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THESIS

AN ANALYSIS OF THE COSTS AND BENEFITS IN IMPROVING THE T56-A-427 INTERCONNECTOR HARNESS END AND MATING THERMOCOUPLE END CONNECTOR UNDER THE AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM (CIP)

by

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June, 1994

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An Analysis of the Costs And Benefits In Improving The T56-A-427 Interconnector Harness End And Mating Thermocouple End Connector Under The Aircraft Engine Component Improvement Program (CIP)

by

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This thesis is a study validating the cost effectiveness of the Component Improvement Program for aircraft engines. It determines the costs and benefits derived from the Navy incorporating Power Plant Change 111 which improved the interconnector harness end and mating thermocouple end connector of the T56-A-427 engine. Useful maintenance data pertaining to this component was extracted from the Naval Logistics Data Analysis (NALDA) system. Cost data pertaining to the Power Plant Change was taken from two sources, the Manufacturer's Engineering Program Description (EPD) and the Naval Air System Command's Configuration Change Control Board (CCCB) document. Based on the author's analysis, the improvement to the interconnector harness end and mating thermocouple end connector was cost-effective from both a financial break-even point in that the cost to produce the improvement will be recovered after three years, and from a Net Present Value analysis on this improvement which shows that the U.S. Navy will save more than $400,000 during the expected fifteen-year life cycle of the engine.

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I. INTRODUCTION

A. BACKGROUND

The Component Improvement Program (CIP) is the Department of Defense's program to improve safety, reliability, and maintainability for aircraft engines, propellers and power systems. The CIP provides for continuing improvement in aircraft engine hardware, procedural safety, reliability, maintainability and corrective action of service-related deficiencies after the first procurement funded aircraft has been accepted. [Ref. 1] Continuing over the life of the aircraft engine, the CIP ensures that older inventory aircraft engines remain operational.

This thesis is a study of the Navy's Engine CIP and more specifically, a study of the Navy's CIP effort on the T56-A-427 engine used on the E-2C(plus) Hawkeye aircraft. Over all, this thesis will determine the costs and benefits associated with improving the interconnector harness end and mating thermocouple end connector used on the T56-A-427 engine, which was improved through the CIP.

This thesis is a continuation of on-going research on aircraft logistics support at the Naval Postgraduate School started in 1990 at the request of N-881, the Naval Aviation Maintenance Division of the office of the Assistance Chief of

Naval Operations (Air Warfare), and AIR-536, the Propulsion and Power Division of the Naval Air Systems Command. This request for research has been generated by the fact that no new tactical Navy aircraft are expected until the year 2005, and except for the F/A-18, all current inventory types are out of production. [Ref. 2]

Several thesis research projects have been completed at the Naval Postgraduate School concentrating on the CIP and its effects on engine reliability, maintainability and durability. These projects have focused on quantifying both the CIP investment cost and the resulting savings during the life cycle after a modification to a component on the engine has been made. One of the major goals of the Naval Postgraduate School's research effort is to validate that the CIP for aircraft engines is cost-effective.

B. OBJECTIVES

The objectives of this thesis are:

1. To understand the process that currently exists in the CIP that allows for funding of certain Engineering Change Proposals (ECP) over other ECP's.

2. To determine how much CIP and O&MN money was spent to design and implement one high impact ECP for the T56-A-427 engine, and to determine what, if any, were the problems associated with its implementation.

3. To measure the maintenance manhours and material costs for the selected component before and after the CIP funds were expended and relate the costs of the improvement with the benefits that it provided.

4. To compare the CIP costs with the actual and projected life cycle cost savings resulting from the component's improvement.

C. SCOPE AND LIMITATIONS

This thesis focuses on the T56-A-427 engine used on the Navy's E-2C(plus) Hawkeye aircraft. This engine was chosen because it is the latest major improvement to the long line of T56 series engines and data on the engine is being monitored closely by the Fleet Introduction Team (FIT) located at the Naval Air Station Miramar, California. More specifically, this research focuses on the costs and projected benefits which have resulted from improving the interconnector harness end and the mating thermocouple end connector. The changes were made to this component to better withstand the vibration and high temperature environment found inside the engine nacelle which were the two main reasons why the old component failed so often. This CIP project was one of ten T56-A-427 CIP projects of the Allison Gas Turbine Division of the General Motors Corporation during the fall of 1991. [Ref. 3] The limitations to this research is that it only looks at this one improvement to this one component of the T56-A-427 engine.

D. THESIS PREVIEW

Chapter II provides literature review on previous thesis research efforts focusing on the CIP and their conclusions.

Chapter III provides a brief technical description of the T56-A-427 engine, CIP funding involving the T56 engine, the ECP selected for this research, the methodology used for the actual collection of maintenance data, and presentation of the maintenance data. Chapter IV contains a life cycle cost (LCC) analysis of two models; one without the ECP modification incorporated and one with the ECP incorporated. Chapter V is a break-even and Net Present Value analysis of the differences in the costs between the two models presented in Chapter IV. Finally, Chapter VI presents a summary, conclusions, and recommendations for future study.

II. LITERATURE REVIEW AND PREVIOUS RESEARCH

This chapter presents a review of previous research done on the CIP. The author begins this review with a report done by the Institute for Defense Analysis that is critically important to CIP research. The remaining review focuses on the thesis research done on the CIP at the Naval Postgraduate School.

A. POLICY OPTIONS FOR THE AIRCRAFT TURBINE ENGINE COMPONENT IMPROVEMENT PROGRAM

A paper prepared by the Institute for Defense Analyses (IDA) for the Under Secretary of Defense (Acquisition) investigated the possibility of transitioning CIP to the private sector, the role of CIP overall, the costs and benefits of the CIP program, and the policy options of competing CIP funding. [Ref 4] The paper's authors, Nelson, Harmon and Tyson, describe in detail the role of CIP as an integrated effort that exceeds the maturation period of the aircraft engine following Full Scale Development (FSD). These authors describe the function of the CIP as being an engineering and design effort, which includes the testing and manufacturing of parts and also the management of the integration of the parts into the engine. They explain in detail the resources required to accomplish a CIP task that includes a design team, a database, and also a plan for integration of long range objectives for the engine program over its life time. The authors show that the value of CIP, this being the cost to the military, has declined significantly, largely due to improvements in the full scale development process, the elimination of performance growth and new application objectives for CIP. For these reasons, they conclude that cost savings obtained from CIP efforts significantly outweigh CIP costs. The authors list the current CIP objectives as being:

> To correct safety of flight problems, service revealed deficiencies in operational use, and failures induced early in accelerated mission testing and lead the force operations.
>
> To improve durability, reliability, maintainability, producibility, and repairability.
>
> To reduce parts costs, engine costs, and life cycle (including fuel costs).
>
> To improve logistics support planning, integration of total effort to obtain improvements, and the opportunity for new technologies insertion.
>
> To retain performance over the engine lifetime in the inventory.

B. EVALUATION OF AIRCRAFT TURBINE ENGINE COMPONENT REDESIGNS

A thesis written by Sudol and Price was a study that examines some of the problems associated with determining the benefits accrued from CIP. [Ref. 5] The backbone of the thesis was the development of a component selection methodology and an analysis procedure for detecting changes in the components logistics parameters. The data source the authors used was the Engine Component Information Feedback Report (ECIFR) which is generated from aviation information provided by organizational level maintenance activities and squadrons. Sudol and Price suggested that a component improvement or "Fix" should have completed the Generic CIP Milestone Timeline through T5, shown in Figure 2.1. below, in order for a component to be able to be considered for validating of the CIP.

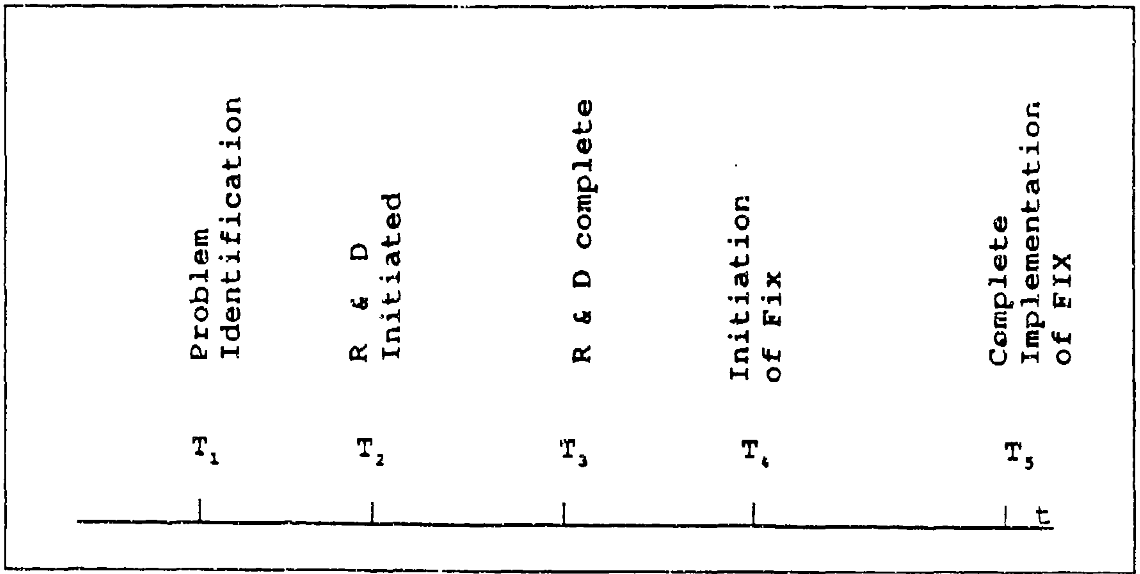

Figure 2.1. Generic CIP Milestones Timeline.

Reaching milestone T5 means that the ECP has been funded, documented as a Power plant Change (PPC), and is fully incorporated throughout the fleet. Also, the authors proposed a logic for selecting a component for study base on historical maintenance data from the ECIFR.

This logic diagram is displayed in Figure 2.2. on the following page. This author has modified it slightly to make it current for the time frame of this writing. Also, what must be noted about the logic diagram is that if the answer to the second decision block question is "no" then it implies that the component was involved in an improvement effort and a change in its historical maintenance data has taken place. Hence, it would be a possible candidate for study.

In their thesis, the authors examined the improvement to one component, the TF-30 Afterburner Igniter Fuel Valve. Using data from organizational and intermediate maintenance activities, the study concluded that the Mean Time Between Failures (MTBF) of the igniter fuel valve had increased from 1000 hours in 1982 to 6000 hours in 1989 because of CIP expenditures. However, throughout the period of time used in their evaluation, several CIP expenditures were made to this component, and the increase in MTBF was gradual. Because of this, the authors posed the question of how to associate a particular increase in engine MTBF with each of the ECPs which had taken place on that engine during the time of study.

Finally, Sudol and Price concluded that first, the CIP program can only be studied at the component level. They based this conclusion on the theory that because of the complex interactions of components attached to an engine, the effects of a specific CIP effort would be lost in the parameters of the system if viewed at the engine level. Secondly, that the

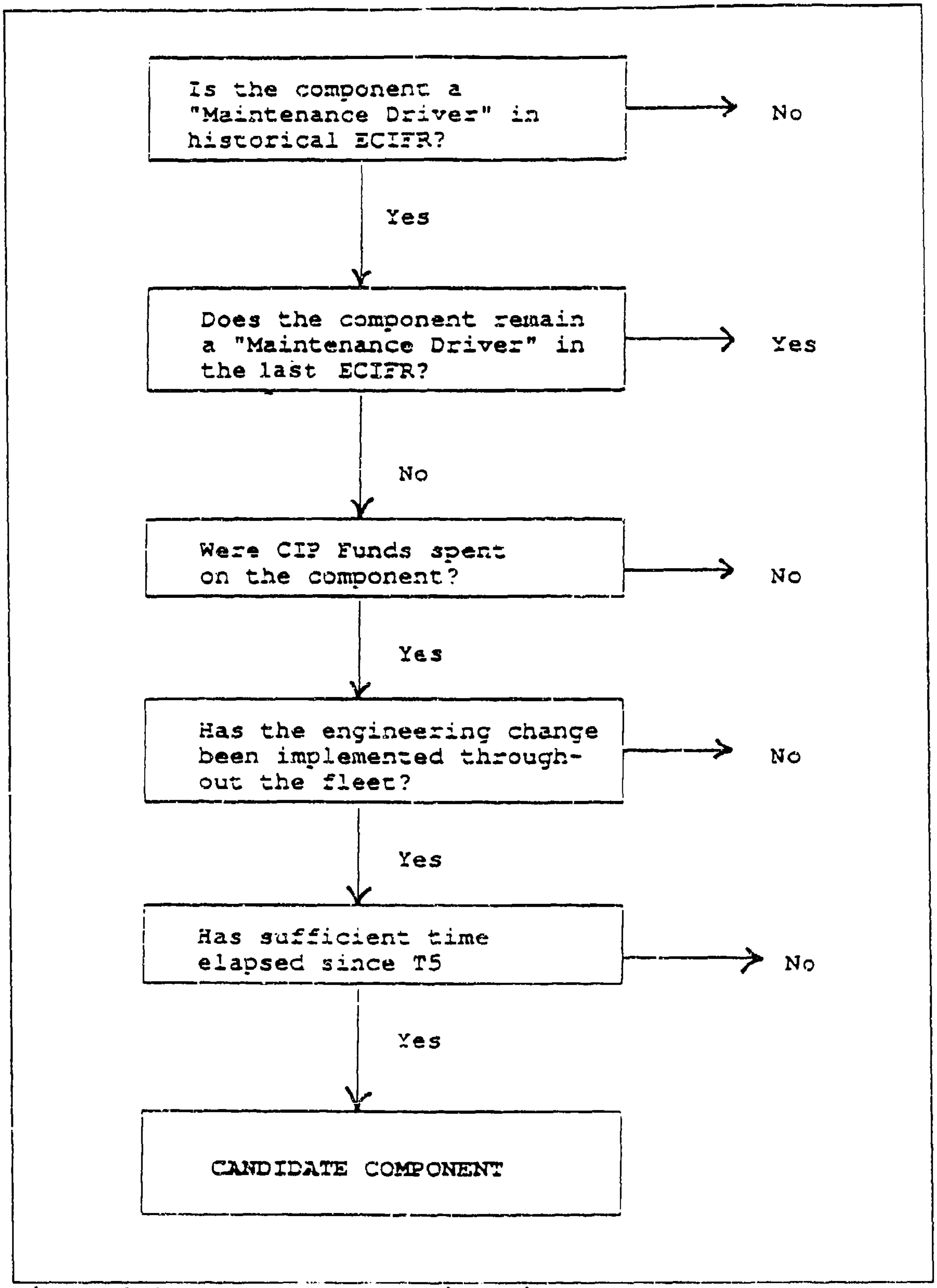

Figure 2.2. Component Selection Diagram.

method of data collection plays a critical role in the ability of the researcher to measure the benefits of a CIP expenditure.

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

Examining the Aircraft Engine CIP with emphasis on measuring the program's impact on costs at the organizational and intermediate levels of maintenance, Borer [Ref. 6] attempted to identify current LCC models used by the Navy and other services to determine CIP benefits. The database used in this research was the Visibility and Management of Operating and Support Costs (VAMCSC) management information system. That system has changed managers since Borer's writing from NAVAIR (AIR-41114B) to the Navy Center for Cost Analysis (NCA-61). Borer also referred to the ECIFR discussed earlier in this thesis.

Comparing data from seven different aircraft (F-14A, A-7E, P-3C, A-6E, S-3A, EA-6B, E-2C, and KC-130F) from 1984 to 1986, Borer compared Mean Flight Hours Between Maintenance Actions (MFHBMA) and Mean Maintenance Hours per Maintenance Action (MMH/MA) at the organizational and intermediate levels of maintenance to support improvements in aircraft reliability and maintainability. He was able to show that there were improvements in both MFHBMA and MMH/MA at the two levels of maintenance included in the research.

Because Borer concentrated his study at the system level, a strong correlation between specific CIP expenditures and specific improved reliability and maintainability was not possible. Borer stated in his thesis that "The Graphs show a definite improvement trend, but there is no clearly identified cause and effect relations between CIP funds and 3M data." This statement reinforces the observation of Sudol and Price, that in order to validate benefits of the CIP, a researcher must do so at the component level and not at the system level.

D. PRELIMINARY ANALYSIS OF THE J-52 AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM

Butler's thesis [Ref. 7] presented a preliminary analysis of the J-52 aircraft engine CIP. He was the first to study the J-52 engine. His objectives in the research were to scrutinize the association of the CIP with the promised improvements and benefits pertaining to the J-52 engine, and to determine the obstacles that exist in the databases when attempting to calculate the success or failure of the component modification. Butler also used the ECIFR to plot the changes in the maintenance data concerning Aborts, Engine Caused Aborts, Mean Time Between Failures, Mean Time Between Maintenance Actions, Mean Time To Repair, Maintenance Actions, total Failures, and the Maintenance Manhours for the entire inventory of J-52 engines.

Next, using ten ECP as the analysis base, Butler showed that only one of the ten ECP's, that being an ECP modification to the engine fuel control, could be directly correlated to a tangible increase in the J-52's performance.

Butler used the cost and savings information off of the ECP packages that were sent to him by Pratt and Whitney. Within the ECP package itself, the manufacturing company usually makes long range assumptions as to what they estimate will be the costs and savings from that particular ECP effort.

Butler found it extremely difficult to collect data on the components he selected for study. He examined the NALDA database, the Maintenance, Material, Management (3M) database, and the Aviation Engineering Maintenance System (AEMS) database, but concluded that while the databases were filled with useful information it was too difficult to use. He resorted to the ECIFR report for his reliability and maintainability values.

E. AN ANALYSIS OF THE CORRELATION BETWEEN THE J-52 COMPONENT IMPROVEMENT PROGRAM AND IMPROVED MAINTENANCE PARAMETERS

Continuing the research effort on the J-52 engine, Gordon [Ref. 8] set out with the same objective as Butler; namely, to make a correlation between the CIP dollars spent on the J-52 engine and improved maintenance parameters at the component level. The major focus of his study revolved around developing a methodology to accomplish his objective using existing databases, open dialogue between the J-52 engine manufacture (Pratt and Whitney), Naval Air Systems Command (NAVAIRSYSCOM), and various Naval Aviation Depot (NADEP) engineers. Gordon was able to construct a methodology using the ECIFR to track Failure Maintenance Actions on five components of the J-52 engine. He targeted his research towards the Failure Maintenance Actions because he felt that it displayed a greater measure of reliability of the engine. Gordon's research effort, as with his predecessors, was unsuccessful in tracking CIP dollars invested on the J-52 for any specific ECP effort.

F. AN ANALYSIS OF THE COST AND BENEFITS IN IMPROVING THE J-52 FUEL PUMP MAIN GEAR SPLINE DRIVE UNDER THE AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM (CIP)

Jones, [REF. 9] continued the research of Butler and Gordon on the J-52 engine. The major objective of Jones was to develop a methodology for extracting maintenance data from the NALDA system and use it to determine the financial Net Present Value and break-even point of a CIP effort. He selected the fuel pump main gear spline drive of the J-52 because this part had only one ECP preformed on it since 1979. With some very extensive investigating, Jones was able to use the NALDA system to determine the number of maintenance actions required on this part prior to the installation of the PPC, the action item document issued to the fleet following a ECP, and also the number of maintenance actions required after the installation.

Using the Equipment Condition Analysis (ECA) "0520" Report, Jones was able to extract the specific maintenance data related to the J-52 fuel pump both before-and-after the PPC was issued. Also, because he was tracking a change that involved maintenance work at the Depot level, Jones used the ECA "301" Report to track fuel pumps that had arrived at the Depot maintenance facility still attached to an engine. Because these two reports list the type of maintenance action taken and the type of malfunction code applied to the fuel pump main gear spline drive, Jones was able to determine the details of the before-and-after maintenance actions very accurately.

Financial data for the fuel pump main gear spline drive modification was acquired from AIR-536, the Naval Aviation Depot Facility (NADEP) Jacksonville, and the engine contractor, Pratt and Whitney. Jones discovered that two key documents were required in order to calculate the total amount of dollars expended on the modification. The total amount of Research Development Test and Evaluation (RTD&E) dollars expended by Pratt & Whitney was revealed on the finalized version of the EPD. The EPD is the contractor's program objective, proposed solution and development schedule for the modification. Jones discovered that once AIR-536 issues the Power Plant Change that the contractor would close out their books on the project and, in so doing, tally the total amount of RTD&E dollars expended on the finalized version of the EPD.

Jones also discovered that the Aircraft Procurement Navy and Operations and Maintenance Navy (APN and O&MN) dollars expended by AIR-536 to buy the modification kits and pay for the installation comes from the Cost and Funding Schedule produced by the NAVAIR Configuration Change Control Board (CCCB). Described in detail in his thesis, Jones lays out the eight steps of the CCCB process, taken from the NAVAIR Configuration Management Policy, NAVAIRINST. 4130.1C, dated January 1992, to be:

Step 1. AIR-1006 (Configuration and Data Management Branch) receives the ECP from AIR-536 and enters it into the Modification Management Information System (MODMIS).

Step 2. After entry into MODMIS, AIR 1006 forwards the ECP to the office of primary responsibility (AIR-536).

Step 3. AIR-536 convenes a Change Proposal Evaluation and Planning Conference with representatives from the following NAVAIR codes:

a. AIR-02 - to determine the method of contracting.

b. AIR-04 - to determine if the change is supportable and ensure all issues regarding the retrofit are addressed.

c. AIR-05 - to review the technical content of the ECP.

d. AIR-114 - to determine any impact the ECP will have on the production requirements.

e. PMA 205 - to determine if training requirements have have been identified.

Step 4. AIR-536 then issues a decision memorandum if the decision is made, based on the results of step 3, to process the ECP.

Step 5. AIR-536 assembles a Change Control Board Package which includes inputs from all matrix organization members. Among the items included in this package are the following:

a. CCCB Change request,

b. Cost and Funding Schedule,

c. Milestone Chart,

d. Implementation Forms which assign implementation responsibilities,

e. Government Furnished Equipment Listing,

f. Support Equipment Requirements Form,

g. AIR-04 routing and concurrence form,

h. AIR-05 routing and concurrence form,

i. Controlling Custodian (TYCOM) [COMNAVAIRPAC/COMNAVAIRLANT] concurrence form,

j. System Safety Assessment Form.

Step 6. The Matrix staffing process, which assigns persons within the matrix organization to the ECP processing effort is completed.

Step 7. After all the required signatures are obtained, AIR-536 will submit the completed CCCB package to AIR-1006, who will update the MODMIS system and schedule the ECP for a formal Change Control Board meeting.

Step 8. The CCCB convenes its scheduled meeting and either approves or disapproves the ECP.

Having investigated all the funding sources associated with the fuel pump main gear spline drive modification, and having calculated all of the maintenance performed on this one component, Jones constructed a life cycle cost analysis of his data in terms of costs and savings and then calculated a break-even point for the CIP effort.

The work of Jones in both the areas of financial data and maintenance data collection, provided a major breakthrough in the Naval Postgraduate School's attempts to validate the CIP. In particular, his methodology for extracting maintenance data from the NALDA system produced the most reliable maintenance support data to date.

It is the objective of this author to take as much as possible, the methodology of Jones and apply it to a different powerplant system, specifically the T56-A-427, and to consider a single component of that engine to provide AIR-536 with another case study validating the CIP.

III. BACKGROUND

The purpose of this chapter is to provide the reader with insight as to the mechanical operation behind a turboprop engine to understand the importance of the component chosen for study. It also provides information on the administrative funding process at Naval Air Systems Command associated with the PPC chosen as the candidate for study. Next, the author presents a detailed narrative of the author's research experiences in developing his methodology for maintenance data collection pertaining to PPC 111. Finally, the last section of this chapter displays the collected maintenance data.

A. T56-A-427 ENGINE TECHNICAL DESCRIPTION

The T56-A-427 Series IV engine is a modernized, improved version of the T56 Series III engine. The engine was developed to solve operational problems associated with the E-2C Hawkeye growth weight. The Navy needed an engine that would maintain a positive single engine rate of climb with the landing gear down, flaps at 20 degrees (take-off configuration for this aircraft), and a take-off gross weight of 54,000 pounds on a hot day with an engine operating at 95% efficiency. The solution to this problem was the T56-A-427 engine.[Ref. 10] The engine consists of one gas turbine power unit driving a single propeller shaft through a reduction gear assembly. The power section of the engine is connected to the reduction gear assembly by way of an extension shaft formally called the torquemeter. The reduction gear assembly has a single propeller output shaft which is offset above the power section centerline. The reduction gear assembly causes a speed reduction of 12.87:1 which translates the rated power section speed of 14,239 RPM to a propeller speed of 1106 RPM. [Ref. 11]

The power section consists of the compressor section, combustion section, turbine section, and the accessories drive housing. The combustion section has six combustion chambers of the flow-through type assembled within a single annular combustion chamber located axially between a fou teen-stage, air-cooled, turbine assembly.

During operation, air enters the power unit through the compressor inlet housing and enters the 14 stage compressor. The compressed air flows through the diffuser to the combustion chamber where fuel is introduced, mixed with air and burned. The hot air gases exit through the turbine vanes and on to the turbine blades where the hot gases cause rotation of the turbine rotor. From that point the turbine rotor drives the compressor and the reduction gear assembly.

Engine operation is controlled by coordinated operation of the engine and the propeller control system. A characteristic of the T56 engine is that changes in power by the pilot are not related to a change in engine speed, but to a change in turbine inlet temperature. During flight operations, the engine maintains a constant speed. This speed is known as the 100% rated speed of the engine and is the design speed at which the most power and best overall efficiency can be obtained. [Ref. 11] Power changes can be affected by changing the fuel flow. An increase in fuel flow causes an increase in the turbine inlet temperature and a corresponding increase in the energy available at the turbine. The turbine will then take this increase in energy and translate it to torque to the propeller. The propeller reacts to the increase in torque with an increase in rotation speed. With the increase in the speed of the propeller, the propeller control system will increase the blade angle of the propeller, thus producing more power to fly, and at the same time maintaining a constant engine RPM.

The fuel control system modulates fuel flow to match a horsepower schedule that varies linearly with the power lever placement. To achieve this horsepower schedule, a Digital Electronic Control (DEC) will vary the fuel flow that is needed by a hydromechanical fuel control. The DEC acts as a supervisory control with the primary operating mode of controlling horsepower. In addition to scheduling horsepower, the DEC controls the Turbine Measured Temperature (TMT) by limiting fuel flow during all engine operating conditions, this meaning that engine control is critical to the turbine measured temperature sent to the DEC. TMT is the average temperature taken off of the engine's fourteen single element thermocouples located in the third stage of the turbine vanes.

Of major importance to this thesis, these fourteen thermocouples are wired in parallel and dispersed about the engine centerline. The thermocouples provide an average indication of the hot gas temperature within the turbine. The thermocouple output signal, as mentioned above, is referred to as TMT and is the primary controlling input used by the DEC for controlling engine power changes. The thermocouples' input signal is also sent to the DEC which provides the input signal to the TMT indicator in the cockpit. The TMT indicator is one of the pilot's primary engine monitoring instruments.

This thesis will concentrate on a recent problem with obtaining accurate information from the thermocouples that has developed on the T56-A-427 engine since its introduction into the fleet. More specifically, this study will investigate the unscheduled and scheduled maintenance actions on the interconnector harness end and mating thermocouple end connector at the firewall shown in Figure 3.1. on the next page.

B. COMPONENT IMPROVEMENT PROGRAM FUNDING FOR THE T56 ENGINE

The Navy's CIP is given its policies, guidelines and responsibilities for administration through NAVAIR Instruction 5200.35. [Ref. 1] According to the instruction, the Navy developed the CIP program in the early 1950's to enhance readiness and reduce life cycle costs for its aircraft

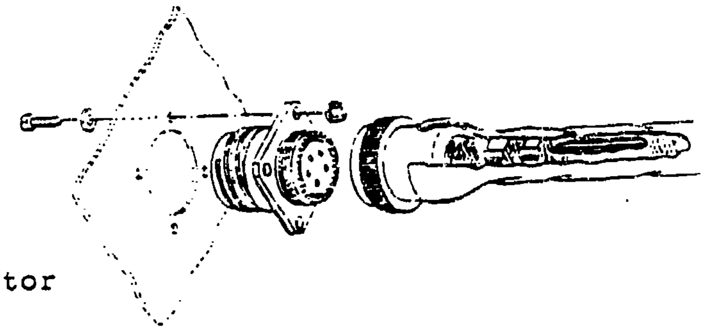

Figure 3.1. Thermocouple Interconnector Harness End and Mating Thermocouple End Connector.

propulsion systems. The instruction delineates the overall policy and responsibilities associated with the administration and management of the CIP for aircraft propulsion systems and related hardware. The instruction lists the three objectives of CIP to be:

1. Maintain an engine design which allows the maximum aircraft availability at the lowest cost to the government (primarily production and support cost);

2. Correct as rapidly as possible, any design inadequacy which adversely affects safety of flight;

3. Correct any design inadequacy which causes unsatisfactory engine operation or adversely affects maintainability and logistic support in service.

The primary function of the CIP program is to solve safety of flight problems that evolve with the aircraft after there has been government acceptance of the first procurement-funded aircraft. The second function of the CIP program is problem avoidance. Early detection of deficiencies in engines and engine components is the strategy of CIP to minimize service problems and to extend service life.

To support the reason for this thesis and the past research done to validate the CIP, Figure 3.2. below displays how the funding for Navy CIP has become more constrained over the past fourteen years. The CIP has been funded at $63,570,000 for FY94. [Ref. 12] The scope of this RDT&E appropriation encompasses thirteen engines and four different propellers.

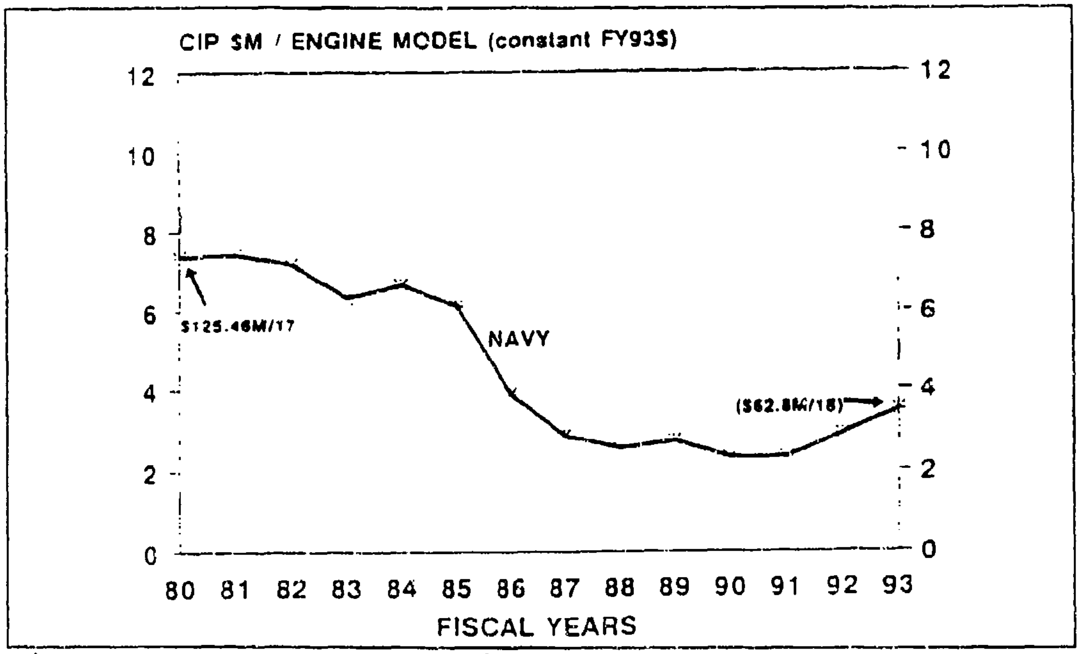

Figure 3.2. Navy CIP Funding.

Because the CIP is a Joint Service program, which includes Foreign Military Sales (FMS) and commercial participation, a network of eight contractors and eight different field activities are used by the Navy to support the CIP. [Ref. 12]

Table 3.1 on the next page is the T56 Engine CIP funding for the past three fiscal years. [Ref 11] What must be noted here is that this funding is for the entire inventory of the Navy's T56 engines. Unfortunately, the author could not determine the breakdown of T56 CIP funding into the different series of T56 engines.

Table 3.1. NAVY T56 ENGINE CIP FUNDING.

ENGINE MODEL	AIRCRAFT	FY(92) $(000)	FY(93) $(000)	FY(94) $(000)
T56	P-3, C-130, E-2C, C-2A(R)	1648	3020	2976

C. THE COMPONENT IMPROVEMENT PROGRAM FUNDING PROCESS TO CREATE POWER PLANTS CHANGE 111

As outlined in Chapter II, there are the eight steps involved in the process of making a ECP into an installed PPC. [Ref. 9] The steps described by Jones and the dates that are of importance to the CIP effort chosen to be validated by this author; namely, PPC 111 (the methodology for studying this power plant change will be discussed later in this chapter), began with step one when Allison Gas Turbine Division General Motors Corporation submitting ECP 2103 to AIR-536 on 17 September 1991. [Ref. 13] Shortly after that date, steps two and three were completed when AIR-536 convened a Change Proposal Evaluation and Planning Conference with representatives from AIR-04, AIR-05, and PMA-231. PMA-231 is the E-2C Hawkeye/C-2A(R) Greyhound Program Manager for Acquisition. Step four of the CIP process for ECP 2103 was completed on 25 November 1991. This step involved the issuing of the decision memorandum by AIR-536 since the planning conference representatives from step three recommended that ECP 2103 be processed.

Following the distribution of the decision memorandum to the various NAVAIR codes, AIR-536 initiated step five by requesting that the appropriate offices complete the Change Control Board Package prior to the target date of 19 December 1991 for the CCCB meeting. [Ref 13] Between the date the decision memorandum was routed and the scheduled date of the CCCB meeting, ECP 2103 was administratively processed through the appropriate NAVAIR codes noted on the decision memorandum so that they could complete the appropriate staffing actions required prior to the CCCB meeting. During this routing process, each office estimates the costs and determines the funding sources required to implement the ECP if it is approved by the CCCB. A major document within the ECP package is the standard NAVAIR Form 13050/2. This form is used as a signature page prior to the CCCB meeting for the appropriate codes to show that they are in agreement with the accounting data for the various labor costs and material items required to implement the ECP. Appendix A provides a copy of the Form 13050/2 which was used in the processing of ECP 2103.

Processing time for the ECP 2103 package ran from 10 December 1991, past the target date of the CCCB meeting to 23 March 1991. Jones' steps six and seven include this administrative process of acquiring the appropriate signatures before the board convenes. The final step in the funding process was step eight, which is the convening of the CCCB. ECP 2103 was presented to the board on 26 March 1991 by Mr. Dan Peckham, E-2C Propulsion Team Leader for AIR-536. The ECP was approved for funding and at that time formally becomes PPC 111.

D. DETERMINING A CANDIDATE FOR STUDY

Before choosing a power plant change to examine, the author talked with Mr. Rich Vernon and Mr. Chuck Hagewood, two T56 engine logistics managers assigned to the T56 Cognizant Field Activity (CFA), also known as the T56 Engine Depot, located at Naval Air Station Alameda. The author made two trips and spent several hours in discussion with these two logistics managers in the process of determining the feasibility of tracking a CIP effort on a T56 engine. Through these discussions, and an examination of the available administrative documents at the CFA, a recent power plant change on the T56 engine was chosen to begin the research process. This power plant change was PPC 99 which was a product of ECP 2059R3 originating from the Allison Gas Turbine Division for the 425 series of T56 engines. [Ref. 14]. This

PPC was of particular interest because of the need for the power plant change which is stated on the front of the ECP under the "need for change" description.

> Navy E2-C aircraft operated by the U.S. Navy have experienced bogdown with the engine. Bogdown is defined as an unsolicited drop in engine speed that may be accompanied by compressor surge and or low speed stagnation. Bogdown is a result of a rapid throttle change where the fuel flow change is rapid and precedes propeller blade angle pitch change. Analysis, engine and flight testing have indicated bogdown can be prevented by the addition of a fuel accumulator in the engine fuel system. A check valve system has been incorporated in series with the accumulator to eliminate excessive power oscillations.

Focusing on this ECP, Mr. Hagewood and the author examined the various ECA reports which can be obtained from the NALDA system. It was hoped that these reports would provide records of historical maintenance deficiencies which might have been used to initiate the CIP process to correct the T56 bogdown problem. However, after several data runs to look at different ECA reports, it was discovered that no relevant data was available. Further discussion with Mr. Hagewood and another T56 logistic manager at the CFA, Mr. Allen Follett, provided the explanation for why the database produced no information on bogdown. Problems concerning bogdown on the T56 were not documented by fleet maintenance personnel in a standardize fashion. The bogdown problems were documented under different categories of maintenance malfunctions. For example, some bogdowns were documented as "compressor surges", while other bogdowns were documented as "engine RPM fluctuation indications". This caused inconsistencies in the reporting data. The reason for this is that bogdown is not listed as a malfunction in the Work Unit Code Technical Manual for E-2C aircraft. [Ref. 15] This malfunction code manual is used by the fleet maintenance personnel for describing maintenance malfunctions on the Visual Information Display/Maintenance Action Form, commonly referred to as the VIDS/MAF, which is the form used for providing maintenance information to the NALDA system.

More importantly, the data system could not be accessed by a particular part number associated with the bogdown malfunction. In the case of PPC 99, parts were added to the engine to alleviate the bogdown malfunction. In contrast, Mr. Hagewood stressed that in order to trace the historical maintenance data on a particular component or part that had been involved with a CIP effort, the PPC would have to modify or change the component or part when the PPC is implemented. The reason for this is that, by implementing the PPC, the part number of the component will change because the PPC directive had been incorporated. This would give the researcher the ability to trace maintenance actions associated with both the old and the new part numbers.

Because of the knowledge gained from this discussion with Mr. Hagewood, the author and Mr. Follett began a search for another, perhaps more detailed, PPC that would be more easily traced using the NALDA system. Using the CFA's most current ECIFR [Ref. 16], the author examined the broad-based nomenclature of component assemblies that were being tracked by the ECIFR as causes for "not mission capable for maintenance" times being recorded on the T56 engine. The author discovered that there was only a small number of component assemblies documented against the T56-A-427 engine. Further discussion about this observation with Mr. Follett revealed the fact that the 427 series T56 was the newest series of T56 engines used by the fleet. Mr. Follett explained the differences in the 427 series compared to the earlier series of T56 engines and he also explained that a E-2C Fleet Introduction Team (FIT) was located at NAS Miramar. The purpose of this team will be discussed later in this chapter.

Again the author reviewed the files at the CFA, but this time the review was targeted at finding a power plant change pertaining to the 427 series of engine. The review proved fruitful; PPC 111, which pertained only to the 427 engine, was found. In examining PPC 111 [Ref. 17], the author discovered that it fit the criteria of recommendations made by Sodol and Price [Ref.4] that it should be based on "maintenance driver." It was also a desirable component to examine based on the recommendations of prior CIP researchers Butler, Gordon, and Jones because it was at the component level. Finally, PPC 111 was a prime candidate to study because it could be tracked in the NALDA system.

E. THE METHODOLOGY FOR COLLECTING MAINTENANCE DATA FOR PPC 111

In developing a methodology to study PPC 111, initial research was directed at establishing a maintenance data source and finding knowledgeable individuals who could aid in the interpretation of the maintenance data. The author discovered that one of the purposes of the E-2C FIT, mentioned above, was to monitor and assist the fleet E-2C (plus) operating units with problems associated with the introduction of the T56-A-427 engine into the fleet. [Ref. 18] Further inquires of FIT team members led the author to Chief Petty Officer Aviation Machinist (ADC) Debert Valle, the FIT T56 engine manager. ADC Valle enlightened the author as to why PPC 111 was important and how the changes in components associated with it were improving the engine. He also said that the PPC has been totally incorporated into the fleet.

When he visited the FIT, the author was given the liberty to investigate the files in an effort to obtain a working knowledge about PPC 111. These files revealed a log of Hazardous Material Reports (HMR) that had been initiated by the fleet squadrons pertaining to hazardous flying conditions related to maintenance malfunction problems. It was found that the T56-A-427 engine had a faulty TMT signal being sent to the engine fuel controlling unit. Valuable insight was gained by examining the collected HMRs on how the fleet squadron maintenance personnel were documenting this problem and, more importantly, which part or parts they concluded were the cause of the problem. Jones [Ref. 9] described the use of the HMR as another form of documentation used by the various NAVAIR codes in monitoring any trend in deficiencies. When he mentioned this to ADC Valle, the author learned that the HMRs were being used by the FIT to force a faster retrofit of PPC 111. [Ref. 19]

From the HMRs the author was able to obtain maintenance data about the thermocouple problem that he considered germane to this thesis. By interpreting the entries on the HMRs using the cookbook style directions for filing a HMR report from Chapter Five of OPNAVINST 4790.2E [Ref. 20], the author was able to identify three part numbers found by the fleet maintainers to be the faulty items responsible for the TMT problems associated with the thermocouple harness assembly. These part numbers and their associated nomenclature are:

23032692 - Thermocouple Harness Assembly;

23030745 - Connector Assembly Plug;

23038786 - Harness Assembly Interconnecting Wiring.

Further investigation revealed that several different work unit code numbers were also used to identify the thermocouple system or sub-system on the HMRs. A work unit code number is used to identify the system or subsystem on which maintenance is performed. Unfortunately, on several HMR reports, this entry was left blank. This variance in documenting the correct system or sub-system on the engine was caused by the different interpretations of the Work Unit Code Manual [Ref. 15] by the maintenance personnel documenting the discrepancy on the VIDS/MAF. [Ref. 21] The predominant work unit codes and their associated nomenclature are:

29E1M20 - Power Plant Cable Assembly;

223D370 - Turbine Thermocouple Harness Assembly.

Knowing these part numbers and work unit code numbers, the author had to next determine a method of extracting maintenance data from the NALDA system which could be used to calculate total maintenance manhours spent on correcting failures of the three parts listed above. The three part numbers were used because two of the part numbers (23038786 and 23032692) are cited in PPC 111 as being the parts which need to be replaced, and the third part number 23030745, the connector assembly plug, which is the end connector on the harness end (see Fig. 3.1). [Ref. 22]

In order to complete this task, the author, with the help of the FIT Maintenance Administrate Manager, Chief Petty Officer Aviation Administration (AZC) Fred Beierly, first ran a FCA Report 518. This report is a ranking program that is a work unit code to part number cross reference ranking report that displays all removed item/installed item part numbers associated with each work unit code. To search for the part numbers in the report, work unit codes 223D370 and 29E1M20 were used, and a report period was selected from January 1989 to December 1994. The report produced thirteen different part numbers that had been documented against the search sequence work unit codes for that time frame, and the number of occurrences each of part number, under the two work unit code, had been entered into the system during the requested time span. As expected, the two part numbers of interest to this thesis were displayed in the report. To eliminate the part numbers which were not of interest, a different ECA report was run; namely, ECA Report 519. This report is a similar ranking report to 518 report, but it is a part number to work unit code cross reference ranking report which lists all work unit codes associated with each search sequence part numbers. The report was generated using part numbers 23030745 and 23038786 for the period from January 1989 to December 1993.

The 519 report produced ten different work unit codes that were in the ECA database that could be matched against the part numbers of interest. These work unit codes and their associated nomenclature are:

2230000 - T56 Turboprop Engine;

91D1300 - Parachute Riser Assembly;

223D380 - P/S Interconnecting Wire Harness;

4281100 - Power Plant Controls Aircraft Wiring;

29E1M00 - Turbine Inlet Temperature Indicating INS;

29E1L70 - Wiring Installation/Assemblies;

4281000 - Wiring Installations;

29E1M20 - Cable Assemblies; and

1435C00 - Unlisted.

The information produced on the 518 and 519 reports allowed the author to see the cross reference between the part numbers in question and the work unit code numbers used by maintenance personnel.

With the end goal in mind of determining the amount of maintenance manhours that were expended on the part numbers in question before PPC 111 was made, the author then turned to the ECA report 530. This report is a detailed description of the results of particular maintenance actions. The description includes qualitative information on "when discovered" codes, "action taken" codes and "malfunction description" codes. It also includes detailed equipment descriptions including type, model and series of aircraft, aircraft bureau number, work unit code, part number and serial numbers. Finally, the report includes a detailed maintenance action record that includes the failed part number and maintenance manhour/elapsed maintenance time data associated with the documented job code number of each entry. The job code number is used by squadrons and maintenance facilities to keep track of jobs.

The author was then able to merge the 530 report with the data produced from the 518 and 519 reports for the time period from January 1989 to December 1993. The resulting data produced by this aggregated report took over three hours to print at the NALDA terminal. However, the 530 report produced exactly the kind of information the author needed to tally the number of manhours documented for fixing the parts in question over the time period of interest.

With this printout, the author then had to extract by hand the events and associated maintenance manhours recorded for the part numbers in question. The maintenance malfunction description codes used to identify the maintenance events which should be included in determining the manhours are listed below:

020 - worn, stripped or frayed;

070 - broken, burst, ruptured, punctured, torn cut;

160 - broken wire defective contact or connector;

374 - internal failure;

450 - open;

615 - shorted including internal.

These were determined to be appropriate based on the author's reading of the HMR reports and discussing of the PPC problem with the FIT team power plant office members.

The next step was to sum the annual maintenance manhours expended on the part numbers in question. This was extremely time-consuming because of the size of the printout.

F. VALIDATION OF THE METHODOLOGY FOR MAINTENANCE DATA COLLECTION

While visiting AIR-536 shortly after the research trip to NAS Miramar, the author realized that he had mistakenly left part number 23032692 out of his data collection from the ECA

530 report. With this in mind, and the fact that he had not completed the summation of the maintenance manhours, the author sought help from the Propulsion Team Leader, Mr. Dan Peckham. Mr. Peckham was able to arrange a meeting between the author and Mr. Chuck Orwig, AIR-71334. Mr. Orwig is the program manager who is responsible for producing the ECIFR. Mr. Orwig introduced the author to Mr. Bob Weaver of the SYS Company, located in Crystal City, Virginia. SYS is the company that physically produces the information printouts for the ECIFR for AIR-71334 [Ref. 23]. Mr. Weaver is the principal information systems operator that produces the ECIFR, and is SYS's point of contact with AIR-71334.

The author and Mr. Weaver went over the printouts 518, 519 and 530. The author explained his main goal, which was to collect maintenance manhour data pertaining to PPC 111, and the specific methodology he was using in collecting the data out of the ECA reports. Mr. Weaver totally agreed with this methodology and stated that it was the correct way to attack the problem with the quality and length of the 530 report that the author had. However, Mr. Weaver explained that he could produce a better quality ECA 530 report with a set of in-house COBOL programs developed by SYS. The forte of these COBOL programs is that they are able to condense large amounts of data into a more user-friendly printout. Mr. Weaver agreed on the author's data merging strategy for the problem at hand. He then made a photocopy of the front page of the author's 530 report to ensure that he had the right input part numbers and work unit codes. The author received Mr. Weaver's printouts on all three part numbers a very short time after their meeting by way of FAX. These printouts proved to be just what the author needed to complete his data collection. A summary of the O-level and I-level maintenance manhours for 1990-1993 is shown in Table 3.2. below. Appendix B is a copy of the ECA 530 report produced by Mr. Weaver.

Table 3.2. TOTAL MAINTENANCE MANHOUR AND EVENTS SUMMARY.

YEAR	Total O-Level Manhours	Total I-Level Manhours	Total O-Level Maint Events	Total I-Level Maint Events
1990	220.9	0.0	2	0
1991	165.2	0.0	5	0
1992	73.8	3.0	6	2
1993	324.5	52.2	24	4

G. OTHER MAINTENANCE MANHOURS ASSOCIATED WITH PPC 111

Research of the HMRs indicated that squadron commanding officers of E-2C (plus) squadrons were concerned that the length of time required by the ECP/PPC process would be unacceptably long. They wanted an immediate solution to the problem associated with the interconnector harness end and mating thermocouple end connector. For this reason, the squadrons, with the assistance of the FIT team, recommended that the thermocouple harness connector cannon plug (part Number 23023745) be cleaned and treated every 14 days instead of the already established 28 days. This recommendation was approved by NADEP North Island, which was the E-2C CFA, in June of 1991. [Ref.24]

The author decided that the added number of expended manhours consumed in performing the cleaning of the cannon plug should be included in the total maintenance manhours associated with the PPC 111 because the procedure involved leaning the parts that PPC 111 was going to fix. To calculate the yearly manhours used to perform this inspection and cleaning, the following reasoning was used. The actual procedure takes on average 0.5 manhours. [Ref. 25] The 28-day inspection is done on the average 13 times a calendar year on one aircraft. Reducing the time between inspections to 14 days increases the number of cleanings of the cannon plug to 26 times a year. Thus, for each aircraft, 13 times .05 manhours or 6.5 extra manhours would be expended per year. To calculate the total yearly sum of O-level maintenance manhours expended would be the product of 6.5 and the total number of aircraft in operation during the time period from 1 June 1991 to 31 March 1994. March 31, 1994 is used as a ending date due to the fact that all squadrons had the PPC incorporated on their aircraft by this date, and the practice of the 14-day inspection was returned to the 28 day cycle.[Ref. 25] The annual total number of E-2C (plus) aircraft in operation during this time period was obtained from an aircraft status summary report provided by the FIT team.[Ref. 26] The increase in O-level maintenance manhours and maintenance events per year is displayed in Table 3.3. below. This procedure only involved O-level maintenance and did not require any I-level maintenance.

Table 3.3. ADDITIONAL MAINTENANCE MANHOURS AND EVENTS SUMMARY.

Year	Total Number of Aircraft	Total O-Level Manhours	Total O-Level Maint Events
1991	22	71.5 (1/2 year)	143
1992	29	188.5	377
1993	34	221	442
1994	39	126.5 (1/4 year)	253

H. NO MAINTENANCE MANHOURS TO INSTALL PPC 111

During his research, the author discovered that no actual O-level maintenance manhours were expended on the installation of PPC 111. The reason is that one Allison Field Representative, Mr. Richard Williams, performed all of the PPC installations at a rate of approximately four hours per aircraft.[Ref. 27] This issue was discussed with the Allison

Engineering Customer Service Representative, Mr. Tom Ryan, at the Allison plant in Indianapolis, IN. He explained to the author that Mr. Williams was paid out of the Allison Production Support Funds, and that no extra Navy funds (CIP, OM&N or APN) were used to install PPC 111. [Ref. 28] The author also addressed this issue with Mr. Peckham at AIR-536. According to him the installation of PPC 111 was considered a "Free-Bee" by the Navy. For these two reasons, the author elected not to include any Navy maintenance manhours for installation in his calculations.

IV. PRESENTATION OF BEFORE-AND-AFTER LIFE CYCLE COSTS

A. BACKGROUND

This chapter presents the life cycle financial data associated with the T56-A-427 interconnector harness end and the mating thermocouple end connector before and after the incorporation of PPC 111. The results will be used in the cost-benefit analysis in Chapter V. Two life cycle cost models will be presented. The first model shows the actual and estimated costs of the E-2C (plus) fleet of aircraft as if PPC 111 was not incorporated. The second model displays the actual and estimated cost of the E-2C (plus) fleet of aircraft with the PPC 111 change incorporated. The author assumed that the T56-A-427 engine would have a useful operational life through year 2005, since no new tactical Navy aircraft are expected until that year.[Ref. 2]

The financial cost data included in this chapter is:

1. Research and Development (R&D), or CIP costs required to generate the PPC 111. This information comes from the first page of the finalized EPD No. 5647.1.07RA, [Ref. 29] which was produced by Allison and provides detailed information on the PPC. The EPD also records decisions made at the contractor's CIP conferences and the progress of the CIP research and development. After the "fix" has been designed and a PPC has been issued to the fleet, a final version of the EPD is published with the total historical CIP R&D costs required to identify and engineer the "fix." [Ref. 30]

2. Navy (APN) investment costs to purchase the PPC 111 modification kits and other APN funds that were included with the approval of ECP 2103. These other costs were the

cost of printing the technical directives, obsolescent equipment costs, reworked equipment costs, and the cost of test equipment. Also included is the cost to change the existing E-2C (plus) procurement contract to incorporate the ECP on aircraft still on the production line. This cost information comes from the Cost and Funding and Milestones Charts in the CCCB package. (Appendix A)

3. All known and estimated maintenance costs associated with the maintenance actions or events at the O and I levels of maintenance that were presented in Chapter III.

The financial cost data does not include any transportation costs to ship the modification kits to NAS Miramar since this information could not be found. Also, the author determined that there would not be any way to determine inventory carrying costs pertaining to the modification kits because the kits were sent directly to the FIT facility instead of Navy's supply system. The kits were held then at the FIT facility until the Allison field representative could install the kits on the aircraft. [Ref. 19] No material costs for consumable maintenance materials, such as electrical wiring, safety wire and cleaning fluids were included in the analysis, because these materials were not kept track of by the maintenance personnel for each particular job. [Ref. 19]

The historical (1990 to 1993) and projected (1994 to 2005) costs a.e presented in "then year" dollars to aid in the analysis to be done in Chapter V.

B. ACTUAL COSTS OF THE R&D AND APN INVESTMENTS ASSOCIATED WITH PPC 111

The CIP R&D costs to design the new interconnector harness end and thermocouple end connector, and the APN procurement costs to purchase the modification kits and pay for various other procurement costs noted above are presented in Appendix A. The actual R&D or CIP investment costs of $80,000 were paid out in the year of 1990 which is the year that Allison did research and development work on this CIP effort. The APN investment costs required to pay for the modification kits totaled $67,666. A total of 78 kits, at a cost of $867.51 each, were purchased in 1992 as shown on the Cost and Funding Milestones Chart (Appendix A).

Other costs were also incurred in 1992. They are shown on the second page of Appendix A. The cost to reproduce the technical publications to implement PPC 111 totaled $450. The cost of the obsolete equipment that Allison charged to the Navy, because of PPC 111, amounted to $10,317. The type of equipment this money paid for was not documented by NAVAIR. [Ref. 31] The cost Allison charged to rework old equipment and to facilitate the new design required by PPC 111 was $10,560. This type of equipment was not documented by NAVAIR either. [Ref. 31] Test equipment used by Allison in the R&D process totaled $1,500. The cost to add PPC 111 to Navy E-2C (plus) aircraft engines still on the production line during April of 1992 was $13,549. [Ref. 32] The total of the kit costs and these other costs was $104,042.

These R&D and APN "then year" costs will be used later in this chapter when the author presents the after or modified

(PPC 111 incorporated) life cycle costs for the E-2C (plus) fleet in Table 4.2.

C. LABOR RATES FOR "O" LEVEL AND "I' LEVEL MAINTENANCE

Labor costs at an hourly rate for O and I levels of maintenance for the T56-A-427 engine were acquired by the author from the VAMOSC database. [Ref. 33] The labor rates acquired were for each of the past years up to and including the year 1993. For the labor rates beyond that year, the author estimated the labor rate using a 6.1% increase which was the average increase over the last four years. This method was also used by Jones. [Ref. 9] The labor rates are used to calculate the maintenance labor costs at the O-level and I-level that were expended and are estimated to be expended because of failures pertaining to the component. These values are shown in Tables 4.1. and 4.2. in the process of determining the annual maintenance labor costs.

D. CURRENT CONFIGURATION TOTAL ANNUAL LIFE CYCLE COSTS (PPC 111 NOT INCORPORATED)

Table 4.1. on the next page provides the actual and estimated life cycle costs for the E-2C (plus) fleet of aircraft as if PPC 111 was not incorporated. All costs are shown in "then-year" dollars.

Column 1 presents the annual total number of unscheduled maintenance actions at the O-level involving the

Table 4.1. CURRENT CONFIGURATION TOTAL ANNUAL LIFE CYCLE COSTS

YEAR	COL1 UNSCH EVENTS O-LEVEL MAINTENANCE	COL 2 UNSCH EVENTS I-LEVEL MAINTENANCE	COL 3 SCHEDULED EVENTS O-LEVEL	COL 4 UNSCH MAINTENANCE MAN HOURS O-LEVEL	COL 5 UNSCH MAINTENANCE MANHOURS I-LEVEL	COL 6 SCHEDULED MAINTENANCE MANHOURS O-LEVEL COL3X.5MMH/EVE[illegible]	COL 7 TOTAL O-LEVEL MAINTENANCE MANHOURS COL(4+6)
1990	2	0	156	220.9	0.00	78.00	298.90
1991	5	0	429	165.2	0.00	214.50	379.70
1992	6	2	754	73.8	3.00	377.00	450.80
1993	24	4	884	324.5	52.20	442.00	766.50
1994	48	5	1014	648	65.25	507.00	1,135.00
1995	96	5	1014	1296	65.25	507.00	1,803.00
1996	192	5	1014	2592	65.25	507.00	3,099.00
1997	312	5	1014	4212	65.25	507.00	4,719.00
1998	312	5	1014	4212	65.25	507.00	4,719.00
1999	312	5	1014	4212	65.25	507.00	4,719.00
2000	312	5	1014	4212	65.25	507.00	4,719.00
2001	312	5	1014	4212	65.25	507.00	4,719.00
2002	312	5	1014	4212	65.25	507.00	4,719.00
2003	312	5	1014	4212	65.25	507.00	4,719.00
2004	312	5	1014	4212	65.25	507.00	4,719.00
2005	312	5	1014	4212	65.25	507.00	4,719.00

COL 8 TOTAL I-LEVEL MAINT MANHOURS COL 5	COL 9 O-LEVEL MMH LABOR COST/HOUR	COL 10 I-LEVEL MMH LABOR COST/HOUR	COL 11 TOTAL O-LEVEL MAINT LABOR COST COL 7 X COL 9	COL 12 TOTAL I-LEVEL MAINT LABOR COST COL 8 X COL 10	COL 13 TOTAL COST MAINT LABOR (THEN YEAR) COL(11+12)
0	$14.18	$17.03	$4,238.40	$0.00	$4,238.40
0	$15.28	$18.35	$5,801.82	$0.00	$5,801.82
3.00	$16.45	$19.76	$7,415.66	$59.28	$7,474.94
52.2	$17.08	$20.51	$13,091.82	$1,070.62	$14,162.44
65.25	$18.12	$21.74	$20,928.60	$1,418.54	$22,347.14
65.25	$19.22	$23.06	$34,653.66	$1,504.67	$36,158.33
65.25	$20.39	$24.47	$63,188.61	$1,596.67	$64,785.28
65.25	$21.63	$25.96	$102,071.97	$1,693.89	$103,765.86
65.25	$22.94	$27.54	$108,253.86	$1,796.99	$110,050.85
65.25	$24.33	$29.21	$114,813.27	$1,905.95	$116,719.22
65.25	$25.81	$30.99	$121,797.39	$2,022.10	$123,819.49
65.25	$27.38	$32.88	$129,206.22	$2,145.42	$131,351.64
65.25	$29.05	$34.89	$137,086.95	$2,276.57	$139,363.52
65.25	$30.82	$37.01	$145,439.58	$2,414.90	$147,854.48
65.25	$32.70	$39.27	$154,311.30	$2,562.37	$156,873.67
65.25	$34.69	$41.66	$163,702.11	$2,718.32	$166,420.43

interconnector harness end and mating thermocouple end connector. For the years 1990 to 1993, the actual number of maintenance actions that occurred are shown. To determine the number of maintenance events for the year 1994 to 2005, the author contacted the FIT team Engine Program Manager, ADC Valle. He told the author that from his experiences in monitoring the connector problem, an estimate of failures per aircraft per year would increase to four events within the next three years. [Ref. 34] To establish a second opinion on the number of maintenance events for these years, the author also contacted Mr. Dan Peckham, E-2C Propulsion Team Leader at AIR-536. Mr. Peckham strongly agreed with the expert opinion of the FIT Team Program Manager. [Ref. 35] To achieve the total number of maintenance events equal to four per aircraft by 1997, the author doubled the number of maintenance events from the previous year starting in 1994. Then for 1997, 39 times 4 or a total of 312 maintenance actions were assumed. From that year on, the number of maintenance events were assumed to remain constant at 312 until 2005.

Column 2 contains the annual number of I-level unscheduled events that occurred for the years 1990 to 1993. I-level maintenance events for the year 1994 to 2005 could not be estimated by the FIT Team Engine Program Manager because historical maintenance data showed that most failures were corrected at the O-level. For that reason, the author estimated that the I-level events would increase by one for the year 1994 and then remain constant from that year on.

Column 3 presents the number of scheduled events at the O-level. These are the actual 28-day inspections (1 January 1990 to 1 June 1991) and the 14-day inspections (1 June 1991 to 31 December 2005) that would be expected to occur for the entire life cycle. The methodology for determining this number of scheduled events per year was discussed in Chapter III.

Column 4 shows the annual maintenance manhours expended at the O-level to perform the unscheduled maintenance on the faulty component. The actual maintenance manhours are displayed for the years 1990 to 1993. For the years 1994 to 2005, the author calculated the average number of maintenance manhours per event for the year 1993, 13.5 hours, and multiplied this by the total number of events in column 1. The author concluded that the average number of manhours per event for 1993 was a better estimate to use than the averages from preceding years because the maintenance personnel would become used to correcting the faulty component.

Column 5 contains the unscheduled maintenance manhours expended at the I-level. For the years 1990 to 1993, the actual numbers are shown. For 1994 and later, the author used the same reasoning as mentioned above for column 4. The average number of hours used 13.05. That value was then multiplied by the number of events in column 2.

Column 6 presents the total of maintenance manhours expended to perform the scheduled inspections at the O level. It is the product of column 3 and 0.5 maintenance manhours per event. The use of the 0.5 manhours was discussed in detail in Chapter III.

Column 7 contains the sum of columns 4 and 6. It provides the total amount of O-level manhours per year for scheduled and unscheduled events.

Column 8 contains the total I-level maintenance manhours per year. Because there was no scheduled I-level maintenance performed on the component, column 8 is the same as column 5.

Column 9 contains the "then-year" O-level maintenance manhour labor rate (cost) per hour. The source of this information and the calculation for the future years was discussed earlier in Section C of this chapter.

Column 10 contains the "then-year" I-level maintenance manhour labor rate. The same calculation that was done for O-level maintenance was done for I-level for future years.

Column 11 presents the "then-year" total O-level maintenance labor costs. It is the product of column 7, the total hours, and column 9, the labor rate per hour.

Column 12 presents the "then-year" total I-level maintenance labor costs. It is the product of column 8, the total hours, and column 10, the labor rate per hour.

Column 13 contains the sum of column 11 and column 12. It is the total cost in "then-year" dollars for maintenance on the interconnector harness end and thermocouple end connector.

The amounts in column 13 will be compared in Chapter V with similar costs associated with the modified or PPC 111 incorporated life cycle model to be presented next.

E. MODIFIED CONFIGURATION TOTAL ANNUAL LIFE CYCLE COSTS (PPC 111 INCORPORATED)

Table 4.2 on the next page presents the actual and estimated costs that have and are projected to occur with PPC 111 installed on the Navy's E-2C (plus) fleet of aircraft. The first 13 columns present the calculation of total annual maintenance labor costs. Maintenance events and manhours for the years 1990 to 1994 are the actual amounts. An estimate for the number of maintenance events and total manhours beyond 1994, was made which will be discussed later in this section. Column 14 contains the R&D costs and the procurement costs for the modification kits. This information was presented at the beginning of the chapter in Section B.

Column 1 contains the actual and predicted annual number of unscheduled O-level maintenance events. For the years 1990 to 1993, it is the same as column 1 of Table 4.1. For 1994, it is the total number of actual maintenance events after the PPC 111 incorporation (recall that all PPC 111 changes were made by March 1994). Further investigation by the author has revealed that both failures in 1994 occurred due to reasons attributed to the installation of the PPC 111 change. The failures occurred on two different aircraft assigned to two

Table 4.2. MODIFIED CONFIGURATION (PFC 111 INCORPORATED) TOTAL ANNUAL LIFE CYCLE COSTS

YEAR	COL1 UNSCH EVENTS O-LEVEL MAINTENANCE	COL 2 UNSCH EVENTS I-LEVEL MAINTENANCE	COL 3 SCHEDULED EVENTS O-LEVEL	COL 4 UNSCH MAINTENANCE MAN HOURS O-LEVEL	COL 5 UNSCH MAINTENANCE MANHOURS I-LEVEL	COL 6 SCHEDULED MAINTENANCE MANHOURS O-LEVEL COL3X.5MMH/EVENT	COL 7 TOTAL O-LEVEL MAINTENANCE MANHOURS COL(4+6)
1990	2	0	156	220.9	0.00	78.00	$298.90
1991	5	0	429	165.2	0.00	214.50	$379.70
1992	6	2	754	73.8	3.00	377.00	$450.80
1993	24	4	884	324.5	52.20	442.00	$766.50
1994	2	0	634	129.4	0.00	317.00	$446.40
1995	1	0	507	13.5	0.00	253.50	$367.00
1996	1	0	507	13.5	0.00	253.50	$267.00
1997	1	0	507	13.5	0.00	253.50	$267.00
1998	1	0	507	13.5	0.00	253.50	$267.00
1999	1	0	507	13.5	0.00	253.50	$267.00
2000	1	0	507	13.5	0.00	253.50	$267.00
2001	1	0	507	13.5	0.00	253.50	$267.00
2002	1	0	507	13.5	0.00	253.50	$267.00
2003	1	0	507	13.5	0.00	253.50	$267.00
2004	1	0	507	13.5	0.00	253.50	$267.00
2005	1	0	507	13.5	0.00	253.50	$267.00

COL 8 TOTAL I-LEVEL MAINT MANHOURS COL 5	COL 9 O-LEVEL MMH LABOR COST/HOUR	COL 10 I-LEVEL MMH LABOR COST/HOUR	COL 11 TOTAL O-LEVEL MAINT LABOR COST COL 7 X COL 9	COL 12 TOTAL I-LEVEL MAINT LABOR COST COL 9 XCOL 10	COL 13 TOTAL COST MAINT LABOR (THEN YEAR) COL(11 +12)	COL 14 INVESTMENT COST TOTALS SECTION B CHAPTER IV	COL 15 TOTAL LABOR AND INVESTMENT COST (THEN YEAR) COL(11 + 14)
0	$14.18	$17.03	$4,238.40	$0.00	$4,238.40	$80,000.00	$84,238.40
0	$15.28	$18.35	$5,801.82	$0.00	$5,801.82	0	$5,801.82
3.00	$16.43	$19.76	$7,415.66	$59.28	$7,474.94	$104,042.00	$111,516.94
52.2	$17.08	$20[illegible]	$13,031.82	$1,070.62	14162.442	0	$14,162.44
0	$18.12	$21	$8,088.77	$0.00	$8,088.77	0	$8,088.77
0	$19.22	$23.[illegible]	$5,131.74	$0.00	$5,131.74	0	$5,131.74
0	$20.39	$24.47	$5,444.13	$0.00	$5,444.13	0	$5,444.13
0	$21.63	$25.96	$5,775.21	$0.00	$5,775.21	0	$5,775.21
0	$22.94	$27.54	$6,124.98	$0.00	$6,124.98	0	$6,124.98
0	$24.33	$29.21	$6,496.11	$0.00	$6,496.11	0	$6,496.11
0	$25.81	$30.99	$6,891.27	$0.00	$6,891.27	0	$6,891.27
0	$27.38	$3[illegible]38	$7,310.46	$0.00	$7,310.46	0	$7,310.46
0	$29.05	$3[illegible].89	$7,756.35	$0.00	$7,756.35	0	$7,756.35
0	$30.82	$37.01	$8,228.94	$0.00	$8,228.94	0	$8,228.94
0	$32.70	$39.27	$8,730.90	$0.00	$8,730.90	0	$8,730.90
0	$34.69	$41.66	$9,262.23	$0.00	$9,262.23	0	$9,262.23

different squadrons, with both squadrons documenting a high amount of O-level maintenance manhours against the discrepancies. The author asked the FIT why there were so many manhours spent correcting these two problems. He learned that both squadrons' maintenance departments were under the assumption that the interconnector harness end and thermocouple end connector problem had been eliminated when PPC 111 was incorporated on the aircraft. Therefore, several hours were spent trouble-shooting the aircraft before the faulty component was discovered. [Ref. 36] In both cases, new components were supplied to the squadrons by the FIT where, as mentioned earlier, the modification kits were held. The faulty components were sent to Allison for investigation.

For the years 1995 and beyond, the author had to make a determination as to how many failures were expected to occur on the PPC 111 incorporated component. The Allison Engineering Program Description [Ref.29] listed the total number of failures with the "fix" incorporated as zero. For any explanation of this reasoning, the author sought the help of Mr. Gary Bergoine at Allison Gas Turbine Division General Motors Corporation, T56 Engineering Programs. Mr. Bergoine explained that Allison's program objective concerning the interconnector harness end and mating end connector was to design a "fix" that would eliminate all of the maintenance actions on the component. Allison terms this as reducing the failure rate from "reasonably probable" to "remote." Mr.

Bergoine explained that the meaning of "remote" to the Allison engineers is that the failure will never occur again. [Ref. 37] Mr. Bergoine also explained that the two PPC 111 incorporated component failures for 1994 were not considered failures of the component, but failures due to installation. However, Mr. Bergoine did think that a reasonable estimate of one failure per year would be, at most, the best probable estimate for considerations of life cycle modeling. For this reason, the author used one unscheduled maintenance event per year for the years 1995 and beyond.

Column 2 presents the total number of annual unscheduled maintenance events at the I-level. Like column 1, the years 1990 to 1993 are the same as in Table 4.1. For the years 1994 and later, the author concluded that no unscheduled maintenance actions would be expected to occur at the I-level. This is because the number of failures historically requiring I-level maintenance were so few that if only one failure per year were expected then I-level maintenance would probably not be involved with the corrective actions required.

Column 3 presents the total number of scheduled maintenance events at the O-level. The column reflects the same information as column 3 in Table 4.1. until 1994. As mentioned in Chapter III, the practice of the 14-day inspection was stopped by the end of March 1994 and the 28-day inspection was resumed. As mentioned in Chapter III, the number of scheduled events from 1995 to 2005 was the product of 13 times per year per aircraft and the number of aircraft in the fleet that year.

Column 4 contains the annual total number of maintenance manhours expended or expected to be expended on correcting deficiencies of the component. For 1994 the author has included the actual manhours expended with the two failures mentioned above. For the years 1995 and later, the author used the same amount of manhours per maintenance event that was used for estimating future years in Table 4.1. The 13.5 hours per event is a more reasonable estimate considering that the squadrons will be expecting a failure and would know how to fix the failed component.

Column 5 contains the unscheduled maintenance manhours per event for I-level maintenance. For the years 1994 and beyond, the yearly amount of hours expended would be zero because there are expected to be no I-level unscheduled events (see column 2).

Column 6 presents the scheduled maintenance manhours expended per year. It is the product of column 3 and .5 maintenance manhours per event.

Column 7 presents the total number of maintenance manhours, both scheduled and unscheduled, at O-level maintenance. It is the sum of column 4 and column 5.

Column 8 contains the total I-level maintenance manhours. It is the same as column 5 since there are no scheduled maintenance actions at I-level.

Column 9 presents the O-level maintenance manhour labor (cost) rate. It is the same as column 9 in Table 4.1.

Column 10 is the I-level maintenance manhour labor (cost) rate. It is the same rate used in column 10 of Table 4.1.

Column 11 presents the total annual costs of O-level maintenance. It is the product of column 7 (the total number of hours) and column 9 (the rate per hour).

Column 12 presents the total annual costs of I-level maintenance. It is the product of column 9 and column 10.

Column 13 contains the total annual costs of maintenance labor. It is the sum of column 11 and column 12.

Column 14 presents the total R&D and APN investment costs for PPC 111 discussed in Section B of this chapter.

Column 15 presents the total annual costs for labor and investment. It is the sum of column 13 and column 14.

V. COMPARISON AND ANALYSIS OF THE TWO LIFE CYCLE MODELS

OMB Circular A-94 [Ref. 38] requires that investments made by federal agencies be analyzed using break-even and Net Present Value analyses.

A. BREAK-EVEN POINT ANALYSIS

A break-even analysis will give insight into when the savings or benefits from an investment are expected to be equal to or exceed the costs associated with making the investment. Hopefully, the break-even point will occur prior to the end of the equipment's useful life. In the case of the investment for PPC 111, this should be prior to the year 2005.

Table 5.1. presents the results of the break-even analysis. The first two columns present the total annual costs in "then year" dollars for the two life cycle models of Chapter IV. Column 1 was obtained from column 13 of Table 4.1. It shows the total annual expenditures expected to accrue assuming that PPC 111 was not incorporated. Column 2 is from column 15 of Table 4.2. It shows the total annual expenditures expected to accrue when PPC 111 is incorporated. Column 3 is the difference between column 1 and column 2, and represents the annual increase in costs (shown in parentheses) or the savings resulting from incorporating PPC 111. Column 4 contains the cumulative sum of the savings from column 3 and

Table 5.1. BREAK-EVEN ANALYSIS

YEAR	COL 1 EXPENDITURE CURRENT COL 13 TABLE 4.1	COL 2 EXPENDITURE MODIFIED COL 15 TABLE 4.2	COL 3 DELTA CASH FLOW YEARLY SAVINGS COL(1-2)	COL 4 CUMULATIVE SAVINGS COL 3 + COL 4 PREVIOUS YEAR
1990	$4,238.40	$84,238.40	($80,000.00)	($80,000.00)
1991	$5,801.81	$5,801.81	$0.00	($80,000.00)
1992	$7,474.94	$111,516.94	($104,042.00)	($184,042.00)
1993	$14,162.44	$14,162.44	$0.00	($184,042.00)
1994	$22,347.14	$8,088.76	$14,258.38	($169,783.62)
1995	$36,158.33	$5,131.74	$31,026.59	($138,757.03)
1996	$64,785.28	$5,444.13	$59,341.15	($79,415.88)
1997	$103,765.86	$5,775.21	$97,990.65	$18,574.77
1998	$110,050.85	$6,124.98	$103,925.87	$122,500.64
1999	$116,719.22	$6,496.11	$110,223.11	$232,723.75
2000	$123,819.49	$6,891.27	$116,928.22	$349,651.97
2001	$131,351.64	$7,310.46	$124,041.18	$473,693.15
2002	$139,363.52	$7,756.35	$131,607.17	$605,300.32
2003	$147,854.48	$8,228.94	$139,625.54	$744,925.86
2004	$156,873.67	$8,730.90	$148,142.77	$893,068.63
2005	$166,420.43	$9,262.23	$157,158.20	$1,050,226.83

shows the break-even point of this analysis. The break-even point occurs when the sign of the cumulative sum changes from negative to positive. The earliest break-even point for PPC 111 occurs in the year 1997. This is considered to be the earliest possible break-even point for this investment because it does not consider the time value of money. If discounting was used in this analysis, the break-even point would occur at a later point in time.

B. NET PRESENT VALUE ANALYSIS

Present Value is the value today of an amount of money in the future. For the purpose of this thesis, the Net Present Value for this CIP investment was calculated in FY94 constant dollars with a capital discount rate of 10%. This discount rate is the generally accepted rate used by the Department of Defense.

Table 5.2. presents the Net Present Value analysis. Columns 1 and 2 are the same as in Table 5.1. Column 3 contains the present value factor used for cash flows in the past and the discount factor for cash flows in the future. The present value factor is 1.10^n where n is the number of years into the past from 1994. The discount factor is used for all cash flows in the future. It is defined as $1/1.10^n$ where n is the number of years into the future from 1994. Column 4 contains the present value of the annual expenditures from the current configuration model. It is the product of column 1 and column 3 and represents the present worth of the annual cash flows. Column 5 shows the present value of the annual expenditures from the modified configuration model. It is the product of column 2 and column 3. The sum of the present value dollar amounts is displayed at the bottom of column 6 and column 7 and is the Net Present Value (NPV) of the each model.

Table 5.2. NET PRESENT VALUE ANALYSIS

YEAR	COL 1 EXPENDITURE CURRENT COL 13 TABLE 4.1	COL 2 EXPENDITURE MODIFIED COL 15 TABLE 4.2	COL 3 PRESENT VALUE FACTOR 1990-1993 DISCOUNT FACTOR 1995-2005	COL 4 PV EXPENDITURE CURRENT COL 1 * COL 5	COL 5 PV EXPENDITURE MODIFIED COL 2 * COL 5
1990	$4,238.40	$84,238.40	1.46	$6,205.44	$123,333.44
1991	$5,801.81	$5,801.81	1.33	$7,722.21	$7,722.21
1992	$7,474.94	$111,516.94	1.21	$9,044.68	$134,935.50
1993	$14,162.44	$14,162.44	1.10	$15,578.68	$15,578.68
1994	$22,347.14	$8,088.76	1.00	$22,347.14	$8,088.76
1995	$36,158.33	$5,131.74	0.91	$32,871.18	$4,665.21
1996	$64,785.28	$5,444.13	0.83	$53,541.54	$4,499.28
1997	$103,765.86	$5,775.21	0.75	$77,960.47	$4,338.98
1998	$110,050.85	$6,124.98	0.68	$75,166.16	$4,183.44
1999	$116,719.22	$6,496.11	0.62	$72,473.41	$4,033.57
2000	$123,819.49	$6,891.27	0.56	$69,892.76	$3,889.94
2001	$131,351.64	$7,310.46	0.51	$67,404.14	$3,751.42
2002	$139,363.52	$7,756.35	0.47	$65,014.10	$3,618.39
2003	$147,854.48	$8,228.94	0.42	$62,704.73	$3,489.87
2004	$156,873.67	$8,730.90	0.39	$60,481.55	$3,366.14
2005	$166,420.43	$9,262.23	0.32	$53,026.67	$2,951.23
		NET PRESENT VALUE		$751,434.87	$332,446.07
				DIFFERENCE IN NPV	$418,988.80

The savings from incorporating PPC 111 is obtained by subtracting the total from column 6 from the total of column 7, a total of $418,988.80 in FY94 constant dollars.

In conclusion, both the break-even analysis and the comparison of Net Present Values with and without incorporation of PPC 111 show that PPC 111 is, indeed, cost-effective.

VI. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The objective of this thesis was to validate the cost-effectiveness of the aircraft engine Component Improvement Program (CIP) for an Engineering Change Proposal (ECP) which was implemented into the fleet as a Power Plant Change (PPC). To achieve this objective, the costs and expected savings (benefits) associated with this CIP effort needed to be determined. The Power Plant Change was PPC 111 for the T56-A-427 engine. PPC 111 replaced the thermocouple interconnector harness end and mating thermocouple end connector which transmit engine temperatures to the Digital Electronic Control (DEC) for controlling ngine power changes.

Chapter I provided the thesis objectives, scope and limitations of the research effort, and a preview of this thesis. Chapter II provided a literature review of previous research done on the Component Improvement Program by the Institute for Defense Analysis and the Naval Postgraduate School. Chapter III provided insight into the mechanical operation behind the T56 turboprop engine, the administrative funding process at the Naval Air Systems Command to procure the PPC 111. The chapter also includes a detailed narrative of the author's experiences in developing his methodology for maintenance data. Chapter III ends with the description of the maintenance data collection process and the information obtained about PPC 111.

In Chapter IV the research and development costs; procurement costs of modification kits; technical directives printing costs; obsolete and reworked equipment costs; test equipment costs; changes in the original E-2C (plus) procurement contract costs and maintenance actions costs were estimated out to the year 2005 for two different life cycle models. The first model presents the expenditures as if PPC 111 had not been incorporated and the second model presents the expenditures with PPC 111 incorporated. The actual cost data for R&D was obtained from the finalized version of the Engineering Program Description (EPD), a document of Allison Gas Turbine Division, General Motors Corporation. The APN cost data was from the Cost and Funding Milestones Chart from NAVAIR's Configuration Change Control Board (CCCB). The costs of past and expected future maintenance actions were calculated using labor rates obtained from the Naval Center for Cost Analysis' Visibility and Management of Operating Support Costs (VAMOSC).

Chapter V presented the cost-benefit analyses for PPC. These took two forms; a break-even analysis and a Net Present Value analysis. In the Net Present Value analysis, the author determined the present value of the annual expenditures of the two models using a capital discount rate of 10%. A comparison of the present worth of the two configurations was then determined by summing the present value of annual cash flows for each.

B. CONCLUSIONS

From the comparison of the life cycle costs with and without PPC 111, it was determined that Power Plant Change 111 is cost-effective. The break-even point was found to occur after year 1997. The difference between the net present value totals of the two alternatives showed a savings in FY94 dollars of $418,988.80 because of the incorporation of this PPC.

Measuring the effectiveness of the aircraft engine CIP program is a complex process which is further complicated by the difficulties of acquiring maintenance data from the NALDA system, understanding the coordination process between the many offices at Naval Air Systems Command to implement the ECP, and the funding approval process of the Configuration Change Control Board (CCCB).

Because this study only examined one component, the reader is cautioned in interpreting the results of this thesis to be conclusive for every component improved under the CIP program. The author chose his component of study to simplify the data collection process.

C. RECOMMENDATIONS

The author recommends that future CIP program researchers use the data collection methodology used in this thesis to examine maintenance data on a component prior to the Power Plant Change modification. Furthermore, another approach that will aid CIP researchers is the methodology used by Jones'. [Ref. 9] The two data collection methodologies are parallel in structure but use different Equipment Condition Analysis reports to collect maintenance data. The break-even analysis and Net Present Value analysis methodology should also be used in future studies.

The author also recommends that follow-on study of PPC 111 be conducted to validate cost estimates for the rest of the life cycle of the T56 engine. Because this PPC was recently incorporated, there is a high awareness within the E-2C (plus) squadrons pertaining to the improvements that the PPC should have made to the interconnector harness end and mating thermocouple end connector. In particular, maintenance data should be tracked closely using the author's data collection methodology. If reality is different from the estimates then the break-even analysis and Net Present value analysis should be redone.

Finally, the author recommends that additional education and training in the NALDA system be available at the Naval Postgraduate School to faculty and students in the Logistic Management Curriculum. The NALDA database is the primary source of logistics information for aircraft maintenance and support. If training and access to the system was available at the Naval Postgraduate School, the funding and time constraints involved in traveling to NALDA sites would disappear. Research students would have more time to acquaint themselves with the system and understand its limitations.

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33. Telephone conversation between the author and Mr. Alan Doremann from the Naval Center for Cost Analysis (NCA-61) on 24 March, 1994.

34. Telephone conversation between the author and Chief Petty Officer (Aviation Machinist) Debert Valle, Engine Program Manager, E-2C Fleet Introduction Team, NAS Miramar, San Diego, CA, 31 May, 1994.

35. Telephone conversation between the author and Mr. Dan Peckham, E-2C Propulsion Team Leader, Naval Air Systems Command AIR-536, Washington, D.C., 01 June, 1994.

36. Telephone conversation between the author and Chief Petty Officer (Aviation Machinist) Debert Valle, Engine Program Manager, E-2C Fleet Introduction Team, NAS Miramar, San Diego, CA, 20 May, 1994.

37. Telephone conversation between the author and Mr. Gray Bergoine, T56 Engineering Programs, Allison Gas Turbine Division, General Motors Corporation, Indianapolis, IN, 20 May, 1994.

38. Executive Office of the President, Office of the Management and Budget, Washington, D.C., Circular A-94, Revised, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs,* October 29, 1992.

APPENDIX A

CCB CHANGE [illegible]/DIRECTIVE

CLASSIFICATION: UNCLASSIFIED — PRIORITY

Allison Gas Turbine Division, GMC

ECP 2163 — CCB NUMBER: 921-0226

T56-A-427 ENGINE THERMOCOUPLE HARNESS FIREWALL CONNECTOR (R-2C+)

Originator	Code	Extension	Date Prepared	Nature of Change
Ben Peckham	A-536220	27466	12/10/91	R&M

(a) Allison Gas Turbine letter JJC:T91-999 of 17 September 1991

Contract Numbers	Articles Affected	Quant. of Articles		
00019-87-C-0372	T56-A-427	17	15	2
Prior Contracts	T56-A-427	76	0	76
00019-91-C-0245	T56 (KITS BOA)			
	TOTAL: ⟶	93	15	78

Mandatory Considerations	No	Yes	Action Required
A. GFE affected	X		
B. Support equipment affected	X		
C. Computer program affected	X		
D. Human factors affected	X		AIR-5313
E. ...	X		AIR-1000
F. ...	X		AIR-5...
G. Foreign military sales affected	X		AIR-503
H. Program management proposal	X	X	21 Jan 92

S/N 113798 MAR 92

Training A/L, GR 455Y2F1 2-10-92

1.0 — Routine

PPC 011

1 months after authorization to proceed

NONE

The fleet has experienced several failures of the thermocouple harness connector which are attributed to deterioration of the phenolic insulator due to the high temperature and vibration environment of the nacelle. Intermittent open circuits in the thermocouple connector have sent false indications to the digital electronic trim control (DETC) with resulting horsepower decreases. The purpose of this change, which was submitted by reference (a), is to incorporate a new firewall connector that is rated in excess of current nacelle temperature measurements and has passed the vibration/temperature tests.

Allison has advance ordered several (12) connectors to protect the production schedule.

AFP Not Required
CDW3 A-10041 2/3/92

1. AIR-4106E: Issue implementation letter.
2. AIR-21421: Issue change order.
3. AIR-536220: Issue technical approval letter
4. NATSF: Coordinate pubs
5. AIR-11432E: Issue appropriate funding document for 78 kits
6. PMA-231: Fund NATSF and Issue PD to AIR-535 for APN-1 funds PD to AIR-412E for APN-5 funds.
7. AIR-53622: Prepare PR for Production Nonrecurring.

Provided w/ECP

Warranty N/A to this change

ENCLOSURE(5) UNCLASSIFIED

NAVAIR FORM 13050/2 (REV. 2-80) (DACS)	CLASSIFICATION: UNCLASSIFIED	CCB NO. 921-0228
PRICE INFORMATION AND FUNDING SOURCE (PRIOR AND CURRENT FISCAL YEARS ONLY)		PRICES QUOTED GOOD UNTIL (DATE) N/A

ACT. KEY	ITEM	PRODUCTION NAVY	PRODUCTION NAVY	RETROFIT NAVY	RETROFIT NAVY	TOTAL	FUNDS REQUIRED & AVAILABLE: PRODUCTION	FUNDS REQUIRED & AVAILABLE: RETROFIT
A	ENG DESIGN DEV. & TEST	NICP				NICP		
B	DRAWINGS	NICP				NICP		
C	LOGISTIC PLANNING							
D	TECH. PUB PREPARATION	NICP				NICP		
E	DATA OR PROVISIONING	NICP				NICP		
F	GOV'T FURNISHED EQUIPMENT							
G	KITS FOR BASIC EQUIP			78 KITS @	~~$67,666~~ $867.51 ea	$67,666		PMA-231D
H	MOD OF BASIC EQUIP	NICP		NICP		NICP		
I	KITS FOR TRAINERS							
J	MOD OF TRAINERS							
K	KITS FOR SPARES							
L	MOD OF SPARES							
M	PUBLICATIONS	NICP				NICP		
N	PUBS & TD PRINTING & DIST				$450	$450		PMA-231D
O	NEW SUPPORT/REPAIR PARTS							
P	INTERIM SPARES							
Q	TOOLING							
R	TRAINERS							
S	SUPPORT EQUIPMENT							
T	SE KITS							
U	SE SPARES							
V	PRODUCTION RETROFIT							
W1	Obsolescence		$10,317			$10,317		PMA-231D
W2	Rework		$10,560			$10,560		
X	Test Equip		$1,600			$1,500		PMA-231D
	TOTALS		$22,377		$68,116	$90,493		

CODE	31. CONCURRENCES (SIGNATURE)	DATE
AIR-53632D	[illegible signature]	
AIR-5116C	[illegible signature]	2/4/92
AIR-552310	[illegible signature]	3/13/92
AIR-4106E	[illegible signature]	
AIR-410C1	[illegible signature]	3/12/92
AIR-~~[illegible]~~ 2/4/21	[illegible signature]	3/23/92
PMA-231~~[illegible]~~ A	[illegible signature]	3/21/92
AIR-551182	[illegible signature]	3/11/92
AIR-5165	[illegible signature]	3/2/92
AIR-11423B	Mary D. [illegible]	3/20/92

32. CCB MEMBERS (SIGNATURE)	33. APPROVED	DISAPPROVED
SYSTEMS AND ENGINEERING: [illegible signature] 3/21/92	✓	
[illegible signature]	✓	
[illegible signature]	✓	
[illegible signature]	✓	
N/A		
CCB CHAIRMAN: [illegible signature]	✓	

Presented by D. Rostkum, AIR-55621D, 27466

DATE 03/26/92

34. IMPLEMENTING ACTIONS

ACTION	ACTION KEY (S)	ACTION CODE	ACTION REQ'D MLT DATE	OTHER INFORMATION
CHANGE ORDER	W1, W2, X	AIR-21421		PMA-231 RD to AIR-536, AIR-536 funding PR to AIR-21
IMPLEMENTATION LETTER	ALL	AIR-4106E		
TECHNICAL DIRECTIVE	D, E	AIR-4106E		
AIR 5362 LTR TO SAALC, KELLY AFB	ALL	AIR-53622D		Tech. Approval ltr
PROCUREMENT REQUEST	G	AIR-11423E		Kits
MILITARY INTERDEPARTMENTAL PURCHASE REQUEST				
MASTER GOVERNMENT FURNISHED EQUIPMENT LIST CHANGE				
Coordinate Pubs	M, N	NATSF		PMA-231 to fund NATSF
REQUISITION OR ALLOTMENT				

CC.. AND FUNDING SUMMARY

SHEET 1 OF 1

921-0228

[ ] ATTRITION	ECP RAMEC NO. 2103	LOGISTICS MANAGER AIR-4106E		CCB NO. D21-0160	
[X] PRODUCTION	ECP ORIGINATOR ALLISON GAS TURB.	EQUIPMENT AFFECTED T56-A-427		TD NO. PPC-	
[X] RETROFIT	ECP SPONSOR AIR-53622D	OSIP NO. P-92		TD CATEGORY ROUTINE	

ELEMENT	INSTAL M/HRS 3.0	QTY BY FY 92	93	94	CCD KEY	TASKED ACTIVITY	IMPL ACTY (AIR CODE)	TYPE FUNDS	(FY 92) FUNDING COST	APPROVAL	(FY 93) FUNDING COST	APPROVAL	(FY 94) FUNDING COST	APPROVAL
1. NONRECURRING ENGINEERING														
A. DESIGN/DEVELOPMENT AND TEST					A	AGTD	AIR-536		NICP					
B. DRAWINGS					B	AGTD	AIR-536	R&D	NICP					
2. NONRECURRING ILS														
A. LSA/MAINTENANCE PLANS/SRL					C									
B. TECH DIRECTIVE PREPARATION					D	AGTD	AIR-4106E	APN-1	NICP					
C. DCN's OR PROVISIONING					E	AGTD	AIR-4106E	APN-1	NICP					
3. GFE					F									
4. MODIFICATION COSTS														
A. KITS FOR BASIC EQUIPMENT		78			G	AGTD	AIR-~~[illegible]~~ 114286	APN-5	$67,666	PMA-231D				
B. MOD OF BASIC EQUIPMENT		10	40	20	H	O,I & D	TYCOM	O&MN	NTN	TYCOM	NTN	TYCOM	NTN	TYCOM
C. KITS FOR MAINT. TRAINERS					I	CONTRACTOR SUPPORT								
D. MOD OF MAINT. TRNR					J									
E. KITS FOR OPS TRAINERS					I									
F. MOD OF OPS TRNR					J									
G. KITS FOR SPARES					K									
H. MOD OF SPARES					L									
5. SUPPORT COSTS														
A. PUBLICATIONS					N	AGTD	NATSF	APN-1	NICP					
B. PUBS PRINT & DISTRIBUTION					N	NPPSO	NATSF	APN-1	ICP					
C. TD PRINT & DISTRIBUTION					N	NPPSO	NATSF	APN-5	$450	PMA-231D				
D. NEW SPARES/REPAIR PARTS					O									
E. INTERIM SPARES					P									
F. TRAINING					Q									
G. TRAINERS (NEW/NONRECURRING)					R									
H. SE NEW/NONREC (13050/2C)					S									
I. SE ILS					T									
J. SE SPARES/REPAIR PARTS					U									
6. PRODUCTION RECURRING					V									
7. OBSOLESCENCE					W1	AGTD	AIR-~~53622~~ [illegible]	APN-1	$10,317	PMA-231D				
8. REWORK					W2	AGTD	AIR-~~53622~~ [illegible]	APN-1	$10,568	PMA-231D				
9. TEST EQUIPMENT					X	AGTD	AIR-~~53622~~ [illegible]	APN-1	$1,500	PMA-231D				

PREPARED BY:	CODE:	PHONE:	DATE:	AIR-04 APPROVAL:	CODE:	DATE:	PMA APPR:	CODE:	DATE:
ADCS WAYNE ANDERSON	4106E	692-9126	3/19/92	R Haydon	AIR 410C1	3/19/92	—		

MILESTONE CHART

SHEET 1 OF 1

921-0228

[ ] ATTRITION ECP NO. 2183 LOGISTICS MANAGER AIR-4106E CCB NO. D2-8168

[X] PRODUCTION ECP ORIGINATOR ALLISON EQUIPMENT AFFECTED T56-A-427 ENGINES TD NO. PPC-

[X] RETROFIT ECP SPONSOR AIR-53622D OSIP NO. 7-92 TD CATEGORY ROUTINE

ELEMENT	QTY BY FY			TASKED ACTIVITY	FY 92			CY 92									FY 93			CY 93									FY 94			CY 94								
	92	93	94		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1. PROCUREMENT																																								
A. CCB APPROVED				AIR-1006						Δ																														
B. CHANGE IMPLEMENTER/ORDER PLACED				AIR-214						Δ																														
C. DRAWING's AGTD				~~AIR-336~~						Δ																														
D. VALIDATION																																								
E. BOM's OR PROVISIONING				AGTD						Δ																														
2. PROD INCORP (FIRST ARTICLE DELIVERY)				AGTD								Δ																												
3. GFE DELIVERY SCHEDULE																																								
4. RETROFIT																																								
A. TECH DIRECTIVE (PROPOSED,APP'D,DIST)				AGTD						Δ		Δ		V																										
B. BASIC EQUIP KIT DELIVERY SCHEDULE	78			AGTD										40		38																								
C. BASIC EQUIP MOD SCH (INC VAL/VER)	18	48	20	U,I,D										2	←																	→	4							
D. KITS FOR MAINT. TRAINERS				CONT																																				
E. MOD OF MAINT. TRAINERS																																								
F. KITS FOR OPS TRAINERS																																								
G. MOD OF OPS TRAINERS																																								
H. KITS FOR SPARES																																								
I. MOD OF SPARES																																								
5. LOGISTICS SUPPORT																																								
A. LSA/MAINT. PLAN/SKL																																								
B. TECH MANUAL DATA PACKAGE DELIVERED				AGTD							Δ								V																					
C. TECHNICAL MANUALS DELIVERED				NATSF															Δ			V																		
D. INTERIM SUPPORT/MSD																																								
E. NEW SPARES/REPAIR PARTS																																								
F. INTERIM SPARES/MSD																																								
G. REPAIR PARTS DELIVERY																																								
H. TRAINING SCHEDULE																																								
I. TRAINERS (NEW/NONRECURRING)																																								
6. PRODUCTION RECURRING																																								
OBSOLESCENCE				AGTD						Δ																														
REWORK				AGTD						Δ																														
TEST EQUIPMENT				AGTD						Δ																														

REMARKS :

Allison
GAS TURBINE DIVISION
General Motors Corporation

ENGINEERING PROGRAM DESCRIPTION

E.P.D. NO. 5647.1.07RA

PROPOSED ___ ACTIVE X INACTIVE ___ COMPLETED ___

PROGRAM TITLE: Thermocouple Harness Firewall Connector

PRIORITY: P

PROGRAM START DATE: 5/90

PROGRAM REV. DATE: 5/90

MODELS AFFECTED: T56-A-427 (Series IV)

DATE OF FORM: 2/91

CLOSING ACTION:

APPROVED: James L. Dillard
CHIEF PROJECT ENGINEER

PROBLEM DEFINITION/CAUSE/BACKGROUND

The E-2 aircraft has experienced intermittent thermocouple signal flutter. A flutter in the thermocouple signal fails DEC because DEC thinks the engine is hotter than it actually is due to intermittent open circuit. This problem has been traced to the firewall connector. This connector completes the circuit from the thermocouple harness to the innerconnector harness. The cause of signal flutter is due to pins vibrating in the connector's electrical receptor.

The T/C harness to I/C harness was initially designed into the 427 from Series III engines. The connector has been in use for over 30 years in the field. Military Standard MIL-C-5015 describes the connector. The connector is a safety wired style connector.

IMPACT OF PROBLEM

HAZARD ASSESSMENT: IV-B Negligible/Reasonably Probable

OVERHAUL COSTS: NO

IN-FLIGHT SHUTDOWNS: NO

SPARE/REPLACEMENT PART COSTS: YES

FIELD UNSCHEDULED ENGINE REMOVALS (UER'S): YES

INCIDENT HISTORY

There are five field service reports (FSR's) generated against the T/C Firewall Connector. This Connector is causing an intermittently open circuit, which causes abnormal temperature indications during starts and engine operation.

The Navy fleet crews have developed a procedure that will start the engine. This procedure defeats the temperature limiter by switching engine control off the temperature signal. This can result in an engine failure if the connector problem is confused with a mechanical problem.

PROGRAM COST

PREVIOUS YEAR	CURRENT YEAR (1990)	NEXT YEAR (1991)	COST TO COMPLETE	TOTAL COST
$ -0-	$ 80,000	$ -0-	$ -0-	$ 80,000

APPENDIX B

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REPORT NBR:  R0530                                     EQUIPMENT CONDITION ANALYSIS
PREPARED:    31 MAR 1994
                                                  DETAILED MAINTENANCE ACTION RECORD
                                                   REPORT PERIOD:  JAN 89 THRU JAN 94
T/M:  E2
--------------------- EQUIPMENT ----------------------*-------------------- MAINTENANCE ACTION/DESCRIPTION ----------
                                                      *                                                                 C
TYPE BUREAU  WORK                                     *                                                 ENT   MAINT     O
EQPT SERIAL  UNIT                     MFG             *------ JCN ------   M METER T W M ACT ACT   A MAL  OR    MAN-      R
CODE NUMBER  CODE   PI   PART NUMBER  CODE  SERIAL NBR ORG DATE  SEQ SUF   C TIME  M D L ORG DATE  T CODE DAY   HOURS     R

AEBC 163840 2230370     23032692      90625 092        PR2 92189 333       A 1496  B K 1 PR2 92197 R 170   6.5   12.5
                        23032692      96906 0000                           E 1484
                                                                                       2 P9C 92212 D 000   3.0    3.0
AEBC 163849 29E1N20     23032692      81625 055        PR2 93080 240       E 2148  B H 1 PX2 93125 R 430  10.4   20.3
                        23032692      81625 081                            E 2148
                        23032692      63005 023                            A 1975      2 D9K 93089 C 070   3.6    4.0
            FAILED PARTS ASSOCIATED                    REF    MFG   A  MAL      M      DATE   REQ  DATE
            WITH THE ABOVE ARE:         PART NUMBER    SYMBOL CODE  T  CODE QTY L PRI  ORD    NBR  RCVD

                                        CA3642138      CON REC 71468 R  615   01 2  02 93083 0188 93089

AEBC 163848 29E1N20     23032692      63005 046        PR2 93089 370       E 1861  B H 1 PR2 93091 R 160   9.5   19.5
                        23032692      81625 055                            E 1861
                                                                                       2 D9K 93091 9 615   9.3    9.3
AEBC 163848 29E1N20     23032692      81625 023        PR2 93098 360       A 1976  B H 1 PR2 93099 R 615  15.5   40.0
                        23032692      81625 068                            A 1875
                                                                                       2 D9K 93099 A 160   4.0    6.0
TMZA 383303 2230000     23032692      81625 023        D8K 93099 898       E 1298  B 0 2 D9K 93099 9 160  16.0   21.0
                        23032692      81625 000                            E 1298
TMZA 383303 2230000     23032692      81625 023        D8K 93111 801       E 0000  B 0 2 D9K 93111 T 814   0.0    0.0
                        23032692      81625 023                            E 0000
AEBC 163851 2230360     23032692      63005 0          PR4 93119 005       E 0709  D L 2 P9C 93140 1 374   0.0    0.0
AEBC 163697 2230360     23032692      63005 054        PR7 93138 377       E 1535  B H 1 PR7 93141 R 020   7.0   12.3
                        23032692      63005 042                            E 1535
                                                                                       2 P9C 93140 1 374   0.0    0.0
AEBC 163697 2230360     23032692      63005 093        PR7 93138 383       E 1502  B H 1 PR7 93141 R 105   4.8    9.6
                        23032692      63005 174                            E 1502
                                                                                       2 P9C 93140 1 374   0.0    0.0
AEBC 163539 29E1N20     23032692      81625 150        PR2 93157 138       E 2319  B H 1 PR2 93176 C 160  17.0   34.0
            FAILED PARTS ASSOCIATED                    REF    MFG   A  MAL      M      DATE   REQ  DATE
            WITH THE ABOVE ARE:         PART NUMBER    SYMBOL CODE  T  CODE QTY L PRI  ORD    NBR  RCVD

                                        MS2104306             96906 R  117   01 1  02 93157 0951 93157
                                        23032692              50625 R  160   01 1  02 93157 0902 93157

                                                                                       2 D9K 93163 9 615   6.0    6.9
AEBC 164107 2230370     23032692      63005 102        PR4 93293 005       / 1859  B H 1 PR4 93296 R 160   5.5   11.0
                                                                                       2 P9C 93295 1 374   0.0    0.0
TN.  383790 2230370     23032692      63005 000        P8C 93306 918       E 1298      2 P9C 93301 C       2.0    2.0
```

```
REPORT NBR: R0530                          EQUIPMENT CONDITION ANALYSIS                                    PAGE    1
PREPARED:    29 MAR 1994
                                           DETAILED MAINTENANCE ACTION RECORD
                                           REPORT PERIOD:  JAN 89 THRU JAN 94
T/M:  22
---------------------------- EQUIPMENT ---------------------------*--------------------------- MAINTENANCE ACTION/DESCRIPTION --------------------
                                                                  *                                                                  CT I
TYPE BUREAL  WORK                                                 *                                                  ENT   MAINT    OY C  DRCT
EQPT SERIAL  UNIT                         MFG                     *------- JCN ------   M METER T W M ACT ACT    A MAL   OR    MAN-     RP C  MATL C
CODE NBR  *  CODE    PI    PART NUMBER    CODE    SERIAL NBR ORG DATE  SEQ SUF       C TIME  M D L ORG DATE   Y CODE  DAY   HOURS    RE C  COST C

AEBC 163497 29C11A3      23038736         63005 069        PR7 903__ 186          E 3370  B A 1 PR7 90346 R 615   32.2   67.4                E
                         23030786         63005 030             -                 E 0370                                                     G
AEBC 163694 29E1L70      23038786         63005 017        PR7 91046 239          E 0266  B D 1 PR7 91062 R 450   29.0   33.2                E
                         23038786         63005 028                               E 0266                                                     G
YHZA 363167 2230000      23038786         63005 0          D97 92251 410          E 0000  C 0 2 D97 92268 A 804   14.5   19.0                E
AEBC 163___ 4281100      23038786         63005 083        PR4 92251 141          A 1430  B K 1 PR4 92251 B 070    5.1   10.2                E
             FAILED PARTS ASSOCIATED                       REF   MFG   A  MAL       M    DATE    REQ   DATE
             WITH THE ABOVE ARE:        PART NUMBER        SYMBOL CODE  T  CODE QTY L PRI ORD     NBR   RCVD

                                        23038786                     09528 K  020    01 1

                                                                                        2 D97 92267 C 450.    0.0    0.0
AEBC 163693 4281100      2303878_         63003 083        PR4 92258 110          M 1439  B K 2 PPC 92258 * 374    0.0    0.0                E
YHZA 363309 22_0380      2303878_         63003 025        PR7 92315 119 1D       E 0000  B K 2 PPC 93022 1 020    7.1    7.1                E
                         23038786         63005 000                               C 0001                                                     G
AEBC 163539 1435C00      2303878_         63005 071        PR2 93049 072          C 1351  B C 2 D9K 93150 9 070    6.0    6.0                E
             FAILED PARTS ASSOCIATED                       REF   MFG   A  MAL       M    DATE    REQ   DATE
             WITH THE ABOVE ARE:        PART NUMBER        SYMBOL CODE  T  CODE QTY L PRI ORD     NBR   RCVD

                                        M18193190438065 CONNECT 3146_ R  070    01 2  02 93054 0182 93147
                                        M18193190438065 CONN    31461 R  070    01 2  02 93052 0103 93055

AEBC 163849 2230380      23038786         63003 103        PR2 93064 207          A 1974  B K 1 PR2 93077 R 160   11.0   22.0                E
                         2303878_         63006 115                               A 1974                                                     G
                                                                                        2 D9K 93065 A 799    1.5    1.5
>AEBC 163846 2_21020     23038786         63003 03_        PR2 93084 331          A 1836  B K 1 PR2 93085 R 140    8.0   16.0                E
                                                                                        2 D   93150 9 070    9.5    9.5
             FAILED PARTS ASSOCIATED                       REF   MFG   A  MAL       M    DATE    REQ   DATE
             WITH THE ABOVE ARE:        PART NUMBER        SYMBOL CODE  T  CODE QTY L PRI ORD     NBR   RCVD

                                        M18193190438065 CONN    31471 R  070    01 2  02 93086 0117 93147

YHZA 113167 2230000      23030745         63005 0          PR7 93131 074          E 1213        1 PR7 93146 C          2.3    4.7                E
YHZA 113175 2230900      23030745         63005 0          PR7 93131 076          E 1672        1 PR7 93146 C          2.4    4.2                E
AEBC 163696 9101300      23030745         63005 0          PR7 93131 259          E 1636  B K 1 PR7 93132 C 070    9.3   14.3                E
YHZA 113326 2230000      23030745         63005 093        PR7 93131 326          E 1502        1 PR7 93139 C          4.8    4.2                E
YHZA 113316 2230000      23030745         63005 05_        PR7 93131 328          E 1535        1 PR7 93139 C          5.4    6.0                E
AEBC 1636_3 4281000      23038786         63006 000        PR4 93195 127          A 1895  R C 1 PR4 93197 R 160   23.0   44.0                E
                         23038786         63006 000                               A 1895                                                     G
AEBC 16____ 4281100      23038736         63005 06_        PR4 93197 581          A 0000  B       _ 93209 1 374    0.0    0.0                E
```

PREPARED: 29 MAR 1994

DETAILED MAINTENANCE ACTION RECORD
REPORT PERIOD: JAN 89 THRU JAN 94

T/M: E2

TYPE EQPT CODE	BUREAU SERIAL NUMBER	WORK UNIT CODE	PI	PART NUMBER	MFG CODE	SERIAL	NBR	JCN ORG	JCN DATE	JCN SEQ	JCN SUF	M C	METER TIME	T M	W D	N L	ACT ORG	ACT DATE	A T	MAL CODE	EMT OR DAY	MAINT MAN-HOURS	CT QY RP RE	I C C C	DRCT MATL COST	C C
THZA	113182	2230000		23030743	63005	0		PR7	93243	331		E	0521			1	PR7	93247	C		10.0	10.4				E
AEBC	164107	29E1N00		23038786	63005	12672		PR4	93280	014	8	E	1758	8	A	1	PR4	93281	R	160	21.0	42.0				8
				23038786	63005	12872						E	1758													8
				23038786	63005	086						E	1758			2	PPC	93283	1	374	0.0	0.0				E
AEBC	1644/5	4281100		23038786	63005	017		PR2	94027	100		E	0386	8	8	2	PPC	94027	1	374	0.0	0.0				E

APPENDIX C

The following is a list of acronyms as they are used in this in this thesis:

CIP	Component Improvement Program
AIR	Naval Air Systems Command
ECP	Engineering Change Proposal
O&MN	Operations and Maintenance Navy
FIT	Fleet Introduction Team
LCC	Life Cycle Cost
IDA	Institute for Defense Analyses
FSD	Full Scale Development
ECIFR	Engine Component Improvement Feedback Report
PPC	Power Plant Change
MTBF	Mean Time Between Failures
VAMOSC	Visibility and Management of Operations and Support
NCA	Navy Center for Cost Analysis
MFHBMA	Mean Flight Hours Between Maintenance Actions
MMH/MA	Mean Maintenance Hour per Maintenance Action
NALDA	Naval Aviation Logistics Data Analysis
3M	Maintenance, Material, and Management
NADEP	Naval Aviation Depot
ECA	Equipment Condition Analysis
RDT&E	Research Development Test and Evaluation
EPD	Engineering Project or Program Description
APN	Aircraft Procurement Navy

CCCB Configuration Change Control Board

MODMIS Modification Management Information System

DEC Digital Electronic Control

TMT Turbine Measured Temperature

FMS Foreign Military Sales

PMA Program Manager for Acquisition

CFA Cognizant Field Activity

VIDS/MAF Visual Information Display/ Maintenance Action Form

FIT Fleet Introduction Team

HMR Hazardous Material Report

NPV Net Present Value

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