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AN ANALYSIS OF THE CORRELATION BETWEEN THE J52 ENGINE COMPONENT IMPROVEMENT PROGRAM AND IMPROVED MAINTENANCE PARAMETERS

by

Leonard Bret Gordon

December 1992

Thesis Advisor: Alan W. McMasters

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An Analysis of the Correlation Between the J52 Component Improvement Program and Improved Maintenance Parameters

by

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ABSTRACT

This thesis is a study of the J52 Engine Component Improvement Program (CIP). The objective of the thesis was to determine if the correlation between J52 CIP expenditures and improved maintenance parameters at the component level could be quantified. The major focus of the study revolved around developing a methodology to accomplish the objective using existing databases and open dialogue between the J52 engine manufacturer(Pratt & Whitney), NAVAIRSYSCOM Engine Program Manager, and various NADEP engineers. The methodology evolved using the Fuel Nozzle Support Assembly and was validated using the Fuel Pump. The thesis reached the conclusion that observed improvements in maintenance parameters can be linked to CIP expenditures at the component level.

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INTRODUCTION

A. BACKGROUND

The quality of military aircraft engines over the last 35 years has increased significantly. A major contributor to this increase is the Componert Improvement Program (CIP). This element of the acquisition process is not only designed to increase the quality and life of the engine, but reduce the Life Cycle Cost (LCC) as well. However, for programs in these times of austere budget cuts, funding justification becomes paramount. The Navy has not always been successful in obtaining their funding level requested for CIP. Recent trends have shown CIP funding as having leveled off. One of the inherent problems with programs of this nature is that once it is justified and funded there are no established tracking methods to determine if the changes are accomplished as originally intended. Merely showing through a Return on Investment (ROI) model that Life Cycle Costs (LCC) will be reduced by virtue of incorporating a particular Engineering Change Proposal (ECP) is not justification alone for CIP funding. A method needs to be established as a follow-on to measure the impact that these changes are supposed to have.

B. J52 HISTORY

The Pratt & Whitney J52 engine is an ideal platform to study the impacts of CIP. It is a mature engine that began development in 1956 and was originally designated the JT8A-1. The first engine, redesignated the J52-P-3, was qualified in 1958 and saw its first flight installed in the Air Force missile the Hound Dog. In 1957 the Navy chose the J52-P-6A to power the forthcoming A-6A Intruder. The J52-P-6 still serves as the powerplant for the Navy's TA-4J training aircraft. In 1961 the newly developed J52-P-8 engine was selected to power the Douglas A-4 Skyhawk light attack aircraft. These aircraft, powered by the J52, experienced combat action throughout the Viet Nam conflict.[Ref. 1]

In 1969, the U.S. Navy elected to build an electronic warfare version of the A-6 to assist the defenses. However, the four-man EA-6B Prowler required more thrust than the P-8 could provide. In 1969 the P-408 was developed to meet this new requirement. By 1970 the P-408 was also selected to power the Marines' A-4M.[Ref. 2]

By 1989, improved derivatives of the J52 engine, the P-6C, P-8C, and P-408A, were approved for incorporation in the Fleet. When an improved derivative of an engine is introduced, it is redesignated with an alpha character at the end of its previous designation. The basic difference between the J52 derivatives is the amount of thrust they are able to provide their respective platforms.

The J52 completed production in 1990 establishing a remarkable record for Pratt & Whitney of 30 continuous years of J-52 engine production. A total of 5000 engines were produced with approximately 2200 remaining in the U.S. Navy inventory. Due to recent contracts calling for an improved engine to power the new Advanced Capability EA-6B, Pratt & Whitney has initiated plans to reopen the J-52 production line in the 1993-94 time frame to commence production of it's newest derivative, the P-409.[Ref. 2]

C. OBJECTIVES

The objectives of this thesis are:

- to develop a procedure for measuring the effectiveness of CIP, comparing the change of maintenance parameters (e.g., Failure Maintenance Actions) at the component level from an established baseline year to present.
- to determine if existing databases are sufficient to accomplish the above objective.
- to provide further justification for continued/increased funding of CIP.

D. SCOPE AND LIMITATIONS

The scope of this research revolves around the J52-P-8C engine. Data in this study refers to those particular engines from 1979 through 1991. Conversion from the P-8B to the P-8C began in 1990. Through 1991, only 154 engines have been converted to the P-8C. These 154 engines provide an ideal sample size to measure any changes in maintenance parameters at the component level.

E. PREVIOUS RESEARCH

Research in the area of aircraft engine logistics support by the Naval Postgraduate School has been underway for several years. This research was requested by OP-51, the Naval Aviation Maintenance Division of the Office of the Assistant Chief of Naval Operations (Air Warfare), and NAVAIR Code 526, the Propulsion and Power Division of the Naval Air Systems Command.

The aircraft turbine engine Component Improvement Program has been the topic of several theses over the last two years. The following are the abstracts from each thesis:

1. Evaluation of Aircraft Turbine Engine Redesigns

> This thesis is a study of the Aircraft Turbine Engine Component Improvement Program (CIP). The study examines some of the problems associated with determining benefits accrued from CIP. The major thrust of the thesis was developing a component selection methodology and an analysis procedure for detecting changes in logistics parameters. The data source was the Engine Component Information Feedback Report (ECIFR). Data for this report come from aviation organizational level maintenance activities and squadrons. The thesis reached the conclusion that the effects of CIP are more effectively assessed at the component level rather than at the system level. The thesis further demonstrated the logical and data collection difficulties encountered in the process of isolating and measuring the incremental benefits obtained from CIP expenditures.[Ref. 3]

2. An Analysis of the Aircraft Engine Component Improvement Program (CIP); A Life Cycle Cost Approach

> Increasing budgetary constraints have prompted actions to reduce the maintenance cost of current naval aircraft. This thesis examines the Aircraft Engine Component Improvement Program (CIP), its impact on these costs at the organizational and intermediate levels of maintenance, and savings from these improvements. The objectives of the research were to identify current life cycle cost (LCC) models used by the Navy and/or the other services to determine CIP benefits, to validate on-going LCC-oriented computer programs, and to provide the basis for development of an improved LCC-oriented computer program. This thesis is organized into areas covering CIP objectives and considerations, system effectiveness,

reliability, LCC and related data and models, aircraft data used for LCC, CIP/LCC computer models, return on investment (ROI) analysis program of the F-14A TF30-P-414A engine improvements, conclusions and recommendations. Based on the ROI analysis and ECIFR reports, the engine improvement program has been cost effective.[Ref. 4]

3. An Appraisal of Cost-effectiveness Models Used in the Air Force and Navy Aircraft Engine Component Improvement Programs

This thesis examines the cost-effectiveness models used by the Air Force and Navy to assist with the decision-making process of their Component Improvement Programs (CIP). The focus is on a comparison of the elements of the two models and the reasonableness of each model's results. A sensitivity analysis was performed on significant input parameters to determine what effect errors in these parameters would have on the predicted return-on-investment (ROI) results. The author concluded that, although the models provide insight into the life-cycle-cost (LCC) of aircraft engines, they are extremely sensitive to errors in certain input variables and should not be relied upon for CIP budget justification.[Ref. 5]

4. Evaluation of the Cost Effectiveness Analysis Model Being Developed for the Component Improvement Programs of the Air Force and the Navy

This thesis examines the Cost Effectiveness Analysis (CEA) model used by the Air Force to assist with the decision making process of their Component Improvement Program (CIP). The emphasis was on studying the model for its use in the Naval Component Improvement Program. With an example provided by General Electric, a sensitivity analysis was performed to determine the cost drivers of the model. For the example, the major cost drivers were found to be the Incorporation Style, Kit Hardware Cost, and the Spare Parts Factor. Next a simple simulation was conducted to determine how random component failures affect the life cycle cost variability of the CEA model. The author concluded that additional simulation studies should be conducted for other causes of variation. A detailed analysis of the model formulas and assumptions are needed as part of a users' manual.[Ref. 6]

5. Preliminary Analysis of the J-52 Aircraft Engine Component Improvement Program

> This thesis presents a preliminary analysis of the J-52 aircraft engine Component Improvement Program (CIP). The objectives of the research were to scrutinize the association of the CIP with promised improvements and benefits pertaining to the J-52 engine and to determine the obstacles that existing data bases present when an attempt is made to calculate the success or failure of a component modification....Analysis shows that...the overall trends have been promising with regard to improving engine maintainability, reliability and safety related factors.[Ref. 1]

F. THESIS PREVIEW

The thesis is organized in the following manner:

- Chapter II provides the background, role, objectives, functions, and management of the Component Improvement Program (CIP).
- Chapter III outlines the initial methodology used to determine the impact of CIP expenditures on observed improved maintenance parameters at the component level.
- Chapter IV applies the methodology outlined in Chapter III, revises it and provides a new methodology to be followed.
- Chapter V includes a summary, conclusions and recommendations on the outcome of the research.

II. BACKGROUND

A. CIP HISTORY

Engine product improvement is not a new concept to the military. In the 1940s, engineering support services were funded by an add-on to the production selling price of engines and associated parts. Not only was this money used to improve existing engines, but some was being funneled by the contractors for developing prototypes. The military inventory of engines increased dramatically during the Korean War. This increase meant that contractors were receiving large sums of money via the add-on that the government had little control over. In order for the government to obtain direction, control and visibility of the funds, CIP was created in the early 1950s. Over the years, CIP has been streamlined into a program with specific objectives and functions. For example, the building of prototypes with CIP funds is now expressly forbidden.[Ref. 7]

B. CIP AND PROGRAM MANAGEMENT

One of the dilemmas facing Program Managers is when to deploy a new aircraft into operational service. Historically, when developing an aircraft prototype, airframes are developed in four to six years and engines take upwards to eight years. Ideally, the development of the engine should precede the airframe development by several years in order to release a fully mature aircraft. However, it hardly makes sense to design and develop an engine without knowing its application. The last engine that started development without an application was the T-64 in the late 1950s[Ref. 7].

A tradeoff often occurs during Full Scale Development (FSD) of the engine. Does the Program Manager wait for the engine to reach maturity, delaying its operational introduction while driving up unit costs, or does the Program Manager release an immature engine to meet operational commitments? The Program Manager must weigh the pros and cons of meeting operational commitments with a platform that does not meet all specifications, or risk the wait and deploy an aircraft with a mature engine that may become technologically obsolete in the interim. Fortunately, the Program Manager has a vehicle for insuring that engines reach maturation after they are brought into operational service. That vehicle is the Component Improvement Program.[Ref. 3]

C. CIP OBJECTIVES, FUNCTIONS, AND MANAGEMENT

1. Objectives

The Navy's objectives with respect to the CIP are provided in NAVAIRINST 5200.35. The objectives are to:

- maintain an engine design which allows the maximum aircraft availability[1] at the lowest total cost to the government.
- correct, as rapidly as possible, any design inadequacy which adversely affects anything deemed safe for flight[2].
- correct any design inadequacy which causes unsatisfactory engine operation or adversely affects maintainability[3] and logistic support in service.

2. Functions

In addition to CIP objectives, NAVAIRINST 5200.35 also lists CIP functions. They are:

a. Problem Solving

- Resolution of flight safety problems
- Investigation, analysis, and resolution of service revealed difficulties or problems as reported by the engine user. Difficulties are identified by Material Deficiency Reports; accident and incident reports;

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[1]Availability is defined as a measure of the degree to which a system is in an operable and committable state at the start of a mission when the mission is called for at a random point in time. [Ref. 8]

[2]Safe for flight is defined as anything that impacts the material condition of an aircraft which, considering mission requirements and environmental conditions, permits it to be launched, flown, and landed safely and ensures the aircrew has, as a minimum, the operable equipment for safe flight required by NATOPS. [Ref. 9]

[3]Maintainability is defined as a characteristic of design and installation. This characteristic is expressed as the probability that an item will be retained in, or restored to, a specified condition within a given period if prescribed procedures and resources are used. [Ref. 8]

reports to contractor representatives; written reports through prescribed channels; or oral/written reports given at engine CIP reviews.

- Design and test verification of required improvements.

b. Problem Avoidance

- Aggressive mission testing of engines and components for early detection of deficiencies in the test cell to minimize service problems and to extend initial part lives.
- Design and test verification of required improvements.
- Improved engine maintainability, durability, and reliability.

c. Other

- Retention of the engine ability to perform to the engine model specification.
- Reduced operation and support costs.
- Generation of information needed for power plant change revisions.
- Where applicable, engineering of new support equipment for new parts, accessories, or maintenance and inspection techniques.

3. Management

The Component Improvement Program is jointly managed and funded by the Navy, Army, and Air Force. Under this tri-service agreement, careful coordination is required when CIP efforts are initiated on a shared engine. Funding also comes from Foreign Military Sales customers and engine contractors if the engine has substantial commercial application. The unique Navy applications of CIP are managed by the Propulsion Power Division (AIR-536) of the Naval Air Systems Command. Assistance is provided by the Maintenance Policy and Engineering Division (AIR-411). Specific responsibilities:

a. Propulsion and Power Plant Division (AIR-536)

- Plan, budget, allocate CIP funds.
- Implement, execute and manage the program.
- Coordinate the program with the Air Force and the Army to obtain the maximum support within the limits of funds available.
- Integrate Foreign Military Sales for CIP.
- Justify the level of funding required to incorporate modification resulting from approved engineering change proposals.

b. Maintenance Policy and Engineering Division (AIR-411)

- Assess the logistic support impact of proposed engineering changes and make required adjustment to the maintenance plan or integrated logistic support program.[Ref.10]

D. CIP AND TOTAL QUALITY MANAGEMENT

The basic fundamentals of CIP have been following the concepts of Total Quality Management(TQM) since its inception. The Department of Defense (DoD), and more specifically the U.S. Navy, has embraced the philosophy of TQM. In a letter from the Chief of Naval Operations to all Flag officers, Admiral Kelso recognized "the unique role that Navy leadership plays in developing and implementing...operational objectives", and renamed the TQM concept to Total Quality Leadership (TQL). The letter goes on to highlight TQL's theme of needing "...to identify, analyze, improve and redesign the individual processes of...operations in order to improve and redesign the product."[Ref. 11]

A more in-depth definition of TQM is necessary to appreciate its direct correlation to CIP.

> TQM is the application of methods and human resources to control the processes that produce defense materiel, with the objective of achieving continuous improvement in quality. The DOD TQM strategy also addresses the concurrent need to motivate U.S. industry to greater productivity. It is a strategy for improving the quality of DOD processes and products and achieving substantial reduction in the cost of ownership throughout a systems life cycle.[Ref. 12]

Thus, CIP can be viewed as TQM for aircraft engines.

E. CIP FUNDING

Funding for CIP faces the same obstacles as all funded programs in DoD. Annual Congressional review of the budget and changing priorities, whether political or military, will impact the level of funding from year to year. The uncertainty in funding often precludes any initiative on the part of the contractor to reduce LCC or improve maintainability/reliability parameters.

Each Service has a unique challenge in attaining the required level of funding to meet CIP objectives.

> Engine CIP costs are not included in the purchase price of engines. Such costs are incurred subsequent to engine sale as the major part of the follow-on engineering effort to continue the improvement of engine reliability and maintainability.[Ref. 13]

From a Program Manager's and contractor's perspective, a grey area often exists between Procurement funds and Research, Development, Test, and Evaluation (RDT&E) funds. CIP was initially funded with appropriations from Title III, Procurement funds (APN). In 1979, in an effort to clear up this grey area, Congress directed that CIP funding would fall under Title IV, RDT&E funds, beginning in FY 80.

Each Service must defend CIP as a program element under their respective RDT&E account. Once funding levels are determined, each service allocates funds to engines that are unique to their service. For those engines that are used by more than one service, a lead service is assigned. The lead service maintains contracting responsibility and receives appropriate funding from joint users. All engine users are required to pay for their respective engine CIP costs on an equitable basis. This includes engine users that result from Foreign Military Sales (FMS).

> The major advantage of...engine CIP is that, through contributing a fair share of the cost of a CIP for a given engine, each participating country realizes the benefits of the total experiences of the world wide inventory of that engine.[Ref. 13]

III. METHODOLOGY

This Chapter explains the methodology used to determine if a correlation exists between measurable improvements in maintenance parameters and CIP funding.

A. DATA SEARCH

Perhaps the biggest stumbling block when conducting research of this nature is knowing not only what data you want, but more importantly knowing what data is available and where it can be obtained. Previous research conducted on J52 CIP answered the important "where" question and was relied on heavily throughout the research effort. However, the challenge that remained was determining what data was significant to this particular experiment. To accomplish this it was imperative to know what databases are available and the standard report forms that are generated. The data bank used in this research comes from the Naval Aviation Logistics Data Analysis (NALDA) System and is comprised of many databases.

1. Naval Aviation Logistics Data Analysis (NALDA) System

NALDA evolved from a need for improved data analysis capabilities to support growth in sophistication and complexity of naval air weapons and associated support systems. Its primary objective is to utilize state-of-the-art management information systems technology to provide centralized logistics data analysis capabilities. NALDA's capabilities furnish a wide spectrum of uses for managers, engineers, analysts and logisticians using the system. Specialized NALDA-trained operators are capable of customizing reports based on specific requests by querying the various databases of the NALDA System.[Ref. 14]

The predominant report which culls its data from the NALDA System and was useful to this research was the Engine Component Improvement Feedback Report (ECIFR). This report provides summarized Maintenance and Material Management (3-M) data for selected aircraft engines. Below is a table of maintenance parameters the ECIFR provides data for and the corresponding report number which contains it.[Ref. 15]

TABLE I

MAINTENANCE PARAMETER AND CORRESPONDING ECIFR REPORT NUMBER

PARAMETER	ECIFR REPORT NUMBER
EFH; FMA	JETMF32L, JETMF34N, JETMF34P
EFH; MA	JETMF32L, JETMF34N, JETMF34P JETMF35J, JETMF35O, JETMF35I
Aborts; FMA	JETMF32F, JETMF32H
Engine Removals and Failed Engine Removals	JETMF32I
Maintenance Man Hours; EFH	JETMF32L, JETMF34N, JETMF34P JETMF35J
Elapsed Maintenance time	JETMF32L
Non Mission Capable Hours	JETMF100
Component Removals	JETMF35O, JETMF35I

Careful consideration had to be given to each report to determine if it could provide the specific engine or component data requirements.

B. DETERMINING CIP BENEFITS

Although the need for much of the RDT&E that comes under the auspices of CIP is identified by Fleet personnel, the efforts virtually go unnoticed in the Fleet unless a Power Plant is issued as the direct result of a CIP funded ECP. The RDT&E monies expended on CIP engineering, testing, manufacturing, quality control and management functions are considered sunk costs. The benefits of CIP with respect to PPCs are not reaped until APN funds are released for spare parts, parts kits or whatever hardware is necessary to implement the proposed change. Even after APN funds are released, it can take years before the PPC is fully incorporated and any measurable impact on maintenance parameters are observed.[Ref. 3]

The immediate objectives of CIP are safety of flight and correcting service-revealed deficiencies during early operational service. Research by Nelson, Harmon and Tyson revealed a direct correlation between solving these problems and reducing Class A accidents.[Ref. 7]

Reducing LCC by improving durability, reliability, maintainability, producibility, and repairability is the long term objective of CIP[Ref. 7]. It is ironic to note that CIP projects are rarely undertaken to meet this long term objective due to immediate fiscal year funding constraints. The philosophy of spending money to make (save) money becomes applicable in this type of scenario.

The benefits derived from CIP are numerous. Using CIP as a fall back for releasing an engine early into Production from Full Scale Development (FSD) is considered a cost saver. The dollars saved are difficult to quantify, yet it's contributions to cost savings are undeniable.

> It is neither militarily nor economically sensible to attempt to find all engine problems during FSD. There is a need to continue aircraft turbine engine maturation during the entire operational life of an engine. The military services seek a balance between FSD and CIP to allow the engine to be produced and fielded at some reasonable cost....[Ref. 7]

Perhaps the three most important benefits that result from reducing LCC are 1) a reduction in engine related Class A accidents rate, which is defined as engine-caused aircraft attrition, 2) a reduction in the unscheduled engine removal rate, which is a major driver of spares requirements and 3) an increase in the average time between depot level overhauls (ATBO).[Ref. 7]

Nelson, Harmon and Tyson used LCC models as a means to assess the benefits that CIP has on reducing costs [Ref. 7]. The primary measuring stick they used was the ATBO due to its direct effect on depot costs. The impact that CIP has had on the J52 is unquestionable. In particular, the ATBO has risen significantly for both the P-6C and the P-8C in the time frame being observed in this thesis investigation. Figure 1 illustrates these trends. This method appears to incorporate the cumulative effect that CIP has on LCC rather than attributing cost savings to an improvement in any of the maintenance parameters of a specific component. This thesis attempts to isolate this improvement to a specific component and credit it to CIP expenditures.

C. FOCUS OF THE ANALYSIS

The main impetus of this research revolves around determining if a correlation exists between improved maintenance parameters and CIP funding for the P-8C version of the J-52 engine. The first step was to determine the

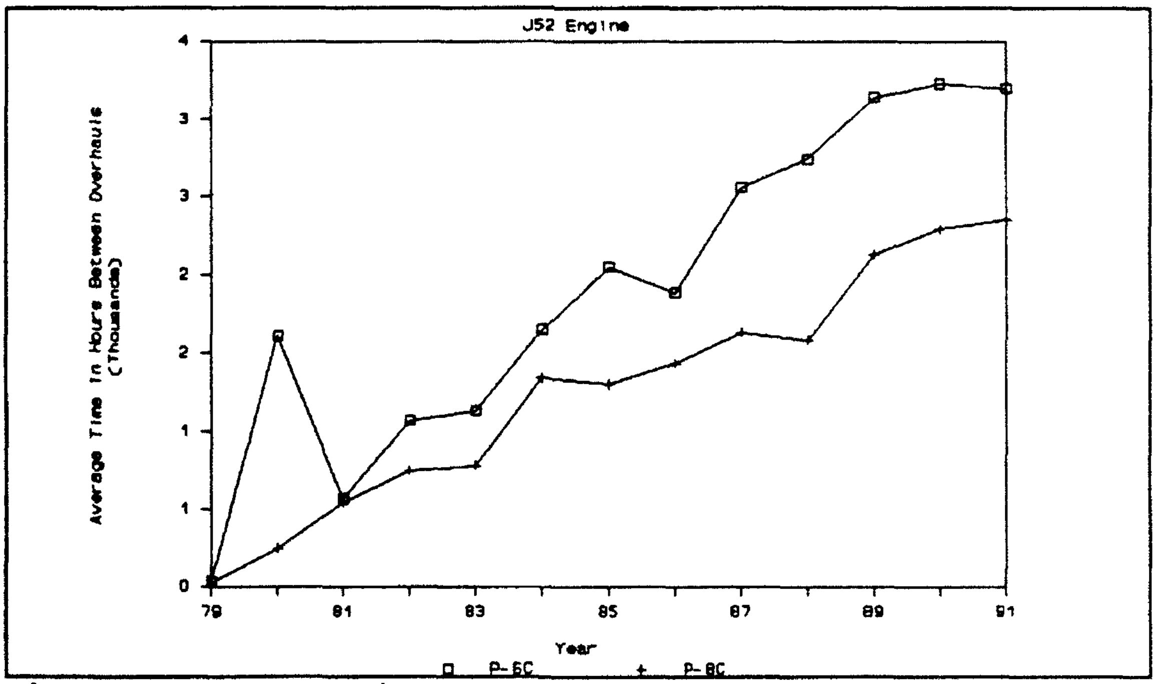

Figure 1 Average Time In Hours Between Overhaul (ATBO) for the J52-P-6C and J52-P-8C.

maintenance parameter that will most readily reveal any significant changes from year to year. Since Failure Maintenance Actions (FMAs) have the greatest impact on operational commitments/capabilities, it is the one that is considered as having the greatest impact. Previous research attempting to isolate component improvement used the maintenance parameter Mean Time Between Failure (MTBF) as a measuring stick. MTBF is a function of both FMAs and Engine Flight Hours (EFHs) and is calculated by dividing the number of EFHs by the number of FMAs. Since several of the components in this analysis experienced zero FMAs in an observed year, it was deemed inappropriate to try to graph a parameter with zero in its denominator.

During the time frame studied, the ratio of J52-P-8C total FMAs to the number of total Maintenance Actions (MAs) in a year and the ratio of total FMAs to every 10 EFHs declined as displayed in Figure 2. This relationship held true for all individual components as well. Therefore, using the number of FMA is considered an appropriate measuring stick for this study.

The second step was to determine which components to evaluate. The ECIFR report JETMF34N, titled "Maintenance Actions and Manhours by Work Unit Code", lists the components that account for 80% of all MAs in a given year in descending order of frequency. The ECIFR breaks all its report forms out by aircraft. However, a query can be formulated to break

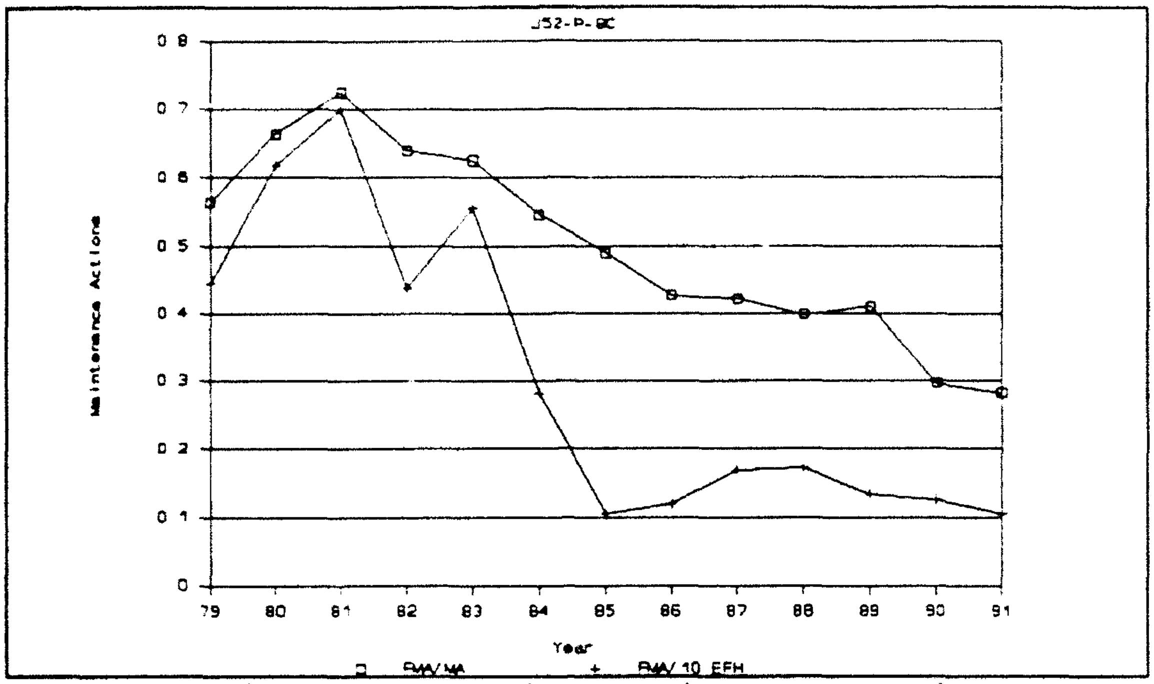

Figure 2 Ratio of Total Failure Maintenance Actions to the Number of Maintenance Actions and the Ratio of Failure Maintenance Actions to Every 10 Engine Flight Hours.

specific reports out by engine. Report JETMF34N also cites the number of FMAs attribu*ed to each component.

As mentioned in Chapter I, the twelve-year time period of 1979 through 1991 was selected for conducting this analysis. The components that were the top ten MA drivers for the years 1979 and 1980 were next selected as a basis for determining if any improvements occurred over this twelve-year time frame. Eight components were common to both years. The eight common components and their average number of FMAs per year for 1979 and 1980 in descending order of frequency of occurrence were:

Nomenclature	Average FMA per Year (79-80)
- Combustion Chamber Assembly	651.0
- Fuel Nozzle Support Assembly	305.5
- (Main) Fuel Control	155.0
- Fuel Nozzle	122.0
- Fuel Pump	65.5
- Fuel Pressure Differential Switch	64.0
- Lubrication System	60.0
- Fuel Hose (Lines)	46.5

From these eight, the top four were considered as candidates for further analysis by virtue of the relatively large amount of FMAs occurring in the baseline years. However, any component can be considered a candidate for study. The FMAs for the top four components were then plotted over time from 1979 to 1991. If a decreasing trend in FMAs was noted, that component was considered a candidate for continued study.

The third step was to research the various PPCs issued to determine if any directly impacted the candidate components. A J52 Navy cross reference file, PPC to ECP, was obtained from Pratt & Whitney. This listing provided in numerical order the PPC, its respective ECP, the area of the engine it affected, and the date it was issued. In addition, Power Plant Bulletins (PPBs) are listed in the back. If the subject area cited the candidate component, the issue date was then noted to determine if it had been issued prior to the observed decreasing trend. If it had, it is then necessary to ascertain the percentage of incorporation in a given year. Establishing the percentage of incorporation validates the relative impact the PPC has on the observed maintenance parameter. The PPC's corresponding ECP is then referenced to determine what contract the ECP was funded from.

Once a direct correlation is established between an improved maintenance parameter and a PPC, determining the amount of CIP dollars expended is fairly easy. A Return on Investment Model can then be incorporated to determine the ratio of CIP dollars expended to projected cost savings. Projected cost savings can also be determined from the elementary cost effectiveness analysis enclosure of the ECP.

IV. ANALYSIS

A. COMPONENT ANALYSIS

1. Determining Component Candidates

The FMAs for the Combustion Chamber Assembly, Fuel Nozzle Support Assembly, Main Fuel Control and Fuel Nozzle were graphed over the established time period (1979-1991) and are displayed in Figures 3 through 6. The Combustion Chamber Assembly, Fuel Nozzle Support Assembly and the Fuel Nozzle remained candidates for continued study because of their consistent decreasing trends in FMAs. The Main Fuel Control was initially eliminated because of the erratic behavior of the plot that occurred between 1986 through 1989.

2. Analyzing Issued Power Plant Changes

The Pratt & Whitney listing of Power Plant Changes (PPC) was reviewed to determine if any PPC had been issued during the 1979-1991 time frame for the candidate components. Unfortunately, none were identified. The listing's subject line describes the area of the engine being impacted by the PPC, but it is vague and often only cites the sub-component involved. Even if a PPC had been identified, it would not have been possible to obtain the PPC percentage of incorporation. This is because the NALDA databases would not be able

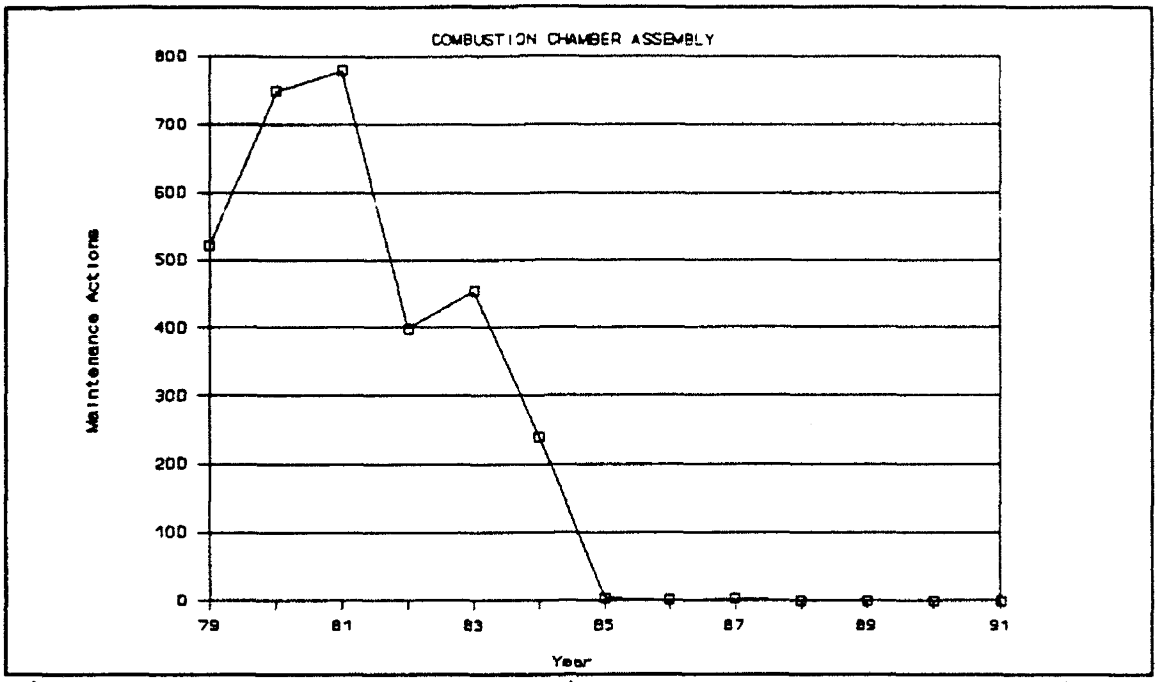

Figure 3 J52-P-8C Combustion Chamber Assembly Failure Maintenance Actions.

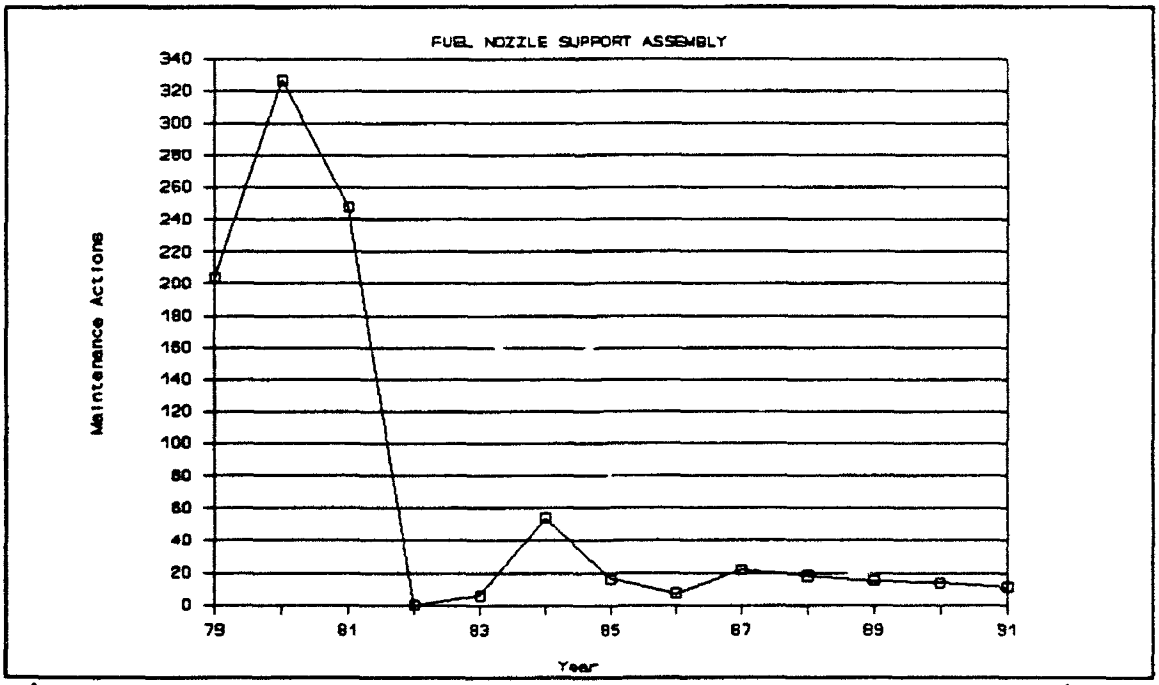

Figure 4 J52-P-8C Fuel Nozzle Support Assembly Failure Maintenance Actions.

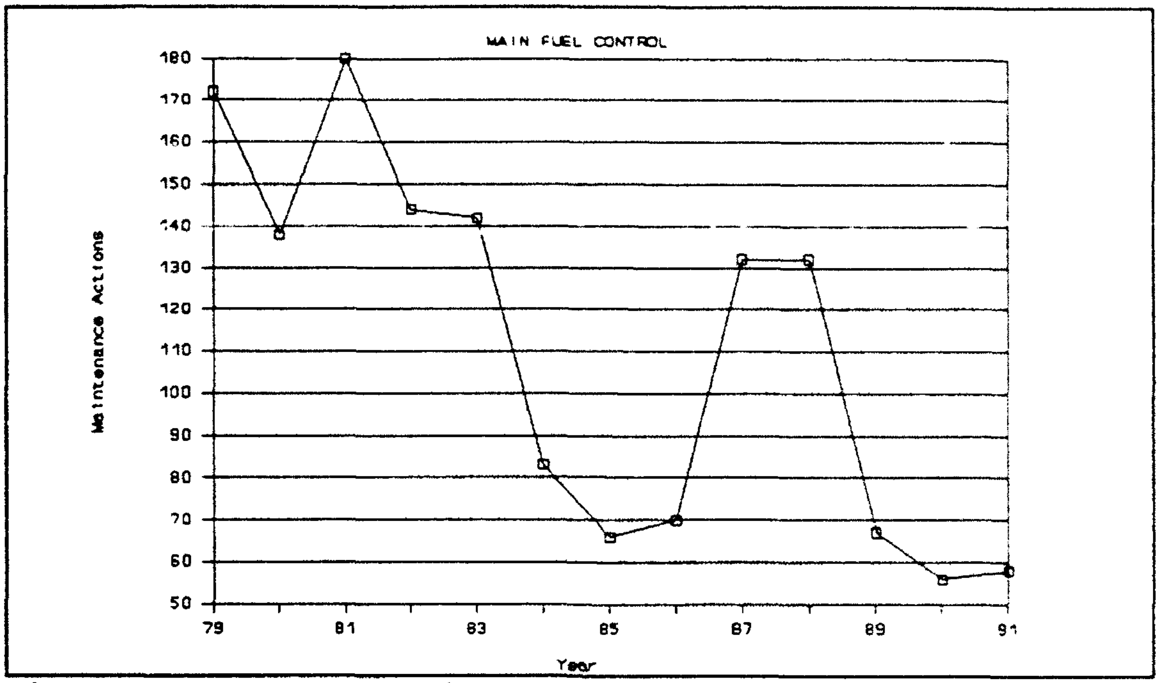

Figure 5 J52-P-8C Main Fuel Control Failure Maintenance Actions.

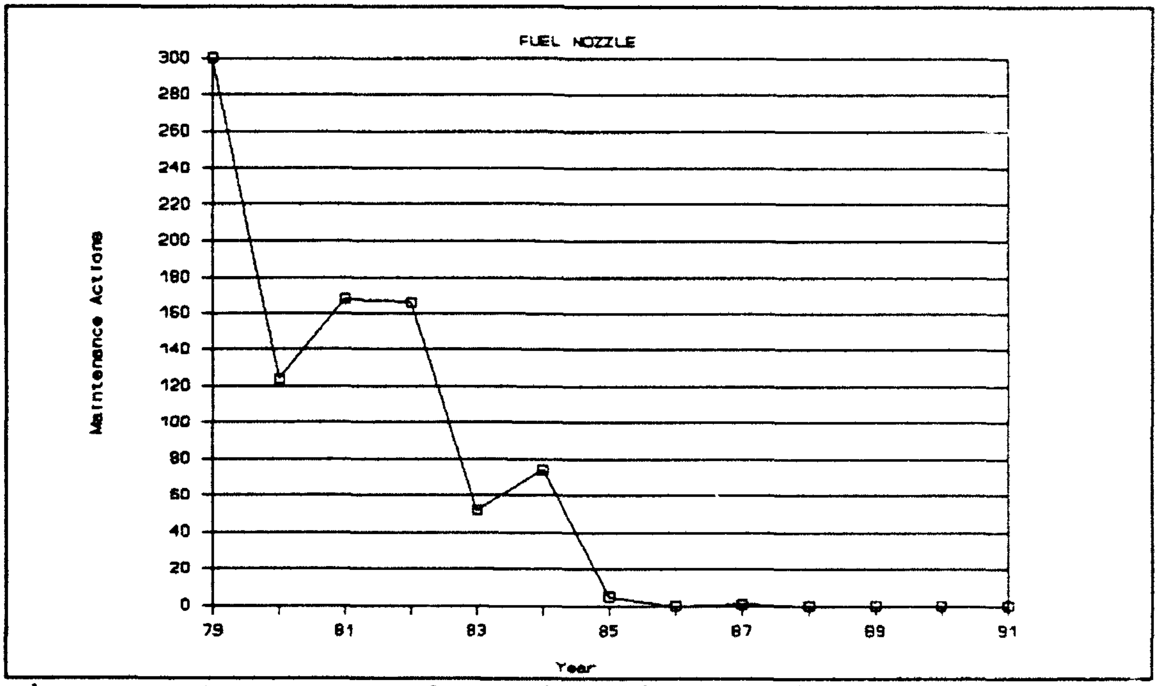

Figure 6 J52-P-8C Fuel Nozzle Failure Maintenance Actions.

to isolate the 154 engines being analyzed in this study out of a total population of 1140.

3. Detecting Malfunction Trends

It was apparent a new approach to the methodology proposed in Chapter III had to be formulated. At this same point in the analysis, Pratt & Whitney J52 Project Engineer Bob Barrett was consulted in a final attempt to link any PPCs to the candidate components. Mr. Barrett pointed out that the analysis should not be limited to PPCs. There are two other sources of information which could prove beneficial. They are Power Plant Bulletins (PPBs) and Engineering Project Descriptions (EPDs). PPBs are issued for a one-time inspection to determine whether a given condition exists and specifies what action shall be taken if the condition is found [Ref. 16]. These bulletins often provide a catalyst for EPDs.

> Whenever evaluation of a reported engine problem indicates corrective action is required, an Engineering Project Description (EPD)...is prepared. The EPD... contains a brief description of the problem and a general description of proposed corrective actions. Accepted EPDs...result in the development of corrective measures which are reported in related Engineering Change Proposals (ECPs). When accepted by the USN for its engines, ECPs result in the issuance of a Power Plant Change.[Ref. 13]

These two sources of information provided the turning point for this study.

The new approach adopted involved analyzing the symptoms rather than the fix (PPC). ECIFR report JETMF34P, titled "Major Causes for Maintenance on the High Maintenance Action Work Unit Codes", lists the nature of the malfunction and number of maintenance actions attributed to the malfunction. This report was scrutinized for the major causes of failure maintenance actions for the candidate components.

It was noted that "cracked, crazed" was the predominant malfunction for the Combustion Chamber Assembly in the baseline years (1979 and 1980). The baseline years also revealed that the majority of malfunctions experienced by both the Fuel Nozzle Support Assembly and the Fuel Nozzle were attributed to a "defective spray pattern". Mr. Barrett confirmed a theory suggested by the author that the malfunctions cited for the Fuel Nozzle Support Assembly and Fuel Nozzle could have been attributed to either one. It is often a subjective call by the operator/maintenanceman which component to attribute the "defective spray pattern" malfunction. Therefore, data for the Fuel Nozzle Support Assembly and the Fuel Nozzle were combined and are referred to henceforth as the Fuel Nozzle Support Assembly.[Ref. 17]

B. ECP/EPD ANALYSIS

Mr. Barrett searched his J52 EPD files to see if Pratt & Whitney had previously conducted any RDT&E relating to the Combustion Chamber Assembly or the Fuel Nozzle Support Assembly. The EPD files revealed that previous RDT&E resulted in an Engineering Change Proposal (ECP number 426052), dated 20 April 1979, which proposed a change to the Fuel Nozzle Support Assembly. This change featured an improved lockwasher for the Fuel Nozzle Retaining Nut[Ref. 18]. The question remained as to whether this improvement actually resolved the "defective spray pattern" malfunction.

1. Malfunction and Component Correlation

A link had to be established between the Fuel Nozzle Nut and the "defective spray pattern" malfunction. The PPB section of the PPC to ECP cross reference file was then reviewed for applicable PPBs. PPB 182 was identified in the listing as being issued for a torque check of fuel nozzle retaining nut in replacement nozzles. A FAX copy of PPB 182 was then obtained by the author from NAS Whidbey Island, a major west coast site for J52s. This bulletin was originally issued in April 1977. It required all J52 P-8B and P-408 organizational, intermediate and depot activities conduct a torque inspection of the *Fuel Nozzle Retaining Nut in* Replacement Nozzles overhauled by Naval Air Rework Facility Jacksonville, Florida. Paragraph 10C verified the correlation between Fuel Nozzle Retaining Nuts and "defective spray pattern".

> Disassemble engine as required to gain access to the fuel nozzle and support assys...any movement of the nut is cause for rejection of the fuel nozzle and support assy. Engines found to contain one or more loose fuel nuts should be inspected for damage resulting from improper spray patterns.[Ref. 19]

Mr. Barrett was then asked by the author to identify some telltale signs of a "defective spray pattern" in an engine. An interesting observation was made by Mr. Barrett at this time. He noted that the "cracked, crazed" malfunction of the Combustion Chamber Assembly could be related to the "defective spray pattern" of the Fuel Nozzle Support Assembly. Figure 7 was plotted in an attempt to connect the two problems and their resolution. The Figure suggests a close connection.

2. ECP/EPD Review

A relationship between the "defective spray pattern" and the loose Fuel Retaining Nut on the Fuel Nozzle Support Assembly had now been established. Next, the list of PPBs and PPCs was once again reviewed to see if any were issued relating to this component. Again, there were none. Further scrutiny of the ECP document revealed that the change proposal stipulated the change was to take place on the production line. Additional discussions with Mr. Barrett of Pratt &

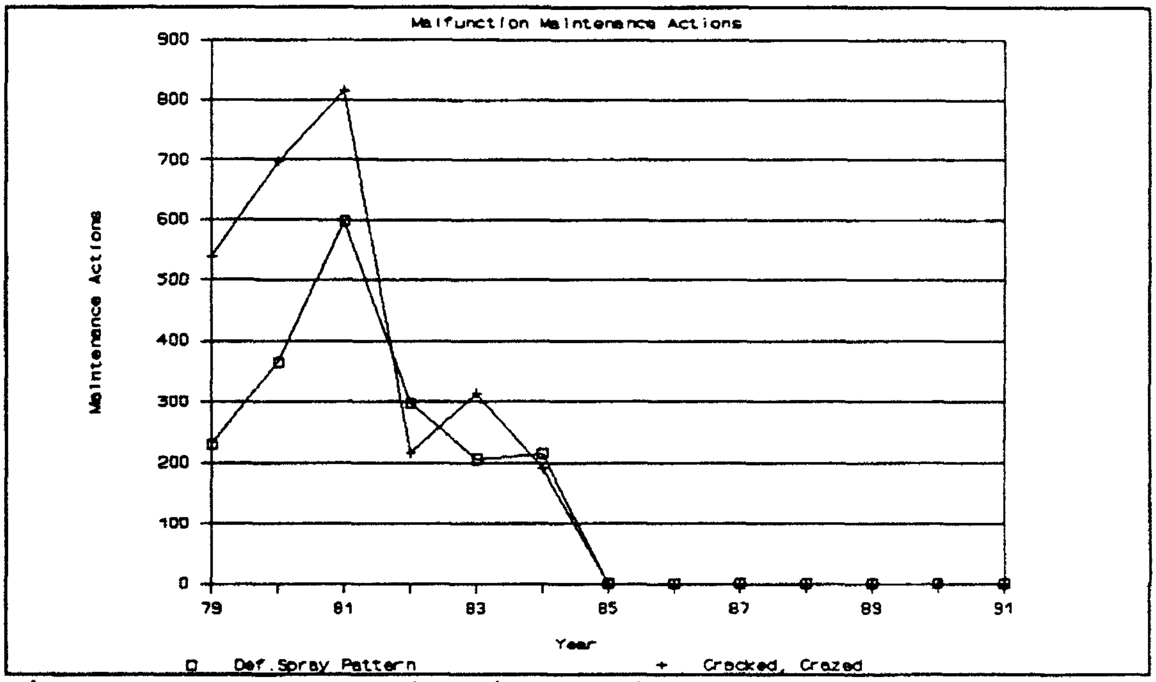

Figure 7 J52-P-8C Combustion Chamber Assembly and Fuel Nozzle Support Assembly Malfunctions.

Whitney suggested that, in addition to incorporation on the production line, the change could also have been incorporated on engines in the Fleet whenever one was returned to the Depot level for overhaul. This suggestion was confirmed with NADEP Jacksonville, Florida. In approximately 1981, NADEP Jacksonville began incorporating the redesigned lockwashers for the Fuel Nozzle Nut whenever an engine came in for any type of overhaul.[Ref. 17; 20]

Once the correlation had been established, the Naval Air Systems Command (NAVAIR) was called to determine the amount of CIP funds that had been expended in this effort. Unfortunately, the current records had only information back as far as 1984. However, Linda Boyd, NAVAIR contract specialist, confirmed that this methodology can determine the amount of CIP expenditures with an ECP issued after 1984.[Ref. 21]

C. OBSERVATIONS

The methodology initially incorporated was an overly simplistic attempt to correlate improved maintenance parameters to CIP funding. The majority of the roadblocks revolved around Power Plant Changes (PPCs). The first roadblock encountered involved trying to tie the improved maintenance parameters directly to a specific Power Plant Change (PPC) using only the Pratt & Whitney ECP to PPC cross reference file. This proved very difficult because the PPC subject line was limited to a very brief description.

The very nature of PPC incorporation presented the next roadblock and again prevented the author from directly tieing the improved maintenance parameters to a PPC. Sometimes the incorporation of PPCs is not very ordered. They are often incorporated only during scheduled Depot overhauls. However, if, when being overhauled, there are no APN dollars released for parts kits, spares etc., then incorporation gets delayed until the next scheduled overhaul. It is not unusual for a PPC to be incorporated in excess of ten years after issue. Therefore, it was very difficult to merely ascertain the applicability of a PPC by virtue of its issue date.

This lead to the third roadblock of trying to determine the percentage of PPC incorporation in a given year with a specific population of engines. The NALDA database could only provide PPC incorporation data for the entire engine population. Limiting this study to a number of engines less than the entire population precluded the author from obtaining this information.

These problems forced the author to rethink his methodology. The following are the step by step procedures suggested by the author:

1. Determine the appropriate maintenance parameter to be measured.

For this study the Failure Maintenance Action parameter was selected.

2. Determine the components to be evaluated.

ECIFR report JETMF34N, titled "Maintenance Actions and Manhours by Work Unit Code", lists the components that account for 80% of all maintenance actions. From this list, initially consider only those that have a significant amount of FMAs attributed to them.

3. Plot over an established time frame the selected maintenance parameter for the selected components.

If an improving trend is noted, the component remains a candidate for further study.

4. Review PPCs to determine if one can be linked to the component being analyzed.

5. Whether or not a link can be established, analyze the major causes of failure for each candidate component and plot them over the established time frame.

ECIFR report JETMF34P, titled "Major Causes for Maintenance on the High Maintenance Action Work Unit Codes", lists the nature of the malfunction and number of maintenance actions attributed to the malfunction. If an improving trend is noted, the component remains a candidate for further study.

6. Review ECPs and EPDs to determine if any RDT&E relating to the components being studied had been conducted.

7. Determine if the RDT&E efforts contributed to resolving the malfunctions causes.

Engineers at the cognizant manufacturing plant are a good source for this information.

8. If the RDT&E efforts contributed to the malfunction resolution, determine how the correction was incorporated.

The ECP is a good reference to determine if the change was incorporated via a PPC, on the production line, or by attrition at the Depot.

9. Obtain the contract number for the ECP and determine the amount of CIP funding that was expended for the effort.

D. VALIDATION OF METHODOLOGY AND CONCLUSIONS

To validate the methodology, two more components were analyzed. These were the next two in the descending order of FMA occurrence(Step 2). The Main Fuel Control had been previously eliminated as a candidate component because of the erratic behavior of the plot that occurred between 1986 through 1989(see Figure 5). However, it was reconsidered for analysis at this time(Step 3).

The Pratt & Whitney PPC to ECP cross reference file was perused to determine if any PPCs had been issued that would impact the Main Fuel Control(Step 4). Power Plant Changes 264 and 286 were identified as affecting the Main Fuel Control.

After looking through ECIFR report JETMF34P(Step 5) and conferring with Pratt & Whitney engineers, it was concluded that the malfunctions identified could not be linked to the areas addressed in the two PPCs. Therefore, it was again eliminated as a candidate component.

The next component analyzed was the Fuel Pump. Its FMAs were plotted over time and are displayed in Figure 8. Because

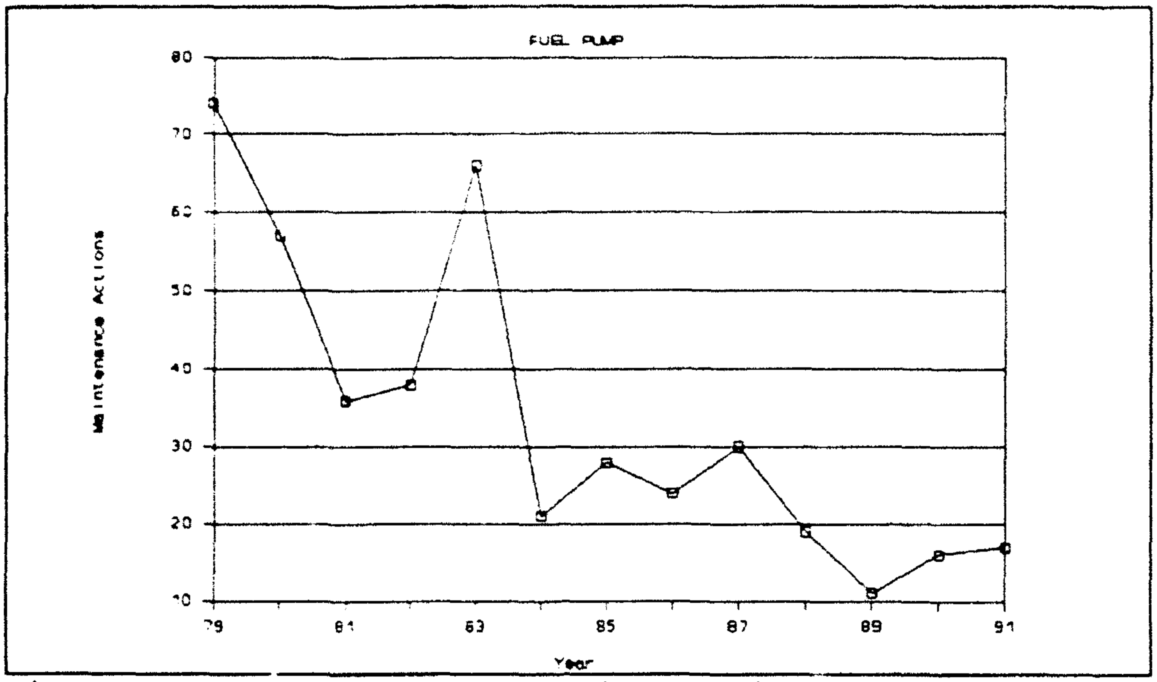

Figure 8 J52-P-8C Fuel Pump Failure Maintenance Actions.

of its decreasing trend, it is considered a candidate for further study(Step 3).

The Pratt & Whitney PPC to ECP cross reference file was again perused to determine if any PPCs had been issued that would impact the Fuel Pump(Step 4). "Main fuel pump internal spline wear" was the subject title in the cross reference file identifying PPC 268 as a possible connection to the candidate component.

ECIFR report JETMF34P was then reviewed and the causes for malfunction for the Fuel Pump were plotted over time. The malfunction "worn, stripped, chaffed, frayed" was the only cause with a decreasing trend and is displayed in Figure 9. Therefore the component remained a candidate for further study(Step 5). Malfunction data for 1981, 82, 88 and 90 is

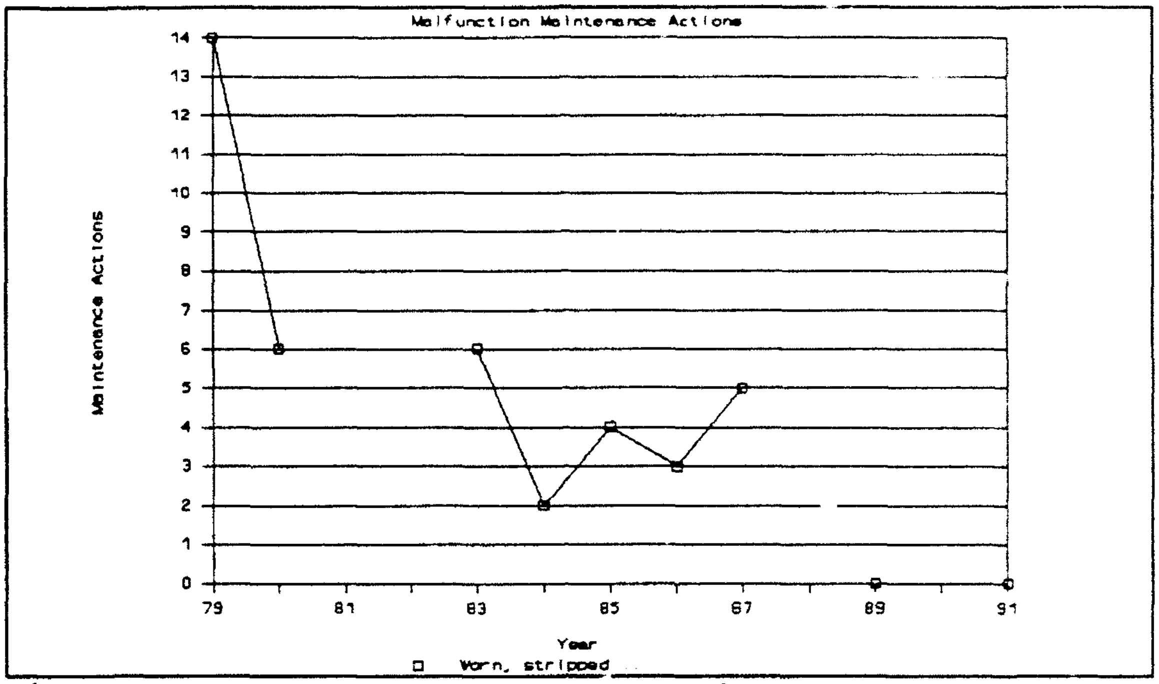

Figure 9 J52-P-8C Fuel Pump Malfunction.

not included in the graph because ECIFR report JETMF34P lists the major causes for maintenance for only the top 10 High Maintenance Action components. The Fuel Pump was not one of the top 10 High Maintenance Action components for those years.

Pratt & Whitney was then called to determine which ECP was responsible for issuing PPC 268. ECP number 426626 was identified and pertinent sections of the ECP were FAXed to the author for review(Step 6). Again, a link had to be established between the "worn, stripped, chaffed, frayed" malfunction and the Fuel Pump. PPB number 189, issued in December 1978, was identified in the PPC to ECP cross reference file as being issued to perform an inspection to determine Fuel Pump spline "wear". A FAXed copy of PPB 189 was received from NADEP Jacksonville.

> Purpose: To inspect J52 engine Fuel Pump drive couplings to determine the presence and magnitude of spline wear.[Ref. 22]

Once again a link had been established between the malfunction and the candidate component. In this case, the resolution to the malfunction was attributed to a PPC(Steps 7 and 8).

Although the number of maintenance actions attributed to this malfunction is relatively low compared to the observed malfunctions of the other components, its critical safety-of-flight attributes cannot be ignored. Engineering Change Proposal 426626 cited the following example:

> In August 1979 a P-8B powered A-6E (BuNo 155636) operating out of MCAS Cherry Point, suffered a port engine flameout when increasing power prior to takeoff due to pump spline wearout.[Ref. 23]

The contract for ECP 426626, dated 20 October 1980, could not be referenced for the same reason previously cited; i.e., no ECP records prior to 1984 are maintained at NAVAIR(Step 9).

This validation confirms the author's opinion that the methodology is sound and it provides a correlation between the J52 Engine Component Improvement Program and improved maintenance parameters at the component level.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The main objective of this thesis was to determine if a correlation exists between CIP expenditures and observed improved maintenance parameters at the component level.

To begin this analysis, the author had to become educated on the Component Improvement Program (CIP). Chapter II provided the background and the role CIP has played since its inception. In addition, Chapter II outlined CIP objectives, functions and management. Chapter III addressed the initial methodology to determine the correlation objective. Chapter IV incorporated this methodology for a specific J52 component and revised it as a consequence of the analysis process. The process was repeated for two more components to validate the methodology.

B. CONCLUSIONS

It is the conclusion of the author that the effects of CIP can be measured at the component level. The author concurs with previous research conducted that any attempt to measure effects at the engine level would prove fruitless. The engine as a system, which is comprised of hundreds of components aligned in series and parallel, would probably experience negligible change in measurable maintenance parameters as a result of an improved maintenance parameter of one component.[Ref. 3]

However, the approach proposed from the results of this study differed from previous research. The RDT&E efforts, outlined in the Engineering Project Descriptions (EPDs) and Engineering Change Proposals (ECPs), were referenced and heavily relied on for developing the methodology. Although determining the amount of CIP funds expended for the components examined in this thesis was not accomplished in this study, the method prescribed will assist future studies in determining CIP impact. In addition, future studies do not have to limit themselves to only the top ten degraders in a given year. It is appropriate to apply the procedures outlined in Chapter IV to any component deemed worthy of study.

It is the conclusion of the author that the methodology employed in this study should be beneficial in measuring the impact of CIP on other engines as well. Research of this nature is still needed to justify future CIP expenditures.

C. RECOMMENDATIONS

The J52 is a mature engine platform and provides an ideal history for further study of the impact of CIP expenditures on performance. It is recommended that historical data be assimilated and retained for future research efforts. Engine Program Managers should have immediate access to data regarding Engineering Change Proposals (ECPs), Engineering

Project Descriptions (EPDs) and their respective contracts. Maintaining hard copies of the actual ECP/EPD would be an adequate start. Further research in the area of CIP will help uncover additional data that should be maintained and easily referenced.

The NALDA databases and more specifically the ECIFR, proved invaluable tools throughout this study. Having immediate access to these databases would be very beneficial. The time lag in data request and data receipt is very time consuming and very inconvenient. It is recommended the Naval Postgraduate School send an individual for NALDA training. Training takes two weeks and is offered free of charge, not including TAD expenses. Training sites vary throughout the year. To obtain this training to become a NALDA user, contact NAVAVNMAINTOFF at the following phone numbers:

- Commercial (301) 863-4454
- Autovon 356-4454

Finally, it is recommended that follow-on studies be conducted to verify and improve the methodology developed in this thesis.

LIST OF REFERENCES

1. Butler, R.S., *Preliminary Analysis of the J-52 Aircraft Engine Component Improvement Program,* M.S. Thesis, Naval Postgraduate School, June 1992.

2. FAX received from Mr. Bob Barrett, code 731-12, Pratt & Whitney West Palm Beach, Florida containing J52 History; 27 October 1992.

3. Price, L.D. and Sudol, E.G., *Evaluation of Aircraft Turbine engine redesigns,* M.S. Thesis, Naval Postgraduate School; June 1990.

4. Borer, C.J., *An Analysis of the Aircraft Engine Component Improvement Program (CIP): A Life Cycle Cost Approach,* M.S. Thesis, Naval Postgraduate School, December 1990.

5. Davis, J.D., *An Appraisal of Cost Effectiveness Models Used in the Air Force and Navy Aircraft Engine Component Improvement Program,* M.S. Thesis, Naval Postgraduate School, December 1991.

6. Crowder, G.L., *Evaluation of the Cost Effectiveness Analysis Model Being Developed for the Component Improvement Programs of the Air Force and the Navy,* M.S. Thesis, Naval Postgraduate School, June 1992.

7. Nelson, J.R., *Policy Options for the Aircraft Engine Component Improvement Program,* Institute for Defense Analysis, Alexandria, Virginia, May 1987.

8. Department of Defense, DOD Instruction 3235.1, *Test and Evaluation of System Reliability, Availability and Maintainability,* March 1982.

9. Chief of Naval Operations, OPNAV Instruction 4790.2E, *Naval Aviation Maintenance Program, Volume III,* 1 January 1989.

10. Department of the Navy, NAVAIR Instruction 5200.35, *Policy, Guidelines and Responsibilities for the Administration of the Aircraft Engine Component Improvement Program (CIP),* 25 January 1982.

11. Chief of Naval Operations UNCLASSIFIED Memorandum Ser 00/00500214 to All Flag Officers, Subject: Total Quality Leadership, 13 August 1990.

12. Defense Systems Management College, *Defense Manufacturing Management; Guide for Program Managers, April 1989.*

13. Department of the Navy, NAVAIR Instruction 13700.14, *Aircraft Engine Component Improvement Program (CIP) for Foreign Military Sales; Policy for NAVAIR Implementation of,* 2 February 1981.

14. Naval Aviation Maintenance Office NALDA Overview and General Information, 1 January 1991.

15. Naval Air Systems Command, *Engine Component Improvement Feedback Report,* Prepared by Naval Weapons Engineering Support Activity, Washington, D.C., 17 March 1989.

16. Telephone conversation between Ms. Maxine Newbury, code 04A, AIMD NAS Whidbey Island, Washington and the author, 7 December 1992.

17. Telephone conversation between Mr. Bob Barrett, code 731-12, Pratt & Whitney, West Palm Beach, Florida and the author, 3 December 1992.

18. Pratt & Whitney Aircraft Group, Engineering Change Proposal Number 426052; 20 April 1979.

19. Naval Air Rework Facility, Jacksonville, Florida UNCLASSIFIED Naval Message 152200Z to J52 Maintenance Activities, Subject: J52 Power Plant Bulletin (PPB) Nr 182; Fuel Nozzle Retaining Nut; Torque Inspection, April 1977.

20. Telephone conversation between Mr. Randy Griffith, code 33310, NADEP Jacksonville, Florida and the author, 4 December 1992.

21. Telephone conversation between Ms. Linda Boyd, code 536P4, NAVAIRSYSCOM, Washington, D.C. and the author, 8 December 1992.

22. Naval Air Rework Facility, Jacksonville, Florida UNCLASSIFIED Naval Message 121433Z DEC 78, to J52 Maintenance Activities, Subject: J52 Power Plant Bulletin (PPB) NR 189; Inspection of Fuel Pump Drive Couplings for Spline Wear, December 1978

23. Pratt & Whitney Aircraft, Engineering Change Proposal Number 426626; 20 October 1980.

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