THE POTENTIALITIES OF DECEPTION AS A SURVIVAL AID FOR A RETALIATORY MISSILE FORCE

Sorrel Wildhorn
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This Memorandum is a general assessment of the potentialities of deception as a survival aid for a retaliatory missile force. The discussion is aimed at stimulating planners, operations analysts, and weapon designers towards investigation of specific deception schemes that might promise substantial payoffs. The research contained herein is part of a study of force structure for general war, the Alternative Central War Strategies (ACWS) Project. The ACWS Project is a continuation and extension of work on strategic capabilities begun at the request of General White in 1960. It attempts to associate with strategic objectives particular modes of force employment, declaratory policy, and force structure.

This Memorandum is also relevant to a continuing study under Project RAND that examines strategic missile operations and survivability prospects.
SUMMARY

This Memorandum examines the potentialities of deception as a survival aid for a retaliatory missile force. Deception is viewed as an alternative concept, or adjunct, to such recognized approaches as degrees of hardening and dispersal of fixed installations, mobile basing, semi-mobile basing, active defense, and others. The term deception can refer to a wide variety of measures. As used herein, deception refers to any measure that induces a conservative planner to assign a fraction of his attacking force to "false targets," thus diluting his attack and correspondingly increasing the expected surviving fraction of the defender's retaliatory force. It is not the intention of this Memorandum to outline specific schemes and their application to various missile system concepts, nor to discuss the possible effects of enemy espionage and/or reconnaissance on the efficacy of the deception measures.

The analysis is conducted in generalized cost-effectiveness terms assuming that deception is successful; i.e., that the attacker is not aware that some targets are false or that he may suspect or know that some are false but is incapable of distinguishing the real from the false target. The selected payoff measure is the expected number of surviving missiles normalized with respect to the number that a fixed budget could buy and operate for a fixed period of time. Its sensitivity to the basic variables such as relative cost of deception, relative allocation between the real system and deception measure, and the uncertain nature of enemy attack (relative weight and effectiveness) is examined to uncover parameter ranges where deception might be useful.
Inexpensive deception measures show handsome payoffs over a very wide range of enemy attack characteristics. This suggests that the uncertain nature of an enemy attack need play only a minor role in the decision to implement a cheap deception scheme. For example, in the serious contingency of very low ($\leq 25$ per cent) U.S. missile survivability, deception measures amounting to 10 per cent of the system cost may increase the surviving fraction by 17 to 50 per cent over the no-deception case for enemy relative attack weights between 1.0 and 5.0 and single-shot kill probabilities between 0.25 and 0.99. Good payoffs are also indicated for the case of high ($\geq 50$ per cent) U.S. missile survivability.

Moderate-cost deception measures (roughly 25 per cent of system cost), in general, show more limited utility, although substantial in some cases. When costs rise above 40 per cent of system cost, payoffs rapidly diminish and deception becomes a worthless endeavor except for the case of near parity in force ratio and very low ($< 10$ per cent) U.S. missile survivability; payoffs remain good in this contingency.

The planner also should consider that a deception scheme might fail outright or that its success might be only temporal. Two hedges against these contingencies are suggested: (1) if possible, design the deception scheme so as to retain the option to convert (preferably cheaply) to the "real thing" in the future, and (2) allocate the budget to a greater-than-optimal fraction of missiles so that, although payoffs are decreased if deception is successful, penalties are lessened if deception fails.
ACKNOWLEDGMENTS

The author wishes to express his appreciation to L. J. Russell and J. A. Lockett for their help in performing the calculations.
# CONTENTS

**PREFACE** ................................................................. iii
**SUMMARY** ............................................................... v
**ACKNOWLEDGMENTS** ....................................................... vii
**LIST OF FIGURES** ......................................................... xi
**LIST OF TABLES** ......................................................... xiii

Section

I. INTRODUCTION ............................................................ 1

II. COST-EFFECTIVENESS ANALYSIS .......................................... 3

III. RESULTS ................................................................. 7
    General Trends ........................................................ 7
    Low U.S. Missile Survivability (≤ 25 per cent) .................. 32
    High U.S. Missile Survivability (≥ 50 per cent) ............... 34

IV. THE CONTINGENCY THAT DECEPTION MIGHT FAIL .................. 36

V. CONCLUSIONS .......................................................... 39
LIST OF FIGURES

The major portion of the title for each figure remains the same. Listed here are only the differentiating subtitles. The figure titles all begin:

"Expected fraction of surviving missiles versus fraction purchased..."

1. \(N_A/M_0 = 0.5, C_D/C_M = 0.1\) ........................................ 8
2. \(N_A/M_0 = 0.5, C_D/C_M = 0.25\) ..................................... 9
3. \(N_A/M_0 = 0.5, C_D/C_M = 0.4\) ..................................... 10
4. \(N_A/M_0 = 0.75, C_D/C_M = 0.1\) .................................... 11
5. \(N_A/M_0 = 0.75, C_D/C_M = 0.25\) .................................... 12
6. \(N_A/M_0 = 0.75, C_D/C_M = 0.4\) .................................... 13
7. \(N_A/M_0 = 1.0, C_D/C_M = 0.1\) ..................................... 14
8. \(N_A/M_0 = 1.0, C_D/C_M = 0.25\) ..................................... 15
9. \(N_A/M_0 = 1.0, C_D/C_M = 0.4\) ..................................... 16
10. \(N_A/M_0 = 1.5, C_D/C_M = 0.1\) .................................... 17
11. \(N_A/M_0 = 1.5, C_D/C_M = 0.25\) .................................... 18
12. \(N_A/M_0 = 1.5, C_D/C_M = 0.4\) .................................... 19
13. \(N_A/M_0 = 2.0, C_D/C_M = 0.1\) .................................... 20
14. \(N_A/M_0 = 2.0, C_D/C_M = 0.25\) .................................... 21
15. \(N_A/M_0 = 2.0, C_D/C_M = 0.4\) .................................... 22
16. \(N_A/M_0 = 3.0, C_D/C_M = 0.1\) .................................... 23
17. \(N_A/M_0 = 3.0, C_D/C_M = 0.25\) .................................... 24
18. $N_A/M_O = 3.0$, $C_D/C_M = 0.4$ .......................... 25

19. $N_A/M_O = 5.0$, $C_D/C_M = 0.1$ .......................... 26

20. $N_A/M_O = 5.0$, $C_D/C_M = 0.25$ .......................... 27

21. $N_A/M_O = 5.0$, $C_D/C_M = 0.4$ .......................... 28

22. $N_A/M_O = 10.0$, $C_D/C_M = 0.1$ .......................... 29

23. $N_A/M_O = 10.0$, $C_D/C_M = 0.25$ .......................... 30

24. $N_A/M_O = 10.0$, $C_D/C_M = 0.4$ .......................... 31
LIST OF TABLES

1. Parameter Ranges Studied ............................................. 6
2. Parameter Ranges for which $\frac{E[M_S]}{M_0}$ Increases by at least
   10% over the No-Deception Case .................................... 33
3. Incremental Surviving Fraction—(Low Survivability:
   $\frac{E[M_S]}{M_0} \leq .25$ for $M/M_0 = 1$) ....................... 34
4. Incremental Surviving Fraction—(High Survivability:
   $\frac{E[M_S]}{M_0} \geq .50$ for $M/M_0 = 1$) ....................... 35
5. Surviving Fraction with Alternative Allocation Policies:
   $C_D/C_M = 0.1$ .................................................... 38
I. INTRODUCTION

The problem of ensuring a moderate to high degree of survivability for a retaliatory missile force when subjected to an enemy pre-emptive attack or first-strike has received a good deal of careful attention. Alternative concepts include:

1) various degrees of hardening of fixed installations
2) hardening plus some sort of active defense
3) semi-mobility (infrequent or very slow movement),
4) mobility (truck, rail, barge, ship, submarine, airplane, satellite)
5) simple proliferation (more of the same),
6) rapid response--launch (before struck) on basis of warning
7) fixed, semi-mobile, or mobile basing, including some elements of deception
8) various combinations of the concepts listed above

This Memorandum examines the potentialities of deception as a survival aid. Deception can include a wide variety of measures ranging from attempts at concealment, introduction of decoy missiles, decoy sites, and mobile decoy carriers, to partial measures where sites are empty (false) part of the time and full (real) part of the time. It is not the intention of this Memorandum to outline specific measures and their application to various missile system concepts, nor to discuss the possible effects of enemy espionage and/or reconnaissance on the efficacy of the measures.

Attention is focused on one particular effect: the implications of inducing a conservative enemy planner to assign a fraction of his attacking force to "false" targets, thus diluting his attack and,
correspondingly, increasing the expected surviving fraction of the
defender's retaliatory force. The analysis is conducted in generalized
terms, using cost-effectiveness to measure potential payoffs and the
sensitivity of these payoffs to variations in the significant parameters.
It is assumed in the analysis that deception is successful in the sense
that the attacker is not aware that some targets are false, or that he
may suspect or know that some are false but is incapable of distinguishing
the real from the false target. In the latter case, conservative plan-
ning would dictate that all targets be attacked.

With a fixed budget for a retaliatory missile force, the expected
number of missiles surviving is determined as a function of the relative
cost of the deception measure to the missile system, the relative
investment in real missiles to false targets, the relative weight of
enemy attack, and the effectiveness of each attacking enemy missile.
The expected number of real missiles surviving appears to be an appro-
priate measure of effectiveness in this problem, especially when compared
with the reference case of no deception. In Sec. II the model is
developed in normalized form to preserve a maximum of generality. In
this way, it may serve as a framework in which specific schemes may
be tested and subjected to various enemy threats.

Since the analysis assumes that deception is completely successful,
sensible planning should also consider the possibility that successful
deception may be only temporal or may even prove disastrously unsuccess-
ful. Two hedge policies are discussed briefly in Sec. IV.
II. COST-EFFECTIVENESS ANALYSIS

Without specifying either a precise missile system concept or a deception measure, it is possible to show cost-effectiveness relationships in a generalized fashion. The central assumptions in the analysis are that the real and false targets are indistinguishable from each other in the attacker's war plans and that the targets are so dispersed in space and/or time that an attack on one does not affect an adjacent target (no bonus damage). The term "target" may take on a variety of meanings depending on the characteristics and critical elements of the particular missile system. It may be the missile itself, whether exposed or sheltered; the missile launcher or carrier; the missile shelter or exit; the launch control elements of the system; or some other vital element of the system. The point is that whatever "the target" means for a specific system, the deception measure employed attempts to replicate the same target. In the analysis that follows the terms target and missile (whether real or false) are used interchangeably. It should be also understood that a target or missile site, in the context of a specific system, may include several missiles--as may be the case in a missile train or barge.

The problem may be stated concisely in the following way: if a fixed budget (initial procurement plus 5-year operation) is to be allocated between a real missile system and a deception measure designed to create false targets, what is the expected fraction of real missiles surviving relative to the number of missiles that could be procured and operated if no deception measures were contemplated--as a function of the relative cost of the deception measure to the missile system,
the relative investment in real missiles to false targets, the relative
weight and effectiveness of the enemy attack? A simple, discrete,
uniform assignment model is employed and assumes that the attacker's
missiles are assigned uniformly to both real and false targets.

Let

\[ B = \text{the fixed budget allocated to real missiles and false targets for procurement and 5-year operation} \]

\[ C_M = \text{average 5-year system cost per missile} \]

\[ C_D = \text{average 5-year system cost per false target} \]

\[ M_O = B/C_M = \text{maximum number of missiles that budget will buy (no-deception case)} \]

\[ M = \text{number of missiles actually procured and operated} \]

\[ D = \text{number of false targets actually procured and operated} \]

\[ T = M + D = \text{total number of targets presented to attacker} \]

\[ N_A = \text{number of attacker's reliable missiles (or warheads or bombs) impacting in the target area} \]

\[ P_A = \text{single-shot kill probability of attacker's missile against the defender's target. This parameter lumps the defender's hardness level (for fixed hardened installations) with the attacker's warhead effectiveness (CEP and yield for blast-sensitive targets or other appropriate parameters for targets sensitive to other weapon effects)} \]

\[ E[M_S] = E[M_S] + E[D_S] = \text{expected number of targets surviving attack} \]

\[ E[M_S] = \text{expected number of real missiles surviving} \]

\[ E[D_S] = \text{expected number of false targets surviving} \]
If the parameters are normalized with respect to \( M_0 \), the expected fraction of real missiles surviving is expressed by:

\[
\frac{E[M_S]}{M_0} = \left[ \frac{C_D/C_M}{M_0 + \frac{C_D}{C_M} - 1} \right] (1-p_A)^n \left( 1 + \frac{M}{M_0} \left( \frac{C_D}{C_M} - 1 \right) \right) - p_A \frac{N_A}{M_0}
\]

where

\[
n \leq \left\{ \frac{N_A/M_0}{\left[ 1 + \frac{M}{M_0} \left( \frac{C_D}{C_M} - 1 \right) \right]} \right\} \leq n + 1 \quad ; \quad n = 0, 1, 2, \ldots
\]

\[
M_0 = B/C_M
\]

\[
P = \frac{1 - (M/M_0)}{C_D/C_M}
\]

*If \( m_1 \) of \( T \) defender's targets have \( n \) attacker's missile assigned to them, and \( m_2 \) of \( T \) defender's targets have \((n+1)\) attacker's missiles assigned to them then \( m_1 + m_2 = T \) and \( n m_1 + (n+1) m_2 = N_A \)

where

\[
n \leq \left\{ \frac{N_A}{T} = \frac{N_A}{M+D} \right\} \leq n + 1
\]

hence

\[
E[T_S] = m_1 (1-p_A)^n + m_2 (1-p_A)^{n+1}
\]

or

\[
E[T_S] = (1-p_A)^n \left[ (1+n p_A)(M+D) - p_A N_A \right]
\]

If real and false targets are indistinguishable, then
Calculations were made for a wide range of parameter values to ensure that the relevant cases would be treated. The range of parameters studied is summarized in Table 1.

Table 1
PARAMETER RANGES STUDIED

<table>
<thead>
<tr>
<th>Relative Cost ((C_D/C_M))</th>
<th>Fraction Missiles Purchased ((M/M_0))</th>
<th>Relative Weight of Attack ((N_A/N_0))</th>
<th>Attacker's Single Shot Kill Probability ((p_A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 - 0.4</td>
<td>0.1 - 1.0</td>
<td>0.5 - 10.0</td>
<td>0.10 - 0.99</td>
</tr>
</tbody>
</table>

\[
E[M_S] = \frac{M}{T} \cdot E[T_S] = \left(\frac{M}{M+D}\right) E[T_S]
\]

and

\[
E[M_S] = \left(\frac{M}{M+D}\right) (1 - p_A)^n \left[ (1 + np_A)(M+D) - p_A N_A \right]
\]

Now, for a fixed budget, \(M\), \(D\), and \(M_0\) are related by

\[
E = C_M M_0 = C_M M + \left(\frac{C_D}{C_M}\right) C_M D
\]

Using this relation, and normalizing with respect to \(M_0\), the expression for \(\frac{E[M_S]}{M_0}\) in terms of \(C_D/C_M\), \(N_A/M_0\), \(M/M_0\), and \(p_A\) turns out as shown above.
III. RESULTS

GENERAL TRENDS

Figures 1-24 present some computational results. The expected fraction of real missiles surviving is shown as a function of the fraction purchased, with $p_A$ as a parameter. Note that when $M/M_0 = 1$, this is the no-deception case. The figures are grouped in threes with the relative weight of enemy attack, $N_A/M_0$, constant for values of $C_D/C_M = 0.1, 0.25,$ and $0.4$. $N_A/M_0$ values of $0.5, 0.75, 1, 1.5, 2, 3, 5,$ and $10$ are treated. Since the calculations employ a discrete assignment model, the figures should actually indicate discontinuities in the first derivative. In certain cases where slope discontinuities are marked, this is so indicated; where slight, the curves are merely faired.

Some general trends emerge from an examination of the figures. As one would expect, in most cases a preferred allocation exists between missiles and false targets for which the expected surviving fraction is maximal. In the face of an ineffective attacking missile, in general, the optimal allocation is clearly all missiles and no false targets.

As relative enemy attack size and warhead effectiveness grow, an ever-increasing slice of the budget must be allocated to false targets in order to maximize the expected surviving missile fraction.

Cheap deception measures, when successful, have potentially spectacular payoffs over a wide range of enemy attack characteristics. So much so, that the decision-maker's uncertainties with regard to enemy attack characteristics might play only a minor role in the decision to implement a truly inexpensive deception measure.
Fig. 1 — Expected fraction of surviving missiles versus fraction purchased
\( N_A / M_0 = 0.5; \ C_D / C_M = 0.1 \)
Fig. 2 — Expected fraction of surviving missiles
versus fraction purchased
$N_A/M_0 = 0.5$; $C_D/C_M = 0.25$
Fig. 3 — Expected fraction of surviving missiles versus fraction purchased
$N_A/M_0 = 0.5; C_D/C_M = 0.4$
Fig. 4 — Expected fraction of surviving missiles versus fraction purchased

\( \frac{N_A}{M_0} = 0.75; \quad \frac{C_D}{C_M} = 0.1 \)
Fig. 5 — Expected fraction of surviving missiles versus fraction purchased
\[ N_A/M_0 = 0.75, \ C_D/C_M = 0.25 \]
Fig. 6 — Expected fraction of surviving missiles versus fraction purchased

\[ \frac{E[M_s]}{M_0} \]

\[ \frac{M}{M_0} \]

\[ N_A/M_0 = 0.75; \ C_D/C_M = 0.4 \]
Fig. 7 — Expected fraction of surviving missiles versus fraction purchased

\( \frac{E[M_S]}{M_0} \)

\( \frac{M}{M_0} \)

\( P_a = 0.1, 0.3, 0.5, 0.7, 0.9, 0.9999, 0.99999999999 \)

\( N_A / M_0 = 1.01, C_D / C_M = 0.1 \)
Fig. 8 — Expected fraction of surviving missiles versus fraction purchased

\[ \frac{E[M_S]}{M_0} \]

\[ M/M_0 \]

\[ P_A = 0.1 \]

\[ 0.99 \]

\[ 0.95 \]

\[ 0.9 \]

\[ 0.7 \]

\[ 0.5 \]

\[ 0.3 \]

\[ 0.2 \]

\[ 0.1 \]

\[ 0 \]

\[ N_A/M_0 = 1.0 \]

\[ C_D/C_M = 0.25 \]
Fig. 9 — Expected fraction of surviving missiles versus fraction purchased

\[ \frac{E[M_s]}{M_0} \]

\[ \text{versus fraction purchased} \]

\[ \frac{N_A}{M_0} = 1.0; \quad \frac{C_d}{C_M} = 0.4 \]
Fig. 10 — Expected fraction of surviving missiles versus fraction purchased

$N_A/M_0 = 1.5; \ C_D/C_M = 0.1$
Fig. II — Expected fraction of surviving missiles versus fraction purchased

\[ \frac{E[M_s]}{M_0} \]

\[ \frac{M}{M_0} \]

\[ N_A / M_0 = 1.5; \quad C_D / C_M = 0.25 \]
Fig. 12 — Expected fraction of surviving missiles versus fraction purchased

\[ \frac{E[M_S]}{M_0} \]

\( M/M_0 \)

\( \rho = 0.1 \)

\( \rho = 0.3 \)

\( \rho = 0.5 \)

\( \rho = 0.7 \)

\( \rho = 0.9 \)

\( \rho = 0.95 \)

\( \rho = 0.99 \)

\( N_A/M_0 = 1.5 \), \( C_D/C_M = 0.4 \)
Fig. 13 — Expected fraction of surviving missiles versus fraction purchased

\[ \frac{E[M_S]}{M_0} \]

\[ \frac{M}{M_0} \]

\( N_A/M_0 = 2.0 \), \( C_D/C_M = 0.1 \)
Fig. 14 — Expected fraction of surviving missiles versus fraction purchased

\( N_A/M_O = 2.0 \), \( C_D/C_M = 0.25 \)
Fig. 15 — Expected fraction of surviving missiles 
versus fraction purchased 
$N_A/M_0 = 2.0$; $C_D/C_M = 0.4$
Fig. 16 — Expected fraction of surviving missiles versus fraction purchased

\[ \frac{E[M_S]}{M_0} \]

\[ M/M_0 \]

\( P_a = 0.1 \quad 0.3 \quad 0.6 \quad 0.7 \quad 0.9 \quad 0.95 \quad 0.99 \)

\[ N_A/M_0 = 3.01 \quad C_D/C_M = 0.1 \]
Fig. 17 — Expected fraction of surviving missiles
versus fraction purchased
$N/A/M_0 = 3.0$, $C_D/C_M = 0.25$
Fig. 18 — Expected fraction of surviving missiles versus fraction purchased

$N_A/M_0 = 3.0 \;\; \; C_D/C_M = 0.4$
Fig. 19 — Expected fraction of surviving missiles versus fraction purchased
$N_A / M_A = 5.0 ; C_D / C_M = 0.1$
Fig. 20 — Expected fraction of surviving missiles versus fraction purchased
\( N_A / M_0 = 5.0; \ C_D / C_M = 0.25 \)
Fig. 21 — Expected fraction of surviving missiles versus fraction purchased

\[ \frac{E[M_S]}{M_0} \]

\[ M/M_0 \]

\[ P_A = 0.1 \]

\[ N_A/M_0 = 5.0; \quad C_D/C_M = 0.4 \]
Fig. 22 — Expected fraction of surviving missiles versus fraction purchased

$N_A/M_0 = 10.0$, $C_D/C_M = 0.1$
Fig. 23—Expected fraction of surviving missiles versus fraction purchased
\[ \frac{E[M_0]}{M_0} \]

\[ P = 0.1 \]

\[ N_A/M_0 = 10.0; \ C_D/C_M = 0.25 \]
Fig. 24 — Expected fraction of surviving missiles versus fraction purchased
\( N_A / M_0 = 10.0 \), \( C_D / C_M = 0.4 \)
Since the utility of successful deception measures is so strongly dependent on the parameters mentioned previously, it is worthwhile summarizing the cases where handsome payoffs appear possible (see Table 2). For illustrative purposes an arbitrary criterion is used to screen out the less relevant cases. The table shows \( p_A \) ranges for which a preferred choice of \( N/A_0 \) promises at least a 10 per cent increase in \( E[M_S]/M_0 \) over the no-deception case, for fixed values of \( N/A_0 \) and \( C_D/C_M \). Succeeding sections elaborate on several of the particularly significant cases.

LOW U.S. MISSILE SURVIVABILITY (\( \leq 25 \) PER CENT)

A class of important cases arises when the serious contingency of low U.S. missile survivability is considered. This may be the result of high enemy single-shot kill probability \( (p_A) \), and/or a heavy attack \( (N/A_0) \). If one examines cases for which the expected fraction surviving (with no deception measures) is very low (say \( \leq .25 \)), an appreciation of the potential utility of deception is evident. Table 3 lists several such cases.

The maximum incremental improvement in the surviving missile fraction is shown for a range of attack weights and kill probabilities and for cheap \( (C_D/C_M = .1) \), moderate- \( (C_D/C_M = .25) \), and high-cost \( (C_D/C_M = .40) \) deception measures. Note that up to 50 per cent more of the no-deception force may survive moderate attack weights \( (N/A_0 \approx 1) \) when cheap deception measures are used. Furthermore, the utility of deception is more pronounced for very high values of \( p_A \). Against moderate to very heavy attacks \( (1 < N/A_0 \leq 5) \) payoffs remain high (up to 40 per cent more survivors), although somewhat diminished.
Table 2

PARAMETER RANGES FOR WHICH $\frac{E[M_{s}]}{N_{0}}$ INCREASES BY AT LEAST 10% OVER THE NO-DECEPTION CASE

<table>
<thead>
<tr>
<th>$\frac{N_{A}}{M_{0}}$</th>
<th>$\frac{C_{D}}{C_{M}}$</th>
<th>Optimal $\frac{M}{M_{0}}$ (Depends on $p_{A}$)</th>
<th>$p_{A}$</th>
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<tbody>
<tr>
<td>.5</td>
<td>.1</td>
<td>.9</td>
<td>&gt; .9</td>
</tr>
<tr>
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<td>.25</td>
<td>.5-.8</td>
<td>&gt; .4</td>
</tr>
<tr>
<td></td>
<td>.40</td>
<td>---</td>
<td>*</td>
</tr>
<tr>
<td>5.0</td>
<td>.1</td>
<td>.3-.8</td>
<td>&gt; .2</td>
</tr>
<tr>
<td></td>
<td>.25</td>
<td>.3-.7</td>
<td>&gt; .3</td>
</tr>
<tr>
<td></td>
<td>.40</td>
<td>---</td>
<td>*</td>
</tr>
<tr>
<td>10.0</td>
<td>.1</td>
<td>.4-.8</td>
<td>&gt; .1</td>
</tr>
<tr>
<td></td>
<td>.25</td>
<td>.4-.6</td>
<td>&gt; .3</td>
</tr>
<tr>
<td></td>
<td>.40</td>
<td>---</td>
<td>*</td>
</tr>
</tbody>
</table>

*Deception measures are ineffective over the entire range of $p_{A}$.  


Table 3

**INCREMENTAL SURVIVING FRACTION** -- $\Delta \left( \frac{E[M_S]}{M_0} \right)$

(LOW SURVIVABILITY: $\frac{E[M_S]}{M_0} \leq .25$ for $\frac{M}{M_0} = 1$)

<table>
<thead>
<tr>
<th>$N_A/M_0$</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_A$</td>
<td>.75-.99</td>
<td>.65-.99</td>
<td>.5-.99</td>
<td>.25-.99</td>
</tr>
<tr>
<td>$\Delta \left( \frac{E[M_S]}{M_0} \right)$; $(C_D/C_M = .1)$</td>
<td>.30-.50</td>
<td>.27-.40</td>
<td>.27-.34</td>
<td>.17-.27</td>
</tr>
<tr>
<td>$\Delta \left( \frac{E[M_S]}{M_0} \right)$; $(C_D/C_M = .25)$</td>
<td>.15-.32</td>
<td>.12-.20</td>
<td>.10-.13</td>
<td>0-.09</td>
</tr>
<tr>
<td>$\Delta \left( \frac{E[M_S]}{M_0} \right)$; $(C_D/C_M = .40)$</td>
<td>.06-.23</td>
<td>0-.09</td>
<td>0-.05</td>
<td>0-.04</td>
</tr>
</tbody>
</table>

Moderate-cost deception measures ($C_D/C_M = .25$) also pay off quite handsomely against moderate attacks resulting in up to 32 per cent increased survivability. Against heavier attacks, their utility rapidly diminishes.

High-cost deception measures ($C_D/C_M = .40$) are only useful in the case of near parity in force ratio and high values (> 90 per cent) of the attacker's kill probability. As the relative deception cost increases above 40 per cent, deception rapidly becomes a worthless endeavor.

**HIGH U.S. MISSILE SURVIVABILITY (≥ 50 PER CENT)**

In these cases the utility of deception is less clear and definitely limited. Table 4 presents similar payoff data.
Table 4

INCREMENTAL SURVIVING FRACTION -- \( \Delta \left( \frac{E[M_S]}{M_0} \right) \)

(HIGH SURVIVALITY: \( \frac{E[M_S]}{M_0} \geq .50 \) for \( M/M_0 = 1 \))

<table>
<thead>
<tr>
<th>( N_A/M_0 )</th>
<th>.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_A )</td>
<td>.1-.96</td>
<td>.1-.5</td>
<td>.1-.4</td>
<td>.1-.3</td>
<td>.1-.15</td>
</tr>
<tr>
<td>( \Delta \left( \frac{E[M_S]}{M_0} \right) ); ( C_D/C_M = .1 )</td>
<td>0-.17</td>
<td>0-.17</td>
<td>0-.15</td>
<td>0-.15</td>
<td>~.10</td>
</tr>
<tr>
<td>( \Delta \left( \frac{E[M_S]}{M_0} \right) ); ( C_D/C_M = .25 )</td>
<td>0-.07</td>
<td>0-.05</td>
<td>0-.02</td>
<td>0-.02</td>
<td>~0</td>
</tr>
<tr>
<td>( \Delta \left( \frac{E[M_S]}{M_0} \right) ); ( C_D/C_M = .40 )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

High-cost deception measures \( (C_D/C_M \geq .40) \) appear worthless. Moderate-cost measures prove marginal, at best. However, inexpensive measures show definite worth; up to 17 per cent more of the force may survive in the face of attack weights between .5 and 2 and moderate to high kill probabilities.
IV. THE CONTINGENCY THAT DECEPTION MIGHT FAIL

Previous discussion has assumed explicitly that deception proves successful. Any planner necessarily must consider other contingencies. What if successful deception proves only temporal? What is the likelihood that a deception measure will fail disastrously? Clearly, the likelihood of success depends on many factors: the nature of the specific measure, the operational concept of the missile system, enemy espionage and reconnaissance efforts, and one's own security efforts. As stated previously, it is not the intention of this Memorandum to discuss specific schemes, specific missile system concepts, or possible effects of enemy espionage and reconnaissance activities. Rather, some general remarks on two types of hedge policies are in order. One approach is the option to convert deception schemes to the "real thing." The other concerns the rationale which a planner might employ in allocating his budget between the real system and the deception scheme. The two are not mutually exclusive; indeed, they can be complementary.

A highly desirable property that might well be designed into a deception scheme is the option to convert (preferably cheaply) to the "real thing" at some time in the future. A scheme may be envisaged as an effective interim measure only, due to its inherent weaknesses in the face of enemy espionage and/or reconnaissance efforts over an extended period of time, or due to deliberate over-all strategic design. A situation illustrative of the latter is the desire of a nation, on the wrong end of a missile or force gap, to narrow the gap as rapidly and effectively as possible. While building its retaliatory force capability
at maximum speed, an effective deception measure might provide a short term increase in retaliatory potential until parity or superiority is achieved. The option to convert to the real system would be particularly desirable for low-confidence measures.

In allocating the investment between the real system and the deception scheme one can also attempt to hedge against failure of deception. One buys more than the optimal fraction of missiles, accepting some decrease in the expected payoff if deception is successful, but decreasing the penalty in the event of partial or complete failure. This assumes that enemy capabilities are reasonably predictable. With serious uncertainties as to future enemy capabilities any allocation represents some compromise (off-optimum) payoff. This is readily apparent in the following example.

Suppose

a) The relative cost is estimated as roughly \( C_D/C_M = .1 \)

b) Enemy single-shot kill probability estimates are \( .5 \leq p_A \leq .7 \)

c) Relative attack weight is uncertain, but approximate parity is desired; i.e., \( 1.0 \leq \frac{N_A}{N_0} \leq 1.5 \).

Table 5 shows the expected surviving fraction for the optimal allocations, a compromise allocation that hedges against disaster, and the reference case of no deception, for both extreme situations in which deception is fully successful and a complete failure. Optimal allocation, over the attack parameter range shown, varies from 75 to 87 per cent missiles. The postulated hedge allocation assumes 90 per cent missiles.
Table 5
SURVIVING FRACTION WITH ALTERNATIVE ALLOCATION POLICIES
\((c_d/c_m = 0.1)\)

<table>
<thead>
<tr>
<th>(N_A/M_0)</th>
<th>1.0</th>
<th>1.0</th>
<th>1.5</th>
<th>1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P_A)</td>
<td>0.5</td>
<td>0.7</td>
<td>0.5</td>
<td>0.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deception</th>
<th>Optimal Allocation ((N/M_0))</th>
<th>(.87)</th>
<th>(.80)</th>
<th>(.80)</th>
<th>(.75)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(E[M_S]/M_0)</td>
<td>.67</td>
<td>.60</td>
<td>.59</td>
<td>.51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Successful</th>
<th>Hedge Allocation ((N/M_0=0.9)): (E[M_S]/M_0)</th>
<th>.66</th>
<th>.57</th>
<th>.55</th>
<th>.41</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Missiles ((N/M_0=1.0)): (E[M_S]/M_0)</td>
<td>.50</td>
<td>.30</td>
<td>.38</td>
<td>.20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deception</th>
<th>Optimal Allocation ((N/M_0))</th>
<th>.46</th>
<th>.25</th>
<th>.28</th>
<th>.09</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(E[M_S]/M_0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fails</th>
<th>Hedge Allocation ((N/M_0))</th>
<th>.47</th>
<th>.28</th>
<th>.34</th>
<th>.16</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(E[M_S]/M_0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All Missiles (E[M_S]/M_0)</td>
<td>.50</td>
<td>.30</td>
<td>.38</td>
<td>.20</td>
</tr>
</tbody>
</table>

Note that, if deception is successful, the maximum gains of 17 to 31 per cent (that are possible with optimal allocations) are reduced to 16 to 21 per cent using the hedge allocation. On the other hand, if deception fails, the maximum penalties of 4 to 11 per cent (that are imposed with optimal allocations) are reduced to 3 to 4 per cent using the hedge allocation. Also, in cases where the surviving fraction is low (e.g., \(N_A/M_0 = 1.5\), \(P_A = 0.7\) on Table 5) small percentage improvements in the penalties could mean almost double the number of surviving missiles. Hence, the hedge policy illustrated here strikes a reasonable balance between the extreme eventualities of complete success and utter failure.
V. CONCLUSIONS

Among the various approaches aimed at increasing the survivability
of a retaliatory missile force, deception measures show promise as an
alternative method, or adjunct, to such concepts as hardening, mobility,
dispersal, rapid response, and active defense. A generalized cost-
effectiveness analysis indicates that potential payoffs may range from
nil to huge. Cheap deception measures, when successful, show handsome
payoffs over a wide range of enemy attack characteristics. For example,
in the serious case of very low (≤ 25 per cent) U.S. missile survivability,
decception measures of about 10 per cent of the system cost may increase
the surviving fraction by 17 to 50 per cent. Good payoffs are also
indicated for the contingency of high (≥ 50 per cent) U.S. missile
survivability. Moderate-cost deception measures (25 per cent of system
cost), in general, show more limited utility, although substantial in
some cases. When costs rise above 40 per cent of system cost, payoffs
rapidly diminish and deception becomes a worthless endeavor, except for
the case of near parity in force ratio and very low (< 10 per cent)
U.S. missile survivability; payoffs remain good in this contingency.

The planner also should consider that successful deception may be
temporal or that deception might fail. Two types of hedges are suggested:
(1) the option to convert (preferably cheaply) a deception scheme to
the "real thing" in the future; and (2) allocating the budget to a
greater-than-optimal fraction of missiles so that, although payoffs are
decreased if deception is successful, penalties are lessened if deception
fails.