2.482	2.027	1.697	1.458	1.283	1.155	0	0	0

PROBABILITY OF KILL BEFCRE MISSILE NUMBER X IS FIREC

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 125600 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELOCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE = 5.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.00	.01	.01	.01	.02	.02	.02	.03	.03	.03
20	C	.01	.01	.02	.02	.03	.04	.04	.05	.05	.06
30	C	.01	.01	.02	.02	.03	.03	.04	.04	.05	.05
40	C	.01	.01	.02	.02	.03	.03	.04	.04	.05	.05
50	C	.01	.01	.02	.02	.03	.03	.03	.04	.04	.04
60	C	.01	.01	.02	.02	.02	.03	.03	.03	.04	.04

X = 2 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.01	.01	.02	.02	.03	.03	.04	.04	.04	.05
20	C	.01	.03	.04	.05	.06	.07	.08	.10	.11	.12
30	C	.02	.04	.07	.09	.11	.13	.14	.16	.18	.20
40	C	.02	.05	.07	.09	.11	.13	.15	.16	.18	.19
50	0	.02	.05	.07	.09	.10	.12	.13	.15	.16	.17
60	0	.02	.04	.06	.08	.1C	.11	.12	.13	.14	.15

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	C	.01	.01	.C2	.03	.03	.04	.05	.05	.06	.07
20	C	.02	.03	.05	.06	.08	.09	.11	.12	.14	.15
30	C	.03	.06	.08	.11	.13	.15	.18	.20	.22	.24
40	C	.04	.08	.12	.15	.19	.22	.25	.27	.30	.32
50	C	.05	.10	.15	.19	.23	.26	.29	.32	.35	.37
60	C	.05	.10	.14	.18	.21	.24	.26	.29	.31	.32

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	C	.01	.02	.03	.04	.04	.05	.06	.07	.08	.09
20	C	.02	.04	.06	.08	.10	.11	.13	.15	.17	.18
30	C	.03	.07	.10	.13	.15	.18	.21	.23	.26	.28
40	C	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
50	C	.07	.13	.18	.23	.28	.32	.35	.39	.42	.44
60	C	.09	.16	.23	.29	.34	.38	.42	.45	.48	.51

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.976	3.952	3.928	3.904	3.88C	3.857	3.834	3.811	3.788	3.766
20	4	3.944	3.890	3.836	3.784	3.733	3.683	3.633	3.585	3.538	3.492
30	4	3.909	3.821	3.737	3.656	3.579	3.504	3.432	3.363	3.297	3.233
40	4	3.878	3.763	3.655	3.554	3.459	3.370	3.287	3.208	3.135	3.C66
50	4	3.849	3.711	3.585	3.471	3.367	3.272	3.186	3.107	3.035	2.969
60	4	3.831	3.682	3.551	3.436	3.334	3.245	3.167	3.097	3.037	2.983

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 125600 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELCCITY =, 19C KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	0	.01	.01	.02	.02	.03	.03	.04	.04	.04	.05
20	C	.01	.03	.04	.05	.06	.07	.08	.1C	.11	.12
30	C	.02	.04	.07	.09	.11	.13	.14	.16	.18	.20
40	C	.02	.05	.07	.09	.11	.13	.15	.16	.18	.19
50	0	.02	.05	.07	.09	.1C	.12	.13	.15	.16	.17
60	C	.02	.04	.06	.08	.10	.11	.12	.13	.14	.15

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	C	.01	.C1	.02	.03	.03	.04	.05	.05	.06	.07
20	C	.02	.03	.05	.06	.08	.09	.11	.12	.14	.15
30	0	.03	.06	.08	.11	.13	.15	.18	.20	.22	.24
40	0	.04	.08	.12	.15	.19	.22	.25	.27	.30	.32
50	C	.05	.1C	.15	.19	.23	.26	.29	.32	.35	.37
60	0	.05	.10	.14	.18	.21	.24	.26	.29	.31	.32

X = 3 NO. CF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	1C
10	0	.01	.02	.03	.04	.04	.05	.C6	.07	.08	.09
20	0	.02	.04	.06	.08	.1C	.11	.13	.15	.17	.18
30	C	.03	.C7	.10	.13	.15	.18	.21	.23	.26	.28
40	0	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
50	0	.07	.13	.18	.23	.28	.32	.35	.39	.42	.44
60	0	.09	.16	.23	.29	.34	.38	.42	.45	.48	.51

X = 4

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	1C
10	C	.01	.C2	.03	.04	.05	.06	.07	.08	.09	.1C
20	C	.02	.05	.07	.09	.11	.13	.15	.17	.19	.21
30	C	.04	.08	.11	.15	.18	.21	.24	.27	.29	.32
40	C	.06	.11	.16	.20	.24	.28	.32	.35	.38	.41
50	0	.C8	.14	.20	.26	.31	.35	.39	.43	.46	.49
60	0	.10	.18	.25	.31	.37	.41	.45	.49	.52	.54

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	4	3.968	3.936	3.905	3.874	3.843	3.813	3.783	3.753	3.724	3.694
20	4	3.926	3.855	3.785	3.716	3.65C	3.584	3.521	3.459	3.398	3.339
30	4	3.876	3.757	3.643	3.534	3.429	3.330	3.234	3.143	3.055	2.971
40	4	3.827	3.665	3.515	3.374	3.243	3.120	3.006	2.899	2.799	2.706
50	4	3.779	3.579	3.398	3.234	3.085	2.951	2.829	2.719	2.619	2.529
60	4	3.74C	3.513	3.315	3.142	2.991	2.859	2.744	2.644	2.556	2.479

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 125600 SQ. MILES CRUISE VELOCITY = 145 KTS. DASHVELOCITY =, 190 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE =10.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.01	.02	.02	.03	.03	.04	.04	.04	.05
20	0	.01	.03	.04	.05	.06	.07	.08	.10	.11	.12
30	0	.02	.04	.07	.09	.11	.13	.14	.16	.18	.20
40	0	.02	.05	.07	.09	.11	.13	.15	.16	.18	.19
50	0	.02	.05	.07	.09	.10	.12	.13	.15	.16	.17
60	0	.02	.04	.06	.08	.10	.11	.12	.13	.14	.15

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.02	.03	.04	.04	.05	.06	.07	.08	.09
20	0	.02	.04	.06	.08	.10	.11	.13	.15	.17	.18
30	0	.03	.07	.10	.13	.15	.18	.21	.23	.26	.28
40	0	.05	.10	.14	.18	.22	.25	.28	.31	.34	.37
50	0	.07	.13	.18	.23	.28	.32	.35	.39	.42	.44
60	0	.09	.16	.23	.29	.34	.38	.42	.45	.48	.51

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.03	.04	.05	.06	.07	.09	.10	.11	.12
20	0	.03	.05	.08	.11	.13	.15	.18	.20	.22	.24
30	0	.04	.09	.13	.17	.20	.23	.27	.30	.33	.35
40	0	.06	.12	.18	.23	.27	.31	.35	.39	.42	.45
50	0	.08	.16	.23	.29	.34	.38	.43	.46	.49	.52
60	0	.11	.20	.28	.34	.40	.45	.49	.52	.55	.58

X = 4

NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	1C
10	0	.02	.03	.05	.06	.08	.09	.11	.12	.14	.15
20	0	.04	.07	.10	.13	.16	.19	.22	.25	.27	.30
30	C	.06	.11	.16	.20	.24	.28	.32	.36	.39	.42
40	C	.08	.15	.21	.27	.32	.37	.41	.45	.48	.52
50	C	.10	.19	.27	.33	.39	.44	.49	.53	.56	.59
60	0	.13	.23	.32	.39	.45	.51	.55	.58	.61	.64

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.957	3.914	3.872	3.830	3.789	3.749	3.709	3.670	3.631	3.592
20	4	3.904	3.811	3.721	3.634	3.550	3.468	3.389	3.312	3.238	3.166
30	4	3.843	3.694	3.553	3.420	3.293	3.174	3.061	2.954	2.852	2.756
40	4	3.784	3.585	3.403	3.235	3.081	2.939	2.809	2.689	2.578	2.476
50	4	3.722	3.476	3.257	3.062	2.889	2.736	2.599	2.477	2.369	2.273
60	4	3.656	3.363	3.112	2.899	2.716	2.559	2.426	2.311	2.213	2.129

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 125600 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELOCITY = 390 KTS.
TIME TO FIRE FIRST MISSILE = 5.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.00	.01	.01	.02	.02	.03	.03	.04	.04	.04
20	0	.01	.02	.04	.05	.06	.07	.08	.09	.10	.11
30	0	.02	.04	.07	.09	.11	.13	.15	.16	.18	.20
40	0	.03	.05	.07	.10	.12	.14	.16	.17	.19	.21
50	0	.03	.05	.07	.09	.11	.13	.14	.16	.17	.18
60	0	.03	.05	.07	.09	.10	.12	.13	.14	.15	.16

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.01	.02	.03	.04	.04	.05	.06	.07	.07
20	0	.02	.04	.05	.07	.09	.10	.12	.13	.15	.16
30	0	.03	.06	.09	.12	.15	.17	.20	.22	.24	.26
40	0	.05	.09	.13	.17	.21	.25	.28	.31	.34	.36
50	0	.07	.13	.18	.23	.28	.32	.36	.39	.42	.45
60	0	.09	.16	.23	.29	.34	.39	.43	.47	.50	.53

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10
20	0	.02	.05	.07	.09	.11	.13	.15	.17	.19	.21
30	0	.04	.08	.11	.15	.18	.21	.24	.27	.30	.32
40	0	.06	.11	.16	.21	.25	.29	.33	.37	.40	.43
50	0	.08	.15	.22	.27	.33	.37	.42	.45	.49	.52
60	0	.10	.19	.27	.34	.39	.45	.49	.53	.56	.59

X = 4

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	0	.01	.03	.04	.05	.07	.08	.09	.10	.11	.13
20	C	.03	.06	.09	.11	.14	.16	.19	.21	.23	.26
30	0	.05	.09	.14	.18	.22	.25	.29	.32	.35	.38
40	0	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
50	C	.09	.18	.25	.31	.37	.42	.47	.51	.54	.57
60	C	.12	.22	.31	.38	.44	.49	.54	.58	.61	.64

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.964	3.928	3.893	3.858	3.824	3.790	3.756	3.723	3.690	3.658
20	4	3.916	3.834	3.755	3.678	3.602	3.529	3.458	3.388	3.320	3.254
30	4	3.857	3.720	3.590	3.466	3.348	3.235	3.127	3.024	2.926	2.833
40	4	3.798	3.610	3.435	3.273	3.123	2.983	2.853	2.732	2.620	2.515
50	4	3.735	3.496	3.282	3.089	2.915	2.758	2.617	2.490	2.376	2.273
60	4	3.666	3.376	3.125	2.907	2.718	2.553	2.411	2.287	2.179	2.086

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 125600 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELOCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE = 5.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.01	.02	.03	.04	.04	.05	.06	.07	.07
20	0	.02	.04	.05	.07	.09	.10	.12	.13	.15	.16
30	0	.03	.06	.09	.12	.15	.17	.20	.22	.24	.26
40	0	.05	.09	.13	.17	.21	.25	.28	.31	.34	.36
50	0	.07	.13	.18	.23	.28	.32	.36	.39	.42	.45
60	0	.09	.16	.23	.29	.34	.39	.43	.47	.50	.53

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10
20	0	.02	.05	.07	.09	.11	.13	.15	.17	.19	.21
30	0	.04	.08	.11	.15	.18	.21	.24	.27	.30	.32
40	0	.06	.11	.16	.21	.25	.29	.33	.37	.40	.43
50	0	.08	.15	.22	.27	.33	.37	.42	.45	.49	.52
60	0	.10	.19	.27	.34	.39	.45	.49	.53	.56	.59

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.03	.04	.05	.07	.08	.09	.10	.11	.13
20	0	.03	.06	.09	.11	.14	.16	.19	.21	.23	.26
30	0	.05	.09	.14	.18	.22	.25	.29	.32	.35	.38
40	0	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
50	0	.09	.18	.25	.31	.37	.42	.47	.51	.54	.57
60	0	.12	.22	.31	.38	.44	.49	.54	.58	.61	.64

X = 4 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	C	.02	.03	.05	.06	.08	.09	.11	.12	.14	.15
20	C	.04	.07	.10	.13	.16	.19	.22	.25	.27	.30
30	C	.06	.11	.16	.21	.25	.29	.33	.37	.40	.43
40	C	.08	.15	.22	.28	.33	.38	.43	.47	.51	.54
50	C	.11	.20	.28	.35	.41	.47	.51	.55	.59	.62
60	C	.13	.25	.34	.42	.48	.54	.58	.62	.65	.68

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.952	3.905	3.859	3.813	3.768	3.723	3.679	3.636	3.593	3.551
20	4	3.893	3.789	3.689	3.591	3.497	3.406	3.318	3.233	3.150	3.070
30	4	3.823	3.655	3.496	3.346	3.204	3.070	2.943	2.823	2.710	2.602
40	4	3.743	3.506	3.288	3.088	2.904	2.735	2.579	2.436	2.304	2.183
50	4	3.654	3.345	3.072	2.828	2.611	2.418	2.246	2.093	1.957	1.835
60	4	3.557	3.177	2.853	2.575	2.336	2.132	1.957	1.807	1.678	1.567

PROBABILITY OF KILL BEFORE MISSILE NUMBER X IS FIRED

TOTAL NUMBER OF MISSILES ON SUBMARINE IS 4 RADAR SEARCH ANGLE = 360 DEGREES
SEARCH AREA = 125600 SQ. MILES CRUISE VELOCITY = 225 KTS. DASHVELOCITY =, 390 KTS.
TIME TO FIRE FIRST MISSILE =10.0 MIN. TIME TO FIRE EACH ADDITIONAL MISSILE =10.0 MIN.

X = 1 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.01	.02	.03	.04	.04	.05	.06	.07	.07
20	0	.02	.04	.05	.07	.09	.10	.12	.13	.15	.16
30	0	.03	.06	.09	.12	.15	.17	.20	.22	.24	.26
40	0	.05	.09	.13	.17	.21	.25	.28	.31	.34	.36
50	0	.07	.13	.18	.23	.28	.32	.36	.39	.42	.45
60	0	.09	.16	.23	.29	.34	.39	.43	.47	.50	.53

X = 2 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.01	.03	.04	.05	.07	.08	.09	.10	.11	.13
20	0	.03	.06	.09	.11	.14	.16	.19	.21	.23	.26
30	0	.05	.09	.14	.18	.22	.25	.29	.32	.35	.38
40	0	.07	.13	.19	.25	.30	.34	.38	.42	.45	.49
50	0	.09	.18	.25	.31	.37	.42	.47	.51	.54	.57
60	0	.12	.22	.31	.38	.44	.49	.54	.58	.61	.64

X = 3 NO. OF A/C RADAR RANGE (MILES)	0	1	2	3	4	5	6	7	8	9	10
10	0	.02	.04	.06	.07	.09	.11	.13	.14	.16	.18
20	0	.04	.08	.12	.15	.19	.22	.25	.28	.31	.34
30	0	.07	.13	.18	.23	.28	.33	.37	.41	.44	.48
40	0	.09	.17	.25	.31	.37	.42	.47	.51	.55	.58
50	0	.12	.22	.31	.39	.45	.51	.56	.60	.63	.66
60	0	.15	.27	.37	.45	.52	.58	.62	.66	.69	.72

X = 4 NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	0	.03	.05	.07	.10	.12	.14	.16	.18	.20	.22
20	0	.05	.10	.15	.19	.23	.27	.31	.35	.38	.41
30	0	.08	.16	.22	.29	.34	.39	.44	.48	.52	.56
40	0	.11	.21	.30	.37	.44	.50	.55	.59	.63	.66
50	0	.15	.27	.37	.45	.52	.58	.63	.67	.70	.73
60	0	.18	.32	.43	.52	.59	.65	.69	.73	.75	.78

EXPECTED NUMBER OF MISSILES FIRED

NO. OF A/C RADAR RANGE (MILES)	C	1	2	3	4	5	6	7	8	9	10
10	4	3.935	3.871	3.808	3.746	3.686	3.627	3.569	3.512	3.456	3.401
20	4	3.858	3.723	3.594	3.470	3.351	3.238	3.129	3.025	2.926	2.831
30	4	3.772	3.561	3.365	3.182	3.012	2.854	2.707	2.570	2.443	2.324
40	4	3.678	3.388	3.128	2.894	2.683	2.494	2.323	2.169	2.030	1.904
50	4	3.575	3.208	2.890	2.615	2.376	2.169	1.990	1.833	1.697	1.578
60	4	3.466	3.024	2.658	2.354	2.101	1.890	1.715	1.568	1.445	1.342

APPENDIX C

COMPUTATIONAL AID

This appendix, through the use of the computational flow sheets on the following pages, is designed as an aid in the calculation of results that may be desired, but that are not presented in Appendix B. Needed exponential and sine function values will be found in Appendix D.

Some additional symbols are introduced for computational ease. Their use in each case is self-evident, and none of the new symbols is used outside of this appendix.

COMPUTATIONAL FLOW DIAGRAM

A	R	N	T1	T2	n	V_c	V_d	δ

$B_1 = \delta \pi R^2 =$ ________

$T_x = (T1 + (X - 1)T2)/60$ $X = 1, 2, \ldots, n$

$T_1 =$ ________

$\vdots$

$T_n =$ ________

$$Q = \begin{cases} \sin(\delta\pi) & 0 < \delta \leq 0.5 \\ 1 & 0.5 \leq \delta \leq 1.0 \end{cases} = \_\_\_\_\_\_\_\_$$

$C_x = (2)(R)(V_c)(T_x)(Q)$ $x = 1, 2, \ldots, n$

$C_1 =$ ________

$\vdots$

$C_n =$ ________

$$P(D) = 1.0 - e^{-N(B_1 + C_n)/A} = \_\_\_\_\_\_\_\_$$

$\leq R$

		Yes	No
$T_1V_d =$	________	____	____
$\vdots$			
$T_nV_d =$	________	____	____

Is $T_xV_d \leq R$ or $> R$?

COMPUTATIONAL FLOW DIAGRAM (Con't)

If $\leq R$:

$$P_K(X) = \left[1.0 - e^{-N(B_1 + C_x)/A}\right]\left[\left(\frac{B_1}{B_1 + C_x}\right)\left(\frac{T_x V_d}{R}\right)^2\right] = \_\_\_\_\_\_$$

If $> R$:

$$P_K(X) = \left[1.0 - e^{-N(C_x + B_1)/A}\right]\left[\left(\frac{B_1}{B_1 + C_x}\right) + \left(\frac{C_x}{B_1 + C_x}\right)\left(1.0 - R/T_x V_d\right)\right]$$

$$= \_\_\_\_\_\_$$

$P_K(1) = \_\_\_\_\_\_$

⋮

$P_K(n) = \_\_\_\_\_\_$

$$E(X) = n - \sum_{i=1}^{n} P_K(i) = \_\_\_\_\_\_$$

APPENDIX D

NEGATIVE EXPONENTIAL TABLE

X	-X	X	-X	X	-X
0	1.000	.50	.607	1.00	.368
.01	.990	.51	.600	1.01	.364
.02	.980	.52	.595	1.02	.361
.03	.970	.53	.589	1.03	.357
.04	.961	.54	.583	1.04	.353
.05	.951	.55	.577	1.05	.350
.06	.942	.56	.571	1.06	.346
.07	.932	.57	.566	1.07	.343
.08	.923	.58	.560	1.08	.340
.09	.914	.59	.554	1.09	.336
.10	.905	.60	.549	1.10	.333
.11	.896	.61	.543	1.11	.330
.12	.887	.62	.538	1.12	.326
.13	.878	.63	.533	1.13	.323
.14	.869	.64	.527	1.14	.320
.15	.871	.65	.522	1.15	.317
.16	.852	.66	.517	1.16	.313
.17	.844	.67	.512	1.17	.310
.18	.835	.68	.507	1.18	.307
.19	.827	.69	.502	1.19	.304
.20	.819	.70	.497	1.20	.301
.21	.811	.71	.492	1.21	.298
.22	.803	.72	.487	1.22	.295
.23	.795	.73	.482	1.23	.292
.24	.787	.74	.477	1.24	.289
.25	.779	.75	.472	1.25	.287
.26	.771	.76	.468	1.26	.284
.27	.763	.77	.463	1.27	.281
.28	.756	.78	.458	1.28	.278
.29	.748	.79	.454	1.29	.275
.30	.741	.80	.449	1.30	.273
.31	.733	.81	.445	1.31	.270
.32	.726	.82	.440	1.32	.267
.33	.719	.83	.436	1.33	.264
.34	.712	.84	.432	1.34	.262
.35	.705	.85	.427	1.35	.259
.36	.698	.86	.423	1.36	.257
.37	.691	.87	.419	1.37	.254
.38	.684	.88	.415	1.38	.252
.39	.677	.89	.411	1.39	.249
.40	.670	.90	.407	1.40	.247
.41	.664	.91	.403	1.41	.244
.42	.657	.92	.399	1.42	.242
.43	.651	.93	.395	1.43	.239
.44	.644	.94	.391	1.44	.237
.45	.638	.95	.387	1.45	.235
.46	.631	.96	.383	1.46	.232
.47	.625	.97	.379	1.47	.230
.48	.619	.98	.375	1.48	.228
.49	.613	.99	.372	1.49	.225

NEGATIVE EXPONENTIAL TABLE (CONT.)

X	-X	X	-X	X	-X
1.50	.223	2.00	.135	2.50	.082
1.51	.221	2.01	.134	2.51	.081
1.52	.219	2.02	.133	2.52	.080
1.53	.217	2.03	.131	2.53	.080
1.54	.214	2.04	.130	2.54	.079
1.55	.212	2.05	.129	2.55	.078
1.56	.210	2.06	.127	2.56	.077
1.57	.208	2.07	.126	2.57	.077
1.58	.206	2.08	.125	2.58	.076
1.59	.204	2.09	.124	2.59	.075
1.60	.202	2.10	.122	2.60	.074
1.61	.200	2.11	.121	2.61	.074
1.62	.198	2.12	.120	2.62	.073
1.63	.196	2.13	.119	2.63	.072
1.64	.194	2.14	.118	2.64	.071
1.65	.192	2.15	.116	2.65	.071
1.66	.190	2.16	.115	2.66	.070
1.67	.188	2.17	.114	2.67	.069
1.68	.186	2.18	.113	2.68	.069
1.69	.185	2.19	.112	2.69	.068
1.70	.183	2.20	.111	2.70	.067
1.71	.181	2.21	.110	2.71	.067
1.72	.179	2.22	.109	2.72	.066
1.73	.177	2.23	.108	2.73	.065
1.74	.176	2.24	.106	2.74	.065
1.75	.174	2.25	.105	2.75	.064
1.76	.172	2.26	.104	2.76	.063
1.77	.170	2.27	.103	2.77	.063
1.78	.169	2.28	.102	2.78	.062
1.79	.167	2.29	.101	2.79	.061
1.80	.165	2.30	.100	2.80	.061
1.81	.164	2.31	.099	2.81	.060
1.82	.162	2.32	.098	2.82	.060
1.83	.160	2.33	.097	2.83	.059
1.84	.159	2.34	.096	2.84	.058
1.85	.157	2.35	.095	2.85	.058
1.86	.156	2.36	.094	2.86	.057
1.87	.154	2.37	.093	2.87	.057
1.88	.153	2.38	.093	2.88	.056
1.89	.151	2.39	.092	2.89	.056
1.90	.150	2.40	.091	2.90	.055
1.91	.148	2.41	.090	2.91	.054
1.92	.147	2.42	.089	2.92	.054
1.93	.145	2.43	.088	2.93	.053
1.94	.144	2.44	.087	2.94	.053
1.95	.142	2.45	.086	2.95	.052
1.96	.141	2.46	.085	2.96	.052
1.97	.139	2.47	.085	2.97	.051
1.98	.138	2.48	.084	2.98	.051
1.99	.137	2.49	.083	2.99	.050

SIN(X) TABLE

X EXPRESSED IN RADIANS

X	SIN	X	SIN	X	SIN
0	0	.55	.523	1.10	.891
.01	.010	.56	.531	1.11	.896
.02	.020	.57	.540	1.12	.900
.03	.030	.58	.548	1.13	.904
.04	.040	.59	.556	1.14	.909
.05	.050	.60	.565	1.15	.913
.06	.060	.61	.573	1.16	.917
.07	.070	.62	.581	1.17	.921
.08	.080	.63	.589	1.18	.925
.09	.090	.64	.597	1.19	.928
.10	.100	.65	.605	1.20	.932
.11	.110	.66	.613	1.21	.936
.12	.120	.67	.621	1.22	.939
.13	.130	.68	.629	1.23	.942
.14	.140	.69	.637	1.24	.946
.15	.149	.70	.644	1.25	.949
.16	.159	.71	.652	1.26	.952
.17	.169	.72	.659	1.27	.955
.18	.179	.73	.667	1.28	.958
.19	.189	.74	.674	1.29	.961
.20	.199	.75	.682	1.30	.964
.21	.208	.76	.689	1.31	.966
.22	.218	.77	.696	1.32	.969
.23	.228	.78	.703	1.33	.971
.24	.238	.79	.710	1.34	.973
.25	.247	.80	.717	1.35	.976
.26	.257	.81	.724	1.36	.978
.27	.267	.82	.731	1.37	.980
.28	.276	.83	.738	1.38	.982
.29	.286	.84	.745	1.39	.984
.30	.296	.85	.751	1.40	.985
.31	.305	.86	.758	1.41	.987
.32	.315	.87	.764	1.42	.989
.33	.324	.88	.771	1.43	.990
.34	.333	.89	.777	1.44	.991
.35	.343	.90	.783	1.45	.993
.36	.352	.91	.790	1.46	.994
.37	.362	.92	.796	1.47	.995
.38	.371	.93	.802	1.48	.996
.39	.380	.94	.808	1.49	.997
.40	.389	.95	.813	1.50	.997
.41	.399	.96	.819	1.51	.998
.42	.408	.97	.825	1.52	.999
.43	.417	.98	.831	1.53	.999
.44	.426	.99	.836	1.54	.999
.45	.435	1.00	.841	1.55	1.000
.46	.444	1.01	.847	1.56	1.000
.47	.453	1.02	.852	1.57	1.000
.48	.462	1.03	.857		
.49	.471	1.04	.862		
.50	.479	1.05	.867		
.51	.488	1.06	.872		
.52	.497	1.07	.877		
.53	.506	1.08	.882		
.54	.514	1.09	.887		

APPENDIX E

COMPUTER PROGRAM

The computer program included in this appendix is designed to make all P(D), $P_K(X)$, and E(X) calculations mentioned previously. The exponential formulation is used.

The program is written in FORTRAN-63, and is divided into subroutines for the various calculations. If only P(D) results are desired, Subroutines KILL and EXPNR can be removed, and vice versa. Comment cards have been used for ease in tracking through the logic.

The program was checked out on a CDC-1604.

```
      PROGRAM MISSILE
      TYPE INTEGER VA,VVC,VVD,VT1,VT2,VR,VDEL

C TYPE INTEGER VARIABLES ARE INPUT DATA. EACH REPRESENTS THE NUMBER OF
C VALUES OF A PARTICULAR PARAMETER TO BE USED.  MAXIMUM VALUES ARE
C INDICATED BY COMMENT AND DIMENSION STATEMENTS.

      COMMON/BLOCK1/A(6),VD(6)/
     1BLOCK2/VC(6),R(6),DEL(6)/
     2BLOCK3/T1(6),T2(6)/
     3BLOCK4/RVC2(6,6),TIME(6,4,6),PIR2D(6,6)/
     4BLOCK5/PK1(4,6,11)/
     5BLOCK6/VA,VVC,VVD,VT1,VT2,VR,VDEL

C INPUT UNITS FOR VARIABLES ARE,  SPEEDS - KNOTS,   TIMES - HOURS,
C  AREAS  -  SQUARE MILES ,  RANGES  -  MILES.

      READ 1000,VA,VVC,VVD,VT1,VT2,VR,VDEL,N,(A(I),I=1,6),(VC(I),I=1,6)
     1,(VD(I),I=1,6),(T1(I),I=1,6),(T2(I),I=1,6),(R(I),I=1,6),(DEL(I),I=
     21,6)
 1000 FORMAT(7I6/,I6/,7(6F12.4/))

C SUBROUTINE COMPUTE CALCULATES AND STORES OFT USED COMBINATIONS OF
C PARAMETERS

      CALL COMPUTE (N)

C SUBROUTINE DETEC CALCULATES AND PRINTS P(D).

      CALL DETEC (N)

C SUBROUTINE KILL CALCULATES AND PRINTS P(KILL). E(X) IS CALLED IN THIS
C ROUTINE.

      CALL KILL (N)
      END
```

```
      SUBROUTINE COMPUTE (N)
      COMMON/BLOCK2/VC(6),R(6),DEL(6)/
     1BLOCK3/T1(6),T2(6)/
     2BLOCK6/VA,VVC,VVD,VT1,VT2,VR,VDEL/
     3BLOCK4/RVC2(6,6),TIME(6,4,6),PIR2D(6,6)
      TYPE INTEGER VA,VVC,VVD,VT1,VT2,VR,VDEL
      DO 1,I=1,VR    $ DO 1 J=1,VVC
C RVC2 = TWO * RADAR RANGE * CRUISE VELOCITY
    1 RVC2(I,J)= 2.0 * R(I) * VC(J)
      DO 2 I=1,VT1    $ DO 2 J=1,N    $ DO 2 K=1,VT2
C TIME = TIME TO FIRE FIRST PLUS (X - 1) * TIME TO FIRE EACH ADDITIONAL
    2 TIME(I,J,K)= T1(I) + (J - 1) * T2(K)
      DO 3 I=1,VR     $ DO 3 J=1,VDEL
C PIR2D = DELTA * PI * RADAR RANGE SQUARED
    3 PIR2D(I,J) = DEL(J) * R(I) * R(I) * 3.14159
      END
```

```
      SUBROUTINE DETEC (N)
      TYPE INTEGER  VA,VVC,VVD,VT1,VT2,VR,VDEL
      COMMON/BLOCK1/A(6),VD(6)/
     1BLOCK2/VC(6),R(6),DEL(6)/BLOCK3/T1(6),T2(6)/
     2BLOCK4/RVC2(6,6),TIME(6,4,6),PIR2D(6,6)/
     3BLOCK6/VA,VVC,VVD,VT1,VT2,VR,VDEL
      DIMENSION PD1(11)
      WRITE (51,100)
  100 FORMAT(1H1,45X,28HPROBABILITY   OF   DETECTION////)
      DO 1 I=1,VA   $  DO 1 J=1,VVC   $  DO 1 K=1,VT1

C ELIMINATES CASES WHERE TIME TO FIRE FIRST MISSILE IS LESS THAN TIUE
C TO FIRE EACH ADDITIONAL MISSILE.

      DO 1 L=1,VT2   $   IF(T2(L).LE.T1(K))3,1
    3 DO 1 M=1,VDEL
      DEG = DEL(M)*360
      T1M = T1(K)* 60    $   T2M = T2(L)* 60
      WRITE(51,150) A(I),DEG,VC(J),N,T1M,T2M
  150 FORMAT(19X,11HSEARCH AREA,F7.0,14H  SQUARE MILES,20X,18HRADAR SEAR
     1CH ANGLE,F4.0,8H DEGREES,/19X,15HCRUISE VELOCITY,F4.0,6H KNOTS,20X
     2,34HNUMBER OF MISSILES ON SUBMARINE IS,I2/,11X,26HTIME TO FIRE FIR
     3ST MISSILE,F4.1,8H MINUTES,11X,36HTIME TO FIRE EACH ADDITIONAL MIS
     4SILE,F4.1,8H MINUTES//,19H NUMBER OF AIRCRAFT,13X,1H0,7X,1H1,7X,1H
     52,7X,1H3,7X,1H4,7X,1H5,7X,1H6,7X,1H7,7X,1H8,7X,1H9,6X,2H10/,14H RA
     6DAR  SEARCH,/14H RANGE (MILES)/)
      DO 1 I1=1,VR   $ IF(DEL(M).LT.0.5)4,5
    4 ALPHA = PIR2D(I1,M) + RVC2(I1,J) * SINF(DEL(M)*3.14159) * TIME(K,N
     1,L)
      GO TO 6
    5 ALPHA = PIR2D(I1,M) + RVC2(I1,J) * TIME(K,N,L)

C COMPUTES P(D),S FOR N AIRCRAFT USING PREVIOUSLY SET PARAMETERS.
C ELIMINATES CALCULATIONS WHERE NUMBER OF AIRCRAFT EXCEEDS ONE, AND WHEN
C TOTAL AREA SEARCHED BY ALL AIRCRAFT IN ONE RADAR SWEEP EXCEEDS 1.2
C TIMES THE AREA TO BE SEARCHED.

    6 DO 13  J1=1,11
      Z=(J1-1)*PIR2D(I1,M)/A(I)
      IF(Z.GE.1.2)11,10
   11 IF(J1.GT.2)12,10
   12 PD1(J1)=0    $   GO TO 13
   10 PD1(J1) = 1.0 - EXPF(-(J1-1)*ALPHA/A(I))
   13 CONTINUE
    7 WRITE(51,175)R(I1),(PD1(L1),L1=1,11)
  175 FORMAT(5X,F3.0,24X,F2.0,4X,10(F6.4,2X)//)
    1 CONTINUE
      END
```

```
      SUBROUTINE KILL (N)                                               00000400
      COMMON/BLOCK1/A(6),VD(6)/                                         00000405
     1BLOCK2/VC(6),R(6),DEL(6)/                                         00000406
     5BLOCK3/T1(6),T2(6)/                                               00000407
     2BLOCK4/RVC2(6,6),TIME(6,4,6),PIR2D(6,6)/                          00000408
     3BLOCK5/PK1(4,6,11)/                                               00000409
     4BLOCK6/VA,VVC,VVD,VT1,VT2,VR,VDEL                                 00000410
      TYPE INTEGER VA, VVC,VVD,VT1,VT2,VR,VDEL                          00000415
      DO 1 I=1,VA  $  DO 1 J=1,VVC  $  DO 1 K=1,VVD                     00000420

C ELIMINATES CASES WHERE DASH VELOCITY IS LESS THAN OR EQUAL TO CRUISE  00000421
C VELOCITY.                                                             00000422

      IF(VD(K).LE.VC(J))1,2                                             00000423
    2 DO 12 L=1,VDEL  $  DO 12 M=1,VT1                                  00000425

C ELIMINATES CASES WHERE TIME TO FIRE FIRST MISSILE IS LESS THAN TIME   00000428
C TO FIRE EACH ADDITIONAL MISSILE.                                      00000429

      DO 12 II=1,VT2  $  IF(T2(II).GT.T1(M))12,3                        00000430
    3 T11=T1(M)*60  $ T22=T2(II)*60  $  DEG=DEL(L)*360                  00000435
      WRITE(51,500)N,DEG,A(I),VC(J),VD(K),T11,T22                       00000440
  500 FORMAT(1H1,29X,60HPROBABILITY  OF  KILL  BEFORE  MISSILE  NUMBER  00000445
     1X  IS  FIRED//15X,40HTOTAL NUMBER OF MISSILES ON SUBMARINE IS,I2,00000446
     216X,20HRADAR SEARCH ANGLE =,F4.0,8H DEGREES/,7X,13HSEARCH AREA =,F00000447
     37.0,13H SQUARE MILES,10X,17HCRUISE VELOCITY =,F4.0,6H KNOTS,10X,1500000448
     4HDASH VELOCITY =,F4.0,6H KNOTS/,5X,28HTIME TO FIRE FIRST MISSILE =00000449
     5,F4.1,8H MINUTES,14X,38HTIME TO FIRE EACH ADDITIONAL MISSILE =,F4.00000450
     61,8H MINUTES////)                                                 00000451
      DO 4 N1 =1,N  $ WRITE(51,2001)N1  $ DO 4 JJ=1,VR                  00000455
      IF(DEL(L).LT.0.5)5,6                                              00000456
 2001 FORMAT(6X,2HK=,I2,/19H NUMBER OF AIRCRAFT,13X,1H0,7X,1H1,7X,1H2,7X00000457
     1,1H3,7X,1H4,7X,1H5,7X,1H6,7X,1H7,7X,1H8,7X,1H9,6X,2H10/,14H RADAR 00000458
     2 SEARCH,/14H RANGE (MILES)//)                                     00000459
    5 Q=SINF(DEL(L)*3.14159) $ GO TO 7                                  00000465
    6 Q=1.0                                                             00000466
    7 ALPHA=PIR2D(JJ,L)+RVC2(JJ,J)*Q*TIME(M,N1,II)                      00000485
      TVD = TIME(M,N1,II) * VD(K)                                       00000490
      IF(TVD.LE.R(JJ))8,9                                               00000495
    8 FAC=DEL(L)*3.14159*TVD*TVD/ALPHA   $ GO TO 10                     00000500
    9 FAC=1.0-RVC2(JJ,J)*Q/(DEL(L)*3.14159*R(JJ)*VD(K)+2.0*VC(J)*TVD*Q) 00000505

C COMPUTES P(KILL),S FOR N AIRCRAFT USING PREVIOUSLY SET PARAMETERS.    00000509

   10 DO 11 KK=1,11                                                     00000510
      Z=(KK-1)*PIR2D(JJ,L)/A(I)                                         00000511
      IF(Z.GT.1.2.AND.KK.GT.2)15,14                                     00000512
   15 PK1(N1,JJ,KK)=0  $  GO TO 11                                      00000513
```

SUBROUTINE KILL (CONT.)

```
   14 PK1(N1,JJ,KK)=(1.0-EXPF(-(KK-1)*ALPHA/A(I)))*FAC                    00000514
   11 CONTINUE                                                             00000522
      WRITE(51,2000)R(JJ),(PK1(N1,JJ,KL),KL=1,11)                          00000525
 2000 FORMAT(5X,F3.0,24X,F2.0,4X,10(F6.4,2X)//)                            00000530
    4 CONTINUE                                                             00000535
      CALL EXNR(N,I,J,K,T11,T22,DEG)                                       00000536
   12 CONTINUE                                                             00000537
    1 CONTINUE                                                             00000540
      END                                                                  00000550
```

```
      SUBROUTINE EXNR(N,B,C,D,T11,T22,DEG)                              00000600
      COMMON/BLOCK1/A(6),VD(6)/                                         00000605
     1BLOCK2/VC(6),R(6),DEL(6)/                                         00000606
     2BLOCK5/PK1(4,6,11)/                                               00000607
     3BLOCK6/VA,VVC,VVD,VT1,VT2,VR,VDEL                                 00000608
      DIMENSION EX1(6,11)                                               00000615

C  B,C, ANDD ARE SIMPLE SUBSCRIPT INTEGERS                              00000619

      TYPE INTEGER B,C,D,VR                                             00000620
      WRITE(51,100)N,DEG,A(B),VC(C),VD(D),T11,T22                       00000625
  100 FORMAT(1H1,41X,37HEXPECTED  NUMBER  OF  MISSILES  FIRED,///15X,40H00000630
     1TOTAL NUMBER OF MISSILES ON SUBMARINE IS,I2,16X,20HRADAR SEARCH AN00000631
     2GLE =,F4.0,8H DEGREES/,7X,13HSEARCH AREA =,F7.0,13H SQUARE MILES,100000632
     30X,17HCRUISE VELOCITY =,F4.0,6H KNOTS,10X,15HDASH VELOCITY =,F4.0,00000633
     46H KNOTS/8X,28HTIME TO FIRE FIRST MISSILE =,F4.1,8H MINUTES,14X,3800000634
     5HTIME TO FIRE EACH ADDITIONAL MISSILE =,F4.1,8H MINUTES,////19H NU00000635
     6MBER OF AIRCRAFT,13X,1H0,7X,1H1,7X,1H2,7X,1H3,7X,1H4,7X,1H5,7X,1H600000636
     7,7X,1H7,7X,1H8,7X,1H9,6X,2H10/14H RADAR  SEARCH/14H RANGE (MILES)/00000637
     8/)                                                                00000638
      DO 1 I=1,VR $ DO 2 J=1,11 $ EX11 =0 $ DO 11 N1=1,N                00000650
      IF(J.GT.1)10,11                                                   00000651
   10 IF(PK1(N1,I,J).EQ.0)12,11                                         00000652
   12 EX1(I,J) = 0  $ GO TO 2                                           00000653
   11 EX11 = EX11 +  PK1(N1,I,J)                                        00000655
      EX1(I,J) = N - EX11                                               00000665
    2 CONTINUE                                                          00000671
    1 WRITE(51,200)R(I),(EX1(I,I1),I1=1,11)                             00000675
  200 FORMAT(5X,F3.0,24X,F2.0,4X,10(F6.3,2X)//)                         00000680
      END                                                               00000685
```