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ECONOMIC ANALYSIS OF REDESIGN ALTERNATIVES FOR THE RESFMS INFORMATION SYSTEM

by

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Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

This study is a practical example of economic analysis of information systems and of the software cost estimation problem as applied to software development in the Department of Defense. Economic analysis methods and the difficulty of software cost estimation are demonstrated using the proposed redesign of the Reserve Financial Management System (RESFMS), an information system operated by the U.S. Naval Reserve. The mandate for economic analysis in the Department of Defense and procedures applicable to information systems are discussed. Two alternatives are analyzed: the status quo and a redesign proposed by Commander Naval Reserve Force (COMNAVRESFOR). Costs to be considered for each alternative are described. Since the major cost of the redesign will be software development, the problem of software development cost estimation is discussed. An estimate of software development cost is produced. This estimate and other identified costs are used to calculate present value of savings, savings/investment ratio, and discounted payback period for the redesign alternative as compared to the status quo. Risk analysis, using a monte carlo simulation, is then performed to determine the range of possible outcome values and probabilities for each. The result of the economic analysis is a recommendation that RESFMS be redesigned as proposed by COMNAVRESFOR.

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I. INTRODUCTION

A. BACKGROUND

Intuitively the proposal seemed economically beneficial to the Naval Reserve: take an information system costing over three million dollars per year to operate on a mainframe computer and move the system to a network of minicomputers costing a few hundred thousand dollars to purchase and the same each year to operate. The savings should be substantial and system support might even improve, since the operators of the mainframe had not been very responsive to user requests lately. This was the proposal presented to me when Commander Naval Reserve Force (COMNAVRESFOR or CNRF)[1] staff members asked, in July 1991, for an economic analysis of the redesign alternatives for the Reserve Financial Management System (RESFMS). As it turns out, more than a year later, the outcome of the analysis produced results similar to those which intuition suggested. However, the process of evaluation uncovered questions and raised issues not originally considered which are of great import to the success of any redesign effort. Also, no matter how strongly managers are convinced that an information system development project would be beneficial, if that judgement is not based in objective analysis, funds for development will not be approved in the

[1]Members of the Naval Reserve generally refer to Commander Naval Reserve Force as COMNAVRESFOR. For purposes of brevity in correspondence or references it is sometimes shortened to the four letters CNRF. This usage will be preserved such that the body of the text will use COMNAVRESFOR, and tables, graphs, and references will generally use CNRF.

Department of Defense (DoD). Therefore, a formal analysis of alternatives was not only instructive to the planning process, but required by DoD policy.

B. OBJECTIVES

The primary objective of the study was to ascertain the economic benefits, if any, to the Naval Reserve of redesigning RESFMS to operate in a hardware environment other than the mainframe on which it runs at present. This analysis was to be done in a manner consistent with current DoD directives and following established economic analysis principles.

The target hardware configuration for the redesign was determined by COMNAVRESFOR personnel and presented to me for use in the economic analysis. Yet, although the type of computer to be used was determined, the number of minicomputers required to run RESFMS was not determined prior to my evaluation. Therefore, one of the first objectives of this study was to validate the adequacy of the computer chosen to effectively operate RESFMS, and to determine the number of computers required for this purpose.

The next objective of the study was to determine all current system costs and benefits and to estimate alternative system costs and benefits. Determination of current system costs was fairly straightforward. However, estimation of alternative system costs turned out to be the most difficult part of this entire study. The determination of hardware costs was relatively simple. The estimation of the cost of developing new system software, on the other hand, was a daunting problem which caused further study and analysis of the problem of software cost estimation in general, and of the problem in the Department of Defense, in particular.

The final objective of this study was to analyze the costs and benefits identified in such a way that decision makers could use the analysis as a basis for program development approval or disapproval. In keeping with this objective, an analysis has been made using several economic analysis tools and risk analysis procedures applied to the results. Consequently, the final outcome of the study provides not single values, but ranges of values and probabilities of outcomes for decision maker evaluation.

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

This study is limited to the alternatives and data provided by COMNAVRESFOR for analysis. General principles and procedures examined, such as economic analysis, software development cost estimation, and risk analysis, will be discussed as they relate to information systems development in the Department of Defense. Assumptions related to specific items of the analysis will be discussed when those items are described and evaluated.

D. ORGANIZATION OF STUDY

One reason why an economic analysis of redesign alternatives for RESFMS is being performed is because such an analysis is required within DoD. To understand what is required and why, it is helpful to examine the background of economic analysis in general as well as the history and current requirements for economic analysis in DoD.

These issues, along with a description of assumptions for this study that result from current DoD directives, will be discussed first.

In order to understand the rationale for a proposed redesign of RESFMS, the history of its development and evolution should be understood. Knowledge of the current configuration is essential to understanding current operating costs and benefits; and the target configuration and rationale used to determine it are useful in understanding the potential costs and benefits of the redesign alternative. Therefore, a discussion of these aspects of RESFMS will be next.

Since the process of economic analysis is central to this study, and the selection of economic analysis tools critical to the results obtained, the structure of economic analysis, definitions of major terms, and description of appropriate tools will be examined. The economic analysis tools selected for this study will be listed and briefly explained.

The problem of estimating the cost of software development for RESFMS was the most significant problem encountered in this study. Therefore, a chapter will be devoted to an explanation of the nature of the software cost estimation problem in general, some of the methods and tools available to produce estimates, and the applicability of this problem to information systems development in DoD.

Next, a detailed description of costs chosen for this analysis is presented. Special attention is given to the source data, reasoning, assumptions and methods used to determine software development cost estimates in the case of RESFMS.

Once the tools have been chosen and all costs identified and quantified, the analysis is performed. The first computations of economic analysis were done using actual costs, if known, and expected values if cost was uncertain. Then, risk analysis is performed using the full range of possible values for uncertain cost estimates. The results of risk analysis show a range of possible outcomes and the probability of obtaining those values.

Finally, a recommendation will be made, based on the results of economic analysis, as to what alternative will have the highest probability of positive financial benefit for the Naval Reserve.

While, economic analyses provide *guidelines* for making decisions, some person or group must ultimately accept the risk and make the decisions.

B. INFORMATION SYSTEM EXPENDITURES

In the last three decades, rapid advancement in information systems (IT) technology has resulted in major investment in IT hardware, software, and related systems by both large corporations and very small firms (Cash and others, 1988). An indication of the scope of these investments and investing trends can be obtained by looking at capital investment in high-technology industries.

> It is clear that United States capital investment is increasingly turning towards high-technology industries. ... Capital expenditures for basic industrial equipment have been reduced from 25% of all capital spending in the 1960s to present levels of less than 13% of all capital spending. Meanwhile, spending for high-tech equipment rose from 12% in the 1960s to present levels of more than 30% of all capital spending. (Strassmann, 1985)

The need to analyze these growing expenditures and informed decisions has caused organizations to apply economic analysis methods to ADPE acquisition and information system development.

C. GOVERNMENT REGULATIONS CONCERNING ADPE

The Congress of the United States, recognizing the importance of capital expenditure on ADPE, has enacted legislation and given policy direction through hearings and reports. In October 1965 Congress enacted Public Law 89-306, known as the Brooks Act, establishing the basic policy for the management of data processing equipment in the Federal Government. Public Law 99-500, known as the Paperwork

Reduction Reauthorization Act of 1986, expanded the scope of the Brooks Act "to include telecommunications resources, software, and computer-related services such as computer service bureaus and contract programming." (GSA Overview Guide, 1990)

The Brooks Act charges the Office of Management and Budget (OMB) with developing management policy and providing fiscal control of ADPE. In its circular entitled "Management of Federal Information Resources", the general principles of ADPE acquisition and development are stated. One of the principles cited states:

> In order to minimize the cost and maximize the usefulness of government information activities, the expected public and private benefits derived from government information, insofar as they are calculable, should exceed the public and private costs of the information. (OMB Circular A-130, 1985)

To determine if benefits derived do, in fact, exceed the costs, one must use some form of economic analysis. Procedures and policies for economic analysis of ADPE in the government are delineated by the General Services Administration (GSA).

According to the Brooks Act, GSA is to "coordinate and provide for the economic and efficient purchase, lease, and maintenance of automated data processing equipment by Federal agencies." Although GSA is given exclusive authority to procure ADPE resources, it is also granted the power to delegate authority for procurement to Federal agencies as necessary. (GSA Overview Guide, 1990)

The primary document containing GSA regulations for automated data processing equipment is the Federal Information Resources Management Regulation (FIRMR). In the FIRMR, automated data processing equipment and associated information systems are referred to as Federal Information Processing (FIP) resources. In its section on acquisition, the FIRMR directs that an analysis of alternatives be made prior to acquiring or developing any system and that "in the analysis of alternatives, agencies shall calculate the total estimated cost, using the present value of money, for each feasible alternative unless the cost of the acquisition is $50,000 or less." (FIRMR, 1990) It also directs, when calculating the cost of each alternative, agencies must follow guidance in OMB Circular No. A-94, "Discount Rates to be Used in Evaluating Time-Distributed Costs and Benefits."[2] The FIRMR, further, specifically lists those costs to be included and those to be excluded in any analysis.

Using its power to delegate, GSA has set criteria to determine which acquisitions and development efforts must be reviewed and approved by GSA itself, and which may be approved by the government agency acquiring the system. Each agency, in turn, has produced its own set of regulations and directives governing FIP resource acquisition within that agency.

D. FIP RESOURCE ACQUISITION AND MANAGEMENT IN DOD

The armed services are the heaviest user of FIP resources in the U.S. Government (Kellner, 1991), spending almost nine billion dollars on automatic data processing in

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[2]OMB Circular A-94 specifically states: "This Circular would not apply to the evaluation of decisions concerning how to select automatic data processing equipment, guidance for which is OMB Circular No. A-54 and OMB Bulletin No. 60-6." Yet, GSA, in the FIRMR, §201-20.203-1 (c), directs: "Agencies shall follow guidance in OMB Circular No. A-94, 'Discount Rates to be Used in Evaluating Time-Distributed Costs and Benefits,' when calculating the cost of each alternative." Since the FIRMR is the most recent of the documents (1990 vice 1972), it takes precedence and procedures in OMB Circular A-94 are to be followed in spite of the disclaimer.

1990 alone (HASC, 1989). To manage these resources, the Department of Defense (DoD) has established its own procedures and regulations regarding FIP resources. DoD Directive 7920.1, "Life-Cycle Management (LCM) of Automated Information Systems (AISs)," DoD Directive 7920.2, "Automated Information System (AIS) Life-Cycle Management Review and Milestone Approval Procedures," and DoD Directive 5000.1, "Defense Acquisition," all require that regulations found in the FIRMR be followed in FIP resource acquisition. As noted earlier, the FIRMR requires an economic analysis of alternatives. Within DoD, procedures to be followed in this economic analysis are found in DoD Directive 7041.3, "Economic Analysis and Program Evaluation for Resource Management." Individual services, including the Department of the Navy (DoN) have written their own directives, following OMB, GSA, and DoD guidance, which further spell out procedures to be followed in each service. The general principles of economic analysis found in methods used in the private sector are found in these directives as well. Thus, careful consideration is to be given to the time value of money and the effects of interest rates and inflation.

In spite of this plethora of direction concerning automatic data processing systems, DoD has experienced significant problems analyzing, acquiring, developing and managing these systems. A series of reports from both houses of Congress between 1988 and 1990 documented these problems. Responding to GAO reports of mismanagement of ADPE in DoD, the House Armed Services Committee (HASC) recommended, in July 1989, that the services' automatic data processing request be reduced by $165.5 million. The HASC also stipulated a requirement that DoD develop a plan of action by February

1, 1990 on how to resolve the identified problems. The implication was that further reductions would result if the deadline were not met.

E. DOD CORPORATE INFORMATION MANAGEMENT INITIATIVE

In response to the above HASC requirements, Deputy Secretary of Defense Donald Atwood announced, in October 1989, a Corporate Information Management (CIM) initiative. This initiative involves radical changes in the way information resources are managed in DoD. A thorough discussion of the tenets and implications of CIM is beyond the scope of this thesis. However, it is important to understand the basic premise of CIM and its effects on automatic data processing system development.

Central to the philosophy and method of CIM is the concept that "it is *not* about technology; it is about business processes and managing information." (Brewin, 1991) The theory is that businesses "gain strategic advantage by changing the way they work, not by automating old or inefficient methods." (Brewin, 1991) Thus, CIM seeks to have all DoD agencies analyze their basic business processes. Once a business process is understood, it can be redesigned with the goal of achieving the greatest efficiency possible in every business activity. Then, and only then, is information technology considered as a means of implementing this process.

> By supporting functional managers in streamlining business methods, DoD's corporate information management initiative will aid the Department in achieving the aggressive savings targets established by the Defense Management Report. To achieve the highest savings, CIM investments must be based on a functional economic analysis of business activities or operations. (DDI Memo, 1991)

The functional economic analysis now required for all CIM, and thus ADPE, investment decisions has been spelled out in memoranda and training presentations to DoD management personnel. The functional economic analysis, also called a Business Case, follows and amplifies upon policy and procedures contained in DoD Directive 7041.3 described above. One part of a Business Case is an analysis of alternatives for information systems to support a redesigned business process. This analysis of alternatives is to follow the guidelines set forth in the FIRMR, and in OMB, DoD, and Department of the Navy (DoN) directives except as amended by CIM. The chief effects of CIM on this part of the analysis are an increased emphasis on the financial impacts of risk, and the requirement to express potential benefits in cash terms. Specific procedures will be discussed in Chapter IV.

The directives and guidelines discussed so far, all apply to all agencies within DoD. The Naval Reserve, as part of the Department of the Navy (DoN), is a DoD agency. Commander Naval Reserve Force (COMNAVRESFOR) is responsible for operating and developing several information systems. One of those systems is the Reserve Financial Management Systems (RESFMS), which has been proposed as a candidate for redesign. Project approval and allocation of funds for the redesign of RESFMS will be contingent upon the results of a Business Case presented by COMNAVRESFOR to higher approval authority.

F. RESFMS BUSINESS CASE ASSUMPTIONS

The purpose of this thesis is to perform an economic analysis of the alternatives for the Reserve Financial Management System (RESFMS). Such an economic analysis will be part of the Business Case presented by COMNAVRESFOR to gain approval for proceeding with the redesign effort. The other usual component of a Business Case is an analysis of the business processes of the agency making the proposal. An analysis and redesign of the business process of the Naval Reserve is beyond the scope of this thesis. I assume that such an analysis, if required, has already been done and that the functional requirements of RESFMS, generated by COMNAVRESFOR, support efficient business processes of the Naval Reserve. I further assume that a decision has already been made that an information system, in the form of RESFMS, provides the best means to perform the functional requirements given.

This analysis, then, will meet the requirements for an analysis of alternatives for an information system that may be a part of a Business Case to be produced by the Naval Reserve and used as a decision tool when considering future budget and development plans.

III. RESERVE FINANCIAL MANAGEMENT SYSTEM (RESFMS)

A. DESCRIPTION OF RESFMS

The Reserve Financial Management System (RESFMS) is an information system used by the Naval Reserve to manage the Reserve Personnel Navy (RPN) appropriation account, to issue active duty orders to reservists, and to arrange for travel for reservists in conjunction with both active duty and inactive duty training orders. As such, the system crosses two major Department of Defense (DoD) functional areas: Manpower, Personnel and Training (MPT), and Financial Management (FM).

B. HISTORY OF RESFMS

In the 1970s, the Naval Reserve operated an information system for issuing active duty orders, called Order Writing, and a system for accounting, called RPN Accounting, as two distinct systems operating on separate mainframe computers. There was no interface between these systems. Information from one system was manually transferred to the other. In 1979 the Naval Reserve experienced an over-obligation of the RPN account due to poor management of active duty order issue and travel expenses. An over-obligation of a Congressional appropriation is prohibited by law under Title 31 United States Code 1517, and may incur serious consequences for the person responsible such as suspension without pay, removal from office, fines, or imprisonment (Practical Comptrollership, 1992). As a result, Congress mandated in 1980 that the Naval Reserve would develop an information system to correct the accounting and order writing problems, that no more over-obligations would occur, and that the new system must be operational by 1984 (Lacy, 1992).

Staff members of COMNAVRESFOR assigned to Code 10, the computer systems management division, decided the new system would have three integrated subsystems: Active Duty Order Writing, Travel, and RPN Accounting. They decided on an incremental development approach. Navy Regional Data Automation Center (NARDAC), New Orleans was contracted to develop and run the system on their Sperry 1100/90 mainframe computer. They wrote the programs in COBOL and used a proprietary hierarchical database provided by Sperry called DMS1100. The Active Duty Order Writing module was first operational in February 1983, and the Travel module in April 1984. In 1983 NARDAC informed the Naval Reserve that they would be unable to produce the entire system and meet the 1984 deadline. NARDAC suggested that a civilian contractor be hired to do the RPN Accounting module. Therefore, the Naval Reserve contracted with CACI, Inc. who subcontracted with SYSCON, Inc. to produce the RPN Accounting module. RPN Accounting was first operational in October 1984. Upon system completion, SYSCON, Inc. was contracted to provide software maintenance and NARDAC provided hardware maintenance and support. Initial design, development, and implementation of the system cost nine million dollars. Since 1984, the company providing contract software maintenance has changed twice. Total system costs through 1990 were in excess of $50 million including both investment and operating expense (Blaylock, 1990).

In January 1987 RESFMS became the first Navy information system to be certified as compliant with requirements prescribed for federal agencies by the Office of Management and Budget (OMB), General Accounting Office (GAO), Department of the Treasury, Department of Defense (DoD), and Department of the Navy (DoN). Very few of the 121 Navy accounting systems have achieved this certification.

C. EVOLUTION OF RESFMS

Since its inception, seven major additional functions, and four major system interfaces have been added to RESFMS (Lacy, 12 August 1991). Many small features have been added as well. These additions will be discussed in the following section on current configuration. Considerable effort has also been directed toward software maintenance which has modified the structure and size of many programs considerably. This maintenance effort has been needed both because of changes in the operating environment and because of the methods and procedures which were used in initial software development.

1. Changes in Operating Environment

In May 1986, Burroughs acquired Sperry (Barbetta, 1986). The merged company, called Unisys, offered a hardware upgrade to a new machine, the Unisys 1100/92. This upgrade was installed in NARDAC New Orleans in the late 1980s. The 92 is similar to the 90 but has two CPUs instead of one. The two processors can operate as a tightly coupled pair, essentially doubling the computing power of 7.5 MIPS to a rating of 15 MIPS. The processors can also be de-coupled in software and operate as two separate computers sharing the same peripherals. Minor changes in code were required to run RESFMS on the upgraded machine.

More important to the maintenance effort was the fact that a number of additional functions, features and interfaces were added to the system between 1984 and 1991. For example, additional functions included order generation for Health Sciences Education Command (HSTEC), issuance of travel claim vouchers, and calculations using the Uniform Chart of Accounts (UCA). Features added included Three Minute Orders and batch printing of active duty orders (Lacy, 12 August 1991). New interfaces were also added with Micro Claims Processing System (MCPS), Integrated Disbursing and Accounting Financial Management System (IDAFMS), Centralized Expenditures/Reimbursement Processing System (CERPS), and Navy Standard Claimancy Accounting Module (NSCAM) (CNRF RESFMS Briefing Notes, June 1991). These additions required numerous software patches. Since they were not part of the original design, integration and debugging were very difficult.

2. Problems of Initial Software Development

a. Analysis and Design

Inadequate requirements analysis and product design were performed before coding initially began in 1981. NARDAC adopted a "code and fix" approach to development, believing that there was insufficient time to do a thorough job of requirements analysis and design prior to coding. One result of the lack of adequate design is that more errors are included in the code. If coding begins without a clear idea of where the project is headed and exactly how to get there (the result of detailed design), many false starts are made on segments of program code, not all of which are removed during debugging. Even the debugging process suffers from poor design. Without a detailed product design, detailed test plans cannot be generated that fully test all program segments and functions. The result is that the system still includes many undiscovered errors even after it is made operational and those errors may be difficult to find because of the poor structure and design. Such is the case with RESFMS (Lacy, 30 June 1992). Therefore, the Active Duty Order Writing and Travel modules have been very difficult to maintain.

b. Redundant Code

Since coding was begun without a clear idea of overall product design, procedures that should have been identified as common to many parts of the application were not. As a result, when sections of the program were encountered with similar function to those previously coded, large sections of code were copied and slightly modified to fit the new situation. Modern programming practice and structured design principles would have these common procedures located in a single common module using changing input parameters to produce the variations of output (Pressman, 1992). Thus, if system maintenance dictates that the procedure needs to be modified, it can be easily found and changed in one location which results in the required modification to the entire system. In RESFMS the opposite is true. In order to change one particular function, all instances of a segment throughout the application must be found and changed. This has created numerous problems for maintenance programmers.

c. *Database Design*

The database was not well designed. It was not adequately normalized, was created piecemeal, contained redundant elements with different names, and contained data never used by the application.

d. *Global Variables*

Global variables were also common. With many different modules acting on the same common variables, maintenance programmers often found that small changes in one module had unplanned and unwanted effects throughout the system.

3. The Maintenance Challenge

When Systems Engineering and Management Associates, Inc. (SEMA) took over as software maintenance contractor for RESFMS in 1989, they inherited a system that had been poorly designed and coded with little structure, redundant code, redundant data elements, little structure, and prone to errors. Because of both poor programming practices and addition of functions and interfaces, by 1989 RESFMS had grown in size to include (Lacy, 12 August 1991):

- Over two million lines of COBOL code
- 4,500 COBOL programs
- 250 record types in database
- 15.5 million records in database

Even though the system was fully functional and had met stringent audit standards, the continued discovery of errors and the addition of new functions and interfaces made it a maintenance nightmare.

4. The Maintenance Solution

The COMNAVRESFOR program manager, Ms. Coreen Lacy, mandated that for the first eight months of the new contract no software coding changes were to be made. She tasked SEMA with a thorough analysis of the system, to ensure that, when changes and fixes were eventually made, the maintenance programmers would fully understand how the system worked and what effect their changes would make (Lacy, 1992). In addition, a configuration control system was implemented to track Automated Data Service Requests (ADSR) and an error identification and tracking system established using Problem Tracking System Reports (PTSR).

5. The Result

This policy has paid great dividends. Ms. Lacy (30 June 1992) reports that errors have decreased and lines of code have been reduced from a high of over two million to about 1.36 million lines of executable COBOL code. More importantly for this analysis, thorough analysis of the current system has allowed SEMA personnel to do requirements analysis, database redesign, and product design for a proposed re-engineered RESFMS.

D. CONFIGURATION AND FUNCTION OF RESFMS

Currently RESFMS contains four integrated subsystems:

- Active Duty Order Writing (AT/ADT)
- Inactive Duty Training Travel (IDTT)
- Travel
- RPN Accounting

The AT/ADT, Travel, and RPN Accounting subsystems are fully implemented on a UNISYS 1100/92 mainframe computer operated by Navy Computer and Telecommunications Station (NCTS) New Orleans.[3] Interface with the central mainframe is via microcomputers, emulating UNISYS terminals, located at 179 Reserve Sites throughout the United States. Typically, a Zenith 248 computer, equipped with an emulator board, functions as a dumb terminal connected via modem to leased telephone lines, operating at 9,600 bits per second (bps). These leased telephone lines feed directly to the UNISYS 1100/92 mainframe at NCTS, New Orleans.

IDTT is processed by stand-alone modules on microcomputers at all of the 353 Reserve sites throughout the United States. Processed data from the IDTT modules in the field is passed via modem and dial-up telephone lines to the mainframe-based subsystems of RESFMS for further processing or storage.

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[3]Navy Regional Data Automation Center, New Orleans (NARDAC) recently changed its name to Navy Computer and Telecommunications Station, New Orleans (NCTS). The organization and equipment referred to as part of the original development of RESFMS are the same, but the name has changed.

1. AT/ADT Subsystem

The AT/ADT subsystem of RESFMS is currently used to issue approximately 300,000 sets of active duty orders per year. Originally, the Active Duty Order Writing subsystem issued Annual Training (AT) orders for only Selected Reservists (SELRES), that is, those in an active drilling status in a reserve unit. Currently, RESFMS allows on-line request and subsequent printing of Annual Training (AT) and Active Duty Training (ADT) orders for SELRES, Individual Ready Reserve (IRR), and Health Science Educational Training Command (HSETC) personnel. Orders may be requested either individually or in batch. Program managers at Reserve Headquarters approve the requests then pass them electronically to Travel as appropriate. After travel arrangements have been made, orders may be printed at the requesting site. Under certain circumstances, orders may be printed within minutes of making the request. This feature is called 3-minute Orders.

In addition, AT/ADT performs many management functions related to issuing and accounting for active duty orders. The system tracks and routes the request for orders through verification, approval, travel arrangements, accounting, and other appropriate stages of order generation. Modification and cancellation of order requests are also processed. Program managers are assisted through the tracking of days of active duty allotted (budgeted) versus those obligated. A history of active duty performed is maintained for individual reservists and Retirement Points are calculated and transmitted to Inactive Manpower and Personnel Management Information System (IMAPMIS)[4]. Finally, RPN accounting transactions are generated for action by the RPN Accounting subsystem.

2. IDTT Subsystem

IDTT processes and generates approximately 200,000 orders and transportation requests per year for SELRES receiving training away from their normal drill site while in a drill status (not on active duty). Accounting is also provided for IDTT funds which are part of the RPN appropriation. A budget operating target (OPTAR) is issued to field activities for IDTT expenditures. The IDTT module, operating as a stand-alone system on a microcomputer, allows the local Reserve Commanding Officer to keep track of these funds while issuing IDTT orders. Status of funds is periodically passed to the central RESFMS mainframe via dial-up modem and batch reporting. The AT/ADT module processes IDTT order information and passes accounting data to the RPN Accounting module for financial update. If airline travel arrangements are required in conjunction with IDTT orders, the request for travel is transmitted to RESFMS Travel vial dial-up modem for processing. Travel arrangements are made and tickets disseminated in a manner similar to that used for travel with active duty orders.

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[4]IMAPMIS runs on mainframe computers at Defense Finance and Accounting Center (DFAS), Cleveland, Ohio. It contains the master records of all Reserve personnel and financial information. Among other functions, IMAPMIS is used to issue reserve drill pay checks mailed by DFAS Cleveland to individual reservists or transmitted to their bank accounts. Retirement and promotion information is also retained there.

3. Travel

The Travel subsystem processes about 167,000 travel arrangements and 60 million dollars of associated bills per year for travel associated with both active duty and IDTT orders. Commercial airline reservations and ticketing are arranged through Scheduled Airline Ticket Office (SATO). Tickets can be electronically transmitted to teleticketing machines at 44 major Reserve sites, or to airlines themselves for issue. A Government Transportation Request (GTR) or a Request for Transportation Services (RTS) may be generated as appropriate. The system assists the Reserve Headquarters staff in selecting transportation that both meets operational needs and is the lowest cost which can be obtained at the time of ticketing. Thus, transportation requests are processed for Government Transportation System (GTS), or Military Airlift Command (MAC) flights, for commercial airline flights, charter bus, commercial bus, and rail transport.

An important benefit of the Travel subsystem is that it supports Ticketing Adjustment and Unused Ticket Recoupment. Thus, if a ticket is issued for official travel and not used, the Travel subsystem allows expeditious cancellation of the ticket, recoupment of funds, and reallocation of resources. Over ten million dollars in travel funds were recouped and reused in FY91 alone (Lacy, 30 June 1992).

4. RPN Accounting

Full financial accounting and fund execution management for the $700 million Reserve Personnel Navy appropriation are provided by the RPN Accounting module of RESFMS. In addition to accounting transaction entry and processing, it provides general ledger posting for Commitments, Obligations, and Accounts Payable. RPN Accounting tracks the RPN appropriation execution versus the budget plan. It provides numerous reports for use within the Naval Reserve as well as those required by outside agencies such as Financial Information Processing Center (FIPC) New Orleans. An on-line *ad hoc* inquiry capability is available to COMNAVRESFOR Finance (Code 06), Manpower (Code 02), and to FIPC New Orleans.

5. External Interfaces

RESFMS also supports interfaces with six other systems:

- Inactive Manpower and Personnel Management Information System (IMAPMIS).
- Micro Claims Processing System (MCPS).
- Reserve Headquarters System (RHS).
- Integrated Disbursing and Accounting Financial Management System (IDAFMS).
- Centralized Expenditures/Reimbursement Processing System (CERPS).
- Navy Standard Claimancy Accounting Module (NSCAM).

Figure 1 on the following page shows the current configuration of RESFMS.

E. REASONS TO REDESIGN

1. Size and Inefficiency of Current Software Configuration

Extensive software maintenance efforts have reduced the size of RESFMS to 1,360,000 lines of code (LOC). However, the maintenance patching process combined with an initial poor design of some modules have caused the system to still be difficult

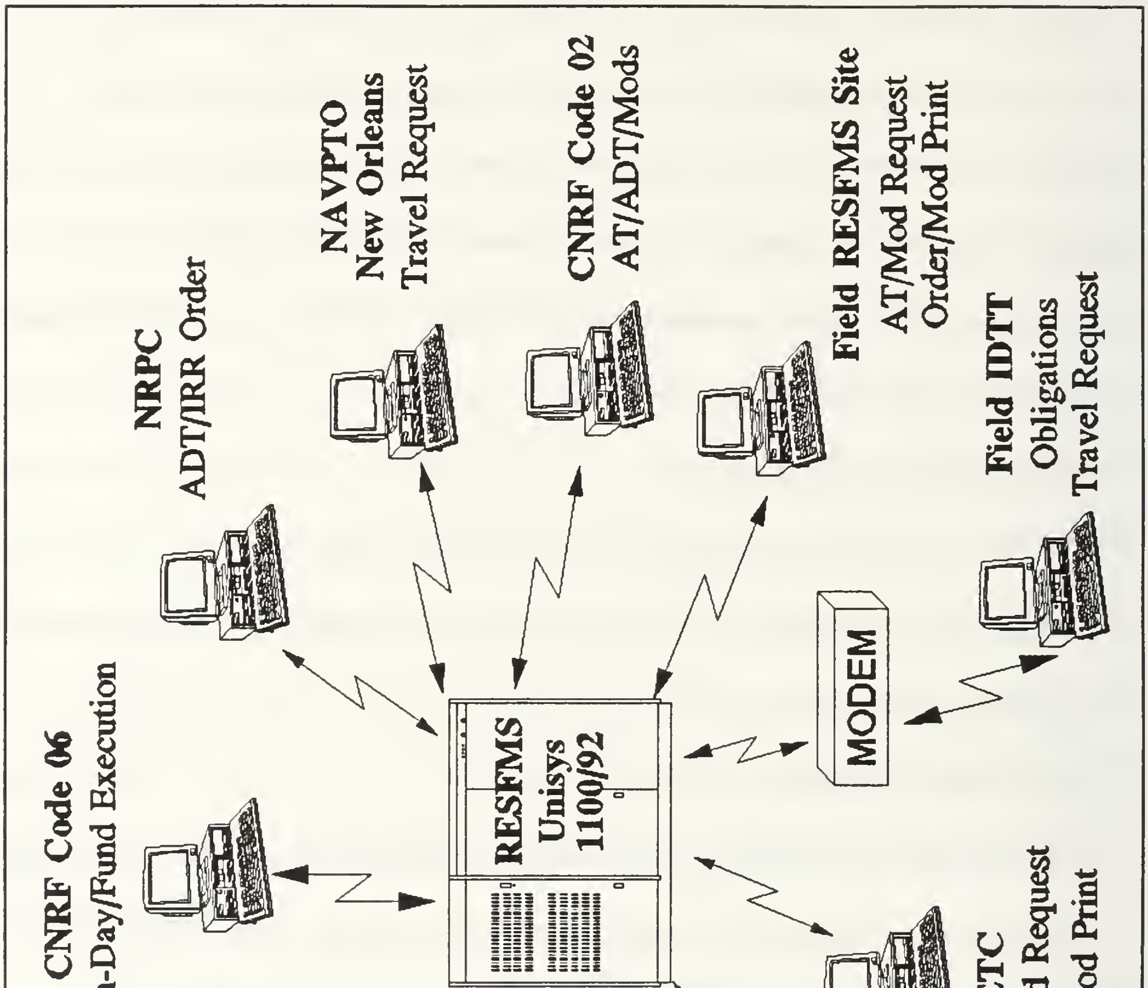

Figure 1 Current RESFMS Configuration.

to maintain (Furrey, 7 June 1992). COMNAVRESFOR spent $1,777,000 in FY90 and $1,608,000 in FY91 on software maintenance for RESFMS. Systems maintenance programmers and analysts estimate that a well designed rewrite of RESFMS should only be between 450,000 and 720,000 LOC or 33% to 52% of the current size (Lazar, 16 July 1992).[5] Program managers estimate that such a system, programmed in an easy to maintain language, such as Ada, using modern programming practice and design, such as structured programming with loosely coupled, functionally independent modules, would require annual maintenance costing less than half of the current software maintenance budget (Furrey, 7 June 1992).

2. Operating Costs for Hardware

RESFMS is still running on the Unisys 1100/92 provided by NCTS New Orleans. Navy Industrial Fund (NIF) charges to COMNAVRESFOR for services provided by NCTS were $3,040,000 for FY90 and $3,514,000 for FY91. In addition to believing that these charges are excessive, COMNAVRESFOR managers feel that the service provided by NCTS should be rated as very poor (CNRF RESFMS Briefing Paper, August 1991). Response by NCTS personnel to problems is often slow. The charges for service are based on a fixed price contract (Blaylock, 1990). Thus, even if COMNAVRESFOR reprogrammed RESFMS to consume fewer computer resources, charges for NCTS service would not necessarily decline proportionally. This leaves

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[5]The manner in which these estimates were derived will be explained in Chapter VI in the discussion of costs considered for RESFMS.

COMNAVRESFOR few alternatives to reduce the operating costs of RESFMS, which they have identified as excessive, if they continue to use NCTS operated hardware support.

3. Telecommunication Costs and Inadequacies

Telecommunication charges make up almost a quarter of the RESFMS total operating expenses (CNRF RESFMS Budget Expenditure, 14 May 1992). COMNAVRESFOR paid $2,253,000 in FY90 and $1,991,000 in FY91 to AT&T and NCTS for communication charges related to RESFMS. These charges result from the fact that COMNAVRESFOR leases dedicated communication lines connecting 179 sites across the continental United States to the Unisys 1100/92 at NCTS New Orleans. RESFMS is currently programmed so that microcomputers at the remote sites function only as dumb terminals and all processing is done centrally by the mainframe. Every menu, prompt, screen, and report is generated by the Unisys 1100/92 in New Orleans and transmitted over the leased telephone lines to the remote sites. Data transmission, at 9,600 bps, is very slow by today's standards[6] and the potential processing power of the remote microcomputers is ignored in the present configuration. Also, 175 of the 354 Naval Reserve sites are not connected to RESFMS, because the cost of connecting and maintaining dedicated data lines to these sites is prohibitive.

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[6]NAVNET and DDN use 56 kilobits per second lines, while FTS 2000 offers T1 lines running at 1.54 megabits per second.

4. Integration With Other Naval Reserve Systems

Since the inception of RESFMS, the Naval Reserve has developed a number of new information systems. Sensing both the potential benefits and problems associated with multiple system operation, in 1986 the COMNAVRESFOR Director of Information Systems (Code 10) drafted, and the Commander, then RADM Smith, adopted the Reserve Command Management Information Strategy (RESCOMMIS), a comprehensive plan for the development, operation, and maintenance of information technology in the Naval Reserve. Part of this strategy involves integration of all Reserve systems as well as the pursuit of modern technologies and procedures.

The first system developed completely under RESCOMMIS was the Reserve Standard Training Administration and Readiness Support system (RSTARS). Development and implementation of RSTARS has been successful (Rautenberg, 15 September 1991). RSTARS is a microcomputer based distributed process connected via dial-up modem to a centrally managed master database. The master database is maintained by the Reserve Headquarters System (RHS) which runs on a cluster of DEC VAX minicomputers and uses a Sharebase database machine for data storage. This hardware is physically located in COMNAVRESFOR Information Systems (Code 10) facilities in east New Orleans. At each Reserve site throughout the U.S., a stand-alone module of RSTARS manages the personnel files, unit assignments, promotions, attendance records, pay records, training requirements, and other administrative data required for Selected Reservists. Modifications to this data are sent, in the form of change transmittals, to RHS for validation and storage. RHS validates all changes, and provides the interface to other Navy MPT systems requiring the data, such as IMAPMIS.

The interface between RHS and RESFMS is not a continuous connection. In spite of the fact that much of the personnel data stored in RSTARS and RHS is exactly the same as that required by RESFMS, there is no sharing of this data. Changes to personnel data which affect RESFMS operation are sent twice a month from RHS as an update to the RESFMS database. It is not unusual for a Reserve site to have newly assigned reservists who wish to perform their annual active duty for training (AT). Frequently, personnel data required by RESFMS for order generation has not yet been received from RHS and a headquarters staff representative must manually enter the data into RESFMS to allow the request for orders to proceed. In my last assignment I was the Manpower Department Head at a major reserve site. This lack of interface between RESFMS and RHS caused what I considered to be a significant burden on my administrative support personnel trying to get active duty orders for Selected Reservists. It is not just a problem in the view of users in the field, however. COMNAVRESFOR information systems personnel believe that the data redundancy between RESFMS and RHS creates problems with data integrity and consumes computer mass storage capacity that could be better used for other Naval Reserve applications (Furrey, 14 May 1992).

F. DECISION TO REDESIGN

COMNAVRESFOR managers decided in 1991 that a redesign of RESFMS should be seriously examined. As a result of their success with RSTARS, they believed a similar configuration could be employed with RESFMS. The active duty order request process could be reprogrammed as a module of RSTARS, or at least be compatible with RSTARS. Using the power of microcomputers already located at reserve sites, request entry, error checking, and request formatting could all be done off-line. The formatted request could then be transmitted as a transaction via dial-up modem, or sent over a packet switching network such as the Defense Data Network (DDN). As a result, dedicated data lines would no longer be needed and the telecommunication lease expenses could be saved.

Experience with RHS has also shown that a large, data-intensive process could be programmed to run on a minicomputer while maintaining acceptable system performance. They concluded that the power of a mainframe was no longer required for RESFMS and that a network of minicomputers might provide a more cost effective replacement. In early 1991 study of Local Area Network (LAN) technology and minicomputers had been initiated to seek a solution for other Naval Reserve requirements and to meet goals set in RESCOMMIS. As a result of that study, a decision was made to purchase six AT&T 3B2/600G minicomputers off government contract and establish an ethernet LAN at Naval Reserve headquarters in New Orleans. Experience with these computers and this LAN indicated that the 3B2/600G performed just as well or better than the VAX cluster running RHS. (Albro, 7 April 1992)

In April 1991 AT&T acquired NCR (Karpinski, 22 April 1991). The newly merged company began offering NCR's computing technology as upgrades to AT&T computers (Zipper, 10 December 1990)(NCR letter, 22 June 1992). AT&T had already established its 3B2/600G on government contract, and so added the 3B2/GR as an upgrade to that computer on the contract. The AT&T 3B2/GR runs a RISC based processor and the UNIX operating system. It provides significant performance enhancements over the 3B2/600G. COMNAVRESFOR Code 10 made plans to upgrade all COMNAVRESFOR 3B2/600G computers to the 3B2/GR configuration as soon as possible (Albro, 20 May 1992).

G. AUTHOR'S INVOLVEMENT

In September 1991, I was asked to assist the Naval Reserve by performing an economic analysis of alternatives for RESFMS to possibly be used in budget proposals requesting funds for redesign and system acquisition. The goal of the redesign was to reduce telecommunication costs, reduce system maintenance costs, improve functionality, and improve system integration with other Reserve information systems. Possible alternatives were:

- Maintain the status quo
- Continue processing on the Unisys 1100/92 but change the telecommunication interface
- Redesign and recode the entire system to run on a network of minicomputers and use microcomputers as front end processors in the field

The target system for complete redesign was to be the AT&T 3B2/GR minicomputer in order to maintain compatibility and consolidated maintenance support with minicomputers already in use.

H. TELECOMMUNICATION COSTS NO LONGER A FACTOR

In April 1992 I learned of a decision by CNRF management that changed the alternatives to be studied for economic analysis. Approval had been received for a proposed Reserve Data Communications Technology Upgrade. This proposal involves the establishment of ethernet LANs at 33 major reserve sites. The 33 sites are strategically located and suitably equipped so that the other 320 small reserve sites can connect to the LANs by use of a dial-up modem and regular telephone line. These LANs will be connected to a long-haul communications carrier via an AT&T 3B2/GR minicomputer operating as a gateway. The 3B2 runs UNIX as its operating system and the TCP/IP network protocols are built into UNIX, thus negating the need to purchase additional network management software. The long-haul communications are to be provided by NAVNET, a packet switching network connecting U.S. Navy commands. The LANs will improve interconnectivity at each site and, via NAVNET, will assure communication with headquarters. NAVNET was chosen because it provides the functionality which the 1991 COMNAVRESFOR LAN study determined was required to meet RESCOMMIS data needs, and it is centrally funded, that is, no usage charges will be made to CNRF for packets transmitted on NAVNET. Communications expenses will be incurred only for the links from the Reserve site to the nearest NAVNET gateway.

Knowing of the LAN project approval and NAVNET communications capability soon to be available, Mr. Tom Albro of CNRF began investigating the potential for connecting users to RESFMS on the Unisys 1100/92 using NAVNET and TCP/IP protocols (Albro, 7 April 1992). Experiments conducted in May 1992 confirmed that completely satisfactory connectivity and functionality could be achieved using TCP/IP protocols on a packet switching network with little or no change to current RESFMS software (Albro, 20 May 1992). Therefore, a large portion of the telecommunications costs for RESFMS can be eliminated with no software redesign and no more hardware purchase than that already approved for the LAN project. This option will be pursued regardless of any decision on RESFMS redesign. Since reduction in communication charges will be the same for both the status quo and complete redesign, any consideration of costs or benefits associated with data communication are now irrelevant to this analysis.

I. MAINFRAME TO MINICOMPUTER DECISION

One significant hardware configuration question remains. Given the size and complexity of RESFMS, can it be moved to minicomputers? If yes, how many minicomputers will be required to provide acceptable capacity and performance?

In order to answer these questions a measure of performance and capacity had to be found that could be meaningfully applied to both computer configurations and to the process as it currently runs. This kind of comparison is difficult.

> It is almost impossible to make general statements about different configurations of hardware running under different operating systems. Only the grossest kinds of comparisons can be made. Happily, it is really only the grossest kinds of comparisons that are necessary to determine whether there are significant hardware cost differences between different machine system populations. (Lorin, 1988)

Although a thorough analysis would require benchmark testing of CPU performance, knowledge of memory operations, page size, paging algorithms, and other details of system I/O, an adequate comparison could be made with simpler measures (Suh, 1991). It was determined that a comparison of five measures would be sufficient:

- CPU performance measured in MIPS
- Amount of configured memory (RAM) measured in megabytes
- I/O throughput measured in bits per second
- Mass storage capacity/requirements measured in megabytes
- Number of simultaneous users supported/required

Performance data for the Unisys 1100/92 and for RESFMS was obtained from NCTS Pensacola, which maintains all performance data for NCTS computers throughout the southeast United States. Sales and technical representatives for AT&T were contacted to obtain performance and configuration data for the 3B2.

The Unisys 1100/92 has two processors, each rated at 7.5 MIPS. The processors may be coupled together to yield a combined processing capacity of 15 MIPS. The 1100 at NCTS New Orleans has 16 Megabytes of RAM, 8 Megabytes (MB) of which is configured for RESFMS. Maximum I/O throughput is 5.0 Megabits per second (Mbps). Mass storage may be attached in increments of 1.61 Gigabytes (GB). Maximum capacity depends on number of disk drives installed. Operators claim the system can support up to 1024 simultaneous TCP/IP users. A comparison with the AT&T 3B2/GR is provided in Table I below.

The AT&T 3B2/GR is rated at 25 MIPS. It may be configured with either 32 MB or 64 MB of RAM. COMNAVRESFOR is purchasing computers configured with 64 MB of RAM. I/O bus speed, and therefore the maximum I/O throughput, is 5.0 Mbps. Each 3B2/GR may be configured with up to 50 GB of mass storage. However, COMNAVRESFOR is purchasing 3B2/GRs with a maximum of 15 GB per computer. Each 3B2/GR can support up to 256 simultaneous TCP/IP connections and, with UNIX, multiple computers can be connected, increasing the number of simultaneous users supported in multiples of 256. RESFMS performance statistics for the period September 1991 through December 1991 show that RESFMS never used more than 12% of the Unisys 1100/92 CPU capacity. Mass storage for RESFMS required between 11.0 GB and 13.8 GB. The number of simultaneous users, with the present software architecture and configuration, was as many as 340.

Table I COMPARISON OF UNISYS 1100/92 AND AT&T 3B2/GR

	Unisys 11/92	*AT&T 3B2/GR*
Processor Speed	15 MIPS	25 MIPS
RAM	16 MB	64 MB
Maximum I/O Throughput	5.0 Mbps	5.0 Mbps
Hard Disk Size	1.61 GB	1.2 GB
Maximum Mass Storage	Unknown	50 GB
Mass Storage Configured	15 GB	15 GB
Simultaneous Users	1024	256

From the above statistics it appears that the 3B2/GR is more capable than the Unisys 1100/92 in processing power and speed, and it can be configured to support I/O operations in sufficient quantity and speed to meet the needs of RESFMS. Based on the analysis of current maintenance programmers, it can be assumed that a redesigned RESFMS will be smaller and not require as much mass storage or I/O throughput as the current system. Since the 3B2/GR is adequate to the current configuration numbers, it may be assumed it will be more than adequate for a redesigned system. The only concern will be support of simultaneous users. Yet, a stated purpose of the redesign is to change the system architecture to take advantage of minicomputer front-end processing of data. This change will greatly reduce the number of simultaneous users and negate concerns about the 3B2/GR's ability to manage required communication connections.

Thus, it may be concluded that a redesigned RESFMS could be run on a single AT&T 3B2/GR if necessary and that two 3B2/GRs running in tandem would provide better performance and reliability than the single Unisys 1100/92 does at present.

J. MOST SIGNIFICANT ECONOMIC FACTOR

With the questions of alternative systems configurations and capabilities settled, the consideration of costs and benefits become paramount. The costs of the current system may be readily obtained from COMNAVRESFOR records. Most of the costs of the proposed redesigned system are also straightforward. However, the cost of redesigning and reprogramming the software, as we will see in the following chapters, is both difficult to estimate and is crucial to this analysis.

IV. STRUCTURE OF ECONOMIC ANALYSIS

A. DEFINING THE PROCESS

The process of economic analysis has been described by Haga and Lang (1991) as "a systematic, six step procedure for comparing alternative means to meet an objective." The steps they define are as follows:

- Define the Objective
- Formulate Assumptions
- Choose Possible Alternatives
- Compare Alternatives
- Perform Sensitivity Analysis

The step of choosing possible alternatives is further divided into three distinct activities:

- Determine Costs
- Determine Benefits
- Interface Costs and Benefits for Each Alternative

In order to determine costs and benefits, we must know how to define them. In order to interface, that is compare, costs and benefits we must apply appropriate economic analysis methods. Although the methods of comparison are similar for both public and private organizations, the analysis of public projects is "considerably more sophisticated than that for private sector projects." (Lang, 1989) The reason public project analysis is more complex is because we deal not only with revenues and costs, as in private projects, but also with benefits.

Since the economic analysis of RESFMS concerns a U.S. Government, and thus public, project, it is imperative to obtain a precise definition of costs and benefits. It is also essential to determine which economic analysis procedures are applicable and how to apply them.

B. COSTS

Cost in the public sector can be defined as "a cash expenditure for operating, maintaining, and administering a public project." (Lang, 1989) Cost may also be viewed as inputs or flows of resources into the project, whereas benefits are outputs or results of the project (Haga and Lang, 1991).

It is important in any economic evaluation to include all potential costs of each alternative in the analysis. DoD Instruction 7041.3 directs that in evaluations of alternatives for projects within DoD "costs of each alternative will be exhaustive". It goes on to delineate three categories of costs to be included:

- Research and Development (R&D)
- Investment Costs
- Recurring or Operations Costs

These categories of costs apply to all types of development and acquisition projects within DoD. The project which is the subject of this analysis, the redesign of RESFMS, involves the conversion of an information system to new equipment and software. In the case of projects involving replacement, augmentation or conversion of existing information processing assets, the FIRMR directs that any cost that can be stated in dollars shall be included with four notable exceptions that shall not be included (FIRMR, 1990):[7]

- Conversion of existing software and databases that would be redesigned regardless of whether or not augmentation or replacement systems are acquired
- Purging duplicate or obsolete software, databases and files
- Development of documentation for existing application software
- Improvements in management and operating procedures

Since the proposed redesign of RESFMS will be a conversion project, these guidelines can be used to determine costs applicable to this analysis.

In summary, costs for this analysis should be exhaustive, should include R&D, Investment, and Operations costs and should be expressed in terms of dollars. Software related costs that will be incurred regardless of the development decision are not to be included in this analysis, nor are costs for improved management and operating procedures.

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[7]Examples of costs that should be included can be found in FIRMR Bulletin C-14.

C. BENEFITS

In private sector project analysis, the negative value of costs can be compared to the positive value of revenues, or to the market-value of potential system products or results. Many public sector projects have few or no revenues to evaluate and the products or results of system operation are not traded in the marketplace, making a market-value approach useless (Quirin and Wiginton, 1981). Public sector project alternatives can be evaluated on their relative costs, but cost alone does not always provide an accurate analysis of system desirability. Therefore, a comparison of costs to benefits is often required.

Lang (1989) defines the benefit of a public sector project as "a cash advantage or other favorable consequence flowing to the public." He goes on to say that benefits "are not difficult to identify, but are relatively difficult to quantify and to price." In this context, then, benefits could be described not only as outputs but also as "synonymous with results, effectiveness, utility, or performance." (Haga and Lang, 1991).

Many benefits may be assigned cash values. For instance, the construction of a bridge may reduce the number of miles driven by commuters each day and thus save on the consumption of gasoline. Given the number of commuters, average miles of driving saved, average fuel consumption, and cost of gasoline, these savings to the public can be quantified in specific money terms. Reducing the commuter miles driven daily may also reduce the amount of air pollution in the city, making the air cleaner and the city a more pleasant place to live. How does one assigne dollar value to a "more pleasant place to live?" The answer may be that a monetary value cannot be assigned, that this benefit is what Lang (1989) calls an irreducible benefit. If so, then a means of evaluation other than monetary valuation must be found.

A number of techniques have been developed to compare and evaluate benefits in public sector projects. One method is to use Benefit Cost Ratio (Walker, 1991). Haga and Lang (1991) provide a methodology for both quantifying benefits and for dealing with non-quantifiable output measures. DODI 7041.3 describes a method of graphical comparison of benefits and costs. These methods are all effective ways of dealing with benefits that are irreducible to monetary terms.

Yet, while in the past almost all benefits were handled as irreducibles, much more effort is being spent today on costing, or estimating the monetary value, of benefits (Lang, 1989). In fact, the Department of Defense under CIM has recently mandated that all benefits will be expressed "in cash terms so that realization of benefits can be monitored and audited" (DDI Memo, July 1991). If we express benefits in cash terms, we do not require any extraordinary method of economic analysis or comparison. More importantly from the management standpoint of CIM, if we have devised means to quantify benefits in dollar amounts, we can use those means to verify that the proposed benefits do, in fact, accrue from system implementation.

Therefore, in the analysis of RESFMS, any outputs of the system which become part of the evaluation should be quantified in monetary terms in order to satisfy current DoD directives.

D. DISCOUNTING

As stated earlier, the concept of the time value of money is at the heart of economic analysis. What Quirin and Wiginton (1981) call the "bird-in-the-hand" principle states simply that it is preferable to receive early benefits than later benefits. The process of discounting allows us to account for this preference. Discounting calculates the present value of a future cost or benefit. Present value is obtained by applying a discount factor to a cost or benefit.

In the Department of Defense, a ten percent discount factor is to be used when evaluating investment projects (DODI 7041.3 and OMB Circular A-94). Although established in 1972, this rate is still considered to be representative. It is an estimate of the average, pre-tax, rate of return on private investment, after adjusting for inflation. Thus, the ten percent discount rate may be considered as "the weighted average opportunity cost of taking money from the private sector." (Haga and Lang, 1991)

When evaluating investment decisions in the Department of Defense we apply discounting by following a two step process. First, make all estimates of the costs, savings, and benefits in terms of constant, base year dollars. Second, compute the present value of all cash flows by applying a ten percent discount factor. (Haga and Lang, 1991)

E. ECONOMIC LIFE

The length of time over which a project will be evaluated, the economic life, is an important factor in any economic analysis. A period that is too short may unfairly penalize alternatives that require high initial investments and may also hide the negative effects of alternatives that have high out-year costs. Choosing an economic life that is too long may incorrectly attribute value to alternatives that will be obsolete or worn out before the final years of the analysis.

There are three factors that determine economic life (Haga and Lang, 1991):

- Mission Life - The period of anticipated asset need.
- Physical Life - The period the asset may be used before physically wearing out.
- Technological Life - The period the asset may be used before it becomes technologically obsolete.

The economic life chosen for analysis of alternatives is usually the shortest of the mission, physical and technological lives. (Haga and Lang, 1991)

F. ANALYSIS TOOLS

Of the economic analysis tools available for public and private sector investment decision analysis, there are six techniques which are appropriate for evaluation of information systems. (Walker, 1991)

1. Present Value Analysis (PV)

This method determines each alternative's costs as stated in terms of their present value. It requires all alternatives to be of equal economic lives. This procedure is to be used when the economic life of a project is more than three years (Haga and Lang, 1991 and DODI 7041.3).

Present value analysis is the primary economic analysis tool and its calculations become the basis for calculations by other analysis tools. When costs and benefits considered can be quantified in terms of dollars, present value analysis is the preferred technique. Other economic analysis tools complement present value analysis by providing means of comparing alternatives when they are of unequal lives, or when costs and benefits cannot be expressed in dollars. Additional information is also provided by some techniques amplifying the present value analysis results. However, unless a mistake is made, other methods will never contradict the results obtained by present value analysis.

2. Uniform Annual Cost (UAC)

When evaluating alternatives with unequal economic lives, the Uniform Annual Cost method may be used to rank the alternatives. Because it is based on present value analysis, if the alternatives evaluated have equal economic lives, UAC is redundant to present value analysis. (Walker, 1991)

3. Savings/Investment Ratio (SIR)

This ratio computes the relationship between future cost savings and the investment required to obtain those savings. "Because saving is a necessary ingredient, you use this if, and only if, you have a status quo alternative." (Haga and Lang, 1991) DODI 7041.3 states that the Savings/Investment Ratio should be shown when evaluating cost-reduction investment proposals involving incremental costs.

4. Discounted Payback (PB)

Discounted Payback simply measures the amount of time it takes for an alternative to pay for itself. It determines what period of time is required for the accumulated present value of cost savings to offset the total present value cost of an alternative. (Haga and Lang, 1991) Again, since savings are involved, this method may be used if, and only if, there is a status quo alternative.

5. Break Even Analysis (BE)

When an information system will have variable costs as well as fixed investment requirements, Break Even Analysis may be useful. Garrison (1988) describes Break Even Analysis as finding the point where a project's total expenses equal its total revenue. This point will also be where the decision maker will be indifferent to whether the project should be undertaken or not.

6. Benefit/Cost Ratio (BCR)

BCR computes the ratio between outputs (benefits) of a project and inputs (costs). BCR can be used to compare both quantitative and non-quantitative benefits. Of the six techniques judged applicable to information systems, this is the only technique that can be used to evaluate non-monetary benefits.

G. SELECTION OF TOOLS FOR RESFMS

One of the alternatives for RESFMS will be a status quo alternative and a chief aim of the redesign is cost savings. Therefore, both Saving/Investment Ratio and Discounted Payback would be appropriate analysis methods. Since costs and benefits will be expressed in dollars, Present Value Analysis is appropriate and preferred as a primary evaluation tool. The chosen economic life will be equal for all alternatives, which would make Uniform Annual Cost redundant to Present Value Analysis. There are no costs that vary with work load. Thus Break Even Analysis is probably not appropriate. Recently published CIM policy (DDI Memo, 23 July 1991) directs that any benefits used in an economic analysis be valued in monetary terms. The primary purpose of the redesign is cost savings, not added benefit. The benefits that will accrue are difficult to quantify in monetary terms. A Benefit/Cost Ratio might be useful, but would be unacceptable to CIM reviewers unless the benefits were in monetary terms. Techniques for comparing costs and cost savings will probably be more than adequate for the analysis. Therefore, Benefit/Cost Ratio will not be used.

The economic analysis of alternatives for RESFMS, then, will involve Present Value Analysis, Saving/Investment Ratio, and Discounted Payback analysis of each alternative using the standard DoD discount rate of ten percent.

H. RISK ANALYSIS

The economic analysis process is, by its nature, uncertain. No matter how conscientious one is in identifying and evaluating costs and benefits, the process must use estimates and estimates involve uncertainty.

> If the economic evaluation method used does not reflect this uncertainty, then every assumption built into an economic analysis is a "best guess" and the final economic result is a consolidation of these "best guesses." Making decisions on the basis of such "best guess" calculations alone can be hazardous. (Stermole, 1984)

Therefore, the last step of the economic analysis procedure is an evaluation of uncertainty, or risk analysis.

A number of methods exist for risk analysis. They range from simple methods to highly complex simulations. The method generally preferred in private corporations in the 1980s was categorical ranking of risk (Strassmann, 1990). The types of risk are described by adjectives (such as high, low, moderate, disaster). Then the risk types are converted to numeric scales by assigning weights to each category. More elaborate evaluations can be made by increasing the number of risk indicators to be ranked.

Sensitivity analysis is a means of evaluating the effects of uncertainty by varying various parameters and thus determining their effect on the economic evaluation results. (Stermole, 1984) First, computations are made with the best estimate of values for each variable. Then, by changing the values of variables within reasonable limits and recomputing the results, the effects of each variable on the final outcome can be readily seen. (Haga and Lang, 1991) Through sensitivity analysis, critical strategic variables can be identified for careful attention by the decision maker and, if the project is approved, for close observation by the program manager.

Probably the most sophisticated method of analyzing risk, and one gaining in popularity, is financial simulation using computer models (Strassmann, 1990). Simulation requires that you be able to assign probability distributions to each major cost determinant (Haga and Lang, 1991). Several commercially available software packages exist that work on microcomputers as either stand-alone programs or as add-in features to spreadsheet programs.[8] These software packages generally use randomly generated numbers and a Monte Carlo method (such as spinning an imaginary roulette wheel) to simulate the probability of occurrence of costs and benefits. When the simulation is finished, the relative frequency of the various values can be plotted on a chart or graph. This form of simulation and display of results can be useful in the analysis of project risk.

Sensitivity analysis and risk analysis of economic evaluations in the Department of Defense has been encouraged for more than twenty years (DODI 7041.3). However, recently it has taken on new import. The Director of Defense Information has directed, as a part of CIM policy, that calculations of cost and benefit for information systems projects in DoD will be adjusted to reflect the financial impacts of risk (DDI Memo, 23 July 1991). Therefore, in the analysis of alternatives for RESFMS, an evaluation of financial risk of the estimates will also be made.

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[8] Some examples of simulation software packages for microcomputers are: Risk Analysis and Simulation (for DOS), and @Risk (add-in program for Lotus 1-2-3), both from *Palisade Corporation*, Newfield, N.Y., and Crystal Ball-Forecasting and Risk Management, *Market Engineering Corporation*, Denver, Colorado (for Macintosh).

V. PROBLEMS WITH SOFTWARE DEVELOPMENT COSTING

A. COST ESTIMATION METHODS

The cost of redesigning and reprogramming the software for RESFMS is the most difficult to estimate and the most critical to this analysis of all of the costs associated with the redesign alternative. The problem of devising accurate and reliable cost estimates for the development of software systems is not new, nor is it unique to this analysis. Four methods to estimate software development cost appear in the literature (Hihn and Habib-agahi, 1991):

1. Price to Win

The method dubbed by Boehm (1981) as "Price to Win" in the private sector involves making the cost estimate equal to that believed necessary to win the job. The same reasoning may be applied in the public sector to those estimates made to equal the amount (or schedule) believed to be desired (or politically acceptable) by those who will approve the project.

2. Analogy

This method involves reasoning by analogy with known previous development efforts. The actual costs of completed projects are related to an estimate of the cost of a similar new project. Boehm (1981) points out that the major advantage of this method is that it is based on actual project experience. The disadvantage is that it is unclear to what degree the previous project effort is actually representative of the effort required on the new project.

3. Expert Judgement

When expert judgement is used, one or more experts are consulted who use their experience and knowledge of the proposed project to estimate the effort, and thus cost required. The disadvantage of expert judgement is that it "is no better than the expertise and objectivity of the estimator, who may be biased, optimistic, pessimistic, or unfamiliar with key aspects of the project." (Boehm, 1981) The estimate obtained by expert judgement may also not be repeatable by any other estimator.

4. Algorithmic Models

These methods use one or more algorithms which produce an estimate of the costs as a function of some number of variables considered to be cost drivers. The algorithms may be manually applied or incorporated into an automated costing tool. Boehm (1981) describes the five most common forms of estimation algorithms:

- Linear models
- Multiplicative models
- Analytic models
- Tabular models
- Composite models

All algorithmic models require some measure of project size as an input. The advantage of algorithmic models is that they are objective, repeatable, and generally efficient. However, the estimate produced is no more accurate than the sizing inputs and cost driver ratings used, and this constitutes the main disadvantage of algorithmic models. First, it may be difficult to obtain an accurate size estimate at the time the cost estimate is most needed. Second, the cost driver ratings used must be validated and calibrated for the particular organization doing the development. None of these models is generic in the sense of being able to apply the model to all development sites universally without modification or calibration of some sort.

B. COCOMO

Probably the most well known and widely studied software cost model is the hierarchy of models called COCOMO, for *COnstructive COst MOdel*, described by Boehm (1981). Boehm's hierarchy involves three models: Basic COCOMO, Intermediate COCOMO, and Advanced COCOMO. COCOMO is an example of an algorithmic model. Basic COCOMO is a static, single-value model. It computes development effort (in man-months) and costs (in dollars) as a function of program size expressed in number of lines of code. Intermediate COCOMO expands on the basic model by using a set of cost drivers to modify the estimate. These cost drivers are numeric values derived from a subjective assessment of system, hardware, personnel, environmental, and project attributes. Advanced, or Detailed COCOMO incorporates all the attributes of

Intermediate COCOMO and adds an assessment of the cost driver's impact on each phase of the software development process.

The phases of software life-cycle used in COCOMO are those of the waterfall model. Originally presented by Royce (1970), and widely used in the 1970s and 1980s, the waterfall model has been codified in U.S. Government and Department of Defense directives and instructions as the primary means of development and documentation of information systems. The seven project activity phases for which COCOMO computes effort are:

- Plans and Requirements
- Product Design
- Programming
- Integration and Test
- Development
- Maintenance

COCOMO was developed as a result of an analysis of 63 software projects completed by TRW, Inc. (Boehm, 1981). Many algorithmic models are described only in general terms because all or part of the model includes proprietary information. COCOMO is explained in detail, with reference to both rationale and actual computation of each aspect of the model. COCOMO also provides effective tools for software project management throughout each phase of development. Thus, COCOMO has become the centerpiece of software project estimation and management instruction, as well as the basis for other automated estimating tools.

C. SOFTWARE SIZE METRICS

Most of the algorithmic models for cost estimation use, as their basic input, a measure of project size in terms of lines of code (LOC) or thousands of lines of code (KLOC). LOC has also been used extensively as a productivity measure to determine project progress and programmer efficiency. Those who favor using LOC as a measure claim that there is high correlation between LOC and software development costs, that LOC can be easily counted, and that "a large body of literature and data predicated on LOC already exists." (Pressman, 1992)

Another term for LOC, used by Boehm (1981), is delivered source instructions (DSI), or thousands of DSI (KDSI). The slightly different terminology suggests one of the problems with LOC measures: although the measure appears to be objective, the definition of what constitutes one line of code, or one source instruction, is not always clear. This and other problems with the metric are discussed in detail by Jones (1986). The use of LOC as a metric also penalizes well-designed but shorter programs, and does not easily adapt to measuring nonprocedural languages such as Fourth Generation Languages (4GL). The most important problem for cost estimation, however, is that using LOC requires a level of detail which may be difficult to achieve at the time the estimate is required (Pressman, 1992).

D. FUNCTION POINTS

An alternative to size metrics such as LOC is the measurement of software "functionality" or "utility." Function oriented metrics were first proposed by Albrecht (1979) while serving as Program Manager of the Application and Maintenance Measurement Program for IBM (Behrens, 1983).

Albrecht's basic premise was that all the functions present in an application can be measured by examining the factors which are the "outward manifestations of any application" (Albrecht, 1979). The procedure is to, first, list and count the number of external user inputs, outputs, queries, and the number of external and internal master files.

> Each of these categories of input and output are counted individually and then weighted by numbers reflecting the relative value of the function to the user/customer. The weighted sum of the inputs and outputs is called "function points." (Albrecht and Gaffney, 1983)

The weighted sum is then adjusted for other development environment factors such as communication complexity and time criticality. A subjective judgement of these general environmental factors is converted into a numeric value called Degree of Influence (DI) which serves as the basis for a General Characteristics Adjustment (GCA) to the function point count.

The final product of this process is a number that can be used as a relative measure of program functionality and complexity. By computing function points for various systems and comparing the amount of programmer and analyst effort required to produce the system, a metric can be found to estimate project cost. For instance, a given organization may find that average productivity is five function points per man-month effort. If a proposed project has 200 function points, this organization can expect to expend 40 man-months producing the application. By applying the locally determined cost per man-month, a dollar cost estimate can also be made.

The advantage of function point analysis is that a far better picture of project function and complexity can be obtained than that achieved with LOC estimates. Function points also give a measure of programming effort independent of program language used. The following table (Pressman, 1992 and Jones, 1986), illustrates this fact by showing a rough estimate of the average lines of code required to build one function point in various programming languages:

Table II AVERAGE LINES OF CODE PER FUNCTION POINT

Programming Language	*LOC/FP (Average)*
Assembly language	300
COBOL	100
FORTRAN	100
Pascal	90
Ada	70
OBJECTIVE-C	25
Fourth-generation languages (4GL)	20
Code generators	15

Examination of the above data shows that one LOC of Ada provides approximately 1.4 times the "functionality" as one LOC of COBOL (Pressman, 1992). In other words, a program written in COBOL taking (on average) 1,000 LOC should only take about 700 LOC, or be only 70 percent as large, if rewritten in Ada.

One disadvantage of using function points is that, although it may appear very objective and straightforward, counting of function points involves subjective judgements. Still, the advantages of function points as a software productivity, project estimation, and project management tool are considered by some to be significant (Behrens, 1983).

E. RELIABILITY OF MODELS

Boehm (1981) asserted that models such as COCOMO could be expected to provide an estimate of cost within 20% of the actual cost 70% of the time. In spite of great effort to improve cost estimation and develop new models, the statistics have not changed much today. Stephen Gross (1992), AIS Division Head of the Naval Center for Cost Analysis, related his work in validating a new automated cost model for DoD use called SASET for *Software Architecture, Sizing, and Estimating Tool.* He stated that the criteria for acceptance of this model was that its predicted cost should be within 20% of the actual system cost 80% of the time. To validate the model, researchers used historical data from 25 systems developed for the Department of Defense. Using perfect information of project size and complexity, as determined by project completion, the model could predict within 20% of the correct cost 80% of the time (Gross, 1992).

However, at the time a cost estimate is required, before the project begins, perfect information of project size and complexity is not available. One can easily see that if the size estimate used is 70% accurate and the model 80% accurate, we only have a 56% chance, or slightly better than even odds, of being within 20% of actual project cost.

Therefore, the better our understanding of the design of the system, the more accurate will be our estimate of effort. Actually, this statement is true regardless of the method used for cost estimation. If we use an algorithmic model, a fairly detailed description of system design will be required to make a reliable estimate of lines of code required to implement the system. If function points are used, a detailed description of system requirements and an accurate estimation of all input and output is needed to make the calculation. Even expert opinion and analogy require some knowledge of system design for a adequate estimate to be made. The dilemma then becomes: how much project development does one complete before making an estimate of cost and effort required? Pressman (1992) states that no matter attractive it may be to delay estimation until very late in the project, this is not a practical option. He suggests instead that several techniques be used "in tandem, each used as a cross-check for the others." (Pressman, 1992) This analysis of RESFMS will use just such an approach.

F. THE SOFTWARE COST ESTIMATION PROBLEM IN DOD

Current DoD policy requires that a business case or functional economic analysis be done prior to project approval. Part of the business case is a cost/benefit analysis for the proposed information system. Project approval must be received before funds are budgeted for the project. In order to determine an estimate of project costs and benefits, system requirements and some level of product design must be performed. Yet, requirements analysis and product design are the first two phases of the project for which we are seeking approval. What then can be done? Or better, what is in fact done?

The FIRMR, OMB circulars, GSA guides, and DoD directives all state that requirements analysis as a part of project planning should begin as early as possible. Agencies are encouraged to develop strategic plans for business activities and information resource (IR) needs. From strategic plans come tactical plans indicating specific IR systems required for mission fulfillment. When IR system development needs are identified, a program manager (PM) should be appointed and project planning should begin (GSA Overview Guide, 1990). DoD instructions reinforce this concept. DoD Instruction 7920.2 describes the AIS life-cycle management process, the milestones required and activities in each phase. Request for Milestone 0 ends the Need Justification Phase and involves submission of a Mission Needs Statement (MNS).

> The MNS is approved at Milestone 0, and the DoD Component is authorized to initiate the Concepts Development Phase and to expend resources for the activities of that Phase as planned. (DODI 7920.2, 7 March 1990)

The recognition of a need to expend resources in planning for future systems development is not confined to government publications and directives. Strassmann (1990) states that five percent of an organization's information budget should be directed to development plans. Since Strassmann is now Director of Defense Information (DDI), one would think this opinion would be strongly reinforced in practice. Yet, in spite of the encouragement in GSA publications, the opinion of Strassmann, and wording of DoD instructions, DoD budget management personnel will not allow any funds to be identified explicitly for IR projects until that project has been fully approved for development or redesign.

This fact is evident in examination of the RESFMS budget. A strong argument can be made for the need to redesign RESFMS. Yet, because RESFMS is considered a fully deployed system, and no redesign has been officially approved, no monies are designated for any redesign activities, nor have they been for the last two years. If a budget line item for development had any value other than zero, Navy budget personnel would cut the organization's total budget by that amount and zero out the line item. The reasoning would be that there was no authorization for expending such funds on a fully deployed system.

This mentality is not unique to the Naval Reserve. Interviews with CAPT Faubel (1992), the comptroller for Commander in Chief Atlantic Fleet, and with David Spivey (1992) of the U.S. Army Corps of Engineers confirm that the reasoning is the same in their organizations as well. Gross, of the Navy Center for Cost Analysis, does not believe that this presents a problem. He believes that if a commander feels a project is needed the commander will find the money somewhere in his budget to perform the needed cost analysis. He also stated that, in his experience, major commands desiring to develop systems had "plenty of money" available for this purpose (Gross, 1992). Others do not agree.

Both CAPT Faubel (1992) and Mr. Spivey (1992) acknowledged that it is a serious problem that money is not officially available until after a project is approved, yet a portion of the first phases of project development must be done in order to obtain good cost estimates required for project approval. Neither, however, wished to see a DoD requirement to explicitly identify funds for this purpose in a budget, and especially not if a specific figure or percentage were tied to the requirement. Both preferred to spend funds out of operating expenses, under the heading of general project management, thus allowing more organizational discretion in the execution of the budget. William Curtis (1992) of the Software Engineering Institute (SEI) stated that this is indeed a problem. He felt that it is not just a problem in the Department of Defense, but also in industry. However, it is not recognized as a problem in industry. He felt that insufficient resources were being devoted in general to the activities required to perform good cost estimates for software development projects before decisions are made to proceed with those projects.

Therefore, even though it is widely recognized that resources should be expended to provide the information required for a reasonable cost estimate before system development approval, these resources cannot now be explicitly identified in DoD budgets. The assumption of this discussion is that funds are available in the program management budget of every agency to support these activities. This assumption may not be true for all agencies needing to develop IR systems, especially not in times of a declining budget. In the case of the Naval Reserve, such excess funds do not exist. The Naval Reserve may not be unique in this regard.

Unlike most DoD agencies, the U.S. Army Corps of Engineers receives both an appropriated budget and significant nonappropriated income from services provided to other governments and outside agencies. The Corps of Engineers has been successful in information system development (Spivey, 1992). It has had a series of excellent commanders who understood the problems and advantages of information system development and who have been supportive of expenditures in support of re-engineering efforts in the Corps. In spite of this environment, and a long period of increasing defense budgets in the 1980s, Spivey (1992) stated that getting money to do proper requirements analysis and system cost estimates was still a problem--one that they have so far overcome, but still a problem. If an organization such as the Corps of Engineers experiences a problem with this, what then do agencies without the same resources and expertise do?

G. RESPONSE TO THE PROBLEM IN DOD

As a result of my experience and interviews with several information system managers who did not wish to be quoted, I believe agencies do one of several things:

1. Take the Money "Out of Hide"

Whether the money is really available or not, some agencies "bite the bullet" and expend resources originally designated for other activities to perform the work needed to justify and cost a proposed system or redesign. If the system desired is a new development, Operation and Maintenance (O&M) funds may be used--this at the expense of personnel or training. The House Armed Services Committee reported that the Department of Defense planned to spend about nine billion dollars on ADP systems in FY90 and that three quarters of that amount was to come out of O&M (HASC, 1 July

1989). It is reasonable to assume that if the services planned to spend this much O&M to continue projects already approved, they would be willing to hide the cost of requirements analysis and cost estimates by spending O&M funds for those activities as well.

If the system exists but needs redesign, money may be diverted from software maintenance efforts to plan for the redesign. In the case of RESFMS, the poor initial design caused maintenance programmers to be forced to do systems analysis and design activities just to adequately perform maintenance. The results of that design effort have been used by the author as a basis of cost estimates.

2. Seek Outside Help

Some organizations seek outside help, either by paying for consultants, or by getting "free" assistance from other agencies or sources, such as Naval Postgraduate School thesis students. If consultants are hired, this option becomes the same as the first--funds are taken "out of hide" to hire them.

3. Guess

In order to meet the requirement for an estimate of system development costs, some organizations use a form of Analogy or Expert Judgement to provide an estimate. The accuracy of the reasoning depends on many factors including: historical data available from previous projects, capability and experience of the estimator, and resources that have been expended in developing requirements analysis and design proposals. The resulting estimate may be fairly accurate, or nothing more than a wild guess. For reasons discussed below, the wild guess is more likely.

4. Price to Win

Many organizations adopt a "Price to Win" strategy and use a cost which is believed to be politically acceptable, that is, a cost figure that is judged to be what will be approved. The practice of estimating costs based on external constraints can also be found outside DoD. A study of cost estimation methods in actual use at Jet Propulsion Laboratories found this practice prevalent there as well:

> The cost estimating process can be seriously impacted by conditions of severe budget or schedule constraints. The result is that the estimator's job becomes less one of estimating costs and more one of analyzing system and functional tradeoffs. In many cases, if there is strong motivation to accept the work, the job may be accepted under the assumption that any inconsistencies between requirements, cost and schedule will be resolved while the task is under development. ... Thirty percent of the respondents reported being budget constrained while 20 percent reported being schedule constrained. (Hihn and Habib-agahi, 1991)

If the politically acceptable approach is taken, requirements are then developed to match the cost, but the report is written as if the opposite had occurred. If the writers of the report understand the reasoning of reviewers well enough, any examination of the reasoning will find no problem with the estimate, for the requirements listed and the cost estimate will be completely consistent, since the former are constrained by the latter. Unfortunately, the requirements may not describe what is actually needed by the organization. So, if the project is approved, the requirements will undoubtedly change when actual development begins.

5. Combination

Many organizations use a combination of approaches depending on what resources are available, what the political climate is at the time, and what expertise is available.

H. ACCURACY OF DOD COST ESTIMATES

How accurate will these estimates be? A look at recent Congressional hearings and GAO reports suggests the answer. Reports of the House Armed Services Committee (HASC, July 1989)(Endoso, July 1992), House Appropriations Committee (HAC, August 1989), House Committee on Government Operations (HOC, November 1989), and numerous GAO reports have documented serious problems with DoD information systems management. Cost overruns in the hundreds of millions of dollars have been noted. Reasons cited, in addition to poor management and poor communication within DoD, have included (HOC, November 1989):

- Inaccurate cost and benefit estimates
- Incomplete historical cost data
- Estimators untrained in cost estimation techniques
- Excessive requirements growth (changes)

Although the Congressional and GAO reports did not make the connection between requirements growth and poor planning or bad initial cost estimates, the author believes that they are strongly related. If the estimate is flawed to begin with, those developing the system will have no compunction about changing the requirements later to suit their needs. Although this is not the only reason for requirements growth, it is a contributing factor.

I. REASONS FOR POOR DOD COST AND BENEFIT ESTIMATES

The reasons for poor cost and benefit estimates and the reasons for cost overruns and management failures in Department of Defense information system projects are interrelated. There is no one single cause, and the several causes overlap in their effects. The reasons for these problems include the following:

1. Funds Not Identified Explicitly

Budget managers in DoD are seeing fewer and fewer discretionary dollars due to declining total budget authority and the existence of large fixed-cost operating expenses. The more items designated by Congress, or higher authority, as "fenced" for a particular purpose, the less budget flexibility the organizations have to meet their changing obligations. In this environment it is natural that budget managers would not want funds for information system development feasibility studies to be explicitly designated in the budget. Yet, if we do not identify these funds accordingly we will never have any way to tell how much we are really spending on proposed system cost estimates. More important, it is likely that little or no money will be spent for this purpose. In times of declining budgets, the undesignated funds in the budget will be spent for other contingencies. The question becomes one of what we are willing to give up in order to provide an analysis of needs for the future. Planning and cost estimation activities will receive scant funding, the research done will be scarce, and the marginal results will be presented as if a full and adequate analysis had been done. If the ruse is not discovered and the project is approved, it is highly probable that serious cost problems will result due to extensive changes in requirements during development.

2. Political Pressure for a Particular Cost Figure

The House Committee on Government Operations identified a potential cause of major system cost overruns as "the establishment of arbitrary cost caps by senior management" (HOC, November 1989). These caps are usually unrelated to information technology (IT) system requirements. The problem still exists. In fact, the problem is even worse now in a period of dramatic decline in Department of Defense funding.

3. Poor Historical Data

Good cost estimation requires good historical data. Congress identified the "lack of credible empirical data about the operation to be automated" (HOC, November 1989) as a major contributor to erroneous cost estimates in DoD. Not only is there a lack of data on the particular function to be automated, but there is little data available on the performance of DoD organizations producing similar projects in the past.

One goal of the Software Engineering Institute (SEI) is to help organizations improve the software development process. In performing this function, SEI conducts Software Process Assessments (SPA) of organizations to determine their present level of performance and suggestions for improvement. A significant element required for organizations to progress to higher levels of software process performance is collection of detailed historical and operational data on the software development process as it is performed in that organization. As a result of SPAs conducted, members of SEI estimate that most DoD organizations are functioning at the lowest level of Software Process performance due, in large part, to lack of software process data collection and analysis. (Curtis, May 1992)

4. Lack of Trained Estimators

The lack of individuals trained in "industrial cost estimation techniques as applied to automated systems" (HOC, November 1989), identified by Congress in 1989, is still a problem. In response to this problem, DoD established the Information Resources Management College (IRMC) as part of the National Defense University. The IRMC has developed a syllabus and a number of tools and resources for project managers. Yet, the courses at IRMC are not required of information system project managers, nor is equivalent training required. Worse, the course has not been designated as officially satisfying training requirements for Materiel Professionals who will be managing software development projects. Commands wishing to send personnel to IRMC must pay for this training.

SEI also offers outstanding training in software project management, software requirements engineering, and numerous other related skills. DoD personnel may receive this training at considerably lower cost than individuals from private industry, yet the cost is still significant.

The training suggested by Congress and provided by both IRMC and SEI is not mandatory. No requirement exists for DoD organizations to have members who have received this or equivalent training. More important, budget funding for training is often not available. Travel/training is one of the few discretionary portions remaining in current budgets. In times of budget decline, the travel/training portion of the budget is one of the first items to be cut. The result is that, even if organizations want to get training for their members, the funds are often not available to pay for training fees or for the travel involved.

An added problem with the lack of trained personnel is that, even when organizations seek outside consultants they cannot be assured of a good cost estimate. One option for obtaining feasibility studies and cost estimates is to contract with another government organization[9], or some commercial contractor to provide the study and report. If the organization contracting for the study has no members trained in cost estimation to oversee the process, there is no way to judge the quality or applicability of the report received.

5. Inadequate Cost Models and Tools

In order to produce an adequate estimate, all the tools and methods available now require a reasonable estimate of project size and complexity as an input to the model. Also required is that the model be calibrated to a particular organization. Since we already know that, in DoD, few historical data are collected, few trained personnel

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[9]An example of a government organization that can provide needed expertise is the Office of Technical Assistance (OTA) of the U.S. General Services Administration (GSA). Within OTA are the Federal Systems Integration and Management Center (FEDSIM) and the Office of Software Development and Information Technology (OSDIT). Both can provide valuable assistance in evaluating, developing, and managing information systems. (GSA Overview Guide, 1990)

exist, and few funds are available for requirements analysis prior to cost estimation, the models will produce marginal estimates in their present form.

J. THE DOUBLE DILEMMA

Performing product design prior to cost estimation has disadvantages as well as advantages. In a rapidly changing environment, postponing design allows planners to consider many options. In recent years rapid technological advances have been the norm. Improvements have been made in hardware performance and in software languages and tools available. Postponing detailed design keeps the project flexible, but produces unreliable cost estimates. Performing detailed design prior to cost estimation provides much better cost estimates but "locks in" a system architecture that may be inadequate or obsolete by the time the system is developed. This double dilemma is faced by all information system developers, but it is most acute in DoD because of the long, mandated approval and development process.

Most large projects for the Department of Defense have taken several years to develop. For instance the House Government Operations Committee (1989) reported on four major DoD systems that had been in development for over eight years. The process of approving the project prior to development is also complex and time consuming. Thus, if a detailed design is required as an input to a cost estimate, if a cost estimate is required prior to project approval, and if the approval process takes a matter of months or years, the whole design could be obsolete by the time development begins. Also, since the DoD AIS management process is based on the waterfall model, it is difficult to take advantage of newer development models such as Incremental Development, Evolutionary Prototyping, and Rapid Prototyping. If a new development model is used, documentation to support the old waterfall method must still be generated. This documentation requirement increases the effort required and extends the time necessary for development. The process needs to be changed.

K. RECOMMENDATIONS TO IMPROVE SOFTWARE COST ESTIMATION IN DOD

Measures which, if taken, would mitigate or eliminate the problems identified are as follows:

1. Legitimize Expenditures for Feasibility Studies

In order to ensure that proper planning and estimation is being done, the expenditure of funds should be explicitly authorized for feasibility studies prior to project approval. The approval of Milestone 0 and the Mission Needs Statement should automatically trigger a non-zero line item entry in the organization's budget for research and development of the system. For fully deployed systems needing redesign, a similar, but different milestone system should be devised that would authorize funds to be explicitly identified for redesign and development of the follow-on system upon the approval of Redesign Milestone 0. Specific figures should not be mandated, but organizations should be encouraged to allocate five percent of their information systems budget to planning for future system development. This authorization should be included in pertinent budget directives as well as in Life-Cycle Management directives, so that budget managers will recognize the legitimacy of this funding.

2. Streamline the Development Process

DoD directives should be changed to allow for new development models such as Incremental Development and Evolutionary Prototyping. The documentation requirements should be modified to reflect the differences in development models. Automated tools should be developed or acquired to assist in and speed up the design, evaluation, and development of systems.

3. Mandate Training and Provide Funding to Support It

Sufficient numbers of personnel trained in information system management and cost estimation techniques will never be available until both the training is required and funding is provided to obtain it. Congress has been inclined to cut DoD budget authorizations for information systems when problems with program management and cost overruns have occurred. Citing unsatisfactory progress, Congress recently targeted $300 million of ADP funding for possible cuts (Endoso, 1992). Congress itself identified lack of training as a problem in 1989 (HOC, November 1989). Therefore, DoD should ask, and Congress should approve the restoration of targeted ADP funding with a stipulation that the money is to be used for travel and training expenses for software cost estimation and software management. DoD should change policies and directives to indicate that IRMC training and equivalent courses (such as SEI and Naval Postgraduate School) are allowed and required of all software project managers and their assistants. The goal should be to ensure that trained personnel will be present, by the end of FY93, in every DoD organization that performs development.

4. Mandate Historical Data Collection and Set Standards

Collection of historical data on software development efforts is essential and should be mandatory for not only DoD agencies but also all contractors that work for DoD agencies. The data collected should be available for reference at the local command where it was gathered and as part of a central DoD repository. Contractor data should be supplied to the database as part of contract deliverables. In order for this to be effective and not be onerous, DoD should not only stipulate required data format but also provide automated tools to aid in collecting the data. Ideally, historical data collection would be built into and integrated with project management tools. This would both increase the chances that the data would be collected and eventually improve the project management process.

5. Improve the Cost Models

Although implementing the previous four recommendations would dramatically improve the accuracy of current cost models, research should continue into improved costing models and tools. Several DoD organizations are attempting currently to provide better costing tools. SASET contains an example of an attempt to perform cost estimation in a new way. Developed by Martin Marietta Denver Astronautics division under contract to the Air Force Cost Center, SASET is a proprietary algorithmic model for cost estimation that operates in two modes. If size of the project in LOC is available a cost estimate can be produced using conventional means. SASET is innovative, however, in that it has a mode in which a description of the function to be performed can be used to generate an estimate of effort required. The input required is not a function point analysis as described by Albrecht, but a description of module function such as: "Accounts Receivable Accounting Module." Based on a database of prior DoD projects, an average size and effort required to program a module performing that function is estimated. This is definitely a move in the right direction, but it needs to be refined. The database of DoD projects is too small and contains mostly real-time system development statistics. The model may be calibrated to a particular site, but that process presents the same problems as other cost models.

If innovative cost estimation models can be developed to be integrated with the project management tools suggested above that also collect historical data, significant progress can be made toward achieving both accurate cost estimates and proficient program management.

VI. COST AND LIFETIME ESTIMATES

A. COSTS CONSIDERED FOR RESFMS

Two alternatives for RESFMS will be compared, a status quo alternative and a redesign alternative. Costs for the status quo alternative were determined by examining budget documents for RESFMS and through interviews with Mr. Ron Chamberlain, COMNAVRESFOR Budget Director (13 May 1992) and LCDR Furrey, RESFMS Redesign Project Manager (14 May 1992). To determine costs for the redesign alternative, cost estimation techniques had to be applied to data provided by COMNAVRESFOR staff and SEMA contractor personnel.

1. Costs for Status Quo Alternative

The largest single cost item for RESFMS in its current configuration is payment for services provided by NCTS New Orleans. NCTS provides both hardware operation and service to the Naval Reserve. In addition to operating the Unisys 1100/92 mainframe computer, associated Input/Output devices, and mass storage, NCTS also provides four individuals to operate a help desk. The help desk accepts calls from users seeking information and assistance. The help desk personnel answer questions and refer problems to technical staff for corrective action.

NCTS New Orleans is a Navy Industrial Fund activity. Such activities receive their initial funding from a revolving fund called the Defense Business Operations Fund (DBOF), formerly referred to as the Navy Industrial Fund (NIF). Because the term DBOF is relatively new, most Navy personnel still refer to such activities as NIF activities. NIF activities perform services for other DoN or DoD activities and charge those customer activities according to the cost of providing the service. The customer activities pay for NIF services out of their appropriated funds budget. (Practical Comptrollership, January 1992) These monies are commonly referred to as "NIF charges."

NIF charges for RESFMS operation were $3,040,000 in FY90 and $3,514,000 in FY91 (CNRF Ad Hoc Budget Expenditure, 1992). With optimistic estimates, the lowest projected figure for NIF charges in the next 6 years is $2,841,000 in FY93 (CNRF Ad Hoc Budget Projection, 1992). From discussions with LCDR Furrey (14 May 1992) and Mr. Chamberlain (13 May 1992), I believe that prudent management may hold NIF charges between the FY90 and FY91 figures. Although the FY93 figure is possible, it is not probable that costs can be reduced to that degree. Inadequate data exist to determine a distribution of values other than these three points. Rough modeling can still be done, however, using a triangular distribution (Mendelsohn et al., 1991). Therefore, using a triangular distribution, I have selected $3,514,000 as the high value, $2,841,000 as the low value and $3,040,000 as the most probable, producing an expected value of $3,131,667 for NIF costs.

The second largest cost factor in the current configuration is payment to contractors for software maintenance. In FY91, COMNAVRESFOR paid $1,608,000 to SEMA, the contractor currently providing software maintenance for RESFMS. In FY92, because of DoD budget cuts, the software maintenance budget has been capped at $1,050,000. Future DoD budget cuts may force further reductions in the RESFMS maintenance budget. The absolute minimum acceptable maintenance level for RESFMS in its current configuration is nine full time maintenance programmers (Furrey, 1992). COMNAVRESFOR pays SEMA $4,853 per man-month for services rendered. This figure includes all overhead and fringe benefits (Chamberlain, 1992). Nine programmers for one year at this rate would cost $524,124 and this is, therefore, the minimum acceptable maintenance budget. Using a triangular distribution with $1,608,000 as the high, $524,124 as the low and the current $1,050,000 as the most likely figure, produced an expected value for software maintenance of $1,116,393.

On COMNAVRESFOR staff are five government civilian employees, two managers and three support personnel, who are assigned to RESFMS. Total cost for civilian personnel, including fringe benefits, is $307,000 (CNRF Ad Hoc Budget Execution, 1992). Expenses for supplies, including software provided to contractors, diskettes distributed to field sites, and office supplies was $100,000 in FY91 (CNRF Ad Hoc Budget Execution, 1992). Cost to the Naval Reserve of operating computer and support equipment at COMNAVRESFOR headquarters in support of RESFMS was $60,000 (CNRF Ad Hoc Budget Execution, 1992). RESFMS management and support personnel are required to travel in order to provide training for users and to attend management meetings in Washington, DC. Travel associated with RESFMS cost $34,000 in FY91 (CNRF Ad Hod Budget Execution, 1992). I believe these figures are representative of what can be expected in future years. Expected annual costs for the Status Quo Alternative which will be used in this analysis are summarized in Table III.

Table III RESFMS STATUS QUO COSTS

NIF Charges to NCTS	$3,131,667
Software Maintenance (SEMA)	$1,116,393
CNRF Civilian Personnel	$307,000
Supplies	$100,000
Operations at CNRF	$60,000
Travel	$34,000
Annual Costs	$4,749,060

2. Costs for Redesign Alternative

a. Software Cost Considerations

The largest single cost item for the redesign of RESFMS is the cost of software development. After system implementation, the largest cost in any single year will be software maintenance expense. In order to determine the amount of these costs, software cost estimation methods, such as those discussed in Chapter V, must be used. To determine the cost of software development, an estimate of effort in terms of man-months is calculated. The number of man-months required is then multiplied by the known cost of a contractor man-month to produce a dollar cost estimate.

Also important to economic analysis is the length of time required for the development effort, or the number of schedule months, since this figure affects the amount of lead time required. Nine man-months of effort can be accomplished in nine months by one programmer, or in one month by nine programmers. Distribution of effort in a software project has been shown to take on the shape of a classic curve first described analytically by Lord Rayleigh (Pressman, 1992). Norden (1980) analyzed empirical data from software development projects to confirm that the Rayleigh curve describes the optimum distribution of effort. Many software cost estimation tools incorporate Rayleigh curve calculations of distribution to determine an optimum schedule for development of the project being estimated.

b. COMNAVRESFOR Estimation of Development Effort

When the redesign of RESFMS was first proposed, in mid 1991, COMNAVRESFOR management personnel asked SEMA contractors for an estimate of effort and schedule required to reprogram the system. The requested estimate was constrained by the assumption that only nine programmers would be used for development and that this number would remain constant throughout development. The target configuration for RESFMS was also not fully determined at the time of this estimate. Based on expert opinion of maintenance programmers, analogy with similar projects performed by other SEMA programmers, and the constraints given, an estimate of 77 schedule months for nine programmers, or a total of 693 man-months of effort was produced (CNRF RESFMS Briefing, August 1991). In June of 1992, after target system configuration had been decided, programming language and tools chosen, and initial system design nearly complete, the estimate was revised to 42 schedule months for nine programmers, or a total of 378 man-months of effort.

For purposes of this analysis, I chose to derive an estimate of development effort and cost by independent means from those used by COMNAVRESFOR staff personnel. Using sizing and functional data provided by COMNAVRESFOR and SEMA personnel, I have produced estimates with three different cost estimation tools.

c. *Function Point Estimate*

Two of the 18 software maintenance programmers and analysts for RESFMS have been tasked with preparing for RESFMS redesign. To date, system requirements, preliminary design, and product design are essentially complete (Furrey, 14 May 1992). Using this data, SEMA personnel have calculated function points (FP) for the redesigned system using procedures devised by Albrecht (1984) and a program for IBM compatible personal computers written in Pascal by SEMA programmers. The result of their analysis for each of the three major modules of RESFMS is shown in Table IV (Lazar, 16 July 1992).

Table IV UNADJUSTED FUNCTION POINT COUNT

RESFMS Module	*Unadjusted FP*
AT/ADT	763
Travel	655
RPN Accounting	1252
Total System	2670

If we assume that relative functionality should be an indicator of relative program size, examination of the above data indicates that AT/ADT should be approximately 61% and Travel 52% as large as RPN Accounting.

To obtain the final function point value, the initial function point count (FC) is adjusted for general characteristics (GC). There are 14 general characteristics and each may have a degree of influence (DI) value between zero and five. DI is subjectively determined for each of the 14 general characteristics and these values are summed to produce a single GC value. The final function point measure (FP) is determined by the following formula (Albrecht, 1984):

$$FP = FC\,[0.65 + (0.01 \times GC)]$$

SEMA analysts determined that GC for the redesigned RESFMS should be 39 (Lazar, 16 July 1992). Using this value in the formula above produces a function point value of 2776.8 for the redesigned system.

Since determination of degree of influence for each of the general characteristics is subjective and descriptions given allow ranges of values (Albrecht, 1984), different values for GC could be reasonably determined. I have gained knowledge of RESFMS system characteristics through my use of the current system in my previous two commands. Further, I have learned how the system will change in the redesign through interviews with Lacy (30 June 1992), Furrey (14 May 1992), and Lazar (16 July 1992). Using this knowledge, I examined the descriptions of function point general characteristics (Albrecht, 1984) and calculated the possible GC minimum and maximum values. Minimum GC was calculated by taking known characteristics of RESFMS and assigning the minimum suggested numeric value for degree of influence for each of those characteristics. Using this methodology a minimum GC of 21 was obtained. Repeating the process, but taking the maximum value suggested in each case, a maximum GC of 55 was obtained. Using the minimum GC of 21 and unadjusted function point count provided by SEMA analysts, a function point value of 2296.2 is obtained for RESFMS. If the maximum GC of 55 is used, a value of 3204.0 is the result.

If function points have been used at a software development activity consistently and historical data has been collected and retained for previous projects, a measure of effort required can be computed in terms of function points per man-month. Unfortunately, neither SEMA nor COMNAVRESFOR have collected and retained such consistent data. However, an estimate of effort to produce this system can still be made, but it will have to rely on rules of thumb for general industry averages and thus be less accurate than that derived from empirical data. To compensate for the lack of accuracy, I made several estimates in order to determine a feasible range for the desired value.

Industry averages for productivity in terms of function points tend to fall between five and six function points per man-month of effort (Pressman, 1992; Zwieg, 9 May 1992). Use of fourth-generation languages or integrated Computer Aided Software Engineering (CASE) tools can increase productivity to 15 or 20 function points per man-month (FP/MM). Programmers recoding RESFMS will be using an integrated CASE environment called Ada Sage, which was produced under contract to the U.S. Department of Energy and is available at no cost to government agencies. The output of Ada Sage is Ada programming code which is then compiled for the target hardware configuration. Even though integrated CASE tools increase productivity, manual coding is sometimes required to adapt the output to a particular system configuration or function. Also, any new programming tool set or environment, no matter how easy to use, requires some amount of time for programmers and analysts to acquaint themselves with the features of the tool and become adept at its use (Zwieg, 9 May 1992).

The RESFMS redesign project will be the first time that SEMA programmers have used Ada Sage and the first time they have programmed in the Ada language. The Navy Center for Cost Analysis has determined that organizations using Ada experience significant savings in software maintenance effort and expense as compared to those using other programming languages. Savings are also apparent in initial development efforts, for second and subsequent projects. However, a large penalty, in the form of training time, is imposed on organizations in their first use of Ada (Gross, 5 May 1992). Therefore, productivity gains associated with use of CASE tools will probably be negated by loss of productivity due to training time required for the first use of Ada. Considering all the above, I have used both the five FP/MM and six FP/MM productivity figures and the low, high, and SEMA estimates of GC to produce six possible values for RESFMS redesign effort using function points. These estimates are shown in Table V.

Table V TOTAL MM EFFORT BASED ON FUNCTION POINT ESTIMATES

Source of Estimate	*FP Value*	*5 FP/MM*	*6 FP/MM*
Low GC Value	2296.2	459.24	382.70
High GC Value	3204.0	640.80	534.00
SEMA Estimate	2776.8	555.36	462.80

d. Estimate of Redesign Effort Using LOC

As discussed previously, a number of models exist which use lines of code (LOC) as a size input to produce an estimate of effort required for software development. Two factors significantly affect the accuracy of a particular model's estimate: whether or not the model has been calibrated for the particular organization performing the development and the accuracy of the LOC input estimate.

Insufficient historical data exists to calibrate models specifically to Commander Naval Reserve Force or SEMA projects. However, the problem of calibration could be mitigated if models were used which had been calibrated to Department of the Navy or Department of Defense projects. Models so calibrated would be less accurate in this analysis than if they had been calibrated for the specific development organization, but considerably more accurate than models calibrated for civilian industry use.

In the case of RESFMS, a status quo system exists which may be used as a basis for LOC estimates of the redesign. In June 1992 a utility program was run by SEMA maintenance personnel which counts lines of code in COBOL. This program was used to determine the exact LOC counts for each RESFMS module. The results as reported by Ben Lazar (16 July 1992) were:

Table VI RESFMS CURRENT CONFIGURATION LINES OF CODE

Program Module	*LOC*	*Total LOC*
RPN	275,668	
RPN PROC	60,831	
Total RPN		336,449
AT/ADT	572,532	
Travel	361,227	
AT/ADT-Travel PROC	89,190	
Total AT/ADT-Travel		1,022,949
Total RESFMS		1,359,398

The term PROC in the above table refers to modules of program code that are common support modules called, and used repeatedly, by applications programs. Thus RPN PROC is the LOC for support programs used by the RPN accounting application module, and AT/ADT-Travel PROC is a LOC count of support programs used in common by both the AT/ADT and the Travel modules. In order to compute the total LOC for each subsystem, the RPN PROC LOC should be added to RPN and the AT/ADT-Travel PROC LOC should be split evenly between AT/ADT and Travel with half added to each (Lazar, 16 July 1992).

Special note should be taken of the relative size of the modules. From function point analysis it was determined that the AT/ADT module should, ideally, be 61% as large as RPN Accounting, and that Travel should be 52% as large as RPN. If it is assumed that the RPN PROC is counted as part of the RPN function and that the AT/ADT-Travel PROC may be equally divided among the two modules which share the PROCs, then RPN Accounting is 336,449 LOC, AT/ADT is 617,127 LOC, and Travel is 405,822 LOC. Thus, AT/ADT is actually 183% and Travel 121% as large as RPN Accounting. Why is there such a disparity between the actual figures and those one would predict based on function points?

The answer lies in the way RESFMS was developed. The AT/ADT module and the Travel module were the first programmed. They were also both produced by NARDAC New Orleans. RPN Accounting was produced by civilian contractors. It is obvious from both historical data (Lacy, 30 June 1992) and current condition of the code (Lazar, 16 July 1992) that little or no design was done prior to the start of coding, that structured programming techniques were not used, and that huge amounts of code was redundantly copied throughout the modules. The AT/ADT and Travel modules are, therefore, considerably larger than optimum design would indicate. On the other hand, SEMA maintenance programmers assert that the RPN Accounting module is well designed and reasonably efficient (Lazar, 16 July 1992). RPN Accounting is probably 10% larger than optimum due to growth from software maintenance patches inserted during the last seven and a half years of operation (Lazar, 16 July 1992), but is otherwise well programmed. Therefore, consensus of RESFMS managers and programmers (Furrey, 14 May 1992)(Lacy, 30 June 1992)(Lazar, 16 July 1992) is that the proportions calculated from function point analysis are very close to optimum for a redesigned system and the RPN Accounting module may be used as a baseline to determine what size the programs should be if written in COBOL.

Using this reasoning I have developed both a Low and a High estimate for LOC to be used as input for cost estimation models. Both estimates assume that the relative size of the RPN PROC to RPN Accounting module is consistent with the amount of support programs to applications programs that will be present in the final system. The High estimate assumes that the RPN Accounting module is the correct size, as is, for the redesigned system and makes no adjustment to LOC estimate for RPN Accounting. In the High estimate, AT/ADT is computed at 61% of the size of RPN Accounting and Travel is computed as 52% of RPN Accounting.

The Low estimate assumes that RPN Accounting is 10% too large at present and adjusts its size downward. Also, consideration is given for the fact that the target system will be programmed in Ada which is more efficient than COBOL. Recall that, on average, Ada requires only 70% as many lines of code as COBOL to produce the same relative functionality (Pressman, 1992). Therefore, I have further adjusted the RPN Accounting module downward to account for the use of Ada. If we adjust 90% for maintenance growth and 70% for Ada use, our final estimate will be 63% as large as the original (0.9 x 0.7 = 0.63). The result is that the estimate for RPN Accounting is reduced from its present size of 336,500 LOC in COBOL to approximately 212,000 LOC in Ada. The Low estimate takes this as the new baseline for RPN Accounting and calculates AT/ADT as 61% and Travel as 52% of this reduced baseline. A summary of LOC estimates used for this analysis is found in Table VII below.

Table VII LOC VALUES USED FOR RESFMS COST ESTIMATES

Module	*Low LOC Estimate*		*High LOC Estimate*	
RPN	173,850		276,000	
RPN Support	38,150		60,500	
RPN Total		212,000		336,500
AT/ADT	106,200		168,250	
AT/ADT Support	23,300		37,000	
AT/ADT Total		129,500		205,250
Travel	90,600		143,500	
Travel Support	19,900		31,500	
Travel Total		110,500		175,000
RESFMS Total		452,000		716,750

A third LOC estimate to be considered is a variation of the Low LOC estimate. One of the goals of the CIM initiative is increased reuse of software within DoD. The Director of Defense Information has stated that one goal of CIM is to achieve 50% reuse of code in developing new systems. The RPN Accounting module of RESFMS is a large financial accounting program with accommodations to the unique aspects of Naval Reserve record keeping. It is very likely that up to 50% of the RPN Accounting module could be provided by reused generic accounting modules. This possibility would greatly reduce the effort required to redesign the entire RESFMS system. To allow for the possibility of incorporating reused Ada programs in RESFMS, I have added a third LOC estimate which adjusts the Low LOC estimate to account for 50% of the RPN Accounting module being constructed of reused code.

The Naval Center for Cost Analysis, in Washington, DC, distributes two software cost estimation tools that use LOC as an input: REVIC, for *REVised Intermediate Cocomo*, and SASET, for *Software Architecture, Sizing, and Estimating Tool*. Both are available in versions which run on personal computers. Using these two cost estimating tools and the three LOC estimates described above, I have produced a series of estimates of effort required for development and for maintenance effort necessary to sustain a redesigned RESFMS.

e. REVIC Estimate of RESFMS Redesign Effort

REVIC is simply the Intermediate COCOMO model (Boehm, 1981) adapted for use in the Department of Defense. It is *revised* because it has been calibrated based on empirical data from DoD projects, and because it adds a new development mode, the Ada mode, to account for the difficulties of using Ada for the first time (Gross, 5 May 1992). The user is queried for values for 20 Environmental Factors, such as programmer capability and database size, that are used to compute the environmental modifier in the COCOMO model (Kile, 1991). Just as COCOMO allows for adjustments to its calculation for software modification efforts, REVIC queries the user to determine if a particular module is being produced as an initial development effort or as a modification of existing code. If modules are designated as being modified, REVIC asks what percent of redesign and recode will be required. The result of REVIC's calculations is an estimate of effort required, in man-months, and an estimate of the optimum number of schedule months. These estimates are displayed for each phase of development as well as a summary of the total effort. REVIC also computes an estimate of life cycle maintenance effort required for 15 years of operation.

REVIC divides effort and schedule estimates into those required for six phases of system development:

- Software Requirements Engineering
- Preliminary Design
- Critical Design
- Code & Unit Testing
- Integration & Test
- Development Test & Evaluation

Software analysts working on RESFMS have completed activities equivalent to the first two phases of the REVIC model, that is Software Requirements Engineering and Preliminary Design. Therefore, estimates used for this analysis and derived using REVIC have had the values for Software Requirements Engineering and Preliminary Design phases subtracted from the totals reported by REVIC.

The redesign of RESFMS will largely involve recoding existing COBOL programs in a new language, Ada. Actual change in functionality will be small. SEMA analysts estimate that functional design will change only 10% to 30% from current functionality (Lazar, 16 July 1992). Even in the AT/ADT and Travel modules that are so poorly coded, the actual design will change little. Almost all the gains in efficiency will result from improved coding practice and use of common modules instead of redundant code. Even though, in this analysis, the values computed for the Preliminary Design Phase will be discarded, it is important to accurately estimate the amount of design change in a COCOMO software modification cost estimate. This is because the design activity is not confined to those phases with "design" in their title (Boehm, 1981). Design activities occur in varying amounts in almost all phases. Thus, the percent change in design affects estimates of effort for all phases of development. For this evaluation I have chosen a design change value of 20% for use in all REVIC cost estimations.

Results of REVIC calculations using the three described LOC estimates as input and subtracting values for Software Requirements Engineering and Preliminary Design phases were as follows:

Table VIII REVIC DERIVED ESTIMATES

LOC Estimate	*Total MM*	*Sched Mos*
50% Reuse in RPN	321.3	25.9
Low LOC Estimate	356.1	26.7
High LOC Estimate	504.9	29.8

f. SASET Estimate of RESFMS Redesign Effort

SASET was developed by Martin Marietta Denver Aerospace Corporation under contract to the Air Force Cost Center. The Naval Center for Cost

Analysis has validated SASET for Navy projects using empirical data from 25 DoD software development projects (Gross, 5 May 1992). SASET uses proprietary algorithms for its calculations. An interesting feature is that LOC estimates can, and should, be divided up into systems programs, application programs, and support programs if possible. Also, whether the code is being initially programmed, modified, or ported to a new hardware platform makes a difference in estimates of effort required to develop. The more specific the user can be concerning the function, use, and development pattern of individual modules, the better will be the estimate that SASET produces (Silver et al., 1990). In addition to a LOC estimate, the user is required to enter values for 32 factors concerning system characteristics, programmer proficiency, and development environment. The values for these 32 factors are used to determine both budget and schedule multipliers that affect the estimate of effort and schedule required. Output may be obtained in a number of forms. I chose to receive a measure of effort in man-months and optimum schedule in calendar months by phase of development. Maintenance effort required can be computed if the user so desires.

The description of RESFMS PROC module functions (Lazar, 16 July 1992) is close to, but does not exactly match, the description of support software in SASET estimation (Silver, 1990). To provide for the possibility of error in designation of software type, I have used SASET to calculate estimates both with support software (PROC modules) separate and with them lumped into the application LOC estimate. RESFMS redesign will not involve coding any systems software. In this case then, entries in SASET would be appropriate only for applications and support module LOC.

Since breaking out support software from applications software LOC involves two entries each for RPN, AT/ADT, and Travel modules, I refer to this entry format as "6 Module." Since lumping PROC modules with its associated application involves only one entry each for the three major modules, I refer to this option as "3 Module."

Software development as defined by SASET is broken into ten phases:

- Systems Requirements
- Requirements Allocation
- Software Requirements
- Preliminary Design
- Detailed Design
- Code
- Checkout
- Unit Testing
- Physical and Formal Quality Testing, Integration
- Systems Test & Integration

SEMA software analysts working on RESFMS redesign have already completed actions equivalent to the first four phases computed by SASET. Therefore, estimates used for this analysis and derived using SASET have had the values for Systems Requirements, Requirements Allocation, Software Requirements, and Preliminary Design subtracted from the totals reported by SASET.

In order to produce a reasonable range of estimates using SASET, five sets of input values were used: Low LOC with 50% reuse of code in the RPN module (called "50% Reused" in the tables and graphs), Low LOC 3 Module, Low LOC 6 Module, High LOC 3 Module, and High LOC 6 Module. The results of these calculations are shown in Table IX.

Table IX SASET DERIVED ESTIMATES

LOC Estimate	*Total MM*	*Sched Mos*
50% Reused	336.79	20
Low LOC 6 Module	439.96	21
Low LOC 3 Module	488.82	21
High LOC 6 Module	697.71	25
High LOC 3 Module	775.15	25

g. *Summary of Software Development Effort Estimates*

Using the three cost estimation tools, a total of 14 estimates of effort were derived: three using Function Point Analysis, five using REVIC, and six using SASET. The estimates range from a low of 321.3 MM to a high of 775.15 MM. The mean value is 496.83, and standard deviation is 135.46. The mean value will be used in initial economic evaluation and the standard deviation is needed for risk analysis. A summary of the estimates of effort is found in Figure 2.

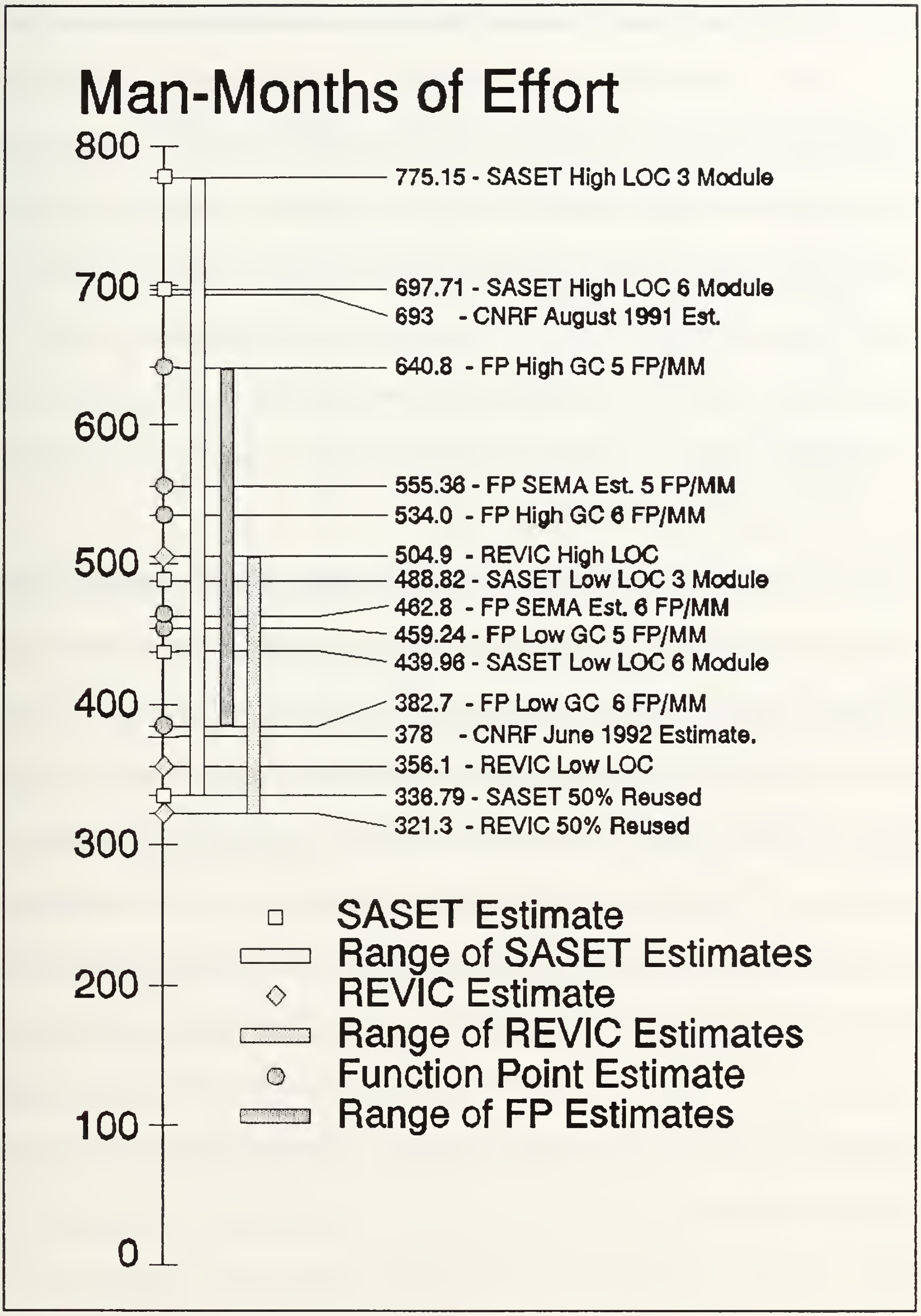

Figure 2 Estimates of Effort for RESFMS Redesign

h. Software Maintenance Estimates

Both REVIC and SASET allow computation of the level of effort that will be required to maintain the system during its extended life-cycle. These values are generally expressed in terms of a full-time software person month (FSP). One FSP is the equivalent of one software maintenance person working one full month, and 3.5 FSP would be the equivalent of three and a half full-time software personnel working for one month on the project. The FSP figures can be multiplied by 12 to obtain an annual maintenance figure in man-months (MM) and this figure can be multiplied by the cost per MM to obtain annual maintenance cost.

Since the 50% Reuse estimate results in a system exactly as large and complex as the Low LOC estimate, the maintenance required on such systems would be the same. Also, when using SASET, though dividing LOC estimates for modules into support and applications portions resulted in different estimates of development effort than lumping them together, it made no difference in the resulting maintenance effort estimation. Therefore, four sets of values were derived for FSP requirements for maintenance: two from REVIC and two from SASET. The mean and standard deviation of the four estimates was calculated for each year of maintenance. The mean of the maintenance FSP values was used in the initial economic analysis and the standard deviation used later in risk analysis computations. Values derived for maintenance are displayed in Table X.

Table X FSP ESTIMATES FOR SOFTWARE MAINTENANCE

YEAR	*REVIC Low*	*REVIC High*	*SASET Low*	*SASET High*	*Mean*	*Std Dev*
1	6.9	9.8	2.36	3.74	5.700	3.32902
2	6.0	8.5	1.89	2.99	4.845	2.99255
3	5.3	7.5	1.53	2.43	4.190	2.73016
4	4.6	6.6	1.30	2.06	3.640	2.42592
5	4.6	6.6	1.06	1.68	3.485	2.58747
6	4.6	6.6	1.00	1.59	3.447	2.62723
7	4.6	6.6	0.88	1.40	3.370	2.70966
8	4.6	6.6	0.77	1.21	3.295	2.78980

i. ***Hardware Investment and Technical Support***

The target computer configuration for the RESFMS redesign is an AT&T 3B2/GR. Earlier analysis determined that RESFMS could run on a single 3B2/GR if it were configured with at least 14 GB of mass storage, but that the number of possible simultaneous uses and limitations on network connections per computer would indicate that two 3B2/GRs would be optimum. Also, the operation of two computers for the same application would allow for system redundancy and backup in case the primary computer fails.

Vendor representatives for the AT&T contract provided cost figures for the computers and vendor support that would be required (NCR letter, 22 June 1992). The configuration recommended includes the following items for each computer purchased:

- 3B2/GR computer with RISC processor running at 25 MIPS
- 64 Megabytes of RAM
- 15 Gigabytes of hard disk storage
- Multi-Network Processor board to allow connection of 256 simultaneous users
- Cables and connectors
- Storage cabinets for all equipment
- POSIX operating system software (a form of UNIX)
- TCP/IP network software for UNIX systems

Total cost for this configuration is $129,892.47. Two computers would thus cost $259,784.94. These computers would require vendor supplied maintenance. Vendor maintenance for the hardware would cost $3,344.09 per year. Maintenance support for the software (operating system and network software) would cost $562.56 per year. AT&T will supply this maintenance support for up to five years. After that time support may be purchased from other vendors at a cost near, or below, that quoted by AT&T (Albro, 13 July 1992).

COMNAVRESFOR is already operating a network of 3B2/GR computers used for other applications. Sufficient space, air conditioning capacity, and electrical power are available to easily add four to six new computers to this network. Addition of two new computers for RESFMS would not require any additional construction, nor would they use any significant amounts of additional utilities than those already in operation. Computer room operations support would require the addition of the equivalent of one and a half technical support personnel to meet the needs of the additional workload. Cost of technical support personnel would be $68,000 per person, including overhead and fringe benefits (Albro, 13 July 1992). Cost of technical support for the new computers would thus be $102,000 per year.

j. Other Operational Costs of Redesign Alternative

NCTS New Orleans currently provides the service of a help desk for RESFMS support. If the system were redesigned, this help desk function would have to be provided by COMNAVRESFOR. The help desk function would be provided by SEMA contract personnel and would, therefore, cost the Naval Reserve $4,852.40 per month per person. Four individuals would be required for the help desk function. Sufficient telephone and office space already exist at COMNAVRESFOR facilities to accommodate this function. Therefore, total additional cost would be $232,915.20 per year.

Management and support personnel attached to COMNAVRESFOR and now assigned to RESFMS would continue this function with the redesigned system. No additional tasking would be required, but neither would their workload be reduced. Supplies and travel requirements of the current system should also remain fairly constant if a redesigned system begins operation. Since SEMA contractors are physically located in COMNAVRESFOR spaces, and system requirements and design are already determined, no additional travel should be required by development personnel. Therefore, costs for COMNAVRESFOR civilian personnel, supplies, and travel are the same as those found in the current system and would begin to be attributed to the redesigned system upon initiation of system operation.

Software tools that will be used by programmers and analysts working on the redesign have either already been purchased or are available from other government agencies at no cost to the Naval Reserve. COMNAVRESFOR is providing all software tools for SEMA contract programmers. Much of the initial programming will be done on personal computers and then the code will be recompiled for the 3B2/GR. This will allow much greater programmer productivity, since the 3B2/GR will only have to be shared for testing of finished program modules. COMNAVRESFOR already owns sufficient numbers of personal computers to support a full development effort on RESFMS redesign and will provide these computers to SEMA for their use. Therefore, no additional costs will be incurred for either software tools or development computer assets.

B. BENEFITS CONSIDERED FOR RESFMS

Even though benefits for RESFMS will not be formally or financially analyzed, it is important to verify that the benefits of the redesigned system are at least equivalent with those of the existing system. Otherwise, any cost savings that may accrue from a redesign may be mitigated by reduced functionality or reduced benefits.

A briefing document prepared for COMNAVRESFOR (CNRF RESFMS Briefing Paper, August 1991) has identified the following benefits derived from the current RESFMS configuration:

- Significantly Improved Management of RPN Funds
- Fund Utilization Improved from 98% of 330M in FY82 to 99.97% of 683 M in FY87
- Allowed Reuse of $5M in Travel Funds Recouped from Tickets in FY88/89
- Improved Tracking of Active Duty Orders
- Reduced Time to Generate Orders
- Fully Certified Accounting System January 1987

Since the redesigned system will have the same functional requirements as the current system, and will be programmed by personnel currently maintaining RESFMS, there is ample evidence to assume that benefits of the current system will be present in the redesigned system.

The primary disadvantages of the current system are:

- High Cost of Operation
- Poor Service Provided by NCTS
- 175 Reserve Sites of 354 Total Not Connected to RESFMS

This analysis will determine if costs of operation are less for the redesigned system. Service will no longer be provided by NCTS, but taken in house to COMNAVRESFOR. With more direct attention and close control, which are not available when dealing with a separate agency, service and support should be better in the redesigned system. Finally, the redesign includes a new user interface that will be designed to allow connection to RESFMS by all 354 Reserve sites. Since benefits of the redesigned system should be equal or greater than the current system, a straight comparison of costs should be sufficient for the redesign decision.

C. PROJECT LIFE

As stated earlier, economic life is that period over which savings and benefits are expected to accrue; and the economic life chosen for analysis of alternatives is usually the shortest of technological, mission, or physical life (Haga and Lang, 1990). Sometimes it is necessary to make investments several years prior to the beginning of the economic life, which is when the project begins producing savings or benefits. The period between initial investment and beginning of economic life is called "lead time" (Haga and Lang, 1990). Project life is the combination of lead time and economic life.

In the case of RESFMS, if new AT&T 3B2/GR computers are purchased they will have a physical life of eight to ten years. If the Unisys 1100/92 is retained, it will probably have a similar physical life because the system was only recently upgraded from an 1100/90 to the 1100/92. Mission life is indefinite, since the function being performed is essential to Naval Reserve operations and will continue to be a need for the foreseeable future. Technological life is more difficult to determine. Even though available technology may quickly and dramatically improve, both the 3B2/GR and the Unisys 1100/92 are adequate for the task at present. The question becomes one of maintainability and cost-effectiveness of technological replacement. NCTS claims that they can provide effective maintenance indefinitely for the Unisys 1100/92 or any chosen NCTS operated follow-on computer. AT&T will provide full maintenance support for the 3B2/GR for five years. A number of other contractors are available to provide maintenance after five years. Therefore, a ten year hardware system life is feasible.

RESFMS has already been operational for nine years. Investment in software development began two years before the first module was operational making RESFMS project life, to date, eleven years. The Director of Defense Information has stated that one goal of CIM is to achieve 20 year and greater system life for DoD information systems. Therefore, an additional ten years of project life for RESFMS in its present configuration is also feasible.

Estimates of schedule for software development of the redesign alternative vary from 20 to 29.8 months. SASET has been more thoroughly tested and calibrated for development projects in the Department of Defense and is, therefore, probably more reliable (Gross, 5 May 1992). The schedule estimates from SASET ranged from 20 to 25 months. It would be reasonable to assume that, if ample resources are applied and an optimum schedule pursued, software development for the redesign would probably require approximately two years. If however, sufficient funding is not initially made available or the high development man-month estimates prove correct, a three year lead time may be required. This means that, for this economic analysis, there will be a lead time of two or three years before a new system will begin generating savings and benefits. During this time the current configuration will continue to operate.

Considering all these factors, I have chosen a project life of ten years due to the physical life limit of the 3B2/GR computers. Economic life starts when the system begins to generate savings or benefits. Thus, the economic life will be either seven or eight years depending on whether a three or two year lead time is used. Both scenarios will be considered and results for each calculated in the analysis of alternatives for RESFMS.

VII. ANALYSIS

A. PROJECT LIFE CYCLE

The project life cycle will begin with the purchase of at least one AT&T 3B2/GR computer. In order to provide adequate computer resources for testing COMNAVRESFOR desires to have two 3B2/GR computers dedicated to the development effort (Furrey, 14 May 1992). Since it will be necessary to test software on the target computer platform from the earliest stages of development, the purchase and installation of two 3B2/GR computers should take place at the beginning of YEAR ONE of project life. Development should take two or three years, during which software development costs and 3B2/GR technical support will be needed. The current configuration of RESFMS will continue to operate during this lead time. However, costs of operating the current configuration will not be considered during this lead time because these costs will be incurred regardless of which alternative is selected. The first year in which a system begins generating benefits is the beginning of economic life. Economic life will begin in YEAR THREE of project life, if a two year lead time is used, or YEAR FOUR, if a three year lead time is used. Therefore, the economic life for comparison will be from YEAR THREE to YEAR TEN of project life in the case of two year lead time, and from YEAR FOUR to YEAR TEN of project life in the case of three year lead time. Salvage value will not be considered in this analysis as it is anticipated that technological advances in the next ten years will render salvage value of the computer equipment zero.

B. DISCOUNTED COSTS

Department of Defense directives stipulate that costs will first be calculated in constant year dollars and that a ten percent discount factor will then be applied to calculate the present value of future costs.

One way to compute the present value of costs is to use a formula and compute the exact discount factor for the time the cost is incurred. For instance, if costs occurred monthly, the formula could be used to calculate a different discount factor for each month. This method is very tedious and time consuming. If costs are evenly distributed throughout the year, a similar result can be obtained by simply averaging the discount factors for the beginning and the end of year to determine a mid-year factor and applying this factor to the total costs for the year.

A table of ten percent discount factors may be found in Appendix B. These are mid-year factors and their use assumes an investment or cost is evenly distributed throughout the year. For costs or investments which occur at a particular point in time, not distributed throughout a year, a different set of discount factors should be used.

In the case of RESFMS only the cost of initial purchase of the 3B2/GR computers occurs at a single point in time, at the beginning of YEAR ONE. All other costs can be assumed to be evenly distributed throughout the year in which they occur. Therefore the discount factors found in Appendix B may be applied to all costs in this analysis except the cost of initial investment for 3B2/GR computers. Since the purchase of 3B2/GRs comes at the beginning of YEAR ONE the present value of that cost will be exactly the same as the cost itself. In other words, a discount factor of 1.0 is appropriate for this initial investment.

One way to represent the fact that initial investments occur prior to the evenly distributed costs incurred in YEAR ONE is to place them in a column labeled YEAR ZERO. The discount factor applied then in YEAR ZERO is 1.0 and the factor applied in YEAR ONE and subsequent years is the mid-year factor from Appendix B. This is the method suggested by Haga and Lang (1991) and the method which will be used in this analysis.

C. PRESENT VALUE

Present Value analysis was done comparing the Status Quo and Redesign alternatives considering both two year and three year lead times. Results of Present Value analyses for the two year lead time assumption are summarized in Table XI. Results of Present Value analyses for the three year lead time assumption are summarized in Table XII.

Table XI PRESENT VALUE - TWO YEAR LEAD TIME

	Net Present Value
Status Quo	$21,9969,150
Redesign	7,653,445
Savings	$14,315,705

Table XII PRESENT VALUE - THREE YEAR LEAD TIME

	Net Present Value
Status Quo	$18,226,891
Redesign	6,804,361
Savings	$11,422,530

Tables XIII through XX show the detailed analysis of the net present value of both the Status Quo and Redesign alternatives. Each Table showing a ten year cash flow has been split into two tables for ease in reading. In this analysis, the expected value for the following variables was used and was computed using the type of distribution indicated:

- Status Quo Software Maintenance - Triangular Distribution
- NIF Charges to NCTS - Triangular Distribution
- Man-Months of Development Effort - Normal Distribution
- Redesign Annual Software Maintenance - Normal Distribution

Values were derived as described in Chapter VI.

Table XIII PRESENT VALUE OF STATUS QUO - TWO YEAR LEAD TIME - YEAR ZERO TO YEAR FIVE

NET PRESENT VALUE ANALYSIS

ALTERNATIVE: STATUS QUO - TWO YEAR LEAD TIME - YEAR ZERO TO YEAR FIVE

YEAR	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Recurring Cost:						
Software Maintenance (SEMA)				$1,116,393	$1,116,393	$1,116,393
NIF Charges to NCTS				$3,131,667	$3,131,667	$3,131,667
Operations at CNRF				$60,000	$60,000	$60,000
CNRF Civilian Personnel				$307,000	$307,000	$307,000
Supplies				$100,000	$100,000	$100,000
Travel				$34,000	$34,000	$34,000
TOTAL UNDISCOUNTED COSTS	$0	$0	$0	$4,749,060	$4,749,060	$4,749,060
x DISCOUNT FACTOR	x 1.000	x 0.954	x 0.867	x 0.788	x 0.717	x 0.652
TOTAL DISCOUNTED COSTS	$0	$0	$0	$3,742,259	$3,405,076	$3,096,387
CUMULATIVE DISCOUNTED COST	$0	$0	$0	$3,742,259	$7,147,335	$10,243,722

Table XIV PRESENT VALUE OF STATUS QUO - TWO YEAR LEAD TIME - YEAR SIX TO YEAR TEN

NET PRESENT VALUE ANALYSIS

ALTERNATIVE: STATUS QUO - TWO YEAR LEAD TIME - YEAR SIX TO YEAR TEN

YEAR	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
Recurring Cost:					
Software Maintenance (SEMA)	$1,116,393	$1,116,393	$1,116,393	$1,116,393	$1,116,393
NIF Charges to NCTS	$3,131,667	$3,131,667	$3,131,667	$3,131,667	$3,131,667
Operations at CNRF	$60,000	$60,000	$60,000	$60,000	$60,000
CNRF Civilian Personnel	$307,000	$307,000	$307,000	$307,000	$307,000
Supplies	$100,000	$100,000	$100,000	$100,000	$100,000
Travel	$34,000	$34,000	$34,000	$34,000	$34,000
TOTAL UNDISCOUNTED COSTS	$4,749,060	$4,749,060	$4,749,060	$4,749,060	$4,749,060
x DISCOUNT FACTOR	x 0.592	x 0.538	x 0.489	x 0.445	x 0.405
TOTAL DISCOUNTED COSTS	$2,811,443	$2,554,994	$2,322,290	$2,113,332	$1,923,369
CUMULATIVE DISCOUNTED COST	$13,055,165	$15,610,159	$17,932,449	$20,045,781	$21,969,150
PRESENT VALUE OF STATUS QUO					$21,969,150

Table XV PRESENT VALUE OF REDESIGN - TWO YEAR LEAD TIME - YEAR ZERO TO YEAR FIVE

NET PRESENT VALUE ANALYSIS

ALTERNATIVE: REDESIGN - TWO YEAR LEAD TIME - YEAR ZERO TO YEAR FIVE

YEAR	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
One-time Cost:						
Purchase of Hardware	$259,785					
Recurring Costs:						
Vendor Hardware Support		$3,344	$3,344	$3,344	$3,344	$3,344
Vendor System S/W Support		$563	$563	$563	$563	$563
Software Development		$1,205,409	$1,205,409			
Software Maintenance				$331,904	$282,119	$243,979
Help Desk (4 persons)				$232,915	$232,915	$232,915
CNRF Civilian Personnel				$307,000	$307,000	$307,000
CNRF Computer Support		$102,000	$102,000	$102,000	$102,000	$102,000
Operations at CNRF				$60,000	$60,000	$60,000
Supplies				$100,000	$100,000	$100,000
Travel				$34,000	$34,000	$34,000
TOTAL UNDISCOUNTED COSTS	$259,785	$1,311,316	$1,311,316	$1,171,726	$1,121,941	$1,083,801
x DISCOUNT FACTOR	x 1.000	x 0.954	x 0.867	x 0.788	x 0.717	x 0.652
TOTAL DISCOUNTED COST	$259,785	$1,250,995	$1,136,911	$923,320	$804,432	$706,638
CUMULATIVE DISCOUNTED COST	$259,785	$1,510,780	$2,647,691	$3,571,011	$4,375,443	$5,082,081

Table XVI PRESENT VALUE OF REDESIGN - TWO YEAR LEAD TIME - YEAR SIX TO YEAR TEN

NET PRESENT VALUE ANALYSIS

ALTERNATIVE: REDESIGN - TWO YEAR LEAD TIME - YEAR SIX TO YEAR TEN

YEAR	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
<u>One-time Cost:</u>					
Purchase of Hardware					
<u>Recurring Costs:</u>					
Vendor Hardware Support	$3,344	$3,344	$3,344	$3,344	$3,344
Vendor Systems S/W Support	$563	$563	$563	$563	$563
Software Development					
Software Maintenance	$211,953	$202,927	$200,744	$196,231	$191,864
Help Desk (4 persons)	$232,915	$232,915	$232,915	$232,915	$232,915
CNRF Civilian Personnel	$307,000	$307,000	$307,000	$307,000	$307,000
CNRF Computer Support	$102,000	$102,000	$102,000	$102,000	$102,000
Operations at CNRF	$60,000	$60,000	$60,000	$60,000	$60,000
Supplies	$100,000	$100,000	$100,000	$100,000	$100,000
Travel	$34,000	$34,000	$34,000	$34,000	$34,000
TOTAL UNDISCOUNTED COSTS	$1,051,775	$1,042,750	$1,040,566	$1,036,053	$1,031,686
x DISCOUNT FACTOR	x 0.592	x 0.538	x 0.489	x 0.445	x 0.405
TOTAL DISCOUNTED COST	$622,651	$560,999	$508,837	$461,044	$417,833
CUMULATIVE DISCOUNTED COST	$5,704,732	$6,265,731	$6,774,568	$7,235,612	$7,653,445
PRESENT VALUE OF REDESIGN					$7,653,445

Table XVII PRESENT VALUE OF STATUS QUO - THREE YEAR LEAD TIME - YEAR ZERO TO YEAR FIVE

NET PRESENT VALUE ANALYSIS

ALTERNATIVE: STATUS QUO - THREE YEAR LEAD TIME - YEAR ZERO TO YEAR FIVE

YEAR	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Recurring Cost:						
Software Maint (SEMA)					$1,116,393	$1,116,393
NIF Charges to NCTS					$3,131,667	$3,131,667
Operations at CNRF					$60,000	$60,000
CNRF Civilian Personnel					$307,000	$307,000
Supplies					$100,000	$100,000
Travel					$34,000	$34,000
TOTAL UNDISCOUNTED COSTS	$0	$0	$0	$0	$4,749,060	$4,749,060
x DISCOUNT FACTOR	x 1.000	x 0.954	x 0.867	x 0.788	x 0.717	x 0.652
TOTAL DISCOUNTED COSTS	$0	$0	$0	$0	$3,405,076	$3,096,387
CUMULATIVE DISCOUNTED COST	$0	$0	$0	$0	$3,405,076	$6,501,463

Table XVIII PRESENT VALUE OF STATUS QUO - THREE YEAR LEAD TIME - YEAR SIX TO YEAR TEN

NET PRESENT VALUE ANALYSIS

ALTERNATIVE: STATUS QUO - THREE YEAR LEAD TIME - YEAR SIX TO YEAR TEN

YEAR	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
Recurring Cost:					
Software Maint (SEMA)	$1,116,393	$1,116,393	$1,116,393	$1,116,393	$1,116,393
NIF Charges to NCTS	$3,131,667	$3,131,667	$3,131,667	$3,131,667	$3,131,667
Operations at CNRF	$60,000	$60,000	$60,000	$60,000	$60,000
CNRF Civilian Personnel	$307,000	$307,000	$307,000	$307,000	$307,000
Supplies	$100,000	$100,000	$100,000	$100,000	$100,000
Travel	$34,000	$34,000	$34,000	$34,000	$34,000
TOTAL UNDISCOUNTED COSTS	$4,749,060	$4,749,060	$4,749,060	$4,749,060	$4,749,060
x DISCOUNT FACTOR	x 0.592	x 0.538	x 0.489	x 0.445	x 0.405
TOTAL DISCOUNTED COSTS	$2,811,443	$2,554,994	$2,322,290	$2,113,332	$1,923,369
CUMULATIVE DISCOUNTED COST	$9,312,906	$11,867,900	$14,190,190	$16,303,522	$18,226,891
PRESENT VALUE OF STATUS QUO					$18,226,891

Table XIX PRESENT VALUE OF REDESIGN - THREE YEAR LEAD TIME - YEAR ZERO TO YEAR FIVE

NET PRESENT VALUE ANALYSIS

ALTERNATIVE: REDESIGN - THREE YEAR LEAD TIME - YEAR ZERO TO YEAR FIVE

YEAR	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
One-time Cost:						
Purchase of Hardware	$259,785					
Recurring Costs:						
Vendor Hardware Support		$3,344	$3,344	$3,344	$3,344	$3,344
Vendor Systems S/W Support		$563	$563	$563	$563	$563
Software Development		$803,606	$803,606	$803,606		
Software Maintenance					$331,904	$282,119
Help Desk (4 persons)					$232,915	$232,915
CNRF Civilian Personnel					$307,000	$307,000
CNRF Computer Support		$102,000	$102,000	$102,000	$102,000	$102,000
Operations at CNRF					$60,000	$60,000
Supplies					$100,000	$100,000
Travel					$34,000	$34,000
TOTAL UNDISCOUNTED COSTS	$259,785	$909,513	$909,513	$909,513	$1,171,726	$1,121,941
x DISCOUNT FACTOR	x 1.000	x 0.954	x 0.867	x 0.788	x 0.717	x 0.652
TOTAL DISCOUNTED COST	$259,785	$867,675	$788,548	$716,696	$840,128	$731,505
CUMULATIVE DISCOUNTED COST	$259,785	$1,127460	$1,946,008	$2,632,704	$3,472,832	$4,204,337

Table XX PRESENT VALUE OF REDESIGN - THREE YEAR LEAD TIME - YEAR SIX TO YEAR TEN

NET PRESENT VALUE ANALYSIS

ALTERNATIVE: REDESIGN - THREE YEAR LEAD TIME - YEAR SIX TO YEAR TEN

YEAR	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
One-time Cost:					
Purchase of Hardware					
Recurring Costs:					
Vendor Hardware Support	$3,344	$3,344	$3,344	$3,344	$3,344
Vendor Systems S/W Support	$563	$563	$563	$563	$563
Software Development					
Software Maintenance	$243,979	$211,953	$202,927	$200,744	$196,231
Help Desk (4 persons)	$232,915	$232,915	$232,915	$232,915	$232,915
CNRF Civilian Personnel	$307,000	$307,000	$307,000	$307,000	$307,000
CNRF Computer Support	$102,000	$102,000	$102,000	$102,000	$102,000
Operations at CNRF	$60,000	$60,000	$60,000	$60,000	$60,000
Supplies	$100,000	$100,000	$100,000	$100,000	$100,000
Travel	$34,000	$34,000	$34,000	$34,000	$34,000
TOTAL UNDISCOUNTED COSTS	$1,083,801	$1,051,775	$1,042,750	$1,040,566	$1,036,053
x DISCOUNT FACTOR	x 0.592	x 0.538	x 0.489	x 0.445	x 0.405
TOTAL DISCOUNTED COST	$641,610	$565,855	$509,905	$463,052	$419,602
CUMULATIVE DISCOUNTED COST	$4,845,947	$5,411,802	$5,921,707	$6,384,759	$6,804,361
PRESENT VALUE OF REDESIGN					$6,804,361

D. SAVINGS/INVESTMENT RATIO

The SIR shows the "relationship between *future cost savings and the investment necessary to obtain those savings*" (Haga and Lang, 1991). Savings only accrue during the economic life of the project. Investment is normally made during the lead time period. In the case of RESFMS, savings begin to accrue in YEAR THREE (two year lead time) or YEAR FOUR (three year lead time) and continue to YEAR TEN. In each of these years, the current year value of the Redesign Alternative is subtracted from the current year value of Status Quo costs to determine annual savings. The appropriate discount factor from APPENDIX B is then applied to obtain the present values of annual savings. The present value of savings for each year in the economic life are summed to form the present value of total savings, PV_S.

In a similar manner, the current year costs of investments are totaled. Then the appropriate discount factor is applied to determine present value of each year of investment. The sum of all investment years produces the present value of total investment, PV_I. To determine the SIR, the following formula is used:

$$SIR = \frac{PV_S}{PV_I}$$

Tables XXI and XXII detail the computations for PV_S and PV_I; first, in the case of two year lead time, and then, for a three year lead time.

Table XXI PRESENT VALUE OF SAVINGS AND INVESTMENTS - TWO YEAR LEAD TIME

PRESENT VALUE OF SAVINGS - TWO YEAR LEAD TIME

YEAR	YEAR 3	YEAR 4	YEAR 5	YEAR 6
STATUS QUO Annual Costs	$4,749,060	$4,749,060	$4,749,060	$4,749,060
REDESIGN Annual Costs	$1,171,726	$1,121,941	$1,083,801	$1,051,775
ANNUAL SAVINGS	$3,577,333	$3,627,119	$3,665,259	$3,697,285
x DISCOUNT FACTOR	0.788	0.717	0.652	0.592
PV OF ANNUAL SAVINGS	$2,818,939	$2,600,644	$2,389,749	$2,188,793
CUMULATIVE PV OF SAVINGS	$2,818,939	$5,419,583	$7,809,332	$9,998,125

YEAR	YEAR 7	YEAR 8	YEAR 9	YEAR 10
STATUS QUO Annual Costs	$4,749,060	$4,749,060	$4,749,060	$4,749,060
REDESIGN Annual Costs	$1,042,750	$1,040,566	$1,036,053	$1,031,686
ANNUAL SAVINGS	$3,706,310	$3,708,494	$3,713,006	$3,717,374
x DISCOUNT FACTOR	0.538	0.489	0.445	0.405
PV OF ANNUAL SAVINGS	$1,993,995	$1,813,453	$1,652,288	$1,505,536
CUMULATIVE PV OF SAVINGS	$11,992,120	$13,805,573	$15,457,861	$16,963,397

PRESENT VALUE OF INVESTMENT - TWO YEAR LEAD TIME

YEAR	YEAR 0	YEAR 1	YEAR 2
ANNUAL INVESTMENT	$259,785	$1,311,316	$1,311,316
x DISCOUNT FACTOR	1.000	0.954	0.867
PV OF ANNUAL INVESTMENT	$259,785	$1,250,995	$1,136,911
CUMULATIVE PV OF INVESTMENT	$259,785	$1,510,780	$2,647,691

Table XXII PRESENT VALUE OF SAVINGS AND INVESTMENTS - THREE YEAR LEAD TIME

PRESENT VALUE OF SAVINGS - THREE YEAR LEAD TIME

YEAR	YEAR 4	YEAR 5	YEAR 6	YEAR 7
STATUS QUO Annual Costs	$4,749,060	$4,749,060	$4,749,060	$4,749,060
REDESIGN Annual Costs	$1,171,726	$1,121,941	$1,083,801	$1,051,775
ANNUAL SAVINGS	$3,577,333	$3,627,119	$3,665,259	$3,697,285
x DISCOUNT FACTOR	0.717	0.652	0.592	0.538
PV OF ANNUAL SAVINGS	$2,564,948	$2,364,882	$2,169,833	$1,989,139
CUMULATIVE PV OF SAVINGS	$2,564,948	$4,929,830	$7,099,663	$9,088,802

YEAR	YEAR 8	YEAR 9	YEAR 10
STATUS QUO Annual Costs	$4,749,060	$4,749,060	$4,749,060
REDESIGN Annual Costs	$1,042,750	$1,040,566	$1,036,053
ANNUAL SAVINGS	$3,706,310	$3,708,494	$3,713,006
x DISCOUNT FACTOR	0.489	0.445	0.405
PV OF ANNUAL SAVINGS	$1,812,386	$1,650,280	$1,503,768
CUMULATIVE PV OF SAVINGS	$10,901,188	$12,551,468	$14,055,236

PRESENT VALUE OF INVESTMENT - THREE YEAR LEAD TIME

YEAR	YEAR 0	YEAR 1	YEAR 2	YEAR 3
ANNUAL INVESTMENT	$259,785	$909,513	$909,513	$909,513
x DISCOUNT FACTOR	1.000	0.954	0.867	0.788
PV OF ANNUAL INVESTMENT	$259,785	$867,675	$788,548	$716,696
CUMULATIVE PV OF INVESTMENT	$259,785	$1,127,460	$1,916,008	$2,632,704

The resulting values for PV_S and PV_I are then used to compute the SIR. Thus the SIR computation for the two year lead time situation is as follows:

$$SIR_2 = \frac{PV_S}{PV_I} = \frac{\$16{,}963{,}397}{\$2{,}647{,}691} = 6.407$$

The SIR computation for the three year lead time situation is as follows:

$$SIR_3 = \frac{PV_S}{PV_I} = \frac{\$14{,}055{,}236}{\$2{,}632{,}704} = 5.339$$

E. DISCOUNTED PAYBACK ANALYSIS

In order to compute discounted payback (PB), the present value of investment and an annual savings figure are required. In many cases the annual savings figure is constant throughout the economic life. However, in the case of RESFMS, the annual savings figure increases, in constant year dollars, each successive year of economic life. Therefore, for this analysis the savings from the first year of economic life will be used, since the first year of savings will be the lowest annual amount and thus yield the worst case value of the payback factor.

To determine discounted payback, the present value of investment, PV_I, is divided by the annual savings in constant year dollars. To this result is added the cumulative discount factor from APPENDIX B, Table B for the number of years of lead time.

When the final value obtained is compared with APPENDIX B, Table B cumulative discount factors, the year in which payback occurs can be determined.

For RESFMS, payback was calculated for both two and three year lead time. In the case of two year lead time, the cumulative factor is computed as follows:

$$\frac{PV_I}{\text{Annual Savings for YEAR 3}} = \frac{\$2,647,691}{\$3,577,333} = 0.740$$

This value is then adjusted for lead time by adding the cumulative factor from APPENDIX B for two years.

$$0.740 + 1.821 = 2.561$$

Comparison with APPENDIX B, Table B shows that 2.561 falls between the YEAR TWO cumulative value of 1.821 and the YEAR THREE cumulative value of 2.609. This means that payback occurs within YEAR THREE, or before the end of the first year of economic life.

In the case of three year lead time, the cumulative factor is computed:

$$\frac{PV_I}{\text{Annual Savings for YEAR 4}} = \frac{\$2,632,704}{\$3,577,333} = 0.736$$

This value is then adjust for lead time by adding the cumulative factor from APPENDIX B, Table B for three years.

$$0.736 + 2.609 = 3.345$$

Comparison with APPENDIX B, Table B indicates that 3.345 falls between the YEAR FOUR cumulative value of 3.326 and the YEAR FIVE cumulative value of 3.977. Thus payback occurs shortly after the beginning of YEAR FOUR, or in the second year of economic life.

F. RISK ANALYSIS

In order to assess the amount of risk involved in this economic analysis, and to determine most probable outcomes, a *financial simulation* was conducted using @RISK. @RISK is a risk analysis and modeling tool, produced by *Palisade Corporation*, Newfield, N.Y.[10] It functions as an add-in program to Lotus 1-2-3[11].

Using a Monte Carlo type simulation, an analysis tool such as @RISK can allow decision makers to determine relative interaction between variables, and possible ranges of values that may be expected from project execution. Probability of positive outcomes may also be determined.

In the case of RESFMS, four types of values were varied for purposes of the simulation. In the Status Quo alternative, Software Maintenance and NIF Charges to NCTS were both varied using a Triangular distribution as shown in Table XXIII.

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[10]The particular version of @RISK used for this simulation was the Student Edition of @RISK, Version 1.55, distributed by Addison-Wesley Publishing Company, Inc.

[11]Lotus 1-2-3 is a registered trademark of Lotus Development Corporation.

Table XXIII STATUS QUO VARIABLE COSTS

Variable Cost:	High	Low	Most Probable
Software Maintenance	$1,608,000	$524,124	$1,050,000
NIF Charges to NCTS	$3,514,000	$2,841,000	$3,040,000

In the Redesign alternative, development effort in Man-Months, and annual maintenance FSP were varied using a Normal distribution. An examination of software maintenance FSP projections shows that, even though the estimates vary widely between REVIC and SASET outputs, the values are always higher in the early years and taper off as project life progresses. To insure this relationship was consistently portrayed in the simulation, the first year FSP value was made an *Independent* variable and all subsequent years of maintenance effort were made *Dependent* variables. Although all years of maintenance effort varied individually, the trend of the *Independent* variable was used to determine the trend of the *Dependent* variables. For instance, if the value for the first year of maintenance, in any single iteration of the simulation, was below the mean, then values for subsequent years of maintenance would be chosen from below the mean. This assured the proper cost trends would be simulated. Table XXIV below lists variables in the redesign alternative and values used for simulation.

Monte Carlo type simulation was done using 4,000 iterations for the two year lead time scenario. Due to computer time constraints, a simulation using 1,000 iterations was done for the three year lead time scenario. Results of the simulation were calculated for

Table XXIV REDESIGN ALTERNATIVE VARIABLES

Variable Value	Mean	Standard Deviation
Man-Months of Development	496.83	135.46
Year 1 FSP	5.7000	3.32902
Year 2 FSP	4.8450	2.99255
Year 3 FSP	4.1900	2.73016
Year 4 FSP	3.6400	2.42592
Year 5 FSP	3.4850	2.58747
Year 6 FSP	3.4475	2.62723
Year 7 FSP	3.3700	2.70966
Year 8 FSP	3.2950	2.78980

Man-Months of Development Effort, Present Value (PV) of Savings, Savings/Investment Ratio (SIR), and Discounted Payback Factor (PB).

Results of the simulations in the form of histograms and associated statistics are displayed on the following pages. The distribution of values and probabilities for Man-Months of Development is identical for both two year and three year lead time. The resulting cost is simply distributed evenly over the number of years of lead time. Therefore, the distribution for Man-Months of Effort is only displayed once, in Figure 3 and Table XXV. The results for the the two year lead time scenario follow. PV of Savings is displayed in Figure 4 and Table XXVI, SIR in Figure 5 and Table XXVII, and PB in Figure 6 and Table XXVIII. Then the results of the three year lead time are displayed. PV of Savings is displayed in Figure 7 and Table XXIX, SIR in Figure 8 and Table XXX, and PB in Figure 9 and Table XXXI.

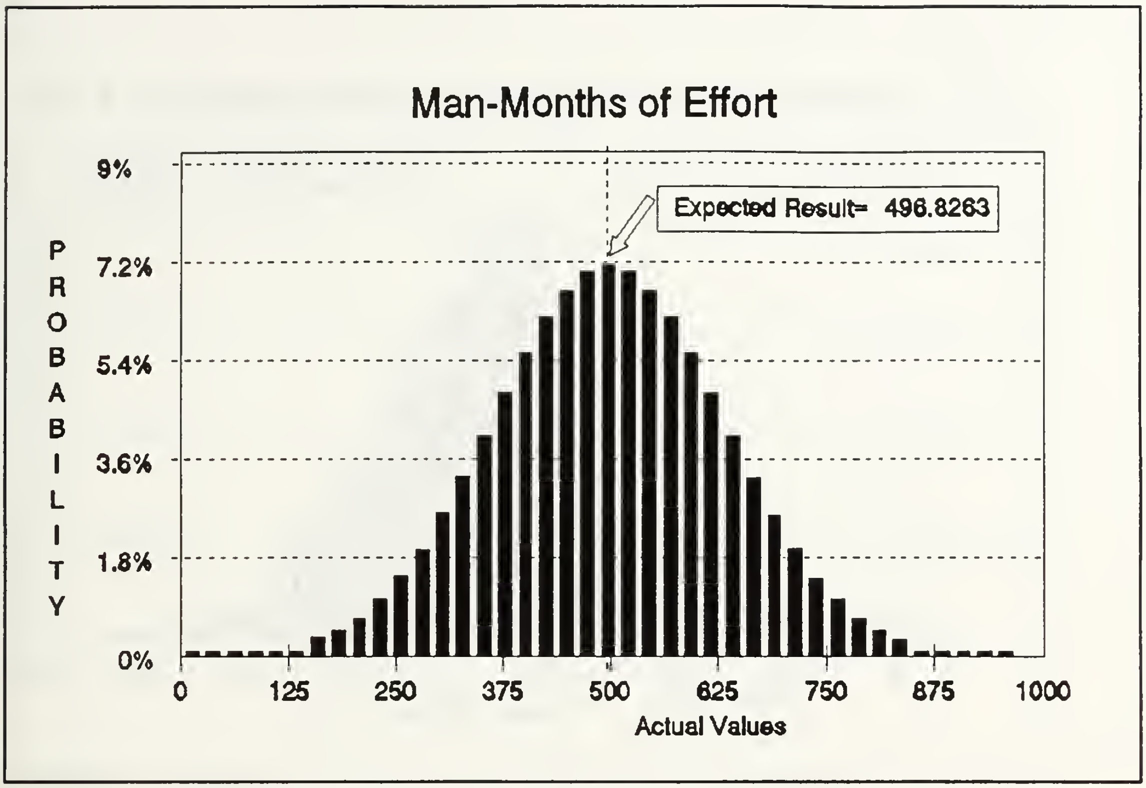

Figure 3 Man-Months of Effort for RESFMS Software Redesign

Table XXV RISK ANALYSIS STATISTICS FOR MAN-MONTHS OF EFFORT

Expected/Mean Result	= 496.8263
Maximum Result	= 968.7614
Minimum Result	= 1.12505
Range of Possible Results	= 967.6363
Standard Deviation	= 135.4097
Iterations	= 4000

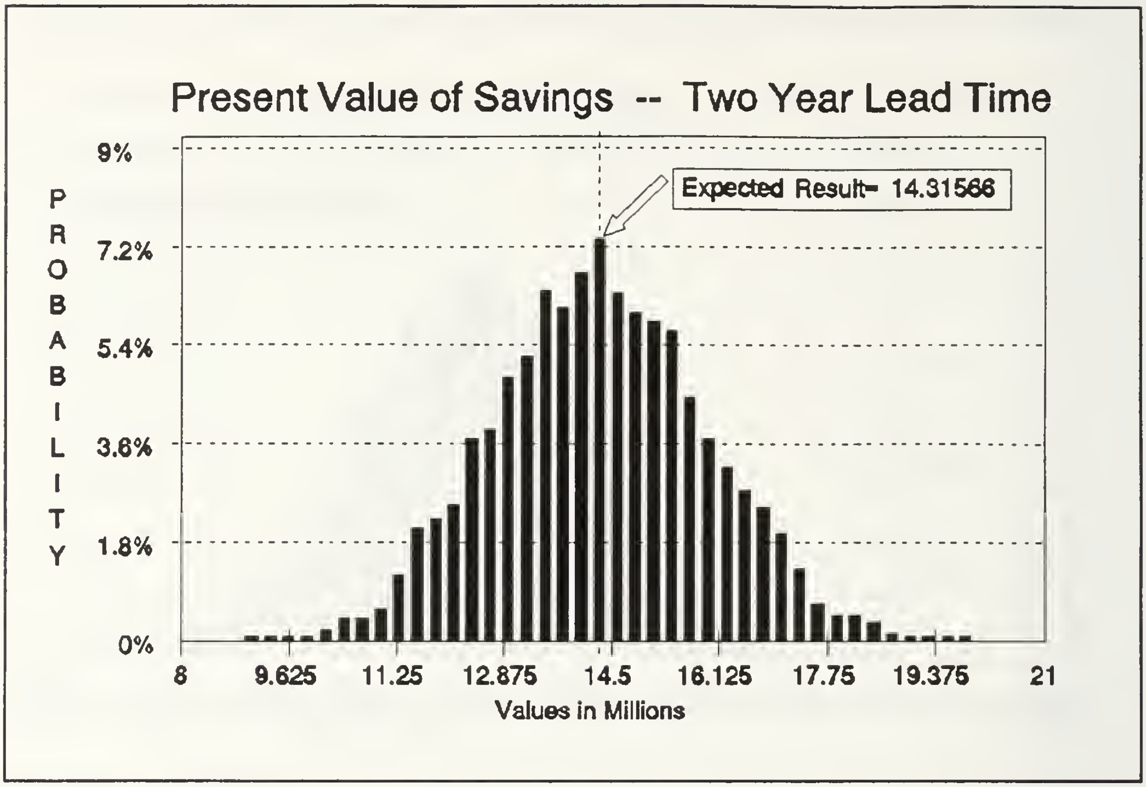

Figure 4 Present Value of Savings - Two Year Lead Time

Table XXVI RISK ANALYSIS STATISTICS FOR PRESENT VALUE OF SAVINGS -- TWO YEAR LEAD TIME

Expected/Mean Result	= 14,315,660
Maximum Result	= 19,968,080
Minimum Result	= 8,915,915
Range of Possible Results	= 11,052,170
Probability of Positive Result	= 100%
Probability of Negative Result	= 0%
Standard Deviation	= 1,637,532
Iterations	= 4,000

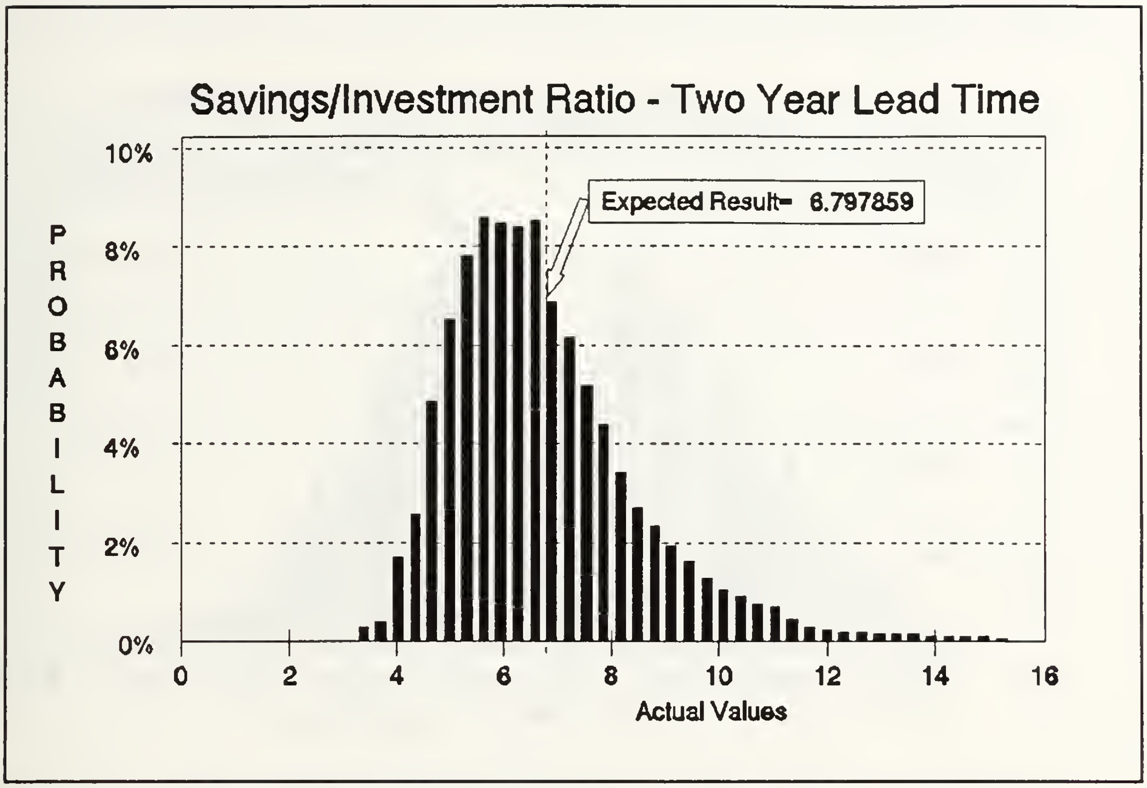

Figure 5 Savings/Investment Ratio - Two Year Lead Time

Table XXVII RISK ANALYSIS STATISTICS FOR SAVINGS/INVESTMENT RATIO -- TWO YEAR LEAD TIME

Expected/Mean Result	= 6.797859
Maximum Result	= 39.27233
Minimum Result	= 3.214479
Range of Possible Results	= 36.05785
Probability of Positive Result	= 100%
Probability of Negative Result	= 0%
Standard Deviation	= 2.008756
Iterations	= 4,000

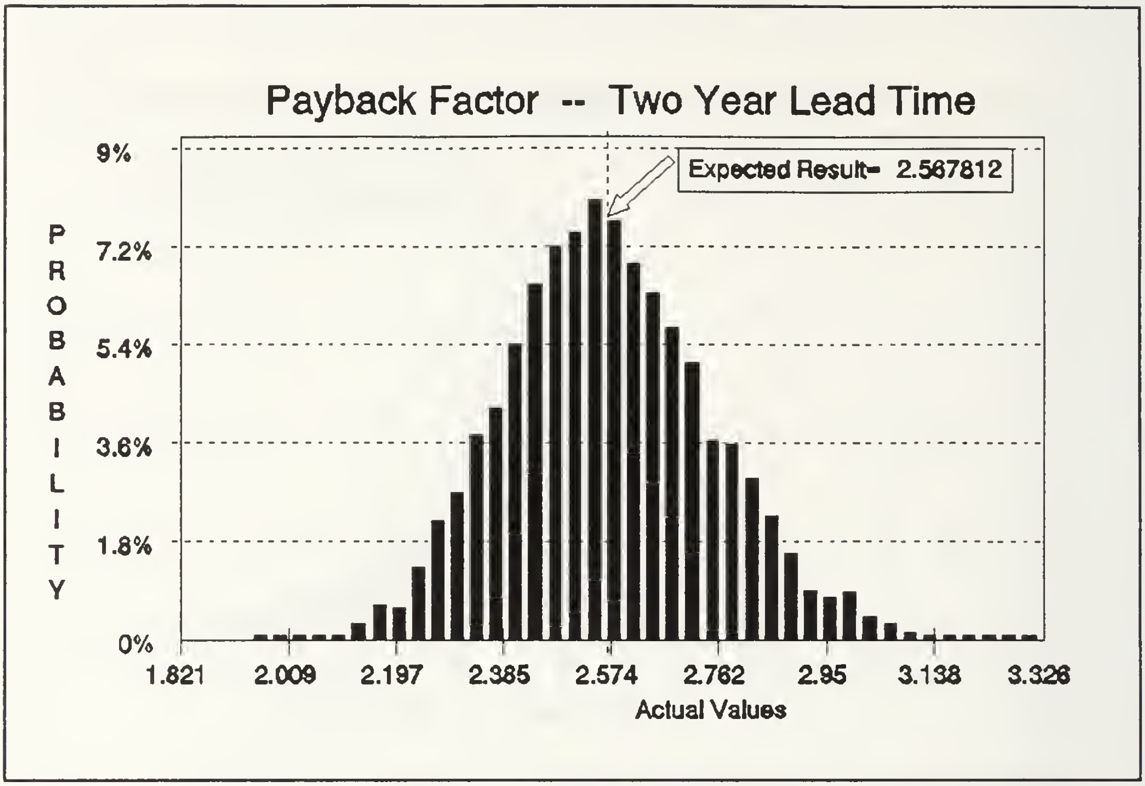

Figure 6 Discounted Payback Factor - Two Year Lead Time

Table XXVIII RISK ANALYSIS STATISTICS FOR DISCOUNTED PAYBACK FACTOR -- TWO YEAR LEAD TIME

Expected/Mean Result	= 2.567812
Maximum Result	= 3.318428
Minimum Result	= 1.941221
Range of Possible Results	= 1.377207
Probability of Positive Result	= 100%
Probability of Negative Result	= 0%
Standard Deviation	= 0.1837197
Iterations	= 4,000

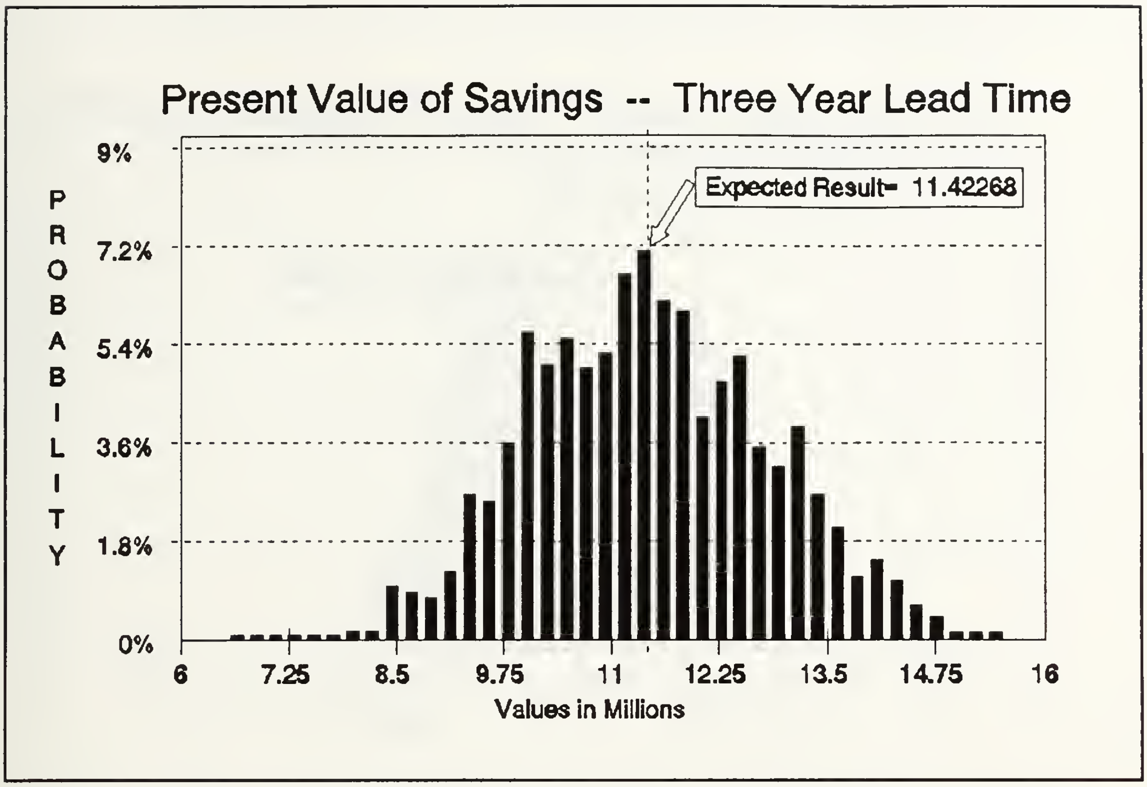

Figure 7 Present Value of Savings - Three Year Lead Time

Table XXIX RISK ANALYSIS STATISTICS FOR PRESENT VALUE OF SAVINGS -- THREE YEAR LEAD TIME

Expected/Mean Result	= 11,422,680
Maximum Result	= 15,543,950
Minimum Result	= 6,527,336
Range of Possible Results	= 9,016,610
Probability of Positive Result	= 100%
Probability of Negative Result	= 0%
Standard Deviation	= 1,407,193
Iterations	= 1,000

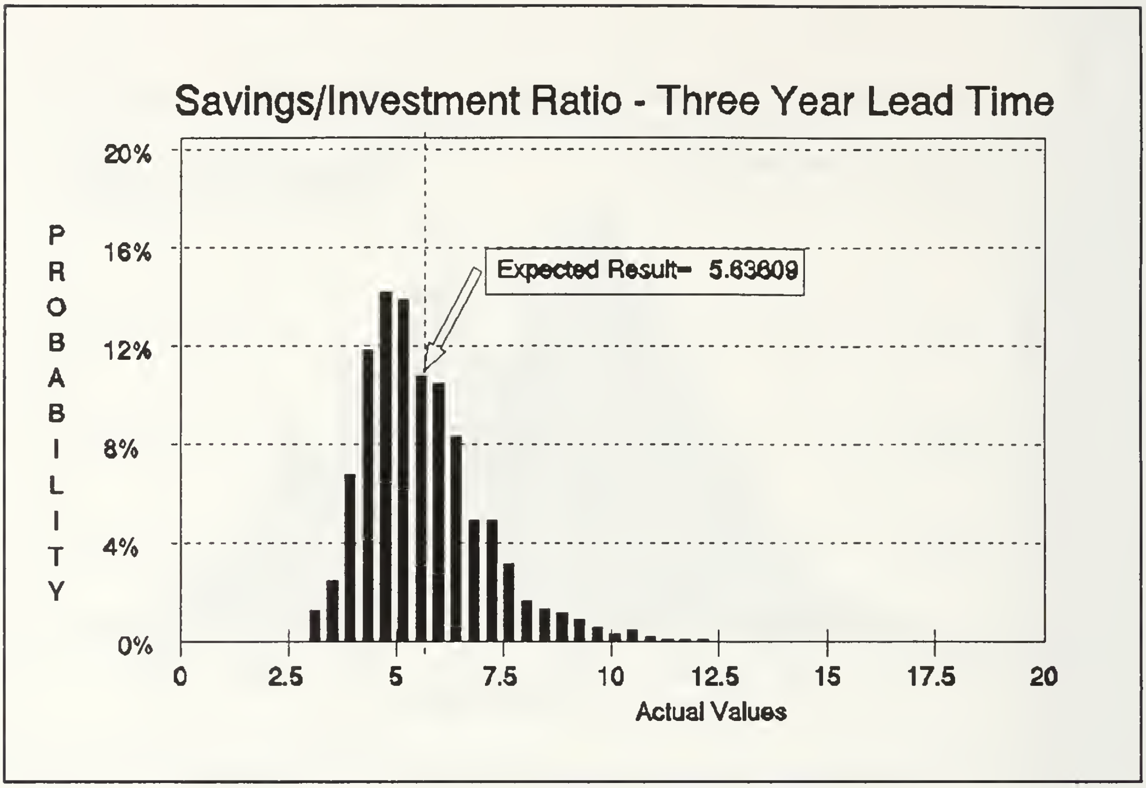

Figure 8 Savings/Investment Ratio - Three Year Lead Time

Table XXX RISK ANALYSIS STATISTICS FOR SAVINGS/INVESTMENT RATIO -- THREE YEAR LEAD TIME

Expected/Mean Result	= 5.63609
Maximum Result	= 19.34061
Minimum Result	= 2.862788
Range of Possible Results	= 16.47782
Probability of Positive Result	= 100%
Probability of Negative Result	= 0%
Standard Deviation	= 1.567336
Iterations	= 1,000

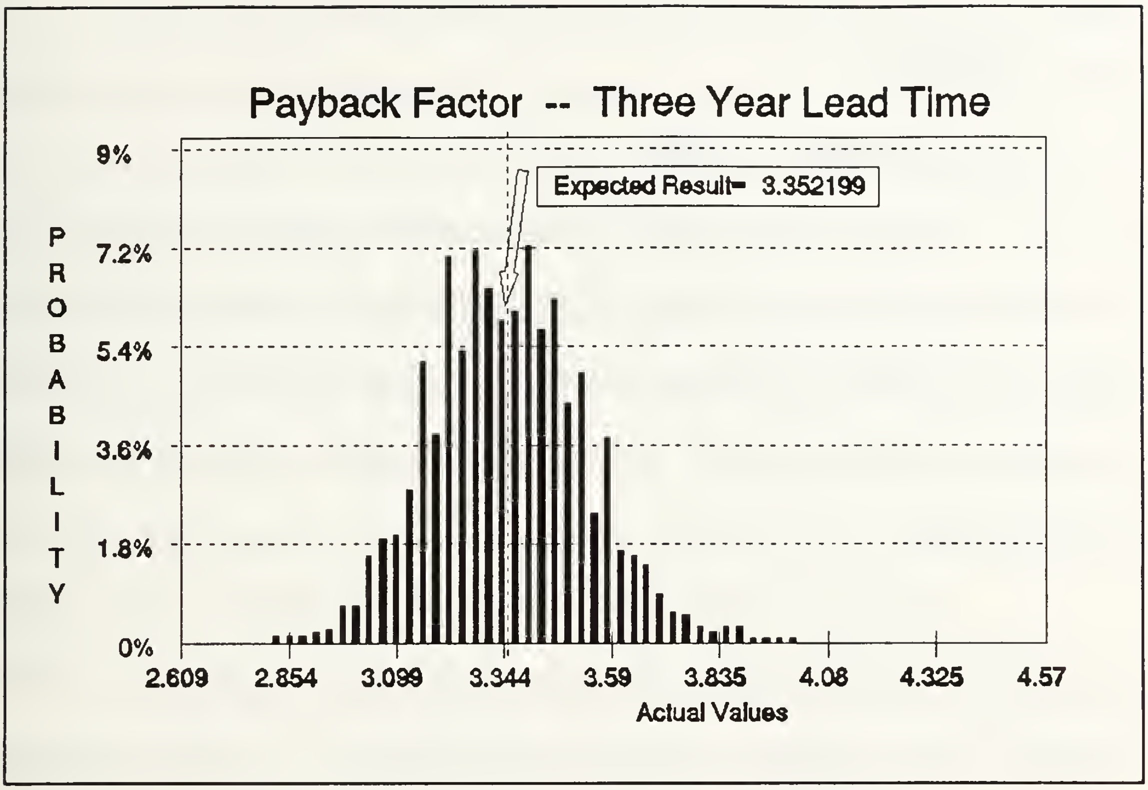

Figure 9 Discounted Payback Factor - Three Year Lead Time

Table XXXI RISK ANALYSIS STATISTICS FOR DISCOUNTED PAYBACK FACTOR -- THREE YEAR LEAD TIME

Expected/Mean Result	= 3.352199
Maximum Result	= 4.01652
Minimum Result	= 2.808435
Range of Possible Results	= 1.208085
Probability of Positive Result	= 100%
Probability of Negative Result	= 0%
Standard Deviation	= 0.1789016
Iterations	= 1,000

G. FINDINGS

1. Comparison of results

In the economic analysis using expected values of variables, all three economic analysis tools used produced results favoring the redesign alternative. Using Net Present Value analysis, present value of the savings were positive. The three year lead time yielded the lower value, which was still in excess of $11 million over the life of the project.

A SIR greater than 1.0 should be obtained before a project should be considered economically sound (Haga and Lang, 1991). In the case of RESFMS, expected value computations indicate a SIR of 5.339 for the three year lead time alternative, and 6.407 if development is completed in two years.

Discounted payback analysis shows that payback is expected to occur within the first two years of economic life. For the two year lead time scenario, payback was within the first year of economic life. In the three year scenario, payback is expected to occur soon after the beginning of the second year of economic life. This is a short payback period and indicates a strong economic investment.

2. Risk Analysis

Examination of histograms and related statistics for financial simulation performed for the RESFMS project supports the positive results of expected value computations discussed above.

In simulation of both two and three year lead time scenarios, PV of savings remained positive for all iterations of the simulation. Probability of a positive result was 100% for both scenarios. The minimum result obtained by simulation was $6,527,336, calculated in the three year lead time scenario. Examining the histograms, we find the cumulative probability for a PV of savings value greater than $11 million is more than 90% for the two year lead time and about 60% for the three year lead time. Therefore, regardless of lead time scenario chosen, PV of savings can be expected to be no less than $6.5 million and there is more than a 60% percent chance that it will be greater than $11 million.

Worst case for SIR in the simulations still shows a ratio of 2.86 in the three year lead time scenario. Probabilities indicate that a value above 5.0 is much more likely. Thus, even in the worst case, SIR would indicate the redesign alternative is an economically sound project to pursue.

Simulation results for discounted payback analysis show that payback will probably occur within two years of project implementation regardless of whether lead time is two or three years. The worst case found in the simulations was a value of 4.016 in the three year lead time scenario. Even this very low probability result would have payback occur within the third year after the beginning of economic life. Since economic life is expected to last seven years in the three year lead time scenario, savings beyond the value of initial investment would still accrue for at least three years more.

Therefore, risk analysis shows no probability of negative values, given the range of values and assumptions made in this analysis. I have endeavored to accurately portray ranges of possible values, to include all possible costs, and to completely quantify significant economic risk. As a result, I believe the risk analysis simulations performed are a reliable indicator of potential outcomes.

3. Patterns Discerned

All results obtained were positive. There were no negative results. Even the worst case results of simulations show PV of savings, SIR, and payback periods well within acceptable ranges for project approval. All these results affirm the economic prudence of pursuing the redesign of RESFMS. Baring unforseen technical problems that significantly alter development effort estimates, RESFMS redesign should be economically successful.

VIII. RECOMMENDATION

A. RESULTS OF ECONOMIC ANALYSIS

The results of all economic analyses indicate a favorable economic outcome if the RESFMS redesign is implemented. All factors considered in this analysis favor the redesign over the status quo. A preliminary technical analysis reveals no significant areas of concern, involving hardware, resulting from the move of RESFMS from a mainframe environment to a minicomputer. The primary expense, and greatest effort required, will come from rewriting software code. In spite of the difficulty encountered in deriving an estimate of the cost of software development, I believe that a reasonable range of potential values was produced and adequate risk analysis performed to ensure that potential costs were reliably represented.

Since the results of all tools used and of all simulations performed strongly indicate the economic soundness of the redesign alternative, I recommend that the redesign of RESFMS to operate in the configuration described in this analysis be approved and initiated. It is significant to note that greater savings, higher SIR, and shorter payback were all predicted for the two year lead time than for the three year lead time scenario. Actual schedule duration for the redesign development effort will be determined by the level of funding made available for the project. If funding is low and spread out over several years, fewer programmers will be assigned and project development will be delayed. Although this analysis indicates that positive results will still be achieved, those results will be less than can be obtained if wholehearted approval is given and adequate resources are allocated to allow a short development time.

B. OTHER CONSIDERATIONS

Even though the redesign of RESFMS would mean significant savings to the Naval Reserve, there are two factors which may prevent the development effort from being approved. First, monies to operate systems and monies to develop systems do not necessarily come from the same appropriation. Also, there are very specific approval procedures required for development efforts that do not apply to currently operating systems. In particular, the nearly $300,000 required to purchase two 3B2/GR minicomputers would necessarily come from the Other Procurement Navy (OPN) appropriation and would require special approval before it could be spent (Practical Comptrollership, 1992). Also, if the cost of software development is not competitively bid and exceeds $250,000, or is competitively bid and exceeds $2.5 million, an Agency Procurement Request must be sent to GSA for approval (GSA Overview Guide, January 1990). These additional requirements and constraints might cause approval to be delayed, or the project to be canceled as the Naval Reserve competes with other DoD agencies for Information System development and acquisition funds. COMNAVRESFOR personnel must effectively communicate the significant savings that a redesigned RESFMS can produce and as a result obtain funding and approval required to continue.

The second consideration is that, although moving RESFMS to minicomputers controlled by COMNAVRESFOR may produce great savings for the Naval Reserve, it may not necessarily save the Department of the Navy anything at all. In fact, depending on what NCTS does in response, it may actually cost DoN more than the status quo. This is due to the fact that NCTS is a Navy owned and operated organization. Thus, NCTS funding comes from DoN budgets just as COMNAVRESFOR funding does. If NCTS is charging COMNAVRESFOR based on actual costs of maintaining their facility, and if no replacement customers are found when COMNAVRESFOR moves, these overhead costs may still be incurred by the Navy as a whole but no longer charged to the Naval Reserve. Of course, a reasonable person would conclude that if NCTS is not providing cost effective service then the Navy should reconsider its support. In any case, the actions of NCTS are beyond the scope of this analysis. What is clear from this analysis is that the Naval Reserve can save significant amounts of future operating expense if RESFMS is redesigned. If all Navy activities pursued projects that resulted in operating expense savings, the Navy as a whole would have to benefit. Therefore, the redesign of RESFMS should be evaluated on its own merits and a development decision should not be affected by short term effects on other service agencies.

C. CONCLUSION

This economic analysis indicates that a clear economic advantage to the Naval Reserve will result from a redesign of RESFMS. It logically follows that the Department of the Navy will ultimately benefit from reduced cost in funding the Naval Reserve. To gain maximum savings, adequate resources should be allocated to develop the new system in minimum time. Therefore, the Naval Reserve should pursue a redevelopment effort and DoN fully support the effort to allow early realization of projected savings.

APPENDIX A

ACRONYMNS AND ABBREVIATIONS

ADSR	Automated Data Service Request
ADPE	Automated Data Processing Equipment
ADT	Active Duty Training
AIS	Automated Information System
AT	Annual Training
BCR	Benefit/Cost Ratio
BE	Break Even
bps	bits per second
CASE	Computer Aided Software Engineering
CERPS	Centralized Expenditure Register Processing System
CINCLANTFLEET	Commander in Chief, U.S. Atlantic Fleet
COMNAVRESFOR	Commander Naval Reserve Force
CNRF	Commander Naval Reserve Force
CNRF Code 02	Commander Naval Reserve Force Director of Finance
CNRF Code 06	Commander Naval Reserve Force Director of Manpower and Personnel
CNRF Code 10	Commander Naval Reserve Force Director of Information Systems

CPU	Central Processing Unit
DBOF	Defense Business Operating Fund
DDI	Director of Defense Information
DDN	Defense Data Network
DoD	Department of Defense
DODD	Department of Defense Directive (same as Instruction)
DODI	Department of Defense Instruction (same as Directive)
DoN	Department of the Navy
DI	Degree of Influence
DSI	Delivered Source Instructions
FC	Unadjusted Function Point Count
FIP	Federal Information Processing
FIPC	Financial Information Processing Center
FIRMR	Federal Information Resources Management Regulation (published by U.S. General Services Administration)
FM	Financial Management
FP	Function Point(s)
FSP	Full-time Software Person
FY	Fiscal Year
GAO	General Accounting Office
GB	Gigabytes
GC	General Characteristics

GCA	General Characteristics Adjustment
GTS	Government Travel System
GSA	U.S. General Services Administration
GTR	Government Transportation Request
HASC	U.S. House of Representatives Committee on Armed Services (House Armed Services Committee)
HSETC	Health Science Education Training Command
IDTT	Inactive Duty Training Travel
IFPUG	International Function Point User Group
IMAPMIS	Inactive Manpower and Personnel Management Information System
I/O	Input/Output
IR	Information Resources
IRM	Information Resources Management
IRMC	Information Resources Management College (within National Defense University)
IRR	Individual Ready Reserve
IT	Information Technology
KDSI	Thousands of Delivered Source Instructions
KLOC	Thousands of Lines of Code
LCM	Life-Cycle Management
LAN	Local Area Network

LOC	Lines of Code
MAC	Military Airlift Command
MB	Megabytes
Mbps	Megabits per second
MCPS	Microcomputer Claims Processing System
MIPS	Millions of Instructions Per Second
MM	Man-month (of effort)
MNS	Mission Needs Statement
MPT	Manpower Personnel and Training
NARDAC	Navy Regional Data Automation Center (now called NCTS)
NAVPTO	Navy Passenger Transportation Office
NCTS	Navy Computer and Telecommunication Station (formerly NARDAC)
NIF	Navy Industrial Fund
NRPC	Naval Reserve Personnel Center
OMB	Office of Management and Budget
OPTAR	Operating Target (for budget expeditures)
PM	Program Manager
PTSR	Problem Tracking System Report
PB	Discounted Payback Period
PV	Net Present Value Analysis
R&D	Research and Development

RAM	Random Access Memory
RESCOMMIS	Reserve Command Management Information Strategy
RISC	Reduced Instruction Set Computing
RTS	Request for Transportation Services
RHS	Reserve Headquarters System
RPN	Reserve Personnel Navy (Congressional appropriation)
RSTARS	Reserve Standard Training Administration and Readiness Support
RTSS	Reserve Training Support System
SASET	Software Architecture, Sizing, and Estimating Tool
SATO	Scheduled Airline Ticket Office
SELRES	Selected Reservists
SEI	Software Engineering Institue, Carnegie Mellon University
SEMA	Systems Engineering and Management Associates, Inc.
SIR	Savings/Investment Ratio
SPA	Software Process Assessment (performed by SEI)
TCP/IP	Transmit Control Protocol/Internet Protocol
UAC	Uniform Annual Cost
UCA	Uniform Chart of Accounts

APPENDIX B

PROJECT YEAR DISCOUNT FACTORS

Year	Table A PRESENT VALUE OF $1 (Single Amount used when cash flows accrue in varying amounts each year).	Table B PRESENT VALUE OF $1 (Cumulative Uniform Series to be used when cash flows accrue in the *same* amount each year).
1	0.954	0.954
2	0.867	1.821
3	0.788	2.609
4	0.717	3.326
5	0.652	3.977
6	0.592	4.570
7	0.538	5.108
8	0.489	5.597
9	0.445	6.042
10	0.405	6.447
11	0.368	6.815
12	0.334	7.149
13	0.304	7.453
14	0.276	7.729
15	0.251	7.980
16	0.228	8.209
17	0.208	8.416
18	0.189	8.605
19	0.172	8.777
20	0.156	8.933
21	0.142	9.074
22	0.129	9.203
23	0.117	9.320
24	0.107	9.427
25	0.097	9.524

NOTE: Table B factors represent the cumulative sum of Table A factors through any given project year.

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