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AN ANALYSIS OF THE AIRCRAFT ENGINE
COMPONENT IMPROVEMENT PROGRAM (CIP):
A LIFE CYCLE COST APPROACH

by

Chris J. Borer

December 1990

Thesis Advisor: Thomas P. Moore

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Increasing budgetary constraints have prompted actions to reduce the maintenance cost of current naval aircraft. This thesis examines the Aircraft Engine Component Improvement Program (CIP), its impact on these cost at the organizational and intermediate levels of maintenance, and savings from these improvements. The objectives of the research were to identify current life cycle cost (LCC) models used by the Navy and/or the other services to determine CIP benefits, to validate on-going LCC-oriented computer program. This thesis is organized into areas covering CIP objectives and considerations, system effectiveness, reliability, LCC and related data and models, aircraft data used for LCC, CIP/LCC computer models, return on investment (ROI) analysis program of the F-14A TF30-P-414A engine improvement, conclusions and recommendations. Based on the ROI analysis and ECIFR reports, the engine improvement program has been cost effective.

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AN ANALYSIS OF THE AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM (CIP): A LIFE CYCLE COST APPROACH

by

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Submitted in partial fulfillment
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ABSTRACT

Increasing budgetary constraints have prompted actions to reduce the maintenance cost of current naval aircraft. This thesis examines the Aircraft Engine Component Improvement Program (CIP), its impact on these costs at the organizational and intermediate levels of maintenance, and savings from these improvements. The objectives of the research were to identify current life cycle cost (LCC) models used by the Navy and/or the other services to determine CIP benefits, to validate on-going LCC-oriented computer programs, and to provide the basis for development of an improved LCC-oriented computer program. This thesis is organized into areas covering CIP objectives and considerations, system effectiveness, reliability, LCC and related data and models, aircraft data used for LCC, CIP/LCC computer models, return on investment (ROI) analysis program of the F-14A TF30-P-414A engine improvement, conclusions and recommendations. Based on the ROI analysis and ECIFR reports, the engine improvement program has been cost effective.

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I. INTRODUCTION

Following a period of exceptional growth in the 1980's, the Department of Defense (DOD) budget is confronted with Congressional reductions, deficit control measures, and the Persian Gulf Crisis. These factors are forcing DOD organizations to face the possibility of an extended period of severe financial constraints and budgetary uncertainty.

The Department of Defense has historically been concerned about implementing cost-effective systems and equipment at the operational force level. As a result, DOD wrote the *Reliability and Maintainability* Directive [Ref. 1].

This directive emphasizes the following fundamental objectives of reliability and maintainability improvement:

- Increase operational reliability and maintainability.
- Reduce maintenance and logistic support cost.
- Minimize acquisition cost and schedule of systems, subsystems and equipment.
- Minimize recurrence of failures and maintenance or repair difficulties.

The main principle of this directive translates into the maximization of return on investments in reliability and maintainability improvements. The emphasis of this directive is to be achieved through reliability and maintainability engineering. Reliability engineering concentrates on prevention, detection and correction of design deficiencies, weak parts, and workmanship defects. Maintainability engineering reduces maintenance and repair times, number of tasks required for each preventive and corrective maintenance action, and the need for special tools and test equipment.

One way to increase aircraft weapon systems reliability and maintainability is to solve and prevent flight safety, operating, and support cost problems of aircraft engines. Aircraft engines are expensive and consist of complex assemblies and components such as the starter, compressor, turbine, fuel system, electrical system, and transmission. Congress has placed increasing emphasis on acquisition strategies and cost considerations in the development, procurement and improvement programs of aircraft engines in the 1970's. This congressional interest in aircraft engines and aircraft engine component improvement programs (CIP) was stressed during FY81 RDT&E budget programming and reprogramming hearings.

An example of congressional interest in aircraft engines and CIP is apparent in the following statement of *Robert A. Moore, Deputy Under Secretary for Tactical Warfare Programs, Department of Defense*, before the House Armed Services Committee, February 1980:

> Let me discuss briefly the overall objectives of our engine program plan and emphasize that almost every aspect of this program, certainly the key aspects of the program, are joint service in nature. There are three primary objectives. First of all, we must solve the existing problems that we have with operational aircraft and engines, the F100 and TF30 problems, and place great emphasis on the component improvement programs directed toward resolving the serious operational problems we have had with both the F-15 and F-14 engine. The second element of the program, which is also important, is to maintain a viable alternative to the F100 engine, as you know, in the F-15 and F-16 aircraft as well as an alternative to the TF30 engine in the F-14, should the component improvement programs for both those engines not succeed. For this alternative, of course, we are pursuing the F101X or the renamed F101 derivative fighter engine activity. The third major element of the program is directed toward the next generation engine.... [Ref. 2]

A. THESIS OBJECTIVES

The objectives of this thesis are:

- To examine the methods and associated costs of the aircraft engine component improvement program in order to assess the program's net savings and benefits.
- To show the relationship between the aircraft engine component improvement program (CIP), reliability, maintainability and maintenance support cost for the aircraft to be studied (F-14A, A-7E, P-3C, A-6E, S-3A, EA-6B, E-2C, and KC-130F).
- To acquire information about life cycle analysis and life cycle costing methods being currently used by the military services.
- To apply life cycle costing methods or return on investment to estimate F-14A TF30 engine CIP benefits.

The thesis format will be in the following chapter layout. Chapter 1 contains an introduction to CIP, its functions, funding, and evaluation process. Chapter 2 contains background information on CIP concepts, such as system effectiveness, reliability and maintainability, life cycle costing, and aircraft subsystem life cycle cost. Chapter 3 describes the economic analysis process and life cycle cost models. Chapter 4 contains a cost benefit analysis of CIP on a selected aircraft engine, using the AIR-536 ROI analysis computer program, and a description of aircraft and engine research data acquired. Chapter 5 contains the author's conclusions and recommendations. The appendix contain aircraft statistical data, engine operating and cost data, life cycle cost algorithms, and analysis printouts.

B. TRI-SERVICE AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM

All major weapon systems require continued engineering support following full scale development, especially complicated systems such as aircraft engines. Once an aircraft is deployed, any necessary change or modification is often expensive.

Expenses also increase with the age of the engine. For example, the J52 and T58 are operational engines designed and developed over three decades ago.

To cope with engine problems, the Joint Services (Army, Air Force, and Navy) developed the Tri-Service Aircraft Engine Component Improvement Program. This tri-service program is jointly funded and managed. This management program helps to eliminate duplication of effort, and provides a larger base of experience than that available from only one service. The services' objectives of CIP are to provide engineering support and testing to:

- Identify and correct engine safety problems in a timely manner.
- Identify and resolve engine deficiencies.
- Reduce engine life cycle cost by improving reliability, durability, maintainability, and producibility.
- Maintain or extend the service life limits of the engine.

C. NAVY'S AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM

The Navy developed the CIP concept in the early 1950's to enhance readiness and reduce life-cycle cost for its aircraft propulsion systems and related components. In 1980, to comply with DOD Directive 5000.40, the Navy wrote the NAVAIR Instruction 5200.35, *Policy, Guidelines and Responsibilities for the Administration of the Aircraft Engine CIP* [Ref. 3].

The NAVAIR division responsible for coordination, funding, and technical management of the Navy's aircraft propulsion[1] and power equipment is the Propulsion and Power Division (AIR-536). The NAVAIR division which assesses CIP for the logistic support impact of proposed engineering changes and makes

[1]Aircraft propulsion components include: aircraft engines, transmissions, starters, generators, propellers, auxiliary power units (APU), electrical and fuel systems. NAVAIR Instruction 5400.1 lists the aircraft propulsion systems and related components that AIR-536 is responsible for.

adjustments to the maintenance plan or integrated logistic support program is AIR-411.

The Propulsion and Power Division's organizational chart is shown in Figure 1. As depicted in Figure 1, AIR-536 project engineers are responsible for certain propulsion components and separated into four branches: Tactical Air Engines, Special Purpose Engines, Integration and Power Systems, and Engineering and Acquisition Support. Each project engineer is responsible for the evaluation of proposals and the allocation of competitive funding for CIP and to meet the following CIP objectives:

- Maintain an engine design which allows the maximum aircraft availability at the lowest total cost to the government (primarily production and support cost).
- Correct, as rapidly as possible, any design inadequacy, which adversely affects the safety-of-flight.
- Correct any design inadequacy, which causes unsatisfactory engine operation or adversely affects maintainability and logistic support in service.
- Improve, restore and maintain the system effectiveness of operational Navy and Marine Corps propulsion and power equipment including: 1) fixed and rotary wing aircraft engines, 2) helicopter transmissions, 3) starters, 4) propellers, 5) auxiliary power units (APU's), and 6) electrical systems. [Refs. 3, 4]

CIP is both reactive and proactive throughout an engine's life cycle to resolve newly identified problems, and to find ways to reduce costs of aircraft and engine ownership. This can be done by improving aircraft readiness, and operational reliability and maintainability. Other aircraft industries have similar processes with program titles such as: *Sustaining Engineering, Follow-on R&D Contracts, Pre-Planned Product Improvement, and Engineering Change Orders*. Aircraft engines represent a large budgetary expense for both the military and commercial aircraft industries. Therefore, there is a need for post-development engineering processes to keep engines performing effectively and safely in the field [Ref. 5].

CIP allows for the redesign of engine parts through continued engineering efforts and testing. It also provides improved engine serviceability for parts,

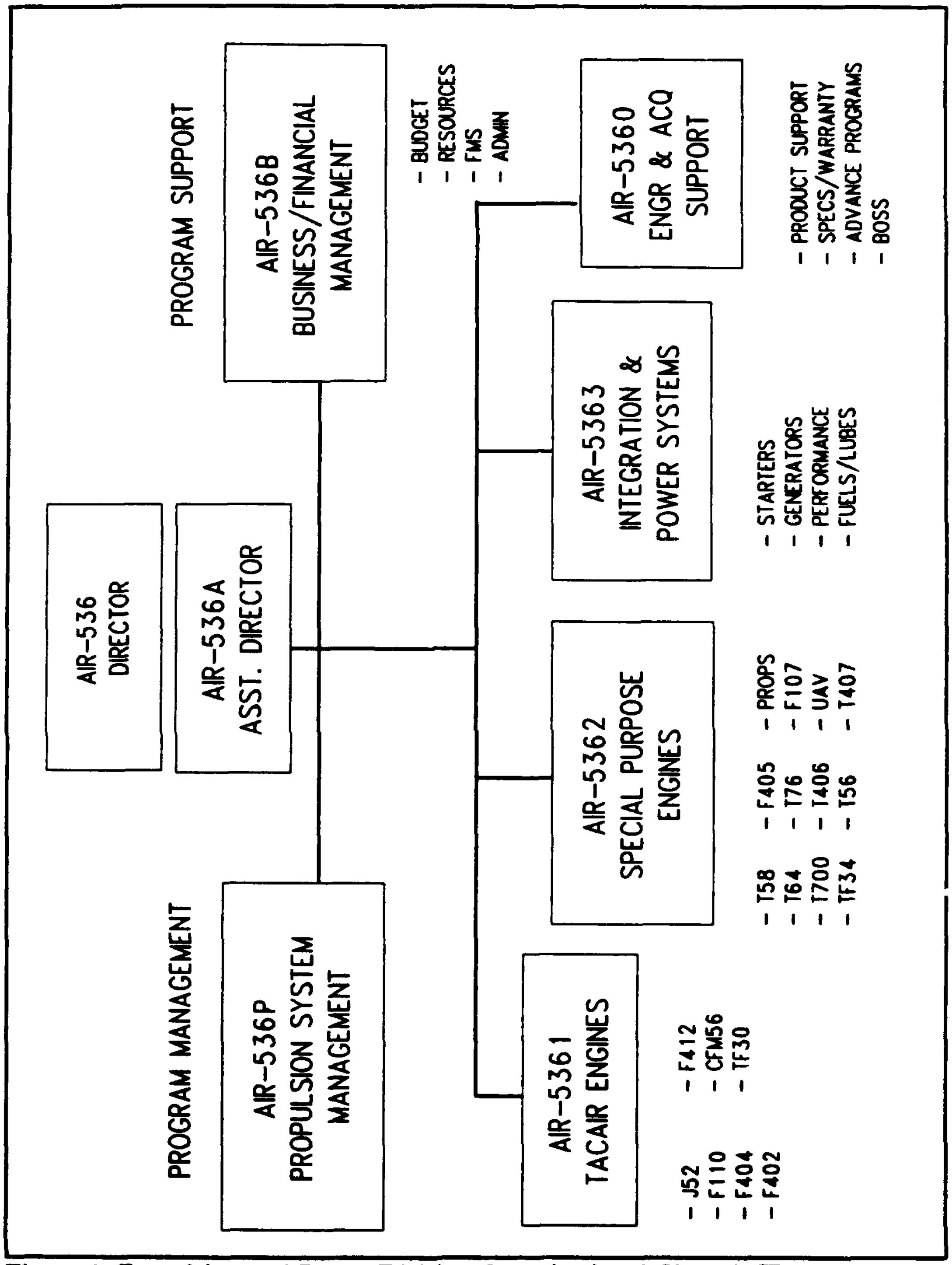

Figure 1 Propulsion and Power Division Organizational Chart (AIR-536)

maintenance techniques, and increases in engine overhaul intervals. CIP is not intended to increase the engine's basic performance characteristics (i.e., thrust, weight, or fuel consumption) beyond that contained in the specification for the engine model. CIP provides engineering support from the time the first engine of a type and model is introduced into the fleet until the last engine of that type leaves the active inventory. CIP does the follow-on engineering to identify and resolve all problems encountered by a model during active service, not just those related to the original design specification.

1. Functions of CIP

CIP contains the following functions:

- Problem Solving. Investigation and resolution of flight safety problems. Correction of service-revealed flight safety problems is the highest priority of the CIP.
- Problem Avoidance. Aggressive mission testing of engines and components for early detection of deficiencies, and verification testing of required improvements.
- Product Improvement. Improve engine maintainability, durability and reliability, and reduce the cost of engine ownership.
- Product Maturation. Provide engineering support to retain the engine's ability to perform over the lifetime of the engine in the inventory. Use this opportunity to insert improved technology into the engine, its support equipment, accessories and replacement parts. [Refs. 6, 7]

2. CIP Funding

The funding to support CIP is determined yearly by Congress and the Navy. The planning values are programmed in the Five Year Defense Plan (FYDP), and these values change each year as a result of the budget process. The total funding for CIP is shared with joint military services, Foreign Military Sales customers (FMS), and the engine manufacture. Funding support is initiated for all engine programs when an engine is qualified and goes into full scale development (FSD). Initial funding for a new engine CIP is planned based upon specific experience from research, development and testing, full scale development and general experience from prior engine programs. Figure 2 represents a typical CIP funding profile. The highest amount of CIP funding is required during initial engine introduction; however, the engine's mid-life problems and upgrades require additional funding.

During the 1970's, Congress frequently raised the issue of Production Funds (APN) versus RDT&E Funds for CIP. In November 1979, Congress directed that all CIP would be funded under the military services' RDT&E appropriation, starting in FY80 [Refs. 6:p. 6, 8:p. 122]. Engine CIP is now a program element

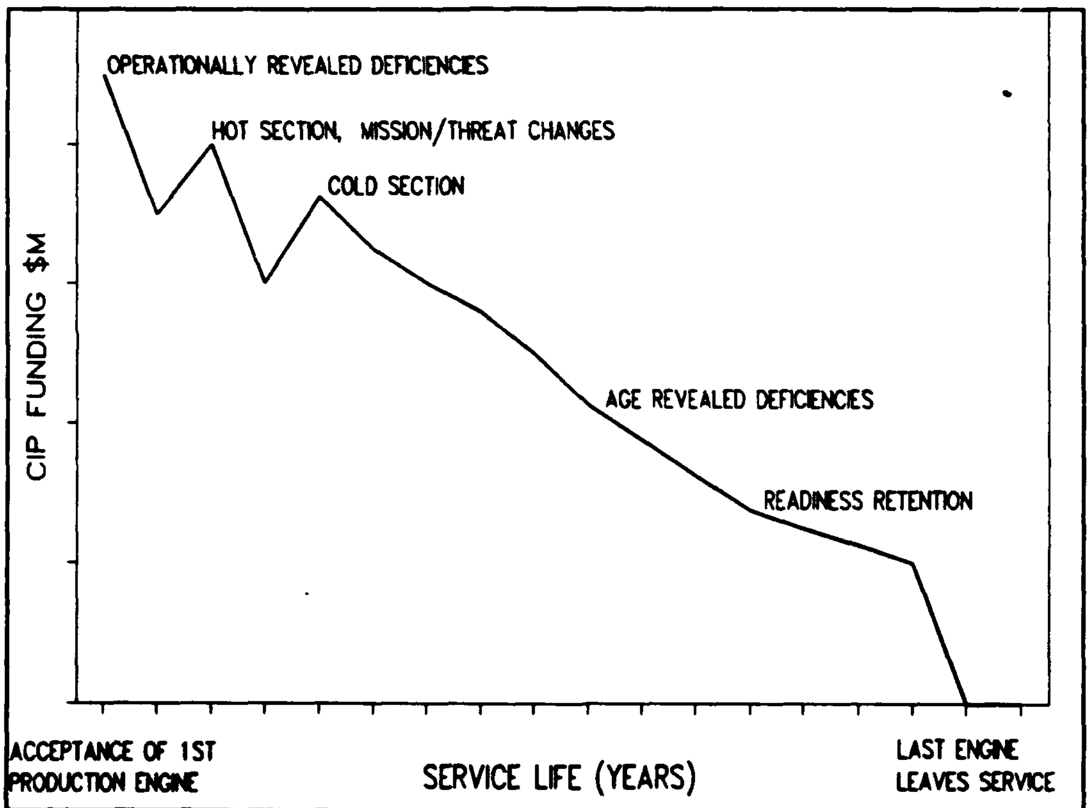

Figure 2 Typical Engine CIP Requirements. Source: AIR-536 CIP Briefing Overview

(PE) of the military services' RDT&E budgets. Table I shows the DOD Program Acquisition Costs for CIP PE. The Navy's PE is 0604268N, and the Air Force and Army PE's are 0604268F and 0203752A, respectively. Each PE provides for such funding activities for engines and related components.

TABLE I
FY 1990/91 R.D.T.&E. PROGRAM BUDGETS

			Fiscal Year ($ in thousands)		
P.E. NO.	NOMENCLATURE	1988	1989	1990	1991
0604268F	AIRCRAFT ENGINE CIP	91,009	92,993	112,494	137,325
0604268N	AIRCRAFT ENGINE CIP	33,262	35,675	43,073	47,323
0203752A	AIRCRAFT ENGINE CIP	6,144	5,683	5,828	6,970

SOURCE: *U.S. Weapon Systems Costs, 1989*

The Navy's CIP fund is specifically identified in the RDT&E budget for propulsion systems, such as the T56, F402, or F404 engines, propellers, and APU's. Appendix A contains Navy's funding information for CIP related programs from fiscal year 1970 to 1993. During the year, CIP funds may be reappropriated from one engine to another. The principle focus of CIP funding is to eliminate safety of flight conditions by correcting the condition or design of those engine parts, components, and support equipment that limits engine reliability and maintainability, and cannot be corrected under warranty or other contract provisions. As the engine approaches the end of its life cycle, the emphasis shifts from flight safety to decreasing life cycle costs, wear out rates, obsolescence rates, and retaining engine performance.

3. CIP and the Program Manager

Despite the intent of the DOD and the Services, there are many factors that often prevent, or at least hinder, complete adherence by the program managers to CIP objectives. These factors are particularly troublesome for the program manager of a less than major program[2] who normally has severe manpower, funding, and schedule constraints. The decisions that most affected engine reliability and maintainability were made in the early stages of the particular engine's development. For example, the program manager may be faced with making a decision between a reduction in a weapon system average unit cost versus a weapon system life cycle cost. The program manager is responsible for holding down costs and reducing the production and development schedule. Congressional review poses a threat for the program manager in that the program may be canceled if costs and schedules are not kept near their targets.

As the program progresses from the conceptual phase through validation and full scale development, the definition of the system expands in detail. At the start of the program, the program manager may only minimally define the maintenance concept and maintenance requirements. The cost estimating might be based on previous and similar weapon systems versus the actual cost of the weapon system hardware. This cost estimating concept was verified in an article written by Bryan, Rosen, and Marland on program manager's life cycle cost estimates in which they state:

> While life-cycle cost estimates will be required for submittal at milestone I of the Defense System Acquisition Review Council, very little specific information on system configuration is known in this phase.... [Ref. 9:pp. 2-7]

[2]A less than major program is defined by DOD to be an equipment acquisition which involves less than $75 million in research, development, test and evaluation (RDT&E or R&D) funds or less and $300 million in production funds.

The maintenance concept will only be minimally defined, and the initial cost breakdown structure and corresponding cost-estimate may be greater than needed. For example, the yearly cost of replenishment spares would likely be a percent of hardware acquisition costs based on the history of similar programs. However, due to advances in material and manufacturing technology, the cost of these spares would most likely be less than estimated. Also, life cycle cost models have usually been developed by a particular program office concerned primarily with creating a model to estimate costs for the problem at hand. Bryan, Rosen, and Marland also go on to say:

> Because system-peculiar cost elements and estimating relationships are often embedded in the computer program, however, another program manager is faced with significantly modifying an existing model or developing a new one for use on a new program. [Ref. 9: pp. 5-7]

Additionally, when a system such as an aircraft or a subsystem such as an engine is procured, a contractor will maximize profits by delivering systems with the lowest reliability that the government will accept. Some acquisition contracts are written in which the contractor has guaranteed or warranted a mean time between failure (MTBF). The contractor may be required to repair or replace such systems that fail to meet the specified MTBF during the warranty period. This is insurance against short term difficulties, since most warranties are for only the first year. Still, there exists no insurance for those systems that have gone beyond their warranty period, or for those systems for which a warranty never existed.

4. CIP Evaluation Process.

Competitive procurement of CIP engineering support is required by Federal Acquisition Regulations (FAR). To allocate CIP funding among solicited contractor proposals competitively, the following factors are evaluated and are considered approximately equal in importance:

- Non-monetary Benefits. The extent of system effectiveness that will bring about benefits to the Navy.
- Life Cycle Cost (LCC) savings and Return on Investment (ROI). The value of total LCC savings, ROI ratio, and the time in months to break even on the investment.
- Technical Risk. The probability that the design, development, and qualification of the engine can be completed on schedule and within cost.
- Incorporation Risk. The probability that once qualified a problem solution can be implemented on schedule and within cost.
- Reasonableness of Contract Cost. The reasonableness of labor rates and material cost to make the proposed improvement.
- Past Program Performance. The extent to which an on going program is meeting its cost, schedule, and technical objectives. [Refs. 4:p. 16, 6:p. 6-8]

II. BACKGROUND

The purpose of this chapter is to familiarize the reader with the concepts of system effectiveness, operational dependability, operational capability, operational availability, reliability, maintainability, supportability, reliability growth and models, and life cycle cost. The various definitions of these terms are discussed, as are the relationships among them. These useful concepts are important to understand better engine CIP. Figure 3 lists DOD's system reliability and maintainability parameters.

The following engine CIP terms are defined in detail in the *Component Improvement Program Technical Evaluation Plan* [Ref. 4:pp. 5-7].

A. SYSTEMS EFFECTIVENESS

System[3] effectiveness (SE) is a measure of how well the engine is performing in the fleet. SE is measured by operational availability $\mathbf{A_o}$, operational capability $\mathbf{C_o}$, and operational dependability $\mathbf{D_o}$, with operational availability broken down into reliability, maintainability, and supportability [Ref. 4:pp. 5-7].

The SE approach to CIP has the objective of organizing and managing CIP in a closed loop, feedback type of information system. A NAVAIR management information system entitled *Engine Component Improvement Feedback Report (ECIFR)* publishes engine "Health-of-the-Fleet" indicators. These indicators are analyzed to identify specific engine problem areas, then CIP efforts are addressed and focused accordingly [Ref. 10]. Table II summarizes the SE or "Health-of-the-Fleet" parameters.

1. Operational Dependability (D_o)

Operational dependability is the probability that the equipment, if up and ready at the beginning of the mission, is able to complete the mission successfully

[3]System here is defined at the weapon system level, the aircraft. The subsystems of an aircraft system include the airframe, engine, avionics, armament, and support equipment.

SYSTEM RELIABILITY AND MAINTAINABILITY PARAMETERS

OBJECTIVES **PARAMETERS** **TERMS (EXAMPLES)**

<u>OPERATIONAL EFFECTIVENESS</u>

- READINESS, OR AVAILABILITY
  - -- READINESS-RELATED RELIABILITY PARAMETER
    MEAN TIME BETWEEN DOWNING EVENTS (MTBDE)
  - -- READINESS-RELATED MAINTAINABILITY PARAMETER
    MEAN TIME TO RESTORE SYSTEM (MTTRS)
- MISSION SUCCESS, OR DEPENDABILITY
  - -- MISSION RELIABILITY PARAMETER
    MISSION TIME BETWEEN CRITICAL FAILURES (MTBCF)
  - -- MISSION MAINTAINABILITY PARAMETER
    MISSION TIME TO RESTORE FUNCTIONS (MTTRF)

<u>OWNERSHIP COST REDUCTION</u>

- MAINTENANCE MANPOWER COST
  - -- MAINTENANCE-RELATED RELIABILITY PARAMETER
    MEAN TIME BETWEEN MAINTENANCE ACTIONS (MTBMA)
    MEAN TIME BETWEEN FAILURE (MTBF)
    MEAN TIME BETWEEN MAINTENANCE (MTBM)
  - -- MAINTENANCE-RELATED MAINTAINABILITY PARAMETER
    DIRECT MANHOURS PER MAINTENANCE ACTION (DMH/MA)
- LOGISTIC SUPPORT COST
  - -- LOGISTICS-RELATED RELIABILITY PARAMETER
    MEAN TIME TO REPAIR (MTTR)
    MEAN TIME BETWEEN REPLACEMENT (MTBR)
    MEAN TIME BETWEEN REMOVALS (MTBR)
  - -- LOGISTICS-RELATED MAINTAINABILITY PARAMETER
    TOTAL PARTS COST PER REMOVAL, ALL LEVELS OF REPAIR

Figure 3 System Reliability and Maintainability Parameters
Adapted from: DOD Directive 5000.40, *Reliability and Maintainability*

TABLE II
SYSTEM EFFECTIVENESS (SE) SUMMARY

SYSTEM EFFECTIVENESS (SE) SUMMARY

SE OBJECTIVE	INDICATOR LIMITS		
Health of the Fleet Indicator Parameter	**Red**	**Yellow**	**Green**
D_O Dependability			
FA/1000 EFH Failure Aborts	> 2.5	2.5 - 2	< 2
C_O Capability			
FER/1000 EFH Failure Engine Removals	> 2	2 - 1	< 1
A_O Availability			
NMC/EFH Not Mission Capable	> 4	4 - 2	< 2
Reliability			
EFH/F MTBF	< 20	20 - 30	> 30
CR/1000 EFH Component Removals	> 10	10 - 7.5	< 7.5
Maintainability			
EFH/MA MTBMA	< 10	10 - 20	> 20
EMT/MA MTTR	> 10	10 - 7.5	< 7.5
MMH/EFH Maintenance Index	> 1.5	1.5 - 1	< 1
Supportability	no indicator limits		

SOURCE: GE's *Component Improvement Program* and *Engine Component Improvement Feedback Report (ECIFR)*

[Ref. 4:p. 6]. Engine CIP gives operational dependability the highest priority. A fleet indicator of operational dependability is Failure Aborts per 1000 Engine Flight Hours (FA/1000 EFH) [Ref. 9:p. 3].

2. Operational Capability (C_o)

Operational capability is the ability of the equipment to do its intended mission. CIP restores engines to specification performance limits, but not beyond

[Ref. 4:p. 6]. A fleet indicator is Failure Engine Removals per 1000 Engine Flight Hours (FER/1000 EFH) [Ref. 9:p. 3].

3. Operational Availability (A_o)

Availability is a measure of the degree to which an item is in an operable and committable state at the start of a mission, when the mission is called for at a randomly chosen point in time [Ref. 11]. Operational Availability is the basic readiness requirement for a system or equipment. A_o is the mean percentage of time the system is available for use in its intended operational environment. The warfare program sponsor (i.e., NAVAIR, NAVSEA, NAVMAT) establishes A_o in the system's acquisition documentation [Refs. 4:p. 6, 12]. A fleet indicator of A_o is reflected in the tabulations of Not Mission Capable hours (NMC) and Not Mission Capable per Engine Flight Hour (NMC/EFH) [Ref. 9:p. 3].

B. RELIABILITY

Reliability is the probability that an item can do its intended function for a specified period under stated conditions [Ref. 13:p. 12]. Reliability is also frequently defined in terms of mean time between failure (MTBF), mean time to failure (MTTF), or mean time between maintenance (MTBM). MTBF and component removals are indicators of equipment reliability. CIP can correct reliability deficiencies that affect A_o, C_o, and D_o. Reliability is measured in the fleet by the following two indicators, Engine Flight Hours per Failure (EFH/F) and Component Removals per 1000 Engine Flight Hours (CR/1000 EFH) [Ref. 9].

C. MAINTAINABILITY

Engine maintainability is the ability to restore the propulsion equipment to ready for issue (RFI) condition under specified logistics conditions. Mean time to repair (MTTR) is an indicator of the equipment's inherent maintainability. The importance of maintainability becomes obvious as approximately thirty percent of DOD's Operation and Maintenance budget is appropriated for system maintenance activities.

Indicators of maintainability are the number of Maintenance Actions (MA), such as the number of Engine Flight Hours per Maintenance Action (EFH/MA), the Elapsed Maintenance Time per Maintenance Action (EMT/MA), or Maintenance Man Hours per Engine Flight Hour (MMH/EFH) [Ref. 9].

D. SUPPORTABILITY -- LOGISTIC SUPPORT

Logistic support is the ability to satisfy the material and administrative requirements to restore the operation of a failed propulsion equipment or component. An indicator of logistic support is mean downtime per failure (MDT). CIP may support parts forecasting by providing life limits and wear out rates. It may be used to develop new inspection processes, limits, or repair procedures. For example, it may even be used to develop training aides needed to avoid system effectiveness problems [Ref. 6:p. 10].

A fleet indicator of supportability is measured in terms of Engine Cannibalization (EC) or Mean Downtime per failure (MDT). The EC measurement is an approximation of the logistic support delay index [Ref. 9].

E. RELIABILITY DEGRADATION

Degradation in reliability can be a result of the interaction of the machine with man or the environment, or because of system operation. For example, excessive handling, too frequent preventive maintenance, or poor corrective maintenance can degrade system reliability.

During corrective maintenance, it is possible for non-failed parts to be removed and returned for repair, or to be discarded, resulting in inaccurate failure rate data. Scheduled maintenance also can introduce defects into satisfactory systems. For example, defects can be due to foreign objects left in an assembly, parts replaced improperly, or lubricants being improperly applied.

F. RELIABILITY GROWTH

Initially systems will have inherent reliability and performance deficiencies that may not have been foreseen and were not detected and eliminated in early design or production stages. The goal of reliability growth is to increase the system's reliability to stated levels by eliminating several inherent system failure modes.

The basic elements of reliability growth are:

- Detecting the causes of failures.
- Feedback on the problems identified.
- Redesign effort based on the problems identified.
- Fabrication of hardware.
- Verifying that the corrective action works. [Ref. 14:pp. 23-26]

1. Reliability Growth and Engine CIP

Reliability growth during the deployment of a system is an extremely expensive proposition. During the aircraft deployment period, NAVAIR's engine CIP reliability objective is to screen engine components by analyzing the available failure data acquired from engine maintenance 3-M data. By analyzing these data, specific engine components can be selected for engineering study.

2. Other Reliability Growth Factors

Other factors that affect the reliability characteristics of the engine will improve with time due to planned growth of the engine or the experience of the maintainer or operator. This is sometimes referred to as the learning process. This learning process includes the familiarization with the engine, the development of more efficient tools and test equipment, and improvement in maintenance manuals and management.

G. RELIABILITY GROWTH MODELS

Reliability growth models[4] are analytical models that account for changes in reliability due to modifications and corrective action. There are several reliability growth models found in published literature.[5] Most of these models account for changes in the R&D and testing phases of a reliability program. These models are useful in determining a test plan for the system and are used to monitor the progress of the program. These models could be probabilistic or statistical in nature.

The probabilistic model does not consider the actual information and data available during the testing phase, but uses estimated data. The statistical model, however, uses actual data from the testing phase and "time to failure" data. There are limitations and uncertainties inherent in both models.

H. LIFE CYCLE COST/COSTING

Life cycle cost (LCC) must be applied early in a program to get maximum effectiveness. The DOD *Design to Cost (DTC)* Directive stresses early application of DTC/LCC management and procurement principles in all programs, both major and less than major [Ref. 15].

The life cycle cost of a system includes acquisition, ownership (operation, maintenance, support, etc.), and disposal cost. A LCC model will estimate these costs for a given set of parameters and data over any portion of a system's life, such as the design phase, investment phase, or the operating phase. Cost estimates for each of the phases are summed together to give a total life cycle cost estimate. A LCC model may be used during a phase of the system's life to provide an estimate for a current or future phase.

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[4]The term "model" is used to refer to the sets of equations which, together with certain other statements, can be developed into an executable software package or computer program.

[5]Listed in Appendix A from the text by B.S. Dhillon, *Life Cycle Costing, Techniques, Models and Applications*, 1989, pp. 283-348, are 500 references on life cycle costing, operating cost and miscellaneous text and papers.

The thrust of life cycle costing is not just to minimize cost, but to optimize life cycle cost through tradeoffs in design and cost [Ref. 16]. LCC models serve as the analytical tools used to find the effect design tradeoffs will have on acquisition and operating and support costs. Thus, these models can be the appropriate tool for examining tradeoffs between cost and different levels of availability, provided availability is adequately defined in the models. Availability is a function of reliability and maintainability, and is a parameter to be included in LCC models [Ref. 13:p. 122].

Reducing an engine's cost, and more specifically, its life cycle cost, is a critical criterion in justifying engine CIP funding. The ability to use analytical tools to examine and optimize tradeoffs between readiness (availability) and cost is vital to the CIP's effectiveness.

I. AIRCRAFT SUBSYSTEMS LIFE CYCLE COST

The overall life cycle cost of an aircraft weapon system can be broken down to its subsystems: airframe, engine, avionics, armament, and support equipment. The engine is a major contributing subsystem in the life cycle cost of an aircraft weapon system. To calculate the total life cycle costs for specific engines, all relevant cost elements and associated actual costs for any engine and its programs must be clearly defined.

The life cycle process of an engine encompasses the entire spectrum of research, development, procurement, and ownership. Figure 4 illustrates the role CIP plays and its commitment to the aircraft engine design and development process. As shown, CIP is interwoven with the requirements for the aircraft weapon system. When there is a military requirement for a new or modified engine, CIP is interactive. CIP capitalizes on feedback from operational experience, research and development, and expectations from new technology to satisfy the military engine need [Ref. 17:pp. 2-1 to 2-7].

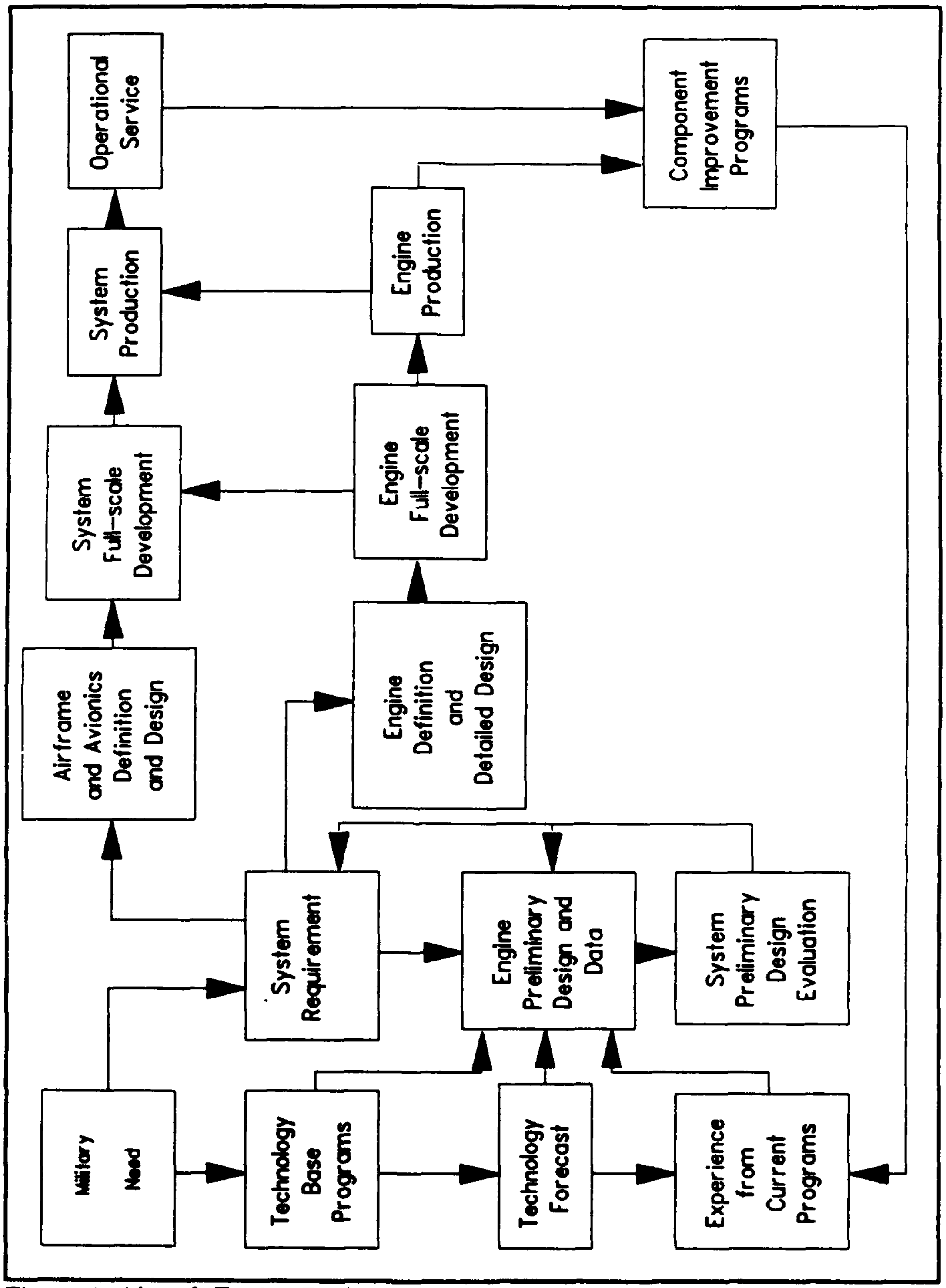

Figure 4 Aircraft Engine Design and Development Process [Ref. 16: pg. 24].

J. THE VISIBILITY AND MANAGEMENT OF OPERATING AND SUPPORT COST

The Visibility and Management of Operating and Support Cost (VAMOSC) is a management information system (MS). The MS is a "bottom-up" cost visibility system that consolidates maintenance hours and costs by Work Unit Code (WUC) within Type/Model/Series (T/M/S). Whenever possible, actual costs are computed and reported. If actual costs are not available, the costs are estimated and allocated by generally accepted accounting procedures.

The data, reported in the form of hours, costs and maintenance action counts, are obtained from the Navy's 3M (maintenance and material management) system through the Naval Aviation Logistics Data Analysis (NALDA) Fleet Originated Job (FOJ) file, the Aviation Supply Office (ASO) files for commercial contracts and the Depot Master Component Rework Control (MCRC) System for Naval Aviation Depot (DEPOT) repairs.

The 3M reporting system provides data relative to organizational and intermediate levels of maintenance and support activities. The Naval Aviation Depot Operations Center (NADOC) MCRC System data base provides the average DEPOT repair costs associated with the component rework program. The ASO contract data provides similar information relative to component repair cost by National Item Identification Number (NIIN) for components repaired by commercial vendors and by Depot Maintenance Interservice Support Agreements (DMISA).

The MS currently processes data on 116 T/M/S aircraft. The basic criterion for selection in the MS is the total number of flight hours accumulated within the reporting period, generally one fiscal year. At the present time, aircraft with a total of less that 100 hours for the period are not reported within VAMOSC-AIR. The population of 116 T/M/S aircraft selected accounts for over 99 percent of the total flight hours reported by Navy and Marine aircraft within the reporting period.

K. ACCURACY OF THE VISIBILITY AND MANAGEMENT OF OPERATING AND SUPPORT COST MANAGEMENT INFORMATION SYSTEM

The VAMOSC MS uses productive work hours and action taken counts from the NALDA data bases as well as the counts for the issues of repairable parts and the issues of consumable items. Indirect work hours for the organizational and intermediate levels of maintenance are not reported. Material cost for those levels of maintenance are captured from 3M requisition data reported to NARDACs. As recently as 1983, only 32 percent of requisition data was being reported to the NALDA data base. There is no indication that percentage has improved since 1983.

Productive labor cost is a fully burdened rate as provided from the Personnel Cost Model maintained by OP-162. While this model has not been updated since 1984, labor rates for 1985 and 1986 were inflated in accordance with standards established in the Management By Objectives Memorandum from the U.S. Office of Management and Budget (OMB A-76). Productive labor hours are those hours documented on the Maintenance Action Forms by productive work center personnel. The composite averages for maintenance levels one and two were obtained through the comparison of OP-162 burdened rates against actual manning documents for a variety of organizational and intermediate activities for E-6 (Petty Office 1st Class) and below.

The amount of data captured within the VAMOSC-AIR MS reporting process has increased steadily since 1980. Data is still limited, however, to those Type Equipment Codes (TECs) having "A" in the first position (aircraft) and does not yet include data for other TECs. Aircraft engine cost data will be made available beginning in year 1991 in a limited format. Cost data for other TECs (support equipment, mission mounted equipment, automated test equipment, etc.) will also be available by special request late in year 1991 on an ad hoc basis from the VAMOSC Program Manager.

VAMOSC-AIR MS cost data cannot currently be used for cost comparisons with VAMOSC systems of other services as standard cost elements have not been established. VAMOSC-AIR MS reports were developed, implemented, and are being produced with the boundaries of existing reporting systems as established under the VAMOSC Study Report, dated 3 April 1975. The current boundaries are those data bases established by OPNAV (OPNAVINST 4790.2E), NALDA, and NARDAC for collecting maintenance and material data from 3M sources. Some of the specific boundaries involves: types of data, the nomenclature, type equipment code designation, and type of maintenance action code designation.

III. ECONOMIC ANALYSIS

Economic analysis can be used to systematically investigate problems of alternate investment proposals. The basic principles of economic analysis can be incorporated into the economic model developed. Thus, an understanding of both the model and the principles of economic analysis is necessary.

The basic DOD economic cost categories are:

- Research and development (R&D) and non-recurring investment cost.
- Recurring investment cost.
- Operational cost.
- Sunk costs.
- Incremental costs. [Ref. 18:pp. 1-5]

The following are DOD economic categories to be considered during economic analysis:

- Performance parameters.
- Economic life.
- Quantifiable and non-quantifiable benefits. [Ref. 18:pp. 4-5]

A. COST ANALYSIS PROCESS

The cost analysis process includes a detailed life cycle cost model and aspects of risk, sensitivity, and data comparison analyses. Also, research, development, test and evaluation cost concerns are included as well as acquisition, operation, and support costs over the effective life of the system.

B. ECONOMIC ANALYSIS MODEL

Economic analysis can be performed by hand or by a computer. But first, the economic model algorithms, which contain some of the mathematical equations used for the outputs of the economic model, need to be described and developed. The output of the economic analysis can then be used to support the decisions as to exactly which engine programs will be selected and in what order.

Investment of CIP dollars in Engineering Change Proposals (ECP) or Power Plant Changes (PPC) are future dollar savings. When the ECP proposal is submitted for review, future dollar savings are expressed as calendar time or flight hours to Return of Investment (ROI). These future dollar savings come from reduced logistics support cost and spare parts inventories, and, possibly, the prevention of aircraft losses.

A main objective of CIP is to reduce the cost of ownership of the engine. A submitted CIP proposal needs justification. The contractor or engineer may formulate the justification to increase flight safety, to increase mission effectiveness, or to decrease aircraft or engine operating cost.

A contractor or engineer could use a justification method that compares an old engine component to a replacement component. For example, the replacement component may be cheaper to procure or repair. It may have an increased MTBF. The component may require less preventive maintenance or the scheduled maintenance may be extended due to a possible increase in the time between engine removals.

Another important cost concern is the possibility of airframe modification for component compatibility with the aircraft. If airframe modification is required, the necessary materials for performing the modification are furnished in an airframe retrofit kit. Additionally, the airframe modification may need the expertise of depot or intermediate activities. This manpower requirement will increase the cost of the change. If an airframe modification is not required, this will have no cost impact on the decision.

C. LIFE CYCLE COST MODEL DESCRIPTION

There are several life cycle cost models described in the published literature [Refs. 19:pp. 737-742, 20:pp. 193-204]. The types of life cycle cost models presented in the literature are grouped into two broad categories: specific life cycle cost models and non-specific life cycle cost models. Specific life cycle cost models are those developed for particular equipment or systems. Non-specific cost models are generalized and are not tied to any specific equipment or systems.

According to Dhillon [Ref. 21:pp. 210-238], a life cycle cost model develops cost projections for all three phases of a system's service life. The three phases are the RDT&E phase, the acquisition phase, and the operation and support phase. Within each of these phases, subsidiary cost categories are found and universal parameters are stated such as labor rates and secondary calculations. A second reference, Blanchard, categorizes life cycle cost into four phases: research and development, production and construction, operational maintenance, and system retirement and phase out [Ref. 21]. Dhillon's life cycle model of three phases is used in this thesis for the CIP ROI calculations.

Costs and resource quantities are calculated by cost category for each year. Since there may be deployment changes within a given year, the model should be able to be adjusted to allow for monthly variance. Cost category calculations may therefore be made for the average number of systems operating within the year or the maximum number of systems operating within the year. The model should also be able to perform cost calculations in constant, inflated, or inflated and discounted dollars.

Spares, support equipment, and manpower quantities are based on the maximum number of operating systems, while quantities of maintenance actions are based on the average number of operating systems.

1. Research, Development, Test, and Evaluation Phase

The total RDT&E cost is the cost attributed to various subcategories within the RDT&E phase. Cost subcategories of the RDT&E phase include the following:

- System/Project Management Cost
- System Test and Evaluation Cost
- Training Cost
- Data Cost
- Demonstration and Validation Cost
- Research and Development Cost
- Software Cost

2. Acquisition Cost

The total acquisition cost represents the initial investment cost once the system is approved for procurement. The costs identified under this heading are those generally associated with the design, development, and procurement of systems and support items necessary to make the system operational. Cost subcategories of the acquisition phase include the following:

- Production Tooling and Test Equipment Cost
- Production Start-up Cost
- Sub-system Acquisition Cost
- System Shipping and Storage Containers Cost
- Pre-Production Engineering Cost
- Pre-Production Units Refurbished Cost
- Installation Cost
- Support Equipment Cost
- Hardware Spares Cost
- Spares Reusable Containers Cost

- Technical Data Cost
- Initial Training and Training Devices Cost
- Facilities Cost, i.e., a new or modified engine test cell
- Initial Item Management Cost
- Initial Software Development Cost
- Miscellaneous Acquisition Cost
- Warranty Cost

3. Operation and Support Costs

The total operation and support costs are the costs of operation, maintenance, and support of systems and support equipment for all maintenance levels over the life of the system. Subcategories of the operation and support costs phased over the three levels of maintenance (depot, intermediate, organizational) include the following:

- Operation Labor Cost
- Repair Labor Cost
- Support Equipment Maintenance Cost
- Recurring Training Cost
- Repair Consumable/Material Cost
- Condemnation Spares Replenishment Cost
- Technical Data Revisions Cost
- Transportation Cost
- Facilities Operating Cost
- Recurring Item Management Cost
- Software Maintenance Cost
- Contractor Services Cost
- Engineering Changes Cost
- Recurring Warranty Cost

D. CUMULATIVE LIFE CYCLE COST MODEL

If the CIP proposal is intended to reduce the operating cost of the system, the cost of implementation should be compensated for by savings in operating costs. Thus, the life cycle cost of the modified engines should be less than that of the unmodified ones. Since the end-item is the aircraft, the life cycle cost of the aircraft with the modified engine(s) should be less than that of an unmodified aircraft.

1. Cumulative Life Cycle Cost - Ideal Case

The life cycle economics of this situation are illustrated in Figure 5. The cumulative cost of what will be denoted as the no-action alternative is represented by Curve I. This is the management option to do nothing and co.:tinue as before. Curve II represents the cumulative cost of an alternative that provides future cost savings. This curve represents costs over time of implementing the proposal.

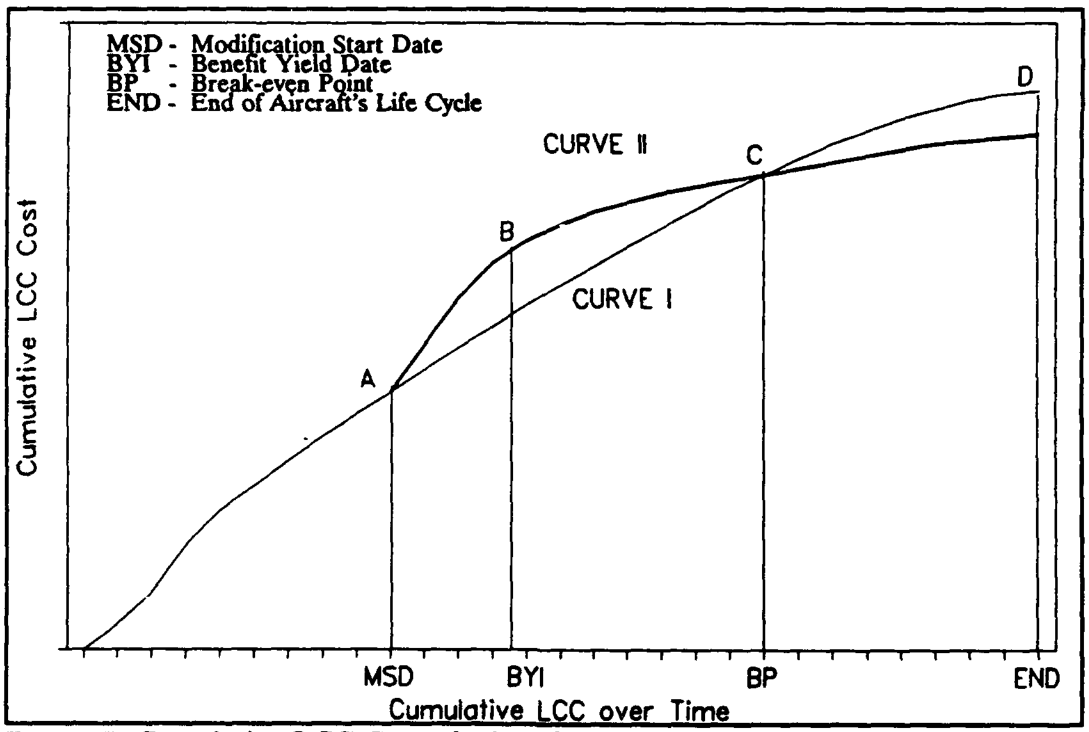

Figure 5 Cumulative LCC Cost of Aircraft and Engine Versus Time - Ideal Case

The slope of Curve II represents rates of expenditure. Point A is the engine modification base month or start date (MSD). This is the date when the modification program is initiated and it is the first year in which expenditures have to be made. The steeper slope of Curve II between Point A and Point B represents the increased rate of expenditure due to design, development, and implementation of the action alternative. Point B shows when the implementation and modification program is complete and the start of the benefit yield from implementation (BYI). This is the point in time at which the action alternative begins yielding benefits.

The reduced slope of Curve II after Point B represents the reduced operating costs of the action alternative. Point C is the break-even point (BP) when the savings from reduced operating cost exactly compensates for the cost of implementation. Point D represents the estimated end of the aircraft/engine's economic life. Figure 5 represents an ideal case where the investment is recovered within the life cycle of the aircraft. Figures 6 and 7 represent cases that are not so favorable.

2. Cumulative Life Cycle Cost - Break-even Case

Figure 6 is similar to Figure 5, except that it represents the case where the investment is recovered only slightly or breaks even at the end of the aircraft's life. In Figure 6 there is a reduction in operating cost after BYI (point B). The decreasing slope of Curve II after point B represents reduced cumulative costs. This reduction in costs is due to the lower system operating costs of the action alternative, but the reduction is not enough to recover the investment before the end of the aircraft or the engine's economic life, indicated by point C.

Further factors are required for this case before the action alternative would be chosen. The program manager has to decide the significance of each factor, and then establish relative weighting values for each factor. These values will vary depending on problem definition, the system operational requirements, the system effectiveness and pay-back period on reliability and maintainability investment.

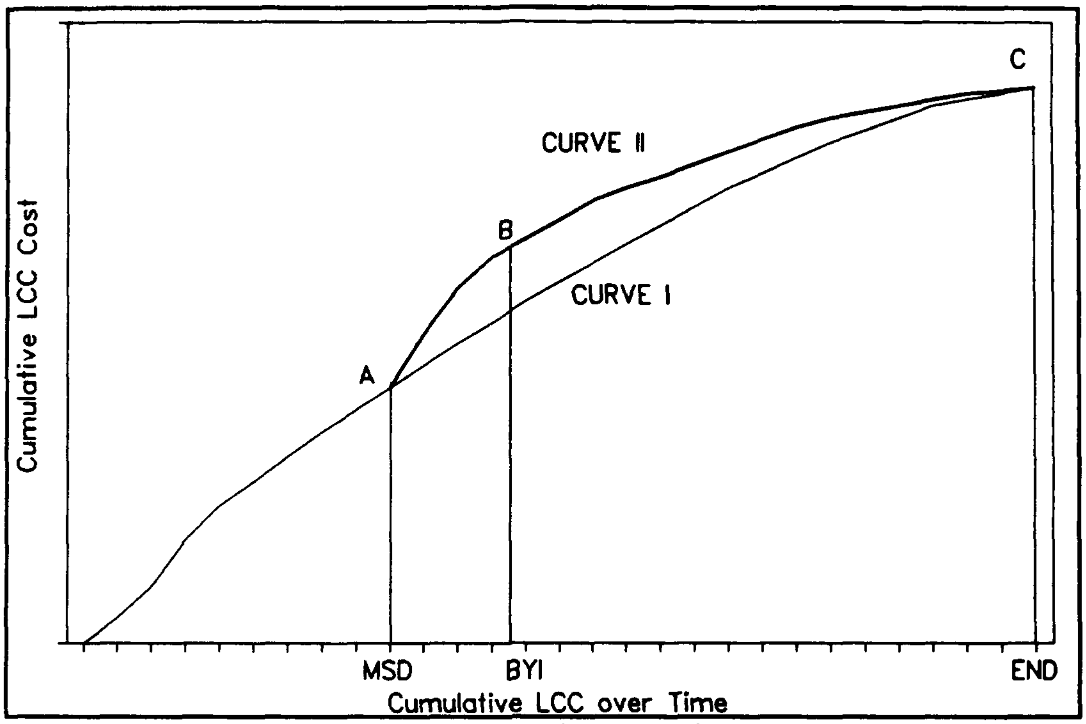

Figure 6 Cumulative LCC Cost Of Aircraft and Engine Versus Time - Investment Recovered Within the End of Engine's Life Cycle

The factors that should be evaluated are: benefits, LCC and ROI, technical risk, implementation risk, the analysis approach, and program objectives [Ref. 4:pp. 11 - 13].

3. Cumulative Life Cycle Cost - No Return Of Investment

Figure 7 represents the case where there is no significant reduction in operating cost. In this case a break-even point is not obtained no matter how long the analysis is continued. This cumulative life cycle model shows a continuing trend toward higher ownership cost.

Nelson's article suggests that a continuing increasing trend in ownership cost is due to increasing depot cost, which is a primary reason for this trend [Ref. 18:pp. 2-1 to 2-7].

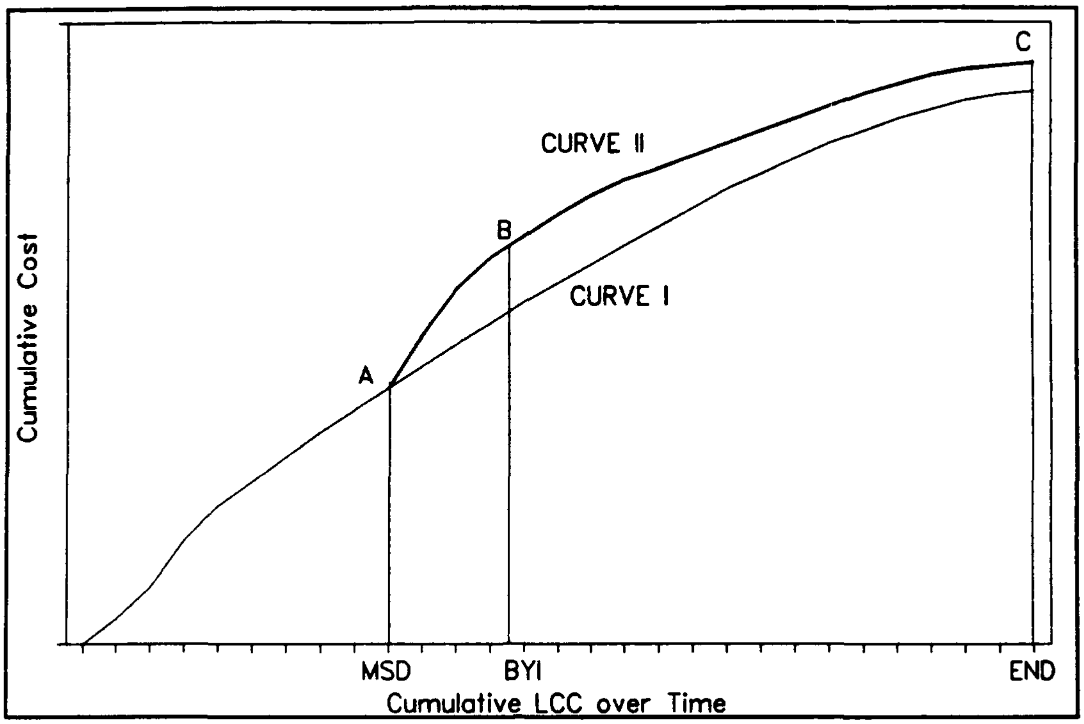

Figure 7 Cumulative LCC Cost Of Aircraft and Engine Versus Time - Investment is Never Recovered

4. Analyzing Engine CIP Cost Effectiveness

In analyzing the cost effectiveness of engine CIP for decision making purposes, the following is required. First, the cost difference between each action alternative and the no-action alternative must be determined. This is called the delta cost. This delta cost is represented by the vertical separation of Curves I and II as shown in Figures 5, 6, and 7. It is important that this cost be determined for the entire life cycle of the aircraft. If reduced operating cost is the justification for the proposal, there should be a break-even point that occurs before the end of the aircraft's life. An engine CIP is not usually considered a long term investment, so this break-even point should occur within a short time.

E. NAVY MAJOR WEAPON SYSTEM LIFE CYCLE COST MODEL

This model was developed by the Navy for major weapon systems. It has five major cost components: research and development cost (*RDC*), operating and support cost (*OSC*), associated systems cost (*ASC*), investment cost (*IC*), and termination cost (*TC*). This model is expressed as follows:

$$L_{CC} = RDC + OSC + ASC + IC + TC \qquad (1)$$

where, L_{CC} is the life cycle cost. The components of the research and development cost (*RDC*) are validation cost and full scale development cost [Ref. 22].

The following elements belong to operating and support cost (*OSC*):

- Depot supply cost.
- Operating cost.
- Personnel support and training cost.
- Depot maintenance cost.
- Second destination transportation cost.
- Organizational and intermediate maintenance activity cost.
- Sustaining investment cost.
- Installation support cost.

The components of associated system cost (*ASC*) are investment cost, and operating and support cost of associated systems. The investment cost is expressed as:

$$IC = PC + GIC \qquad (2)$$

where:

- *IC* is the investment cost.
- *GIC* is the government investment cost (e.g. industrial machinery).
- *PC* is the procurement cost.

The termination cost, *TC*, is expressed as:

$$TC = \sum_{j=1}^{N} [S_j] \ (STC) \qquad (3)$$

where:

- N is the years in life cycle
- STC is the termination cost of one unit of the the major system
- S_j is the number of major systems put out of action during year j.

F. ENGINE LIFE CYCLE COST ELEMENTS

Table III lists all the cost elements included in acquisition and ownership of an engine. Engine life cycle cost is the sum of all elements of acquisition and ownership costs. Engine acquisition cost includes the aspects of RDT&E and procurement,

TABLE III
CLASSIFICATION OF LIFE CYCLE COSTS

Cost Element	Acquisition	Ownership	Weapon System Related
RDT&E	X		
Flight Test	X		
Tooling	X		
Proc. of Install Engine	X		
CIP		X	
Spare Engine		X	
Spare Parts (base/depot)		X	
Depot Labor		X	
Base Labor		X	
ECPs - mod/retrofit	X	X	
Support Equipment (peculiar/common)	X	X	
Transportation	X	X	
Management	X	X	
Facilities	X	X	
Training	X	X	
Engine Attrition			X
Fuel			X

comprising the design, development, testing, manufacture, and delivery to the field. Engine ownership cost consists of the operating and support maintenance costs for organizational, intermediate and depot activities. Weapon system related costs include fuel and attrition due to accidents and catastrophic failures [Ref. 18:pp. 2-5].

G. LIFE CYCLE COST SENSITIVITY ANALYSIS

Sensitivity analysis measures the impact of key parameter changes on life cycle cost and operational availability. Each parameter is independently varied over a user-selected range of possible values, and the life cycle model generates tables or graphs of the results. Sensitivity parameters may be hardware related, maintenance level related, or other, such as:

- System operating time (hours, month)
- Mean time between failures (MTBF)
- Mean time to repair (MTTR)
- Spares turnaround time (TAT)
- Maintenance labor rate
- Maintenance personnel turnover rate
- Shipping cost per pound
- Material cost per repair
- Unit cost
- Production quantity/rate

H. LIFE CYCLE COSTING BENEFITS, DRAWBACKS, AND IMPORTANT POINTS

There are benefits and drawbacks of life cycle costing like any other idea. Some of the benefits are that life cycle costing:

- Is useful to control programs.
- Is a tool for making a selection among competing contractors.

- Is beneficial in comparing the cost of competing projects.
- Is useful in reducing total cost.
- Allows for decision making associated with equipment replacement, planning, and budgeting. [Ref. 23:pp. 42-43]

Some drawbacks of the life cycle costing process are:

- The accuracy of data is doubtful.
- That obtaining data for the analysis is difficult.
- That it is costly and time consuming. [Ref. 22:p. 42]

Some important points associated with life cycle costing are that management plays an important role in making the life cycle costing effort worthwhile. Both the manufacture and the user are required to organize effectively to control life cycle cost. Life cycle costing is gaining importance as a technique for strategic decisions, design optimization, and detailed trade-off studies. The objective of life cycle costing is to obtain the maximum benefit from limited resources. Accurate data are indispensable for reliable life cycle cost estimates. A cost analyst with excellent knowledge and experience may compensate for various data base difficulties. No matter how reliable the estimator is, some surprises may still occur. The life cycle cost model must include all concerned costs associated with the program. The risk management is the essence of life-cycle costing. Throughout the life of the program, the trade-offs between life cycle cost, performance, and design to cost must be performed. [Ref. 22:p. 43]

IV. ANALYSIS - COST BENEFITS

Chapter III of this thesis has reviewed the life cycle process of aircraft engines and has attempted to bring into focus factors relevant to the benefits and costs associated with engine acquisition and ownership. Chapter I dealt with the major elements of CIP. Chapter II dealt with definitions and concepts of system effectiveness, reliability and maintainability, and life cycle costing. Chapter III discussed economic analysis, life cycle cost models and their algorithms for comparative purposes to identify practices that may be adopted by NAVAIR for improving its life cycle cost model. Chapter IV contains cost estimates, which were calculated by the author, in aircraft maintenance at the organizational, intermediate, and depot levels. Chapter IV also contains an analysis of a LCC model to determine CIP cost benefit effectiveness for an engineering change proposal (ECP) of a selected aircraft engine using these cost estimates.

The author's assumption for CIP cost benefit analysis is that the ECP is intended to reduce the operating cost of the aircraft. Since aircraft maintenance cost is a subset of the aircraft's operating cost, there should be a method for estimating maintenance costs per flight hours. For instance, there is presently a lack of aircraft ownership data in the particular form needed for analysis. There is a need to break aircraft cost into categories such as historical cost for a specified period of time and a breakdown of aircraft subsystems. At present, it appears that one way to estimate the organizational and intermediate cost of maintenance labor for an engine is to examine the Visibility and Management of Operating and Support Costs (VAMOSC) management information system (MS), as a source of data.

The following procedure was developed by the author for doing a cost benefit analysis of a F-14A TF30-P-414 engine ECP:

- Determine available aircraft and engine data resources.
- Collect F-14A aircraft and TF30-P-414 engine data from the contractor, 3-M reports, and NAVAIR engineers.
- Select a TF30-P-414 ECP for benefit analysis. The ECP selected was the TF30 476 mod.
- Determine what data are applicable for the LCC program.
- Enter data into the LCC program and run the LCC program.
- Perform validations and sensitivity analysis of the LCC program results.

In order to determine the availability of existing LCC models and related computer programs, the author contacted several sources. The first source was the LCC/Affordability Studies Team Director, Mr. Phil Pels of NAVAIR-5242E, concerning the availability of NAVAIR LCC computer programs. According to Mr. Pels, his team at NAVAIR is redoing the current LCC computer program. He also stated that that AIR-536 has a simple LCC model called *Return of Investment (ROI) Analysis Program* [Ref. 24]. AIR-536 provided to the author the ROI analysis program for evaluation of CIP. The author also contacted the Defense Systems Management College and the Air Force's Operational Research Department. However, their computer programs for LCC models arrived too late to be used to validate the ROI estimates.

Appendix B provides additional information about the Defense Systems Management College's personal computer software module called *Cost Analysis Strategy Assessment (CASA)* and its life cycle model algorithms. The Department of the Air Force's *Cost Effectiveness Analysis Model for Program Task Plans and Engineering Change Proposals (CEAMOD)* was developed primarily for a mainframe computer and was partially developed for a personal computer. Cost savings is shown in spreadsheet format. Yearly costs are broken down into two columns, the present cost and the proposed cost. CEAMOD is "For Official Use Only" and personnel needing additional information about it should contact the Air Force's Lead Operations Research Analyst for additional information.

A. DATA FOR LIFE CYCLE COSTING

To conduct a costing benefit appraisal, the required applicable information and data have to be identified and collected. Additionally, in order to have effective life cycle cost estimates, the availability of reliable cost data is vital. Since accurate data are vital to life cycle costing, Dhillon suggests the following areas be addressed:

- Responsibility of the cost analyst.
- Ground rules and assumptions.
- Estimating procedures.
- Treatment of uncertainties.
- Required precision and accuracy of the analysis.
- Data availability.
- Data bias.
- Data obsolescence.
- Data orientation towards the problem.
- Data applicability.
- Data comparability to other existing data.
- Data co-ordination with other information. [Ref. 22:p. 40]

B. VISIBILITY AND MANAGEMENT OF OPERATING AND SUPPORT COST MANAGEMENT INFORMATION SYSTEM FOR LIFE CYCLE COSTING

The Visibility and Management of Operating and Support Costs (VAMOSC) management information system (MS) is a program which collects, processes, and reports historical data on the operating and support (O&S) costs of major defense systems and subsystems. These costs are key elements in the total life cycle cost of a weapon system and, as such, represent vital information in the decision making process. Within the Navy there are two separate VAMOSC management information systems: VAMOSC-AIR and VAMOSC-SHIPS. [Ref. 25:pp. 1-3]

NAVAIR 41114 sponsors the VAMOSC-AIR MS program and provides a cost-effective operating and support cost management information system. According to the Naval Aviation Maintenance Office (NAMO), the Air Maintenance Subsystem (VAMOSC-AIR MS) report provides a reliable source of historical Naval aircraft cost data [Ref. 26:pp. 2-3]. VAMOSC provides printed reports of aircraft system operating and support cost by aircraft Type/Model/Series (T/M/S). This report can even provide maintenance cost data to the aircraft's 5th digit work unit code (WUC) or "black box" level[6].

According to Mrs. Toni Felkamp, NAVAIR 41114B VAMOSC Program Manager, the VAMOSC data base is not yet set up to contain engine data by type equipment code (TEC) [Ref. 27]. The VAMOSC-AIR report summarized to the 2nd digit WUC level of the aircraft was used to obtain engine cost data for this thesis. NAVAIR has future plans to improve the application of this data base to include all types of equipment including engines. This data base will lead to a higher quality cost tracking and cost estimation system at all levels of repair. Table IV illustrates a typical weapon system level operating and support cost breakdown structure used by NAVAIR to develop the VAMOSC-AIR data base.

The VAMOSC historical data base provides maintenance support costs, which include scheduled and unscheduled maintenance labor and material. VAMOSC maintenance data are derived from the 3M (Maintenance & Material Management) reporting system. Thus, the costs are based on 3M Maintenance Actions Forms (MAFs), Support Action Forms (SAFs), and Technical Directive Compliance (TDC) forms, as reported by fleet personnel.

The VAMOSC cost differences between aircraft are due to aircraft design and operational and support characteristics [Ref. 28:pp. 2-1 to 2-12]. Appendix C

[6]The WUC is a code that identifies an aircraft system, subsystem, set, major component, reparable sub-assembly or part of an end item. For example, the radar, the engine, and the electrical system may be represented by a two digit WUC. The WUC can be given supplementary digits representing individual components of this subsystem, such as the "black box".

contains additional VAMOSC information and a sample copy of the F-14A [OCT. 86 - SEPT. 87] VAMOSC microfiche printout.

With the availability of VAMOSC data, an analysis of possible engine CIP benefits, such as a trend of reduced maintenance support cost could be developed over a period of time. This would be a time consuming process to acquire all the aircraft microfiches for a specific engine, and then collect engine WUC data from the microfiche for the database.

C. COST CATEGORIES

The three levels of maintenance for naval aircraft are organizational, intermediate, and depot. The costs of direct labor, support labor, and consumable material will be used to estimate the aircraft maintenance cost per flight hour. The depot level costs will be derived from the VAMOSC-AIR MS report due to the limited amount of cost information data available. The actual costs at the

TABLE IV
WEAPON SYSTEM BREAKDOWN COST STRUCTURE

WEAPON SYSTEM LEVEL
<u>O&S COST BREAKDOWN STRUCTURE</u>

PERSONNEL
- OFFICER
- ENLISTED

OPERATING CONSUMABLES
- POL
- OTHER

REPLENISHMENT SPARES
- ATTRITIONS + SURVEYS

DEPOT
- COMPONENT REWORK
- ENGINE REWORK
- AIRFRAME REWORK

INDIRECT

organizational and intermediate maintenance levels are reported as accurately as possible, but depot costs are entirely based on the estimated number of maintenance actions at a standard cost per action [Ref. 29:p. 8]. Due to the lack of actual data, no conclusions were made about the depot level. The estimated depot costs in the VAMOSC-AIR MS reports will be considered in the thesis calculations when cost savings are projected for reliability improvements. Additional calculations used in this thesis are that the inverse of mean flight hours between maintenance action (MFHBMA) is mean maintenance actions per flight hour (MMA/FH), and the product of MMA/FH and mean maintenance manhour per maintenance action (MMH/MA) is the mean maintenance manhours per flight hour (MMH/FH).

1. Direct Labor Cost Data

The labor rate from the VAMOSC-AIR MS reports is a composite average labor rate calculated for each maintenance level, provided from the personnel cost model maintained by OP-162. Direct labor cost is calculated only for scheduled and unscheduled maintenance. The composite labor rates used are $11.03/hr at the organizational level and $13.25/hr at the intermediate level. These rates vary each year and can be found in the VAMOSC-AIR MS report.

2. Support Labor Cost Data

Support labor cost is in support of direct maintenance actions. Support labor cost was derived from the relationship between MMH/FH and the support labor hours per flight hour (SLH/FH). SLH/FH was plotted against MMH/FH for each aircraft at the organizational and intermediate levels, and a simple linear regression was done. The resulting correlation coefficient was $r^2 = 0.934$. With these results the author derived support labor hours per direct maintenance manhours (SLH/DMH).

3. Consumable Parts Cost Data

The consumable cost per flight hour is the mean number of maintenance actions (of all types) per flight hour (MMA/FH) times the cost per maintenance action ($/MA). Using frequency of failure, MMA calculated as weighted mean of all WUC's MAs.

4. Reliability & Maintainability (R&M) Data

In developing the maintenance cost function, VAMOSC reports for the selected aircraft (F-14A, A-7E, P-3C, A-6E, S-3A, EA-6B, E-2C, KC-130F) were used as the source of data. The three fiscal years of VAMOSC reports for 1984, 1985, and 1986 were used to establish average values for Reliability and Maintainability (R&M) at each maintenance level. This was done to lessen any inaccuracies from reporting a single year of data. The two primary measures of R&M, mean flight hours between maintenance actions (MFHBMA) and mean maintenance hours per maintenance action (MMH/MA), are scheduled and unscheduled maintenance. Table V lists the values for each of these measures for each aircraft type at the organizational and intermediate levels of maintenance. The aircraft types are listed in descending order of yearly maintenance cost per flight hour. This order of aircraft types will be used in all data tables. The mean flight hours between maintenance actions at the organizational level is the dominant factor in the yearly maintenance cost for the aircraft listed in Table V.

This dominance can be seen by comparing the organizational savings to intermediate savings, for a five percent improvement in either MFHBMA or MMH/MA. For example, Table VI shows that for a F-14A aircraft a five percent organizational level improvement in either MFHBMA or MMH/MA results in a savings of $11.77 per flight hour. However, a five percent I level improvement results in a savings of only $5.76 per flight hour. The savings at the intermediate level represents the smallest potential savings. Therefore, increasing organizational MFHBMA or decreasing organizational MMH/MA will result in the largest savings, compared to intermediate maintenance. An improvement of maintenance procedures to reduce the MMH/MA is an example of an approach to achieve maintenance cost reduction. Improvements to decrease the MMH/MA of an aircraft may concentrate on engine component accessibility and ease of removal and quick repair through the use of modular parts.

TABLE V
R&M DATA FOR FISCAL YEARS 84-86

AIRCRAFT TYPE	ORGANIZATION LEVEL		INTERMEDIATE LEVEL	
	MFHBMA	MMH/MA	MFHBMA	MMH/MA
EA-6B	0.233	6.140	1.111	11.037
A-6E	0.270	5.694	1.071	10.821
F-14A	0.286	6.324	1.034	9.310
S-3A	0.268	4.946	1.277	11.872
A-7E	0.326	5.196	1.429	8.857
E-2C	0.316	4.716	1.676	11.117
KC-130F	0.508	6.983	2.013	11.477
P-3C	0.462	5.031	1.765	9.412

TABLE VI

ORGANIZATIONAL AND INTERMEDIATE MAINTENANCE COST CALCULATIONS

	ORGANIZATIONAL LEVEL			INTERMEDIATE LEVEL				RANKING	RATIO	
	MFHBMA	MMH/MA	MMH/MFH	MFHBMA	MMH/MA	MMH/MFH	$/FH	$/FH	MMH/MA	MMH/MFH
F14A	0.286	6.324	22.1119	1.034	9.31	9.0039	$350.74	(3)	1.472	0.407
A7E	0.326	5.196	15.9387	1.429	8.857	6.1980	$249.08	(5)	1.705	0.389
P3C	0.462	5.031	10.8896	1.765	9.412	5.3326	$184.23	(8)	1.871	0.490
A6E	0.270	5.694	21.0889	1.071	10.821	10.1036	$353.92	(2)	1.900	0.479
S3A	0.268	4.946	18.4552	1.277	11.872	9.2968	$315.55	(4)	2.400	0.504
EA6B	0.233	6.140	26.3519	1.111	11.037	9.9343	$407.81	(1)	1.798	0.377
E2C	0.316	4.716	14.9241	1.676	11.117	6.6331	$243.84	(6)	2.357	0.444
KC130F	0.508	6.983	13.7461	2.013	11.477	5.7014	$219.37	(7)	1.644	0.415

	5% O LEVEL IMPROVEMENT							SAVINGS		SAVINGS (O/I) RATIO
								$/FH		BENEFIT
F14A	0.301	6.324	21.0063	1.034	9.31	9.0039	$338.97	$11.77	(2)	2.0433
A7E	0.343	5.196	15.1417	1.429	8.857	6.1980	$240.59	$ 8.49	(5)	2.1396
P3C	0.486	5.031	10.3451	1.765	9.412	5.3326	$178.43	$ 5.80	(8)	1.6991
A6E	0.284	5.694	20.0344	1.071	10.821	10.1036	$342.69	$11.23	(3)	1.7367
S3A	0.282	4.946	17.5325	1.277	11.872	9.2968	$305.72	$ 9.83	(4)	1.6517
EA6B	0.245	6.140	25.0343	1.111	11.037	9.9343	$393.77	$14.03	(1)	2.2071
E2C	0.333	4.716	14.1778	1.676	11.117	6.6331	$235.90	$ 7.95	(6)	1.872
KC130F	0.535	6.983	13.0588	2.013	11.477	5.7014	$212.05	$ 7.32	(7)	2.006

				5% I LEVEL IMPROVEMENT						
F14A	0.286	6.324	22.1119	1.088	9.31	8.5537	$344.98	$ 5.76	(4)	
A7E	0.326	5.196	15.9387	1.504	8.857	5.8881	$245.11	$ 3.97	(6)	
P3C	0.462	5.031	10.8896	1.858	9.412	5.0659	$180.82	$ 3.41	(8)	
A6E	0.270	5.694	21.0889	1.127	10.821	9.5985	$347.46	$ 6.47	(2)	
S3A	0.268	4.946	18.4552	1.344	11.872	8.8319	$309.60	$ 5.95	(3)	
EA6B	0.233	6.140	26.3519	1.169	11.037	9.4376	$401.45	$ 6.36	(1)	
E2C	0.316	4.716	14.9241	1.764	11.117	6.3014	$239.60	$ 4.25	(5)	$10.65 $/MMH O LEVEL
KC130F	0.508	6.983	13.7461	2.119	11.477	5.4164	$215.73	$ 3.65	(7)	$12.80 $/MMH I LEVEL

5. Cost Data

To establish an average yearly cost in the categories of direct labor, consumable parts, and support labor in constant dollars, the three years of cost data from the VAMOSC-AIR MS reports were converted individually to constant 1989 fiscal year dollars. Division by a budget deflator for the individual year converted the historical costs to constant dollars. The composite deflators used for FY's 84-86 were 0.8580, 0.8842, and 0.9056 respectively [Ref. 30]. Appendix D contains a list of the composite deflators from fiscal year 1970 to 1992.

To obtain the costs per flight hour ($/FH), the yearly costs for direct and support labor were divided by the annual number of flight hours. The costs of consumable parts were converted to a cost per maintenance actions ($/MA). The costs of repairables is included in the depot cost calculations. Table VII lists these maintenance costs for each aircraft at each maintenance level.

TABLE VII
AIRCRAFT COST DATA FOR FISCAL YEARS 84-86

AIRCRAFT TYPE	ORGANIZATIONAL LEVEL			INTERMEDIATE LEVEL		
	LABOR ($/FH)		($/MA)	LABOR ($/FH)		($/MA)
	DIRECT	SUPPORT	CONSUMABLES	DIRECT	SUPPORT	CONSUMABLES
EA-6B	281.4	245.0	9.92	123.2	3.1	200.62
A-6E	226.3	192.2	19.66	129.9	3.1	77.73
F-14A	234.3	218.0	47.20	116.3	5.3	112.85
S-3A	199.1	207.9	28.64	119.8	4.6	44.90
A-7E	170.7	214.1	20.48	80.1	2.1	69.20
E-2C	160.4	136.2	37.50	85.7	1.6	131.32
KC130F	147.8	108.3	19.80	73.7	2.1	84.19
P-3C	116.3	82.6	33.05	70.1	2.1	76.96

With the R&M and cost data in these forms, an hourly cost function was developed:

$$COST\ PER\ FLIGHT\ HOUR\ (\$/FH) = \frac{(M)(L)+P+(S)(M)(L)}{R} \qquad (4)$$

where:

- M is mean maintenance manhours per maintenance action (MMH/MA).
- L is labor rate in dollars per maintenance hour ($/MH).
- P is average consumable parts cost per maintenance action ($/MA).
- S is rate of support labor hours per direct maintenance hour (SLH/DMH).
- R is mean flight hours between maintenance actions (MFHBMA).

6. Aircraft Maintenance Cost Per Flight Hour

Given that before a maintenance action occurs at the intermediate level, a maintenance action occurred at the organizational level to create the demand for maintenance. MMA/FH at the intermediate level can be derived from the MMA/FH at the organizational level thus the cost functions at both levels can be combined. The following cost per flight hour function was developed:

$$\$/FH = (\frac{1}{R_o})(M_oL_o+P_o+S_oM_oL_o)+F(\frac{1}{R_o})(M_iL_i+P_i+S_iM_iL_i) \qquad (5)$$

where:

- R_o is the MFHBMA at the organizational level.
- M_o is the MMH/MA at the organizational level.
- P_o is the organizational consumable costs per maintenance action ($/MA).
- L_o is the organizational labor rate ($/MH).
- S_o is the support labor hours per direct maintenance hour (SLH/DMH).
- F is the percent of organizational maintenance actions that will generate intermediate actions.

- M_i is the MMH/MA at the intermediate level.
- P_i is the intermediate consumable costs per maintenance action ($/MA).
- L_i is the intermediate labor rate ($/MH).
- S_i is the support labor hours per direct maintenance hour (SLH/DMH).

The percent of organizational level maintenance action that will generate intermediate level maintenance action is given as [$MFHBMA_o/MFHBMA_i$] or the ratio of MMA/FH (intermediate) to MMA/FH (organizational) for the eight aircraft. Table VIII, column 4 lists MMA/FH_i to MMA/FH_o aircraft ratios.

Table IX lists maintenance cost per flight hour by aircraft. The total annual maintenance cost of each is determined by its yearly flight hour usage. CIP R&M improvements should decrease the aircraft's yearly flight hour cost. Therefore, with the estimated yearly flight hour cost calculated and given the aircraft's projected annual number of flight hours, the results may be graphed similar to the cumulative life cycle cost model, discussed in Chapter III.

TABLE VIII SUPPORT LABOR HOURS PER MAINTENANCE HOUR AND RATIO OF I LEVEL MMA/FH TO O LEVEL MMA/FH			
AIRCRAFT TYPE	O LEVEL SLH/DMH	I LEVEL SLH/DMH	I MMA/FH TO O MMA/FH
EA-6B	0.8714	0.0244	0.2093
A-6E	0.8566	0.0240	0.2522
F-14A	0.9248	0.0460	0.2763
S-3A	1.0571	0.0386	0.2098
A-7E	1.2617	0.0265	0.2282
E-2C	0.8564	0.0188	0.1885
KC-130F	0.7405	0.0288	0.2527
P-3C	0.7115	0.0308	0.2616

TABLE IX AIRCRAFT COST PER FLIGHT HOUR				
AIRCRAFT	TOTAL	O LEVEL	I LEVEL	D LEVEL
EA-6B	1487.	569.	311.	607.
A-6E	1329.	489.	205.	635.
F-14A	1430.	619.	239.	572.
S-3A	1466.	511.	159.	796.
A-7E	1051.	447.	130.	474.
E-2C	1054.	414.	165.	475.
KC-130F	764.	294.	117.	353.
P-3C	754.	270.	114.	370.

D. RETURN ON INVESTMENT PROGRAM ANALYSIS

Return On Investment (ROI) is an analysis of the tradeoff between current dollars and future dollars. ROI is used to reduce the uncertainty of choice among proposed Engineering Planning Documents (EPD), Engineering Project Descriptions (EPN), and Engineering Change Proposals (ECP) through quantitative comparison of investment cost, time to return investment, and reductions in operating cost associated with these proposals. ROI is calculated using the ROI Analysis Program, developed for AIR-536, and designed to be run on a DOS compatible personal computer. The program analysis incorporated here uses version 4.1 of ROI.

The emphasis in the ROI program is on Navy operating costs such as maintenance manhours, repair materials, equipment loss, and downtime on the weapon system. The events that generate these operating costs are:

- Inspections.
- Scheduled maintenance events.
- Unscheduled maintenance events.
- Personnel/equipment losses.

The ROI Analysis Program will be used in this thesis to analyze the cost benefits of the F-14A TF30-P-414A engine improvement.

1. F-14A TF30-P-414 Engine Improvement

Development of the TF30 engine began in 1958. It was chosen as the power plant for the F-111 and the A-7A aircraft. Later, the engine was modified to create the TF30-P-412A for the F-14A. In 1977 the TF30-P-412A was modified to create the TF30-P-414. This latter modification involved a new first stage, new compressor rotor blades and a strengthened fan case to ensure containment.

During the late 1970s the F-14A TF30-P-414 was experiencing basic engine technical problems. NAVAIR engineers and contractors were using CIP funds to solve these problems. Some of these problems were:

- Stall - an engine stall which is not self-recovering and requiring the pilot to shut down the engine and then restart it. Prior to 1978, the engine stall rate was over two per 1000 engine flight hours.
- Turbine Overtemperature - burning and cracking of the high pressure turbine vanes and blades.
- Reliability - the engine control accounted for 27.6 percent of TF30 unscheduled maintenance actions.
- Durability - the turbine and augmenter accounted for almost 50 percent of the unscheduled maintenance actions. This is a result of overtemperature conditions or hot spots from the combustion process and the high number of cycles during a flight.
- Low Cycle Fatigue - problems with cracks and failure of the compressor and turbine discs, from engine pressure loading and unloading.

In 1979, the TF30 was the Navy's highest priority engine effort. The Navy and Pratt & Whitney executed a plan to correct the durability and compressor stall problems. An incentive contract for the TF30-P-414 to create the TF30-P-414A engine improvement was signed by Pratt & Whitney and NAVAIR in July 1979. Engineering development and testing was completed by April 1981. Retrofit kits were available beginning in October 1982 and the complete TF30-P-414 engine inventory was converted to the TF30-P-414A configuration by 1988.

It was estimated that the stall rate of approximately 1.45 stalls per 1000 engine flight hours would be reduced by 50 percent upon incorporation of the P-414A changes. The hot section inspection (HSI) interval of 550 hours for the current P-414 configuration was also projected to increase to 1000 hours with P-414A improvements. The TF30-P-414A low cycle fatigue improvement would add another 4000 hours to the engine, making a 6000 hour total engine life. Additionally, the engine problems accounted for about three percent of the F-14A's non-mission capable rate (NMC) in the late 1970s.

2. Results Of The F-14A TF30-P-414 Engine Improvement

The F-14A TF30-P-414 engine improvement process began back in 1979. The corrective action taken was to:

- Revise the mid-compressor bypass schedule to provide engine operation at flight conditions below 0.5 mach.
- Revise afterburner suppression to give an additional stability margin during engine afterburner steady-state and shutdown system operations.
- Improve engine maintenance procedures including those for the air inlet control system, engine fuel control system rigging, inlet seals, control system contamination, and trouble shooting.
- Improve pilot procedures through training improvements and Naval Air Training and Operating Procedures Standardization Program (NATOPS) revisions.

The engine overhaul interval for the TF30-P-414A improved from 1200 hours to 4800 hours in 1989. One goal of the TF30-P-414A improvement package was to decrease the engine NMC rate effect on the F-14A by 50 percent. This goal of this improvement has been accomplished and the NMC rate has remained below one percent for the past six years. One possible reason for the NMC rate remaining below one percent is due to the TF30-P-414A engine improvement.

Since CIP funding addresses either safety related items or only the most critical readiness degraders, to determine the general trend of the TF30-P-414 and the TF30-P-414A engine, the 10 ECIFR "health of the fleet" parameters were plotted[7]. Appendix E plots the parameters: engine flight hours per failure; engine flight hours per maintenance action; aborts per 1000 engine flight hours; failure aborts per 1000 engine flight hours; engine removals per 1000 engine flight hours; failure engine removals per 1000 engine flight hours; maintenance manhours per engine flight hour; elapsed maintenance time per maintenance action; not mission

[7]The source of data for the TF30-P-414 health of the fleet indicator graphs is the Engine Component Improvement Feedback Report (ECIFR). ECIFR is prepared by Naval Weapons Engineering Support Activity Information Systems Department providing a collection of 12 month reports, providing engine and engine component statistical data. Examples of ECIFR reports are: engine related NMC hours; aborts; causes for engine removals; engine related maintenance manhours and maintenance actions. These graphs contain two sets of data from calendar year 1987. This is the year in which ECIFR data reports included both the TF-30-414 engine and the TF30-P-414A engine.

capable hours per engine flight hour; and component removals per 1000 engine flight hours.

The graphs show a definite improvement trend, but there is no clearly identified cause and effect relations between CIP funds and 3M data. A possible reason for trend improvement is the effort made at the fleet squadrons to keep acceptable readiness figures for their squadron. A newly assigned squadron commanding officer's goal is to obtain higher readiness figures than the previous commanding officer. Methods to increase readiness is by not documenting on VIDS/MAFs extra manhours on aircraft and engines, by not documenting parts obtained from "parts lockers" which are not accounted for, and by not documenting cannibalizations from squadron aircraft or other squadrons.

3. Sensitivity Analysis Of The F-14A TF30 Engine Improvement

With the assistance of Mr. Scott Cote and Mr. John Bentz of Naval Air Development Center (NADC), the F-14A TF30-P-414A improvement was selected for ROI analysis. Appendix F shows a computer printout of the ROI analysis program and results. With a CIP investment of $152,300,000 in the TF30-P-414A, the total estimated calendar time to return of investment is 7.34 years from the initiation of the modification process.

The ROI analysis program uses a data value of cost per NMC hour. The author disagrees with the current procedure in calculating the cost of an aircraft's NMC hour. The current procedure is taking the cost of the aircraft and dividing it by the amortization period in hours. For instance, a 50 million dollar F-14 amortized over 20 years (175,320 hours) equates to $285 per NMC hour. From the author's aircraft maintenance experience, this is not the cost associated with not having the weapon system available for use during any hour of the planned utilization period, such as when the aircraft is preparing to launch off a carrier.

The author performed a sensitivity analysis to validate the ROI analysis program results. The sensitivity analysis procedure used by the author was to vary the range of each selected ROI input parameter from 50 percent to 1000 percent of its base value. Some of the parameters that were varied were: fuel cost; cost per maintenance manhour; cost per not mission capable hour; inspections per flight hour; elapsed maintenance time per inspection; maintenance manhours per inspection; replacement frequency per flight hour; elapsed maintenance time per replacement; maintenance manhours per replacement; cost of replacement; maintenance actions per engine flight hour; elapsed maintenance time per maintenance action; maintenance manhours per maintenance action; and cost per maintenance action. Appendix G contains a spreadsheet listing ROI analysis program results when varying the selected parameter with the following percentages: 50; 60; 70; 80; 90; 100; 110; 120; 130; 140; 150; 160; 170; 180; 190; 200; 300; 400; 500; and 1000. The procedure used was to select an input parameter, charge the parameter base value by one of the previous values, input this value in the ROI analysis program, and record the results. This is a time consuming procedure, since the ROI analysis program must be rerun each time. This was done 487 times in the course of the sensitivity analysis. The affect on ROI total calendar time ranges from 3 years to "out of range."[8]

The parameters that affected the results the most were plotted and the graphs are presented in Appendix G. The graphs are divided into two categories. The first category involves parameter changes in operational data before the engine modification, and the second category is parameter changes in expected operational data after the engine modification. This is referred to as before the fix and after the fix in both the ROI analysis computer program and in Figure 8. These two categories were selected to determine what input error, if any, would affect the results. Figure 8 presents the ROI sensitivity results in a simple manner. Each parameter and its range of total calendar time in years to return the investment are shown in the figure. Only the parameters that had a range of results were included in this figure.

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[8]The "out of range" condition occurs when the parameter value causes the ROI analysis program to output a negative value or output an "out of range" syntax error.

A sensitivity analysis was performed on the operational data both before and after the fix. The author's assumption is that there will be a smaller chance of an error in the before fix operational data. There is less chance of an error because the before fix operational data is based on a current statistical engine data base. There is a possibility of an error in after the fix operational data because these data will be based on estimates from NAVAIR project engineers or the engine manufacture's engineers.

The results presented in Figure 8 graphically show that if the input parameter EMT per MA is varied from 7.1 hours to 25.6 hours, the range of ROI results is from 6.49 to 15.4 years. Appendix H contains graphs of all of the parameter ranges and ROI results.

The graphs show that when the input parameter is varied by a percent, increase or decrease, the ROI results does not correlate to a linear relationship. An error in replacement per flight hour, maintenance actions per engine flight hour, elapsed maintenance time per maintenance action, maintenance manhour per maintenance action, and the cost per maintenance action affect the total years to return investment the most.

OPERATIONAL DATA BEFORE FIX

```
                          Total Years to Return Investment
Parameter        3     5     6     7     8     9     11     13     15     +
                 .     .     .     .     .     .     .      .      .      .
Cost per MMH                   CCCCCC
Cost per NMC hr JJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJJ>
Insp per FH                          III
EMT per Insp                          EE
MMH per Insp                          MM
Repl per FH     RRRRRRRRRRRRRRRRRRRRRRRRR
EMT per Repl                         BBB
MMH per Repl                          AA
Cost of Repl          *PPPPPPPPPPPPPPPPPPPPPPPPPP
MAs per EFH     FFFFFFFFFFFFFFFFF+
EMT per MA       GGGGGGGGGGGGGGGGGG+
MMH per MA            DDDDDDDDDDD
Cost per MA     NNNNNNNNNNNNNN+
```

EXPECTED OPERATIONAL DATA AFTER THE FIX

```
                          Total Years to Return Investment
Parameter        3     5     6     7     8     9     11     13     15     +
                 .     .     .     .     .     .     .      .      .      .
Insp per FH                          iiii
EMT per Insp                          eee
MMH per Insp                          mm
Repl per FH                      rrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrrr+
EMT per Repl                          bbb
MMH per Repl                         aa
Cost of Repl                         ppppp*
MAs per EFH       fffffffffffffffffffffffff+
EMT per MA                       gggggggggggggggggggggggggggggggggggggggg+
MMH per MA                           ddddddddddddd+
Cost per MA       nnnnnnnnnnnnnnnnnnnnnnnnnnnnnnn+
```

Key:
The letter represents the parameter value used in the ROI analysis program.
The lower case letter represents upper case with an apostrophe (i.e., n = N').
+ The parameter caused an "out of range" output for ROI analysis program.
* The parameter was limited to 6 digits for input to ROI analysis program.

Figure 8 Parameter Ranges for the Sensitivity Analysis of TF30-P-414A ROI Program Analysis Output

IV. CONCLUSIONS - RECOMMENDATIONS

The major problem confronted during the thesis research was the lack of readily accessible aircraft and engine cost data. For example, engine modification cost data are not readily maintained in a data base. To extract engine cost data, the researcher must collect every ECP, EPD, EPN for a specific engine and model, and develop an engine cost database. Furthermore, aircraft cost data are maintained only on microfiche. To obtain such data, the researcher must contact the VAMOSC program manager and submit a request for an aircraft, time period, and type of report (2 digit or 5 digit WUC). The 2 digit WUC report is only available for the years 1987 to present. This WUC report is more useful than the 5 digit WUC report because it includes the separation of maintenance cost into airframes, avionics, and power plants available. For any year before 1987, the researcher must formulate a database from the 5 digit WUC reports and then do a substantial amount of searching and sorting to get the data that are consolidated by airframe, avionics, etc.

Therefore, it is recommended that the Navy begin collecting aircraft and engine cost data at all levels of maintenance, and associate aircraft in the database with specific engine types. Currently, efforts have just begun to separate aircraft maintenance costs into categories by airframe, avionics, and power plant. It is recommended that this be done with the data for years prior to 1987. Additional data that are needed include depot costs for engines, the cost of repair parts for overhauls, the cost of consumable parts, the cost of replacing condemned repairables, and the repair, transportation, and storage of engine components.

The fighter and attack aircraft flight profile is different from the patrol aircraft flight profile. The fighter and attack pilot may make many more engine power adjustments, while the patrol pilot will stay on station for hours, making minimal throttle adjustments. More frequent changes can accelerate fatigue induced failures. Therefore, it is recommended that the Navy begin collecting engine data concerning engine duty cycles and develop measurement indicators, such as duty cycles per engine hour, or failures per duty cycle for fighter and attack aircraft first, then for patrol and other aircraft.

Until a comprehensive aircraft life cycle cost model is developed, it is recommended that NAVAIR continue to use its ROI analysis program. However, the following recommendations for improvement of the current ROI analysis program are suggested by the author.

First NAVAIR should revaluate the current method to estimate the cost of aircraft downtime. The current approach is to take the total life cycle cost for the aircraft weapon system and divide by the estimated total number of hours in the aircraft's life cycle. For example, for the F-14A this figure is $285 per hour. This value is then used for the F-14A NMC shortage cost. This is not the value of a F-14A aircraft in its ability not to perform its mission. A F-14 on 5-minute alert in the North Arabian Sea has a value of more than $285 per NMC hour. The following factor should be included: the probability of both the two F-14's not launching, times the value of the carrier, divided by the total number of hours in a day and the total number of F-14's. This would be estimated value of a F-14 for 1 hour. If a carrier is worth $1 billion, probability of launch is 95 percent, and there are 450 F-14's, the additional factor would equate to $231.60 per hour on alert.

Performing a sensitivity analysis using the ROI analysis program is time-consuming. Each parameter requires a data entry change reflecting a range of values, and the output values then recorded. It becomes even more difficult if you plan on changing more than one parameter. Therefore, the second recommendation for improvement is to consider the incorporation of sensitivity analysis as an optional part of the ROI analysis program. This would provide a method to determine whether or not to probe further for better input data or to reduce risk and uncertainty in the CIP decision process.

APPENDIX A

NAVY CIP FUNDING FISCAL YEARS 1970 - 1993

NAVY CIP FUNDING FY1970 - FY1993

EQUIPMENT	APPLICATION	FY 70	FY 71	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
J52 ENGINE	A-4, A-6	8037	5712	5175	4940	3443	2048	1868	1616	2772	2678
J57 ENGINE	RF-8	1052	997	844	800	823	545	344	52	148	0
J79 ENGINE	F-4, A-5	1000	1500	500	450	400	250	400	800	800	800
J85 ENGINE	F-5, T-2	0	500	750	500	400	540	350	500	690	700
TF30 ENGINE	A-7, F-14	9990	9281	10614	8088	5974	7235	6207	3426	4000	17053
TF41 ENGINE	A-7	6500	5135	6750	6396	5900	3990	9727	10729	10466	7969
F402 ENGINE	AV-8	0	0	5293	5000	3200	3480	3259	4105	5805	10400
TOTAL AIR-5361		26579	23125	29926	26174	20140	18088	22155	21228	24681	39600
T56 ENGINE	P3,C130,E2,C2	2364	1182	1250	1104	993	900	500	1020	1000	1100
T58 ENGINE	H-2,H-3,H-46	1963	2500	2500	3375	1871	1659	1550	1479	1621	1700
T64 ENGINE	H-53	1500	2500	2800	1400	1300	1400	1400	1400	1500	1500
T76 ENGINE	OV-10	1250	740	600	547	400	400	310	790	800	1000
T400 ENGINE	H-1	1404	1250	1401	1136	675	839	693	600	550	1015
TF34 ENGINE	S-3	0	0	300	12500	5500	5250	5010	5500	6500	5900
PROPELLERS	P3,C130,E2,C2,OV10	1021	1327	1845	1196	1350	1960	1982	1499	1200	1200
RECIPS		500	350	650	500	550	500	500	500	400	300
TOTAL AIR-5362		10002	9849	11346	21758	12639	12908	11945	12788	13571	13715
STARTERS/APU	ALL	586	394	556	575	664	80	601	545	289	249
TRANSMISSIONS	H1,H2,H3,H46,H53										
TOTAL AIR-5363		586	394	556	575	664	80	601	545	289	249
TOTAL CONTRACT EFFORT		37167	33368	41828	48507	33443	31076	34701	34561	38541	53564
IN-HOUSE EFFORT											
NAPC-TRENTON		4268	5006	2599	3652	4285	2659	3317	1582	1314	2600
NAPTC-TRENTON	ELECTRICAL	0	0	153	109						
NATC-PAX RIVER		228	539	389	338	356	848	1100	1611	2150	800
NATC ELECTRICAL		1190	855	948	890	880	826	795	700	1050	830
NAEC-LAKEHURST									0	23	0
NAEC-LAKEHURST	ELECTRICAL								0	29	
NADC-WARMINSTER		30	30	35	38	70	252	375	410	257	400
NWSC-CRANE	ELECTRICAL	130	100	26	51	120	100	95	150	208	170
NAVWESA						5	0	15	200	332	410
NRL								6	54	112	0
NAC-INDIANAPOLIS											
NWS-SEAL BEACH									60		
NADEP-NORFOLK		140	7	0	0	0	0	0	0	0	58
NADEP-NORTH ISLAND											
NADEP-ALAMEDA		16	0	33	0	11	0	0	49	0	59
NADEP-JACKSONVILLE		30	0	0	0	0	0	0	0	0	40
NADEP-CHERRY POINT											
NARF-QUONSET POINT		0	0	47							
NARF-PENSACOLA		0	37								
OTHER SUPPORT		12	10	9	0	18	21	92	1700	4	106
TOTAL FIELD STATION		6044	6584	4239	5078	5745	4706	5795	6516	5479	5473
FUELS & LUB		19	134	516	367	128	793	1390	624	601	1264
J48		80	75	60	100						
J65		1138	1300	1177	1000	995	500	500	300		
J34		110	86	51							
T53		250	244	250							
TIRAS				174	354	356	365	445	98		
CONSTANT SPEED						73					
TRAVEL											
TOTAL IN-HOUSE		7641	8423	6467	6899	7297	6364	8130	7538	6080	6737
TOTAL CIP ALLOCATION		44808	41791	48295	55406	40740	37440	42831	42099	44621	60301

NAVY CIP FUNDING FY1970 - FY1993 (cont)

EQUIPMENT	APPLICATION	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	REQ FY 91	REQ FY 92	REQ FY 93
J52 ENGINE	A-4, A-6	2415	2750	3080	3096	3300	6750	8054	5666	4093	2275	2200	2400	2100	2000
J52-409										2310	6999	0	0	0	0
J57 ENGINE	RF-8	0	25	30	30	35	55	58	0	0	0	0	0	0	0
J79 ENGINE	F-4, A-5	600	850	469	265	414	308	248	90	120	30	0	0	0	0
J85 ENGINE	F-5, T-2	500	525	470	480	370	475	297	45	60	15	124	0	0	0
TF30 ENGINE	A-7, F-14	24531	16665	9350	7253	7700	7400	4777	1210	1727	439	1069	1100	700	0
TF41 ENGINE	A-7	4900	4250	4000	4241	3300	3500	3000	360	90	30	0	0	0	0
F402 ENGINE	AV-8	11155	9809	9750	13800	5848	6281	3500	3398	3000	3300	4300	3800	3600	3700
F404GE ENGINE	F/A-18	2100	14460	28788	24055	25003	16845	8655	5442	5109	5605	8248	9800	11500	12000
F404PW ENGINE	F/A-18									0	810				
F110 ENGINE	F-14									2815	5491	5268	5500	9500	10000
F404/F5D2														0	0
TOTAL AIR-5361		46201	49334	55937	53220	45970	41614	28589	16211	19324	24994	21209	22600	27400	27700
T56 ENGINE	P3,C130,E2,C2	825	1200	1598	2456	1800	2250	3075	975	769	1225	403	300	300	300
T56-427	E2									400	1011	1029	1200	1700	1500
T58 ENGINE	H-2,H-3,H-46	1200	1870	1600	1100	1300	1417	1236	1218	616	0	452	0	0	0
T64 ENGINE	H-53	850	985	678	750	850	833	875	770	719	206	203	0	0	0
T76 ENGINE	OV-10	751	832	938	800	736	800	664	483	235	434	225	0	0	0
T400 ENGINE	H-1	351	1702	924	1000	900	726	0	82	237	239	300	0	0	0
T700 ENGINE	SH-60B				1830	7200	7000	5000	2886	1069	718	924	1100	980	300
TF34 ENGINE	S-3	4000	4000	3870	3740	3500	2860	2500	1584	244	707	798	700	500	0
PROPELLERS	P3,C130,E2,C2,OV10,V22	750	1000	990	1278	1531	1257	963	397	446	270	450	350	300	300
RECIPS		225	300	325	325										
F405-RR-400	T-45												1000	2900	2800
T406	V-22												2000	4500	5000
LRAACA (GE38)	P-3 DERIVATIVE														1500
TOTAL AIR-5362		8952	11889	10923	13279	17817	17143	14313	8395	4735	4810	4784	6650	11180	11700
STARTERS/APU	ALL	40	65	680	761	447	955	0	206	0	0	0	0	0	0
TRANSMISSIONS	H1,H2,H3,H46,H53,V22					100	0	870	414	0	0	0			
TOTAL AIR-5363		40	65	680	761	547	955	870	620	0	0	0	0	0	0
TOTAL CONTRACT EFFORT		55193	61288	67540	67260	64334	59712	43772	25226	24059	29804	25993	29250	38580	39400
IN-HOUSE EFFORT															
NAPC-TRENTON		2850	3016	4690	4654	7824	7959	715	4645	6816	4996	6038	5700	6500	6500
NATC-PAX RIVER		1200	865	1288	2544	4453	4037	1899	2403	889	1242	605	1400	2000	2000
NATC ELECTRICAL		900	900	900	800	800	0	370	850	670	887	650	750	800	800
NAESU					69	0	0	0	78	0	0	15	0	0	0
NAEC-LAKEHURST		0	0	0	0	0	0	0	0	138					
NADC-WARMINSTER		359	349	275	400	724	991	795	646	465	395	225	400	400	233
NADC	ELECTRICAL					100	0	0	0	0	0	55	0	0	0
NWSC-CRANE	ELECTRICAL	300	300	900	900	600	1208	375	784	640	782	756	700	600	600
NAVWESA		434	260	191	10	170	175	199	319	350	390	200	500	600	600
NPS												9			
NRL		10	0	103	0	5	113	100	88	0	0	0	0	0	0
NAC-INDIANAPOLIS						91									
NADEP-NORFOLK		96	336	71											
NADEP-NORTH ISLAND							225	147	130	100					
NADEP-CHERRY POINT			5	0	0	0	60	76	7	0	11	6	0	0	0
OTHER SUPPORT															
TOTAL FIELD STATION		6149	6031	8418	9377	14767	14768	4676	9950	10068	8703	8559	9450	10900	10733
FUELS & LUB		2377	3646	5611	3400	3239	3639	2392	951	981	676	996	1939	2987	2945
V.T. CHEN										298	124	303	500	500	500
TRAVEL						99	144	148	113	133	176	160	160	170	180
TOTAL IN-HOUSE		8526	9677	14029	12777	18105	18551	7216	11014	11480	9679	10018	12049	14557	14358
HOLD/DEFERRAL				24	1	1						2213			
TOTAL CIP ALLOCATION		63719	70965	81593	80038	82440	78263	50988	36240	35539	39483	38224	41299	53137	53758

APPENDIX B

COST ANALYSIS STRATEGY ASSESSMENT (CASA) MODEL ALGORITHMS

This appendix describes the Defense Systems Management College software module called Cost Analysis Strategy Assessment (CASA), version 2.01, which operates on an IBM compatible personal computer. CASA is part of the Program Manager's Support System (PMSS) which is a government management tool to aid acquisition executives and managers in their decision-making processes. CASA is primarily an analyst's tool, developed to estimate the cost of a weapon system and to be more user friendly than other cost models. For additional information on CASA contact:

Defense Systems Management College
ATTN: Software Distribution Center
Fort Belvoir, VA 22060-5426

This appendix contains some of the important mathematical equations used for the outputs of the CASA LCC model. The equations are listed and then the variables within the equations are described. If any of the variables are not input variables, i.e., if they are calculated within the model, then the equations for those variables are also shown. This continues until all variables are described in terms of the input variables. Equations for calculated variables are only shown once. Equations are not repeated for subsequent uses of calculated variables.

Appendix B is divided into three parts: Appendixes B.1, B.2, and B.3 describe the research, development, test and evaluation costs; acquisition costs; and operation and support costs equations, respectively. Costs shown are in constant dollars. These sections are further divided into subsections for each cost category.

Costs and resource quantities are calculated for each cost category for each year of the study. Since there may be deployment changes during a year, the number of operating systems may vary from month to month. Calculations are therefore made either for the average number of systems during each year or the maximum number of systems during each year.

Spares, support equipment, and manpower quantities are based on the maximum number of systems, while quantities of maintenance actions are based on the average.

Several subscripts are used in describing the inputs and outputs. A list of these subscripts and their uses is shown below:

Subscript	Use or Representation
i	Hardware item (1, 2, ..., *NI*).
j	Support equipment item (1,2,..., *NSE*).
k	Maintenance levels (1,2, or 3).
y	Years of the study (*INITYR*, *INITYR*+1,..., *ENDYR*).
z	Counter for particular years when a cost is incurred.

The *NI* and *NSE* variables above represent the number of hardware items and support equipment items, respectively. *N* is the number of miscellaneous entries and will vary for different categories. *INITYR* and *ENDYR* are the initial and last years of the study, respectively.

The total life cycle cost is the sum of the research, development, test and evaluation, acquisition and operation and support costs and is defined by the following equation:

$$LCC = TRDTE + TACQ + TOS \qquad (B.1)$$

where:

- *LCC* is Total Life Cycle Cost,
- *TRDTE* is Total Research, Development, Test and Evaluation Cost,
- *TACQ* is Total Acquisition Cost, and
- *TOS* is Total Operation and Support Cost.

B.1 RESEARCH, DEVELOPMENT, TEST AND EVALUATION COSTS

The total research, development, test and evaluation cost (*TRDTE*) is the cost attributed to the initial research and development to determine the feasibility of the system to be procured.

$$TRDTE = RDTESPM + RDTESTE + RDTET + RDTED + RDTEDV + RDTERD + RDTESOFT + RDTEOTH + \sum_{i=1}^{NI} RDTE_i \qquad (B.2)$$

where:

- *TRDTE* is total research and development cost.
- *RDTESPM* is system/project management cost.
- *RDTESTE* is system test and evaluation cost.
- *RDTET* is training cost.
- *RDTED* is data cost.
- *RDTEDV* is demonstration and validation cost.
- *RDTERD* is research and development cost.
- *RDTESOFT* is software cost.
- *RDTEOTH* is other cost.
- $RDTE_i$ is research, development, test, and cost per hardware item, if any occurs.
- *NI* is number of hardware items.

B.2 ACQUISITION COSTS

The total acquisition cost (*TACQ*) is the initial investment cost to the user. The costs identified are those generally associated with designing, developing, and procuring systems and support items needed to make the systems operational.

$$TACQ = \sum_{y=INITYR}^{ENDYR} (TPTTE_y + TPSUC_y + TSA_y + TSSSC_y + TECNRC_y$$

$$+ TRPP_y + TIC_y + TSEC_y + THSC_y + TSRC_y + TTDC_y + TITC_y \qquad (B.3)$$

$$+ TCTD_y + TCNF_y + TIIM_y + TISWDC_y + TMIAC_y + TWTY_y)$$

where:

- $TACQ$ is Total Acquisition Cost.
- $INITYR$ is the initial year of the study.
- $ENDYR$ is the last year of the study.
- $TPTTE_y$ is production tooling and test equipment cost in year y.
- $TPSUC_y$ is production start-up cost in year y.
- TSA_y is system acquisition cost in year y.
- $TSSSC_y$ is system shipping and storage containers cost in year y.
- $TECNRC_y$ is pre-production engineering non-recurring cost in year y.
- $TRPP_y$ is pre-production units refurbishment cost in year y.
- TIC_y is installation cost in year y.
- $TSEC_y$ is support equipment cost in year y.
- $THSC_y$ is hardware spares cost in year y.
- $TSRC_y$ is spares reusable containers cost in year y.
- $TTDC_y$ is technical data cost in year y.
- $TITC_y$ is initial training cost in year y.
- $TCTD_y$ is training devices cost in year y.
- $TCNF_y$ is new or modified facilities cost in year y.
- $TIIM_y$ is initial item management cost in year y.
- $TISWDC_y$ is initial software development cost in year y.
- $TMIAC_y$ is miscellaneous acquisition cost in year y.
- $TWTY_y$ is warranty price in year y.

The following subsections provide the equations and definitions for each acquisition cost category.

B.3 Operation and Support Costs

The total operation and support cost (TOS) is the total cost of operating, maintaining, and supporting all systems and support equipment at all maintenance levels over the life of the equipment.

$$TOS = \sum_{k=1}^{3} TOSL_k \qquad (B.4)$$

where:

- TOS is the total operation and support (O&S) cost over the life of the equipment.
- $TOSL_k$ is the total operation and support cost at the k^{th} maintenance level.

$$TOSL_k = \sum_{y=INITYR}^{ENDYR} (TCOL_{ky} + TCRL_{ky} + TCSEM_{ky} + TCRT_{ky} + TCRPM_{ky} +$$
$$+ TCRC_{ky} + TCCSR_{ky} + TCTDR_{ky} + TCTRAN_{ky} + TCRF_{ky} \qquad (B.5)$$
$$+ TCRIM_{ky} + TCSWM_{ky} + TCCS_{ky} + TCECP_{ky} + TCMOS_{ky} + TCRWTY_{ky})$$

where:

- *INITYR* is the initial year of the study.
- *ENDYR* is the last year of the study.
- $TCOL_{ky}$ is operation labor cost ($k=1$, organizational level only) in year y.
- $TCRL_{ky}$ is repair labor cost at the k^{th} level in year y.
- $TCSEM_{ky}$ is support equipment maintenance cost at the k^{th} level in year y.
- $TCRT_{ky}$ is recurring training cost at the k^{th} level in year y.
- $TCRPM_{ky}$ is repair parts and materials cost at the k^{th} level in year y.
- $TCRC_{ky}$ is repair consumables cost at the k^{th} level in year y.

- $TCCSR_{ky}$ is condemnation spares replenishment cost at the k^{th} level in year y.
- $TCTDR_{ky}$ is technical data revisions cost at the k^{th} level in year y.
- $TCTRAN_{ky}$ is transportation cost at the k^{th} level in year y.
- $TCRF_{ky}$ is recurring facilities cost at the k^{th} level in year y.
- $TCRIM_{ky}$ is recurring item management cost at the k^{th} level in year y.
- $TCSWM_{ky}$ is software maintenance cost at the k^{th} level in year y.
- $TCCS_{ky}$ is contractor services cost at the k^{th} level in year y.
- $TCECP_{ky}$ is engineering changes cost (k=3, depot level only) in year y.
- $TCMOS_{ky}$ is miscellaneous operation and support costs at the k^{th} level in year y.
- $TCRWTY_{ky}$ is recurring warranty cost at the k^{th} level in year y.

APPENDIX C

VISIBILITY AND MANAGEMENT OF OPERATING AND SUPPORT COST MANAGEMENT INFORMATION SYSTEM

A. REPORT COST ELEMENT DEFINITIONS

The following definitions will assist in interpretation of the microfiche copy of the F-14A total component maintenance cost report from VAMOSC.

Total Component Maintenance Cost Report For All Navy (Scheduled and Unscheduled)

This report summarizes labor and material costs for organizational, intermediate and deport level maintenance actions. Labor costs are reported for direct labor hours, support hours and Technical Directive Compliance (TDC) labor hours. Indirect labor costs are reported for organic depot only. Material costs are reported for consumable material used and for attrition and surveyed (condemned) items.

The direct labor and material costs for the organizational and intermediate levels of maintenance are divided between scheduled and unscheduled cost elements. The labor and material costs for depot repair and overhaul are reported for depot commercial rework, and items surveyed. Commercial rework includes DMISA costs. The reporting level is at the two-digit WUC level with each Type Equipment Code (TEC) or T/M/S breakdown. An average labor rate is computed for military personnel performing maintenance work at the organizational or intermediate levels of maintenance. The price for consumable material is obtained from the Navy Maintenance Support Officer (NAMSO) data containing NIIN and the current price.

The individual cost elements in the report are:

a. Organizational Level: Identified by a "1" code in the maintenance level field of the record type "A" created from Visual Information Display System/Maintenance Action Form (VIDS/MAF), or "1" in the maintenance level field of the Support Action Form (SAF), as reported by record type "01".

Labor - direct organizational labor cost for scheduled and unscheduled maintenance obtained from the product of direct labor hours times the organizational labor rate. The direct labor hours are obtained from the VIDS/MAF, record type A, and the labor rate is constant value for all TECs.

Consumable Material - direct organizational material cost for scheduled and unscheduled maintenance is obtained from the product of quantity issued times the unit price. The direct material quantity and NIIN is obtained from the related requisition document, record type 60, and the price from NAMSO files by NIIN.

Support Labor - organizational labor cost for the support of direct maintenance actions. The support labor hours are collected at the TEC level from the Support Action Form (SAF) through the FOJ file, record type 01, and then allocated on the basis of direct labor hours to the individual WUCs. The cost of support labor is obtained from the product of support hours times the organizational labor rate.

Technical Directive Compliance (TDC) Labor - organizational labor cost for the TDC effort in support of the direct maintenance actions. The TDC labor hours are collected from the VIDS/MAF, record type A. The labor rate used is the organizational level constant rate.

b. Intermediate Level: Identified by a "2" or "3" in the maintenance level field of the record type A of the VIDS/MAF record or the SAF record type "01". Maintenance level "3" identifies depot level maintenance performed at the intermediate level.

Labor - direct intermediate labor cost for scheduled and unscheduled maintenance obtained from the product of direct labor hours times the intermediate labor rate. The direct labor hours are obtained from the VIDS/MAF, record type A, and the labor rate is a constant value for all TECs.

Consumable Material - direct intermediate material cost for scheduled and unscheduled maintenance is obtained from the product of the quantity issued times the unit price.

Support Labor - intermediate labor cost for the support of direct maintenance actions. The support labor hours are collected at the TEC level from the SAF through the FOJ file, record type 01, and then allocated on the basis of direct labor hours to the individual WUCs. The cost of support labor is obtained from the product of support hours times the intermediate maintenance level labor rate.

TDC Labor - intermediate labor cost for the TDC effort in support of the direct maintenance actions. The TDC labor hours are collected from the VIDS/MAF, record type A. The labor rate used is the organizational maintenance level labor rate.

Attrition Costs - maintenance costs obtained from the product of the unit replacement cost for the NIIN times the number of Beyond Capability of Maintenance (BCM) code 9 actions declared at the intermediate level. A BCM-9 is a supply code that signifies condemned material.

c. *Depot Level*: Costs computed for BCM code 1 - 8 actions transferred to the depot for repair/rework at the current fiscal year depot Navy Industrial Fund (NIF) rate. Based on historical experience, the BCM actions are costed for anticipated work at a depot, commercial contractor or DMISA activity or for survey if the item is beyond repair. All costs are computed at the NIIN level and summed to the WUC.

Depot Direct Labor Cost - direct depot labor cost for labor performed on repair rework. It is calculated as the product of the estimated number of depot repairs times the average depot direct labor rate per repair.

Depot Indirect Labor Cost - indirect depot labor cost for labor performed on repairs or rework. The cost is the product of the estimated number of depot repairs times the average depot indirect labor rate per repair.

Depot Material Cost - direct material cost for material used in the repair and rework of components at a depot. The cost is the product of the estimated number of depot repairs times the average depot material cost per repair.

Commercial Labor Cost - labor cost for work related to repair and rework of components sent to commercial contractors or DMISA activities. The cost is the product of the estimated number of commercial repairs times the average commercial labor rate per repair.

Commercial Material Cost - material cost of government furnished material for work related to repair and rework of components sent to commercial contractors or DMISA activities. The cost is the product of the estimated number of commercial repairs times the average commercial labor rate per repair.

Survey Costs - costs for components that are beyond repair or rework. The cost is the product of the estimated number of components that will be surveyed times the unit replacement cost of a particular NIIN.

e. *TDC Labor* - labor cost at the depot level for the TDC effort is not reported as a separate line item within the Naval Aviation Depot Operations Center (NADOC) MCRC system or the ASO contract files.

f. *WUC Total Cost* - Total of all costs for a WUC line item including labor, material, support, and TDC costs.

g. *Pre-Ex Material* - material costs for items that were not charged at the WUC level of reporting. Taken from requisition documents, record type "67", by organization code and summed to TEC level.

h. *Organizational TDC Material* - total cost of TDC material at the organizational level, calculated from the associated VIDS/MAF requisition document, record type "64".

i. *Intermediate TDC Material* - total cost of TDC material at the intermediate level.

j. *Depot TDC Material* - total cost of TDC material at the depot level.

k. *Grand Total* - total cost for all cost elements for a specific TEC.

AIRCRAFT = F-14A TYPE EQUIPMENT = AFWA OCT. 86 - SEPT. 87
TOTAL COMPONENT MAINTENANCE COSTS (IN THOUSANDS OF $)

ORG.LEVEL LABOR RATE = 11.03 PER HOUR
INT.LEVEL LABOR RATE = 13.25 PER HOUR

ALL-NAVY SQUADRONS

WORK UNIT CODE	ORGANIZATION MAINTENANCE LABOR SCH	ORG. LABOR UNSCH	ORG. CONSUM SCH	ORG. CONSUM UNSCH	ORG. SUPPT LABOR	ORG. TDC LABOR	INTERMEDIATE MAINTENANCE LABOR SCH	INT. LABOR UNSCH	INT. CONSUM SCH	INT. CONSUM UNSCH	INT. SUPPT LABOR	INT. TDC LABOR	ATTR	DEPOT COMPONENT REPAIR NADEP D-LAB	NADEP I-LAB	NADEP MAT	COMMERC LABOR	COMMERC MAT	SURV	DEPOT TDC LABOR	WUC TOTAL COST
03	4807	49	50	5	4499	1	150	1	73	8	1	0	0	1	1	5	2	0	0	0	11853
04	1751	8	1	9	10184	0	0	0	0	0	109	0	0	0	0	0	0	0	0	0	12056
11	1361	1404	320	2209	2185	52	44	313	151	3952	2	173	0	410	383	1969	580	168	833	0	16517
12	97	318	123	526	328	14	6	36	10	193	0	15	0	48	45	230	1	0	88	0	2078
13	348	1061	261	1320	1113	93	201	889	256	2942	5	56	0	866	807	4214	156	46	1401	0	16035
14	236	1712	81	1025	1539	3	18	484	37	1385	2	2	0	389	342	1853	3370	980	748	0	14226
23	87	1127	71	568	959	1	18	186	3	184	1	6	0	510	476	2444	8	3	57	0	6703
29	54	1019	36	541	848	17	18	931	43	1771	5	3	0	250	233	1203	389	113	569	0	8041
41	32	575	35	1146	679	15	8	141	4	368	1	2	0	65	61	312	767	223	226	0	4458
42	54	1045	38	863	868	61	4	286	5	493	1	25	0	212	199	1023	51	15	682	0	3945
44	171	339	672	1225	402	1	8	57	18	210	0	0	0	18	17	86	169	38	5	0	3416
45	86	605	123	1061	546	18	27	133	23	181	1	2	0	70	65	337	730	212	179	0	4399
46	55	932	69	1179	780	9	47	239	210	521	1	0	0	397	370	1899	270	79	296	0	7335
47	7	44	4	18	40	0	26	59	5	54	0	0	0	14	13	66	16	5	10	0	381
49	15	162	20	183	140	5	5	176	9	259	1	4	0	24	23	117	43	12	30	0	1228
51	11	175	5	221	166	0	1	139	0	81	1	3	0	82	76	399	117	34	3	0	1494
56	15	648	7	100	324	1	7	1560	3	2852	8	4	0	504	472	2428	368	107	192	0	9800
57	6	542	4	70	433	1	4	1130	4	1228	6	4	0	81	76	391	256	74	130	0	4438
58	0	3	0	0	2	0	0	2	0	12	0	0	0	0	0	0	3	1	0	0	23
62	0	12	2	1	10	0	0	8	0	24	0	0	0	1	0	2	15	4	0	0	79
63	8	303	66	305	246	1	2	313	0	276	2	0	0	48	45	232	1	0	11	0	1839
64	2	86	8	26	69	0	1	55	0	40	0	0	0	0	0	2	14	4	0	0	307
65	7	228	0	1477	185	1	1	406	1	359	2	0	0	5	5	25	103	27	3	0	2835
66	2	2	2	4	3	0	22	5	11	3	0	0	0	1	1	3	0	0	0	0	59
67	1	27	0	1	22	4	0	21	1	55	0	0	0	6	6	30	0	0	3	0	177
69	12	507	35	125	410	5	8	1416	18	1601	7	1	0	146	137	703	798	232	60	0	6221
71	6	242	1	29	196	9	3	363	1	163	2	8	0	129	120	620	160	67	32	0	2123
72	4	101	10	92	83	13	1	88	1	87	0	0	0	21	20	100	131	38	6	0	796
73	41	217	0	19	204	0	372	710	1	135	5	0	0	59	49	229	320	93	0	0	2454
74	116	2930	80	1063	2407	43	53	4069	54	7145	20	14	0	892	832	4294	5074	1599	63	0	30708
75	95	479	33	435	454	8	163	260	29	522	2	1	0	405	378	1940	617	179	64	0	6064
76	29	296	53	360	257	4	9	470	7	583	2	7	0	76	71	369	133	39	133	0	2898
77	5	84	0	10	71	1	17	57	7	16	0	0	0	9	9	50	89	26	7	0	458
91	19	51	149	208	55	6	170	19	175	63	1	24	0	13	12	61	0	0	18	0	1044
93	6	8	31	28	9	8	46	6	73	32	0	0	0	7	7	34	0	0	0	0	283
96	0	1	3	13	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	20
97	24	93	315	385	92	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	912
99	63	515	53	603	458	13	52	524	39	1719	2	175	0	156	146	748	529	155	169	0	6099
TOTAL	11631	17950	2747	17445	31449	403	1512	15550	1273	29518	190	515	0	5915	5517	28418	15250	[illegible]	9998	0	195802

TOTAL OPERATING F-14A AIRCRAFT 459

TOTAL FLIGHT HOURS 108318.4

PRE-EX MAT 25
ORG TDC MAT 25
INT TDC MAT 10
DEP TDC MAT C

GRAND TOTAL FOR F-14A 195862

*** A - DC1 ***

AIRCRAFT = F-14A TYPE EQUIPMENT = AFWA OCT. 86 - SEPT. 87
TOTAL COMPONENT MAINTENANCE COSTS ($K)
UNSCHEDULED
ALL-NAVY SQUADRONS

ORGANIZATION LABOR RATE = $11.03 PER HOUR
INTERMEDIATE LABOR RATE = $13.25 PER HOUR

WORK UNIT CODE	MATERIAL LEVEL-1 REPAIR	LEVEL-2 REPAIR	LEVEL-2 ATTRI	LEVEL-3 REPAIR NADEP	LEVEL-3 REPAIR COMM.	LEVEL-3 SURVEY	TOTAL MATERIAL	LABOR LEVEL-1 MAINT*	LEVEL-2 MAINT*	LEVEL-3 DIRECT NADEP	LEVEL-3 DIRECT COMM.	TOTAL LABOR	TOTAL COST	UNSCHED. COST/ FAILURE ($)	MFHBF	MFHBMA
03	5	8	C	0	0	0	13	49	1	0	0	50	63	315CC.	$4159.0	355.1
04	1	0	0	0	0	0	1	8	0	0	0	8	9	450C.	$4159.0	2083.0
11	2209	3952	0	1871	159	783	8974	1404	313	389	551	2657	11631	881.	8.2	2.9
12	526	193	0	175	0	80	974	318	36	36	0	390	1364	342.	27.1	11.3
13	1320	2942	0	3505	38	1160	8965	1061	889	719	130	2799	11764	1051.	9.7	4.3
14	1025	1385	0	1776	975	696	5857	1712	484	373	3352	5921	11778	1054.	9.7	6.2
23	568	184	0	2380	3	54	3189	1127	186	497	8	1818	5007	1295.	28.0	16.1
29	541	1771	0	1162	112	535	4121	1019	931	241	384	2575	6696	552.	8.9	5.7
41	1146	368	0	294	216	217	2241	575	141	61	743	1520	3761	629.	18.1	11.9
42	863	493	0	1015	15	677	3063	1045	286	210	51	1592	4655	688.	11.4	7.6
44	1225	21C	C	69	38	5	1547	339	57	16	149	559	2106	261.	12.4	9.6
45	1061	181	0	333	21C	175	196C	605	133	69	722	1529	3489	647.	20.1	13.2
46	1179	521	0	1830	74	290	3902	932	239	384	256	1811	5713	758.	14.4	6.2
47	18	54	0	55	4	8	139	44	59	11	13	127	266	178.	72.3	48.8
49	183	259	0	109	12	29	592	162	176	23	43	404	996	317.	34.5	23.0
51	221	81	0	394	34	3	733	175	139	81	117	512	1245	409.	35.3	22.5
56	100	2852	0	2421	107	190	5670	648	1560	503	367	3078	8748	695.	8.6	6.4
57	70	1228	0	388	73	130	1889	542	1130	80	251	2003	3892	454.	12.6	10.0
58	0	12	0	0	1	0	13	3	2	0	3	8	21	618.	3185.8	1067.6
62	1	24	0	2	4	0	31	12	8	1	15	36	67	288.	[illegible].9	337.4
63	305	276	0	232	0	11	824	303	313	48	1	665	1489	243.	17.7	12.0
64	26	40	0	2	4	0	72	86	55	0	14	155	227	177.	84.3	52.5
65	1477	359	0	25	26	3	189C	228	406	5	96	735	2625	559.	23.1	16.9
66	4	3	0	0	0	0	7	2	5	0	0	7	14	203.	1569.8	820.6
67	1	55	0	30	0	3	89	27	21	6	0	54	143	204.	154.5	97.8

AIRCRAFT = F-14A TYPE EQUIPMENT = AFWA OCT. 86 - SEPT. 87
COMPONENT COST SUMMARY
UNSCHEDULED

ALL-NAVY SQUADRONS

	MATERIAL: LEVEL-1 REPAIR	MATERIAL: LEVEL-2 REPAIR	MATERIAL: LEVEL-2 ATTRI	MATERIAL: LEVEL-3 REPAIR NADEP	MATERIAL: LEVEL-3 REPAIR COMM.	MATERIAL: LEVEL-3 SURVEY	TOTAL MATERIAL	LABOR: LEVEL-1 MAINT*	LABOR: LEVEL-2 MAINT*	LABOR: LEVEL-3 DIRECT NADEP	LABOR: LEVEL-3 DIRECT COMM.	TOTAL LABOR	TOTAL COST	UNSCHED. COST/ FAILURE ($)	MFHBF	MFHBMA
TOTAL ALL WUCS ($K)	17445	29518	0	26884	4451	5562	83860	17950	15550	5594	15048	54142	138002	611.	0.5	0.2
PRCNT PER COST CATEGORY	12.6	21.4	0.0	19.5	3.2	4.0	60.8	13.0	11.3	4.1	10.9	39.2	100.0			

PERCENT OF COST CATEGORY

														TOTAL COST($K)	COST($)/FAIL
AF	29.2	28.7	0.0	27.3	26.3	48.9	29.6	25.4	11.1	27.1	26.8	21.8	26.5	36609.	925.
PP	6.4	6.6	0.0	13.2	2.6	10.6	8.7	12.0	7.2	13.2	2.6	8.1	8.5	11703.	731.
AV	64.5	64.6	0.0	59.6	71.1	40.5	61.7	62.7	81.7	59.7	70.6	70.0	65.0	89690.	527.

MAINT. LEVEL COST SUMMARY ($K)

	MATERIAL	LABOR	TOTAL
SQUADRON(1)	17445.	17950.	35395.
INTERMEDIATE(2)	29518.	15550.	45068.
DEPOT(3)	36897.	20642.	57539.

FLIGHT HOUR SUMMARY

COMBAT	5255.	COMBAT	2286.
NON-COMBAT	103064.	NON-COMBAT	62902.
TOTAL FH	108318.	TOTAL FLIGHTS	65188.

				LEVEL-1	LEVEL-2
COST($) PER FH	MATERIAL ONLY	774.	MA/FH	3.1	1.0
	MATERIAL + DEPOT LABOR	965.	MH/FH	15.0	10.8
	MATERIAL + ALL LABOR	1274.			

COST ($) PER OPERATING AIRCRAFT 300658.

*** B - DC2 ***

AIRCRAFT = F-14A TYPE EQUIPMENT = AFWA OCT. 86 - SEPT. 87
TOTAL COMPONENT MAINTENANCE COSTS ($K)
SCHEDULED
ALL-NAVY SQUADRONS

ORGANIZATION LABOR RATE = $11.03 PER HOUR
INTERMEDIATE LABOR RATE = $13.35 PER HOUR

WORK UNIT CODE	MATERIAL: LEVEL-1 REPAIR	MATERIAL: LEVEL-2 REPAIR	MATERIAL: LEVEL-2 ATTRI	MATERIAL: LEVEL-3 REPAIR NADEP	MATERIAL: LEVEL-3 REPAIR COMM.	MATERIAL: LEVEL-3 SURVEY	TOTAL MATERIAL	LABOR: LEVEL-1 MAINT*	LABOR: LEVEL-1 SUPPORT*	LABOR: LEVEL-1 TDC*	LABOR: LEVEL-2 MAINT*	LABOR: LEVEL-2 SUPPORT*	LABOR: LEVEL-2 TDC*	LABOR: LEVEL-3 DIRECT NADEP	LABOR: LEVEL-3 DIRECT COMM.	LABOR: LEVEL-3 INDIRECT	LABOR: LEVEL-3 TDC	TOTAL LABOR	TOTAL COST
03	50	73	0	5	0	P	128	6807	4699	1	150	1	0	1	2	1	0	11662	1179C
C4	1	C	C	0	0	0	1	1751	10186	0	0	1C9	0	0	0	0	0	12C46	12C47
11	328	151	0	98	8	50	635	1361	2185	52	44	2	173	2C	29	19	0	3885	452C
12	125	1C	0	54	0	8	195	97	328	14	6	0	15	11	1	11	0	483	678
13	261	256	0	708	7	241	1473	348	1113	93	201	5	56	144	26	136	0	2124	3597
14	81	37	0	77	5	52	252	236	1539	3	18	2	2	16	18	15	0	1849	2101
23	71	3	0	65	0	3	142	87	959	1	10	1	0	13	0	13	0	1092	1234
29	34	43	0	41	1	35	154	56	848	17	18	5	3	9	5	8	0	967	1121
41	35	6	0	18	7	7	71	32	479	15	8	1	2	4	24	3	0	568	639
42	58	5	0	8	0	5	76	56	848	61	4	1	25	2	0	2	0	1017	1093
44	672	18	0	17	0	1	708	171	402	1	8	0	0	4	0	3	0	589	1297
45	123	23	0	4	2	4	156	86	544	18	27	1	2	1	8	1	0	690	846
46	69	210	0	61	4	8	332	55	780	9	47	1	0	13	14	12	0	931	1263
47	4	5	0	11	1	1	22	7	40	0	26	0	0	2	3	2	0	80	1C2
49	2C	9	0	7	0	1	37	15	140	5	5	1	4	2	0	1	0	173	21C
51	5	0	0	4	0	0	9	11	146	C	1	1	3	1	C	1	0	164	173
56	7	3	0	7	0	2	19	15	524	1	7	0	4	1	0	1	0	561	580
57	6	6	0	3	1	0	12	6	433	1	.	6	4	1	2	1	0	458	470
58	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	2
62	2	0	0	0	0	0	2	0	10	0	0	0	0	0	0	0	0	10	12
63	46	0	0	1	0	0	47	8	246	1	2	2	0	0	:	0	0	259	306
64	8	0	0	0	0	0	8	2	69	0	1	0	0	0	0	0	0	72	80
65	0	1	0	0	2	0	3	7	185	1	1	2	0	0	7	0	0	203	206
66	2	11	0	3	0	0	16	2	3	0	22	0	0	1	0	1	0	29	45
67	0	1	0	1	0	0	2	1	22	4	0	0	0	0	0	0	0	27	29
69	35	18	0	7	3	0	63	12	410	5	8	7	1	1	10	1	0	455	518

AIRCRAFT = F-14A TYPE EQUIPMENT = AFWA OCT. 86 - SEPT. 87
TOTAL COMPONENT MAINTENANCE COSTS ($K)
SCHEDULED
ALL-NAVY SQUADRONS

WORK UNIT CODE	MATERIAL: LEVEL-1 REPAIR	LEVEL-2 REPAIR	LEVEL-2 ATTRI	LEVEL-3 REPAIR MADEP	LEVEL-3 REPAIR COMM.	SURVEY	TOTAL MATERIAL	LABOR: LEVEL-1 MAINT+	LEVEL-1 SUPPORT+	LEVEL-1 TDC+	LEVEL-2 MAINT+	LEVEL-2 SUPPORT+	LEVEL-2 TDC+	LEVEL-3 DIRECT MADEP	LEVEL-3 DIRECT COMM.	LEVEL-3 INDIRECT	TDC	TOTAL LABOR	TOTAL COST
TOTAL ALL WUCS ($K)	2747	1273	0	1336	58	437	6051	11631	31449	403	1512	190	515	318	206	297	0	46521	52572

ADDITIONAL SCHED. COSTS FOR AIRCRAFT ($K)

PREXPENDABLE CONSUMABLE COST(LEVEL 1)	25
PREXPENDABLE CONSUMABLE COST(LEVEL 2)	0
TDC MATERIAL COST	34

	LEVEL-1 REPAIR	LEVEL-2 REPAIR	LEVEL-2 ATTRI	LEVEL-3 REPAIR MADEP	LEVEL-3 REPAIR COMM.	SURVEY	TOTAL MATERIAL	LEVEL-1 MAINT+	LEVEL-1 SUPPORT+	LEVEL-1 TDC+	LEVEL-2 MAINT+	LEVEL-2 SUPPORT+	LEVEL-2 TDC+	LEVEL-3 DIRECT MADEP	LEVEL-3 DIRECT COMM.	LEVEL-3 INDIRECT	TDC	TOTAL LABOR	TOTAL COST
ADJUSTED TOTAL							6110											46521	52631
PRCNT	5.2	2.4	0.0	2.9	0.1	0.8	11.5	22.1	59.8	0.8	2.9	0.4	1.0	0.6	0.4	0.6	0.0	88.4	100.0
PER COST CATEGORY							11.6											88.4	
PERCENT OF COST CATEGORY BY SUBSYSTEM:																			
AF	30.7	41.4	0.0	61.3	34.5	80.3	44.4	91.1	63.8	40.4	27.7	62.6	47.8	61.0	36.9	61.3	0.0	68.9	66.
PP	3.8	3.6	0.0	6.9	1.7	8.7	4.9	1.2	5.7	4.5	2.4	3.2	0.6	6.9	2.4	7.1	0.0	4.4	4.
AV	65.5	55.0	0.0	31.8	63.8	11.0	50.8	7.7	30.5	55.1	69.9	34.2	51.7	32.1	60.7	31.6	0.0	26.7	29.

MAINT. LEVEL COST SUMMARY ($K)

	MATERIAL	LABOR	TOTAL
SQUADRON(1)	2797.	43483.	46280.
INTERMEDIATE(2)	1283.	2217.	3500.
DEPOT(3)	2031.	821.	2852.

FLIGHT HOUR SUMMARY

COMBAT	5255.	COMBAT	2286.
NON-COMBAT	103064.	NON-COMBAT	62902.
TOTAL FH	108318.	TOTAL FLIGHTS	65188.

COST($) PER FH				LEVEL-1	LEVEL-2
	MATERIAL ONLY	56.	MA/FH	1.5	0.1
	MATERIAL + DEPOT LABOR	64.	MH/FH	5.7	1.0
	MATERIAL + ALL LABOR	486.			

COST ($) PER OPERATING AIRCRAFT 114664.

*** C - 002 ***

AIRCRAFT = F-14A TYPE EQUIPMENT = AFWA OCT. 86 - SEPT. 87
TOTAL MAINTENANCE ACTION MATRIX
ALL-NAVY SQUADRONS
UNSCHEDULED MAINTENANCE ONLY

WORK UNIT CODE	LEVEL-1 ACT	LEVEL-1 B/C	LEVEL-1 R	LEVEL-1 T	LEVEL-1 FAIL-IP	LEVEL-2 ACT	LEVEL-2 B/C	LEVEL-2 A	LEVEL-2 Z	LEVEL-2 BCM 9	LEVEL-2 FAIL-IP	LEVEL-2 BCM1-9	LEVEL-3 COMM REPAIRS	LEVEL-3 MADEP REPAIRS	LEVEL-3 MADEP SURVEYS	TOTAL M-A	TOTAL FAIL
C3	285	8	7	2	2	20	2	79	1	0	0	0	0	0	0	305	2
C4	49	4	0	0	2	3	0	11	0	0	0	0	0	0	0	52	2
11	36107	26279	1381	642	13407	2421	822	978	82	0	1337	869	119	604	134	37524	13201
12	9390	5561	558	234	4032	334	223	135	20	0	424	216	5	187	26	9590	3994
13	20649	7976	8516	1434	10041	10465	5996	39277	953	0	3541	1849	179	1443	228	25094	11193
14	15706	7292	4346	1723	10138	5271	2707	1008	142	0	4280	1766	367	1228	169	17460	11171
23	6533	3325	1310	367	3822	865	122	86	4	0	609	686	4	672	11	6763	3865
29	17693	5026	5973	2742	10030	6170	4336	1581	144	0	6173	1921	256	1583	80	19011	12136
41	8711	4996	1817	784	5733	1577	772	286	34	0	1497	802	329	430	39	9099	5978
42	13557	8281	2150	919	9106	2452	1063	773	30	0	1611	641	126	445	69	14291	9543
44	11110	9599	515	312	8756	509	440	56	24	0	542	165	56	38	48	11251	8737
45	7783	4840	1521	818	5200	1591	682	378	31	0	1233	572	209	284	16	8220	5395
46	16202	4459	3311	1051	6558	3633	2116	1051	131	0	3104	1142	125	961	76	17539	7540
47	1810	768	698	161	1182	944	561	150	47	0	686	137	9	122	6	2218	1498
49	4165	1781	1399	518	2732	1564	1307	207	103	0	1518	238	13	192	33	4555	3139
51	4461	1336	1801	755	2818	1871	796	218	104	0	1527	779	207	481	1	4815	3047
56	14962	3055	7315	2867	9823	8156	6379	3591	232	0	7449	1719	375	1287	57	17055	12596
57	9787	1200	5174	2069	6047	5333	5019	2501	222	0	5789	831	212	383	227	10813	8565
58	42	8	23	8	30	39	12	25	0	0	13	1	1	0	0	58	34
62	275	116	128	26	234	109	47	48	0	0	75	32	29	3	0	321	233
63	8657	3658	2590	660	5573	2491	2107	425	64	0	2471	407	1	403	3	9055	6133
64	1990	926	637	195	1382	376	444	92	6	0	438	27	26	1	0	2062	1285
65	5462	1546	2492	550	3866	2868	2519	639	57	0	2574	120	84	21	14	6398	4497
66	92	19	30	3	34	52	40	11	0	0	47	8	0	8	0	132	69
67	1032	534	188	43	652	218	131	45	8	0	148	23	0	23	0	1108	701
69	11920	2323	5606	1859	7149	5844	6452	2070	161	0	7294	1036	408	590	40	13603	10083
71	6092	1264	2828	915	3559	2875	1635	1070	91	0	2625	941	126	811	4	6573	4547
72	2289	887	893	257	1496	858	454	207	29	0	803	369	135	219	5	2457	1725
73	5400	618	3126	867	3585	2541	1878	717	88	0	2691	859	158	275	422	5910	6480
74	57373	11138	27703	8363	36400	29315	28137	6184	721	0	30980	3974	2192	1753	32	63617	48274

AIRCRAFT = F-14A TYPE EQUIPMENT = AFWA OCT. 86 - SEPT. 87
MAN HOUR MATRIX
ALL-NAVY SQUADRONS

WORK UNIT CODE	UNSCHEDULED MAINTENANCE LEVEL-1 TOTAL	MH/MA	LEVEL-2 TOTAL	MH/MA	LEVEL-3 TOTAL	MH/MA	SCHEDULED MAINTENANCE LEVEL-1 TOTAL	MH/MA	LEVEL-2 TOTAL	MH/MA	LEVEL-3 TOTAL	MH/MA	SUPPORT LEVEL-1 TOTAL	SUPPORT LEVEL-2 TOTAL	TDC LEVEL-1 TOTAL	TDC LEVEL-2 TOTAL	TDC LEVEL-3 TOTAL
03	4420	15.5	82	4.1	0	0.0	617111	8.1	11311	33.3	63	21.0	426049	111	60	0	0
04	710	14.5	12	4.0	0	0.0	158794	18.4	8	2.0	0	0.0	923515	8261	6	0	0
11	127330	3.5	23614	9.8	24052	39.8	123441	3.3	3295	3.3	1257	34.9	198160	109	4680	13059	0
12	28853	3.1	2726	5.1	2231	11.9	8823	1.9	668	2.4	685	6.2	29766	9	1298	1124	C
13	96159	4.7	6710C	6.3	44965	31.2	31558	4.4	15139	3.5	9110	31.7	100914	4C3	8465	42C3	C
14	153221	9.9	36510	6.9	23C85	18.8	21420	4.7	1394	3.9	10CC	29.4	139566	181	263	179	0
23	102162	15.6	14049	16.2	30652	45.6	7919	3.4	1393	12.9	821	17.5	86977	74	62	0	0
29	92346	5.2	70282	11.4	14828	9.4	4925	2.5	1381	5.9	323	8.7	76848	356	1496	195	0
41	52128	6.0	10654	6.8	3769	8.8	2869	2.5	620	4.3	226	6.1	43671	50	1352	164	0
42	94790	7.0	21598	8.8	12945	29.1	4864	3.0	281	6.1	106	26.5	78749	107	5563	1905	0
44	30697	2.8	4292	8.6	881	23.2	15471	2.2	629	5.3	217	21.7	36471	21	110	0	0
45	54870	7.0	10020	6.3	4241	14.8	7816	4.7	2029	5.3	46	6.6	69517	60	1649	168	0
46	84549	5.2	18079	5.0	23698	25.2	4949	3.0	3532	4.6	786	31.4	70709	101	777	32	C
47	3962	2.2	4420	4.7	692	5.7	655	1.9	1940	4.2	140	5.6	3647	32	13	1C	0
49	14682	3.5	13297	8.5	1401	7.3	1381	2.6	371	7.7	95	11.9	12695	67	414	274	0
51	15824	3.5	10477	5.6	5080	10.6	965	1.8	85	3.0	55	7.9	13261	51	21	197	0
56	38781	3.9	117735	14.4	30938	26.0	1365	2.4	509	9.4	89	14.8	67529	581	121	318	0
57	49181	5.8	85305	16.0	4968	13.0	548	2.1	323	8.7	41	13.7	39294	424	78	284	0
58	229	5.5	159	4.1	0	0.0	8	2.7	1	1.0	0	0.0	188	1	8	0	0
62	1089	4.0	617	5.7	31	10.3	10	3.3	0	0.0	0	0.0	870	3	8	0	0
63	27487	3.2	23605	9.5	2933	7.3	694	1.9	175	6.5	11	11.0	22268	116	55	16	0
64	7786	3.9	4188	7.3	26	26.0	168	1.7	108	5.7	0	0.0	6281	22	0	0	0
65	20862	3.6	30636	10.7	318	13.1	622	2.3	108	5.1	0	0.0	16817	151	54	13	C
66	199	2.2	367	7.1	0	0.0	166	1.1	1645	3.9	40	1.1	284	10	31	0	0
67	24C6	2.3	1566	7.2	379	16.5	65	1.6	24	4.0	7	7.0	1935	7	357	4	0
69	45923	3.9	106863	18.3	8898	15.1	1114	2.8	970	9.7	84	21.0	37164	532	487	63	0
71	21923	3.6	27400	9.5	7865	9.7	387	2.0	218	7.3	28	9.3	17788	137	795	27	0
72	9145	4.0	6626	7.7	1313	6.0	406	2.3	47	4.7	0	0.0	7548	32	1178	6	0
73	19649	3.6	33591	21.1	3733	13.6	3756	3.2	28107	16.3	207	2.3	18493	410	8	17	0
74	285627	4.6	307107	18.5	93830	30.7	10567	3.8	4015	6.8	1394	21.1	218227	1533	3904	1047	0
75	43467	2.8	19593	3.9	23372	42.3	8610	2.6	12209	3.4	1591	54.9	41132	156	696	99	0
76	26869	4.4	35459	17.9	4555	5.7	2674	3.0	712	7.5	1C7	7.1	23357	179	341	564	0
77	76C7	2.8	4288	11.8	622	41.5	498	2.9	1257	7.3	0	0.0	6416	26	76	C	0
91	4619	2.0	1410	3.4	422	9.0	1691	1.0	12842	3.3	391	10.9	4988	70	587	1820	0
93	725	2.6	335	2.8	266	22.2	361	1.1	3467	2.3	188	20.9	839	19	10	1	0
96	76	1.7	13	2.6	0	0.0	35	0.8	27	1.9	0	0.0	94	0	0	3	0
97	8669	1.4	9	1.8	0	0.0	2164	3.4	1	1.0	0	0.0	8389	0	245	0	0
99	66726	6.4	39518	10.7	9264	16.6	5702	3.2	3933	6.0	400	10.8	61526	128	1216	13231	0

*** F - OC1 ***

AIRCRAFT = F-14A TYPE EQUIPMENT = AFWA OCT. 86 - SEPT. 87
MAN HOUR MATRIX
ALL-NAVY SQUADRONS

WORK UNIT CODE	UNSCHEDULED MAINTENANCE LEVEL-1 TOTAL	MH/MA	LEVEL-2 TOTAL	MH/MA	LEVEL-3 TOTAL	MH/MA	SCHEDULED MAINTENANCE LEVEL-1 TOTAL	MH/MA	LEVEL-2 TOTAL	MH/MA	LEVEL-3 TOTAL	MH/MA	SUPPORT LEVEL-1 TOTAL	SUPPORT LEVEL-2 TOTAL	TDC LEVEL-1 TOTAL	TDC LEVEL-2 TOTAL	TDC LEVEL-3 TOTAL
TOTAL	1627346		1173602		346231		1054752		114216		19708		2851802	14530	36468	39023	0
AVERAGE MH/MA		4.7		10.4		21.0		4.1		5.3		19.0					
PRCNT AF	25.		11.		27.		91.		28.		61.		64.	62.	41.	48.	0.
AVER. AF		5.0		6.9		27.2		6.9		5.1		25.8					
PRCNT PP	12.		7.		13.		1.		2.		7.		6.	3.	4.	0.	0.
AVER. PP		8.0		12.0		20.2		3.0		8.1		12.6					
PRCNT AV	63.		82.		6C.		8.		70.		32.		31.	35.	55.	52.	0.
AVER. AV		4.3		11.0		19.2		2.7		5.3		13.6					

APPENDIX D

COMPOSITE DEFLATOR[1]

FISCAL YEAR	CONSTANT FY 1982 $	CONSTANT FY 1989 $
1970	.3841	0.3049
1971	.4126	0.3275
1972	.4372	0.3471
1973	.4658	0.3698
1974	.5095	0.4045
1975	.5671	0.4502
1976	.6097	0.4840
1977	.6572	0.5217
1978	.7034	0.5584
1979	.7626	0.6054
1980	.8453	0.6710
1981	.9335	0.7410
1982	1.0000	0.7938
1983	1.0430	0.8280
1984	1.0808	0.8580
1985	1.1138	0.8842
1986	1.1408	0.9056
1987	1.1699	0.9287
1988	1.2097	0.9603
1989	1.2597	1.0000
1990	1.3124	1.0418
1991 est	1.3692	1.0869
1992 est	1.4246	1.1309

[1]SOURCE: *Budget of the United States Government, Fiscal Year 1991*, Historical Table 1.3.

APPENDIX E

F-14A AIRCRAFT - TF30-P-414A STATISTICAL SUMMARY

Only data for four time periods are shown below due to the size of the ECIFR data base. The ECIFR terms used below are explained on the following page.

	OCT87-SEP88	JUL88-JUN89	JAN89-DEC89	APR89-MAR90
AIRCRAFT (avg)	303.2	294.6	307.9	311.7
ENGINES (avg)	606.4	589.2	615.8	623.4
SORTIES	74260.0	74283.0	73659.0	73133.0
FLIGHT HRS	121101.0	121415.0	118923.0	117906.0
ENG FLT HRS	242202.0	242830.0	237846.0	235812.0
EFH/F, MTBF	36.3	36.3	35.5	33.5
EFH/MA, MTBMA	14.5	14.1	14.0	14.0
MAINT ACTION	16761.0	17280.0	17014.0	16875.0
ENG CANNIBAL	100.0	142.0	155.0	135.0
FOD MA	177.0	235.0	205.0	190.0
FOD/1000 EFH	0.7	1.0	0.9	0.8
CR/1000 EFH	6.3	6.6	6.7	6.5
FAILURES	6677.0	6698.0	6700.0	7035.0
EMT	80417.5	93125.8	91376.5	92898.3
EMT/MA, MTTR	4.8	5.4	5.4	5.5
MAN HOURS	207645.0	255270.2	255233.1	262014.5
MMH/EFH	0.9	1.1	1.1	1.1
MMH/MA	12.4	14.8	15.0	15.5
NMC HRS	213575.2	246281.2	205262.1	197002.8
% NMCS	30.4	36.5	37.1	36.8
% NMCM	69.6	63.5	62.9	63.2
NMC/EFH	0.9	1.0	0.9	0.8
ABORTS	461.0	386.0	384.0	393.0
% IN-FLT	32.5	32.1	28.9	29.3
% FAILURE	63.8	65.5	62.8	64.6
A/1000 EFH	1.9	1.6	1.6	1.7
FA/1000 EFH	1.2	1.0	1.0	1.1
ENG REMOVALS	542.0	595.0	554.0	535.0
ER/1000 EFH	2.2	2.5	2.3	2.3
FER/1000 EFH	0.3	0.3	0.3	0.4
A_o	92.0	90.5	92.4	92.8

SOURCE: *ECIFR - JETMF400 REPORT*

APPENDIX E (cont)

Statistical Summary (ECIFR) Glossary

AIRCRAFT	average number of aircraft in reporting status.
EFH/F, MTBF	engine flight hours per failure, (mean time between failure).
EFH/MA, MTBMA	engine flight hours per maintenance action, (mean time between maintenance action).
MAINT ACTION	total number of engine job control number (JCN) related maintenance actions.
ENG CANNIBAL	total number of engine level WUC maintenance cannibalizations.
FOD MA	foreign object damage (FOD) maintenance actions.
FOD/1000 EFH	FODs maintenance actions per 1000 engine flight hours.
CR/1000 EFH	number of engine component removals (minus the number of engine removals) per 1000 engine flight hours.
EMT	elapsed maintenance time, calculated as the sum of elapsed maintenance time at both O and I levels of maintenance.
EMT/MA, MTTR	elapsed maintenance time per maintenance action.
MAN HOURS	sum of engine related manhours at both O and I levels of maintenance.
MMH/EFH	maintenance manhours per engine flight hours.
MMH/MA	maintenance manhours per maintenance action.
NMC HRS	not mission capable hours, the number of hours the aircraft is unable to perform its missions due to the engine.
% NMCS	percent of total NMC hours due to supply.
% NMCM	percent of total NMC hours due to maintenance.
NMC/EFH	not mission capable hours per engine flight hour.
ABORTS	total number of before and in-flight aircraft aborts due to the engine.
% IN-FLT	percent of engine related aborts discovered in-flight.
% FAILURE	percent of engine related aborts that were due to engine failure.
A/1000 EFH	aborts per 1000 engine flight hours.
FA/1000 EFH	failure aborts per 1000 engine flight hours.
ENG REMOVALS	engine removals based on number of engine WUC maintenance actions.
ER/1000 EFH	engine removals per 1000 engine flight hours.
FER/1000 EFH	the number of engine removals due to failure per 1000 engine flight hours.
A_O	operational availability, calculated as (EIS-NMC)/EIS.

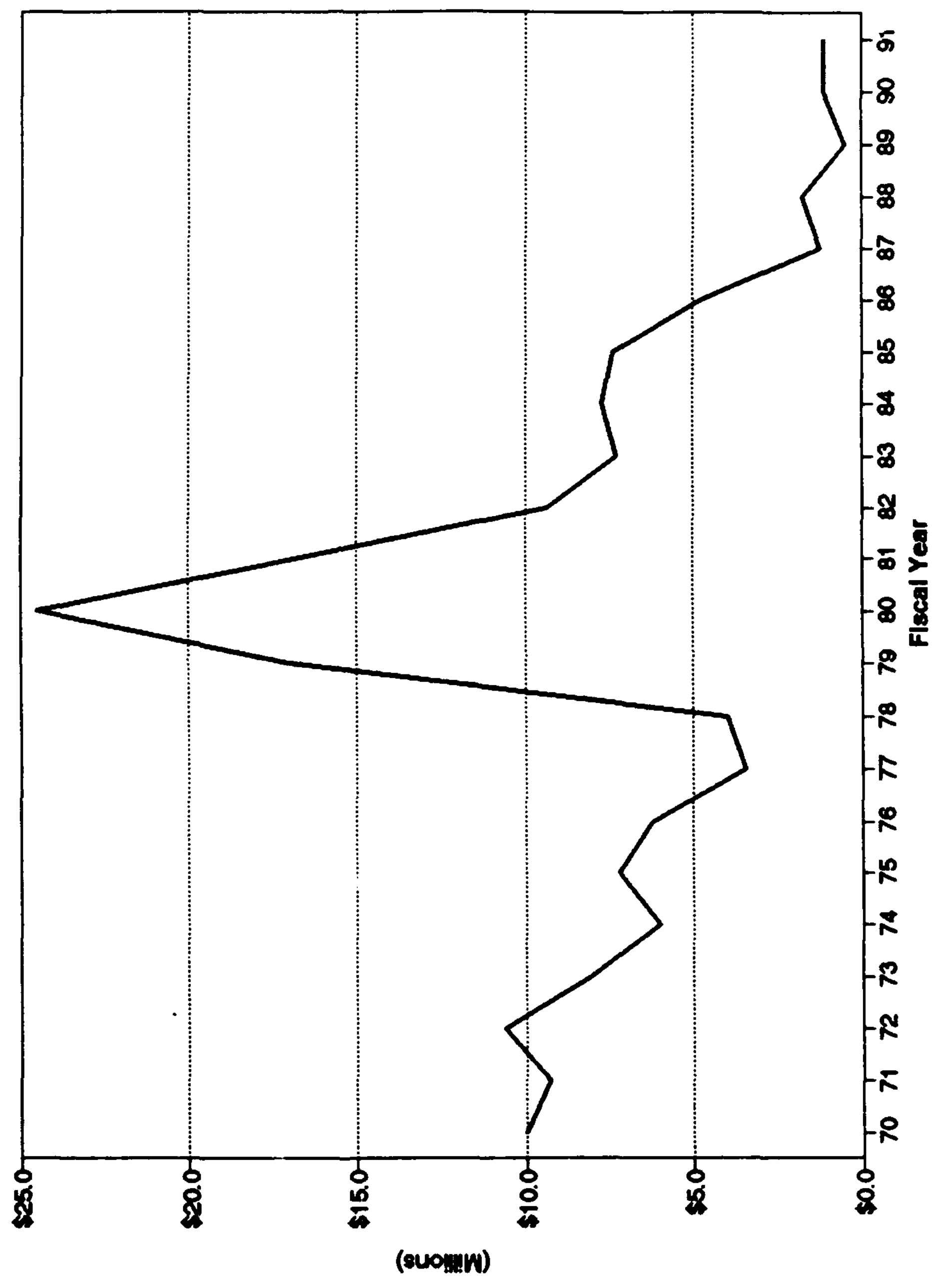
APPENDIX E (cont)

F-14A TF30-P-414 Graphs

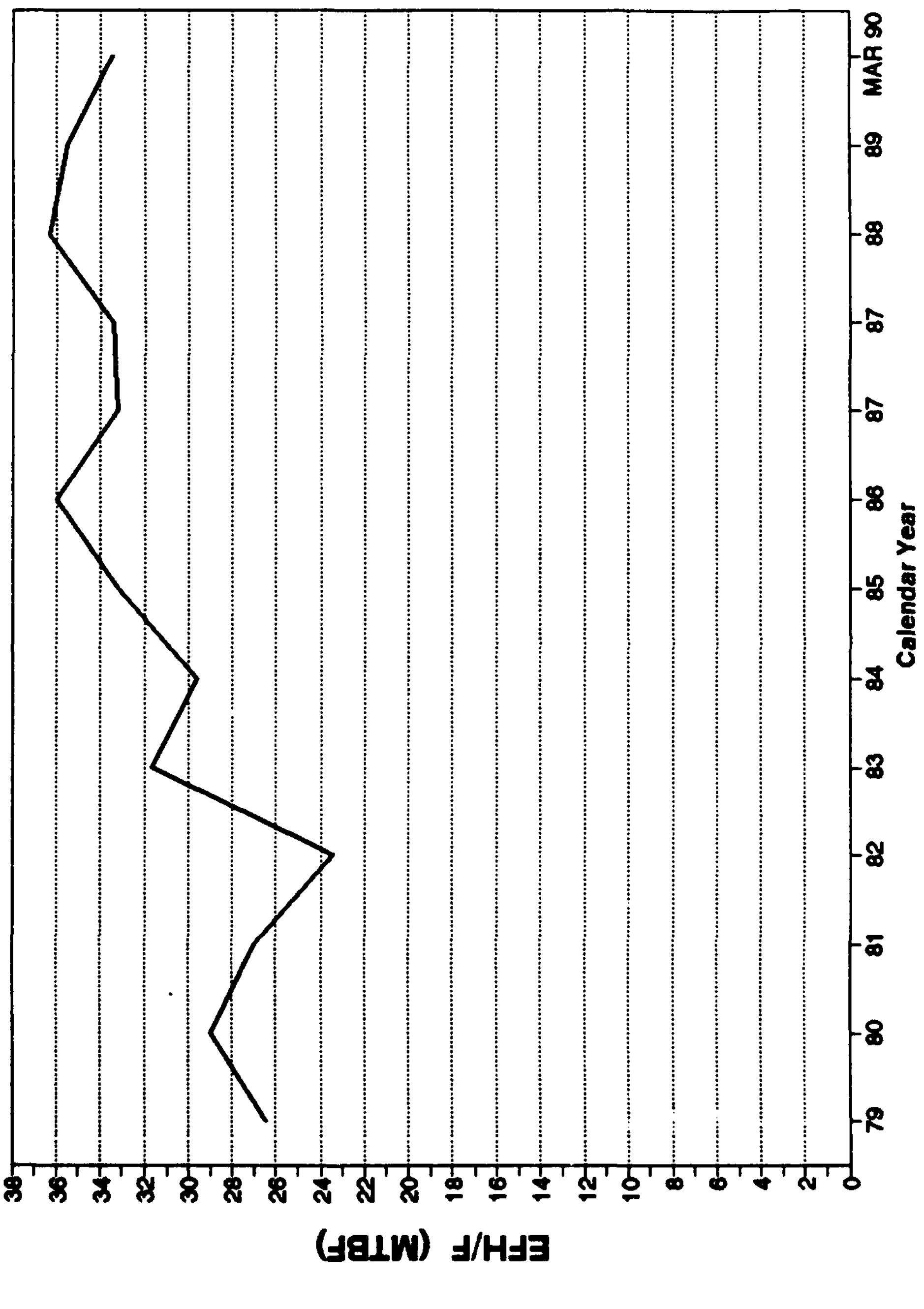
Shown below is a list of 11 variables that are graphed over time for the TF30 engine. The CIP funding graph (graph number 1) covers the period from FY70 to FY91 for the TF-30 engine. Note that the TF-30 is used in the F-14A and the A-7E. The source of CIP funding data is NAVAIR (AIR-536), Propulsion and Power Division. Graphs 2 thru 12 cover the period January 79 to March 90. The source of data for these graphs is the ECIFR. Note that two CY87 dates are shown on the horizontal scale. This year the ECIFR produced engine reports on both the TF30-P-414 and TF30-P-414A. Prior to CY87 the ECIFR produced engine reports only on the TF30-P-414 and after CY87 the ECIFR produced engine reports only on the TF-30-414A.

1. CIP FUNDING
2. ENGINE FLIGHT HOURS PER FAILURE (MTBF)
3. ENGINE FLIGHT HOURS PER MAINTENANCE ACTION
4. ABORTS PER 1000 ENGINE FLIGHT HOURS
5. FAILURE ABORTS PER 1000 ENGINE FLIGHT HOURS
6. ENGINE REMOVALS PER 1000 ENGINE FLIGHT HOURS
7. FAILURE ENGINE REMOVALS PER 1000 ENGINE FLIGHT HOURS
8. MAINTENANCE MAN HOURS PER ENGINE FLIGHT HOUR
9. ELAPSED MAINTENANCE TIME PER MAINTENANCE ACTION
10. NOT MISSION CAPABLE HOURS PER ENGINE FLIGHT HOURS
11. COMPONENT REMOVALS PER 1000 ENGINE FLIGHT HOURS

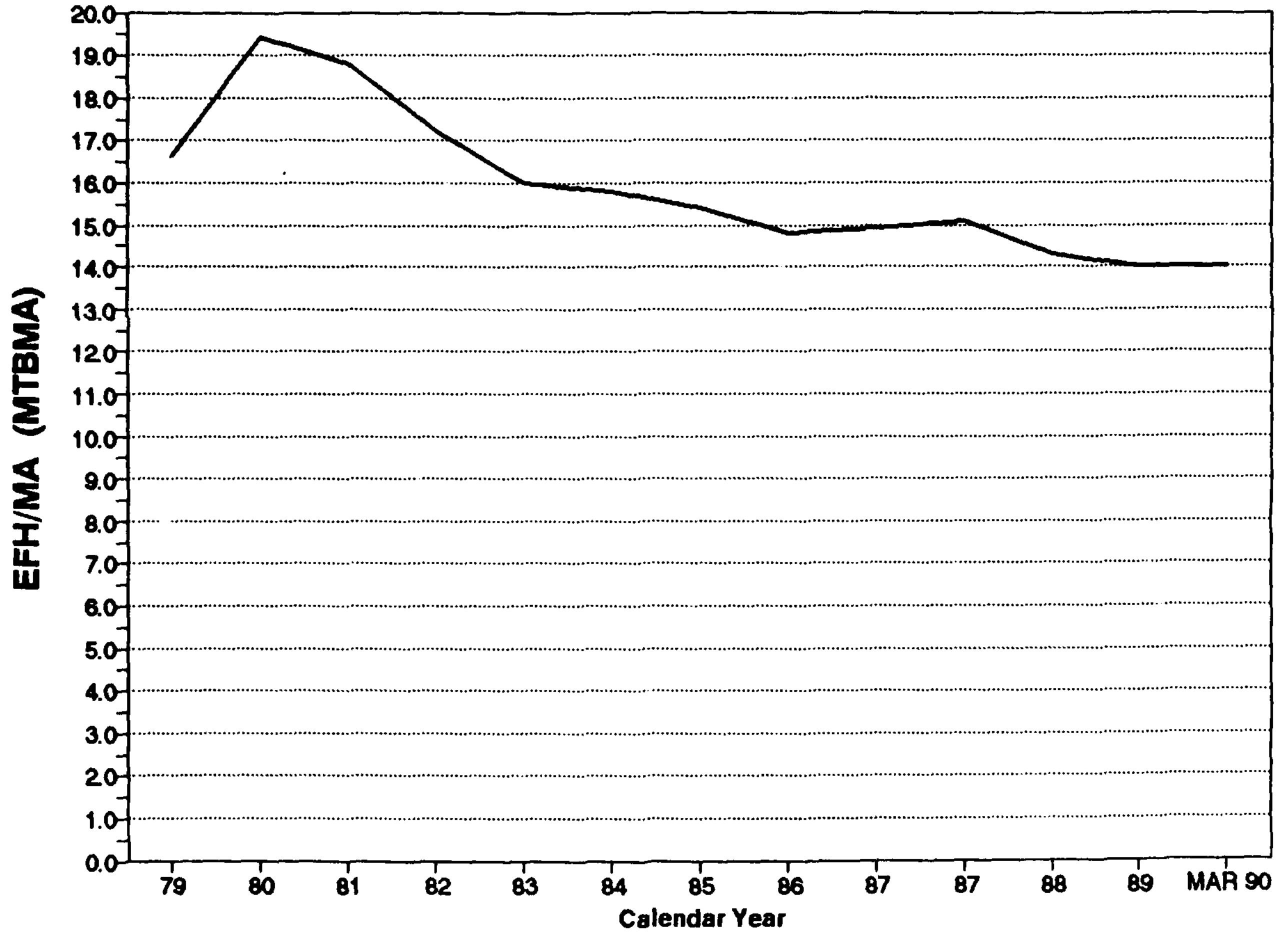
CIP FUNDING
FOR THE (F-14A & A-7) TF30 ENGINE

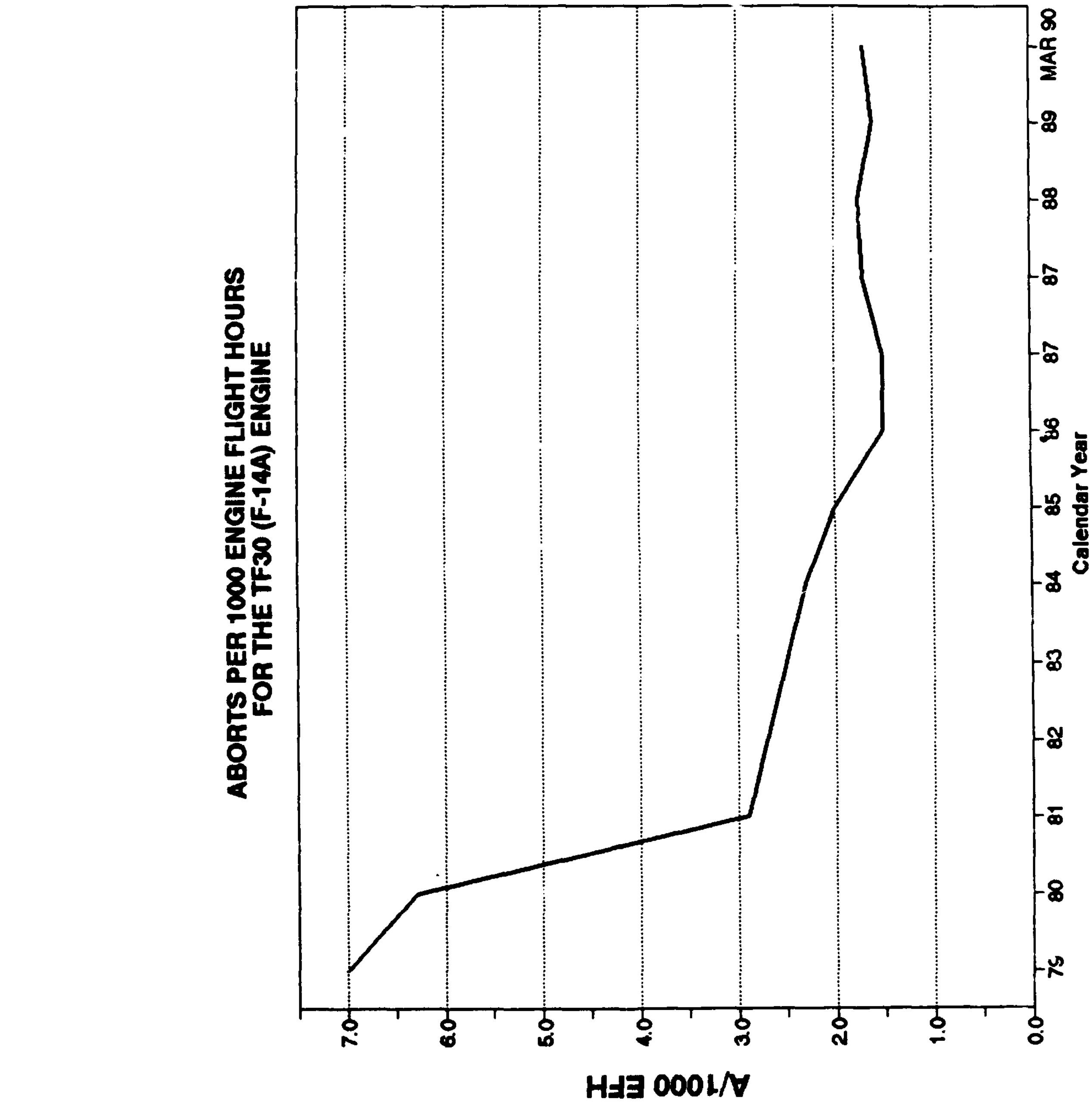


ENGINE FLIGHT HOURS PER FAILURE
FOR THE TF30 (F-14A) ENGINE

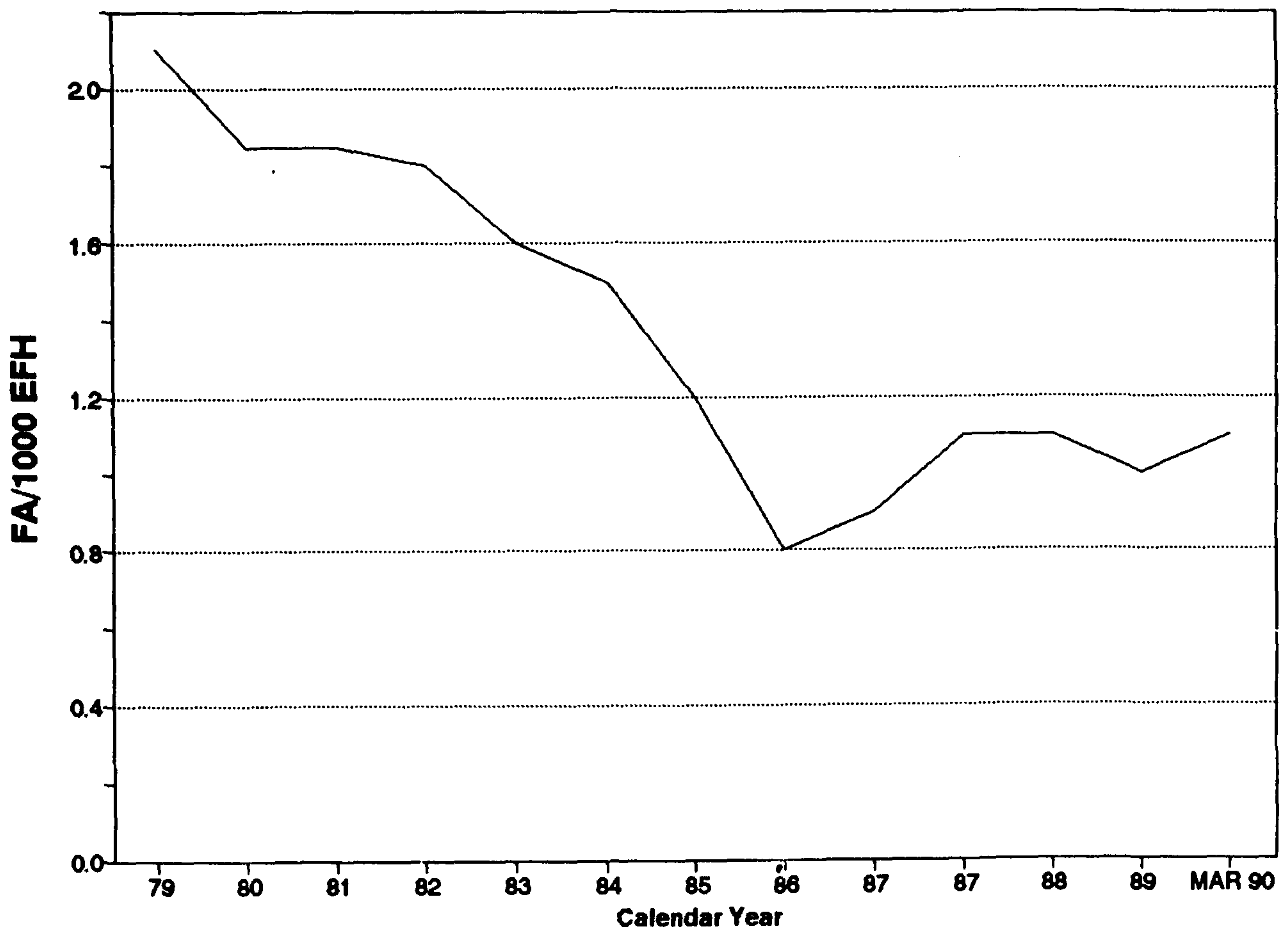


ENGINE FLIGHT HOURS PER MAINTENANCE ACTION FOR THE TF30 (F-14A) ENGINE

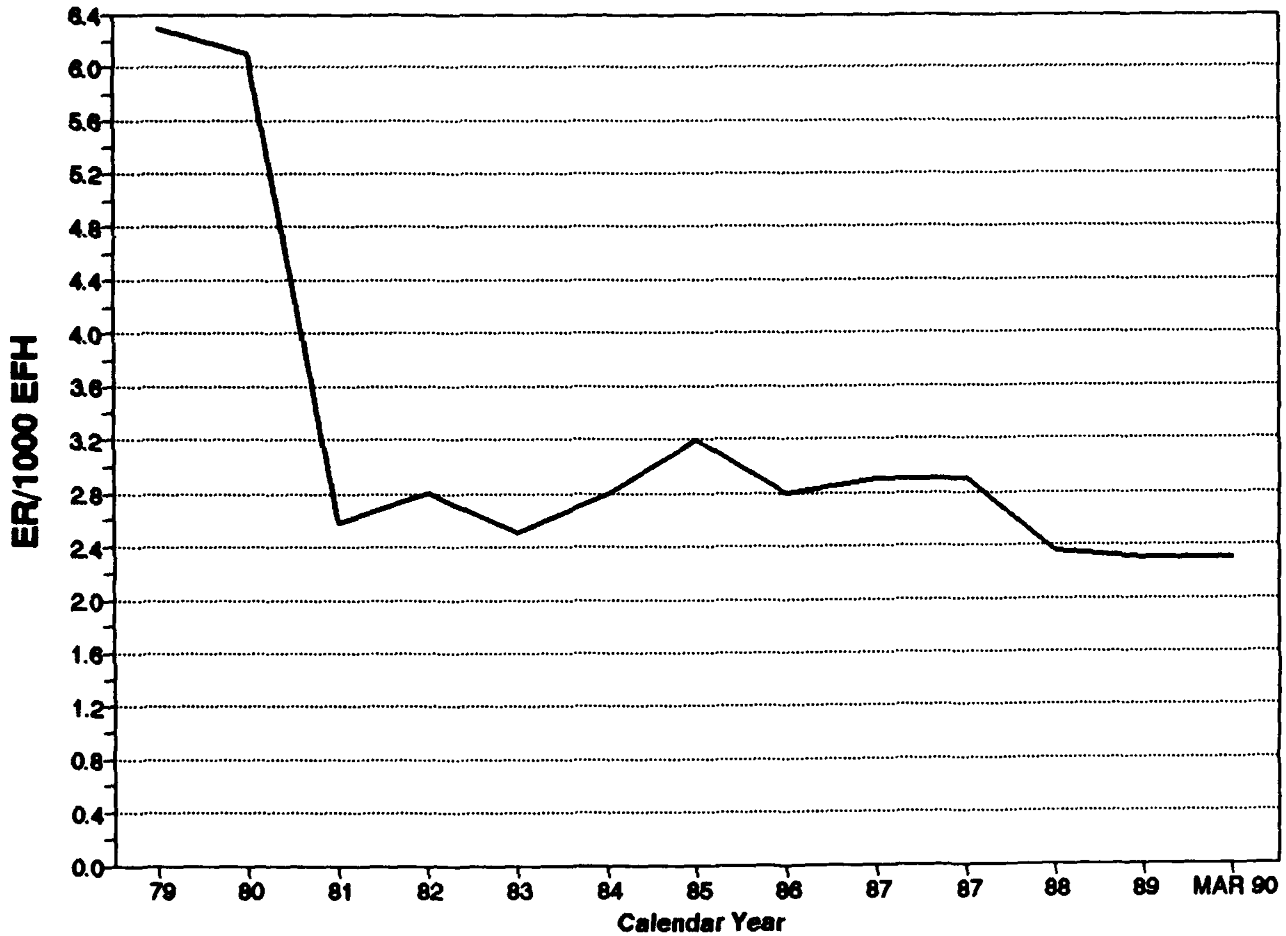



ABORTS PER 1000 ENGINE FLIGHT HOURS
FOR THE TF30 (F-14A) ENGINE
A/1000 EFH
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
79
80
81
82
83
84
85
86
87
87
88
89
MAR 90
Calendar Year

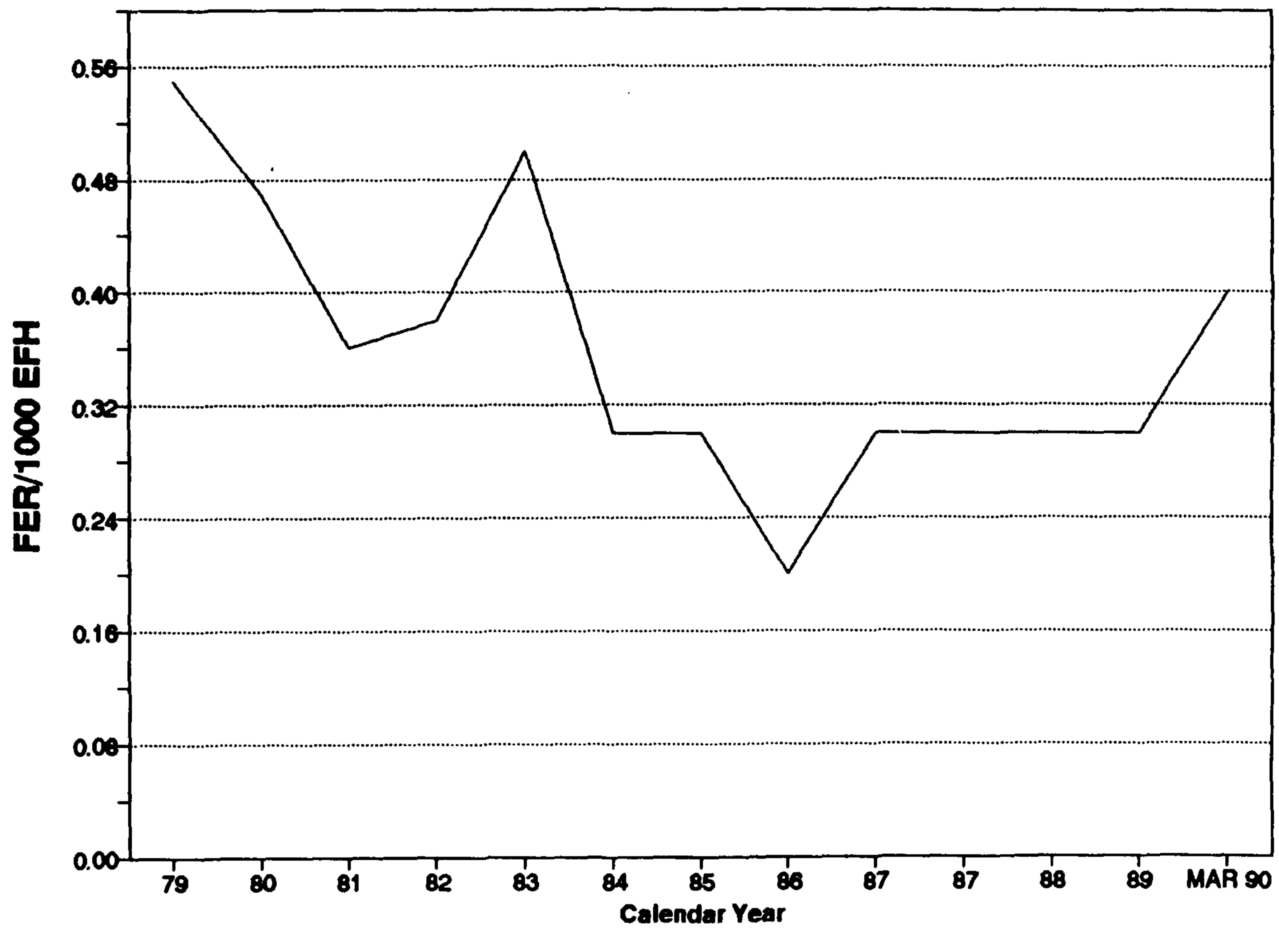
FAILURE ABORTS PER 1000 ENGINE FLIGHT HOURS FOR THE TF30 (F-14A) ENGINE



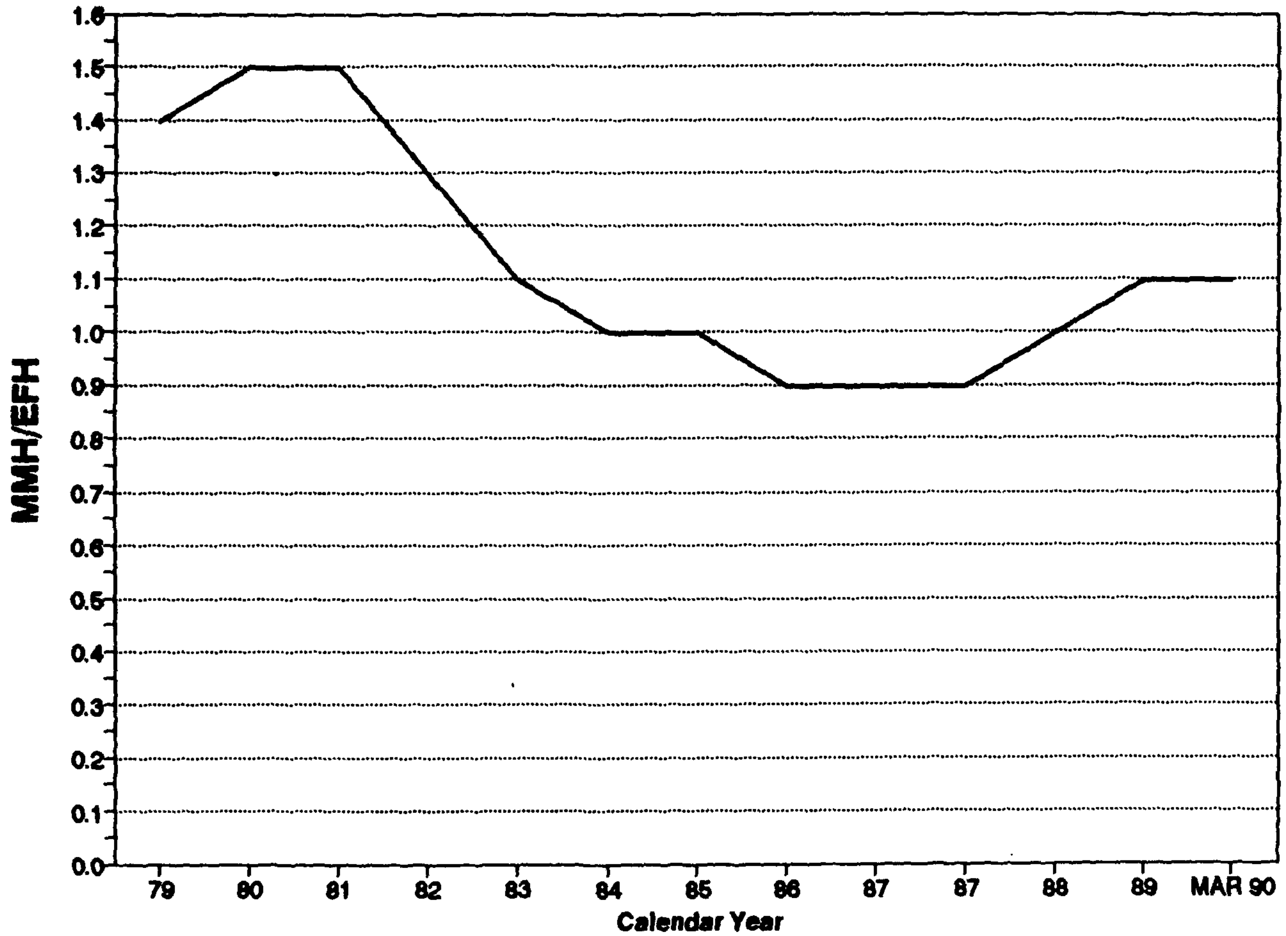
ENGINE REMOVALS PER 1000 ENGINE FLIGHT HOURS FOR THE TF30 (F-14A) ENGINE



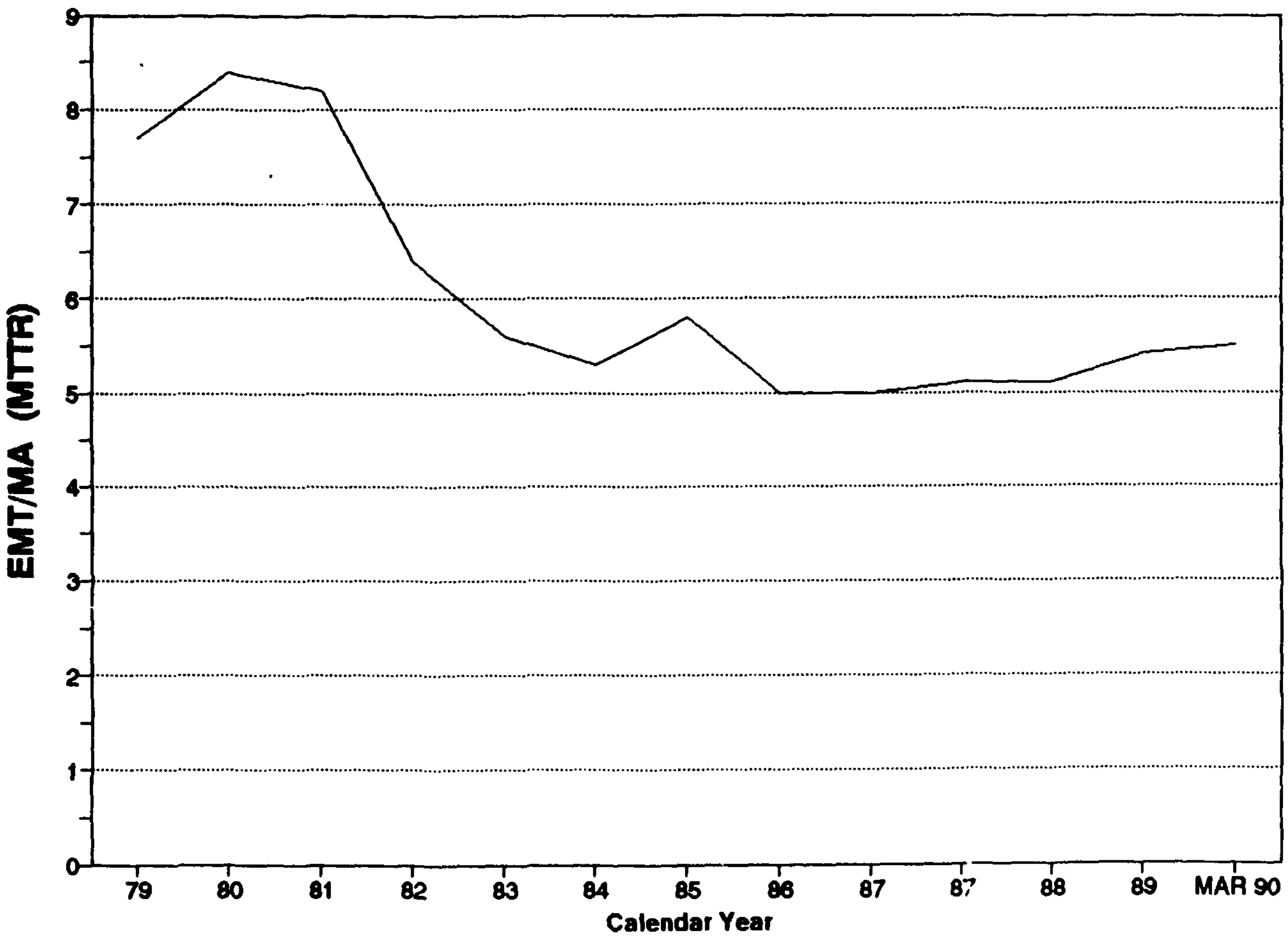
FAILURE ENGINE REMOVALS PER 1000 ENGINE FLIGHT HOURS FOR THE TF30 (F-14) ENGINE



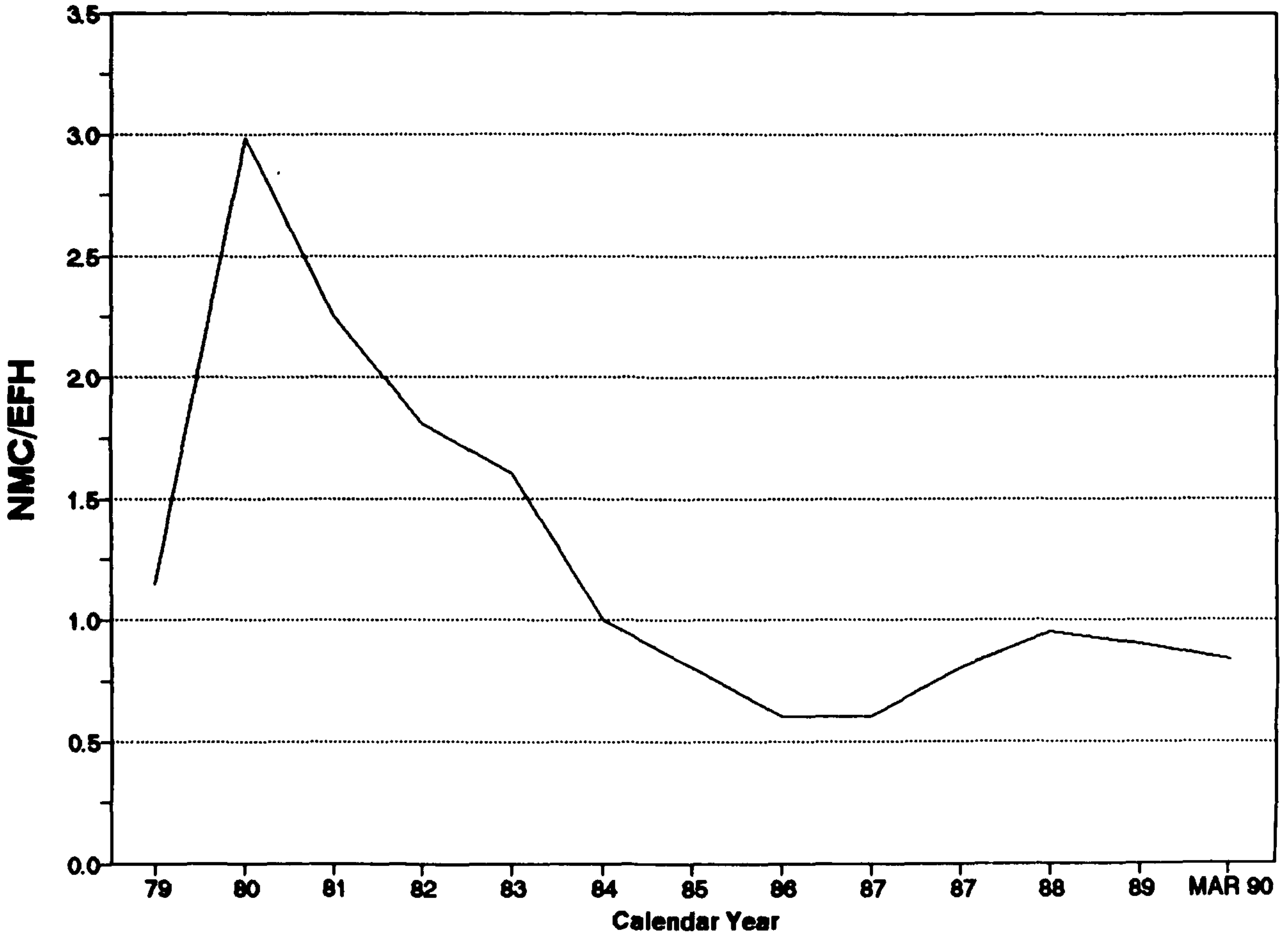
MAINTENANCE MAN HOURS PER ENGINE FLIGHT HOUR FOR THE TF30 (F-14A) ENGINE



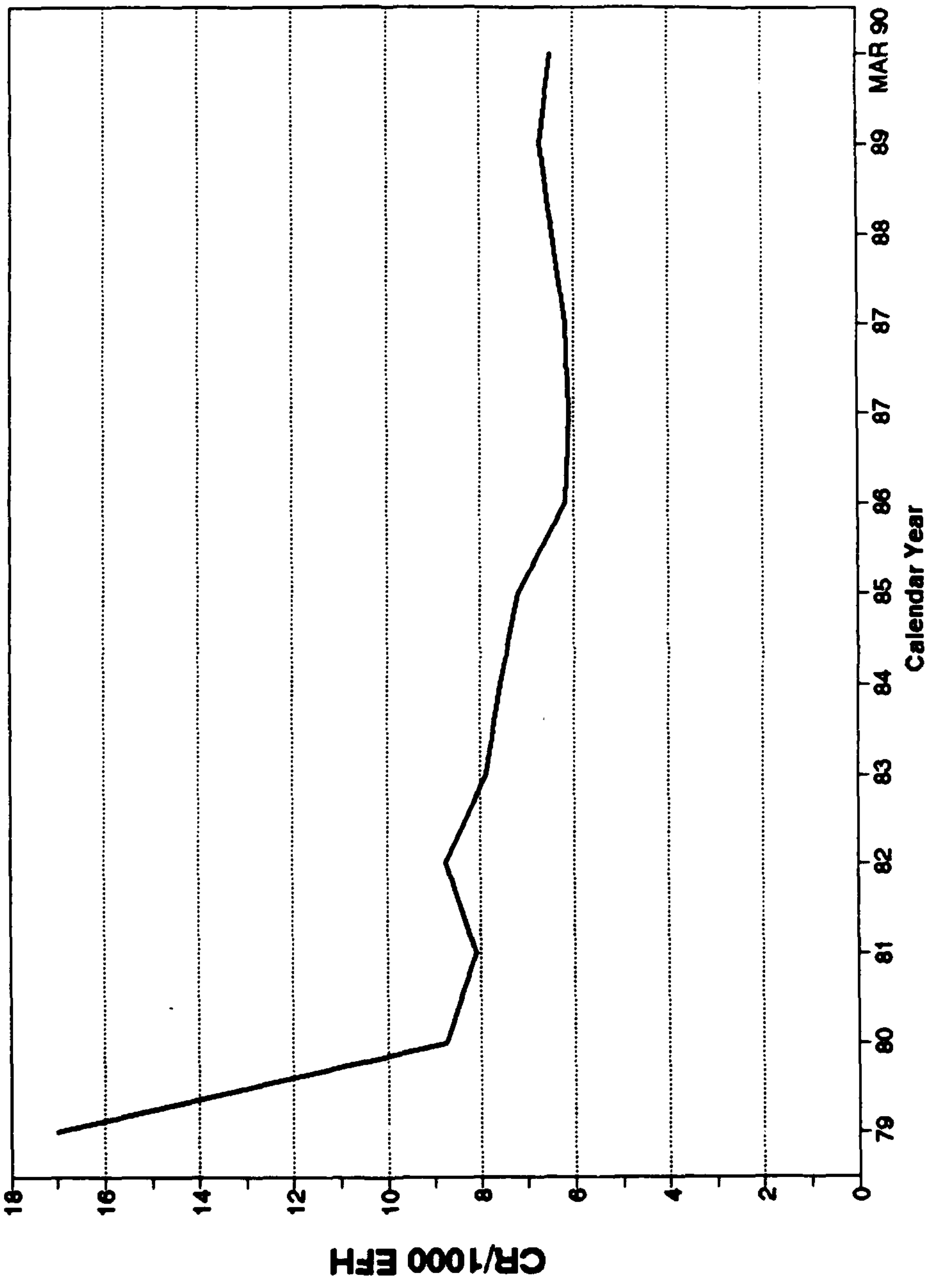
ELAPSED MAINTENANCE TIME PER MAINT. ACTION FOR THE TF30 (F-14) ENGINE



NOT MISSION CAPABLE HOURS PER ENGINE
FLIGHT HOUR FOR THE TF30 (F-14A) ENGINE



COMPONENT REMOVALS PER 1000 ENGINE FLIGHT HOUR FOR THE TF30 (F-14A) ENGINE



APPENDIX F

TF30 ROI ANALYSIS

Appendix F is divided into three sections: return on investment assumptions (the first two pages), return on investment computer output (the next twelve pages), and return on investment sensitivity analysis.

A. RETURN ON INVESTMENT ASSUMPTIONS - INPUT TO ROI PROGRAM

<u>OPERATIONAL DATA BEFORE FIX</u>

0.1	Engine flight hours per scheduled, last page of output.		
0.2	18 years expected life		
0.3	Cum. Flt. Hrs	(from schedule) x 2 =	4,367,150
0.4	Cost of weapon systemF-14A ($46.65M) F-14D ($62.54M) =		$50M
0.5	Amortization Period:	number of hours in 20 years =	175,320
0.6	Cost per NMC hour:	$50M/175,320 =	$285
0.7	Cost per MMH (O & I level):	NALC supplied number=	$40
0.8	Cost of Fuel:		$1.00
0.9	Cost of personnel loss:	NAVAIR supplied number =	$330,000
1.1	not used		
1.2	NMC (EMT) per Inspection:		5.0 hrs
1.3	MMH per Inspection:		7.0 hrs
1.4	TF30 replaced at 1200 hrs:	repl. freq =	0.000833
1.5	NMC (EMT) per replacement:		10.0 hrs
1.6	MMH per replacement:		20.0 hrs
1.7	Cost of replacement:		$500000
1.8	MAs per EFH:	ECIFR data =	0.060610
1.9	NMC per MA (EMT + other):	ECIFR data =	47.5 hrs
1.10	MMH per MA:	ECIFR data =	26.4 hrs
1.11	Cost per MA:	Engine cost data =	$47327
1.12	Not used		
1.13	Personnel loss frequency:	NAVSAFECEN provided =	0.32
1.14	Number of gallons of fuel per FH:	NAVAIR supplied =	1090

EXPECTED OPERATIONAL DATA AFTER FIX

2.1	Inspection Frequency after fix: 550 hrs	freq = 0.001818
2.2	NMC (EMT) per Inspection:	5.0 hrs
2.3	MMH per Inspection:	7.0 hrs
2.4	TF30 replaced at 4800 hrs:	repl. freq = 0.000208
2.5	NMC (EMT) per replacement:	10.0 hrs
2.6	MMH per replacement:	20.0 hrs
2.7	Cost of replacement: (max 6 digits)	$2,499,993 used $999,999
2.8	MAs per EFH:	ECIFR data 0.070420
2.9	NMC per MA (EMT + other):	ECIFR data 14.2 hrs
2.10	MMH per MA:	ECIFR data 13.2 hrs
2.11	Cost per MA:	Engine cost data $47327
2.12	Not used	
2.13	Personnel loss frequency:	NAVSAFECEN provided 0.32
2.14	Number of gallons of fuel per FH:	NAVAIR supplied 1090

NAVAIR (AIR-536) RETURN-ON-INVESTMENT ANALYSIS SYSTEM

ENGINE: TF30-P AIRCRAFT TYPES: F-14A
EPN/EPD: ECP: 476 MOD
DESCRIPTION: 1979: 412; 1988: 414A; INC3 INSPECTION

A. BASIC DATA

[0.0 COST AND OTHER BASIC DATA]

0.1	Engine Flight Hours per Year	W		S
0.2	Expected Remaining Life of Engine	Z		18
0.3	Total Expected EFH Remaining	X		0
0.4	Cost of Weapon System	K	$	50000000
0.5	Amortization Period for Weapon System	Y		175320
0.6	Cost per NMC Hour (J=K/Y)	J	$	285
0.7	Cost per MMH (O & I level)	C	$	40
0.8	Cost of Fuel (per gallon)	f	$	1.00
0.9	Cost of Personnel Loss (Training Costs)	U	$	330000

[1.0 OPERATIONAL DATA]

	Engine Inspections			
1.1	Inspection Frequency (Insp per FH)	I		0.00
1.2	NMC (EMT) per Inspection	E		5.0
1.3	MMH per Inspection	M		7.0
	Scheduled Maintenance			
1.4	End-of-Life Replacement Freq.(Repl per FH)	R		0.000833
1.5	NMC (EMT) per Replacement	B		10.0
1.6	MMH per Replacement	A		20.0
1.7	Cost of Replacement (materials/parts, depot labor, test, fuel, et al)	P	$	500000
	Unscheduled Maintenance			
1.8	Maintenance Action Frequency (MAs per EFH)	F		0.060610
1.9	NMC per MA (EMT + other downtime)	G		47.5
1.10	MMH per MA	D		26.4
1.11	Cost per MA (Materials/parts, depot labor, test, fuel, et al)	N	$	47327
	Equipment Losses			
1.12	Aircraft Loss Frequency (Loss per FH)	H		0.00000000
1.13	Personnel Loss Frequency (Loss per event)	L		0.320000
	Specific Fuel Consumption			
1.14	Number of Gallons of Fuel per FH	g		1090

A. BASIC DATA

[2.0 EXPECTED OPERATIONAL DATA AFTER THE FIX]

	Engine Inspections		
2.1	Inspection Frequency after Fix (Insp per FH)	I′	0.001818
2.2	NMC (EMT) per Inspection	E′	5.0
2.3	MMH per Inspection	M′	7.0
	Scheduled Maintenance		
2.4	End-of-Life Replacement Freq. (Repl per FH)	R′	0.000208
2.5	NMC (EMT) per Replacement	B′	10.0
2.6	MMH per Replacement	A′	20.0
2.7	Cost of Replacement (materials/parts, depot labor, test, fuel, et al)	P′	999999
	Unscheduled Maintenance		
2.8	Maintenance Action Freq After Fix (MAs/ EFH)	F′	0.070420
2.9	NMC per MA	G′	14.2
2.10	MMH per MA	D′	13.2
2.11	Cost per MA (Materials/parts, depot labor, test, fuel, et al)	N′	$ 47327
	Equipment Losses		
2.12	Aircraft Loss Freq After Fix (Loss per FH)	H′	0.00000000
2.13	Personnel Loss Freq After Fix (Loss per event)	L′	0.320000
	Specific Fuel Consumption		
2.14	Number of Gallons of Fuel per FH	g′	1090

[3.0 INVESTMENT COST DATA]

3.1	Investment Costs of ECP (Table 2)	Q	152300000

B. EXPECTED IN-SERVICE COST PER FLIGHT HOUR BEFORE FIX

[1.0 COST OF INSPECTIONS BEFORE FIX]

	[[1.1 LABOR COSTS]]			
1.1.1	Inspection Frequency	I		0.001818
1.1.2	MMH per Inspection	M		7.0
1.1.3	Cost per MMH	C	$	40
	Total Labor Costs	I(MC)	$	0.51
	[[1.2 NMC Costs]]			
1.2.1	Inspection Frequency	I		0.001818
1.2.2	EMT per Inspection	E		5.0
1.2.3	Cost per NMC Hour	J		285
	Total NMC Cost	I(EJ)	$	2.59
	Total Costs of Inspections Before Fix	I(MC+EJ)	$	3.10

[2.0 COST OF END-OF-LIFE REPLACEMENTS BEFORE FIX]

	[[2.1 LABOR AND MATERIALS COSTS]]			
2.1.1	End-of-Life Replacement Frequency	R		0.000833
2.1.2	MMH per Replacement	A		20.0
2.1.3	Cost per MMH	C	$	40
2.1.4	Cost of Replacement Materials/Parts	P	$	500000
	Total Labor & Materials Costs	R(AC+P)	$	417.1664
	[[2.2 NMC COSTS]]			
2.2.1	End-of-Life Replacement Frequency	R		0.000833
2.2.2	EMT per Replacement	B		10.0
2.2.3	Cost per NMC Hour	J		285
	Total NMC Cost	R(BJ)	$	2.374050
	Total Costs Replacements Before Fix	R(AC+P+EJ)	$	419.54045

B. EXPECTED IN-SERVICE COST PER FLIGHT HOUR BEFORE FIX (cont.)

[3.0 COST OF MAINTENANCE BEFORE FIX]

	[[3.1 LABOR AND MATERIALS COSTS]]		
3.1.1	Maintenance Action Frequency	F	0.060610
3.1.2	MMH per MA	D	26.4
3.1.3	Cost per MMH	C	$ 40
3.1.4	Cost of Materials/Parts	N	$ 47327
	Total Cost of Maintenance	F(CD+N)	$ 2932.49363
	[[3.2 NMC COSTS]]		
3.2.1	Maintenance Action Frequency	F	0.060610
3.2.2	NMC per MA	G	47.5
3.2.3	Cost per NMC Hour	J	285
	Total NMC Costs	F(GJ)	$ 820.507875
	Total Cost of Maintenance Before Fix	F(CD+N+GJ)	$3753.001505
	[4.0 COST OF AIRCRAFT/PERSONNEL LOSS BEFORE FIX]		
	[[4.1 COST OF WEAPON SYSTEM LOSS]]		
4.1.1	Aircraft Loss Frequency	H	0.00000000
4.1.2	Cost of Weapon System	K	50000000
	Total Cost of Weapon System Loss	$	0.000000
	[[4.2 COST OF PERSONNEL LOSS]]		
4.2.1	Aircraft Loss Frequency	H	0.00000000
4.2.2	Personnel Loss Frequency	L	0.320000
4.2.3	Cost of Personnel	U	$ 330000
	Total Cost of Personnel Loss	H(LU)	$ 0.000000
	Total Cost WS & Personnel Loss Before, Fix	H(K+LU)	$ 0.000000
	[5.0 COST OF FUEL CONSUMPTION BEFORE FIX]		
5.1	Specific Fuel Consumption	g	1090
	Total Expected Cost per FH without Fix	T	$5265.641645

$T = I(MC+EJ) + R(AC+P+BJ) + F(CD+N+GJ) + H(K+LU) + gf$

C. EXPECTED IN-SERVICE COST PER FLIGHT HOUR AFTER FIX

[1.0 COST OF INSPECTIONS AFTER FIX]

	[[1.1 LABOR COSTS]]			
1.1.1	Inspection Frequency	I'		0.001818
1.1.2	MMH per Inspection	M'		7.0
1.1.3	Cost per MMH	C'	$	40
	Total Labor Costs	I' (M'C')	$	0.51
	[[1.2 NMC Costs]]			
1.2.1	Inspection Frequency	I'		0.001818
1.2.2	EMT per Inspection	E'		5.0
1.2.3	Cost per NMC Hour	J'		285
	Total NMC Cost	I'(E'J')	$	2.59
	Total Costs of Inspections After Fix	I'(M'C'+E'J')	$	3.10

[2.0 COST OF END-OF-LIFE REPLACEMENTS AFTER FIX]

	[[2.1 LABOR AND MATERIALS COSTS]]			
2.1.1	End-of-Life Replacement Frequency	R'		0.000208
2.1.2	MMH per Replacement	A'		20.0
2.1.3	Cost per MMH	C'	$	40
2.1.4	Cost of Replacement Materials/Parts	P'	$	999999
	Total Labor & Materials Costs	R'(A'C'+P')	$	208.166192
	[[2.2 NMC COSTS]]			
2.2.1	End-of-Life Replacement Frequency	R'		0.000208
2.2.2	EMT per Replacement	B'		10.0
2.2.3	Cost per NMC Hour	J'		285
	Total NMC Cost	R'(B'J')	$	0.592800
	Total Costs Replacements After Fix	R'(A'C'+P'+B'J')	$	208.758992

C. EXPECTED IN-SERVICE COST PER FLIGHT HOUR AFTER FIX (cont.)

[3.0 COST OF MAINTENANCE AFTER FIX]

	[[3.1 LABOR AND MATERIALS COSTS]]		
3.1.1	Maintenance Action Frequency	F'	0.070420
3.1.2	MMH per MA	D'	13.2
3.1.3	Cost per MMH	C'	$ 40
3.1.4	Cost of Materials/Parts	N'	$ 47327
	Total Cost of Maintenance	F'(C'D'+N')	$3369.949100
	[[3.2 NMC COSTS]]		
3.2.1	Maintenance Action Frequency	F'	0.070420
3.2.2	NMC per MA	G'	14.2
3.2.3	Cost per NMC Hour	J'	285
	Total NMC Costs	F'(G'J')	$ 284.989740
	Total Cost of Maintenance After Fix	F'(C'D'+N'+G'J')	$3654.938840

[4.0 COST OF AIRCRAFT/PERSONNEL LOSS AFTER FIX]

	[[4.1 COST OF WEAPON SYSTEM LOSS]]		
4.1.1	Aircraft Loss Frequency	H'	0.00000000
4.1.2	Cost of Weapon System	K'	50000000
	Total Cost of Weapon System Loss	H'K'	$ 0.000000
	[[4.2 COST OF PERSONNEL LOSS]]		
4.2.1	Aircraft Loss Frequency	H'	0.00000000
4.2.2	Personnel Loss Frequency	L'	0.320000
4.2.3	Cost of Personnel	U'	$ 330000
	Total Cost of Personnel Loss	H'(L'U')	$ 0.000000
	Total Cost WS & Personnel Loss After Fix	H'(K'+L'U')	$ 0.000000

[5.0 COST OF FUEL CONSUMPTION BEFORE FIX]

5.1	Specific Fuel Consumption	g'	1090
	Total Expected Cost per FH without Fix	T'	$ 4956.79752

$$T' = I'(M'C' + E'J') + R'(A'C' + P' + B'J') + F'(C'D' + N' + G'J') + H'(K' + L'U') + g'f$$

D. RETURN ON INVESTMENT

[1.0 INVESTMENT COSTS]

TOTAL INVESTMENT COSTS	Q	$ 152300000
[2.0 BENEFIT = IN-SERVICE COST REDUCTION		
2.1 Expected cost per FH without Fix	T	$ 5265.641645
2.2 Expected Cost per FH with Fix	T'	$ 4956.797522
Cost Reduction per FH	(T - T') = S	$ 308.844123
Cost Reduction for Total period	(T-T')(W)Z = V	$ 662883079.42
3.0 RETURN	(V-Q)	$ 510583079.42
4.0 RATIO: BENEFIT/INVESTMENT	V/Q	4.35
5.0 RETURN ON INVESTMENT	(V-Q)/Q	3.35
6.0 FLIGHT HOURS TO RETURN INVESTMENT	Q/S	493129.020946
YEARS TO RETURN INVESTMENT	(Q/S)/W	4.59 years
One-Half Installation Period (Years)		2.75 years
TOTAL CALENDAR TIME TO RETURN INVESTMENT		7.34 years

11/13/90 FLIGHT HOURS TABLE: TF30-P-414A

Description: ESTIMATED PHASE IN/OUT SCHEDULE

ECP Installation Start Date: 11/1982 Stop Date: 06/1988

YEAR	FLT.HRS	CUM.HRS	YEAR	FLT.HRS	CUM.HRS
1982	0	0	1992	155,710	1,609,655
1983	40,625	40,625	1993	134,510	1,744,165
1984	81,250	121,875	1994	116,580	1,860,745
1985	121,875	243,750	1995	98,640	1,959,385
1986	162,500	406,250	1996	80,710	2,040,095
1987	203,125	609,375	1997	62,770	2,102,865
1988	243,750	853,125	1998	44,840	2,147,705
1989	233,970	1,087,095	1999	26,900	2,174,605
1990	193,210	1,280,305	2000	8,970	2,183,575
1991	173,640	1,453,945			

APPENDIX G

SENSITIVITY ANALYSIS OF TF30 414A ROI

Alpha Letters Represent The Parameter Changed Resulting in Total Calendar Time to Return Investment

parameter range	f	C	K	J	I	E	M	R	B	A	P	F	G	D	N	I'	E'	M'	R'	B'	A'	P'	F'	G'	D'	N'	L'
50%	7.34	7.46	7.34	20.0	7.37	7.33	7.34	12.3	7.35	7.35	12.3	--	--	7.63	--	7.33	7.33	7.34	6.68	7.34	7.34	6.69	4.29	6.49	7.21	4.37	7.34
60%	7.34	7.43	7.34	13.0	7.36	7.33	7.34	9.83	7.35	7.35	9.85	--	--	7.56	--	7.33	7.34	7.34	6.81	7.34	7.34	6.81	4.48	6.63	7.23	4.56	7.34
70%	7.34	7.41	7.34	9.71	7.35	7.34	7.34	8.80	7.35	7.35	8.81	--	--	7.50	--	7.34	7.34	7.34	6.94	7.34	7.34	6.94	4.75	6.79	7.26	4.85	7.34
80%	7.34	7.39	7.34	8.52	7.35	7.34	7.34	8.17	7.35	7.35	8.19	--	9.77	7.45	--	7.34	7.34	7.34	7.05	7.34	7.34	7.06	5.12	6.96	7.29	5.20	7.34
90%	7.34	7.37	7.34	7.87	7.35	7.34	7.34	7.70	7.35	7.34	7.72	--	8.18	7.40	--	7.34	7.34	7.34	7.19	7.34	7.34	7.19	5.77	7.13	7.32	5.86	7.34
100%	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34	7.34
110%	7.34	7.32	7.34	6.99	7.34	7.35	7.35	7.04	7.34	7.34	7.06	5.74	6.82	7.30	5.99	7.35	7.35	7.34	7.52	7.34	7.34	*	--	7.59	7.37	10.8	7.34
120%	7.34	7.30	7.34	6.67	7.34	7.35	7.35	6.78	7.34	7.34	6.81	5.10	6.40	7.25	5.33	7.35	7.35	7.35	7.73	7.35	7.34	*	--	7.89	7.40	--	7.34
130%	7.34	7.28	7.34	6.41	7.34	7.35	7.35	6.56	7.34	7.34	6.58	4.72	6.11	7.20	4.99	7.35	7.35	7.35	7.95	7.35	7.34	*	--	8.23	7.44	--	7.34
140%	7.34	7.26	7.34	6.21	7.34	7.35	7.35	6.37	7.34	7.34	6.39	4.45	5.88	7.16	4.70	7.35	7.35	7.35	8.19	7.35	7.34	*	--	8.63	7.47	--	7.34
150%	7.34	7.24	7.34	6.04	7.34	7.35	7.35	6.21	7.34	7.34	6.23	4.27	5.66	7.12	4.49	7.36	7.35	7.35	8.47	7.35	7.35	*	--	9.19	7.50	--	7.34
160%	7.34	7.22	7.34	5.90	7.34	7.36	7.35	6.08	7.33	7.34	6.09	4.15	5.48	7.08	4.34	7.36	7.36	7.35	8.82	7.35	7.35	*	--	9.99	7.53	--	7.34
170%	7.34	7.20	7.34	5.74	7.33	7.36	7.35	5.96	7.33	7.34	5.98	4.10	5.33	7.04	4.23	7.36	7.36	7.35	9.28	7.35	7.35	*	--	11.5	7.57	--	7.34
180%	7.34	7.18	7.34	5.61	7.33	7.36	7.35	5.81	7.33	7.34	5.86	3.98	5.21	7.00	4.14	7.36	7.36	7.35	9.85	7.35	7.35	*	--	15.4	7.60	--	7.34
190%	7.34	7.17	7.34	5.50	7.33	7.36	7.35	5.72	7.33	7.34	5.74	3.93	5.11	6.96	4.07	7.37	7.36	7.35	10.8	7.35	7.35	*	--	--	7.64	--	7.34
200%	7.34	7.15	7.34	5.39	7.33	7.36	7.35	5.62	7.33	7.34	5.64	3.84	5.02	6.93	4.01	7.37	7.36	7.35	12.4	7.35	7.35	*	--	--	7.70	--	7.34
300%	7.34	6.98	7.34	4.77	7.33	7.39	7.35	5.00	7.31	7.33	*	3.40	4.38	6.56	3.54	7.39	7.39	7.35	--	7.35	7.35	*	--	--	8.10	--	7.34
400%	7.34	6.81	7.34	4.39	7.33	7.41	7.36	4.60	7.29	7.33	*	3.24	4.09	6.29	3.34	7.42	7.41	7.36	--	7.36	7.35	*	--	--	8.60	--	7.34
500%	7.34	6.66	7.34	4.18	7.33	7.43	7.36	4.35	7.27	7.32	*	3.16	3.94	6.08	3.23	7.45	7.43	7.36	--	7.36	7.35	*	--	--	9.30	--	7.34
1000%	7.34	6.11	7.34	3.65	7.32	7.54	7.38	3.83	7.19	7.30	*	3.03	3.40	5.33	3.06	7.59	7.54	7.38	--	7.39	7.36	*	--	--	--	--	7.34

* 6 digit limited (input)

-- out of range

gal fuel per FH	(g')	cost per gallon fuel $1.00	$1.50	$2.00	$2.50	$3.00	$3.50
872	80%	6.20	5.88	5.59	5.38	5.21	5.08
981	90%	6.66	6.40	6.20	6.03	5.88	5.73
1090	100%	7.34	7.34	7.34	7.34	7.34	7.34
1199	110%	8.54	9.75	13.4			

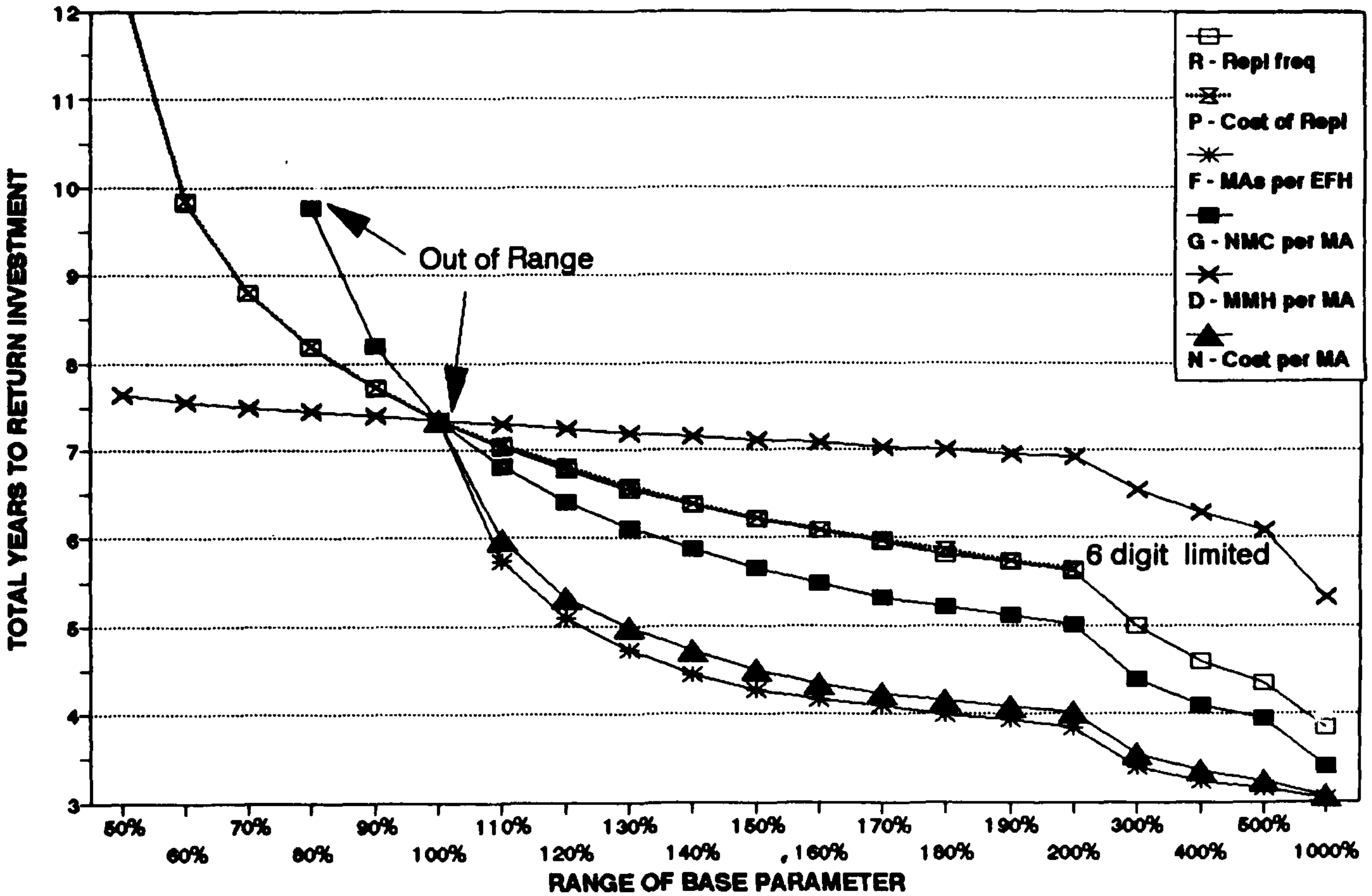
APPENDIX H

SENSITIVITY ANALYSIS - GRAPHS

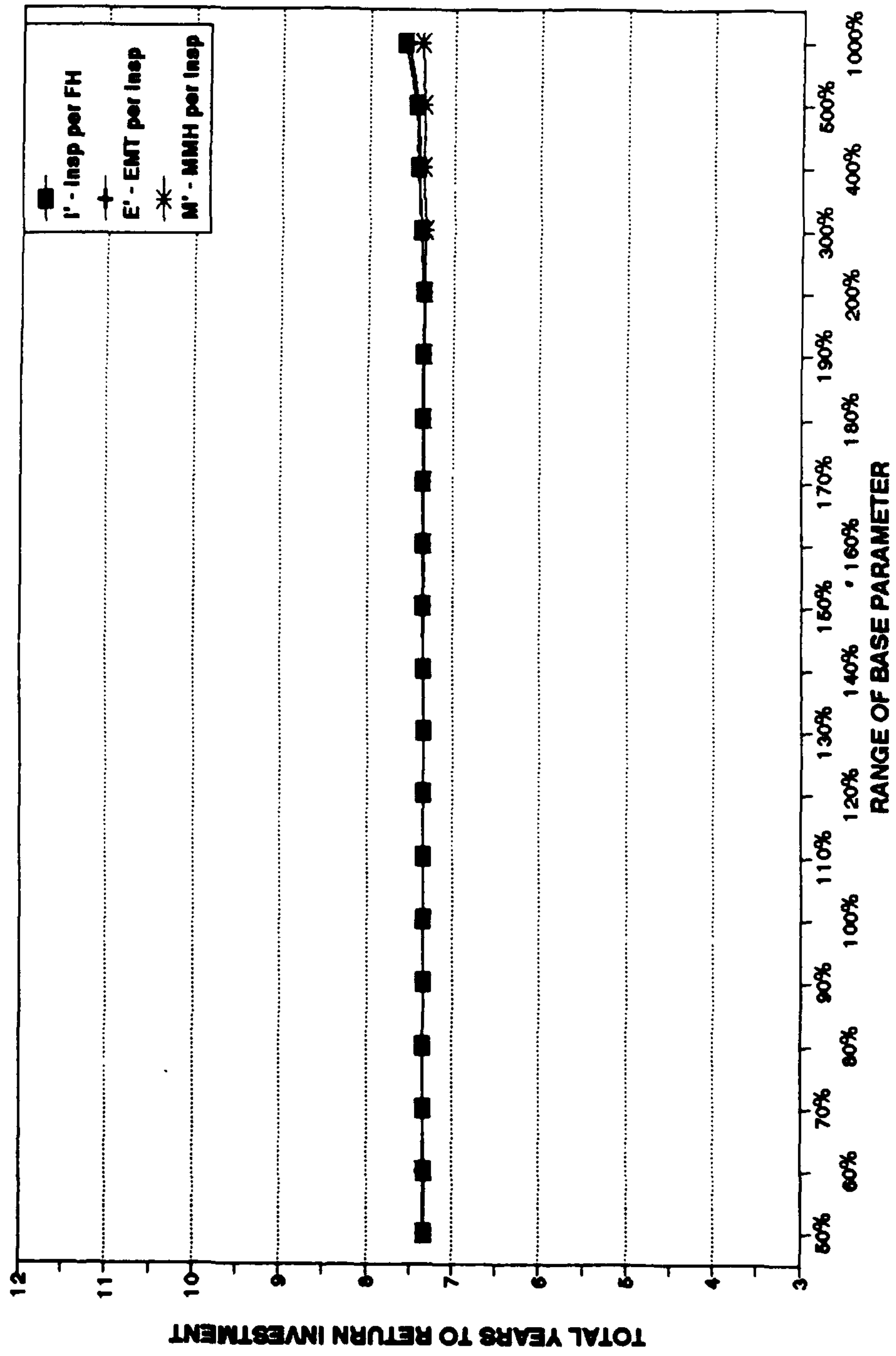
PARAMETER

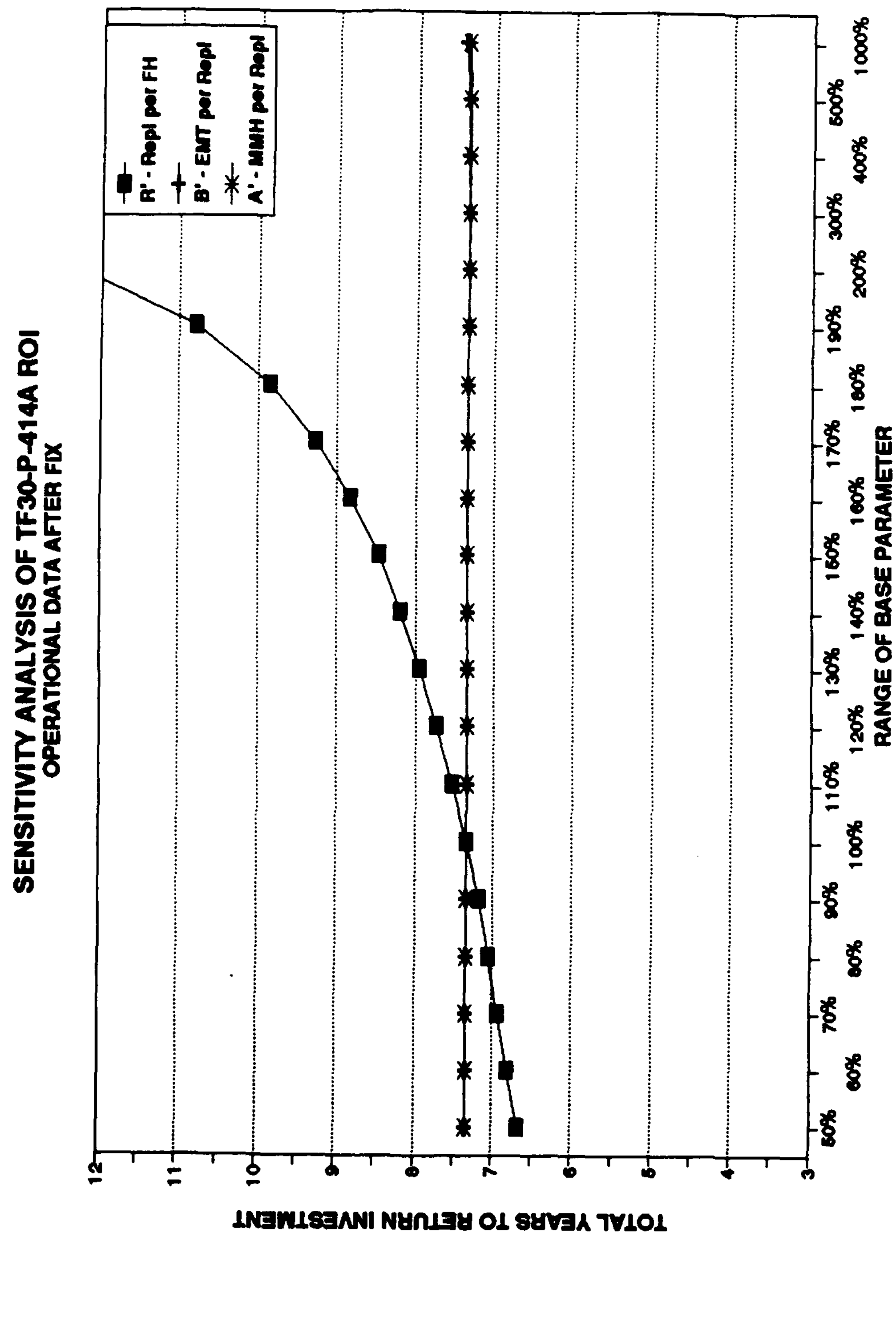
1. R - Replacement frequency;
   P - Cost of replacement;
   F - MAs per engine flight hour;
   G - NMC per MA;
   D - MMH per MA;
   N - Cost per MA.
2. I' - Inspections per flight hour;
   E' - EMT per inspection;
   M' - MMH per inspection.
3. R' - Replacement per flight hour;
   B' - EMT per replacement;
   A' - MMH per replacement.
4. P' - Cost of replacement;
   F' - MAs per engine flight hour;
   G' - NMC per MA.
5. D' - MMH per MA;
   N' - Cost per MA;
   L' - Personnel loss frequency.
6. f - changes in fuel consumption and fuel prices.

SENSITIVITY ANALYSIS OF TF30-P-414A ROI
OPERATIONAL DATA BEFORE THE FIX

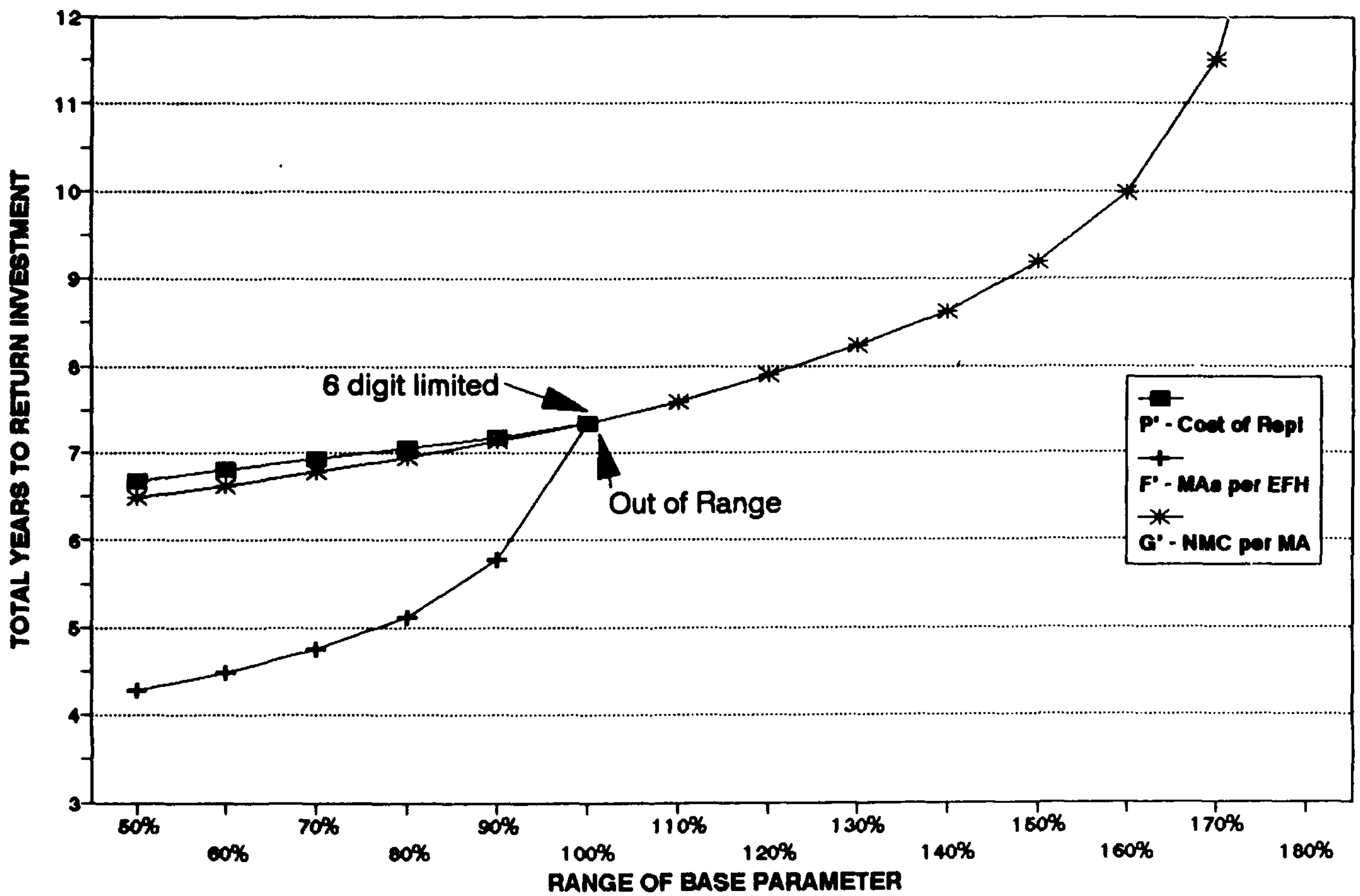


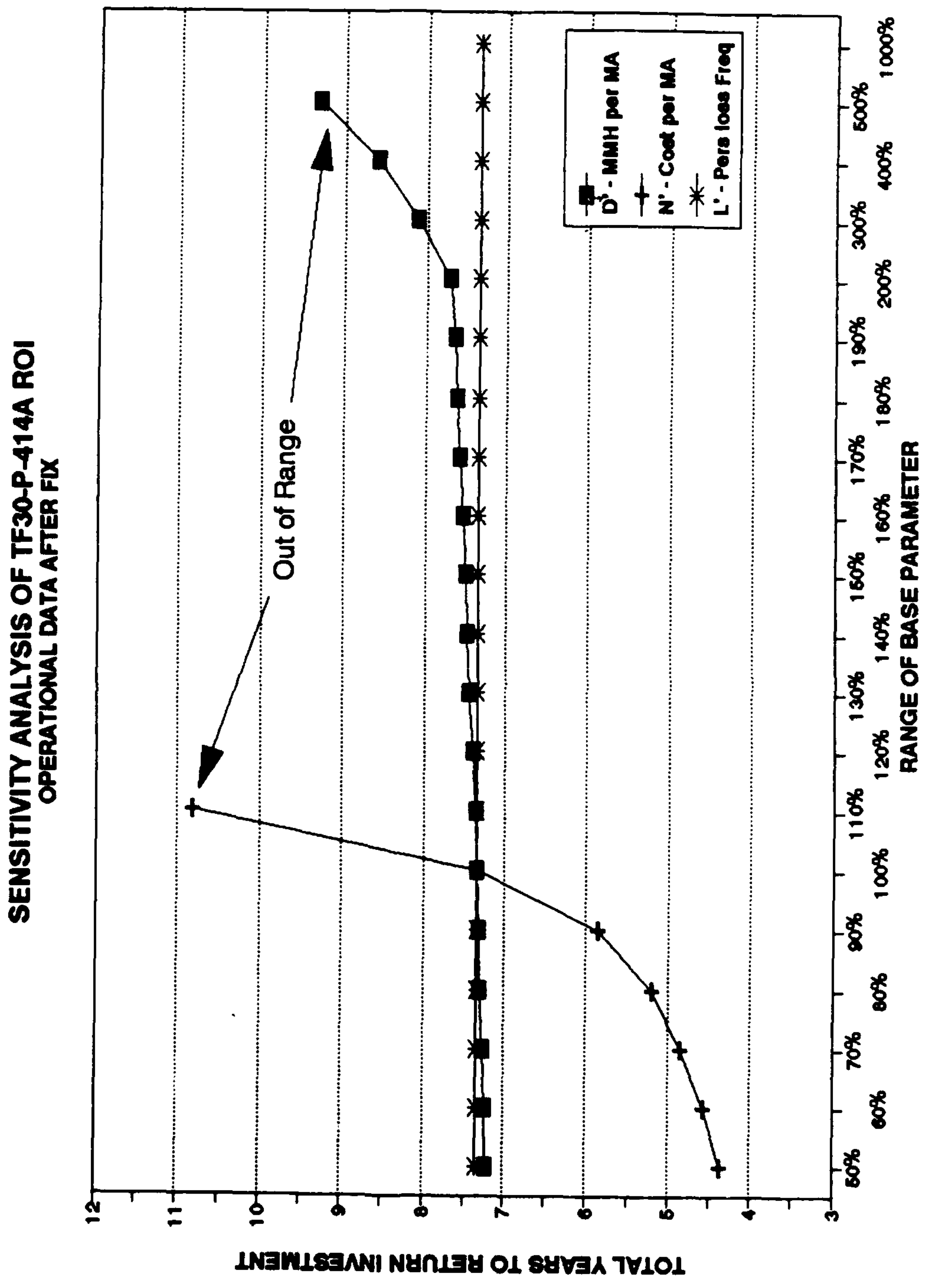
SENSITIVITY ANALYSIS OF TF30-P-414A ROI
OPERATIONAL DATA AFTER FIX




SENSITIVITY ANALYSIS OF TF30-P-414A ROI
OPERATIONAL DATA AFTER FIX
R' - Repl per FH
B' - EMT per Repl
A' - MMH per Repl
TOTAL YEARS TO RETURN INVESTMENT
12
11
10
9
8
7
6
5
4
3
RANGE OF BASE PARAMETER
50%
60%
70%
80%
90%
100%
110%
120%
130%
140%
150%
160%
170%
180%
190%
200%
300%
400%
500%
1000%

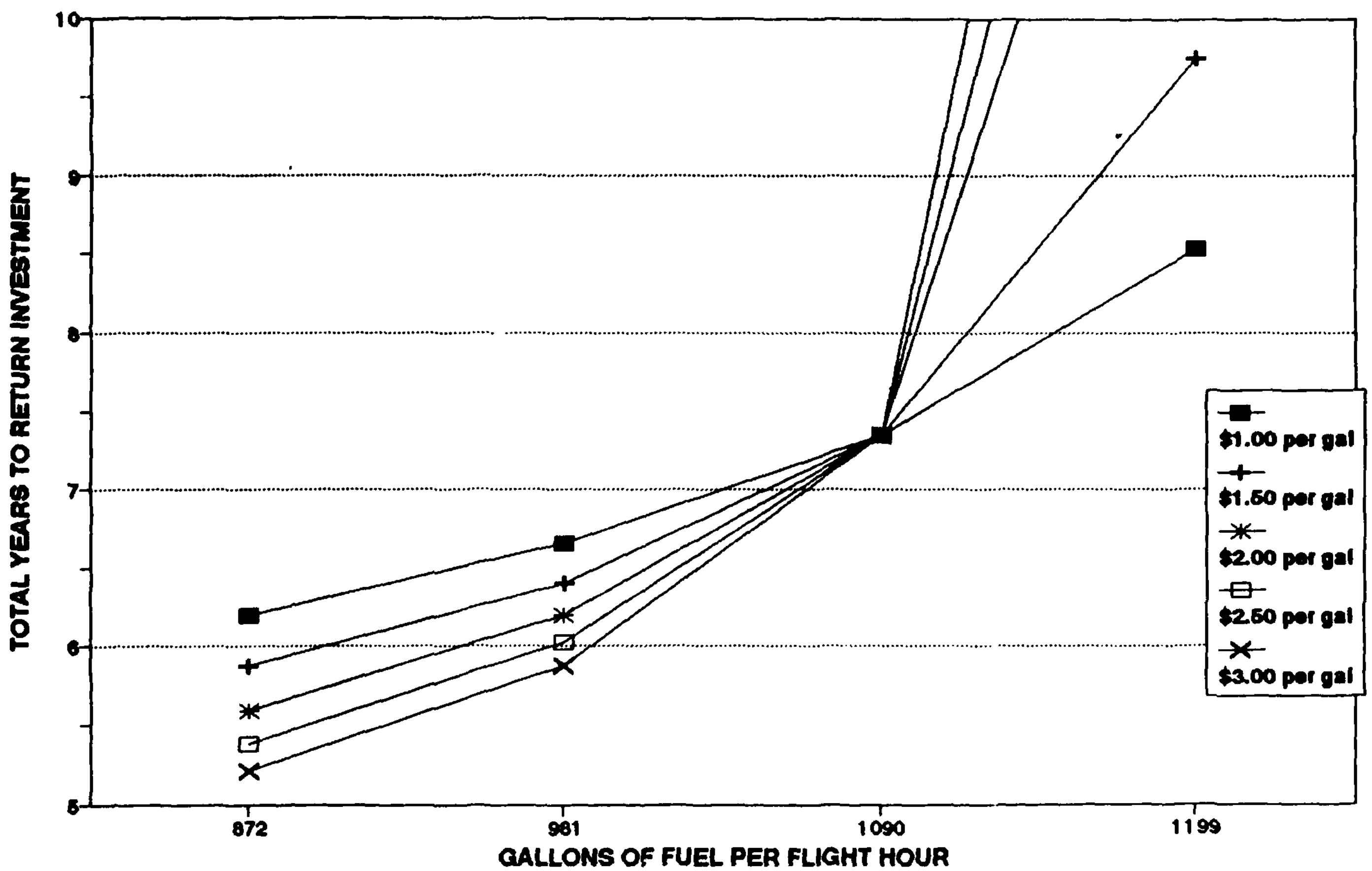
SENSITIVITY ANALYSIS OF TF30-P-414A ROI
OPERATIONAL DATA AFTER FIX





SENSITIVITY ANALYSIS OF TF30-P-414A ROI
OPERATIONAL DATA AFTER FIX
TOTAL YEARS TO RETURN INVESTMENT
12
11
10
9
8
7
6
5
4
3
Out of Range
D' - MMH per MA
N' - Cost per MA
L' - Pers loss Freq
50%
60%
70%
80%
90%
100%
110%
120%
130%
140%
150%
160%
170%
180%
190%
200%
300%
400%
500%
1000%
RANGE OF BASE PARAMETER

SENSITIVITY ANALYSIS OF TF30-P-414A ROI
CHANGES IN FUEL CONSUMPTION AND PRICES



APPENDIX I

1990 ENGINE COST DATA[1]

ENGINE	NEW ENGINE COST	REPORTABLE REPAIR COST[2]
F110-GE-400	3,062,648	50,000
F402-RR-402/4/6/8	3,459,500	139,945
F404-GE-400	1,650,615	14,101
J52-P-6B	164,694	21,999
J52-P-8B	1,136,825	55,029
J52-P-408	1,300,000	22,772
J57-P-10/22/420	111,863	25,772
J60-P-3A	82,747	9,228
J79-GE-8D/10B	581,000	36,269
J85-GE-4A/B	112,985	22,987
J85-GE-5J	86,452	31,977
J85-GE-21A	332,070	42,808
JT-8D-9A	885,000	36,666
JT-12-A8	1,100,000	24,133
PT6-A25	171,014	13,156
PT6-A34B	214,500	13,156
PT6-A41/42	214,500	9,631
R2800-52W	41,000	23,104
T400-CP-400	207,560	18,178
T400-CP-401	207,560	11,050
T400-WV-402	227,060	16,393
T53-L-11/13B	163,431	22,703
T56-A7/9/10	75,536	38,458
T56-A14	644,068	36,179
T56-A16	191,952	36,939
T56-A423/5/6	644,068	36,868
T56-A427	1,385,993	40,500
T58-GE-8F	73,800	10,996
T58-GE-10	271,317	12,426
T58-GE-16	688,200	12,782
T58-GE-400	688,200	26,928
T64-GE-6B	124,877	23,529
T64-GE-413	231,000	42,069
T64-GE-415	491,280	23,002
T64-GE-416	775,500	19,558
T700-GE-401	475,300	8,036
T76-G-418/419	215,000	13,774
T76-G-420/421	265,000	18,598
TF30-P-414/A	2,499,993	47,327
TF34-GE-400	1,027,000	44,102
TF-41-A2	1,875,946	28,670
TF41-A402	1,875,946	39,600

[1]SOURCE: *1990 Engine Cost Data for Aviation Mishap Reporting*, Naval Safety Center Norfolk message 171510Z APR 90.

[2]When an engine is damaged and can be repaired, this is the total engine repair cost including parts and materials for all three levels of maintenance.

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