3/7/79

SAND79-8211
Unlimited Release

Systems Studies Department FY78 Activity Report

Vol. 2 - Systems Analysis

T. S. Gold

Sandia Laboratories

SF 2900 Q(7-73)

MASTER

SAND79-8211
Unlimited Release
Printed February 1979

SYSTEMS STUDIES DEPARTMENT FY78 ACTIVITY REPORT

VOL. 2. SYSTEMS ANALYSIS

Theodore S. Gold
Systems Studies Department 8320
Sandia Laboratories, Livermore

CONTENTS

SYSTEMS STUDIES DEPARTMENT FY78 ACTIVITY REPORT
VOL. 2. SYSTEMS ANALYSIS

Introduction

Sandia, a Department of Energy (DOE) multiprogram laboratory, has missions relevant to both U.S. defense and energy programs. Sandia's prime responsibility is research and development related to nuclear weapons. In addition, it is engaged in a variety of advanced energy technology projects.

The Systems Studies Department at Sandia Laboratories Livermore (SLL) has two primary responsibilities:

- to provide computational and mathematical services*

- to perform "systems analysis" studies

Computing and Mathematics are covered in Volume 1. This document (Volume 2) describes the FY78 Systems Analysis highlights. This description is an unclassified overview of activities and is not complete or exhaustive.

The objective of our systems analysis activities is to evaluate the relative value of alternative concepts and systems. Results of the studies provide input to various decision processes within the laboratories, the DOE, the Department of Defense (DOD), the Nuclear Regulatory Commission, and other government agencies. These decisions include generating system and technology requirements, choosing among design options, planning programs and allocating resources.

SLL systems analysis activities reflect Sandia Laboratory programs and in 1978 consisted of three distinct study efforts:

- National security - evaluations of strategic, theater, and navy nuclear weapons issues,

- Energy technology - particularly in support of Sandia's solar thermal programs,

- Nuclear fuel cycle physical security - a special project conducted for the Nuclear Regulatory Commission.

Highlights of these activities are described in the following sections. A setting for these descriptions is provided by the Epilogue which contains a brief exposition of our approach to studies.

---

*In November 1978, a separate Computing and Mathematics Department was created and Nuclear Weapon Safety and Reliability responsibilities added to the Systems Studies Department.

National Security

The DOE's major responsibilities in the U.S. Nucler Weapons program are the design, development, and production of nuclear weapons and the maintenance of a nuclear weapon technology base second to none. Fulfilling these responsibilities requires that DOE be knowledgeable regarding potential applications for its technology. Therefore, DOE's nuclear weapon laboratories have historically supported small in-house investigations of nuclear weapon acquisition, deployment and employment issues. At SLL, these are performed by the Systems Studies Department.

The number of staff engaged in nuclear weapon related systems studies at SLL has remained relatively constant in recent years, averaging about a dozen professionals including computer programming support. Usually several "area" type studies addressing relatively broad issues are in process. These area studies serve as the foundation for evaluations of specific concept and design options.

A trend of our studies is closer involvement with the military services. Such involvement, by increasing our understanding of the problems associated with nuclear weapon deployment and employment, helps ensure the relevance of the Laboratories' research and advanced technology efforts. These closely coupled study efforts also lead to a richer DOE/DOD dialogue over weapon requirements. Such dialogue is vital to encourage cost-performance tradeoffs.

The Department of Defense is responsible for specifying nuclear weapon military characteristics, i.e., requirements for safety, reliability, size, weight, lethality, security, command control, operation flexibility and other features. However these requirements cannot be based solely on needs (desires) but also upon knowledge of technology options and the costs of achieving various performance standards. Thus, the Department of Energy not only has a responsibility to offer new technologies to improve performance, but also to identify opportunities for significant cost savings. Cost performance tradeoffs provide the vehicle to determine the impacts (dollars, resources, risks) of desired performance standards and achieve cost effective designs.

Our major National Security related study areas in 1978 were battlefield nuclear weapons, fleet air defense, and strategic nuclear warhead and targeting issues. Although most of the results are classified, the general study effort can be described.

Battlefield Nuclear Weapon Studies

Background

For several years, we have been investigating various aspects of theater nuclear weapon utility, focusing upon potential roles for nuclear weapons on the battlefield. Our efforts included participation in several Army and Air Force sponsored studies: Tactical Nuclear Force Mix, 155 mm Nuclear Artillery Modernization, and air to ground Standoff Missile options.

In support of our study efforts, we developed several methodologies, including interactive computer models to allocate and assess two-sided nuclear fire under various collateral damage constraints. We also obtained the Division War Game, DIVWAG, from the Army. In 1977, we used our modified version of this model in a preliminary study of the role of nuclear weapons in redressing a deteriorating conventional defense. This initial effort led to a joint SLL/Army battlefield nuclear weapon study, our major theater nuclear activity the past year.

Highlights

The V Corps Nuclear Contingency Study is a cooperative effort between the U.S. Army and Sandia Laboratories to investigate NATO tactical nuclear weapon employment concepts. The Army participants are the U.S. Army V Corps, (headquarters in Frankfurt, Germany) and the U.S. Army Nuclear and Chemical Agency (Fort Belvoir, VA).

Thus far, the study has accomplished the following:

- development of a detailed scenario of a hypothetical Warsaw Pact attack in the V Corps sector ending in the failure of the conventional defense; this scenario then serves as the basic test bed for examining nuclear weapon options;

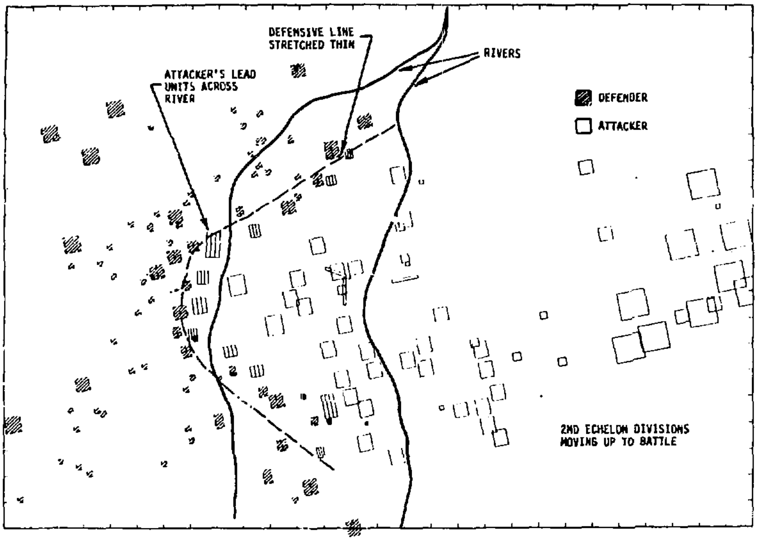
- examination of a variety of nuclear weapon employment plans to determine the impact of different concepts, number and types of weapons, timing, and other factors, on the scenario outcome;

- initial development of concepts for post nuclear operations.

The conventional scenario was created with the assistance of the DIVWAG model. We chose the DIVWAG for our studies for a variety of reasons: its use by the Army to study conventional weapon issues, its potential to handle both conventional and nuclear operations, its combination of relatively fine resolution and broad scale, and its flexibility. Sandia modifications to DIVWAG included improved nuclear operations and enhanced computer-generated graphics which allow us to use the model with a small staff.

Force organization and disposition, defense plan concepts, and the perceived threat were provided by the V Corps staff. Development of the scenarios and nuclear weapon employment concepts took place at SLL with the assistance of the Army Nuclear and Chemical Agency.

Preliminary results were presented to V Corps and nuclear planning staffs at other NATO commands early in the summer of 1978. V Corps then used these study results to help prepare the nuclear play for Exercise Certain Shield in September 1978. Certain Shield, a large multi-divisional, multi-national field exercise, involved significant nuclear operations including weapon supply and release procedures and the development and execution of employment plans. SLL personnel were invited to observe the exercise and gather perceptions and data to improve our modeling capability. The interactive coupling of modeling and field exercises enhances the value of each and provides deeper insight and understanding of the role of nuclear weapons.



POSITION OF UNITS JUST PRIOR TO BREAKTHROUGH

Figure 1 consists of computer generated graphics from DIVWAG depicting the situation during one of the conventional scenarios.

Attacking units have made significant penetration, and are beginning to breach the defender's main battle area. The defender has committed all its current reserve forces and has lost his ability to maneuver forces to meet the threat.

The objective in generating these scenarios is not to predict the outcome of a conventional battle. Rather, it is to plausibly depict possible outcomes which can then be used to investigate the relative value of various nuclear weapon design and doctrinal options.

FIGURE 1

Navy Studies

Background

Our 1978 efforts concentrated upon fleet air defense, in particular, warhead options for the standard (SM-2) surface-to-air interceptor.

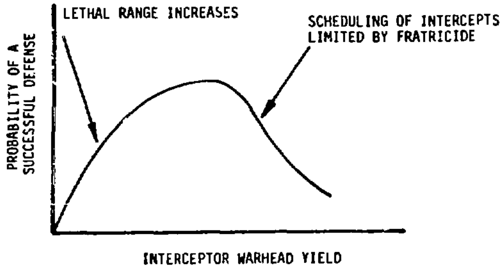
The problem of accounting for unknown futures when making weapon acquisitions are heightened for the Navy where major and expensive platforms may remain in service for several decades -- well into the 21st century for today's acquisition. Modern aircraft carriers, including aircraft, cost several billion dollars and the total investment in a naval task force is many times as much. There is, quite understandably, concern about the defense of this concentration of resources in the face of growing threat capabilities. The key issues we are addressing: what do nuclear warheads contribute to such defenses, what are desirable warhead characteristics and finally, are they worth the cost?

Highlights

SLL chaired the Systems Analysis subcommittee to the Standard Missile Warhead Project Officers Group and developed and coordinated the study plan for the involved DOE and Navy laboratories. The report of the subcommittee findings will be available in early 1979. Our contribution included developing a model to simulate engagement of the interceptor and its target; then using the model to compare the effectiveness of alternative warheads in a variety of engagement scenarios. Sensitivity studies were performed to evaluate how performance depends upon fuzing scheme, warhead, interception performance, and associated costs. We were able to show a preferred warhead choice over a wide range of parameters and to suggest improvements in the original fuzing concept.

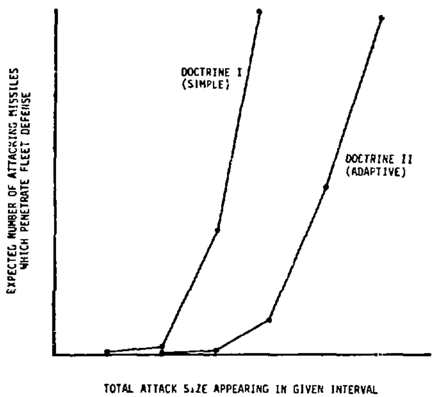
The effort in support of the SM-2 program concentrated on the effectiveness of defensive missiles at intercept. The larger issue is the value of nuclear defensive missiles in task force defense. Is the improvement they offer over conventional warheads worth the increased costs? For this purpose, we are developing a general event simulation of task force defense to examine the relation among threat characteristics, defense objectives, tactics and capabilities (Figure 2).

FIGURE 2A - WARHEAD YIELD



Successful defense against multiple threats requires a warhead with sufficient lethal range and the ability to schedule multiple intercepts. As yield increases, the probability of successful defense first increases due to increased lethal range and then decreases as fratricide effects (damage to defense interceptors resulting from a defensive burst) limit the scheduling of intercepts.

FIGURE 2B - ENGAGEMENT DOCTRINE



The choice of engagement doctrine can also significantly affect defense system performance. Doctrine I uses a relatively straight forward interceptor allocation system. By contrast, the superior Doctrine II represents a more complicated target priority scheme in which the targets are classified by number of intercepts already scheduled, the distance from the fleet and other factors.

FIGURE 2 - Two Fleet Defense Issues

Strategic Weapon Studies

Background

In the late 1960's and through the early 1970's, strategic nuclear weapon issues - ballistic missile defense, missile penetration, vulnerability - were the major subject of SLL Systems Analyses. After several years of relative inactivity, we are re-establishing study efforts in the strategic area. Our new strategic studies are motivated by the need to address warhead options for future delivery systems, considering the impact of potential strategic arms limitations and comprehensive test ban treaties as well as targeting and other policy alternatives.

Highlights

In addition to several Sandia initiated projects, we cooperated with the Air Force on two cruise missile studies, helping identify missions and evaluate warhead options. We also provided input to the DOD Nuclear Targeting Policy Review, a major effort to redefine U.S. nuclear posture. These inputs addressed various implications of uncertainty upon strategic targeting options.

Much of our effort was devoted to the development of models and analysis capabilities to support the studies efforts. These include:

A computer model which uses iterative optimization techniques to generate aimpoints which maximize damage to very large collections of targets (Figure 3).

A system to assign relative values to military installations. This system is compatible with the widely used DIA economic value approach and allows the combining of military and economic targets into a unified installation base for analysis purposes.

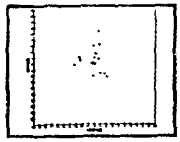
An interactive-graphics model which enables a user to modify weapon aimpoints in order to meet population avoidance criteria.

Target Value
Target Data
Weapon Characteristics
No. of Arriving Weapons
(Accounting for Survival and Penetration)

INPUT

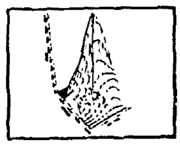
Target ↓ *Clustering*

A CLUSTER OF TARGETS



Aimpoint ↓ *Optimization*

A VALUE SURFACE FOR THE CLUSTER



Damage ↓ *Aggregation*

MEASURES OF EFFECTIVENESS

Figure 3 illustrates the general aimpoint selection and damage assessment procedure. Central to the analysis is a computer model for the selection of optimal aimpoints. Weapon parameters and physical data on installations are inputs which can be varied to determine the impact of design options and intelligence uncertainty. The values assigned to installations-- representing the importance of individual installations-- are also varied to investigate alternative mission priorities. The target data is processed to identify "clusters" of installations which can be damaged by a single weapon. The model identifies the optimal aimpoint within each cluster. Next, collections of clusters are considered and aimpoints adjusted for the effects of multiple weapons. Finally, various measures of effectiveness are developed, including drawdown curves indicating total damage versus number of weapons.

FIGURE 3 - STRATEGIC WARHEAD ANALYSIS PROCEDURE

Background

Sandia's energy technology projects are of relatively recent origin, most of them starting within the past 5 years. They now account for about 25% of the total Laboratories' program. The objective of our energy related systems analysis - similar to the weapons studies - is to provide input to Lab and DOE decisions by comparing the value of alternatives. However there are differences. The Federal government is the ultimate consumer of the products resulting from our weapon related research and development. This is not (for the most part) the case with energy technology. Therefore, decisions made during government sponsored energy research, development, and demonstration must account for eventual commercialization potential. Just as a close working relation with the DOD is essential for our weapon studies, a similarly close involvement is required with the potential customers for energy technology.

The primary energy-related system study activity in 1978 was support of the DOE's Large Power (Solar) System Program for which SLL provides the technical management. In addition, we also conducted studies relevant to energy storage issues.

The goal of the Large Power program is the cost-effective production of thermal and electrical energy in large quantities. Sandia's activities include in-house research as well as the technical management of DOE contracts with industries and universities. The Systems Studies Department supports the program by performing studies and providing computer models for use by industry and universities. The studies range from cost and performance evaluations of proposed designs to applications analysis which help establish the goals necessary to insure economic attractiveness of these systems. The latter type studies must be of sufficient scope to consider competing technologies and energy policy and planning issues.

Our major cost performance study, completed in 1977, evaluated the alternative subsystems proposed for the 10 MWe Solar Thermal Pilot Plant to be built near Barstow, California. Working closely with the design contractors, the involved electrical utility, and Sandia project engineers, we obtained consistent cost and performance data. The data was used as input to various models to estimate the cost of producing electricity. Rather than optimizing for the Pilot Plant size, the cost performance estimates were based upon postulated commercial size operation.

These analyses indicated that first generation solar technology is several times more expensive than today's alternative electrical energy sources. The objective of current programs is to narrow this cost differential.

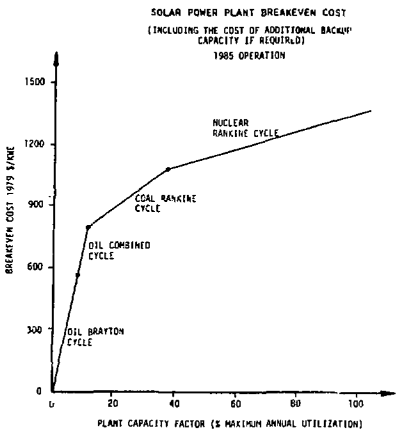
Highlights

Solar Energy

Hybrid and Repowered Solar Plants - Breakeven Cost Analysis

We used breakeven cost analyses (Figure 4) to evaluate several proposed solar electric applications. Hybrid solar plants are capable of steam production from both solar energy and fossil fuels and possibly could alleviate the need for energy storage capability. Our analysis of such plants indicated that, if the solar equipment is to have significant value, there can be only limited energy production from the fossil side, and as a corollary, for high plant capacity factors (i.e., high utilization) energy storage must be included.

The objective of another proposed application, repowering, is to modify fossil fired electric plants to enable the use of solar energy; thus, transforming existing fossil plants into hybrid solar plants. Because of the National Energy Act and the rapidly escalating cost of oil and natural gas, the repowering of existing plants is viewed as an attractive early opportunity for energy displacement by solar thermal.



The breakeven cost (or value) of a concept is the cost of the most economic alternative. Therefore, the breakeven costs of solar power plants depend on the cost and performance of nonsolar plant types. The most economic alternative depends on the plant capacity factor. Figure 4 shows the solar breakeven cost as a function of capacity factor and indicates the plant type that solar must compete with.

FIGURE 4

It was also felt in some quarters that since these plants already existed, a utility could afford to pay much more for the solar equipment than it could in an all new solar plant. However our analysis of this latter issue indicated that the value of solar equipment in new and repowered plants is roughly equal; moveover there are situations in which it is worth less in a repowered plant because extensive equipment modification may be needed.

Optimum Size of Solar Thermal Electric Plants

Economies of scale apply to the costs of many solar plant subsystems. However, other factors tend to limit the size; for example, the attenuation of reflected light in air. Therefore, solar systems have an optimum size; that is, if the plant is larger or smaller, the collected energy will be more expensive. Our analysis shows the optimum size is in a range attractive to electric utilities (~ 100 MWe) and further that, for plant sizes within a factor of two of optimum, the cost of energy does not increase by more than several percent.

Computer Models

In addition to developing models to support our own studies, we provide such models to the solar contractor community. Two computer codes were completed and released in FY78. The Solar Thermal Electric Annual Energy Calculator (STEAEC) code computes the annual net electric production of a solar thermal plant based on hourly insolation, temperature, and windspeed data. BUCKS is used for life cycle cost analysis of solar plants and calculates annual required revenue and busbar energy costs. Other codes have been developed and will be released in 1979.

Workshops

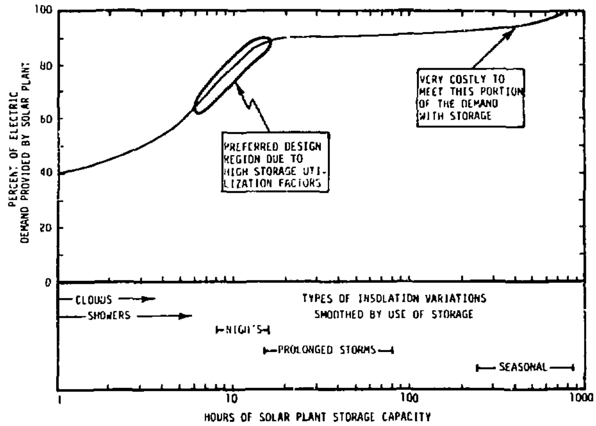
We sponsored two workshops during the fiscal year. The workshop on cost and performance calculations of solar thermal electric power plants held in November 1977, reviewed the methodology used in BUCKS and STEAEC. About 50 people from government-sponsored labs, electric utilities, and solar contractors attended.

The workshop on Systems Studies for Central Solar Thermal Electric had two aims -- education of utility representatives on the solar electric options, and education of the DOE contractors on the economic issues which will affect the viability of solar plants. The workshop, held at the University of Houston in March, was attended by over 100 people including representatives of 15 utilities.

Energy Storage

Seasonal Storage of Energy for Solar Plants

Complete provision of load demand with solar energy is difficult because of the variable length of the day over a year and bad weather in winter. Seasonal storage of energy - storing energy during the long cloudless days of summer for use during the winter - using chemical reactions was conceived of as a way of solving the problem. However, analysis of the costs and efficiencies associated with chemical systems indicated that, from an economic standpoint, a hybrid solar fossil system is preferable (Figure 5).



The amount of storage required for a solar thermal electric plant depends on two factors: the cost of storage relative to the rest of the plant and the type of insolation variations which need to be smoothed. Figure 5 shows the percent of electrical demand provided by the solar portion of a hybrid power plant as a function of the hours of storage available. As storage is added to a solar plant, the output electricity increases. While 100 percent of demand could be met by adding many hundreds of hours of storage, such plants run more economically with far fewer hours and use fossil fuel to cover for prolonged storms and seasonal variations.

FIGURE 5

Applications Analysis of Fixed Site Hydrogen Storage

We explored potential applications and requirements for fixed site storage in a scenario of wide spread hydrogen use. An envisioned hydrogen production/distribution/end-use cycle was examined to identify the storage needs for both continuous and intermittent sources including solar. The most pressing need for storage was found to be at the distribution point, in concurrence with current natural gas practice. Caverns and similar underground storage techniques are the most promising modes due to their low cost relative to other options examined. Since a large volume of natural gas storage is presently in service, we did not identify a pressing need to develop fixed site hydrogen storage technology beyond the conversion of this underground storage to hydrogen.

Background

A major responsibility of the Nuclear Regulatory Commission (NRC) is to protect the public from misuse of the nuclear energy fuel cycle. This responsibility includes establishing appropriate safeguards for the nuclear industry. In support of this objective and to provide input to regulation and licensing decisions, we participated in an NRC program which studied physical security requirements and alternatives.

Our focus was the transportation of nuclear material and the associated physical security implications. In particular, our task was to develop methods of analyses to formulate and evaluate alternative protection strategies. This effort differed from most of our studies in that the emphasis, as directed by NRC, was on developing general methods rather than addressing specific issues.

The basic relations among the objective, mission, functions and components of a transportation safeguard system are shown in Figure 6.

The major challenge in the program is to develop ways to measure the value of proposed security systems. The fundamental questions are: How should each safeguard dollar be invested, and how much security is enough? The first of these is more tractable and one can reasonably expect analysis to shed considerable light upon preferred tactics and allocation of a given level of resources to the various components of a security system. The second

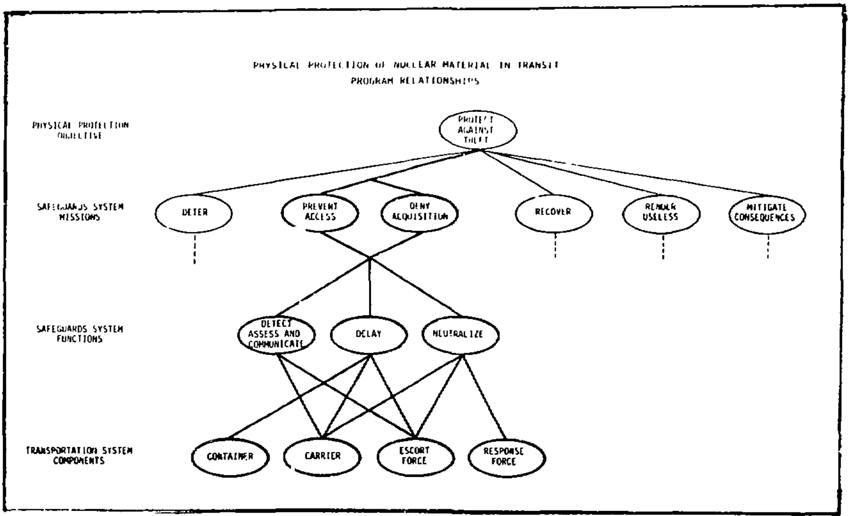


FIGURE 6

question is much tougher, especially since it is so difficult to predict the motivation and capabilities of potential threats. However, analysis, by examining the impact of a range of adversary actions and attributes, may help provide insight as to what additional safeguard dollars might buy.

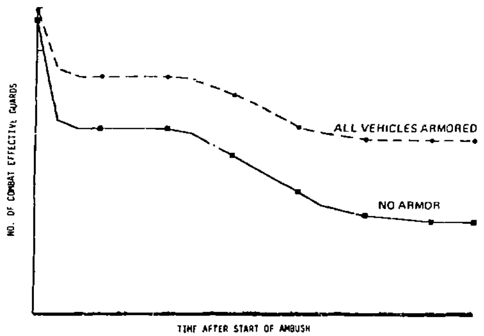
Highlights

Several methodologies relevant to NRC Physical Security issues were developed and applied to exemplary studies. We reviewed and used existing DOD methodologies when appropriate as well as interacted with DOE's own safeguard activities for government-owned nuclear materials.

In order to ensure more efficient use of Sandia resources, we transferred responsibility for this program to SLA at the beginning of FY79.

Convoy Characteristics

In order to address the relative value of alternative convoy configurations and tactics against an armed attack, a computer simulation, SOURCE, was developed. SOURCE is a flexible time-stepped Monte Carlo model and allows extensive variations in both convoy configuration and adversary characterization. Performance measures include the number and condition of surviving guards and the probability of emergency signal generation (Figure 7).



SOURCE output includes the number of combat-effective guards as a function of time after the start of an ambush. Figure 7 illustrates a use of the model: comparison of alternative protective schemes. Results shown are the average over many Monte Carlo simulations for a single set of convoy and adversary parameters.

FIGURE 7

Availability of Local Law Enforcement Agency Officers

We developed a method to estimate the number of police available along prescribed highway routes to support a safeguard system. The method - using FBI and census data as input to approximate the actual location of police - is incorporated in a computer model called COPS (COunt Police Support). COPS can help identify soft spots along a route as well as compare alternate routes with respect to police coverage.

Weapon Evaluation

The Small Arms Casualty Effects Model, SACEM, was developed to compare the effectiveness of small-bore weapons. The model estimates the level of incapacitation inflicted on a target accounting for weapon characteristics, firer proficiency, and target range, posture, and exposure.

Conflict Evaluation

The evaluation of the factors which affect the outcome of armed conflicts that might occur during a theft attempt presents serious problems. The outcomes are strongly dependent upon human initiative and behavior as well as details of the local conditions (terrain, weather, etc.). This situation is not very amenable to analytical modeling approaches; even detailed computational simulations fall far short of reality and cannot provide absolute performance measures. In an attempt to help illuminate the relative performance of alternative systems and tactics in a variety of conflict situations, we developed two families of models.

SABRES are individual-resolution computer simulations of combat between groups using small arms weapons accounting for the effects of terrain, visibility, cover, and movement. They feature an interactive capability, allowing an analyst to draw on his own expertise to develop scenarios which can then be run on a Monte Carlo basis to generate statistical results. The model also treats the attacker's attempt to penetrate any barriers deployed to delay access to the cargo. Suppression (degradation of performance under fire) and the allocation of defenders and attackers to various tasks are considered.

Board games represent an alternative to computerized simulations. In a game, the decisions are not preprogrammed but are made by the players during the course of play. We have developed such a game, AMBUSH, portraying a hypothetical conflict between a truck convoy and an adversary group attempting to hijack its cargo. It is designed as a two-player (or team) game. Realism can be increased by use of an umpire to monitor information flow between the players. AMBUSH allows a wide range of scenario variation: route selection, terrain, weapons, number of participants, deployment, tactics.

SABRES and AMBUSH are tools which may provide the Nuclear Regulatory Commission a capability for exploring strategy and tactics, rapidly acquainting newcomers with road transit physical protection problems and training guards.

EPILOGUE

Systems Studies at SLL - Some Philosophy and Features

The objective of SLL's Systems Studies activity is to evaluate the relative value of alternatives. Thus, it falls within that general class of intellectual endeavors variously known as systems analysis, operations research, policy analysis, the systems approach, cost benefit analysis, etc.; which has proliferated in both government and the private sector in the past two decades.

These endeavors are alternatively characterized as:

- vital tools, based upon solid scientific foundation, for decision making in the modern world,
- a waste of resources in attempting to measure the unmeasurable.

Those of us engaged in this activity at SLL strive to make it at least a useful tool.

Whatever their differences in emphasis, these above mentioned endeavors have the following elements in common:

- an objective
- a set of alternatives (strategies, hardware systems, etc.)
- a model to test the performance of the alternatives
- measures to identify the impacts (benefits, costs)
- a criterion (some function of these impacts) to compare the alternatives

Finally, the output is the preferred order of the alternatives and, if the study is especially successful, the identification of new alternatives: one good new idea is worth n evaluations, where n is a large number.

Systems analysis can be described as a three phase process consisting of a

front end - formulating and researching the problem, establishing system boundaries. This is characterized by reading, listening, collecting, thinking, groping, and little visible output;

middle - constructing and using a model to obtain results. This is a focused, busy time with plenty of visible ouptut (computer printouts stacked on every horizontal surface).

back end - interpreting and attempting to verify the results, re-examining assumptions, disseminating conclusions. This period involves the search for the mythical decision maker and is characterized by feelings of frustration interrupted by occasional euphoria.

Often, not nearly enough time is devoted to the front end and the interpretation, re-examination, and verification functions in the back end.

Perhaps the most difficult and challenging task is establishing a meaningful system boundary. In spite of claims to the contrary, successful analyses do not account for all factors; the analyst must consciously decide what to leave out as well as what to include. A good system boundary, in addition to surrounding a relevant and tractable problem, should also facilitate connections and tradeoffs with other problems and issues.

The role of research cannot be overstated. The model builder who states, "give me the inputs and I will give you the answers" rarely accomplishes relevant and useful analysis. There are no short cuts to such analysis which depends, to a great extent, upon the analyst's in-depth knowledge of the alternatives.

The Systems Studies staff at SLL includes engineers, physical scientists, and mathematicians, several with strong economic backgrounds. The number of staff currently is about 20. Our studies generally focus upon technical cost-performance tradeoffs and perhaps are not as ambitious as some that attempt to address a broader range of societal impacts. Many of our studies address acquisition issues. The scope must be sufficiently broad to explore the relations between these acquisition alternatives and higher level policy options.

The major source of uncertainty in any acquisition decision is our ignorance of the future. In addition, when dealing with national security and safeguard systems, the behavior of human adversaries adds another dimension to the uncertainty. These are truly unknowns and their treatment does not lend itself to quantitative risk analysis, e.g., using density functions characterizing the probability of possible outcomes. There is no general solution to this problem - one treats these uncertainties as best as one can - using research, imagination, (un)common sense, sensitivities, etc.

Models play a vital role in the systems analysis process. These models, particularly those used in national security and safeguard studies, tend to be descriptive rather than predictive, highlight sensitivities rather than develop optimums, and offer insight rather than absolute answers. Such models are often attacked for being imperfect, unrealistic, etc.; they usually are. However, some sort of model - mental, verbal, physical, symbolic - plays a role in any decision process. The issue is not whether to use a model but rather what kind of model to use. In particular, are the increased costs of developing and using certain classes of models (e.g., computerized) justified by benefits they offer.*

In summary, and acknowledging inherent limitations, we believe good systems analysis can help compare alternatives, generate new alternatives, explore ends-means relations and in general help focus the decision process, raise the level of debate and leave us better prepared to handle the unexpected when it arrives.

*However a too literal adherence to such justification leads to the logical absurdity of requiring a systems analysis to decide to do a systems analysis to decide to ...

Presentations and Publications

Presentations, informal and formal, are the primary means of communicating our results. These presentations are made to our DOE and NRC sponsors, to many DOD agencies both in the United States and Europe, congressional and executive branch staffs, other government laboratories, contractors and universities, and to conferences of various organizations including the Military Operations Research Society, the Operations Research Society of America, and the International Solar Energy Society.

Unclassified Publications

1. K. P. Berkbigler, Estimating the Availability of LLEA Officers, SAND77-8626, July 1977

2. K. P. Berkbigler, Estimates of LLEA Officer Availability, SAND78-8657, May 1978

4. J. M. Brune, BUCKS--Economic Analysis Model of Solar Electric Power Plants, SAND 77-8279, February 1978

5. J. M. Brune, "Hybrid and Repowered Solar Electric Plants," published in the Proceedings of the 1978 Meeting of the American Section of the International Solar Energy Society

6. J. M. Brune, Recommendations for the Conceptual Design of the Barstow, CA Solar Central Receiver Pilot Plant - Executive Summary, SAND77-8035, October 1977

7. E. D. Eason, "Collector Cost and Performance Trade-off Studies," published in the 1978 DOE Workshop on Systems Studies for Central Solar Thermal Electric

8. R. J. Gallagher, S. C. Keeton, K. Stimmel, P. De Laquil, The Evaluation of Road-Transit Physical Protection Systems, SAND78-8650, June 1978

9. R. J. Gallagher, K. G. Stimmell, N. R. Wagner, The Configuration of Road Convoys: A Simulation Study, SAND77-8625, July 1977

10. T. S. Gold, Nuclear Weapons and Computers, prepared for U.S. Department of Energy, March 1978, Summary Volume

11. J. D. Hankins, "Optimal Module Sizing for Solar Central Receiver Thermal Electric Power Plants," published in the Proceedings of the 1978 Meeting of the American Section of the International Solar Energy Society

12. J. J. Iannucci, P. J. Eicker, "Central Solar/Fossil Hybrid Electrical Generation: Storage Impacts," published in the Proceedings of the 1978 Meeting of the American Section of the International Solar Energy Society

13. J. J. Iannucci, R. D. Smith, C. J. Swet, "Energy Storage Requirements for Autonomous and Hybrid Solar Thermal Electric Plants," International Solar Energy Congress, New Delhi, India, January 1978, (published in the Proceedings)

14. S. C. Keeton, P. De Laquil, Conflict Simulation for Surface Transport Systems, SAND77-8624, July 1977

15. J. K. Piastiras, "Capacity Displacement for Solar Plants," published in the Proceedings of the 1978 Meeting of the American Section of the International Solar Energy Society

16. R. L. Rinne, Physical Protection of Nuclear Material In-Transit Quarterly Reports, SAND78-8243, September 1978; SAND78-8242, July 1978

17. R. L. Rinne, The Evaluation of Safeguards Systems for Nuclear Material in Transit - The Development of the Program Plan, SAND77-8249, July 1977

18. G. E. Strandin, J. Mansfield, HITSMORE Users Manual: A Computer Program to Assess B77 Laydown Reliability, SAND77-8054, March 1978

19. N. R. Wagner, A Survey of Threat Studies Related to the Nuclear Power Industry, SAND77-8254, July 1977

20. J. B. Woodard, Role of Storage in Determining the Value of a Solar Plant in an Electric Grid," published in the Proceedings of the 1978 DOE Workshop on Systems Studies for Central Solar Thermal Electric

21. J. B. Woodard, G. J. Miller, STEAEC--Solar Thermal Electric Annual Energy Calculator Documentation, SAND77-8278, January 1978

Distribution:

W. J. Howard, 2
L. D. Smith, 1200; Attn: R. G. Clem, 1250
J. M. Wiesen, 1220
W. L. Stevens, 1230
W. C. Myre, 1700
R. L. Peurifoy, Jr., 4300; Attn: E. E. Ives, 4330
J. A. Hood, 4360
G. S. Brown, 4361 (5)
A. W. Snyder, 4400; Attn: D. J. McCloskey, 4410
G. R. Otey, 4440
L. D. Chapman, 4416
J. H. Scott, 4700; Attn: V. L. Dugan, 4720
J. A. Leonard, 4721
J. F. Banas, 4722
W. P. Schimmel, 4723
D. B. Shuster, 5000; Attn: A. A. Lieber, 5610
W. F. Roherty, 5611
J. W. Keizur, 5612
T. S. Edrington, 5613
J. L. Dossey, 5614
T. B. Cook, Jr., 8000; Attn: A. N. Blackwell, 8200
W. J. Spencer, 8100; Attn: J. F. Barham, 8110
J. L. Wirth, 8150
R. D. Cozine, 8160
D. J. Bohrer, 8111
H. M. Witek, 8115
A. T. Jones, 8116
J. B. Wright, 8151
G. N. Beeler, 8152
A. S. Rivenes, 8162
R. L. Rinne, 8201 (5)
B. F. Murphey; Attn: D. M. Schuster, 8310
G. W. Anderson, 8330
W. Bauer, 8340
D. L. Hartley, 8350
T. S. Gold, 8320 (30)
F. J. Murar, 8322
J. E. Struve, 8324 (20)
P. J. Eicker, 8326 (20)
L. D. Hostetler, 8328 (20)
O. H. Schreiber, 8329
L. Gutierrez, 8400; Attn: R. C. Wayne, 8450
Publications and Public Information Division, 8265, for TIC (27)
F. J. Cupps, 8265/Technical Library Processes Division, 3141
Technical Library Processes Division, 3141 (2)
Library and Security Classification Division, 8266-2 (3)