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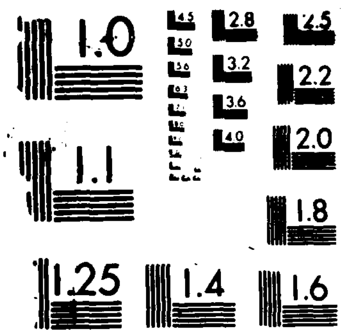

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PEACEKEEPER TEST STRATEGY:

A PILOT DECISION ANALYSIS

THESIS

Walter W. Darnall, Jr
Major, USAF

AFIT/GLM/LSY/87S-17

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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ABSTRACT

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PEACEKEEPER TEST STRATEGY: A PILOT DECISION ANALYSIS

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

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Major, USAF

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Preface

I believe that better ways must be found to gather and analyze intercontinental ballistic missile reliability data. The costs associated with flight testing and the dwindling number of test assets require that we make the best possible use of all the data we obtain. My desire is to stimulate thought on the subject of ICBM testing in the hope that others who share similar concerns will continue to look for new and innovative methods of obtaining and analyzing test data.

I could not have written this thesis without the help of many others. Lt Col John Dumond of the Air Force Institute of Technology faculty gave me many of his free hours, often on short notice, so that I could have the benefit of his knowledge of ICBM operations and testing. Many friends and former colleagues assigned to the Strategic Air Command and the Air Force Operational Test and Evaluation Center were generous in their time and expertise. They provided the information necessary to accomplish this undertaking. A special thanks is in order for my advisor, Capt Joe Tatman. His patience, understanding, teaching ability, and insight were indispensible. His enthusiasm for the project was contagious and got me through more than one dark hour.

Special recognition is required for my wife Suzann and my daughters Charly and Amanda. Without their love and support, this thesis could not have been completed.

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Abstract

A pilot decision analysis was conducted to determine an optimal test strategy for the PEACEKEEPER intercontinental ballistic missile weapon system. Air Force officers experienced with PEACEKEEPER were consulted and their inputs combined into an influence diagram. The resulting model was solved using the Performa software program and showed that, while launching six missiles per year gives the largest expected value, little additional information is gained after the third launch. This simple model indicates that a new, more comprehensive decision-making process is possible. The model is flexible and can be easily expanded to incorporate any factors that a decision maker might want to consider before expending his scarce resources. It allows relationships between the variables to be readily shown and more fully understood. This pilot model is a starting point from which new insights may be developed through the integrated use of currently available weapon system data.

PEACEKEEPER TEST STRATEGY: A PILOT DECISION ANALYSIS

I. Introduction

Background

Intercontinental Ballistic Missile (ICBM) reliability data is used by the Joint Chiefs of Staff (JCS) in planning the Single Integrated Operations Plan (SIOP) (6:7). Historically, this reliability data has been obtained through field testing, using simulated electronic launch-MINUTEMAN (SELM) exercises, and flight tests on the Western Test Range as depicted in Figure 1 (10). This was possible because, until recently, there were adequate numbers of test assets available to ensure a viable test program for each of the different MINUTEMAN configurations. This will not be the case with the new PEACEKEEPER system. PEACEKEEPER may be deployed in limited numbers, in more than one basing mode, and with limited test assets; therefore the traditional methods for gathering ICBM reliability data may no longer be able to detect system degrades with the same degree of confidence as in the past.

Historically, Strategic Air Command (SAC) planners have only used flight and ground tests to collect ICBM system reliability data (8). The availability of test assets allowed for a robust flight test program and the large number of deployed missiles allowed for 11 interconnected missiles and their two associated launch control

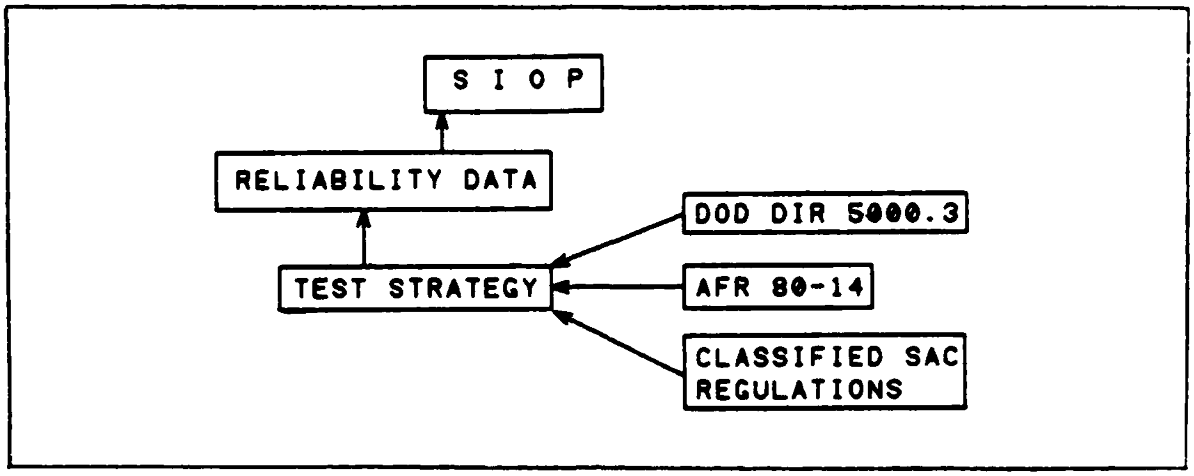

Figure 1. Test Strategy Relationships

centers (LCC) to be taken off alert status for SELM testing. The JCS could maintain their confidence that the reliability numbers obtained from these testing programs were truly representative of the systems on alert status because an adequate number of data points could be gathered. Combining these two methods also gives an approximation of an operational launch. The SELM test exercises operational ground support equipment and missile electronics from generation of the launch command up to, but not including, booster ignition. Flight testing utilizes randomly selected missiles from the operational force that are removed from their launch facility, transported to Vandenberg AFB, and launched from modified launch facilities. Combining the ground test (operational equipment generating signals to the missile) and flight test (missile receiving signals and launching) provides a complete, if broken, sequence of events that is representative of the sequence experienced by a missile launched from an operational launch facility.

Department of Defense (DOD) Directive 5000.3 requires that testing be as conducted in a manner that is as operationally realistic as possible (6:3;7:17). This has been determined by SAC to mean SELM and flight testing (9;10;11). This strict interpretation of DOD Directive 5000.3 was appropriate in an era of adequate flight test assets and the ability to obtain SELM data. However the PEACEKEEPER program may fall short in both of these areas. A Congressional Budget Office study has determined that while SAC has proposed a "modest" flight test program, it will require too many missile launches and should therefore be reduced (5:14,15). The simulated electronic launch-PEACEKEEPER (SELP) program will be scaled down from the SELM program because while removing 11 MINUTEMAN missiles from alert status affects only 1.1 percent of that system, removing 11 PEACEKEEPERS involves 22 percent of the silo deployed portion of that system - an unacceptably large percentage (11). SAC believes that they have proposed a program using the absolute minimum number of tests (8,10). Since the confidence in the ability to detect a degrade in the system's reliability is currently a direct result of the number of tests conducted, reducing the number of test assets below the minimum number required results in a decrease in the confidence that can be placed in those reliability numbers.

SAC has a requirement to determine the reliability of the PEACEKEEPER weapon system. They are faced with the choice of continuing with traditional means of ICBM testing and potentially not having test assets remaining towards the end of the system's life, or finding ways of reducing the average yearly requirement for the number of test flights. There are historical precedents for both alternatives. The TITAN ICBM weapon system had not been flown in an operational test launch between 1969 and its deactivation in 1987. MINUTEMAN II has seen a reduced number of flight tests in recent years with only eight flight tests conducted since 1980 (16). Yet the TITAN system was still included in the SIOP until the final missile was deactivated and MINUTEMAN II continues to be part of the SIOP (11).

Statement of the Problem

The Air Force must determine a testing strategy for the PEACEKEEPER system. Using decision analysis, can a pilot model be developed that captures the essential variables and relationships that determine what this strategy will be?

Purpose of the Study

This was a pilot, or preliminary, decision analysis because of the limitations stated below. Its purpose was to present a viable procedure for accomplishing the actual decision by identifying and analyzing the basic issues of the decision.

Summary of Results

Influence diagrams proved to be useful in determining the key variables and relationships between the variables that affect the decision making process. Analysis of the model using the Performa decision analysis software program provided answers to questions that a decision maker would want to know.

The pilot model provided a framework from which a full-scale analysis can be developed. The model is a very simplified representation of the problem and is mainly useful for determining the most important relationships. The potential for decision analysis to handle such a problem was established and a model was developed that the Air Force could use in further understanding this decision problem.

Limitations of the Study

There were two major limitations to this study:

Restriction from use of classified material. This thesis remained unclassified. This was a limitation because the actual reliability numbers gathered from ICBM testing are classified. For operations security reasons, numbers used in this thesis were unclassified approximations that were not related to the actual numbers. Because the numbers used can make a difference in the final decision, the decision derived from this study cannot be strictly applied to the actual situation. This is easily alleviated by replacing the unclassified numbers with the correct, classified data and reanalyzing the data.

Use of Substitute Decision Maker. The actual decision maker for this problem would have been a general officer, probably the Commander-In-Chief, Strategic Air Command. Not having access to the real decision maker and his staff, information was gathered from many officers knowledgeable in various aspects of ICBM acquisition, operations, testing, and evaluation. These inputs were combined into a simple model that the author believes is representative of the current environment. However, each decision analysis is tailored to a specific decision maker. As soon as the decision maker changes, the analysis must be reaccomplished to reflect the new decision maker. For this decision analysis to be usable, the actual decision maker would have to be used. Additionally, the actual decision maker would have expert resources available to provide him and the analyst with more accurate inputs to the decision analysis model.

Definitions

For the purposes of this study, the following terms are defined:

Decision: A decision is an "irrevocable allocation of resources" (9:23). It is differentiated from an outcome, which is a state that occurs as a result of what decision is made. The decision maker can make a decision but has no absolute control over what the outcome of the decision will be.

Decision analysis: "The process of an analyst working closely with a decision maker to build a mathematical model relevant to a decision" (14). Its purpose is to help the decision maker better understand the decision problem by developing a quantitative model to represent a decision problem. The model is then analyzed mathematically to assist the decision maker in gaining insight and understanding into the problem (13:1-2).

Decision maker: The individual who will ultimately make the decision. This person has the power to commit the organization to a course of action.

Pilot analysis: "A simplified, approximate, but comprehensive, analysis of a decision problem" (9:12). It helps to provide understanding and communications about the problem and is used as an aid in preparing the final decision analysis.

Values: Represent the desirability of each outcome.

II. Decision Process

Department of Defense Directive 5000.3, dated 12 Mar 86, states that "The primary purpose of all T&E (Test and Evaluation) is to make a direct contribution to the timely development, production and fielding of systems that meet the user's requirements and are operationally effective and suitable" (6:2). Air Force Regulation (AFR) 80-14 allows for combining Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E) if "separate testing would cause ... increases in system acquisition costs or in resources" (7:7). Because of "the limited time available for testing, fiscal limitations, and because ICBM tests are generally destructive in nature" a combined DT&E/OT&E program has been established for the PEACEKEEPER weapon system (6:2).

The system's test cycle is composed of DT&E, Initial Operational Test and Evaluation (IOT&E), Follow-on Operational Test and Evaluation (FOT&E) (I), and FOT&E(2) Phases I and II. Each testing period has its own unique objectives depending on the maturity of the system and each agencies charter. SAC, the Ballistic Missile Office (BMO), and the Air Force Operational Test and Evaluation Center (AFOTEC) are involved in the decision on how an ICBM will be tested but their influence varies with the maturity of the system. Figure 2 summarizes the proposed test program.

Test Phase	**DT&E**	**IOT&E**	**FOT&E(1)**	**FOT&E(2) Phase I**	**FOT&E(2) Phase II**
Launches	1-10	11-16	17-20	21-45	46-end
Responsible Organization	BMO	BMO/ AFOTEC	BMO/ AFOTEC	SAC	SAC
Purpose	Initial design and performance evaluation	Increased system integration	Further integration and system testing after 1st missile deployed	Initial *SIOP* planning factors	Update *SIOP* planning factors and detect degrades

Figure 2. Proposed PEACEKEEPER Test Program

Developmental Test and Evaluation (DT&E)

According to DoD Directive 5000.3, "DT&E is that T&E conducted throughout various phases of the acquisition process to ensure the acquisition and fielding of an effective and supportable system by assisting in the engineering design and development and verifying attainment of technical performance specifications, objectives, and supportability" (6:4). Air Force Systems Command (AFSC) has overall management responsibility for the combined DT&E/OT&E/FOT&E(1) program (7:2). According to AFR 80-14 the DT&E objectives are to:

a. Assess critical issues.
b. Determine how well the contract specifications have been met.
c. Identify and report system deficiencies.
d. Determine system compatibility and interoperability with existing and planned equipment or systems.
e. Report reliability in relation to the approved reliability growth plan, and to estimate maintainability, availability, and logistics supportability of the system at maturity.
f. Certify that the system is safe and ready for dedicated OT&E.
g. Validate any configuration changes caused by correcting deficiencies, modifications, or product improvements.
h. Assess human factors and identify limiting factors.
i. Assess the technical risk and evaluate compliance with the specifications, in relation to operational requirements (including reliability, maintainability, and availability), life cycle costs, and schedules.
j. Determine system response or hardness to the nuclear and conventional environments in order to support system survivability assessment as directed, and to assess system vulnerability, including hardness features and radioelectronic combat vulnerability.
k. Verify the accuracy and completeness of the technical orders developed to maintain and operate the weapon system.
l. Gather information for training programs and technical training materials needed to support the weapon system.
m. Provide information on environmental issues to be used in preparing environmental impact assessments.

n. Determine system performance limitations and safe operating parameters (7:7).

AFSC tasked the BMO, headquartered at Norton AFB in San Bernardino, Ca., to be the System Program Office (SPO) for PEACEKEEPER. As the implementing command for DT&E, BMO:

a. Assigns the test director to manage DT&E.
b. Integrates DT&E and OT&E requirements to form a combined test plan to accommodate the T&E needs of the implementing and OT&E commands. The combined test plan will integrate the schedule and resource requirements, but will not affect the test objectives of either the developmental test plan or the operational test plan.
c. Provides the test articles necessary to support both the DT&E and OT&E portions of the combined test program.
d. Arranges for support resources and establishes schedules necessary to carry out the combined test program.
e. Reviews and approves all safety aspects of the combined test program.
f. Provides the interface with the system contractor (7:8).

Although there is no distinct break point between DT&E and IOT&E, the first 10 launches, which initially evaluated the system components and integrated them into the launch facility, could be considered DT&E flights.

Initial Operational Test and Evaluation (IOT&E)

IOT&E is conducted in an environment that becomes increasingly more operationally realistic as the testing program proceeds. According to AFR 80-14, "the primary purpose of Air Force OT&E is to ensure that only operationally effective and suitable systems are delivered to the operating forces" (7:7). The IOT&E objectives are to:

a. Evaluate the operational effectiveness and operational suitability of the system.
b. Answer unresolved critical operational issues.
c. Identify and report operational deficiencies.
d. Recommend and evaluate changes in system configuration.

e. Provide information for developing and refining:
   (1). Logistics and software support requirements for the system.
   (2). Training, tactics, techniques, and doctrine throughout the life of the system.
f. Provide information to refine operation and support (O&S) cost estimates and identify system characteristics or deficiencies that can significantly affect O&S costs.
g. Determine if the technical publications and support equipment are adequate.
h. Assess the survivability of the system in the operational environment (7:8).

Flights 11 through 16 may be considered to have been IOT&E flights. They consisted of launches that increasingly integrated the components into more of the final production configuration. BMO was responsible for conducting the tests and worked closely with AFOTEC to incorporate AFOTEC's increasing inputs into each test's objectives.

AFOTEC, as the OT&E command, has an increasing interest in the test program through FOT&E(1). They participate in the OT&E process through the completion of the combined test program (7:3) and:

a. Assign the test director and deputy test director to conduct OT&E.
b. Prepare the OT&E plan for integration into the combined plan.
c. Coordinate on the combined test plan.
d. Arrange for OT&E peculiar resources.
e. Conduct and report on the OT&E, and make an independent operational evaluation (7:8).

Follow-on Operational Test and Evaluation (FOT&E)

FOT&E began after the first operational missile was deployed. This final testing period is separated into three catagories: FOT&E(1) will continue to be conducted by BMO and closely aligned with AFOTEC objectives (BMO flight test missiles 17-20); FOT&E(2) Phase I is scheduled to begin in 1989 when SAC begins to launch missiles that have previously been operationally deployed; and FOT&E(2) Phase II. FOT&E(1) began with BMO flight 17, the first launch after an operational missile had been deployed. The remaining three flights will take place under BMO control with AFOTEC and SAC participation, through 1989. FOT&E(2) Phase I testing for the silo deployed missiles is planned to begin in 1989 and will consist of SAC conducting 24 launches over a three year period (10). Although the objectives and responsibilities for conducting this testing are not specifically listed as are those for the previous phases, this testing is designed to assess the deployed system accuracy and reliability and provide a data base of SIOP planning factors (2). Plans for Phase I testing for rail garrison deployed missiles have not been finalized (10). The rail garrison Phase I may also have the additional objective of determining whether the missiles from the different basing modes can be regarded as having similar characteristics and can therefore be regarded as coming from the same population, or if they are different and two separate testing programs must be developed (2).

Phase II testing begins after the completion of Phase I and continues for the deployed life of the system. It is designed to update SIOP planning factors and to provide a means of detecting system degrades (2). If the results of Phase I testing indicate that the missiles from the two deployments come from the same population, Phase II is scheduled to consist of 84 launches. If the results indicate significant differences in performance between the missiles from the different basing modes, further assessment will be made as to how many additional test assets will be required (10,12).

Relationships

BMO, SAC, and AFOTEC work together during all phases of the weapon system's life. SAC states the need for a system and its top level operational requirements. HQ USAF/AQQ validates requirements and publishes the Program Management Directive (PMD) that formalizes the system's requirements. BMO acquires a system designed to comply with the validated requirements. AFOTEC insures that test objectives are met that verify the new system is adequate to meet the validated mission requirements. SAC then tests the deployed system. Finally, depending on the scope of the work, SAC, BMO and AFOTEC may all participate in the development and fielding of system modifications. SAC, BMO, and AFOTEC receive direction from HQ USAF/AQQ who in turn responds to direction provided from the Office of the Secretary of Defense (OSD) and the Executive branch of government. Congress provides funding, thereby mandating the force size. See Figure 3.

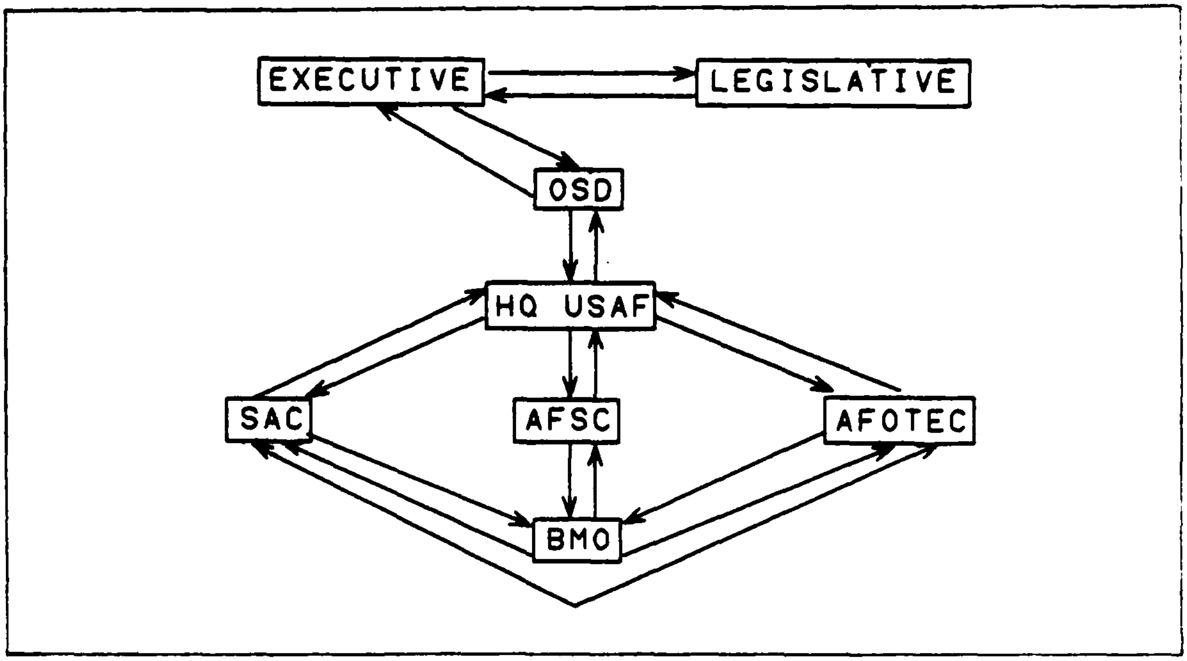

Figure 3. Top Level Organizational Relationships

All these agencies are participants in the formulation of a test strategy. Given that the Executive branch, OSD, and HQ USAF have supported the concept of acquiring the PEACEKEEPER system and have provided for the appropriate funding levels in the proposed budgets, Congress must still appropriate the monies. BMO, SAC, and AFOTEC work together to determine the best test strategy based on this funding level. During early DT&E testing, BMO has most of the responsibility for formulating test objectives, with SAC and AFOTEC overseeing the tests. As the system matures and the test articles begin to more closely resemble the final deployment configuration, AFOTEC becomes more involved with formulating test objectives to verify the system while BMO maintains responsibility for the testing. SAC has some input into the test objectives but mainly observes and analyzes the test results for their operational implications. When SAC assumes responsibility for testing the deployed force at FOT&E(2) Phase I, they control the tests and BMO and AFOTEC have their role reduced to developing and testing system modifications.

SAC, through the 549th Weapon System Evaluation Squadron (WSES), determines how many test launches are required to meet Weapon System Evaluation Guide (WSEG) 92D, DoD Directive 5000.3, and AFR 80-14 guidance. By using the equations:

$$P=1-(1-DR)\exp n \qquad (1)$$

or

$$n=[\ln(1-p)]/[\ln(1-DR)] \qquad (2)$$

where

P is the confidence of detecting the failure mode

D is the percentage of degrade in reliability caused by the failure mode

R is the initial (nondegraded) reliability

n is the number of missiles

the 549th WSES determines how many missiles must be launched in order to comply with JCS guidance that requires a "stated degree of confidence of detecting failure modes that degrade reliability by certain amounts" (3). A confidence of .90 and a degrade of .10 was used in the Congressional Budget Office report and in the WSES 30 Nov 1982 Memo For Record (5:8;1:1). The actual confidence and degrade probabilities are classified.

The following assumptions are required to be made in order to use these equations:

1) The failure mode of interest is always masked by other failures.
2) All failures of the system are detectable by analysts.
3) The new failure mode is independent of the original failure mode.
4) The test size is based on the ability to detect at least one of the failure modes.
5) The degrade in reliability is assumed to occur instantaneously (4:1).

Current testing guidelines do not specify the time period over which the confidence of detecting a degrade is required, therefore, the interval for detecting the failure mode may be from one to several years. This being the case, an "n" of 21 can be launched all in one year, giving a launch rate of 21 missiles per year, or spread over three years, giving a launch rate of seven missiles per year. The number of years that are required to accumulate the desired confidence of detecting a degrade is determined from "n" and the yearly launch rate. By multiplying the number of years the system is expected to be fielded with the yearly launch rate, the total number of test assets required for the life of the system can be determined.

This determination is presented through HQ SAC/DOMV to the HQ SAC/DO, LG, and XP staffs for their coordination as depicted in Figure 4. Their coordinated position is presented to the Commander-in-Chief, Strategic Air Command and he gives the final approval (16). This decision on test levels is relayed through HQ SAC/XPQ to the BMO and HQ USAF/AQQ. If AQQ accepts these levels for inclusion in the PMD, they are then included in the budget submission to Congress and BMO begins the necessary contractual efforts to obtain the missiles, predicated on Congressional funding. Congress can accept these levels by providing full funding or can fund at a different level. If this level is lower than that requested by the Air Force, SAC must return and ask for additional assets or adjust their test program to work within the Congressionally mandated constraints. The funding request for missile assets does not occur only in one year, but is spread over several years. The requests are based on the number of required missiles, what BMO believes to be an economical buy rate, and how many missiles have previously been funded.

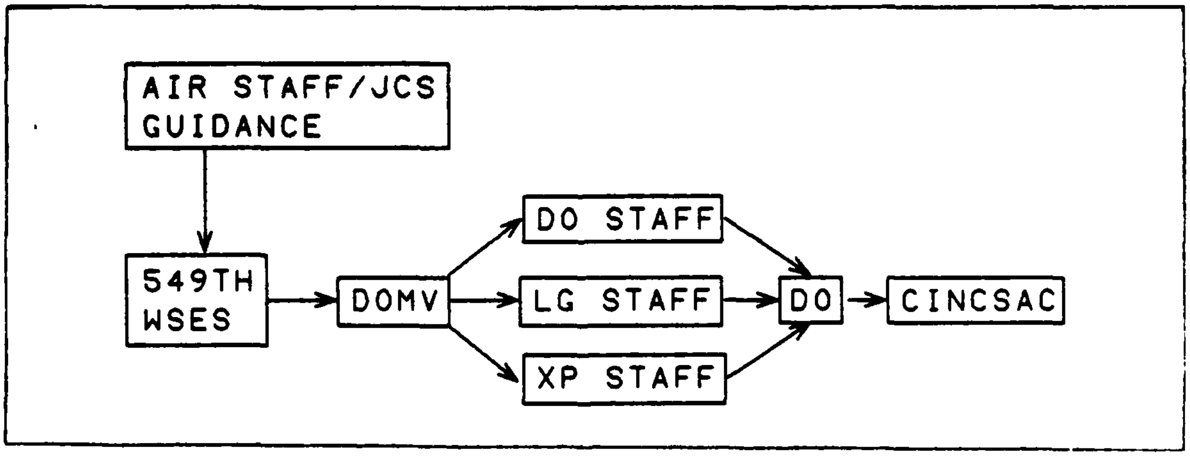

Figure 4. HQ SAC Information Flow to Decision Maker

SAC is asking for 108 test missiles for silo-based PEACEKEEPER testing. 24 launches are planned over the first three years for FOT&E(2) Phase I. The other 84 launches are planned for FOT&E(2) Phase II and are evenly spread over the remaining 12 year expected life of the system. If an additional 50 operational PEACEKEEPER missiles are deployed in the rail garrisoned basing mode, SAC would like to conduct an FOT&E(2) Phase I consisting of 24 missiles to be launched over three years in order to determine if there is a difference in the missiles from the two basing modes. If no difference is found, the testing would resume with results being applied to both systems. If a difference is found, separate programs would have to be conducted to test each system. The current PMD only provides for an additional 12 missiles (12).

With this understanding of the overall testing philosophy and the agencies responsible for formulating the test philosophies, the model is now discussed.

III. Methodology

The model was developed based on inputs from many Air Force officers having current or past experience in one or more of the fields concerning ICBM requirements generation, operations, testing, evaluation, and acquisition. These inputs were meshed with the author's four years of experience in MINUTEMAN III operations, three years experience at Vandenberg AFB in both MINUTEMAN and PEACEKEEPER testing, and three years at Detachment 2, Headquarters Strategic Air Command assigned to the Ballistic Missile Office at Norton AFB. In these assignments he has had the responsibility for generating and articulating SAC requirements to the BMO and its contractors as well as monitoring the developmental progress of the PEACEKEEPER and Small ICBM systems. The model resulted from the interactions depicted in Figure 5.

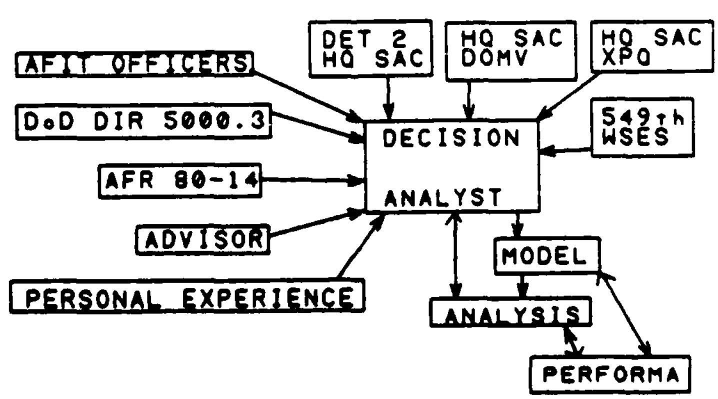

Figure 5. Thesis Development

The author began by conducting telephone conversations with officers currently assigned to HQ/SAC XPQM and DOMV, Detachment 2 HQ/SAC and the 549th WSES. The current status of the PEACEKEEPER acquisition and deployment in both the silo and rail garrison basing modes was obtained. Issues surrounding the determination of the number of missiles to deploy, various basing mode concepts, and the number of missiles that are required to conduct a test program were reviewed. The current status as well as projections for the future of the MINUTEMAN test program were discussed. Parallels were drawn between the test programs for the TITAN, MINUTEMAN II, MINUTEMAN III, and PEACEKEEPER programs in light of past test policies, current numbers of MINUTEMAN II and MINUTEMAN III test assets, projected requirements for MINUTEMAN II and MINUTEMAN III assets, stated and proposed requirements for PEACEKEEPER test assets for both basing modes, current and projected funding for PEACEKEEPER test assets, and the contractual and projected lifetime of the PEACEKEEPER system.

Unclassified regulations were reviewed to establish the basis for how and why testing occurs.

Finally, three instructors from the Air Force Institute of Technology (AFIT) faculty each separately agreed to assume the role of the decision maker for whom the model would be built. The officers represented a variety of backgrounds and experiences in working with ICBMs, with one having been stationed at the BMO working in systems acquisition, another having HQ SAC experience, and the third having been assigned to an operational ICBM unit as a missile crew member and later as a missile maintenance officer. This last officer was also assigned to AFOTEC and participated in the development of the first PEACEKEEPER test plan.

Each officer was asked to take a top level view of the test program as if he were making the Air Force decision on what the test policy should be. No restrictions were placed on the options which could be considered and the officers were especially encouraged to develop alternatives to flight testing. The potential outcomes for each option and the test program as a whole were considered and the question of why have a test program at all was discussed. The field of decision makers was then narrowed to one officer based on the more rapid development of his model. Since his model was based on the goal of meeting the confidence levels set forth in DoD Directive 5000.3, the model grew to represent a better way of determining how many flight test missiles are needed to meet this guidance as opposed to discovering alternatives or complements to flight testing.

More conversations were held with various members of the 549th WSES in an effort to more fully understand their role in developing the number of flight test missiles and the equations they use.

The model was developed based on the inputs from each of the decision makers, information obtained from officers assigned to SAC, and the author's experience and judgement. The last decision maker was again contacted for his estimations of the abilities of launch analysts to identify failure modes based on the various combinations of launches and failures associated with a range of zero to three missiles. The author assigned probabilities to the two degrees of degrade that were present in the model and then assigned values to all the possible outcomes. The emphasis was on developing a model that is structurally correct. True values and probabilities can be obtained from the decision maker as the pilot model is expanded into a full-scale analysis.

The model was analyzed using the software program Performa, version 1.0. A worth lottery was calculated and stochastic sensitivity analysis conducted. The model was then expanded to include three degrees of degrade and the possible number of launches was expanded to eight. Estimations of the analysts' abilities to determine failure modes were expanded by the author based on those previously given by the decision maker. A new set of values was assigned by the author. The expanded model was first analyzed in order to determine the number of launches per year that gave the maximum value. Various other analyses were then performed to determine probability distributions that might prove of interest to a decision maker.

IV. Model Structure

Overview

A format was needed that would show not only the various pieces of information that are needed, but would also show how the pieces relate to each other. The use of influence diagrams accomplished this. The resulting model, shown in Figure 6, consists of a decision variable (NOMSLS), three random variable (DEGRADE%, DETECT, and FAILURES), a value variable (V), and arcs between the variables indicating their relationships. The value (V) of the test program is dependent on the number of missiles launched (NOMSLS), the percentage of the force that is degraded (DEGRADE%), and the ability of the analysts to detect the degrade mode (DETECT). Missiles are limited in quantity, may cost up to $98 million each, and are expended upon being launched (10). This is a large price to pay, so a program that requires the fewest number of launches is preferred. The pilot model only covers a time period of one year. This time period can be lengthened or compressed as necessary.

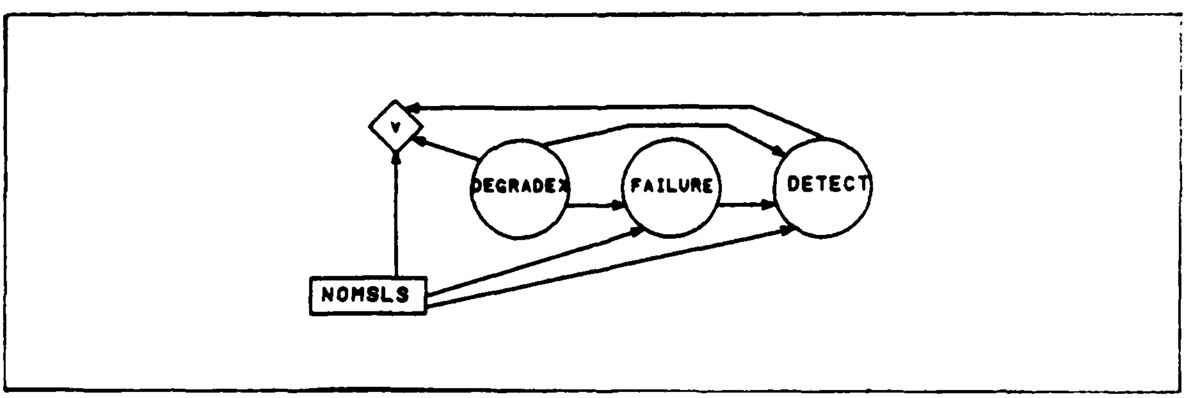

Figure 6. Pilot Model

The DEGRADE% effects the value of the test program in that large degrades are more important to discover than are small degrades. A decision maker might be less willing to expend valuable test assets to uncover a five percent degrade than he would to discover a fifty percent degrade. Larger degrades may also be easier to detect because they should be observed more often.

A missile that fails is of value only if the cause of the failure can be discovered. Otherwise, it only represents a worry. The ability of the analysts to DETECT the cause(s) of failures is a significant input into the value of any test program. Analysts are not perfect and neither is the equipment that gathers the data for them. This model does not assume that every failure will be identified with 100 percent accuracy.

The ability to detect a degrade mode is dependent on the number of missiles launched, the number of failures that occur, and the number of tests that result in failures. The more missiles launched, the greater should be the probability of launching one or more missiles that have the failure mode present.

The number of failures, then, is dependent on the degree to which the force is degraded and the number of missiles launched.

Description of Variables

The decision variable (NOMSLS or number of missiles) represents the decision maker's choice of how many test missiles to launch. It contains the alternatives of launching 0, 1, 2, 3, 4, 5, 6, 7, or 8 missiles per year. A maximum of eight flights that can be launched from Vandenberg AFB each year without imposing severe constraints upon resources at both Vandenberg AFB and F.E. Warren AFB (10;12). Arcs from NOMSLS to V, FAILURES, and DETECT indicate that these variables are dependent on the choice of NOMSLS.

The random variable DEGRADE% represents the proportion of the force that is degraded by the failure mode. It contains the possibilities of 2%, 10%, or 50% (.02, .10, or .50) of the force being degraded. The probabilities for these states occurring were set in accordance with the following values:

Outcome	.02	.10	.50
Probability of occurrence	.50	.30	.20

The outcomes were chosen by the author based on various levels of concern with failure modes being present in the missile force. The examples in both the Congressional Budget Office report and the 549th WSES memos use a 10% degrade, hence the choice of that number (5:8;1:1). A number below this threshold, .02, was chosen so as to observe the effects of having a relatively insignificant failure mode while .50 was chosen so as to observe the effects of having a very significant failure mode present. The probabilities of occurrence were assigned in the belief that, given the historical reliability of missile systems, smaller degrades are more probable than larger ones. It would be easy to replace these outcomes and probabilities with others as directed by a more knowledgeable decision maker or his experts.

The random variable FAILURES represents the number of test missiles that fail. It contains the possible outcomes of 0, 1, 2, 3, 4, 5, 6, 7, and 8. The variable shows the probability of the number of failures occurring dependent on the percentage of the force that is degraded (from DEGRADE%) and the number of missiles that are launched (from NOMSLS). For this pilot model, the number of failures was modeled as a binomial random variable with "n" being the number of missiles launched (NOMSLS) and "p" being the proportion of the force degraded by a failure mode (DEGRADE%).

The random variable DETECT describes the probability that an analyst will identify a failure mode. This ability is conditioned on NOMSLS, FAILURES, and DEGRADE%. See Appendix A.

The value variable describes the relative goodness of each of the possible outcomes. It is based on the concept of having a nominal 90 percent alert rate for the force and the decision maker's willingness to accept some lower alert rate for a one week period in order to have the opportunity to run the test program. As examples, a value of 5 means that the decision maker would be willing to have an 85 percent (90 - 5) alert rate for one week. A value of -3 means that the decision maker would want his alert rate to be 93 (90 - (-3)), an increase above the nominal, before he would allow the testing to take place. These values were chosen by the author only as an attempt to show differentiation between the desirability of the possible outcomes. The values are not needed for model to answer many of the questions of interest to a decision maker. They are easily replaced by a value determination method that a decision maker might find more preferable. The values are listed in Appendix B.

This structure outlines the basic decision analysis problem, identifying the important variables and showing their relationships. Now it is possible to analyze the model in order to answer questions that are important to the decision maker.

V. Results

The specific findings in this chapter are only useful for illustrating the kind of information that this model can provide to a decision maker. They should not be considered solutions in and of themselves because the data used in the pilot model are only approximations of the actual data. What is important is the kind of information that this model can provide. The current model shows many important relationships. The substance of these relationships will take on even more meaning when actual data is used.

Maximum Expected Value

The model was analyzed to obtain the maximum expected value. Figure 7 uses influence diagrams to illustrate the steps used to obtain the maximum expected value. Removing each random variable into the value node, which corresponds to mathematical expectation, left the value dependent on the number of missiles to be launched as shown in Table 1.

Table 1. Maximum Expected Value

NOMSLS	V
0	-3.166
1	1.2377
2	0.254
3	1.2197
4	1.711
5	1.9083
6	1.9679
7	1.9113
8	1.7598

The decision maker would have the greatest value for a program that launches six missiles per year. However, it is noted that launching other than zero or two missiles gives values that range over a distance of only 0.7482. This indicates that more data might be needed in order to arrive at the best decision.

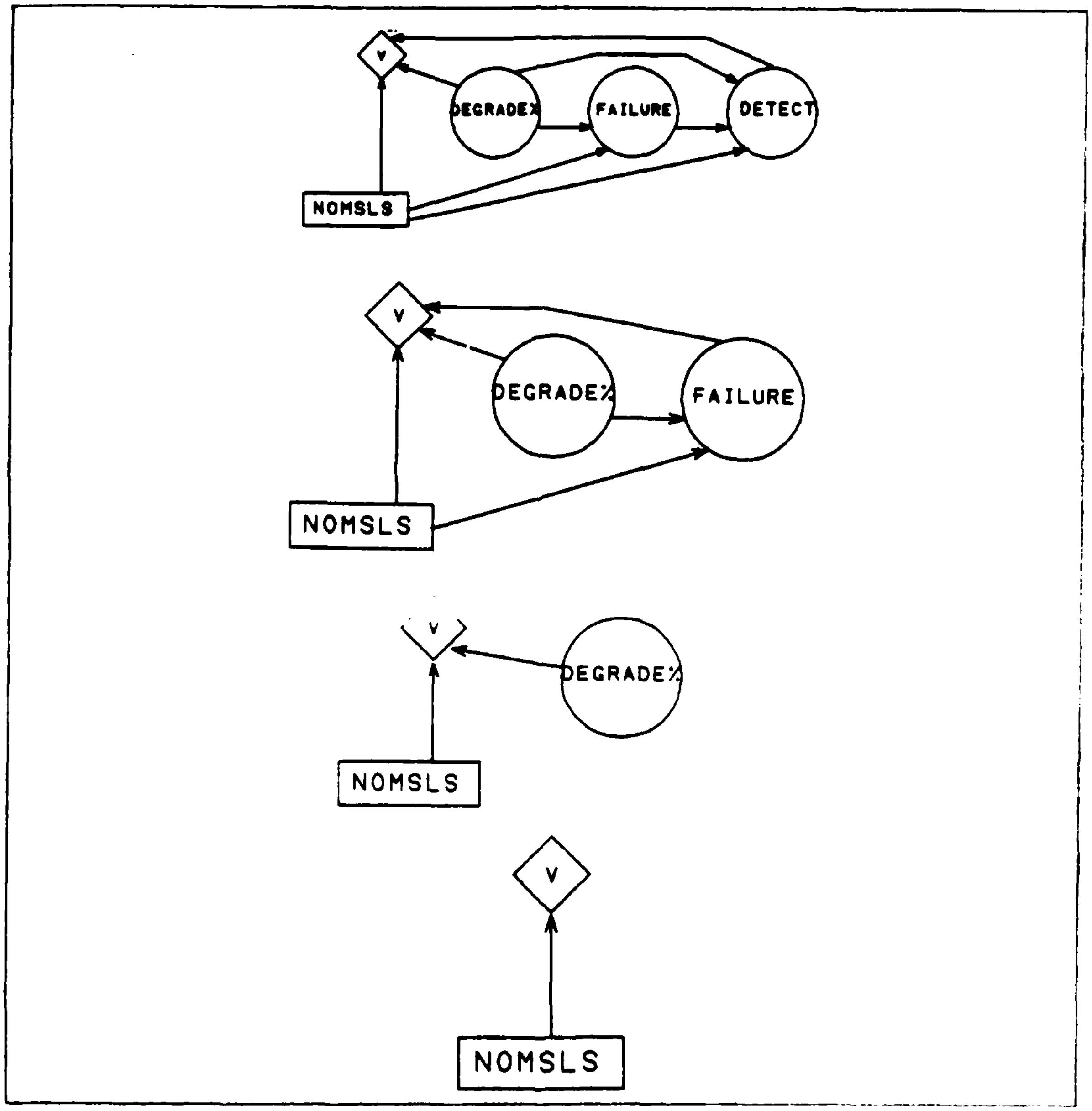

Figure 7. Steps to Calculate Maximum Expected Value

Figure 8 depicts how the model can be further analyzed to find the expected value based on the percentage of the force that is believed to possess the degrade. Table 2 shows that launching zero missiles gives the largest expected value if the degrade is believed to affect only two percent of the force.

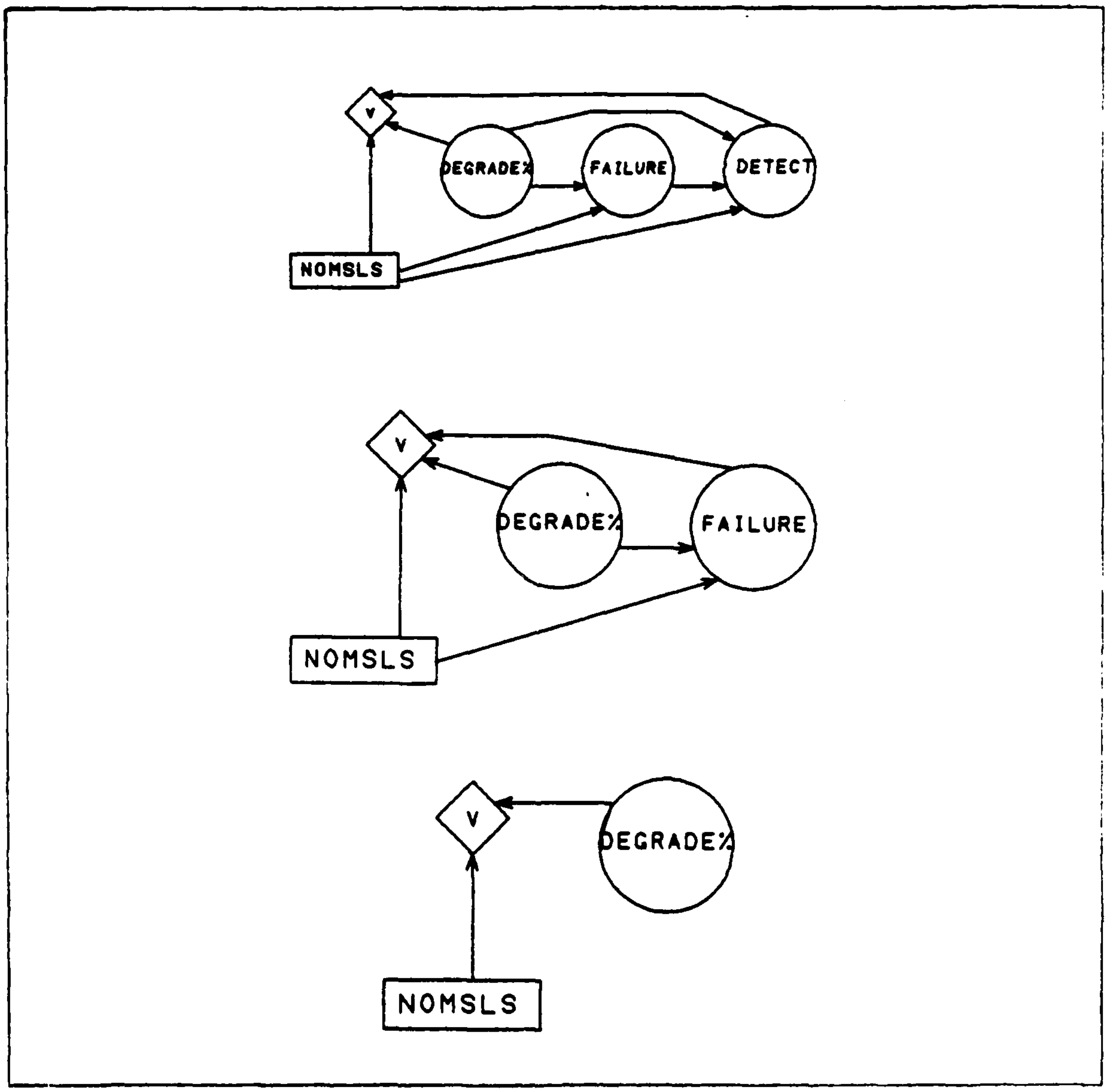

Figure 8. Expected Value Dependent on DEGRADE%

Table 2. Expected Values For 2 Percent Degrade

DEGRADE%	NOMSLS	V
.02	0	-0.97
.02	1	-1.8736
.02	2	-9.3053
.02	3	-9.1891
.02	4	-8.9765
.02	5	-8.8823
.02	6	-8.7977
.02	7	-8.722
.02	8	-8.6552

A degrade affecting a larger portion of the force shows different values, as listed in Table 3.

Table 3. Expected Values For 10 Percent Degrade

DEGRADE%	NOMSLS	V
.10	0	-2.77
.10	1	-3.585
.10	2	-4.3862
.10	3	-3.9524
.10	4	-3.385
.10	5	-3.1743
.10	6	-3.1973
.10	7	-3.2763
.10	8	-3.3928

While launching zero missiles still gives the largest expected value, the range of values shows a difference of only 1.6162, again possibly indicating that there is not much difference between the options and that other data may be valuable in formulating the final decision. Finally, a degrade affecting a large percentage of the force gives the expected values listed in Table 4.

Table 4. Expected Values For 50 Percent Degrade

DEGRADE%	NOMSLS	V
.50	0	-9.25
.50	1	16.25
.50	2	31.1125
.50	3	35.0
.50	4	36.0737
.50	5	36.5087
.50	6	36.6298
.50	7	36.2759
.50	8	35.526

The largest expected value is obtained with six launches, however the range of values between three and six launches is only 1.6298. As in the other cases, more data may be helpful.

With either a five or ten percent degrade, launching zero missiles gives the maximum expected value, which in both cases is negative. The possible existence of a 50 percent degrade dominates the outcomes for the complete model's maximum expected value and the number of missiles that should be launched.

Sensitivity of Failure to DEGRADE%

The probability of a failure occurring is dependent on the proportion of the force that is degraded (DEGRADE%) and the number of missiles launched (NOMSLS). Table 5 lists these probabilities.

Table 5. Probability of Failure

FOR .02

NOMSLS	FAILURES 0	1	2	3	4	5	6	7	8
0	1.00	.00	.00	.00	.00	.00	.00	.00	.00
1	.98	.02	.00	.00	.00	.00	.00	.00	.00
2	.96	.03	.01	.00	.00	.00	.00	.00	.00
3	.94	.05	.01	.00	.00	.00	.00	.00	.00
4	.92	.07	.01	.00	.00	.00	.00	.00	.00
5	.90	.09	.01	.00	.00	.00	.00	.00	.00
6	.89	.10	.01	.00	.00	.00	.00	.00	.00
7	.87	.12	.01	.00	.00	.00	.00	.00	.00
8	.85	.14	.01	.00	.00	.00	.00	.00	.00

FOR .10

NOMSLS	FAILURES 0	1	2	3	4	5	6	7	8
0	1.00	.00	.00	.00	.00	.00	.00	.00	.00
1	.90	.10	.00	.00	.00	.00	.00	.00	.00
2	.81	.18	.01	.00	.00	.00	.00	.00	.00
3	.73	.24	.03	.00	.00	.00	.00	.00	.00
4	.66	.29	.05	.00	.00	.00	.00	.00	.00
5	.59	.33	.07	.01	.00	.00	.00	.00	.00
6	.53	.35	.10	.01	.01	.00	.00	.00	.00
7	.48	.37	.12	.02	.01	.00	.00	.00	.00
8	.43	.38	.15	.03	.01	.00	.00	.00	.00

FOR .50

NOMSLS	FAILURES 0	1	2	3	4	5	6	7	8
0	1.00	.00	.00	.00	.00	.00	.00	.00	.00
1	.50	.50	.00	.00	.00	.00	.00	.00	.00
2	.25	.50	.25	.00	.00	.00	.00	.00	.00
3	.13	.37	.37	.13	.00	.00	.00	.00	.00
4	.06	.25	.38	.25	.06	.00	.00	.00	.00
5	.03	.16	.31	.31	.16	.03	.00	.00	.00
6	.02	.09	.23	.32	.23	.09	.02	.00	.00
7	.01	.06	.16	.27	.27	.16	.06	.01	.00
8	.00	.03	.11	.22	.28	.22	.11	.03	.00

Probability of at Least One Failure Occurring

Table 6 lists the probability of at least one failure occurring, given the probability distribution of any of the degrade percentages being present.

Table 6. Probability of At Least One Failure Occurring

N	Probability of seeing at least one failure
0	0.0
1	0.14
2	0.2268
3	0.2857
4	0.32947
5	0.36466
6	0.39456
7	0.4209
8	0.44467

Launching the six missiles indicated by the maximum expected value provides less than a 40 percent chance of seeing at least one failure. Launching the largest possible number of missiles per year provides less than a 45 percent chance of seeing at least one failure. Figure 9 shows how these probabilities were derived.

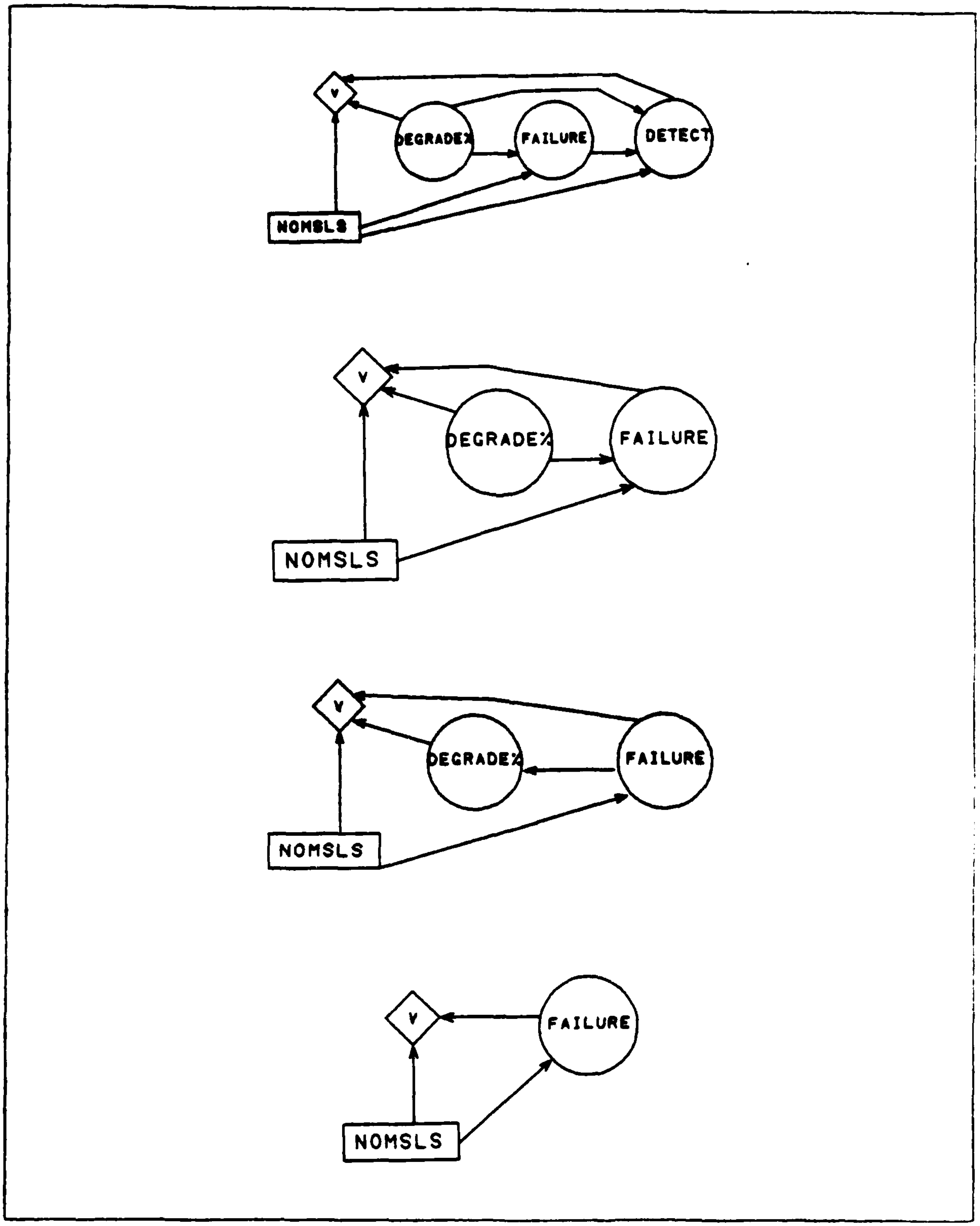

Figure 9. Probability of Failure Occurring

Probability of Detecting the Failure Mode

If the decision maker believes that the analysts will not be able to discover the cause of failure, the model gives the greatest expected value of -3.4 to launching zero missiles. If the analysts will always discover the failure mode, launching one missile gives the greatest expected value of 41.4317. However, analysts tend not to be perfectly good or bad. The probabilities of detecting the failure mode based on the number of missiles launched are listed in Table 7. Figure 10 depicts the steps taken in order to obtain these probabilities.

Table 7. Analyst's Probability of Detecting the Failure Mode

	PROBABILITY OF DETECTION	
NOMSLS	NO	YES
0	.99	.01
1	.8777	.1223
2	.7866	.2134
3	.7268	.2732
4	.6951	.3049
5	.6758	.3242
6	.6593	.3407
7	.6453	.3547
8	.6329	.3671

Launching six missiles means that there is only a 34 percent chance of detecting a failure mode. Eight launches improves this by less than three percent.

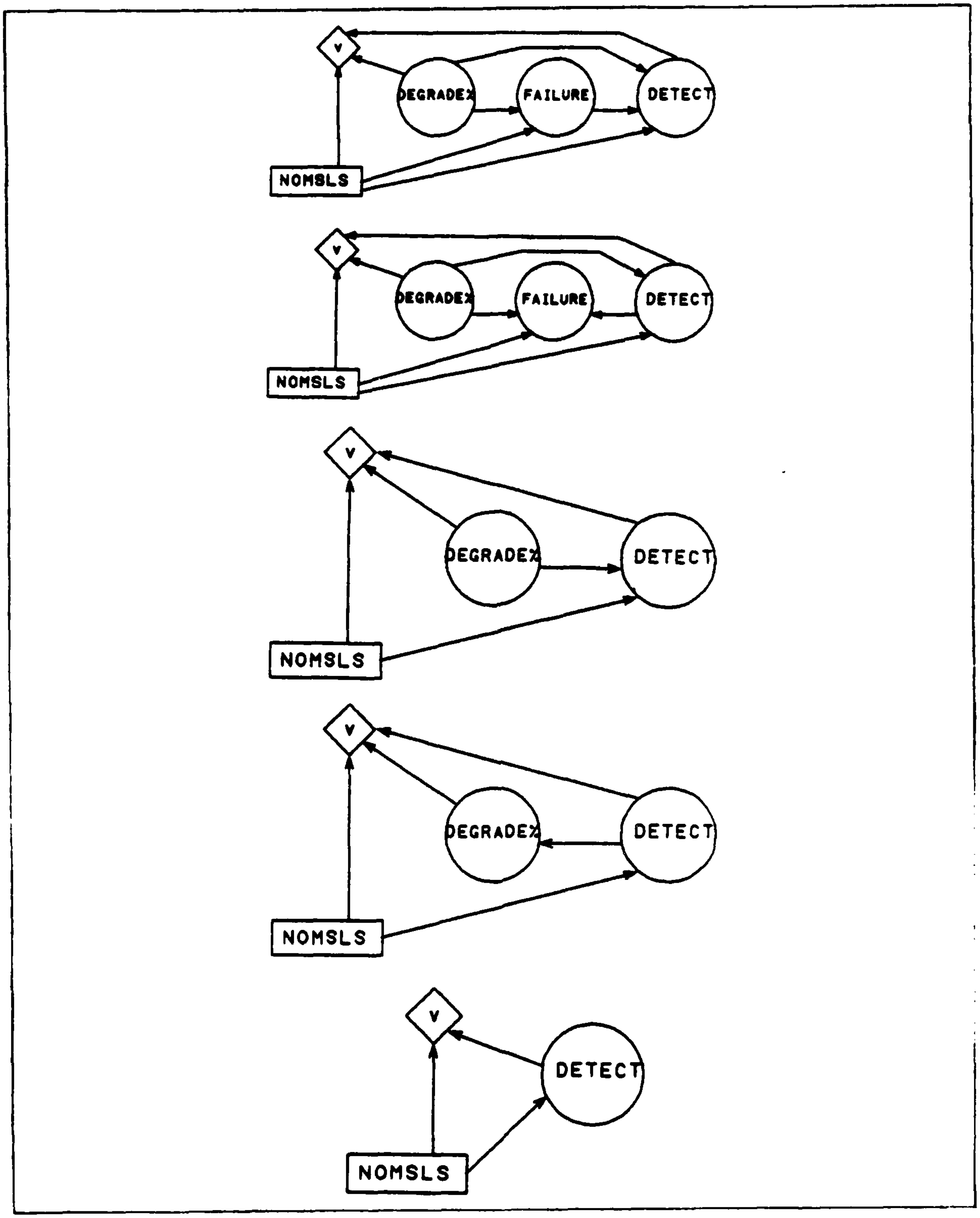

Figure 10. Probability of Detecting Failure Mode

Detection Dependent on Degrade

The probability of detecting a failure mode depends on the percentage of the force that is degraded, as shown in Table 8.

Table 8. Probability of Detecting a Failure Mode

NOMSLS	DETECT at .02	DETECT at .10	DETECT at .50
0	.01	.01	.01
1	.03	.11	.38
2	.05	.20	.63
3	.07	.29	.75
4	.09	.33	.79
5	.10	.36	.83
6	.11	.38	.86
7	.12	.40	.89
8	.12	.41	.91

Launching six missiles provides an 11 percent confidence of detecting a two percent degrade, a 38 percent confidence of detecting a ten percent degrade, and an 86 percent confidence of detecting a 50 percent degrade. If eight missiles are launched in the year, there is only a 41 percent probability of detecting a ten percent degrade. A 90 percent confidence of detecting a degrade can be achieved over a one year period only if eight missiles are launched and half the force is affected by the degrade.

Probability of DEGRADE% Based on FAILURES

The proportion of the force that is degraded may not be known. The test program should be able to give the decision maker information concerning how much of the force is degraded based on the number of missiles launched and the number that failed. Table 9 shows the DEGRADE% distribution dependent on the number of missiles launched and the number of failures that occur.

Table 9. Probability That Level of Degradation Exists

		PROBABILITY DEGRADE%		
NOMSLS	FAILURES	.02	.10	.50
0	0	.5	.3	.2
1	0	.57	.31	.12
1	1	.07	.21	.72
2	0	.62	.31	.07
2	1	.11	.31	.58
2	2	.00	.06	.94
3	0	.66	.31	.03
3	1	.16	.41	.43
3	2	.01	.10	.89
3	3	.00	.01	.99
4	0	.69	.29	.02
4	1	.21	.50	.29
4	2	.01	.16	.83
4	3	.00	.02	.98
4	4	.00	.02	.98
5	0	.71	.28	.01
5	1	.26	.56	.18
5	2	.02	.25	.73
5	3	.00	.04	.96
5	4	.00	.01	.99
5	5	.00	.00	1.00
6	0	.73	.26	.01
6	1	.30	.59	.11
6	2	.03	.37	.60
6	3	.00	.07	.93
6	4	.00	.01	.99
7	5	.00	.01	.99
7	6	.00	.00	1.00
7	7	.00	.00	1.00
8	0	.76	.23	.01
8	1	.36	.60	.04
8	2	.07	.62	.31
8	3	.01	.18	.81
9	4	.00	.02	.98
8	5	.00	.01	.99
8	6	.00	.00	1.00
8	7	.00	.00	1.00
8	8	.00	.00	1.00

VI. Recommendations

This pilot analysis should be used as a basis for developing a complete decision analysis as an aid in determining the appropriate test strategy for the PEACEKEEPER weapon system. To become a full-scale decision analysis model and become a factor in the decision making process, the value formulation must be redefined in terms that the decision maker believes appropriate, accurate probabilities must be identified and assigned to the variables, and the model must be expanded to include all relevant variables of the decision problem.

Value Redefinition

A better method of determining the value of an strategy based on the expected outcomes needs to be identified and incorporated into the model. The use of a willingness to give up a percentage of the force alert rate for a period of time in order to detect a failure mode is a simple measurement, but it may not be realistic. Starting from an assumed 90 percent alert rate only allows for a minimum value of -10. This restricts the range of values to which an undesirable outcome can be assigned because there cannot be an alert rate higher than 100 percent. For example, the value for launching three missiles and not being capable of detecting the failure mode is the same, -10, (meaning that the alert rate would have to be raised to 100 percent before that outcome would be equivalent to all others) independent of the percentage of the force that is degraded. However, it is worse to not detect the failure mode in a force that is 50 percent degraded than to not detect it in a force that is only degraded by two percent. Thus, the two outcomes are not equal. Discovering an accurate method of determining the values of test strategies may prove to be a difficult task. Values based on the cost of maintaining the degraded portion of the force and the cost of the test program needed to discover the degradation may provide more useful information.

Probability Assessments

Estimates concerning the true ability of analysts to discover failure modes should be obtained and incorporated. This could be done in conjunction with the expansion of the model. The different failure modes can be broken out of the FAILURE variable and separate variables developed for each failure, group of failures, or combination of failures. Partial failures can be included as can the possibility that a failure mode might be masked by other failure modes. The analysts' abilities to both identify an existing failure mode and not to identify a mode that does not exist, can be incorporated into the model against each of the listed failures instead of as an overall average. This should give much better determinations of the ability to detect degrades because this ability should vary depending on the type, severity, and number of degrades present. Discovering these estimates may be a time consuming task depending on how the level of failures are expanded. Influence diagrams can be of help in determining what estimates are needed. 1st Strategic Aerospace Division, Test Analysis Division (1 STRAD/TOH) may help provide the needed probabilities.

Assumptions of independence should be discarded where they are not appropriate. For example, the binomial probabilities of failure based on the number of missiles launched should be replaced with probabilities that more accurately reflect the interaction of different failure modes, the knowledge that is gained from one test to the next, etc. This would more accurately reflect the true dynamics of the problem. The use of influence diagrams may make this a relatively easy task.

The probabilities associated with DEGRADE%, the part of the force having the failure mode present, also needs to be refined. The percentages of degradation and their likelihood of occurrence may need to be changed to reflect the concerns of the decision maker and his experts. This can be accomplished with the use of historical data and the judgement of experts in the field. These changes will result in different numbers being generated by the analyses, but do not change the structure of the model.

Model Expansion

The results of other than flight tests can now be incorporated into the model to improve its fidelity. The results of aging and surveillance testing can be used to help predict booster performance. Service Star data can be incorporated to help predict reentry vehicle performance. Data from simulated electronic launches and other operational base ground tests can be used along with test launch data to provide an overall system evaluation. This is an unexplored area but one the author believes may be of the most benefit in advancing ICBM testing. Influence diagrams will be essential to help understand the complexity of the relationships. Although this incorporation of non-flight test data may be a long, iterative process, full of discussions and arguments, it may also prove to be the most insightful.

The model can provide an up-to-the-minute confidence of being able to detect a system degrade based on the results of testing done to date. For example, while the decision maker may allow a three year period over which to be able to achieve a level of confidence in detecting a degrade, this model can easily be expanded to show the current probability of detecting the degrade at any time within that three year period.

Differences between launches can be taken into account. By using separate variables in the influence diagrams to represent the various modes, responses to launch signals transmitted via ground cables can be separated from those transmitted via radio. In the same way, peacetime, fully capable systems can be differentiated from post-attack, or degraded systems.

If PEACEKEEPER is deployed in multiple basing modes, influence diagrams allow the respective results to be segregated for individual basing mode assessment, yet combined to give an overall weapon system analysis. But the model does not have to be limited to the PEACEKEEPER weapon system. The same analyses can be accomplished for any system. For example, MINUTEMAN III missiles based at F.E. Warren AFB can be looked at as a variable separate from those based at Minot AFB or all can be combined for a total force evaluation.

Different aspects of the flight profile can be addressed. By including the appropriate variables, the probability of failure(s) occurring in a particular phase of flight can be analyzed. The effects of range, reentry angle, type of reentry vehicle, and number of reentry vehicles on accuracy and survivability can be looked at separately, in combination, or removed from the model, depending on the information being sought. Effects of weather in the terminal area can be included in the model and looked at in the same manner. The degree of difficulty in doing this is based on the number and complexity of the variables that the decision maker believes should be included. Sensitivity analysis bases in the influence diagram should be of great help in identifying the variables that have the most effect on the model.

Summary

Building an accurate model of the system test process will require extensive, yet relatively simple analyses of the test data that currently exists. The analyses that need to be accomplished will be identified through the building of the influence diagram. As relationships between variables are identified, various alternatives, outcomes, and their associated probabilities will be needed to fill out the model. Research through the existing historical data base and consultations with experts should reveal the needed answers.

A decision analysis model will not generate new test data. It does provide a methodology to show how the variables in the tests fit together. The use of appropriate software tools then provides a means of analyzing both the data and the relationships so as to provide the decision maker with more insight and understanding upon which to base his final decision.

VII. Conclusions

This pilot decision analysis model, based on the decision analysis methodology and influence diagrams, can provide the required information and insight that a decision maker needs in order to formulate a strategy for testing the PEACEKEEPER weapon system. The methodology provides a structure that enhances communications between participants in the decision making process while the graphical representation provided by the use of influence diagrams is extremely helpful in understanding the problem. Building the influence diagram requires mapping the variables under consideration and their inter- dependencies, a process that provides valuable insight as the decision maker is able to look at the problem as a whole instead of as a series of unconnected events.

Assumptions are made explicit in the model and can be easily seen and challenged. Influence diagrams, because of their flexibility, allow many assumptions to be relaxed. Finally, the model can be effectively analyzed on a microcomputer using the Performa decision analysis software program. Analysis of the pilot model has shown the ability to provide information concerning the maximum expected value of the complete model and for each level of degradation. Probabilities of a degrade being present in the force, seeing the occurrence of at least one failure, and identifying the failure mode were analyzed.

Data used for this thesis can be easily replaced with actual data. By this simple step, the model can provide more, useful information to a decision maker than was here-to-fore possible.

Appendix A: Probabilities of Detection

P	F	#	N	Y	I
.02	0	0	.99	.01	0
		1	.98	.02	0
		2	.97	.03	0
		3	.96	.04	0
		4	.95	.05	0
		5	.95	.05	0
		6	.95	.05	0
		7	.95	.05	0
		8	.95	.05	0
	1	0	0	0	1
		1	.4	.6	0
		2	.38	.62	0
		3	.39	.61	0
		4	.4	.6	0
		5	.42	.58	0
		6	.44	.56	0
		7	.46	.54	0
		8	.48	.52	0
	2	0	0	0	1
		1	0	0	1
		2	.2	.8	0
		3	.22	.78	0
		4	.24	.76	0
		5	.25	.75	0
		6	.26	.74	0
		7	.27	.73	0
		8	.28	.72	0
	3	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	.05	.95	0
		4	.06	.94	0
		5	.07	.93	0
		6	.08	.92	0
		7	.09	.91	0
		8	.10	.90	0
	4	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	.04	.96	0
		5	.05	.95	0
		6	.08	.92	0
		7	.085	.015	0
		8	.09	.91	0
	5	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	.03	.97	0
		6	.04	.96	0
		7	.05	.94	0
		8	.07	.93	0
	6	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	.02	.98	0
		7	.03	.97	0
		8	.04	.96	0
	7	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	0	0	1
		7	.02	.98	0
		8	.03	.97	0
	8	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	0	0	1
		7	0	0	1
		8	.01	.99	0
		0	.99	.01	0
		1	.95	.05	0
		2	.90	.10	0
		3	.84	.16	0
		4	.83	.17	0
		5	.83	.17	0
		6	.84	.16	0
		7	.85	.15	0
		8	.86	.14	0

Appendix A: Continued

P	F	#	N	Y	I
	1	0	0	0	1
		1	.40	.60	0
		2	.38	.62	0
		3	.39	.61	0
		4	.40	.60	0
		5	.42	.58	0
		6	.44	.56	0
		7	.46	.54	0
		8	.48	.52	0
	2	0	0	0	1
		1	0	0	1
		2	.20	.80	0
		3	.18	.82	0
		4	.17	.83	0
		5	.19	.81	0
		6	.19	.91	0
		7	.20	.80	0
		8	.20	.80	0
	3	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	.05	.95	0
		4	.055	.945	0
		5	.06	.94	0
		6	.07	.93	0
		7	.08	.92	0
		8	.09	.91	0
	4	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	.035	.965	0
		5	.05	.95	0
		6	.07	.93	0
		7	.08	.92	0
		8	.09	.91	0
	5	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	.025	.975	0
		6	.03	.97	0
		7	.04	.96	0
		8	.04	.96	0

P	F	#	N	Y	I
	6	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	.015	.985	0
		7	.015	.985	0
		8	.02	.98	0
	7	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	0	0	1
		7	.02	.98	0
		8	.02	.98	0
	8	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	0	0	1
		7	0	0	1
		8	.01	.99	0
	0	0	.99	.01	0
		1	.75	.25	0
		2	.63	.37	0
		3	.57	.43	0
		4	.60	.40	0
		5	.70	.30	0
		6	.80	.20	0
		7	.85	.15	0
		8	.90	.10	0
	1	0	0	0	1
		1	.50	.50	0
		2	.32	.68	0
		3	.25	.75	0
		4	.26	.74	0
		5	.27	.73	0
		6	.30	.70	0
		7	.35	.65	0
		8	.40	.60	0

P	F	#	N	Y	I
	2	0	0	0	1
		1	0	0	1
		2	.20	.80	0
		3	.21	.79	0
		4	.23	.77	0
		5	.25	.75	0
		6	.26	.74	0
		7	.27	.73	0
		8	.28	.72	0
	3	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	.05	.95	0
		4	.06	.94	0
		5	.065	.935	0
		6	.07	.93	0
		7	.075	.925	0
		8	.08	.92	0
	4	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	.03	.97	0
		5	.04	.96	0
		6	.045	.955	0
		7	.05	.95	0
		8	.055	.945	0
	5	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	.02	.98	0
		6	.025	.975	0
		7	.03	.97	0
		8	.035	.965	0
	6	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	.015	.985	0
		7	.015	.985	0
		8	.02	.98	0

P	F	#	N	Y	I
	7	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	0	0	1
		7	.01	.99	0
		8	.015	.985	0
	8	0	0	0	1
		1	0	0	1
		2	0	0	1
		3	0	0	1
		4	0	0	1
		5	0	0	1
		6	0	0	1
		7	0	0	1
		8	.001	.999	0

Appendix B: Values

N	P	D	V
0	.02	N	-1
0	.10	N	-3
0	.50	N	-10
0	.02	Y	2
0	.10	Y	20
0	.50	Y	65
0	.02	I	-1000
0	.10	I	-1000
0	.50	I	-1000
1	.02	N	-2
1	.10	N	-6
1	.50	N	-10
1	.02	Y	2
1	.10	Y	17
1	.50	Y	60
1	.02	I	-1000
1	.10	I	-1000
1	.50	I	-1000
2	.02	N	-10
2	.10	N	-9
2	.50	N	-10
2	.02	Y	3
2	.10	Y	14
2	.50	Y	55
2	.02	I	-1000
2	.10	I	-1000
2	.50	I	-1000
3	.02	N	-10
3	.10	N	-10
3	.50	N	-10
3	.02	Y	1
3	.10	Y	11
3	.50	Y	50
3	.02	I	-1000
3	.10	I	-1000
3	.50	I	-1000
4	.02	N	-10
4	.10	N	-10
4	.50	N	-10
4	.02	Y	1
4	.10	Y	10
4	.50	Y	48
4	.02	I	-1000
4	.10	I	-1000
4	.50	I	-1000

N	P	D	V
5	.02	N	-10
5	.10	N	-10
5	.50	N	-10
5	.02	Y	1
5	.10	Y	9
5	.50	Y	46
5	.02	I	-1000
5	.10	I	-1000
5	.50	I	-1000
6	.02	N	-10
6	.10	N	-10
6	.50	N	-10
6	.02	Y	1
6	.10	Y	8
6	.05	Y	44
6	.02	N	-1000
6	.10	N	-1000
6	.50	N	-1000
7	.02	N	-10
7	.10	N	-10
7	.50	N	-10
7	.02	Y	1
7	.10	Y	7
7	.50	Y	42
7	.02	I	-1000
7	.10	I	-1000
7	.50	I	-1000
8	.02	N	-10
8	.10	N	-10
8	.50	N	-10
8	.02	Y	1
8	.10	Y	6
8	.50	Y	40
8	.02	I	-1000
8	.10	I	-1000
8	.50	I	-1000

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VITA

Major Walter W. (Pete) Darnall, Jr was born on 11 May 1954, in Mount Hope, West Virginia. He graduated from high school in Aberdeen, Maryland in 1954 and attended the United States Air Force Academy from which he received the Degree of Bachelor of Science in International Affairs and in Behavioral Science and his commission in 1976. He was assigned to the 90 Strategic Missile Wing as a missile crew member from 1977 until 1980. He received his Degree of Master of Arts in Psychology in 1980 from the University of Northern Colorado. He then attended Squadron Officer's School in residence and was assigned to Vandenberg AFB, California in the TOP HAND program. From 1983 to 1986 Major Darnall was assigned to Detachment 2, Headquarters Strategic Air Command at Norton AFB, California. He completed Air Command and Staff College through the seminar program in 1984. Major Darnall entered the School of Systems and Logistics, Air Force Institute of Technology, in June 1986. He is married to Suzann Corlette Darnall (nee Dale) and they have two daughters, Charly and Amanda.

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