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TR-3505

AN ACQUISITION STRATEGY COMPARISON MODEL (ASCM)

Volume I - Executive Summary and Report

3 May 1982

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A detail of a prototype computerized model for acquisition strategy comparison. An interactive menu selection process is used to obtain a general description of the weapon system concept and program objectives. The model and the user then interact to successively reduce the number of strategy alternatives to a small set containing the preferred alternatives for a particular situation. Prototype model limited to two categories of weapon systems, tactical missiles and electronic subsystems. Volume II discusses the internal relationships between risk, time & cost used in the model.

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ABSTRACT

The authors have developed a prototype computerized model for acquisition strategy comparison. An interactive menu selection process is used to obtain a general description of the weapon system concept and program objectives. The model and the user then interact to successively reduce the number of strategy alternatives to a small set containing the preferred alternatives for a particular situation. Reasonable agreement with program experience has been demonstrated.

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EXECUTIVE SUMMARY

Under the sponsorship of the Defense Systems Management College (DSMC), The Analytic Sciences Corporation (TASC) has developed a prototype Acquisition Strategy Comparison Model (ASCM). The objective of this phase was to develop and demonstrate a computerized model and data base for evaluating acquisition strategy alternatives. Results demonstrated both the feasibility of such a concept and general agreement with program experience.

The scope of the current effort was intentionally limited to two categories of weapon systems, tactical missiles and selected electronic subsystems. The data base developed consists of data on 37 programs plus ancillary data. It is adequate for prototype demonstration, but cannot be considered complete for full program application. Data collection and analysis efforts for both the current effort and potential future phases are documented herein.

The model is structured to duplicate a logical process which might be employed by a program manager to select an acquisition strategy for his program. This process is summarized as follows:

- Identify feasible strategies
- Reduce the set of feasible strategies to a set consisting of those strategies with the highest probability of achieving the desired result
- Further reduce the set of possible strategies by funding limitations

- Narrow the choices even further by eliminating "second-best" options via detailed comparative analysis.

This successive reduction process typically results in deleting a vast majority of the possible strategies, leaving a small number of strategies for further in-depth tradeoff analysis. The model also presents the relative costs and benefits associated with the different options, and it can be exercised to highlight sensitivities to program or risk variations.

The report provides a detailed description of the entire process, an illustrative example incorporating sensitivity analysis, and a real-world example of results from the AN/SLQ-32 program (a Navy ship-based electronic warfare program).

These examples provide ample evidence that the prototype model provides results consistent with program experience. Furthermore, they demonstrate the insights the model is capable of providing:

- To illustrate the interrelationships among acquisition strategy alternatives and key influencing factors
- To emphasize that acquisition strategy encompasses the entire acquisition process and demonstrate that the selection of an acquisition alternative for one phase should not be made independently of other phase options
- To highlight the importance of risk identification and risk management early in the program.

Collectively, these findings provide a strong indication of the potential utility of the model as a teaching aid to program management students at DSMC and elsewhere.

Combined with more in-depth data collection and analysis to support the myriad of internal relationships, ASCM could also provide early planning support to program management personnel.

Finally, the data base and analytic structure provide an excellent first step toward the development of a unique and badly needed acquisition strategy research tool.

Based on the success of the prototype model, TASC strongly endorses the following recommendations:

- Implement ASCM as a teaching aid in the program management curriculum at DSMC (through the development of user-friendly software)
- Perform additional data collection and analysis of tactical missile system and electronic subsystem development and production phases in order to validate and refine key model parameters and relationships. (This will vastly increase the validity and realism of the prototype model.)
- Perform additional research and analysis to refine, update, modify, and validate (as required) two key methodologies incorporated in the model (again, this will vastly increase the validity and realism of the prototype model)
- Expand the scope of the model to include additional categories of weapon systems in order to provide maximum utility to the overall defense community
- Perform research into the feasibility of expanding the scope of the model to include a model of the concept exploration process. (Given such a model, a user could begin with a perceived operational need, determine likely concepts to address that need, and then assess tradeoffs among the competing concepts.)

1. INTRODUCTION

1.1 BACKGROUND

Under the sponsorship of the Defense Systems Management College (DSMC), The Analytic Sciences Corporation (TASC) previously assessed the feasibility of developing an analytic model to aid in selecting an acquisition strategy for research, development, and production of major weapon systems. Results from that assessment of significance to the current effort are as follows:

- The elements of acquisition strategy were described as a set of strategy alternatives over four acquisition phases
- Preliminary estimates of quantitative relationships were developed which indicate the expected result of pursuing a particular acquisition strategy
- Examination of four major weapon system acquisition programs indicated a sufficient quantity and quality of data to support the development of an historical data base, but an intense effort was required for collection
- The development of an analytic model for use in selecting an acquisition strategy was deemed feasible. The quantifiable relationships developed would measure the expected result of pursuing each feasible acquisition strategy. To evaluate the strategies, TASC recommended the use of decision analysis techniques and the development of a multi-attribute utility model which could be tailored to meet the needs and constraints of each particular program

- A three-phase approach for full model development was recommended. Phase I consisted of the development of a preliminary computerized model combined with a data collection effort sufficient to obtain first-order estimates of required parameters. Phase II consisted of model evaluation by using the preliminary model to assist program managers with acquisition strategy decisions, performed concurrently with additional data base development. The final phase consisted of updating the model to include lessons learned during the evaluation phase, followed by full model implementation and documentation.

A complete presentation of these findings is contained in TASC report TR-1375, "Feasibility and Development Study for a System Acquisition Strategy Model - Final Report", dated 12 January 1981.

1.2 OBJECTIVE

Not surprisingly, the reactions to the findings and conclusions contained in the feasibility assessment constituted a mixed review. There was little disagreement concerning the basic findings and even only minor doubt concerning the feasibility, in a theoretical sense, of developing a model along the lines described. The main concern was one of implementation. Was it possible, in a real-world sense, to develop and implement such a model that would provide reasonable results? In an attempt to reduce the uncertainty associated with realistically implementing such a model, the scope of the subsequent phase was altered.

The main objective for this phase was to develop and demonstrate a computerized model and data base for evaluating acquisition strategy alternatives. Specific tasks were as follows:

- TASK A - Demonstrate an acquisition strategy model for two categories of weapon systems or subsystems. The demonstration shall be structured to illustrate the complex interrelationships for all significant program variables discussed in Phase I, to form the basis for approval of Phase III, and to provide an early indication of implementation requirements, i.e., input-output data, computer capacity, facilities, and the like. Comparison with program experience shall be the basis for determining adequacy of the demonstration

- TASK B - Provide DSMC with two copies of all programs, subroutines, modules and access to data associated with TASK A. Support DSMC analysis of program data, algorithms, or output results

- TASK C - Develop specifications and requirements for Phase III and Phase IV to include time and cost considerations, architecture, and interface requirements

- TASK D - Provide periodic review meetings to be held at the completion of significant task accomplishments.

The two categories of weapon systems and subsystems agreed upon for the demonstration model were tactical missiles and key military electronic subsystems. The primary rationale for their selection is as follows:

- Both categories are used by all three services, thus providing a broader base for the demonstration

- Electronic subsystems, such as the guidance and control system, are typically key components of tactical missiles. It was believed that interdependencies might exist which could be exploited, particularly in the data collection and analysis arena

- From previous research, TASC had obtained production cost histories on a number of tactical missiles and electronic subsystems. The use of this existing data would reduce the data collection effort.

Two principal deliverables were associated with this effort. The first and most important was a formal demonstration of the model. This demonstration was conducted at DSMC on February 19, 1982. In addition, several members of the DSMC staff experienced interactive use of the model on March 2 at TASC's facilities in Arlington, Virginia. This report is the other principal deliverable and it documents the research effort, together with results, findings, conclusions, and recommendations.

1.3 CONTENT OF REPORT

This report consists of two volumes. This volume contains an executive summary and the main report. The remaining chapters of this volume provide a description of the model, together with some examples, followed by the conclusions and recommendations resulting from this effort. Volume II consists of appendices which provide a detailed description of the inner workings of the model plus details of the data collection and analysis efforts.

2. MODEL DESCRIPTION

2.1 PHILOSOPHY

One hypothesis underlying the model's overall approach concerns the effort required to transform a weapon system concept into a producible hardware (and software) configuration. This effort is considered to be relatively independent of time. The same basic tasks are required to develop a weapon system today as were required twenty or thirty years ago. The order in which the tasks are performed may differ, the nature of overlap among the tasks may vary, and the names associated with the activities may change on a regular basis. However, the basic tasks remain relatively static. Histories of missile development programs support this hypothesis.

ASCM builds upon this hypothesis. Its philosophy is that the lessons learned in prior programs can provide invaluable guidance in choosing the acquisition strategy consistent with the goals and objectives of a program today. In this light, ASCM can be viewed as a computerized lessons-learned algorithm.

An equally important philosophy concerns the model's implementation. There was a concentrated effort throughout the development to align the logical structure of the model with a possible logical process employed by a program manager in selecting an acquisition strategy for his program. That process can be summarized into four key steps:

- Identify all feasible strategies
- Reduce the set of feasible strategies to a smaller set consisting of those strategies with the highest probabilities of achieving the desired result

- Further reduce the set of possible strategies by financial limitations
- Perform detailed comparative analysis of those remaining to eliminate "second best" options.

ASCM follows this logical process.

In developing an initial model of any large and complex process, there is frequently an inverse relationship between the level of detail addressed by the model and the probability of creating a successful model. The generally accepted approach in these cases is to keep the initial model as simple as possible and address only those factors deemed most crucial to the process. For our case, over 150 factors were identified during the feasibility study as potentially relevant to an acquisition strategy decision. For initial model development, the factors considered to be most critical in the majority of situations were combined into higher level aggregate factors, and other less critical factors were not considered. Expansion and refinement of the model to include missing factors, such as life cycle cost implications, and to expand upon aggregrate factors is best accomplished after the initial model is demonstrated to be reasonable.

2.2 ACQUISITION STRATEGY ALTERNATIVES

The first step in using ASCM is to understand the concept of acquisition strategy employed. As background to this concept, DODI 5000.2, 19 March 1980, defines acquisition strategy as follows (emphasis added by authors):

> "Acquisition strategy is the conceptual basis of the overall plan that a program manager follows in program execution. It reflects the management concepts that shall be used in directing and controlling all elements of the acquisition in response to specific goals and objectives of the program and in ensuring that the system being acquired satisfies the approved mission need. Acquisition strategy encompasses the entire acquisition process. The strategy shall be developed in sufficient detail, at the time of issuing the solicitations, to permit competitive exploration of alternative system design concepts in the Concept Development phase. Additionally, sufficient planning must be accomplished for succeeding program phases, including production, for those considerations that may have a direct influence on competition and design efforts by contractors. The acquisition strategy shall evolve through an iterative process and become increasingly definitive in describing the interrelationship of the management, technical, business, resource, force structure, support, testing and other aspects of the program."

Consistent with this definition, ASCM looks at acquisition strategy in a macro-perspective and considers it to consist of 25 strategy alternatives spanning four acquisition phases (Figure 2.2-1). These alternatives encompass the feasible options identified for the development of a new weapon system and for a modification program for an existing weapon system. An in-depth discussion of each alternative is contained in the final report for the prior feasibility assessment (TASC Report TR-1375). A brief description of the alternatives by acquisition phase appears in the following sections.

PHASE 0: Concept Exploration

- Directed concept
- By non-industrial firms
- By industrial firms
- Jointly

PHASE 1: Demonstration and Validation (D&V)

- Waive
- Contract definition
  - by non-industrial firm(s)
  - by single industrial firm
  - by multiple industrial firms
- Subsystem/component development
  - by non-industrial firm(s)
  - by single industrial firm
  - by multiple industrial firms
- System prototype
  - by non-industrial firm(s)
  - by single industrial firm
  - by multiple industrial firms

PHASE 2: Full-Scale Development (FSD)

- Incremental development
  - by single source
  - by multiple sources
- Partial concurrency
  - by single source
  - by multiple sources
- Full (extreme) concurrency (Single source)

PHASE 3: Production and Deployment

- Single source, no options
- Single source with options
- Single source, multi-year contract
- Leader-follower
- Licensing
- Second sourcing

Figure 2.2-1 Acquisition Strategy Alternatives

2.2.1 Concept Exploration

The primary objective of concept exploration is to examine feasible solutions of a perceived operational need and to select for further development those solutions which exhibit the highest potential. The alternatives for this phase basically concern where this effort is performed. Although time and cost distributions for this phase are included in the model, they contribute very little to the insight provided by the model. Since the prototype model was restricted to tactical missiles and key electronic subsystems, the model in its current state principally concerns the development options for a pre-defined concept. Further research into feasible approaches to modeling the concept exploration process and its function would be appropriate.

2.2.2 Demonstration and Validation

The principal objective of the Demonstration and Validation Phase is to demonstrate that the technology required to implement a particular concept is primarily an engineering application, rather than an experimental effort. The alternatives for this phase span two dimensions. The first dimension concerns the scope of work performed. The four options in this dimension range from doing nothing (Waive), to paper analysis (Contract Definition), to building select hardware (Subsystem/ Component Development), to building a system prototype. The second dimension concerns the organization performing the work.

These options consist of non-industrial firms*, a single industrial firm, or multiple industrial firms.

2.2.3 Full-Scale Development

The primary objective of Full-Scale Development is intense analysis and refinement of the system design (including peripheral equipment) to ensure that the pre-production prototypes will meet performance thresholds. The alternatives for this phase principally concern timing, or the degree of concurrency employed, and the number of development firms.

2.2.4 Production and Deployment

For Phase 3, Production and Deployment, the options concentrate on the single source versus dual source decision with variations allowed for each case.

An in-depth discussion of each alternative is contained in the prior feasibility study.

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*The term non-industrial organizations is used for brevity: the broad intent is to include government engineering centers, laboratories, arsenals, federally funded research centers, educational institutions, not-for-profit corporations, and profit-oriented firms that do not manufacture or produce hardware or computer software. The principal distinction is that this group usually lacks the insight into the discrete segment of the industrial economy that will ultimately dictate the production price of the end item and create or inhibit a competitive environment. Further, a technology transfer must occur whenever the transition from non-industrial firms to industrial firms occurs.

2.3 DESCRIPTION OF SCENARIO

2.3.1 Category Selection

The prototype model consists of three segments, displayed in Figure 2.3-1. The objective of the first phase is to build a user-defined baseline scenario. This is accomplished through a series of computer-generated questions and user responses selected from a menu. The first question concerns the category of the weapon system concept. For the prototype procedure, there are three options:

- Development of a new tactical missile system
- Development of a major modification to an existing tactical missile
- Development of a key electronic subsystem.

2.3.2 Setting the Stage

The next question asks when the analysis is to begin. For the prototype model, it is recommended that the analysis begin with either Phase 1 or Phase 2. Beginning the analysis with Phase 0 is permitted but not recommended for reasons discussed in 2.2.1. If the user is interested only in production alternatives, indepth analysis with program specific parameters is far superior to the general relationships included in the model. Accordingly, beginning the analysis with Phase 3 is not an option.

If the user response begins the analysis with Phase 1 or Phase 2, the computer responds with questions concerning the strategy alternatives pursued in the prior phases, together with the time and cost of each alternative. There are two principal reasons for these questions:

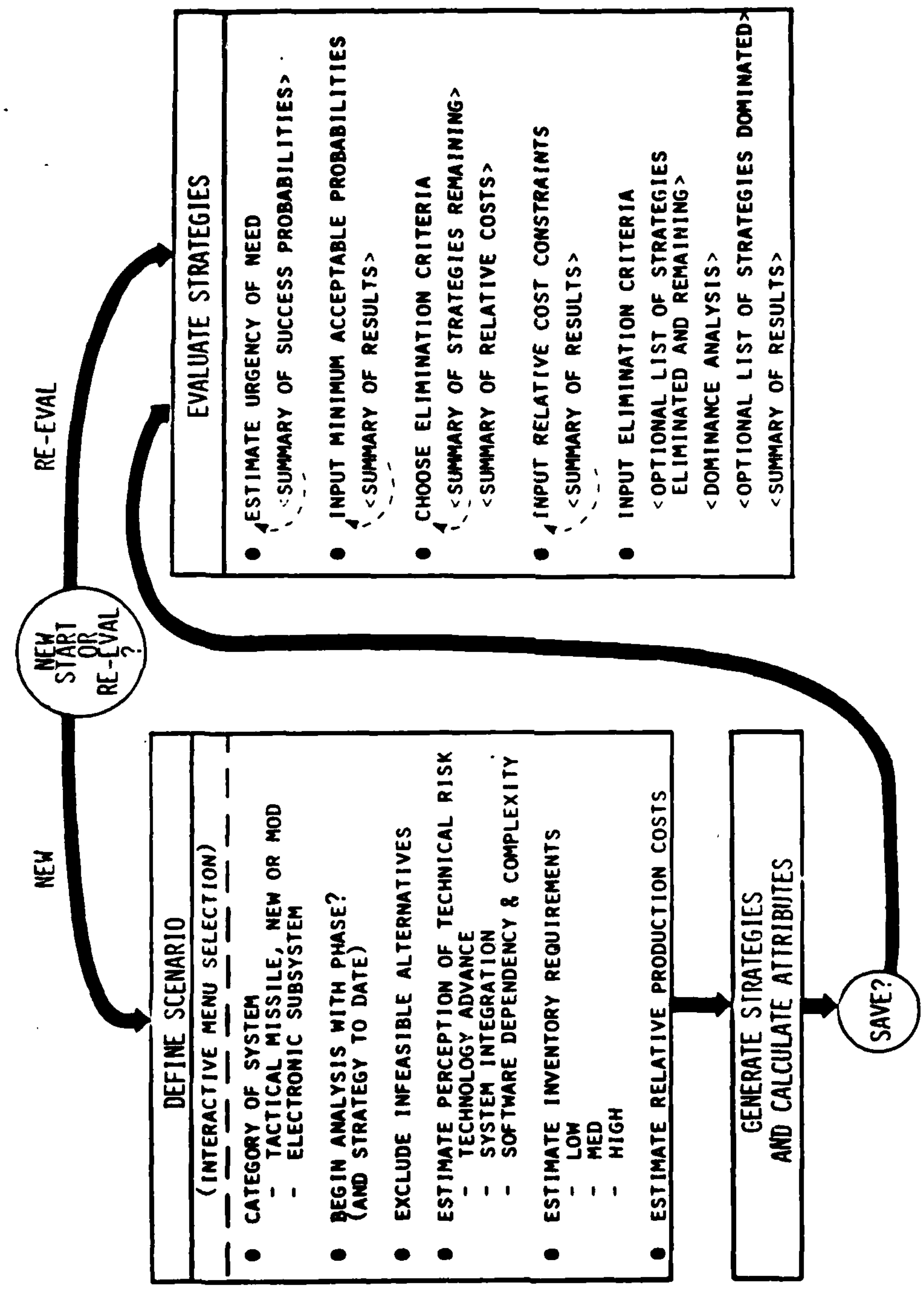

Figure 2.3-1 Model Overview

- All combinations of the phase alternatives are not realistically feasible. Knowledge of the strategy pursued in prior phases enables the model to limit its analysis to only those combinations which are feasible

- Requiring the user to identify the alternatives pursued in prior phases together with the time and cost involved reinforces the concept that acquisition strategy does encompass the entire acquisition process; thus emphasizing that the selection of an acquisition alternative for one phase should not be made independently of other phase options.

Next, the user can eliminate from consideration alternatives which may not be feasible (or acceptable) for his specific situation, although feasible for weapon systems development in general. Alternatives should be eliminated at this point only if it would be impossible to (or he would not be permitted to) execute that alternative should it appear attractive.

2.3.3 Perception of Technical Risks

The next series of questions are crucial to the description of the baseline scenario. These questions are designed to capture the user's perception of the technical risk associated with developing his weapon system concept. In this model, technical risk is separated into three distinct categories:

- Level of technology advance - the concept embodied in this category is the magnitude of the technology increase over the existing state of the art

- Degree of required system integration - a large weapon system with many complex internal and external interfaces is a high-technology risk program; not necessarily because it embodies advanced technology, but because it is vulnerable to a large number of error sources

- Level of software dependency and complexity - a weapon system using off-the-shelf components with few interfaces may still be dependent on a large and complex computer software development effort. If the software is critical to the operation of the system, its development could pace the development of the entire system.

For each of the three technical risk categories, the user is asked for the best estimate of his program's level of risk at the start of the analysis (e.g., if he stated previously that the analysis was to begin with Phase 1, the risk estimates should correspond to that time). For each category, the levels of risk are expressed on an arbitrary scale from one to nine. A one corresponds to virtually no risk, while a nine corresponds to maximum risk. Definitions have been provided for intermediate points along the scale (Table 2.3-1). However, these definitions are not cast in concrete. The intent is to provide a guide to aid the user. If the user feels uncomfortable with these definitions, his own intuition should be used. The relative placement on the scale of his program risk given the scale provided is the important aspect.

TABLE 2.3-1

LEVELS OF TECHNICAL RISK

Risk Level	RISK CATEGORY		
	TECHNOLOGY ADVANCE	SYSTEM INTEGRATION	SOFTWARE DEPENDENCY AND COMPLEXITY
9	TOTAL - All new technology must be developed	TOTAL - All interfaces constitute a totally new design	TOTAL - Highly complex and delays cause total disruption
7	MAJOR - Several subsystems require major advances	MAJOR - Several interfaces constitute a totally new design	MAJOR - Complex and delays cause major disruption
5	MODERATE - At least one subsystem requires major advances	MODERATE - At least one interface constitutes a totally new design	MODERATE - Somewhat complex and delays cause moderate disruption
3	MINOR - At least one subsystem needs some improvement	MINOR - At least one interface needs redesign	MINOR - Minor complexity and delays cause slight disruption
1	NONE - Off-the-shelf technology	NONE - Items can be plugged in "as is"	NONE - Not complex and delays cause no disruption
2, 4, 6, 8 - Intermediate Values			

In addition to estimating the risk in each category, the user is asked for his degree of confidence in that estimate. Again, this is defined by an arbitrary scale from one to nine where one stands for total uncertainty and nine stands for total certainty. Definitions are provided for intermediate points (Table 2.3-2). The purpose of including this aspect is to include uncertainty in the model.

TABLE 2.3-2
DEGREES OF CONFIDENCE

Level	Definition
9	Absolutely certain
7	Reasonably certain
5	Sounds reasonable
3	Somewhat unsure
1	Total uncertainty
2, 4, 6, 8	- Intermediate Values

2.3.4 Estimating Inventory Requirements

The next input to the baseline scenario is an estimate of inventory requirements. This is expressed as the number of systems to be produced and the number of years of production (e.g., 5000 systems to be produced over 7 years). The user should provide this information for a low quantity estimate, a moderate quantity estimate, and a high quantity estimate. This permits the model to include uncertainty in projected inventory requirements defined during early development periods. The relative ability of the strategies to accomodate different quantity estimates is captured in the model. If there is a significant variation among the inventory estimates, this influences the desirability of the strategies, and it will be reflected in the results obtained.

2.3.5 Estimating Relative Production Cost

The final input to the baseline scenario is an estimate of the system's relative production cost compared to all systems in that weapon system category* (for the prototype model, the two categories are tactical missiles and key electronic subsystems). Again, an arbitrary scale from one to nine is used. Definitions are provided in Table 2.3-3. As before, the user is asked for his degree of confidence in this estimate using the previously defined scale (Table 2.2-2). This concludes the first segment of the model.

TABLE 2.3-3
SCALE FOR RELATIVE PRODUCTION COST ESTIMATE

Level	Definition
9	Well above average
7	Above average
5	Average
3	Below average
1	Well below average
2, 4, 6, 8	- Intermediate Values

* This subjective assessment of production cost was chosen over a more precise indicator (such as first unit cost or average cost over the production run) primarily for simplicity. Early in the development of a weapon system, a user of the model is more likely to have a feeling that his production costs are going to be relatively expensive (or inexpensive) compared to similar weapon systems than he is to know a precise value in some base year dollars.

2.4 GENERATION OF STRATEGIES AND CALCULATION OF ATTRIBUTES

This segment of the model requires no user involvement. Typically, the user has to wait for a few seconds while the computer performs several calculations. Based upon the input provided during the prior phase, the model generates a set of allowable acquisition strategies and computes several attributes for each, principally:

- A probability distribution of the time required to reach initial operational capability (IOC)
- A probability distribution of the development cost
- A probability distribution of production cost for each input estimate of inventory requirements
- Probability distributions of the technical risk remaining in each category at the completion of FSD.

Once this is completed, the model outputs the number of strategies generated and gives the user the option to save the information for future reference.

2.5 EVALUATION OF ALTERNATIVES

2.5.1 Probability of Success

The first step in the evaluation segment is to reduce the set of strategies based on the probability of meeting the perceived urgency of need. To accomplish this, the user inputs two estimates: the number of months from the beginning of his initial phase to the earliest desired IOC and the number of months to the latest acceptable IOC. This approach was chosen to bound the urgency of need concept.* The model then displays the relative capability of the strategies to successfully meet these specified IOC requirements (see Figure 2.5-1). The three levels identified on the left of each table correspond to three arbitrarily defined pre-production design stability indicators. The following definitions are provided to indicate the intent of the categorization:

- Level 1 - Virtually all technical risks have been eliminated. The system is ready for mass production
- Level 2 - Minor technical problems persist, but minor system modifications during production should resolve them
- Level 3 - Somewhat more significant technical problems remain. Limited production only (perhaps in conjunction with planned product improvement) is recommended.

The numbers along the top of each column (0.10, 0.20, etc.) are probabilities of success. They indicate the probability of successfully achieving the IOC requirement with a specified level of design stability. An entry in the table corresponds to the number of strategies which have a probability at least as great as that indicated of successfully meeting the IOC requirement at the indicated level of design stability. For example, in Table I of Figure 2.5-1, the number 48 appears in the third row (representing Level 3)

*Another consideration influencing this approach stemmed from the historical review. It was common for the IOC requirements stated early in the development effort to be substantially modified. Actual times required to reach IOC were typically much longer than those desired.

Table I - Earliest Desired IOC

	Probability of Success at Least as Great as:								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
Level 1	186	168	108	90	30	18	0	0	0
Level 2	228	186	168	108	90	30	18	0	0
Level 3	246	228	186	168	108	90	48	0	0

Table II - Latest Acceptable IOC

	Probability of Success at Least as Great as:								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
Level 1	186	168	108	90	30	30	0	0	0
Level 2	228	186	168	108	90	30	30	0	0
Level 3	246	228	186	168	108	90	60	30	0

Figure 2.5-1 Probability of Success

under the column headed by 0.70. Thus, there are 48 strategies that can successfully meet the earliest desired IOC with a probability of at least 0.70 at design stability Level 3 or better. Note that if one were unwilling to accept Level 3 design stability and require a more stable design, there are less strategies available. Only 18 strategies have a probability of success of at least 0.70 at Level 2 and there are no strategies with a probability of success as high as 0.70 at design stability Level 1.

From this, the user is asked to eliminate those strategies whose probabilities of success are unsatisfactorily low (or conversely, to select for further consideration only those strategies whose probabilities of success are satisfactorily high). This is accomplished by specifying a minimum acceptable probability of success for each IOC and level of design stability. For the example displayed in Figure 2.2-3, one might choose to enter 0.5, 0.6, and 0.7 as the minimum acceptable probabilities for Levels 1, 2, and 3, respectively, for the earliest desired IOC, and 0.6, 0.7, 0.8 as the minimum acceptable probabilities for the latest acceptable IOC for levels 1, 2, and 3, respectively.

This input corresponds to six criteria used for strategy comparison. It is common for the strategies which maximize the probability of success for the early IOC to be distinct from the strategies which maximize the probability of success for the late IOC. Because of this phenomenon, the model responds with a summary of the results obtained by evaluating the strategies against the six criteria. The format for the summary is as follows:

N_1 strategies satisfy all six criteria

N_2 additional strategies satisfy 5 criteria and are within a probability of 0.10 on the sixth

N_3 additional strategies satisfy 4 criteria and are within a probability of 0.10 on the other two

N_4 additional strategies satisfy 3 criteria and are within a probability of 0.10 on the other 3

The notation N_1, N_2, N_3, and N_4 stand for the number of strategies in each category. Depending on how the minimum acceptable probabilities were specified, it is common for some of the N_1 through N_4 to be zero. (There even are occasions when all four are zero). Accordingly, the user is given the option to specify other minimum acceptable probabilities and reevaluate the strategies against a new set of criteria. This process may be iterated until the user is satisfied with the results obtained.

Once reasonable satisfaction with these results is obtained, the user has four options available for selecting the strategies to consider for further analysis:

- Consider only those N_1 strategies that satisfy all six criteria
- Consider those $N_1 + N_2$ strategies that satisfy at least five criteria and are "close" (i.e., within a probability of 0.10) on the sixth
- Consider those $N_1 + N_2 + N_3$ strategies that satisfy at least four criteria and are "close" on the other two
- Consider those $N_1 + N_2 + N_3 + N_4$ strategies that satisfy at least three criteria and are "close" on the other three.

Once this option is specified, the model then prints a summary of the phase alternatives in the strategies selected for further analysis. An example of the format used in this summary is displayed in Figure 2.5-2.

The following summarizes the number of the 30 strategies remaining for analysis which include the indicated alternatives:

FOR PHASE 1:	Prototype Non-industrial	12
	Prototype Single Industrial	6
	Prototype Multiple Industrial	12
FOR PHASE 2:	Incremental - Single Source	18
	Incremental - Multiple Sources	12
FOR PHASE 3:	Single Source - No Options	5
	Single Source - Options	5
	Single Source - MYC	5
	Licensing	5
	Leader/Follower	5
	Second Sourcing	5

Figure 2.5-2 Summary of Phase Alternatives

2.5.2 Relative Cost Considerations

The next step in the evaluation process considers the differences in expected cost among the remaining strategies. The computer first displays three tables such as those presented in Figure 2.5-3. The tables compare development cost to total program cost, in a relative sense, for each of the low, moderate, and high estimated inventory requirements. The horizontal scale in each table is normalized to the highest development cost (expected value plus one standard deviation) associated with the strategies under consideration. The vertical scale in each table is normalized to the highest total program cost (expected value plus one standard deviation) associated with the strategies under consideration for that inventory requirement. An entry in the table represents the number of strategies whose expected development cost and total program cost lie in the range indicated. For example, in the table representing the moderate production quantity in Figure 2.5-3, there are eight strategies (out of the total of 30 remaining) whose expected development cost is between 30% and 40% of the maximum and whose total program cost is between 90% and 100% of the maximum.

Tradeoffs frequently exist among development cost and production cost. If there is considerable variation among the low, moderate, and high inventory estimates, some of these tradeoffs may be readily apparent. Others may be more subtle.

The user is now given the opportunity to eliminate additional strategies from consideration based upon these relative cost comparisons. This is accomplished in a manner similar to that employed with specifying minimum acceptable probabilities.

In this case, the input is maximum acceptable relative cost for development and for total program cost corresponding to the three inventory estimates. For example, in Figure 2.5-3, a user may specify 0.5 as the maximum relative development cost if his R&D funds are severly limited. If a limitation on R&D funds is not a driving concern, he may choose to enter 1.0 which eliminates development cost as a significant attribute. Maximum total program cost is specified in a similar manner. For example, 0.7., 0.9, and 0.8 may be reasonable input for the example in Figure 2.5-3 for the low, moderate, and high inventory estimates, respectively.

This input corresponds to four criteria upon which the strategies are compared. Results are displayed in a manner similar to that used for probabilities of success:

- N_1 strategies satisfy all four criteria
- N_2 additional strategies satisfy 3 criteria and are within 10% on the fourth
- N_3 additional strategies satisfy 2 criteria and are within 10% on the other two

The notation N_1, N_2, and N_3 stand for the number of strategies in each category. Again, it is common for some of the N_1 through N_3 to be zero. Accordingly, the user is given the option to select other maximum acceptable relative costs and reevaluate the strategies with the new set of criteria. This process may be repeated until the user is satisfied with the results.

Once reasonable satisfaction is obtained, the user has three options for selecting the strategies for further analysis:

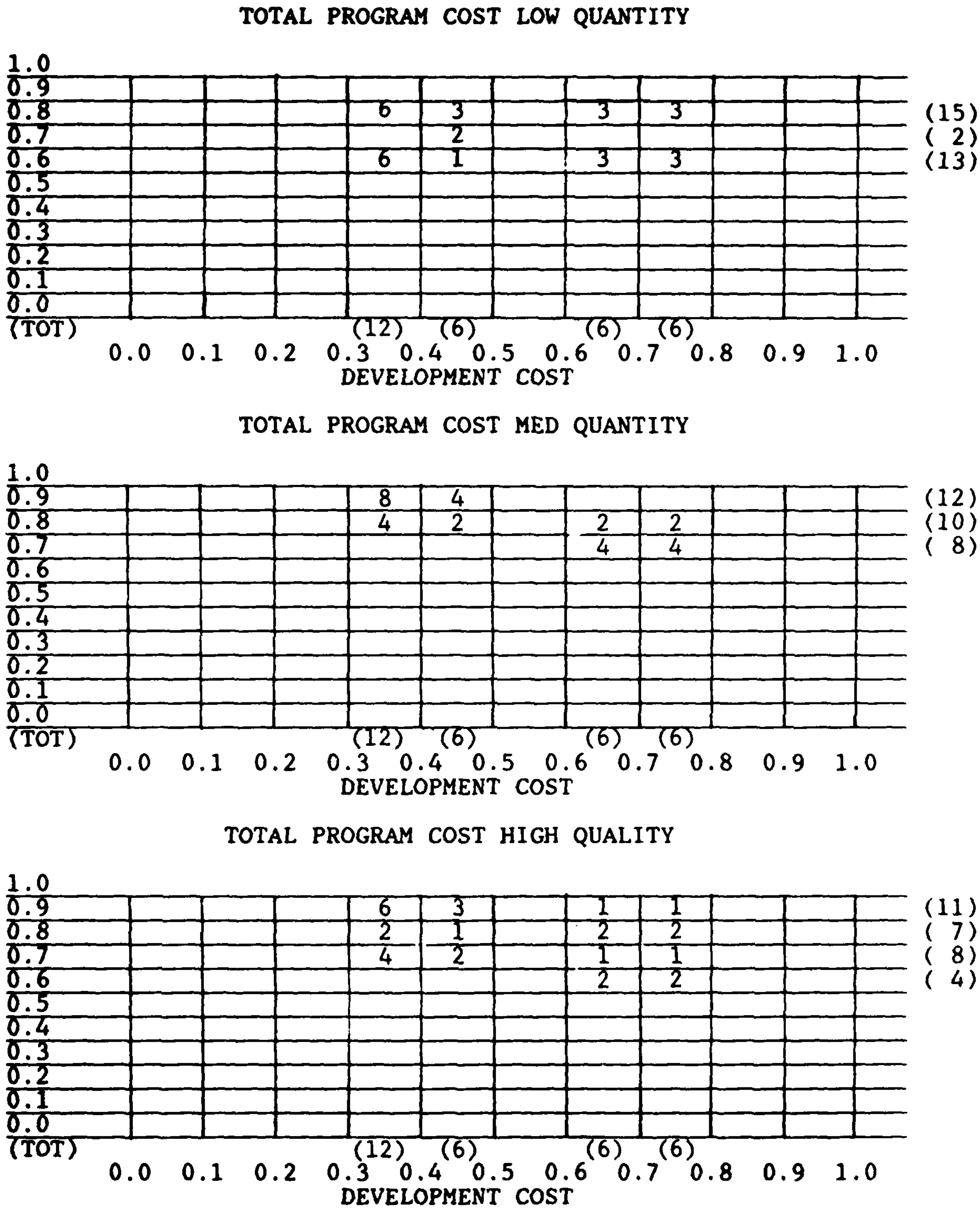

Figure 2.5-3 Relative Cost Comparisons

- Consider only those N_1 strategies that satisfy all four criteria
- Consider those $N_1 + N_2$ strategies that satisfy three criteria and are "close" on the fourth
- Consider those $N_1 + N_2 + N_3$ strategies which satisfy two criteria and are "close" on the other two.

Once this option is specified, the model displays the number of strategies eliminated (if any) and gives the user the option of displaying those strategies eliminated as well as listing those strategies remaining.

2.5.3 Dominance Analysis

This portion of the evaluation requires no user involvement. The remaining strategies are compared to each other to determine any "second-best" choices. Basically, one strategy is considered to dominate another if it is clearly superior to the other strategy in at least one (or more) attribute(s) and at least as good on all others. This comparison is not performed in an absolute sense. Rather, two attributes are considered to be equivalent if they are reasonably close to each other. Similarly, for one attribute to be considered superior to another, it must be better by more than a prespecified threshhold. Combining these two considerations into a single algorithm is somewhat unique and was implemented in an experimental fashion. Further research into the full implication of the approach is justified. More details of the methodology are provided in Appendix A.

Once the dominance analysis is completed, the computer displays the number of strategies eliminated. The user then has the option of displaying those strategies.

2.6 RESULTS

The results of the analysis consist of strategies not eliminated by one or more criteria. Typically, only a small number of strategies remain. These are displayed, together with the following principal attributes:

- Probability of success by the earliest desired IOC by level of design stability
- Probability of success by the latest acceptable IOC by level of design stability
- Relative development cost
- Relative total program cost by low, moderate, and high inventory estimates.

A sample of the display is provided in Figure 2.6-1.

#	Phase 1	Phase 2	Phase 3
1	Prototype Non-industrial	Incremental - Single Source	Single Source - MYC
2	Prototype Non-industrial	Incremental - Single Source	Leader/Follower
3	Prototype Non-industrial	Incremental - Single Source	Second Sourcing
4	Prototype Non-industrial	Incremental - Multiple Sources	Single Source - MYC
5	Prototype Non-industrial	Incremental - Multiple Sources	Leader/Follower
6	Prototype Non-industrial	Incremental - Multiple Sources	Second Sourcing
7	Prototype Single Industrial	Incremental - Single Source	Single Source - MYC
8	Prototype Single Industrial	Incremental - Single Source	Leader/Follower
9	Prototype Single Industrial	Incremental - Single Source	Second Sourcing

STR	Probability of Success						Relative Costs			
	Early IOC			Late IOC			DEV	TOTAL		
#	L1	L2	L3	L1	L2	L3		LQ	MQ	HQ
1	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.66	0.91	0.94
2	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.81	0.84	0.78
3	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.81	0.84	0.78
4	0.60	0.68	0.76	0.64	0.73	0.82	0.68	0.63	0.73	0.81
5	0.60	0.68	0.76	0.64	0.73	0.82	0.68	0.84	0.76	0.69
6	0.60	0.68	0.76	0.64	0.73	0.82	0.68	0.84	0.76	0.69
7	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.66	0.91	0.94
8	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.81	0.84	0.78
9	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.81	0.84	0.78

Figure 2.6-1 Summary of Results

3. EXAMPLES

This chapter discusses two examples. The first is hypothetical and it includes variations indicative of sensitivity analyses potentially useful in a teaching environment. The second example is an application of the model to a real program with all inputs provided by the program manager.

3.1 AN ILLUSTRATIVE EXAMPLE

The example described in this section is purely hypothetical. The intent of this section is to demonstrate the operation of the model and to illustrate how user-supplied inputs during the evaluation segment affect the results.

3.1.1 Baseline Scenario

This example concerns the development of a new tactical missile system. The weapon system concept was directed (concept exploration phase was skipped), and the analysis is to begin with Phase 1 - Demonstration and Validation. All strategy alternatives included in the model are considered feasible. Parameters defining the perception of technical risk are as follows:

Risk Category	Risk Level	Confidence Level
Technology Advance	7 - Major	7 - Reasonably Certain
System Integration	7 - Major	7 - Reasonably Certain
Software Dependency and Complexity	7 - Major	9 - Absolutely Certain

Estimates of inventory requirements were specified with a wide variation so that tradeoffs dependent upon the actual quantity should exist. Parameters provided are as follows:

- Low estimate - 2000 systems produced over 2 years
- Moderate estimate - 20,000 systems produced over 8 years
- High estimate - 60,000 systems produced over 15 years.

Relative production costs were estimated as average (5) with a confidence level of 5 (sounds reasonable).

From this input, 264 possible acquisition strategies were generated.

3.1.2 Baseline Evaluation

Earliest desired IOC and latest acceptable IOC estimates of 144 months (12 years) and 168 months (14) years were provided. While this time frame may seem excessive, it is not uncommon in weapon system development programs, especially where high technology programs are concerned. Probabilities of success generated are displayed in Figure 3.1-1. The minimum acceptable probabilities selected are circled.

TABLE 1
EARLIEST DESIRED IOC

PROBABILITY OF SUCCESS AT LEAST AS GREAT AS:

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
LEVEL 1	186	168	108	90	30	18	0	0	0
LEVEL 2	228	186	168	108	90	30	18	0	0
LEVEL 3	246	228	186	168	108	90	48	0	0

TABLE 2
LATEST ACCEPTABLE IOC

PROBABILITY OF SUCCESS AT LEAST AS GREAT AS:

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
LEVEL 1	186	168	108	90	30	30	0	0	0
LEVEL 2	228	186	168	108	90	30	30	0	0
LEVEL 3	246	228	186	168	108	90	60	30	0

Figure 3.1-1 Probabilities of Success

The results of applying these criteria were that 30 strategies satisfied all six criteria. The other "close" categories were all empty (i.e., contained zero strategies). The summary of these 30 strategies by phase is as follows:

FOR PHASE 1:	Prototype Nonindustrial	12
	Prototype Single Industrial	6
	Prototype Multiple Industrial	12
FOR PHASE 2:	Incremental - Single Source	18
	Incremental - Multiple Sources	12
FOR PHASE 3:	Single Source - No Options	5
	Single Source - Options	5
	Single Source - MYC	5
	Licensing	5
	Leader/Follower	5
	Second Sourcing	5

Relative cost comparisons of these 30 strategies are provided in Tables 3.1-1 through 3.1-3. It was decided not to eliminate any of the strategies at this point for cost considerations, primarily to discover how many strategies would be eliminated by the dominance analysis.

The result was that 21 of the 30 strategies were eliminated as being "second-best" options. The output summary of results is displayed in Figure 3.1-2.

The implication of these results are as follows:

- For the high-risk situation described, when urgency of need is not great, one should build a full system prototype during D&V and perform incremental FSD. Tradeoffs exist between non-industrial and industrial firms, as well as single and dual source FSD
- Production options are mainly dependent upon estimated inventory requirements. The high estimate justifies dual source production, the low estimate does not. For the moderate estimate, there are other tradeoffs involved
- The probability of a successful program is relatively high.

TABLE 3.1-1

TOTAL PROGRAM COST LOW QUANTITY

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
1.0												
0.9												
0.8				6	3		3	3				(15)
0.7					2							(2)
0.6				6	3							(13)
0.5												
0.4												
0.3												
0.2												
0.1												
0.0												
(TOT)				(12)	(6)		(6)	(6)				

DEVELOPMENT COST

TABLE 3.1-2

TOTAL PROGRAM COST MED QUANTITY

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
1.0												
0.9				8	4							(12)
0.8				4	2		2	2				(10)
0.7							4	4				(8)
0.6												
0.5												
0.4												
0.3												
0.2												
0.1												
0.0												
(TOT)				(12)	(6)		(6)	(6)				

DEVELOPMENT COST

TABLE 3.1-3

TOTAL PROGRAM COST HIGH QUANTITY

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	
1.0												
0.9				6	3		2	1				(11)
0.8				2	1		2	2				(7)
0.7				4	2		1	1				(8)
0.6							2	2				(4)
0.5												
0.4												
0.3												
0.2												
0.1												
0.0												
(TOT)				(12)	(6)		(6)	(6)				

DEVELOPMENT COST

There are 9 strategies remaining. The following summarizes the relative attributes of these strategies. Complicated trade-offs exist among these attributes. Trade-off analysis more detailed and more in-depth than is possible here is recommended.

	PHASE 1	PHASE 2	PHASE 3
1	Prototype Non-industrial	Incremental - Single Source	Single Source - MYC
2	Prototype Non-industrial	Incremental - Single Source	Leader/Follower
3	Prototype Non-industrial	Incremental - Single Source	Second Sourcing
4	Prototype Non-industrial	Incremental - Multiple Sources	Single Source - MYC
5	Prototype Non-industrial	Incremental - Multiple Sources	Leader/Follower
6	Prototype Non-industrial	Incremental - Multiple Sources	Second Sourcing
7	Prototype Single Industrial	Incremental - Single Source	Single Source - MYC
8	Prototype Single Industrial	Incremental - Singe Source	Leader/Follower
9	Prototype Single Industrial	Incremental - Single Source	Second Sourcing

STR #	PROBABILITY OF SUCCESS						RELATIVE COSTS			
	EARLY IOC			LATE IOC			DEV	TOTAL		
	L1	L2	L3	L1	L2	L3		LQ	MQ	HQ
1	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.66	0.91	0.94
2	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.81	0.84	0.78
3	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.81	0.84	0.78
4	0.60	0.68	0.76	0.64	0.73	0.82	0.68	0.63	0.73	0.81
5	0.60	0.68	0.76	0.64	0.73	0.82	0.68	0.84	0.76	0.69
6	0.60	0.68	0.76	0.64	0.73	0.82	0.68	0.84	0.76	0.69
7	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.66	0.91	0.94
8	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.81	0.84	0.78
9	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.81	0.84	0.78

Please note -- The use of multiyear contracting assumes a relatively stable design for initial production. If this is not the case, single source with or without options would be the alternatives.

Figure 3.1-2 Summary of Results

3.1.3 Variation A -- Increased Urgency of Need

The same baseline was reevaluated under an extreme urgency-of-need situation for such a high technology program. Earliest desired IOC and latest acceptable IOC inputs were 72 months (6 years) and 96 months (8 years), respectively. The resultant probability of success tables are displayed in Figure 3.1-3. Minimum acceptable probability specifications are circled. Not surprisingly, the probabilities of success are greatly reduced.

TABLE 1

EARLIEST DESIRED IOC

PROBABILITY OF SUCCESS AT LEAST AS GREAT AS:

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
LEVEL 1	36	0	0	0	0	0	0	0	0
LEVEL 2	102	12	0	0	0	0	0	0	0
LEVEL 3	192	30	0	0	0	0	0	0	0

TABLE 2

LATEST ACCEPTABLE IOC

PROBABILITY OF SUCCESS AT LEAST AS GREAT AS:

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
LEVEL 1	186	114	18	0	0	0	0	0	0
LEVEL 2	228	186	102	0	0	0	0	0	0
LEVEL 3	246	228	162	54	12	0	0	0	0

Figure 3.1-3 Probabilities of Success

The result of applying these criteria was as follows:

- 18 Strategies satisfy all 6 criteria
- 18 Additional strategies satisfy 5 criteria and are within a probability of .10 on the sixth
- 18 Additional strategies satisfy 4 criteria and are within a probability of .10 on the other two
- 12 Additional stategies satisfy 3 criteria and are within a probability within of .10 on the other three

The top two categories (consisting of 36 strategies) were selected for further analysis. The summary by phase of these 36 strategies is as follows:

FOR PHASE 1:	Prototype Non-industrial	6
	Prototype Single Industrial	12
	Prototype Multiple Industrial	18
FOR PHASE 2:	Full Concurrency - Single Source	18
	Partial Concurrency - Single Source	12
	Partial Concurrency - Multiple Sources	6
FOR PHASE 3:	Single Source - No Options	6
	Single Source - Options	6
	Single Source - MYC	6
	Licensing	6
	Leader/Follower	6
	Second Sourcing	6

Relative cost comparisons are presented in Table 3.1-4 through 3.1-6. Again, no strategies were eliminated based upon relative cost. Dominance analysis eliminated 27 of the 36 strategies. A summary of the results is displayed in Figure 3.1-4.

TABLE 3.1-4

TOTAL PROGRAM COST LOW QUANTITY

1.0											
0.9					15			3			(18)
0.8											
0.7					12						(12)
0.6					3			3			(6)
0.5											
0.4											
0.3											
0.2											
0.1											
0.0											
(TOT)					(30)			(6)			

DEVELOPMENT COST (0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0)

TABLE 3.1-5

TOTAL PROGRAM COST MED QUANTITY

1.0											
0.9					22						(22)
0.8					8			2			(10)
0.7								4			(4)
0.6											
0.5											
0.4											
0.3											
0.2											
0.1											
0.0											
(TOT					(30)			(6)			

DEVELOPMENT COST (0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0)

TABLE 3.1-6

TOTAL PROGRAM COST HIGH QUANTITY

1.0											
0.9					20			1			(21)
0.8					10			2			(12)
0.7								1			(1)
0.6								2			(2)
0.5											
0.4											
0.3											
0.2											
0.1											
0.0											
(TOT)					(30)			(6)			

DEVELOPMENT COST (0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0)

There are 9 strategies remaining. The following summarizes the relative attributes of these strategies. Complicated trade-offs exist among these attributes. Trade-off analysis more detailed and more in-depth than is possible here is recommended.

Phase 1	Phase 2	Phase 3
1 Prototype Single Industrial	Partial Concurrency - Single Source	Single Source - MYC
2 Prototype Single Industrial	Partial Concurrency - Single Source	Leader/Follower
3 Prototype Single Industrial	Partial Concurrency - Single Source	Second Sourcing
4 Prototype Single Industrial	Full Concurrency - Single Source	Single Source - MYC
5 Prototype Single Industrial	Full Concurrency - Single Source	Leader/Follower
6 Prototype Single Industrial	Full Concurrency - Single Source	Second Sourcing
7 Prototype Multiple Industrial	Partial Concurrency - Multiple Sources	Single Source - MYC
8 Prototype Multiple Industrial	Partial Concurrency - Multiple Sources	Leader/Follower
9 Prototype Multiple Industrial	Partial Concurrency - Multiple Sources	Second Sourcing

STR #	PROBABILITY OF SUCCESS						RELATIVE COSTS			
	EARLY IOC			LATE IOC			DEV	TOTAL		
	L1	L2	L3	L1	L2	L3		LQ	MQ	HQ
1	0.13	0.16	0.19	0.32	0.40	0.47	0.42	0.69	0.91	0.95
2	0.13	0.16	0.19	0.32	0.40	0.47	0.42	0.91	0.87	0.80
3	0.13	0.16	0.19	0.32	0.40	0.47	0.42	0.91	0.87	0.80
4	0.17	0.23	0.29	0.29	0.39	0.51	0.42	0.69	0.91	0.95
5	0.17	0.23	0.29	0.29	0.39	0.51	0.42	0.91	0.90	0.82
6	0.17	0.23	0.29	0.29	0.39	0.51	0.42	0.91	0.90	0.82
7	0.13	0.16	0.19	0.32	0.40	0.47	0.78	0.67	0.73	0.82
8	0.13	0.16	0.19	0.32	0.40	0.47	0.78	0.91	0.77	0.70
9	0.13	0.16	0.19	0.32	0.47	0.47	0.78	0.91	0.77	0.70

Please note - The use of multi-year contracting assumes a relatively stable design for initial production. If this is not the case, single source with or without options would be the alternatives.

Figure 3.1-4 Summary of Results

Implications of these results are as follows:

- Even with the rather extreme urgency of need specified, a program of relatively high technology justifies a full system prototype during D&V
- A certain amount of concurrency is mandated by the urgency of need
- Production options are again principally a function of inventory estimates
- Probability of success is greatly reduced.

3.1.4 Variation B -- Increased Urgency of Need and Alternate Selection Criteria

The same situation as Variation A is evaluated. However, this time the top three categories resulting from applying the probability of success criteria (consisting of 54 strategies) are selected. The summary of the strategies by phase is as follows:

FOR PHASE 1:	Subsystem Dev Single Industrial	6
	Subsystem Dev Multiple Industrial	12
	Prototype Non-industrial	6
	Prototype Single Industrial	12
	Prototype Multiple Industrial	18
FOR PHASE 2:	Partial Concurrency - Single Source	24
	Partial Concurrency - Multiple Sources	12
	Full Concurrency - Single Source	18
FOR PHASE 3:	Single Source - No Options	9
	Single Source Options	9
	Single Source - MYC	9
	Licensing	9
	Leader/Follower	9
	Second Sourcing	9

This relaxation in success criteria resulted in subsystem development becoming an option during D&V. Again, no strategies were eliminated on cost consideration; however, dominance analysis eliminated 39 of the 54 strategies. A summary of the 15 remaining strategies are displayed in Figure 3.1-5.

The implications are that subsystem development during D&V combined with partial currency during FSD become a viable option under the scenario described. The probability of success is lowered, but not drastically.

3.1.5 Variation C -- Limited R&D Funding

This variation consists of the baseline scenario with the baseline evaluation (Section 3.1.2) up through the relative cost comparisons presented in Tables 3.1-1 through 3.1-3. This evaluation was performed under the assumption of limited R&D funds and a .5 was entered as maximum development cost. No constraints were placed on total program cost. Of the 18 strategies satisfying this criteria, 12 were eliminated via dominance analysis. A summary of the six remaining strategies are displayed in Figure 3.1-6.

This one added criteria thus restricted development options to single source development. With this reduction, it should be noted that under the moderate and high inventory estimates, total program cost is increased.

3.2 A REAL-WORLD EXAMPLE

The AN/SLQ-32 Shipboard Electronic Warfare System program began in October 1971 with the objective of developing and procuring a coherent series of electronic warfare systems

. There are 15 strategies remaining. The following summarizes the relative attributes of these strategies. Complicated trade-offs exist among these attributes. Trade-off analyses more detailed and more in-depth than is possible here is recommended.

	Phase 1	Phase 2	Phase 3
1	Subsystem Dev Single Industrial	Partial Concurrency - Single Source	Single Source - MYC
2	Subsystem Dev Single Industrial	Partial Concurrency - Single Source	Leader/Follower
3	Subsystem Dev Single Industrial	Partial Concurrency - Single Source	Second Sourcing
4	Subsystem Dev Multiple Industrial	Partial Concurrency - Multiple Sources	Single Source - MYC
5	Subsystem Dev Multiple Industrial	Partial Concurrency - Multiple Sources	Leader/Follower
6	Subsystem Dev Multiple Industrial	Partial Concurrency - Multiple Sources	Second Sourcing
7	Prototype Single Industrial	Partial Concurrency - Single Source	Single Source - MYC
8	Prototype Single Industrial	Partial Concurrency - Single Source	Leader/Follower
9	Prototype Single Industrial	Partial Concurrency - Single Source	Second Sourcing
10	Prototype Single Industrial	Full Concurrency - Single Source	Single Source - MYC
11	Prototype Single Industrial	Full Concurrency - Single Source	Leader/Follower
12	Prototype Single Industrial	Full Concurrency - Single Source	Second Sourcing
13	Prototype Multiple Industrial	Partial Concurrency - Multiple Sources	Single Source - MYC
14	Prototype Multiple Industrial	Partial Concurrency - Multiple Sources	Leader/Follower
15	Prototype Multiple Industrial	Partial Concurrency - Multiple Sources	Second Sourcing

STR #	PROBABILITY OF SUCCESS						RELATIVE COSTS			
	EARLY IOC			LATE IOC			DEV	TOTAL		
	L1	L2	L3	L1	L2	L3		LQ	MQ	HQ
1	0.09	0.13	0.18	0.20	0.30	0.41	0.34	0.65	0.90	0.94
2	0.09	0.13	0.18	0.20	0.30	0.41	0.34	0.88	0.86	0.80
3	0.09	0.13	0.18	0.20	0.30	0.41	0.34	0.88	0.86	0.80
4	0.09	0.13	0.18	0.20	0.30	0.41	0.61	0.61	0.71	0.81
5	0.09	0.13	0.18	0.20	0.30	0.41	0.61	0.84	0.75	0.69
6	0.09	0.13	0.18	0.20	0.30	0.41	0.61	0.84	0.75	0.69
7	0.13	0.16	0.19	0.32	0.40	0.47	0.42	0.69	0.91	0.95
8	0.13	0.16	0.19	0.32	0.40	0.47	0.42	0.91	0.87	0.80
9	0.13	0.16	0.19	0.32	0.40	0.47	0.42	0.91	0.87	0.80
10	0.17	0.23	0.29	0.29	0.39	0.51	0.42	0.69	0.91	0.95
11	0.17	0.23	0.29	0.29	0.39	0.51	0.42	0.91	0.90	0.82
12	0.17	0.23	0.29	0.29	0.39	0.51	0.42	0.91	0.90	0.82
13	0.13	0.16	0.19	0.32	0.40	0.47	0.78	0.67	0.73	0.82
14	0.13	0.16	0.19	0.32	0.40	0.47	0.78	0.91	0.77	0.70
15	0.13	0.16	0.19	0.32	0.40	0.47	0.78	0.91	0.77	0.70

Please note -- The use of multi-year contracting assumes a relatively stable design for initial production. If this is not the case, single source with or without options would be the alternatives.

Figure 3.1-5 Summary of Results

There are 6 strategies remaining. The following summarizes the relative attributes of these strategies. Complicated trade-offs exist among these attributes. Trade-off analysis more detailed and more in-depth than is possible were is recommended.

	Phase 1	Phase 2	Phase 3
1	Prototype Non-Industrial	Incremental - Single Source	Single Source - MYC
2	Prototype Non-Industrial	Incremental - Single Source	Leader/Follower
3	Prototype Non-Industrial	Incremental - Single Source	Second Sourcing
4	Prototype Single Industrial	Incremental - Single Source	Single Source - MYC
5	Prototype Single Industrial	Incremental - Single Source	Leader/Follower
6	Prototype Single Industrial	Incremental - Single Source	Second Sourcing

STR #	PROBABILITY OF SUCCESS						RELATIVE COSTS			
	EARLY IOC			LATE IOC			DEV	TOTAL		
	L1	L2	L3	L1	L2	L3		LQ	MQ	HQ
1	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.66	0.91	0.94
2	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.81	0.84	0.78
3	0.60	0.68	0.76	0.64	0.73	0.82	0.38	0.81	0.84	0.78
4	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.66	0.91	0.94
5	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.81	0.84	0.78
6	0.62	0.71	0.79	0.64	0.74	0.82	0.39	0.81	0.84	0.78

Please note -- the use of multiyear contracting assumes relatively stable design for initial production. If this is not the case, single source with or without options would be the alternatives.

Figure 3.1-6 Summary of Results

for near fleet-wide installation. The program manager from program inception to the third year of production was Capt. Robert A. Hullander, U.S.N., Ret. Capt. Hullander was a major contributor to the prior acquisition strategy model feasibility study. During the development of the prototype model, he participated as a consultant on a few issues, but he was not aware of the status of the model until its completion. At that time, he agreed to help evaluate the prototype model.

3.2.1 Scenario

After a test run through the model, Capt. Hullander proceeded to describe the AN/SLQ-32 scenario in terms of model parameters. The scenario described is as follows:

- System category -- electronic subsystem
- Concept was directed -- no concept exploration was performed
- Strategy analysis began with Phase 1
- Use of non-industrial firms was not feasible during the D&V Phase
- All alternatives during FSD and production were input as possible, although there were political considerations which made some difficult
- Technical risk
  - Technology Advance - moderate (5) with reasonable certainty (7)
  - System Integration - total (9) with absolute certainty (9)
  - Software Dependency & Complexity - moderate (5) with absolute certainty (9)

- Inventory requirements were for 300 systems to be produced over 4 years with no uncertainty (i.e., low, moderate, and high estimates were identical)
- Relative production costs would be 7 (Above average) with a confidence level of 7 (Reasonably certain).

Given this scenario, 174 possible strategies were generated.

3.2.2 Evaluation

Urgency of need was input as 60 months (5 years) as the time to the earliest desired IOC and 78 months (6½ years) as the time to the latest acceptable IOC. These were based upon the actual 5-year time span the program office used as a goal and the achieved time to IOC of slightly over 6 years. Summaries of the probability of success are displayed in Figure 3.2-1. Minimum acceptable probabilities specified are circled.

At this point Capt. Hullander expressed some surprise at the magnitude of the probabilities (i.e. they seemed too low). As discussed earlier, this is not surprising due to the assumption of independence in their calculation. A proper accounting for dependence among stochastic variables is always a non-trivial task. This situation is no different. Additional research is warranted if realistic probabilities are desired. However, as a relative measure, the existing probabilities are reasonable.

TABLE 1

EARLIEST DESIRED IOC

PROBABILITY OF SUCCESS AT LEAST AS GREAT AS:

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
LEVEL 1	90	30	0	0	0	0	0	0	0
LEVEL 2	108	48	18	0	0	0	0	0	0
LEVEL 3	132	72	48	18	0	0	0	0	0

TABLE 2

LATEST ACCEPTABLE IOC

PROBABILITY OF SUCCESS AT LEAST AS GREAT AS:

	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
LEVEL 1	144	102	30	0	0	0	0	0	0
LEVEL 2	144	144	102	30	0	0	0	0	0
LEVEL 3	168	144	144	66	30	0	0	0	0

Figure 3.2-1 Probabilities of Success

The results of evaluating the 174 strategies against the input criteria are as follows:

- 0 strategies satisfy all 6 criteria
- 18 additional strategies satisfy 5 criteria and are within a probability of 0.10 on the sixth
- 12 additional strategies satisfy 4 criteria and are within a probability of 0.10 on the other two
- 0 additional strategies satisfy 3 criteria and are within a probability of 0.10 on the other three.

All 30 strategies accounted for were selected. The summary of these strategies by phase follows:

FOR PHASE 1:	CD Single Industrial	6
	CD Multiple Industrial	12
	Prototype Single Industrial	6
	Prototype Multiple Industrial	6
FOR PHASE 2:	Incremental - Single Source	12
	Incremental - Multiple Sources	6
	Full Concurrency - Single Source	12
FOR PHASE 3:	Single Source - No Options	5
	Single Source - Options	5
	Single Source - MYC	5
	Licensing	5
	Leader/Follower	5
	Second Sourcing	5

Since the inventory estimates were identical, one table is sufficient to display relative cost comparisons (Table 3.2-1).

TABLE 3.2-1

RELATIVE COST COMPARISON

1.0	0.0 – 0.1	0.1 – 0.2	0.2 – 0.3	0.3 – 0.4	0.4 – 0.5	0.5 – 0.6	0.6 – 0.7	0.7 – 0.8	0.8 – 0.9	0.9 – 1.0	
0.9								2			(2)
0.8					3		5	4			(12)
0.7					9		1	4			(14)
0.6								2			(2)
0.5											
0.4											
0.3											
0.2											
0.1											
0.0											
(TOT)					(12)		(6)	(12)			

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

DEVELOPMENT COST

Capt. Hullander stated he would prefer not to eliminate arbitrarily any alternatives based upon cost. Thus, all 30 strategies were subjected to dominance analysis. This analysis resulted in 26 of the 30 strategies being eliminated. The 26 "second-best" strategies are displayed in Table 3.2-2.

TABLE 3.2-2
"SECOND-BEST" STRATEGIES

PHASE 1	PHASE 2	PHASE 3
CD Single Industrial	Incremental - Single Source	Licensing
CD Multiple Industrial	Incremental - Single Source	Single Source - No Options
CD Multiple Industrial	Incremental - Single Source	Licensing
CD Multiple Industrial	Incremental - Single Source	Leader/Follower
CD Multiple Industrial	Incremental - Single Source	Second Sourcing
CD Multiple Industrial	Incremental - Multiple Sources	Licensing
Prototype Single Industrial	Full Concurrency - Single Source	Leader/Follower
Prototype Single Industrial	Full Concurrency - Single Source	Second Sourcing
Prototype Multiple Industrial	Full Concurrency - Single Source	Single Source - No Options
Prototype Multiple Industrial	Full Concurrency - Single Source	Licensing
Prototype Multiple Industrial	Full Concurrency - Single Source	Leader/Follower
Prototype Multiple Industrial	Full Concurrency - Single Source	Second Sourcing
CD Single Industrial	Incremental - Single Source	Single Source - No Options
CD Single Industrial	Incremental - Single Source	Single Source - Options
CD Single Industrial	Incremental - Single Source	Leader/Follower
CD Single Industrial	Incremental - Single Source	Second Sourcing
CD Multiple Industrial	Incremental - Single Source	Single Source - Options
CD Multiple Industrial	Incremental - Single Source	Single Source - MYC
CD Multiple Industrial	Incremental - Multiple Sources	Single Source - No Options
CD Multiple Industrial	Incremental - Multiple Sources	Leader/Follower
CD Multiple Industrial	Incremental - Multiple Sources	Second Sourcing
Prototype Single Industrial	Full Concurrency - Single Source	Single Source - No Options
Prototype Single Industrial	Full Concurrency - Single Source	Single Source - Options
Prototype Single Industrial	Full Concurrency - Single Source	Licensing
Prototype Multiple Industrial	Full Concurrency - Single Source	Single Source - Options
CD Single Industrial	Incremental - Single Source	Single Source - MYC

3.2.3 Results

A summary of the four strategies remaining are displayed in Figure 3.2-3. Note that if a more stringent comparison criteria is used, only two strategies remain, 2 and 3.*

- Multiple source contract definition followed by multiple source incremental FSD followed by a single source multi-year production contract
- Single source prototype followed by single source FSD with full concurrency followed by a single source multi-year production contract.

The tradeoffs between the two options are as follows:

- The first option has the larger probability of success for the earliest desired IOC and the lower total program cost
- The second option has the larger probability of success for the later IOC and the lower development cost.

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* As discussed in Section 2.5.3, the dominance analysis portion of the model incorporates the concept of "closeness." One strategy is not allowed to dominate another if their respective attributes are relatively close. This is accomplished by comparing attributes against a pre-specified threshold. Three different thresholds are used; the smaller the threshold, the more stringent the comparison criteria. A message is printed when the use of alternative thresholds varies the results.

	Phase 1	Phase 2	Phase 3
1	CD Multiple Industrial	Incremental - Multiple Sources	Single Source - Options
2	CD Multiple Industrial	Incremental - Multiple Sources	Single Source - MYC
3	Prototype Single Industrial	Full Concurrency - Single Source	Single Source - MYC
4	Prototype Multiple Industrial	Full Concurrency - Single Source	Single Source - MYC

STR #	PROBABILITY OF SUCCESS						RELATIVE COSTS			
	EARLY IOC			LATE IOC			DEV	TOTAL		
	L1	L2	L3	L1	L2	L3		LQ	MQ	HQ
1	0.25	0.33	0.42	0.30	0.40	0.51	0.76	0.69	0.69	0.69
2	0.25	0.33	0.42	0.30	0.40	0.51	0.76	0.65	0.65	0.65
3	0.21	0.27	0.33	0.37	0.49	0.60	0.60	0.78	0.78	0.78
4	0.21	0.27	0.33	0.37	0.49	0.60	0.73	0.82	0.82	0.82

Please note -- the use of multi-year contracting assumes a relatively stable design for initial production. If this is not the case, single source with or without options would be the alternatives.

Please note -- if we apply a somewhat more stringent companion criteria, strategy(s) 1 4 are dominated by the remaining.

Figure 3.2-3 Summary of Results

The actual strategy pursued by Capt. Hullander for the AN/SLQ-32 was the first of the two preferred (CD + Incremental + MYC) and IOC was slightly more than 6 years following program inception.

At the conclusion of this exercise, Capt. Hullander remarked that he and his staff had manually performed a similar analysis at the start of the program; they itemized what they considered to be the candidate alternatives with the highest probability of satisfying their goals and sequentially eliminated "second-best" alternates based upon a number of criteria.

By relying principally on their experience and judgement, Capt. Hullander and his staff spent approximately one month in the early days of the program accomplishing this analysis. Key influencing factors were as follows:

- Moderate technology advance combined with compressed schedule requirements
- Small inventory requirements
- No significant constraint on R&D money
- Ceiling on production money.

These factors were applied to the strategies identified as having potential, and rough estimates for both time and cost were generated for each. The chosen strategy emerged from this analysis.

A computerized model will probably never duplicate the judgement and insight possessed by an experienced and intelligent program manager. However, the degree of similarity in the results gives credence to the idea that a fully developed model properly supported by data might provide useful assistance. In this example, perhaps detailed management analysis could have been applied only to the two or three preferred strategies output by the model. In other cases, strategy alternatives overlooked by the staff may offer potential. In any case, supplementary analysis which can be provided in a short time period (no more than a few hours including sensitivity analysis) appears justified.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The examples analyzed in Chapter 3 provide ample evidence that the prototype model provides results consistent with program experience. The examples of sensitivity analyses presented in Section 3.1.3 through 3.1.5 illustrate the insights the model is capable of providing regarding the interrelationships among acquisition strategy alternatives and key influencing factors such as the following:

- Perception of technical risk
- Urgency of need
- Development cost
- Production cost
- Estimated inventory requirement.

The concept that acquisition strategy encompasses the entire acquisition process is emphasized. A user not experienced in program management can experience first hand why the selection of an acquisition alternative for one phase should not be made independently of other phase options. Furthermore, insight into the importance of risk identification and risk management early in the program is provided.

Collectively, these findings provide a strong indication of the potential utility of the model as a teaching aid to program management students at DSMC and elsewhere. As evidenced by the AN/SLQ-32 example, ASCM may also be able to provide early planning support to a program manager, given more in-depth data collection and analysis to support the myriad of internal relationships.

4.2 RECOMMENDATIONS

Recommendations stemming from this development effort fall into three categories:

- Model implementation
- Model update and refinement
- Model expansion

4.2.1 Model Implementation

ASCM should be implemented as a teaching aide in the program management curriculum at DSMC. Although the prototype model has demonstrated its potential utility as a teaching aid, the current software is inadequate for that purpose. The objective was to demonstrate model capability and utility, not software elegance. The software is not "user-friendly," sensitivity analysis is laborious, and software documentation consists of no more than a listing of the source code.

The prototype model should be expanded into a validated software system with additional capability needed for successful operation in the teaching and research environments:

- The interface between the model and the user should be expanded to provide a high degree of assistance and protection, and to make it user-friendly

- The software should be structured to facilitate the answering of "what if" questions via easily executed sensitivity analyses
- The entire system should be well documented.

4.2.2 Model Update and Refinement

The prototype model contains several parameters and relationships which are considered preliminary in nature due to the lack of complete data.

The specific data on 37 programs plus the ancillary data proved sufficient for prototype demonstration. However, since data provide the principal determinants in most relationships, an expanded data base would provide vastly increased validity and realism to the model. Additional data collection and analysis of tactical missile system and electronic subsystem development and production phases should be performed. The effort should expand the existing data base and focus on validating and refining the following model parameters and relationships:

- Second source start-up costs
- Interrelationships between savings due to competition and savings due to multiyear contracting
- Effect of dual sourcing FSD on production costs
- Multiple source development costs
- Similarities and differences between new system development and existing system modification

- Interrelationships among successive phase alternatives
- Risk reduction relationships among Phase 1 and Phase 2 alternatives.

The prototype model uses numerous techniques and methodologies to implement the overall concept of successively reducing the number of strategy alternatives to a small set containing the preferred alternatives for a particular situation. Two of these methodologies are worthy of further research and analysis:

- The methodology used for calculating the probability of success for a given strategy incorporates an assumption of independence among the constituent probabilities which is not entirely valid. Additional research into the most appropriate formulation for incorporating identifiable dependencies would greatly enhance the validity of the model
- The dominance analyses performed by the model incorporates a concept of "closeness". This concept implies that due to the softness in the calculation of the attributes, one strategy alternative should not dominate another if their attributes are reasonably close to each other. This concept was incorporated into the prototype model with an experimental methodology which should be refined and its implications analyzed.

TASC recommends that the necessary research and analysis be performed to refine, update, modify, and validate (as required) these two methodologies.

4.2.3 Model Expansion

In order to provide maximum utility to the defense community, the scope of the model should be expanded to include other categories of weapon systems. Detailed data collection and analysis for additional categories of weapon systems should be performed and the results incorporated into the model. Potential candidates include the following:

- Tracked vehicle systems
- Attack helicopters
- Transport helicopters
- Aircraft (fighters, bombers, etc.)
- Ships
- Guns
- Specialized electronics.

The scope of the model should also be expanded to include a model of the concept exploration process. The primary objective of concept exploration is to examine feasible solutions to a perceived operational need and to select for further development those solutions which exhibit the highest potential. The existing model begins with the development options for a pre-defined concept. Given a model of the concept exploration process, a student could begin with a perceived operational need and determine likely concepts to address that need. Each of these concepts could then be processed by ASCM and the trade-offs assessed among the competing concepts. A preliminary investigation of feasibility is recommended.