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Employing Organizational Modeling and Simulation to Reduce F/A-18E/F F414 Engine Maintenance Time

15 December 2006

by

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Prepared for: Naval Postgraduate School, Monterey, California 93943

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Abstract

The goal of this project was to determine how to decrease the F414 engine throughput time at the Aircraft intermediate Maintenance Division (AIMD) at Naval Air Station (NAS) Lemoore, California. To achieve this goal, organizational modeling was employed to evaluate how changes to the organizational structure of the Lemoore AIMD affected engine throughput time. Data collected to build the organizational model was acquired via interviews with AIMD personnel. A baseline model of the AIMD organization was developed for the purpose of modeling the organization's current structure and performance. The actual, real-world duration required to conduct F414 maintenance was compared to the duration predicted by the model and determined to be within 3%. Once confidence was gained that the baseline model accurately depicted the organization's actual F414 maintenance performance, modifications or interventions to the model were made to evaluate how organizational changes would affect F414 maintenance duration. Interventions included paralleling the tasks associated with accomplishing administrative paperwork when initially receiving the F414 engine, and tasks associated with on-engine maintenance, combining personnel positions, adding personnel, and modifying the duration and frequency of meetings. The modeled results of these modifications indicated that the paralleling effort significantly decreased the F414 maintenance duration; likewise, decreasing meeting frequency and slightly increasing duration also facilitated a decreased duration.

Keywords: AIR*Speed*, Organizational Modeling, Simulation, Cycle-time, Virtual Design Team (VDT), Aviation Intermediate Maintenance Activity (AIMD), F414 engine

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Last but certainly not least, the authors wish to especially thank Karin Hagan, Amy Slack and Isabelle Slack. Their love and support through long nights and longer weekends of research was the fuel that kept the engines of this study running strong. The family unit provides an incredible foundation for growth and opportunity. The devotion and support granted by our families throughout this endeavor was absolutely essential for us to accomplish this research effort.

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Major Joel Hagan received a Masters of Business Administration degree from the Naval Postgraduate School in December of 2006. Major Hagan also has a Masters of Science degree in Aeronautical Engineering from the Air Force Institute of Technology, and is a graduate of the Air Force Test Pilot School. He has over 15 years of Department of Defense acquisition experience with an emphasis in Test and Evaluation. His recent experience includes developmental flight test of the F-22 aircraft at Edwards Air Force Base and threat systems analysis while assigned to the Secretary of the Air Force Rapid Capabilities Office at the Pentagon.

Captain William Slack received a Masters of Business Administration degree from the Naval Postgraduate School in December 2006. He enlisted in the United States Marine Corps in 1995 as an infantryman. He accepted a commission as a 2ndLt upon receiving a Bachelors of Business Administration from the University of Central Arkansas with emphasis on Management in 1999. He attended the Basic Aviation Supply Officers Course at the Navy Supply Corps School in Athens, Georgia. As an Aviation Supply Officer, Captain Slack has served with the Marine Aviation Logistics Squadron 36 in Okinawa Japan and the Marine Aviation Logistics Squadron 24 in Kaneohe Bay, Hawaii. He is currently assigned to Headquarters Marine Logistics Base, Albany, GA.

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I. Introduction

A. Background

The Aircraft Intermediate Maintenance Division (AIMD) at Naval Air Station (NAS) Lemoore, CA—hereafter referred to as AIMD Lemoore—has worked aggressively to employ many of the tools of the Enterprise AIR*Speed* (AIR*Speed*) program, a component of the Naval Aviation Readiness Integrated Improvement Program (NAVRIIP) enabling the operationalizing of cost-wise readiness across the naval aviation enterprise.[1] AIMD Lemoore has achieved a number of process-improvement successes under AIR*Speed* by utilizing the program's prescribed tools of Theory of Constraints (TOC), Lean, and Six Sigma. In an effort to achieve further successes, AIMD Lemoore teamed with the Naval Postgraduate School's (NPS) Graduate School of Business and Public Policy (GSBPP) to explore the tool of organizational modeling as a method for identifying potential modifications to the organization, which may, as a result, improve AIMD performance. Specifically, AIMD Lemoore was interested in identifying options for decreasing maintenance throughput time of the F414, the jet engine used to power the F/A-18E/F aircraft. This paper presents the results of an NPS GSBPP program to model the AIMD Lemoore F414 maintenance organization (hereafter referred to as the 400 Division) for the purpose of identifying potential alternate organizational constructs which may reduce F414 throughput time.

B. Research Objective

The overall objective of this effort was to provide the 400 Division with recommendations on how its organization may be restructured in order to decrease F414 maintenance cycle-time. To meet this objective, NPS developed an

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[1] Naval Air Forces Public Affairs Office, "Enterprise AIRSpeed," Available from http://www.cnaf.navy.mil/AIRSpeed/
main.asp?ItemID=402; accessed 16 January 2006.

organizational model of the 400 Division which accurately describes its current F414 maintenance process. This model was then modified, a process termed "intervention," to characterize the benefits of such interventions to the reduction of F414 maintenance cycle-time.

Along with the objective of improving F414 maintenance at NAS Lemoore, a broader objective of this research was to take a first step toward a much more complex program to assess the impact of the AIR*Speed* program on AIMD's throughout the Navy. Modeling an AIMD before and after the implementation of AIR*Speed* would significantly enhance the ability to quantify, both in terms of dollars and performance, the impact of the AIR*Speed* program.

C. Scope

This MBA project only considered the portion of the NAS Lemoore AIMD 400 Division that accomplishes F414 maintenance. It considered only tasks associated with maintenance efforts—starting from receipt of the engine by the 400 Division to the point at which the engine is determined to be ready for issue (RFI). Although other maintenance work and collateral duties not directly associated with F414 maintenance were not directly modeled, generic, non-core tasks were modeled which required personnel to perform functions other than F414 maintenance. By doing so, limitations on the 400 Division personnel's time to accomplish F414 maintenance were accurately characterized. The scope of this effort was further limited by modeling the maintenance of only a single engine.

This project modeled the AIMD 400 Division post AIR*Speed* implementation. No attempt was made to model or compare with pre-AIR*Speed* operations. Future research may be needed to address these issues.

Modeling of the 400 Division was accomplished using the POWer 1.1.6 software developed by Dr. Raymod E. Levitt and the Virtual Design Team at Stanford University. The capabilities and limitations inherent in this software at the time of this study were employed to model the 400 Division. No attempt was made to modify this software.

Once the organizational model of the 400 Division was developed, only modifications to the properties of the components of the model (such as actors, tasks, etc.) were made when identifying how the 400 Division may be restructured in order to decrease F414 maintenance cycle-time. No attempt was made to extract information from the model not normally available through standard POWer interfaces and outputs such as Gantt, Backlog, and Functional Risk charts.

No attempts were made to compare simulated results with actual performance. Future research is needed to track AIMD performance post-implementation of selected interventions and to compare it to predicted performance by the simulator.

D. Methodology

The methodology followed in this MBA project is divided into five major phases listed below.

1. A literature review was conducted to first gain a broad understanding of organizational modeling and then to gain a more specific understanding of the organizational modeling techniques employed by the Virtual Design Team at Stanford University, techniques which underpin the POWer software employed in this research. This literature review established the necessary base on which to begin development of the 400 Division organizational model.

2. Several months were spent becoming familiar with the POWer software. Tutorials designed to familiarize new users with the software were accomplished. In addition, in-depth research into understanding the capabilities and limitations of the software was explored. Finally, the POWer users' manual was thoroughly reviewed to understand the properties associated with the various software elements such as *actors*, *tasks*, *re-work links*, etc., and how they could be used to model the 400 Division F414 maintenance operation.

3. Three site visits to the NAS Lemoore AIMD 400 Division were conducted, which consisted of multiple interviews of personnel ranging

from the AIMD officer in charge (OIC) to junior enlisted personnel conducting daily maintenance tasks on the F414 engines. Information was collected during these interviews to properly structure the 400 Division model in POWer and accurately characterize the properties of each of the software elements.

4. A model of the 400 Division was developed using the information collected from site visits as well as numerous phone and e-mail exchanges. Through these exchanges, properties of the modeled elements were progressively modified until the model accurately characterized the operation of the 400 Division F414 maintenance process. This was considered the baseline model.

5. Based on recommendations from 400 Division personnel, as well as insight gained by NPS personnel into 400 Division operations, modifications (also termed "interventions") to the 400 Division organization which had potential for decreasing F414 maintenance throughput were identified. Each intervention was separately modeled by altering the baseline 400 Division model. Comparisons between this modified model and the baseline model were made to determine the utility of each intervention in terms of decreasing F414 maintenance throughput. Finally, the baseline model was modified to include all individual interventions which were determined to have utility in decreasing F414 maintenance throughput. This model which employed a combination of interventions was also compared to the baseline to determine its utility.

E. Organization of Research

This MBA project is organized into five chapters. The first chapter is an introduction of the project which describes the background, the objective, scope, and methodology. The second chapter presents a literature search which provides a basis for understanding both organizational modeling in general and techniques specific to the POWer software developed by the Stanford University Virtual Design Team employed in this project. The third chapter discusses the methodology for conducting this modeling effort. It begins with a description of the NAS Lemoore AIMD 400 Division, and then proceeds to discuss how the 400 Division F414 maintenance process was modeled. The fourth chapter discusses the results of the effort to model the current 400 Division F414 maintenance process, as well as the results of the individual interventions modeled in an effort to determine how to modify the 400 Division in order to decrease F414 throughput time. Chapter IV also presents the results of the combined intervention. Finally, Chapter V presents conclusions that can be made regarding this project, and recommendations for how the 400 Division may want to restructure its organization to decrease F414 maintenance throughput time.

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II. Literature Review

A. Computational Organizational Modeling

Computational organizational modeling, a new predictive modeling technique, has come of age. This tool has the potential to help assess how changes to an organization (implemented as a result of shifts in management philosophy, such as Total Quality Management) may or may not benefit the organization's performance.[2] Computational organizational modeling enables one to develop a computer model of an organization and predict how changes to that organization will affect its overall performance. By developing such a model, organizations have the ability to "test" how various organizational structures and management techniques may affect the quality of their output. Computational organizational modeling is different from many other quality-improvement techniques in that it does not focus on the production process, but instead on the organizational structure that manages that production process and on the information flow through that organization necessary to execute the production process. By improving both the quality of the organization and the flow of information through it, the quality of the organization's output can be improved.

Computational organizational modeling extends beyond traditional organizational theories which describe organizations as a whole, trying to assess the effect of inputs and changes on an organization—often in terms of broad generalizations.[3] In contrast, computational organizational modeling assesses the performance of an organization at a detailed level—considering discrete organizational elements such as individual personnel, specific tasks and meetings. It

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[2] Raymond E. Levitt, "Computational Modeling of Organizations Comes of Age." Computational & Mathematical Organization Theory 10 (2004): 127-145.

[3] John C. Kunz, Raymond E. Levitt and Yan Jin, "The Virtual Design Team: A Computational Simulation Model of Project Organization." Communications of the Association for Computing Machinery 41, no. 11 (1998): 84-92.

then aggregates the results of the interactions between these elements to define an overall effect of inputs or changes to an organization. The technique of organizational modeling is analogous to modeling employed in the natural sciences such as finite element modeling (FEM) or computational fluid dynamics (CFD) modeling. Finite element modeling and CFD modeling both break down the larger structure being modeled into smaller elements, with each element having its own characteristics (such as modulus of elasticity, density, viscosity, etc.). With an understanding of how these elements interact, the overall effect of a force or moment on the larger structure can be assessed by determining the effect of the force on the various elements and, subsequently, each element on the other. In a similar way, organizational modeling is accomplished by breaking down an organization into smaller elements such as tasks, people, and communication methods (each with their own characteristics such as time required to accomplish a task, experience of workers, clarity of communication, etc.), and assessing how changes to an organization may affect each element and, subsequently, how those elements in turn affect the overall organizational performance.[4]

This detailed level of organizational characterization allows managers to design their organization in the same way engineers design bridges or buildings. Organizational modeling allows managers to evaluate, in a virtual environment, the effects of organizational structures in order to identify the optimal structure—resulting in the best output—for their company. It allows them to identify which personnel in their organization have the greatest potential for being over-tasked and when this over-tasking will occur. Organizational modeling also allows managers to identify which tasks have the highest probability for taking longer than planned due to limitations imposed by the organizational structure.

Organizational modeling is not only useful in a proactive sense; it can also be used retroactively by modifying the structure of existing organizations that wish to

[4] Raymond E. Levitt, "Computational Modeling," 127-145.

improve their output. Although organizational modeling would ideally be used to design an organization from the ground up, due to its infancy, most of the successes with organizational modeling have resulted from redesigning organizations. Employing the tools of organizational modeling, managers can perform multiple "what-if" analyses to assess how changes in personnel, task ordering, even meeting duration, may affect overall organizational performance. It's not difficult to see the benefits of such a capability. Gaining similar insight without the aid of a modeling tool would be impossible. Organizations could not withstand the dynamics of change after change simply to determine what works best and what does not. In the past, determining which would work and which would not was left up to high-priced executives with incredible insight—a characteristic not common to all of us. Organizational modeling allows all managers, not just those with super-human abilities, to assess how best to structure their organization to optimize performance.

Though building or bridge designs benefit from the employment of FEM and CFD modeling to optimize their structures, organizations are far more complicated. As a result, a number of different methods for conducting organizational modeling have been developed. Professor Richard Burton, for example, has developed the OrgCon model which employs a rule-based engine that points out misfits between an organization's goals and how the organization is being managed.[5] Another model with a slightly narrower focus is Masuch and Lapotin's AAISS which specifically models clerical tasks. This model is more detailed and employs artificial intelligence algorithms.[6] POWer, developed by Dr. Raymond Levitt and the Virtual Design Team (VDT) at Stanford University, is the third model, and that which was employed in this MBA project,.

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[5] Samuelson, Douglas A, "Designing Organizations," ORMS Today (December 2000): 3.

[6] John C. Kunz, Raymond E. Levitt and Yan Jin, "The Virtual Design Team," 84-92.

B. Virtual Design Team—POWer

POWer is based on macro-contingency theory and describes work in terms of information flow.[7] Predecessor work that led to the development of POWer was initiated under a 1992 National Science Foundation grant to develop a method for modeling fast-paced organizations. This initial work has continued under multiple other grants until now.[8]

POWer is based on the premise that no matter what business an organization is in, be it production of widgets, design of skyscrapers, or providing hotel rooms, one thing they all have in common is they must process information effectively to do their job well.[9]

1. Theoretical Basis for POWer

The assessment that organizations can be modeled in terms of information flow is based on J.R. Galbraith's theory of information processing. According to Galbraith, information transfer and processing is dynamic. Due to the complexity of information and, many times, the sheer amount of it, there are often instances when an individual is unable to process all of the information he is given because he does not have the skill or experience to make decisions quickly enough. As a result, a problem, or as Galbraith defines it, an *exception*, is created. Exceptions are common in today's fast-paced world in which we are inundated with requests from e-mail, voice mail, cell phones, black-berries, etc. In Galbraith's view, organizations are modeled primarily as hierarchies, and it's through these hierarchies that exceptions are passed up the "chain of command" to be handled by more experienced individuals. Along with the hierarchical structure by which exceptions

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[7] Jan Thomsen, John C. Kunz, Raymond E. Levitt and Clifford I. Nass, A Proposed Trajectory of Validation Experiments for Computational Emulation Models of Organizations, 1998, Stanford University Center for Integrated Facility Engineering, Working Paper #47.

[8] Mark Nissen and Raymond Levitt, Toward Simulation Models of Knowledge-Intensive Work Processes, 2002, Stanford University Center For Integrated Facility Engineering, Working Paper #77.

[9] John C. Kunz, Raymond E. Levitt and Yan Jin, "The Virtual Design Team," 84-92.

are passed, Galbraith notes there are also exchanges of information between individuals on equal levels in an organization. These information exchanges can also be used to handle exceptions, and are often more effective than those moving up the chain of command since they tend less to overload upper level managers and create additional exceptions.[10]

Along with Galbraith's views on information processing, POWer employs a number of heuristics to determine how long a task will take and the quality of the decision an individual makes. For example, with respect to duration, tasks will take longer to accomplish if the individual assigned to a task does not have the appropriate skills or experience required to accomplish a task. In terms of information processing, the individual will often have to request others, either at his level or above him, make a decision that he is unable to make; this will take time. The individual to whom the request is being made may now be overloaded, which could create another exception at his level. Of course, once a decision is made, that information has to be passed back to the original individual who requested assistance. All of this communication and information transfer takes time.[11]

2 POWer Modeling Capability

It should be reassuring for individuals employing POWer as their method of organizational modeling that it has a solid theoretical basis. From a practical application point of view, of equal, if not greater, interest to managers employing POWer is what aspects of an organization POWer is capable of representing. The next section covers the components of an organization that can be modeled using this software.

An individual employing POWer is able to define a number of characteristics that apply to the overall organization, such as: its experience level, the degree of

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[10] J.R. Galbraith, Organizational Design (Reading, MA: Addison-Wesley, 1977).

[11] J.R. Galbraith, Organizational Design.

managerial centralization, the prevalence of informal communication versus formal, and the level of environmental influences that adversely impact an organization's ability to execute. Along with top-level organizational characteristics such as these, POWer is capable of modeling specific tasks an organization accomplishes in terms of a number of variables such as task duration, skills required to accomplish the task, and the priority of the task relative to others. Also modeled are actors: positions that must be filled to execute the project tasks. These actors are modeled in terms of the skill level and experience required for that position, where that position falls in term of hierarchical structure, and the amount of full-time personnel that are expected to fill this position. Finally, meetings are also modeled. Meetings are an important aspect of POWer's organizational modeling since they provide a reliable method for information transfer. Meetings are modeled in terms of their priority relative to other project activities, meeting start time, and duration.[12]

Along with the organizational components in the POWer software presented above, there are links that connect these components. There are successor links which connect tasks identifying precedence and any delays that must occur between the end of one task and the start of another. There are assignment links which assign primary and secondary responsibility for a task to actors. There are supervisory links which link actors and define a hierarchical order for which actors may make decision for other actors. There are meeting assignment links which identify which actors may attend which meetings. There are communication links which connect tasks when communication is required between these tasks for them to be accomplished successfully. There are rework links which link two tasks such that if the task that occurs later in the process is accomplished incorrectly, the earlier task must be re-accomplished—along with all other tasks between it and the task that was accomplished incorrectly.[13]

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[12] eProjectManagement (ePM™), LLC, SimVision® Users' Guide, 2003.

[13] eProjectManagement (ePM™), SimVision® Users' Guide.

Clearly, POWer presents managers with a flexible tool for modeling their organizations. Not all of the elements presented in this section need to be defined in a model. An organizational model can be very basic in structure while still presenting valuable insight into how a manager can structure an organization to optimize the quality of its output. Often, because organizational modeling is inherently far more complicated than other types of modeling (such as FEM or CFD), experience has shown that simpler organizational models are often most accurate and provide the greatest insight.

3. POWer Application

Through its detailed elements, POWer provides managers a great deal of flexibility and strength in modeling their organization to determine how best to structure it for optimal performance. Earlier versions of POWer have been employed by several organizations to accurately predict how organizational changes would affect quality and performance. Lockheed-Martin (L-M) is one example. In the late 1990s, L-M reorganized to become more "agile" by outsourcing certain manufacturing functions and decentralizing its engineering decision making. Virtual Design Team was used to assess these efforts in terms of product delivery time and quality. It was also used to predict how varying levels of design engineering support provided to subcontractors would affect their performance. Virtual Design Team predicted L-M would encounter problems resulting from the reorganization to include identifying specific tasks that would take longer than predicted due to the need for greater support by a particular vendor. Since the task identified was on the critical path, the model predicted an increase in schedule and cost. Several months into the program, the predicted problems materialized—along with the associated cost and schedule overruns.[14]

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[14] Jan Thomsen, John C. Kunz, Raymond E. Levitt and Clifford I. Nass, A Proposed Trajectory of Validation Experiments for Computational Emulation Models of Organizations, 1998, Stanford University Center for Integrated Facility Engineering, Working Paper #47.

Additional examples of such organizational modeling employing earlier versions of POWer include a second L-M case where organizational modeling was successfully used to decrease the development time for L-M's entrant into the Evolved Expendable Launch Vehicle (EELV) program by 80%. Earlier versions of POWer were also used by John Deere to decrease the time required to design new heavy machinery by 50% while also improving quality. Finally, the software was used by Norway's Stratfjord Sub-Sea Satellite Project to shorten development of a sub-sea oil production module from three to two years.[15]

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[15] Samuelson, Douglas A, "Designing Organizations," ORMS Today (December 2000): 3.

III. Methodology

A. Description of Modeled Organization

Three site visits to Naval Air Station Lemoore Aircraft Intermediate Maintenance Division, along with multiple phone and e-mail exchanges, were conducted by Naval Postgraduate School personnel in order to collect information on and understand the operations of the 400 Division and its F414 maintenance processes. The model of the 400 Division is made up of four sections.

Production control (PC) is the section in which all required paperwork for engine processing takes place. The section consists of personnel with Navy Enlisted Classifications (NEC) of AVIATION MAINTENANCE ADMINISTRATION MAN (AZ). The primary duties for the AZ are to screen logbooks, maintain AMES/SAMES databases, and to ensure that transactions are maintained using the Naval Aviation Logistics Command Management Information System (NALCOMIS). In addition, PC also consists of a billet position called a Controller. Although the Controller does not have a NEC, the position is staffed by a highly qualified person who is familiar with the engine repair process. This position's primary duties include: tracking daily progress of engine maintenance, ensuring that all sections within the 400 Division are working towards mutual maintenance goals and providing guidance on work priorities for the 400 Division.

The F414 Engine repair section (41V) is the section primarily responsible for the direct maintenance of the F414 engine. This section consists of personnel with the NEC of AVIATION ELECTRICIAN'S MATE (AD). The primary duties for the AD are: performing third-degree maintenance at the Intermediate Level on the F414-GE-400 Turbofan Jet Engine in support of the F/A-18E/F aircraft, troubleshooting various electronic control components—including the Full Authority Digital Electronic Control (FADEC), removing and replacing various engine modules, and performing required inspections.

The 400 Division also possesses an in-shop supply warehouse which houses an inventory of authorized modules. The supply (05E) section consists of personnel with the NEC of STOREKEEPER (SK). The primary duty of the SK is to maintain accountability for the inventory assigned to the 400 Division, ensure that material is properly screened for correct paperwork, and provide status for incoming/outgoing supply material within the 400 Division.

The test-cell section (450) houses the two static test-cell operations centers. This is where the engine is tested for correct operation. The 450 section consists of personnel with the NEC of AD. The primary functions of the AD include: operating the aircraft engine test cells and portable test facilities in order to test and evaluate engine performance, performing pre-run-up, inspection, power-plant test, recording, and evaluation of data, performing periodic maintenance, corrosion control and minor repair of aircraft engine test systems.

B. Modeled Characteristics

Development of the 400 Division F414 maintenance process model was similar to most model development in that tradeoffs were made when determining which characteristics of the actual organization to model, and which to forego. The greater the number of characteristics modeled, the closer the model will depict reality. At the same time, the time and cost associated with modeling characteristics increases with the number of characteristics modeled. This section describes the rationale for modeling to the degree of resolution described in the following section, Model Development.

1. Positions

The positions modeled were those that directly impacted the F414 maintenance process. These positions included those individuals who directly worked on the engine, those that accomplished the paperwork associated with engine maintenance, and those senior enlisted personnel who supervised these efforts. Modeling of leadership personnel above these positions was kept to the minimum individuals who would directly make decisions pertaining to F414 engine maintenance. When collecting data to develop this model, 400 Division personnel were queried to determine who was the individual authorized to resolve any questions associated directly with F414 maintenance actions such as tearing down the engine, testing the engine, etc. Only those individuals and their associated positions that were authorized to resolve questions regarding F414 maintenance were modeled.

Considering the focus of this model is assessing the flow of information and the handling of problems (or exceptions), great emphasis was placed on accurately modeling the time each position had to accomplish F414 maintenance tasks, and, thus, handle the associated flow of information. To accurately model time available to each position, the full-time equivalent or FTE for that position had to be accurately defined. To do so, 400 Division personnel assigned to each modeled position were questioned about how much time they spent working F414 tasks and how much time was spent working collateral duties such as training, writing performance appraisals, professional development activities, etc. Once this fraction was established, it was further divided by 6 to account for the fact that this model accounted for only a single engine when in fact the 400 Division has the capacity to conduct maintenance on 6 engines. Since maintenance on all 6 engines consists of the same tasks, it was determined acceptable to model a single engine with personnel having only 1/6 the available time. In addition, off-core tasks described below were added to a position's workload to occupy a servicemember's time when not conducting F414 maintenance.

2. Tasks

Initially, F414 maintenance tasks were modeled at a high level to keep the model simple. The resulting model resolution was not sufficient to accurately identify potential courses of action for decreasing F414 throughput time. Consequently, greater detail was added to the top-level tasks to better characterize the efforts accomplished by the 400 Division when conducting F414 maintenance. This effort benefited from previous AIR*Speed* efforts conducted by the 400 Division which specifically identified these detailed tasks, their durations, and personnel responsible.

When interviewing 400 Division personnel identifying the F414 maintenance tasks, two tasks were identified as taking significantly greater time than necessary: engine acceptance, and receipt of spare parts from the F414 depot in Jacksonville, FL. The task of accepting an engine from the operational squadrons should, ideally, take approximately 30 minutes. It is, on average, currently taking 14 days. This increased duration is the result of a number of factors ranging from simple data-entry errors to failure to keep logbooks current. The receipt of spare parts from the depot at Jacksonville should, ideally, occur just prior to the parts being needed for maintenance. Currently, certain F141 modules are readily available in the on-site supply warehouse, while the 400 Division is waiting several weeks to a month for other modules. The 400 Division is well aware that these two tasks are driving the long duration of their F414 maintenance process, and they are vigorously working with the operational units and the depot at Jacksonville to resolve them. With respect to this modeling effort, it was determined that certain organizational modifications could be made to the 400 Division which may positively impact the long-duration engine-Acceptance process. Consequently, the current average 14-day delay associated with this process was modeled. In contrast, there were no indications that potential organizational modifications identified by this study would positively impact the spare-parts delays. Consequently, these delays were not modeled. Instead, it was assumed that spare parts were available to maintain the engines.

3. Off-core Tasks

To ensure positions were continually occupied throughout the F414 maintenance process, as they would be in reality, off-core tasks were added to the model to simulate maintenance work personnel would be accomplishing other than maintenance of the single engine being modeled. A single off-core task was assigned to each position with varying durations depending on the configuration of the 400 Division being considered. The actual off-core task duration was set to ensure that the position assigned to the task was completed at the same time as the final F414 maintenance task was accomplished, or very soon thereafter. This ensures that the off-core tasks are not in the critical path.

4. Meetings

Meetings were accurately modeled primarily in terms of their duration and attendance. Only those meetings which directly affected F414 maintenance were modeled. Although 400 Division personnel attended meetings not modeled, it was assumed that no information associated with F414 maintenance was transferred during these meetings. This is a conservative assumption.

5. Re-work Links

Due to the highly centralized control in the 400 Division by the Controller, ensuring that critical exit criteria were met for critical steps in the F414 maintenance process, the amount of rework was minimized. The majority of rework occurred, as expected, after the engine test cell. Consequently, rework from this task was modeled. All other rework was considered to be insignificant an unquantifiable by 400 Division personnel, and hence was not modeled.

C. Modeled Development

1. Positions

Based on the knowledge gained from personnel at NAS Lemoore's AIMD, a model of the 400 Division executing F414 maintenance was developed. The first step in this development was to identify the individuals in the 400 Division responsible for executing the tasks required to conduct F414 maintenance, and to characterize the hierarchy of information flow among these individuals. Figure 1 presents this organizational structure.

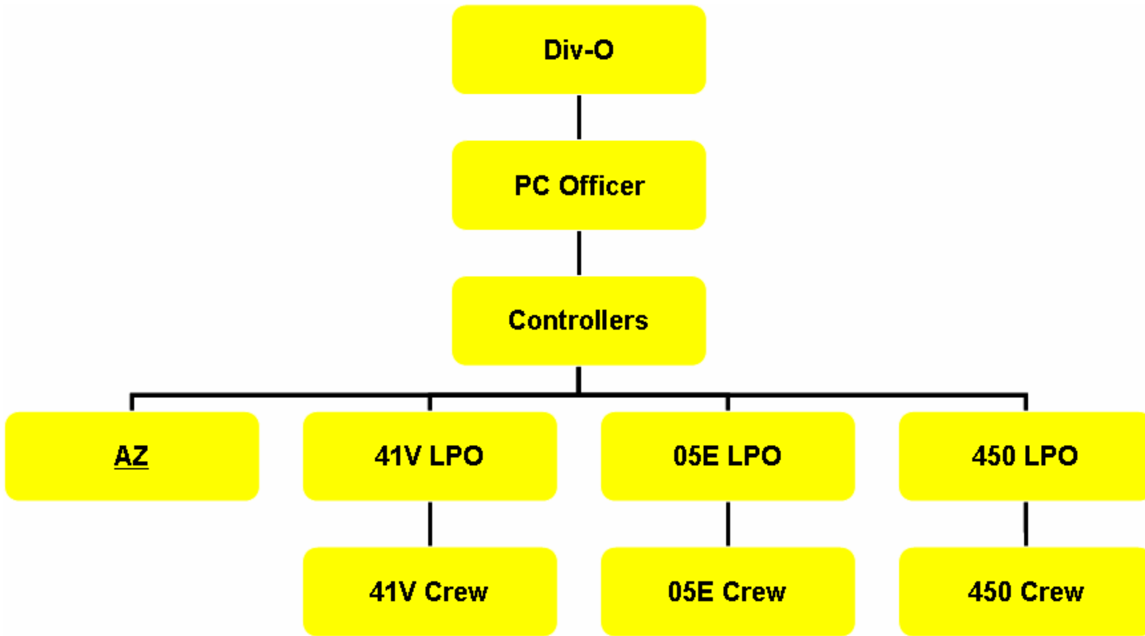

Figure 1. 400 Division Information Hierarchy

The terminology used in Figure 1 and throughout this report to reference individuals and groups are consistent with terminology used in the Navy's aircraft intermediate maintenance community. For clarity, these terms are defined as follows:

1. Div-0: Division Officer, normally a Navy Lieutenant
2. PC Officer: Production Control Officer, normally a senior chief petty officer
3. AZ: Administrative personnel
4. 41V: Personnel who directly conduct F414 maintenance
5. 05E: Supply personnel dedicated to the 400 Division
6. 450: Personnel responsible for conducting final tests of the F414
7. LPO: Leading Petty Officer, individual responsible for directing the crew

Along with the information hierarchy structure presented in Figure 1, information was also collected from 400 Division personnel regarding the number of personnel assigned to each position, their skills and skill levels, their experience levels, which tasks each position was responsible for accomplishing, and the amount of time they normally devote to accomplishing those tasks. A sample of this information for the Controller position is presented in Table 1. Similar information for all positions is presented in Appendix A.

Table 1. Sample Position Properties—Controller

Property	Value	Unit
Position	Controllers	N/A
Culture	Generic	N/A
Role	sl	N/A
App-Experience	Med	N/A
FTE	0.65	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium Controller Skill - High AZ Skill - Medium 41V LPO Skill - Medium 41V Crew Skill - Low 05E LPO Skill - Medium 05E Crew Skill - Low 450 LPO Skill - Medium 450 Crew Skill - Low	N/A
Staff:		N/A
Person	Allocation	Team Lead
5	0.65	Y - 1 Person

The value given to each position was simply the name of the position. The culture for all positions was generic. The appropriate role for each position was defined according to the location of the position in the information hierarchy presented in Figure 1. The Div-O was defined as the program manager. All crew positions, as well as the AZ position, were defined as sub-team roles. The roles for all positions between the Div-O and crew positions in the information hierarchy were defined as sub-team lead. Since military personnel regularly move in and out of positions in the 400 Division, such that certain individuals' application experience may be high while others' may be low, application experience was set to medium for all positions as an average value. The full-time equivalent (FTE), which is the percentage of time a position has to dedicate to accomplishing all of the F414 work it is assigned, was calculated by multiplying the number of personnel assigned to a position by the average percent time they have available to accomplish all of the F414 tasks they are assigned, and then dividing the product by 6 (since the model only accounts for one of six engines the 400 Division is capable of processing at any one time). Each position had a specific skill set which it was capable of performing. The skill set for each position was aggregated into a single skill defined by that position. For example, the Controller position was defined to have the Controller skill. Each position was given a high skill rating for the skill associated with that position. For example, in Table 1, the Controller position was given a High Controller skill rating. If a given position, for example the Controller, had a position below it in the information hierarchy defined in Figure 1, for example, the 41V LPO position, the position higher in the information hierarchy was given a skill rating of medium for those skills associated with positions one level below it in the information hierarchy. For example, the Controller position in Table 1 was given a medium 41V LPO skill rating. Similarly, a given position would be given a low skill rating for any position two levels below it in the information hierarchy. For example, the Controller in Table 1 was given a low 41V Crew skill rating. The allocation for personnel assigned to a given position was defined as the percentage of an individual's time available to work in a given position. Since personnel were not staffed to positions in this model, this variable did not apply.

2. Tasks

The next step in developing the model was to identify the tasks required to accomplish F414 maintenance. In reality, these first two steps occurred concurrently as NPS personnel interviewed 400 Division personnel and gradually understood how the 400 Division operated. Figure 2 presents a generalized picture of the tasks that are accomplished when conducting F414 maintenance.

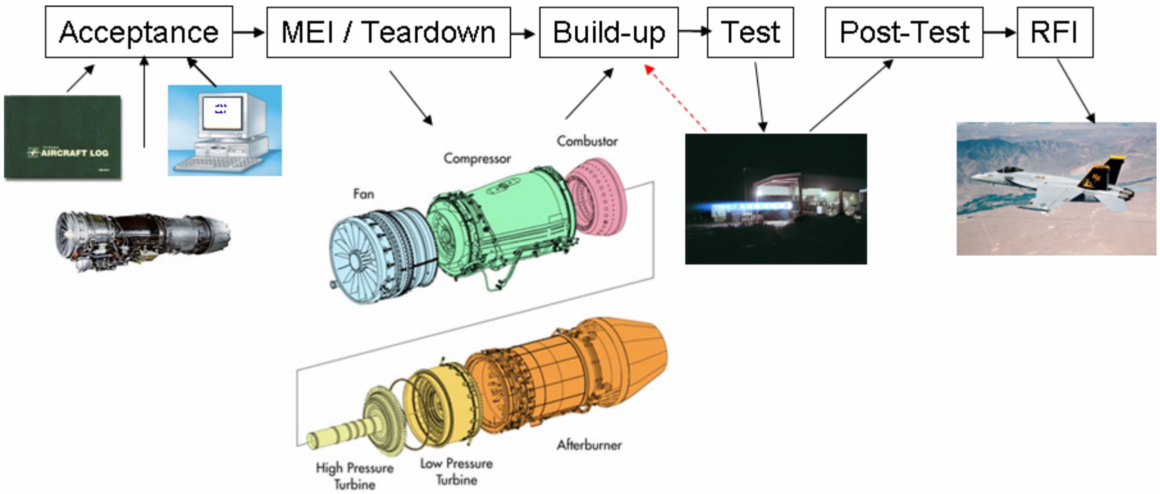

Figure 2. Generalized F414 Maintenance Tasks

Initially, the F414 engine is received from the operational F/A-18E/F squadrons by 400 Division personnel. Administrative, or AZ personnel, then begin the process of comparing information in the engine logbook to information in two central databases (AEMS and SAME), which track specific parts on the engine and engine movement respectively. Prior to maintenance action commencing on the engine, AZ personnel have to resolve any discrepancies between the engine logbook, AEMS, and SAME. This effort can take as little as 30 minutes if everything is accurate, or it can take several weeks. Currently, the average time is 14 days. Once the initial paperwork is complete, the 41V LPO assigns a 41V crew to the engine. These personnel, normally a crew of 3 individuals, conduct a major engine inspection (MEI) followed by an engine teardown to determine which of the F414 engine modules are good, and which need replacing. The intermediate maintenance concept for the F414 only allows the engine to be broken down to the module level. The F414 consists of 6 modules—fan, compressor, combustor, high pressure turbine, low pressure turbine, and afterburner. If it is determined that a module is defective, it is packaged and sent to the Navy Depot at Jacksonville, FL. A replacement module is then pulled from the supply warehouse. The engine is then built back up, again by 41V crew personnel, with good modules. Following the buildup phase, the engine is sent to the test cell where the 450 LPO assigns two 450 crew personnel to install test instrumentation on the engine and run pre-defined profiles to assess the engine's operability. If the engine fails the test cell, it may either be fixed on the test stand by 450 or 41V crew personnel or it may be sent back to the buildup phase for 41V crew personnel to conduct more detailed maintenance. This failure on the test stand is considered re-work. Once the engine passes the test cell, it is returned to the maintenance hanger where 41V crew personnel conduct a post-test inspection to ensure nothing was damaged during the engine run. At this point, AZ personnel complete necessary paperwork, and the engine is signed off as ready for issue (RFI)—which means it can now be issued to an operational F/A-18E/F squadron for installation into an operational aircraft. Each step in the process presented in Figure 2 is overseen and directed by the Controllers. The PC officer and the Div-O take no direct action in terms of standard F414 maintenance, but are available to handle problems encountered by Controller personnel and others in the information hierarchy.

Initial modeling of the process presented in Figure 2 indicated a need for a more detailed understanding of the F414 maintenance tasks. Further research revealed a higher task resolution, summarized in Figure 3.

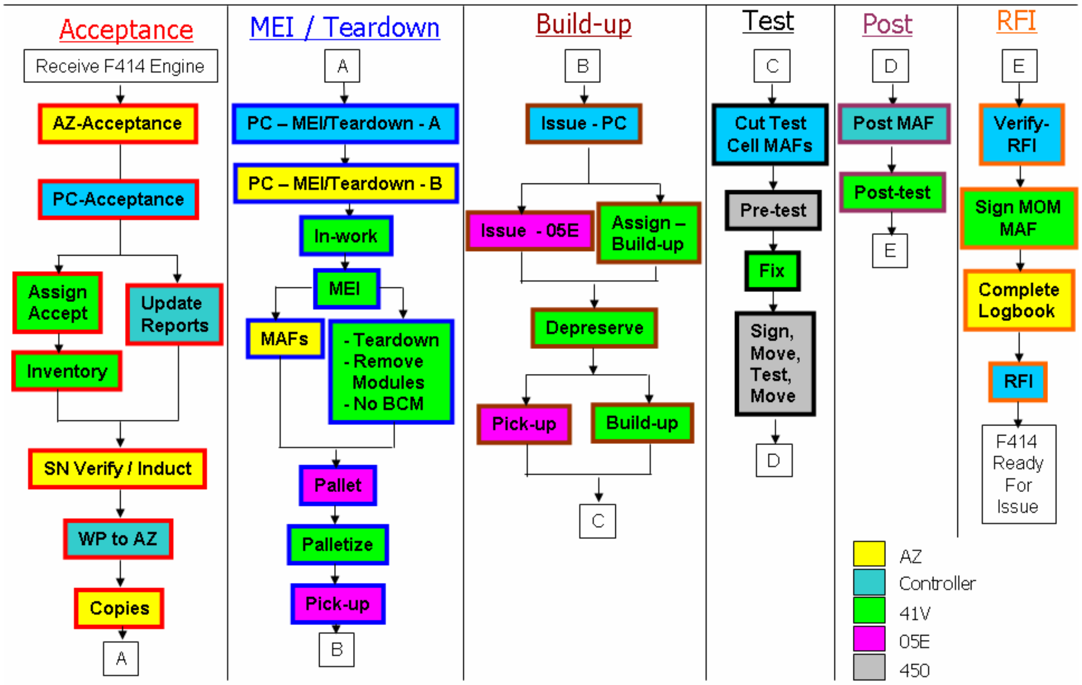

Figure 3. F414 Detailed Maintenance Process

Each column presented in Figure 3 correlates with the general tasks presented in Figure 2. The interior color coding of each box, representing a task, identifies the position, AZ, Controller, 41V, etc, responsible for accomplishing that task. The border color of each box identifies which general task category identified in Figure 2 with which this task is associated. For example, the AZ Acceptance task has a yellow interior—indicating this task is accomplished by personnel assigned to the AZ position. It also has a red border, which indicates it is associated with the general task of Acceptance presented in Figure 2. The details of efforts associated with accomplishing each task presented in Figure 3 are elaborated in Appendix B. The 400 Division's F414 maintenance process was modeled on the task level presented in Figure 3.

Along with the detailed task structure presented in Figure 3, information was also collected from 400 Division personnel regarding:

- The nominal duration required for each task.

- Whether each task could be accomplished more quickly if additional personnel were added.
- The skills required to accomplish each task, the priority of each task.
- How difficult it was to understand the requirements of each task.
- How difficult it was to accomplish each task.
- The percent of time that individuals assigned to accomplish a task spend working on that particular task relative to all other tasks (associated with F414 maintenance) to which they are assigned.

A sample of this information is presented in Table 2. A complete set of this information for all tasks presented in Figure 3 is presented in Appendix C.

Table 2. Sample Task Properties—AZ-accept

Property	Value
Task	**AZ Accept**
Effort	14 Days
Effort-Type	Work-Duration
Required Skill	AZ Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
AZ	2%

Task names were based on standard 400 Division terminologies. Effort defines the nominal duration a given task requires. Effort-type for most tasks was defined as either "Work-duration" or "Work-volume." Work-duration tasks, which comprised most of the primary F414 maintenance tasks, are tasks that will take a specific period of time, irrespective of the number of personnel assigned to accomplish the task. For example, the 400 Division determined that tearing down an engine optimally takes three individuals. Adding more individuals would simply result in personnel getting in the way of each other. As a result, the effort type for this task is considered Work-duration. In contrast, Work-volume tasks are those tasks that will take less time if more personnel are assigned to the task. Each task was assigned a specific skill—which positions assigned to accomplish that task should have. If the assigned position doesn't have that skill, the task will take longer. The priority for each task was set according to its importance. The requirement complexity defined how difficult it was for personnel assigned to that task to understand the requirements to accomplish the task. This value was set to a nominal value of medium for most tasks. The solution complexity is a measure of how difficult it is to accomplish a task once an individual understands what needs to be done. Since the 400 Division personnel are all very well trained and the F414 maintenance process was well defined, this value was set to low for most tasks. Uncertainty was defined by the amount of communication that needed to be accomplished between personnel assigned to different positions to accomplish a task. Based on the well-defined nature of the F414 maintenance tasks, and the high skill level of those accomplishing the tasks, it was assessed that relatively little communication would be required. Hence, uncertainty was set to low for most tasks. The allocation for personnel assigned to a given task was defined as the percentage of time a position has to accomplish a specific assigned task as compared to total amount of time the position can dedicate to accomplishing all of the F414 tasks it is assigned.

3. Off-core Tasks

Along with modeling F414 maintenance tasks, off-core (or dummy tasks) were also modeled. These tasks were modeled to occupy a position's time when not specifically working F414 tasks. The properties associated with all off-core tasks were similarly configured—excluding the variables of effort and allocation. A sample of the properties associated with the off-core tasks is presented in Table 3.

Table 3. Sample Off-core Task Properties—Controller

Task	Controller Dummy Task
Effort	2.9 Days
Effort-Type	Work Volume
Required Skill	Generic
Priority	Low
Requirement Complexity	Med
Solution Complexity	Low
Uncertainty	Med
Fixed Cost	0
Position Assigned (Primary)	**Allocation**
Controller	0.0855

The effort for each off-core task was set to a value that resulted in that off-core task being accomplished at the same time or very soon after the F414 maintenance tasks were accomplished. The priority for the off-core tasks were all set to low so that these tasks would not take priority over the F414 maintenance tasks. Requirement complexity and uncertainty were both set to their default values of medium. Solution complexity was set to low since most collateral duty tasks are easier than an individual's primary tasks. A position's allocation to an off-core task was set such that the sum of that allocation and all other allocations for tasks to which that position was assigned equaled 100%. In other words, the off-core task allocation was set so the position was always working.

4. Meetings

Meetings were modeled as a key method for regularly and reliably transferring information between positions. The meetings that were modeled were only those that directly affected F414 maintenance. Although 400 Division personnel attended other meetings, the time required doing so (and the resulting decrease in time available to accomplish F414 maintenance) was accounted for in the model by the appropriate full-time equivalent definition and off-core tasks. In general, the 400 Division had a set of morning meetings to kick off the day's work, and a set of afternoon meetings to wrap-up the day's work. There was also a meeting that occurred every other Thursday afternoon. Those meetings and their general purposes are discussed in Table 4.

Table 4. 400 Division F414 Meetings

Meeting	Purpose
0630 41V-PC Meeting	Coordination of daily F414 maintenance activities between the 41V LPO and the Controllers
Pre-0700 PC Meeting	Coordination of daily activities among the Controllers
41V Pre-0700 Meeting	Relay of information gained in 0630 41V-PC Meeting by 41V LPO to 41V Crew
0700 Meeting	General meeting between Div-O, PC Officer, all Controllers, and all LPOs to discuss daily maintenance activities
05E Post-0700 Pass-down Meeting	Relay of information gained in the 0700 meeting by 05E LPO to 05E Crew
450 Post-0700 Pass-down Meeting	Relay of information gained in the 0700 meeting by 450 LPO to 450 Crew
PC End-of-day Meeting	Summarize daily maintenance activities and overview of next day's activities
41V End-of-day	Summarize daily maintenance activities and overview of next day's activities
05E End-of-day Meeting	Summarize daily maintenance activities and overview of next day's activities
Buffer Management Meeting	Highlight/resolve top-level problems associated with F414 maintenance

Along with understanding the purpose of each of these meetings, other key information was gained from 400 Division personnel to accurately model the impact of these meetings. This information included the priority of the meeting as compared to other meetings and tasks, meeting duration, interval between meetings, if it was a regularly scheduled meeting and meeting time. A sample of this information is presented in Table 5. A complete set of this information for all meetings is presented in Appendix D.

Table 5. Sample Meeting Properties—0700 Meeting

Property	Value	Unit
Meeting	**0700 Meeting**	N/A
Priority	High	N/A
Duration	20	min
Interval	1	Day
Repeating	Y	N/A
Schedule-till-end	Y	N/A
Meeting Time	30	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	Div-O	1
	PC Officer	1
	Controller	1
	41V LPO	1
	05E LPO	1
	450 LPO	1

The meeting property value describes the meeting. The priority of all meetings, as defined by 400 Division personnel, was high. Meeting duration, interval, and time were defined by 400 Division personnel. All meetings were scheduled until the end of the simulation. All meeting start times were referenced off the Start milestone. Attendance and allocation were defined by 400 Division personnel. Allocation defined the percentage of personnel assigned to a given position who attended the meeting. For example, 100% of the Controllers attended the 0700 meeting. Hence, their allocation was 1.0.

5. Re-work Links

The re-work that occurs in the 400 Division is at the engine test-cell phase of the maintenance. According to 400 Division personnel, 3% to 5% of the F414 engines fail the test cell. Of these 3% to 5%, 75% to 80% have to go back to the Buildup task to be fixed while 20 to 25% have to go back to the Teardown task to be fixed. Based on this information, the rework strength of the link between the engine test cell and the buildup was defined to be 0.031, [(5% + 3%)/2]*[(80% + 75%)/2], and the link between the engine test cell and the teardown was defined to be 0.009, [(5% + 3%)/2]*[(25% + 20%)/2].

6. General Program Properties

Along with the properties for the specific model elements defined in this model development sub-section (positions, tasks, meetings, etc.), there were also elements of the overall program that were defined in the model. Those elements are defined in Table 6.

Table 6. Program Properties

Property	Value	Unit
Program	400 Div F414 Engine	N/A
Work-Day	480	min
Work-Week	2400	min
Start Date	20001102080000	N/A
Team Experience	Med	N/A
Centralization	High	N/A
Formalization	Low	N/A
Matrix Strength	Med	N/A
Communication Probability	0.3	N/A
Noise Probability	0.1	N/A
Functional Exception Probability	0.075	N/A
Project exception Probability	0.075	N/A
Backlog Interval	0	min
Demand Interval	0	min
Case	Baseline	N/A
Behavior	Devault	N/A
Seed	1	N/A
Trials	100	N/A
Description	BLANK	N/A

The program value was the name of the program being modeled: 400 Division F414 engine. The duration of the work day and work week, 8 hrs/day and 5 days/week, were defined by 400 Division personnel. Not included in the modeling effort was the one-hour lunch break, since work was not being accomplished during lunch. The start date was set to its default value since we were not concerned with absolute dates but relative dates or the duration of the program. Team experience was set to medium since as personnel regularly enter and leave the 400 Division work-force, the average experience of the overall team would be at a medium level. Centralization was modeled as high since a relatively small group of senior enlisted personnel, the Controllers, very much directed the entire F414 maintenance operation. Formalization was modeled as low since most communications regarding F414 maintenance, in the opinion of 400 Division personnel, occurred informally between positions. Matrix strength was modeled as medium based on the assessment of 400 Division personnel that they equally attend meetings as well as participate in informal communications. Communication probability was set to a value of 30%, a relatively low value, based on the assessment of 400 Division personnel that there normally isn't a great need for personnel to communicate with individuals outside of the task on which they are working. The 400 Division, through its implementation of AIR*Speed* initiatives, has very much streamlined its maintenance processes such that each process is very well defined and understood by those accomplishing the tasks; and the interfaces between tasks are minimal. These efforts have enhanced F414 maintenance efficiency and decreased the need for extraneous communication. Noise probability was set to 10%. According to the *SimVision Users' Guide*, documentation for the POWer software, a value of 10% is considered "significant but common."[16] 400 Division personnel considered this to be an accurate assessment of the number of unexpected tasks they are given from outside the 400 Division. The functional exception and project exception probability properties do not specifically apply to the 400 Division model. These properties are more appropriate for describing new projects versus a well-defined process such as F414 maintenance. These properties were both set to 0.075, a nominal value according to the *SimVision Users' Guide*.[17] All remaining property values were left unchanged from their default values since they were not specifically required to model the 400 Division F414 maintenance process.

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[16] eProjectManagement (ePM™), SimVision® Users' Guide.

[17] Ibid.

D. Model Evaluation

Once the model was constructed, the F414 maintenance duration predicted by the model was compared to the ideal duration to ensure the model accurately predicted real-world performance. The ideal duration was calculated by summing the duration of all tasks occurring in series and adding to that the longest duration task of any grouping of tasks that occurred in parallel. For example, referencing Figure 3, the duration required for the Acceptance phase of F414 maintenance was calculated by summing the following tasks.

1. AZ-Acceptance
2. PC-Acceptance
3. SN Verify/Induct
4. WP to AZ
5. Copies

Added to this summation was the longer of the summation of the Assign Accept and Inventory tasks or the Update Records task. Similar procedures were followed for the other major phases of F414 maintenance to calculate their ideal duration. The duration of all major phases were then summed to calculate the overall ideal duration for the F414 maintenance process.

Although it was not possible to perfectly model the 400 Division and achieve an exact match between the modeled duration and the ideal duration, it was important to achieve a close comparison.. Doing so increased confidence that predicted benefits identified by modifications made to the model are accurate. Descriptions of these modifications are presented in the following section of this chapter.

E. Interventions

Once the model was determined to accurately depict current 400 Division F414 maintenance procedures, modifications were made to the model to evaluate alternate 400 Division organizational structures which might help reduce F414 throughput duration. This process is termed intervention.

The following seven interventions to the baseline model were evaluated.

1. Parallel Acceptance task with all other tasks
2. Combine AZ and Controller positions
3. Combine 41V and 450 positions
4. Decrease organization's centralization
5. Add additional personnel to each position
6. Alter current meetings' duration and frequency
7. Combining meetings

These seven interventions were identified as potentially decreasing F414 throughput duration based on recommendations from 400 Division personnel and from insight gained by NPS personnel during interviews with 400 Division personnel. Along with evaluating each intervention and comparing it to the baseline model, a combination of those interventions which modeling indicated had the greatest potential for decreasing F414 throughput duration were evaluated and compared against the baseline model as well. The following sub-sections present a brief description of each intervention.

1. Paralleling Acceptance Task

The current F414 maintenance process presented in Figure 2 shows a serial process initiated by the Acceptance tasks. 400 Division personnel have indicated that it may be beneficial to conduct the Acceptance tasks parallel with all of the other tasks as depicted in Figure 4.

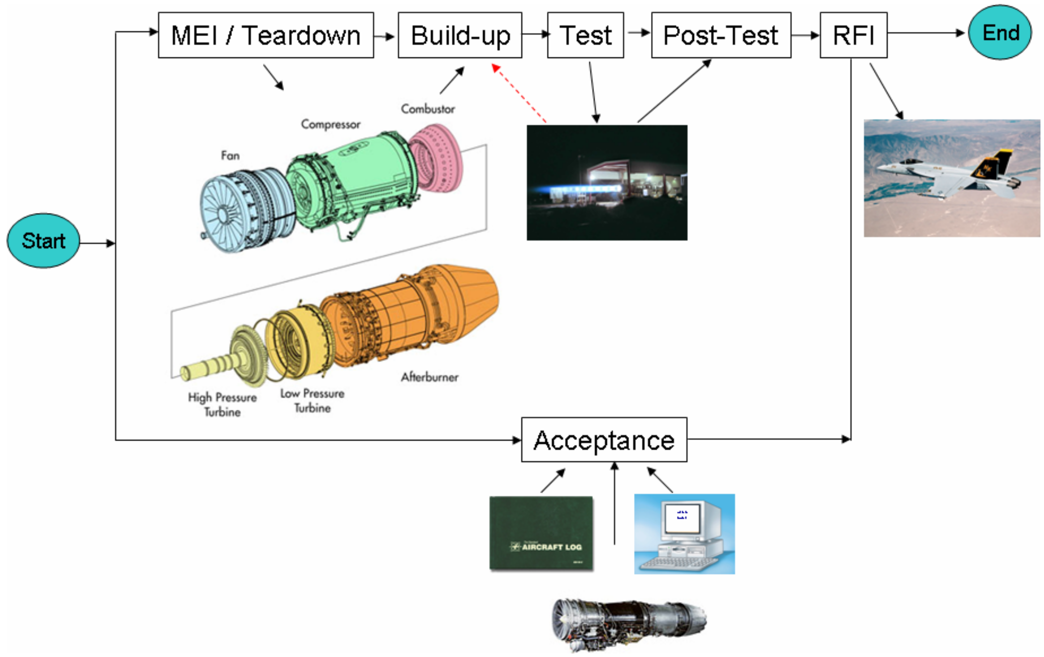


Figure 4. Intervention #1—Paralleling Acceptance Process

The philosophy behind this paralleling effort is that irrespective of the correlation between the engine logbook, AEMS database and SAME database, maintenance work needs to be accomplished on the engine. There is little significant information that is gained via the Acceptance process that is required by the other steps in the F414 maintenance process. Hence, there may be benefit to allowing AZ personnel to begin resolving engine paperwork at the same time that 41V personnel are allowed to begin working on the engine. The impetus behind this intervention was initial steps currently being taken by 400 Division personnel to parallel the Acceptance process, although paralleling to the degree proposed here had not been attempted—in part due to a lack of understanding the benefits of doing so as compared to the risks.

2. Combining AZ and Controller Positions

In this intervention, personnel assigned to the AZ and Controller positions, along with their associated FTEs, are combined into a single position. This single position is then assigned the combination of tasks originally assigned to both the AZ and Controller positions in the baseline model. A depiction of this intervention is presented in Figure 5.

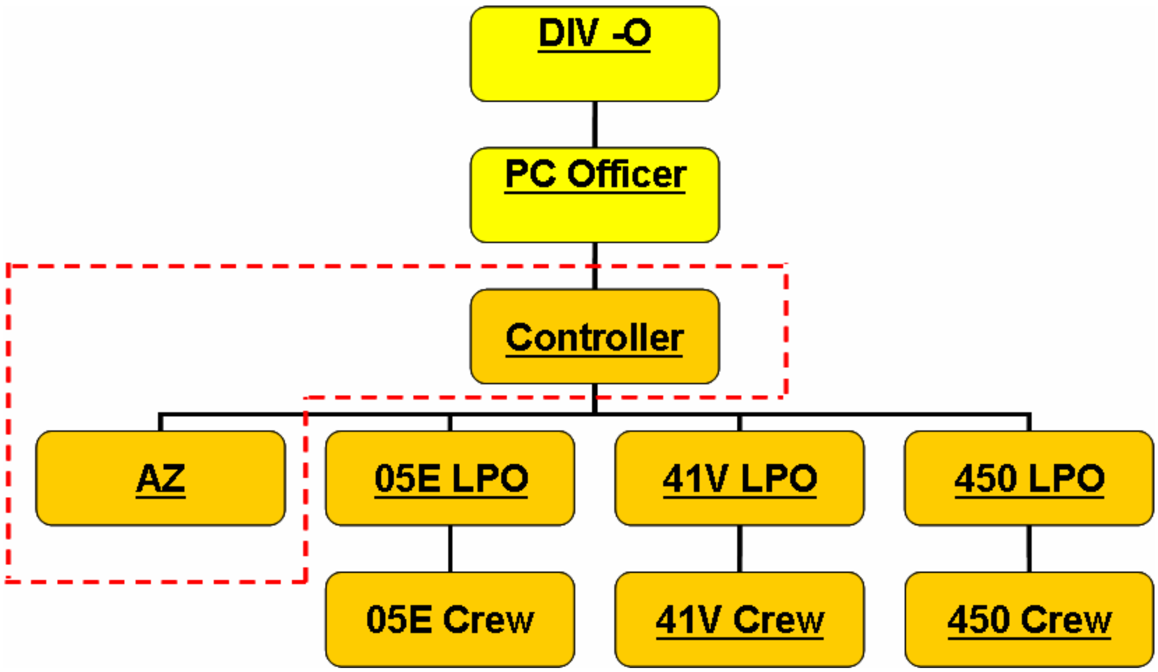


Figure 5. Intervention #2—Combining AZ and Controller Positions

This intervention was evaluated in two sub-interventions. In the first sub-intervention, there was no retraining given to the combined personnel. In the second sub-intervention, retraining was provided. The rationale for this comparison was to quantify the impact of training, a facet of reorganization which is often left out or not budgeted for. The impetus behind this intervention was an indication from 400 Division personnel that AZ personnel were capable of accomplishing the Controller position with a little more retraining.

3. Combining the 41V and 450 Positions

The training and experience of 41V (engine maintenance), and 450 (engine test), personnel is very similar. This intervention assessed the benefit of combining these two positions as presented in Figure 6.

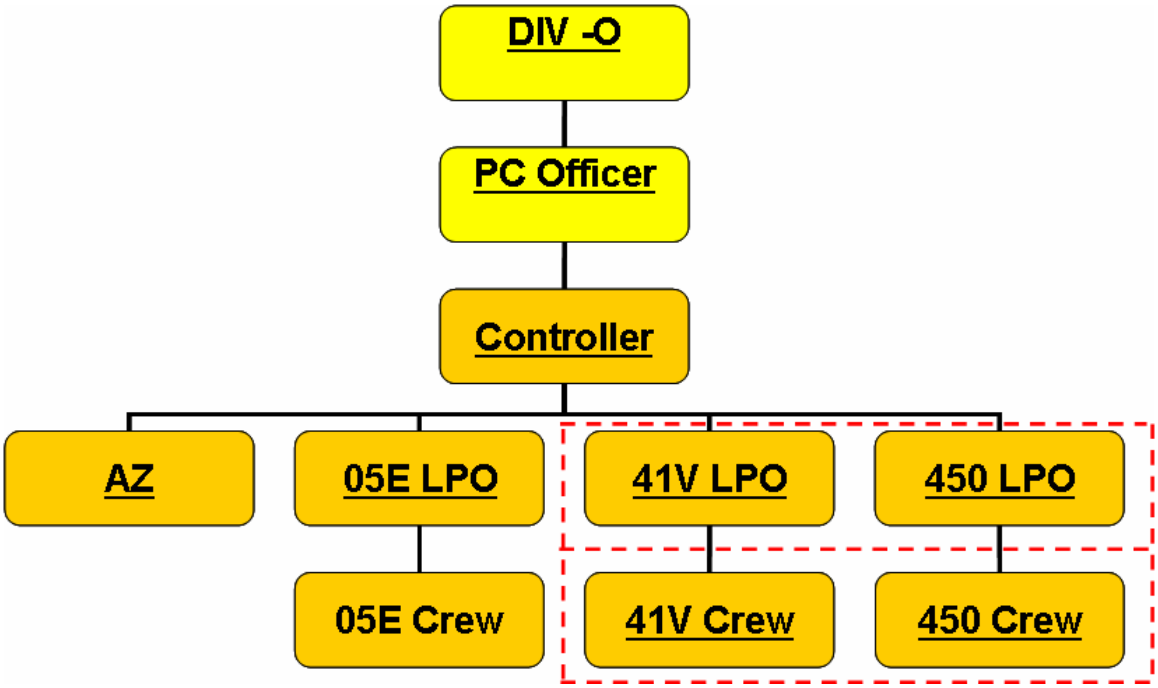


Figure 6. Intervention #3—Combining 41V and 450 Personnel

This intervention separately combines the 41V LPO and 450 LPO positions into one position, assigning to it all of the tasks originally assigned to the 41V LPO and 450 LPO positions in the baseline model. Similarly, the 41V Crew and 450 Crew positions are combined into a single position, assigning to it all of the tasks originally assigned to the 41V Crew and 450 Crew positions in the baseline model. For the same rationale as the AZ and Controller combination, this intervention was evaluated first without retraining personnel and then with formal retraining to assess the impact.

4. Decreasing Centralization

One of the impacts of AIR*Speed* is to decrease the centralized control of an organization by pushing authority for decision-making to the lowest possible level. This fourth intervention assesses the impact of such decreased centralization on the 400 Division. In the context of the model, this is implemented by simply changing the Centralization property from high to low.

5. Adding Personnel

As the Navy consolidates its F414 intermediate maintenance to the AIMD at NAS Lemoore, and specifically to the 400 Division, the leadership at the AIMD and 400 Division will be concerned with how to allocate additional personnel gained from organizations such as NAS Oceana. For example, is it more beneficial to add personnel to the existing 3-person maintenance teams working an F414 engine or to instead create more teams? The purpose of this intervention was to assess the impact of adding additional personnel to existing positions. Personnel were added separately to the AZ, Controller, 41V Crew, 05E Crew, and 450 Crew positions while holding personnel at all other position constant relative to the base model. The impact of these additions in terms of F414 throughput time was then compared to the baseline model.

6. Altering Meeting Duration and Frequency

The 400 Division holds a number of morning and afternoon meetings to coordinate personnel. Considering the well-defined nature of F414 maintenance tasks and the highly skilled nature of the 400 Division personnel, there is a possibility that altering meeting duration and or frequency may decrease F414 throughput duration. To assess these alterations, a matrix was developed that described various combinations of meeting duration and frequency or interval. That matrix is presented in Figure 7. Modifications were made to specific meetings according to this matrix, and the affect on project duration and functional risk were assessed. The meeting chosen to evaluate these changes in duration and frequency was the 0700 morning meeting. This meeting was chosen because it is considered a key meeting by 400 Division personnel to effectively transferring information throughout the Division. All key personnel associated with F414 maintenance attend this meeting to coordinate accomplishing their daily tasks.

Project Duration (Days)	Interval Between Meetings (Days)					
Meeting Duration (Min)		**1**	**2**	**3**	**4**	**5**
	20					
	30					
	45					
	60					
	90					
	120					

Figure 7. Intervention #6—Altering Meeting Duration and Frequency

The matrix in Figure 7 depicts 30 separate cases. The baseline model result in this matrix to which all other cases are compared is presented at the intersection of the 1-day interval and 20-min duration. This same matrix was used to record the impact on functional risk resulting from the changes in meeting duration and frequency

7. Combining Meetings

Again considering the large number of 400 Division morning and afternoon meetings, along with the well-defined nature of F414 maintenance tasks and the highly skilled nature of the work-force, there may be potential benefit to decreasing F414 throughput time by combining some of these meetings, and using the time saved to work on the engines. This intervention is evaluated by first combining all of the morning meetings to include the 0630 41V-PC Meeting, Pre-0700 41V Meeting, Pre-0700 PC Meeting, 0700 Meeting, Post-0700 05E Flow-down, and Post 0700 450 Flow-down Meetings, and comparing the F414 maintenance throughput time to the baseline model. This intervention is also assessed by combining the morning meetings presented above, and then separately combining the afternoon meetings to include the PC End-of-day, 41V End-of-day, and 05E End-of-day meetings such that there is one combined morning meeting and one combined afternoon meeting. This is then compared to the baseline.

8. Combining Intervention

Based on the results of these single interventions, which are presented in the following section, a combined intervention was compared to the baseline model as well. This combined intervention was a model modified with those single interventions presented above which decreased the F414 maintenance throughput time.

F. Evaluating Interventions

Interventions were evaluated by comparing metrics predicted by the baseline model and the model employing the interventions. Four metrics were used to compare the baseline model and the seven interventions along with the combined intervention described in the previous section. The first metric was project duration, which is the duration required to accomplish maintenance of a single F414 engine. This duration was an output of the model in both text and graphic, the latter in the form of a Gantt chart. Duration was compared both qualitatively (as presented in Figure 8) and quantitatively. It was considered the most important metric when evaluating interventions.

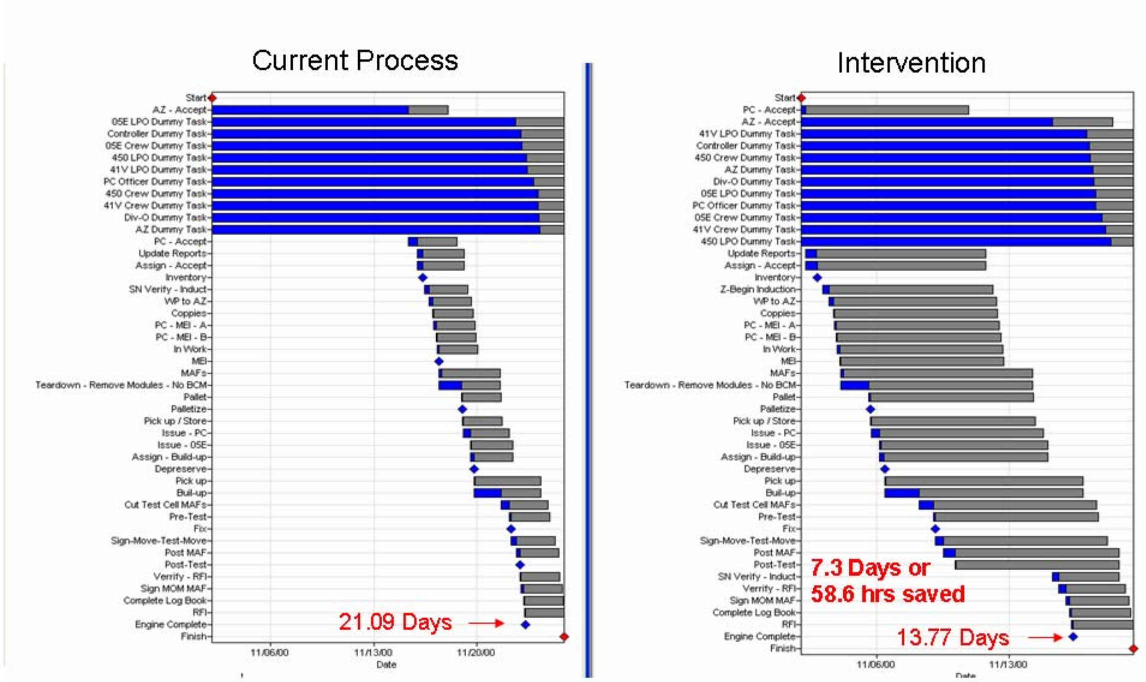


Figure 8. Comparing Duration

A second metric compared was position backlog. Position backlog is a measure of the number of days of work a position has yet to accomplish. It is analogous to the size of a person's in-box. A position with a high backlog poses a risk of increasing project duration and decreasing output quality. Position backlog is presented as a line graph of number of backlog days versus time, as presented in Figure 9. Each colored line represents the backlog for a particular position—as denoted by the key associated with each graph.

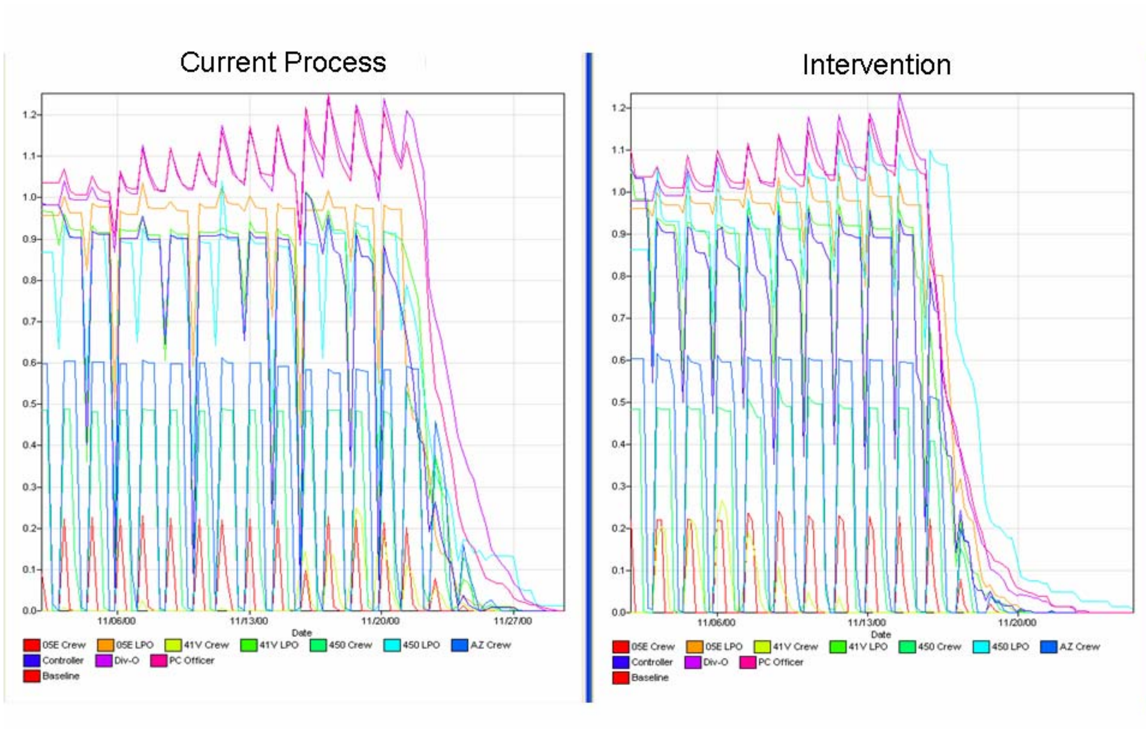


Figure 9. Comparing Position Backlog

A third metric used to compare intervention results to the baseline model was cost. Although absolute cost was not a concern for this study, relative changes in costs were of interest. Of particular interest were interventions resulting in increases in costs associated with the major tasks of engine teardown, buildup, and test. Cost was calculated by the model and outputted in both text and graphic. It was compared both quantitatively and qualitatively, the latter by use of bar graphs as presented in Figure 10.

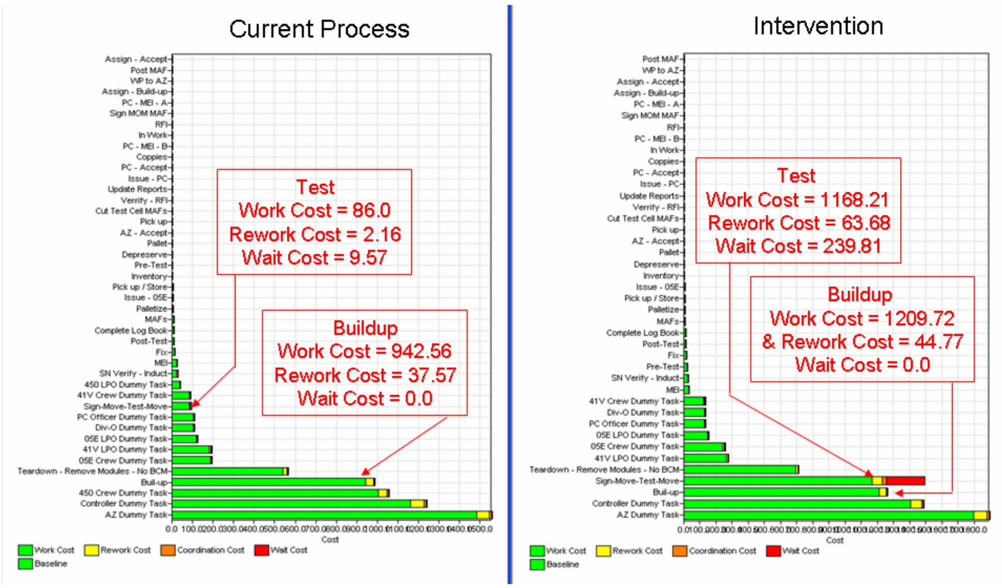


Figure 10. Comparing Cost

The fourth metric used to compare intervention results to the baseline model was functional risk. Functional risk is the risk that an engine produced in this maintenance process has defects due to rework and the inability of personnel to handle problems (or "exceptions"). Qualitative comparisons of functional risk were made using charts similar to those presented in Figure 11.

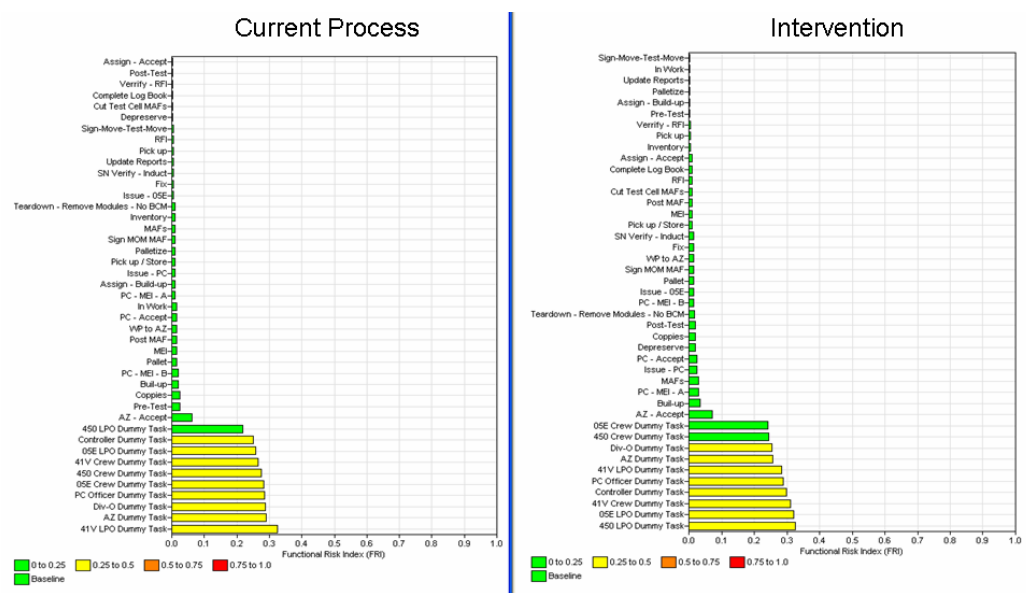


Figure 11. Comparing Functional Risk

These four metrics—project duration, position backlog, cost, and functional risk—were used to compare the baseline model, which represents the 400 Division's current status, and models with one of the seven interventions implemented to determine the relative benefit of these interventions. For any given intervention, the impact on each of the four metrics was categorized as positive, negative, or no impact, and appropriately color coded as green, red, or yellow. For example, a decrease in project duration resulting from an intervention would be considered positive, green, while an increase in cost or risk would be considered negative, red. These color codes were then used to make an overall assessment of each intervention as to whether or not it was beneficial to implement. Once all seven interventions were separately assessed, a model was developed that implemented or combined all of those interventions determined to be beneficial. This combined intervention was also evaluated using the same four metrics and color coding described earlier in this sub-section. Recommendations presented in this report are based on results evaluated using the methodology presented in this sub-section.

IV. Results

A. Introduction

This chapter begins with a presentation of the baseline model results. Following this is a presentation of a summary of the results of the seven individual interventions and the combined intervention described in Chapter III. Finally, details regarding the individual interventions and the combined intervention are presented.

B. Baseline Model Evaluation

The duration of the critical path required to accomplish F414 maintenance was calculated to be 21.77 days. The baseline model predicted 21.09 day duration to accomplish F414 maintenance. Since these two durations were within 3% of each other, there was high confidence that the baseline model accurately predicted 400 Division organizational performance. Initially, there was some concern that the predicted duration was longer than the ideal duration. Subsequent discussions with Virtual Design Team personnel at Stanford University alleviated these concerns by explaining that if the personnel modeled have a medium skill level, the simulated duration and ideal duration would be the same. In contrast, if the personnel modeled have high skill levels, as is the case for certain personnel performing certain tasks in this model, the modeled duration may be less than the ideal duration. With this understanding and only a 3% difference between the two durations, it was determined that the model accurately represented the 400 Division and was suitable for use in evaluating potential modifications to the 400 Division. A depiction of the final model is presented in Figure 12.

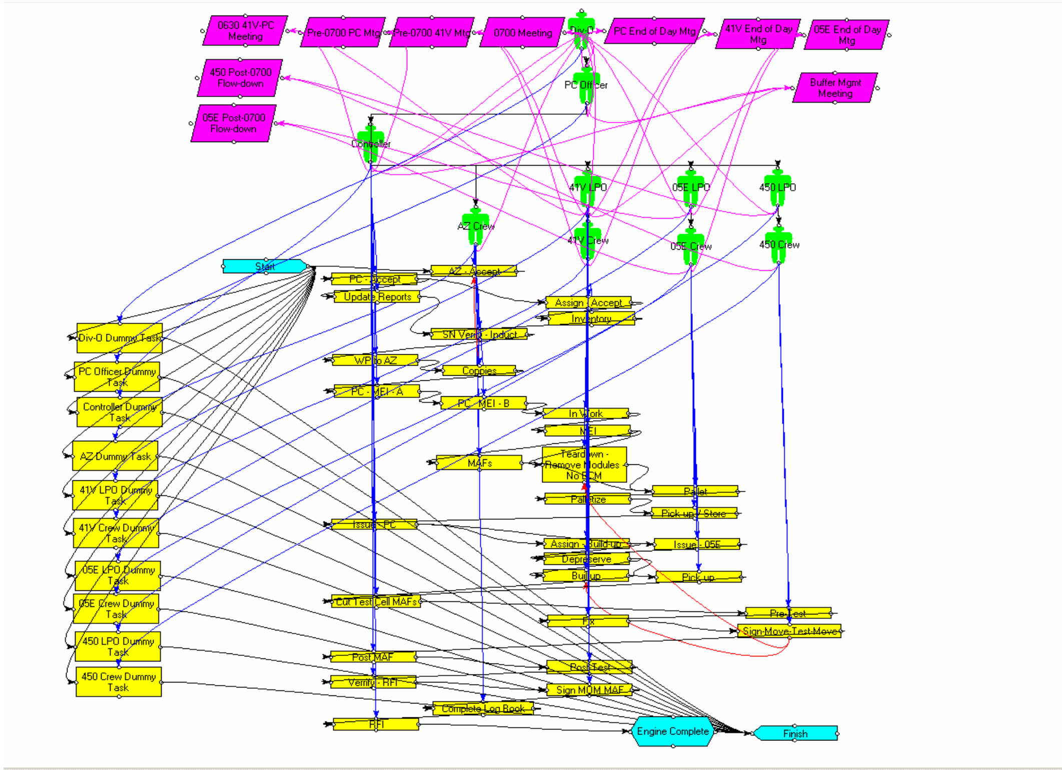


Figure 12. Baseline Model

The fuchsia slanted boxes at the top of Figure 12 represent meetings held by the 400 Division. The little green men represent the position being modeled, e.g., Controllers, 41V Crew, etc. The yellow boxes in the center of the figure represent the primary F414 maintenance tasks while the yellow boxes in a vertical line on the left of the figure represent the off-core or dummy tasks. The remaining blue polygons represent milestones in the maintenance process, e.g., start, finish, and completion of engine maintenance.

C. Interventions

1. Summary of Results

This sub-section summarizes the results of the seven interventions to the baseline model as well as to the combined intervention. The results indicate that the first intervention, paralleling the engine Acceptance process, has the greatest benefit on decreasing F414 throughput duration. Along with this intervention, other interventions that were beneficial were decreasing centralization and separately combining the morning and afternoon meetings. Table 7 and Table 8 present a summary of the results of these single interventions.

Table 7. Single Intervention Results Summary #1

Intervention	Affect On...			
	Project Duration	Backlog	Cost	Risk
Parallel engine acceptance	58.56 hour decrease	Decrease for most positions	No significant impact	Increase in AZ Acceptance task Risk
Combine Controller & AZ positions Without Training	110 hour increase	Decrease in Controller and AZ backlog. Increase in Div-O and PC backlog over time	AZ Acceptance task work and rework cost increase by 205.6 & 11.72 respectively	Increase in AZ Acceptance Task Risk
Combine Controller & AZ positions With Training	56.7 hour increase	Decrease in Controller and AZ backlog. Increase in Div-O and PC backlog over time	AZ Acceptance task work and rework cost increase by 140.1 & 4.18 respectively	Increase in AZ Acceptance Task Risk
Combine 41V & 450 positions Without Training	132.6 hour increase	Slight decrease in 41V and 450 backlogs	Increase in Buildup and rework costs – 267.16 & 7.2 Increase in Test work, rework, & wait costs – 1082.21, 61.52, & 230.24	3/4 top risk areas assigned to combined 41V-450 positions vs. 2/4 currently
Combine 41V & 450 positions With Training	67.6 hour increase	Slight decrease in 41V and 450 backlogs	Increase Buildup cost 267.15 & decrease rework costs – 3.29 Increase in Test work, rework, & wait costs – 303.4, 5.63, & 93.41	3/4 top risk areas assigned to combined 41V-450 positions vs. 2/4 currently
Decreased Centralization	4.4 hour decrease	No significant impact	Slight increase in Buildup task rework cost of 9.86	No significant impact

Table 8. Single Intervention Results Summary #2

Intervention	Affect On Predicted Project Duration	Affect On Functional Risk
Add AZ Personnel	1.87 min saved / individual	No significant impact
Add Controller Personnel	6.82 min lost / individual	No significant impact
Add 41V Crew Personnel	0.91 min lost / individual	No significant impact
Add 05E Crew Personnel	10.51 min saved / individual	No significant impact
Add 450 Crew Personnel	4.42 min saved / individual	No significant impact
Vary 0700 meeting duration & frequency	Greatest benefit from Less Frequent meetings = 6.56 hrs	No correlation between risk and meeting interval or duration
Vary 0630 Meeting frequency	Greatest benefit from increasing time between meetings to greater than 2 days. Max benefit = 1.6 hours	Slight increase in risk when increasing time between meetings
Combine Morning Meetings leaving End of Day meetings Separate	No significant impact	No significant impact to Functional Risk when combining meetings
Separately Combine Morning meetings and End of Day Meetings	Greatest benefit from increasing time between meetings to greater than 1 day Max benefit = 7.28 hrs	No significant impact to Functional Risk when combining meetings

The interventions of paralleling the Acceptance tasks, decreasing centralization, increasing duration between meetings, and combining morning and afternoon meetings all decrease project duration. Detailed discussion of these results is presented in the following sub-sections.

A summary of the combined intervention incorporating all of these single interventions is presented in Table 9. These results indicate a 35% decrease in F414 throughput duration with a slight decrease in the backlog of most of the personnel.

Table 9. Combined Intervention Results Summary

Intervention	Affect On...			
	Project Duration	Backlog	Cost	Risk
Combined Interventions	58.96 hour or 35% decrease – Driven by acceptance paralleling effort	Backlog of most positions decrease. 450 LPO backlog increases	26.3 decrease in Buildup rework and 10.49 increase in teardown rework	No significant impact

2. Intervention #1—Paralleling Acceptance Task

This intervention had the greatest benefit to decreasing F414 maintenance duration. Maintenance duration was decreased from 21.09 days, the base model predicted duration, to 13.77 days, a decrease of 7.32 days. The impact of this intervention on individual task durations and the overall duration decrease are depicted in Figure 13.

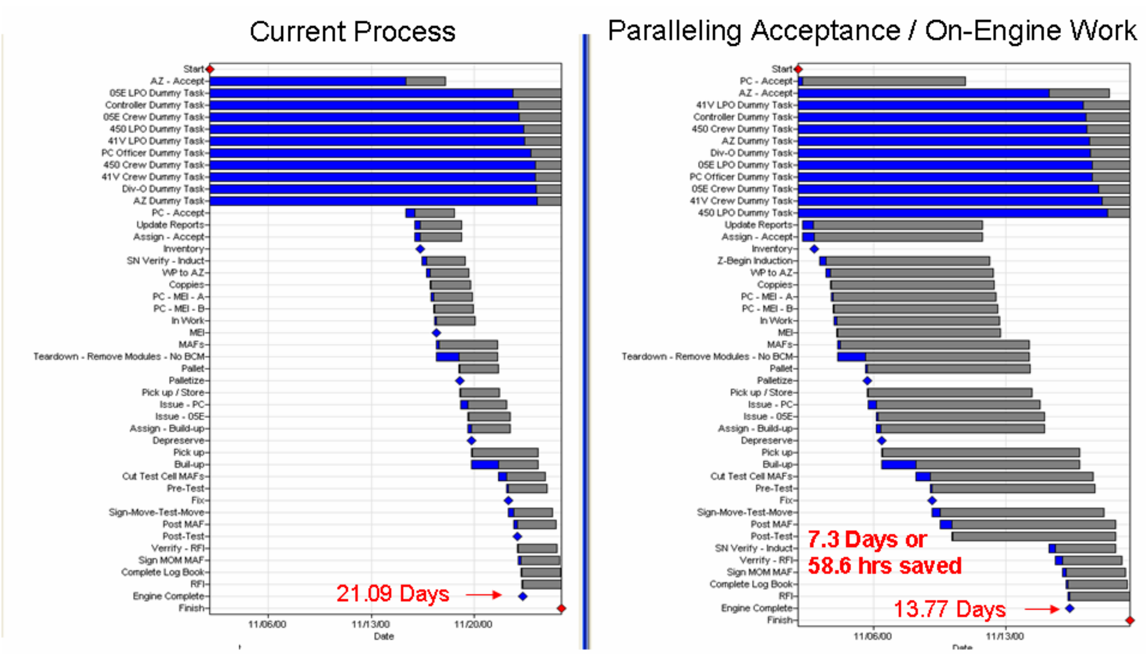


Figure 13. Intervention #1—Paralleling Acceptance Task—Impact on Duration

The blue bars represent the duration of the individual tasks. The second through eleventh tasks presented in the two Gantt charts in Figure 13 are the off-core or dummy tasks—modeled to account for all other work a position needs to accomplish other than the tasks associated with maintaining a single F414 engine, the other tasks presented in these Gantt charts. The reason for the decreased duration can be seen by observing the AZ Acceptance task in the two Gantt charts. In the left chart, the current process, the 14-day AZ Acceptance task must be accomplished before any other engine maintenance-related tasks, or non-off-core task, can be accomplished. By paralleling the AZ Acceptance process, the Gantt chart on the right in Figure 13 shows that engine maintenance related tasks other than the AZ Acceptance task can begin at the same time the AZ Acceptance task begins, working in parallel. The result is a 7.32 day decrease in maintenance duration.

Although paralleling the AZ Acceptance task decreased F414 maintenance duration, the impact to other aspects of the organization had to be considered. One aspect to consider was the impact on each position's backlog. Figure 14 presents a comparison of the position backlog of the baseline model and the model in which the paralleled Acceptance process was implemented.

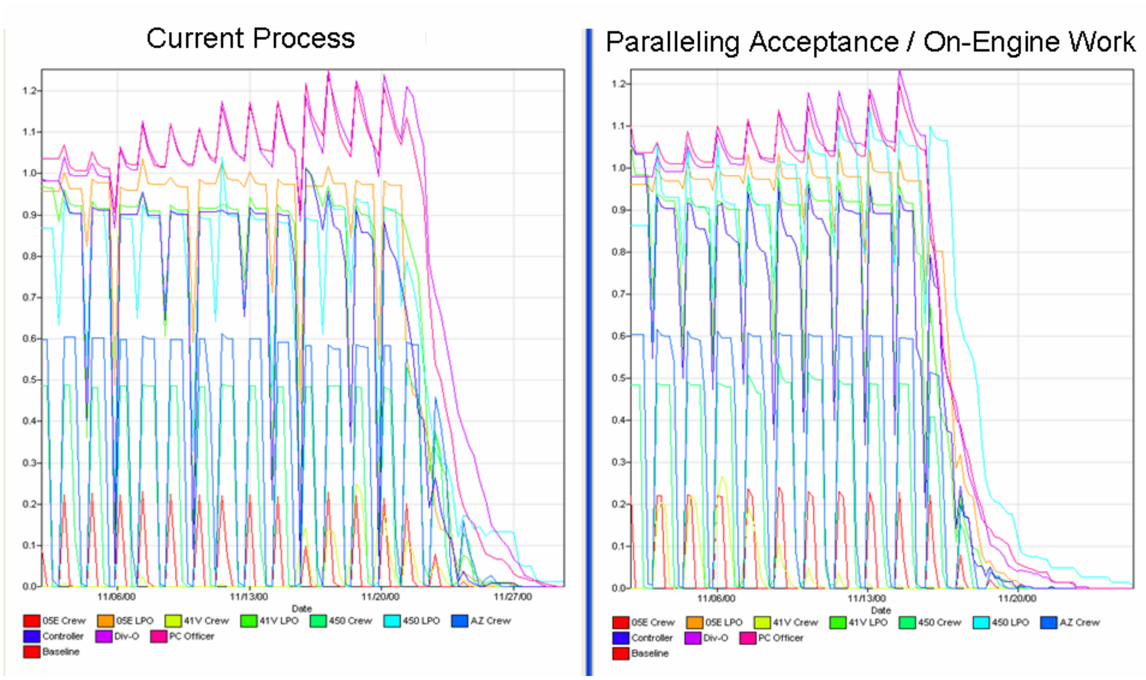


Figure 14. Intervention #1—Paralleling Acceptance Task—Impact on Position Backlog

Figure 14 presents a slight decrease in position backlog resulting from this intervention. In general, backlog is low both for the baseline case and for the case with the paralleled Acceptance-effort intervention.

Although absolute cost was not a focus of this project, relative cost changes resulting from interventions were of interest. Figure 15 presents a comparison between the cost figures associated with the baseline model and those associated with the model employing the intervention. Figure 15 indicates no significant impact on cost as a result of implementing this intervention.

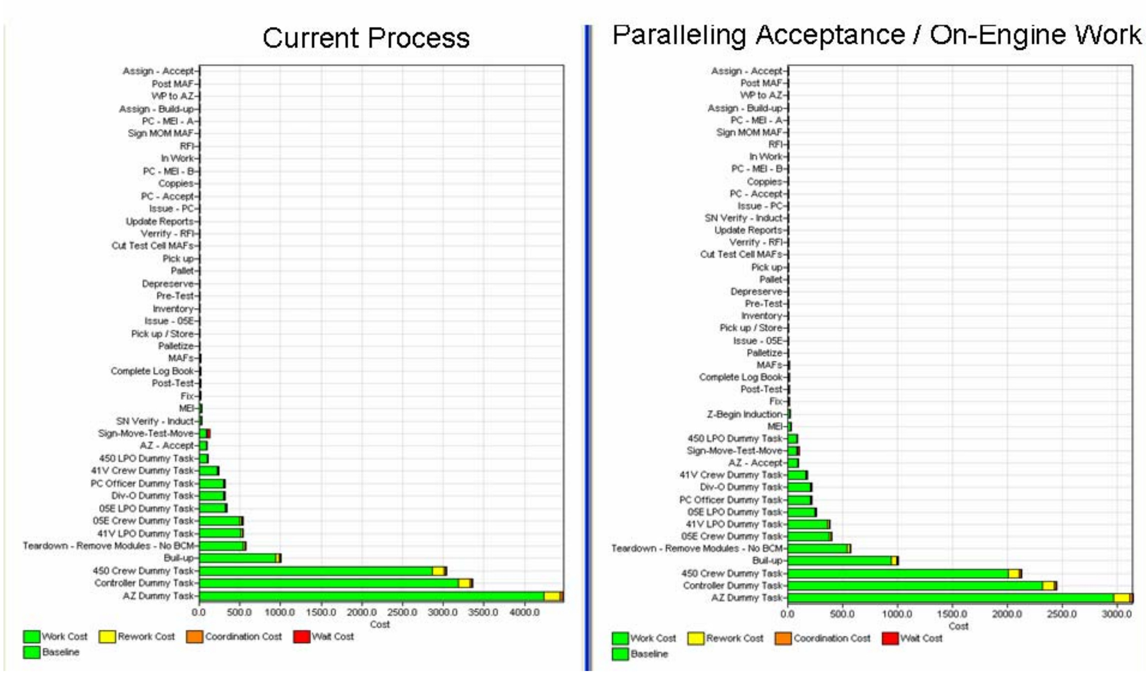


Figure 15. Intervention #1—Paralleling Acceptance Task—Impact on Cost

Finally, the risk associated with employing this intervention was assessed by comparing the functional risk of reach task for the baseline model with those for the model implementing the intervention. Figure 16 presents this comparison, which indicates a slight increase in functional risk for the AZ Acceptance task. This is not unexpected since this task is now being accomplished in conjunction with other tasks. As a result, the time originally devoted to AZ personnel accomplishing this task by Controller personnel to handle problems or exceptions is decreased when this intervention is implemented; the Controllers now have to assist not only the AZ personnel, but also other personnel accomplishing engine maintenance tasks at the same time.

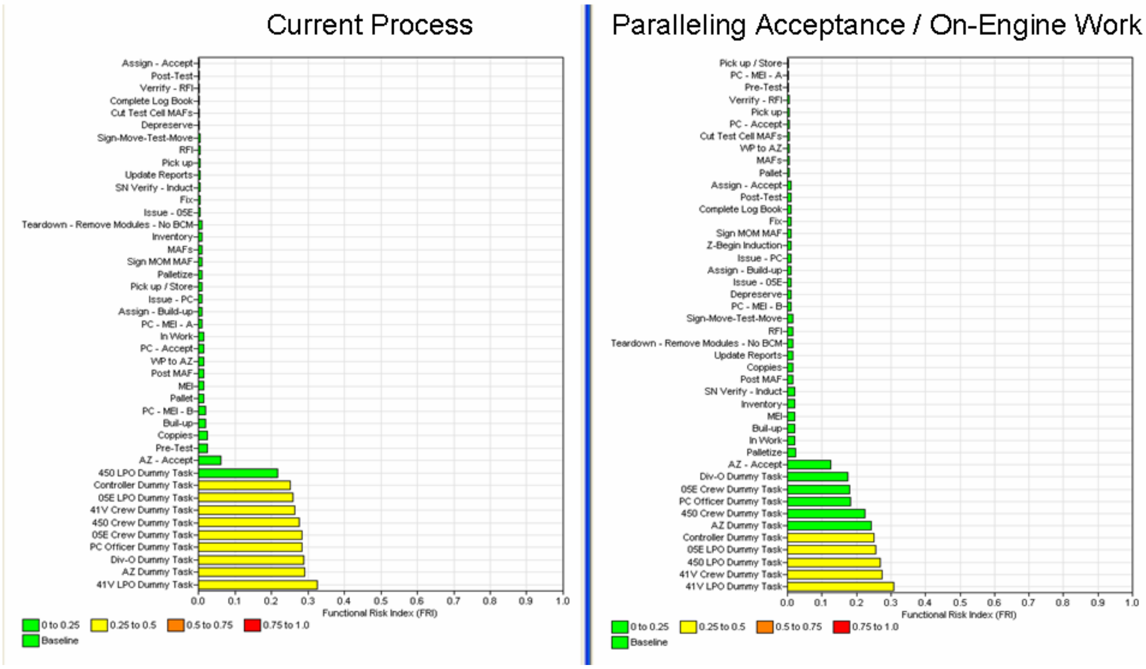


Figure 16. Intervention #1—Paralleling Acceptance Task—Impact on Functional Risk

The overall rating for this intervention is presented in Table 10. It was considered to be beneficial because the intervention resulted in a significant decrease in project duration, a slight decrease in position backlog, no significant impact on cost, and an increase in functional risk for only a single task.

Table 10. Intervention #1—Paralleling Acceptance Task—Overall Assessment

Intervention	Affect On...			
	Project Duration	Backlog	Cost	Risk
Parallel engine acceptance	58.56 hour decrease	Decrease for most positions	No significant impact	Increase in AZ Acceptance task Risk

Comparisons between the baseline model and the model employing a specific intervention or interventions were made for all remaining interventions. Figures analogous to Figures 13–16 were also developed. For ease of readability, those figures are presented in Appendix D. The remainder of this chapter will provide a description of intervention results in text only.

3. Intervention #2—Combining AZ and Controller Positions

This intervention was accomplished first without formally retraining personnel in the AZ and Controller positions, and then with the formal retraining. Irrespective of whether or not formal retraining occurred, the project duration was greater for this intervention than for the baseline, or current, case. Without formal retraining, project duration was 34.84 days—as opposed to the baseline project duration of 21.09 days. Formal retraining helped decrease this difference, although even with formal retraining, project duration was still 28.18 days. Combining the AZ and Controller positions helps decrease the duration of several of the tasks, especially the longer-duration tasks of teardown and buildup, because there are more individuals at the Controller level who can assist in handling exceptions generated by positions responsible for these larger tasks. It appears that by handling these exceptions, there is less time being given to the tasks originally assigned specifically to AZ personnel, such as the AZ Acceptance task. As a result, the overall impact is an increase in project duration. Although formal training helps formerly dedicated Controller personnel to better accomplish formerly AZ specific tasks, the training isn't sufficient; project duration is still greater than the baseline case.

For both cases, with and without formal retraining, the backlog associated with the combined AZ-Controller position is less than the backlog for either position when they are not combined. Unfortunately, in both cases, the backlog for the Division Officer and the PC officer both increase. This is the result of more exceptions being given to the PC Officer (the position directly above the combined AZ-Controller position), and the Division Officer (the position directly above the PC Officer) because there is a greater concentration of personnel in the combined AZ-Controller position that have direct access to the PC Officer and indirect, but close, access to the Division Officer.

There are significant increases in the work and re-work costs associated with the AZ Acceptance task resulting from this intervention. Work costs increase from $88.85 to $294.40, and rework costs increase from $3.97 to $15.69. These work and rework costs decrease when formal training occurs. In this case, work costs increase from $88.85 to $228.98, and rework costs increase from $3.97 to $8.15. Nonetheless, there is still an increase resulting from the increase in AZ Acceptance tasks duration. Because the task takes longer, it costs more. The tasks takes longer because AZ personnel are not dedicated to accomplishing this and other tasks they were originally focused on, but instead, are working both AZ-specific tasks and Controller-specific tasks.

Finally, this intervention's impact on functional risk is a significant increase in the risk of accomplishing the AZ Acceptance task risk. This task is long in duration already. Combining the AZ and Controller position increases the duration of the project, and the combined AZ-Controller position assigned to this task now is covering not only AZ-specific tasks but Controller tasks as well. AZ personnel originally dedicated to accomplishing this task now have the added duties of handing exceptions from 41V, 05E and 450 personnel—which they previously didn't have to handle. All of these factors result in this increased functional risk.

4. Intervention #3—Combining 41V and 450 Positions

Combining the 41V and 450 positions had similar results to combining the AZ and Controller positions. Project duration, both with and without formal retraining, increased as a result of this intervention. Combining the 41V and 450 positions without retraining resulted in a project duration of 37.69 days as opposed to 21.09 days for the baseline case. With retraining, project duration increased to 29.54 days. The increase in duration results from a combination of factors. First, most of the tasks accomplished by 41V and 450 personnel are defined as "work-duration" tasks; this title indicates they take a finite amount of time—and adding more personnel to help accomplish each task doesn't catalyze its completion. Second, although adding more personnel to a position responsible for work-duration tasks does not speed up task accomplishment, it does create more exceptions which need to be handled by individuals at higher levels. As a result, the overall duration for the project increases.

However the duration may increase, this intervention results in a decreased backlog for both the combined 41V-450 LPO position and the 41V-450 crew position. Increasing personnel available to accomplish tasks ensures all duties assigned to these combined positions are handled quickly and don't pile up.

Costs increase as a result of this intervention, specifically costs associated with long-duration tasks originally assigned specifically to 450 personnel (such as the Test task) and to 41V personnel (such as the Buildup task). Without formal retraining, the Test task work and rework costs increase from $86.00 to $1168.21 and from $2.16 to $63.68 respectively. With formal retraining, the Test task work and rework costs increase from $86.00 to $389.40 and from $2.16 to $7.79 respectively. This clearly shows the positive impact training has on decreasing Test task costs if positions are combined. Similarly, without formal retraining, the Buildup task work and rework costs increase from $942.56 to $1209.72 and $37.57 to $44.77 respectively. With formal retraining, the Buildup task work and rework costs increase from $942.56 to $1209.72 and $37.57 to $34.28 respectively. For this task, there is actually a decrease in rework cost as a result of the combination and formal training. Yet, with more personnel assigned to these combined positions, there is an increase in the number of exceptions being created—which increases the duration of tasks and consequently, their cost.

Risk associated with those tasks originally assigned to 41V and 450 personnel specifically increases in the case where no formal retraining occurs. This makes sense, since increased personnel without formal training simply gives you more and greater opportunities for problems to occur. The risk is decreased when formal training occurs, although the risks associated with certain 41V- and 450-specific tasks such as testing and buildup are still higher than for the baseline model.

5. Intervention #4—Decreasing Centralization

Decentralizing control results in a slight decrease in project duration from the baseline duration of 21.09 days to 20.54 days. Decentralization is a focus of the AIR*Speed* effort, and this modeling indicates that there is benefit in doing so. Decentralization allows individuals at lower levels to make decisions, decreasing the number of exceptions that need to be handled by personnel at higher levels, thus shortening project duration.

There is no significant impact on backlog for any position as a result of increasing decentralization. This is not surprising since decentralization is a global variable that applies to all positions in the model. As a result, there should be no change to individual backlog.

Increasing decentralization has the effect of slightly increasing rework cost. For example, rework costs for the Teardown task increase from $20.22 to $21.56 while rework costs for the Buildup task increase from $37.57 to $47.43. Although increasing decentralization allows individuals at lower levels to make decisions and accomplish tasks more quickly, doing so also increases the possibility of rework: individuals at lower levels usually do not take advantage of expertise at higher levels by having them assist in handling exceptions. The result is an increase in rework cost.

For the same reason, it might be expected that functional risk associated with completing tasks may increase as well. This is not the case for this model. It appears that although there may be some small amount of additional rework which slightly increases rework costs, the amount is not sufficient to increase functional risk. As a result, there is no significant impact to functional risk as a result of this intervention.

6. Intervention #5—Adding Personnel

Although adding personnel to certain positions (such as AZ, 450 Crew and 05E Crew) slightly decreased project duration, this slight decrease was on the order of minutes when adding up to 10 additional personnel. Adding personnel to the Controller and 41V Crew positions resulted in a similar increase in project duration, again on the order of minutes resulting from the addition of up to 10 personnel. Effectively, adding personnel has no appreciable effect on project duration.

Similarly, although Functional risk fluctuates slightly, almost in a sinusoidal manner as personnel are added, it too is appreciably unaffected by the addition of personnel. The Functional Risk Index fluctuates on the order of ±0.2: not significantly.

The rationale for this lack of change is that most tasks were modeled as "work-duration" tasks. By definition, adding personnel to positions responsible for these tasks should not, and does not have an affect on the modeled outcome.

7. Intervention #6—Altering Meeting Duration and Frequency

The impact of altering the 0700 morning meeting duration and frequency on project duration and functional risk are presented in Table 11. The top number in any given cell is the project duration measured in days while the bottom number is the functional risk index. Although Gantt charts delineating project duration and bar charts describing task-specific risk, similar to those presented in Figure 13 and Figure 16 respectively, were developed to calculate project duration and functional risk presented in the following two tables, the charts are not presented in this report.

Table 11. Intervention #6—Altering Meeting Duration & Frequency—Impact on Project Duration & Functional Risk

Project Duration (Days) / Functional Risk Index	Interval Between Meetings (Days)					
		1	**2**	**3**	**4**	**5**
Meeting Duration (Min)	**20**	21.09 0.59	20.46 0.62	20.53 0.69	20.27 0.76	20.39 0.70
	30	20.85 0.62	20.56 0.66	20.72 0.87	20.34 0.67	20.46 0.66
	45	20.85 0.62	20.56 0.66	20.72 0.87	20.80 0.71	20.55 0.66
	60	21.29 0.70	20.6 0.58	20.82 0.65	20.53 0.75	20.61 0.71
	90	21.69 0.67	21.12 0.73	20.98 0.69	20.72 0.59	20.40 0.74
	120	22.29 0.73	21.48 0.73	20.95 0.74	20.92 0.64	20.60 0.68

With respect to the top number in each cell, the red and green values identify the longest and shortest project durations respectively. Similarly, with respect to the bottom number in each cell, the red and green values identify the highest and lowest functional risk index. The solid-line circled numbers indicate the longest and shortest durations measured for all cases evaluated while the dashed-line circled numbers indicate the largest and smallest functional risk index.

These data indicate that irrespective of meeting duration, there is a clear benefit to decreasing meeting frequency to every other day. This is depicted in Table 11 as increasing the interval between meetings to two days. It is not as clear that there is significant additional benefit to further decreasing meeting frequency or increasing duration between meetings to every three days or greater. Generally speaking, less meeting frequency or a greater interval between meetings appears to result in shorter project duration. The data less clearly indicates the impact of meeting duration, although shorter meetings appear to result in shorter project duration. There does not appear to be a correlation between functional risk and meeting duration or frequency. This is considered a positive result; action can be taken to potentially shorten project duration by increasing the interval between 0700 morning meetings while not affecting the overall functional risk of the program.

These results which indicate that increasing the interval between meetings and decreasing meeting duration results in a decrease in project duration make sense. The 400 Division personnel are highly skilled, and the F414 maintenance tasks they are performing are well-defined, well-understood tasks. Decreasing meeting frequency and duration allows greater time for personnel to work on engine-maintenance tasks. A potential drawback to decreasing meeting frequency and duration is less reliable information transfer. Although this may occur to some degree, the relative detriment is not as important as the benefit of greater time to work on the engine—the highly skilled workforce is capable of making accurate decisions regarding their well-defined, well-understood tasks without as many meetings.

8. Intervention #7—Combining Meetings

Figure 17 presents the impact on project duration of first combining the all of the morning meetings, and then of separately combining the morning meetings and the afternoon meetings. Figure 18 presents the impact on functional risk of making these same two combinations of meetings.

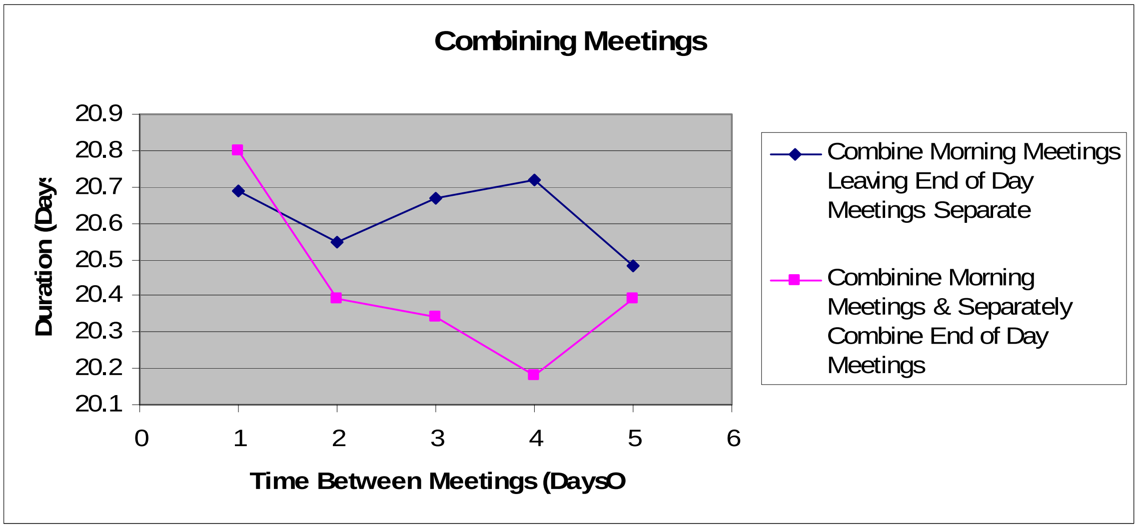


Figure 17. Intervention #7—Combining Meetings—Impact on Project Duration

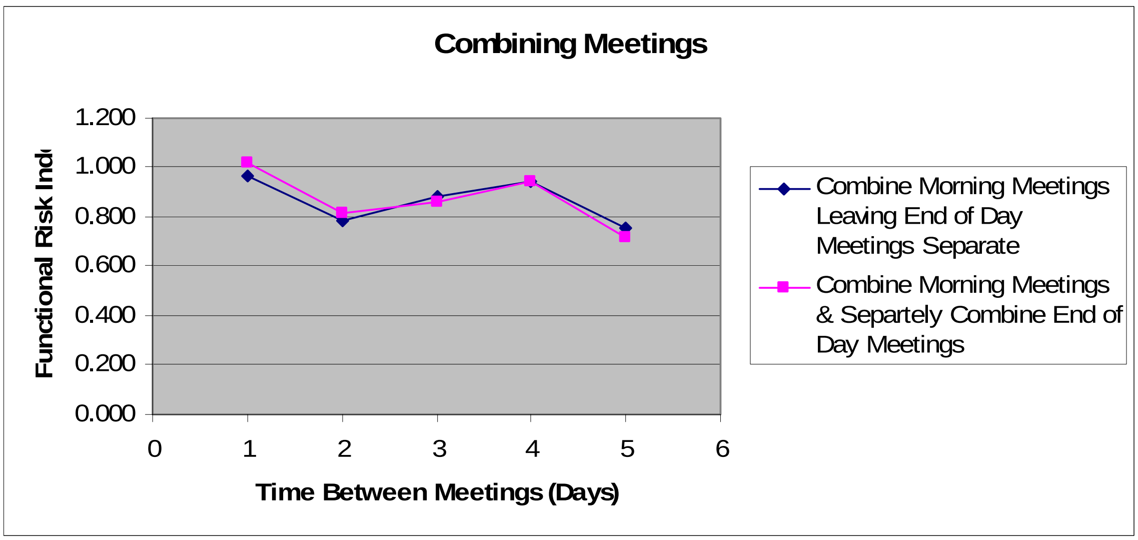


Figure 18. Intervention #7—Combining Meetings—Impact on Functional Risk

Data presented in Figure 17 indicate that there is no clear impact on project duration as a result of combining only the morning meetings and leaving the afternoon meetings separated. In contrast, when the afternoon meetings are combined such that there is one mass meeting in the morning and one in the afternoon, the result is a decrease in project duration. Irrespective of which meetings are combined, data presented in Figure 18 indicates that this intervention causes no impact on functional risk. This is a positive indication—separately combining morning and afternoon meetings leads to a decrease in project duration while not adversely affecting functional risk.

These results indicate that it is important for information to consistently be shared between positions. If the morning meetings, by virtue of being combined, facilitate the transfer of information to personnel in all positions, afternoon meetings should do the same. Failure to combine the afternoon meetings results in an increased possibility that different or worse conflicting information is received by different positions, which may contradict information received in the morning meetings.

9. Combined Intervention

The combined model entailed the following interventions:

1. Intervention #1—Paralleling the Acceptance Task
2. Intervention #4—Decreasing Centralization from High to Low
3. Intervention #6—Decreasing 0700 meeting frequency to every 2 days
4. Intervention #7—Separately combining morning & afternoon meetings

The impact of these combined interventions on project duration was a decrease from 21.09 days to 13.72 days. This is a 35% decrease in F414 throughput time. Similar to most of the single interventions, the backlog for most of the positions decreased with only one position, the 450 LPO having an increase. In general, this is positive, especially considering the large decrease in project duration. With respect to costs, there was a slight increase in the Teardown task rework cost from $26.44 to $36.93 and a slight decrease in the Buildup task rework cost from $48.43 to $22.13. Overall, the changes in cost were not considered significant. Finally, there was no significant impact on functional risk as a result of these combined interventions.

These combined interventions all make sense and are driven in large part by the results of Intervention #1, paralleling the Acceptance task. This intervention results in the greatest change to the 400 Division organizational structure, and has the greatest positive impact.

V. Conclusions and Recommendations

A. Conclusions

The results of this study lead to the conclusion that four of the seven modifications or interventions to the 400 Division considered in this study would be beneficial to reducing the F414 throughput duration. Those interventions are the following.

1. Intervention #1—Paralleling the Acceptance Task
2. Intervention #4—Decreasing Centralization from High to Low
3. Intervention #6—Decreasing 0700 meeting frequency to every 2 days
4. Intervention #7—Separately combining morning & afternoon meetings

The greatest benefit to reducing the F414 throughput duration comes from paralleling the Acceptance task, a task that precedes and is in series with all other F414 engine-maintenance tasks. Although by implementing this intervention, there is an increased functional risk associated with the Acceptance task; this increase in risk is minor relative to the significant decrease in throughput time from 21.09 days to 13.77 days. There is also a decrease in position backlog as a result of this intervention, a result that is prevalent across all interventions.

Decreasing centralization has a positive impact on decreasing F414 throughput duration as well, although not to the degree as paralleling the Acceptance task. This intervention results in only a 4.4 hour decrease in duration as opposed to the first intervention, which resulted in a 58.56 hour decrease. Nonetheless, decreasing centralization, a benefit realized through the implementation of AIR*Speed*, is beneficial to reducing project duration.

Decreasing the 0700 meeting frequency from every day to every other day has a clear benefit to reducing F414 throughput duration. This intervention benefits from the highly skilled 400 Division work-force and the well-defined, well-understood tasks associated with F414 maintenance, allowing personnel to spend more time working on engine maintenance and less time exchanging information in meetings. Although results indicate there may be additional benefit to further reducing frequency of the 0700 meeting, the benefit to reducing F414 throughput duration is less clear. This intervention is a strong candidate for implementation since there is clear benefit to reducing project duration while having no adverse impact on functional risk.

Separately combining the current morning meetings and the afternoon meetings such that there is one morning meeting and one afternoon meeting that all personnel attend results in a reduction in F414 throughput duration. The benefit of making this intervention is a reduction in duration of approximately 7.28 hours. Although the benefit is not as great as paralleling the Acceptance task, it nonetheless exists. At the same time this benefit is gained, there is also no increase in functional risk.

Unfortunately, the benefits associated with combining these four interventions is not additive. This makes sense based on their interrelated nature. When combining the interventions, the benefit to reducing the F414 throughput duration is nonetheless significant in that there is a reduction of over 35% from the baseline case representing the current 400 Division organization. In conjunction with this benefit, there is a decrease in backlog for all positions excluding one, the 450 LPO, and there is no adverse impact to cost or functional risk.

Two other interventions considered, combining the AZ and Controller positions and combining the 41V and 450 positions, results in increases in F414 throughput duration, increases in cost, and risk with the only predicted benefit being a decrease in position backlog for the combined positions. Clearly, these interventions are not beneficial to the 400 Division.

Finally, the intervention associated with adding additional personnel did not affect F414 throughput duration, and had no impact on risk. Obviously, there would be no benefit to implementing this intervention.

B. Recommendation

The following recommendations are based on the philosophy that the 400 Division should start to slowly implement the interventions presented in the previous section that reduce F414 throughput duration. One intervention should be implemented at a time and then evaluated prior to implementing a second intervention. The first intervention to be implemented is that which can be un-implemented if the results of the implementation are not as predicted by this study or are not deemed beneficial to 400 Division operations. As a result, the 400 Division should implement the four interventions listed in the previous section in the following order.

1. Intervention #6—Decreasing 0700 meeting frequency to every 2 days
2. Intervention #7—Separately combining morning & afternoon meetings
3. Intervention #4—Decreasing Centralization from High to Low
4. Intervention #1—Paralleling the Acceptance Task

The 400 Division should implement intervention #6 first and assess the impact. If the impact is deemed beneficial, they should proceed to implementing intervention #7. Following each intervention, the 400 Division should assess the benefit and determine if continuing with the intervention is appropriate and if implementing further interventions is warranted. Conducting the 0700 meeting every other day is a relatively easy organizational change which should result in a decrease in F414 throughput duration. At the same time, it is an organization change that can be reversed if deemed necessary. In contrast, paralleling the Acceptance task would be an organizational change which would be less easy to reverse, but at the same time, it would catalyze the greatest reduction in F414 throughput duration.

C. Future Research

The 400 Division should report the results of their implementation efforts to NPS. By doing so, NPS could assist the 400 Division in understanding any differences between modeled and actual results, and offer assistance in making modifications to the proposed interventions which may further benefit the 400 Division. At the same time, additional organizations within the NAS Lemoore AIMD, e.g., the Airframe Division, the Avionics Division, etc, should be separately modeled to identify potential organizational changes which may improve their processes. Consideration should then be given to integrating these separate models to develop a model of the complete AIMD. This would aid in identifying modifications to the larger organization, which would, in turn, benefit information flow.

Clearly, organizational modeling is not limited to the AIMD at NAS Lemoore. The model developed for this study could be modified to represent engine maintenance division in other AIMD units across the Navy. Although the interventions identified in this study reduce the F414 throughput duration, each organization is, at least to some degree, unique. Care should be given to ensure the model of each organization accurately describes the information flow through that specific organization. This research should be completed prior to researching potential interventions to achieve whatever goal is sought. Nonetheless, organizational modeling is a powerful tool which, in this study, has provided some key insights into improving the NAS Lemoore AIMD F414 maintenance process.

Similar studies of other Navy organizations likewise have the potential for identifying methods of improving information flow through their organization, leading to improved organizational performance.

Appendix A—Position Properties

A. Division Officer Position Properties

Property	Value	Unit
Position	Div-O	N/A
Culture	Generic	N/A
Role	pm	N/A
App-Experience	Med	N/A
FTE	0.05	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium Controller Skill - Med AZ Skill - Low 41V LPO Skill - Low 41V Crew Skill - Low 05E LPO Skill - Low 05E Crew Skill - Low 450 LPO Skill - Low 450 Crew Skill - Low	N/A
Staff:		N/A
Person	Allocation	Team Lead
1	0.30	Y

B. Production Control officer Position Properties

Property	Value	Unit
Property	Value	Unit
Position	PC Officer	N/A
Culture	Generic	N/A
Role	sl	N/A
App-Experience	Med	N/A
FTE	0.05	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium Controller Skill - High AZ Skill - Low 41V LPO Skill - Med 41V Crew Skill - Low 05E LPO Skill - Med 05E Crew Skill - Low 450 LPO Skill - Med 450 Crew Skill - Low	N/A
Staff:		N/A
Person	Allocation	Team Lead
1	0.30	Y

C. Controller Position Properties

Property	Value	Unit
Property	Value	Unit
Position	Controllers	N/A
Culture	Generic	N/A
Role	sl	N/A
App-Experience	Med	N/A
FTE	0.65	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium Controller Skill - High AZ Skill - Medium 41V LPO Skill - Medium 41V Crew Skill - Low 05E LPO Skill - Medium 05E Crew Skill - Low 450 LPO Skill - Medium 450 Crew Skill - Low	N/A
Staff:		N/A
Person	Allocation	Team Lead
5	0.65	Y - 1 Person

D. AZ Position Properties

Property	Value	Unit
Property	Value	Unit
Position	AZ	N/A
Culture	Generic	N/A
Role	st	N/A
App-Experience	Medium	N/A
FTE	1.19	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium AZ Skill = High	N/A
Staff:		N/A
Person	Allocation	Team Lead
6	0.85	Y - 1 Person
2	1.00	N

E. 41V LPO Position Properties

Property	Value	Unit
Property	Value	Unit
Position	41V LPO	N/A
Culture	Generic	N/A
Role	sl	N/A
App-Experience	Med	N/A
FTE	0.1	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium 41V LPO Skill = High 41V Crew - Medium	N/A
Staff:		N/A
Person	Allocation	Team Lead
1	0.60	Y

F. 41V Crew Position Properties

Property	Value	Unit
Property	Value	Unit
Position	41V Crew	N/A
Culture	Generic	N/A
Role	st	N/A
App-Experience	Medium	N/A
FTE	3.44	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium 41V Crew Skill = High	N/A
Staff:		N/A
Person	Allocation	Team Lead
9	0.80	Y - 1 Person
15	0.90	N

G. 05E LPO Position Properties

Property	Value	Unit
Property	Value	Unit
Position	05E LPO	N/A
Culture	Generic	N/A
Role	sl	N/A
App-Experience	Medium	N/A
FTE	0.058	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium 05E LPO Skill = High 05E Crew Skill = High	N/A
Staff:		N/A
Person	Allocation	Team Lead
1	0.35	Y

H. 05E Crew Position Properties

Property	Value	Unit
Property	Value	Unit
Position	05E Crew	N/A
Culture	Generic	N/A
Role	st	N/A
App-Experience	Medium	N/A
FTE	0.427	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium 05E Crew Skill = High	N/A
Staff:		N/A
Person	Allocation	Team Lead
3	0.75	Y - 1 Person
1	0.30	N

I. 450 LPO Position Properties

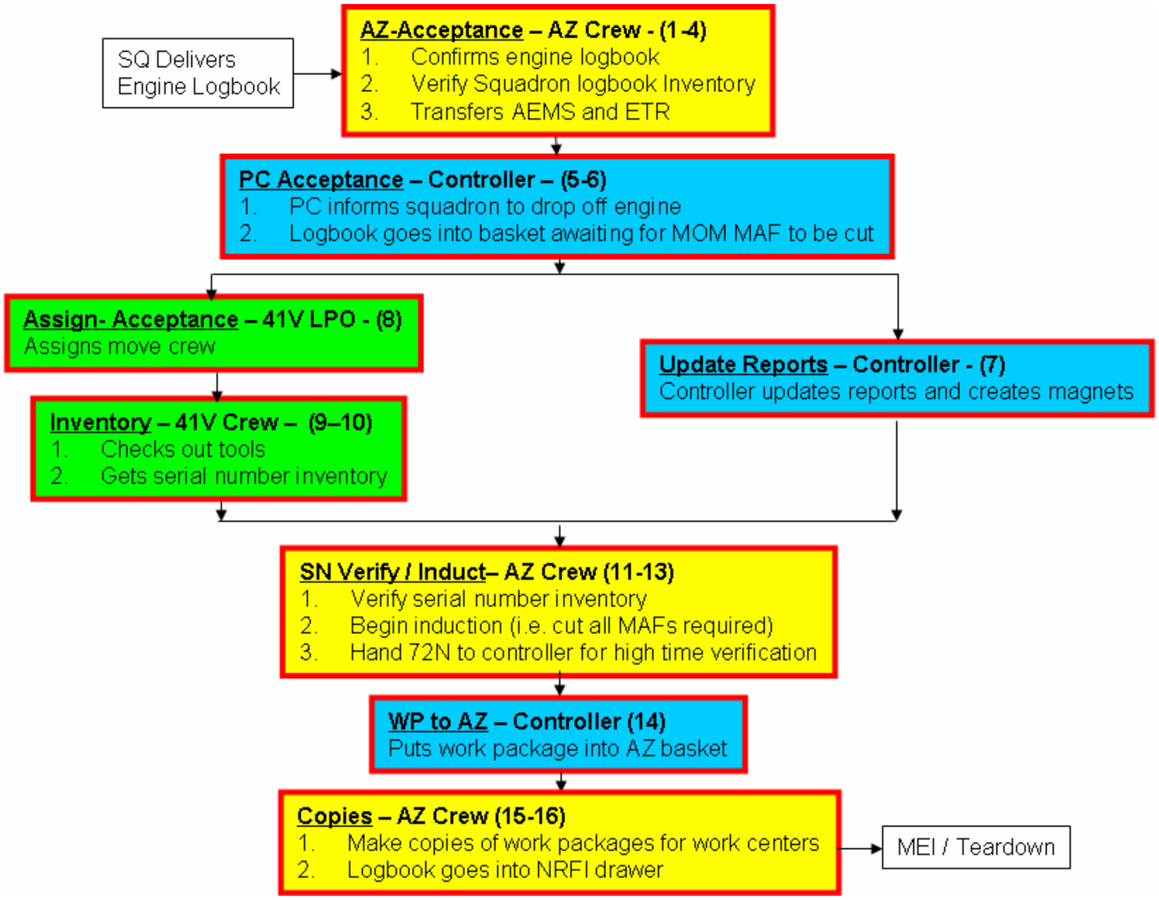
Property	Value	Unit
Property	Value	Unit
Position	450 LPO	N/A
Culture	Generic	N/A
Role	sl	N/A
App-Experience	Medium	N/A
FTE	0.0167	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium 450 LPO Skill - High 450 Crew - Medium	N/A
Staff:		N/A
Person	Allocation	Team Lead
1	0.10	Y

J. 450 Crew Position Properties

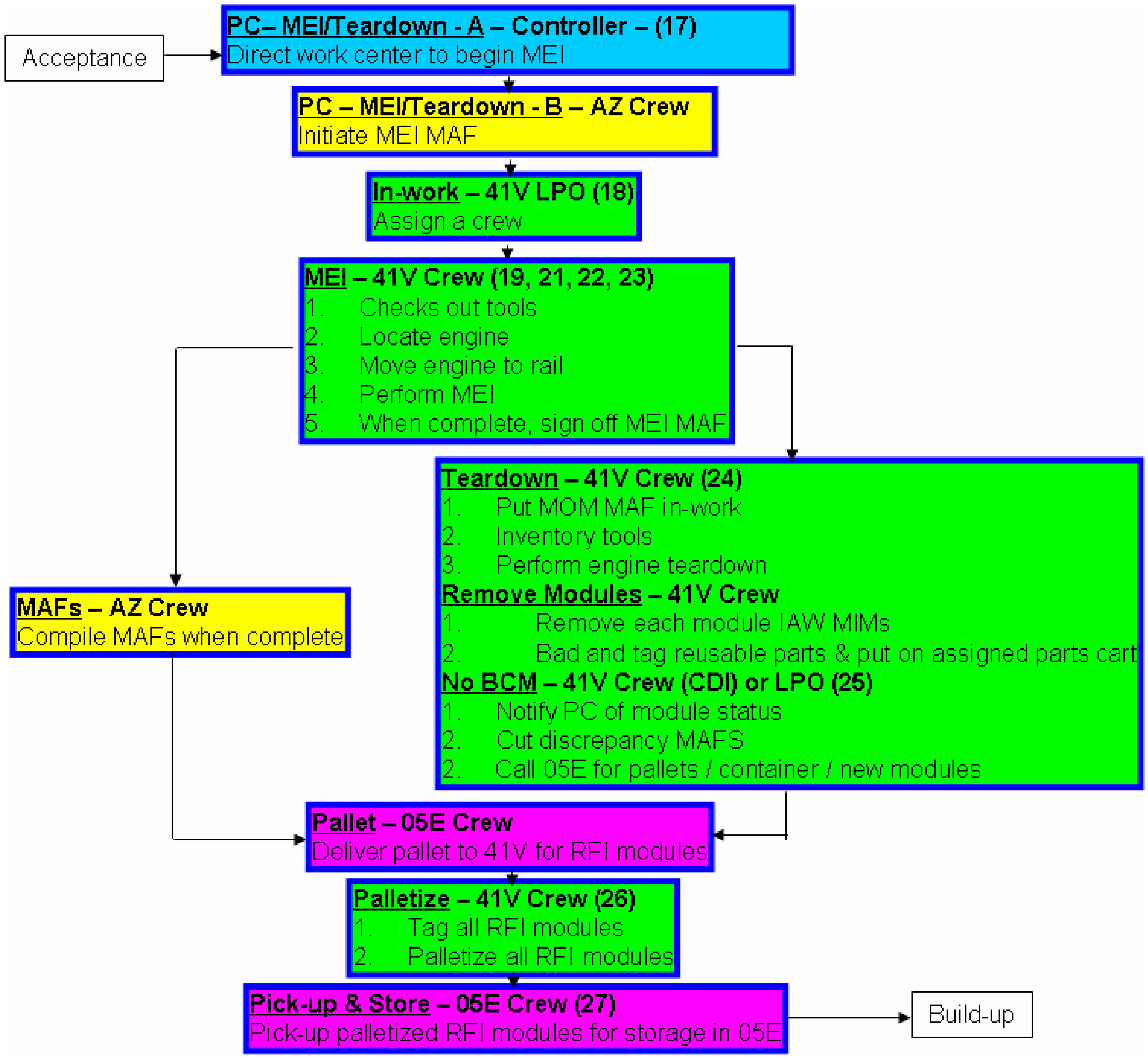
Property	Value	Unit
Property	Value	Unit
Position	450 Crew	N/A
Culture	Generic	N/A
Role	st	N/A
App-Experience	Medium	N/A
FTE	0.975	FTE
Salary	50	FTE/hr
Skill Rating	Generic - Medium 450 Crew Skill - High	N/A
Staff:		N/A
Person	Allocation	Team Lead
9	0.65	Y

Appendix B—Detailed Task Description

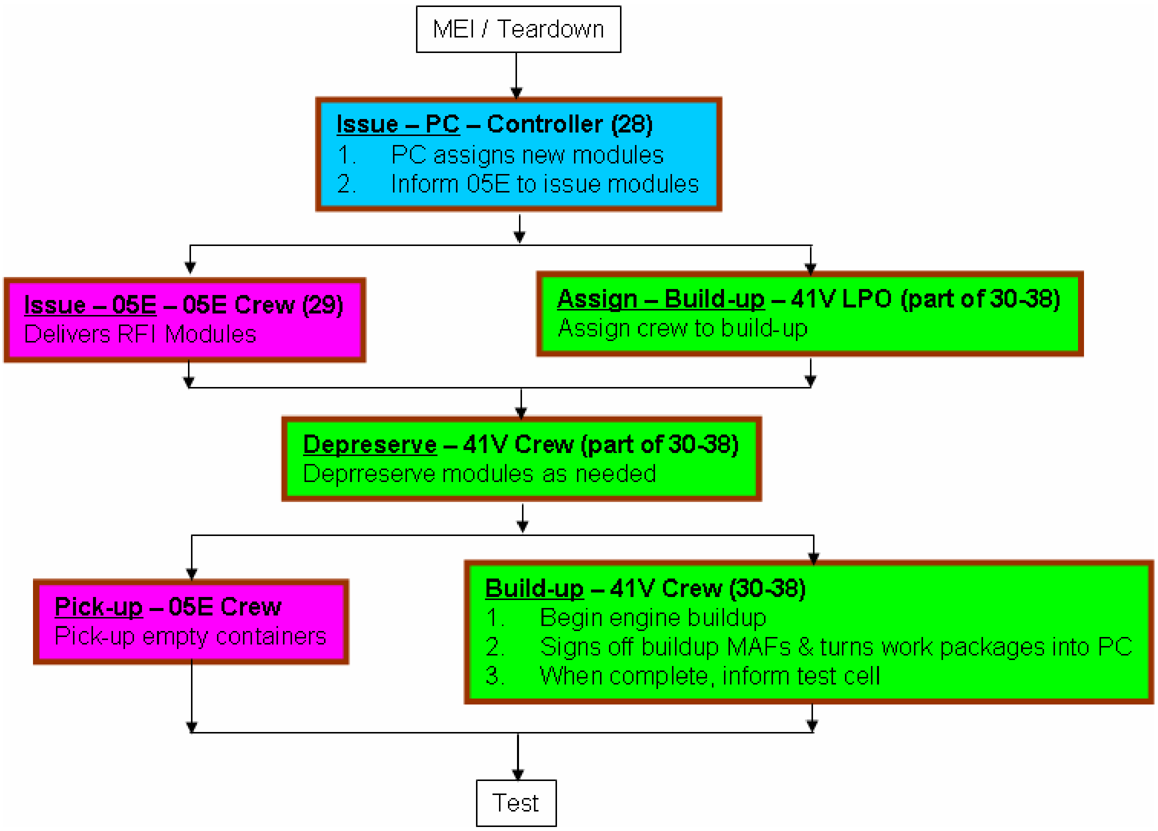
A. Acceptance Task



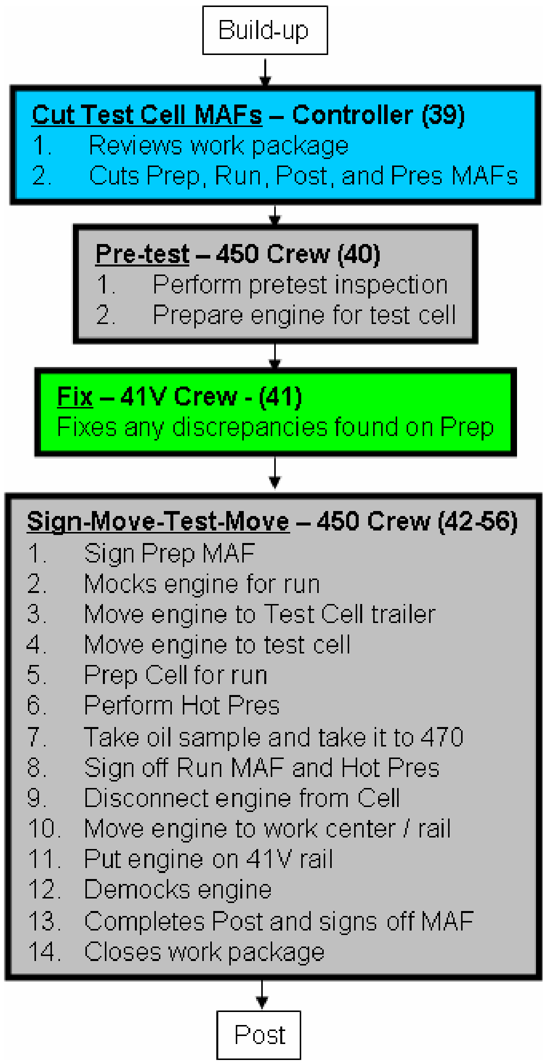
B. MEI/Teardown Task



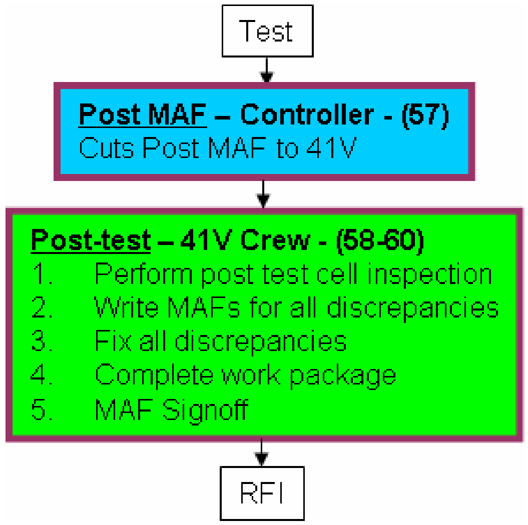
C. Buildup Task



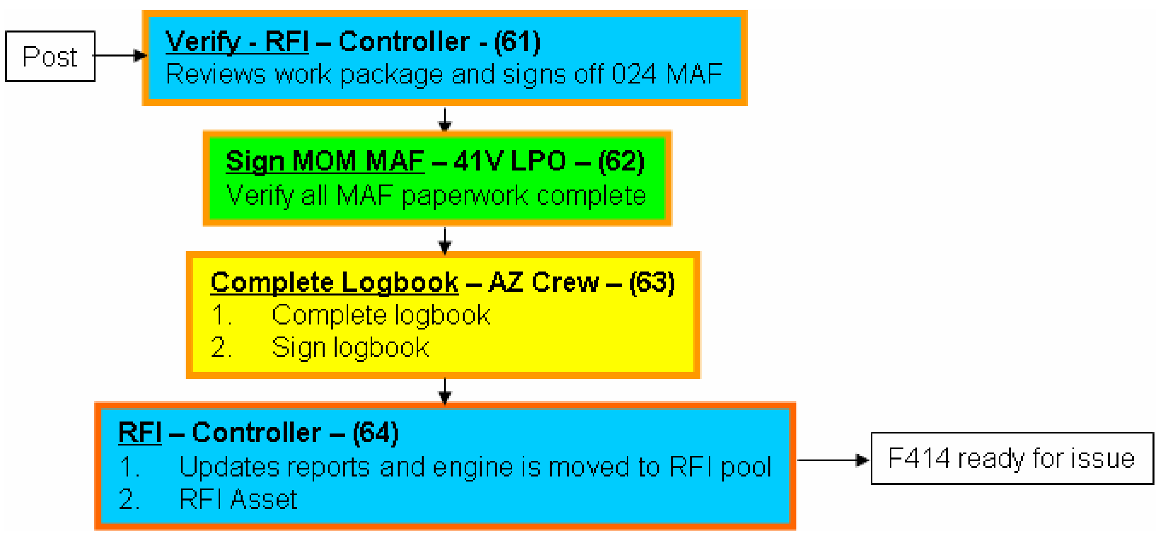
D. Test Task


Build-up
Cut Test Cell MAFs – Controller (39)
1. Reviews work package
2. Cuts Prep, Run, Post, and Pres MAFs
Pre-test – 450 Crew (40)
1. Perform pretest inspection
2. Prepare engine for test cell
Fix – 41V Crew - (41)
Fixes any discrepancies found on Prep
Sign-Move-Test-Move – 450 Crew (42-56)
1. Sign Prep MAF
2. Mocks engine for run
3. Move engine to Test Cell trailer
4. Move engine to test cell
5. Prep Cell for run
6. Perform Hot Pres
7. Take oil sample and take it to 470
8. Sign off Run MAF and Hot Pres
9. Disconnect engine from Cell
10. Move engine to work center / rail
11. Put engine on 41V rail
12. Democks engine
13. Completes Post and signs off MAF
14. Closes work package
Post

E. Post-Test Inspection Task



F. Ready-For-Issue (RFI) Task



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Appendix C—Detailed Task Properties

A. AZ Accept

Property	Value
Task	**AZ Accept**
Effort	14 Days
Effort-Type	Work-Duration
Required Skill	AZ Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
AZ	2%

B. PC Accept

Property	Value
Task	**PC Accept**
Effort	15 min
Effort-Type	Work-Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
PC	1%

C. Update Reports

Property	Value
Task	**Update Reports**
Effort	15 min
Effort-Type	Work Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
Controller	2%

D. Assign—Acceptance

Property	Value
Task	**Assign - Acceptance**
Effort	6 min
Effort-Type	Work Duration
Required Skill	41V LPO Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V LPO	2%

E. Inventory

Property	Value
Task	**Inventory**
Effort	45 min
Effort-Type	Work Duration
Required Skill	41V Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V Crew	2%

F. SN Verify/Induct

Property	Value
Task	**SN Verify / Induct**
Effort	177 min
Effort-Type	Work Duration
Required Skill	AZ Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
AZ	20%

G. WP to AZ

Property	Value
Task	**WP to AZ**
Effort	2 min
Effort-Type	Work Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
Controller	1%

H. Copies

Property	Value
Task	**Copies**
Effort	4 min
Effort-Type	Work Duration
Required Skill	AZ Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
AZ	2%

I. PC-MEI/Teardown—A

Property	Value
Task	PC - MEI / Teardown - A
Effort	3 min
Effort-Type	Work Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	Allocation
Controller	0.015

J. PC-MEI/Teardown—B

Property	Value
Task	PC - MEI / Teardown - B
Effort	5 min
Effort-Type	Work Duration
Required Skill	AZ Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	Allocation
AZ	0.015

K. In-Work

Property	Value
Task	**In-Work**
Effort	20 min
Effort-Type	Work Duration
Required Skill	41V LPO
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V LPO	4%

L. MEI

Property	Value
Task	**MEI**
Effort	2.9 Hr
Effort-Type	Work Duration
Required Skill	41V Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Medium
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V Crew	7%

M. MAF's

Property	Value
Task	**MAFs**
Effort	3 Hr
Effort-Type	Work Duration
Required Skill	AZ Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Med
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
AZ	5%

N. Teardown/Remove Modules/No BCM

Property	Value
Task	**Teardown / Remove Modules / No BCM**
Effort	12.75 Hr
Effort-Type	Work Duration
Required Skill	41V Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	High
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V Crew	37%

O. Pallet

Property	Value
Task	**Pallet**
Effort	11 min
Effort-Type	Work Duration
Required Skill	05E Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
05E Crew	20%

P. Palletize

Property	Value
Task	**Palletize**
Effort	160 min
Effort-Type	Work Duration
Required Skill	41V Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V Crew	1%

Q. Pick-up & Store

Property	Value
Task	**Pick-up & Store**
Effort	60 min
Effort-Type	Work Duration
Required Skill	05E Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
05E Crew	20%

R. Issue—PC

Property	Value
Task	**Issue - PC**
Effort	15 min
Effort-Type	Work Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
Controller	1.50%

S. Issue—05E

Property	Value
Task	Issue - 05E
Effort	60 min
Effort-Type	Work Volume
Required Skill	05E Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	Allocation
05E Crew	20%

T. Assign—Buildup

Property	Value
Task	Assign - Build-up
Effort	5 min
Effort-Type	Work Duration
Required Skill	41V LPO Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	Allocation
41V LPO	4%

U. Depreserve

Property	Value
Task	**Depreserve**
Effort	17.5 min
Effort-Type	Work Duration
Required Skill	41V Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V Crew	3%

V. Pick-up

Property	Value
Task	**Pick-up**
Effort	7 min
Effort-Type	Work Duration
Required Skill	05E Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
05E Crew	20%

W. Buildup

Property	Value
Task	**Build-up**
Effort	18.275 min
Effort-Type	Work Duration
Required Skill	41V Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V Crew	0.45

X. Cut Test Cell MAFs

Property	Value
Task	**Cut Test Cell MAFs**
Effort	15 min
Effort-Type	Work Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
Controller	3%

Y. Pre-Test

Property	Value
Task	**Pre-Test**
Effort	25 min
Effort-Type	Work Duration
Required Skill	450 Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
450 Crew	10%

Z. Fix

Property	Value
Task	**Fix**
Effort	113 min
Effort-Type	Work Duration
Required Skill	41V Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V Crew	5%

AA. Sign—Move—Test—Move

Property	Value
Task	**Sign - Move - Test - Move**
Effort	378 min
Effort-Type	Work Duration
Required Skill	450 Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
450 Crew	42%

BB. Post MAF

Property	Value
Task	**Post MAF**
Effort	2 min
Effort-Type	Work Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
Controller	1%

CC. Post-Test

Property	Value
Task	**Post-Test**
Effort	2.5 Hr
Effort-Type	Work Duration
Required Skill	41V Crew Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V Crew	0.03

DD. Verify RFI

Property	Value
Task	**Verrify - RFI**
Effort	19 min
Effort-Type	Work Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
Controller	2%

EE. Sign Mom MAF

Property	Value
Task	**Sign MOM MAF**
Effort	15 min
Effort-Type	Work Duration
Required Skill	41V LPO Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
41V LPO	2%

FF. Complete Log Book

Property	Value
Task	**Complete Log Book**
Effort	100
Effort-Type	Work Duration
Required Skill	AZ Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
AZ	0.115

GG. RFI

Property	Value
Task	**RFI**
Effort	6
Effort-Type	Work Duration
Required Skill	Controller Skill
Priority	High
Requirement Complexity	Medium
Solution Complexity	Low
Uncertainty	Low
Fixed Cost	0.00
Position Assigned (Primary)	**Allocation**
Controller	1.50%

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Appendix D—Meeting Properties

A. 0630 41V-PC Meeting

Property	Value	Unit
Meeting	**0630 41V-PC Meeting**	**N/A**
Priority	High	N/A
Duration	8	min
Interval	1	Day
Repeating	Y	N/A
Schedule-till-end	Y	N/A
Meeting Time	0	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	Controller	0.167
	41V LPO	1

B. Pre-0700 PC Meeting

Property	Value	Unit
Meeting	**Pre-0700 PC Meeting**	N/A
Priority	High	N/A
Duration	15 min	min
Interval	1	Day
Repeating	y	N/A
Schedule-till-end	y	N/A
Meeting Time	10	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	Controllers	1

C. 41V Pre-0700 Meeting

Property	Value	Unit
Meeting	41V Pre-0700 Meeting	N/A
Priority	High	N/A
Duration	10	min
Interval	1	Day
Repeating	y	N/A
Schedule-till-end	y	N/A
Meeting Time	10	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	41V LPO	1
	41V Crew	1

D. 0700 Meeting

Property	Value	Unit
Meeting	0700 Meeting	N/A
Priority	High	N/A
Duration	20	min
Interval	1	Day
Repeating	Y	N/A
Schedule-till-end	Y	N/A
Meeting Time	30	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	Div-O	1
	PC Officer	1
	Controller	1
	41V LPO	1
	05E LPO	1
	450 LPO	1

E. 05E Post-0700 Pass-down Meeting

Meeting	**05E Post-0700 passdown Meeting**	N/A
Priority	None	N/A
Duration	10	min
Interval	1	Day
Repeating	y	N/A
Schedule-till-end	y	N/A
Meeting Time	50	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	05E LPO	1
	05E Crew	1

F. 450 Post-0700 Pass-down Meeting

Property	Value	Unit
Meeting	**450 Post-0700 pass-down Meeting**	N/A
Priority	High	N/A
Duration	10	min
Interval	1	Day
Repeating	Y	N/A
Schedule-till-end	y	N/A
Meeting Time	60	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	450 LPO	1
	450 Crew	1

G. PC End-of-Day Meeting

Property	Value	Unit
Meeting	**PC End of Day Meeting**	N/A
Priority	High	N/A
Duration	10 min	Hour
Interval	1	Day
Repeating	y	N/A
Schedule-till-end	y	N/A
Meeting Time	470	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	End	N/A
Last Lag	0	Day
		Allocation
Attendence	Controller	1
	AZ	1

H. 41V End-of-Day Meeting

Property	Value	Unit
Meeting	**41V End of Day**	N/A
Priority	High	N/A
Duration	0.125	Hour
Interval	1	Day
Repeating	Y	N/A
Schedule-till-end	Y	N/A
Meeting Time	470	Min
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	41V LPO	1
	41V crew	1

I. 05E End-of-Day Meeting

Property	Value	Unit
Meeting	**05E End of Day Meeting**	N/A
Priority	High	N/A
Duration	15	Hour
Interval	1	Day
Repeating	y	N/A
Schedule-till-end	y	N/A
Meeting Time	470	Min
First Milestone	None	N/A
First Lag	0	Day
Last Milestone	None	N/A
Last Lag	0	Day
		Allocation
Attendence	05E LPO	1
	05E Crew	1

J. Buffer Management Meeting

Property	Value	Unit
Meeting	**Buffer Management Meeting**	N/A
Priority	High	N/A
Duration	1	Hour
Interval	2	Week
Repeating	Y	N/A
Schedule-till-end	Y	N/A
Meeting Time	30.5	hrs
First Milestone	Start	N/A
First Lag	0	Day
Last Milestone	Finish	N/A
Last Lag	0	Day
		Allocation
Attendence	PC Officer	1
	Controllers	1
	41V LPO	1

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Appendix D—Comparison of Baseline Model Results to Models Employing Interventions

A. Intervention #1—Paralleling Acceptance

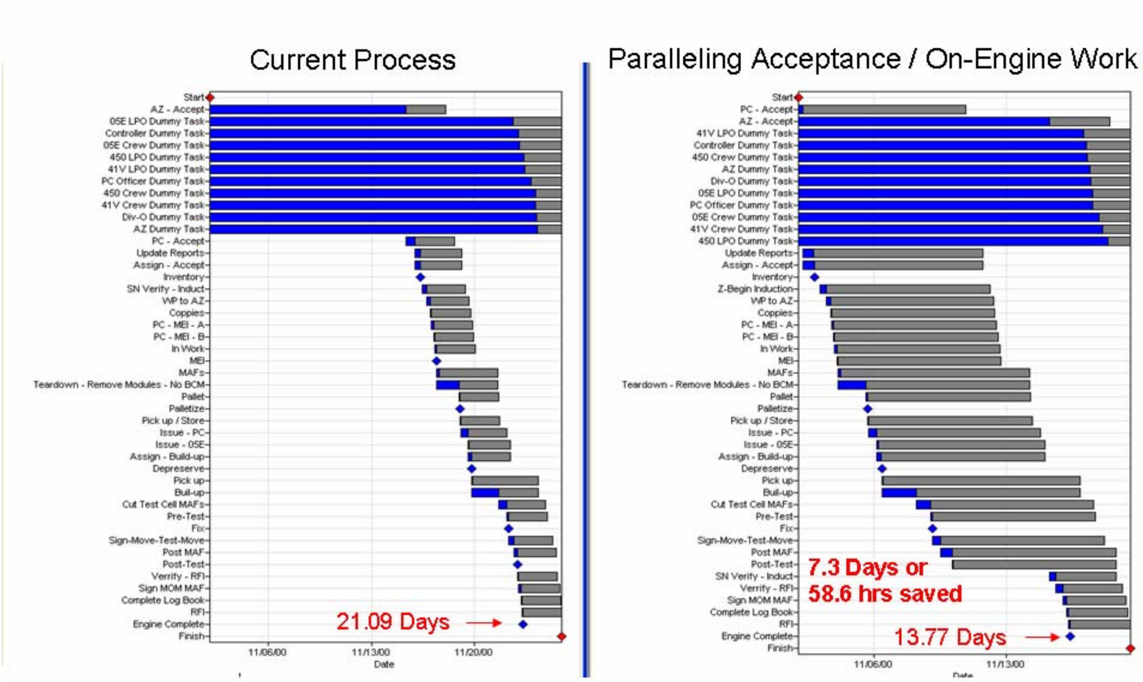

Figure 19. Intervention #1—Paralleling Acceptance Task—Impact on Duration

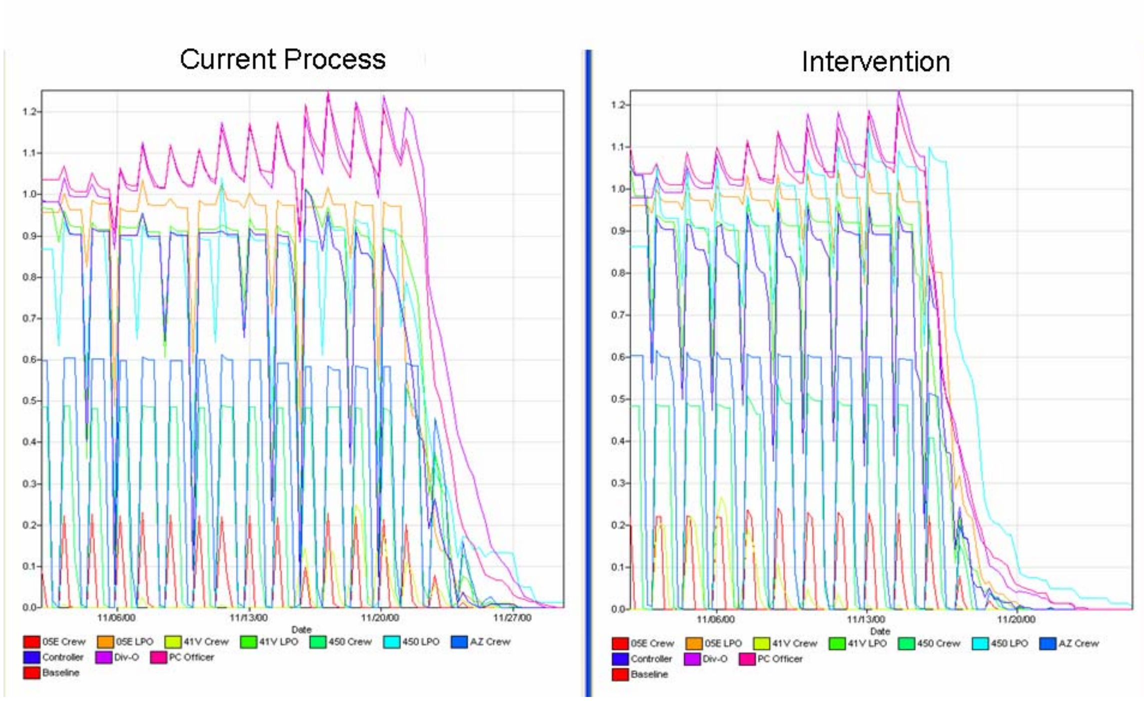

Figure 20. Intervention #1—Paralleling Acceptance Task—Impact on Position Backlog

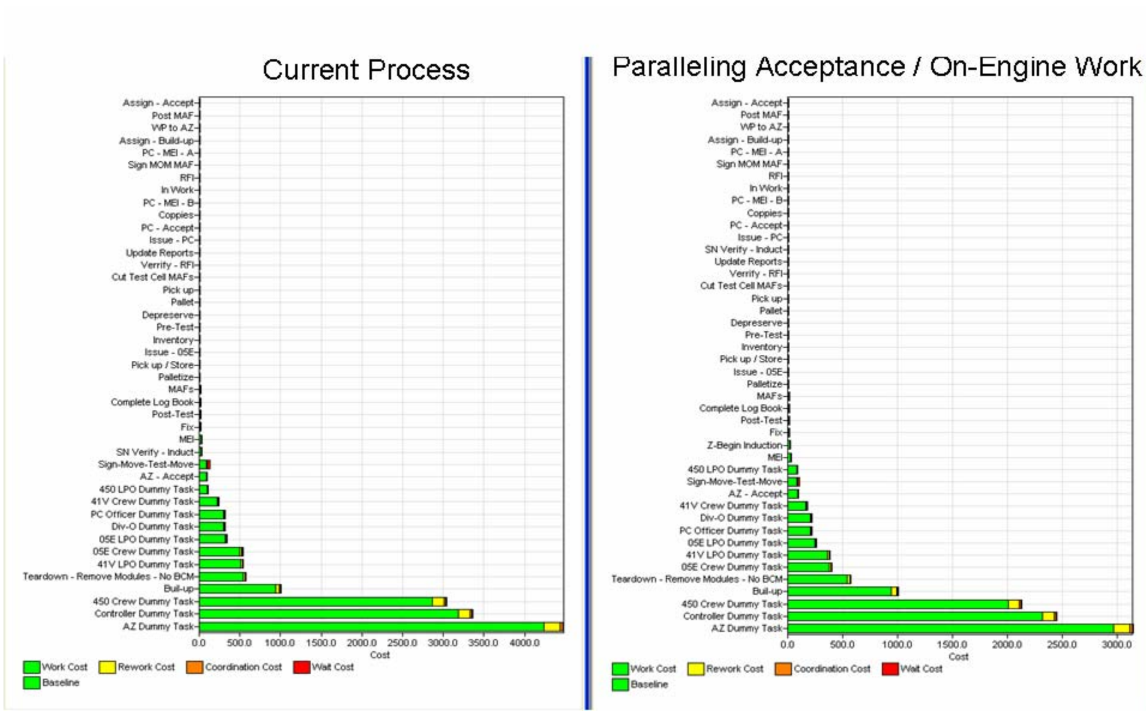

Figure 21. Intervention #1—Paralleling Acceptance Task—Impact on Cost

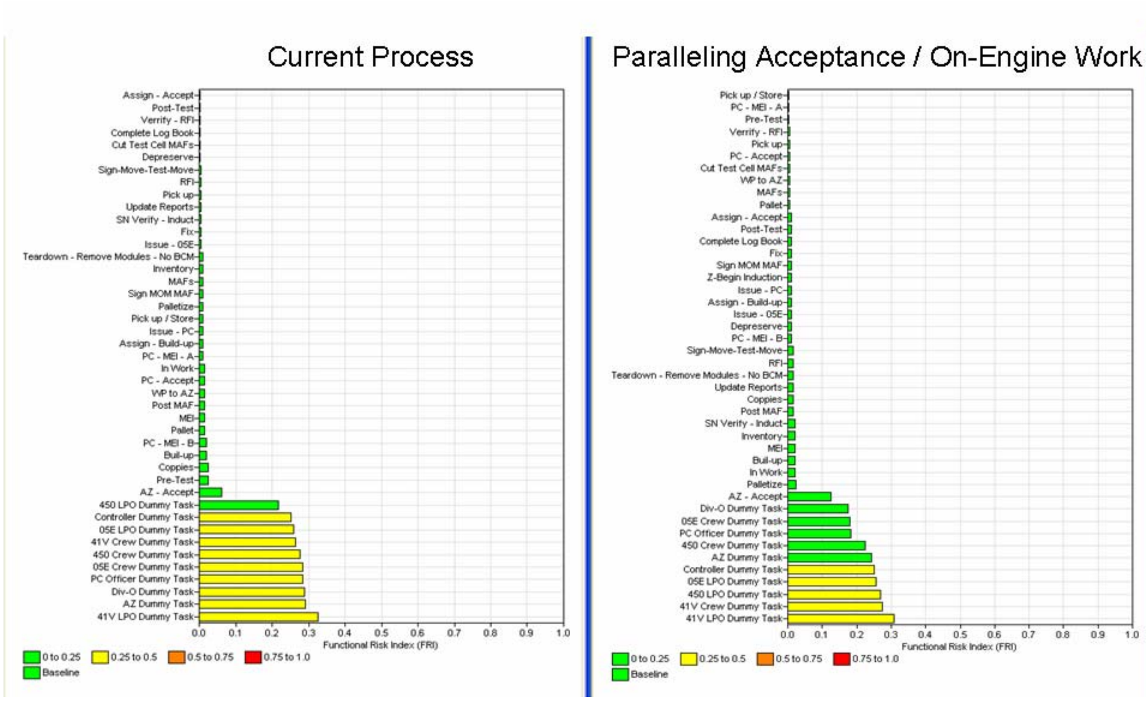

Figure 22. Intervention #1—Paralleling Acceptance Task—Impact on Functional Risk

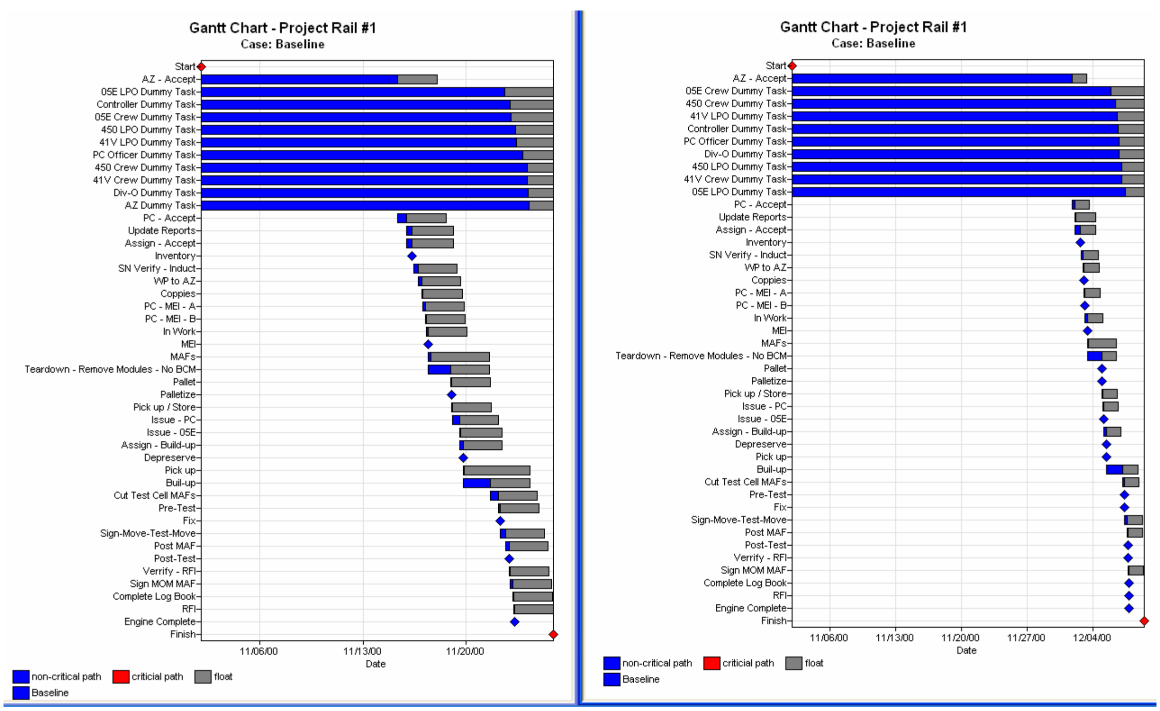

Figure 23. Intervention #2—Combining Controller & AZ positions (Without skill retraining)—Impact on schedule

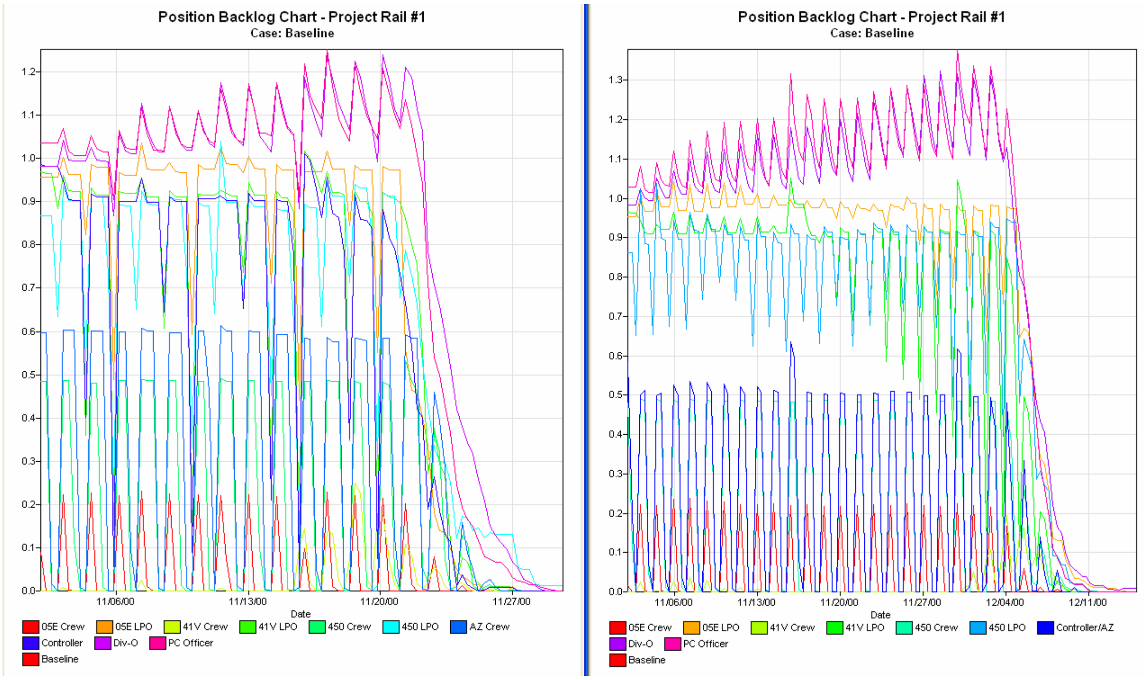

Figure 24. Intervention #2—Combining Controller & AZ positions (Without skill retraining)—Impact on Backlog

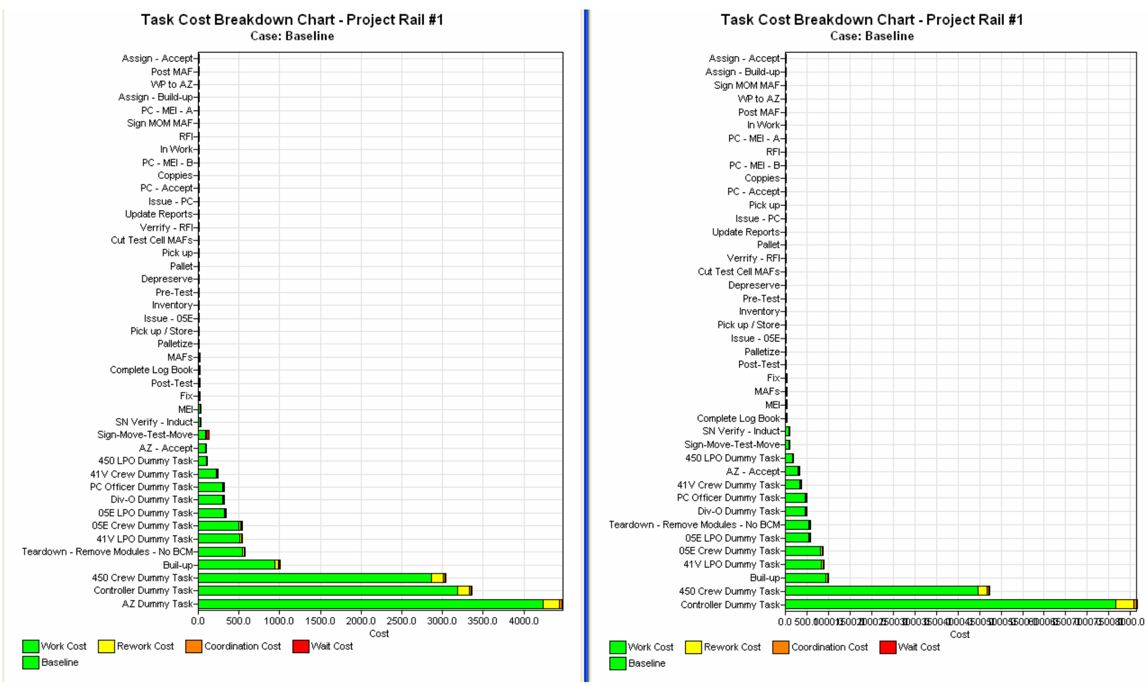

Figure 25. Intervention #2—Combining Controller & AZ positions (Without skill retraining)—Impact on Cost

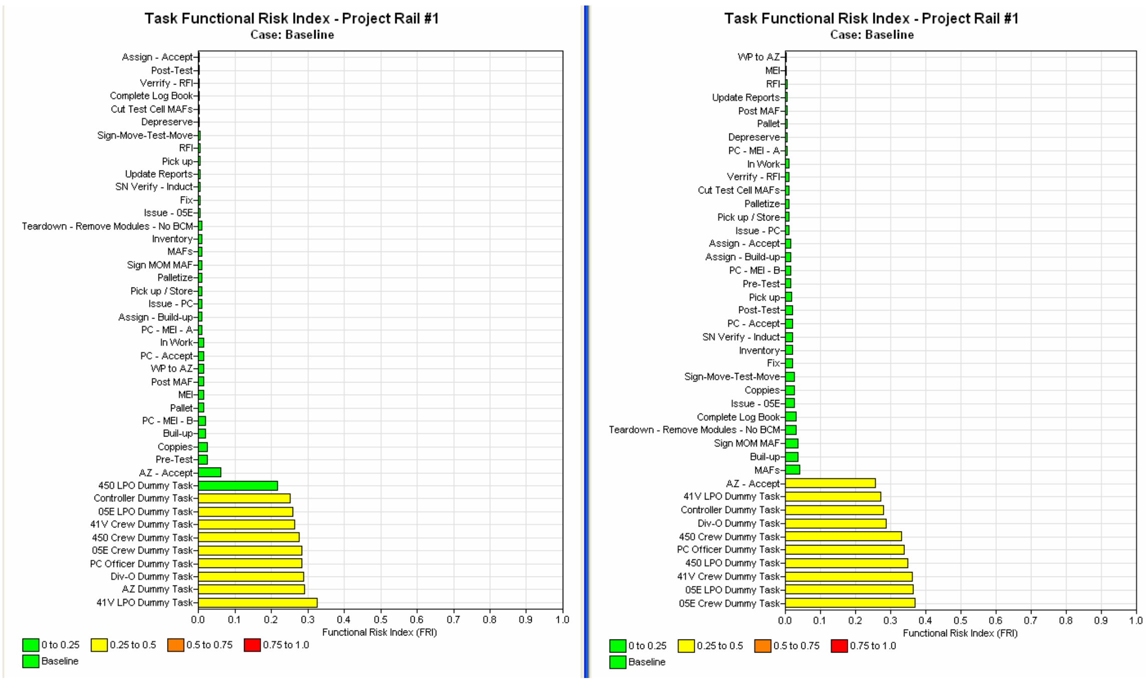

Figure 26. Intervention #2—Combining Controller & AZ positions (Without skill retraining)—Impact on Task functional Risk

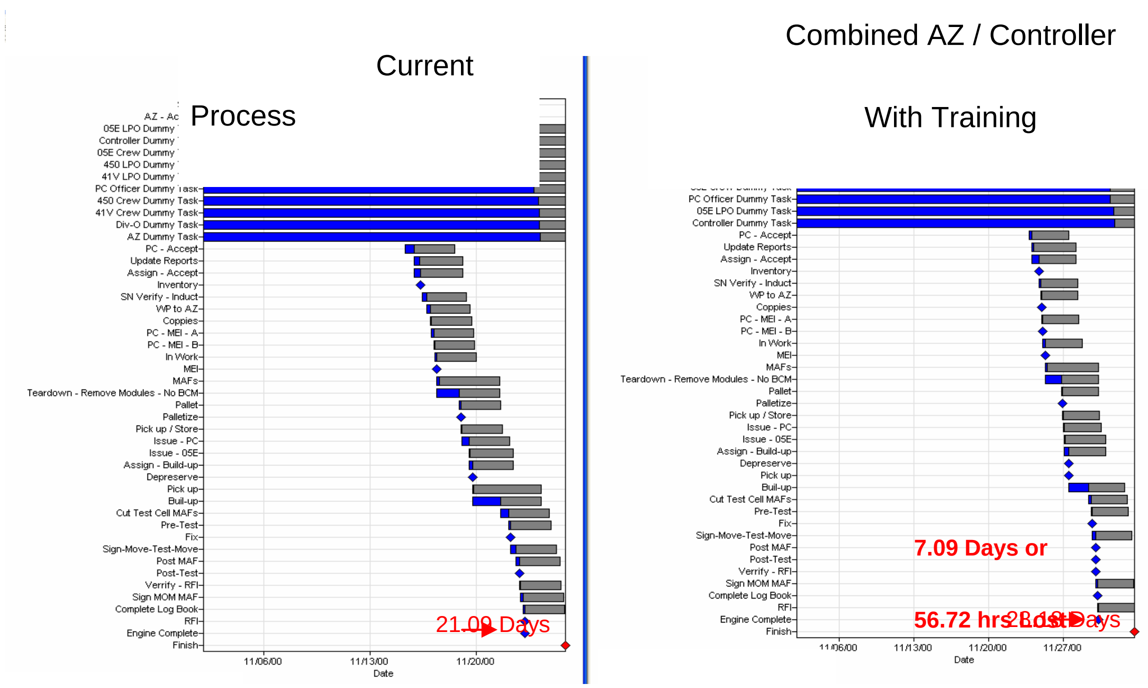

Figure 27. Intervention #2—Combining Controller & AZ positions (With skill retraining)—Impact on Schedule

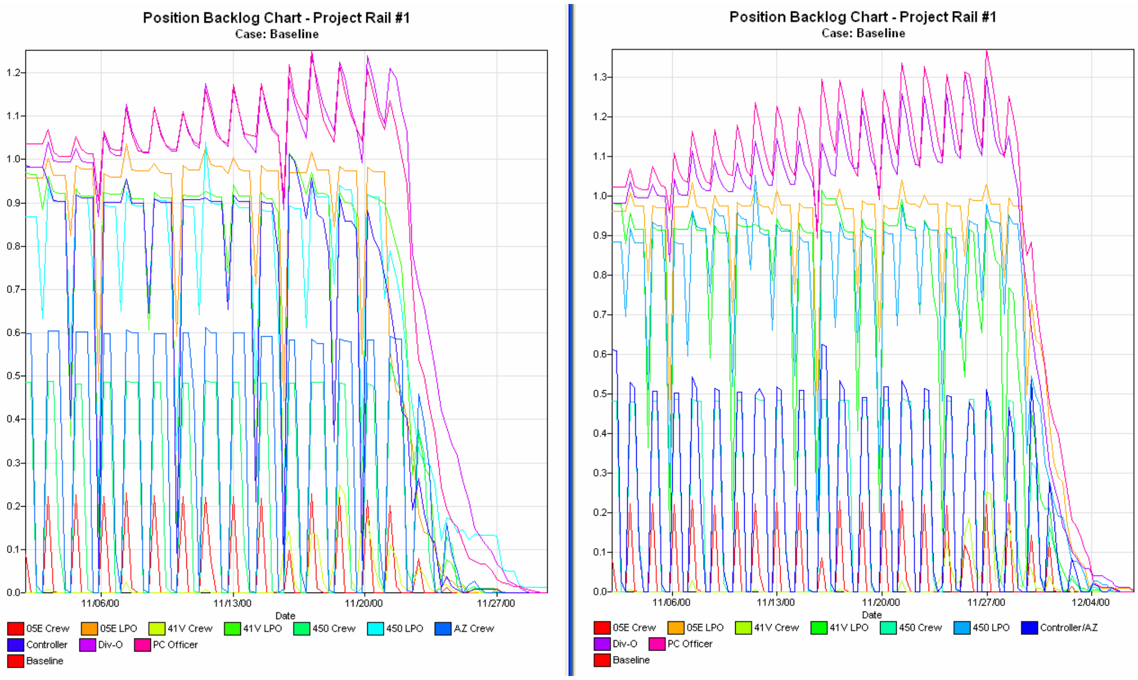

Figure 28. Intervention #2—Combining Controller & AZ positions (With skill retraining)—Impact on Backlog

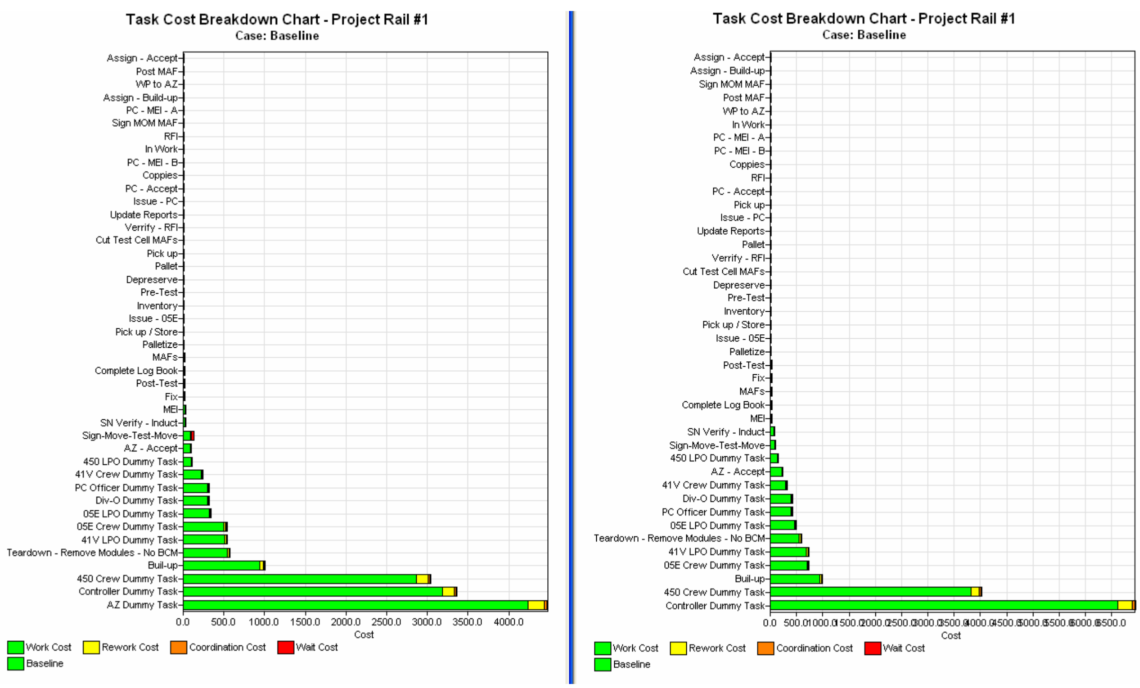

Figure 29. Intervention #2—Combining Controller & AZ positions (With skill retraining)—Impact on Cost

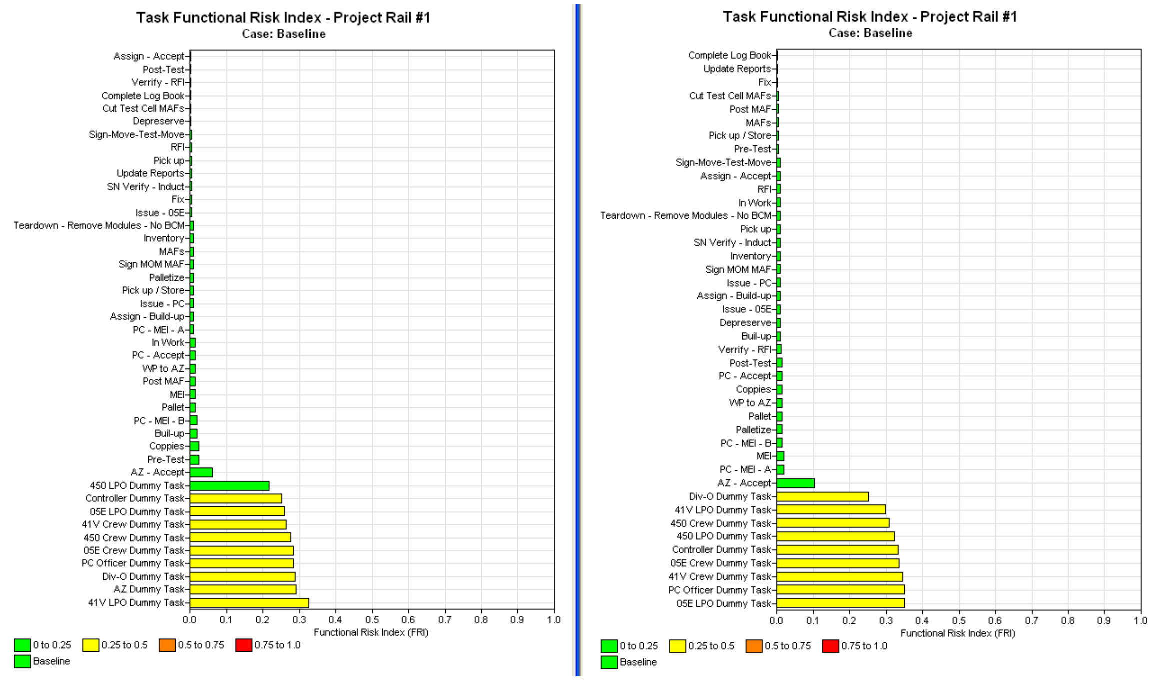

Figure 30. Intervention #2—Combining Controller & AZ positions (With skill retraining)—Impact on Task functional Risk

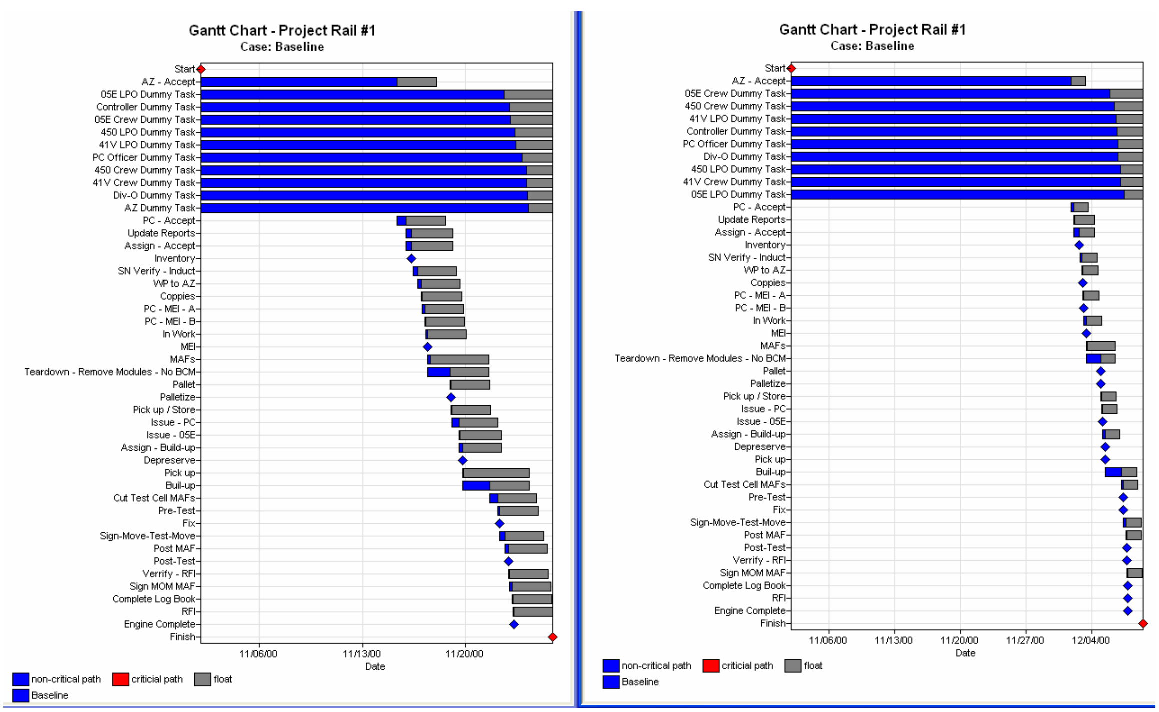

Figure 31. Intervention #3—Combining 41V & 450 positions (Without skill retraining)—Impact on Schedule

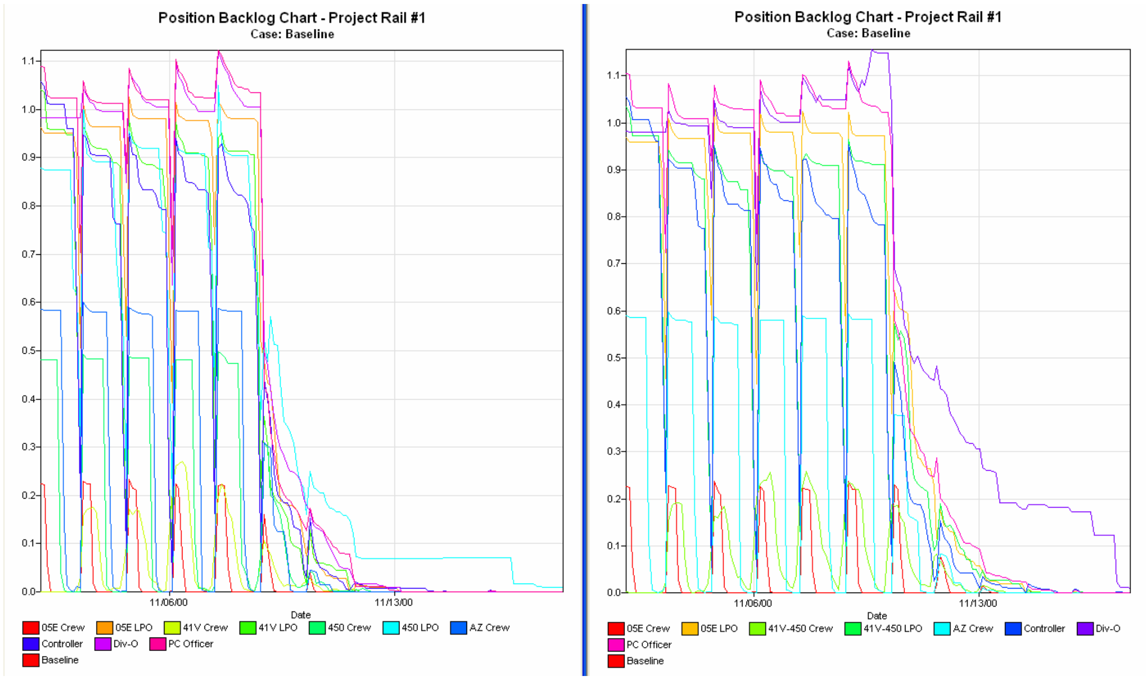

Figure 32. Intervention #3—Combining 41V & 450 positions (Without skill retraining)—Impact on Backlog

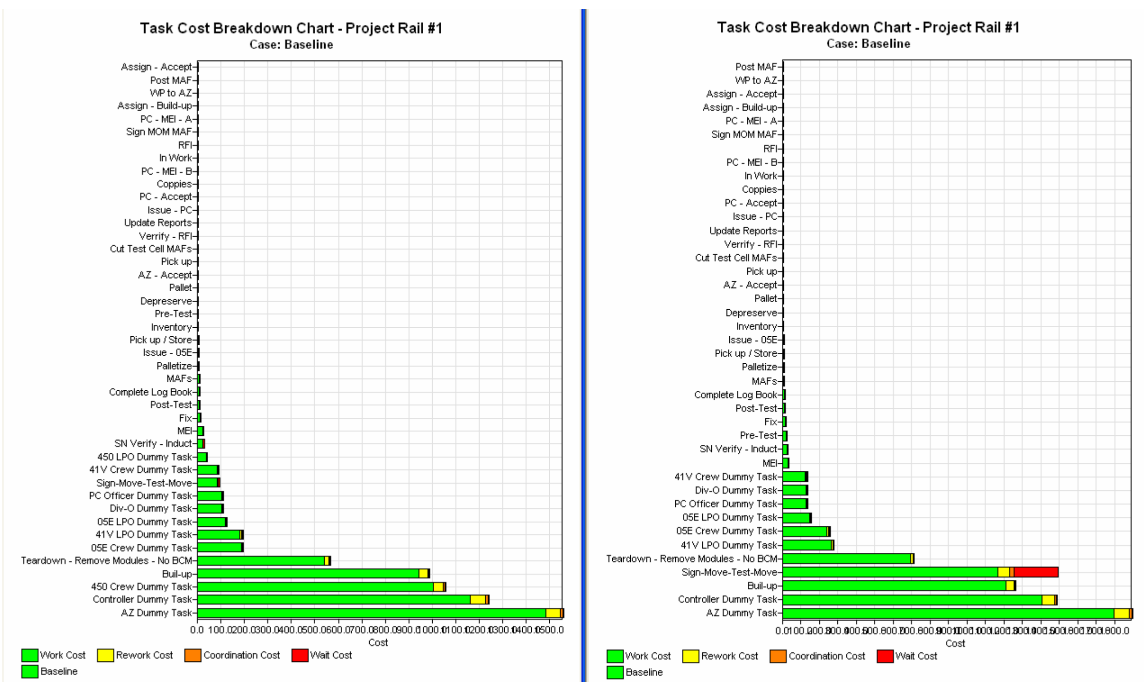

Figure 33. Intervention #3—Combining 41V & 450 positions (Without skill retraining)—Impact on Cost

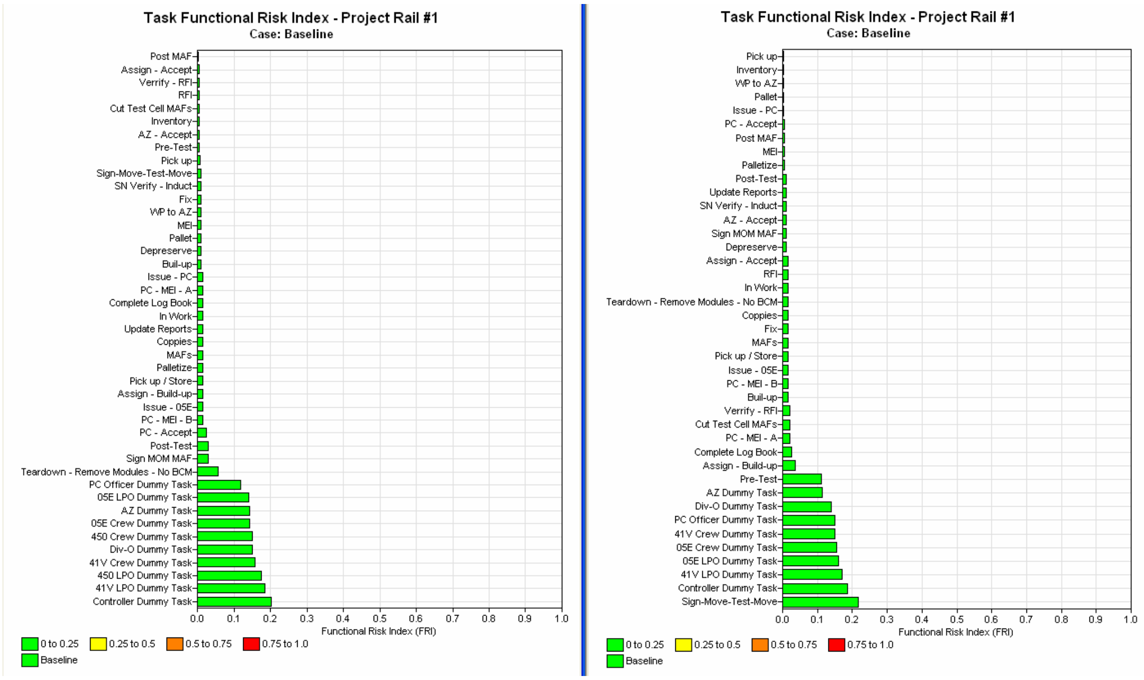

Figure 34. Intervention #3—Combining 41V & 450 positions (Without skill retraining)—Impact on Task Functional Risk

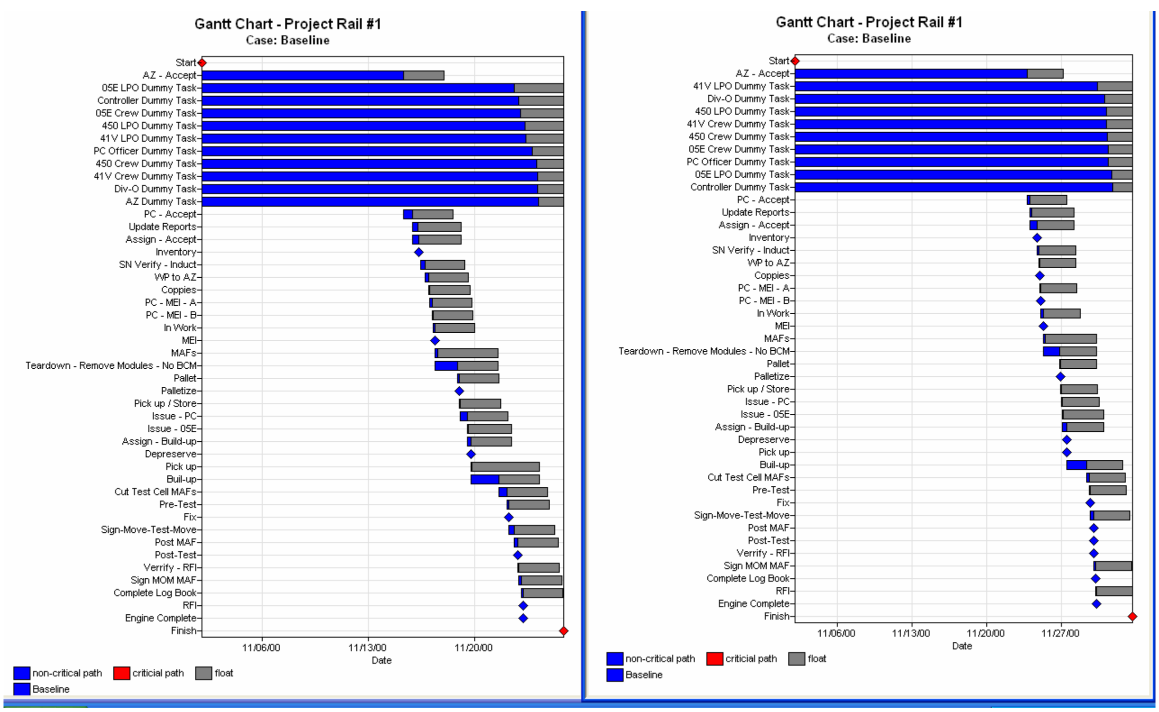

Figure 35. Intervention #3—Combining 41V & 450 positions (With skill retraining)—Impact on Schedule

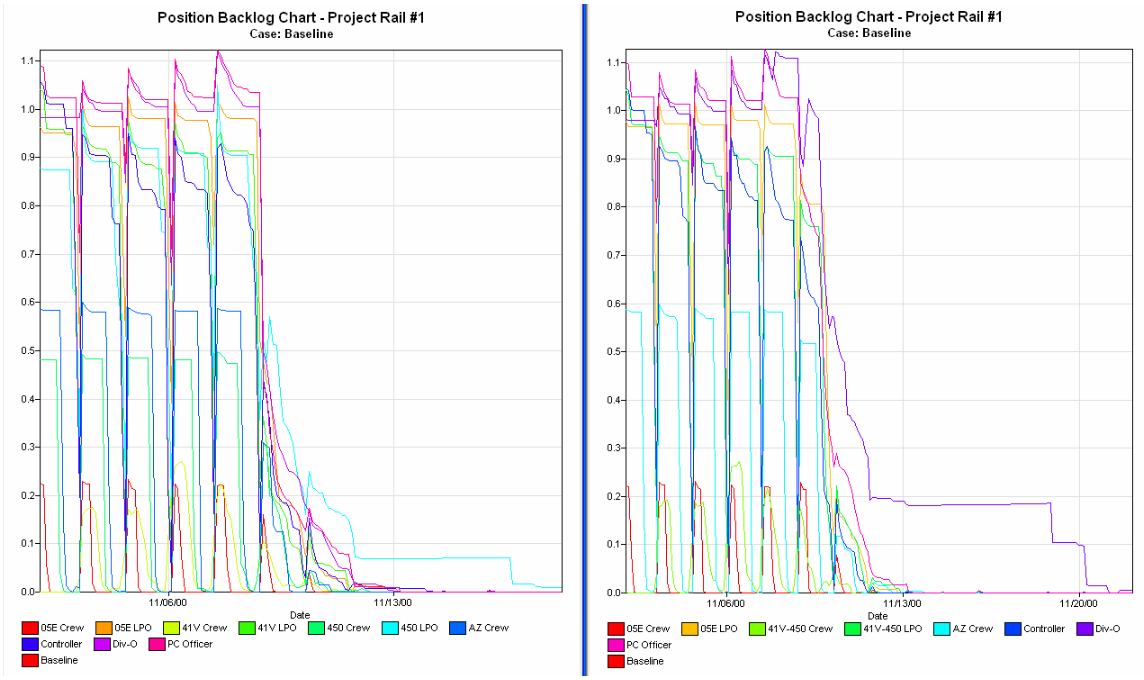

Figure 36. Intervention #3—Combining 41V & 450 positions (With skill retraining)—Impact on Backlog

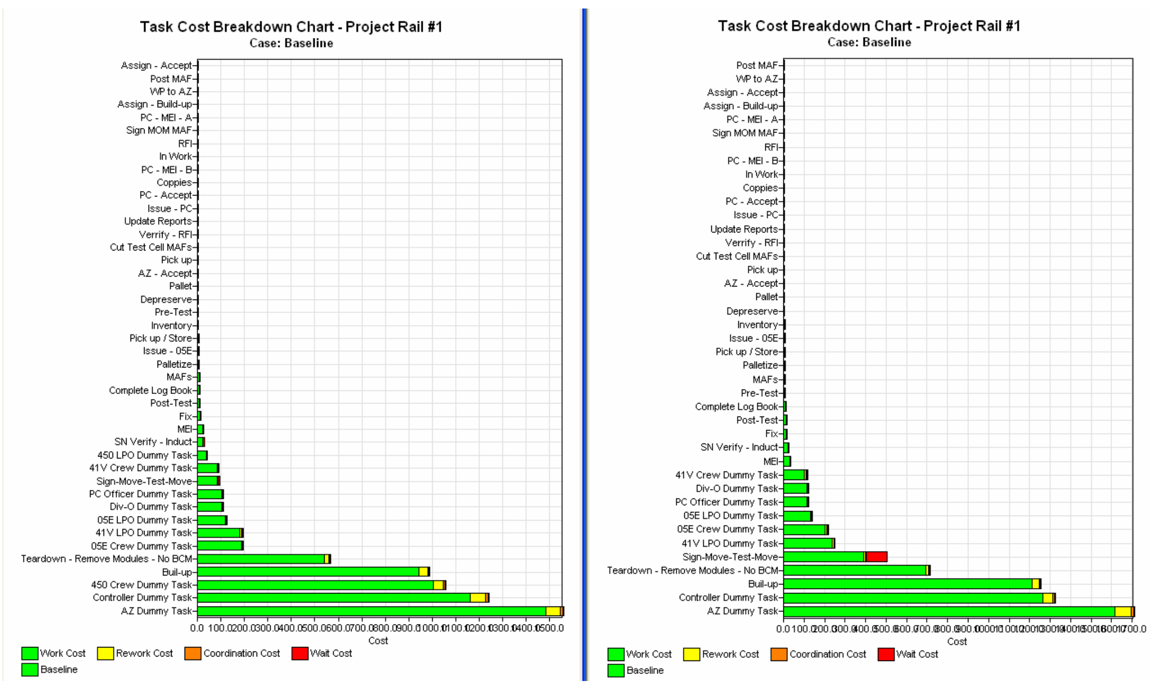

Figure 37. Intervention #3—Combining 41V & 450 positions (With skill retraining)—Impact on Cost

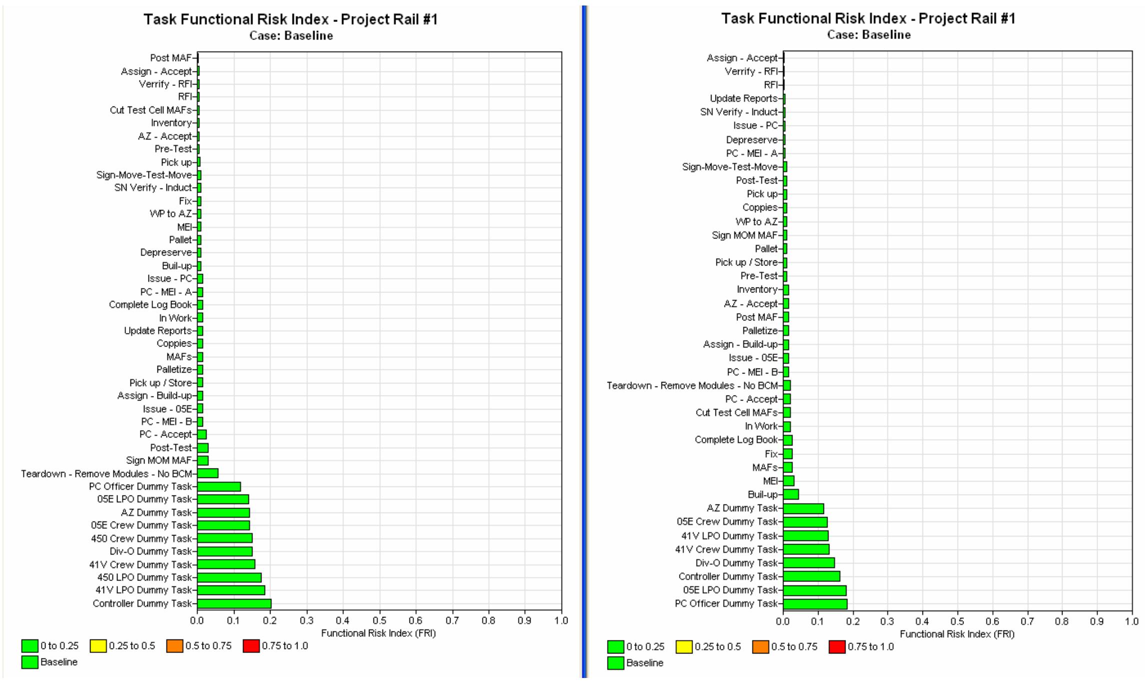

Figure 38. Intervention #3—Combining 41V & 450 positions (With skill retraining)—Impact on Task Functional Risk

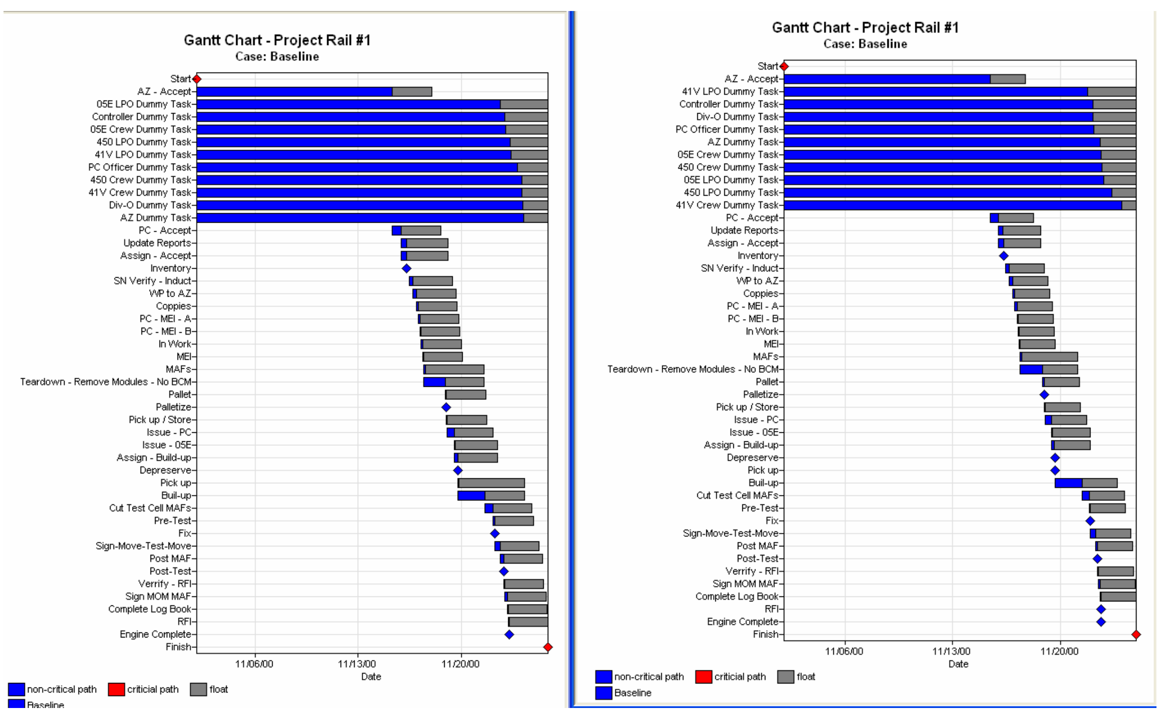

Figure 39. Intervention #4—Decreasing Centralization—Impact on Schedule

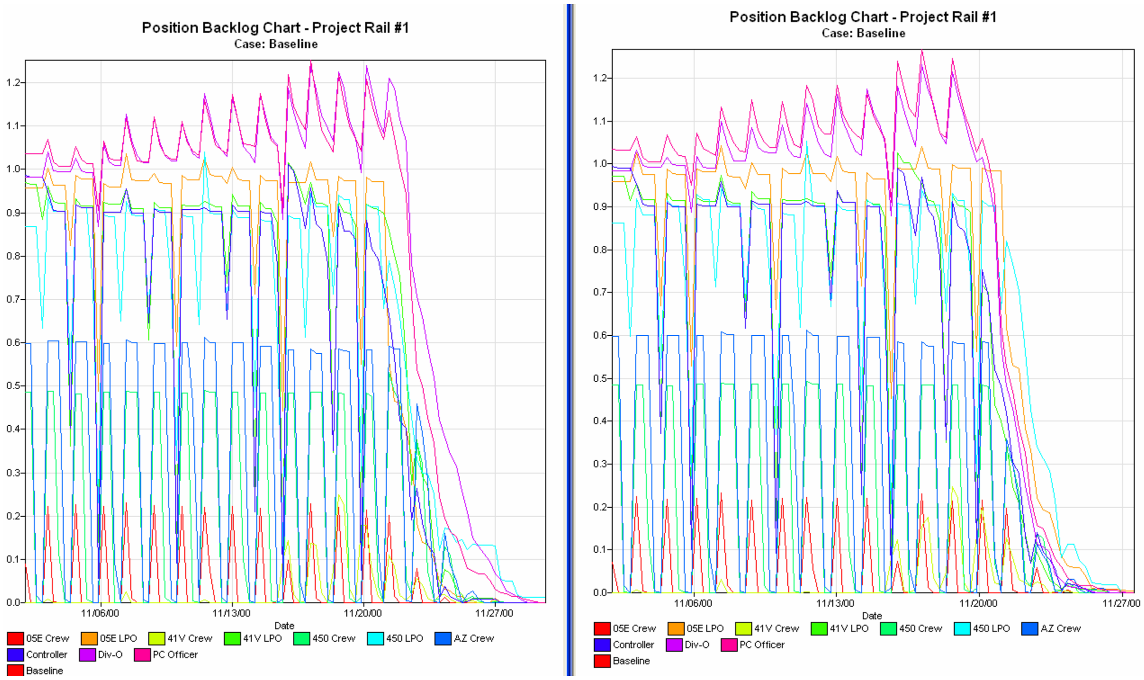

Figure 40. Intervention #4—Decreasing Centralization—Impact on Backlog

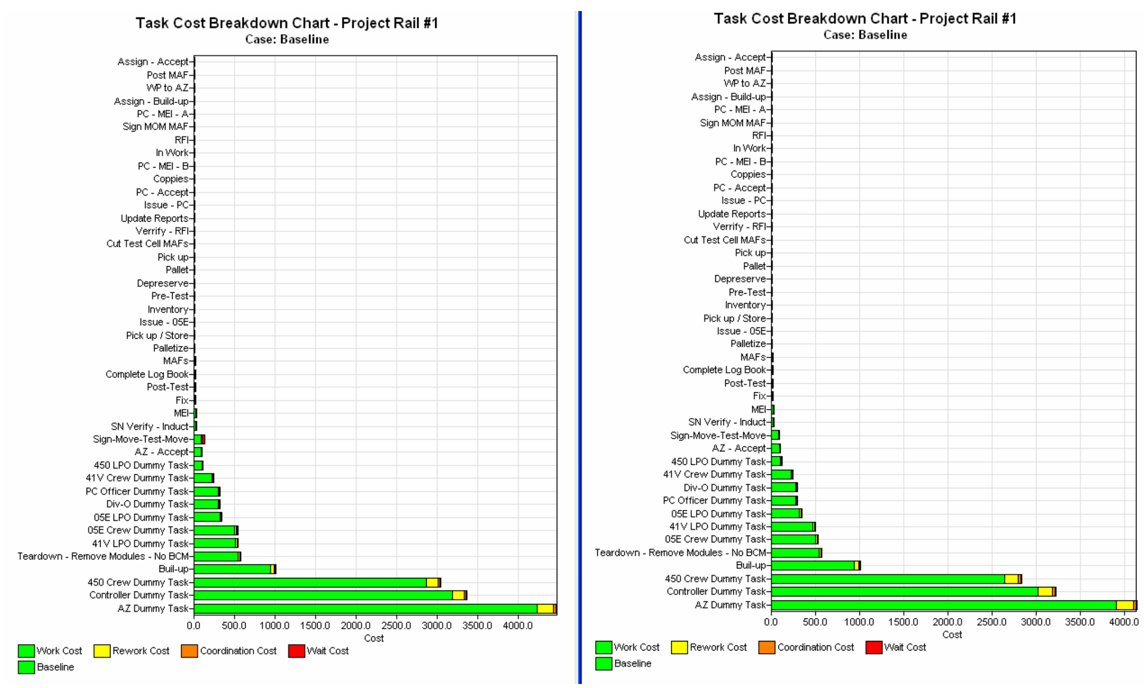

Figure 41. Intervention #4—Decreasing Centralization—Impact on Cost

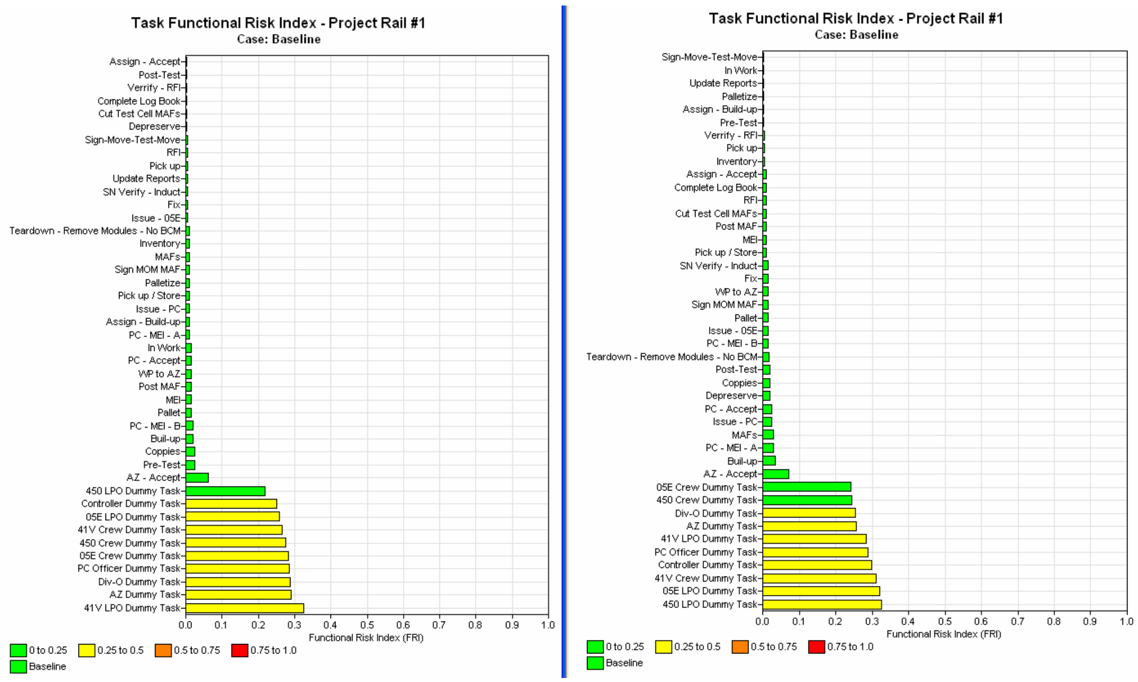

Figure 42. Intervention #4—Decreasing Centralization—Impact on Task Functional Risk

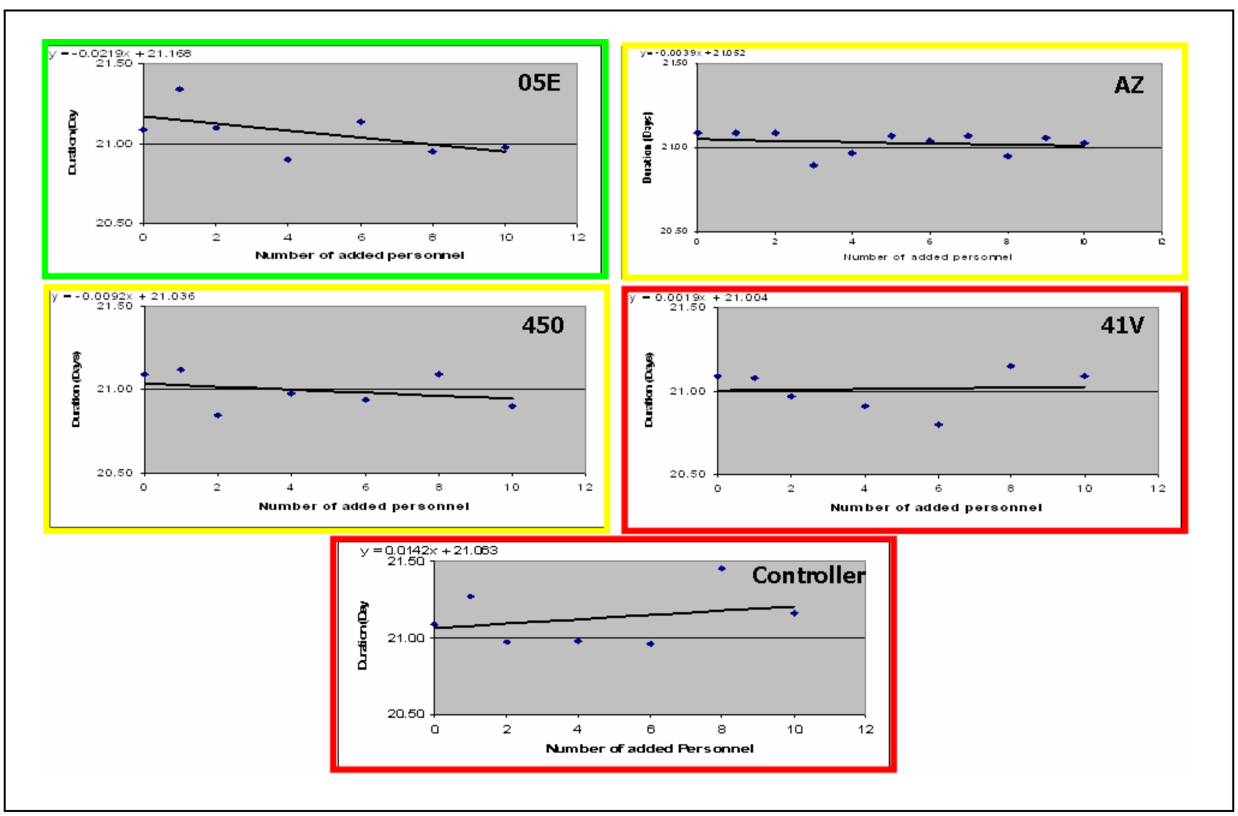

Figure 43. Intervention #5—Adding Personnel—Impact on Project Duration

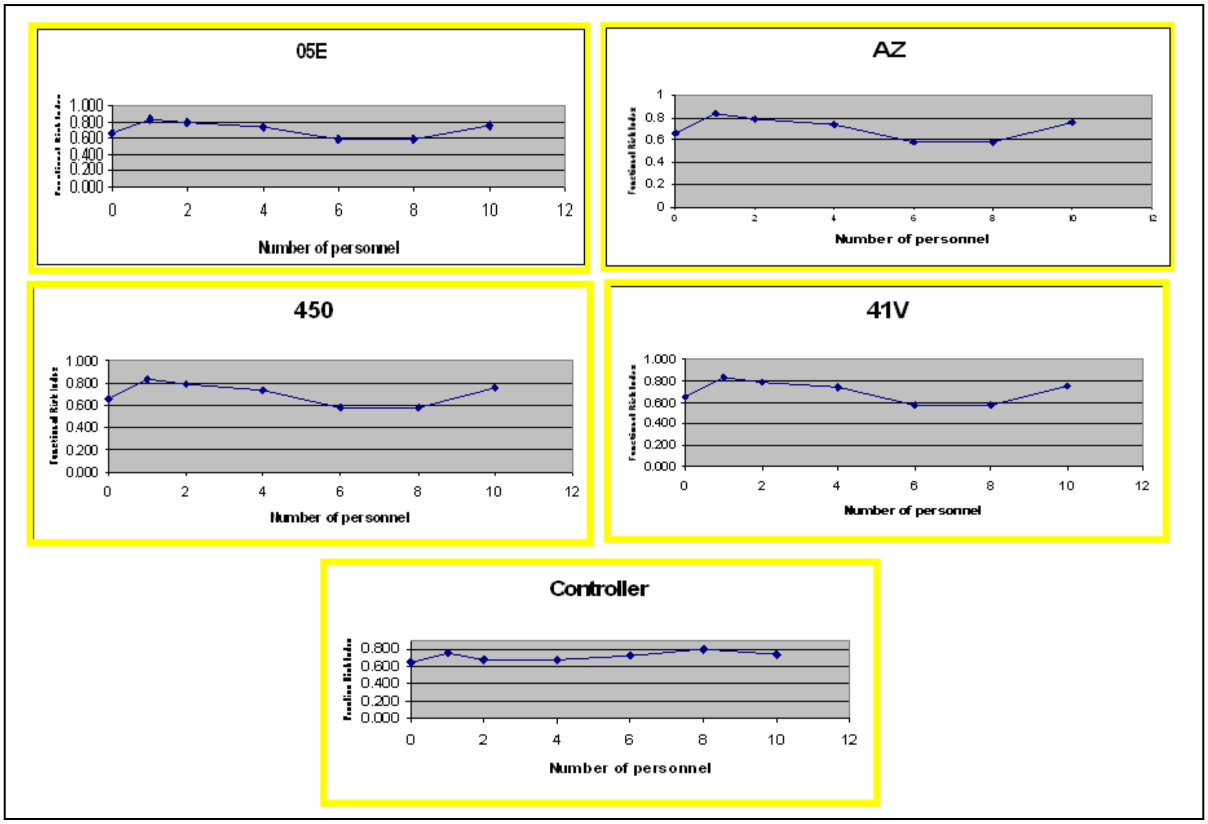

Figure 44. Intervention #5—Adding Personnel—Impact on Task Functional Risk

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