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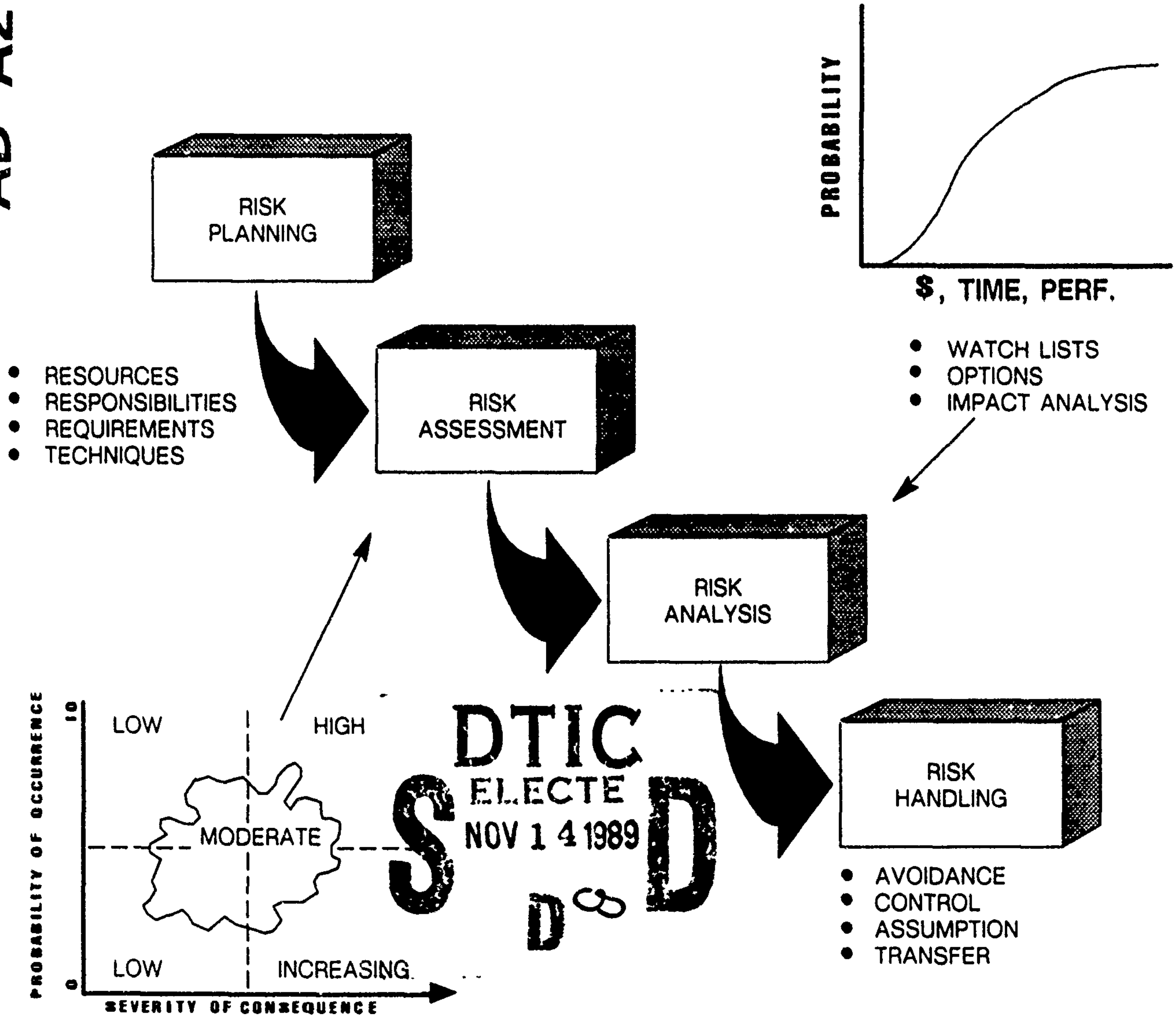
CONCEPTS AND GUIDANCE



- RISK IDENTIFICATION
- RISK QUANTIFICATION
- RISK FACETS

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RISK MANAGEMENT

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DSMC PREFACE

WE NEED YOUR HELP

In 1986, the General Accounting Office issued a report on then current DOD efforts relative to technical risk assessment. This stimulated many introspective activities to improve the management of risk in a weapon systems program. Updating the 1983 DSMC *Risk Assessment Techniques* guide was one of those efforts. This updated Guide is the result.

Introspective activities centered on three key points:

Program management is risk management or, in other words, the program manager's job is to manage risk.

Management of risk requires not only the management of technical risk, but includes managing cost risk, schedule risk, programmatic risk and supportability risk. All are important in program management.

There are no "textbook" answers to risk management. Each situation is different and each circumstance requires a slightly different approach. Therefore, it should be obvious that this Guide cannot be a panacea. It presents several concepts and methodologies, many from the acquisition community, which have been integrated into a holistic framework. This is to say that we authors may have missed something good that is "out in the field."

We solicit your help. Use this Guide for awhile. Try it out. If you have additional information, if you are aware of other methodologies, if you used other techniques or approaches that worked for you, please let us know. The Defense Systems Management College intends to revise this Guide and republish it in FY90. Please send your comments by September 30, 1989.

The Risk Management Guide was developed by The Analytic Sciences Corporation (TASC) under contract to DSMC. As coordinator, I extend my thanks to all offices and contractors providing information. I want to acknowledge the extensive efforts and valuable inputs of Mr. Bernie Rudwick and Commander Tom Withers of DSMC, and Mr. Troy Caver, formerly of DSMC, whose valuable insight and assistance contributed materially to developing this Guide.

Harold J. Schutt
Associate Dean,
Department of Research
and Information

March 1989

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FOREWORD

This Risk Management Guide is designed to provide program management offices with a reference book for dealing with program risk related to systems acquisition. There is no single "best" technique for managing risk. Thus, the guide provides an introduction to the concepts of risk and an overview of the techniques for managing risk. This approach allows the reader to select the most appropriate risk strategy for their circumstances. The guide alerts readers to the many problems and issues faced in acquisition risk management and deals with many of the issues raised in the 1986 General Accounting Office (GAO) report on Technical Risk Assessments. (Ref. F1)

This guide has been designed to be used both as an aid in classroom instruction and as a reference book for practical application. It is intended to aid all levels of program managers and designated "risk" analysts. More experienced program managers may want to skip the introductory chapter and some of the appendices. The chapter/reference matrix in Figure FI is intended to serve as a quick look- up chart to the book for easy field reference.

SCOPE

This handbook is limited to program/project risk management as it relates to the DOD acquisition process. It does not cover "insurance risk", "safety risk", or "accident risk" which are generally considered to be outside of the DOD acquisition management realm. Focus is placed on risk management from a program office viewpoint. Program management offices are charged with the responsibility of making decisions which inherently have an element of uncertainty. As can be seen, there is no clear cut distinction between program management and risk management. Risk management is an integral part of the program management function. Risk management should be thought of as a program management methodology rather than an independent function distinct from other program management functions.

PROCESS STEPS \ GUIDE CHAPTERS/SECTIONS	INTRODUCTION 1-1	RISK CONCEPTS 3-1	RISK DEFINITION 3-1	RISK FACETS & INTERRELATIONSHIPS 3-4	RISK MANAGEMENT PERSPECTIVES 3-9	RISK MANAGEMENT STRUCTURE 4-1	RISK MANAGEMENT PLANNING 4-1	RISK ASSESSMENT 4-5	RISK ANALYSIS 4-9	RISK HANDLING 4-12	EXECUTING THE RISK MANAGEMENT PROCESS 5-1	ASSESSMENT TECHNIQUES 5-3 TO 5-20	ANALYSIS TECHNIQUES 5-20 TO 5-53	HANDLING TECHNIQUES 5-54	RISK MANAGEMENT IMPLEMENTATION 6-1	ORGANIZATION 6-2	RESOURCES 6-8	TECHNIQUE SELECTION 6-7 TO 6-17	COMMUNICATING RISK DATA 6-19	CONTRACTOR RISK MANAGEMENT 7-1	GOVERNMENT RESPONSIBILITIES 7-1	CONTRACTOR RESPONSIBILITIES 7-3	THE FUTURE OF RISK MANAGEMENT 8-1	APPENDICES A THRU G	BASIC PROBABILITY E-1	POLICY C-1
DETERMINING THE NEED	✓																									✓
UNDERSTANDING RISK		✓	✓	✓	✓																				✓	
PLANNING FOR RISK MANAGEMENT						✓	✓								✓	✓	✓	✓	✓							✓
ORGANIZING FOR RISK MANAGEMENT							✓				✓	✓			✓	✓										
REQUIRING CONTRACTOR RISK MANAGEMENT															✓					✓	✓	✓				
RISK IDENTIFICATION						✓		✓			✓	✓	✓		✓		✓	✓								
RISK QUANTIFICATION						✓	✓	✓			✓	✓	✓						✓						✓	
ANALYZING PROGRAM RISKS						✓			✓		✓		✓					✓	✓							
COMMUNICATING RISK											✓								✓							
HANDLING RISK						✓				✓	✓			✓						✓	✓	✓				
MONITORING CONTRACTOR RISK MANAGEMENT																				✓	✓	✓				
RESEARCHING RISK MANAGEMENT		✓	✓	✓	✓	✓					✓				✓								✓			
TOOLS											✓	✓	✓	✓										✓		
POLICY																								✓		✓
PROBABILITY THEORY																								✓	✓	

Figure FI Quick Look-Up Reference Chart

Risk Management is "a method of managing that concentrates on identifying and controlling the areas or events that have a potential of causing unwanted change." "... it is no more and no less than informed management." (Ref. F2)

APPROACH

Risk is approached in this handbook from a holistic viewpoint. That is, risk is addressed as a single entity, consisting of different facets (technical, programmatic, supportability, cost, and schedule) as illustrated in Figure FII. While technical issues are a primary source of risk and figure prominently throughout the book, they must also be balanced with the management of other aspects of the program (other risk facets). Therefore, a fair amount of time is spent examining each of the facets of risk so the reader can obtain an understanding of the inter-relationships that can exist between the facets.

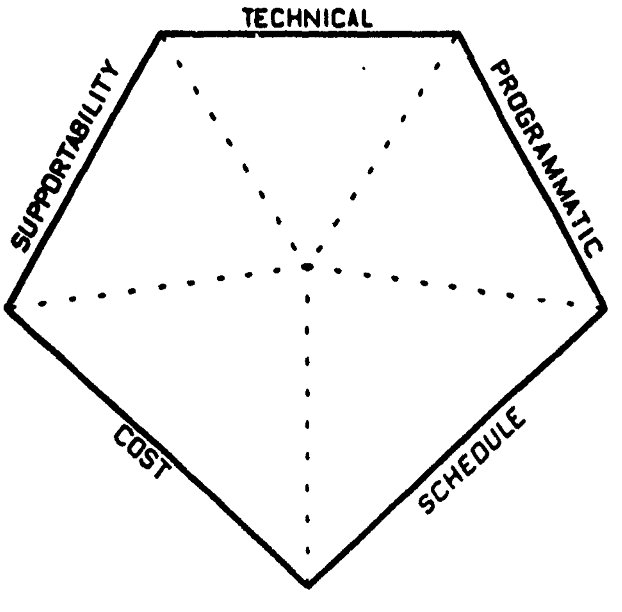

Figure II The Five Facets of Risk

NOTES ON GUIDE USE

While using this handbook, keep in mind that risk is a complex concept subject to individual perception. Some people are risk takers and some people are risk averse. Hence, it is difficult to develop a universal set of rules for dealing with risk. Guidance, structure, and sample handling techniques are contained in this guide which follow sound management practices. While the principles, practices, and theories presented herein hold true in nearly all situations, under certain circumstances the rules by which risk is evaluated may change drastically. For example, in times of extreme threat people do extraordinary things. They will take risks that under ordinary circumstances would be deemed "unacceptable". Hence, high risk programs are not always bad, and the acquisition of high risk programs should not necessarily be avoided. Rather, they should be rigorously monitored and controlled.

In developing this guide, extensive surveys were carried out with over 70 program offices and 25 contractors*. The risk techniques resulting from this survey effort have not been evaluated for all circumstances. The user is responsible for determining the validity and appropriateness of a particular technique for his/her own application.

* Over 380 surveys were actually sent to government and industry.

References:

F1 "Technical Risk Assessment: The Status of Current DoD Efforts", U.S. General Accounting Office, April, 1986.

F2 Caver, T.V., "Risk Management as a Means of Direction and Control," *Fact Sheet Program Managers Notebook*, Defense Systems Management College, (Fort Belvoir), No. 6.1, April 1985.

Chapter 1
INTRODUCTION

"The job of a program manager is to allocate resources to achieve goals with minimum risk."

1.1 EXECUTIVE SUMMARY AND GUIDE OVERVIEW

The risk guide is structured in a tutorial fashion. It begins with a brief review of the history or risk management within DOD and some discussion on why it is necessary (Chapter 2). The next chapter (Chapter 3) then defines risk in terms relevant to program management and establishes the basic concepts necessary to understand the nature of risk. After giving the reader an understanding of the basic concepts of risk, the book then defines the structure and process used in risk management which can be applied to all program phases. Chapter 5 presents the specific techniques necessary to successfully execute the process set out in Chapter 4. At this point, readers will be prepared to precede with the actual execution of risk management. The core chapter (Chapter 6) wraps up the information in the previous chapters by discussing the implementation issues program managers will face in executing a risk management program. Two special topics are then covered which serve as supplemental material to the process; contractor risk management and the future of risk management. This "building block" order is represented by Figure 1.1-1.

The risk guide also contains seven appendices intended to serve as reference material and provide backup detail for some of the concepts presented in the text of the guide. These are as follows:

- Risk Sources – an abbreviated list – intended to be a starting risk "checklist"
- Bibliography – this is a comprehensive bibliography on acquisition risk management
- Existing Policy – this is a series of extracts from current policies governing the acquisition process as they relate to risk management

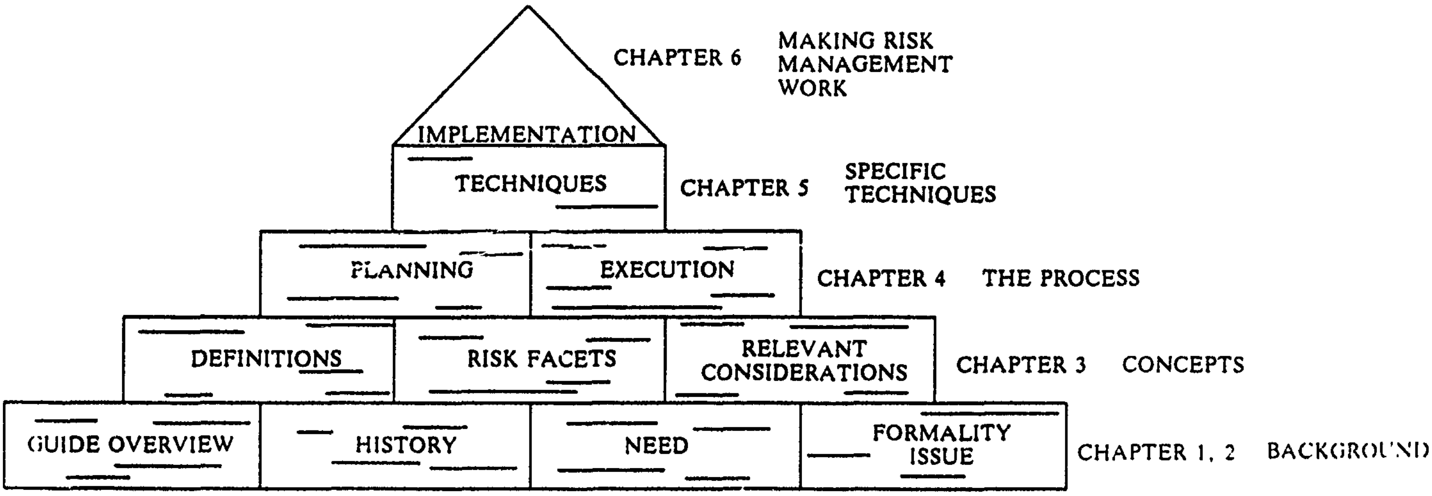

Figure 1.1–1 Risk Guide Structured Approach

- Definitions/Acronyms – self– explanatory
- Basic Probability Concepts – intended as a refresher and basic primer for the material in the text
- Quantifying Expert Judgments – narrative of ways to transform qualitative information into quantitative information during expert interviews
- Special Notes on Software – because of the growing complexity and difficulty in managing software programs, this appendix was included to provide a starting point for help.

1.2 NOTES ON THE GAO REPORT

Within the 1986 GAO report cited earlier (Ref F1), there were five criteria developed that were considered essential in the assessment[1] of technical risk. These criteria really apply to more than just "technical" risk.

(1) *prospective assessment:* Possible future technical problems are considered, not just current problems.

(2) *planned procedures:* Assessment is planned and systematic, not incidental.

(3) *attention to technical risk:* There is explicit attention to technical risk, not just to schedule or cost risk with consideration of technical risk left implicit.

(4) *documentation:* At a minimum, technical risk assessment procedures and results are written down in some form.

(5) *reassessment in each acquisition phase:* New or updated assessments are made in order to detect changes in risk during a system's development.

As the reader progresses through the guide, the importance of adhering to these criteria will become evident. Without an understanding of the complexity of dealing with risk, these criteria appear to be merely reasonable. With an understanding of the complexity of risk, their importance is seen as critical. It is the intent of this book to bring the reader up to a knowledge level where these criteria are viewed as mandatory for successful risk management.

1 NOTE. The GAO used the term "assessment" to include a more comprehensive set of risk activities than as defined in this book. (See Chapter 4).

Chapter 2
BACKGROUND

2.1 HISTORY

It has long been recognized that risk management provides valuable information to program management personnel. Deputy Secretary of Defense David Packard wrote a memorandum to the military services in 1969 that listed inadequate risk assessment as a major problem area in system acquisition. In 1981, Deputy Secretary of Defense Frank C. Carlucci, III, published a memorandum (Reference 2-1) which included 32 "initiatives" (these became known as the Carlucci initiatives) aimed at improving the acquisition process. Initiative 11 required Department of Defense (DOD) action to increase the visibility of technical risk in budgets of weapon systems acquisition programs. Then in 1986, the United States General Accounting Office released a report titled; *Technical Risk Assessment – The Status of Current DOD Efforts*, which examined the methodology used for assessing technical risks within 25 program offices (Reference 2-2). The deficiencies found by the GAO prompted the development of this guide.

2.2 THE ISSUE OF FORMALITY

In order for the risk management process to work, it must become formal, systematic, and applied in a disciplined manner. That is not to say that all programs should require formal risk management. It merely means that to obtain the maximum benefit from risk management, it must become a systematic process. There have been, in the past, several problems which prohibited risk management from becoming a clearly understood process. The intent of this book is to address these problems and thereby lay the ground work for institutionalizing risk management. The risk management "structure" used throughout this book is depicted in Figure 2.2-1.

This structure is defined in Chapter 4. Note that "risk management" refers to the

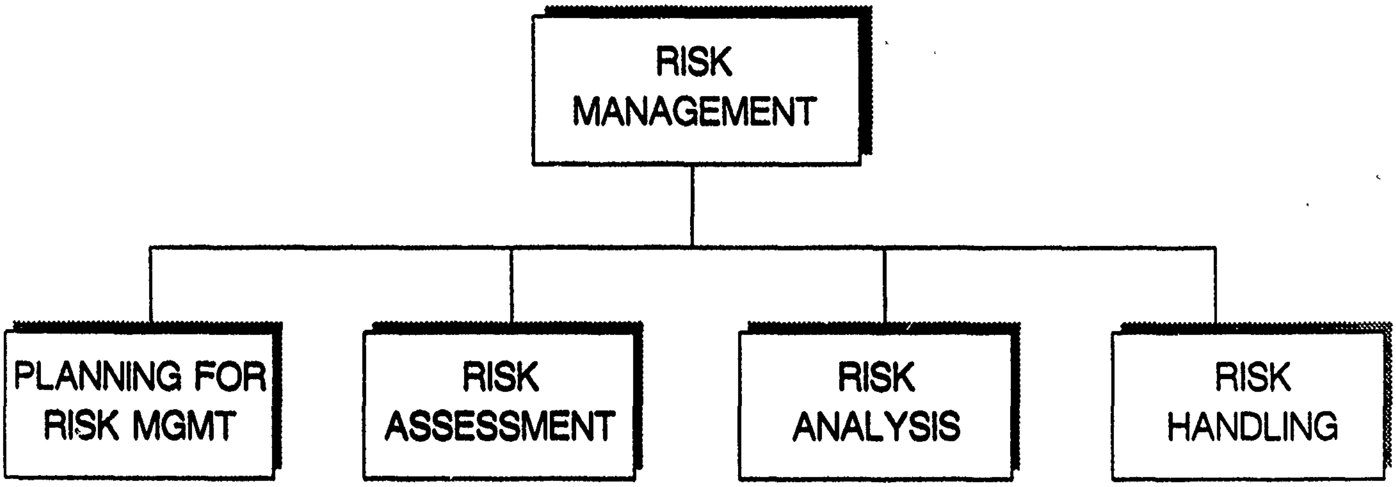

Figure 2.2-1 Risk Management Structure

sum total of four specific elements. Assessment, Analysis, and Handling refer to the actual execution of the process while Planning represents most of the preparation activity.

2.3 THE RISK MANAGEMENT NEED

Most decisions, including the most simple, involve risk. Take, for example, the decision of whether to drive or fly on a business trip; the cost and time differentials are easily obtained, but the safety factor and the probability of arriving on time for a meeting can become very complicated.

With this example in mind, a "success criteria" is necessary early in the effort in order to set down the most important elements in the risk assessment. If cost alone is the only success criterion, then the risk determination is simple; determine the cost to fly and compare this to the expense of driving. The next success criterion might be safety. One method of transportation will be safer than the other. Statistics concerning accidents per 1000 miles traveled are available to evaluate this criterion. If a third criterion is added, such as on-time arrival for a meeting, then dependability of the transportation method must be entered into the calculation. Airline on-time statistics and the dependability of the auto and the road conditions should be evaluated.

As the success criterion is expanded and made more complicated, the decision-making becomes more complicated. It is obvious from the example that some risk (perhaps increased cost) is acceptable, while being late for the meeting may be an unacceptable risk. Certainly, not arriving safe and sound is completely unacceptable.

Today's weapon systems are increasing in technical complexity, and this increasing complexity increases the risk. Program decisions are heavily biased toward cost and schedule goals. While cost and schedule are understood, the impact of cost/schedule decisions as they relate to technical performance risk are usually not as clear. A formal methodology for evaluating the impacts of decision-making and foreseeable problems is necessary. In addition, this methodology should aid in identifying any practical and effective work-arounds in order to achieve the program goals.

Proper risk management requires a systematic approach to the identification of problems. The sizing and resolution of these problems can only help in the determination of choices, given certain causes and effects. In order to insure that the approach is systematic, it would include the communication of risk as seen by each diverse technical function to the *single* decision maker in order to obtain the maximum program benefit in terms of performance, cost, and schedule.

While many program managers use intuitive reasoning (guessing) as the starting point in the decision-making process, it behooves the astute manager to go beyond the intuitive reasoning or experience factor in decisions involving significant risks. As a minimum, a manager should attempt to obtain the level of risk and the impact of the action on the progress of the program. If the risk is of such consequence as to cause the entire program to fail, then it may not be acceptable and some other plan must be formulated.

In today's defense environment, there are factors that must be carefully examined for risk in order to understand the necessity for risk management. The project manager must be aware of potential cost and schedule perturbations; frequently the survival of a project (and perhaps the manager) depends on the control of these elements.

Given the above description of the defense environment and the qualifications for effective program management, it is advisable for all programs to perform some documented risk management activity, either qualitative or quantitative. All DAB programs should have formal, intense risk management activities while smaller, less critical programs may require less effort. The ultimate authority is the program manager. He must make the judgment based on performance, cost, and schedule challenges faced on the project.

2.4 CHAPTER 2 KEY POINTS

- Risk Management is required by policy (see Appendix C)
- Risk Management should be formal and systematic
- Risk is an integral part of decision-making
- Greater pressure on DoD requires more effective risk management
- Most programs should have some level of documented risk management activity.

References

2-1 Carlucci, F.C., III, "Improving the Acquisition Process," Memorandum for Secretaries for the Military Departments, Chairman of the Joint Chiefs of Staff, Under Secretaries of Defense, Assistant Secretaries of Defense, General Counsel, Assistants to the Secretary of Defense, the Deputy Secretary of Defense, Washington, D.C., April 30 1981.

2-2 "Technical Risk Assessment: The Status of Current DoD Efforts," General Accounting Office, April 1986.

Chapter 3
RISK CONCEPTS

3.1 EXPANDED DEFINITION OF RISK

Risk is defined as the probability of an undesirable event occurring *and* the significance of the consequence of the occurrence. This is different than uncertainty which considers only the likelihood of occurrence of the event. (The traditional view of risk defines it as a situation in which an outcome is subject to an uncontrollable random event stemming from a *known* probability distribution. Uncertainty is normally thought of in traditional terms as an outcome subject to an uncontrollable random event stemming from an *unknown* probability distribution. While these definitions have their place in statistics, they are of limited value in program or project risk management.) Although risk and uncertainty are often used interchangeably, they are not the same. What this means to the program management office is that to truly understand whether an item is "risky", they must have an understanding of the potential impacts resulting from the occurrence/nonoccurrence of the event. Figure 3.1-1 illustrates this concept. Note that some judgment must be used in determining risk in this manner. For example, an event may have a low likelihood of occurring, but the consequences of the event, should it occur, can be catastrophic. Most people would not consider this to be a high risk item as might be indicated in the Figure 3.1-1 diagram. This situation can be related to that of flying in a commercial jet aircraft. The probability of a crash is low, but generally, the consequences are indeed grave. While most people do not consider flying a high risk, many do feel uncomfortable because of the consequences of "failure". This example also highlights the great degree of subjectiveness in actually rating risk. It is highly dependent on an individual's perception of what is personally acceptable. Using Figure 3.1-1 as a reference, there are three separate inputs required to determine the level of risk. The first input is the "probability of occurrence of the event." This variable can often be estimated using statistical references based on history. Probability theory can play an important role in determining the value of this variable.

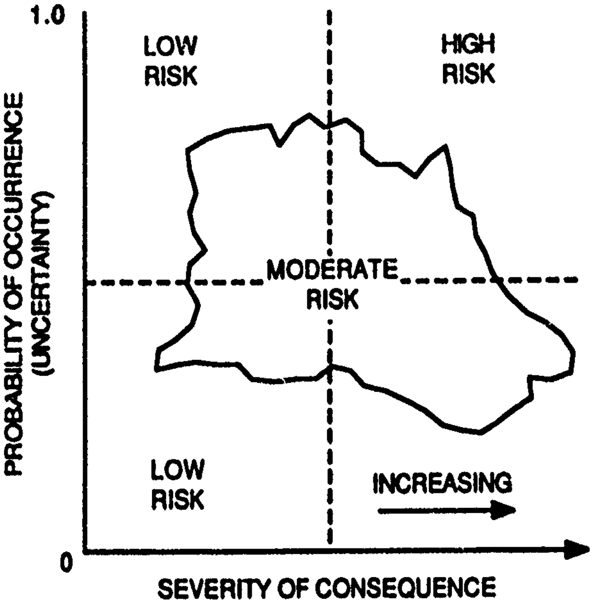

Figure 3.1-1 Concept of Risk

The second input is "severity of consequence if the event should occur". This variable requires the management team to identify what the consequences are and the degree of the impact. Here, statistics and probability theory can play a role in determining the degree of impact once it has been identified. Note, however, that probability has a limited role and is not always appropriate.

The third input required is subjective judgment concerning the combination of the first two. There can be little disagreement about the level of risk if the first two variables are:

- low likelihood/low consequence – low risk
- high likelihood/high consequence – high risk
- high likelihood/low consequence – low risk (to the overall success of the program).

As you move towards the low likelihood/high consequence quadrant of the figure, the risk level becomes more subject to individual interpretation and requires strict program guidelines for rating the risk. Disagreements among participants may occur in rating risk. While program managers must rely on several "technical experts" in the risk management process, they must also be prepared to make the final judgment on the rating of risk. Some guidelines on the rating of risk are contained in 4.3-2 of this guide. It is important to note that a program with many moderate risk items may in fact be a high risk program, while a program with just a few high risk items may have a lower overall risk rating. These situations usually require some type of modeling to ascertain the "program" risk level.

Many attempts have been made to mathematically model this subjective quantification of risk. Probability distributions are one such method frequently used (see Appendix E). One last item to be considered in looking at the nature of risk is the concept of opportunity. There must always be some potential gain from successfully executing an activity with risk. As the potential gain increases, so does the acceptability of higher levels of risk. If there is no real opportunity, then there is no reason to pursue an activity with risk.

3.2 RISK FACETS

After obtaining an understanding of the nature of risk, the next step is to lay the groundwork for managing it. Risk must be segmented into manageable pieces. The first "cut" is to break it into classifications relating to the source of the risk.

3.2.1 Introduction

Risks to a program manager are all rooted in the determination to deliver a specified product or level of performance at a specified time for a specified cost. The program manager risks failure in three ways and combinations thereof. The product may not be up to the performance level specified, the actual costs may be too high, or delivery may be too late. A wide variety of problems can arise to keep a program manager from meeting cost, schedule, and performance objectives. All programs that are properly planned will provide the manager with some reserve funds and slack time to work around unanticipated problems and still meet original cost, schedule, and performance goals. There is, of course, a risk that the original cost, schedule, and performance goals were unattainable, unrealistic, or conflicting and it would be impossible to meet all of them.

There are five facets of risk that are necessary to segment and manage the cost, schedule, and performance issues faced on a project:

- Technical - (performance related)
- Supportability - (performance related)
- Programmatic - (environment related)
- Cost
- Schedule.

Cost and schedule risks are treated somewhat differently than the other three in that they are (more or less) indicators of project status. Note, however, that cost and schedule can become a major source of program risk. This will be discussed in detail later.

3.2.2 Classifying Risk into the Facets

Understanding and classifying a risk into one or more of the five facets requires an examination of the source of the risk. It is not always easy to determine into which category a particular risk belongs, and just for the sake of classification, it's not all that important. However, understanding the source of the risk and the impact area(s) as well as providing a structure to examine risk are critical elements if the risk is to be managed effectively. Figure 3.2-1 depicts sample risks from each facet.

3.2.3 Technical Risk

Technical risk can be defined as the risk associated with evolving a new design to provide a greater level of performance than previously demonstrated, or the same or a lesser level of performance subject to some new constraints. The nature and causes of technical

TYPICAL TECHNICAL RISK SOURCES	TYPICAL PROGRAMMATIC RISK SOURCES	TYPICAL SUPPORTABILITY RISK SOURCES	TYPICAL COST RISK SOURCES	TYPICAL SCHEDULE RISK SOURCES
Physical Properties	Material Availability	Reliability & Maintainability	Sensitivity to Technical Risk	Sensitivity to Technical Risk
Material Properties	Personnel Availability	Training	Sensitivity to Programmatic Risk	Sensitivity to Programmatic Risk
Radiation Properties	Personnel Skills	O&S Equipment	Sensitivity to Supportability Risk	Sensitivity to Supportability Risk
Testing/Modeling	Safety	Manpower Considerations	Sensitivity to Schedule Risk	Sensitivity to Cost Risk
Integration/Interface	Security	Facility Considerations	Overhead/G&A Rates	Degree of Concurrency
Software Design	Environmental Impact	Interoperability Considerations	Estimating Error	Number of Critical Path Items
Safety	Communication Problems	Transportability		Estimating Error
Requirement Changes	Labor Strikes	System Safety		
Fault Detection	Requirement Changes	Technical Data		
Operating Environment	Political Advocacy			
Proven/Unproven Technology	Contractor Stability			
System Complexity	Funding Profile			
Unique/Special Resources	Regulatory Changes			

Figure 3.2–1 Sample Risks by Facet

risks are as varied as military system designs. Many, if not most, technical risks are the result of the demand for ever greater performance from new systems and equipment. What is technically risky when first attempted may be routine a few years later. Risky areas on a system with high performance requirements may be routine on other systems with lower performance requirements. The ever present requirement to minimize or maximize physical properties of systems and equipment further adds to the risks associated with higher performance requirements.

Many of the "ilities" such as reliability, maintainability, etc. must be addressed in system acquisition. Each can be viewed as additional design requirements placed on designers attempting to evolve an efficient design capable of the desired performance level. Each of these added design requirements can be a source of risk.

It is not easy to describe all possible technical risks, because when examined at the lowest level of detail, there are so many of them. There are usually many items to be designed and integrated with other items. There may be several design objectives for each site and each item–design objective combination is subject to many "ility" requirements, as well as cost and schedule constraints. Appendix A contains an abbreviated list of technical risk areas. It does not break out types of risks by components, parts, subassemblies, assemblies, subsystems, and systems for all the many associated integration design tasks. The list also does not address all possible aspects of performance, which vary widely from system to system. As the design architecture, performance, and other requirements and program constraints become known on a given program, a more detailed list of risks should be prepared based on system peculiar information.

3.2.4 Programmatic Risk

Programmatic risk can be defined as those risks which include obtaining and using applicable resources and activities which may be outside of the program's control, but can affect the program's direction. Generally, programmatic risks are not directly related to improving the state-of-the-art. Programmatic risks are grouped into categories based on the nature and source of factors that have the potential to disrupt the program implementation plan.

- Disruptions caused by decisions made at higher levels of authority directly related to the program
- Disruptions caused by events or actions affecting the program, but not directed specifically at it
- Disruptions caused primarily by the inability to foresee production related problems.
- Disruptions caused by imperfect capabilities
- Disruptions caused primarily by the inability to foresee problems other than those included in the first four categories.

These risks tend to be a function of the business environment. Appendix A has a more detailed listing of sample programmatic risks.

3.2.5 Supportability Risk

Supportability risk can be defined as the risk associated with fielding and maintaining systems which are currently being developed or have been developed and are being deployed. Note that supportability risk is comprised of both technical and programmatic aspects. Certainly, any design effort (which may contain technical challenges) should consider what the supportability issues are likely to be when the system is fielded. Another example is training, which is generally a programmatic risk but quickly becomes a supportability risk when maintenance and operations support become the driving factors. There are ten Integrated Logistic Support Elements that present potential sources of risk. These involve both technical and programmatic issues.

- Maintenance Planning
- Manpower & Personnel
- Support Equipment
- Technical Data
- Training
- Training Support
- Computer Resources Support
- Facilities
- Packaging, Handling, Storage, and Transportation
- Design Interface.

It is important to understand that any given risk area may belong to more than one facet as illustrated above (e.g., a particular piece of support equipment may pose a technical challenge *and* have significant supportability implications).

3.2.6 Cost and Schedule Risk

There is a long history of DoD Weapon program cost/schedule growth with considerable Congressional criticism thereof. In an era of limited DoD budgets, cost and schedule growth in one program dictates reductions in one or more others. Therefore, the risk of cost and schedule growth is a major concern. This problem is further complicated by the fact that performance and design technical problems are sometimes solved by increasing the planned program scope and thereby program cost and schedule.

Cost and schedule growth is the difference between the estimated program cost and schedule and the actual cost and schedule. Therefore, there are two major cost/schedule risk areas bearing on cost/schedule growth.

- The risk that the estimate set an unreasonably low cost/schedule objective
- The risk that the program will not be carried out in an efficient and prudent manner so as to meet reasonable cost/schedule objectives.

The outcome of the second of these two risk areas is not primarily a cost/schedule analysis related risk, that is, anything cost/schedule analysts or financial analysts can control. The final cost/schedules are primarily a function of the skill of the Program Manager to accommodate unanticipated problems related to technical, supportability, and programmatic risks. The solution or the lack of a good solution for such problems often increases costs and schedules.

The preparation of an unrealistically low baseline cost/schedule estimate or program target cost/schedule estimate fall into four categories (prior to a pricing decision). These are:

- Inadequate system description
- Inadequate historical cost/schedule data base
- Lack of sound methods relating historical costs/schedules to new program costs
- Incomplete cost/schedule estimate.

Note that from this context, there are few true cost or schedule risks. There are occasions where this statement does not hold true. For example, test windows can drive entire programs to a degree, as can funds available for a specific item. Generally, true cost and schedule risks are few and far between when the source of the risk is closely examined. More often than not, cost and schedule uncertainty are a reflection of technical, programmatic, and supportability risk.

3.2.7 Facet Organization

It was mentioned previously that there are "risk drivers" and "risk indicators." The risk drivers are usually the technical, programmatic, and supportability facets – which leave the cost and schedule facets as the indicators. This is often, but not always the case. Generally when an item is contracted for, there is a specified performance level to be met. This includes design criteria, supportability factors, performance criteria and a host of other specifics. It is then asked what it will actually take to build this item in terms of resources (time and money). It is paramount that the item satisfy the need. The tendency then is to focus on the performance requirements – not cost or schedule. Unfortunately cost and schedule tend to be the yardstick by which decisions are made – and the tradeoffs between cost, schedule, and performance are not well understood. This is one of the advantages of performing risk management. It attempts to draw reality into the relationship between the risk facets. There are occasions where a project is undertaken with the understanding that the product will be the best possible within the dollar and time constraints dictated. In these instances the cost and schedule facets become the drivers and the other facets may become the indicators. Few projects have such clear cut goals. More often than not, the program management office must strive to achieve a balance between the facets to reach seemingly conflicting goals in performance, cost, and schedule. For simplicity, this guide will treat technical risk, programmatic risk, and supportability risk as the predominate factors driving cost risk and schedule risk. This is illustrated in Figure 3.2-2.

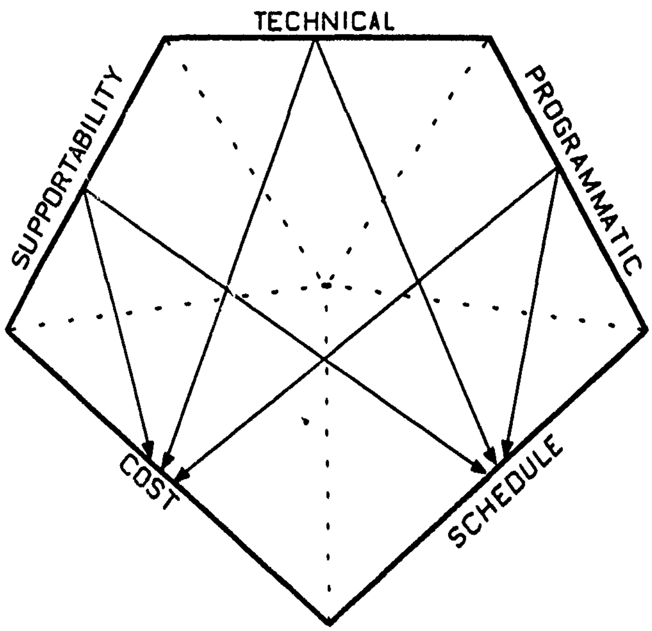

Figure 3.2-2 Relationship Between The Five Risk Facets

By now it is easy to see that the risk facets are not independent of one another. While a design risk is of a technical nature it may have cost, schedule, supportability, and programmatic impacts. Or, a tight test window presenting a schedule risk, may have serious technical impacts. The facets may also change with time. What started as a technical risk in the design of a product may surface years later as a supportability risk factor that has serious cost and schedule impacts. A useful approach is to examine all facets *whenever* a risk is identified in one facet.

This discussion was not intended to imply that cost and schedule manage themselves; that is certainly not true. The intent was to emphasize the importance of managing the *source* of the risk in any program. Frequently, this is some factor rooted in technical, programmatic, or supportability characteristics.

3.3 OTHER RELEVANT CONSIDERATIONS

There are two other points worthy of mention when discussing risk concepts from a program office viewpoint. Both deal with our acquisition management structure (to a degree) and are discussed in the following two sections.

3.3.1 The Two Perspectives of Risk Management

Program/project risk management must be viewed from two perspectives defined as follows:

- Short term - dealing with the current program phase and immediate future
- Long term - dealing with anything beyond the short term.

Like many other aspects of risk management, the distinction between the two perspectives is somewhat unclear. Further explanation will help to clarify and justify the separation. The short term perspective normally refers to managing risk related to satisfying the immediate needs of the project - i.e., "this is the performance level I need to achieve today", and, "how are my contractors managing to achieve this?" The long term perspective deals with "what can I do today to ensure that downstream the program will be successful?" This might include, among other things, introducing supportability engineering and producibility engineering into the design process early in the program. The two perspectives are closely related. In achieving the desired performance level (short term goal) materials that are difficult to work with and/or require new manufacturing techniques as yet unproven may be utilized to solve the problem (introducing a long term risk). As with any good management decisions, the short term and long term implications must be well understood. Only if these implications are known can they be acted on (risk handling) early enough to significantly reduce the chance of undesirable results. Another look at the two perspectives to aid in understanding the differences is illustrated in Figure 3.3-1. In this figure an overall design has been selected for a given project which has certain elements of risk. This was a decision that obviously had long term implications. The task now at hand for the program manager is to complete the design selected within the resources made available. This particular program manager has selected some technical, cost, and schedule parameters to manage "risk" on an operational day to day basis (short term risk management). Again, this does not preclude his decisions in managing short term risk from having significant long term impacts.

3.3.2 Realities of the Government Program Office Function

Under ideal program management conditions, the same management team would stay with a program from the definition phase through production. However, ideal conditions rarely exist and a given program will likely see several management teams. The transition in program management personnel often creates voids in the risk management process These voids are in the information/knowledge gained about the program from previous activity. Precious time must be spent becoming familiar with the program — often at the sacrifice of long term planning and risk management. The introduction of a formal system for recording, analyzing, and acting on program risk facilitates the transition process and, when done properly, forces long term risk management. The approach to formal risk management is contained in Chapters 4, 5, and 6. While it is desirable to make decisions based on long term implications, it is not always feasible. The program management office is often forced to act on risk from a short term rather than long term perspective. One reason has already been mentioned – the change in personnel. Another reason is program advocacy. Sudden shifts in priorities can wreak havoc on long term plans (this is a risk area in and of itself). The result is short term actions to adjust to the new priorities. Often these kinds of decisions are made before a thorough evaluation of the long term impacts can be conducted. Lastly, in some instances long term impacts are not always visible at the time the decision must be made.

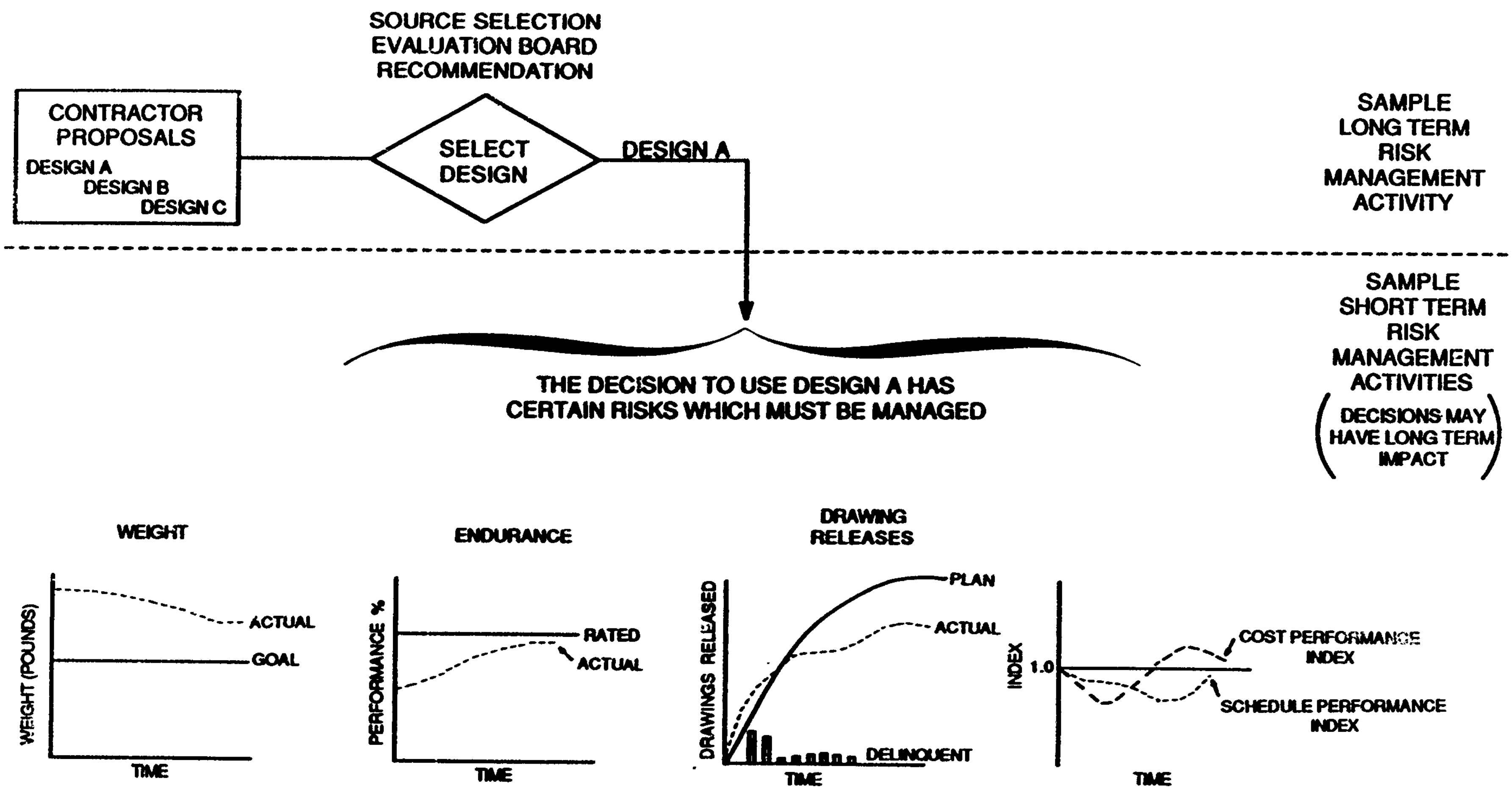

Figure 3.3–1 Short/Long Term Risk Perspective

There are day to day operational risks that must be addressed to complete any given phase of a program. The solutions developed to handle these risks must always be examined from a long term viewpoint and must provide the program manager a strong argument to defend his/her position. As has been pointed out in many studies, actions taken early in a program's development have a major effect on the overall performance and cost over the life of the program as illustrated in Figure 3.3-2. (Ref. 3-1).

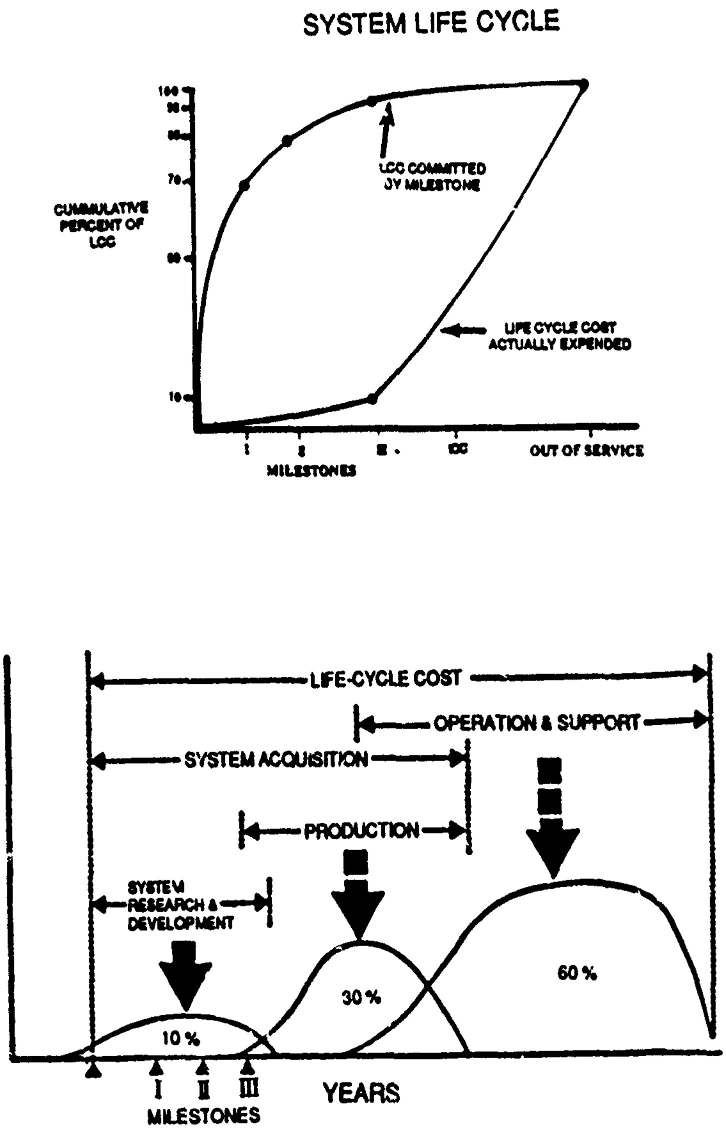

Figure 3.3-2 Life Cycle Cost

3.4 CHAPTER 3 KEY POINTS

- Risk considers both likelihood and consequence
- Rating risk is a subjective process requiring strict guidelines
- There are five facets to risk:
  - technical
  - programmatic
  - supportability
  - cost
  - schedule
- The risk facets are strongly interrelated
- Most risk sources are rooted in technical, programmatic, or supportability factors
- Risk has a short term and long term perspective.

References

3-1 "Integrated Logistics Support," Defense Systems Management College, Fort Belvoir, Virginia, October 1985.

Chapter 4
THE RISK MANAGEMENT STRUCTURE

4.1 INTRODUCTION

This chapter presents the recommended structure for executing risk management. Recognition must be given to the fact that in the past there have been several different structures and definitions used for basically the same concept. This has been a source of continuing confusion in the field of risk management. Figure 4.1-1 illustrates the most common of the previous terminology/structures used in the risk field. It is important to note that all of these previous structures/approaches do not clearly distinguish between the terms risk assessment/risk analysis/risk management. Previous efforts have not established standard terminology. This chapter will clarify and define each of these terms so that communications regarding "risk" can be more effective. Risk management consists of four separate but related activities as depicted in Figure 4.1-2. "Risk Management" is the "umbrella" title for the processes used to manage risk. This chapter focuses on defining and explaining the elements of risk management. As with any process, there are two basic stages: Planning, then execution, which includes monitoring and control (Reference 4-1).

4.2 RISK PLANNING

4.2.1 Need/Purpose

Risk is present in some form and degree in most human activity. It is certainly present in the systems acquisition business. Risk is characterized by the fact that:

- It is usually at least partially unknown
- It changes with time
- It is manageable - in the sense that human action may be applied to change its form and degree.

Planning for the management of risk makes ultimate sense in order to:

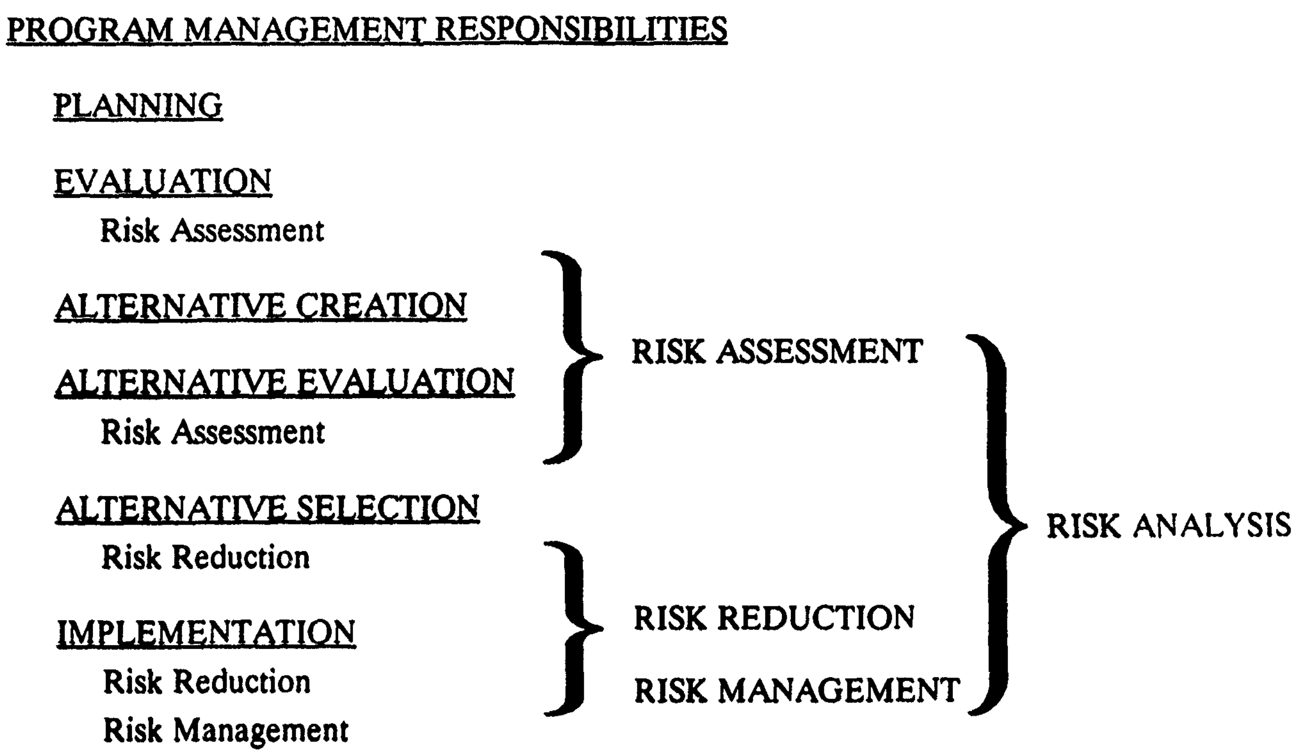

Figure 4.1-1 Previous Risk Structure

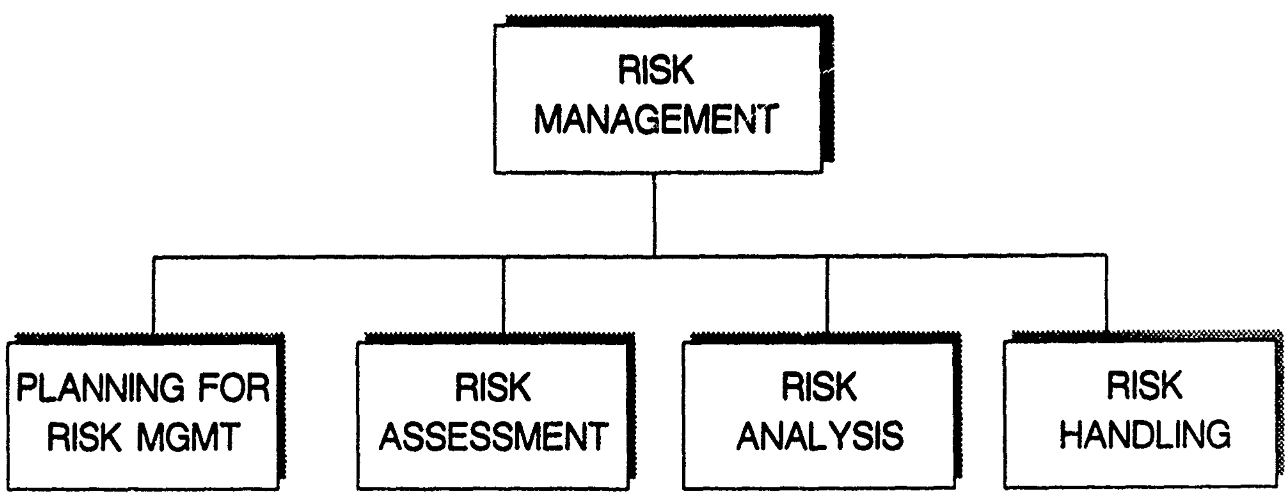

Figure 4.1-2 Updated Risk Management Structure

- Eliminate risk wherever possible
- Isolate and minimize risk
- Develop alternate courses of action
- Establish time and money reserves to cover risks that cannot be avoided.

The purpose of risk management planning is simply to force organized purposeful thought to the subject of eliminating, minimizing, or containing the effects of undesirable occurrences.

4.2.2 Timing

Risk is a word that exists only in the future tense. *There are no past risks – only actual occurrences.*

Risk management planning is sensibly done and redone as an integral part of normal program planning and management. Some of the more obvious points for revisiting the risk management plan include:

- In preparation for major decision points
- In preparation for and immediately following technical reviews and audits (see MIL-STD-1521)
- Concurrent with the review and update of other program plans and specifications
- In preparation of POM submittals.

4.2.3 Risk Management Plan

Most major programs are guided by a series of "plans" (e.g., PMP, TEMP) that provide the rationale and intended processes through which the program will be executed. A Risk Management Plan is a sensible part of this suite of guiding documents. Such a plan would publish the results or latest status of the risk management planning process.

At this writing, the concept of a Risk Management Plan is gaining favor within DOD. The content and format are not nearly as mature as the other plans. Thus program managers have almost total freedom to structure the document to suit their situation. As a starting point, consider the following paragraphs as a guide to the possible content of a Risk Management Plan (Figure 4.2-1).

System Description and Program Summary – This material should be the same in all the program's plans. It should provide the basis of reference for the reader to understand the operational need, the mission, and the major functions of the system. It should include key operational and technical characteristics of the system. A program summary would include a description of the organizational relationships and responsibilities of the participating organizations. It would also include an integrated program schedule.

1. PART I - DESCRIPTION
    - 1.1 MISSION
    - 1.2 SYSTEM
        - 1.2.1 SYSTEM DESCRIPTION
        - 1.2.2 KEY FUNCTIONS
    - 1.3 REQUIRED OPERATIONAL CHARACTERISTICS
    - 1.4 REQUIRED TECHNICAL CHARACTERISTICS
2. PART II - PROGRAM SUMMARY
    - 2.1 SUMMARY REQUIREMENTS
    - 2.2 MANAGEMENT
    - 2.3 INTEGRATED SCHEDULE
3. PART III - APPROACH TO RISK MANAGEMENT
    - 3.1 DEFINITIONS
        - 3.1.1 TECHNICAL RISK
        - 3.1.2 PROGRAMMATIC RISK
        - 3.1.3 SUPPORTABILITY RISK
        - 3.1.4 COST RISK
        - 3.1.5 SCHEDULE RISK
    - 3.2 STRUCTURE
    - 3.3 METHODS OVERVIEW
        - 3.3.1 TECHNIQUES APPLIED
        - 3.3.2 IMPLEMENTATION
4. PART IV - APPLICATION
    - 4.1 RISK ASSESSMENT
        - 4.1.1 RISK IDENTIFICATION
        - 4.1.2 RISK QUANTIFICATION
        - 4.1.3 IDENTIFICATION SUMMARY
    - 4.2 RISK ANALYSIS
    - 4.3 RISK MANAGEMENT (HANDLING TECHNIQUES)
        - 4.3.1 RISK REDUCTION MILESTONES
        - 4.3.2 RISK QUANTIFICATION
        - 4.3.3 RISK BUDGETING
        - 4.3.4 CONTINGENCY PLANNING
5. PART V - SUMMARY
    - 5.1 RISK PROCESS SUMMARY
    - 5.2 TECHNICAL RISK SUMMARY
    - 5.3 PROGRAMMATIC RISK SUMMARY
    - 5.4 SUPPORTABILITY RISK SUMMARY
    - 5.5 SCHEDULE RISK SUMMARY
    - 5.6 COST RISK SUMMARY
    - 5.7 CONCLUSIONS
6. PART VI - BIBLIOGRAPHY
7. PART VII - APPROVAL

Figure 4.2-1 Risk Management Plan

Approach to Risk Management - Under this heading would be the intended approach (specific to the program) for executing the processes of:

- Risk Assessment
- Risk Analysis
- Risk Handling.

Also appropriate would be the definitions, measurement techniques, and risk rating methods for:

- Technical Risk
- Programmatic Risk
- Supportability Risk
- Schedule Risk
- Cost Risk.

A description of the structure to be used to identify and assess project risks and an overview of the methods and techniques for risk analysis would be valuable.

Application Issues and Problems - This section would include the procedures and processes for:

- Identifying risks
- Quantifying risk
- Use of tools to analyze risk
- Applying specific actions to manage risk.

Other Relevant Plans - Every major program is governed by a set of plans that include:

- Program Management Plan (PMP)
- Systems Engineering Management Plan (SEMP)

- Acquisition Plan (AP)
- Test and Evaluation Master Plan (TEMP)
- Manufacturing Plan (MP)
- Integrated Logistics Support Plan (ILSP).

These plans provide insights into items of risk. Typically they are not written from a risk viewpoint, but when one reads them with an eye to raising risk questions, they provide valuable information. These plans should be reviewed before, during, and after preparation of the Risk Management Plan. These plans may suggest items of risk. The Risk Management Plan may suggest items that need to be addressed in the other plans. While the Risk Management Plan deals with analyzing and managing risk, risk should be identified and highlighted in any or all plans where it is appropriate.

4.3 RISK ASSESSMENT

4.3.1 Identification

Risk Identification is the first step in the risk assessment process. Risks cannot be assessed or managed until they are identified and described in an understandable way. Risk identification is an organized thorough approach to seek out the real risks associated with the program. It is *not* a process of trying to invent highly improbable scenarios of unlikely events in an effort to cover every conceivable possibility of outrageous fortune.

Approaches – Expert interviews, analogy comparisons, and the evaluation of the program plans are techniques that are especially strong in the risk identification segment. The objective of the risk identification segment is to obtain straight forward English language narrative statements describing the program risks. Mathematical techniques are not appropriate here. Chapter 5 describes in great detail the techniques for executing the risk management process – including risk identification.

Baselining Risk – Risk exists only in relation to the two states of uncertainty – total failure (usually 0% probability) and total success (usually 100% probability). The risk assessment process attempts to treat risk in a probabilistic manner and the process is significantly simplified if we are able to define total failure and total success. Defining one or both of the "baseline programs" is worth some effort in order to obtain a benchmark on the continuum (Figure 4.3-1). It is certainly desirable but difficult to describe the technical content of a 0 percent and 100 percent probability program. Usually, however, the technical content is given and the baseline is expressed as the 0% and 100% probable schedule and cost values to achieve the technical content. After defining a baseline position, it becomes easier to quantify risk in terms of each impact area on a meaningful scale.

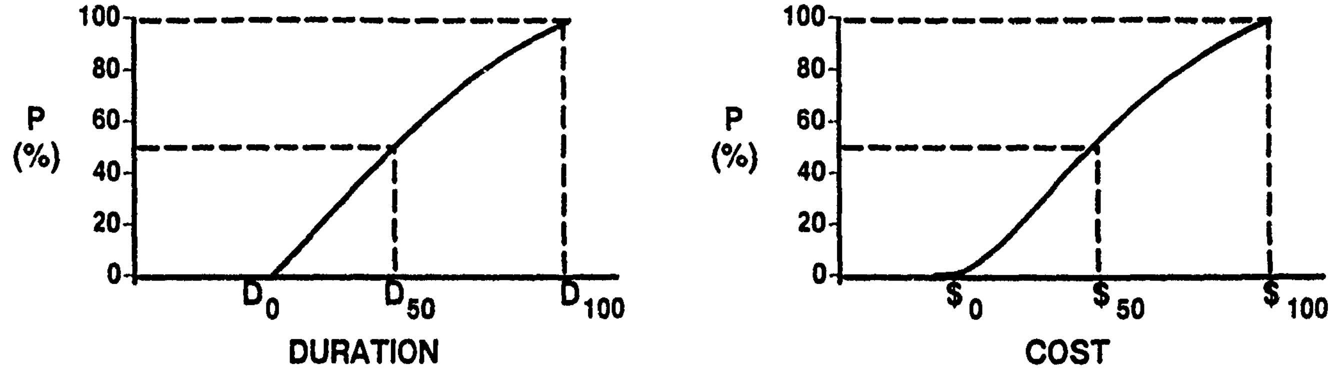

Figure 4.3–1 Risk Baselines

For baseline definition, we are seeking D_0 and $\$_0$ or D_{100} and $\$_{100}$

Checklist Concept – The purpose of any program is to achieve a specifiable set of goals. The basic risk identification question becomes, "What are the events or facts that may reasonably occur which will prevent the achievement of program goals?" Occurrences whose outcomes are irrelevant to program goals have no risk. The search should be directed toward the "show stoppers" that will have a major impact on the program. The key to risk identification is the systematic combing through the total program. Figure 4.3–2 offers a matrix that can serve as a tool to organize this process.

The Top Level Risk Matrix is applied at the total program level as a starting point. The concept can be refined and carried to greater detail as needed.

Defining Program Goals – One would expect this step to be an easy task. More than likely, it will be a thought provoking and controversial process. Requirements specified in the PMD should all be included as goals. If direction is missing or not explicit enough to be included as a goal, this process identifies that fact (which in itself is an important risk reduction action). All goal blocks on the matrix should be covered. A goal block that cannot be filled out to the satisfaction of the program manager is an alert for direction and/or definition. The program manager should precipitate some action to fill the void.

Defining Program Strategies – Program strategies represent the plan(s) for achieving the goals. In the ideal case, the strategy blocks in the matrix should contain references to chapters or paragraphs in one or more of the program plans. If this is not the case, the plans are inadequate. This causes the greatest risk of all – that of not having a plan to reach a goal. The Top Level Risk Matrix can serve as a forcing function to insure the plans address all goals.

		PROGRAM PHASE			
		CE/DV	FSD	PRODUCTION	DEPLOYMENT
TECHNICAL	GOALS				
	STRATEGY				
	RISKS				
PROGRAM	GOALS				
	STRATEGY				
	RISKS				
SUPPORT	GOALS				
	STRATEGY				
	RISKS				
SCHEDULE	GOALS				
	STRATEGY				
	RISKS				
COST	GOALS				
	STRATEGY				
	RISKS				

Figure 4.3-2 Top Level Risk Matrix

Identifying Risks – A simple first step in risk identification is to evaluate the appropriateness of the strategies against the goals. Counterproductive strategies cause risk. The very imperfect world of systems acquisition frequently forces the program manager to do things that are counterproductive or suboptimum. Highlighting these anomalies is a powerful contribution to risk identification.

4.3.2 Preliminary Quantification

After the risk identification process has produced a well documented description of the program risks and before risk analysis begins in earnest, some organization and stratification of the identified risks is beneficial. Preliminary quantification is intended to provide some prioritization of the risks for further evaluation. Heavy mathematical treatment is not desired here.

Rating Schemes and Definitions – The degree of risk existing in a given situation is a reflection of the personality of the risk taker. Twenty people can look at the same situation and assign twenty different risk values to it. A risk rating scheme built against an agreed set of definitions provides a framework for eliminating some of the ambiguity.

The rating system can (and probably should) be very simple – such as High, Medium, Low. Using the notion that the degree of risk is a judgment reflecting the probability of occurrence and the severity of impact. Figure 4.3–3 offers a conceptual diagram for a risk rating mechanism. The definition issue becomes one of identifying impacts and deciding on a scale (s) and then shaping the boundaries between the three regimes.

With a defined risk rating scheme in place (at least tentatively), the task of evaluating and quantifying each of the identified risks may be accomplished against this structure.

Interviewing Experts – The technique of interviewing experts is discussed in detail in Section 5.2. The objective is to gather information from the technical experts that will allow the analyst to rate the risk.

Using Analogies – Analogy comparison is discussed in detail in Section 5.3. It is an attempt to learn from other programs or situations. Analogy comparison is a technique used for many things, e.g., cost estimating. The caution in this case is to differentiate between "analogous programs" and "programs with analogous risks."

4.4 RISK ANALYSIS

4.4.1 Definition and Description

The transition from risk assessment activities to risk analysis activities is gradual. There is some amount of analysis that occurs during the assessment process. For example, if, in the process of interviewing an expert, a risk area is identified, it is logical to pursue information on the magnitude of the risk, the consequences if the risk becomes reality, and the

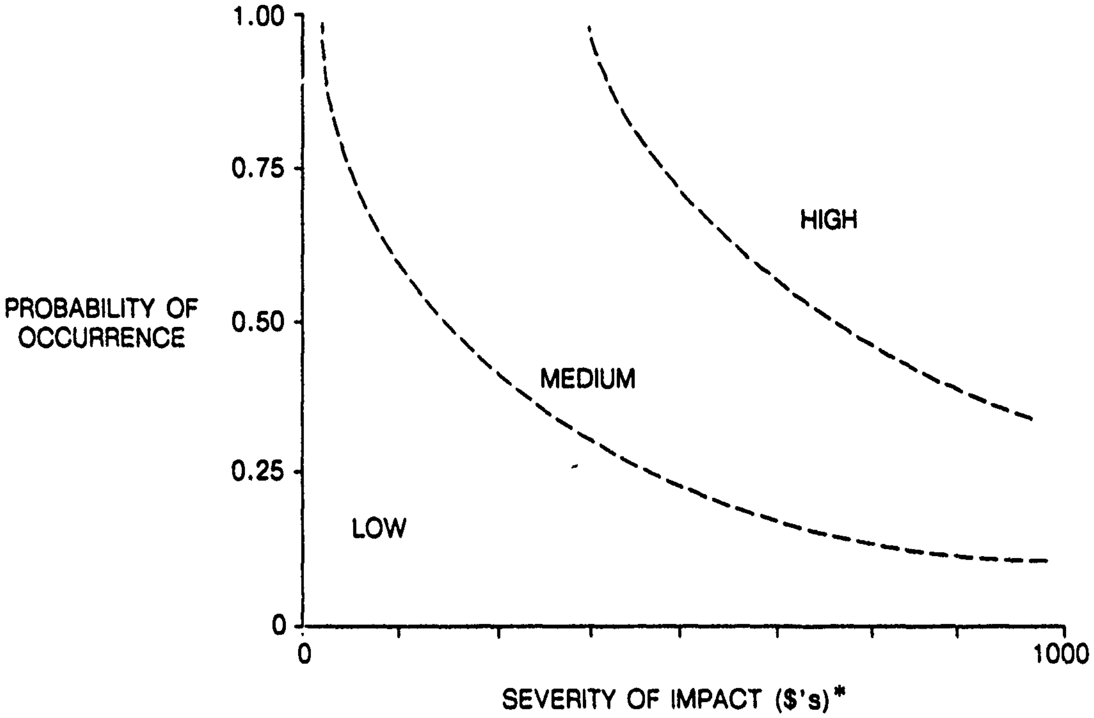

Figure 4.3-3 Risk Rating

* Could be cost, schedule, performance, or some other measurable factor. May also be combinations or multiple scales for each parameter.

possible ways of dealing with it. The latter two actions are generally considered a part of the analysis process but occur during the risk identification activities of a formal risk management effort. This is illustrated in Figure 4.4-1.

As time progresses in a grass roots risk management effort, the risk analysis function grows independent from the assessment function. The process generally becomes more of a top level analysis with the impacts being evaluated against total project/program completion or subsystem completion. Risk Analysis involves an examination of the change in consequences caused by changes in the risk input variables. Sensitivity and "what-if" analysis are examples of the activities that should take place during risk analysis.

4.4.2 Products of Risk Analysis

One of the most useful products of the analysis process is the watchlist. The watchlist serves as the worksheet that managers use for recording risk management progress (Ref 4.2).

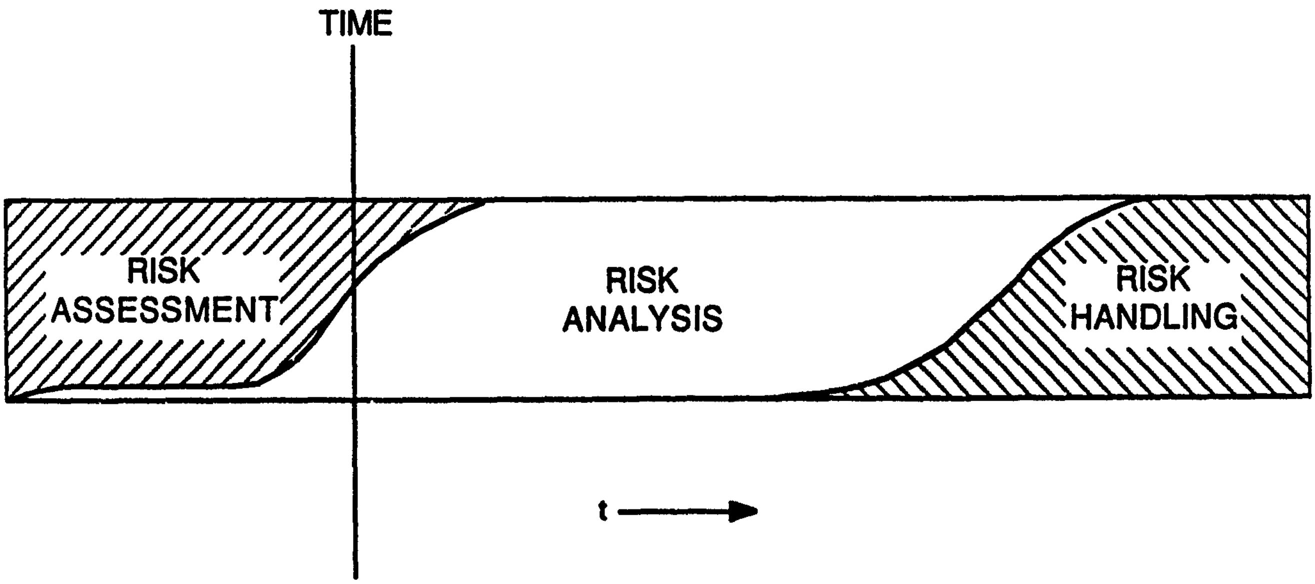

Figure 4.4–1 Process Time Phasing

An example of a watchlist is shown in Figure 4.4–2. Watchlists provide a convenient and necessary form to track and document activities and actions resulting from the risk analysis process. Cumulative probability distribution, another useful product of risk analysis, is illustrated in Figure 4.4–3. The cumulative probability distribution curve is a common, conventional method used to portray cost, schedule, and performance risk. Program management offices can use cumulative probability distributions by determining an appropriate risk level (threshold) for the item and reading from the curve the corresponding target cost, schedule, or performance. This is a typical output of many automated risk tools. Appendix E has a more detailed explanation of probability curves. The results of risk analysis are extremely valuable in presentations to decision–makers. The process of performing risk analysis generally provides an in–depth understanding of the sources and degree of risk and can be quickly portrayed in a few charts. This provides for much more effective presentation/communication to decision-makers of the program/project status. Section 6.5 has suggestions for communicating risk information.

4.5 RISK HANDLING

Risk Handling is the last critical element in the risk management process. It is the action or inaction taken to address the risk issues identified and evaluated in the risk assessment and risk analysis efforts. Generally, these actions fall into one of the following categories.

- Avoidance

EVENT/ITEM	AREA OF IMPACT	HANDLING ACTION
Loss Of Competition	Production Cost	• Break Out • Qualify 2nd Source • Get Tech Data as a Deliverable
Incomplete Logistic Support Analysis	Support Cost	• Contractor Support for 2-3 years • Warranty on High Risk Items • Emphasis in Contractor Reviews • Logistics Reviews
Immature Tech Data Package with many Engineering Changes for Design Fixes	Production Cost with High 1st Unit Cost and many ECPS	• Require Production Engineers on Contractor Design Team • Fixed Price Contract • Competition • Producibility Engineering Planning • Production Readiness Reviews
Long Lead Items Delayed	Production Schedule	• Get Early Identification of Long Lead Items • Contractor Emphasis on Early Delivery • Transfer or Leveling from Less Urgent Programs • Buy a Position in Line for Waiting

Figure 4.4-2 Watchlist Examples

- Control
- Assumption
- Transfer
- Knowledge and research.

4.5.1 Risk Avoidance

The statement "I do not accept this option because of the potentially unfavorable results" reflects what is meant by risk avoidance. There are many situations where a lower risk choice is available from several alternatives. Selecting the lower risk choice represents a risk avoidance decision. This is typical of the evaluation criteria used in source selection. Certainly, not all risk should be avoided in all instances though. There are occasions where a higher risk choice can be deemed more appropriate because of design flexibility, Pre-Planned Product Improvements (P3I), etc.

4.5.2 Risk Control

This is the most common of all risk handling techniques. It is typified by the statement "I am aware of the risk, and I will do my best to mitigate it's occurrence and effect." Risk control is the process of continually monitoring

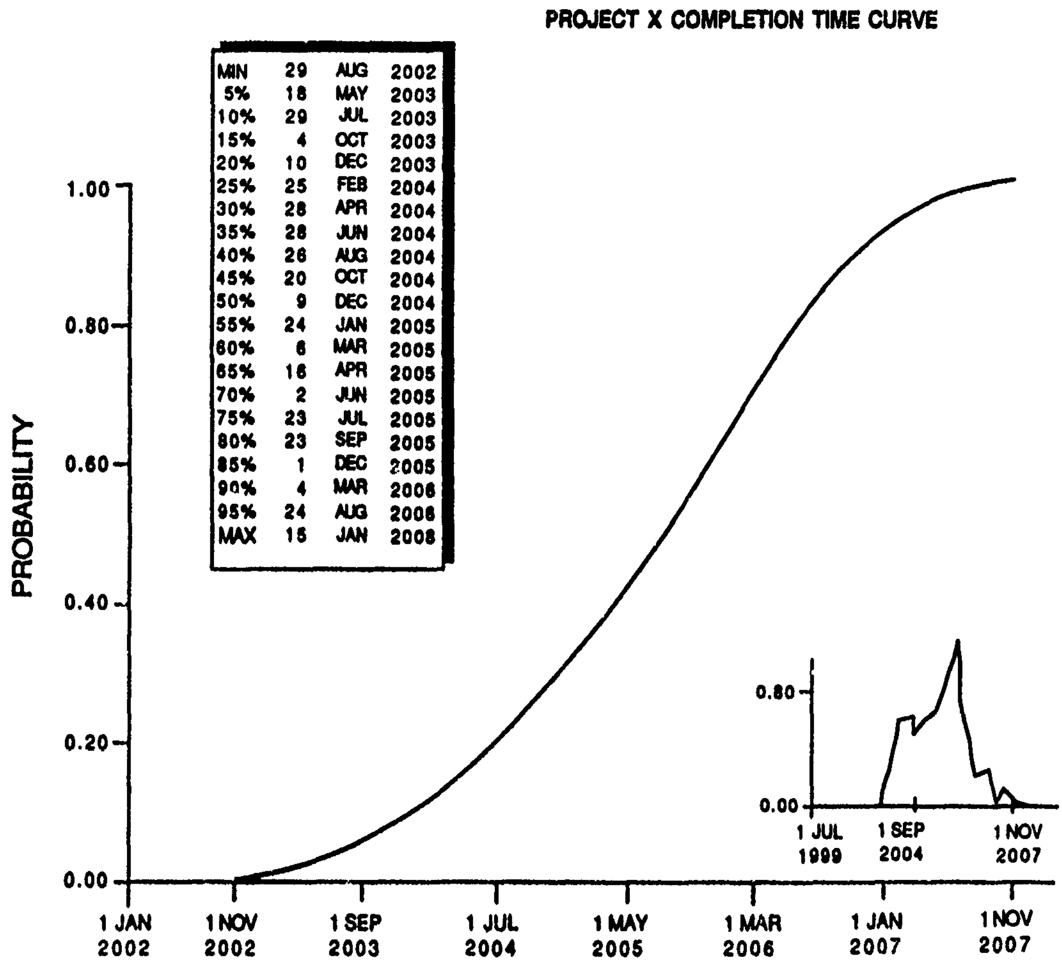

Figure 4.4-3 Cumulative Probability Distribution

and correcting the condition of a program. This often involves the use of reviews, risk reduction milestones, development of fallback positions and similar management actions. Controlling risk involves the development of a risk reduction plan and then tracking to the plan. This includes not only the traditional cost and schedule plans, but also technical performance plans.

4.5.3 Risk Assumption

Risk Assumption is a conscious decision to accept the consequences should the event occur. Some amount of risk assumption is always present in acquisition programs. The program management office must determine the appropriate level of risk that can safely be assumed in each situation as it is presented. An example of risk assumption is permitting programs to have significant amounts of concurrency.

4.5.4 Risk Transfer

There are options available to program offices to reduce risk exposure by sharing risk. There are many ways to share risk with contractors. Type of contract, performance incentives, warranties, etc. are all forms of sharing risk with contractors. Note that many of these only share cost risk. Risk transfer is often beneficial to both the contractor and the government.

4.5.5 Knowledge and Research

While this is not a "true" risk handling technique, it does supply the other methods with valuable information. This is a continuing process that enables the participants to perform risk handling (with the other methods) with greater confidence. It consists of gathering additional information to further assess risk and develop contingency plans.

Risk handling methods are only constrained by the ingenuity and skills contained within the program office. While a conscious decision to ignore (assume) a risk is a viable option, an unconscious decision to do the same is not. A documented action with supporting rationale is recommended in all risk handling options. (Ref. 4-3). Note that the risk handling techniques are not independent of each other. For example, assuming the risk involved in a concurrent program does not preclude the program manager from instituting measures to control inherent risk.

4.6 CHAPTER 4 KEY POINTS

- Risk management is the umbrella function for the key steps
- Risk planning sets out the requirements
- Risk assessment is the process of identifying and quantifying program risks – a well defined rating scheme is critical
- Risk analysis is the process of evaluating program impacts as a results of risk assessment
- Risk handling is the process of executing management actions to mitigate or eliminate the unwanted results of risk
- Risk management is a continual process through all program phases.

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4–3 "Technical Risk Assessment: The Status of Current DoD Efforts," U.S. General Accounting Office, April 1986.

Chapter 5

EXECUTING THE RISK MANAGEMENT PROCESS

Having gained an understanding of the concepts of risk and the structure useful for executing risk management, it is logical to now present some specific techniques that apply to the process.

5.1 INTRODUCTION

All processes require two broad categories of action (Figure 5.1-1):

- Planning
- Execution.

This chapter covers the risk management techniques that have proven useful to both contractors and government program offices in the execution of the risk management process. The planning issues were covered in Section 4.2 and will be reiterated in Chapter 6. There are basically seven steps in the execution portion of risk management as outlined below:

1) Evaluate the achievability of the proposed project against the plan

2) Identify the risk areas

   - Develop a structure to systematically comb through the program and issues (i.e., WBS, checklist)
   - Interview subject area experts
   - Review analogous system data
   - Evaluate the program plans, do they coincide?
   - Examine lessons learned documents (i.e., transition templates, studies, etc.)

3) Quantify the risk areas

   - Develop a consistent scheme for rating risk. Make it quantitative with qualitative backup
   - Assess the likelihood of the risk occurring

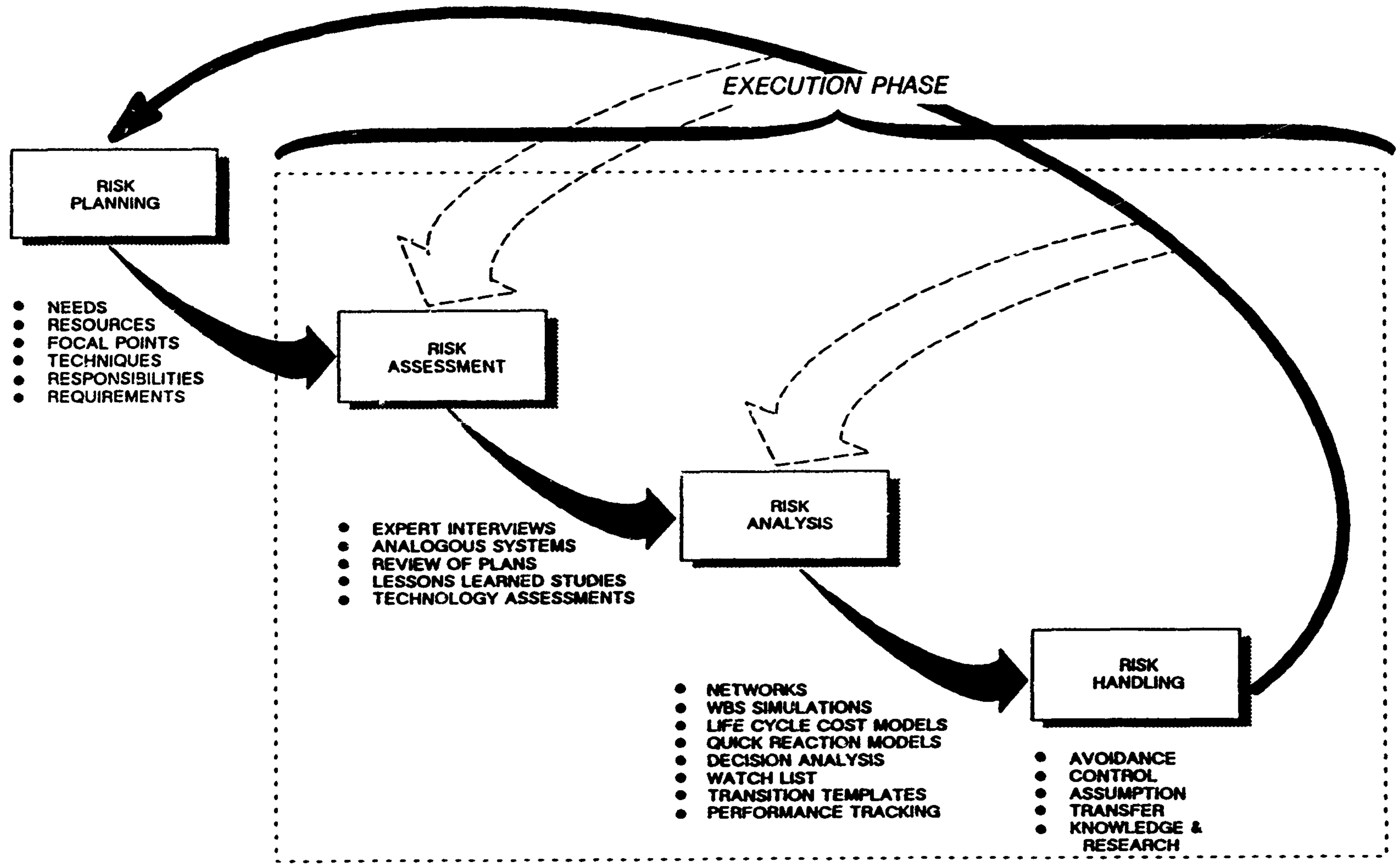

Figure 5.1–1 The Risk Management Process

- Assess the impact severity in terms of cost/schedule/performance

4) Document the risk areas
   - Develop and maintain a management watchlist
   - Develop an effective communication scheme so input from all functional areas is received

5) Utilize an analysis tool designed to meet your specific objectives. Examine the results:
   - In terms of performance/time/cost
   - By system/subsystem
   - Of funding profiles
   - Based on criticality
   - For consistency with analogous systems
   - Of "what-if" analysis

6) Determine the appropriate handling option:
   - Avoid the risk
   - Share the risk with another party
   - Assume the risk
   - Control the risk

7) Implement the appropriate option.

The specific techniques for accomplishing these steps are contained in the following pages of this chapter. Many of the techniques can be used as tools for multiple parts of the process. For example, an in-depth evaluation of a critical path network is very useful for steps 1, 2 and 5 above. It can be used to evaluate *and* identify risks in an approach and serve as an excellent analysis tool. Figure 5.1-2 illustrates which techniques have application in more than one step of the process. The predominant application is represented by a solid circle while secondary applications are represented by a hollow circle.

RISK HANDLING	RISK ANALYSIS	RISK ASSESSMENT	
○	○	●	EXPERT INTERVIEWS 5.2
○	○	●	ANALOGOUS COMPARISONS 5.3
		●	PLAN EVALUATION 5.4
○		●	TRANSITION TEMPLATES 5.5
○	●		DECISION ANALYSIS 5.6
	●	○	ESTIMATING RELATIONSHIP 5.7
○	●	○	NETWORK ANALYSIS 5.8
○	●	○	LIFE CYCLE COST ANALYSIS 5.9
○	●	○	COST RISK/WBS SIMULATION MODEL 5.10
○	●		RISK FACTORS 5.11
○	●	○	PERFORMANCE TRACKING 5.12
○	●	○	COST PERFORMANCE REPORTS ANALYSIS 5.13.1
○	○	●	INDEPENDENT TECHNICAL ASSESSMENT 5.13.2
○	●	○	INDEPENDENT COST ESTIMATES 5.13.3
●			RISK HANDLING TECHNIQUES 5.14
●			RISK AVOIDANCE 5.14, 4.5.1
●			RISK CONTROL 5.14, 4.5.2
●			RISK ASSUMPTION 5.14, 4.5.3
●			RISK TRANSFER 5.14, 4.5.4
●			KNOWLEDGE & RESEARCH 4.5.5

Figure 5.1-2 Technique Application

5.2 EXPERT INTERVIEWS

5.2.1 General

One of the most critical elements or tasks in risk assessment is that of obtaining accurate judgments from technical experts. Unfortunately, this is an area where it is easy to make errors and therefore obtain information that is inaccurate. The interviewing of technical experts to gain information regarding risk is critical for two reasons. First, the information identifies those areas which are perceived as being risky (risk identification). Second, it provides the basis for taking the qualitative information and transforming it into quantitative risk estimates (risk quantification). Reliance on the advice of technical experts is mandatory since all information necessary for an accurate risk assessment usually cannot be derived from previous program data. However, obtaining the information from experts can be frustrating and often lead to less than optimum results.

Nearly all risk analysis techniques require some form of expert judgment input. This makes the acquisition of such judgments extremely important to the overall accuracy of the risk management effort. As previously mentioned, this is a very difficult task to perform, and it is extremely hard to distinguish between "good" and "bad" judgments. This makes the approach and documentation even more important than usual. The program manager or risk analyst performing the effort is likely to get several divergent opinions from many "experts" and he/she must be able to defend the position taken.

5.2.2 Description of Technique

The expert interview technique is relatively straightforward. Basically, it consists of identifying the appropriate expert(s) and methodically questioning them about the risks in their area of expertise as related to the program. There are many methods of accomplishing this as outlined in Appendix F. The technique can also be used with groups of experts. The process is normally aimed at obtaining information on all five facets of risk.

5.2.3 When Applicable

The technique is useful for virtually any program and is recommended for all programs. Expert interviews focus on extracting information about what the program risks are and their relative magnitude. It is most useful in the risk assessment portion of a risk management effort, but it also has application to the other processes as well. When questioning experts about the risks on a program, it is logical to pursue potential handling actions and alternatives as well as information pertaining to the potential impact.

5.2.4 Inputs and Outputs

The technique has two prerequisites (required as input) for application. First, the interviewer must be prepared. The topic must be researched and an interview agenda thought through. Second, the interviewee must be willing to provide the information sought after and be willing to spend the necessary time required to divulge the information to the analyst or manager. The results (output) of such interviews can be qualitative, quantitative, or both. Expert interviews nearly always result in input that can be used in the formulation of a "watchlist". In fact, watchlists frequently evolve from the input of each "expert" functional manager on a program. Another frequently useful output is the formulation of a range of uncertainty or a probability density function for use in any of several risk analysis tools. These can be in terms of cost, schedule, or performance.

5.2.5 Major Steps in Applying the Technique

Since expert interviews result in a collection of subjective judgments, the only real "error" can be in the methodology for collecting the data. If it can be shown that the techniques for collecting the data are not adequate, then the entire risk assessment can become questionable. Unfortunately, there is no sure fire technique for assuring that the data collected is the best possible. The only real assurance can be in the methodology used to collect the data. There are several methodologies available for collecting data, but many must be ruled out because of the time restrictions that usually exist. One combination (there probably are others just as good) which seems to work well consists of the following five steps:

- Identify the right individual
- Prepare for the interview
- Target the interest area
- Solicit judgments and general information
- Quantify the information.

Each of these steps is discussed in the following paragraphs.

Identify the Right Individuals - It is extremely important to identify the correct subject or area expert. If there is any doubt about the level of expertise, it is worthwhile to identify one or two other candidates. It is relatively easy to make a mistake in this area by identifying an expert who knows only a portion of a given area. For example, if you are interested in knowing the risks involved in the test program for a particular project you would want to talk to an expert in the test field. Someone who knows both hardware and software test procedures would be appropriate. The time spent up front identifying the individuals to be interviewed will be well spent. Preliminary phone screens are usually worthwhile. These usually only last about five minutes and can give the analyst a feel as to the level of expertise an individual has as well as helping to focus the questions while preparing for the interview.

Prepare for the Interview - A lot of time can be saved for all parties if there has been adequate preparation by all involved. Some thought should be given as to what areas will be covered during the interview. The methodology for quantifying the expert judgment should be thoroughly understood and rehearsed if necessary. It is much easier to maintain control and direction during the interview if there is an agenda or list of topics to be covered. It is also helpful to understand how the individual expert functions in the organization and how long he has been in the field. It is necessary to keep the ultimate goals of risk identification and quantification in mind while preparing for the interview. This means that there has to be some "open time" during the interview to allow the expert to give the interviewer his/her personal thoughts on areas which may be outside his/her field.

Target the Interest Area – The first portion of the actual interview should be to focus on the previously identified risk areas to obtain verification. This should be kept brief, except where there appears to be a conflict which would require additional information. Next, the interview should move to the individual's area of expertise. This will either confirm that the correct individual is being interviewed or will cause the focus of the interview to change. By targeting the interest area early, more time can be spent within the individual's area of expertise if necessary, or the interview can be changed/ended saving valuable time if there has been an error in identifying the correct individual.

Solicit Judgments and General Information – It is important to let the expert have some time to discuss other areas of the program if he/she desires after completing the target interest areas. If nothing else, the information gained can be used when interviewing in another area to stimulate thoughts and generate another opinion. In many cases an "outside" observer who is involved in the program can identify potential areas of conflict/risk which may not be apparent to the person working in the area where the potential conflict/risk resides. Much of the initial assessment is gained through just a few interviews. This information generally becomes more refined/deleted/expanded as the subject experts are interviewed. Experience has shown that if the expert is cooperative, the information given (even that which is outside the area of expertise), is generally correct. Often additional clarification is required and the expert is unwilling to attempt a quantification but the identification of risk is still valid.

Quantify the Information – This is the most sensitive aspect of any risk analysis. Once the risk areas have been identified, an estimate of their potential impact on the program performance, cost, and schedule must be made. This requires that the expert consider the probability of the given risky event occurring, and what the potential impact may be in terms of performance, cost, and schedule.

5.2.6 Use of Results

Normally, the results of expert interviews feed other techniques or are used in the development of watchlists as described in Section 4.4.2.

5.2.7 Resource Requirements

Interviewing experts requires two specific resources. The first of which is time. While this is one of the most common techniques in use for risk assessment, it is also one which is frequently misapplied because of time limitations. Planned interviews are sometimes shortened or skipped altogether in order to meet other obligations or deadlines by the interviewer and interviewee. A methodical examination of an entire program requires the time of many experts – both from the government and contractor. The second resource requirement is an experienced interviewer. Frequently, experts do not give information which is readily usable for a watchlist or probability density function. Some skill is required to encourage the expert to divulge information in the right format. If an experienced interviewer is not available, the technique can still yield some valuable information if enough time is allocated.

5.2.8 Reliability

When conducted properly, expert interviews provide very reliable qualitative information. The transformation of that qualitative information into quantitative distributions or other measures depends on the skill of the interviewer. The technique is not without problems. Some typical problems that experienced risk analysts have had are listed below.

- Wrong expert identified
- Poor quality information obtained
- Unwillingness of the expert to share information
- Changing opinions
- Conflicting judgments

5.3 ANALOGY COMPARISON/ LESSONS LEARNED STUDIES

5.3.1 General

The "analogy comparison" and "lessons learned" techniques for risk identification and assessment are based on the idea that no new program, no matter how advanced or unique, represents a totally new system. Most "new" programs originated or evolved from already existing programs or simply represent a new combination of existing components or subsystems. A logical extension of this premise is that key insights can be gained concerning the various aspects of a current program's risk, by examining the successes, failures, problems, and solutions of *similar* existing or past programs. The experience and knowledge gained, or "lessons learned" can be applied to the task of identifying potential risk in a program and developing a strategy to handle that risk.

5.3.2 Description of Technique

The analogy comparison and lesson learned techniques involve the identification of past or existing programs that are similar to the Program Management Office (PMO) effort and the review and use of data from these programs in the PMO risk management process. The term "similar" refers to the commonality of the variety of characteristics which defines a program. The analogy may be similar in technology, function, acquisition strategy, manufacturing process, etc. The key is to understand the relationship between the program characteristics and the particular aspect of the program being examined. For example, in many system developments, historic cost data shows a strong positive relationship with technical complexity. Thus when looking for a program in which to analyze cost risk for comparison, it makes sense to examine data from programs with similar function, technology, and technical complexity. The use of data or lessons learned from past programs may be applicable at the system, subsystem or component level. For example, though an existing system's function and quantity produced differ, its processor may be similar in performance characteristics to a current program and thus a valid basis for analogy comparison. Several different programs may be used for comparison to the current project at various levels of the end item.

5.3.3 When Applicable

The application of documented lessons learned or the comparison of old or existing programs to new programs is useful in all phases and aspects of a program. In any situation in which historic data is useful in predicting or anticipating the future, the analogy comparison and lessons learned technique can provide valuable insights into the risk associated with a program. These techniques are especially valuable when a new system is primarily a new combination of existing subsystems, equipment, or components for which recent and complete historical program data is available. When properly done and documented, analogy comparison provides a good understanding of how the program characteristics affect the risk identified and provide a necessary input to many other risk techniques.

5.3.4 Inputs and Outputs

There are three types of data required for use of the technique:

- Description and program characteristics of the new system and its components
- Description and program characteristics of the existing or past programs and their components
- Detailed data for the prior system being reviewed (cost, schedule, performance, etc).

The descriptive data and the program characteristics information is needed to draw valid analogies between the current and past programs. The detailed data is required to evaluate and understand program risks and their potential effect on the current project.

Often technical specialists are needed to help make appropriate comparisons and to help extrapolate or adjust the data from old programs to make inferences about new programs. Technical or program judgments may be needed to adjust findings and data for differences in complexity, performance, physical characteristics or acquisition approaches.

The output from the examination of analogous programs and lessons learned typically becomes the input to other risk assessment and analysis techniques. The review of program lessons learned reports can identify a number of problems to be integrated into a program's watchlist. The length and volatility of past flight test programs is information that would aid in the development of realistic durations in a network analysis of a new program's test schedule. Data from the review of lessons learned and past analogous programs becomes the source of information for the conduct of risk assessment, analysis, and handling techniques.

5.3.5 Major Steps in Applying the Technique

The major steps in the use of analogous system data and lessons learned include the identification of analogous programs, data collection, and analysis of the data gathered. Figure 5.3-1 shows a further breakdown of this process.

The first step is to determine the information needs in this phase of risk management process. This could vary from wanting to assess the risk involved with the development of a custom computer chip for a new application to a broad goal of identifying all of the major risks associated with a program.

The second step is to define the basic characteristics of the new system. This is necessary in order to identify past programs that are similar in technology, function, design, etc. With the new system generally defined the analyst can begin to identify programs with similar attributes for comparison and analysis.

The next steps in this process, being interdependent, are generally done in parallel. The key to the usefulness of analogy comparison is the availability of data on past programs. The new system is broken down into logical components for comparison, while assessing the availability of historical data. There is no use in analyzing a system at a detailed component level against past efforts if that same level of detailed information is not available in past programs. Based on the availability of data, the information needs of the process, and the logical structure of the program, analogous systems are selected and data gathered.

The data gathered for comparison includes the detailed information being analyzed as well as the general characteristics and descriptions of the past programs. The general program descriptive data is essential to insure proper analogies are being drawn and a clear understanding of the relationship between these characteristics and the detailed data being gathered is understood. For the analogy to be valid, there must be some relationship between the characteristic being used to make comparisons and the specific aspect of the program being examined. For example, if there is no basis for relating weight to schedule, weight of the system is a suspect basis for drawing an analogy while doing a schedule assessment.

Often the data collection process and initial assessment leads to a further definition of the system for the purposes of comparison. After this has been accomplished, the last step in the process is the analysis and normalization of the historic data. Comparisons to older systems may not be exact or the data may need to

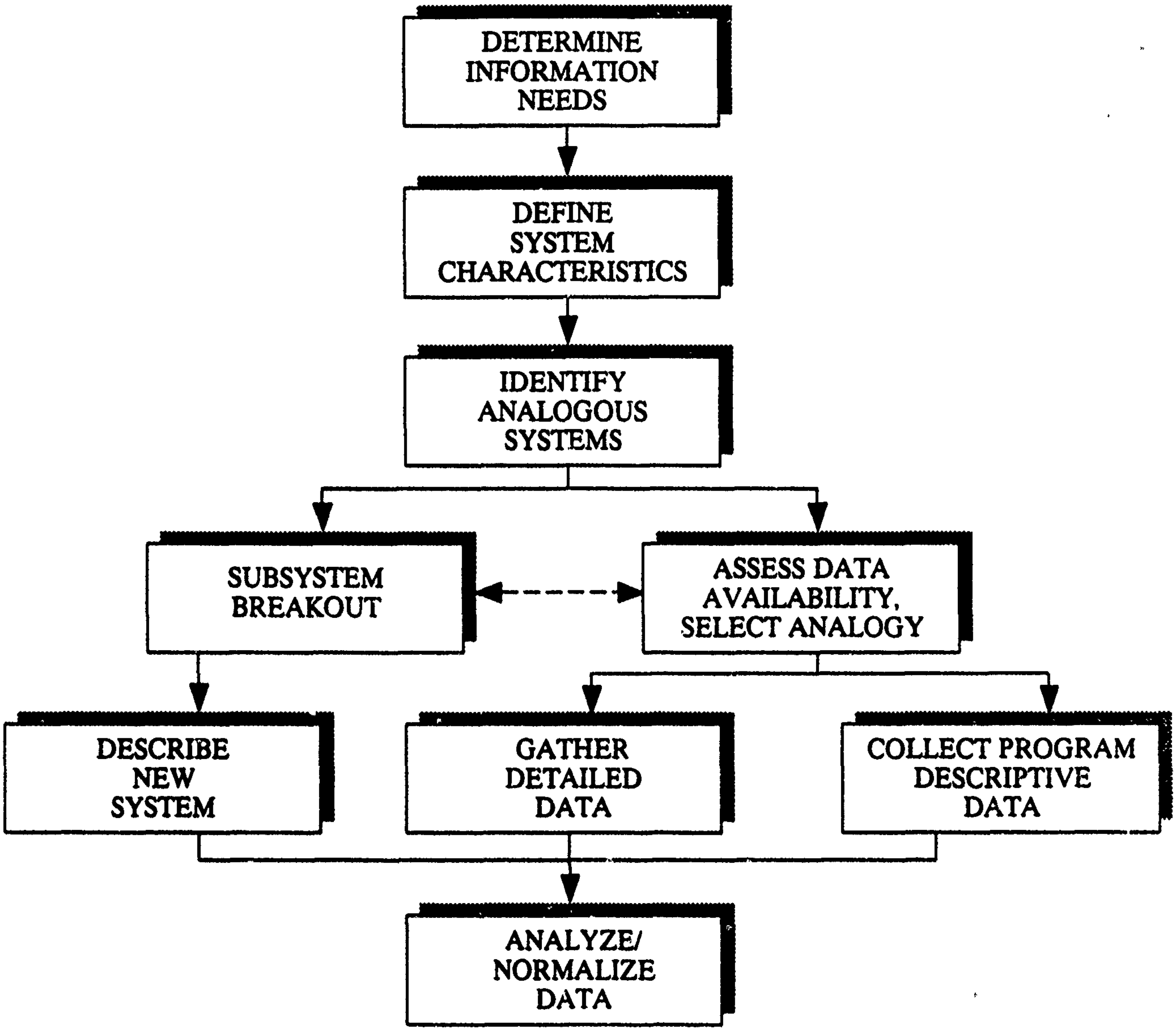

Figure 5.3-1 Analogy Comparison

be adjusted to be used as a basis for estimating the future. For example, in analogy based cost estimating, cost data must be adjusted for inflation, overhead rates, G&A, etc. for accurate comparison. Technical assistance is frequently needed to adjust the data for differences in past versus the current program. The desired output is some insight into the cost, schedule, and technical risks of a program based on observations of similar past programs.

5.3.6 Use of Results

As stated earlier, the output from analogy comparison or the review of lessons learned typically feed other risk techniques. The results may provide a checklist of factors to monitor for the development of problems or a range of cost factors for use in estimating (for example, software lines of code). The results of analogy comparison and lessons learned is risk information. Whether the information is used in a detailed estimate, technology trade-off study or at a system level for a quick test of reasonableness, the results are intended to provide the analyst with information on which to conduct analyses and ultimately base decisions.

5.3.7 Resource Requirements

The use of analogous data and lessons learned studies to gather risk data is a relatively easy task. The selection of proper comparisons and the analysis of the data gathered may require some technical assistance and judgment, but probably not beyond the capabilities of the Program Management Office. The time and effort to accomplish an analogy comparison however, can vary widely. The resources needed are dependent on the depth of the data gathering, the number of different programs, and the availability of historic data. Much effort can be expended gathering a little information. That is why an initial assessment of data availability is important in the selection of analogous programs for comparison.

5.3.8 Reliability

There are two limitations to the use of analogy comparisons and lessons learned. The first, the availability of data, has already been discussed. The absence of program characteristics or detailed data about the new or old system limits the usefulness of the data collected. The second limitation deals with the accuracy of the analogy drawn. An older system may be somewhat similar, but rapid changes in technology, manufacturing, etc., may make comparisons to past programs inappropriate.

5.4 PLAN EVALUATION

5.4.1 General

This technique is directed at highlighting and isolating risks caused by disparities in planning. It evaluates program plans for contradictions and voids. The term "plan" as used in this case means the traditional formal plans to govern the acquisition of a major system. These include:

- Program Management Plan (PMP)
- Systems Engineering Management Plan (SEMP)
- Acquisition Plan (AP)
- Test and Evaluation Master Plan (TEMP)
- Manufacturing Plan (MP)
- Integrated Logistics Support Plan (ILSP)

Other documents, not normally thought of as plans, but key to the success of a program are:

- Work Breakdown Structure (WBS) Index and Dictionary
- Specifications and the Specification Tree

- Statements of Work
- Other "Baseline" Documents

While the first group of plans document the steps in the execution of the program, the latter represent the absolutely critical communication with the contractor(s) about what is to be done. Flaws, inconsistencies, contradictions, and voids in these documents guarantee program problems and introduce significant risk. Figure 5.4-1 illustrates the linkage between the three key documents.

5.4.2 Description of Technique

This technique simply suggests a thorough recurring review of all plans:

- Internally for correctness, completeness, and currency
- Cross check for consistency.

Using the Work Breakdown Structure for Risk Identification - The proper development of a WBS represents in itself a major step in risk avoidance. It constitutes much of the program definition. Its quality, indeed its very existence, provides the framework for planning that sets the standard for the future of the program.

The end result of the WBS development process is the Project WBS. A careful questioning of the Project WBS is appropriate.

- Are all elements of the WBS necessary and sufficient?
- Is there a WBS dictionary and does it adequately explain the content of each element?
- Does the WBS represent what is to be done rather than who is to do it?
- Are all elements of the project WBS present?

  Summary WBS

  Project Summary WBS

  Contract WBS

  Contractor Extension of the Contract WBS.

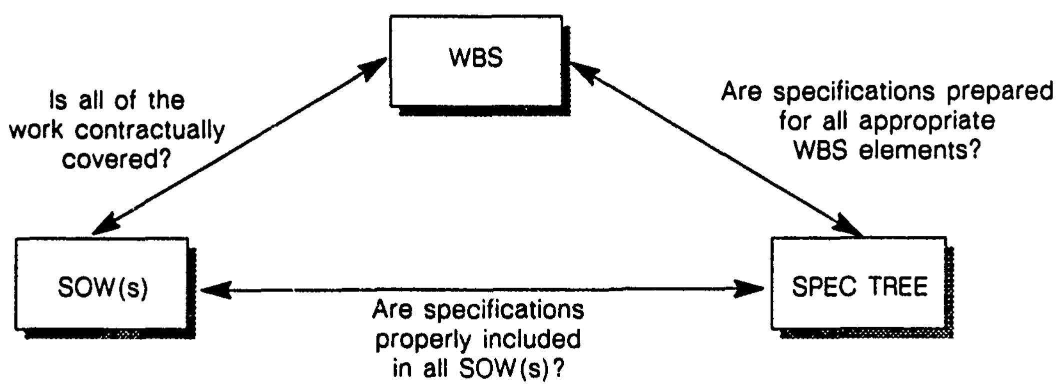

Figure 5.4-1 Plan Evaluation Technique

- Is the procurement strategy reflected in the project WBS?
- Is there any "work" to be done that is not in the WBS?

The WBS offers a framework for organizing and displaying risk factors. The technique of downward allocation and upward summarization through the WBS can be used to highlight discrepancies in most of the program's performance parameters such as weight, electrical power, cooling requirements, system reliability, and cost.

The WBS provides a sensible structure for treating technical risk. A systematic review of each WBS element for risk identification and preliminary rating as discussed in Section 4.3 will yield much information to the risk analyst.

The relationship between the Work Breakdown Structure and the Specification Tree is so important that mapping the relationship is a valuable exercise for the risk analyst. The mapping will highlight inconsistencies between the "work to be done" and the "performance to be achieved".

Figure 5.4–2 illustrates the fact that the project WBS eventually becomes the aggregate of contract WBSs and the contractor's extension thereof which includes subcontractors WBSs. The risk analyst should review the WBS with the question "who is doing what?" as a test of reasonableness of the procurement/contracting strategy. Finally, the WBS represents the framework for cost and schedule performance. A survey of both the cost and the schedule reporting against the WBS identifies possible blind spots in cost and schedule information. As part of this survey, the analyst can gain valuable insights by comparing the numbering schemes for the WBS, the scheduling system(s), and the cost reporting system(s). Ease of translation between and ease of summarization within each of these numbering systems is an indicator of how well traceability among the WBS, schedules, and cost data can be maintained. Incompatibility introduces management risk into the program.

Using Specifications and the Specification Tree for Risk Identification – Some of the discussion above deals with the very important relationship between the WBS and the Spec Tree and the need for compatibility. When that compatibility exists, it is possible to relate the performance to be achieved to the work to be done. Since the specifications represent the source of all technical performance requirements, they are the single most important source of information for the risk analyst attempting to identify, organize, and display items of technical risk. Each performance parameter of a given WBS element represents a possible focus for an expert interview on technical risk.

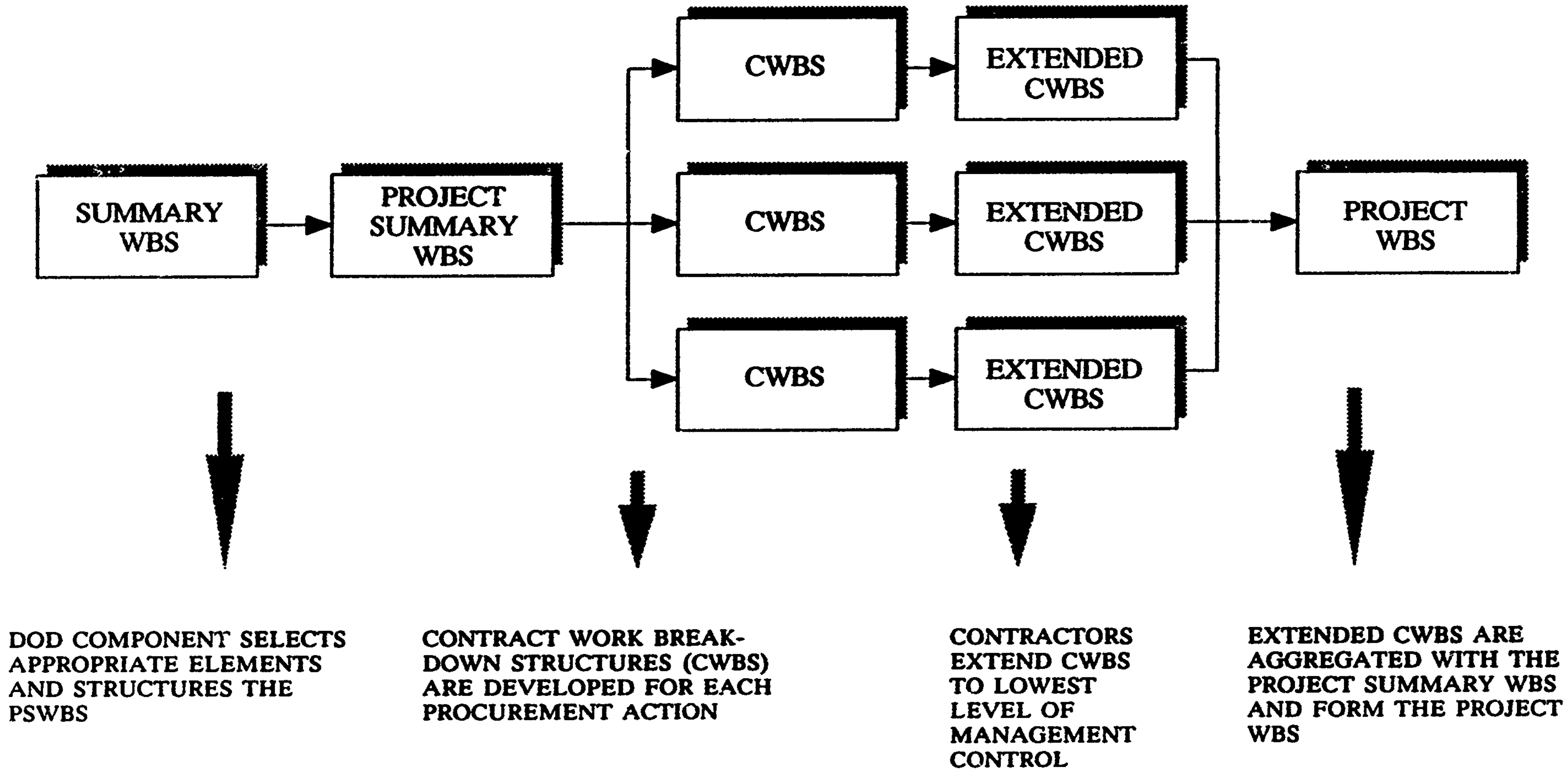

Figure 5.4–2 WBS Preparation/Development

As with the WBS, a survey of the specifications and the specification tree is appropriate for risk identification.

- Does the Spec Tree overlay the WBS so that performance requirements are specified for "whole" WBS elements?
- Are all performance parameters identified even though they may not be specified (i.e., given a discrete value)?
- Is it possible to sensibly discuss the risk of achieving the specified value for the performance parameter?
- Is there a technical performance measurement scheme for each performance parameter?

Using Statement(s) of Work for Risk Identification – The Statement of Work is the single most important communication between the program manager (who wants results) and the contractor (who has to produce the results). If the WBS and the specifications are complete and well done, statements of work are fairly straight forward. The risk analyst is primarily searching for gaps in coverage, (i.e., work and performance requirements that have not been assigned to someone (contractor)).

- Do the SOWs cover whole pieces of the WBS that can be evaluated against whole specifications?
- Do the SOWs represent work that can be contracted in a straight forward manner or will the contracts be politically, legally, or contractually difficult to execute and manage?
- Is all of the work contractually covered?
- Are the SOW requirements properly related to the specifications?

Developing a Technical Risk Dictionary – The concept of dictionaries is understood and fairly well institutionalized in DoD acquisition program offices. The WBS dictionary is well known and well established. More recently, program offices are using the idea of a schedule dictionary to provide the definition of the activities in the program schedule and the assumption that leads to their durations.

This Section 5.4.2 has thus far dealt with a body of information that represents the documented description of the sum and substance of an acquisition program. A technical risk dictionary as conceptualized in Figure 5.4–3 offers a way for the risk analyst to gather this information in a single place in order to facilitate the risk identification/definition process.

The creation of a technical risk dictionary would have been a formidable editorial task until recently. Current word processing and database management software should make the bulk of the task one of electronic cut and paste. Indeed, if document and paragraph numbering are done with a view of interchangeability of data, the technical risk dictionary could be quickly created with a single utility program. This of course applies to the technical content, performance, and task sections of the

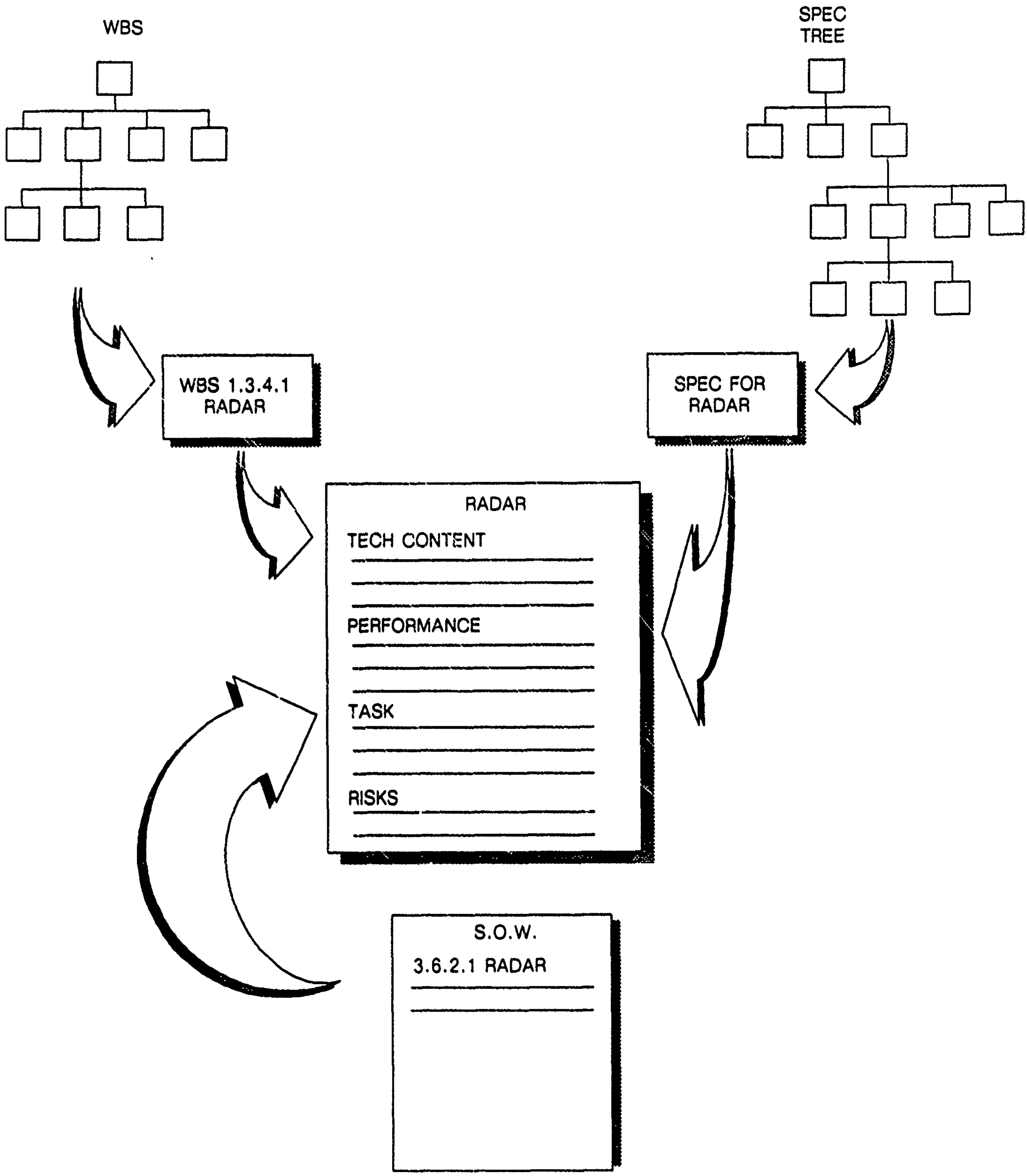

Figure 5.4–3 Technical Risk Dictionary

dictionary which serve as background material for the risk section. The risk section represents original thought contained only in this document.

Defense Systems Management College is engaged in an effort to develop automated tools for the program manager. Two of these, the Automated Program Planning Documentation Model (APPDM), and the Procurement Document Generator (PDG) are intended to aid in the creation and maintenance of the large volumes of textual material required by a typical program office. One of the elements of APPDM is a model Risk Management Plan (discussed in Section 4.2). An extension of this capability to produce a technical risk dictionary is easily within reach.

Using Other Plans for Risk Identification – In Section 4.3.1, the use of a Top Level Risk Matrix to highlight and isolate risks was discussed. It relies heavily on goal definition and strategy development. The presumption is that the strategies expressed in the program plans are directed at meeting the program goals. Comparing the two is a way to identify risks. The same thought process can be applied to produce lower level risk matrices for each of the respective plans (e.g., the TEMP in FSD).

Some particularly astute program managers are formally including discussions of risk within the program plans (as it should be) – either as a section in each chapter or as a separate chapter.

Summary

In the ideal world, where a program management office is staffed with seasoned professionals of long tenure, the Plan Evaluation technique would produce very little results for a large effort. All of the planning documents would have been created in the proper sequence; each with reference to all that preceded it. Eminently logical contracts would have been let with masterful work statements and perfect specifications. In reality, tenure in a program office is very short, planning documents are prepared simultaneously or out of order by a cast of people having a wide range of experience, both totally and within the particular program. Corporate memory is very short and in the early stages when most of the planning is accomplished, most program management offices are grossly undermanned. Therefore, the Plan Evaluation technique is very useful in program management.

5.4.3 When Applicable

This technique is specifically directed at risk identification. It is best used for technical, programmatic, and supportability risk identification. Its utility for cost and schedule risk is considerably less. However, this technique could indicate any missing information concerning deliverables which would impact cost and schedule risks. It is most applicable to the full scale development and production phases of a program. As a risk identification technique, it requires the existence of the plans to be evaluated. As a risk avoidance tool, it can be used during the program planning process.

5.4.4 Inputs and Outputs

The technique operates on the collective body of documentation broadly referred to as "program plans". This includes primarily those documents listed in Section 5.4.1. The output of the technique will typically be:

- A top level risk matrix
- Lower level risk matrices
- A technical risk dictionary
- Updated version of the program plans

5.4.5 Major Steps in Applying the Technique

- Evaluate WBS:
  - Completeness
  - Correctness
- Evaluate Spec Tree:
  - Completeness
  - Correctness
  - Compatibility with WBS
- Evaluate SOWs:
  - Completeness
  - Correctness
  - Compatibility with WBS
  - Inclusion of spec references
- Other plans:
  - Develop lower level risk matrix for each.

5.4.6 Use of Results

The results of this technique are best used to improve the quality and reduce the risks contained in the program plans. The technique also produces descriptive documentation of the technical, performance, programmatic, and supportability risks associated with the program. The technical risk dictionary describes the technical risks and isolates their location. The program manager should use this technique to produce a single, more or less "official" list of program risks that will receive active management attention (i.e., a Watchlist).

5.4.7 Resource Requirements

This technique requires a great deal of thought. It requires experienced, knowledgeable personnel who are intimately familiar with the content of the total program. The deputy program manager leading a small team of senior individuals probably represents the best means of executing this technique.

5.4.8 Reliability

The reliability of this technique is driven by the completeness and far-sightedness of the program plans. The relationship is an inverse one – the better the plans, the fewer the planning risks uncovered.

The major caution for the user of this technique is to not try to force detailed program definition too early. Some inconsistencies exist because of poor planning, others due to a legitimate lack of information.

5.5 TRANSITION TEMPLATES

5.5.1 General

This technique is based on the work performed by the Task Force on "Transition from

Development to Production". Their efforts resulted in publication of DoDD 4245.7–M, "Transition from Development to Production... Solving the Risk Equation", September 1985. This manual is recommended reading for all program managers. It includes extensive work on the identification of program pitfalls based on solid experience. The focus of the book is on disciplined engineering and its impact on the entire management process through all phases of a program. There is also a companion manual, NAVSO P-6671, "Best Practices, How to Avoid Surprises in the World's Most Complicated Technical Process", November 1985. This second document identifies specific practices in use and their potentially adverse consequences. The book then describes the "best practices" which avoid or alleviate these consequences.

5.5.2 Description of Technique

The technique consists of examining a series of "templates" that cover specific areas that may present technical risk to a program. Each template examines an area of risk and then describes methods for avoiding or reducing that risk. Much of the description of the risk and the solution is based on lessons learned from other programs. The areas covered by the templates is illustrated in Figure 5.5–1.

5.5.3 When Applicable

This technique should be used for most programs – either independently or in conjunction with another technique. The information contained within the templates is extremely valuable to all program managers because it is based on actual experiences. The information can be useful for any size program at any phase of development. Since the technique views the acquisition process as a complete process (that is design, test, and production are integral parts of a whole system), the solutions presented reflect the interdependency of each part of the development cycle. In other words, a conscious effort is made to present a solution that lowers the total risk for the entire program – not just the short term problem. NAVAIR frequently uses the templates in the RFP process by requesting contractors to provide information on the templates believed to be applicable to their program.

5.5.4 Inputs and Outputs

Since the technique is not a model, it requires no formal inputs. What it does require is discipline. Some amount of time must be spent in reading the manual and using it to examine risk within a given program. A practical output of the technique was the watchlist which was described in Section 4.4.2.

5.5.5 Major Steps in Applying the Technique

Since the templates cover areas common in nearly every program it is suggested that each template be utilized. After reading the material, individuals and/or groups should evaluate themselves in relationship to the solutions/risk mitigating actions suggested in the

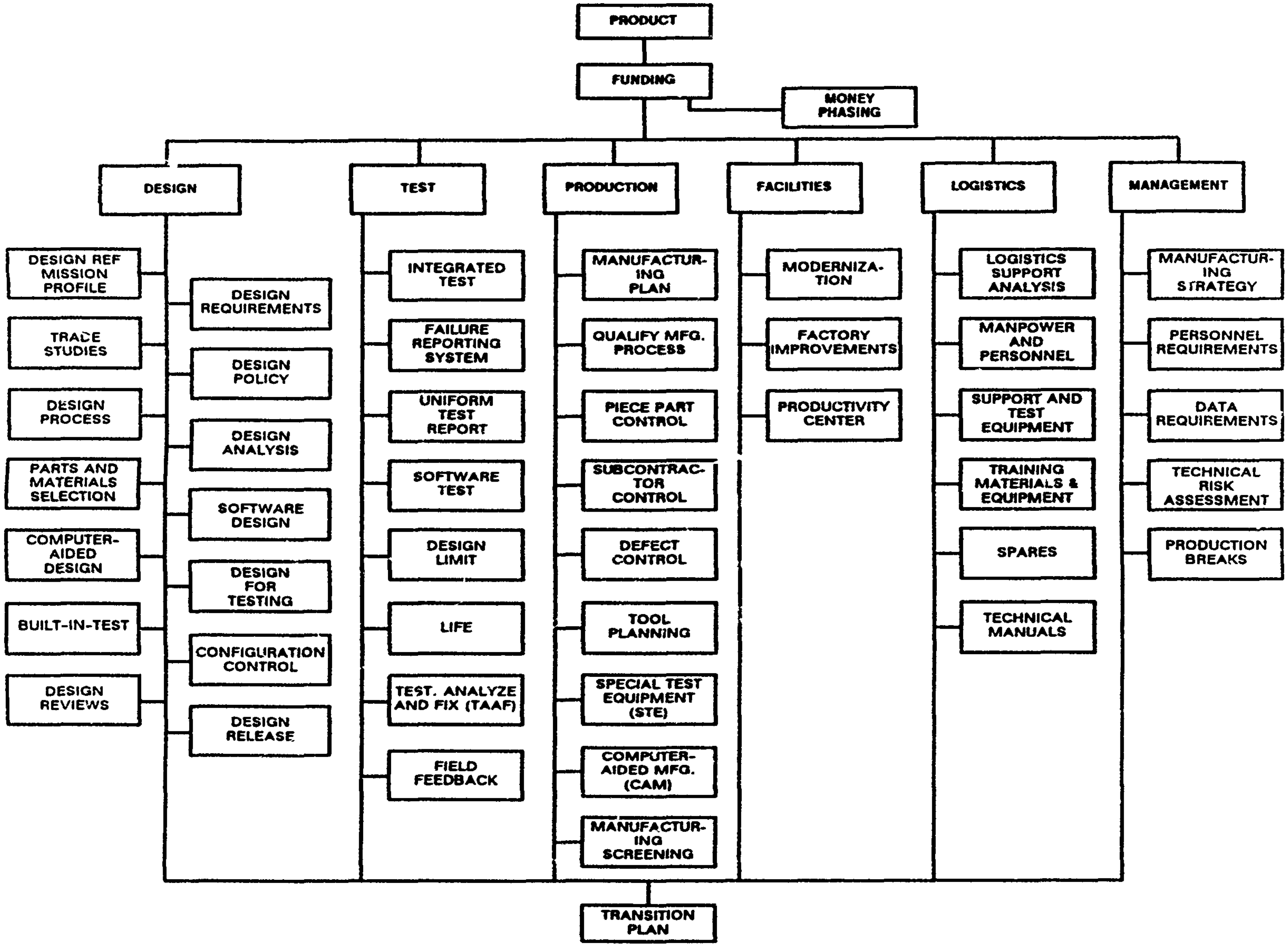

Figure 5.5-1 Critical Path Templates

template. For those areas that are potential "show stoppers", a separate watchlist should be developed and maintained. A semi-annual review of all templates is recommended with updates as the program progresses.

5.5.6 Use of Results

The results from the transition templates can be used in several ways: 1) They can be used in presentations to higher levels of authority; 2) They can be used to influence the contractors current level of activity in an area; 3) They can be used for continued monitoring of progress in each element.

5.5.7 Resource Requirements

Generally, the templates require that the program manager be involved in the risk identification process. Inputs should be provided by all functional managers. The use of the templates is *not* intended to require substantial special skills or extra resources.

5.5.8 Reliability

Two cautions are applicable when using this technique:

- Do not assume that the templates contain all possible technical risks within a given area. While the common problems are identified, this is not an exhaustive list.
- The templates do not contain information regarding several of the programmatic risk areas that should also be examined for risk.

5.6 DECISION ANALYSIS

5.6.1 General

Decision analysis can be used to determine optional strategies when a decision maker is faced with several decision alternatives and an uncertain or risk filled pattern of future events. Before selecting a specific decision analysis technique, the type of decision-making situation that will be encountered must be considered. The classification method for decision-making situations is based upon the knowledge the decision maker has about those future events which are beyond the decision maker's control (known as states of nature). With this in mind, there are two types of decision-making situations.

1) Decision-making under certainty - The process of choosing a decision alternative when the states of nature are known.
2) Decision-making under uncertainty - The process of choosing a decision alternative where the states of nature are unknown.

The decision analysis techniques appropriate for risk assessment are those which take into consideration that the decisions are made under uncertainty.

In many situations where good probability estimates can be developed for the states of nature, the Expected Monetary Value (EMV) method is a popular technique for making decisions. In some situations of decision-making under uncertainty, the decision-maker may have very little confidence in his or her ability to assess the probabilities of the various states of nature. In such cases, the decision-maker might prefer to choose a decision criterion that does not require any knowledge of the probabilities of the states of nature.

5.6.2 Description of Technique

In general, there are three steps in formulating a decision theory problem using the EMV method.

1) The initial step in the decision theory approach is the definition of the problem.
2) For a given problem situation, identify the alternatives that may be considered by the decision-maker. The alternatives which are feasible to the decision maker may be denoted by d_i.
3) Identify those relevant future events which might occur and are beyond the control of the decision-maker. These are referred to as states of nature and may be denoted by s_j.

In decision theory terminology, a particular outcome resulting from a certain decision and the occurrence of a particular state of nature is referred to as the payoff. $V(d_i, s_j)$ denotes the payoff associated with decision alternative d_i and state of nature s_j.

5.6.3 When Applicable

The EMV model is applicable during any phase of a program, although it would typically be generated at the onset of the program to identify the probabilistic courses of action the program may take. Since decision analysis models can be portrayed as decision trees (Figure 5.6-1), it can be applied to network analysis. Probabilistic branching in a network is an example of using decision analysis in a network analysis framework.

5.6.4 Inputs and Outputs

The inputs to the EMV model consist of the decision alternatives to be considered, the states of nature associated with the decision alternatives and the probability of occurrence for each state of nature. The outputs of the EMV method are the expected monetary values for each of the decision alternatives under consideration.

5.6.5 Major Steps in Applying the Technique

The Expected Monetary Value (EMV) criterion requires that the analyst compute the expected value for each alternative and then select the alternative yielding the best expected value. let:

Let: $P(s_j)$ = probability of occurrence for the state of nature s_j

N = number of possible states of nature.

Since one and only one of the N states of nature can occur, provided the analyst provides disjoint options, the associated probabilities must satisfy the following conditions:

$$P(s_j) \geq 0 \text{ for all states of nature } j$$

$$\sum_{j=1}^{n} P(s_j) = P(s_1) + P(s_2) + \ldots + P(s_n) = 1$$

The expected monetary value of a decision alternative d_i is given by:

$$EMV(d_i) = \sum_{j=1}^{n} P(s_j) V(d_i, s_j)$$

In other words, the expected monetary value of a decision alternative is the sum of the product of the payoffs with their respective probabilities. The percentage value for a payoff is the probability of the associated state of nature and therefore, the probability the payoff occurs. The following is an example situation in which the EMV model can be used to make a decision.

SAMPLE PROBLEM

Consider the following example of whether or not to conduct 100% final system tests on a ground based radar system for which production has been reinstated for a quantity of 500. Historically, the radars failure rate, once in the field, has been 4%. The cost to subject each radar to the required tests is $10,000 per radar (total cost = $5 million). Also, the nature of the tests are such that each radar tested will have to undergo some degree of rework. Historically, the cost to reassemble/reinstall each radar, that passes the tests, has averaged $2,000. However, the cost to repair a radar which has failed acceptance tests is $23,000. Once in the field, however, the total cost associated with repairing a defective radar system escalates to $350,000 per radar. With this scenario in mind, the question is whether or not it is more cost effective to conduct 100% testing on the radars or to accept 4% failures in the field.

A decision table can be constructed which will portray this problem with respect to two decision alternatives and the respective states of nature. Table 5.6-1 depicts the decision table for this problem and the associated analysis.

From the decision table, the analyst can depict the problem in the form of a decision tree, which completely portrays the decision (See Figure 5.6-1). Although the tree itself may never be drawn, all relevant events must be listed and an analysis made to determine problems that can occur during each phase of the process of arrival at the decision points. Experts are consulted to identify each problem and possible problem resolutions which can be considered and to assign probabilities to the various problems and resolutions. Any realistic and convenient number of sequential resolution efforts can be postulated.

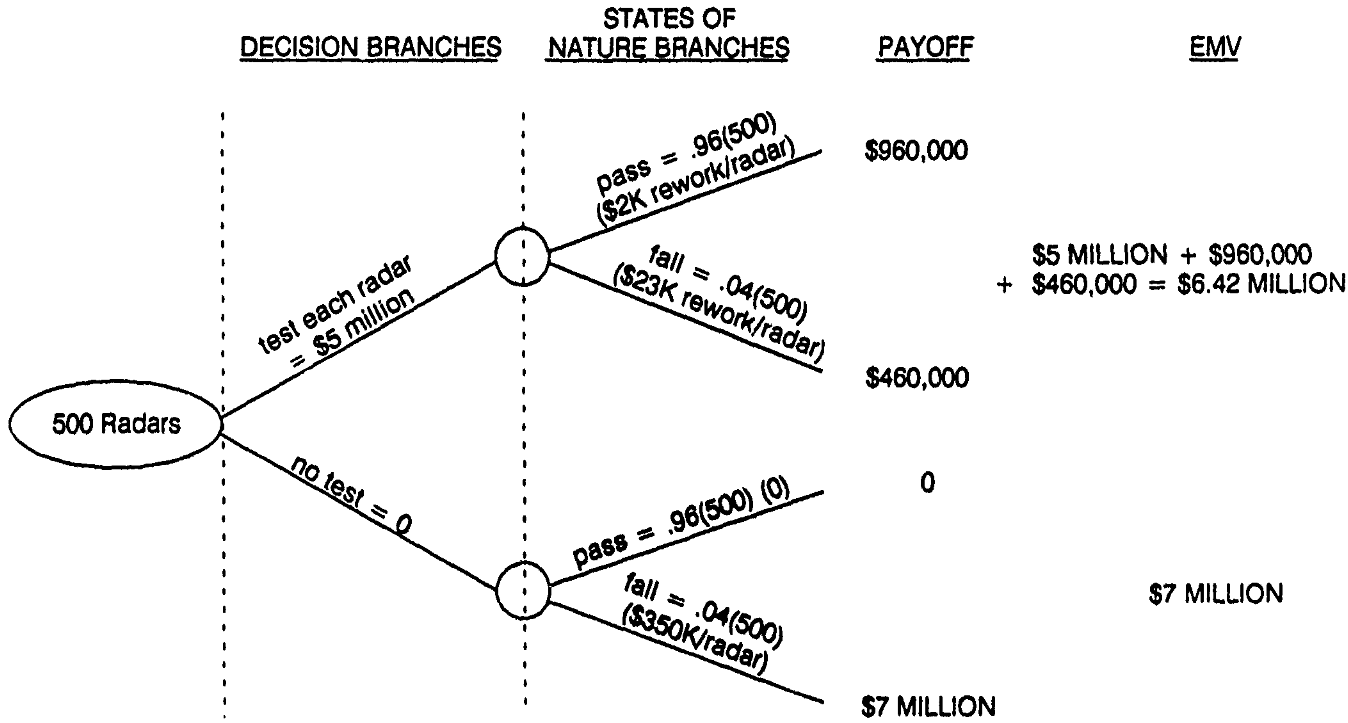

Figure 5.6-1 Decision Tree

Table 5.6-1 **Decision Table**

DECISION ALTERNATIVES	STATES OF NATURE: FAIL $P(S_1) = .04$	STATES OF NATURE: PASS $P(S_2) = .96$
TEST EACH RADAR d_1 = $5,000,000	500 Radars (.04 failures) ($23K rework/radars)	500 Radars (.96 pass) ($2000 rework/radars)
NO TEST d_2 = 0	.04 failures(500 radars) ($350K/radars)	0

Analysis:

EMV (test) = 500 radars ($10,000 test/radar) + 500 radars (.04 failures) ($23K rework/radar) + 500 radars (.96 pass) ($2,000 rework/radar) = $6.42 million

EMV (no test) = .04 failures in field (500 radars) ($350,000/radar) = $7 million

Since objective is to minimize cost, decision would be to test radars.

5.6.6 Use of Results

Given the expected monetary values of the decision alternatives, the analyst's selection of the appropriate alternative is predicated on whether the objective is to maximize profit or to minimize cost. For the sample problem, since the objective was to minimize cost, the analyst would select the alternative with the lowest EMV. When the difference between one or more decision alternatives is small, other programmatic factors may be taken into consideration when making the decision.

5.6.7 Resource Requirements

With respect to resource requirements, the EMV technique is simplistic and can usually be easily calculated once the inputs to the model have been obtained. As the decision problem being modeled becomes more complex, with an increasing number of decision alternatives and states of nature, the time required to create a decision table or a decision tree will also increase.

5.6.8 Reliability of Results

One of the most attractive features of the EMV method of decision analysis is that once the respective inputs to the model have been obtained, there is no ambiguity insofar as the analysis is concerned. The reliability of the results are predicated on the validity of the inputs to the model; that is, with what degree of accuracy the analyst/experts can define all the relevant decision alternatives, states of nature, and respective probabilities.

Another significant benefit of the EMV method is that it diagrammatically portrays the decision alternatives and the associated analysis, making it easier to conceptually understand the problem, the alternatives, and the analysis.

5.7 ESTIMATING RELATIONSHIP

5.7.1 General

The estimating relationship method enables program office personnel to evaluate a program, and based thereon, use an equation to determine an appropriate management reserve or risk funds budget. When using this method, the management reserve funds represent the amount of funding, over and above that determined by cost analysis alone, required for work associated with unanticipated risks. This method was originally developed and is still used for contract, not program costs. The management reserve funds requirement computed is usually expressed as a percentage of the baseline cost estimate. The technique is called an estimating relationship method because it uses some of the same techniques associated with cost estimating relationships (CERs), used in parametric cost estimating.

5.7.2 Description of Technique

The cost estimating relationship method is based on the observation that costs of systems seem to correlate with design or performance variables. The independent variables, often called explanatory variables, are analyzed using regression analysis to describe the underlying mechanism relating such variables to cost. This approach to cost estimating, also called parametric cost estimating, is widely accepted and, even for complex functions, is easy to apply.

This ease of application makes it natural to attempt to use the same techniques to estimate the costs resulting from risks. The approach attempts to discover acquisition program or contract characteristics, as explanatory variables, which can then be correlated with the historically demonstrated need for management reserve or risk funds. Regression analysis using "actual" management reserve funds from past programs, expressed as a percent of total costs, is performed to develop an equation with which to estimate management reserve fund requirements for a new program, not in a database.

The application of this technique is described in Section 5.7.5. In the example describing the application of this technique, four program and prime contractor characteristics, which are known to affect the level of uncertainty, are evaluated by PMO personnel. Each characteristic is assigned a value based on a different scale provided for each characteristic. The four characteristics used are *Engineering Complexity* (zero to five), *Contractor Proficiency/Experience* (zero to three), *Degree of System Definition* (zero to three), and *Multiple Users* (zero or one). The sum of these numerics is entered as the value X, in an estimating equation such as Equation 5.7-1.

$$y = (0.192 - 0.037\ X + .009\ X^2) \times 100$$

Equation 5.7-1 (Ref 5-1)

This formula determines the percentage management reserve requirement, y. The particular model shown in this example is usable only for X values between 2 and 10. Lower values indicate essentially no need for management reserve funds.

5.7.3 When Applicable

This method of estimating the additional funding needed to cover anticipated risks has limited application. First it can only be used if the research has already been done to establish a valid historical relationship between the key program or contract characteristics of similar programs, and management reserve funding requirements. This was done at the USAF Electronics Systems Division (Ref. 5-1). However, no other DoD users of this type of method were found during preparation of the risk handbook. The method is most applicable in the circumstances where good historical program description and management reserve funding requirements are available for several similar programs. If the required risk funding estimating relationship is available, this method has the advantage that it is both quick and easy to apply.

5.7.4 Inputs and Outputs

Input - The inputs to an estimating relationship model, such as Eq. 5.7-1 are judgment values characterizing the four program or contract factors described in Section 5.7.2.

Output – The estimating relationship method provides a percentage figure to be applied to estimated baseline cost to be used to determine the amount of total or contract management reserve funds required. This percentage value is computed using an equation like Eq. 5.7–1, with the X value being the sum of the four factor values determined by PMO personnel.

5.7.5 Major Steps In Applying The Technique

Assuming an appropriate management reserve estimating equation is not available, the first major step in using this method and by far the most difficult, is developing an equation relating program characteristics to management reserve funding requirements. The most difficult part of this step is finding valid historical characteristic and management reserve funding data for enough similar programs to carry out regression analysis. Data from at least ten past programs should be used to develop an estimating relationship equation.

The second part of Step 1 is to determine the program or contract characteristics which drive management reserve funding requirements, and for which historical data has been collected. After the historical data has been collected, it is relatively simple to use regression analysis to identify these characteristics. The summing of judgment level values for each of four program characteristics as done by Electronic Systems Division (ESD) and described in Section 5.7.2, is only one way to develop one or more independent variables for an estimating relationship for management reserve funding requirements. Geometric mean or weighted average techniques could also be used. Multiple regression analysis techniques frequently are used for parametric cost estimating. The second and final major step in using this method is to use the prediction equation derived through regression analysis and the new program or contract characteristic information to compute a percent value for the additional management reserve funds needed to cover anticipated additional costs associated with risk. It may be useful to vary the program description characteristic data somewhat and recompute the estimating equation to assess the impact of such changes in the computed management reserve requirements. This sensitivity analysis is usually prudent because of the uncertainty associated with the predicted program or contract characteristics.

5.7.6 Use of Results

Using this method, the percent value of the estimated contract or program cost is computed and added to the basic cost estimate to cover funds needed for risk. As an example, if the contract cost estimate was $100M and the prediction equation provided a result of 30 percent, $30 million dollars would be added for risk, making the total estimated contract cost $130M.

5.7.7 Resource Requirements

Once a suitable management reserve funding requirement prediction equation is available, only a few hours are required to apply this method. Most of the effort required involves interviewing PMO personnel to obtain their judgments on the contract or program characteristic values to be used. If a prediction equation has to be developed, one to three months of a skilled analyst's time would be required, depending on the difficulty incurred in acquiring the needed data. It is possible that the required data may not be available, and that any amount of effort would not result in the development of a satisfactory prediction equation.

5.7.8 Reliability

This method as implemented by the ESD model provides results that significantly increase cost estimates (based primarily on the extrapolation of historical data which may include costs for risks that have already been experienced) to allow for risk. Because the additional funds are based primarily on judgment values, they are subject to question. If this technique is to be used, it would always be prudent for a PMO to have the method including the prediction equation to be used, reviewed and accepted by higher headquarters, before using it as the basis for a sizable request for additional funds to cover risks. The method can only be used where adequate historical data is available to develop a sound management reserve fund requirement prediction equation.

5.8 NETWORK ANALYSIS

5.8.1 General

Many program managers are familiar with the concept of network based scheduling as a program management tool. Program managers are fully aware that a quality schedule is critical for the effective planning, implementing, and controlling of any program. A quality schedule is essentially a plan of action that is objective oriented. It includes activities/events which must be accomplished to achieve the desired objective. Network based scheduling or networking formalizes the scheduling process and results in a graphical output which displays not only the activities which must be accomplished to complete the program, but also the relationships among the activities (that is, which activities precede, succeed, or are parallel to other activities). The utility of networking in general includes:

- Focusing the attention of all management levels during the planning phase
- Estimating program completion date
- Displaying the scope of the program
- Assessing resource requirements
- Facilitating "what if" exercises
- Highlighting critical activities
- Evaluating performance.

The keys for successful network development are:

- Determine the appropriate level of detail (aggregate, intermediate, detailed)
- Identify relevant activities
- Define relationships among activities (dependency, concurrency)
- Forecast time durations
- Involvement of *all* relevant individuals in all of the above.

In many situations program managers assume the responsibility for planning, scheduling, and controlling projects that consist of numerous separate jobs or tasks performed by a variety of departments, program offices, individuals, etc. Often, these programs are so complex and/or large that the program manager cannot possibly remember all the information pertaining to the plan, schedule, and progress of the program.

In these situations the techniques of PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) have proven to be extremely valuable in assisting program managers in carrying out their program management responsibilities. Besides being one of the original scheduling techniques, PERT, which was developed during the Polaris submarine program in the late 1950's was also the first risk analysis tool. The objectives of PERT were to manage schedule risk by establishing the shortest development schedule, to monitor project progress, and to fund or apply necessary resources for maintaining the schedule. Figure 5.8-1 represents a PERT network.

One of the most significant outputs of a network is the identification of the critical path. The critical path consists of those program activities which must be completed on schedule or the overall program completion date will slip. Activities on the critical path are the "long poles in the tent". In addition, activities can be assigned unique identifier codes. One of the many options this permits is the capability to select those activities related to a specific WBS element which are on the critical path. Activities which are not on the critical path have

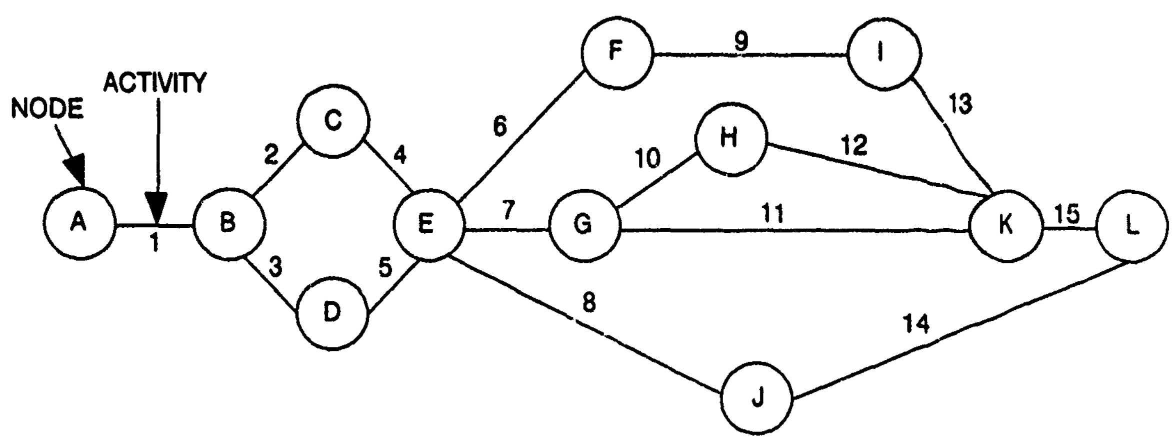

Figure 5.8–1 Program Represented as a Network

slack time associated with them. This means that there is some amount of time that the activity's scheduled completion date can slip without impacting the overall program completion date.

5.8.2 Description of Technique

The original networking technique was based on the Arrow Diagram Method (ADM) or "activity on arrow" method of representing the logical relationships between activities. ADM represents all predecessor and successor activities as finish to start relationships. Successor activities are not initiated until the predecessor is 100% complete. However, since this form of relationship is not always true for predecessor/successor activities, other networking methodologies were developed to more accurately reflect the realities of predecessor/successor dependencies. Newer computer-based networking systems use the Precedence Diagramming Method (PDM) or "activity on node" to represent network logic. PDM allows greater flexibility than ADM in describing predecessor/successor relationships. With PDM, the following relationships can be described in addition to finish to start:

Finish to Finish - successor activity cannot finish until some user specified period of time after the predecessor has completed.

Start to Start - the successor activity cannot start until some user specified period of time after the start of the predecessor.

Start to Finish - the predecessor activity cannot be completed until some specified period of time after the predecessor has started.

Newer network based risk models use PDM as well as conventional ADM. The description that follows is based on the traditional ADM networks because, to date, they are more popular as risk tools. PDM however, is more popular as a scheduling tool.

To accurately reflect the realities of risk related issues, the PERT method of network analysis has been enhanced over the years. Logic has been added which increases the functionality of network analysis as a risk analysis tool. Because of the changes, some of the old terminology has been replaced. The lines are known as arcs instead of activities. Decision points at the initiation or completion of activities and milestones are referred to as "nodes". Nodes can be of three types:

1) *Source nodes* - indicate the initiation of the program.
2) *Intermediate nodes* - indicate milestones or the initiation and termination of arcs.
3) *Terminal nodes* - represent the completion of the program or the failure to complete some segment of the program.

In a probabilistic network, there are two ways in which uncertainty manifests itself. First, activities may have uncertain outcomes in terms of time to complete, cost to complete, or achievement of some technical level of performance. Generally, technical performance is held as a fixed parameter while the other two vary. Second, the initiation of activities emanating from a node may be predictable only in a probabilistic way. For example, a test outcome (pass/fail) may determine whether the next activity is a progressive continuation of a plan or a corrective action. Since the test outcome cannot be predicted with certainty, it assumes a probabilistic nature. The network model represents this by showing at least two arcs emanating from the node representing test activity completion. The analyst can assign probability functions to the arcs to represent the relevant probabilities of completing within time or cost constraints or of meeting performance levels.

An important aspect of network models that is needed to permit realistic simulation of programs is varied "node logic". Node logic refers to the rules which determine when, for example, a decision point is passed and when a subsequent activity initiates.

The more advanced computer programs will allow use of both "AND" and "OR" logic and "DETERMINISTIC" and "PROBABILISTIC" output node logic. The two types of input logic determine whether all ("AND" logic), only one (exclusive "OR" logic), or some ("OR" logic) of the possible arcs entering a node must be completed for the node to be actuated. The two output logics determine whether all ("DETERMINISTIC" logic) or only one ("PROBABILISTIC" logic) arc is initiated upon completion of node actuation.

As previously mentioned, of fundamental importance for network development is the selection of the appropriate level of network detail. The consensus is that completion of a high aggregate level of detail should be accomplished before attempting to model the details of the program structure. Aggregate level networks will provide a more realistic determination of what the detail level networks will contain. However, aggregate level networks will also contain more inherent uncertainty than would be the case at a finer level of detail. As the program requirements and information become more readily available, the network models will evolve to a greater level of detail.

5.8.3 When Applicable

Network analysis has universal application in the program offices. Networks are formulated based on program activities, interrelationships among activities, and constraints (time, money, manpower, technology, etc). Because all programs have these characteristics, network analysis is universally applicable. The application of network analysis is made easier if network based program schedules already exist. If this is the case, the analyst can make the logic modifications required so that the network information can be readily input into a risk analysis software program. If a network does not already exist, one must be created. The time savings which can be incurred transforming an existing network versus creating one provides a strong argument in favor of network based program scheduling from the onset of a program.

5.8.4 Inputs and Outputs

The input for the development of the network risk model consists of probability density functions (See Section 5.2 and Appendix F for discussion on some of the techniques available for quantifying expert judgment). Since input to the network model may initially be qualitative judgment which must be transformed into quantitative information, it is imperative that all individuals who play a relevant programmatic role provide input during the development process. The credibility of the resulting network is affected by the extent to which knowledgeable, relevant program personnel contribute to its development. Standard output from network risk models includes probability curves, barcharts comparing baseline and "risk free" schedules, cost histograms, Cumulative Density Functions (CDFs), the mean, standard deviation of the sample, coefficient of variation, and mode for all specified decision points and activities. These result from executing a Monte Carlo simulation of the network. This is simply modeling the execution of the program many times.

Most packages also produce a "criticality index" for each activity. This index shows how often each activity appeared on the critical path during the course of the simulation process. Cost curves and histograms can also be produced which may indicate the direction the project is taking. This information can be used to continually adjust labor, material, and time estimates.

5.8.5 Steps in Applying the Technique

The first step in the process of modeling a program is for the analyst/manager to manually develop a rough-cut network. In order to develop a realistic model of the program, it is crucial that the analyst identify all the relevant parameters such as nodes, arcs, logic relationships, and Probability Density Functions (PDFs). As previously stated, all relevant program personnel should play a role in developing and validating the network.

Once the rough-cut network has been developed, the analyst can input the information into the computer for processing. There are many software packages currently available for network risk analysis. The whole spectrum from mainframe to microcomputer applications is covered by available software. Some of the packages currently available include:

- PROSIM
- VERT
- VERTPC
- RISNET
- PROJECT/2
- OPERA

and others.

Once the iterative process of developing the rough-cut network has been completed, the data is ready for input and processing by the computer. Using the process known as Monte Carlo simulation, the software determines the most likely course of events. Since one simulation conveys little useful information, the Monte Carlo simulation repeats the process, recalculating the critical path, as many times as necessary (or as defined by the user) to account for all possible scenarios. Typically, 1,000 to 6,000 simulations are processed. The result of these simulations is a statistically calculated scenario that predicts the eventual course of the project with a confidence level as specified by the user.

5.8.6 Use of Results

The output of the network risk analysis process is extremely useful to the program manager. The performance of network risk analysis generally provides an in-depth understanding of the sources and degree of risks. The results of the risk analysis process provide the information required to effectively execute the "risk handling" phase of risk management.

5.8.7 Resource Requirements

Since most network risk assessments accomplished in the DoD are carried out by functional support offices, risk assessment dollar costs should be estimated from manpower requirements. A comprehensive network analysis for a major program may require definition of between 200 and 1000 activities and require two to six man-months of GS-12 to GS-14 analyst effort for gathering information from subject experts for use in formulating probability density functions (PDFs) and for building the network. Obtaining the information required to construct the network usually entails more time and rechecking than might initially seem necessary. This is because the program plan is usually under continual revision and definition, and the support personnel do not fully understand the relationships among the program activities.

Although the difficulty and time required for network definition can pose a problem, the effort of constructing a consistent and acceptable network model forces the responsible participants to plan effectively and to understand how their own segment of the program fits into the whole. Program managers have indicated that this benefit alone can justify all the effort for accomplishment of a formal network risk assessment/analysis.

5.8.8 Reliability

The reliability of network risk analysis is a function of multiple factors. The development of a network which accurately reflects the activities and relationships among activities is crucial to the resulting network analysis. This is why it is imperative that all relevant program personnel provide input to the development and/or modification of the network. The definition of PDFs for the cost, schedule, and performance aspects of the program is also of fundamental importance. Since the Monte Carlo simulations which predict the course of the project are based on the respective PDFs, the accuracy of the PDFs in describing the cost, schedule, and performance parameters of the program is critical for a reliable analysis. The more reliable the network developed, the more reliable the analysis will be.

5.9 LIFE CYCLE COST ANALYSIS

5.9.1 General

A survey of program management offices indicated that directed funding cuts most often were viewed as the source of risk having a major impact on program execution. In order to control the adverse consequences of such a risk, a program manager needs to be able to quickly determine the potential cost implications of new information such as funding constraints pertinent to the program. Other information affecting program costs include new knowledge about a wide range of things such as test failures resulting in schedule slips, or directed production rate reductions. The program manager also needs to have quick access to the potential cost implications of some of the choices that must be made as the program progresses. Many programs meet such needs with a computerized life cycle cost (LCC) model. These models are sometimes called quick reaction cost models or quick reaction models. Such models can be useful for cost estimating, tradeoff analysis, production rate and quantity analysis, warranty analysis, sensitivity analysis, and logistic support studies. Simpler models such as the Quick Cost model developed by DSMC, are focused specifically on the cost implication of changes in yearly production quantities.

5.9.2 Description of Technique

The Life Cycle Cost technique consists of a series of equations which compute program costs based on product and program information. The exact nature of such information will be addressed in Section 5.9.4. However, it will vary from model to model, and may vary significantly from program to program, depending on the nature of the program and its status. An important aspect of life cycle cost models is that given some informed inputs, the model can be run quickly and not only provide a new total life cycle cost estimate, but also can give some insight into where the costs are likely to change. The model equations are usually developed based on logic and experience on similar past programs. The cost elements of life cycle cost models vary significantly. However, where applicable, they usually include development, production, and the full spectrum of extended operating and support costs.

5.9.3 When Applicable

Use of a life cycle cost model is applicable whenever a manager needs a quick estimate of the cost implications of a past or pending event. However, the timely development of useful cost estimates is totally dependent upon having a completed and tested life cycle cost model available for immediate use. Such a model is very applicable to situations where budget cuts are proposed by higher authority and the PMO has only a short time to describe the impact of such cuts. Program managers can get into trouble trying to buy half the quantity for half the cost or the same quantity over a longer period, for the same cost.

5.9.4 Inputs and Outputs

Inputs - Most life cycle cost models have extensive inputs that vary from model to model. Timely use of these models dictates that input values be continually maintained so only those that would change because of recent or pending actions need to be obtained to carry out the desired cost analysis. This is especially important when using detailed life cycle cost models which aggregate costs based on the characteristics of many individual subsystems and line replaceable units. Important input values common to many life cycle cost models include:

- Production quantity by year
- Development test quantities
- Cost quantity curve slopes
- Support equipment requirements
- Number of bases to which equipment will be deployed
- Spares requirements
- Tooling costs and other non–recurring production costs
- Deployment life of system
- Planned utilization rate (i.e., operating hours per year)
- Failure rates, sometimes by subsystem or even component.

Outputs – As with model inputs, the nature and format of the outputs vary widely among life cycle cost models. However, one output option should include an overall summary of total life cycle costs broken out only by appropriation type, (i.e., development, production and operation). Other useful output options include breakouts of the total life cycle cost by:

- Year
- Cost element
- Equipment component
- Combinations of the above.

Output values may be in fixed and specified base year dollar values, or if inflation rates were provided in the input, as dollar values inflated to the year in which they must be appropriated.

5.9.5 Major Steps in Applying the Technique

The first major step in using a life cycle cost model is to develop a model tailored to the nature of the program and anticipated cost information needs. This is a key step because without it generation of timely life cycle cost estimates will not be possible. Developing such a model and gathering the required input values will usually require a significant resource commitment. However, this effort can often be significantly reduced by tailoring an existing life cycle cost model already in use for a similar system.

The second major step is using the life cycle cost model to address a specific issue. This could require a data collection effort, but it should be significantly less than the initial effort to develop a model tailored to a specific PMO. If a model is already available and programmed on a computer, gathering the input data required to run the model is almost always the largest part of the effort required to prepare a life cycle cost estimate.

The last major step is to review the model output and assure that the results are reasonable and address the questions at issue. Any single life cycle cost analysis might involve computation of several to many life cycle cost estimates. The life cycle cost model is only a very crude abstraction of the real world. Therefore, decision makers often demand and will always appreciate logical arguments that tend to substantiate the numerical results provided by the model. It is often prudent to use the model to do sensitivity analysis using a range of input values around the primary input values to see how the changes affect the model computed life cycle cost estimates.

5.9.6 Use of Results

Life Cycle Cost (LCC) analysis results can be used to assess costs and, thereby cost risks associated with many decision issues. Life cycle cost models can be used to develop or carry out:

- LCC estimates
- Production rate and quantity analyses
- Design trade-off analysis
- Cost driver sensitivity analyses
- Resource projections (e.g., manpower, support equipment)
- Repair level analyses
- Warranty analyses
- Spares provisioning and optimization
- Reliability growth analyses
- Operational availability analyses.

5.9.7 Resource Requirements

The development, programming and testing of a PMO tailored life cycle cost model could require 6 to 12 man-months of GS-12 to GS-13 level analyst effort. However, this time can be significantly reduced if an existing LCC model can be found and tailored to the PMO. Several general purpose life cycle cost models are available and were designed to be tailored to specific PMO needs. The Cost Analysis Strategy Assessment (CASA) models were developed for and distributed by the Defense Systems Management College (DSMC) for this purpose. The CASA models are screen-oriented, user-friendly programs and can be operated on microcomputers. Use of these programs could be quickly mastered by GS–12 level analysts using the users guide provided by DSMC with copies of the program. The most significant task associated with using such models is obtaining complete and valid input data. Input data requirements may include key values such as the first unit production costs. The CASA is only one of several LCC models available. Program management office personnel should make every effort to find the LCC model most applicable to their program before initiating efforts to modify an existing LCC model or to develop a new model from scratch.

5.9.8 Reliability

Use of life cycle cost models for analysis are relatively common in the Department of Defense and are widely accepted as a quantitative basis for decision– making. It may enhance the credibility of a PMO analysis in the view of higher levels of authority if an LCC model is selected that has, or is closely related to one that has already gained acceptance. Inquiries should be made to see if such a model is available. All models have the limitation that the input data values must reflect the significant and valid differences among alternatives, if the model is to produce valid and useful cost differences among alternatives.

5.10 COST RISK/WBS SIMULATION MODEL

5.10.1 General

This technique aggregates cost risks for each of several WBS elements of a program into the total program cost risk. The total program cost risk is usually expressed as a cumulative probability distribution of total program cost. Such distribution information can be used to reflect program risk by computing the probability the program can be completed for a specific dollar value or less and what level of funding would be required to have a given probability of completing the program within the available funds. A micro or other computer is required to use this technique, because the analysis requires many repeated computations during simulation operations. Similar cost risk analysis can be performed as part of the analysis of networks by such models as VERT. However, network models usually require significantly more input data than pure cost risk/WBS simulation models.

5.10.2 Description of Technique

This method uses the Monte Carlo simulation analysis method. However, variations of the technique use different probability distributions to describe the cost risk associated with each WBS cost element. Uniform, Triangular, Beta, and other probability distributions have been used for this purpose. Use of the Uniform and Triangular distributions make the computation easier. However, use of the Beta distributions allows the user more freedom in describing WBS cost element uncertainty. Various techniques of this general type differ on how much data they require for each WBS cost element and the format used to present analysis results and assumptions with respect to the interdependence among WBS element costs. The technique uses a random number generator to simulate the uncertainty for individual WBS elements. Once costs have been simulated for each WBS element, they are aggregated to get a total program cost estimate. This process is repeated many times. Each time a new set of WBS element costs are developed is called an "experiment". The results of many such experiments provide a frequency distribution of total costs, reflecting the aggregate of the cost risks associated with all the individual WBS elements.

5.10.3 When Applicable

Use of this technique is applicable when there is a need for knowing the probability the program can be successfully completed at various levels of funding. It is also applicable when there is a need to know what level of funds are needed to achieve a specified probability of completing the program at that level of funding or less. For this technique to be applicable, it is also necessary to be able to obtain sound estimates of the cost uncertainty associated with each WBS element in the program. When a cost estimate broken out by WBS is already available, it is a relatively quick analysis procedure to use.

5.10.4 Inputs and Outputs

Inputs and outputs vary among models implementing this type of analysis technique. As an example of input and output information, a simplified version of the Air Force Systems Command (AFSC) Risk Model will be used. The AFSC Risk Model is probably the most widely used model of this type because its use has been directed as part of all major AFSC cost estimates. One unique aspect of the AFSC Risk Model is that it requires four estimates of cost uncertainty for each WBS element. However, since the model essentially uses only one of these estimates having the highest risk, the discussions of inputs will just address a single set of uncertainty descriptive data for each WBS element.

Inputs - For each model run, five elements of data are required once and five elements of data are required for each and every WBS cost element constituting part of the total program cost estimate. They are:

- For each model run
  - System name
  - Monte Carlo sample size (default value is 2500)
  - Confidence level computation desired (default value is 90 percent)
  - Dollar units used for inputs
  - Date of run
- For each WBS cost element
  - WBS element name
  - Point cost estimate (most likely)
  - Low end of cost range value (percentile defined by model)
  - High end of cost range value (percentile defined by model)

- Level of WBS element cost variance value (judgment value of low, medium low, medium high, or high)

Outputs – The basic WBS simulation model output is illustrated by Table 5.10–1. It shows into which of 60 sequentially increasing cost ranges each of the 2500 simulated total cost estimates fall. As an example, eight of the 2500 simulation experiments produced a total cost estimate between 47.7 and 48.3 million dollars and thereby fell in the tenth interval. Such data can be used to develop total cost probability and cumulative probability curves. Figure 5.10–1 is an example of such a cumulative probability curve based on the results in Table 5.10–1. The same data can also be used to provide output information with respect to the confidence level that a program can be completed for a specified level of funding or the funding required to achieve a specific level of confidence that the program will cost that value or less.

5.10.5 Major Steps In Applying The Technique

The first step in applying this type of technique is to obtain and become familiar with one of several available computer programs implementing it and the associated model user guidance. It will seldom be practical or desirable to develop such a computer program from scratch.

The second major step is to obtain the input data required by the specific model obtained in Step 1. This step is greatly facilitated if a total program cost estimate is already available, broken out by WBS element. If such an estimate is available, the required WBS cost element uncertainty input data can generally be obtained by interviewing PMO personnel. If possible, historical cost data should be reviewed to see how widely similar WBS cost values vary on other programs. The third step is to load the input data into the model and make one or more model runs as necessary. This is generally far less time consuming than gathering the input data.

The last step is to examine the model output results to assure they appear reasonable and provide the type of information needed to show how WBS element risks affect total program cost risk.

5.10.6 Use of Results

The primary use of WBS simulation model results is to show how WBS element risks may cause total program costs to vary from the point estimate used for budgets and other purposes. It can also be used to compare estimated costs for several programs at a specified confidence level, such as 90 percent. Higher headquarters may ask to see such information as part of the normal review process.

Table 5.10–1 Model Output

(EACH INTERVAL EQUALS .63 MILLIONS)

-INTERVAL	RANGE			FREQUENCY	PROBABILITY	CUM PROB
1	42.0000	-	42.6333	0	.000	.000
2	42.6333	-	43.2667	0	.000	.000
3	43.2667	-	43.9000	0	.000	.000
4	43.9000	-	44.5333	0	.000	.000
5	44.5333	-	45.1667	0	.000	.000
6	45.1667	-	45.8000	0	.000	.000
7	45.8000	-	46.4333	0	.000	.000
8	46.4333	-	47.0667	0	.000	.000
9	47.0667	-	47.7000	1	.000	.000
10	47.7000	-	48.3334	8	.003	.003
11	48.3334	-	48.9667	13	.005	.008
12	48.9667	-	49.6000	9	.004	.012
13	49.6000	-	50.2334	11	.004	.016
14	50.2334	-	50.8667	19	.008	.024
15	50.8667	-	51.5000	27	.011	.035
16	51.5000	-	52.1334	45	.018	.053
17	52.1334	-	52.7667	46	.018	.071
18	52.7667	-	53.4000	48	.019	.090
19	53.4000	-	54.0334	72	.029	.119
20	54.0334	-	54.6667	57	.023	.142
21	54.6667	-	55.3000	63	.025	.167
22	55.3000	-	55.9334	89	036	.203
23	55.9334	-	56.5667	101	.040	.243
24	56.5667	-	57.2000	92	.037	.280
25	57.2000	-	57.8334	112	.045	325
26	57.8334	-	58.4667	133	.053	.378
27	58.4667	-	59.1000	130	.052	.430
28	59.1000	-	59.7334	119	.048	.478
29	59.7334	-	60.3667	135	.054	.532
30	60.3667	-	61.0001	120	.048	.580
31	61.0001	-	61.6334	134	.054	.634
32	61.6334	-	62.2667	143	.057	.691
33	62.2667	-	62.9001	99	.040	.731
34	62.9001	-	63.5334	104	.042	.773
35	63.5334	-	64.1667	106	.042	.815
36	64.1667	-	64.8001	85	.034	.849
37	64.8001	-	65.4334	60	.024	.873
38	65.4334	-	66.0667	60	.024	.897
39	66.0667	-	66.7001	41	.016	.913
40	66.7001	-	67.3334	52	.021	.934
41	67.3334	-	67.9667	50	.020	.954
42	67.9667	-	68.6000	52	.021	.975
43	68.6000	-	69.2334	22	.009	.984
44	69.2334	-	69.8667	14	.006	.990
45	69.8667	-	70.5000	2	.001	.991
46	70.5000	-	71.1334	10	.004	.995
47	71.1334	-	71.7667	7	.003	.998
48	71.7667	-	72.4000	6	.002	1.000
49	72.4000	-	73.0334	1	.000	1.000
50	73.0334	-	73.6667	1	.000	1.000
51	73.6667	-	74.3000	0	.000	1.000
52	74.3000	-	74.9334	0	.000	1.000
53	74.9334	-	75.5667	0	.000	1.000
54	75.5667	-	76.2000	1	.000	1.000
55	76.2000	-	76.8334	0	.000	1.000
56	76.8334	-	77.4667	0	.000	[illegible]
57	77.4667	-	78.1000	0	.000	[illegible]
58	78.1000	-	78.7333	0	.000	[illegible]
59	78.7333	-	79.3667	0	.000	1.000
60	79.3667	-	80.0000	0	.000	1.000

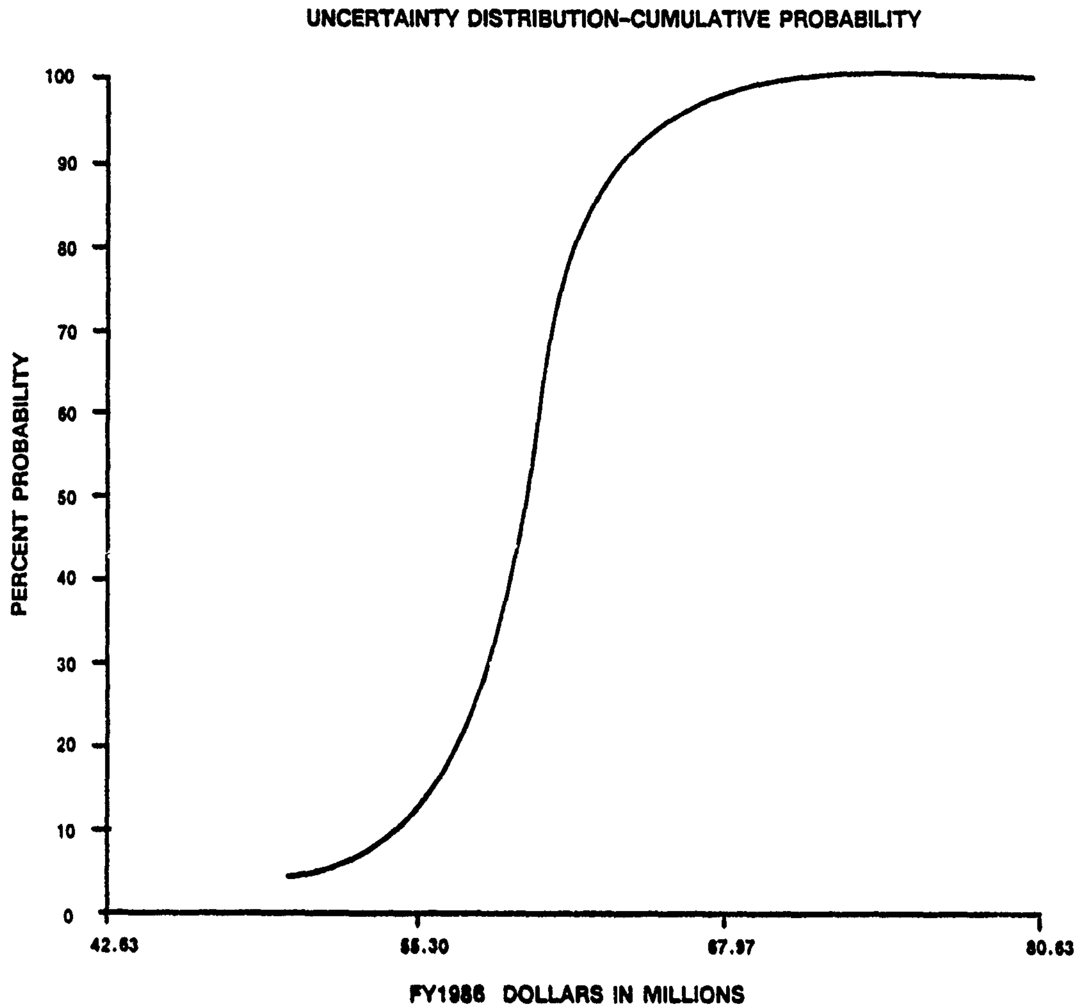

Figure 5.10–1 Model Output

5.10.7 Resource Requirements

The primary resource requirement is a copy of a computer program implementing this method and the associated user guidance. Air Force experience has shown that GS–9 and above cost analysts can quickly learn to run such a model, if supported by PMO specialists in providing WBS cost element uncertainty range and level judgments. A microcomputer is also required. The AFSC risk model runs on a Zenith 100 computer. Other similar models run on IBM PCs.

5.10.8 Reliability

The mathematics and logic of the WBS simulation/cost risk technique is generally sound. An exception is that these models generally do not fully address the interactions between WBS elements. They usually assume either total dependence or total independence among WBS elements. The true situation will probably vary from program to program and will almost always be somewhere between total independence and total interdependence. The greatest limitation of this method is the difficulty in obtaining sound and supportable input values.

5.11 RISK FACTORS

5.11.1 General

This method is often quite simple to apply except for the difficulty in obtaining sound and dependable input values to describe the risk associated with each WBS element. Often the input values are quick judgments made by PMO personnel. The method does not include procedures for systematic and scientific development of the needed input data. The primary use of the method is to estimate the total added program costs that might be expected due to risks associated with the various program WBS elements.

5.11.2 Description of Technique

The basic concept of the Risk Factor method is to determine factors, or multipliers, with which to increase individual baseline WBS element cost estimate to cover additional costs resulting from risks. The objective of using this method is to determine a reasonable budget, above that resulting from a baseline cost estimate, to cover anticipated risk associated cost growth. The method uses a WBS or cost breakdown structure based on a technical breakdown like that shown in Figure 5.11-1.

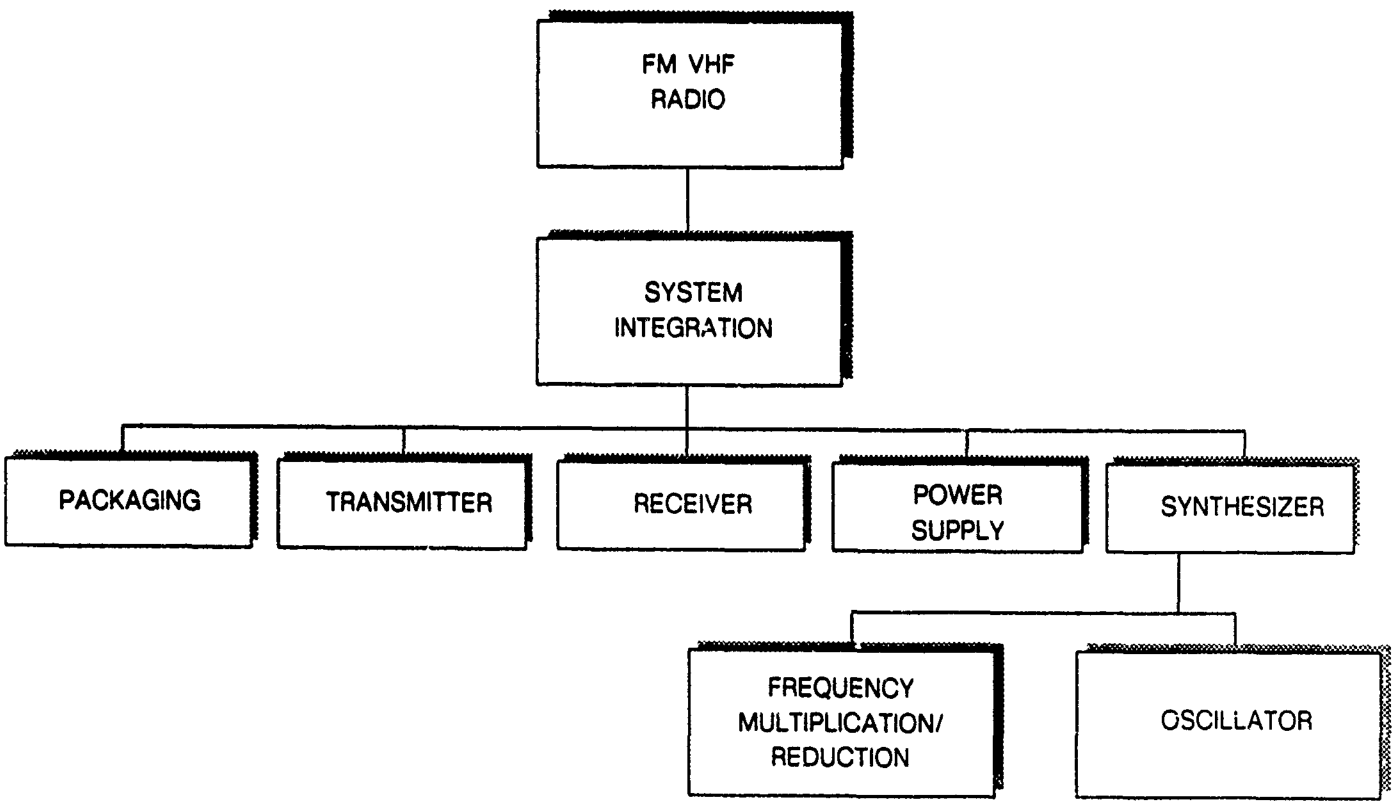

Figure 5.11-1 Cost Breakdown Structure

The baseline cost estimate must have been developed for each cost element. Applying whatever considerations are appropriate, a risk factor is established for each cost element. This factor will generally be a value between 1.0 and 2.0 with 1.0 indicating no risk and 2.0 indicating so much risk that expected costs would be twice the baseline cost estimate values. Every baseline WBS cost estimate is then multiplied by its risk factor to obtain the new WBS element cost estimates. These new estimates summed to get a budget value, which provides a level of funding which will account for technical or other risk.

The obtaining of sound WBS element risk factors is the key feature of this method and may be difficult. There is little documented experience upon which analysts can draw in order to substantiate such factors. Since these factors have a significant impact on the analysis results, it is important that the inputs be obtained from highly experienced technical experts. In other words, the apparent simplicity of the method has not relaxed the requirement that the most experienced PMO personnel take key roles in the analysis. Once a baseline cost estimate has been prepared using cost estimating methods, an analyst should be able to prepare a new cost estimate using risk factors in a relatively short time. The length of time will depend on the difficulty an analyst has in obtaining the assistance of technical experts, and on how detailed a WBS or cost breakdown is involved.

5.11.3 When Applicable

The survey of PMOs on past and current risk analysis utilization showed that only six out of the fifty-seven PMOs responding had used this technique. These six PMOs found the technique useful primarily for POM/BES preparation and program planning. The technique is more applicable early in the life of a program when information is not available to apply some of the more sophisticated risk analysis techniques. This technique is only applicable when a point cost estimate, broken out by WBS element, is available. The method's simplicity makes it applicable to even small, low cost programs.

5.11.4 Inputs and Outputs

Inputs – One primary, and generally available, input of a risk factor assessment is a baseline cost estimate broken out by WBS element. The second primary input is a set of risk factors for each WBS cost element. These factors will usually be subjective judgments of experienced personnel who know the program, its current status, and potential problem areas. The use of check or watch lists and the number of items in the list that apply to each WBS element is one way of helping make a judgment of the level of risk associated with each element.

Output – The output of a risk factor application is a budget or cost estimate increased over the baseline budget (or estimate) by an amount required to cover risk induced costs.

5.11.5 Major Steps in Applying the Technique

The major steps in applying the technique are:

- Obtain a program cost estimate broken out by WBS element. Such estimates should be available and their preparation is not considered to be part of applying this method.
- For each WBS element obtain an estimate for the percent of additional costs that should be added to accommodate additional work resulting from risks. The opinions of knowledgeable technical and experienced program management should be sought and used. Reviewing the lessons learned for similar systems could also provide insight into how much risk might be involved. If similar things have been done before, and by the same people assigned to the current program, risks should be lower. It must be remembered that past programs were also risky and therefore parametric cost estimates based thereon also include some costs to cover risk.
- Recalculate the total program costs by summing all the WBS element costs, each of which has been adjusted by the associated factor percentage increase to accommodate the risks associated with it.

5.11.6 Use of Results

According to the survey of PMO risk analysis applications one or more PMOs found the results of risk factors analysis of some significant use for POM/BES preparation, program status reporting, program planning and DAB milestone briefings. This method has also been used to support U.S. Army TRACE cost risk procedures.

5.11.7 Resource Requirements

Resource requirements for this method can be quite variable. Frequently, the same cost estimator responsible for preparing the baseline cost estimate can also provide the additional risk factor results in a few hours if he/she is provided the WBS element factors by appropriate experts in a timely manner. However, application of the method can become more involved as more technical and other experts are used to derive the individual WBS element risk factors.

5.11.8 Reliability

The reliability of this technique can vary widely both in fact and in the judgment of those reviewing the results. Since use of the technique generally requires judgments based on limited information, the knowledge and skill of those making the judgments will greatly affect the reliability of the results. A quick analysis, where the risk level factor judgments for all WBS elements are made by a single cost analyst, without inputs from technical and other experts, would very likely produce relatively low reliability results. The reliability of this method is increased by providing documented justification for all WBS element factor values used.

5.12 PERFORMANCE TRACKING

5.12.1 General

Much has been written about technical risk. The GAO report on technical risk, April 1986, spent a great deal of time discussing the importance of managing the technical aspects of a program. However, measuring technical risk on any effort that involves furthering the state-of-the-art is a very difficult task, which in and of itself, can involve a great amount of risk. There are some concrete measurements that can be useful in measuring technical advancement progress against preset goals of programs. Many of these are described in a publication entitled "Technical Risk Assessment: Staying Ahead of Real-Time Technical Problems, Visibility and Forecasts" (currently in draft form). This is a Navy document released in March 1986 (Ref. 5-2). Within the document are several recommended measures for evaluating technical progress.

5.12.2 Description of Technique

The technique advocates the use of a Technical Risk Assessment Report, which is updated monthly. The report is based on working level data but is intended to provide an overview of current trends and status. The technique uses a set of standard technical indicators which have been proven to be effective measures of technical performance. In addition to the standard measures, program unique technical indicators are also developed. Each of the measures has clearly defined performance projections and pre-set alert criteria. The standard indicators are shown in Figure 5.12-1 and a sample indicator is shown in Figure 5.12-2.

5.12.3 When Applicable

The performance tracking technique is most useful when there are specific criteria established that are objective and quantifiable. It can best be utilized for the management of near term requirements. The approach can be used with minor modifications on any type of program and could be used in conjunction with more elaborate probabilistic risk models that can examine the corresponding cost and schedule impacts of current technical performance.

5.12.4 Inputs and Outputs

The technique requires that performance be tracked on a monthly basis for each technical indicator selected. This requires full cooperation with the contractor and his active participation in managing risk (a good benefit). The output can be in the form of a risk management report or a briefing. The contents should contain an analysis of each of the indicators current performance and longer term trend.

AREA OF RISK	TECHNICAL RISK INDICATOR (TYPICAL UNIT OF MEASURE)	APPLIES TO: SYSTEM	APPLIES TO: SUBSYSTEM A	SUBSYSTEM B	SUBSYSTEM C	SUBSYSTEM D	SUBSYSTEM E	SOURCE: STATEMENT OF WORK	CONTRACT SPECS	CONTRACTOR PLANS	PRIOR EXPERIENCE
DESIGN	WEIGHT (POUNDS)	X	X	X	X	X	X		X		
	SIZE	X	X	X	X	X	X		X		
	CENTER OF GRAVITY (INCHES FROM REF. POINT)	X	X	X	X	X	X		X		
	THROUGHPUT (CLUSTERS PER MINOR CYCLE)	X							X		
	MEMORY UTILIZATION (PERCENTAGE OF CAPACITY)	X							X	X	
	DESIGN TO COST (DOLLARS)	X	X	X	X	X	X	X			
	DESIGN MATURITY (NUMBER OF DESIGN DEFICIENCIES)	X	X	X	X	X	X	X		X	X
	FAILURE ACTIVITY (NUMBER OF FAILURE REPORTS SUBMITTED)	X	X	X	X	X	X	X		X	X
	ENGINEERING CHANGES (NUMBER OF ECOs)	X	X	X	X	X				X	X
	DRAWING RELEASES (NUMBER OF DRAWINGS)	X	X	X	X	X				X	X
	ENGINEERING MAN-HOURS (MAN-HOURS)	X	X	X	X	X				X	X
TEST	CRITICAL TEST NETWORK (SCHEDULED DATES FOR CRITICAL TEST EVENTS)	X	X	X	X	X				X	X
	RELIABILITY GROWTH (MEAN TIME BETWEEN FAILURES)	X	X	X	X	X		X	X	X	X
PRODUCTION	TRANSITION PLAN (SCHEDULED DATES FOR CRITICAL PRODUCTION EVENTS)	X	X	X	X	X				X	X
	DELIQUENT REQUISITIONS (NUMBER OF DELINQUENCIES)	X	X	X	X	X				X	X
	INCOMING MATERIAL YIELDS (PERCENTAGE OF ACCEPTABLE MATERIAL)	X	X	X	X	X				X	X
	MANUFACTURING YIELDS (PERCENTAGE YIELD)	X	X	X	X	X				X	X
	UNIT PRODUCTION COST (DOLLARS)	X	X	X	X	X		X			
	UNIT LABOR & MATERIAL REQUIREMENTS (MAN-HOURS UNIT & MAT'L COST 'UNIT)	X	X	X	X	X				X	
COST	COST AND SCHEDULE PERFORMANCE INDEX (RATIO OF BUDGETED AND ACTUAL COSTS)	X	X	X	X	X		X			
	ESTIMATE AT COMPLETION (DOLLARS)	X	X	X	X	X				X	
	MANAGEMENT RESERVE FUNDS (PERCENTAGE REMAINING)	X								X	
MGMT	SPECIFICATION VERIFICATION (NUMBER OF SPECIFICATION ITEMS)	X	X	X	X	X			X		
	MAJOR PROGRAM RISK (RANKED LISTING)	X	X	X	X	X					X

Figure 5.12-1 Standard Indicators

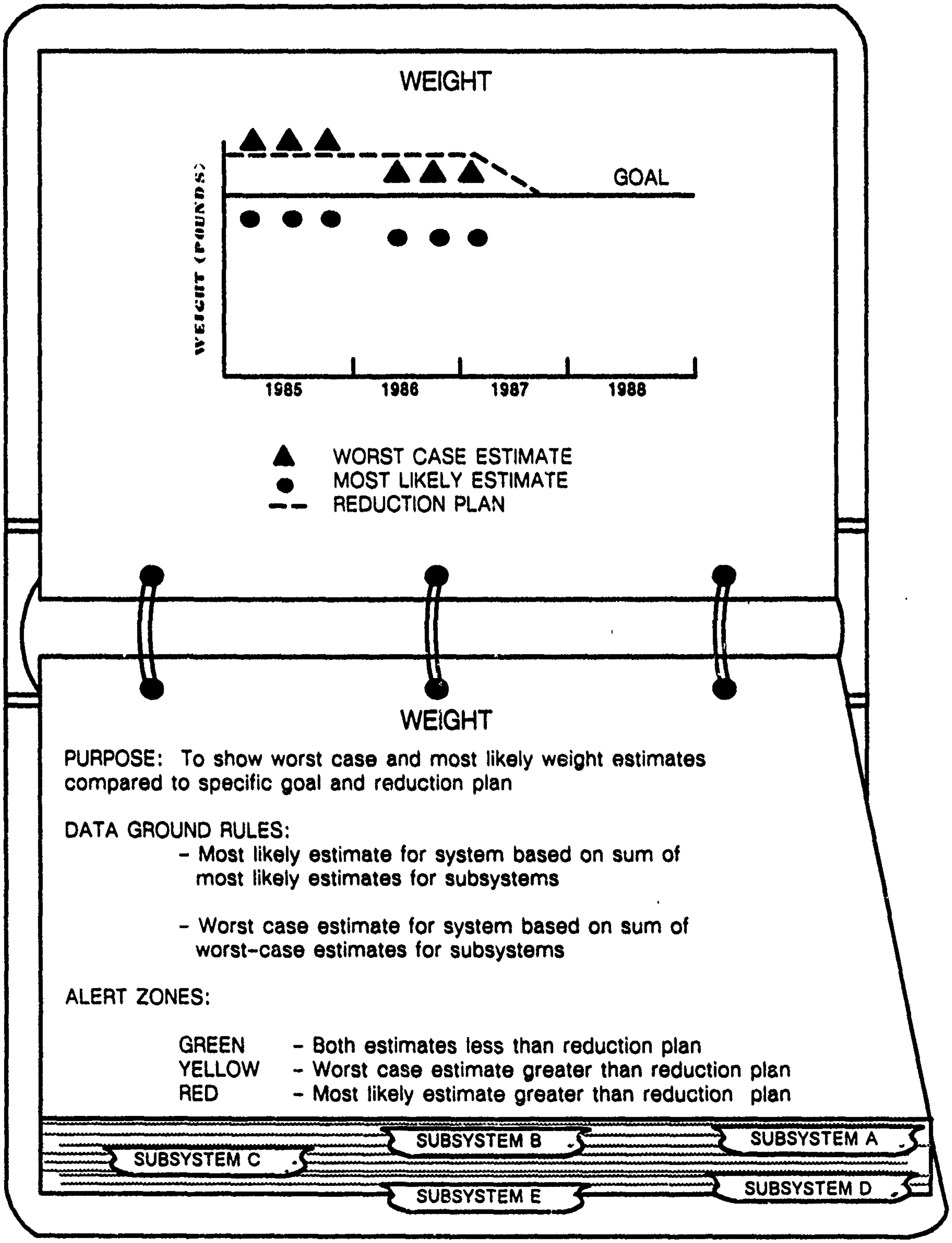

Figure 5.12-2 Sample Indicators

5.12.5 Major Steps in Applying the Technique

One of the first steps in adapting the technical risk assessment method to track risk performance is to select the standard indicators that can be applied to the development program. Many of the standard indicators (Figure 5.12–1) can be used on development programs, and the utility of certain indicators will vary as the program progresses. In the case of an airborne system weight and size are always significant. Weight and size may not be as significant on a system to be installed aboard aircraft carriers, however, if the system is submarine installed, size again becomes important.

The selection of indicators should include ones for the entire program and selected ones for the subsystems. The unusual aspects of a developmental program frequently require the use of special technical indicators.

In the case of space systems, certain indicators are appropriate such as the production of gasses from the material in the product when exposed to a space environment. Figure 5.12–3 shows some potential special indicators.

Each indicator, whether standard or special must have ground rules established for data collection and assessment. This can be in the form of a dictionary and describe the object of the indicator, why it was chosen, the use of the indicator and what is to be done when a signal is generated that indicates a problem is developing. It should be in sufficient detail to inform the system operator of the meaning of the indicator and the relationship of the measurement to risk.

It is advisable to predict the trends that might be expected during the life of the indicator. Expected values may take many different forms or curve functions but should have a traceability to the program goals, either cost, schedule, performance, or various combinations. Evaluation criteria must be set so as to flag a situation that can signal a problem. Color coding such as red, yellow or green for high, medium, or low risk can be used as well as percentage bands for the same type of message. These bands may vary as time progresses, that is, getting tighter as completion is nearing or getting more tolerant as time passes to indicate a risk that is disappearing. In any case, both the program office, contractor, and subsystem contractor(s) should agree and understand the tolerance bands and their significance in order to facilitate rapid corrective action.

All the above would be useless unless a formal, contractually required reporting system is used. This could be in different form, according to the type of the program and the style of the manager. It may be produced in vugraphs in a manner immediately usable by the government manager for required higher level periodic briefings or in a raw form as numerical data points. In any case, it must be in a form immediately applicable by both the contractor and the program manager in making decisions affecting the program.

INDICATORS DERIVED FROM SPECIFICATION REQUIREMENTS	INDICATORS DERIVED FROM PROGRAM REQUIREMENTS
PERFORMANCE CHARACTERISTICS • SPEED, RANGE, CAPACITY, ACCURACY, ETC.	SCHEDULE • FEASIBILITY/PROBABILITY OF TIMELY ACCOMPLISHMENT, ETC.
PHYSICAL CHARACTERISTICS • CENTER OF BUOYANCY, LENGTH, ETC.	RESOURCES • ADEQUACY, DISTRIBUTION, ETC.
EFFECTIVENESS CHARACTERISTICS • RELIABILITY, SAFETY, LOGISTICS SUPPORT, ETC.	TEST PLAN • SUFFICIENCY OF PLANNED TESTING, ETC.
ENVIRONMENTAL CONDITIONS • VIBRATION, TEMPERATURE, SHOCK, ETC.	PROCUREMENT FACTORS • AVAILABILITY OF MULTIPLE SOURCES, ETC.
DESIGN AND CONSTRUCTION • TECHNOLOGY, PACKAGING, MATERIALS, ETC.	

Figure 5.12-3 Sample Special Indicators

As in any system that requires the coordinated efforts of contractors and government technical and management personnel, it is necessary to place someone in charge of insuring that the job is being done accurately and in a timely fashion and that the proper decision-makers are informed of the risk situations.

In summary, the major steps in applying risk measurement techniques are:

1) Applying the standard indicators
2) Selecting special indicators
3) Establishing data definitions
4) Projecting expected trends
5) Setting the evaluation criteria
6) Planning the reporting system
7) Assigning responsibilities.

5.12.6 Use of Results

The technical risk assessment reports furnish the information needed to start any action that might be required to correct potential problems. Each indicator should be examined separately and then examined as related groups of indicators. In using the results, the factors of cost, schedule, and technical risks must be examined simultaneously.

5.12.7 Resource Requirements

This technique requires people with sufficient knowledge and skills in highly specialized technical areas. The data received emanates from many functional groups including fabrication, assembly, engineering, quality control, etc. and must be analyzed by people who have these skills and can make technical analytical assessments of the reports. This does not mean that each functional risk assessment area requires a full time person. While system start–up costs vary, it should not require more than 1–2 man–months of effort. Typically, the sustaining costs are estimated tc be a one person effort for a fairly large program.

5.12.8 Reliability

In order to have a reliable technical risk assessment, it is necessary that all major participants understand the importance of the assessment and be actively involved in establishing and implementing the system. Each member of the team should be involved in the initial assessment of the programs technical risk and help in the selection of the indicators used in tracking the risk. These are the same people that should be providing the updates for each reporting period. The early surfacing of potential problems anticipates the problem prior to failure and with proper management action, failure may be precluded or at least tempered.

5.12.9 Performance Tracking – Supplemental Information

Performance tracking is not new. It has existed in one form or another for many years, but recently it has gained in popularity and use. There are many variations on the theme presented in the above discussion. Since control is one of the most critical elements in risk management, and performance tracking is one of the most effective control techniques, another variation of the method is presented below.

Fully integrated performance measurement – is a capability being developed to integrate technical performance, schedule performance, and cost performance. It is also aimed at providing Earned Value performance measurement capability to Government program offices that are not getting formal contractor performance data. The major steps are as follows:

– Technical Performance –

- From program direction, plans, and specifications, identify specific technical parameters and their value for performance, producibility, quality assurance, reliability, maintainability, support, etc. A few examples are shown in Figure 5.12–4
- Relate each of these technical parameters to specific WBS elements whenever practical. Many of them will only relate to the total system level, but many will come from the Spec Tree which should match the Work Breakdown Structure.
- Define specific methods for calculating, measuring, or observing the value of each technical parameter.
- Assign a specific individual or organization the responsibility for managing the technical parameter and the progress toward achieving the goal value.

PERFORMANCE	*PRODUCIBILITY*	*QUALITY ASSURANCE*
- Speed (KTS) - Weight (Lbs) - Range (NM) - Power (KW) - Turn Rate (Deg/Sec) - Takeoff Distance (Ft) - Climb Rate (Ft/Sec) - Accuracy/CEP (Ft) - Radar Cross Section (Sq Ft)	- Capital ($) - Manpower (People Count) - Facilities (Sq Ft) - Material ($) - Equipment (Machinery Req'd) - Schedule (Time) - Risk (0 - 1.0)	- Scrap, Rework & Repair (% of Labor) - Yield (% of 1st Time Inspection Successes) - Supplier Rating (%) - Quality Costs ($) - Customer Satisfaction (0 - 1.0) - Software (LOC in Violation per 1000 LOC)
RELIABILITY	*MAINTAINABILITY*	*SUPPORTABILITY*
- MTBF (Hrs/Days) - MTTR (Hrs/Days) - LRU vs SRU (%) - Probability of Component/ Assy. Failure (0 - 1.0) - Life Cycle Analysis ($) - Design to Cost ($)	- Standardization (%) - Modularity (%) - Update Ability (0 - 1.0) - Special Equipment ($) - STE ($) - Frequency (Schedule) (Time) - Costs ($)	- Parts Inventory ($) - Costs ($) - Resources (Manpower, Equipment, Facilities) - Modularity (%) - Operational Availability (%) - MTBF (Hrs/Days) - MTTR (Hrs/Days)

Figure 5.12–4 Fully Integrated Performance Measurement Typical Technical Parameters

- Schedule Performance -

- Identify (or create) specific schedule events at which calculation or observation is to be made.
- Determine values or conditions that should be achieved by each milestone. Also set a tolerance or "alarm" value to represent a threshold for corrective action.
- Identify (or create) a specific schedule event at which the goal is to be achieved.
- A plot of the technical performance parameter value against time gives a visual portrayal of the relationship between technical performance and schedule. See Figures 5.12–5 and 5.12–6.

- Cost Performance -

- Assign budgets to each technical performance parameter. These budgets may be real and add up to contractual values or fictitious units just to determine relative weights. There are many different ways to assign these budgets. The only requirement is rationality, traceability, and consistency.
- Distribute the assigned budgets to each of the measurement milestones based on engineering judgment of the percent of the total value associated with each milestone.

	OPR	SPEC OR GOAL	DEVELOPMENT PROGRAM SPECIFIC MILESTONES					PRODUCTION PROGRAM SPECIFIC MILESTONES					
			#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	IOC
PERFORMANCE													
Parameter #1	—	V_{GOAL}	V_{CALC}		V_{OBS}	V_{OBS}	V_{GOAL}						
Parameter #2	—	V_{GOAL}		V_{CALC}	V_{OBS}	V_{GOAL}							
Parameter #3	—	V_{GOAL}			V_{CALC}		V_{OBS}		V_{OBS}	V_{GOAL}			
• •	• •												
QUALITY ASSURANCE													
SCRAP	ABCD	1_{GOAL}			6_{CALC}	5_{CALC}		3_{CALC}	3_{OBS}	2_{OBS}	1_{OBS}		
Factor #2	—	V_{GOAL}					V_{CALC}			V_{OBS}		V_{GOAL}	
Factor #3	—	V_{GOAL}		V_{CALC}		V_{CALC}		V_{OBS}	V_{GOAL}				
• •	• •												
RELIABILITY													
Parameter #1	—	V_{GOAL}	V_{CALC}	V_{CALC}	V_{CALC}	V_{OBS}	V_{OBS}	V_{OBS}	V_{GOAL}				
Parameter #2	—	V_{GOAL}											
• •	• •												
MAINTAINABILITY													
Condition #1	—	C_{GOAL}		C_1		C_2			C_3		C_{GOAL}		
Condition #2	—	C_{GOAL}	C_1	C_2			C_3			C_{GOAL}			
• •	• •												
SUPPORTABILITY													
Condition #1	—	C_{GOAL}			C_1		C_2			C_3			C_{GOAL}
• •	• •												

Figure 5.12–5 Technical Performance Schedule Milestones

CATEGORY:	QUALITY ASSURANCE		
FACTOR:	SCRAP, REWORK & REPAIR		
GOAL:	1%	OPR:	ABCD

METHOD OF CALCULATION:

____

METHOD OF OBSERVATION:

____

MEASUREMENT MILESTONES

MILESTONE	DESIRED VALUE	METHOD	RATIONALE
——— (#3)	6%	CALC	———
——— (#4)	5%	CALC	———
——— (#6)	3%	CALC	———
——— (#7)	3%	OBS	———
——— (#8)	2%	OBS	———
——— (#9)	1%	OBS	———

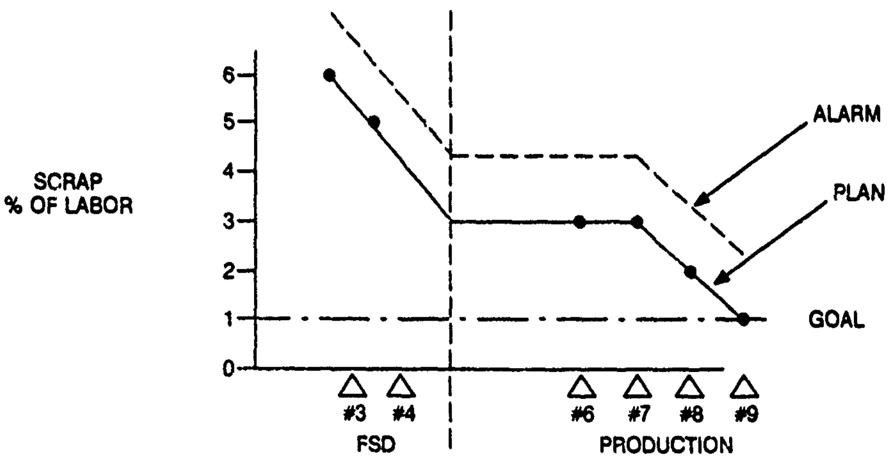

Figure 5.12-6 Technical Performance Management

- Use conventional earned value techniques to measure accomplishment (e.g. 50/50 milestones).
- Apply the schedule performance index to appropriate activities in the resource loaded network to determine the cost impact of the technical and schedule performance.

A quick example may help clarify the technique. Referring to Figure 5.12-5, performance parameter #1 has a numeric goal. A method of calculating progress against the goal has been derived. At selected milestone 1, progress against the goal is calculated. By selected milestone 3, progress against the goal can actually be observed, and by milestone 5, the goal should be attained.

5.13 OTHER COMMON TECHNIQUES

5.13.1 CPR Analysis

Cost Performance Reports (CPR) obtained to comply with DoDI 7000.10 have become useful in uncovering areas where technical problems are causing variances. In this report the contractor explains cost and schedule variances by means of a narrative detailing the specific problem that has caused the variance. Many of the variances reported can signal risk situations as they are developing, such as late vendor or sub-contractor deliveries. The continuation of these types of schedule slips can put an entire program schedule at risk. Normally, Government program managers are limited in what they can do to alleviate these situations except in cases where Government Furnished Properties (GFP) are causing the delays. The GFP shortage situation can sometimes be alleviated by high level coordination with the supplying Government agency. However, this does not always work. For example, DoD control of DOE supplied special weapons is not very effective and the risk of late warhead specifications in terms of weight and size can cause significant risk in the schedule of the carrying vehicle. Schedule problems of this type invariably cause cost problems as vehicle designers scramble to modify designs to accommodate changing specifications. The risk in this situation is that rapid advancement of the design cycle to meet original target dates can be affected by late breaking specification changes.

Cost variances can also be risk involved, as large cost growth can jeopardize a program to the point of causing cancellations. It is naive to not consider cost growth as a significant risk item. The CPR is designed to display cost growth as a variance and then discuss the variance in terms of cause, impact, and any corrective action that might be taken to alleviate the situation.

If the program is receiving the CPR it should be used for risk assessment and analysis by the program manager. The discussion of variances in the format five report can contain data that permits the determination of items that may be presenting new and previously undiscovered risks. These risks should then be investigated to ascertain their effects on the program.

5.13.2 Independent Technical Assessment

General – An independent technical assessment requires people other than those under control of the PMO and therefore will always require approval by some higher level of authority. The timing of such reviews is critical. If problems are found, there must be time to correct them before any critical milestone reviews. This technique has been used by a multi–service program and is cited as substantially reducing program risk, especially that which was associated with tri–service involvement.

Description of Technique – This technique involves a team of experts from outside the PMO reviewing a number of specified aspects of the program. The team usually consists of very senior personnel who can make timely evaluations of PMO activities and progress based on their extensive experience. Such a team can vary in size depending on the size of the program and how many issues the team has been chartered to review. The entire process is usually limited to four to eight weeks of near full time effort. The final product is almost always a briefing to the level of authority authorizing the review and sometimes a written final report.

When Applicable – An acceptable time to use the technique is in support of design reviews. It can also be used to quiet/end perceptions of a troubled program. A good time for an independent technical assessment is when a program is, or is perceived to be in trouble and critics have become vocal. If the trouble is real, this technique will give the PMO added credibility and quiet critics. When possible, such reviews should be scheduled to cause minimum disruption of milestone activities. An independent technical assessment is usually more appropriate during system development than during production.

Inputs and Outputs – The inputs will vary widely depending on the issues shown to be addressed and the expertise of the team members. Team members will obtain the information they need through briefings by PMO personnel, review of PMO documents, interviews and visits to contractors' facilities. The expertise and experience team members bring with them to the team is an important input. The most common output is a briefing to the commander authorizing the review and to others as appropriate. The briefing must address each of several criteria or issues defined at the onset of the review. It should also include recommendations for follow–on action.

Major Steps in Applying the Technique – The following steps are common to most independent technical assessments:

- Direction by a higher level of authority with control of or access to the required expert resources, to conduct the review
- Specification of the issues to be addressed
- Formation of the review team
- Gathering the required information about PMO ob-

jectives, problems, status, resources, and activities

- Analyzing the information gathered
- Presenting the results to the authority who requested the review and to others as appropriate.

Uses of Results – Independent technical assessments are useful for design, acquisition strategy, planning, and implementation coordination. When the review results are favorable, there is instant program risk reduction with associated benefits in meeting pending milestone reviews.

Resources Required – Resources of two types are required to carry out an independent technical assessment. First, a team of up to 10 experts is needed to form the review team. The people required must be experienced and certainly would include some or all at the GS–15 level or above. These people would probably have to commit two to four weeks of effort to the team over a period of four to eight weeks.

In addition to team resource requirements, the PMO has to provide a number of informational briefings and interviews to quickly provide the review team with the required information. Where members of the review team are visiting from out of town, the PMO may be required to perform substantial protocol and administrative tasks. The PMO usually pays all travel costs for team members.

Reliability – The reliability of an independent technical assessment is usually high. The reliability somewhat depends on the quality of the team members, that is their recognized level of expertise. While team independence is essential, cooperation and trust between the team and the PMO is also essential. The PMO must provide all required information and the review team must present a balanced picture while not just focusing on the most negative areas. The major disadvantage of an independent technical assessment is that for a time it can disrupt PMO activities. This is especially true if it points out deficiencies that must be fixed, and there is no time to make the needed fixes prior to an important milestone. Therefore, the timing of the review is important and should be considered in the planning for such reviews.

5.13.3 Independent Cost Estimates

Independent cost estimates must be accomplished one or more times for many DoD programs in accordance with the requirements of the DoD Independent Cost Analysis (ICA) program.

The ICA program came about because of a perception within the Office of the Secretary of Defense (OSD), that PMOs, because of their commitment to achieving program goals, naturally tend to be optimistic regarding the risks and costs of program, particularly in early stages. To provide OSD and senior service decision–makers with data reflecting an independent viewpoint, OSD directed the establishment of the ICA program. The concept was that cost estimators, outside the influence of program advocacy, would develop cost estimates that more accurately portrayed the challenges, risks, and costs associated with the development and production of advanced weapon systems.

In addition, the requirement for independent cost estimates has been contained in public law as follows:

1984 Authorization Act: "...The Secretary of Defense may not approve the full-scale engineering development or the production and deployment of a major defense acquisition program unless an independent estimate of the cost of the program has been submitted to the Secretary of Defense..."

1985 Authorization Act: "...Not later than May 1, 1985, the Secretary of Defense shall submit to the Committees on Armed Services of the Senate and House of Representatives a report on the continued use of the independent cost estimates in the planning, programming, budgeting, and selection process for major defense acquisition in the Department of Defense.

Department of Defense Directive 5000.4 establishes the OSD Cost Analysis Improvement Group (CAIG). This directive discusses how cost estimates are to be presented to the OSD CAIG, and specifies its membership. The OSD CAIG acts as the principal advisor to Undersecretary of Defense Research and Engineering (USDR&E), and the Defense Advisory Board on matters relating to program cost. The OSD CAIG is required to review and recommend action on cost estimates for all major systems. The same directive identifies two types of estimates:

- Independent Cost Estimates (ICE)
- Program Office Cost Estimates (PCE).

An ICA starts with an Independent Cost Estimate (ICE) prepared in response to the DoD ICA program. Developing an ICA basically entails the same procedures, methodologies, and techniques that would be employed to accomplish any other weapon system cost estimate. However, ideally the ICA should select methodologies and techniques different from those underlying the Program Office Cost Estimate (PCE). In addition, an ICA should include a detailed comparison and explanation of differences between the ICA and PCE.

The key aspect of the independent cost estimate is that it is developed in organizational channels separate and independent from the program office. This helps it serve as an analytical tool to validate or cross-check program management office developed cost estimates. This second opinion helps avoid the risk that some significant costs have been overlooked or that PMO program advocacy has resulted in low estimates which could place the success of the program at risk.

To the extent that those preparing independent cost estimates are advised and supported by a technical staff independent of the program office staff, some independent assessment of technical risks may also be accomplished during preparation of an independent cost estimate.

5.14 RISK HANDLING TECHNIQUES

Handling technique classifications were covered in Section 4.5. The possibilities for dealing with risk are as varied as potential sources of risk. It would be impossible to discuss each technique without first describing the complete circumstances under which it is appropriate. The key to developing an appropriate handling of any risk lies in the proper execution of the risk planning, risk assessment, and risk analysis functions. If these are done properly, the impacts of potential actions will be clearly understood and will lead to the best possible risk handling action.

The following Table 5.14–1 shows some of the typical activities that should be performed in each phase of the development cycle. Clearly, management actions to reduce risk should be aimed at performing quality work on each of these items. One of the primary reasons that this structural approach to acquisition exists is to reduce the risks of buying a piece of equipment that does not meet the need, does not live up to the performance requirement, is too costly, or is too late.

5.15 CHAPTER 5 KEY POINTS

- Risk Management techniques can apply to multiple parts of the risk management process
- Some techniques specialize in one aspect of risk
- Techniques should be selected based on program requirements (Chapter 6 provides detail)
- No technique will give you a choice of management actions
- Management actions are limited only by the ingenuity of the program manager.

References

5-1 Evrivaiades, M., *Management Reserve Cost Estimating Relationship*, Cost and Analysis Division, Directorate of Cost Analysis, Comptroller, Hanscom AFB, MA, March 1980.

5-2 "Technical Risk Assessment: Staying Ahead of Real-Time, Technical Problems Visibility and Forecasts", Department of the Navy, March 1986. (Draft)

Table 5.14-1 Typical Activities by Program Phase

CONCEPT EXPLORATION	*DEMONSTRATION/VALIDATION*
Identify Manufacturing Technology Needs	Examine Producibility of Competitive Designs
Identify Critical Materials	Prepare for Production Readiness Review
Evaluate Risk of Manufacturing Alternatives	Prepare Initial Manufacturing Plan
Perform Industrial Base Analysis	Evaluate Long Lead Requirements
Determine Contract Requirements for Dem/Val	Determine Need for LRIP
Define System Level Logistics Requirements (ILSP)	Prepare Initial Production Cost Estimate
Perform Initial Facility Planning	Determine Contract Requirements for FSD
Estimate Life Cycle Cost Performance Goals	Establish Readiness and Supportability Objectives
Develop System Specifications	Prepare for Development and Operational Testing
Conceptualize T&E Program (TEMP)	Determine Acquisition Strategy
FULL SCALE DEVELOPMENT	***PRODUCTION***
Define Required Manufacturing Resources	Ensure Facilities are In Place
Prepare Manufacturing Cost Estimates	Examine Use of Warranties
Perform Production Risk Assessment	Determine Acquisition Strategy
Accomplish Production Planning	Examine Use of Second Source
Assess Long Lead Material Requirements	Integrate Spares Production
Perform Producibility Studies	Perform Fielding Analysis
Complete Manufacturing Plan	Perform Contractor Production Surveillance
Accomplish Development and Operational Testing	Execute Product Improvement Initiatives
Perform Production Readiness Reviews	Implement Value Engineering
Determine Contract Requirements for Production	
Determine Quality & Performance Controls for Production	
Evaluate Impact of Engineering Changes on LCC	
Prepare for Transition to Production	

Chapter 6

RISK MANAGEMENT IMPLEMENTATION

6.1 INTRODUCTION

While the concepts and techniques of risk planning, assessment, analysis, and handling are complex, the greater challenge is in the actual implementation of the risk management process. Program managers and PMOs are almost categorically overcommitted and overextended. In a recent Risk Analysis and Management survey of DoD Program Management Offices (PMO), allocating the resources to implement an effective risk management program was a significant and frequently reported problem. Over 50 percent of the PMOs responded that inadequate program staffing was a major risk area in and of itself. The view of risk management implementation as an additional requirement levied on the program team can appear as an overwhelming task. In actuality, risk management is an integral part of program management, not an additional analysis task. Risk management affects each of the classic elements of management; planning, organizing, directing, and controlling. Risk management plays an important role in the decision making process. In essence, risk management is a subset of sound program management and while the level or activity may vary, risk management should be viewed as an on-going process versus a one time exercise, as illustrated in Figure 6.1-1.

Risk Management implementation means the incorporation of the risk management concepts and techniques into the program management process, not simply the manipulation of a certain model. To this end, this chapter provides guidance for:

- Organizing for Risk Management
- Technique Selection
- Risk Management Resource Allocation
- Communicating Risk
- Developing a Risk Management Capability.

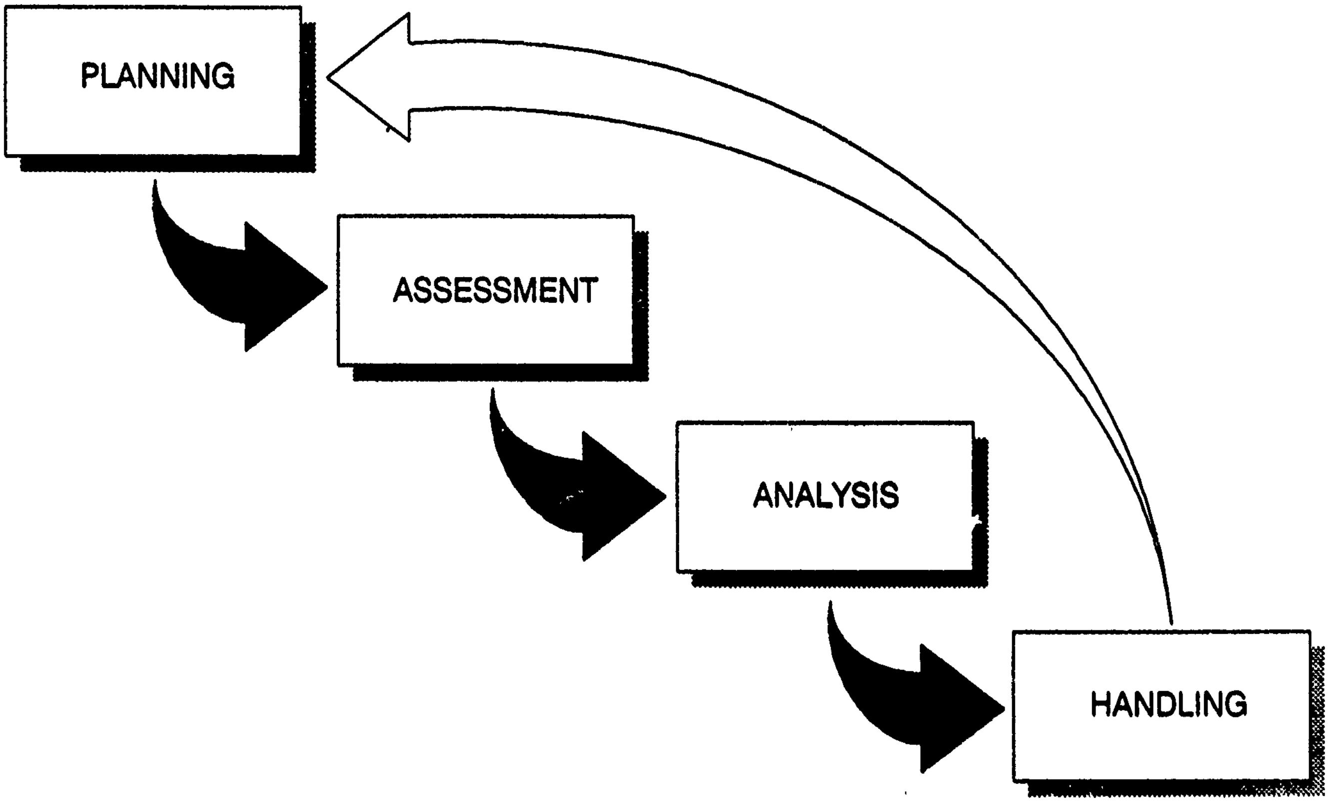

Figure 6.1-1 Risk Management as a Process

As with all efforts, successful risk management implementation is a function of the organization's understanding and commitment to meet the challenge.

6.2 ORGANIZING FOR RISK MANAGEMENT

The program manager is ultimately responsible for the implementation of risk management. The program manager establishes goals for the risk management effort and allocates the resources to accomplish these objectives. While the program manager must oversee this process, risk management activities do not reside solely with the program manager. Risk typically manifests itself in the functional analysis and decision making process. Figure 6.2-1 depicts a sample of functional analysis which often involves the complex interplay of technical, programmatic, supportability, cost, and schedule risk. Functional managers must understand the implications risk has in each of their respective disciplines. Risk management is a significant responsibility in each of the functional manager's jobs. The program manager's role is to provide the motivation and structure to effectively manage risk. The program manager should promote the continual interaction between team members for communication concerning risk management.

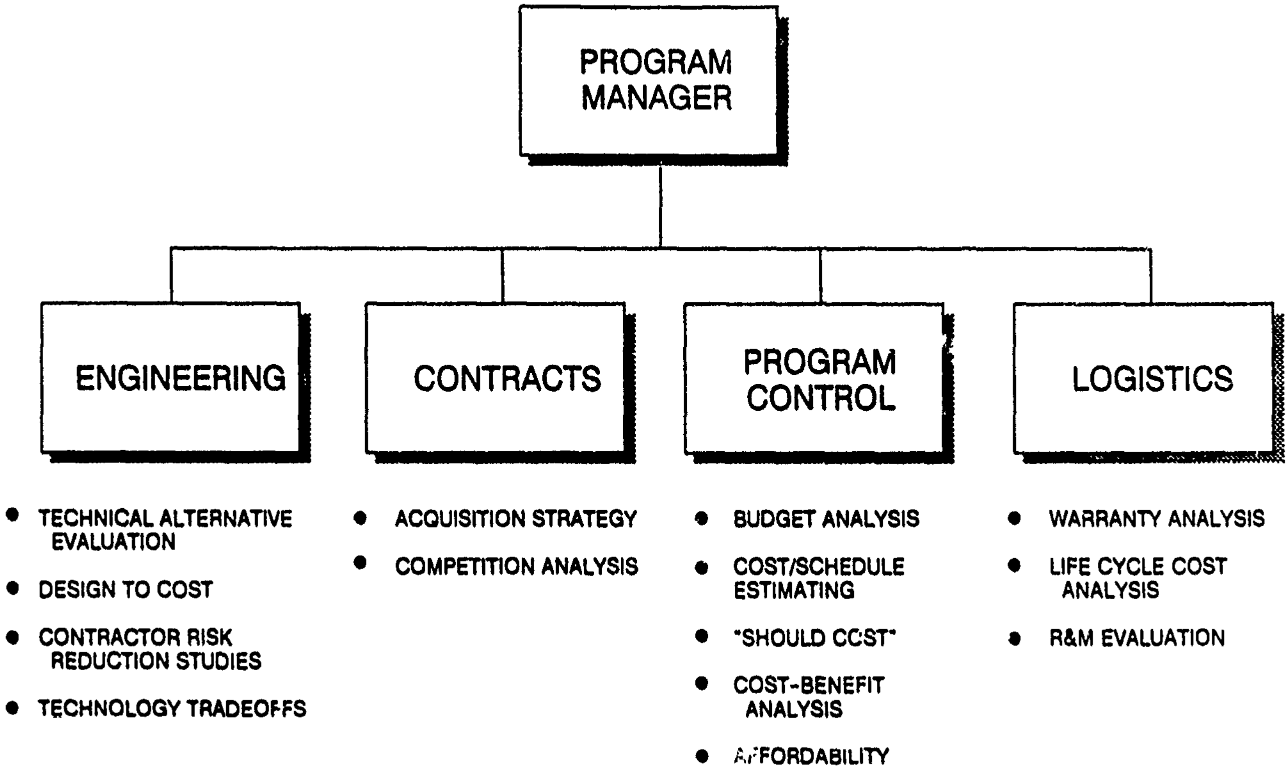

Figure 6.2-1 Functional Roles In Risk Management

While it is clear that risk management is a team function, it is not obvious how to best organize that team to execute the process. A survey of DoD Program Management Offices risk management activities revealed two basic approaches to organizing for risk management that the respondents felt were successful. One group of PMOs designated specific positions to conduct the program's risk management efforts. The number of people allocated varied by the size of the PMO and the risk management techniques being used. The other PMOs felt that risk management was such an integral part of engineering and management that separate personnel were not designated to manage risk and adequate consideration of risk was being accomplished as a normal part of their jobs.

Either approach could be defended for organizing for risk management.Though different, three basic themes appear as guidelines for incorporating risk management into the program management process. First, the program manager is ultimately responsible, as with all aspects of the program, for the planning, allocation of resources, and execution of risk management. Second, risk management is a team function. Each functional manager plays an important role in the identification, analysis, and handling of risk. Third, risk management activities and responsibilities must be specific and assigned to individuals. Actions and responsibilities assigned to groups are, in effect, not assigned. Whether risk management is a full time job or an integral part of a team member's job, risk management actions should be explicit and assignments clear.

6.3 RISK ASSESSMENT AND ANALYSIS TECHNIQUE SELECTION

Establishing objectives and allocating resources to accomplish those objectives is a primary function of the program manager. As depicted in Figure 6.3-1, this function is the basis for risk planning, the first step in the risk management process. At the heart of this planning effort is the selection of the most appropriate risk assessment and analysis techniques for the program. Selection of risk assessment and analysis techniques is the subject of this section. The technique selected shapes the nature of the risk management effort and should be directed towards providing the information necessary to meet the risk management objectives within the resource constraints of the PMO.

This discussion focuses on those risk management techniques described in Chapter 5 that deal specifically with risk assessment and risk analysis. Figure 6.3-2 illustrates the idea that risk management techniques can be loosely categorized by the primary purpose they serve in the risk management process. Generally, the risk identification and quantification techniques can support a variety of risk assessment and analysis approaches. Expert interviewing techniques are equally applicable for obtaining information in doing a network analysis, decision analysis, or developing a life cycle cost estimate. Similarly, the risk handling technique decision is not a function of the risk assessment methodology employed. Insights from the implementation of a Watchlist, for example, support the use of several approaches to risk handling. The type and timing of information needed for specific decision making applications, however, form the guidelines and constraints for the selection of the appropriate risk assessment and analysis technique. The following section provides guidance and a general framework of comparison for the selection of effective techniques for risk assessment and analysis. The answer is not the same for each program, nor does the answer necessarily stay the same for the life of a single program. As illustrated by Figure 6.3-3 the nature and level of risk management activity varies through the acquisition life cycle of a program. The risk assessment and analysis techniques that are effective between Milestone I and II, when a firm technical baseline is not yet established, may be inappropriate in the late production phase of the program. The resources required for risk management activity varies with the techniques, and the techniques used are largely dependent on the objectives of the risk management process.

6.3.1 Technique Selection Criteria

A variety of interrelated factors affect the selection of a technique. The current acquisition phase, size, priority, and complexity of a program all affect the type of information and

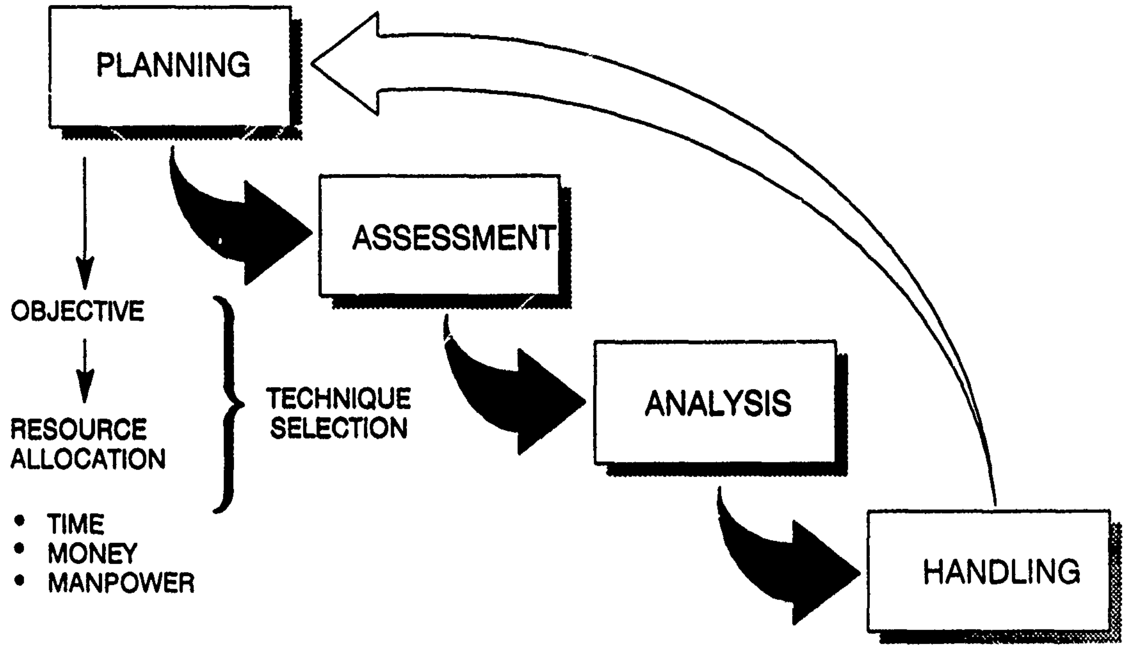

Figure 6.3-1 Technique Selection and Risk Planning

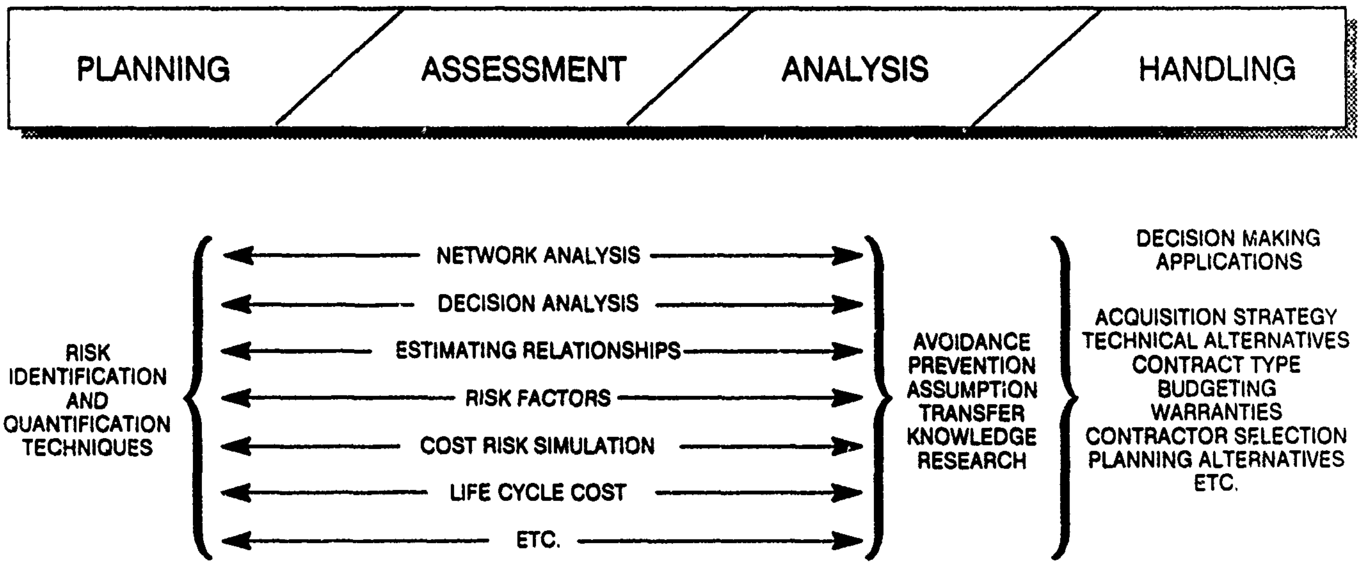

Figure 6.3-2 Risk Techniques Relationships

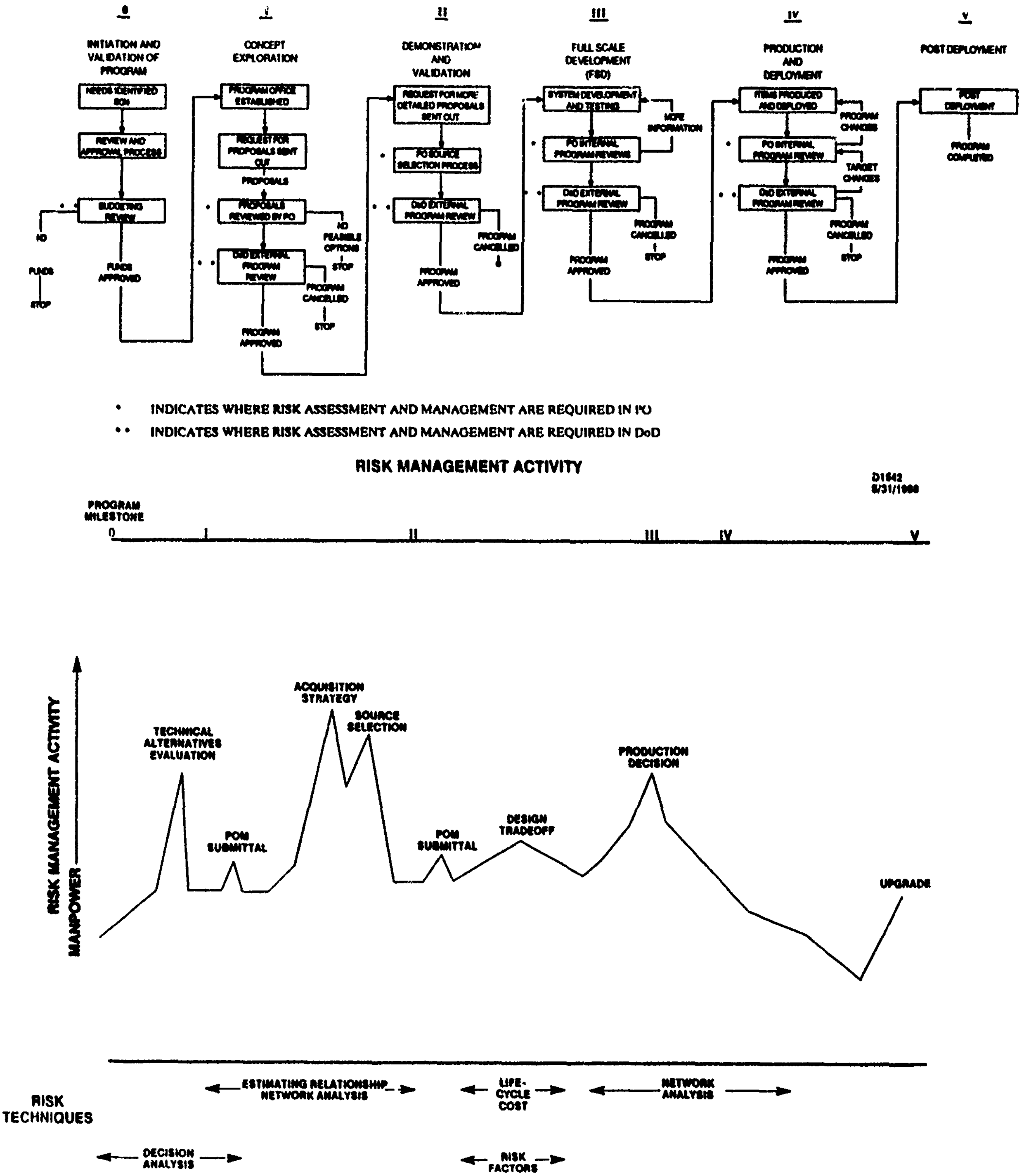

Figure 6.3-3 Risk Management Activity

RESOURCE REQUIREMENTS	APPLICATION	OUTPUT
• COST	• PROGRAM STATUS REPORTING	• ACCURACY
• HARDWARE/SOFTWARE	• MAJOR PLANNING DECISIONS	• LEVEL OF DETAIL
• TIME	• ACQUISITION STRATEGY SELECTION	• UTILITY
• EASE OF USE	• DAB MILESTONE PREPARATION	
• PM COMMITMENT	• DESIGN GUIDANCE	
	• SOURCE SELECTION	
	• POM/BUDGET SUBMITTAL	

Figure 6.3–4 Risk Management Technique Selection Criteria

analysis required to deal with risk. A key consideration and often a major constraint is the availability and capability of resources to devote to risk management. The pressure to do more with less is a constant and pervasive condition in PMOs. Often, organizations also have policies or directives which require the use of one or another risk assessment or analysis technique. The objectives of the risk management effort tie these considerations together and balances their influence in the selection of an appropriate technique.

These factors can be aggregated into three categories for the purposes of discussion and technique evaluation and selection (Figure 6.3–4).

- Resource requirements
- Application
- Output.

Serious consideration of the resources required to execute a particular technique was a recurring theme in the responses to the question of why a particular technique was used by the PMO in the DSMC Risk Management survey results. The second criteria is the application or the decision making process to which the risk assessment or analysis is targeted. The specific purpose or application of the risk information obtained varies and changes. Different techniques better support different applications, thus the application in which the risk information is used is another key criteria category. The third criteria is the actual output from the risk assessment and analysis technique. The accuracy, level of detail, and utility of the technique output should best match the required information for risk management decision making.

The criteria discussed are not all encompassing and clearly other circumstances can influence the selection of a risk technique.

However, these criteria will provide a comparative yardstick for evaluation and a framework for an educated decision to select a technique and implement it in the risk management process.

This section discusses several criteria that can be used to evaluate which risk assessment and analysis technique fits the requirements and constraints of a program's risk management effort. Each of the major techniques is then evaluated against these criteria and a general approach to technique selection is discussed. The intent is not to make technique selection automatic, but to help point out the advantages and disadvantages of different techniques in different circumstances.

6.3.1.1 Resource Requirements

What resources a particular technique requires is often the dominant consideration in the selection process.

The greatest utility with the least time, money, and manpower expended is always the sought after objective. The resource requirements of the various risk assessment and analysis techniques are compared using the following five factors:

- Cost
- Hardware/Software Tools needed/available
- Time to implement
- Ease of Use
- PM Commitment.

The cost identified is a rough approximation of the labor required (in man-months) to conduct or initially set up the risk assessment and analysis. Several techniques are maintained over an extended period of time. The maintenance of these techniques is not considered in the comparative cost figures. Obviously, actual costs vary considerably depending on the size and complexity of the program and the scope of the assessment and analysis. Thus the costs depicted are for comparative purposes. The hardware/software factor simply indicates whether or not (Yes; No) special hardware or software analysis packages are typically needed to use the technique.

Time indicates the duration of time (in months) needed to implement the individual technique. Again, in those techniques requiring continuing maintenance, only the initial time to implement is considered.

Ease of use is a subjective assessment of the relative difficulty in implementing each technique. A three point scale of E (Easy); M (Moderate); D (Difficult) is used to rate each technique.

The last resource requirement factor examined and rated is the program manager's time commitment to successfully implement the technique. Obviously a technique which requires intensive and continual involvement of the program manager would be difficult to implement. A three point scale of S (Slight); M (Moderate); H (Heavy) is used to rate each technique.

Evaluation of the techniques against each of these factors involved in the resource requirements criteria is presented in Section 6.3.2.

6.3.1.2 Technique Application

The following applications are defined here and matched against the capabilities of the techniques evaluated in Section 6.3.2, using a three point scale of H (High); M (Medium); L (Low).

- Program Status Reporting
- Major Planning Decisions
- Acquisition Strategy Selection
- DAB Milestone Preparation
- Design Guidance
- Source Selection
- POM/Budget Submittal.

Program Status Reporting refers to the monitoring of plans, costs, and schedules to ensure that standards are met and problems identified for timely corrective action.

Major Planning Decisions refers to major decisions to which a program manager may be willing to invest significant resources and personal attention.

Acquisition Strategy Selection typically occurs several times throughout the life of a program. Risk assessment and analysis provide key information relevant to the tradeoffs and cost benefit analysis of contract type selection, warranty structuring, etc.

The application of risk assessment and analysis in the Defense Acquisition Board *(DAB) Milestone Preparation* is very direct and important. The objective of the DAB is to insure the major weapon systems planning has been comprehensive and the system is ready to proceed into the next acquisition phase.

The next application category considered in evaluating the techniques is *Design Guidance*. From the consideration of technology alternatives for major weapon systems to the choices of components, each alternative represents a collection of large uncertainties of cost, schedule, and technical performance. In each situation, the program manager will want to understand how the uncertainties relate to one another and how the alternatives compare.

Source Selection evaluations frequently involve the consideration of risk as a determinant of selection. A quantified risk management effort provides the information to substantiate an evaluation. Source selection is a prime application for risk assessment and analysis. The typical short duration of source selections and their necessary restrictive nature place constraints on the type of technique used and the level of detail that can be successfully pursued.

POM/Budget Submittal is an obvious periodic application category. The basic decision of what funds are required to accomplish the program direction is an exercise in understanding and evaluating the interplay of technical, supportability, programmatic, cost, and schedule risk factors.

6.3.1.3 Technique Output

The third group of factors examined to compare and evaluate risk assessment and analysis techniques consider the output of the risk effort in terms of:

- Accuracy
- Level of detail
- Utility.

These factors are defined here and matched against the capabilities of the techniques evaluated in Section 6.3.2 using a three point scale of H (High); M (Medium); L (Low).

Accuracy deals with the basic theoretical soundness of the technique and the necessity for weakening assumptions which may dilute the value of the information obtained in the analysis. Most techniques present an obvious trade-off between ease of use or time commitment and the final accuracy of the analysis results.

Level of Detail is concerned with the output contents capability to provide more detailed insights into cost, schedule, and technical risks. Techniques and how they are applied vary in the breadth, depth, and understanding that the output contents provide.

Utility is a subjective factor which rates the output in a general context of its usefulness to the PMOs. Both the effort involved in the risk assessment and analysis and the end value of information is considered.

The ratings are obviously subjective, but their discussion brings out important considerations in choosing a risk assessment or analysis technique. The feedback from the DSMC Risk Management survey has been utilized in the rating and comparison of the individual techniques.

6.3.2 Technique Evaluation

This section rates and discusses each of the risk analysis and assessment techniques in the context of the previously defined selection criteria. This presentation will not make the selection of a risk technique automatic. Its intention is to provide the PMOs with an informed perspective to evaluate and choose an approach that is suited to meet the objectives of the risk management effort within the ever present resource constraints of a program. Table 6.3-1 is a matrix of the results of evaluating each technique against the previously defined selection criteria.

It is more important to note that some techniques have more applicability to specific program phases. Likewise, each technique yields different information than others. Table 6.3-2 summarizes the technique applicability for each program phase and addresses the type

Table 6.3–1 Risk Analysis Technique Selection Matrix

	RESOURCE REQUIREMENTS					APPLICATION							OUTPUT		
	COST (MAN-MONTHS)	HARDWARE/ SOFTWARE	TIME (MONTHS)	EASE OF USE	COMMITMENT	PROGRAM STATUS REPORTING	MAJOR PLANNING DECISIONS	ACQUISITION STRATEGY SELECTION	DAB MILESTONE PREPARATION	DESIGN GUIDANCE	SOURCE SELECTION	POM/BUDGET SUBMITTAL	ACCURACY	LEVEL OF DETAIL	UTILITY
NETWORK ANALYSIS	(1) 1–3	Y	(1) 1–3	D	S–M	H	H	M	H	M	H	M	H	L–H	H
DECISION ANALYSIS	.5–1	Y	.2–.6	M	S–M	M	H	H	H	M	M	M	L–H	L–H	M
ESTIMATING RELATIONSHIP	.1	N	.1	E	H	N/A	N/A	N/A	N/A	N/A	N/A	H	L	L	L
TRANSITION TEMPLATES	.5	N	.5	E	M	H	H	H	H	H	L	L	M	M	H
LIFE CYCLE COST ANALYSIS	(1) .1–.3	Y	(1) .1–.5	E	M	H	H	M	M	M	H	H	M	M	H
COST RISK/WBS SIMULATION MODEL	(1) .2–.4	Y	(1) .2–.5	E	S	L	L	N/A	N/A	N/A	L	L	L	L	L
RISK FACTOR METHOD	.1–.4	N/Y	.1–.5	E	S	M	N/A	L	N/A	L	L	M	L	M	M
PERFORMANCE TRACKING	1.5	N/Y	1	E	M	H	M	M	M	1 H	N/A	M	M	M	H

(1) If appropriate model available, see text

Y = Yes
N = No

E = Easy
M = Moderate
D = Difficult

S = Slight
M = Moderate
H = Heavy

H = High
M = Medium
L = Low
N/A = Not Applicable

H = High
M = Medium
L = Low

Table 6.3-2 **Program Phase/Technique Application**

	PROGRAM PHASE				INFORMATION YIELD				
	CE	D/V	FSD	PROD	TECH	PROG	SUP	COST	SCHED
EXPERT INTERVIEWS	+	+	+	+	+	0	+	0	0
ANALAGOUS SYSTEMS	0	+	+	+	+	0	0	+	0
PLAN EVALUATION	-	0	+	+	+	0	+	-	-
TRANSITION TEMPLATES/ LESSONS LEARNED STUDIES	0	+	+	+	+	0	+	-	-
NETWORKS	-	+	+	0	+	0	+	+	+
DECISION ANALYSIS	+	+	0	0	0	0	0	0	0
ESTIMATING RELATIONSHIPS	-	-	-	0	-	-	-	+	-
RISK FACTORS	-	0	+	+	-	-	-	+	-
LIFE CYCLE COST MODELS	-	0	0	+	-	-	+	+	-
COST RISK SIMULATIONS	-	-	+	+	-	-	-	+	-
PERFORMANCE TRACKING	O	+	+	+	+	0	+	+	+

- = Relatively weak application/information
0 = Average application/information
+ = Relatively strong application/information

of information likely to be received. This table shows "general" guidelines. There have been, and will continue to be specific applications that are/will be exceptions to the guidance represented in this table. Technique selection should not be based solely on program phase. The type of information desired as a result of the execution of a particular technique must also be considered. For example, while networks are not the optimum risk analysis tool in production, they may be desirable because of their value in planning and control while transitioning from development to production. Similarly, networks may serve a somewhat different purpose in the different phases.

A more thorough discussion of each technique was presented in Chapter 5. This evaluation will summarize the key characteristics to be considered in making the proper selection of a technique.

6.3.2.1 Selection Criteria for Network Analysis Technique

Resource Requirement: The resources required to apply the network analysis technique is dependent on a few factors. One of which is whether or not the networks already exist for the program. If so, they can be utilized for the risk models and much labor can be saved. The scope of the program and the level of detail being modeled also impact the resource requirements (with the larger scope and greater detail requiring significantly more resources). When doing network risk analysis, special software is required. Also, if plots of the networks are desired, plotting equipment will be needed. Since the process of building the networks, capturing expert judgment and understanding the software are not simple tasks, ease of use would be rated as low. PM backing is mandatory for successful network analysis because of the resources required, and the degree of difficulty associated with the process. Although the PM's personal involvement is slight to moderate, the members of the program team must be convinced of the manager's commitment to the task.

Application: Networks have a high degree of utility as discussed in Section 5.8, therefore all of the applications listed are relevant.

Output: With respect to output, the accuracy of the analysis is a function of the validity of the network itself and the PDFs constructed for each activity. The level of detail is determined by management so it can be low, medium, or high. The utility of the networks is generally high, if for no other reason than it forces managers to detail plan before the execution of a program.

6.3.2.2 Selection Criteria for Decision Analysis Technique

Resource Requirement: The decision analysis method is a much simpler technique than network analysis. Because of this, the resources required are significantly less. PM commitment, while required, does not need to be as high as with network analysis.

Application: As with network analysis, decision analysis lends itself well to all of the potential applications listed.

Output: If the program can be accurately modeled, the output will be accurate. The level of detail is specified by the program manager predicated on what he deems necessary. The utility of decision analysis is not as high as network analysis because it does not provide the same diversity of output or address the myriad of questions that network analysis does.

6.3.2.3 Selection Criteria for Estimating Relationships Technique

General: The estimating relationship method is not well understood by many. Many PMO survey responses indicated they had used the technique when they had really used parametric cost estimating methods for some or all of the program cost estimates. Such analysis is more accurately described as all or part of a life cycle cost analysis. The estimating relationship method is defined by the use of parametric estimating methods to estimate risk or management reserve fund requirements. There are currently very few parametric cost models available with which to do this.

Resource Requirements: The primary requirement is the availability of a parametric cost model specifically designed to estimate management reserve or risk funds as a function of one or more program parameters. If such a model is not available, one to three months may be required to develop one. If the required historical data is not available, it may be impossible to develop the required cost model. If a satisfactory model is available, it generally takes only a few days to use it. However, the program manager must support its use so key program personnel will provide the cost analyst with timely judgments or information needed to input the model. The model equations are usually so simple that a handheld calculator can be used to compute required management reserve fund requirements.

Application: The primary use of this method is to compute the management reserve or risk funds to be included in POM and BES funding requirements. It has little or no use for other applications. This is a very easy technique to recompute and update as the program progresses over time and either the level of risk or the basic program cost estimate changes.

Output: The estimating relationship method output is generally a percent value. This value multiplied by the basic program cost estimate provides an estimate of the management reserve or risk funds that must be added to the basic cost estimate to assure the budget includes adequate funds to cover the added costs that will be incurred because of the risks associated with the program. The accuracy of this method is considered low primarily because the historical data bases upon which such models are based are small, and it is often hard to accurately define what funds were spent to address risk on past programs. This method provides little or no detail with respect to which parts of the program are more risky, and therefore, more likely to require additional funding. Since there are so few models of this type available, and even their use are subject to question, the overall utility of this method across the DoD must be considered low.

6.3.2.4 Selection Criteria For Transition Templates Technique

Resource Requirements: This technique requires little additional resources above what is normally necessary to properly manage a program. There are no special hardware/software requirements and the technique is easy to use. It does require discipline on the part of the program management office to regularly review and compare progress against each of the template areas.

Application: The Transition Templates can be used in most of the application categories in Table 6.3-1. The technique is only indirectly useful in the POM/Budget category because it deals with preventive technical aspects rather than cost issues. It can, however, provide insight into the driving forces behind cost and a contractor's methodology for managing a program in a source selection situation.

Output: If the user properly documents the results of his analysis, the output will provide a traceable management checklist that can be used to make sound decisions on technical issues. Again, discipline is a key issue in determining the usefulness of the output. If each of the templates is examined in detail, the user will have a firm understanding of the technical risks faced in the program. Skipping templates because there is no "apparent" risk may save time, but may also miss key problem areas.

6.3.2.5 Selection Criteria for Life Cycle Cost Analysis Technique

General: Life cycle cost analysis has been used widely in the DoD in recent years as a result of growing concern about rapidly increasing operating and support costs. Since economic considerations are an integral part of engineering, life cycle costs can be an important design consideration. There are both PMO unique and general purpose life cycle cost models widely used. The availability of the electronic spreadsheet has greatly facilitated the development and use of life cycle cost models by PMO personnel.

Resource Requirements: Performing a life cycle cost analysis, even one involving many estimates for different scenarios or sets of assumptions can be done relatively easily and quickly, if the model is already available. For large and complex programs, the input data collection process may involve many sources. Even the most complex life cycle cost models can be run on computers of the size available to most PMOs. If a PMO unique model is not available and must be developed, the resource requirements to do this can be greatly reduced if a demonstrated model for a similar system can be tailored to the PMOs needs.

Application: Since cost is an important management consideration, the results of life cycle cost analysis are applicable to many PMO decisions and activity areas. Once a PMO computerized life cycle cost analysis capability has been developed, it is of significant value whenever a quick assessment is needed of the cost implications of design, production rate, or other program changes.

Output: The overall accuracy of life cycle cost analysis is medium. Usually such estimates can be improved if significant additional time is taken to have the prime contractor take a more detailed look at how changes would impact a program. Life cycle cost analysis is better for analyzing the differences among alternatives than accurately predicting future costs Depending on the specific life cycle cost model, the analysis output can provide considerable detail as to where cost might change as the result of program changes. The overall usefulness of life cycle cost analysis is high due to the timely insight it provides relative to a wide range of management decisions.

6.3.2.6 Selection Criteria for Cost Risk/WBS Simulation Model

General: This type of analysis model aggregates the cost uncertainty due to risk for any number of cost elements into a distribution of the cost uncertainty for the entire project. Both DoD and commercial software programs are available to carry out this type of analysis.

Resource Requirements: This analysis method is easy to use after a few hours of hands-on experience. Available programs come with instructions. However, obtaining and substantiating sound values for all the cost element uncertainty information needed to use the method may be difficult. Ideally, the best source of such information would be past experience on similar programs, however, adequate information of this type is seldom available. The analysis computations can be obtained within minutes after the required data has been obtained. Often the required cost element uncertainty data must be based on the judgment of PMO personnel. The program managers commitment is needed to assure PMO personnel provide this information in a timely manner.

Application: The PMO survey indicated limited use of this analysis technique. Only seven percent of PMO completing surveys reported specifically using the technique. Two PMOs reported it to be useful for program planning. There were single reports of it being useful for POM/BES preparation, source selection, and program status reporting.

Output: The accuracy of the output results is limited by the subjective nature of most of the input data used to carry out this type of analysis. The analysis does nothing to increase visibility at a lower level of detail. It does the computation by aggregating detailed information into overall program cost risk information. The overall usefulness of this type of analysis for actually detecting risk, controlling risk, or reducing the impact of risk is limited. However, it can be used to display cost risks known to exist at the cost element level in an aggregate manner the way some management officials wish to see it.

6.3.2.7 Selection Criteria for Risk Factor Technique

General: This analysis method has been widely used to develop an estimate of the funds required to cover added costs resulting from various risks felt to be associated with each of the various work breakdown structure (WBS) elements associated with the program.

Resource Requirements: A cost estimate broken out by WBS element is a prerequisite for this technique. Obtaining WBS element risk factors from adequately qualified experts is the bulk of the effort. The required computations are usually so easy that they have been carried out quickly with only a hand-held calculator. However, if a simple program is not already available to carry out the required computations, it would be best to quickly set up the computations on an electronic spreadsheet.

Application: This analysis method can only be used when a cost estimate broken out by WBS element is already available. It can quickly provide a systematically derived estimate of required funds to cover the costs resulting from risky aspects of the program. It is applicable to any type of product or size of program. It is probably more applicable to smaller programs where the resources and time required to apply more sophisticated techniques cannot be justified. The method can best be applied when PMO personnel with experience on several other programs are available to provide judgments of the level of risk involved with each of the WBS elements.

Output: The output of this analysis method is an estimate of the total funds required to complete the program, including funds to resolve problems caused by risk.

6.3.2.8 Selection Criteria for Performance Tracking Technique

Resource Requirements: The performance tracking technique requires a small amount of additional time above what is normally required to manage a program. Most of this time is in the initial setup of indicators to be used and tracked in monitoring program progress. The level of effort can vary based on contractor reporting requirements as set out in the contract. With this technique, involvement of the contractor is desirable in the initial setup of indicators - their level of involvement will directly affect the program office effort in getting the indicators in place. The use of a spreadsheet and PC are desirable but not mandatory. Once the indicators are in place, minimal resources are required to maintain.

Application: This technique can be used in most of the categories of Table 6.3-1. Since the technique focuses on the monitoring of progress once an item is contracted for, there is little value in using it for the Source Selection process.

Output: The output of the technique is very good in general. If the appropriate indicators were selected, a quantified measure for each potential problem area is graphically presented. These are extremely useful for both management of the program and communcation of the program status to all levels of decision-makers.

6.3.3 Technique Selection Summary

As discussed, the selection of a risk assessment and analysis technique is a function of the application, the information needed, and very importantly, the resources required versus the resources available. Much of the hesitation to implement many of these techniques comes from the concern that they are too time consuming, especially for a small PMO. The results of the DSMC survey and an understanding of the different techniques indicate otherwise. The use of Transition Templates, Risk Factor Methods, and Performance Tracking techniques all can be tailored to provide valuable information without considerable expenditures of resources. Even the network analysis technique can be used selectively with positive results with less than a major team effort. The key to technique selection and successful risk management implementation is the clear communication of the objectives, and the integration of risk management concepts and activities into the normal course of managing the program.

6.4 RISK MANAGEMENT RESOURCE SOURCES

In implementing a risk management effort, the program manager must acquire and allocate the proper resources to tackle the job. The program manager has basically four sources to task in conducting a risk management program.

- Program office
- Functional support office
- Prime contractors
- Support contractors.

Each source has been used successfully by different programs though most respondents to the DSMC Risk Management survey attempted to accomplish the majority of their efforts within their own PMO.

Each source has its strengths and weaknesses to consider and certain criteria should be used when selecting a source. The first criteria is simply the *capability* of the source to accomplish the risk management task. Capability refers to the knowledge and understanding of applying the risk techniques. A second criteria is the *availability* of the resources to accomplish the risk management task. There are only a finite number of hours in a day and days in a week. Though a PMO may be highly skilled and very experienced, their time commitments may necessitate finding other sources for the conduct of certain aspects of the risk management effort. *Objectivity* is another criteria which should be considered. By definition, the PMO is an advocate of the program and as such, the results of their analysis may be viewed externally as prejudiced. Depending on the situation and ultimate use of the results, this may be an important criteria for consideration. The last factor considered is the *responsiveness and familiarity* of the source. This criteria aggregates the technical and program knowledge of the source with the ability to respond to program changes.

Table 6.4–1 captures in a matrix an evaluation of the sources against these four criteria. In terms of capability, the program office's ability generally is technique and organization dependent. Some program offices have individuals who have developed skills and are experienced in various risk techniques. Similarly, those PMOs operating in matrixed organizations who turn to functional support offices will generally find capabilities that vary by technique and organization. The DSMC Risk Management survey found an increasing awareness and capability among PMOs for the conduct of risk management efforts. Prime contractor's capabilities are also dependent on the specific technique and organization. In general, support contractors are available with the capability to accomplish risk management tasks. The availability of the

Table 6.4–1 Resource Selection Criteria

	PROGRAM OFFICE	FUNCTIONAL SUPPORT OFFICE	PRIME CONTRACTOR	SUPPORT CONTRACTOR
CAPABILITY	TECHNIQUE AND ORGANIZATION DEPENDENT	TECHNIQUE AND ORGANIZATION DEPENDENT	TECHNIQUE AND ORGANIZATION DEPENDENT	VARIES
AVAILABILITY	VARIES	VARIES	GENERALLY AVAILABLE/DIRECT COST	AVAILABLE/DIRECT COST
OBJECTIVITY	PROGRAM ADVOCATE	STRONGEST	WEAKEST	CONTROLLED BY PROGRAM ADVOCATE
RESPONSIVENESS FAMILIARITY	STRONG	VARIES	STRONG	MODERATE/DIRECT COST

source obviously varies in the government. It is generally available from the prime and support contractors, but at a direct cost. In terms of objectivity, the PMO is viewed as a program advocate and as such, may be suspect. The support contractor may be more objective, but is controlled to a degree by the PMO. The weakest source in objectivity is the prime contractor for obvious reasons, and generally the strongest source comes from the independence of the functional support office. The PMO and the prime contractor are rated as being familiar with a program and responsive to it. The support contractor is rated as moderate due to the learning that must be accomplished to conduct an assessment and analysis. Keeping the support contractor at a certain level of involvement to improve responsiveness and familiarity is a direct cost to the program. The responsiveness and familiarity of the functional support offices varies. They typically suffer to a lesser degree from the need to learn the program in order to accomplish their risk management task.

In the final assessment, for the selection of a source to accomplish a major part of a program's risk management effort, the program manager should first look to the PMO itself. The benefits in program definition and understanding in conducting the risk management effort, in addition to the information derived for decision-making for the handling of risk, merit the rigorous attempt to accomplish the effort in-house. It is appropriate and necessary, however, to make use of all available sources of expertise in the conduct of a comprehensive risk management effort.

6.5 COMMUNICATING RISK DATA

An important aspect of risk management implementation (which if ignored, can make the best risk assessment and analysis ineffective and incomplete) is the proper communication of risk data to decision-makers. The clear definition of the terminology employed in discussing risk, the presentation of information in a clear and consistent format within a program, and the thorough documentation of the risk data are the basics for successfully communicating information about risk.

No DOD or service standards exist for the clear definition of terms for risk. While this handbook has presented a basic framework for discussing risk, an argument can be made that no universal standard can be employed to compare risk across programs. Given these circumstances, the clear, unambiguous definition of the terminology used to present risk related data must be accomplished for common understanding among program participants and higher command levels.

Beyond terminology, for a full understanding of the risk information, the process and the content of the conduct of the risk management effort must also be captured and communicated. The sources of data, the assumptions made about the program, the methodologies of assessment, analysis, and handling techniques used, and the sensitivity to the risk data of changes in the assumptions, must all be consistently documented and communicated to effectively implement risk management.

Last, though the subject of risk is complex, the presentation of findings and risk data should be straightforward and in a usable format. The depiction of a cumulative probability distribution function from a Monte Carlo network analysis may be informative to an analyst, but meaningless to the decision-maker reaching for a solution to the problem. Risk data must be presented in a usable format that communicates the essential elements of the risk management effort.

6.6 DEVELOPING A RISK MANAGEMENT CAPABILITY

To successfully implement the risk management process, the program manager must also address the capabilities of the PMO to execute that process. The discussion of risk management implementation typically centers around the evaluation and selection of the tools and techniques to be used and the source of manpower to use them. Much of this chapter has focused on these two topics. Figure 6.6-1 illustrates that there are basically four elements of a risk management program which

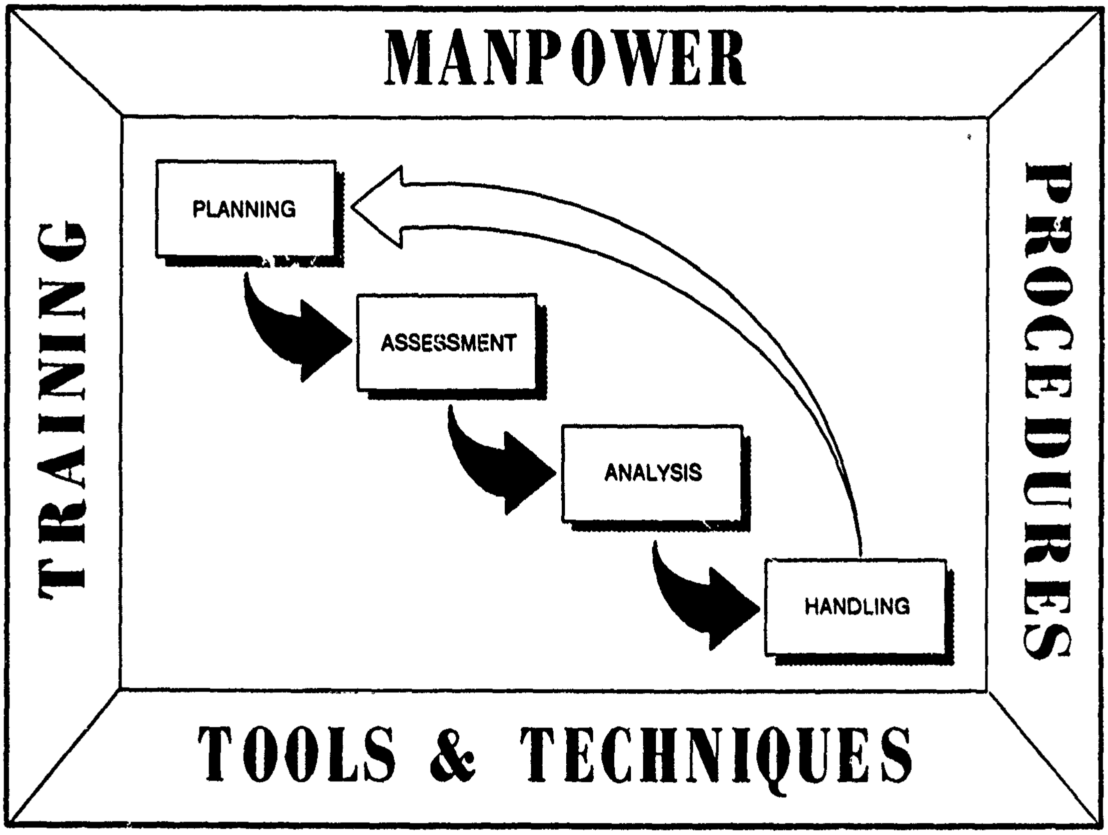

Figure 6.6–1 Risk Management System

support the execution of the risk management process. Each of these elements should be considered when developing an organic risk management capability.

While manpower and technique selection are essential aspects of a risk management program, training and procedures are also critical for successful implementation. Risk management, as discussed earlier, is a team effort. Training in the concepts and techniques of risk management is required for full understanding and effective accomplishment of the objectives of the risk management effort. Training the PMO personnel is a necessary investment to fully reap the benefits of the risk management effort. Procedures are the documented approach to executing the risk management process. Whether contained in a formal risk management plan or not, procedures should be developed which establish direction and responsibility for the conduct of the risk management process.

6.7 CHAPTER 6 KEY POINTS

- Program Managers must organize for risk management

- Risk Management is a team function
- Technique selection should be based on pre-determined criteria
- Proper communication of risk information is as important as the process
- Program Managers should strive to develop their risk management capability.

Chapter 7

CONTRACTOR RISK MANAGEMENT

7.1 GOVERNMENT RESPONSIBILITIES

In preparing a Request for Proposal (RFP) it is essential that the procuring agency squarely face the fact that risk management is part of the acquisition strategy. A formal plan of risk evaluation and reduction should be established by the government very early in each acquisition program. This plan should be tailored to consider the contractor and government risks. The assessment and analysis of each significant element of program risk should be continued throughout the acquisition cycle. The acquisition strategy should lower the risks to reasonably acceptable levels. The procuring agency should include in the RFP requirements for the offerors to describe their approach to identifying and managing the risk inherent in the program. These would most probably include areas such as reliability, maintainability, producibility, quality, design, manufacturing technology, and research along with many others too numerous to mention. In addition, the RFP should include data items such as a Risk Management Plan and a Risk Assessment Report in order to insure that the contractor will seriously plan for risk management and is continuously assessing the risk.

Some sample statements that could be used in an RFP include the following (Ref. 7-1):

"The executive summary shall present a proposal overview, expected performance including reliability, maintainability, producibility, design, and supportability issues, work to be accomplished, trade-offs, risk areas, schedule, special considerations, and any other items necessary to briefly summarize salient proposal characteristics."

Engineering/Design

"The offeror shall describe the engineering/technical tasks to be accomplished during the D/V program which contribute to risk reduction and definition of the substantiated system/subsystem concept. The discussion shall contain the following item:

A discussion of major technical risk items associated with the offeror's proposed system concept, including payoffs which will potentially result from the proposed approach, as well as problem areas. The approach to determining the technical risks involved in your program and your approach to reduc'ng such risks to acceptable levels shall be described. Key development issues and the proposed solution approach shall be identified. The discussion shall present the criteria to be used to evaluate critical decision points and information requirement, and the process to be used to develop, evaluate, and implement fallback positions as required."

R&M

"Describe your approach to determining the technical risk involved in your R&M program and your approach to reducing such risks to acceptable levels. This discussion shall present the criteria you plan to use in determining the criticality of technologies, the techniques used to evaluate critical decision points and information requirements, and the process used to develop, evaluate, and implement fallback positions as required."

Producibility

"Describe the approach to determining the technical risk involved with the design producibility engineering program and the approach to reducing such risks to acceptable levels. This discussion shall present the criteria you plan to use in determining the criticality of technologies, the techniques used to evaluate critical decision points and information requirements, and the process used to develop, evaluate, and implement fallback positions as required."

Quality in Design

"Identify quality in design risks and factor these risks into design trade studies."

Manufacturing Research/Technology

"Provide an assessment of the likelihood that the system design concept can be produced using existing manufacturing technology while simultaneously meeting quality, rate, and cost requirements. Include in your analysis and evaluation of the producibility of the design concept: requirements for critical process capabilities and special tooling development, tests and demonstrations required for new materials, alternate design approaches, anticipated manufacturing risk, potential cost and schedule impacts, and industrial base and surge capabilities."

Project Control System

"The offeror shall describe the approach system and methodology for risk management. This discussion will include how information from the functional areas shall be integrated into the risk management process."

Manufacturing Planning

"Describe the initial manufacturing planning accomplished in the following areas: production risk, risk resolution, and identification of fall back positions, resource requirements, critical materials and processes, long lead requirements, management systems, organization and staffing, and scheduling."

Quality Assurance

"Describe any QA risks you foresee for this program and actions planned to reduce the risks."

Security

"Operational Risks

(a) Level/Amount of Classified: Identify the levels of classification which will be processed as well as the estimated hours per month and percent of total material processed for each category.

(b) Sensitivity/Perishability: Identify any significant factors concerning the sensitivity and/or perishability of the classified data.

(c) Frequency of Processing: Identify the classified processing schedule which will be used; e.g., scheduled, irregular, sporadic, random. Assess the probability of the exact hours of classified use being pinpointed by unauthorized personnel. Describe any facts or circumstances that would make such determinations difficult."

"Technical Risks

(a) Physical Control Space (PCS): Identify the radius in meters of the physical control space available around the systems/equipment/facility. Describe the barriers, doors, fences, walls, etc, that define the PCS. Describe the control exercised over the PCS during duty and non-duty hours. Describe other factors which contribute to control, such as visitor procedures, escort requirements, searches of personnel and/or vehicles, etc. (PCS is the area within which only personnel with Government security clearances are allowed unescorted access.)

(b) PCS Breaches: Identify the type and location relative to the system of any unfiltered telephone or communications lines, ungrounded or unfiltered power lines, conduits, heating and air conditioning ducts, water pipes, etc., that transgress the established PCS.

(c) Building Construction: Describe the building in which the system is housed, e.g., concrete block walls, aluminum doors, no windows.

(d) RED/BLACK Installation: Identify whether classified processors were installed in accordance with RED/BLACK criteria (i.e., installed in accordance with NACSIM 5203).

(e) Shielded Enclosure: Identify whether classified processors are operated within an RF shielded enclosure."

Evaluation Summary

"The overall evaluation of each proposal may include on-site inspections and results of pre-award surveys to provide information to the Source Selection Authority regarding offerors current and future capability to perform all aspects of the program. Risk assessment associated with the major areas of the program will be accomplished. In assessing risk, an independent judgment of the probability of success, the impact of failure, and the alternatives available to meet the requirements will be considered."

7.2 CONTRACTOR RESPONSIBILITY

The contractor should be made aware through written language in the contract that the information contained in the DIDs will be used for risk analysis. It should be the contractors responsibility to make a thorough assessment of risks in proposing the contractual effort. Sufficient information should be included in the proposal to convince the government that the contractor has recognized and quantified the risk inherent in the program. The proposal should identify areas where actions by the government can aid in risk reduction. These can include items such as long lead funding and the necessity for approval of priority status for materials.

In proposing a risk management system, the contractor should highlight how he can use existing internal systems (e.g., his cost and schedule control system) to provide information on risk. The contractor should also concentrate on how he can include risk considerations in normal management practices and in the various items of data provided to the government.

7.3 CHAPTER 7 KEY POINTS

- RFPs should request information about the process that the contractor will use to manage risk
- Contracts should include deliverables containing information regarding risk
- Contractors should formalize risk management.

Reference

7-1 Extracts from ATF RFP Attachment X, F33657-85-R-0062.

Chapter 8

THE FUTURE OF RISK MANAGEMENT

Risk is a fascinating subject. To those who try to understand, it looks a bit different each day – like a crystal reflecting light differently depending on the angle of view. Studying risk leads a person through a wide range of academic disciplines from rigid mathematical probabilities through sophisticated computer models into the behavioral sciences and on to the psychology of risk takers and risk avoiders.

There are many students and practitioners who are convinced they have the single right answer to the understanding and management of risk. Many confuse the tool with the result. Academics want to quantify and analyze. Bureaucrats seek more information, avoid commitment, and criticize. Program managers live with risk. They "own" the problem.

Risk management, in the context of interest here, *is* being practiced within DoD. Not as much as it should be, but more than the critics would allow. Program managers deal with risk daily. Frequently, they think of it as management without suspecting it is risk management. To that extent, the criticism is unjustified. On the other hand, many managers do not seek to identify and resolve risks early, but rather deal only with those risks that appear today. Finally, there are those who attempt to obscure risk in the practice of "not on my watch" program management. To that extent the criticism is very justified.

Risk management can be practiced better than it is. Tools are available. They are not perfect, but they can be improved. We are not living up to the existing capacity. The body of knowledge, available tools, and the computer power is available to make a major step forward in risk management.

If risk is to be properly managed, it must be recognized, acknowledged, and accepted. It must be taken out of the closet. A fundamental culture change is necessary with regard to risk.

- Program Managers must be penalized for not communicating risk rather than for doing so.

- DoD "corporate management" must insist on seeing and hearing about risk and then have the courage to support the risk takers.

Risk management currently suffers from a limited vocabulary and a lack of standard definitions. Communication on the subject would be aided immensely by treatment of the vocabulary and definitions problem.

Risk management currently lacks standardized procedures and techniques. At this stage of development, lack of standardization is NOT a fault. There are many very intelligent people who will devise ingenious and effective techniques if given the requirements and the freedom to be creative.

In the spectrum of the risk management process, the weakest area at present is that of "quantifying expert judgment". Risk identification focuses on capturing the knowledge and judgment of experts. Risk assessment and analysis deals largely with mathematical statements and quantified results. Transitioning from the English language statements of experts to the mathematical expressions required by the analytical tools is done inconsistently.

Strengthening this area will significantly improve the risk management process. Some rudimentary surveys of on-going research in the field indicates that this problem is a natural for the application of expert systems technology and is in fact being worked.

Risk handling is that portion of the process where the program manager attempts to reduce or contain the risks that have been identified, quantified, and analyzed. Risk handling is discussed in Section 4.5 and 5.14 which cover only a small amount of this document. That illustrates the disproportionate share of thought and literature that has gone to risk assessment and risk analysis at the expense of risk handling. The program manager is ultimately left with the question "What can I do about it?" Risk management should benefit greatly from future efforts concentrated in developing and documenting new ideas in risk handling techniques.

APPENDIX A

RISK SOURCES - AN ABBREVIATED LIST

1. TECHNICAL RISK SOURCES

1.1 MAJOR STATE-OF-THE-ART ADVANCE

These are problems that could cause deviations from the planned program resulting from greater than anticipated state-of-the-art advances. This includes areas such as:

- Complexity/difficulty in meeting requirements
- Percent proven technology
- Experience in the field needed
- Lack of work on similar programs
- Special resources needed
- Operating environment
- Required theoretical analysis
- Degree of difference from existing technology.

1.2 NUMEROUS STATE-OF-THE-ART ADVANCES

Deviations from the planned program could result from a greater number of areas than anticipated requiring advanced state-of-the-art techniques and development.

1.3 STATE-OF-THE-ART ADVANCE PROGRESS

Slower than expected progress in advancing the state-of-the-art could affect the planned program.

1.4 LACK OF SUPPORTING STATE-OF- THE-ART ADVANCES

State-of-the-art advances expected from other programs may not be as expected and can have a significant affect on the present program.

1.5 FIELD FAILURES OF STATE-OF-THE-ART ADVANCES

Field failures of state-of-the-art equipment types that were assumed to be ready for incorporation into the planned program can have a negative effect on the program.

1.6 OPERATING ENVIRONMENT

The new system may be required to perform in an unusually harsh environment which would cause problems with the program.

1.7 UNIQUE HARSH REQUIREMENTS

Significant differences between existing design technology and that required for success of the new system can cause deviations in the plans for the new system.

1.8 PHYSICAL PROPERTIES

If the dynamics, stress, thermal, or vibration physical property requirements are different than originally expected, the planned program may not achieve its original goals.

1.9 MATERIAL PROPERTIES

Material property requirements beyond what is usually expected could influence the planned program.

1.10 RADIATION PROPERTIES

Increased radiation stress resistance requirements can result in changes to the program from the original plan.

1.11 MODELING VALIDITY

Models used in developing mathematical and physical predictions can contain inaccuracies affecting the program.

1.12 TESTING INCONSISTENCIES

Inconsistent field test results can cause increased technical risk and require retesting.

1.13 TEST FACILITY COMPATIBILITY

Suitable test facilities may not be available during the required time frame and cause significant scheduling problems.

1.14 EXTRAPOLATION REQUIREMENTS

During the conduct of the program, the need for extensive extrapolation using field test results may hamper the assessment of the program under actual deployment conditions.

1.15 INTEGRATION/INTERFACE

New and unique design adaptability, compatibility, interface standard, and interoperability, etc., requirements can create situations that are not compatible with the original planned program.

1.16 SURVIVABILITY

New requirements for nuclear hardening, chemical survivability, etc., may require revised planning in order to meet original or new goals.

1.17 SOFTWARE DESIGN

Unique software test requirements and unsatisfactory software test results could result in the generation of variances to the basic planned program.

1.18 SOFTWARE LANGUAGE

A new computer language or one unfamiliar to most of those responsible for planning and writing computer software could change the entire perspective of the planned program.

1.19 RELIABILITY

Failure to properly forecast system reliability or failure to obtain predicted reliability growth could cause the program to deviate from its desired course.

1.20 MAINTAINABILITY

Failure to obtain desired maintenance performance with a design that is compatible with proven maintainability procedures can require changes in the maintenance concept.

1.21 FAULT DETECTION

Fault detection techniques may reveal a failure to obtain designed performance and require modification to the program.

2. PROGRAMMATIC RISK SOURCES

2.1 HIGHER AUTHORITY ACTION RISK CATEGORY

2.1.1 Category Definition

Risks falling within this category result from decisions of actions by higher levels of authority – generally by people knowing its impact on the program but who are addressing larger issues.

2.1.2 Specific Higher Authority Action Risks

Priority Risk – Problems that could affect the planned program resulting from changing priority assigned to the program and thereby timely access to testing facilities, funds, materials, etc.

Decision Delay Risks – Disruption of the planned program schedule resulting from delays in obtaining higher level approval to award contracts, proceed to the next phase, etc., can cause program problems.

Inadequate SPO Authority Risks – Planned program delays resulting from the SPO not being given adequate authority to manage the program including having the authority to make timely cost, schedule, and performance trade–off decisions can be a significant risk.

Joint Service Program Decision Risks – Problems and delays that could disrupt the planned program resulting from reduced joint service participation or other user decisions.

Service Roles and Mission Changes – Problems that will cause deviations from the planned program resulting from changing service roles and missions which significantly alter the planned use of the system.

Concurrency – Concurrent development or the preparation for production can cause deviations from the planned program. Concurrency often results in discovery of problems at a time when a cost premium must be paid to resolve problems and keep the program on or near the original schedule.

Funding Constraints – Lack of timely receipt of programmed funds as anticipated can cause deviation from the original plan.

Program Stretch Out – Direction to slip the program schedule from the original plan will cause funding problems.

Continuing Resolution – The requirement to execute a program for a period of time with funds provided by a continuing resolution and the resulting constraints associated with the continuing resolution create unforeseen problems.

National Objectives and Strategies - Changes in national objectives and strategies will cause deviations to the planned program.

2.2 NON-PROGRAM EVENT OR ACTION CATEGORY

2.2.1 Category Definition

Risks falling within this category result from varied events, policy changes, decisions, or actions, not aimed specifically at the program, but disrupting original plans in some manner.

2.2.2 Specific Non Program Event or Action Risks

Inflation - Significantly higher levels of inflation than originally forecast can create funding problems.

Legislation - Higher taxes, new labor laws affecting pay and benefits, social security increases, etc., can cause significant funding problems.

Environmental Impact - Natural disasters such as fires, floods, storms, earthquakes, etc., can cause major schedule delays and cost problems.

Source Selection Protests - Source selection award protests and related legal actions can delay the start of a program with resulting schedule and cost problems.

Labor Disputes - Labor difficulties such as strikes, lock outs, slowdowns, etc. will affect work on the program.

Threat Changes - Threat changes requiring changes in schedule and performance objectives will cause deviations in schedule and cost.

Operating Policies - Changes in operating policies impacting system or system support requirements can cause the program to vary from the original plan.

New Regulations - Added workload or time requirements brought about by new Congressional, DoD, or service direction or policy can create significant variances to the basic planned program.

2.3 PRODUCTION PROBLEM RISK CATEGORY

2.3.1 Category Definition

Risks falling within this category result from unanticipated problems associated with the process of, or resources needed for system production.

2.3.2 Specific Production Problem Risks

Design Stability - The lack of design stability during the production phase can create serious problems in meeting production schedules and cost goals.

Familiarization – If contractor personnel are not familiar with, and do not have experience producing similar systems or equipment, problems in executing the planned program can occur.

Scarce Resource – Shortages of critical materials, components, or parts can delay production and ultimately increase costs.

Tolerance Levels – Closer than usual tolerance levels and difficulties in achieving these tolerance requirements are a subset of familiarization and can cause program problems.

Vendor Base – A shortage of an adequate number of qualified vendors necessary to ensure adequate price competition and a satisfactory supply quantity base can cause both schedule and cost problems.

Capacity – The lack of facilities and tools to produce at the desired rate (rate tooling) can prevent the production flow from reaching the desired level.

Excessive Lead Times – If longer than expected lead times for critical components or services are experienced then the program will slip.

Advance Buy Authorization Limitations – Long lead time requirements can create problems if there is not sufficient advanced buy funding to meet the needs of the program.

Production Readiness – If the contractor fails to be adequately prepared for production, slippage will occur in the program.

2.4 IMPERFECT CAPABILITY RISK CATEGORY

2.4.1 Category Definition

Risks falling within this category are the result of people, organizations, or facilities not performing as well as desired or expected.

2.4.2 Specific Imperfect Capability Risks

Underbidding – If the contractors underbids or buys–in to get contracts and fails to provide the desired products and services on schedule and within budget, then the planned program will be significantly affected.

Subcontractor Control – If the prime contractor does not maintain adequate control of subcontractor quantity, schedule, and cost performance, then the planned program will not make its original goals.

Lack of Financial Strength – If one or more contractors has not been able to adequately finance program requirements, the required work will be delayed or curtailed.

Communication – Problems that could cause deviations from the planned program can result from failure of the subcontractor's and contractor's personnel to keep prime contractor and SPO management informed of problems and potential problems in a timely manner. Likewise, communication problems can occur if management fails to fully communicate direction to all involved in the program in a timely manner.

Forced Placement – If the program is saddled with second string personnel and managers either in the SPO or at key contractors, then serious counterproductive events could occur causing program perturbations.

2.5 OTHER PROGRAM PROBLEMS RISK CATEGORY

2.5.1 Category Definition

Risks falling within this category are generally somewhat different from program to program due to the unique nature or requirements of the product and program. This category does not include production related risks which have been placed in a separate category but could be considered a subset of this category.

2.5.2 Specific Other Program Problem Risks

Available Skills – The shortage of available personnel with the needed technical, management, and other skills to carry out PMO and contractor activities could create problems that affect the planned program.

Security Clearances – Any delays in obtaining required personnel security clearances and facility clearances will have a significant impact upon the basic program.

Secure Test Requirements – The testing of classified equipment can cause difficulties that are associated with testing classified equipment.

Test Safety – Problems that could cause deviations from the planned program can result from the new or unique requirements that testing be non–destructive or that it not interfere with other activities.

Weather – Unusually severe weather related test program delays can cause slippage and cost overruns to the planned program.

Site Survey Results – Historical or archaeological site survey findings could delay site construction and cause significant deployment problems.

Common Support Equipment – If common support equipment is not available as required to operate and maintain the system, then the planned program will suffer schedule and cost problems.

3. SUPPORTABILITY RISK SOURCES (Ref. 1)

3.1 DELAYED DEFINITION OF LOGISTICS CRITERIA

Delayed decisions on reliability and supportability requirements result in suboptimum support. Once the design is committed, the options become limited. Many early fighter aircraft suffered from having design optimized for performance without comparable attention to support aspects such as maintenance accessibility and spare parts reliability. As a result, turn around times and operation and support (O&S) costs were excessive and manpower requirements for some aircraft models approached 100 maintenance man–hours per flight hour (MMH/FH).

3.2 IMPACT OF ENGINEERING CHANGES

A high number of design changes made during the development program can overwhelm Integrated Logistics Support (ILS) planning and create an inability to fully reflect ILS and O&S cost considerations in engineering change decisions.

3.3 LATE ESTABLISHMENT OF READINESS AND SUPPORTABILITY OBJECTIVES

The system engineering process is a key factor in identifying and attaining realistic readiness and supportability objectives. If a well organized process is not started at the program inception and continued throughout the development phases, then the program risks are:

- Increased design, development, and O&S costs
- Schedule delays
- Degraded readiness factors.

3.4 UNREALISTIC R&M REQUIREMENTS

The establishment of unrealistic Reliability and Maintainability (R&M) requirements (as part of the Pre-Program Initiation of Concept Exploration (CE) phases) can lead to increased design and development costs incurred as a result of excessive design iterations. This in turn can cause program delays and costly program support system restructuring in later phases.

3.5 ACQUISITION STREAMLINING

The new DoD initiative on acquisition streamlining may impose restrictions on the ILS Manager as well as the designer early on in the definition of requirements. Although intended to decrease cost and improve efficiency, casual application of such guidance could result in a loss of standardization, attendant cost increases, and the loss of documented lessons learned experience.

3.6 FAILURE TO APPLY LSA DURING CONCEPT EXPLORATION

Failure to participate in the definition of system concepts can produce a system design in follow–on phases that does not meet supportability objectives and requires excessive or unattainable operation and support (O&S) costs as well as manpower to meet the readiness objectives.

3.7 INVALID APPLICATION OF COMPONENT R&M DATA

Design and manufacture determines the mean life and failure rate of components when viewed in isolation. When the parent material system is engaged in its military operational role, these same components should be expected to exhibit replacement rates substantially higher than their handbook value or inherent reliability alone would indicate. The consequences of improperly computed material replacement rates are invalid manpower requirements, incorrect supply support stockage lists, and invalid repair level analyses.

3.8 FAILURE TO STRUCTURE/TAILOR LSA REQUIREMENTS

Failure to establish a Logistics Support Analysis (LSA) plan that is specifically designed to meet the needs of the material system can result in: excessive costs; the performance of unwanted analysis while failing to complete needed studies; and the development of excessive documentation while overlooking critical information needs. ILS lessons learned reports and discussions with ILS Managers have provided numerous examples of these deficiencies.

3.9 LACK OF LCC IMPACT ON DESIGN AND LOGISTICS SUPPORT PROCESS

Life Cycle Cost (LCC) is most effective when it is integrated into the engineering and management process that makes design and logistics engineering choices. This integration must start with program . itiation. Once the ability to influence design is lost, it is very difficult and always more costly to re–establish. Most performance and schedule risks have cost impacts. Performance risks result from requirements which are very costly, or from engineering requirements beyond foreseeable technical capabilities for hardware development. The result can be increased cost from design, development, and test of a replacement item; contract termination costs; increased program buy, and increased O&S costs. Schedule changes can increase costs whether they are shortened or lengthened.

3.10 ACCELERATED PROGRAMS

An accelerated system development program may be required to overcome a critical deficiency in an existing military capability. This "streamlining" can pose the risk of delaying design maturation with frequent configuration changes occurring in late development possibly continuing during initial production and deployment. The added time required to modify LSA records (LSAR) and update ILS elements can lead to an initial period of decreased system readiness.

3.11 IMPROPER CONTRACTING FOR SUPPORT

The major risk area in ILS contracting, in terms of impact and the probability of its occurrence, is the failure to properly contract for data, materials, and services. Included are failures involving contractual promises by the Government to furnish material and services and the imposition of unrealistic delivery of performance schedules. Impacts may include degraded support and readiness, cost growth, and when repeatedly exposed, the loss of taxpayers' goodwill and confidence.

3.12 DELAYED OR INADEQUATE LOGISTICS TEST AND EVALUATION (T&E) PLANNING

The main thrust of the formal Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E) programs is to evaluate system level performance. Logistics test and evaluation has an additional focus on component evaluation and on the adequacy of the ILS elements that comprise the logistic support structure. Failure by the ILS Manager to participate effectively in the initial development of the Test and Evaluation Master Plan (TEMP) during the CE Phase risks the exclusion of critical logistics T&E and the omission of the ILS test funds required in the program and budget documents.

3.13 INADEQUATE PLANNING FOR DATA UTILIZATION

Collecting data without detailed planning for its use can lead to:

- A mismatch of data collection information requirements
- Failure to accomplish the intended purpose of the assessment (such as the update of supply support and manpower requirements and the identification and correction of design deficiencies).

3.14 INCOMPLETE OR DELAYED SUPPORT PACKAGE

Without an adequate test support package on site ready to support the scheduled test, it may be possible to start testing, but the chances are low of continuing on schedule. A support system failure could cause excessive delays, which can incur a schedule slippage and increased test cost due to on–site support personnel being unemployed or for the cost of facilities which are not being properly used.

3.15 INCOMPLETE OR INACCESSIBLE DATA

Without sufficient data being available from each test, and used properly for planning subsequent tests, it is not possible to evaluate the adequacy of the system to meet all of its readiness requirements. Without accurate failure rates, system and component reliability cannot be determined. Without cause of failure established, Failure Modes Effects and Criticality Analysis and Repair of Repairables Analysis cannot be accomplished. Integral to a data management system is the retrieval and reduction of data as well as the collection and storage. Essential to any test program is the ability to document and collect results so that they are readily available to both the engineer and logistician for analysis at completion of the test program. Lacking the necessary data, system design and ILS progress cannot be established, problems cannot be identified, and additional testing may be required.

3.16 UNREALISTIC SCENARIOS

A subtle risk, particularly during development testing, and one which can have lasting impact on the viability of a program, is testing to an unrealistic scenario. Realism does not necessarily mean that the stresses put on the system under test must duplicate those of actual service, since in most cases this is impractical; it does mean, however, that the test is planned to simulate the conditions as closely as possible and differences are carefully documented. Perhaps more significant in ILS testing than stresses applied, is the quality and skill level of personnel maintaining and operating equipment. It is expected during development testing, that highly skilled personnel will be operating and maintaining the equipment, since the main purpose of development testing is to evaluate the hardware itself and to see if it demonstrates the required performance. During operational testing, however, the purpose of the test is to see how the system operates under actual conditions. Moreover, useful data can only be obtained if it is maintained and operated by personnel having the same skill levels and training as the personnel planned to operate and maintain the system when deployed in the field. If operational testing is staffed with military personnel having much more experience and skill than can be expected when deployed, the operational testing will give an unrealistically favorable evaluation, which though favorable to the system, provides misleading information resulting in invalid conclusions.

3.17 ACCELERATED PROGRAMS

Compressed schedules increase the demand for critical assets during the time of normal asset shortages which can create unrecoverable delays.

3.18 SCHEDULE SLIPPAGE

Failure to understand how a schedule slippage in one functional element impacts the other elements and milestone events can ultimately delay the entire program.

3.19 DELAYED FACILITIES PLANNING

Failure to perform timely facility planning can result in substantial deployment delays.

3.20 UPDATING THE DEPLOYMENT PLAN

Failure to keep the deployment plan updated, complete, and coordinated with all concerned management personnel may have a negative impact on the program.

3.21 MANAGING PROBLEMS IN THE DEPLOYMENT PROCESS

Unreported and uncorrected deployment problems can seriously disrupt the process.

3.22 DELAYED POST PRODUCTION SUPPORT (PPS) PLANNING

Continued support of the material system by the industrial base existing in the post-production time frame may not be economically feasible.

3.23 ACCELERATED ACQUISITIONS

Lead times for delivery of non-developmental items can be extremely short, particularly for in-stock commercial items. This poses a substantial risk of deployment with incomplete or inadequate logistic support and attendant degraded readiness.

3.24 CONFIGURATION CONTROL OF COMMERCIAL ITEMS

The Government does not control the configuration of items procured from the commercial marketplace. This presents two potential risks:

- Subsequent competitive procurement of the end item may lead to a total different internal configuration with different support requirements.
- There is no automatic guarantee that original commercial suppliers will continue to manufacture spares and repair parts to fit the Government's configuration.

3.25 INADEQUATE COORDINATION

The Government does not control the configuration of items procured from the commercial marketplace. This presents two potential risks:

- Incomplete or inadequate logistic support at the time of initial deployment
- A decision by one or more Services to go it alone with ILS planning and development of Service-unique logistics support
- Loss of the economies of scale that can be gained by joint ILS performance.

Ref. 1 DSMC Integrated Logistics Support Guide Extracts.

APPENDIX B
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BIBLIOGRAPHY

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APPENDIX C

EXCERPTS ON RISK FROM DOD ACQUISITION POLICY

1. GENERAL

Two important drivers of acquisition policy regulations are DoD Directive 5000.1 and DOD Instruction 5000.2. Both were recently updated and released to the Services (September 1, 1987), and there has not been sufficient time for the Services to align their acquisition policy directives.

2. POLICY DIRECTIVES

This section briefly summarizes the listed directives and regulations of OMB, DOD, and the Services pertaining to risk management. Figure C-1 shows a hierarchy of acquisition risk policy.

a. *Office of Management and Budget*
OMB Circular A-109. *Major System Acquisition* (5 April 1976)

Para 7. "Each agency acquiring major systems should ... tailor an acquisition strategy for each program... The strategy should typically include ... methods for analyzing and evaluating contractor and Government risks."

b. *Department of Defense*

DOD Directive (DODD) 5000.1. *Major and Non-Major Defense Acquisition Programs* (September 1, 1987).

Para C.6.a. "A DOD acquisition program may be designated as a major defense acquisition program because of (among other factors) development risk."

Para D.3. "Acquisition phases are to be tailored to minimize acquisition time and life-cycle costs, consistent with the urgency of need and degree of technical risk involved."

Para D.7. "Affordability, which is a function of cost, priority, and availability of fiscal and manpower resources, shall be considered at every decision milestone and during the Planning, Programming, and Budgeting System (PPBS) proc- :."

Para D.8.b. " DOD Components will seek a balance between development and production risk and the risk associated with not countering the threat."

Para D.8.c. "DOD Components will estimate program, budget, and fund acquisition programs realistically."

Para D.9.a. "During early stages of development, studies shall be conducted to identify trade-offs between cost and Hierarchy of Acquisition Policy performance requirements and to assess technological risk and identify cost drivers and producibility factors associated with new technology."

Para D.9.b. "Commensurate with risk, developing separate alternatives in high-risk areas (among other strategies) shall be considered."

Para D.9.e. "Logistics supportability requirements shall receive emphasis comparable to cost, schedule, and performance requirements."

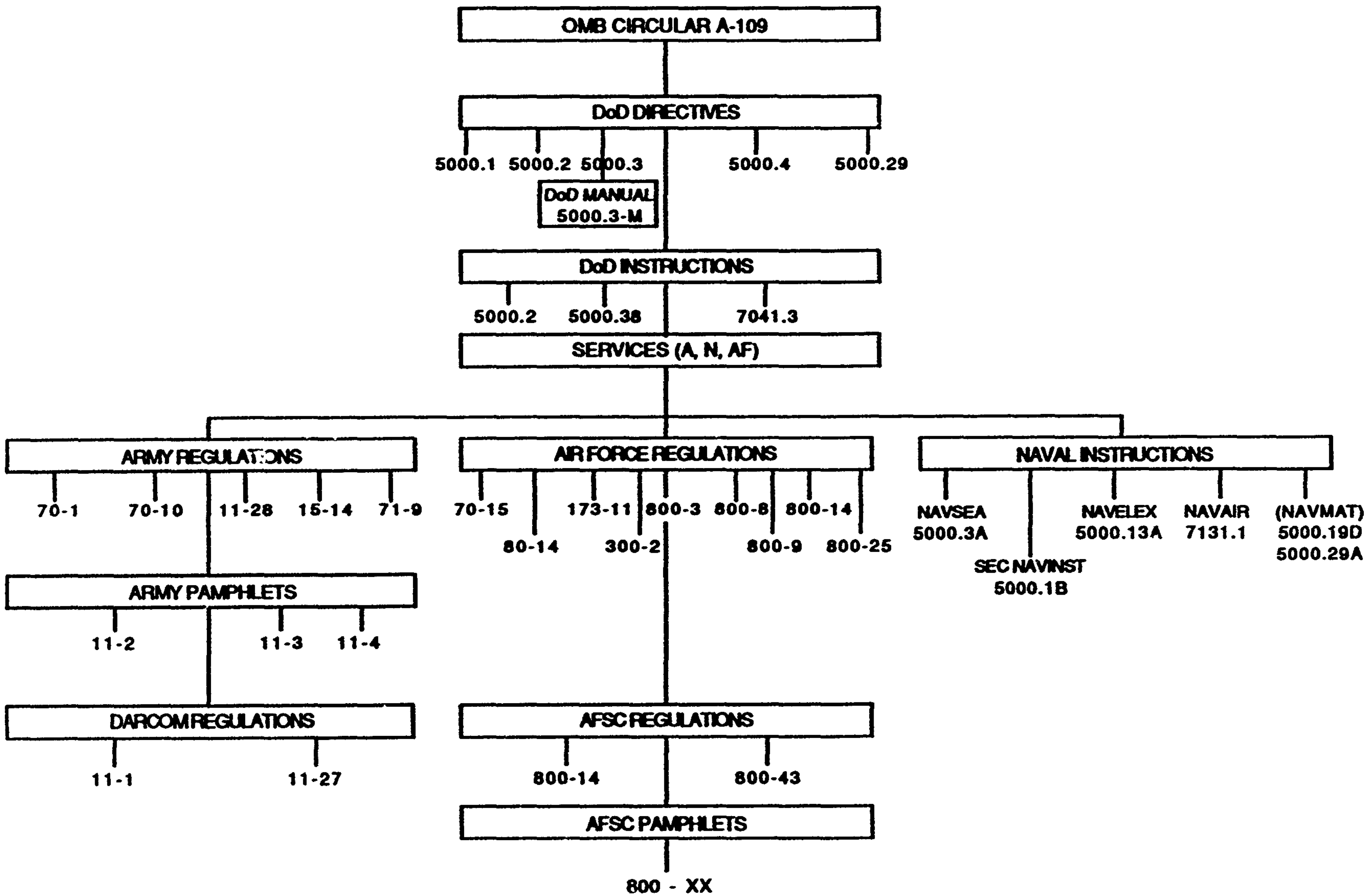


Figure C–1 Hierarchy of Acquisition Risk Policy

Para D.9.f. "Contract type shall be consistent with all program characteristics including risk. For research and development phases, a cost-reimbursable contract sensibly allocates program risk between the contracting parties.

DOD Directive 5000.3. *Test and Evaluation* (March 12, 1986)

Para C.1.c. "Test and evaluation will begin as soon as possible in the system acquisition process to reduce acquisition risks..."

Para 7c. "General provisions of software testing include ... testing of software to achieve a balanced risk with the hardware."

Para C.4.d. "Before Milestone II, T&E shall identify the preferred technical approach, the technical risks, and the feasible solutions. "

DOD 5000.3-M-1 *Test and Evaluation Master Plan (TEMP) Guidelines Appendix A Definitions "Acquisition Risk.* The uncertainty that some element of an acquisition program will produce an unintended result with adverse impact on system effectiveness, suitability, cost, program schedule, or availability for deployment."

DOD Directive 5000.4. *OSD Cost Analysis Improvement Group* (October 30, 1980)

Para 2.e. "The OSD CAIG shall develop methods of formulating cost uncertainty and cost risk information into the acquisition process."

Para C.5. "Quantifying uncertainty by using frequency distributions of cost ranges is desired. Probability distributions and assumptions should be forwarded with range estimates."

Para C.7. "Sensitivity analysis of cost should include technical risks."

DOD Directive 5000.29. *Management of Computer Resources in Major Defense Systems* (April 26, 1976)

"B. *Requirements Validation and Risk Analysis*

3. Risk analysis, preliminary design, hardware/software integration methodology, external interface control, security features (DoD Directive 5200.28, reference (f)), and life cycle system planning shall be included in the review (DSARC II)."

DODI 5000.2. *Defense Acquisition Program Procedures* (September 1, 1987)

Para 3.b. "Defense Acquisition Board deliberations are (among other considerations) program risk versus benefit of added military capability and procurement strategy appropriate to program cost and risk assessments."

Enclosure (3) *Mission-Needed Statement (MNS) Format*

5. *Technology Involved.* "For known alternatives, discuss maturity of the technology planned for the selected acquisition design and

manufacturing processes, with particular emphasis on remaining areas of risk."

Enclosure (4) *System Concept Paper (SCP) and Decision Coordinating Paper (DCP) Formats*

9. *Technology Risks of Selected Alternatives.* "For Milestone II, discuss test and evaluation results that show all significant risk areas have been resolved."

DODI 5000.38. *Production Readiness Reviews* (January 24, 1979)

Para A.2. "The objective of a PRR (Program Readiness Review) is to verify that the production, design, planning, and associated preparations for a system have progressed to the point where a production commitment can be made without incurring unacceptable risks of breaching thresholds of schedule, performance, cost, or other established criteria."

Para E.4. "The DPESO (DOD Product Engineering Services Office) independent production readiness assessment will consist of objective conclusions based on the findings of the PRR and other investigations. This assessment will identify potential problem areas which constitute production, cost, or schedule risks. *Each risk will be expressed in terms of its relative magnitude, and potential consequences.*" [emphasis supplied]

DODI 7041.3. *Economic Analyses and Program Evaluation for Resource Management* (October 19, 1972)

Enclosure (2)

Para B.7. "Risk/Uncertainty Analysis. Risk assessments will be made to determine the expectation or probability that program/project objectives will be realized by following a specific course of action with constraints of time, cost, and technical performance. [emphasis supplied] Actual costs and outputs of many DOD projects differ from those expected at the time of decision. For those cases, and in particular for major weapon systems covered by a Selected Acquisition Review Report or subject to review by the Defense System Acquisition Review Council (DSARC), the impact which could result from this variability should be evaluated."

Para B.7.a. "Independent parametric cost estimates can provide an early test of the reasonableness of cost estimates. Independent parametric cost estimates will be made at key decision points for major weapon systems, e.g., during concept formulation and prior to making major commitments of funds for development and production. These estimates generally consider cost at high levels of aggregation and are predicated on actual historical costs encountered in like or similar programs. As such, they incorporate costs for expected uncertainties on the average. (1) Costs should be derived by parametric techniques and expressed as feasible ranges in terms of the parameters which drive them. *It is most important that estimates be presented as cost ranges related to the probable values of system parameters, characteristics, or attributes which are determined by costs.* [emphasis supplied] (2) These estimates will be available for each DSARC review. Parametric estimates will be derived independent of functional, program manager, or contractor influence. (3) When the independent parametric cost estimate differs from the program manager's current estimate, the latter estimate will be used for economic analysis/program evaluations. Once a program estimate is established as a baseline, a program/project manager will manage his program within that limitation. (4) The program manager's current estimate will be an assessment of the ultimate cost expected for a program/project *including undefinitized contingencies*. [emphasis supplied] As such, the program manager's current estimate should be relatively stable over long periods of time and not change with small incremental changes to the approved program, funding changes, or financial fluctuations. *To the extent possible, schedules and funding should be structured to accommodate program uncertainties and unforeseen problems.*" [emphasis supplied]

Para B.7.b. "Special degrees of risk/uncertainty associated with a particular program/project, may be pointed out quantitatively in an analysis and used for program review purposes. Probability estimates can be developed by testing the sensitivity of key variables on estimated costs and performance. *The probability that each of the possible cost or output estimates may be realized should be discussed narratively when there is no basis for a quantitative estimate.*" [emphasis supplied]

Para B.7.c. "Estimates will be expressed in terms of performance thresholds, goals, or ranges. Program/project estimates will include the limits within which ultimate program cost and technical performance is expected to fall."

3. SERVICE REQUIREMENTS

a. U.S. Army

The following Army directives require or imply a need for risk assessment as shown by excerpts and editorial condensations.

Department of the Army Pamphlet (DA-Pam) 11-2. *Research and Development Cost Guide for Army Materiel Systems* (May 1976).

Para 3.5. Range Versus Point Estimates.

a. "The use of a point estimate does not reflect the uncertainty associated with the estimate. It also implies that it is a precise cost. For these reasons, a range of costs should be provided based on the inherent cost estimating uncertainty. The level at which the ranges can be provided is dependent upon the level at which the costs are estimated. Within the limitations imposed by the database and cost estimating approach employed, ranges should be presented at the highest aggregate level."

b. "In addition, an analysis should be made of the sensitivity of projected costs to all critical assumptions. This should include factors such as the impact of changes in performance characteristics, changes in configuration to meet performance requirements, schedule alternatives, and alternative production processes."

DA–Pam 11-3. *Investment Cost Guide for Army Materiel Systems* (April 1976) Exactly the same words as above.

DA–Pam 11-4. *Operating and Support Cost Guide for Army Materiel Systems* (April 1976). Exactly the same words as above.

Development Acquisition and Readiness Command Regulation (DARCOM–R) 11-1. *Systems Analysis*

Para 4.d. "...RA and DRA are applied to alternative courses of action and permit structuring models that address the uncertainty of cost, schedule, and performance of systems." [RA and DRA mean risk analysis and decision risk analysis, respectively.]

Para 5.c. "An IE and DRA will be completed prior to each decision milestone in major programs which will involve .... (ASARC) or .... (DSARC) proceedings, or in non–major programs for which DA has retained in–process review (IPR) approval authority. For non-major systems, an ASARC will be completed prior to each IPR "unless it is clear that no appreciable time, cost, or performance risk is associated with the decision." [IE means Independent Estimate; ASARC, Army Systems Acquisition Review Council; DSARC, Defense Systems Acquisition Review Council; DA, Department of the Army]

Para 6.d. "Each commander of an R&D or MR Command will: ...3) ensure that IE's and DRA's are initiated for the decision points described in paragraph 5c." [MR means Materiel Readiness.]

Appendix D - *Decision Risk Analysis Guidelines*

"1. a. Define the problem

   b. Establish the decision-maker's preferences for trade-offs between cost, schedule, and/or performance

2. Establish the alternatives

3. Define the events

4. Collect the data

5. Determine the program risks

6. Select the best alternatives

7. Perform sensitivity analysis

8. Communicate the results."

DARCOM–R 11-27. *Life Cycle Management of DARCOM Materiel Chapter 3.* Section II - *Procedures*

Para 3–8.b. "The justifications for by-passing activities and events are ... (2) That the risk for omitting the actions is reasonable when considering the savings of time and resources."

Para 3–8.c. "When requesting the shortening of schedules, the PM will request DARCOM approval and submit a statement including the assessment of risks incurred in shortened plan compared to base plan."

AR-11-28. Economic Analysis and Program Evaluation for Resource Management

Chapter 1

Para 1–6.p. "Where costs for research and development represent a significant portion of total program cost, the decision to conduct research will be supported by an economic analysis which identifies potential follow–on cost savings resulting from the research and development, degree of risk or uncertainty in achieving results, availability of resources, assessment of current technology, and identification of constraints."

Chapter 2

Para 2–2.b. "The structure of analysis will also contain, when appropriate, an assessment of the relative risk or uncertainty of success associated with each of the alternatives considered, including the status quo when applicable."

AR–15–14. *Boards, Commissions, and Committees – Systems Acquisition Review Council Procedures*

Page 4–3. This paragraph states that risk analysis will be presented to HQDA two months before ASARC.

AR–70–1. *Systems Acquisition Policy and Procedures* (12 Nov 1986)

Para 1–5.c Objectives of Army research, development and acquisition are ... "Achieve appropriate balance between need for low risk evolutionary development and more visionary, leap–ahead effort required to maintain technological superiority."

Para 4.5–z Criteria for entering the Dem/Val phase are ... "Production feasibility has been addressed and areas of production risk evaluated including the availability and completeness of TDP. Manufacturing technology needed to reduce production risks to acceptable levels have been identified. Costs and technical plans for meeting alternative surge capacities have been prepared and constraints to attaining expanded production are identified."

Para 4–6.q.(3) Criteria for entering the FSD phase are ... "Production risk has been determined acceptable. Requirements for long lead–time procurements, initial production facilities (IPF), and limited production have been identified and evaluated considering planned production and expanded production requirements for surge and mobilization. The FSD Phase includes PEP provisions to attain producibility, using cost effective manufacturing methods and processes. Manufacturing methods and technology (MMT) deficiencies have been addressed, and included in the PEP program summary requirements."

Para 4–7.i. Criteria for entering the production and development phase are ... "PEP has been conducted, production proveout (product, process, and facilities) has been successful and the chosen surge capacity has been measured by extrapolation from actual production; and economic timely producibility has been determined. Production readiness review and assessment has been completed; production risks have been reduced to acceptable levels; and constraints and remedies to increased production beyond planned surge level are identified."

Para 4–12.c.(4). "An assessment of RAM, RAM-driven O&S costs and product assurance issues will be provided. For each unresolved RAM or quality assurance issue, a proposed resolution shall be provided. This resolution will include assessment of risk, RAM-driven O&S impact on quantitative RAM parameters."

Para 5–1.c.(2). The Acquisition Strategy does the following ... "Identifies potential risks and plans to reduce or eliminate risks."

Para 6–2. "Under AR 71-9, all requirements documents will include provisions for P³I. The drivers for these provisions are technical risk and threat, and O&S cost.

(1) Where an early deployment capability is required, but one or more key component subsystems are judged to be technically risky or the technology is judged to require considerably more maturation than the rest of system, then the requirement documentation should structure acceptable performance criteria or a phased deployment capability (e.g., initial, interim, and objective)."

Para 7–2.a. "The Army Streamlined Acquisition Process (ASAP) is essentially a synergistic combination of common sense measures, derived from lessons learned in a variety of acquisition programs, to achieve the 'surest and shortest' path for low risk developments while eliminating the need for case-by-case exceptions to the traditional acquisition process..."

Para 7–2.F.(9). "Minimum essential test and evaluation necessary to identify the best technical approach to include identification of technical risk and feasible solutions. Test data shall support projection of realistic program performance and suitability thresholds. Modeling and simulation is encouraged to ensure availability of operational effectiveness and suitability projections. The MS II decision will be preceded by sufficient T&E to reduce risk before resources are committed to FSD."

Para 1–7.o. "Technical uncertainty will be continuously assessed. Progressive commitments of resources will be made only when confidence in program outcome is sufficiently high to warrant going ahead."

Para 2–2.a. In conceptual phase, "critical technical issues, operational issues, and logistical support problems are identified for resolution in subsequent phases in order to minimize future development risks."

Para 2–15.a. "Test and evaluation will be conducted as early as possible and throughout the material acquisition process to reduce acquisition risks...."

Para 2–15.c.(4). DT will be used to "demonstrate, during the Full Scale Development Phase and prior to the first major production decision, that the DT accomplished is adequate to insure that engineering is reasonably complete; that all significant design problems ... have been identified; and that solutions to the above problems are in hand."

Para 4–1a. "Department of the Army policy for advanced, engineering, and operational systems development is to -- (1) Conduct system advanced development in promising areas using either single or competitive approaches in order to resolve key technical, cost and/or schedule uncertainties before entering Full-Scale Development Phase. Such efforts should be accomplished with low-level program and full realization of technical risks."

Para 4-1m. "Program sufficient funds to provide for the technical uncertainty inherent in the development effort."

Para 4-1af. "Give consideration to requiring development contractors to provide second sources for high technical risk subsystems/components, whether or not the development contract is sole source or competitive."

AR 70-10. *Research and Development, Test and Evaluation During Development and Acquisition of Materiel* (29 August 1975).

Para 1-4.(3). "During the full-scale development phase and prior to the first major production decision, the DT (Development Test) accomplished will be sufficiently adequate to insure ... that all significant design problems (including compatibility, interoperability, safety, Reliability, Availability, and Maintainability (RAM), and supportability considerations) have been identified, and that solutions to the above problems are in hand."

Para 2-4.c.(5). "As the development cycle continues into DT/OT [Development Test/Operational Test] II, the uncertainty in these estimates should be reduced, and, by the completion of DT/OT III, sufficient testing should have been accomplished so that the uncertainty in estimating the final system performance will be relatively small, ..."

Para 2-5.e. "EDT (Engineering Development Test) is conducted by the contractor and/or the material developer with the primary objective of influencing material design." ... "The purposes of EDT are to ... (3) Eliminate as many technical and design risks as possible or to determine the extent to which they are manageable."

AR 71-9. *Materiel Objectives and Requirements, Para 4-18* "The provisions of P³I will be considered in all developmental material programs and documented in requirements documents as appropriate. The P³I is a strategy that offers an alternative that minimizes technological risk and consciously insures advanced technology through planned upgrades of those deployed systems or subsystems that offer the greatest benefits. In this manner, the lead-time to field technological advances can be shortened while an aggressive scheduling of fielded performance improvements can be expected during the service life of the system."

Para 1-5. "Test and Evaluation will begin as early as possible in the acquisition cycle and will be conducted throughout the system acquisition process as necessary to assess acquisition risks ..."

Para 3-4.k. "Army R&D organizations are to take the following specific actions with respect to the STOG (Science and Technology Objectives Guide): (1) Perform assessment components, or system types, depending upon the detail available. In such cases, risk factors will be constructed judgmentally in full consideration of the engineering, producibility, and budgetary aspects of the program. Specific considerations to be included in this judgment are:

(a) Whether the program requires the development of an item not directly supported as feasible by existing technology.

(b) Whether the program requires the development of an item substantially different from those previously developed.

(c) Whether major integration effort will be necessary even though individual components may in themselves be considered to involve low risk."

Para 5.b. "TRACE computation. The risk factors will be multiplied by the engineering cost estimate at the appropriate level of the WBS. The appropriate level will depend not only on the level of design detail available, but also on the degree of component and subsystem interaction. In those circumstances where a design change of a given component or subsystem appears likely to propagate and cause a design change of a related component or subsystem, a higher level of aggregation will also be required to maintain statistical validity of the overall estimate by including these interdependent effects. The risk factors, when applied at the appropriate level of the WBS as explained above, can be statistically combined to produce the TRACE."

Para 6.a. "The costs of specific program work scheduled for accomplishment during a particular year will be estimated using the TRACE methodology. The TRACE thus compiled for the program 'work year' will be the amount submitted to OSD and the Congress as required for the program for that year. The funds representing the difference between the TRACE and the engineering cost estimate will not be carried in a separate category, but rather will be allocated to the various tasks to which the funds will most likely be applied."

Para 6.b. "To allow for the possibility of cost savings to allow more precise managerial control of funds appropriated for program execution during a budget year, only that amount reflecting the basic (engineering) cost estimated for that year (i.e., the engineering cost estimate consisting of the work costs prior to multiplication by the respective risk factors) will be released initially to the manager for program execution. The remainder of the appropriated program funds will be held in deferral by the DCSRDA and released to the manager only upon request and approval of a justified need. Program funds (obligated authority) not required in the current year program will be considered for designation to the Congress as a means to reduce the requirement for new obligational authority is the subsequent year's budget. Other use of such unneeded funds may be authorized by the DCSRDA, as appropriate."

Letter of Instruction (LOI) for Implementation of the Total Risk Assessing Cost Estimate for Production (TRACE-P) (6 October 1982).

Para 4.b. "The TRACE-P estimate will include consideration of the risks in the following categories; these are explained at Enclosure 1.

(1) Threat Uncertainty
(2) Management
(3) Materials/Purchased Parts
(4) Facilities/Equipment
(5) Labor
(6) Design Changes
(7) Producibility
(8) Performance."

Para 4.c. "Specifically excluded from the estimating of TRACE-P expected risk costs are possible increases that may result from one or more of the following causes:

(1) Quantity changes
(2) Performance improvement to meet an increase threat
(3) Poor management
(4) Inadequate funding in the early years
(5) Unknown unknowns."

Para 4.g. "TRACE-P funds will be held in deferral by the DCSRDA and released to the program/project/product manager only upon request and approval of a justified need."

RDA Cost Realism – Future Development Programs (12 July 1974) DASA Letter

"Our estimate should be unbiased so that we have about an even chance of either going over or under it."

"*It is submitted that cost overruns will continue to be a way of life until adequate recognition is given to the impact of program uncertainty in estimating costs*" [emphasis in original].

"... it remains the fundamental nature of RDT&E ... to involve the unknown. These unknowns *invariably* lead to cost requirements which cannot be individually foreseen at the outset of a development -- yet their cumulative impact can be seen in retrospect with all the assuredness of the laws of probability" [emphasis in original].

"*The provision of flexibility in the funding plan baseline-cost estimates should reflect these probable additional costs.*"

Total Risk Assessing Cost Estimate (TRACE) Deferrals DRCEPC letter (17 April 1978).

Para 2. "A program TRACE refers to its total expected RDT&E costs as agreed to by the ASARC/DSARC. The definition applies both to annual costs and development costs. Funds in excess of the baseline or engineering costs for a particular fiscal year are deferred at the beginning of that year by HQDA (DCSRDA) pending the occurrence of predicted (but unprogrammed) events upon which the funds were based. These funds will be released to the Project Manager (PM) upon a demonstration that they are necessary to offset the cost of such events. If a program adjustment is made during the programming and budgeting cycle, the entire scope of the program should be revaluated and the risk factor recomputed. TRACE funds identified for deferral in the outyear should not be reduced in order to increase the baseline portion if that adjustment is made merely to offset a decrement to the program or to increase its scope."

Para 3. "The funds released from HQDA are expected to be adequate for execution of the known estimated engineering costs. It is DARCOM policy to expect that the PM manage his total program with the funds authorized. Risk contingency (TRACE deferral) funds will be released only if technical/ design problems and/or unexpected delays materialize, and this fact is completely demonstrated in the release request. Release requires both DCSRDA and ASA (R&D) approval."

Para 4. "The PM can indicate at any time that TRACE deferral funds will not be needed. If deferral has not been released by the fifth quarter of availability, the PM will be given the opportunity to justify retention of such deferrals considering that the work upon which they were based may have continued into the second year. Otherwise, disposition of the funds will be determined by the DCSRDA in coordination with the ASA (RL&LD) and CDR DARCOM. The PM may request that the unneeded TRACE deferral funds be released for expanded scope of work in the same weapons systems; however, that request will be evaluated with other unfinanced requirements in other programs."

b. US Air Force

The following Air Force Regulations pertaining to program risk are briefly summarized.

Air Force Regulation (AFR) 70-15. *Source Selection Policy and Procedures* (25 February 1984)

Para 3-4. Assessment of Risk:

a. "Identification and assessment of the risks associated with each proposal are essential The following definitions of risk should be used:

(1) HIGH (H) -- Likely to cause significant serious disruption of schedule, increase in cost, or degradation of performance even with special contractor emphasis and close government monitoring.

(2) MODERATE (M) -- Can potentially cause some disruption of schedule, increase in cost, or degradation of performance. However, special contractor emphasis and close government monitoring will probably be able to overcome difficulties.

(3) LOW (L) -- Has little potential to cause disruption of schedule, increase in cost, or degradation of performance. Normal contractor effort and normal government monitoring will probably be able to overcome difficulties.

b. The acquisition activity or program office should prepare and furnish to the SSEB an independent assessment of potential risks before receipt of proposals.

c. As a part of their proposal, offerors are required to submit a risk analysis which identifies risk areas and the recommended approaches to minimize the impact of those risk on the overall success of the program.

d. The risks which must be assessed are those associated with cost, schedule, and performance or technical aspects of the program. Risks may be inherent in a program by virtue of the program objectives relative to the state of the art. Risks may also occur as a result of a particular technical approach, manufacturing plan, the selection of certain materials, processes, equipment, etc., or as a result of the cost, schedule, and economic impacts associated with these approaches.

e. In evaluating risk, the evaluators must consider the program office assessment, the offeror's assessment and make an independent judgment of the probability of success, the impact of failure, and the alternatives available to meet the requirements.

f. It is the responsibility of the technical evaluation teams to make sure that the cost team is informed of the identified risk areas and the potential for cost impact."

AFR 80-14. *Test and Evaluation* (3 November 1986)

Para 4. "The primary purpose of Development and Operational Test and Evaluations are to identify, assess, and reduce the acquisition risk" (among other purposes).

Para 4c. "After Milestone I, Test and Evaluation is conducted to identify design risks" (among other things).

Para 13i. "Major objectives of Development Test and Evaluation are to assess the technical risk and evaluate compliance with the specification."

Air Force Regulation AFR 173-11, *Independent Cost Analysis Program* (7 Oct 1986).

Para 4.c(9). Risk and Uncertainty Analysis. An explicit assessment of program risk is included as part of each ICA. This applies to all elements of cost, including O&S. When possible, this risk or uncertainty should be quantified in dollars. Risk related to parametric and critical assumptions, e.g., competition savings, technical and schedule uncertainties, improvement curves, factored costs, and cost-estimating techniques, etc., are included.

The purpose of this assessment is to identify areas of cost risk and place the ICA in context for the Air Force decision-maker. The Air Force decision-maker needs to know where the cost sensitivities are in a program. As a minimum, the risk or uncertainty analysis should identify the high-risk cost elements or cost-sensitive assumptions, e.g., weight, competition benefits, cost-improvement curve, etc. The analysis should also show the probable range of the risk parameters and the associated costs over that range.

AFR 300-2. *Managing the USAF Automated Data Processing Program* (24 April 1980).

Para 3.i.(3). "Management will evaluate known risks."

AFR 800-3. *Engineering for Defense Systems,* (17 June 1977).

Para 4.b. [In the validation phase] "... certain technical aspects may need to be intensified, such as technical and cost risk reduction, obtaining a best mix of technical requirements, and other considerations or thresholds as may be described in the PMD."

Para 6.f. The AFSC "programs their research and development (R&D) projects to develop and improve systems engineering methods and techniques (system cost effectiveness, risk assessment, technical performance measurement, etc.)."

AFR 800-8. *Integrated Logistics Support (ILS) Program* (25 June 1986)

Para 6.b.(1). "Ensures acquisition program management policy and guidance emphasizes reliability, maintainability, and supportability equal to cost, schedule, and performance."

AFR 800-9. Manufacturing Management Policy For Air Force Contracts (8 November 1983).

Para 3.(10).a. "Ensure that the program manager evaluates the relationship between producibility, manufacturing risks, productivity, ...and probability of meeting cost-related goals."

AFR 800-14. *Life Cycle Management of Computer Resources in Systems* (29 September 1986).

Para 3-12. "The program manager, with CRWG assistance, will follow the principles in attachment 5 to identify, assess, and control risk associated with computer resources." [CRWG - Computer Resources Working Group]

Risk Management, Attachment 5 (29 September 1986).

Para A5-1. "Risk Management for Computer Resources. In most development programs, there are elements that pose risks to achievement of the cost, schedule, support, or performance objectives of the program. Historically, development of computer resources, especially software, has been one of the high risk elements. Accordingly, computer resource development efforts need to apply risk management to: identify the areas that introduce substantial risk to program objectives; determine the specific causes of the high level of risk; eliminate or mitigate the causes of risk; establish funding reserves, schedule slack, performance margins, and contingency plans to allow for failure of original plans; and monitor high risk areas to obtain early warning of failures and allow timely activation of contingency plans. Risk management efforts must be defined early in the program, documented in a risk management plan, and adjusted as circumstances change. Some common causes of high software development risk and possible corrective actions are listed in Table A5–1."

c. *US Navy*

The following Navy directives address program evaluation including some mention of risk evaluation. Excerpt and editorial summaries are presented.

Secretary of the Navy Instruction (SECNAVINST) 5000.1B *System Acquisition* (8 April 1983).

Para 5.g. Management Principles and Objectives. The instruction presents as a management principle "applying established or evolving technology having a high probability of success. High technical risks may be taken if an extraordinary payoff potential can be demonstrated."

Para 6. "Acquisition Categories. A program is a candidate: ACAT IIS designation by SECNAV, ... if it is a special SECNAV interest, ... because of ... a history of technical, cost, and schedule problems," or "an extraordinary strategy and/or risks."

Para 8. "Decision Milestones. Milestones and phases will be tailored to fit each program to reduce acquisition time and cost, consistent with risk."

Para 8.b. "Milestone II. It should be demonstrated to the decision authority that technical and operational risks have been reduced to acceptable levels."

Enclosure (2) *Management Considerations*

Para 3. "Acquisition Time. Programs shall be planned for system development within the shortest time reasonable. At each milestone, schedule alternatives and inherent risks shall be assessed. Methods to be considered include combination or omission of acquisition phases; smooth transition to production; single concept development; preplanned product improvement; use of alternatives in high risk areas; experimental prototyping of critical components; or coordination of common purchases between different programs."

Para 10. "Test and Evaluation. Test and evaluation are an integral part of the acquisition process to assess technical performance and risks, ... Schedules shall be flexible to allow retest or revaluation as necessary prior to a milestone, and shall avoid duplication commensurate with risk."

Para 14. "Acquisition Risks. Technical, operational, schedule, and cost risks shall be identified as early as possible and assessed continuously. They shall be disclosed in full to the decision authority and addressed realistically at each milestone. A management reserve base on the cost risk shall be established for ACAT I and IIS programs."

Enclosure (4) *Navy Decision Coordinating Paper (NDCP)* Format

Para 1. "Risks. State program risk, including at Milestone I, technological risks to be reduced by R&D and validated by T&E before Milestone II; at Milestone II, demonstrate that all significant risk areas have been resolved and verify that technology is in hand and only engineering (rather than experimental) effort remains; at Milestone III, identify any shortfalls in technical evaluation (TECHEVAL) and OPEVAL results against thresholds."

Naval Materiel Command Instruction (NAVMATINST) 5000.29A *Acquisition Strategy Paper* (6 May 1983).

Para 2. The Acquisition Strategy Paper shall discuss Risk Analysis in Section II - *Risk Analysis* Enclosure (1) "specify the major problems or risk areas which have been considered in selection of an acquisition strategy and which must be overcome to achieve the basic program objectives."

Para 3. Section III - "*Strategy to Achieve Objectives and Implementation* shall contain the 'Risk Management Plan for dealing with areas (technical, costs, schedule, and logistics)', and the business management plan of 'incentives to achieve program thresholds including methods to control costs', and 'incentives to improve reliability and reduce support costs'."

APPENDIX D
ACRONYMS/GLOSSARY

ACSN – Advanced Change/Study Notice

ACAT – Acquisition Category

AD/LD – Document number prefix for documents from the Defense Technical Information Center and the Defense Logistics Information Exchange (respectively)

ADM – Advanced Development Model

AFSARC – Air Force Systems Acquisition Review Council

AFSC – Air Force Systems Command

ALCM – Air Launched Cruise Missile

AMC – Army Materiel Command (Army)

AMT – Amalgamated Military Improvement Plan/Technical Improvement Plan (Navy)

ARB – Acquisition Review Board

ASARC – Army Systems Acquisition Review Council

BCE – Baseline Cost Estimate

BIT – Built–In Test

BITE – Built–In Test Equipment

C_f – Consequence of Failure

CAIG – Cost Analysis Improvement Group

CCB – Configuration Control Board

CDF – Cumulative Distribution Function

CDR – Commander

CDR – Critical Design Review

CDRL – Contract Data Requirements List

CDS – Concept Description Sheet

CE – Concept Exploration

CER – Cost Estimating Relationship

CI – Configuration Item

CM – Configuration Management

CPM – Cost Performance Measurement

CPM – Critical Path Method

CPR – Cost Performance Report

CRISD – Computer Resources Integrated Support Document

CRLCMP – Computer Resources Life Cycle Management Plan

CSC – Computer Software Component

CSCI – Computer Software Configuration Item

C/SCS – Cost/Schedule Control System

C/SCSC – Cost/Schedule Control System Criteria

CSOM – Computer Systems Operator's Manual

CSSR – Cost Schedule Status Report

CWBS – Contract Work Breakdown Structure

DA – Department of the Army

DAB – Defense Acquisition Board

DARCOM – U.S. Army Development and Readiness Command

DCP – Decision Coordinating Paper

DCSRDA – Deputy Chief of Staff for Research, Development, and Acquisition

DID – Data Item Description

DoD – Department of Defense

DOE – Department of Energy

DOT&E – Director Operational Test and Evaluation

DPESO – Defense Product Engineering Services Office

DRA – Decision Risk Analysis

DS – Design Sheet

DSARC – Defense Systems Acquisition Review Council (Changed to JRMB and then to DAB)

DSMC – Defense Systems Management College

DSSP – Defense Standardization and Specification Program

DT – Development Test

DTC – Design to Cost

DT&E – Development Test and Evaluation

DUSDRE – Deputy Under Secretary of Defense for Research and Engineering

D/V – Demonstration/Validation

ECP – Engineering Change Proposal

ECR – Embedded Computer Resources, Engineering Change Request

EDM – Engineering Development Model

EDT – Engineering Development Test

EIMS – End Item Maintenance Sheet

EMV – Estimated Monetary Value

FCA – Functional Configuration Audit

FFBD – Functional Flow Block Diagram

FIS – Facility Interface Sheet

FM – Field Manual (Army)

FQR – Formal Qualification Review

FSD – Full Scale Development

GFE – Government–Furnished Equipment

GFP – Government–Furnished Property

HQDA – Headquarters, Department of the Army

HWCI – Hardware Configuration Item

ICA – Independent Cost Analysis

ICD – Interface Control Document

ICE – Independent Cost Estimate

ICWG – Interface Control Working Group

ILS – Integrated Logistic Support

ILSP – Integrated Logistic Support Plan

IMIP – Industrial Modernization Incentives Program

IOC – Initial Operating Capability

IPR – In Process Review

IPS – Integrated Program Summary

IRA – Industrial Resource Analysis

JMSNS – Justification for Major System New Start

JRMB – Joint Requirements and Management Board (Formerly DSARC, now DAB)

LCC – Life Cycle Cost

LCCP – Life Cycle Cost Plan

LLCSC – Lower-Level Computer Software Components

LOI – Letter of Instruction

LRIP – Low Rate Initial Production

LRU – Line Replaceable Unit

LSA – Logistic Support Analysis

LSAR – Logistic Support Analysis Record

MCCR – Mission-Critical Computer Resources

MCCS – Mission-Critical Computer System

MICOM – U.S. Army Missile Command

MIP – Military Improvement Plan (Navy)

MM/CC – Milestone Measurement/ Cost Correlation

MR – Management Reserve

MR – Material Readiness

MTBF – Mean Time Between Failure

MTBM – Mean Time Between Maintenance

MTBO – Mean Time Between Overhaul

MTTR – Mean Time To Repair

NATO – North Atlantic Treaty Organization

NAVAIR – Naval Air Systems Command

NAVSEA – Naval Sea Systems Command

OCD – Operational Concept Document

OFPP – Office of Federal Procurement Policy

O&M – Operation and Maintenance

OMB – Office of Management and Budget

ONAS – Office of Naval Acquisition Support

OPERA – Open Plan Extension for Risk Analysis

OPEVAL – Operational Evaluation

O&S – Operating and Support, Operation and Support

OSD – Office of the Secretary of Defense

OT – Operational Test

OTA – Operational Test Agency

OT&E – Operational Test and Evaluation

P_f – Probability of Failure

P3I – Pre-Planned Product Improvement

PAE – Physical Achievement Event

PCA – Physical Configuration Audit

PCE – Program Office Cost Estimates

PDF – Probability Density Function

PDM – Program Decision Memorandum

PDR – Preliminary Design Review

PEA – Probabilistic Event Analysis

PEP – Producibility Engineering and Planning

PERT – Program Evaluation Review Technique

PI – Product Improvement

PIP – Product Improvement Plan (Army)

PIRN – Preliminary Interface Revision Notice

PM – Program Manager

PMD – Program Management Directive

PMF – Probability Mass Function

PMI – Proposed Military Improvement (Navy)

PMP – Program Management Plan

POM – Program Objectives Memorandum

PROSIM – Program, Project, or Process Simulator

PRR – Production Readiness Review

PS – Production Sheet

PWBS – Program Work Breakdown Structure

RCE – Risk Cost Estimate

R&D – Research and Development

RDT&E – Research, Development, Test and Evaluation

RFM – Requiring Financial Manager

RFP – Request for Proposal

RISNET – Risk Information Systems and Network Evaluation Technique

R&M – Reliability and Maintainability

R/M/A – Reliability/Maintainability/Availability

RO/RO – Roll On/Roll Off

SBD – Schematic Block Diagram

SCN – Specification Change Notice

SCP – System Concept Paper

SDDM – Secretary of Defense Decision Memorandum

SDR – System Design Review

SECDEF – Secretary of Defense

SEMP – System Engineering Management Plan

SOW – Statement of Work

SQEP – Software Quality Evaluation Plan

SRR – System Requirements Review

SRS – Software Requirements Specification

SSA – Source Selection Authority

SSAC – Source Selection Advisory Council

SSARC – Service System Acquisition Review Council

SSR – Software Specification Review

STOG – Science and Technology Objectives Guide

TDRS – Tracking and Data Relay Satellite

T&E – Test and Evaluation

TECHEVAL – Technical Evaluation

TEMP – Test and Evaluation Master Plan

TIP – Technical Improvement Plan ([illegible]

TLCSC – Top-Level Computer Software Component

TLS – Time Line Sheet

TPM – Technical Performance Measurement

TRACE – Total Risk Assessing Cost Estimate

TRACE-P – Total Risk Assessing Cost Estimate for Production

TRR – Test Requirements Review

TRS – Test Requirements Sheet

TSR – Trade Study Report

USA – U.S. Army

USAF – U.S. Air Force

USN – U.S. Navy

VERT – Venture Evaluation Review Technique

WBS – Work Breakdown Structure

Acquisition Environment – The totality of policies, practices and practical considerations relative to management of acquisition programs.

Acquisition Plan – Encompasses program objectives, direction, and control through the integration of strategic, technical, and resource concerns. Ideally, the acquisition strategy is structured at the outset of the program to provide an organized and consistent approach to meeting program objectives within known constraints.

Activity – A program element consuming time and resources. It can be zero if it is a constraint.

Arc – The line connecting two points in a network.

Coefficient of Variation – Ratio of standard deviation to expected value. (See Standard Deviation and Expected Value). A measure of relative uncertainty.

Confidence Interval – Limits of an uncertain quantity (like cost) between which there is a given probability of occurrence. Expressed as in "the *n* percent confidence interval". The confidence level is the left hand lower confidence interval, so that one may say, "C is the *n*th confidence level", meaning there is an *n* percent probability of cost being between O and C.

Confidence Level – Percentile.

Consistent Judgment Matrix – A judgment matrix that expresses relationships like probabilities, so that if probability of I is m times that of J, and J is n times that of K, then the probability of I is mn times that of K. Since each entry is a ratio, r_{ij}, of the probability of I divided by the probability of J, then r_{ij} times r_{jk} equals r_{ik}.

Constraint – An activity that does not consume time or resources. It acts as a connector between milestones or events.

CER – Cost Estimating Relationship. An estimating relationship in which cost of a system is the mathematical result of a formula having selected system measurements (like thrust or weight) as values in the formula.

Cost Risk – The risk to a program in terms of overrunning the program cost.

Critical Index – The number of times each activity appears on the critical path during simulation.

Critical Path – A path with no slack or float.

CPM – Critical Path Method similar to PERT but activity oriented with single time estimates.

Cumulative Distribution Function – A curve or mathematical expression which associates a probability to all values in the set of values over which it is defined, so that the probability is that of the occurrence of a value less than or equal to a given value.

Decision Analysis – Examination of decision problems by analysis of the outcomes of decision alternatives, the probabilities of arrival at those outcomes, and the intervening decisions between selection of alternatives and arrival of outcomes. The attributes of the outcomes are examined and numerically matched against preference criteria.

Decision Tree - Representation of a decision problem as paths from a present decision through alternative, intermediate decisions and risky events to outcomes. The representation is similar to an increasingly branched tree.

Deterministic - A term generally used to refer to a single iteration of a risk network that has constants reflecting "most likely" values as input parameters. As opposed to "Probabalistic" which has distributions as input parameters that may be sampled many times.

Delphi Technique - The use of a group of knowledgeable individuals to arrive at an estimate of an uncertain situation.

Programmatic Method - A way of describing an expert's uncertainty by presenting a range of PDF diagrams with a selected general shape.

Engineering Change Order Allowance - A budget category to be used for funding changes in the physical or performance characteristics of a system.

Expected Value - The probabilistic average of an uncertain quantity. It equals the sum of all the products of each considered value times its corresponding probability. Also called the mean when applied to all possible values of the uncertain quantity.

Gantt Chart - A bar graph of horizontal bars showing program element commencement and completion against time.

Histogram - A vertical bar chart. A method often used to represent a Probability Mass Function (PMF).

Incentive Share Ratio - The ratio of government-to-contractor assumption of cost or savings related to contract target cost.

Independence (also statistical independence) - The relationship between two or more events when knowledge of the probability of occurrence of one does not alter the probability of another.

ILSP - Integrated Logistics Support Plan: The plan that defines the methods to be used in supporting the system once it is deployed.

Judgment Matrix - A square array of values such that all entries are positive for every entry in row i and column j there is an entry in row j and column i which is the reciprocal of the first.

Life Cycle Cost (LCC): An approach to costing that considers all costs (Government and Contractors) incurred during the projected life of the system, subsystem, or component. It includes total cost of ownership over the system life cycle including all research, development, test and evaluation, initial investment, production, and operating and support (maintenance) cost.

Management Reserve - An amount of budget held aside from direct allocation to program elements as a reserve for contingencies.

Manufacturing Plan - The plan that contains the details of how the system is to be manufactured. Includes the make or buy list of the equipment.

Mode - A point on a probability density function where the probability goes from increasing to decreasing, that is, a maximum.

Model - A partial description of a system using sufficient detail for some analytic or descriptive purpose.

Modified Churchman - Ackoff Method - A means of ordering events in terms of likelihood to occur.

Moment - A function (called the expectation) of a probability law, often referred to as an "nth moment", where n is any number and denotes an exponent on the uncertain quantity. For example, if x is a discrete uncertain quantity, the third moment is the sum of all values of x^3 times the probability of each respective value of x.

Monte Carlo - The simulation technique in which outcomes of events are determined by selecting random numbers subject to a defined probability law. If the random number falls within the limits of an outcome's probability, that outcome is chosen.

Multiplicative Cost Elements - Cost elements whose value is derived by a multiplication of other cost elements.

Network - A collection of points connected by lines.

Network Based Schedule - An objective oriented plan of action that includes all important activities and events.

Network Program Model - Representation of a program by means of a network in which the points (nodes) stand for program decision points or milestones and the lines (arcs) stand for program activities which extend over time and consume resources. Nodes may be regarded as activities requiring no time to complete.

Node - One of a collection of points defining a network.

Normalized Geometric Mean Vector Method - A technique devised to determine the assignment of individual event probabilities and fulfill the axioms of probabilities.

Objective Probability - Probability which can be inferred from objective facts.

Odds - The ratio of probabilities of occurrence and non-occurrence; e.g., for a throw of a fair die the probability of a four is 1/6. The odds are 5 to 1.

Parametric Cost Estimating - Cost estimating by means of obtaining information from a data bank by specific parameters such as weight, size, material composition, etc.

Path – A sequence of arcs.

Percentile – The value of an uncertain quantity, generally referred to as an "*n*th percentile", which is greater than or equal to *n* percent of all values.

PERT – *P*rogram *E*valuation and *R*eview *T*echnique. An early network analysis technique for acquisition programs, in which each activity duration was characterized by its mean or expected values and no uncertainties were incorporated.

Probabilistic Event Analysis – Risk assessment, using a variation of the decision analysis method, developed in reference [54] of Appendix B, Bibliography, Basic Discussion.

Probability Density Function (PDF) – A probability expression such that the area under the function between defined limits of the values on which it is defined represents the probability of the values within those limits.

Probability Function – A mathematical expression, defined for an uncertain quantity, associating a probability with each value or non-redundant combination of values in the set.

Probability Mass Function (PMF) – A function assigning probabilities to each value of uncertain quantity having only discrete or discontinuous values.

Program Advocacy - The personal interest in the program under study to the exclusion of other programs usually without merit.

Program Management Directive (PMD) – A document containing the goals of the program, usually set up as requirements such as cruising speed, dash capability, etc.

Program Management Plan (PMP) - The program plan from feasibility to phase out of the system.

Program Risk - The probability of not achieving a defined cost, schedule, or technical performance goal.

Programmatic Risk - The risks involved in obtaining and using applicable resources and activities that are outside of the programs control, but can affect the program's direction.

Random Number Generator - A computer program capable of providing numbers able to pass statistical tests indicating that any number between the limits of those generated is equally as likely to be generated.

Regression Analysis – Determination of the values of constants in a mathematical expression which gives results that are the closest to the observed values associated with values of the data used in the expression. For example, if cost C is assumed to be the sum of a fixed cost, F, and variable cost, V, for N items, $C = F + VN$. If data shows the expression to be inexact, regression analysis finds values of F and V which give the value, C, closest to those associated with all data values of N. Regression Analysis is a process by which the relationship between paired variables can be described mathematically using the tendency of jointly correlated random variables to approach their mean.

Risk – The condition of having outcomes with known probabilities of occurrence, not certainty of occurrence.

Risk – The combination of the probability of an event occurring and the significance of the consequence of the event occurring.

Risk Analysis – Involves an examination of the change in consequences caused by changes in the risk–input variables.

Risk Assessment – The process of examining all aspects of a program with the goal of identifying areas of risk and the corresponding potential impact.

Risk Assumption – A conscious decision to accept the consequences of the risk occurring.

Risk Avoidance – Risk avoidance is to non–select an option because of potentially unfavorable results. Selection of an option because of lower risk is also risk avoidance.

Risk Control – Risk control is the process of continually monitoring and correcting the condition of the program.

Risk Drivers – The technical, programmatic, and supportability risk facets.

Risk Handling – The last critical element in the risk management process. It is the action or inaction taken to address the risk issues identified and evaluated in the risk assessment and risk analysis efforts.

Risk Identification – Narrative statements describing the program risks.

Risk Management – Relates to the various processes used to manage risk.

Risk Planning – Forcing organized purposeful thought to the subject of eliminating, minimizing, or containing the effects of undesirable occurrences. It allows for (1) eliminating risk wherever possible; (2) isolating and minimizing risk; (3) developing alternate courses of action; and, (4) establishing time and money reserves to cover risks that can be avoided.

Risk Rating Scheme – A method of assigning a risk level such as high, medium , or low risk based on an agreed value assigned to the probability of occurrence and the severity of the impact of failure.

Risk Transfer – The sharing of risk through contractual agreements such as performance incentives, warranties, etc. It can also be between government agencies as in multi–service programs.

Schedule Risk – The risk to a program in not meeting the major milestones.

Simulation – The operation of a model which provides outputs analogous to the system modeled.

Skew – The asymmetry of a probability density function. The skew is to the side of the mode under which lies the greatest area.

Skewness – The measure of the amount of skew.

Slack – The difference between the earliest possible completion time of a path or activity and its latest possible completion time.

Standard Deviation – The square root of the variance. Often used because it is in the same units as the random variable itself, and can be depicted on the same axes as the Probability Density Function of which it is a characteristic.

Standard Normal Function – A probability function centered on zero, with a standard deviation of 1, having a bell shape and covering values that become negatively and positively infinite.

Subjective Probability – An expression of predictability in terms of personal statements obeying the axioms of probability and equal to the probabilities acceptable to the assessor for a substitute gamble.

Supportability Risk – The risks associated with fielding and maintaining systems which are currently being developed or have been developed and are being deployed.

SEMP – *S*ystems *E*ngineering *M*anagement *P*lan. The plan for the system engineering aspects of a program.

Technical Risk – The risk associated with evolving a new design to provide a greater level of performance than previously demonstrated. Includes the same or lesser level of performance subject to new constraints such as size or weights.

TEMP – *T*est and *E*valuation *M*aster *P*lan. The plan for all required testing and evaluation of a system.

Uncertainty – The condition of having outcomes with unknown probabilities of occurrence.

Uniform Distribution – A set of values where every value has an equal probability of occurrence.

Utility Theory – Theory of preference under conditions of risk.

Variance – A measure of the variability of a random variable. The standard deviation squared. Often symbolized as Var ( ).

Work Breakdown Structure – A product oriented family tree division of hardware, software, services, and other work tasks which organizes, defines, and graphically displays the product to be produced, as well as the work to be accomplished to achieve the specified product.

APPENDIX E
BASIC PROBABILITY CONCEPTS

1. INTRODUCTION

This appendix serves as a very basic introduction to probability and statistical concepts that may be useful for risk analysis. The appendix is by no means all inclusive but rather may be thought of as a primer. The appendix is divided into three sections. The first section is an introduction to probability centering on definitions and simple examples. The second section begins with a summary of descriptive statistics including a look at statistical confidence and confidence intervals. The second section then gives an explanation of probability density functions (PDFs) and cumulative density functions (CDFs), which define distributions such as the Uniform, Normal, and Triangular which are relevant to risk analysis. The third section discusses statistical independence, which is the prerequisite for the concept of expected values. Decision tree analysis is illustrated to show the merit of the expected values approach.

Probability

Probability is a concept used by many people everyday. As an example the weatherman predicts a 30 percent probability of rain. This means that in the long run one might expect rain 30 days out of 100 when conditions are the same as they are at the time the forecast is made. For risk analysis a statement might be made to the effect that the developmental stage of weapon system A has a 10 percent probability of a schedule (time) overrun. This is equivalent to saying that of all the developmental stages of weapon systems similar to A, in the past 10 percent have had a schedule overrun.

More formal definitions of probability are given below.

PROBABILITY – "1. The quality or condition of being probable; likelihood. 2. A probable situation, condition, or event. 3. Math. A number expressing the likelihood of occurrence of a specific event, such as the ratio of the number of experimental results that would produce the event to the total number of results considered possible." (*The American Heritage Dictionary*).

PROBABILITY – "In practical situations, probability is used as a vehicle in drawing inferences about unknown population characteristics. Additionally, ..., probability concepts can be used to give us an indication of how good these inferences are," (*Statistical Methods for Business and Economics*) Pffenberger and Patterson, 1977. Reference 1.

Many individuals think of probability in relation to gambling and games of chance such as card playing and dice throwing. They measure the probability of an event in terms of the odds against the event happening. One further example, the throwing of a pair of dice, will illustrate the inverse relationship between probability and "the odds against an event." Throwing an ordinary pair of dice results in one of thirty-six possible outcomes. These are illustrated by Figure E-1.

The probability of throwing a "10" is 3/36 or 0.083. This is three out of the thirty-six

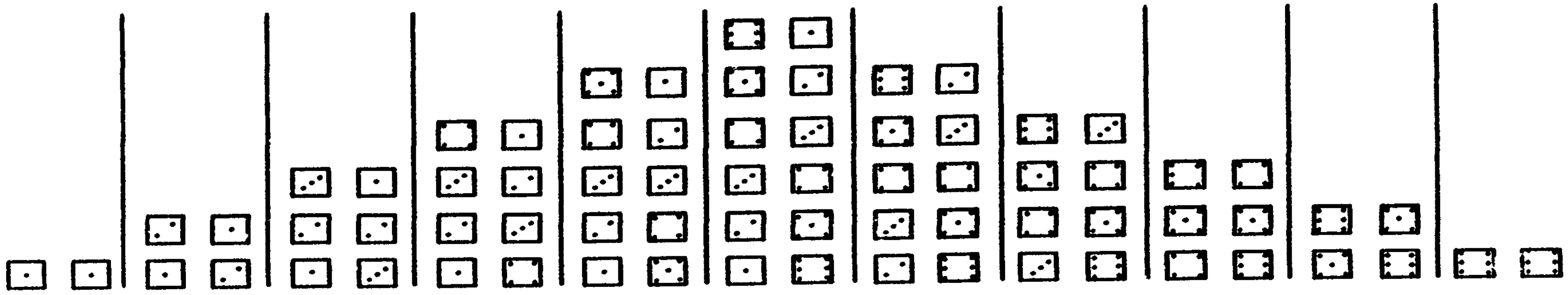


Figure E–1 Dice Throwing Results – Variance possible outcomes result in a "10". The odds against throwing a "10" are "11 to 1." This is since the total number of possible non–10 outcomes, thirty–three, is eleven times the number of outcomes, three, which result in a "10".

Probability is a key quantitative measure associated with many risk assessment techniques. The above examples are simplistic but show how easy it is to comprehend probability concepts. The next two sections expand on the basic premise of probability understanding.

Descriptive Statistics, Confidence, and Distributions

Any group of numbers, such as a sample composed of quantitative evaluations, may be described with the following basic statistical parameters:

- mean
- median
- range
- mode
- variance and standard deviation

These parameters enable the statistician to determine what level of confidence (or assurance) may be accorded to predictive statements about the entire population of numbers. The parameters also help determine of what possible statistical distribution the sample is a part. Conversely, a statistical distribution may be described by such parameters. A statistical distribution is basically just a way to describe which numbers will appear more often (or with a high probability), and which numbers will appear less often (or with a low probability). The following paragraphs define the parameters in some detail and then discuss confidence levels, PDFs and CDFs, and the other relevant distributions applied in risk analysis.

For illustrative purposes let the following numbers represent exam scores for a fictitious introductory statistics course:

75	60	100	65
80	45	25	45
60	90	60	40
50	70	55	10
95	70	85	20
70	65	90	90
65	80	70	55
70			

Let x_i represent these numbers, where i is indexed from 1 to 29. So $X1 = 75, X2 = 80, X3 = 60, \ldots, X28 = 90, X29 = 55$. The mean of these numbers is nothing more than the arithmetic average. The mean is computed thus:

$$\text{MEAN} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{1855}{29} = 63.96$$

where n is the number of exam scores. The mode, the most likely or probable score, is 70. The mode occurred five times more often than any other score. The median is the middle score if the scores are ranked top to bottom. Since there are twenty–nine scores altogether, the median is the fifteenth score, which is a 65. The variance and standard deviation of a group of numbers are an attempt to describe the dispersion or scattering of the numbers around the mean. The variance is computed using the following formula:

$$\text{VARIANCE} = \frac{\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}}{n-1}$$

For this example the variance is:

$$\frac{132275 - \frac{(1855)}{29}}{28} = 486.4$$

The standard deviation is the square root of the variance. The standard deviation has a more intuitive appeal than does the variance since the standard deviation is mathematically the average variation of a value from the mean. For this example the standard deviation is $\sqrt{486.4} = 22.05$. The range is the high score minus the low score. For this example, the range is 100–10=90.

Many times when examining data a "level of confidence" or "confidence interval" is used to indicate what certainty or faith is to be put in the sample that is being taken as representative of the entire population. Far and away the most common measure in the area is the confidence interval for the mean. A statement such as follows is made about a particular sample mean:

"The 95 percent confidence interval for the mean is 56 to 72."

This statement means statistically that of all the possible samples of this size taken out of this population, 95 percent of the samples will have a mean between 56 and 72. It does not mean that 95 percent of all the possible values that are sampled will fall between 56 and 72, which is the common, though faulty, interpretation of the statements.

Confidence intervals are determined by adding and subtracting some calculated value from the mean of the sample. Usually, but not always, this value is based on the standard deviation of the sample. As an example, if the population from which a sample is taken is determined to be normally distributed, and we have assumed this in the previous statements (this determination may be made based on the relative values of the mean, variance and standard deviation, mode, median, range, and other factors), then a 95 percent confidence interval for the population is calculated in this manner:

$$\bar{X} \pm 1.96\ \sigma$$

where $\bar{X}$ is the sample mean and σ is the standard deviation. A 95 percent confidence interval for the mean is calculated in this manner:

$$\bar{X} \pm 1.96 \frac{\sigma}{\sqrt{n}}$$

where $\frac{\sigma}{\sqrt{n}}$ is commonly referred to as the standard error.

One might ask how the population is determined to be normal (or normally distributed) in the first place. Similar groups of numbers have similar relationships between their respective parameters. These similarities help determine which distribution describes the entire population. Typical distributions for problems associated with risk are the Normal, Uniform, Triangular, and Beta. Discussion of the Beta distribution is beyond the scope of this appendix. If the reader requires further information on the Beta distribution, any of several statistics and operations research books readily available can supply the information.

For the normal distribution, 68.3 percent of all possible values lie within one standard deviation of the mean, 95.4 percent lie within two standard deviations, and 99.7 percent lie within three standard deviations. To pictorially show the above, one can look at the Probability Density Function (PDF). The PDF gives the probability that certain values will occur. Figure E-2 below is a PDF for the exam scores example, assuming that the scores are from a normal distribution.

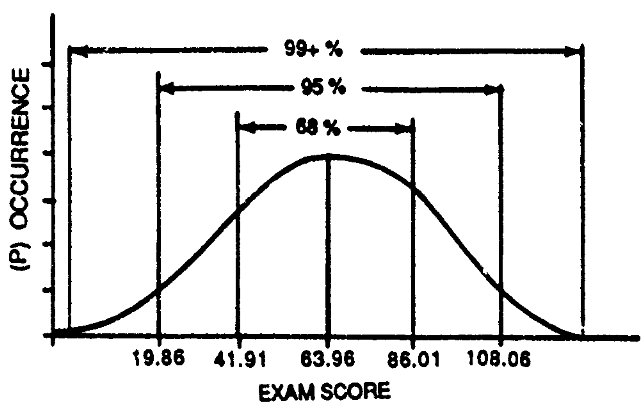


Figure E-2 PDF of a Normal Distribution

The normal distribution is, by strict definition, a continuous distribution. However, Figure E-2 implies that fractional exam scores are possible, but of course it is not realistic in this example. A discussion of the differences between discrete and continuous distribution is beyond this appendix, and since the example is only meant to be used for illustrative purposes, this finer point of statistics will be ignored. Figure E-2 also implies that extra credit is given since scores exceeding 100 are possible, and this could certainly be within the realm of our example. The most important distinction of the normal distributions PDF is the bell shape of the curve. This is the most definitive characteristic of any PDF: shape.

The Cumulative Density Function (CDF) is arithmetically the summation of the PDF. In plainer words, the CDF gives the probability a value (or any value less than the value) will occur. The shape of the various distributions CDFs are distinctive, and the CDF is merely another way of illustrating the distribution. Figure E-3 is a typical CDF for normally distributed values, in this case the exam scores example.

The uniform distribution is used to describe a set of values where every value has an equal probability of occurrence. Returning once again to the exam scores example, one might hypothesize that all possible scores (1, 2, 3, ... 98, 99, 100, ...) have an equal probability of occurrence: 0.01. The PDF for this is illustrated by Figure E-4.

Figure E-5 illustrates the uniform CDF.

The triangular distribution is often used in risk analysis situations to describe the most optimistic, most likely, and most pessimistic durations of some event or activity. The PDF of the triangular distribution, illustrated

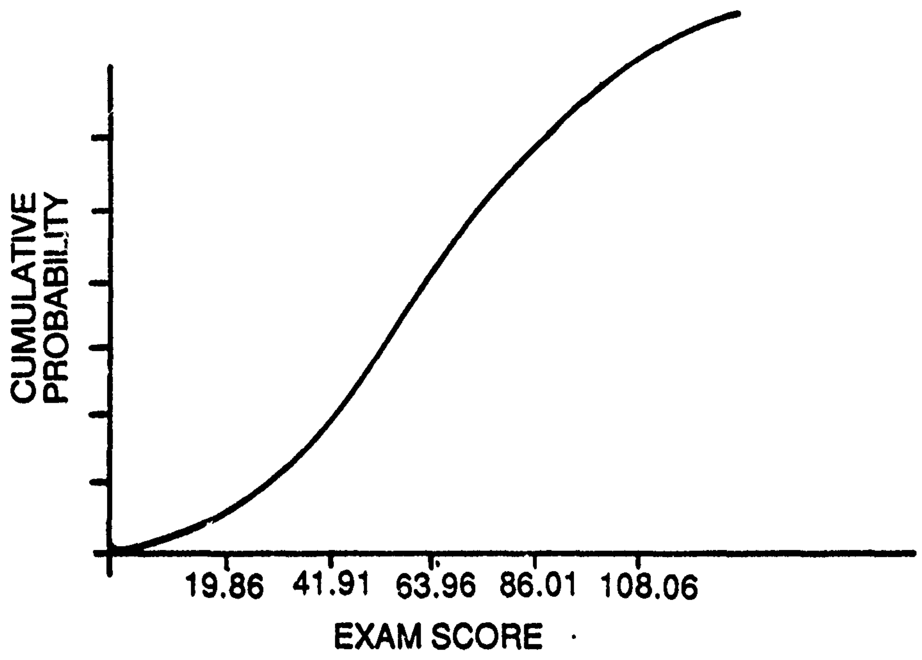


Figure E–3 CDF of a Normal Distribution

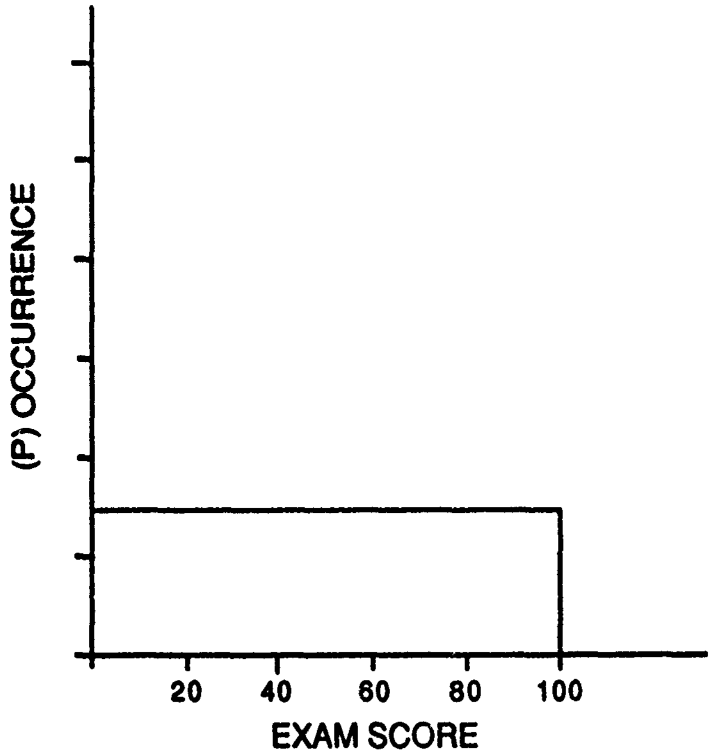


Figure E–4 PDF of a Uniform Distribution

by Figure E–6, is not necessarily symmetric. Indeed, many times the triangular distribution is purposely nonsymmetric or "skewed to the right" to reflect the possibility of very long time durations. These long durations are less likely to occur but do happen occasionally. In the ex–

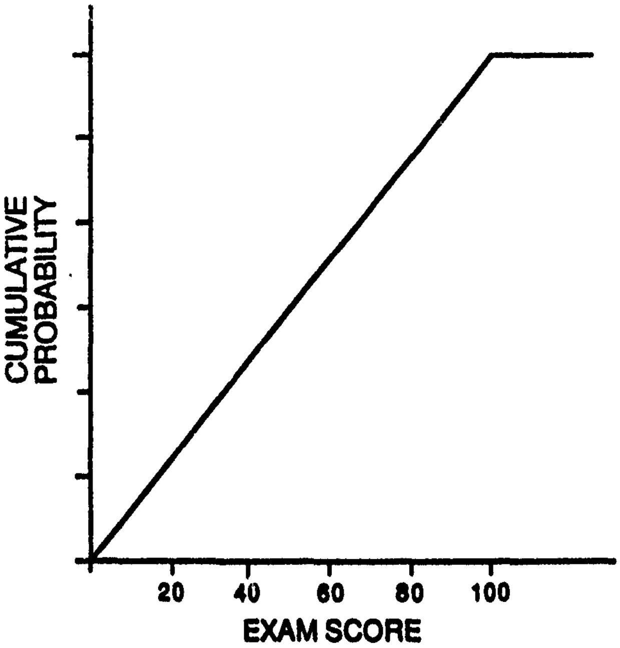


Figure E–5 CDF of a Uniform Distribution

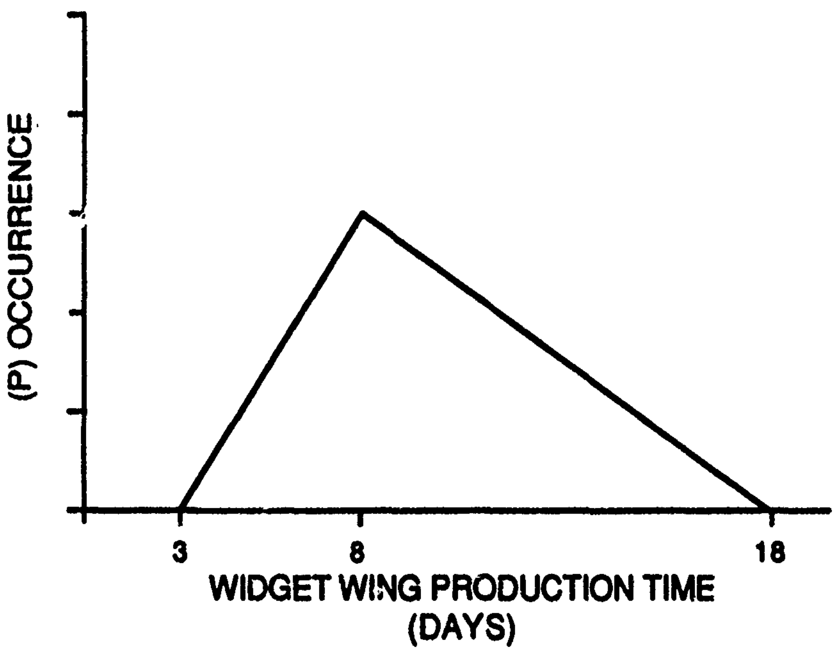


Figure E–6 PDF of a Triangular Distribution

ample shown by Figure E–6, one notices that eight days is the most likely production time for a widget wing. Clearly the average is "to the right" and is very close to 9.3 days. Hence, the triangular distribution, when skewed, has a mode and mean which are clearly different. Contrast this to the normal distribution, where the mode and mean are the same (as is the median).

Independence, Expected Value, and Decision Tree Analysis

Statistical independence is an important concept upon which a good deal of methodologies are based. For this appendix it is important to give a brief definition before going through the basic principles of expected value and decision tree analysis.

Most discussions of statistical independence begin with a tutorial on conditional probability, sample space, and event relationships. Rather than discuss these concepts, a more intuitive (practical) definition of statistical independence is that two events are said to be independent if the occurrence of one is not related to the occurrence of the other. If events are occurring at random, then they are independent. If events are not occurring at random, then they are not independent. A set or group of possible events are said to be mutually exclusive and collectively exhaustive if they are all independent, and the sum of their probabilities of occurrence is 1.0. This is the basic notion behind expected value.

To illustrate the expected value concept, suppose that a game of chance can be played for $1.00. It is a very simple game. The bettor pays $1.00 and has a chance to win $50.00. The bettor may also win $2.00 or no money at all. The dollar amounts and probability of winning are shown by Table E-1.

Table E-1 Expected Values Example

AMOUNT VALUE	PROBABILITY OF WINNING	EXPECTED VALUE
$50.00	0.01	0.50
2.00	0.10	0.20
0.00	0.89	0.00
TOTAL	1.00	$0.70

The bettor would like to know, before actually paying his dollar, what the expected winnings are. The expected value of winnings is the sum of the winning amounts multiplied by their respective probability of occurrence or

($50.00) (0.01) + ($2.00) (0.10) + ($0.00) (0.89) = $0.50 + $0.20 + $0.00 = $0.70.

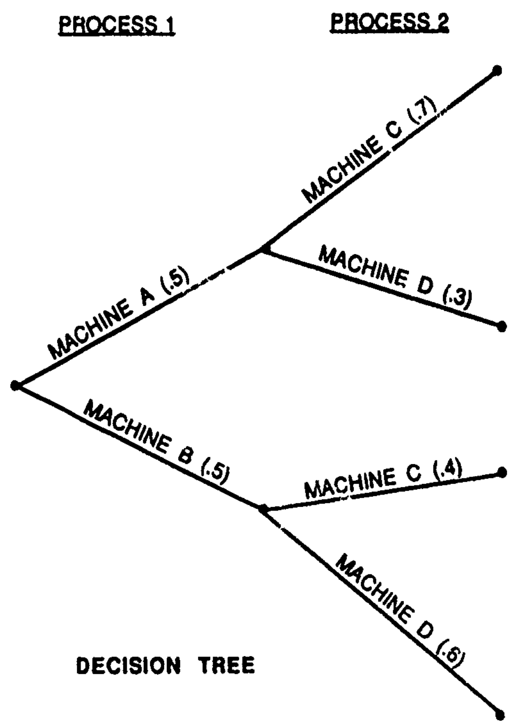
Since the bettor can only expect winnings on the average of seventy cents and pays one dollar to play the game, the net payoff is a negative thirty cents.

One might believe that most individuals, when forced to face this logic, would choose not to play. However this is a very realistic example of gambling and risk. Many individuals would play this game. They are willing to accept the risk of losing $1.00 in order to take a chance at winning $50.00. They are risk-prone. The individual who follows the basic logic of this example and does not play is said to be risk-averse.

Expected value is a notion prerequisite to the following discussion on Decision Tree Analysis. Decision tree analysis attempts to break down a series of events into smaller, simpler, and more manageable segments. Many similarities exist between decision tree analysis and more complicated forms of management and risk analysis, such as the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM). All three forms of analysis presume that a sequence of events can be broken down into smaller and smaller segments, therefore more accurately representing reality.

Decision tree analysis helps the analyst break a problem down into various sectors or branches in order to simplify potential decision-making. As an example, suppose that a widget is being manufactured in the following fashion. Either machine A or machine B can be used for the first step (of a two-step manufacturing process) with equal probability of 0.5. Then the second step has machine C or D processing the widget. Machine C is used 70 percent of the time if the widget was first processed with machine A, and used 40 percent of the time if the widget was first processed with machine B. Otherwise, machine D is used for the second step. Decision tree analysis can be used to help compute the probability of the widget being produced by the various combinations of machines (AC,AD,BC,BD). Figure E-7 illustrates the decision tree and the expected probability for each of the four manufacturing process alternatives.

Note that an alternative's probability is merely the product of the individual processes making up that alternative, since the individual processes are independent of each other. Note also that the sum of the probabilities for all of the four processing alternatives is 1.00.



ALTERNATIVES

AC IS (.5) (.7) = .35
AD IS (.5) (.3) = .15
BC IS (.5) (.4) = .20
BD IS (.5) (.6) = .30

SUM OF PROBABILITIES = 1.00

Figure E-7 Decision Tree

APPENDIX F
QUANTIFYING EXPERT JUDGMENT

I. GENERAL

All risk assessment techniques share a common need, and that is the acquisition of expert judgment as input to any of the risk assessment models. Inherent in judgment is a degree of uncertainty. When acquiring quantifiable expressions of judgment, it is imperative that the axioms of probability not be violated:

1) The probabilities of all possible events must sum to one

2) The probability of any event P(A) must be a number greater than or equal to zero and less than or equal to one ($0 \leq P(A) \leq 1$)

3) The probability of joint events is the product of the probability that one event occurs, and the probability that another event occurs given that the first event has occurred ($P(A) \times P(B|A)$. Under these circumstances, the events are termed dependent

4) When the probability of joint events occurring is simply the product of the probabilities of each $P(A) \times P(B)$, the events are said to be independent. That is, the two events have nothing in common or can occur simultaneously.

The challenge for the analyst is to obtain expert judgment in the areas of cost, schedule and technical performance, which is qualitative by nature. Next, he/she must convert it to a quantitative form, so that the results can be depicted in the form of a probability density function (PDF), which serves as input to the various risk models (keep in mind that this is only necessary when a quantitative model has been selected).

A probability density function (PDF) is a smooth line or curve such as shown in Figure F-1. A PDF of a random variable x is a listing of the various values of x with a corresponding probability associated with each value of the random variable x. For our purposes, x would be a cost, schedule, or performance value. Note that the total area under the curve equals 1.

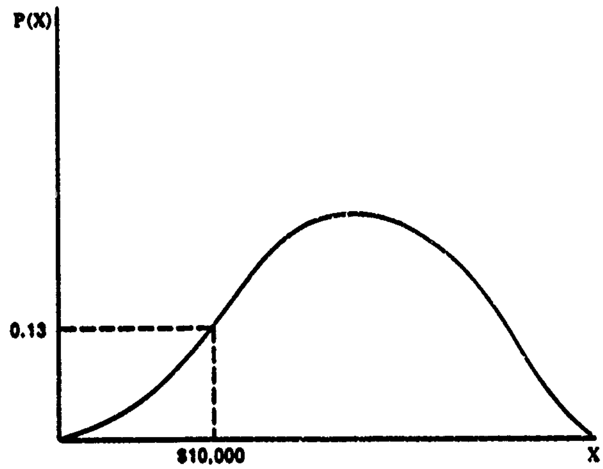


Figure F-1 Probability Density Function

Using Figure F-1, the random variable x might represent a hardware system cost, the probability of the system costing $10,000 would be 0.13.

There are a number of methods which can be used to convert qualitative judgment into quantitative probability distributions. The remainder of this section will focus on a few of the most popular, practical, and accurate techniques for doing so. The techniques discussed were selected because they are relatively simple and easy to master. This factor is of paramount importance, because in most cases the analyst who will be performing this task will have neither the time or the knowledge of the advanced probability concepts required to perform more complex techniques. Those interested in more exotic, complex techniques are referred to Section V – Sources of Additional Information – at the end of this appendix.

The following techniques will be discussed in this appendix:

1) Diagrammatic
2) Direct
3) Betting
4) Modified Churchman/ Ackoff technique
5) Delphi Approach.

II. DESCRIPTION OF TECHNIQUES

1) Diagrammatic

Many analysts prefer the diagrammatic method as a way of capturing and representing an expert's judgment. This method is a simple way of describing an expert's uncertainty by presenting him with a range of PDF diagrams and having the expert select the shape of the PDF which is considered to reflect most accurately the schedule, cost, or technical parameter in question. Using this method, the analyst can ascertain whether the PDF is symmetric or skewed, the degree of variability, etc. For example, if the expert feels that there is a great amount of risk associated with completing an activity within a certain period of time, a PDF skewed to the right may be selected. Likewise, activities with little risk may be skewed to the left. If the expert feels that each value over a given range is equally likely to occur, a uniform distribution may be most appropriate. The analyst and the expert, working together, can select the PDF which most accurately reflect the schedule, cost, or technical item under question.

The diagrammatic method of obtaining PDFs is applicable when the expert has a sound understanding of probability concepts and can merge that understanding with his understanding of the parameters under question. In this way the expert can accurately identify the appropriate PDFs.

2) Direct

The direct method is a relatively simple technique which can be used to obtain subjective probability distributions by asking the expert to assign probabilities to a given range of values.

The direct method of obtaining PDFs is applicable, 1) when questions can be phrased to the respondents in such a way that there is no confusion likely to exist in the respondents mind, and 2) when the results will not violate the axioms of probability. This method is applicable when time/resource constraints do not allow for more complex, resource intensive methods.

The application of the direct method is quite simple. The analyst would define a relevant range and discrete intervals for the parameter for which the PDF is to be constructed. For example, the analyst might define the relevant time duration for a program activity (test of a piece of equipment) to be between 0 and 27 days. The analyst would then break this relevant range down into intervals, say intervals of three days, the resulting formulation would look as follows:

0 - 3 days	16 - 19 days
4 - 7 days	20 - 23 days
8 - 11 days	24 - 27 days
12 - 15 days	

Given these intervals over the relevant range, the analyst would then query the expert to assign relative probabilities to each range. From this, the form of the PDF could be identified. It is imperative that the axioms of probability not be violated.

Besides the application already described, the analyst could request the expert to provide a lowest possible value, a most likely value, and a highest possible value. The analyst then makes an assumption about the form of the density function. That is, is the PDF uniform, normal, beta, triangular, etc?

3) Betting

One method of phrasing questions to experts in order to obtain probabilities for ranges of values (cost/schedule) states the problem in terms of betting. A form of this method, which was described by Winkler (1967), helps the expert (assessor) assess probabilities of events which are in accordance with his judgment. The assumption with this method is that the judgment of the expert may be fully represented by a probability distribution, f(*x*) of a random variable *x*. This method offers the expert a series of bets.

Under ideal circumstances, the bets are actual, not hypothetical. That is, in each case the winner of the bet is determined and the amount of money involved actually changes hands. However, under our circumstances, this is not feasible (or legal!). In each case, the expert must choose between two bets (the expert is not allowed to refrain from betting). The expert must choose between a bet with a fixed probability *q* of winning and 1-*q* of losing, and a bet dependent on whether or not some event *E* (a particular program activity duration range, or cost range) occurs. The bet can be depicted as follows:

Bet 1*a*	-	win \$A if the event *E* occurs
	-	lose \$B if event *E* does not occur
Bet 1*b*	-	win \$A with probability of *q*
	-	lose \$B with probability of 1-*q*.

The expected values of bets 1*a* and 1*b* to the expert are respectively $Ap + Bp - B$ and $Aq + Bq = B$, where P is the probability of event E occurring. The following inferences may be drawn from the experts decision: if bet 1*a* is chosen, $Ap + Bp - B \geq Aq + Bq - B$, so $p \geq q$; likewise if 1*b* is selected $p \leq q$.

By repeating the procedure, varying the value of q, the probability of event E can be ascertained. It is the point at which the expert is indifferent between bets 1*a* and 1*b*, where $p = q$. The degree of precision is dependent on the number of bets and the incremental changes of the value of q.

A way of avoiding the problem of a large number of bets to obtain p would be to assess the probabilities through the use of direct interrogation, and then to use the betting situation as a check on the assumed probabilities.

To complete a PDF, the analyst repeats this procedure over a relevant range of interval values. The analyst then plots the points at the center of the range for each event and smoothes in a curve, so that the area under it equals one, as in Figure F-2. The analyst must ensure that all of the relevant axioms of probability are maintained.

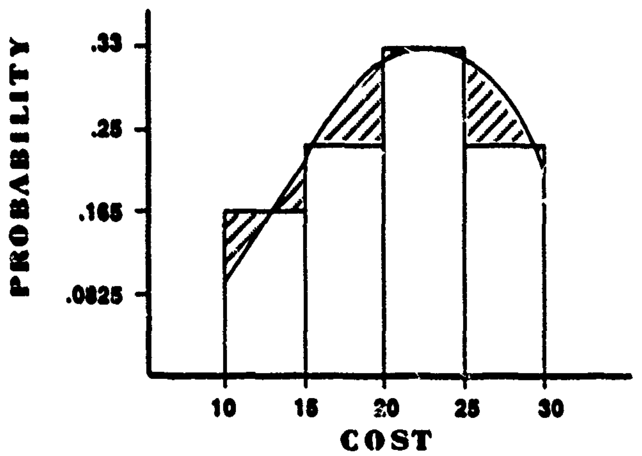


Figure F-2 Fitting a Curve to Expert Judgment

Many people, when questioned one way, are likely to make probability statements that are inconsistent with what they will say when questioned in another equivalent way, especially when they are asked for direct assignment of probabilities. As the number of events increases, so does the difficulty of assigning direct probabilities. Therefore, when this is a problem, the betting method is most appropriate.

To apply the betting technique, we will select one interval for the relevant range to demonstrate how this method can be used to obtain probability estimates and, hence, PDFs. The bet is established as follows:

Bet 1*a*	-	win $10,000 if cost is between $15,100 and $20,000
	-	lose $5,000 if cost is not between $15,100 and $20,000
Bet 1*b*	-	win $10,000 with probability of q
	-	lose $5,000 with probability of $1-q$

The value of q is established initially, and the expert is asked which of the two bets he would take.

The value of q is then varied systematically, either increased or decreased. The point at which the expert is indifferent between the two bets (with the associated q value) provides the probability of the cost being between $15,100 and $20,000. This process is repeated for each interval, and the results used create the PDF associated with the cost of that particular program event.

4) Modified Churchman/ Ackoff Technique

Another method, which can be used to ascertain PDFs for cost, schedule, or performance parameters, is the "Modified Churchman-Ackoff method." This technique builds upon procedures which were presented by Churchman and Ackoff in 1954. This technique was developed as a means to order events in terms of likelihood. The modification to the technique was performed so that once the order of event likelihoods had been accomplished, relative probabilities could be assigned to the events and finally probability density functions developed. So as to be relevant for our purposes, events are defined as range values for cost, schedule, or performance (activity durations) relating to the outcome of a specific activity in a program.

The modified Churchman–Ackoff technique is most appropriate when there is one expert, and that expert has a thorough understanding of the relative ranking of cost/schedule ranges and a limited understanding of probability concepts. The remainder of this section was extracted and modified from the Compendium on Risk Analysis Techniques (1972, see references). Note that while the mathematical calculations appear to make this a very precise technique, it is still an approximation of an expert's judgment and should not be interpreted to be more exact than other similar techniques.

The first step in applying the modified Churchman–Ackoff technique is to define the relevant range of values. That is, the end points, along a range of values with zero probability of occurrence must be specified. These values need only be any low and high values which the expert specifies as having zero probability of occurrence. Next, ranges of individual values within the relevant range must be determined. These ranges of values which will form the set of comparative values for this technique are specified by the following approach:

(1) Start with the low value in the relevant range

(2) Progress upward on the scale of values until the expert is able to state a simple preference regarding the relative probabilities of occurrence of the two characteristic values. If he is able to say that he believes one value has either a greater chance or a lesser chance of occurring that the other of the two values, then it is inferred that the expert is able to discriminate between the two values.

(3) Using the higher of the two previously specified scale values as a new basis, repeat step (2) to determine the next value on the scale.

(4) Repeat steps (2) and (3) until the high end point value of the range of parameters values is approached.

Employing this procedure for the duration required to successfully test a piece of equipment, may yield the results shown in Table F–1.

Table F-1 Characteristic Values for Equipment Test Durations

0_1	=	0 – 3	days
0_2	=	4 – 7	days
0_3	=	8 – 11	days
0_4	=	12 – 15	days
0_5	=	16 – 19	days
0_6	=	20 – 23	days
0_7	=	24 – 27	days

The descending order of probability or occurrence can be determined by applying the following paired comparison method.

Ask the expert to compare, one at a time, the first interval value (0_1) of the set to each of the other values (0_2, 0_3, etc.), stating a preference for that value in each group of two values that he believes has the greater chance of occurring (denoting a greater probability of occurrence by >, and equal chance by =, and a lesser chance by <). The following hypothetical preference relationships could result for a set of seven values ($0_1 < 0_2, 0_1 < 0_3, 0_1 < 0_4, 0_1 < 0_5, 0_1 < 0_6, 0_1 < 0_7$).

Next, ask the expert to compare, one at a time, the second interval values (0_2) of the set to each of the other interval values succeeding it in the set (i.e., 0_3, 0_4, etc.). The following preference relationships might result ($0_2 < 0_3, 0_2 < 0_4, 0_2 < 0_5, 0_2 < 0_6, 0_2 < 0_7$). Continue this process until all values (0_i) have been compared.

Now total the number of times (0_i) value was preferred over other values. The results for this procedure are listed in Table F-2.

Table F-2 Summary of Preference Relationships

0_4	=	6 times
0_3	=	5 times
0_5	=	4 times
0_2	=	3 times
0_6	=	2 times
0_1	=	0 times
0_7	=	0 times

List the values in descending order of simple ordinal probability preference and change the symbols for each value from 0_i to X_j as shown in Table F-3.

Table F-3 Transformation

CHARACTERISTIC VALUE (DAYS)		PREFERENCE RANK	NEW SYMBOL
0 - 3	0_4	1	X_1
4 - 7	0_3	2	X_2
8 - 11	0_5	3	X_3
12 - 15	0_2	4	X_4
16 - 19	0_6	5	X_5
20 - 23	0_1	6	X_6
24 - 27	0_7	7	X_7

Arbitarily assign a rating of 100 points to the characteristic value with the highest subjective probability (e.g., X_1). Then, as in the first step, question the expert regarding the relative chance of occurrence of each of the other values on the ordinal scale in Table F-3 with respect to the value at the top of the scale. Assigning X_1 a rating of 100 points, the expert is first interrogated as to his feeling of the relative chance of occurrence of the second highest scale value (e.g., X_2), with respect to X_1. Does it have 25 percent chance? 60 percent? 70 percent? 80 percent? As much chance of realization as X_1? The relative probability rating, based on 100 points, (i.e., 100 percent as much chance) will then be posted for X_2.

Next, question the expert about the relative chance of occurrence of the next highest scale (e.g., X_3) first with respect to the most preferred value (X_1), and then with respect to the second most preferred scale value (X_2). The resulting numerical ratings should concur. For example, if the expert decides that X_2 has 8/10 as much chance of occurring as does X_1, and that X_3 has 1/2 as much chance as X_1, and 5/8 as much chance as X_2, the ratings become

$X_1 = 100$ points, $X_2 = 80$ points, and $X_3 = 50$ points.

This process continues for each successively lower interval value on the ordinal scale as shown in Table F-3. Determine the relative number of points to be accorded each value with respect to the top scale and with respect to all other values on down the scale which are above the characteristic value in question.

In the event of minor disparities between relative probability ratings for a given value, the average of all such ratings for that characteristic value might be computed. For example, X_4 might be determined to be 3/10 as probable as X_1, 1/4 as probable as X_2, and 1/2 as probable as X_3. The three absolute ratings for X_4 are thus inferred to be 30, 20, and 25 points, respectively. The average of these ratings is 25. However, before averaging such figures, it might be beneficial to have the expert revaluate his relative ratings for X_4 with respect to X_1, X_2, and X_5.

As a result of the above process, the relative probability values shown in Table F-4 might be attained.

Table F-4 Relative Probability Ratings

RX_1	=	100 Probability points
RX_2	=	80 Probability points
RX_3	=	50 Probability points
RX_4	=	25 Probability points
RX_5	=	10 Probability points
RX_6	=	0 Probability points
RX_7	=	0 Probability points

Finally, the scale of relative probability values can be converted directly into a scale of actual probability density values by letting $P(X_1)$ equal the actual subjective probability or occurrence of the highest value. Then, $P(X_2)$ is then defined as:

$$\frac{R(X_2)}{R(X_1)} \, [P(X_1)]$$

Similarly $P(X_i)$ is defined as:

$$\frac{R(X_i)}{R(X_1)} \, [P(X_1)]$$

for i = 2, 3, ..., 7.

Assuming that the independent characteristic values evaluated represent all possible values attainable by the component characteristic, the respective probabilities must sum to 1.0 (i.e., $P(X_1) + P(X_2) + P(X_3) + P(X_4) + P(X_5) + P(X_6) + P(X_7) = 1.0$). Substituting the expressions for $P(X_i)$, i = 2, ..., 7, it follows that:

$$P(X_1) + \frac{R(X_2)}{R(X_1)}[P(X_1)] + \frac{R(X_3)}{R(X_1)}[P(X_1)] + \frac{R(X_4)}{R(X_1)}[P(X_1)]$$

$$+ \frac{R(X_5)}{R(X_1)}[P(X_1)] + \frac{R(X_6)}{R(X_1)}[P(X_1)] + \frac{R(X_7)}{R(X_1)}[P(X_1)] = 1.$$

Solving this equation for $P(X_1)$, the remaining $P(X_i)$, i = 2, ..., 7 can be determined using the relationship :

$$P(X_1) = \frac{R(X_i)}{R(X_1)} \, [P(X_1)] \, .$$

As an illustration, consider the relative probability ratings in Table F-4. Using the values, the preceding equation is given by:

$$P(X_1) + \frac{80}{100} P(X_1) + \frac{50}{100} P(X_1) + \frac{25}{100} P(X_1) + \frac{10}{100} P(X_1) = 1.$$

Solving this equation, $P(X_1) = 0.377$.

This value can be used to determine the remaining probabilities as follows:

$$P(X_2) = \frac{RX_2}{RX_1} P(X_1) = 0.80\,(0.377) = 0.301$$

$$P(X_3) = \frac{RX_3}{RX_1} P(X_1) = 0.50\,(0.377) = 0.189$$

$$P(X_4) = \frac{RX_4}{RX_1} P(X_1) = 0.25\,(0.377) = 0.095$$

$$P(X_5) = \frac{RX_5}{RX_1} P(X_1) = 0.10\,(0.377) = 0.038$$

$$P(X_6) = \frac{RX_6}{RX_1} P(X_1) = 0\,(0.377) = 0.000$$

$$P(X_7) = \frac{RX_7}{RX_1} P(X_1) = 0\,(0.377) = 0.000$$

The resulting probability density appears in Table F–5.

Table F–5 Probability Density

COMPONENT CHARACTERISTIC VALUE	PROBABILITY
X_1	0.377
X_2	0.301
X_3	0.189
X_4	0.095
X_5	0.038
X_6	0.000
X_7	0.000
TOTAL	1.000

5) Delphi Approach

In many cases, expert judgment does not reside solely with one individual, but is spread among multiple experts. Committee approaches to obtaining a group assessment have been found to contain problems relating to interpersonal pressures to a degree that caused researchers at the RAND Corporation to devise a method known as the Delphi to avoid the pressures.

The Delphi technique has become well known in management circles, but is subject to misconception. Too often the term is used to identify a committee or multiple interview process, and these do not share the advantages of the Delphi technique.

The Delphi technique has been extended in recent years to cover a wide variety of types of group interaction. The technique can be used for group estimation, that is, the use of a group of knowledgeable individuals to arrive at an estimate of an uncertain quantity. The quantity can be a cost, a time period associated with an event, or a performance level.

The Delphi technique is most appropriate when:

- The problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis.
- The individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise.

- More individuals are needed than can effectively interact in a face–to–face exchange.
- Time and cost make frequent group meetings unfeasible.
- The efficiency of face–to–face meetings can be increased by a supplemental group communication process.
- Disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured.
- The heterogeneity of the participants must be preserved to assure validity of the results, i.e., avoidance of domination by quantity or by strength of personality ("bandwagon effect").

The Delphi technique differs from other methods of obtaining a group opinion, because it physically separates the group's members from one another in order to reduce irrelevant interpersonal influences. Properly carried out, the technique is facilitated by an analyst obtaining each panel member's opinion and each member's reason for the opinion. The analyst then reduces the opinions and reasons to standard statements in order to preserve anonymity. The analyst then shows the panel member the aggregated opinions of the other panel members in statistical terms. The analyst provides each panel member with the reasons justifying the opinions that differ with the member, and requests revaluation and further substantiation. This iterative feeding back continues until no further substantial change results. At this point, the moderator takes the final individual opinions and computes a set of median values to represent the group opinion. The median value, rather than the average, is used as a central estimate to prevent the estimate from being overly influenced by extreme individual values.

One technique which hold much promise for the future as a means of capturing expert judgment is "expert support systems". Ideally, the expert support system would lead the expert(s) through a series of parameter specific questions (cost and schedule, possibly performance) and generate PDFs based on the responses.

III. RESOURCE REQUIREMENTS

The effort required to conduct expert interviews and generate appropriate PDFs is man–hour intensive. Much time is spent by the analyst with the expert(s) acquiring and quantifying his expertise. The amount of time required to accomplish this task is predicated on the number of PDFs needed (based on the number of activities required as model input and whether cost, schedule, and technical distributions are required). The methods described are basically manual with computer resources not a necessity. However, as the techniques become more complex and expert support systems to accomplish the tasks are developed, computer resources required will escalate dramatically.

IV. RELIABILITY

The reliability of the PDFs obtained through these techniques is affected by a number of factors. Foremost is the degree to which the so called "expert" is in fact an expert. The better understanding the expert has of the parameter being modeled, the more reliable the resulting PDFs will be. The burden also falls on the analyst to select the technique most appropriate for obtaining PDFs. For example, if expertise resides with more than one expert, a Delphi technique would result in much more reliable PDFs than would a direct method of asking only one expert. Likewise, if the expert has very little understanding of probability concepts, it would be inappropriate to ask him to select a PDF from a visual list of options. Under these circumstances, the modified Churchman-Ackoff method or a betting technique would most likely result in more reliable PDFs. In summary, much of the reliability of the PDFs is predicated on the techniques selected by the analyst for constructing them. Therefore, it is important that the analyst know when each technique is most appropriate, given the unique circumstances of that specific program office.

V. Sources of Additional Information

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APPENDIX G
SPECIAL NOTES ON SOFTWARE RISK

While the techniques and processes discussed in the text of the guide do apply to software, they do not address some of the peculiarities that are a part of software development. Software has a tendency to change dramatically during the development cycle when compared to hardware. This brief appendix is intended to generate some thought and suggest some useful actions in managing software development efforts. Additional information can be obtained from Chapter 20 of the DSMC Systems Engineering Management Guide.

One of the most effective risk management (handling) techniques for software is the establishment of a formal Software Quality Assurance program early in the development cycle. The program should establish a "team" of experts whose charter is to explicitly look at issues which will ensure a reliable product in a reasonable time and at a reasonable cost. Some of the issues that the team must evaluate include the following:

- Is independent verification and validation warranted
- Is the development environment adequate
  - tool sets
  - compiler
- Is the higher order language selection appropriate
- Are the requirements clearly stated
- Will rapid prototyping be used
- Has the software approach been baselined
- Has the testing philosophy been established
- Has the development philosophy been established?

Addressing these issues early in the development cycle will help avoid surprises downstream. There are three other documents that may provide useful in software risk management:

AFSCP 800-XX (Draft), Air Force System Command Software Risk Management, Jun 87.

ASD Pamphlet 800-5 Acquisition Management, Software Development Capability/Capacity Review, 10 Sep 87.

Software Reporting Metrics, Electronic Systems Division, AFSC, Hanscom AFB, MA, Nov 85.

These documents contain more specific actions for dealing with software development problems. The basic process for risk management still applies to software - plan, assess, analyze, and handle. Tables G-1 to G-5 are extracts from the draft AFSC pamphlet that may prove useful in quantifying software risk.

The "Software Reporting Metrics" document has proven extremely useful and both the Army and Air Force have issued formal guidance regarding the use of this technique in AMC Pamphlet 70-13 and AFSCP 800-43.

Table G-1 Quantification of Probability and Impact of Technical Failure

TECHNICAL DRIVERS	MAGNITUDE		
	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
REQUIREMENTS			
COMPLEXITY	Simple or easily allocatable	Moderate, can be allocated	Significant or difficult to allocate
SIZE	Small or easily broken down into work units	Medium, or can be broken down into work units	Large or cannot be broken down into work loads
STABILITY	Little or no change to establisned baseline	Some change in baseline expected	Rapidly changing or no baseline
PDSS	Agreed to support concept	Roles and missions issues unresolved	No support concept or major unresolved issues
R&M	Allocatable to hardware and software components	Requirements can be defined	Can only be addressed at the total system level
CONSTRAINTS			
COMPUTER RESOURCES	Mature, growth capacity within design, flexible	Available, some growth capacity	New development no growth capacity, inflexible
PERSONNEL	Available, in place, experienced, stable	Available, but not in place, some experience	High turnover, little or no experience, not available
STANDARDS	Appropriately tailored for application	Some tailoring, all not reviewed for applicability	No tailoring, none applied to the contract
GFE/GFP	Meets requirements, available	May meet requirements, uncertain availability	Not compatible with system requirements, unavailable
ENVIRONMENT	Little or no impact on design	Some impact on design	Major impact on design
TECHNOLOGY			
LANGUAGE	Mature, approved HOL used	Approved or Non-approved HOL	Significant use of assembly language
HARDWARE	Mature, available	Some development or available	Total new development
TOOLS	Documented, validated, in place	Available, validated some development	Unvalidated, proprietary, major development
DATA RIGHTS	Fully compatible with support and follow-on	Minor incompatibilities with support and follow-on	Incompatible with support and follow-on
EXPERIENCE	Greater than 3 to 5 years	Less than 3 to 5 years	Little or none
DEVELOPMENTAL APPROACH			
PROTOTYPES & REUSE	Used, documented sufficiently for use	Some use and documentation	No use and/or no documentation
DOCUMENTATION	Correct and available	Some deficiencies, available	Nonexistent
ENVIRONMENT	In place, validated, experience with use	Minor modifications, tools available	Major development effort
MANAGEMENT APPROACH	Existing product and process controls	Product & process controls need enhancement	Weak or nonexistent
INTEGRATION	Internal and external controls in place	Internal or external controls not in place	Weak or nonexistent
IMPACT	Minimal to small reduction in technical performance	Some reduction in technical performance	Significant degredation to nonachievement of technical performance

Table G-2 Quantification of Probability and Impact of Technical Failure

OPERATIONAL DRIVERS	MAGNITUDE: LOW (0.0 – 0.3)	MAGNITUDE: MEDIUM (0.4 – 0.5)	MAGNITUDE: HIGH (0.6 – 1.0)
USER PERSPECTIVE			
REQUIREMENTS	Compatible with the user environment	Some incompatibilities	Major incompatibilities with "ops" concepts
STABILITY	Little or no change	Some controlled change	Uncontrolled change
TEST ENVIRONMENT	Representative of the user environment	Some aspects are not representative	Major disconnects with user environment
OT&E RESULTS	Test errors/failures are correctable	Some errors/failures are not correctable before IOC	Major corrections necessary
QUANTIFICATION	Primarily objective	Some subjectivity	Primarily subjective
TECHNICAL PERFORMANCE			
USABILITY	User friendly	Mildly unfriendly	User unfriendly
RELIABILITY	Predictable performance	Some aspects unpredictable	Unpredictable
FLEXIBILITY	Adaptable with threat	Some aspects are not adaptable	Critical functions not adaptable
SUPPORTABILITY	Timely incorporation	Response times inconsistent with need	Unresponsive
INTEGRITY	Responsive to update	Hidden linkages, controlled access	Insecure
PERFORMANCE ENVELOPE			
ADEQUACY	Full compatibility	Some limitations	Inadequate
EXPANDABILITY	Easily expanded	Can be expanded	No expansion
ENHANCEMENTS	Timely incorporation	Some lag	Major delays
THREAT	Responsive to change	Cannot respond to some changes	Unresponsive
IMPACT	Full mission capability	Some limitations on mission performance	Severe performance limitations

Table G-3 Quantification of Probability and Impact of Support Failure

SUPPORT DRIVERS	MAGNITUDE LOW (0.0 – 0.3)	MEDIUM (0.4 – 0.5)	HIGH (0.6 – 1.0)
DESIGN			
COMPLEXITY	Structurally maintainable	Certain aspects difficult	Extremely difficult to maintain
DOCUMENTATION	Adequate	Some deficiencies	Inadequate
COMPLETENESS	Little additional for PDSS incorpora ion	Some PDSS incorporation	Extensive PDSS incorporation
CONFIGURATION MANAGEMENT	Sifficient, in place	Some shortfalls	Insufficient
STABILITY	Little or no change	Moderate, controlled change	Rapid or uncontrolled change
RESPONSIBILITIES			
MANAGEMENT	Defined, assigned responsibilities	Some roles and mission issues	Undefined or unassigned
CONFIGURATION MANAGEMENT	Single point control	Defined control points	Multiple control points
TECHNICAL MANAGEMENT	Consistent with operational needs	Some inconsistencies	Major inconsistencies
CHANGE IMPLEMENTATION	Responsive to user needs	Acceptable delays	Nonresponsive to user needs
TOOLS & MANAGEMENT			
FACILITIES	In place, little change	In place, some modification	Nonexistent or extensive change
SOFTWARE TOOLS	Delivered, certified, sufficient	Some resolvable concerns	Not delivered, certified, or sufficient
COMPUTER HARDWARE	Compatible with "ops" system	Minor incompatibilities	Major incompatibilities
PRODUCTION	Sufficient for fielded units	Some capacity questions	Insufficient
DISTRIBUTION	Controlled, responsive	Minor response concerns	Uncontrolled or nonresponsive
SUPPORTABILITY			
CHANGES	Within projections	Slight deviations	Major deviations
OPERATIONAL INTERFACES	Defined,controlled	Some "hidden" linkages	Extensive linkages
PERSONNEL	In place, sufficient, experience	Minor discipline mix concerns	Significant concerns
RELEASE CYCLE	Responsive to user requirements	Minor incompatibilities	Nonresponsive to user needs
PROCEDURES	In place, adequate	Some concerns	Nonexistent or inadequate
IMPACT	Responsive software support	Minor delays in software modifications	Nonresponsive or unsupportable software

Table G-4 Quantification of Probability and Impact of Support Failure

COST DRIVERS	MAGNITUDE: LOW (0.0 – 0.3)	MAGNITUDE: MEDIUM (0.4 – 0.5)	MAGNITUDE: HIGH (0.6 – 1.0)
REQUIREMENTS			
SIZE	Small, non-complex, or easily decomposed	Medium, moderate complexity, decomposable	Large, highly complex, or not decomposable
RESOURCE CONSTRAINTS	Little or no hardware imposed constraints	Some hardware imposed constraints	Significant hardware imposed constraints
APPLICATION	Non real-time, little system interdependency	Embedded, some system interdependency	Real-time, embedded, strong interdependency
TECHNOLOGY	Mature, existent, in-house experience	Existent, some in-house experience	New or new application, little experience
REQUIREMENTS STABILITY	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
PERSONNEL			
AVAILABILITY	In place, little turnover expected	Available, some turnover expected	High turnover, not available
MIX	Good mix of software disciplines	Some disciplines inappropriately represented	Some disciplines not represented
EXPERIENCE	High experience ratio	Average experience ratio	Low experience ratio
MANAGEMENT ENGINEERING	Strong management approach	Good personnel management approach	Weak personnel management approach
REUSABLE SOFTWARE			
AVAILABILITY	Compatible with need dates	Delivery dates in question	Incompatible with need dates
MODIFICATIONS	Little or no change	Some change	Extensive changes
LANGUAGE	Compatible with system & PDSS requirements	Partial compatibility with requirements	Incompatible with system or PDSS requirements
RIGHTS	Compatible with PDSS & competition requirements	Partial compability with PDSS, some competition	Incompatible with PDSS concept, noncompetitive
CERTIFICATION	Verified performance, application compatible	Some application compatible PDSS, some competition	Unverified, little test data available
TOOLS AND ENVIRONMENT			
FACILITIES	Little or no modifications	Some modificastions, existent	Major modifications, nonexistent
AVAILABILITY	In place, meets need dates	Some compatibility with need dates	Nonexistent, does not meet need dates
RIGHTS	Compatible with PDSS & development plans	Partial compatibility with PDSS & development plans	Incompatible with PDSS & development plans
CONFIGURATION MANAGEMENT	Fully controlled	Some controls	No controls
IMPACT	Sufficient financial resources	Some shortage of financial resources, possible overrun	Significant financial shortages, budget overrun likely

Table G-5 Quantification of Probability and Impact of Schedule Failure

SCHEDULE DRIVERS	MAGNITUDE		
	LOW (0.0 – 0.3)	MEDIUM (0.4 – 0.5)	HIGH (0.6 – 1.0)
RESOURCES			
PERSONNEL	Good discipline mix in place	Some disciplines not available	Questionable mix and/or availability
FACILITIES	Existent, little or no modification	Existent, some modification	Nonexistent, extensive changes
FINANCIAL	Sufficient budget allocated	Some questionable allocations	Budget allocation in doubt
NEED DATES			
THREAT	Verified Projections	Some unstable aspects	Rapidly changing
ECONOMIC	Stable commitments	Some uncertain commitments	Unstable, fluctuating commitments
POLITICAL	Little projected sensitivity	Some limited sensitivity	Extreme sensitivity
GFE/GFP	Available, certified	Certification or delivery questions	No application evidence
TOOLS	In place, available	Some deliveries in question	Little or none
TECHNOLOGY			
AVAILABILITY	In place	Baselined, some unknowns	Unknown, no baseline
MATURITY	Application verified	Controllable change projected	Rapid or uncontrolled change
EXPERIENCE	Extensive application	Some dependency on new technology	Incompatible with existing technology
REQUIREMENTS			
DEFINITION	Known, baselined	Baselined, some unknowns	Unknown, no baseline
STABILITY	Little or no change projected	Controllable change projected	Rapid or uncontrollable change
COMPLEXITY	Compatible with existing technology	Some dependency on new technology	Incompatible with existing technology
IMPACT	Realistic, achievable schedule	Possible slippage in IOC	Unachievable IOC

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SUBJECT INDEX

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This guide updates and expands the Defense Systems Management College's 1983 Risk Assessment Techniques Guide. This version was developed in response to the 1986 Government Accounting Office (GAO) report on DOD efforts relative to real assessments. In addition to technical risk, this guide addresses cost risk, schedule risk, programmatic risk, and supportability risk. There are no "textbook" answers to risk management. Each situation is different and requires a slightly different approach. This guide is designed to be used as an aid in classroom instruction and as a reference book for practical application. It is for use by all levels of program managers and designated "risk" analysts.

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