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SIMULATION MODELING OF THE C-5 GALAXY HIGH VELOCITY REGIONALIZED ISOCHRONAL (HVRISO) INSPECTION CONCEPT

THESIS

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AFIT/GLM/ENS/09-6

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AFIT/GLM/ENS/09-6

SIMULATION MODELING OF THE C-5 GALAXY HIGH VELOCITY REGIONALIZED ISOCHRONAL (HVRISO) INSPECTION CONCEPT

THESIS

Presented to the Faculty

Department of Logistics Management

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Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

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March 2009

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SIMULATION MODELING OF THE C-5 GALAXY HIGH VELOCITY REGIONALIZED ISOCHRONAL (HVRISO) INSPECTION CONCEPT

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Approved:

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Abstract

Faced with eroding budgets, Air Mobility Command (AMC) is confronted with implementing simultaneous changes to its isochronal (ISO) inspection process for C-5 aircraft. C-5 inspection criteria will use a Maintenance Steering Group-3 (MSG-3) approach beginning in October, 2009. MSG-3 has been used successfully in civilian aviation since 1980 and AMC hopes to produce similar results. AMC is also consolidating the four docks presently in use to three high-velocity regionalized isochronal (HVRISO) docks. Centralized scheduling by AMC should utilize a dock selection method that minimizes both processing time and queue time when arriving aircraft cannot be immediately inducted into the servicing inspection dock. This study uses discrete-event simulation techniques to test the factors of dock consolidation, MSG-3 ISO completion times, and proposed dock selection methods at various levels. Using a designed experiment, the simulation examines the effects of each factor on aircraft availability. Regression analysis is applied to the simulation results to assess which factors have the greatest impact on processing and queue time.

AFIT/GLM/ENS/09-6

Dedication

I dedicate this thesis to my parents who eventually convinced me just how valuable an education would be and never allowed me to rest on my laurels. Throughout my 20 years of military service, this tough love has always been inseparable from my professional and educational achievements…especially the toughest ones.

Acknowledgments

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Ted Heiman

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I. Introduction

Chapter Overview

The introduction chapter begins with a brief background of the C-5 and required inspections. The background section contains information about the aircraft, identifies the central problem with maintaining the C-5 with reduced budgets, states research questions, and outlines the proposed methodology to examine this problem.

Background

The C-5 Galaxy is one of the largest aircraft in the world. Possessing a huge payload capacity, this giant airframe has provided the Defense Department with strategic airlift capabilities since 1970. The C-5 continues to support many national defense objectives particularly with the current wars in Afghanistan and Iraq. It is an important strategic asset that can carry fully-equipped, combat-ready military units to any staging area in the world with minimal notice. One example of the Galaxy’s workhorse-like capabilities is that it can carry nearly all of the Army's combat equipment to any theater of combat on the globe. These include items such as 74-ton mobile scissors bridges and Patriot missile batteries. The C-5 can then provide the necessary logistical support required to help sustain the same fighting force (“C-5 Galaxy”, 2008).

The Galaxy will continue its crucial role as an airlift workhorse throughout the current Global War on Terrorism. However, the C-5 possesses one serious deficiency the Air Force has had to contend with for almost 40 years: reliability issues. Several initiatives have been undertaken over the years to improve reliability and the resulting availability of the C-5 including the acquisition of 50 additional C-5s during the 1980s ("C-5 Galaxy", 2008). The retirement of 14 C-5s during FY 2005 was deemed necessary to improve reliability for the remaining fleet by providing parts from the cannibalization of these aircraft. The retired aircraft were projected to have even less availability, and would better serve as a ready source of spare parts to augment dwindling resources that could be concentrated on sustaining the C-5s remaining in the fleet and improve availability (Pike, 2006).

Most recently, the Reliability Enhancement and Re-engining Program (RERP) has promised enhanced power and reliability combined with decreased operating costs. The program is very expensive with cost projections ranging from $8.8 billion to $17 billion for all 111 C-5s for a 10 percent boost in reliability (Hebert, 2007). With 2 C-5Bs and 1 C-5A retrofitted with RERP for test and evaluation purposes, Air Force officials recommended that only 47 C-5Bs and 2 C-5Cs (used to support NASA) be RERP retrofitted (Drinnon, 2008). Officials are still struggling to justify how this retrofit would actually provide a net benefit for older C-5As (Knight and Bolkcam, 2008). C-5As are projected to continue struggling with reliability issues thus reducing their return-on-investment estimates (Drinnon, 2008).

While Air Force leaders struggle with these key modernization decisions, Air Mobility Command (AMC) undertook an important initiative to improve C-5 availability. AMC consolidated their eight isochronal inspection sites to three. Isochronal inspections are conducted under a concept that disregards the actual flying hours between inspections. According to Air Force technical manual 00-20-1, an isochronal concept translates flying-hour utilization rates into calendar periods that are usually expressed in days (TO 00-20-1, 2003). This consolidation hopes to achieve three objectives: 1) Faster completion times of isochronal inspections saving 28 days for each inspection; 2) Lower manning requirements with a reduction of 60 manpower positions; and 3) Reductions in support equipment with projected savings of $80 million (Huxsoll, 2007).

By having the same cadre of maintenance specialists perform all isochronals as these inspections come due, the Air Force hopes to gain efficiencies in the process that would otherwise be lost if the work were dispersed over eight bases instead of three. Dover AFB, DE, was chosen as the first HVRISO and has been in operation since 2006 (Osborn, 2007). Westover Air Reserve Base, MA and Martinsburg Air National Guard Base, WV were chosen as the Reserve and Guard components for this HVRISO concept (Osborn, 2007, Harken, 2008).

Problem Statement

All scheduling for HVRISO will be conducted by HQ AMC. The practice of centralized scheduling will permit the most efficient utilization of resources to meet fleet inspection requirements. However, there is one drawback to regionalizing inspection bases that has hindered availability: queue time. Queue time is defined as the time span that the aircraft is awaiting maintenance at the selected HVRISO. Queue time is divided into two categories: *pre-ISO* and *post-ISO*.

Pre-ISO queue time is measured from the time the aircraft arrives at the HVRISO facility until it begins ISO inspection. If inspectors at HVRISO are unable to immediately start work because a previously scheduled inspection is still in progress, pre-ISO queue time would result. Post-ISO queue time is defined as the time span from when all ISO inspections are completed until the inspected C-5 leaves for its next assigned mission or returns to its assigned home station. This can be extended simply because aircrews are not available. Queue time is considered non-value added since the C-5 is not then used for its airlift mission or undergoing required inspections and repairs.

AMC hopes to resolve some of the potential problems associated with having fewer bases perform isochronal inspections with a planned extension of the time intervals between inspections. These new schedules will be implemented during 2009 and will be based on third-generation maintenance steering group (MSG-3) initiatives successfully utilized in civil aviation. Programmed depot maintenance (PDM) inspections will also be performed less frequently. This affects waivers to permit delaying an ISO that are routinely granted when aircraft comes due within 270 days of scheduled PDM.

Research Objectives/Questions

The broad research question we address is: “To what extent will docks be able to sufficiently fulfill inspection requirements with the proposed changes?” How long it takes to complete the dock consolidation will influence aircraft availability. If three HVRISOs are incapable of meeting fleet inspection requirements in a timely manner, aircraft availability could be affected. While the MSG-3 implementation will extend inspection intervals, it will also change requirements. How much dock time is required per ISO could also affect total aircraft availability. In addition, centralized scheduling will select docks well in advance of aircraft inspections coming due. The criteria chosen for dock selection could also impact availability. Permitted overfly days, where aircraft is still available despite being overdue and ISO, might also have an effect.

To answer our research question, we formulated five specific investigative questions, as follows:

Investigative question 1: “To what extent will the consolidation into three HVRISO bases affect aircraft availability and HVRISO flowtime?” Implementation of these consolidation plans could be delayed due to financial, manning, and other considerations. How potential delays might affect availability is of prime interest in this study.

Investigative question 2: “To what extent will adopting MSG-3 initiatives affect aircraft availability and HVRISO flowtime?” While MSG-3 will extend the time intervals between isochronal inspections, these may not be sufficient to prevent excessive queue time if resultant dock times are too long. PDM inspections will be performed less frequently since all PDM intervals will be extended to every eight years.

Investigative question 3: “To what extent will dock selection methods affect aircraft availability and HVRISO flowtime?” Aircraft selection is currently based solely upon the required due date. As other HVRISO docks are added, other criteria could also be considered as other HVRISOs begin operations. Table 1 outlines three dock selection methods this study examined based on potential usage of active duty, Reserves, and ANG docks.

Dock selection methods would resemble Lean and Agile approaches used in manufacturing (Mason-Jones, Naylor, & Towill, 2000; Goldsby & Garcia-Dastugue, 2008). The Lean option would route the same type of inspections and/or aircraft to designated docks. Such an approach would reduce variability of aircraft and inspection types conducted within these docks and would be a similar approach to Lean manufacturing. The Agile option can task HVRISOs with any inspection and would increase the variability of inspections. This would parallel a more Agile approach to dock selection. The Leagile method would apply both approaches according to the situation

Investigative question 4: What effect will a lower allowance of 5% for overfly have on queue time and aircraft availability? A lower 5% overfly allowance would permit up to 24 days of past-due flying. If inspection times are usually short and the dock consolidation is completed rapidly, then queue time will already be minimal and this allowance would not likely have any significant effect on queue time. If the opposite circumstances hold true, then an increased tolerance of 10%, or simply 48 days, may be required to have any appreciable effect on queue time and aircraft availability.

Investigative question 5: Are there any interactions between the three factors considered that can significantly benefit or reduce aircraft availability? A combination of rapid ISO inspection times and a faster dock consolidation would benefit aircraft availability. If this scenario is realized with the proposed system, knowing which dock selection method would produce the best results is beneficial information for AMC. At the other extreme, longer dock times and further delays in consolidation would be detrimental. In this case, dock selection methods may help to mitigate the resulting problems with queue and ISO flow times. Finally, if tradeoffs between long dock times and delayed consolidation are being considered, then knowing which improvements are most beneficial would be critical information.

Research Focus

The main focus of this research is C-5 aircraft inspections. AMC is also considering other aircraft such as KC-135s and C-130s for a regionalized isochronal concept. Lessons learned from this research could apply to future plans for regionalizing the isochronal inspections for these aircraft as well.

Methodology

This research will use the simulation capabilities available in Arena© 10.0 for analysis of the proposed changes to the isochronal inspection concept for C-5 aircraft. A simulation is defined as an imitation of some real state of affairs or processes. Simulating a system this complex generally entails representing only the key characteristics and behaviors of the proposed system. Thus, simulation is well suited for analyzing the impact of these planned changes that involve significant and complex redesigns.

Assumptions/Limitations

This research assumes that the two additional HVRISOs will operate similarly to the HVRISO at Dover. This implies that service rates for each segment of the isochronal inspection process will have no statistically significant difference among the three HVRISOs. A limitation of this assumption is that this can not be verified until after 2010. If permanent differences among the three sites are found, this would limit the validity of this research. All data provided by AMC about service times, value stream maps, and critical paths are assumed valid representations of the present system; errors in these databases or documents cannot be fixed without advice and assistance from AMC. Experts from AMC will help to perform a thorough validation and verification of the simulation model as it is developed. The simulation model will capture key characteristics of the system being examined.

Implications

A validated simulation model permits a “glimpse” into the future of C-5 regionalization. Any lessons learned with this simulation of regionalized maintenance can influence future plans. AMC plans to eventually regionalize all isochronal maintenance with KC-135 and C-130 aircraft being considered for such an effort. There is no definite timeline for implementation.

Summary

In this chapter, first a brief background about the C-5 was presented along with implications for future maintenance concepts. A problem statement was then defined and potential research questions were stated. Focus of this research shall be on C-5 maintenance, but lessons may apply for other aircraft. A brief outline of assumptions and limitations were stated. Finally, the implication areas of the research results are discussed.

II. Literature Review

Chapter Overview

A review of literature revealed that scholarly studies have not yet been conducted regarding the actual performance of the C-5 regionalized isochronal process. This literature review shall highlight important concepts that are either contextually or directly relevant to the C-5 HVRISO concept and C-5 availability. A brief examination of Air Force Smart Operations for the 21st Century (AFSO-21) is first necessary because the HVRISO concept is an AFSO-21 driven initiative. It is imperative to understand the underlying philosophies and ideas associated with AFSO-21 to conduct a serious evaluation of this developing maintenance concept.

An explanation of MSG-3 is also necessary because this is another important initiative affecting HVRISO and C-5 availability. Implementing MSG-3 will change the underlying philosophy of C-5 preventative maintenance including isochronal inspections. An examination of other studies affecting aircraft availability along with important initiatives to improve C-5 availability currently underway using the AFSO-21 tools is also highly relevant.

Other studies that directly addressed aircraft availability are surveyed with particular emphasis on those that directly pertain to the research questions outlined for this thesis. Finally, the simulation modeling used to predict the effect of these initiatives on C-5 RISO flow and aircraft availability is described. Examples of pertinent simulation models analyzing the availability of C-5s will also be reviewed.

Air Force Smart Operations for the 21st Century (AFSO-21)

Dr. Adedeji Badiru outlined the importance of implementing AFSO-21 through operations research (OR). He advocated this approach to further encourage research and development studies to help these initiatives succeed. Dr Badiru defined AFSO-21 as "a coordinated pursuit of operational improvement throughout the US Air Force" (Badiru, 2007, 1). He also stated that AFSO-21 as a process integrates the tools of several management theories including Lean principles, Six Sigma, Theory of Constraints (TOC), Management by Objectives (MBO), Business Process Improvement (BPI), Total Quality Management (TQM), and OR. A brief review of each of these management theories follows.

Lean principles have been used in manufacturing even before World War II. In fact, Henry Ford during the early 20th century practiced some elements of Lean by using interchangeable parts, standardized working, and a moving production line to implement a continuous process flow. Where Ford missed in terms of modern Lean principles was product variety; every Model T chassis ever produced was exactly the same as the first (Russell-Walling, 2007). Lean initiatives within the Air Force are concerned with the elimination of waste or muda as it is known in Lean terminology. Badiru believes that 80% of the effort to implement AFSO-21 will be related to well-known Lean principles (Badiru, 2007).

Muda is viewed as the enemy in a Lean mentality and efforts to expose it in any process are continuous. According to Mathaisel (2006), muda can be revealed in a variety of ways. These include overproduction, inventory (WIP), transportation, processing waste, motion, waiting, and making defective products. How these examples of muda might be exposed in a RISO dock is fairly straightforward.

Aircraft that arrive at the HVRISO too early, before the due date, are an example of overproduction because reducing the intervals directly increases production. Inventory in an isochronal dock could be viewed as the time lags between different facets of the production process. If fabrication work were two days behind schedule and avionics work were two days ahead, then this would indicate more resources should be allocated to fabrication work and less toward avionics. Not all resources can be converted from one purpose to another, but time allotted would certainly be more flexible. Personnel with cross-utilization training could offer another flexible resource.

Transportation is, of course, necessary to the RISO concept since most C-5s will be stationed away from the assigned RISO. From a Lean perspective however, the aircraft should operate exactly where the RISO is located. This, of course, is not practical for military objectives that value asset dispersion as a means to protect those assets and sustain functional capabilities after enemy attacks. Aircraft ideally would arrive at HVRISO after missions so it would not matter where these aircraft were stationed. However, there may be instances where a C-5 must fly from its assigned location to HVRISO.

If the assigned and HVRISO location were one and the same, this would obviously be a huge advantage. This aspect of C-5 locations could also be extended to processing waste, motion, and waiting. By eliminating the need to relocate aircraft from another home station to the RISO, at least one step is eliminated. Motion would also be reduced and waiting could be minimized after the isochronal process is completed.

Making defective products, or creating a substandard aircraft from an isochronal inspection, is obviously waste.

Value stream mapping, a Lean tool that helps to illustrate material and information flows of a process, was used by the Dover HVRISO; a second value stream mapping exercise took place during August 2008 (Smith, 2008). This mapping exercise led to a rapid improvement event where 3 hours of labor were saved by switching the order of tasks to prevent additional aircraft towing. While mapping is a useful technique in Lean, it does not help manage these flows. Managing the value stream requires "a different way of measuring and evaluating a company's results and involves changes to decision-making processes" (Brosnahan, 2008, 61).

Six Sigma is a management technique to cut defect rates and improve quality. Sigma, which is the symbol used in statistics to denote standard deviation, is the measure of how far defective products fall from the "mean" or standardized product of acceptable quality. Reducing the standard deviation among products will reduce the number of products that fall below the minimum acceptable quality standards. Six Sigma consists of five steps commonly known as DMAIC. These are:

1) **D**efine the problem to identify what must be improved.
2) **M**easure what is current against what is desired.
3) **A**nalyze the root causes of the existing gaps between the two states of current and desired.
4) **I**mprove the process by brainstorming solutions, selecting the most suitable one(s), and implementing it (them).
5) **C**ontrol the long-term sustainability of these improvements by establishing mechanisms to monitor, assigning accountability, and other work tools (Hammer, 2002).

Six Sigma has been incorporated within several companies that wish to improve quality. While this is a positive sign of its acceptance, Hammer emphasizes that it complements versus replaces other important management techniques such as Lean principles. Lean principles address how to optimize process flow, an important task that Six Sigma cannot perform. Six Sigma does include use of statistical tools and techniques that are not considered in Lean principles. Lean principles can minimize variation within an existing process. Lean makes processes work faster and more efficiently whereas Six Sigma improves the quality derived from them. Hammer observed, “Six Sigma works within the framework of an existing process, but it does not challenge the process” (Hammer, 2001, 59). Other management tools incorporated with AFSO-21 that do challenge underlying processes are outlined next.

TOC is a theory that was proposed by Dr. Eliyahu M. Goldratt in 1984 and describes an overall management philosophy. It is based on the application of scientific principles using both the Socratic Method and rational thought to guide organizations (Goldratt, 1984). TOC can be a valuable tool designed to facilitate efforts by organizations to continually achieve their goals. The underlying premise of TOC is that every organization has one or more constraints which limit its performance in achieving these goals. The constraints are categorized as either internal or market. To manage and improve the performance of the system, the constraint must first be identified. The constraint(s) are correctly managed according to five focusing steps once a goal is identified (Rahman, 2002; 1998). The key steps in implementing an effective process of ongoing improvement according to TOC are:

> 0) Articulate the goal of the organization. For a C-5 RISO this might be, "Complete C-5 isochronal inspections in the timeliest manner at the least possible cost".

1) Identify the constraint that prevents the organization from obtaining more of the goal. In a C-5 RISO dock, this could be examining the associated expense and timeliness of a task that could be performed either cheaper, quicker, or both.
2) Decide how to exploit the constraint (make sure the constraint is doing things that the constraint uniquely does, and not doing things that it should not do)
3) Subordinate all other processes to above decision and align all other processes to this decision
4) Elevate the constraint (if required, permanently increase capacity of the constraint; "buy more")
5) If, as a result of these steps, the constraint has moved, return to Step 1. Never let inertia become the constraint (Rahman, 2002; 1998).

Goldratt emphasizes that constraints are likely to change over time due either to the successful management of a previous constraint or to a changing environment internal or external to the organization. Because of these “moving” constraints, the TOC process does not terminate and is similar to continuous improvement. Once these new constraints materialize, the process of identifying constraints and applying the five steps repeats (Rahman, 2002; 1998).

MBO is another management technique emphasized in AFSO-21. First introduced during the early 1950s by Peter Drucker in *The Practice of Management* (Russell-Walling, 2007), Drucker states that setting objectives ensured that managers at each level should know why they perform the activities that make up their daily routines. This knowledge makes managers better equipped to achieve the desired results using what resources are available (Russell-Walling, 2007).

Reviewing and, if necessary, resetting the overall organizational goals is the first step in implementing MBO. Decisions regarding which tasks are necessary to obtaining these goals and assigning these tasks to managers is the next important step. These critical tasks are scrutinized to figure out exactly what supporting tasks are important for these higher-level tasks to be successful. This usually means detailing what tasks subordinates can perform to help the manager accomplish their tasks (Russell-Walling, 2007).

Once a task structure is developed within an organization, monitoring and evaluation are the next important steps. An important aspect of MBO is that the goals be achievable, meaning that goals should be challenging to help motivate people, but should not be impossible so they become discouraged. SMART is a clever acronym that outlines the important characteristics of management driven goals (known as smart goals), meaning these goals should be specific, measurable, achievable, realistic, and time-related (Russell-Walling, 2007).

Goals cannot be vague or generalized or else people will be confused and unable to concentrate on what matters. Goals must be specific and measurable. If the goal cannot be measured, then people will not know if they are working toward the goals. Goals must be realistic and have enough resources committed by management to achieve them. If enough resources are not committed to help people achieve the goals, then these goals are probably unrealistic. Finally, goals must be time-related; without a deadline, then there is no incentive for people to achieve the goal in a timely manner. (Russell-Walling, 2007).

BPI is derived from a 1990s management concept previously called business process reengineering (BPR). Michael Hammer is fond of saying that BPR is like “reversing the Industrial Revolution” (Gibson, 1997). While customer needs were continually in flux, Hammer observed that many business processes were far too static to respond appropriately. Hammer blamed this on corporate inertia and being so set in their ways that some were actually investing capital to automate work that had no actual value. He proposed getting rid of this sort of work to further improve the business process. BPR forced people to question rigid corporate rules and outdated premises such as “Why perform this task?” and “If we have to perform this task, why do it this way?” (Hammer and Champy, 2003).

BPR has had more than its share of criticism because many felt it was just another excuse to get rid of people in downsizing efforts. Hammer acknowledges that he failed to account for values and beliefs of workers and modified his existing theory so these should not be ignored. Still BPI is hailed by Hammer and Champy as another revolutionary tool that businesses of the 21st century cannot ignore and must adapt. Hammer wrote in the prologue of *Reengineering the Corporation* that, “Some companies may eschew the term reengineering and employ other phrases, such as process redesign or transformation. But at their heart, such efforts fit our definition perfectly” (Hammer and Champy, 2003, i).

TQM is “a synthesis of different ideas and tools that had evolved in Japan since the Second World War” (Russell-Walling, 2007, 184). Beginning with W. Edwards Deming in his early efforts to instill a consciousness about quality into Japanese manufacturing, TQM concepts have been extended by Joseph M. Duran and Phil Crosby. TQM relies on rigorous education and training of workers, eradicating existing barriers between corporate specialty offices, and the committed involvement of top management. Deming advocated that corporations attain continuous improvement with a cycle of PDCA (Plan, Do, Check, and Action). Duran advocated an additional approach to TQM incorporating planning, control, and improvement (Russell-Walling, 2007). In the later 1970s, when TQM began to find acceptance by American companies who were losing market share to Japanese products, Crosby formulated four corollaries for managing quality:

1) Quality is simply conforming to what is required.
2) Prevention is always preferable to inspection.
3) Zero defects must be the standard of performance.
4) Non-conformance always has costs so quality can be measured in dollars (Crosby, 1979).

While TQM is fairly straightforward compared to other management concepts, it can be difficult to actually implement. The Air Force, like many companies, has attempted to build TQM programs, but with less than spectacular results. During 1991, USAF senior leadership initiated an Air Force-wide commitment to Total Quality. A bed-down of a new Air Force Quality Center occurred in August and was meant to provide the concepts, tools, methods, and advice to achieve a quality-conscious Air Force. The Quality Air Force (QAF) program was implemented in 1992. QAF, the Air Force's adopted acronym for TQM, was defined as both a commitment by leadership and a style of operating that would enhance trust, teamwork, and continuous improvement at all levels within the Air Force (Holmes, 1994). QAF was defined on a foundation of leadership and the integrated system of three components.

The first component was quality focus, which included strategic planning, senior-level guidance and cultural implementation throughout the Air Force. Another component was quality in daily operations which would apply quality concepts within all work-centers. The final component was an actual improvement process which relied on a rigorous team environment and structured approach that would facilitate people working together toward some common objective. (Holmes, 1994). Unfortunately, QAF did not achieve the desired results.

In 1997, a Chief of Staff Blue Ribbon Commission on Organizational Awards and Evaluations released its assessment of QAF. Among its findings were:

1) Guidance from HQ USAF was inadequate on key priorities and results.
2) Air Force Quality was in disarray and falling far short of its potential.
3) Operational Readiness Inspections were not being utilized to an optimal level and, as a result, missed pertinent requirements and opportunities.

The amount of attention that senior leaders paid to QAF waned rapidly after this report was released. Almost a decade would elapse before the Air Force again tried to implement TQM as part of its culture with AFSO-21. Rinehart, a former speechwriter to the undersecretary of the Air Force, rightly points out that, “The shame of service’s failure to adopt quality-improvement practices the first time around, however, is not that Airmen nurtured an unworkable or unworthy idea, but that they induced its birth prematurely and left it to die” (Rinehart, 2006).

OR has been a sustained aspect of AFSO-21 with roots established within the Air Force and DoD as far back as WWII. Using techniques of linear programming, integer programming, scheduling, queuing, network flow analysis, and simulation, OR has consistently shown itself as a versatile contributor to achieving successful Air Force operations. The optimization techniques that were developed during the early 1940s with a special emphasis on enhancing military missions still remain a bedrock of OR. While the U.S. military is still one of the biggest “customers” of OR tools, models and techniques (Badiru, 2007), companies like John Deere and Motorola have saved millions using the same techniques (Ragsdale, 2007). OR will undoubtedly remain important for the Air Force as Airmen continue to find ways of working smarter.

AFSO-21 will provide management tools to Air Force personnel to help improve their processes and activities by making them more rapid and efficient. Maintainers will use these tools for that same purpose. Maintainers, in consultation with maintenance engineers, will also utilize another set of tools to improve their work processes with aircraft specific tasks using MSG-3.

Maintenance Steering Group-3

The Air Force will implement MSG-3 on isochronal schedules with the C-5 in 2009 (O'Neill and Vandersall, 2008). Within today's aircraft industry, MSG-3 is pretty much identical to reliability centered maintenance (RCM), and is currently a standard procedure for aircraft manufacturers in the development of new commercial aircraft. RCM and MSG-3 both rely on Failure Modes and Effects Criticality Analysis (FMECA) for a detailed analysis. FMECA is an extension of Failure Modes and Effect Analysis which focuses on a qualitative analysis of what component failures could induce total system failure. In contrast, FMECA focuses on quantitative parameters of failures with a criticality assigned to each probable failure mode, MSG-3 can also be applied to existing aircraft no longer produced (Rausand, 2004).

The basis for MSG-3 was developed for the airlines during the early 1960s. At that time, airlines routinely directed that aircraft--at some point during its service life--undergo an extensive overhaul. Such an overhaul usually required several days of lost flying time and hundreds of man-hours expended for a total restoration that resulted in a "better than new" aircraft. The purpose of this was to remove all aircraft degradation and to extend the service life as much as possible. Obviously, this process was very expensive. In addition, such extensive maintenance could introduce maintenance induced errors that could also cause failures (Nakata, 2005). In 1968, the commercial aviation industry was introduced to a smarter method of aircraft maintenance. Maintenance Steering Group-1 (MSG-1) criteria were used to develop the initial scheduled maintenance requirements for the Boeing 747-100 aircraft and were accepted by the Federal Aviation Administration (Nakata, 2005).

MSG-1 began a significant way of viewing the technical operations of maintenance, determining maintenance requirements, and developing schedules to accomplish these tasks by aircraft maintenance technicians. The Boeing 747, 757, 767, 777, DC-9/MD-80, DC-10, L-1011, MD-11, Airbus A320, 330, 340, and the Canadair Regional Jet are aircraft lines that used MSG concepts to develop requirements of scheduled maintenance. During the 1970s, MSG-1 was revised into MSG-2. There were still several shortcomings with MSG-2 so MSG-3 was introduced to commercial aviation in 1980 (Nakata, 2005). Dave Nakata, an experienced consultant to airlines seeking to implement MSG-3, observes that a “transition to a MSG-3 based maintenance schedule, with adequate training, can provide air carrier’s a means to reduce aircraft cost of ownership and provide additional strength to their existing safety net” (Nakata, 2005, 4).

The Air Force has now embraced the MSG-3 maintenance concept with plans to implement revised maintenance schedules for the C-5A/B in October, 2009 (Hamlin, 2008). According to the C-5 Fleet Integrated Roadmap, all inspection intervals on C-5 aircraft will be extended to those shown in Table 2-1. Major and minor inspections accomplish different inspection workcards, but both take about the same amount of time to complete. Major isochronal inspections are now accomplished with every other isochronal, but will be accomplished after two minor isochronal inspections are completed under MSG-3. With the C-5 projected to remain in the Air Force fleet until 2040, this 31-year cost avoidance is estimated at $1.38 billion (C-5 Fleet Integrated Roadmap, 2008).

Table 2-1. C-5 Inspection Intervals by Category Before and After MSG-3.

Inspection	Current Inspection Interval	Proposed Post MSG-3 Inspection Interval	Aircraft Affected
Home Station Check (HSC)	105 days	120 days	All
Minor Isochronal	420 days	480 days	All
Major Isochronal	840 days	1,440 days	All
PDM	5 years	8 years	C-5A and C-5C
PDM	7 years	8 years	C-5B

(Source: C-5 Fleet Integrated Roadmap, Table 8, p 20)

While MSG-3 has remained the industry standard for almost 30 years, utilizing artificial intelligence (AI) may offer even further refinements to the basic decision logic of MSG-3. Researchers at Beijing University demonstrated the potential utility of an experimental expert system integrating case-based reasoning with rule-based reasoning for this type of aircraft maintenance planning. Case-based reasoning (CBR) is an AI methodology of recalling what action corrected a problem and applying that same corrective action without regard for system specific rules of logic. By comparing the conditions from a past event to the current one being analyzed, applying the same action may correct the problem if the conditions are similar enough. Rule based reasoning (RBR) is based on the memory of expert system's reasoning that IF some condition exists, THEN a certain remedial action must be taken. While these two approaches appear quite similar, in some cases, they differ. RBR relies on actual cause and effect to establish rules which are then used to troubleshoot a problem. CBR is based more on experience without regard for rigorous rules such as if-then statements. The integrated reasoning uses CBR and RBR separately and then compares their results to each decision. The expert system was based on object-oriented design, and the expert system's validity was demonstrated by applying its logic to a real-world aircraft being serviced in an airline (Liu, et al., 2006).

Improving Aircraft Availability

The Air Force has adopted a High Velocity Maintenance concept to decrease aircraft flow time for maintenance at a depot. This faster throughput is accomplished by increasing man-hours per day. The Develop and Sustain Warfighting Systems target a 20 percent improvement in aircraft availability with a 10 percent reduction in operations and support funding requirements before 2011. One key aircraft availability driver is downtime for maintenance. Benchmarking against commercial practices reveals that the civilian aviation community routinely obtains a velocity of maintenance that is four to ten times higher than the Air Force. The end result for civilian aircraft is much less time spent undergoing maintenance resulting in a direct increase in aircraft availability ("High Velocity", 2008).

If the Air Force can accomplish aircraft maintenance at rates comparable to civil aviation, then a conservative estimate of a 14 percent improvement in aircraft availability is plausible. As an added bonus, greater efficiencies and potential cost reductions could also be achieved ("High Velocity", 2008). However, there are typically numerous processes that must be reviewed before any attempt at reengineering is advisable. The Expeditionary Combat Support System (ECSS) is an important innovation to help the Air

Force track its many processes in a concerted effort to boost aircraft availability rates. The current Aircraft Structural Integrity Program and the Aircraft Availability Improvement Plan also remain important to any future efforts to boost availability (Aimone, 2006). Academia has also shared this interest to minimize aircraft downtime for maintenance and have directly aided these efforts in commercial and military aviation.

Mattioda (2002) conducted research on C-130 gunship aircraft assigned to Air Force Special Operations Command (AFSOC). While these aircraft were not used for airlift, they are also considered high in demand and limited in number. In that aspect, these weapon systems are similar to airlift assets. Increasing aircraft availability would greatly enhance the capability of AFSOC (Mattioda, 2002) just as it would for AMC.

The isochronal inspections for C-130s were at that time conducted once every 365 days. Mattioda stated that opportunities to increase aircraft availability by improving the task scheduling and estimating durations of each phase accurately could exist. Scheduled maintenance such as isochronal inspections are very similar to projects. His thesis proposed that Critical Chain (CC) scheduling, a project management technique, could provide an improved ISO schedule reducing aircraft downtime (Mattioda, 2002).

Mattioda's thesis research modeled the C-130 isochronal process considered in three ways: (1) with the existing process, (2) with any task constraints removed, and (3) with any task and resource constraints removed. He simulated 100 aircraft inspections in each model. These simulated duration times were then compared to estimates provided using Critical Path and Critical Chain scheduling techniques. While the Critical Chain scheduling techniques did not show any direct increase in aircraft availability, he demonstrated that Critical Chain scheduling could identify the potential for increasing aircraft availability by removing policy and scheduling constraints (Mattioda, 2002).

Mattioda pointed out two applications of the Critical Path theory in aircraft maintenance in use within the Air Force during 2002. These were the Periodic Depot Maintenance Scheduling System (PDMSS) and the allocation of resources during C-5 programmed depot maintenance. During a period of 5 years, the C-5 depot repair completion times was extended from a range of 200 to 250 days to over 300 days. The source for this time increase was due to an increase in extensive engine pylon repairs and deterioration of the aft tie box fitting on the horizontal stabilizer. Maintenance personnel eventually realized the tasks were along the CP and brainstormed methods to shorten their duration. Technology and industrial support workers manufactured new parts before the aircraft entered into PDM. This facilitated replacement of the defective parts in record time. Mattioda cited that these processes resulted in two C-5As were completed in 286 days, and a C-5B completed in only 191 days (Mattioda, 2002). The time required for PDM was much longer than isochronal inspections due to the complex nature of the inspection conducted.

Mattioda indicated that the procedures he used to determine the Critical Path and Critical Chain schedules could also be utilized to examine other aircraft inspection processes. This has the potential to estimate any improvements for aircraft availability. Reducing programmed depot maintenance time may provide further aircraft availability well exceeding opportunities that are available at the organizational level. Any slack in the ISO schedule allows the addition of selected depot tasks and these opportunities should be investigated for further reductions in the amount of work that must be accomplished at the depot (Mattioda, 2002). This is consistent with observations by a maintenance office on the C-5 HVRISO at Dover.

Smith (2008) wrote about "certain choke points" in the C-5 isochronal inspection that necessitated a 24-hour, 7-days-a-week work schedule to work toward meeting the 14-day ISO inspection goal. Overtime has also proven necessary in some instances so it is obvious that isochronal inspections for C-5s are subject to constraints like any other project. Smith made two recommendations to decrease throughput time of HVRISOs. First, he suggested that the older C5-As never be scheduled back-to-back since they typically take longer. While not statistically different, on average C5-As required an average of 20.31 days to complete an isochronal inspection and C5-Bs required an average of 17.38 days to complete this process. Another suggestion was to increase the intervals between aircrafts arrivals to allow more time where only one aircraft was being worked at the HVRISO dock (Smith, 2008). The drawback is that this could cause aircraft to go overdue on isochronal inspection. These proposals can be tested using simulation. Several replications can also add a degree of confidence with a low margin of error.

TO 00-20-1 defines PDM as an inspection requiring skills, equipment, and/or facilities not normally possessed by operating locations. Since each RISO will remain an operating location, the PDM concept will still play an important role in sustaining C-5 reliability. With PDMs, individual areas, components, and systems are inspected to a degree beyond technical inspection requirements for the operating locations. Field-level tasks, such as isochronal inspections, may be accomplished at PDM if their accomplishment is economically feasible, but PDM tasks are rarely accomplished at field level due to their complexity (TO 00-20-1, 2003). Barrett and Fraile (2004) prepared a case study of the PDM performance of C-5s at Warner-Robbins AFB, GA, in 2004. While the purpose of this case study was to generate dialogue and learning about Lean processes and the impact on labor-management relations, it briefly examined the Lean processes that led to slashing the completion of C-5 PDM. The C-5 program had by 2004 made significant gains in productivity and schedule.

The initial Lean event involved drawing a top-level value stream map of the entire C-5 PDM process from beginning to end. The map covered 52 processes. Participants also drew a map of the ideal state and formulated an action plan of how to close this gap. The ideal state map featured a streamlined process with eight work cells, visual production controls, and a pull system for parts. The goal was to reduce the actual flow days, which is the average time required to complete depot maintenance and repair on C-5s, down to the 180-day target. This map and action plan provided the architecture for Lean efforts at the C-5 depot over the next two years (Barrett and Fraile, 2004).

Flow days steadily declined from 340 days during FY01 to as little as 229 days as of May 2004. This achievement was even more remarkable considering a surge in demand because of the global war on terrorism (GWOT) with 23 C-5s processed during FY03. This represented a 35% increase over the FY02 demand of 18 C-5s. An important milestone of 100% on-time delivery was achieved in FY04. This was a drastic improvement compared to FY01 when on-time delivery stood at less than 30% (Barrett and Fraile, 2004). The time required for PDM was much longer than isochronal inspections due to the complex nature of the inspection conducted.

Other literature examined processes impacting C-5 availability that occurred between the cycles of isochronal inspections and PDMs. Polomsky (2007) considered the impact of breakdowns at en-route locations and other locations that deviate from these routes for the six primary aircraft fleets utilized by AMC including all versions of the C-5. En-route locations, as opposed to those not en-route, provide varying levels of command, control, communications, logistics support, and aerial port functions. Polomsky's research examined a 5-year summary of AMC's logistical support process (Polomsky, 2007).

The resulting data were used to perform a statistical analysis of AMC off-station aircraft logistic support records. The results described by Polomsky indicate that OCONUS en-route infrastructure was more effective in reducing average not-mission-capable (NMC) time for C-5 aircraft than OCONUS locations that were not en-route. Overall, en-route locations appear to reduce average NMC time by more than 17 hours per required maintenance action for the entire fleet, but estimated a minimum delay of 11 hours to begin maintenance for C-5s. He also found that major inspections for C-5s were conducted at Moron AB, Spain during the Kosovo operations in 1999 (Polomsky, 2007). While not directly addressing isochronal inspections, Polomsky's research indicated the increased importance of and emphasis on reducing NMC times by any available means for all AMC airlift assets including C-5s.

Studies of isochronal, PDMs, and maintenance in transmit, make it clear that aircraft availability is a complex subject. In addition, the Air Force and AMC each take complementary approaches to improving C-5 availability. The Air Force is planning on RERP in hopes of boosting availability by an additional 10-20% while AMC is relying on the HVRISO to improve availability. Quantifying the level of increase in availability using these various approaches is a problem ideally suited for simulation.

Simulation Studies

Simulation is an important OR technique. Badiru advocates simulation as an important tool to use in the project management of technical systems (Badiru, 2007). Managing a HVRISO dock is considered a project management task. Simulation is “the imitation of the operation of a [realistic] process or system over time”. (Banks et al, 2005, 1). Banks et al. advocate use of simulation as an excellent tool to study the complex, internal interactions of a system or subsystem. Further, measuring the effects of changing one or more input parameters such as service times, scheduling, or reduced takt times is prudent prior to committing the required resources into a real system. This kind of experimentation without altering the system is only possible with simulation (Banks et al., 2005). Simulation is obviously an appropriate method to study HVRISO. Other simulation studies have modeled the processes that sustain C-5 availability.

The availability of C-5s has been studied using simulation (Balaban et al., 2000, Ciarallo et al., 2005, Johnson et al., 2008). These simulations, with one exception, did not contend directly with the isochronal process. Balaban et al. designed a simulation to estimate the mission capability rates (MCR) for different modernization schemes implemented on the C-5. Recognizing the C-5 as one of only two strategic airlift aircraft available to carry large outsize cargo, the study sought to address the impact of proposed reliability enhancements to include new engines. Further, this model did consider isochronal inspections as an NMC category and thus included this impact on overall C-5 availability. However the process was implemented every 400 days instead of the 420 day schedule currently utilized (Balaban et al., 2000).

This MCR model was validated and verified across a wide range of assumptions. the model was used by AMC to refine different aircraft fleet configurations and to carry forward the best value recommendation to senior Air Force and DoD decision makers. The model demonstrated that the C-5 can expect to attain a 75% mission capable rate by implementing the full upgrade initiatives. Further, the model can easily be extended to different Air Force aircraft and possibly commercial aircraft through appropriate data sources and assumptions (Balaban et al., 2000).

Ciarallo et al. developed a simulation of a simplified version of a typical AMC mobility system. This example defined, tested and demonstrated a simulation model useful for Mobility Aircraft Availability Forecasting (MAAF). The simulation scenarios considered in the model included only four airbases in the mobility system. These were Ramstein AFB GE, Sigonella IAP IT, Kuwait City IAP KW, and Dover AFB DE. Ramstein AFB owned five C-17s and Dover AFB owned twelve C-5s. The other two airbases functioned in the simulation as en-route locations within the defined mobility system (Ciarallo et al., 2005).

Ciarallo et al. (2005) concluded that the general ability of the MAAF simulation concept, coupled with robust analysis of distribution functions used for simulation data, provides a mobility analyst insight into the range of critical issues. Among these is whether assigned missions can be completed with the resources available. Consolidation to only three aircraft isochronal inspection sites will require C-5 aircraft to travel from their home units to the three designated locations. This should be implemented into any simulation for a robust model of new isochronal process.

A preliminary simulation study of the proposed C-5 isochronal inspection was conducted for an AFIT class project in 2008. Johnson et al. (2008) designed a simulation model to determine the impact of factors such as depot and flying processes to determine the impacts on the time required to conduct an ISO. Also, they attempted to determine the impacts to C-5 availability due to the planned reduction to just three ISO sites and briefly considered alternatives to address these impacts. Most notable of their conclusions was that the entire ISO process must be completed in only 14.25 days. A longer average time period for ISO completion will make the ISO process eventually unmanageable due to excessive waiting time for isochronal docks to be released (Johnson, et al., 2008).

There were limitations in this preliminary study due to time constraints. While an excellent model on which to base a more detailed study, it is not sufficient to make actual recommendations. One assumption made was that all three docks would operating similarly to the RISO at Dover AFB, DE. This assumption is likely tenuous since there are significant differences due to force structures. Dover HVRISO may not have yet fully integrated with an infusion of personnel from Travis AFB, CA where two previous ISO units have closed. The Westover and Martinsburg units will likely utilize a combination of reservists and guard members with some active-duty specialists embedded. These differences in force structures alone may account for some differences.

Table 2-2. Summary of AFSO-21 Literature Review.

Category	Subcategory	Authors	Synopsis
AFSO-21	Lean Principles	Russell-Walling (2007); Badiru (2007); Mathaisel (2006); Smith (2008)	Lean Principles focus on eliminating waste from a process; AFSO-21 will rely heavily on Lean tools; HVRISO at Dover uses Lean tools for this purpose
	Six Sigma	Hammer (2002, 2001);	Six Sigma complements Lean efforts to reduce waste and decrease cycle time in a process by also ensuring or even improving the quality of outputs from those processes
	Theory of Constraints	Goldratt (1984); Rahman (2002, 1998);	Organizations must recognize and overcome their constraints enough to produce at acceptable levels; constraints must be continually managed
	Management by Objectives	Drucker (1986); Russell-Walling (2007);	Tasks in any organization must be linked to intermediate goals and higher-level tasks; intermediate goals must be linked overall objectives
	Business Process Improvement	Gibson (1997); Hammer and Champy (2003);	Some organizational processes are so outdated and inefficient, it is often better to reinvent a new business process
	Total Quality Management	Crosby (1979); Holmes (1994); Rinehart (2006);	Based on the premise of doing things right the first time, every time; a price will be paid for not doing so; an initial attempt in early 1990s to implement in Air Force failed
	Operations Research	Badiru (2007); Ragsdale (2007);	Techniques of linear programming, scheduling, and simulation have been used since WWII within DoD; will likely continue to be used in the future

Table 2-3. Summary of C-5 Availability Literature Review

MSG-3	Reliability Centered Maintenance and Failure Modes and Effects Criticality Analysis	Rausand (2004); Nakata (2005); Liu et. Al (2006); Hamlin (2008); C-5 FIR (2008);	MSG-3 will be an important initiative to improve C-5 reliability by extending intervals between inspections without compromising airworthiness or safety
Improving Aircraft Availability	Iscochronal inspections, critical chain method, programmed depot maintenance, and en-route maintenance	Mattioda (2002); Barrett and Fraile (2004); Polomsky (2007);	Several initiatives to improve aircraft availability currently being attempted; many apply to C-5 availability
Simulation Studies	C-5 availability	Balaban, et al. (2000); Ciarallo, et al. (2005); Johnson, et al. (2008);	Simulation studies are an excellent method for testing the effects of new methods on aircraft availability; simulation models have been successfully built to replicate C-5 availability

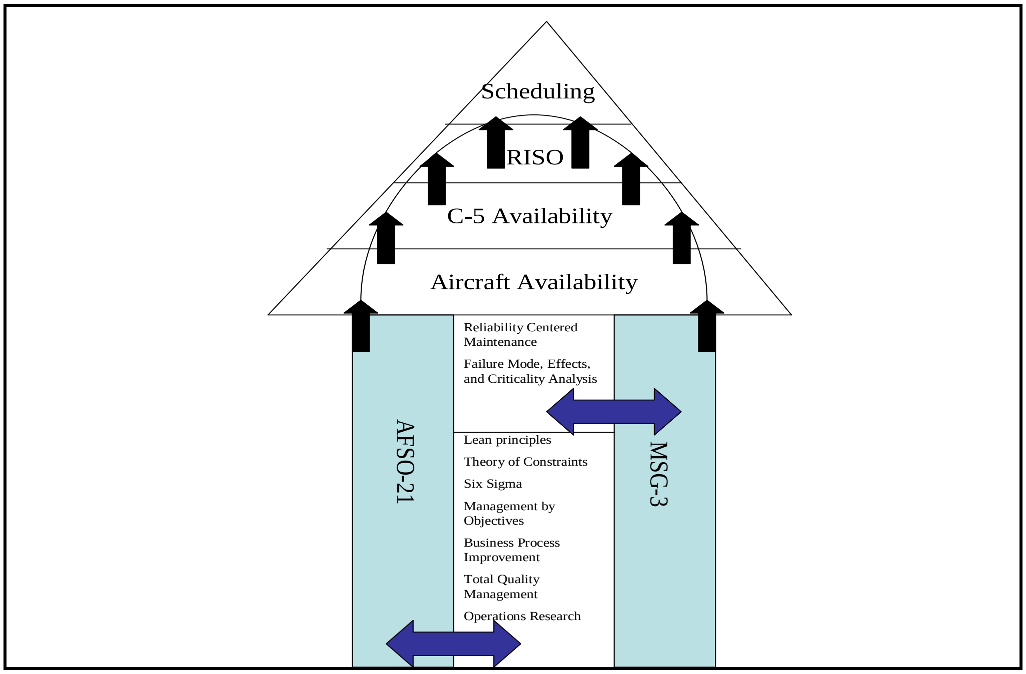


Figure 2-1. Structure Model to Improve Aircraft Availability.

Another important factor not included was the MSG-3 proposal to extend the time between each C-5 ISO from the current standard of 420 days to 480 days. Isochronals would also be accomplished with each PDM, but PDMs would also be extended to 8 years for all aircraft. Implementation of retrofit may also have a net reduction or increase on processing time. Tables 2-2 and 2-3 summarize the literature reviewed for the proposed simulation study of the C-5 HVRISO concept. Figure 2-1 ties together each of the criteria discussed in this literature review as a pictorial that serves to enforce what each portion is meant to accomplish with respect to C-5 availability.

Conclusion

Improving aircraft availability is an interest to the United States Air Force as indicated by numerous studies in recent years. AFSO-21 offers techniques that can help improvement efforts. MSG-3 has been successfully implemented in commercial aviation and will soon be applied to C-5 maintenance schedules. Simulation has been used successfully to help predict the effect of numerous proposals on aircraft availability. Other factors such as the number of available inspection facilities and proposals on how to schedule those facilities will also affect aircraft availability.

III. The Submission of the Journal Article

This chapter consists of an article manuscript intended for submission to the International Journal of Operations Research and Information Systems (IJORIS), a peer-reviewed journal. The methodology and analysis portions of this research are included in this chapter. An introduction, literature review and conclusions are also included. Data to build the simulation models and other analysis not included in the manuscript are presented in the Appendices.

1. Introduction

Breakdowns are hazardous in aviation (Smith, 2006; Cheever, 2001). Aircraft maintenance is critical to reduce the chances of aircraft component failures (Brinkley, 2007; "What Does It Take", 1999). Scheduled maintenance is as crucial to the Air Force mission as it is to civil aviation (Armstrong, 2008). Periodic inspections such as isochronal maintenance (ISO) and programmed depot maintenance (PDM) are vital activities in these preventive measures (Creel, 2008). Maintenance practices within the Air Force are migrating toward centralized maintenance as budgets become increasingly restricted (Bolinger, 2007; Gibbs, 2003). Centralization could help maximize aircraft readiness within today's financial constraints (Durand, 2008; Gellar, 2005). The goal is to attain inspection and repair systems that efficiently use limited resources (Goonan, 2006; Kapoor et al., 2004).

The C-5 Galaxy, one of the largest aircraft in the world, can carry combat-ready military units to any staging area in the world. This airframe provides the Defense Department with strategic airlift capabilities and supports many defense objectives ("C-5 Galaxy", 2008). Thus, efforts to increase C-5 availability are important. Availability is defined as the percentage of time that an aircraft is deemed as flight worthy. Aircraft downtime resulting from maintenance or inspections reduces availability.

The Air Force fleet of 111 C-5 aircraft is divided among active duty (denoted as "Active") units, Air Reserve (denoted as "Reserve") units, and Air National Guard (denoted as "Guard") units. Active C-5 units assigned to Air Mobility Command (AMC) possess 36 C-5 aircraft. Three Reserve units own a total of 42 C-5 aircraft while three Guard units control the remaining 33 C-5 aircraft.

A C-5 ISO consists of a series of processes for a thorough inspection of all aircraft subsystems. Repair actions are initiated if any discrepancies are found. Delayed discrepancies--degradations that were previously deferred for repair-- may also be corrected during this inspection. A minor inspection is mostly a systems reliability check. Major inspections accomplish heavy maintenance that cannot wait until the next PDM inspection. PDM inspections also include a detailed investigation of aircraft structural integrity.

The ISO process begins with an aircraft wash followed by the inspection. This process then routes aircraft to a fuel cell and concludes by performing backline maintenance. An aircraft wash is quite similar to an automobile wash in that it uses an especially equipped facility with a high pressure water source and lifts to access elevated areas. The inspection area is a hangar with specially-designed maintenance stands to facilitate maintenance in normally inaccessible areas including engines, mounting pylons, and t-tail areas. The fuel cell is a designated hangar that permits aircraft fuel tanks to be opened for inspection, maintenance, and resealing. Because only specially trained personnel are permitted to open fuel tanks, this area is normally off limits to non-essential personnel during maintenance on open fuel tanks. Backline maintenance consists of functional checks such as engine runs and landing gear retractions to verify flight worthiness.

AMC is planning three important initiatives--dock consolidation, new inspection procedures, and new selection methods--to sustain C-5 availability with reduced budgets. How these initiatives will help or hinder aircraft availability depends on results obtained after initiative implementation. This is an important consideration and is the focus of this research. AMC needs to know which initiatives will have the greatest effect on aircraft availability. With this information, any necessary improvements can be selected based on their expected impact. Our research offers similar insights for general and commercial aviation professionals contemplating simultaneous changes to inspection criteria and intervals with fewer aircraft inspection sites.

This paper is organized as follows: Section 2 surveys the relevant background for our research. We then describe the specific research problem and the methodology employed. We follow with our analysis results and recommend specific actions for AMC consideration. We conclude by noting study limitations and providing recommendations for future research.

2. Background

AMC hopes to gain efficiencies by directing aircraft inspections through three high-velocity regionalized isochronal (HVRISO) docks. These docks must be organized for rapidly accomplishing isochronal inspections and repairs. By using the same teams to perform all inspections, AMC should gain benefits not possible with just adding docks alone (Daley, 2008). A potential downside is aircraft queue time that occurs when an inspection dock is not available when an aircraft arrives for an inspection. This queue time directly reduces aircraft availability. Because of the coordination required several weeks in advance to select an induction date, avoiding queue time has been an elusive goal. Using fewer inspection docks could also hinder availability (Bagley, 2008). Figure 3-1 illustrates the planned consolidation.

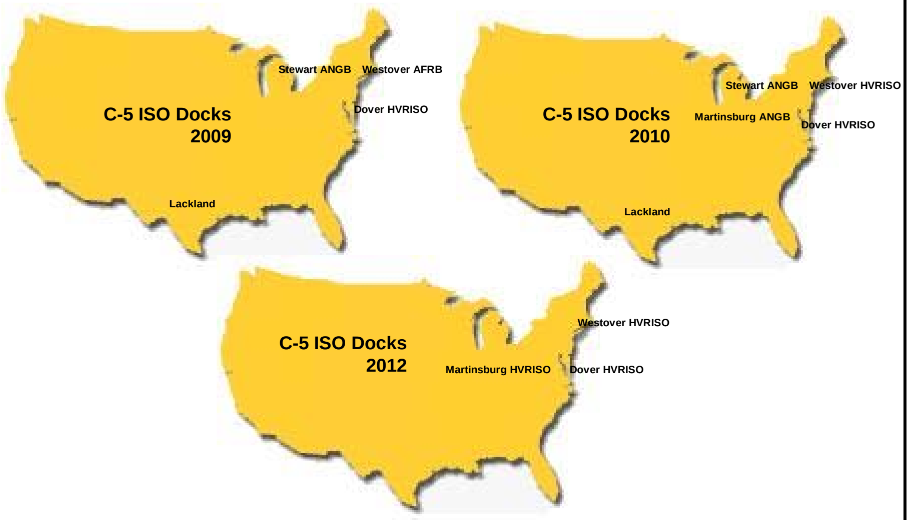


Figure 3-1. Current C-5 ISO Consolidation Plans.

Consolidating to three HVRISO docks presents challenges. Dover AFB, DE currently has the only operational HVRISO dock (Wallace, 2008; “In Step”, 2008). Additional HVRISO docks will be organized the same as Dover. Westover Air Reserve Base, MA will host the Reserve’s HVRISO dock (“Air Force Reserve”, 2006; Goonan, 2006), but has postponed operations until 2010 to first resolve related issues (Harken, 2008). Martinsburg will host the ANG’s HVRISO dock (Cadle, 2007), but does not yet have any operational dock capacity. A Martinsburg dock should become operational during 2010 (Donovan, 2008), but necessary funding could be diverted and delay these plans.

AMC will continue to rely on legacy docks at Stewart and Lackland until all three HVRISOs are operational. Legacy docks operate as traditional inpsection docks. Compared with the HVRISO standard, these docks have a lower number of personnel assigned and have periodic shutdowns throughout the week. Legacy docks typically operate for 16 hours each day, 5 days a week, while the HVRISO runs continuously.

AMC will schedule inspections for all three HVRISO docks. Inducting aircraft into a HVRISO just as a previous aircraft leaves would eliminate queue time. However, schedulers must plan aircraft inductions weeks in advance. While AMC seeks to implement a “best-fit” method of dock selection, other factors may complicate this process. Guard and Reserve units possessing HVRISO docks wish to perform their own C-5 inspections (Bagley, 2008). Major inspections may also be performed at a specific dock (Donovan, 2008). This presents challenges to AMC schedulers since no sufficient dock selection criteria are yet available.

AMC foresees that abandoning legacy inspection methods and extending inspection intervals by using Maintenance Steering Group-3 (MSG-3) concepts may help alleviate problems stemming from dock consolidation delays. By slashing inspection downtime, AMC hopes to boost aircraft reliability by 20 percent (Birchfield, 2007). AMC foresees that MSG-3 inspections will maximize aircraft integrity using reliability-centered maintenance and a systems-based approach favored by commercial aviation (Benoff, 2000). While designed to optimize maintenance schedules during the aircraft design phase, MSG-3 can be applied to older, operational aircraft. As an example of

MSG-3 implementation on an aged airframe, the DC-9 adoption led to a reduction in labor-hours expended for maintenance checks and slashed the number of flow days required. Departure reliability rates of the DC-9 also rose from 96 to over 98 percent. If AMC results are comparable to commercial achievements, MSG-3 will reduce repair times and defer extensive maintenance to PDM inspections. MSG-3 usage on the C-5 starts in 2009 (O'Neill and Vandersall, 2008).

Other research has focused only on the planned consolidation. Johnson et al (2008) examine issues related to dock consolidation. They found that using only three docks would result in significant queue time unless two conditions are met. First, AMC standards for ISO flow must be met consistently, and, second, inspection docks must be released upon starting functional checks to minimize disruptions to dock flow. They conclude that three HVRISO docks are insufficient except under these favorable conditions. They recommend a fourth operational dock be retained until the ISO process can be reduced to about 14 days. Once this standard is met, the fourth dock can be closed without significantly reducing aircraft availability (Johnson et al., 2008).

Smith (2008) outlines how an HVRISO successfully applied Lean principles to streamline processes and reduce dock time. Smith highlights how the 14 day goal for ISO dock flow time remains elusive, but progress is being made (Smith, 2008). Daley (2008) argues that standardized work teams are a key to HVRISO success. He also believes that unless owning units assume more responsibility for delayed discrepancies, disruptions to a productive workflow will result (Daley, 2008). Neither Smith (2008) nor Daley (2008) addresses the planned implementation of MSG-3 inspections, dock selection methods, or possible delays in dock consolidation. By considering these factors, we seek to better understand centralized maintenance concepts within the Air Force.

3. Methodology

We developed a set of discrete-event simulation models to examine the viability of various proposals for dock consolidation, MSG-3 implementation, and dock selection methods. Teleconferences were held with AMC headquarters logistics planners throughout 2008 to reach consensus on the research questions to examine and model logic to implement. Dover AFB was visited to examine the HVRISO organization, facilities, and work methods and conduct interviews with key personnel; this visit helped to validate the model's conceptual flows and to obtain information on process timeframes.

AMC requested that overfly criteria be considered in our simulation study. Overfly represents the time an aircraft is still available for airlift missions despite being overdue for an inspection, and should affect queue time. We constructed our models to address requirements such as updating inspection due dates, determining the next inspection type (major, minor, or PDM) required, dock selection methods, and to capture process and queue times. Simulation models were iteratively developed and refined into three final models used for this study.

The final models use flow data for ISO processes from Dover, Westover, and Stewart to simulate dock performance levels. Lackland ISO performance data were unavailable , so after consulting with our research sponsor, we elected to use Westover data to simulate Lackland ISO performance.

Telephone interviews with PDM personnel revealed that the MSG-3 implementation will allow 220 days to complete a PDM at Warner-Robbins AFB, GA. While no more than 7 aircraft is the preferred number of PDMs in progress, PDM personnel can “surge” to support greater numbers if necessary.

The broad research question we address is: “To what extent will docks be able to sufficiently fulfill inspection requirements with the proposed changes?” How long it takes to complete the dock consolidation will influence aircraft availability. If three HVRISOs are incapable of meeting fleet inspection requirements in a timely manner, aircraft availability is affected. While the MSG-3 implementation will extend inspection intervals, it will also change requirements. How much dock time is required per ISO will also affect total aircraft availability. In addition, centralized scheduling will select docks well in advance of aircraft inspections coming due. The criteria used for dock selection will impact aircraft availability. Permitted overfly days, where an aircraft is still available despite being overdue the inspection, might also have an effect.

As a result, five specific investigative questions were formulated:

Investigative question 1: “To what extent will the dock consolidation to three HVRISO bases affect aircraft availability and HVRISO flowtime?” Implementation of these consolidation plans could be delayed due to financial, manning, and other considerations. How potential delays might affect availability is of prime interest in this study.

Investigative question 2: “To what extent will adopting MSG-3 initiatives affect aircraft availability and HVRISO flowtime?” While MSG-3 will extend the time intervals between isochronal inspections, these intervals may not be sufficient to prevent excessive queue time if resultant inspection times are too long. PDM inspections will be performed less frequently since all PDM intervals will be extended to every eight years.

Investigative question 3: "To what extent will dock selection methods affect aircraft availability and HVRISO flowtime?" Aircraft selection is currently based solely upon the required due date. As other HVRISO docks are added, other criteria could also be considered as other HVRISOs begin operations. Table 3-1 outlines three dock selection methods this study examined based on potential usage of Active, Reserve, and Guard docks.

Table 3-1. MSG-3 Dock Selection Methods Examined.

	Majors	**AMC Minors**	**Reserve Minors**	**ANG Minors**
Lean	Dover Only	Either ANG or Reserve Docks Based on Capacity Levels	Reserve Docks Only	ANG Dock Only
Agile	Any HVRISO	Any Dock	Any Dock	Any Dock
Leagile	Dover Only	Any Dock Except Dover	Any Dock Except Dover	Any Dock Except Dover

These dock selection methods resemble Lean and Agile approaches used in manufacturing (Mason-Jones, Naylor, and Towill, 2000; Goldsby and Garcia-Dastugue, 2008). The Lean option would route the same type of inspections and/or aircraft to designated docks. Such an approach reduces variability of aircraft and inspection types conducted within these docks and is a similar approach to Lean manufacturing. The Agile option can task HVRISOs with any inspection and would increase the variability of inspections. This parallels a more Agile approach to dock selection. The Leagile method would apply both approaches according to the situation.

Investigative question 4: “What effect will a lower allowance of 5% for overfly have on queue time and aircraft availability?” A lower 5% overfly allowance would permit up to 24 days of past-due flying. If HVRISO completion times are usually short and the dock consolidation is completed rapidly, then queue time will already be minimal and this allowance would have a limited effect on queue time. If the opposite circumstances hold true, then an increased tolerance of 10%, or simply 48 days, may be required to have any appreciable effect on queue time and aircraft availability.

Investigative question 5: “What interactions between the three factors considered can significantly benefit or reduce aircraft availability?” A combination of rapid inspections and a faster dock consolidation would benefit aircraft availability. If this scenario is realized with the proposed system, knowing which dock selection method would produce the best results is beneficial information for AMC. At the other extreme, longer dock times and further delays in consolidation would be detrimental. In this case, dock selection methods may help to mitigate the resulting problems with queue and inspection processing times. Finally, if tradeoffs between long dock times and delayed consolidation are being considered, then knowing which improvements are most beneficial would be critical information.

Assumptions

- All C-5 aircraft are identical in configuration.
- PDM inspections will require exactly 220 days.
- HVRISO docks will operate with the same performance characteristics as Dover.
- Lackland legacy dock will operate with the same performance characteristics as Westover’s legacy dock.
- Martinsburg legacy dock will operate with the same performance characteristics as Stewart’s legacy dock.
- PDM can handle a maximum of 15 aircraft simultaneously.
- No C-5 aircraft will be retired or otherwise removed before year 2040.

- No realignments of assigned C-5 aircraft will occur between Active, Reserve, and Guard units.
- We ignore potential relationships between dock selection methods and inspection times. For example, if docks are tasked with both minor and major inspections, then the assumed inspection process time distribution will not change because of the added flexibility.

Model Descriptions

The general conceptual flow of the models is depicted in Figure 3-2. The model logic proceeds as follows:

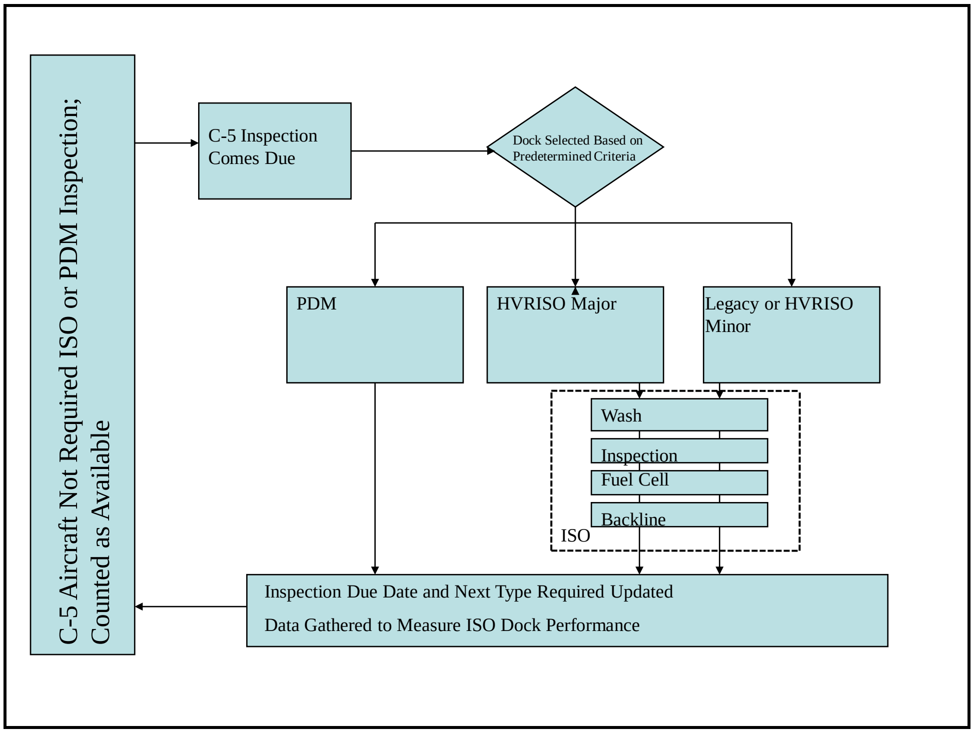


Figure 3-2. Entity Flow Within Simulation Models.

1. Models create 111 entities to represent individual C-5 aircraft in the total Air Force system.
2. Each aircraft entity is assigned individual attributes for tail number, inspection due date, next MSG-3 inspection required, base of assignment, possessing organization (Active, Reserve, or Guard), and locations indicating where minor inspections will be performed.
3. Once entities are created, due dates are compared to simulation time to determine if aircraft is due for inspection.
4. If aircraft is not due for inspection, it is routed to a counter that tallies the number of days available.

5. If aircraft is due for inspection, it is routed to a decision module for dock selection.
6. All PDM inspections simulate Warner-Robbins Air Force Base (WRAFB) processes.
7. If an inspection is due, it is routed according to the Lean, Agile, or Leagile strategies described in Table 3-1.
8. Regardless of which dock selection methods are used, legacy docks can only perform minors.
9. All ISO processes are configured to progress in the simulation models in this sequence: 1) Wash rack; 2) ISO Dock; 3) Fuel Cell; and 4) Backline except for Stewart which uses Awaiting Predock and Predock in place of the Wash.
10. No resource constraints are assumed for awaiting predock, predock, wash rack, fuel cell, or backline processes.
11. Each ISO dock at all locations is assumed to possess a capacity permitting only one aircraft at a time.
12. Data indicating tail number, cumulative wait time for entity, current simulation time, next due date, next inspection due, and current number of replication is recorded.
13. Aircraft days are counted until aircraft again comes due for inspection.
14. Each dock is periodically "closed" to simulate scheduled shutdowns for dock maintenance.

Input Analysis

Distributions of various processing times for three docks were determined using Arena's Input Analyzer©. The times for wash racks, fuel cell, and backline maintenance are based on historical data provided by personnel at Dover and Westover since these processes will likely not change. Stewart personnel included the wash process with their sequential "Awaiting Predock" and "Predock" processes and this is modeled accordingly for this ISO process. Our estimated process time distributions and number of data points for each dock are shown in Table 3-2. Note that the p-values for our Weibull and Beta distributions are estimates because exacts tests are not available; however, these estimates are conservative for the Kolmogorov-Smirnov goodness of fit (Law and Kelton, 2000, 363).

Table 3-2. Distributions Used for Current ISO Facilities.

Location	Sub-process	Distribution	Sample Size
Dover	Wash rack	NORM(0.982, 0.33)	42
	Fuel Cell	LOGN(2.77, 2.23)	
	Backline	ERLA(1.49, 3)	
Westover	Wash rack	0.5 + 5 * BETA(1.21, 1.58)	24
	Fuel Cell	-0.5 + 8 * BETA(0.973, 1.31)	
	Backline	5 + WEIB(9.39, 0.668)	
Stewart	Awaiting Predock	-0.5 + 15 * BETA(0.515, 1.2)	14
	Predock	NORM(5.14, 1.3)	
	Fuel Cell	2.5 + GAMM(3.36, 1.68)	
	Backline	6.5 + 53 * BETA(0.721, 0.975)	

Although different distributions were found for essentially similar processes, different organizational cultures and work rules among Active, Reserve, and Guard units would readily explain these differences. For example, HVRISOs would have faster throughput on these processes because of their organizational structure. Guard units typically maintain older airframes with fewer resources which would logically consume additional downtime.

We used triangular distributions for inspection completion times with ranges appropriate for each dock. Since AMC does not expect significant differences between the time required to accomplish previous inspections and MSG-3 minor inspections, ranges for MSG-3 minor inspections are partially based on historical data. Times for previous inspections capture dock preparation, maintenance stand set-up, repair phase, maintenance operational checkouts, and maintenance tear down. These same procedures apply to MSG-3 minor inspections. Any differences will be due to inspection times.

Experiments

ISO completion times, dock consolidation delays, and dock selection methods were used as controllable factors. Each factor has three levels resulting in 27 experiments. The three levels assignable to inspection completion times represent best, expected, and worst case scenarios. A best case was used where both minor and major inspection mode times are set to the lowest possible value within the selected ranges. This results in a left skewed distribution and would represent situations where docks are experiencing fewer problems than anticipated with implementing MSG-3 or an abundance of skilled personnel at all docks. An expected case is where minor and major inspection mode times are set to the average value within the set ranges selected for each category. The third level represents a worst case where minor and major inspection mode times are set to the highest possible value within the set ranges selected for each category. This might be caused by experiencing problems not anticipated with MSG-3 implementation, a shortage of skilled personnel, or aging aircraft issues such as corrosion. Table 3-3 illustrates these values.

Table 3-3. Assigned Mode Values for Inspection Completion Distribution (in days).

	Dock Selection	Lean			Agile			Leagile		
Probability Density Function Shape	Dock Consolidation Completed NLT Year	2012	2013	2014	2012	2013	2014	2012	2013	2014
◺	Stewart Mode	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
	Westover Mode	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
	HVRISO Minor	7	7	7	7	7	7	7	7	7
	HVRISO Major	20	20	20	20	20	20	20	20	20
△	Stewart Mode	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5	28.5
	Westover Mode	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5	26.5
	HVRISO Minor	11	11	11	11	11	11	11	11	11
	HVRISO Major	24	24	24	24	24	24	24	24	24
◿	Stewart Mode	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
	Westover Mode	41.5	41.5	41.5	41.5	41.5	41.5	41.5	41.5	41.5
	HVRISO Minor	15	15	15	15	15	15	15	15	15
	HVRISO Major	28	28	28	28	28	28	28	28	28

The time required to complete the HVRISO dock consolidation is uncertain. Financial and/or personnel considerations may delay Westover and Martinsburg from achieving transformational milestones. Table 3-4 illustrates the three dock consolidation factor levels selected for modeling. The three levels assignable to dock consolidation delay represent early, expected, and late consolidation.

Table 3-4. Time Span for Selected Dock Consolidation Levels.

Year Level	**Westover Transforms to HVRISO**	**Martinsburg Opens Legacy Dock**	**Martinsburg Transforms to HVRISO**	**Lackland Closes Dock**	**Stewart Closes Dock**
Early (3 years)	2010	2010	2012	2012	2012
Expected (4 years)	2011	2011	2013	2013	2013
Late (5 years)	2012	2012	2014	2014	2014

Each experimental design is termed a scenario. Table 3-5 shows the factor levels assigned to each scenario. These scenarios were then compared for aircraft availability metrics.

Table 3-5. Factors Levels Assigned to Each Scenario.

Scenario	1	2	3	4	5	6	7	8	9
Dock Delay (years)	3	4	5	3	4	5	3	4	5
Inspection Time Distribution	◺			△			◿		
Dock Selection	Lean								
Scenario	10	11	12	13	14	15	16	17	18
Dock Delay (years)	3	4	5	3	4	5	3	4	5
Inspection Time Distribution	◺			△			◿		
Dock Selection	Agile								
Scenario	19	20	21	22	23	24	25	26	27
Dock Delay (years)	3	4	5	3	4	5	3	4	5
Inspection Time Distribution	◺			△			◿		
Dock Selection	Leagile								

Output Data

Data were collected on ISO inspections in the simulation models. This data included:

- Aircraft Tail Number,
- Cumulative Wait Time of Aircraft Entity,
- Current Simulation Time,
- Next Due Date,
- Next Inspection Type Required.

Tail number is used as a unique identifier for each aircraft entity and is used to sort data. The cumulative wait time was an Arena© defined attribute that permits calculation of waiting time for each induction into a dock by deducting the previous cumulative wait time from the current value. Current simulation time and the next due date are self-explanatory values and were used to compute processing time. Next inspection type determines what inspection was just completed.

Data were sorted by replication in separate worksheets by ascending tail numbers. Spreadsheet functions placed the data points in ascending order by due date within the ascending order by tail numbers. Each data entry was processed to compute observed processing time for entire ISO. Spreadsheet cells containing data values were formulated to compute queue time. Queue time that would result from both 5% and 10% overfly rules were both computed and denoted as “Queue Time-24” and “Queue Time-48” respectively. For 5%, if the queue time for a given instance exceeds 24 days, then 24 days are deducted for the queue wait time if 5% overfly were permitted. Otherwise, it was set to 0. Similar computations were used for 10% overfly.

Once these results were computed, they were summed to compute cumulative downtime, compared across scenarios, and analyzed using regression techniques. This was performed for each of the 27 scenarios. We computed aircraft availability as a tally of the number of days an aircraft was not undergoing an ISO or PDM.

Verification

We developed test models to ensure final models could capture the key elements of dock consolidations and MSG-3 concepts. Test models for dock consolidation ensured that routing to specific docks was controlled based on assigned values to selected variables. Other test models ensured that entities were assigned MSG-3 attributes and that these attributes were properly updated as simulation progressed. Dock selection methods were not easily changed based on variables so a model was developed for each of the three dock selection methods examined. We next determined the required number of replications, by running fifty replications each of the three models with worst-case values assigned to each variable. Standard error plots, as shown in Figure 3-3, indicated that 25 replications per scenario would be sufficient.

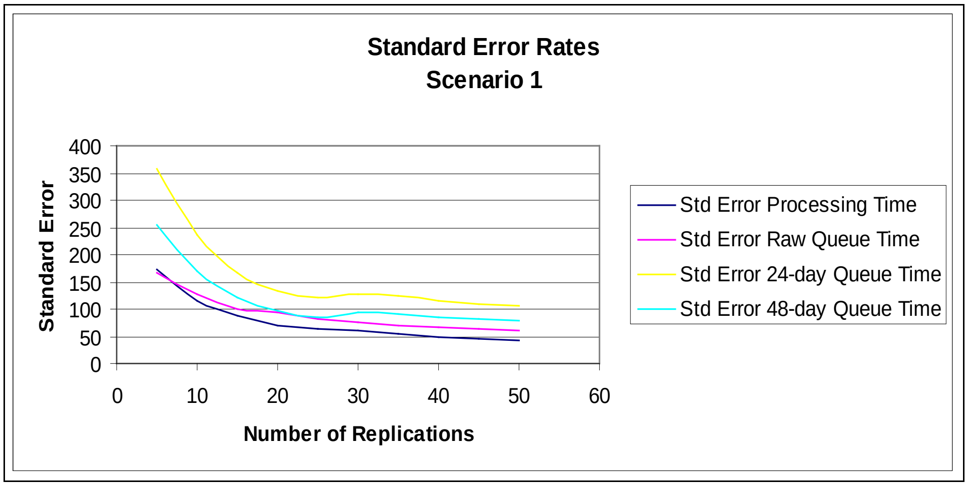


Figure 3-3. Standard Error vs Number of Replications.

4. Results

Regression models used mode values and dock consolidation delays as main effect quantitative predictors. Since the dock selection methods consisted of three classifications, two qualitative variables were necessary (Kutner et al., 2005). Methods were used as predictors with created qualitative predictors named Agile and Leagile. Table 3-6 depicts the values assigned to these variables.

Table 3-6. Assigned Values for Qualitative Variables.

Dock Selection	Agile Variable	Leagile Variable
Lean	0	0
Agile	1	0
Leagile	0	1

Our first regression model for cumulative processing time attained an adjusted R^2 of 0.982 using 22 main effect and interaction variables. See Appendix 3-1 for initial variables considered. We then reduced this model to the four variables (shown in Table 3-7) possessing the highest beta estimates to prevent multicollinearity and overfitting. A final regression analysis of this parsimonious model predicted cumulative processing time with an adjusted R^2 of 0.974.

Table 3-7. Parameter Estimates for Processed Time.

Term	**Beta Estimate**	**Prob>|t|**
Intercept	105,934	0.0000
ISO Inspection Time	978.91	0.0000
ISO Dock consolidation Delay	2120.73	0.0000
Agile	1618.65	<.0001
(Inspection Time-24)*(Agile-0.33333)	357.79	<.0001

Our second model's response variables—cumulative queue time—proved to be a nonlinear function of the predictive variables. To mitigate this, we first computed a natural logarithm of the response, and generated a model using 10 main effect and interaction variables. This regression analysis predicted Queue Time with an adjusted R^2 of 0.98 using these variables. See Appendix 3-1 for initial variables considered. Despite the logarithmic transformation for cumulative queue time, the initial model still had normality problems. A Box-Cox transformation helped correct this (Kutner et a., 2005). See Appendix 3-2 for the complete transformation. The final regression analysis of the parsimonious model using five variables listed in Table 3-8 predicted transformed cumulative Queue Time with an adjusted R^2 of 0.951.

Similar approaches produced good results for both the Queue Time-24 and Queue Time-48 regressions. See Appendix 3-1 for variables considered and Appendix 3-2 for complete transformation used. Regression model attained an adjusted R^2 of 0.980 using nine variables. We then reduced the model to the five variables (shown in Table 3-9) possessing the highest beta estimates. The final Queue Time-24 regression model chosen predicted the 5% overfly rule transformed queue time with an adjusted R^2 of 0.962.

Our final model for Queue Time-48 attained an adjusted R^2 of 0.982 using six main effect or interaction variables and a Box-Cox transformation. See Appendix 3-1 for initial variables considered and Appendix 3-2 for complete transformation used. We then reduced the model to the four variables (shown in Table 3-10) possessing the highest beta estimates to prevent multicollinearity and overfitting. The final Queue Time-48 regression model chosen predicted the 10% overfly rule transformed queue time with an adjusted R^2 of 0.964.

Table 3-8. Parameter Estimates for Parsimonious Model Queue.

Term	Estimate	Prob>|t|
Intercept	98.533	<.0001
Inspection Completion Time	0.239	0.0000
Dock Consolidation Delay	0.581	<.0001
Agile	-0.597	<.0001
Leagile	-0.321	<.0001
(Dock Consolidation Delay-4)*(Agile-0.33333)	-0.127	0.0012

Table 3-9. Parameter Estimates for Parsimonious Model Queue-24.

Term	Estimate	Prob>|t|
Intercept	-6.414	<.0001
Inspection Completion Time	0.361	0.0000
Dock Consolidation Delay	0.991	<.0001
Agile	-1.119	<.0001
Leagile	-0.403	<.0001
(Dock Consolidation Delay-4)*(Agile-0.33333)	-0.0973	0.0012

Table 3-10. Parameter Estimates for Parsimonious Model Queue-48.

Term	Estimate	Prob>|t|
Intercept	-9.981	0.0000
Inspection Completion Time	0.436	0.0000
Dock Consolidation Delay	1.304	0.0000
Leagile	-0.413	<.0001
Agile	-1.478	<.0001

5. Conclusions

Consolidation delays had the strongest influence on cumulative processing time since this factor had the highest observed coefficient estimate for the associated regression models. Permitting major and minor inspections to be performed at any HVRISO using Agile dock selection methods also has a stronger influence on total processing times than the mode value for inspection times. While the beta coefficient estimate for inspection time was lower, this factor was included in the only interaction along with Agile dock selection. If the inspection time mode is 24 days or if Agile dock selection is not used, this interaction is negated. The positive coefficient for the included interaction indicates that Agile dock selection methods will result in higher processing times. Figure 3-4 shows the results of cumulative processing time by scenario.

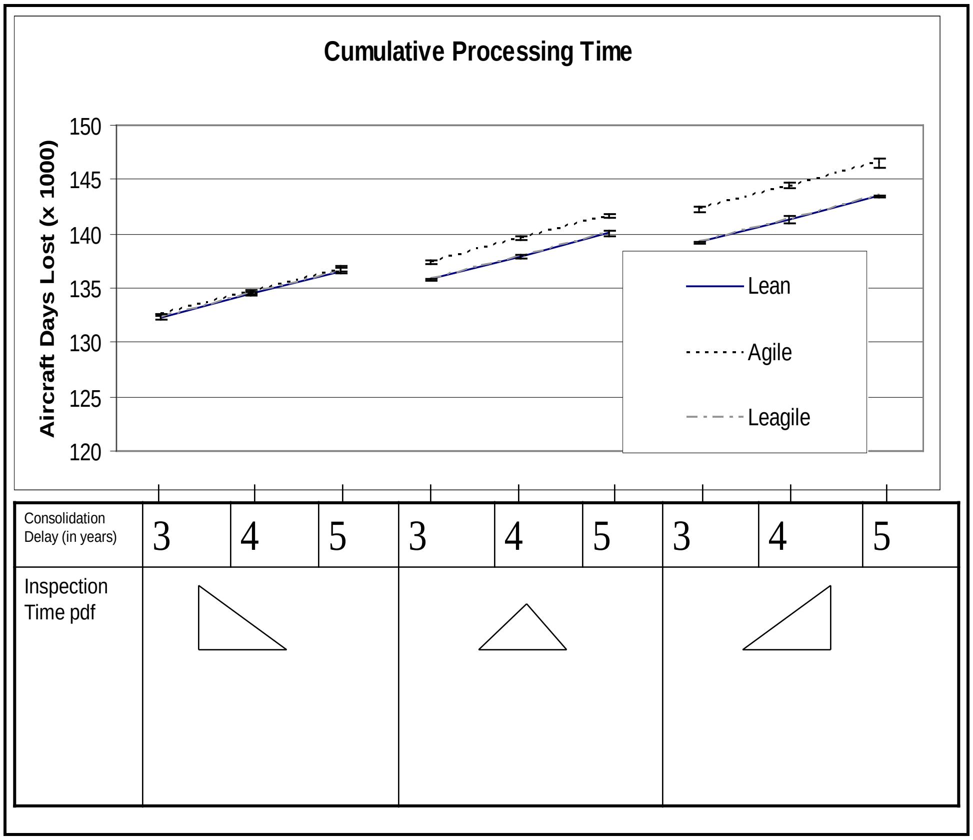


Figure 3-4. Cumulative Processing Time by Scenario.

Cumulative queue time was strongly influenced by both inspection times and dock consolidation delays. Not imposing restrictions on which docks can conduct major and/or minor ISOs had a damping effect on queue times as evidenced by negative coefficient values for these variables. The included interaction demonstrates that cumulative queue time can be lowered significantly with Agile dock selection methods if the dock consolidation is postponed past 2013. Figure 3-5 highlights the resulting queue times observed in each scenario. Similar results were observed for Queue-24 prediction expression. This indicates that allowing a 5% overfly will be influenced by the same factors that influence raw queue time.

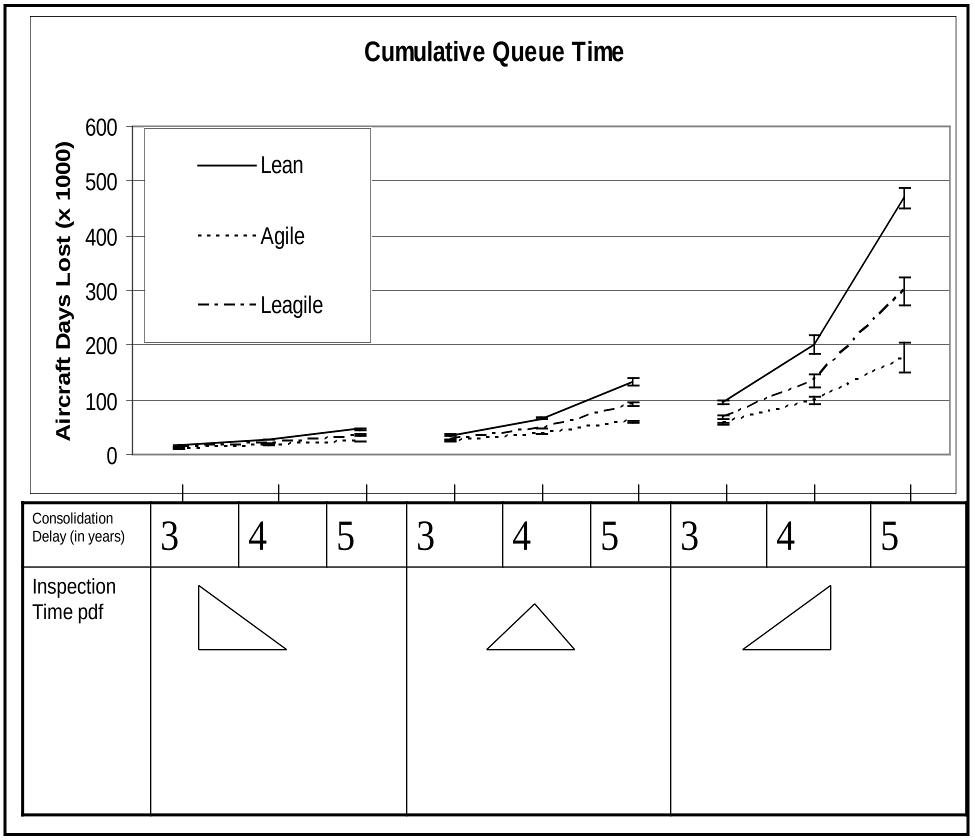


Figure 3-4. Cumulative Queue Time Observed by Scenario.

Cumulative queue time for 10% had no significant interaction variables. As expected, we observed positive correlations for both inspection times and dock consolidation delays with Queue-48 times. Negative correlations were observed for variables denoting Agile and Leagile. This means that applying best-fit selection for all inspections or even for just minors can reduce cumulative queue time.

Agile dock selection methods should not be used if dock consolidation is completed before the year 2013 and if inspection time distributions are right skewed. In these scenarios, Lean dock selection methods or Leagile dock selection methods should be used to keep dock processing times as low as possible. Also, Leagile dock selection methods can reduce queue times without significantly influencing cumulative processing times. However, Agile dock selection methods can significantly reduce queue time if the dock consolidation is delayed and inspection time distributions are left skewed. Figure 3-6 illustrates how processing and queue time can affect availability under these conditions.

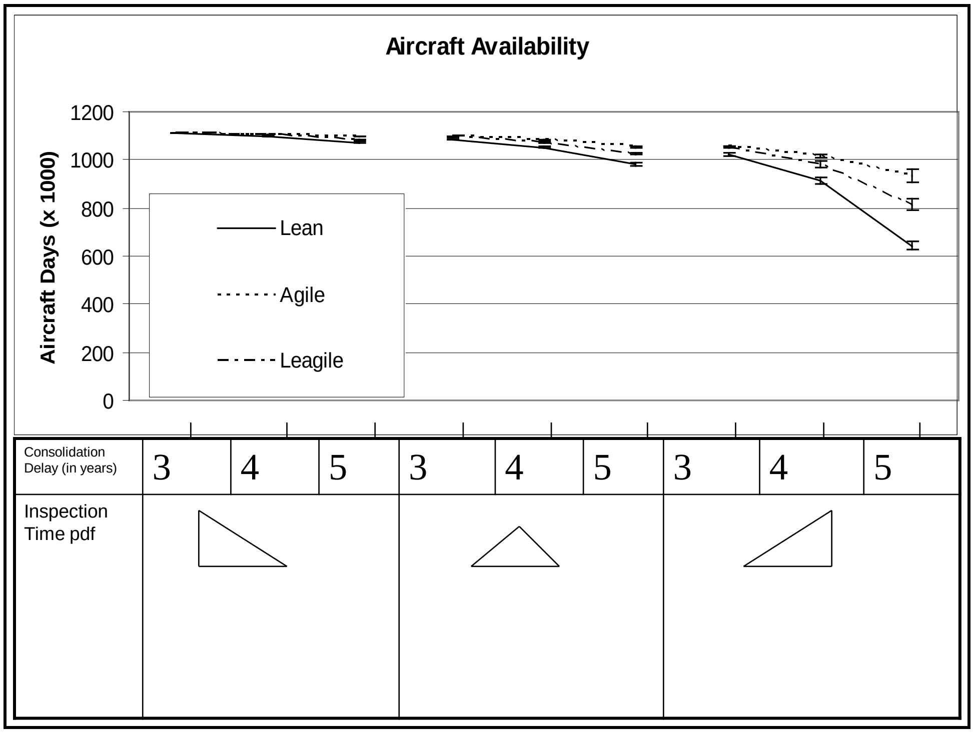


Figure 3-5. Aircraft Availability by Scenario.

AMC should concentrate on completing the dock consolidation to three HVRISOs before 2013. Osborn (2007) observed that 277 lost aircraft-days represent a loss of capability to move up to 10,000 pallets. Since delaying a dock consolidation until 2014 could represent a loss of as much as 400,000 aircraft-days, this could translate to an airlift capability loss as much as 14.5 million pallets during the projected remaining C-5 lifecycle.

If inspection times are usually below the takt time resulting in a right- skewed distribution, then Dover should be tasked to complete all major inspections and remaining docks should complete all minor inspections according to best fit. However, if inspection time distributions are left skewed, then all HVRISOs should be tasked to complete either major or minor inspections with remaining minor inspections scheduled at available legacy docks according to best fit. While this type of dock selection will affect processing time, this method will greatly reduce resulting queue time and would be a sensible trade-off. However, it should be noted that this recommendation does not consider any potential for relationships: If dock selection does influence inspection times, then this must also be taken into account before selecting dock selection methods.

Guard and Reserve units face serious challenges in beginning HVRISO operations in the immediate future. Delays in dock consolidation suggest postponement of Stewart and Lackland dock closures may be necessary after completing this consolidation. While AMC immediately shutdown its spare dock once the Dover HVRISO became operational (Osborn, 2007), this may not be the most suitable approach for the Guard and Reserves to take in standing up their HVRISOs.

Limitations of this study are that inspection times are based solely on estimates and actual dock performance cannot be verified until after the MSG-3 implementation takes effect. The selected ranges include the required takt times so the 20-28 days for majors and the 7-15 days required in HVRISO for minors were selected to “stress” the proposed system so recommendations really only apply to this range of values. Our study ignored any potential effects of converting C-5B and C models to C-5M models. As 49 additional C-5s are converted to M models over the next decade, this may also have an additional effect on the work flow through the limited number of docks.

Future research should consider the appropriate supply chain management strategies based on which dock selection method is most appropriate for the future system. Dock selection favoring a more Agile approach would require HVRISO docks to perform both minors and majors. This approach would require more versatile supply chains. Once the MSG-3 implementation is completed in 2009, more realistic data for dock performance levels will be available. This data can be used in replication studies to more accurately predict which dock selection methods are most appropriate and measure how the dock consolidation timeframe actually affects aircraft availability. Additional research could consider how long two legacy docks slated for eventual shutdown should remain open after the two additional HVRISOs begin operations. Finally, future studies could determine what impact on preventative inspections is realized by converting a portion of the fleet to C-5M models.

Appendix 3-1

Initial Variables Considered for Cumulative Processing Time

Term	**Estimate**	**Prob>|t|**
Intercept	103906.88	0.0000
Inspection Time	1038.9577	0.0000
Dock consolidation Delay	2279.4477	0.0000
Agile	1448.7912	<.0001
Leagile	124.22738	0.1293
(Inspection Time-24)*(Inspection Time-24)	0.055	0.9828
(Inspection Time-24)*(Dock consolidation Delay-4)	62.31	<.0001
(Inspection Time-24)*(Leagile-0.33333)	199.90	<.0001
(Dock consolidation Delay-4)*(Dock consolidation Delay-4)	-51.0035	0.2128
(Dock consolidation Delay-4)*(Agile-0.33333)	188	0.06
(Dock consolidation Delay-4)*(Leagile-0.33333)	361	<.0003
(Inspection Time-24)*(Inspection Time-24)*(Dock consolidation Delay-4)	-14.87	<.0001
(Inspection Time-24)*(Inspection Time-24)*(No Major Restrictions-0.33333)	22.74	0.0001
(Inspection Time-24)*(Inspection Time-24)*(Leagile-0.33333)	-2.3	0.0485
(Dock consolidation Delay-4)*(Dock consolidation Delay-4)*(Inspection Time-24)	-45.3	<.0001
(Dock consolidation Delay-4)*(Dock consolidation Delay-4)*(Agile-0.33333)	-107.89	0.1562
(Dock consolidation Delay-4)*(Dock consolidation Delay-4)*(Leagile-0.33333)	-45.87	0.1818
(Inspection Time-24)*(Dock consolidation Delay-4)*(Agile-0.33333)	14.22	0.3321
(Inspection Time-24)*(Dock consolidation Delay-4)*(Leagile-0.33333)	72.83	0.0874
(Inspection Time-24)*(Dock consolidation Delay-4)*(Agile-0.33333)*(Inspection Time-24)	-204.02	0.3132
(Inspection Time-24)*(Dock consolidation Delay-4)*(No Minor Restrictions-0.33333)*(Inspection Time-24)	-33.02	0.0091
(Inspection Time-24)*(Dock consolidation Delay-4)*(Leagile-0.33333)*(Dock consolidation Delay-4)	-54.77	<.0901
(Inspection Time-24)*(Agile-0.33333)	424.52506	<.0001

Initial Variables Considered for Cumulative Queue Time

Term	**Beta Estimate**	**Prob>|t|**
Intercept	98.441866	0.0000
Inspection Time	0.2395558	0.0000
Dock consolidation Delay	0.581078	0.0000
Agile	-0.597231	<.0001
Leagile	-0.321094	<.0001
(Inspection Time-24)*(Dock consolidation Delay-4)	0.0433787	<.0001
(Dock consolidation Delay-4)*(Agile-0.33333)	-0.126964	<.0001
(Inspection Time-24)*(Agile-0.33333)	-0.061764	<.0001
(Inspection Time-24)*(Leagile-0.33333)	-0.010703	0.0066
(Inspection Time-24)*(Inspection Time-24)	0.0085071	<.0001
(Dock consolidation Delay-4)*(Agile-0.33333)*(Inspection Time-24)	0.0385115	<.0001

Initial Variables Considered for Cumulative Queue Time-24

Term	**Beta Estimate**	**Prob>|t|**
Intercept	-6.509521	0.0000
Inspection Time	0.361206	0.0000
Dock consolidation Delay	0.9908956	0.0000
Agile	-1.119288	<.0001
Leagile	-0.403206	<.0001
(Dock consolidation Delay-4)*(Inspection Time-24)	0.0601085	<.0001
(Inspection Time-24)*(Agile-0.33333)	-0.052842	<.0001
(Dock consolidation Delay-4)*(Leagile-0.33333)	0.228855	<.0001
(Inspection Time-24)*(Leagile-0.33333)	-0.027288	<.0001
(Inspection Time-24)*(Inspection Time-24)	0.0089301	<.0001

Initial Variables Considered for Cumulative Queue Time-48

Term	**Estimate**	**Prob>|t|**
Intercept	-9.981018	0.0000
Inspection Time	0.4361463	0.0000
Dock consolidation Delay	1.3038097	0.0000
Leagile	-0.413341	<.0001
(Dock consolidation Delay-4)*(Inspection Time-24)	0.0617119	<.0001
(Inspection Time-24)*(No Minor Restrictions-0.33333)	-0.035393	<.0001
Agile	-1.477998	<.0001

Appendix 3-2

The complete transformation for Queue Time was

$$\text{LogQueueX} = ((\text{Log (Queue Time)})^{-1} - 1) / -0.00854$$

The inverse function for this transformation is

$$\text{Queue Time} = e^{1/ ((-0.00854*\text{LogQueueX}) + 1)}$$

The complete transformation used for Queue Time-24 was

$$\text{LogQueue24X} = (((\text{Log (Queue Time-24)})^{1.8} - 1) / 11.42$$

The inverse function for this transformation is

$$\text{Queue Time-24} = e^{((11.42*\text{LogQueue24X}) + 1)\text{^}(5/9))}$$

The complete transformation used for Queue Time-48 was

$$\text{LogQueue48X} = (((\text{Log (Queue Time-48)})^{2} - 1) / 18.87$$

The inverse function for this transformation is

$$\text{Queue Time-48} = e^{((18.87*\text{LogQueue48X}) + 1)\text{^}(0.5))}$$

IV. Conclusions and Recommendations

Chapter Overview

Research conducted discrete-event simulation using an experimental design to determine the effects of dock consolidation, mode completion times, and dock selection methods. Based on the results observed, significance of this research and recommendations can be offered.

Conclusions and Significance of Research

How quickly the dock consolidation is completed is the most influential factor on cumulative processing and queue time and must be the first priority of AMC. Another adverse result from delaying the planned dock consolidation is that such an approach risks leaving these legacy docks open for months after all three HVRISOs are finally operational. If a target closure date of 1 October 2014 is applied to the Stewart and Lackland docks in the simulation model, then aircraft will backup at these docks because of having too few HVRISOs for an extended period of time. If the HVRISO docks already have high utilization rates and aircraft are backed up at these locations, then it makes little sense to transfer aircraft waiting at the legacy docks to other docks. This is the type of real-world situation that AMC could face. The only sensible decision under these circumstances would be to leave these docks open for an undetermined length of time to help alleviate any backlog.

Dock selection methods will also have an impact on processing and queue time and must be carefully selected. Higher modes for ISO completion along with delays in dock consolidation implies that excessive cumulative queue time can result. Therefore, the best possible selection under these circumstances is to allow any HVRISO to perform major inspections rather than designate just one HVRISO to perform these inspections and also allowing any available dock to perform minor inspections based on best fit. However, this dock selection method can also result in higher processing times and should be avoided if excessive queue time can already be avoided with lower modes for inspection times along with dock consolidation on or before 2013. Under these circumstances, dock selection methods should designate one HVRISO to accomplish only major isochronal inspections. Other docks should accomplish minor isochronal inspections based on best fit since this can reduce any resultant queue time.

Validation Efforts

To validate the models used, a draft report was submitted to experts in the field upon the completion of the first analysis. This draft stated the purpose of the research, the modeling approaches used, the data utilized, results and likely conclusions were provided. We asked each expert for their thoughts. Unfortunately, no response has been received to this point. However, the model was validated in two other ways.

Notes and observations from the visit to Dover were used to validate the model since dock processes were already well known and understood. The second validation was that the performance of the simulation based on when the consolidation milestones were met, the distributions selected, and the dock selection methods used. The results of the experiments were consistent with results obtained from the Process Analyzer tool.

Recommendations for Action

The time required to complete the dock consolidation is the most important factor for both cumulative processing and queue time. Therefore, the following recommendations are made to AMC:

1. Dock consolidation must be completed at the earliest feasible date, but must not be delayed past 2013.
2. Dock selection methods should be selected based on mode values for inspection times.
3. If high mode values are realized, Agile dock selection methods should be used.
4. If low mode values are realized, Leagile dock selection methods should be used.
5. Inspection times do have an effect on both cumulative processing times and queue times, but in the event that high mode values are realized, only drastic reductions will have any significant effect.

Recommendations for Future Research

Future research can take supply chain management strategies into consideration. Having the right parts at the right place and at the right time will affect the availability of replacement parts, but must be carefully balanced against the needs of field-level maintenance. Future research should consider the appropriate supply chain management strategies based on which dock selection method is most appropriate for the future system. Dock selection favoring a more Agile approach would require HVRISO docks to perform both minors and majors. This approach would require more complex supply chains while Lean and Leagile would simplify supply chains.

This simulation study ignored the potential effects of converting to C-5M models. As all C-5A and C models are converted to the M model, this may also affect dock flow time. Preliminary data for M models should be available in the next few years, and may be used to improve this model.

A better understanding of time requirement to MSG-3 inspection criterion should emerge within a year since this initiative is scheduled to begin in October, 2009. As more is understood about the actual performance of consolidated HVRISO docks and the MSG-3 implementation, future studies should consider how to select docks to minimize transit distance if lower flow times are realized. For example, aircraft assigned to Dover if inducted into the HVRISO there would have zero transit distance. This would help to save fuel costs associated with inducting an aircraft into an inspection dock.

A future study to help determine the potential effects of implementing additional HVRISO docks should be conducted if higher flow times are realized. Any HVRISO will require a long-term commitment to developing skill sets in personnel and should be undertaken only if a substantial benefit can be gained.

Once the MSG-3 implementation is completed in 2009, more realistic data for dock performance levels will be available. This data can be utilized in replication studies to more accurately predict which dock selection methods are most appropriate and measure how the dock consolidation timeframe actually affects aircraft availability. Additional research could consider how long two legacy docks slated for eventual shutdown should remain open after the two additional HVRISOs begin operations. Finally, future studies could be conducted to determine the impact on preventative inspections is realized by converting a portion of the fleet to C-5M models. As events of the MSG-3 implementation and the dock consolidation unfold, more refined simulation methodologies using more realistic data can help validate and fine tune the recommendations made by this study.

Summary

This chapter briefly summarized the research and outlined the conclusions of the research, research significance, validation efforts, recommended actions, and other future research areas.

Appendices contain data tables utilized to model the performance of simulation resources. Other appendices contain output data used to generate the regression models that described how the three examined factors affected cumulative processing and queue times. These data are provided with their sources for future researchers who wish to replicate or expand this research. .

Appendix A: Bridge Schedule for C-5 MSG-3 Implementation

Tail Number	MDS	Majcom	Base	MSG-3 Due	Type Inspection
1	*A*	*ANG*	*Martinsburg*	*11/1/2009*	*Major*
2	*A*	*ANG*	*Stewart*	*12/17/2010*	*Minor 960*
3	*A*	*AMC*	*Travis*	*5/5/2010*	*Minor 2400*
4	*A*	*Reserves*	*Lackland*	*1/23/2010*	*Major*
5	*A*	*Reserves*	*Wright-Pat*	*11/1/2010*	*Major*
6	*A*	*AMC*	*Travis*	*12/26/2010*	*Major*
7	*A*	*ANG*	*Martinsburg*	*10/20/2010*	*Minor 2400*
8	*A*	*Reserves*	*Wright-Pat*	*8/26/2010*	*Minor 2400*
9	*A*	*Reserves*	*Lackland*	*1/24/2011*	*PDM*
10	*A*	*Reserves*	*Lackland*	*7/29/2010*	*Minor 960*
11	*A*	*ANG*	*Martinsburg*	*3/1/2011*	*Minor 480*
12	*A*	*Reserves*	*Lackland*	*7/21/2010*	*Minor 1920*
13	*A*	*ANG*	*Stewart*	*2/3/2010*	*Minor 1920*
14	*A*	*ANG*	*Martinsburg*	*12/16/2010*	*Minor 2400*
15	*A*	*ANG*	*Stewart*	*9/15/2010*	*Minor 480*
16	*A*	*ANG*	*Stewart*	*6/12/2010*	*Major*
17	*A*	*Reserves*	*Lackland*	*5/15/2010*	*Major*
18	*A*	*Reserves*	*Wright-Pat*	*1/5/2011*	*Minor 1920*
19	*A*	*Reserves*	*Wright-Pat*	*5/4/2010*	*Minor 960*
20	*A*	*Reserves*	*Lackland*	*10/11/2009*	*Minor 1920*
21	*A*	*Reserves*	*Lackland*	*8/7/2010*	*Major*
22	*A*	*ANG*	*Stewart*	*7/21/2011*	*Minor 480*
23	*A*	*ANG*	*Stewart*	*3/10/2010*	*Minor 960*
24	*A*	*ANG*	*Memphis*	*1/4/2010*	*Minor 480*
25	*A*	*ANG*	*Martinsburg*	*10/20/2009*	*Minor 960*
26	*A*	*ANG*	*Stewart*	*1/15/2010*	*Minor 960*
27	*A*	*Reserves*	*Wright-Pat*	*11/28/2009*	*Major*
28	*A*	*Reserves*	*Lackland*	*4/7/2010*	*Minor 960*
29	*A*	*ANG*	*Stewart*	*3/20/2010*	*Major*
30	*A*	*Reserves*	*Lackland*	*11/20/2010*	*Minor 960*
31	*A*	*ANG*	*Memphis*	*9/1/2010*	*PDM*
32	*A*	*ANG*	*Memphis*	*12/17/2009*	*Minor 960*
33	*A*	*ANG*	*Memphis*	*7/1/2010*	*Minor 960*
34	*A*	*Reserves*	*Wright-Pat*	*9/24/2010*	*Minor 960*
35	*A*	*ANG*	*Stewart*	*9/4/2010*	*Major*
36	*A*	*ANG*	*Martinsburg*	*12/8/2010*	*Minor 1920*
37	*A*	*ANG*	*Stewart*	*3/28/2010*	*Minor 480*
38	*A*	*AMC*	*Dover*	*2/3/2010*	*Minor 480*
39	*A*	*ANG*	*Memphis*	*10/12/2009*	*Minor 480*
40	*A*	*Reserves*	*Lackland*	*4/27/2011*	*Minor 480*
41	*A*	*ANG*	*Martinsburg*	*1/4/2011*	*Minor 480*

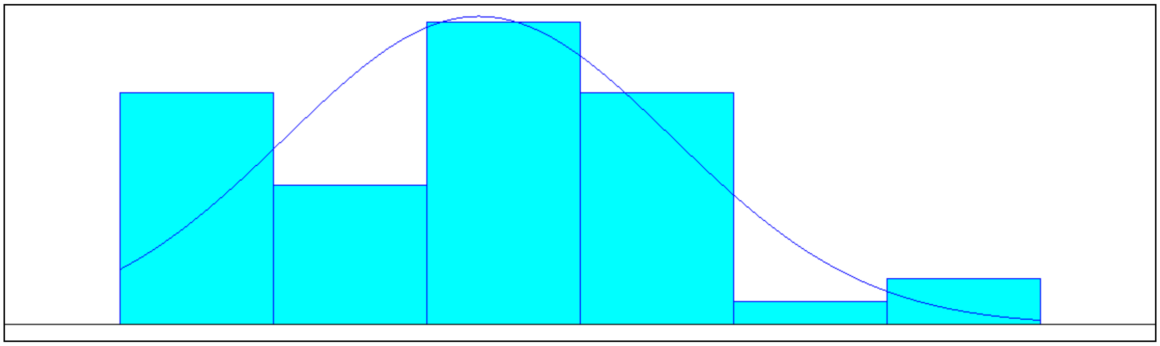
42	*A*	*Reserves*	*Lackland*	*11/10/2009*	*Minor 480*
43	*A*	*Reserves*	*Lackland*	*7/1/2010*	*Minor 2400*
44	*A*	*Reserves*	*Wright-Pat*	*3/11/2010*	*Minor 2400*
45	*A*	*Reserves*	*Wright-Pat*	*5/23/2010*	*Minor 480*
46	*A*	*ANG*	*Memphis*	*7/20/2010*	*Minor 480*
47	*A*	*Reserves*	*Lackland*	*6/21/2011*	*Minor 480*
48	*A*	*ANG*	*Martinsburg*	*11/10/2010*	*Minor 480*
49	*A*	*Reserves*	*Lackland*	*1/16/2010*	*Minor 2400*
50	*A*	*ANG*	*Memphis*	*5/28/2010*	*PDM*
51	*A*	*ANG*	*Stewart*	*1/4/2010*	*PDM*
52	*A*	*Reserves*	*Lackland*	*11/21/2009*	*Minor 2400*
53	*A*	*Reserves*	*Wright-Pat*	*10/4/2010*	*PDM*
54	*A*	*ANG*	*Martinsburg*	*11/29/2010*	*PDM*
55	*A*	*ANG*	*Stewart*	*5/24/2010*	*Minor 1920*
56	*A*	*Reserves*	*Wright-Pat*	*4/10/2010*	*PDM*
57	*A*	*ANG*	*Martinsburg*	*2/21/2010*	*PDM*
58	*A*	*ANG*	*Martinsburg*	*12/6/2009*	*Minor 1920*
59	*A*	*ANG*	*Stewart*	*7/15/2010*	*PDM*
60	*A*	*ANG*	*Memphis*	*3/29/2010*	*Minor 1920*
61	*A*	*Reserves*	*Lackland*	*9/16/2010*	*Minor 1920*
62	*A*	*ANG*	*Memphis*	*10/13/2010*	*Minor 1920*
63	*B*	*AMC*	*Dover*	*6/3/2010*	*Minor 960*
64	*B*	*Reserves*	*Westover*	*1/15/2011*	*Minor 960*
65	*B*	*AMC*	*Dover*	*10/21/2010*	*Minor 960*
66	*B*	*AMC*	*Dover*	*8/27/2010*	*Minor 960*
67	*B*	*AMC*	*Dover*	*3/1/2010*	*Minor 480*
68	*B*	*AMC*	*Dover*	*2/4/2011*	*Minor 480*
69	*B*	*AMC*	*Dover*	*4/26/2010*	*Minor 480*
70	*B*	*AMC*	*Dover*	*12/7/2009*	*Minor 480*
71	*B*	*AMC*	*Dover*	*6/20/2010*	*Minor 480*
72	*B*	*Reserves*	*Westover*	*8/17/2010*	*Minor 480*
73	*B*	*AMC*	*Dover*	*3/29/2011*	*Minor 480*
74	*B*	*AMC*	*Travis*	*10/12/2010*	*Minor 480*
75	*B*	*Reserves*	*Westover*	*12/7/2010*	*Minor 480*
76	*B*	*AMC*	*Travis*	*5/24/2011*	*Minor 480*
77	*B*	*AMC*	*Travis*	*12/11/2009*	*PDM*
78	*B*	*Reserves*	*Westover*	*1/28/2010*	*PDM*
79	*B*	*AMC*	*Dover*	*5/4/2010*	*PDM*
80	*B*	*Reserves*	*Westover*	*6/21/2010*	*PDM*
81	*B*	*AMC*	*Travis*	*3/17/2010*	*PDM*
82	*B*	*AMC*	*Travis*	*11/1/2010*	*PDM*
83	*B*	*AMC*	*Dover*	*9/25/2010*	*PDM*
84	*B*	*Reserves*	*Westover*	*8/8/2010*	*PDM*
85	*B*	*Reserves*	*Westover*	*6/3/2010*	*Minor 2400*
86	*B*	*AMC*	*Dover*	*12/27/2010*	*PDM*

87	*B*	*Reserves*	*Westover*	*4/8/2010*	*Minor 2400*
88	*B*	*AMC*	*Travis*	*12/18/2009*	*Minor 2400*
89	*B*	*Reserves*	*Westover*	*10/21/2009*	*Minor 2400*
90	*B*	*AMC*	*Travis*	*6/21/2010*	*Minor 1920*
91	*B*	*AMC*	*Dover*	*2/13/2010*	*Minor 2400*
92	*B*	*AMC*	*Travis*	*7/28/2010*	*Minor 2400*
93	*B*	*AMC*	*Dover*	*11/11/2010*	*Minor 1920*
94	*B*	*AMC*	*Travis*	*11/19/2010*	*Minor 2400*
95	*B*	*AMC*	*Dover*	*1/14/2011*	*Minor 2400*
96	*B*	*AMC*	*Travis*	*3/1/2010*	*Minor 1920*
97	*B*	*Reserves*	*Westover*	*8/18/2010*	*Minor 1920*
98	*B*	*AMC*	*Travis*	*11/9/2009*	*Minor 1920*
99	*B*	*Reserves*	*Westover*	*4/27/2010*	*Minor 1920*
100	*B*	*AMC*	*Travis*	*9/23/2010*	*Minor 2400*
101	*B*	*AMC*	*Dover*	*10/3/2009*	*Major*
102	*B*	*AMC*	*Travis*	*2/20/2010*	*Major*
103	*B*	*Reserves*	*Westover*	*1/3/2010*	*Minor 1920*
104	*B*	*Reserves*	*Westover*	*12/26/2009*	*Major*
105	*B*	*Reserves*	*Westover*	*4/17/2010*	*Major*
106	*B*	*AMC*	*Travis*	*7/10/2010*	*Major*
107	*B*	*Reserves*	*Westover*	*10/3/2010*	*Major*
108	*B*	*AMC*	*Travis*	*11/28/2010*	*Major*
109	*B*	*Reserves*	*Westover*	*1/23/2011*	*Major*
110	*B*	*AMC*	*Travis*	*11/20/2009*	*Minor 960*
111	*B*	*AMC*	*Dover*	*2/12/2010*	*Minor 960*

Appendix B: Input Analysis for Dover HVRISO Dock

Wash/Depanel	Backline	Fuel Cell
0.75	2.5	4.5
1	4	3
0.75	0.5	2
1.25	3.2	12
0.9	5.8	1.3
1.4	2.5	3.6
0.75	2.55	3.5
1.25	3.2	3.9
1.25	5	3
1.1	10.7	1.4
1.2	6.9	2.1
0.6	3.5	1
1.25	9	2.75
1.6	4.6	2
1	2.2	3
1.1	5.3	2
1	4.1	1
1	4.3	1.75
0.5	9.2	6.8
1.3	5.7	2.75
1.25	2.5	0.7
1	2.8	2.1
1	4.1	3.5
1	2.9	1.6
1	2.95	1.6
1	4.4	0.3
0.8	4.8	1.2
1.7	6.3	1.25
1.1	7.1	1.3
1.8	5	3
0.5	5.8	0.8
0.8	3.6	1.2
0.6	1	8.3
1.3	4.5	1.5
0.6	1	4.5
1.3	1.8	6
0.6	7.3	1.5
0.58	3.16	1.4
0.52	1.25	5
0.6	5	2.4
0.5	11.25	1.5

Wash



Distribution Summary

Distribution: Normal
Expression: NORM(0.982, 0.33)
Square Error: 0.032037

Kolmogorov-Smirnov Test
Test Statistic = 0.114
Corresponding p-value > 0.15

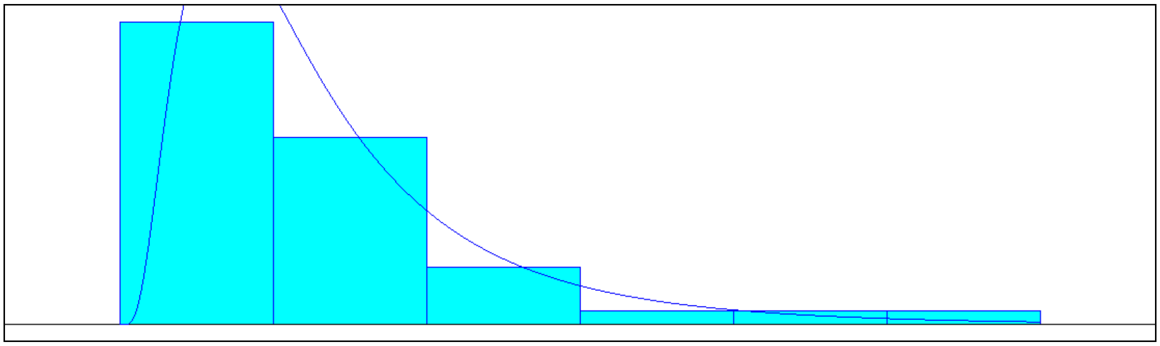
Data Summary

Number of Data Points = 41
Min Data Value = 0.5
Max Data Value = 1.8
Sample Mean = 0.982
Sample Std Dev = 0.334

Histogram Summary

Histogram Range = 0.37 to 1.94
Number of Intervals = 6

Fuel Cell



Distribution Summary

Distribution:	Lognormal
Expression:	LOGN(2.77, 2.23)
Square Error:	0.005538

Kolmogorov-Smirnov Test

Test Statistic = 0.0796

Corresponding p-value > 0.15

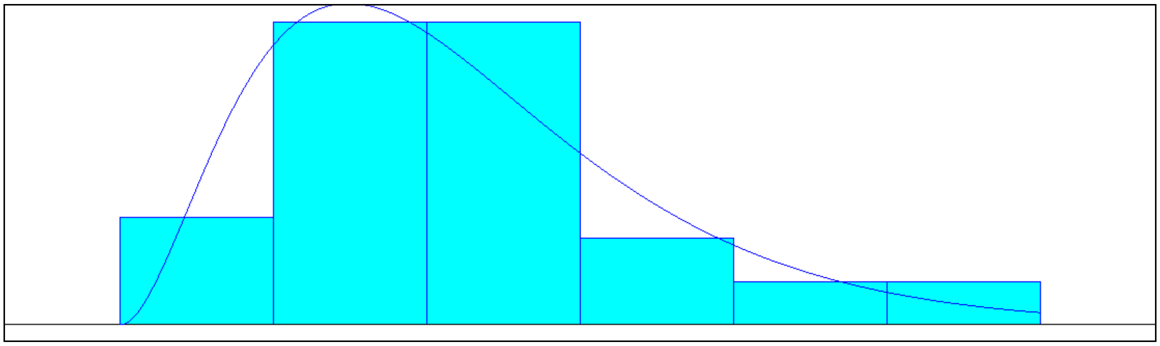
Data Summary

Number of Data Points	= 41
Min Data Value	= 0.3
Max Data Value	= 12
Sample Mean	= 2.78
Sample Std Dev	= 2.26

Histogram Summary

Histogram Range	= 0 to 12
Number of Intervals	= 6

Backline

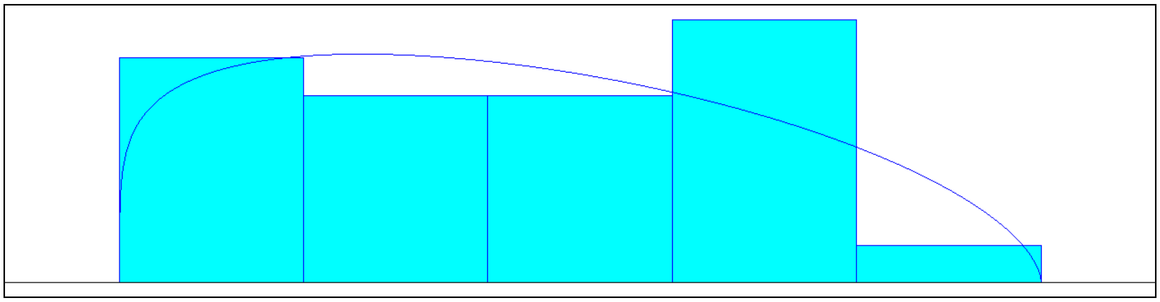


```
Distribution Summary

Distribution:   Erlang
Expression:     ERLA(1.49, 3)
Square Error:   0.009488

Kolmogorov-Smirnov Test
  Test Statistic = 0.0906
  Corresponding p-value         > 0.15

            Data Summary

Number of Data Points           = 41
Min Data Value          = 0.5
Max Data Value          = 11.3
Sample Mean             = 4.47
Sample Std Dev          = 2.51

            Histogram Summary

Histogram Range         = 0 to 12
Number of Intervals     = 6
```

Appendix C: Input Analysis for Westover ISO

Wash	Backline	Fuel Cell
1	18	6
2	11	4
4	11	3
1	12	3
4	28	5
1	14	4
3	6	7
2	15	0
3	15	0
1	8	0
1	20	0
2	5	6
3	6	4
4	16	4
3	9	2
1	5	0
4	121	0
4	16	2
4	9	6
4	15	3
3	14	4
2	9	3
5	11	2
2	18	2

Wash



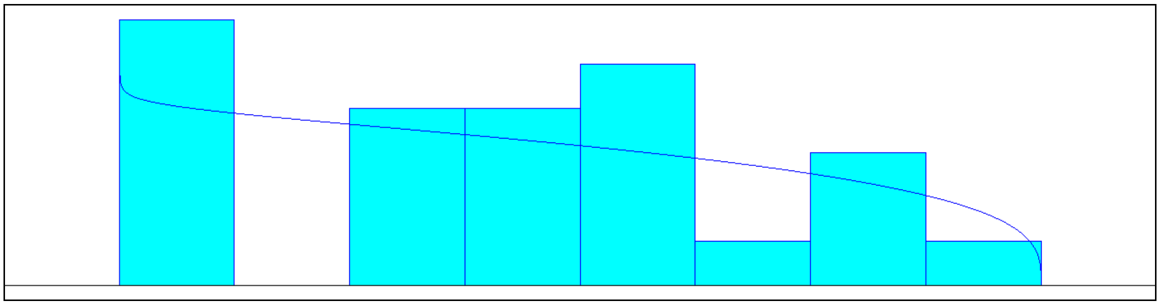
Distribution Summary

Distribution: Beta
Expression: 0.5 + 5 * BETA(1.21, 1.58)
Square Error: 0.017946

D-	D+		Max D
0.100454	0.058788		0.149546
0.058788	0.017121		
0.017121	0.024546		
0.024546	0.066212		
0.066212	0.107879		
0.107879	0.149546		
0.103015	0.061348		
0.061348	0.019681		
0.019681	0.021985		
0.021985	0.063652		
0.063652	0.105319		
0.143437	0.101771		
0.101771	0.060104		
0.060104	0.018437		
0.018437	0.023229		
0.023229	0.064896		
0.14911	0.107443		
0.107443	0.065776		
0.065776	0.02411		
0.02411	0.017557		
0.017557	0.059224		
0.059224	0.10089		
0.10089	0.142557		
0.008206	0.033461		

Critical
Value
$D_{0.10}$
0.2543

Fuel Cell

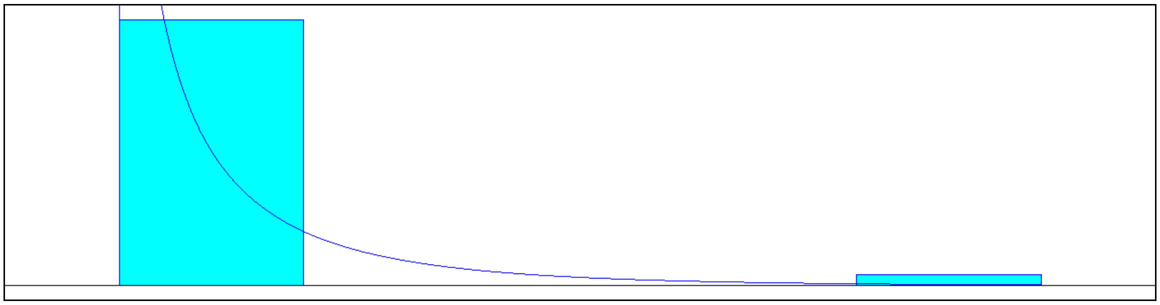


Distribution Summary

Distribution:	Beta
Expression:	-0.5 + 8 * BETA(0.973, 1.31)
Square Error:	0.045485

D-	D+		Max D
0.09119	0.049523		0.22367
0.059068	0.017401		Critical Value $D_{0.10}$
0.027003	0.014664		
0.005008	0.046674		
0.046674	0.088341		0.2543
0.068867	0.110533		
0.009975	0.051642		
0.000695	0.040972		
0.03033	0.071996		
0.061293	0.102959		
0.070472	0.112139		
0.079058	0.120724		
0.075616	0.117283		
0.094266	0.135932		
0.124299	0.165966		
0.136501	0.178168		
0.148116	0.189783		
0.159089	0.200756		
0.182003	0.22367		
0.145714	0.187381		
0.117875	0.159542		
0.130206	0.171873		
0.156797	0.198464		
0.081613	0.12328		

Backline



Distribution Summary

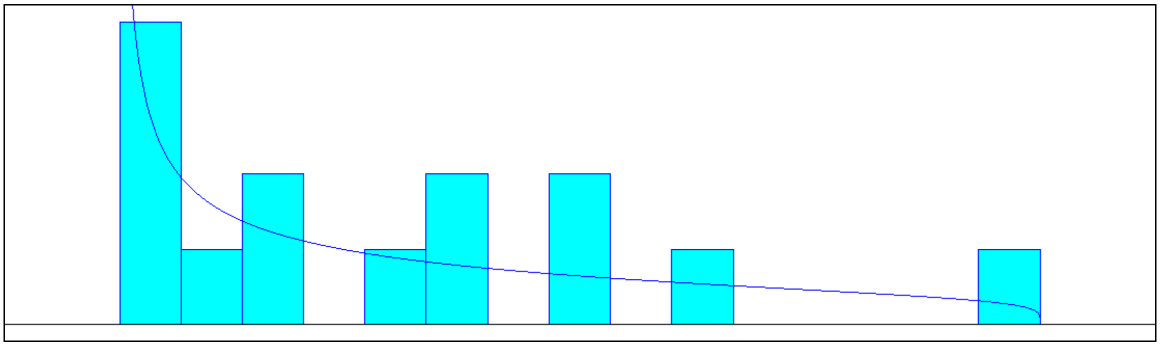
Distribution: Weibull
Expression: 5 + WEIB(9.39, 0.668)
Square Error: 0.027816

Kolmogorov-Smirnov Test
Test Statistic = 0.224
Corresponding p-value > 0.15

Appendix D: Input Analysis for Stewart ISO

AWAITING PRE DOCK	PRE DOCK	FUEL CELL	BACKLINE
2	4	8	20
2	5	14	13
0.35	2	7	8
5	5	11	34
7	6	6	18
1	4	4	34
0.10	4	11	7
0.4	6	17	25
9	5	8	59
5	6	5	49
14	7	3	32
0.12	5	4	39
4	6	5	36
7	7	11	18

Awaiting Predock

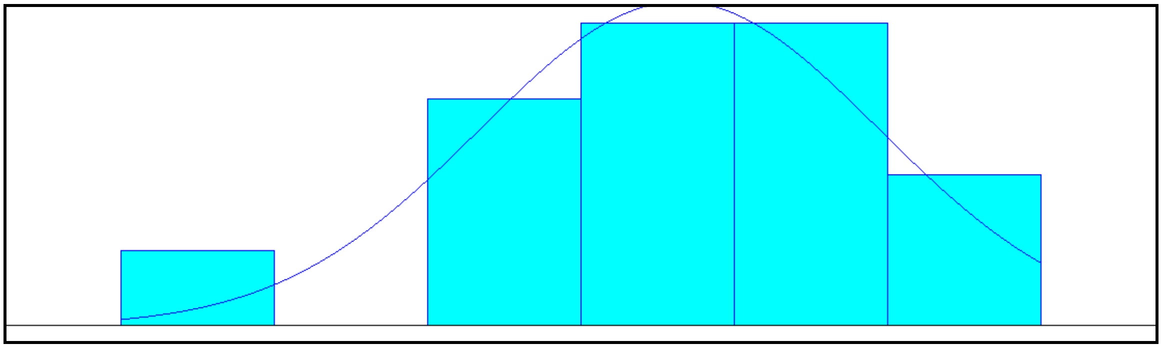


Distribution Summary

Distribution: Beta
Expression: -0.5 + 15 * BETA(0.515, 1.2)
Square Error: 0.039184

D-	D+		Max D
0.212757	0.141339		0.212757
0.144942	0.073513		
0.111417	0.039988		Critical Value $D_{0.10}$
0.047523	0.023906		
0.053911	0.017517		
0.082525	0.011097		0.314
0.011097	0.060332		
0.088912	0.017483		
0.077948	0.00652		
0.00652	0.064909		
0.038351	0.033078		
0.033078	0.104506		
0.018706	0.090135		
0.063244	0.008185		

Predock

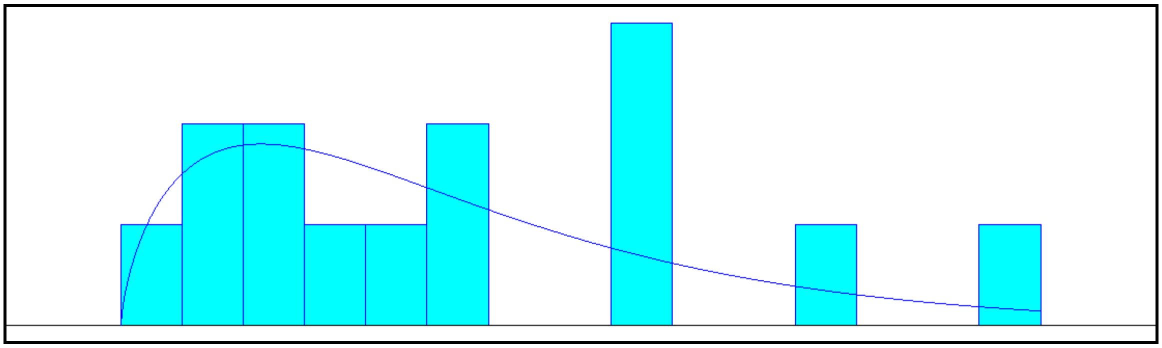


Distribution Summary

Distribution: Normal
Expression: NORM(5.14, 1.3)
Square Error: 0.012407

D-	D+		Max D
0.007849	0.063569		0.174438
0.118836	0.047407		
0.047407	0.024022		Critical Value $D_{0.10}$
0.024022	0.09545		
0.171406	0.099977		
0.099977	0.028548		0.314
0.028548	0.04288		
0.04288	0.114309		
0.174438	0.103009		
0.103009	0.031581		
0.031581	0.039848		
0.039848	0.111276		
0.066609	0.00482		
0.00482	0.076248		

Fuel Cell

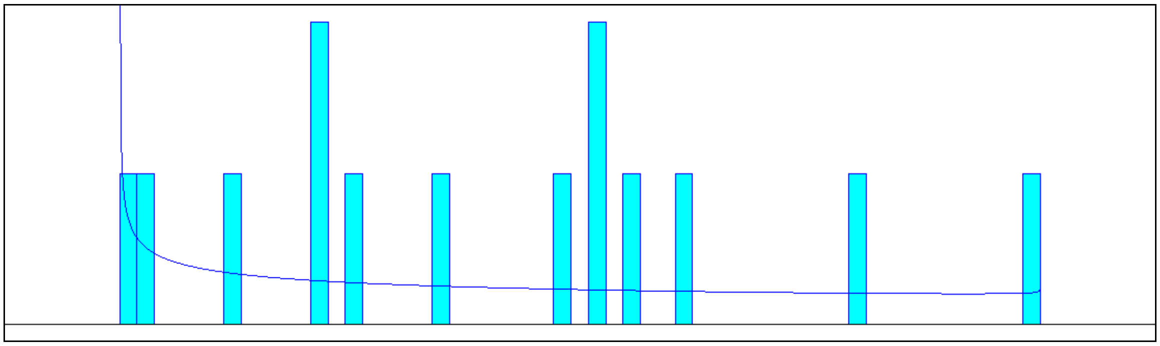


Distribution Summary

Distribution:	Gamma
Expression:	2.5 + GAMM(3.36, 1.68)
Square Error:	0.052386

D-	D+		Max D
0.001403	0.070015		0.226243
0.03516	0.106588		
0.106588	0.178017		Critical Value $D_{0.10}$
0.083386	0.154815		
0.154815	0.226243		
0.090276	0.161705		0.314
0.013391	0.084819		
0.054053	0.017376		
0.017376	0.088804		
0.194015	0.122586		
0.122586	0.051157		
0.051157	0.020271		
0.093428	0.022		
0.0581	0.013328		

Backline



Distribution Summary

Distribution: Beta
Expression: 6.5 + 53 * BETA(0.721, 0.975)
Square Error: 0.069499

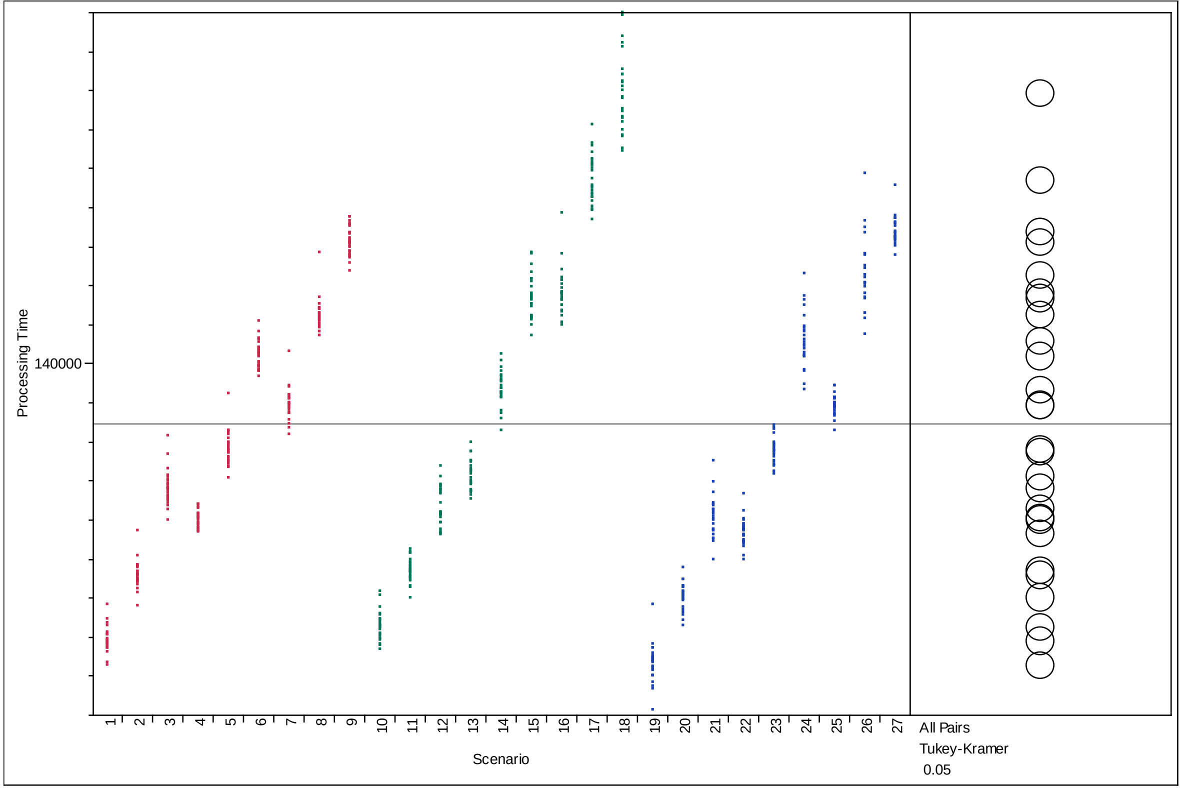
D-	D+		Max D
0.03395	0.037469		0.162697
0.003571	0.067858		
0.073245	0.001816		Critical Value $D_{0.10}$
0.112147	0.040718		
0.040718	0.03071		
0.009467	0.061961		0.314
0.03211	0.039318		
0.081728	0.010299		
0.043216	0.028213		
0.028213	0.099641		
0.067324	0.138752		
0.091268	0.162697		
0.011092	0.082521		
0.063737	0.007691		

Appendix E: Regression Model for Cumulative Processing Times

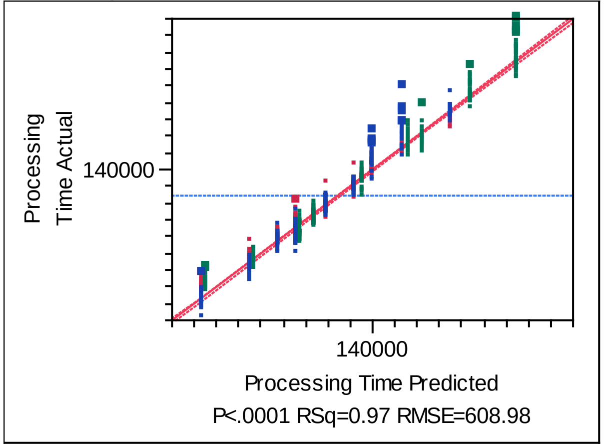
Initial Variables Considered

Term	**Estimate**	**Prob>|t|**
Intercept	103906.88	0.0000
Inspection Time	1038.9577	0.0000
Dock consolidation Delay	2279.4477	0.0000
Agile	1448.7912	<.0001
Leagile	124.22738	0.1293
(Inspection Time-24)*(Inspection Time-24)	0.055	0.9828
(Inspection Time-24)*(Dock consolidation Delay-4)	62.31	<.0001
(Inspection Time-24)*(Leagile-0.33333)	199.90	<.0001
(Dock consolidation Delay-4)*(Dock consolidation Delay-4)	-51.0035	0.2128
(Dock consolidation Delay-4)*(Agile-0.33333)	188	0.06
(Dock consolidation Delay-4)*(Leagile-0.33333)	361	<.0003
(Inspection Time-24)*(Inspection Time-24)*(Dock consolidation Delay-4)	-14.87	<.0001
(Inspection Time-24)*(Inspection Time-24)*(No Major Restrictions-0.33333)	22.74	0.0001
(Inspection Time-24)*(Inspection Time-24)*(Leagile-0.33333)	-2.3	0.0485
(Dock consolidation Delay-4)*(Dock consolidation Delay-4)*(Inspection Time-24)	-45.3	<.0001
(Dock consolidation Delay-4)*(Dock consolidation Delay-4)*(Agile-0.33333)	-107.89	0.1562
(Dock consolidation Delay-4)*(Dock consolidation Delay-4)*(Leagile-0.33333)	-45.87	0.1818
(Inspection Time-24)*(Dock consolidation Delay-4)*(Agile-0.33333)	14.22	0.3321
(Inspection Time-24)*(Dock consolidation Delay-4)*(Leagile-0.33333)	72.83	0.0874
(Inspection Time-24)*(Dock consolidation Delay-4)*(Agile-0.33333)*(Inspection Time-24)	-204.02	0.3132
(Inspection Time-24)*(Dock consolidation Delay-4)*(No Minor Restrictions-0.33333)*(Inspection Time-24)	-33.02	0.0091
(Inspection Time-24)*(Dock consolidation Delay-4)*(Leagile-0.33333)*(Dock consolidation Delay-4)	-54.77	<.0901
(Inspection Time-24)*(Agile-0.33333)	424.52506	<.0001

Oneway Analysis of Processing Time By Scenario



Response Processing Time
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.974567
RSquare Adj	0.974415
Root Mean Square Error	608.9848
Mean of Response	138450.6
Observations (or Sum Wgts)	675

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	4	9521333993	2.3803e+9	6418.371
Error	670	248477899	370862.54	**Prob > F**
C. Total	674	9769811892		0.0000

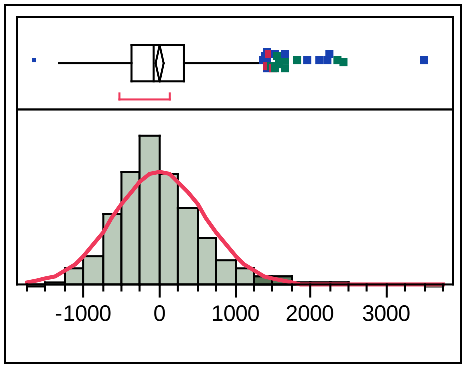
Lack Of Fit

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Lack Of Fit	13	61128363	4702182	16.4897
Pure Error	657	187349536	285159	**Prob > F**
Total Error	670	248477899		<.0001
				Max RSq
				0.9808

Parameter Estimates

Term	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	105934.06	208.9961	506.87	0.0000
Inspection Time	978.91853	7.176955	136.40	0.0000
Dock consolidation Delay	2120.7311	28.70782	73.87	<.0001
Agile	1618.6599	49.7234	32.55	<.0001
(Inspection Time-24)*(Agile-0.33333)	357.79095	15.22462	23.50	<.0001

Distributions
Residual Processing Time



Normal(2.6e-11,607.175)

Quantiles

100.0%	maximum	3513
99.5%		2332
97.5%		1490
90.0%		718
75.0%	quartile	312
50.0%	median	-73
25.0%	quartile	-375
10.0%		-686
2.5%		-1059
0.5%		-1254
0.0%	minimum	-1655

Moments

Mean	2.587e-11
Std Dev	607.17507
Std Err Mean	23.37018
upper 95% Mean	45.887111
lower 95% Mean	-45.88711

N	675

Fitted Normal

Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	2.587e-11	-45.88711	45.887111
Dispersion	σ	607.17507	576.4224	641.42009

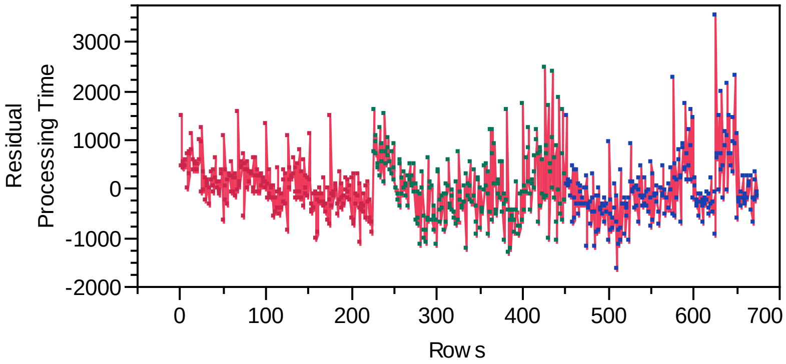
Goodness-of-Fit Test

Shapiro-Wilk W Test

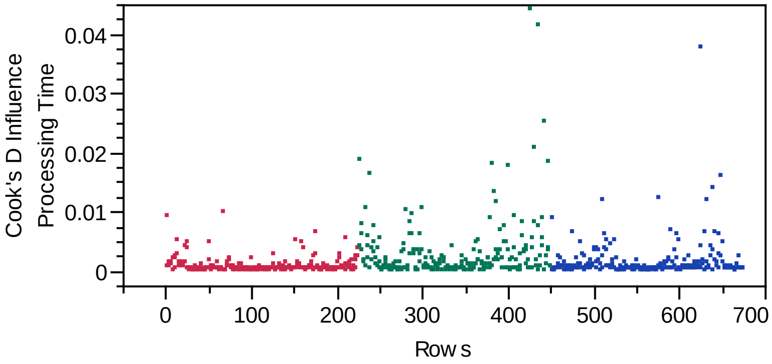
W	Prob<W
0.952165	<.0001

Note: Ho = The data is from the Normal distribution. Small p-values reject Ho.

Runs Plot



Cooks-D Plot



Appendix F: Regression Model for Cumulative Queuing Time

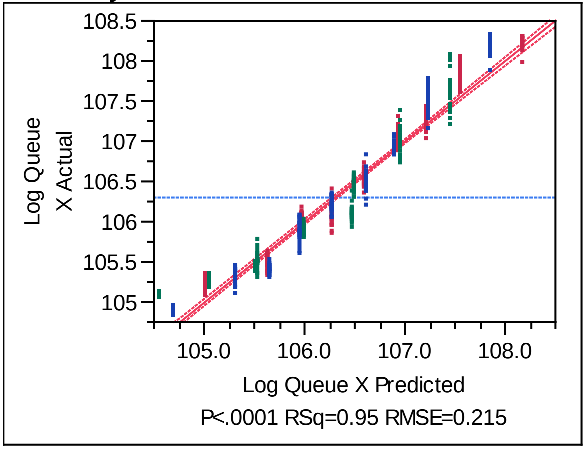
Initial Variables Considered

Term	**Beta Estimate**	**Prob>|t|**
Intercept	98.441866	0.0000
Inspection Time	0.2395558	0.0000
Dock consolidation Delay	0.581078	0.0000
Agile	-0.597231	<.0001
Leagile	-0.321094	<.0001
(Inspection Time-24)*(Dock consolidation Delay-4)	0.0433787	<.0001
(Dock consolidation Delay-4)*(Agile-0.33333)	-0.126964	<.0001
(Inspection Time-24)*(Agile-0.33333)	-0.061764	<.0001
(Inspection Time-24)*(Leagile-0.33333)	-0.010703	0.0066
(Inspection Time-24)*(Inspection Time-24)	0.0085071	<.0001
(Dock consolidation Delay-4)*(Agile-0.33333)*(Inspection Time-24)	0.0385115	<.0001

Parsimonious Model

QueueX

Response Log Queue X
Actual by Predicted Plot



Summary of Fit

RSquare	0.951512
RSquare Adj	0.95115
Root Mean Square Error	0.215016
Mean of Response	106.3002
Observations (or Sum Wgts)	675

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	5	606.94441	121.389	2625.648
Error	669	30.92919	0.046	**Prob > F**
C. Total	674	637.87360		0.0000

Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	21	24.126392	1.14888	109.4361
Pure Error	648	6.802799	0.01050	**Prob > F**
Total Error	669	30.929190		<.0001
				Max RSq
				0.9893

Parameter Estimates

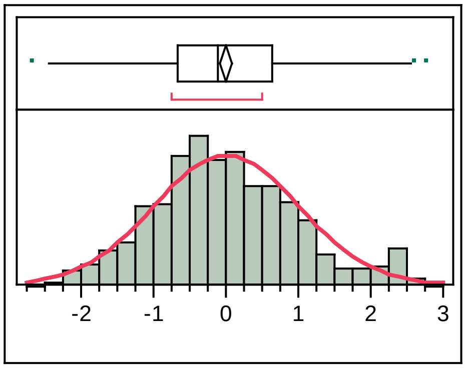
Term	Estimate	Std Error	t Ratio	Prob>|t|	VIF
Intercept	98.532608	0.074484	1322.9	0.0000	.
Inspection Time	0.2395558	0.002534	94.54	0.0000	1
Dock consolidation Delay	0.581078	0.010136	57.33	<.0001	1
Agile	-0.597231	0.020272	-29.46	<.0001	1.3333333
Leagile	-0.321094	0.020272	-15.84	<.0001	1.3333333
(Dock consolidation Delay-4)*(No Major Restrictions-0.33333)	-0.126964	0.021502	-5.90	<.0001	1

Sorted Parameter Estimates

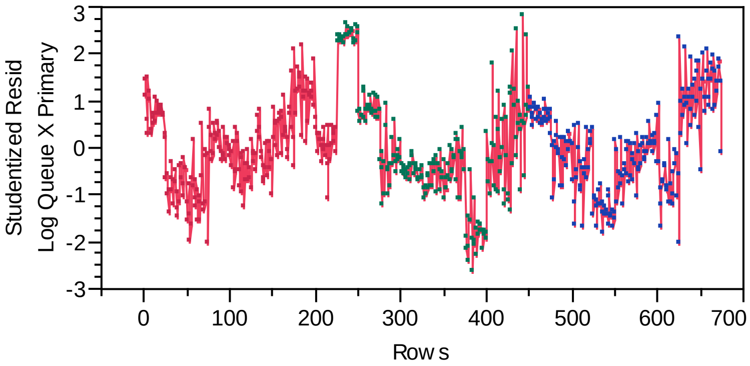
Term	Estimate	Std Error	t Ratio	Prob>|t|
Inspection Time	0.2395558	0.002534	94.54	0.0000
Dock consolidation Delay	0.581078	0.010136	57.33	<.0001
Agile	-0.597231	0.020272	-29.46	<.0001
Leagile	-0.321094	0.020272	-15.84	<.0001
(Dock consolidation Delay-4)*(No Major Restrictions-0.33333)	-0.126964	0.021502	-5.90	<.0001

Distributions

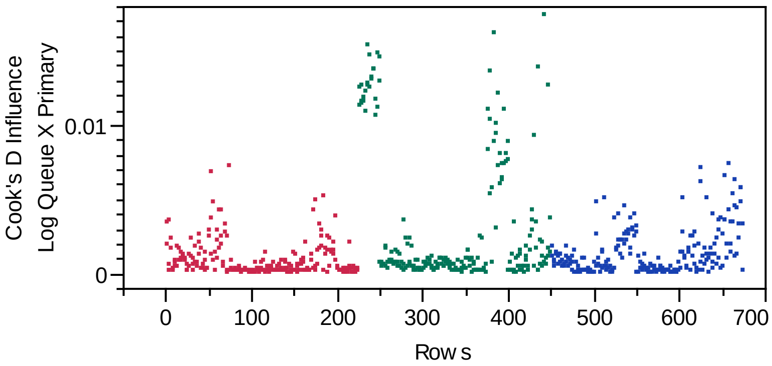
Studentized Resid Log Queue X



Runs Plot



Cooks Distance Plot



QUEUE 24 X

Initial Variable Considered

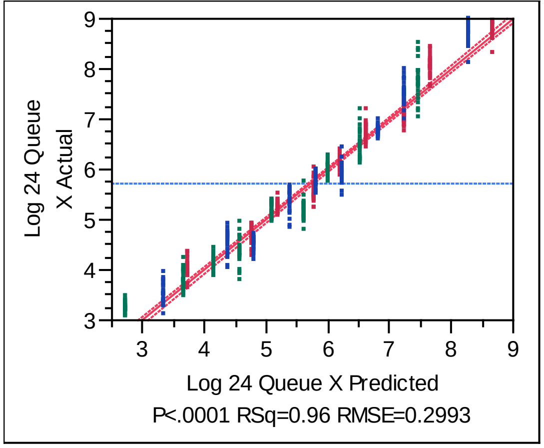
Term	**Estimate**	**Std Error**	**t Ratio**	**Prob>|t|**
Intercept	-6.509521	0.076792	-84.77	0.0000
Inspection Time	0.361206	0.002581	139.96	0.0000
Dock consolidation Delay	0.9908956	0.010323	95.99	0.0000
Agile	-1.119288	0.020647	-54.21	<.0001
Leagile	-0.403206	0.020647	-19.53	<.0001
(Dock consolidation Delay-4)*(Inspection Time-24)	0.0601085	0.003161	19.02	<.0001
(Inspection Time-24)*(Agile-0.33333)	-0.052842	0.006322	-8.36	<.0001
(Dock consolidation Delay-4)*(Leagile-0.33333)	0.228855	0.021899	10.45	<.0001
(Inspection Time-24)*(Leagile-0.33333)	-0.027288	0.006322	-4.32	<.0001
(Inspection Time-24)*(Inspection Time-24)	0.0089301	0.001118	7.99	<.0001

Parsimonious Model

Response Log 24 Queue X

Whole Model

Actual by Predicted Plot



Summary of Fit

RSquare	0.962225
RSquare Adj	0.961942
Root Mean Square Error	0.299324
Mean of Response	5.710763
Observations (or Sum Wgts)	675

Analysis of Variance

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Model	5	1526.7845	305.357	3408.197
Error	669	59.9390	0.090	**Prob > F**
C. Total	674	1586.7235		0.0000

Lack Of Fit

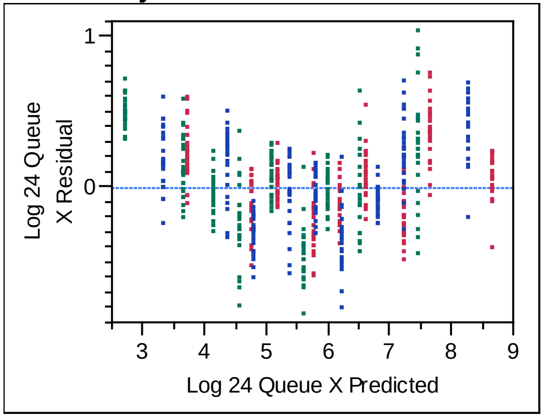
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Ratio**
Lack Of Fit	21	35.776769	1.70366	45.6899
Pure Error	648	24.162182	0.03729	**Prob > F**
Total Error	669	59.938952		<.0001
				Max RSq

Source	DF	Sum of Squares	Mean Square	F Ratio
				0.9848

Parameter Estimates

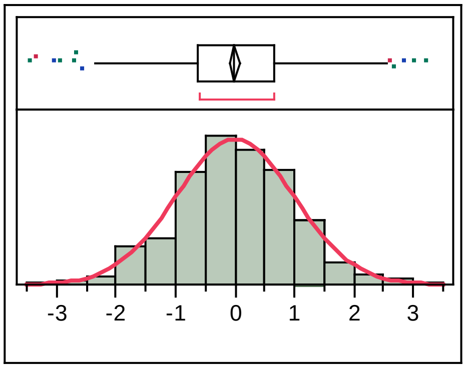
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-6.414266	0.103689	-61.86	<.0001
Inspection Time	0.361206	0.003528	102.40	0.0000
Dock consolidation Delay	0.9908956	0.01411	70.23	<.0001
Agile	-1.119288	0.028221	-39.66	<.0001
Leagile	-0.403206	0.028221	-14.29	<.0001
(Dock consolidation Delay-4)*(Agile-0.33333)	-0.097315	0.029932	-3.25	0.0012

Residual by Predicted Plot



Inspection Time
Leverage Plot

Residuals
Distributions
Studentized Resid Log 24 Queue X



Normal(-0.0004,1.00145)

Quantiles

100.0%	maximum	3.222
99.5%		2.794
97.5%		2.033
90.0%		1.198

75.0%	quartile	0.663
50.0%	median	-0.0071
25.0%	quartile	-0.616
10.0%		-1.294
2.5%		-1.977
0.5%		-3.004
0.0%	minimum	-3.434

Moments

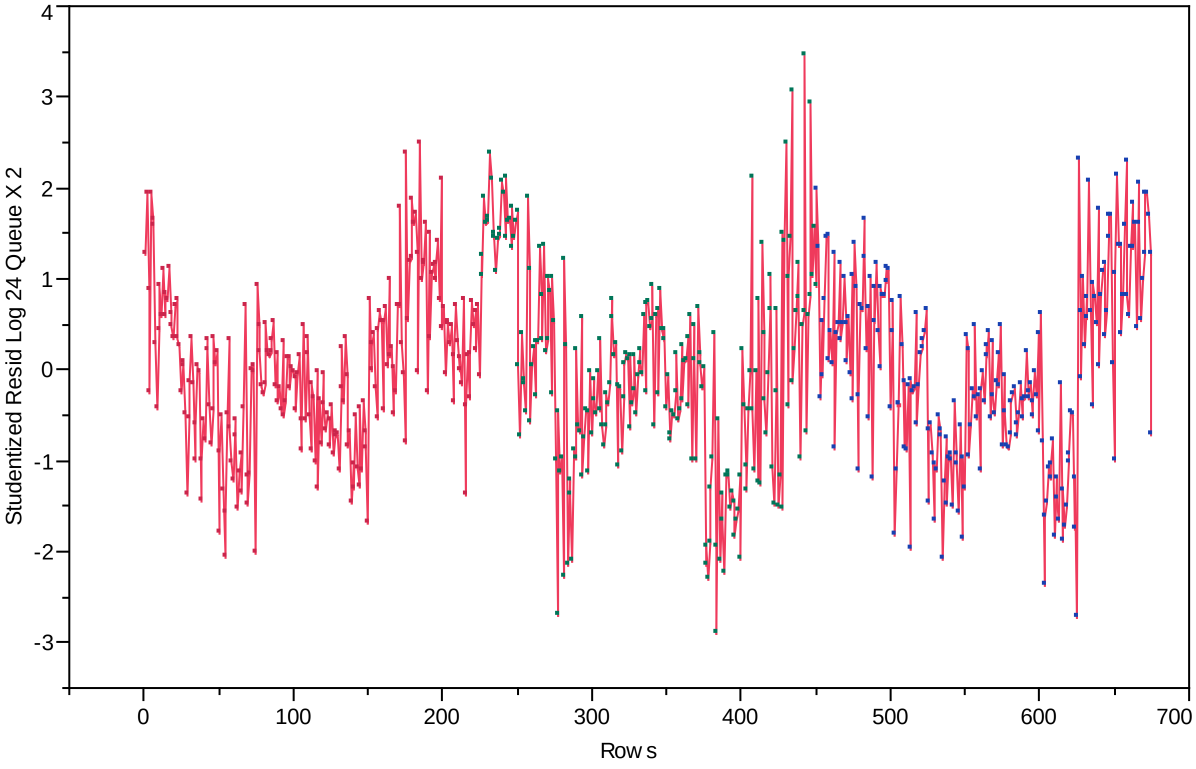
Mean	-0.000417
Std Dev	1.001447
Std Err Mean	0.0385457
upper 95% Mean	0.075267
lower 95% Mean	-0.076101
N	675

Fitted Normal

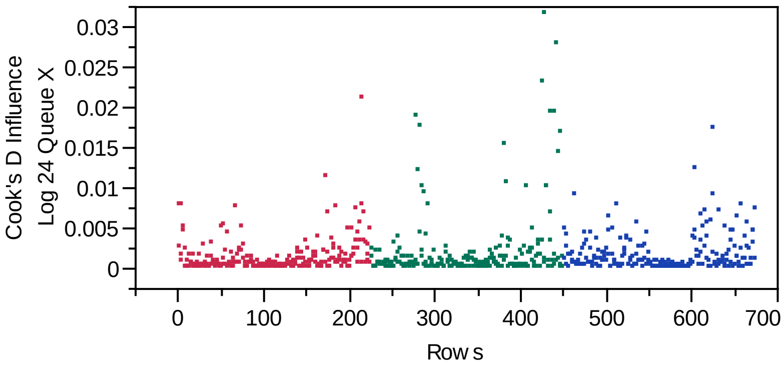
Parameter Estimates

Type	Parameter	Estimate	Lower 95%	Upper 95%
Location	μ	-0.000417	-0.076101	0.075267
Dispersion	σ	1.001447	0.9507249	1.0579292

Runs Overlay Plot



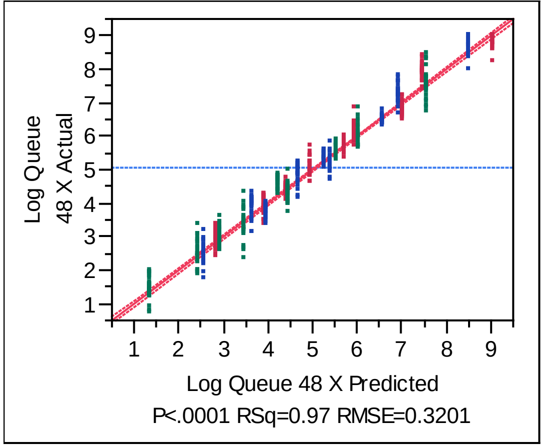
Cooks Distance Overlay Plot



Queue 48X

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-9.981018	0.110871	-90.02	0.0000
Inspection Time	0.4361463	0.003772	115.63	0.0000
Dock consolidation Delay	1.3038097	0.015088	86.42	0.0000
Leagile	-0.413341	0.030175	-13.70	<.0001
(Dock consolidation Delay-4)*(Inspection Time-24)	0.0617119	0.00462	13.36	<.0001
(Inspection Time-24)*(No Minor Restrictions-0.33333)	-0.035393	0.008001	-4.42	<.0001
Agile	-1.477998	0.030175	-48.98	<.0001

Response Log Queue 48 X
Whole Model
Actual by Predicted Plot



Summary of Fit

RSquare	0.972463
RSquare Adj	0.972216
Root Mean Square Error	0.320057
Mean of Response	5.071285
Observations (or Sum Wgts)	675

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	6	2416.5200	402.753	3931.727
Error	668	68.4277	0.102	**Prob > F**
C. Total	674	2484.9477		0.0000

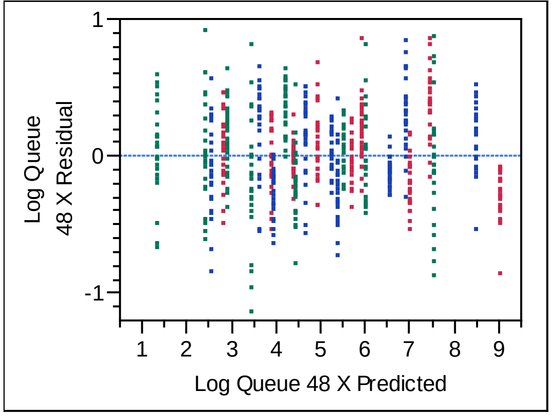
Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	20	21.067867	1.05339	14.4130
Pure Error	648	47.359877	0.07309	**Prob > F**
Total Error	668	68.427744		<.0001
				Max RSq
				0.9809

Parameter Estimates

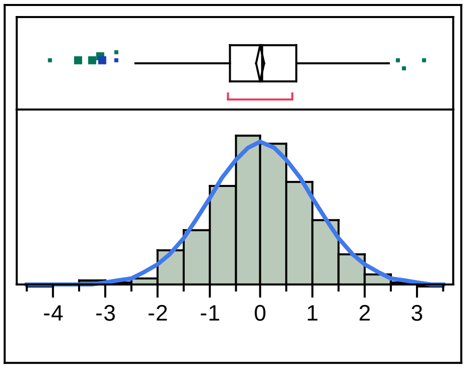
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	-9.981018	0.110871	-90.02	0.0000
Inspection Time	0.4361463	0.003772	115.63	0.0000
Dock consolidation Delay	1.3038097	0.015088	86.42	0.0000
No Minor Restrictions	-0.413341	0.030175	-13.70	<.0001
(Dock consolidation Delay-4)*(Inspection Time-24)	0.0617119	0.00462	13.36	<.0001
(Inspection Time-24)*(No Minor Restrictions-0.33333)	-0.035393	0.008001	-4.42	<.0001
No Major Restrictions	-1.477998	0.030175	-48.98	<.0001

Residual by Predicted Plot

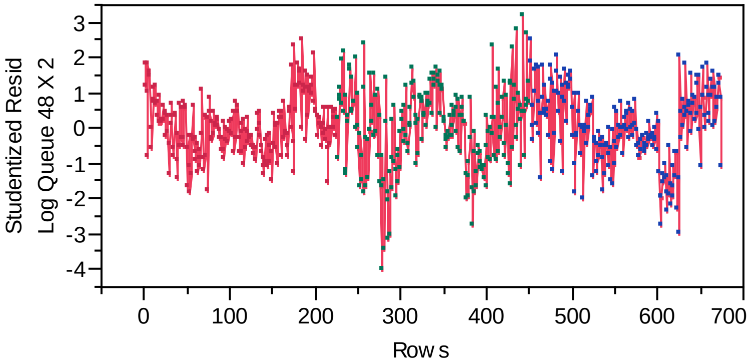


Distributions

Studentized Resid Log Queue 48 X

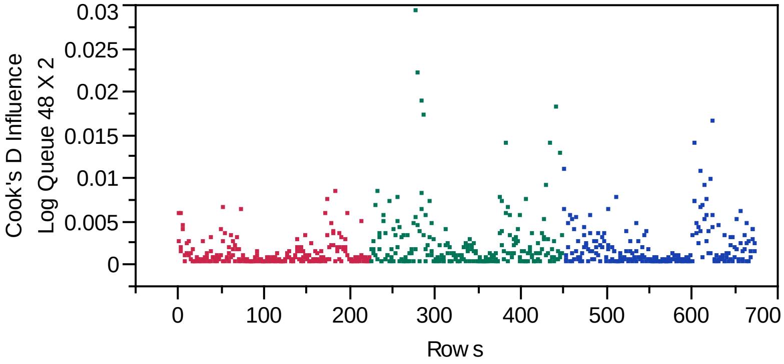


Runs Overlay Plot



Cooks Distance Overlay Plot

Overlay Plot

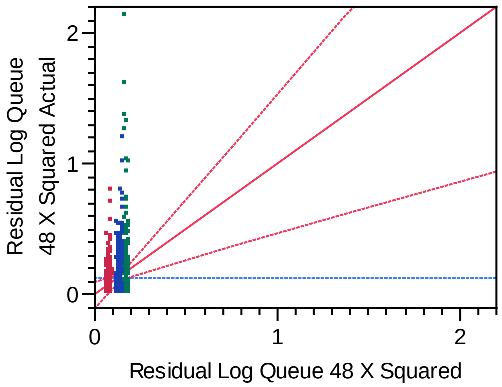


Breusch-Pagan

Response Residual Log Queue 48 X Squared

Whole Model

Actual by Predicted Plot



Predicted P<.0001 RSq=0.04

RMSE=0.2042

Summary of Fit

RSquare	0.036956

RSquare Adj	0.031207
Root Mean Square Error	0.204233
Mean of Response	0.131425
Observations (or Sum Wgts)	675

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	4	1.072435	0.268109	6.4277
Error	670	27.946488	0.041711	**Prob > F**
C. Total	674	29.018923		<.0001

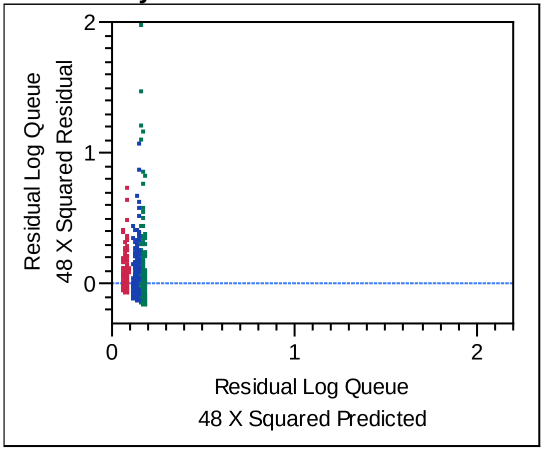
Lack Of Fit

Source	DF	Sum of Squares	Mean Square	F Ratio
Lack Of Fit	22	6.301937	0.286452	8.5759
Pure Error	648	21.644550	0.033402	**Prob > F**
Total Error	670	27.946488		<.0001
				Max RSq
				0.2541

Parameter Estimates

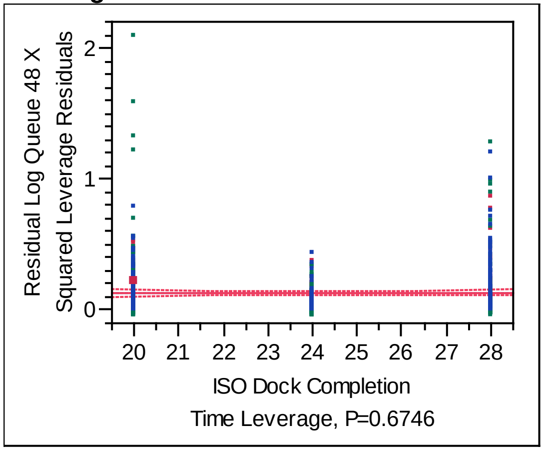
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	0.0859296	0.070748	1.21	0.2250
Inspection Time	0.0010109	0.002407	0.42	0.6746
Dock consolidation Delay	-0.007372	0.009628	-0.77	0.4441
No Minor Restrictions	0.0565062	0.019255	2.93	0.0035
No Major Restrictions	0.0956532	0.019255	4.97	<.0001

Residual by Predicted Plot



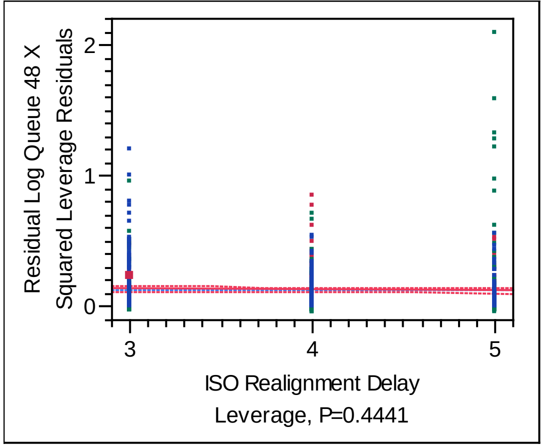
Inspection Time

Leverage Plot



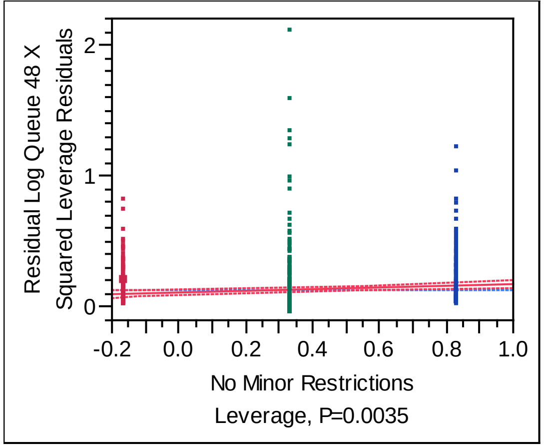
Dock consolidation Delay

Leverage Plot

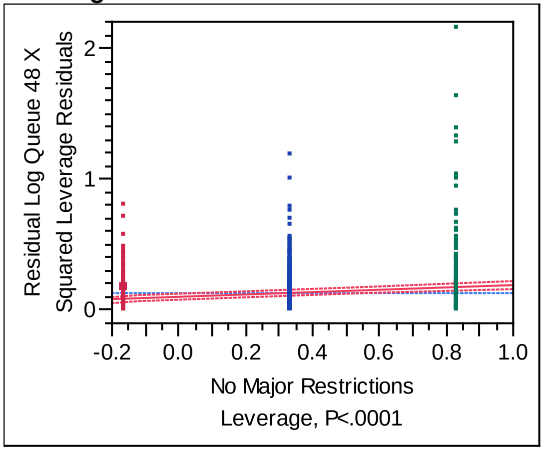


No Minor Restrictions

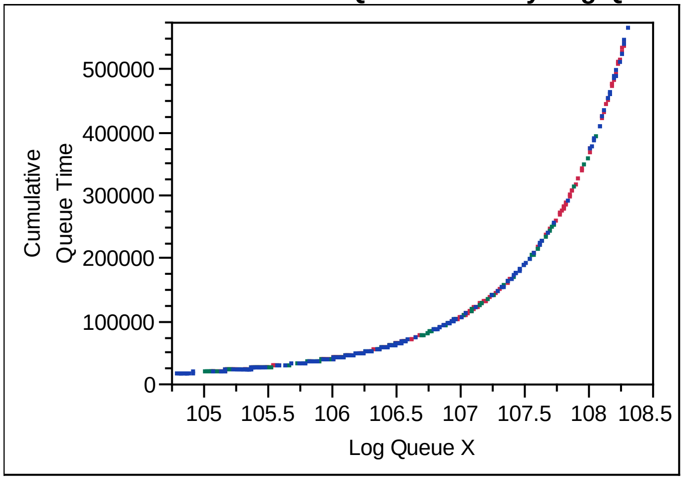
Leverage Plot



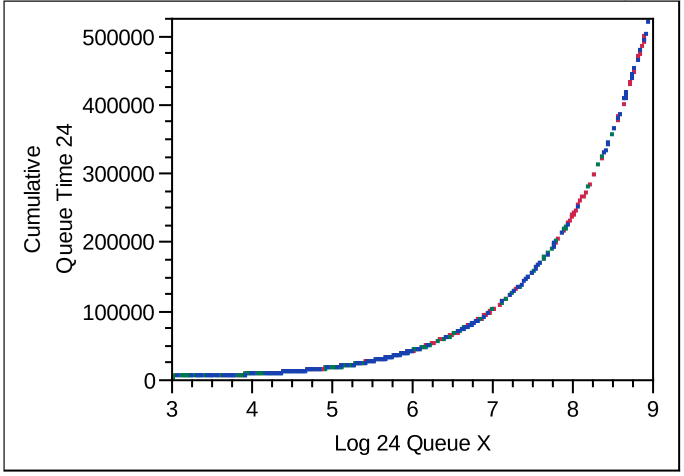
No Major Restrictions
Leverage Plot



Bivariate Fit of Cumulative Queue Time By Log Queue X

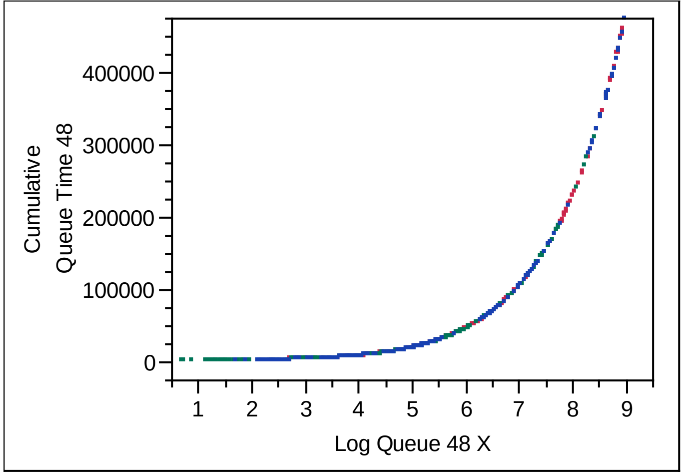


Bivariate Fit of Cumulative Queue Time 24 By Log 24 Queue X



Bivariate Fit of Cumulative Queue Time By Log Queue 48 X

Bivariate Fit of Cumulative Queue Time 48 By Log Queue 48 X



Appendix G. Major and Minor Inspection Takt Times.

Ranges were modified from what was observed. During a 3100-day cycle, an HVRISO dock would be available 2862 days since a dock would be closed for 28 days each year. Since 444 aircraft must be processed for a minor in this time period, this means that a takt time of 6.44 days per minor inspection is the standard. If two docks are performing minors, then each dock must complete a minor inspection every 12.89 days to achieve this takt time. Since the largest observed dock time observed at Dover was 12 days, there would be little point in examining minor inspection performance within these ranges. HVRISO maximum range was extended to 15 days from 12 days to capture the takt time value of 12.89 days.

The major inspection times are based on estimates provided by AMC. Since 111 major isochronal inspections are conducted during the 2862 day cycle, the required takt time based on one HVRISO dock is 25.78 days. This is already included in the stated range for major inspections. The inspection times for minors in legacy docks are based on the observed ranges. For Stewart, the minimum dock time value was 15.5 days and the observed maximum was 41.5 days. For Westover, the minimum dock time value was 15.5 days and the observed maximum was 37.5 days.

Appendix H. Blue Dart.

The C-5 HVRISO: Just Do It!

Aircraft are complex and require periodic full or partial maintenance checks to assess repairs necessary to sustain availability. Such checks are expensive and the associated aircraft downtime can reduce fleet mission effectiveness. Air Mobility Command (AMC) plans to implement practically simultaneous changes to its system of inspection facilities for the C-5 aircraft.

First, AMC will consolidate five inspection sites performing C-5 isochronal inspections into only three. The three new facilities will signify a full adoption of a high-velocity regionalized isochronal (HVRISO) concept for the scheduled maintenance of C-5s. Dover hosts the only C-5 HVRISO currently in operation. Westover and Martinsburg will eventually host additional HVRISOs. Once the three inspection facilities are in place complete the future inspection facilities, traditional docks operating at Stewart and Lackland will then close. By having the same groups of maintenance specialists perform all isochronal inspections and by adopting commercial aircraft condition-based inspection strategies, the Air Force hopes to gain efficiencies in performing these inspections.

Inspections will be conducted under such a strategy utilized within commercial aircraft maintenance since 1980. Maintenance Steering Group-3 (MSG-3) will not only increase the current C-5 inspection intervals, but will apply a more systematic approach to aircraft maintenance and defer much of the heavy maintenance to programmed depot maintenance conducted about every 8 years. By slashing inspection downtime, AMC also hopes to boost aircraft reliability by 20 percent. MSG-3 objectives are to maximize aircraft integrity while minimizing aircraft downtime using reliability-centered maintenance and a systems-based approach favored by commercial aviation. If AMC results are comparable to commercial achievements, MSG-3 will reduce repair times and defer extensive maintenance to PDM inspections. MSG-3 inspection schedules begin during October, 2009.

Bases have traditionally inspected their own aircraft. Since this is no longer possible, previous restrictions may have to be reevaluated. An example of such a restriction would be not allowing Reserve C-5s to be inspected at Guard docks. Proposals to handle dock selections include having one designated dock such as the Dover HVRISO perform all major inspections. In contrast to this, these inspections may be delegated to all the HVRISO docks according to best fit. Minor inspections could be performed only by docks within their owning command or these inspections could be assigned to any available dock according only to best fit criteria.

The reduced number of inspection locations, a new inspection regimen based on MSG-3 criteria, and proposals about dock selection methods raises concerns on whether overall C-5 mission capability may actually be reduced. We simulated these planned revisions in C-5 military aircraft maintenance schedules and locations in a designed experiment to assess the impacts to fleet availability.

Relying on only one HVRISO dock for too long will inevitably increase queue time. The current inspection system already has little flexibility to address any accumulated queue time and this can only be remedied by the availability of additional HVRISOs. We found that the planned consolidation to three HVRISOs must be completed as quickly as possible. If legacy docks are used in-lieu of required HVRISOs for too long, AMC risks incurring a backlog of aircraft inspections and impeding mission readiness possibly for the remainder of the C-5 life cycle.

AMC should consider flexible scheduling methods for HVRISO and legacy docks if dock times for the isochronal inspection are usually lengthy. By selecting docks based on a "best-fit" approach where the next aircraft due inspection is sent to the dock most prepared to begin this aircraft, queue time can be drastically reduced. However, this method of dock selection may increase inspection down times so this dock selection should not be used if dock times are usually low and inherent queue time is already avoided. If dock times are usually short, then major isochronal inspections should be completed at one designated HVRISO such as Dover and minor inspections should be conducted at any other dock according to best fit.

Placing any other additional restrictions on the new inspection system should be avoided at all costs. These restrictions can only serve as a serious hindrance to achieving optimal aircraft availability. Such restrictions are rooted in the past of legacy inspection systems where each base conducted their own inspections. Half-hearted efforts to keep such aspects of now-defunct inspection systems will predictably meet with only limited results. These restrictions quite simply cannot add anything of value to a regionalized system. If AMC wishes to adopt commercial practices for aircraft inspection systems, they must be prepared to fully implement them.

Bibliography

Aimone, M. (2006, November 18). Aircraft Structural Integrity Program (ASIP) for Long Term Sustainment. Retrieved July 10, 2008, from Aircraft Structural Integrity Program website, San Antonio, TX. Web site: http://www.asipcon.com/2006/06_proceed/Tuesday/1200_Aimone.pdf

Air Force Reserve announces new C-5 ISO inspection site. (2006, December 13). *Air Force Reserve Command*. Retrieved August 7, 2008, from http://www.afrc.af.mil/news/story.asp?id=123035105

Armstrong, B. J. (2008, May 16). Keeping the B-52 airborne: 565th AMXS implements new processes. *Tinker Take Off*. Retrieved January 3, 2009, from http://www.tinkertakeoff.com/article.htm?intRecID=15996

Badiru, A. (2007, February). *Smart Ops for the 21st Century*. Retrieved July 10, 2008, from OR/MS Today, the magazine for members of the Institute for Operations Research and the Management Sciences (INFORMS), Lionheart Publishing, Marietta, GA. Web site: http://www.lionhrtpub.com/orms/orms-2-07/frsmartops.html

Badiru, A. (2007, March 27). Technical Systems Project Management. Retrieved July 10, 2008 from Ohio Aerospace Institute. Web site: http://www.oai.org/networking/images/Technical%20Systems%20Project%20Management-Adedeji%20Badiru.pdf

Bagley, D., TSgt (2008, August 2). Request for Information about C-5 RISO Bases. Private e-mail exchange with TSgt Darin Bagley, HQ AMC/A4PM, Scott AFB, IL. Message posted to AFIT E-mail server and archived in personal folder.

Balaban, H. S., Brigantic, R. T., Wright, S. A., & Papatyi, A. F. (2000). *A Simulation Approach to Estimating Aircraft Mission Capable Rates for the United States Air Force.* (J. A. Joines, R. R. Barton, K. Kang, & P. A. Fishwick, Eds.). Retrieved May 16, 2008, from Institute for Defense Analyses, Alexandia, VA and HQ Air Mobility Command, Studies and Analysis Flight, Scott AFB, IL Web site: http://www.informs-sim.org/wsc00papers/136.PDF

Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2005). *Discrete-Event System Simulation (*Fourth ed.). New York: Pearson Education. (Original work published 1999)

Barrett, B., and Fraile, L. (2005, March 23). *Lean at the C-5 Galaxy Depot: Essential Elements of Success*. Retrieved May 18, 2008, from Massachusetts Institute of Technology, Cambridge, MA Web site:

http://lean.mit.edu/index.php?option=com_docman&task=doc_download&gid=1299

Benoff, D. (2000, October). MSG-3: The Maintenance Enhancer. *Business & Commercial Aviation*, *87*(4),153.

Birchfield, H. (2007, August 17). C-5 MSG-3 Brings Cargo Fleet Better Inspection Process to Keep Aircraft Flying. *US Federal News Service*. Retrieved September 14, 2008, from Proquest database: http://proquest.umi.com.ezproxy.libproxy.db.erau.edu/pqdweb?index=3&did=1415549151&SrchMode=1&sid=1&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1233975633&clientId=17916

Bolinger, J. (2007, June 12). Dover Air Force Base opens first-ever Regionalized ISO. *Air Force Reserve Command*. Retrieved July 7, 2008, from Air Force Reserve Command Web site: http://www.afrc.af.mil/news/story.asp?id=123056734

Brinkley, B. (2007). The Effects of Maintenance on Reliability. In *Reliability Web*. Retrieved February 10, 2009, from http://www.reliabilityweb.com/art08/effects_of_maintenance_on_reliability.htm

Brosnahan, J. P. (2008, July). Unleash to Power of Lean Accounting. *Journal of Accountancy, 206*(1),60-66. Retrieved July 22, 2008, from Proquest database: http://proquest.umi.com/pqdweb?index=3&did=1505418351&SrchMode=1&sid=3&Fmt=6&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1216748450&clientId=27547

C-5 Fleet Integrated Roadmap. (2008, July). Warner-Robins AFB, GA: 730 ACSG/656 ACSS.

C-5 Galaxy. (2008, April). *Air Force Link*. Retrieved June 10, 2008, from United States Air Force Web site: http://www.af.mil/factsheets/factsheet.asp?id=84

Cadle, M. (2007, Spring). More Jobs Coming to Martinsburg Air Base: Air Force Selects Base As Regional C-5 Mainteance Site. *Mountaineer Defender*, 6. Retrieved October 4, 2008, from West Virginia National Guard Web site: http://www.wv.ngb.army.mil/pa/publications/defender/07_Q2_Defender.pdf

Cheever, D. (2001, September). The Tokyo shuffle - importance of aircraft maintenance. *Approach*. Retrieved from BNet Business Network Web site: http://findarticles.com/p/articles/mi_m0FKE/is_9_46/ai_80303021

Ciarallo, F. W., Hill, R. R., Mahadevan, S., Chopra, V., Vincent, P. J., & Allen, C. S. (2005, April 2). *Building the Mobility Aircraft Availability Forecasting (MAAF) Simulation Model and Decision Support System*. Retrieved May 20, 2008, from Wright State University, Russ Engineering Center, Dayton, OH and Northrop Grumman, Fairborn, OH Web site: http://www.scs.org/pubs/jdms/vol2num2/Ciarallo-Hill-Mahadevan-pp57-69.pdf

Creel, A. (2008, August 1). Maintenance steering Group to ensure C-5 Galaxy mission capability,availability. In *Robins Air Force Base*. Retrieved September 4, 2008, from Robins Air Force Base Web site: http://www.robins.af.mil/news/story.asp?id=123109072

Crosby, P. B. (1979). *Quality Is Free: The Art of Making Quality Certain* (W. H. Mogan & C. Nagy, Eds.). New York: MacGraw-Hill Book Company.

Daley, D. Colonel (USAF) (2008, Winter). Aircraft Inspection Regionalization…Just Do It! *Exceptional Release*, (110), 78-81.

Donovan, S., 1Lt (2008, 29 September). Request for Information about C-5 RISO Bases. Private e-mail exchange with 1Lt Steven Donovan, 436 MXS/CCM, Dover AFB, DE. Message posted to AFIT E-mail server and archived in personal folder.

Drinnon, R. (2008, February 19). 49 C-5s approved for modernization program. *Air Force Link*. Retrieved May 18, 2008, from Air Force Link Web site: http://www.af.mil/news/story.asp?storyID=123086790

Durand, J. M. (2008). Aircraft Maintenance Organizational Structure Changes: An Antecedent Model. Master's thesis, Air Force Institute of Technology, 2008).

Gellar, A., George, D., Tripp, R. S., Amouzegar, M. A., & Roll, C. R., Jr. (2004). *Supporting Air and Space Expeditionary Forces: Analysis of Maintenance Forward Support Location Operations* (Rep. No. RB-139-AF). Retrieved January 3, 2009, from RAND-Project Air Force Web site: http://www.rand.org/pubs/monographs/2005/RAND_MG151.pdf

Gibbs, D. A. (2003, March). The CIRF and Beyond: Improving Agile Combat Support. *Logistics and Warfighting*, 157-165. Retrieved October, 2008, from http://www.aflma.hq.af.mil/lgj/ Logistics_Warfighting_Mar03_2.pdf

Gibson, R. (1997). Rethinking Business. In *Rethinking the Future: Rethinking Business, Principles, Competition, Control & Complexity, Leadership, Markets, and the World* (p. 8) [Introduction]. (Original work published 1997)

Goldsby, T. J., & Garcia-Dastugue, S. J. (2008). The Manufacturing Flow Management Process. In D. M. Lambert, *Supply Chain Management: Processes, Partnerships, Performance* (3rd ed., pp. 121-142). (Original work published 2004)

Goldratt, E. M., & Cox, J. (1992). *The Goal: A Process of Ongoing Improvement* (2nd ed.). Great Barrington, MA: The North River Press. (Original work published 1984)

Goonan, P. (2006, December 15). Westover welcomes aircraft role. In *The Republican*. Retrieved January 10, 2009, from http://www.masslive.com/news/republican/newslog/index.ssf/mtlogs/ mass_therepublican/archives/2006_09.html?/hampfrank/republican/index.ssf?/base/news-7/1166172366257000.xml&coll=1

Hamlin, D., YF-0830-02 (2008, July 21). Request for Information about C-5 MSG-3 Initiatives. Private e-mail exchange with Mr Dodd Hamlin, Chief, C-5 Reliability Office, 730 ACSG/GFEABA, Warner-Robbins AFB, GA. Message posted to AFIT E-mail server and archived in personal folder.

Hammer, M. (2002, Winter). Process Management and the Future of Six Sigma. *MIT Sloan Management Review, 43*(2), 25-32. Retrieved July 10, 2008, from http://proquest.umi.com/ pqdweb?index=0&did=102779295&SrchMode=2&sid=3&Fmt=6&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1216751 435&clientId=27547

Hammer, M., and Champy, J. (2003). Prologue: Reengineering for the Twenty-First Century. In *Reengineering the Corporation: A Manifesto for Business Revolution* (2nd ed., pp. 1-7) [Preface]. Harper-Collins. (Original work published 2003)

Harken, R., CMSgt (2008, May 19). Request for Information about C-5 RISO Bases. Private e-mail exchange with CMSgt Richard Harken, HQ AMC/A4PM, Scott AFB, IL. Message posted to AFIT E-mail server and archived in personal folder.

Hebert, A. J. (2007, November). The Future Is On The Line. *Air Force Magazine Online, 90*(11). Retrieved May 18, 2008, from Journal of the Air Force Association Web site: http://www.afa.org/magazine/nov2007/1107future.asp

High Velocity Maintenance Merges Processes. (2008, April 1). *Air Force Link*. Retrieved July 10, 2008, from United States Air Force Web site: http://www.af.mil/news/story.asp?id=123095969

Holmes, S. (1994). *The Quality Approach: Helping you Achieve Success in Today's Air Force* (J. Ballance, Ed.). Maxwell Air Force Base, Al: Air Force Quality Institute, Air University.

Huxsoll, D., Major (2007, November 20). Logistics innovations impact warfighters. *Air Force Link*. Retrieved May 19, 2008, from United States Air Force Web site: http://www.af.mil/news/story.asp?id=123076483

In Step With Maj Gen Robert H. McMahon. (2008, Summer). *Exceptional Release*, 14-17. Retrieved January 4, 2009, from Logistics Officer Association Web site: http://www.loanational.org/ER/ excerpts/2008/summer2008/MajGenMcMahon.pdf

Johnson, A., Glasscock, C., Little, A., Muha, M., O'Malley, D., and Bennett, M., "C-5 Isochronal Inspection Process Modeling." Proceedings, Winter Simulation Conference, Miami, FL, 7-10 Dec 08.

Kapoor, K., Dharwada, P., Iyengar, N., Greenstein, J. S., & Gramopadhye, A. K. (2004). *Standardized Auditing and Surveillance of Aircraft Maintenance Operations*. Retrieved December 4, 2008, from Federal Aviation Administration Web site: https://www.hf.faa.gov/docs/508/docs/maintIERC2004WebSAT.pdf

Knight, W., & Bolkcom, C. (2008, April 15). *Strategic Airlift Modernization: Analysis of C-5 Modernization and C-17 Acquisition Issues* (Rep. No. RL34264). Retrieved from Federation of American Scientists Web site: http://ftp.fas.org/sgp/crs/weapons/RL34264.pdf

Kutner, M. H., Nachtsheim, C. J., Neter, J., & Li, W. (2005). *Applied Linear Statistical Models* (5th ed.). New York: McGraw Hill.

Law, A. M., & Kelton, W. D. (2000). *Simulation Modeling and Analysis* (3rd ed.). New York: McGraw-Hill.

Liu, M., Zuo, H., Geng, D., & Cai, J. (2006). Expert system of maintenance review board report based on CBR and RBR. *Aerospace & High Technology* , *32*(5), 521-525. Abstract obtained from *Aerospace Engineering*, 2006. Retrieved July 25, 2008, from CSA Illumina database: http://www-ca2.csa.com.ezproxy.libproxy.db.erau.edu/ids70/ view_record.php?id=6&recnum=1&SID=pe8rvr9ek9mcu6hdihhpe6cob1&mark_id=search%3A6%3A27%2C0%2C10&mark=1

Mason-Jones, R., Naylor, B., & Towill, D. R. (2000). Lean, Agile or Leagile? Matching your supply chain to the marketplace. *International Journal of Production Research*, *38*(17), 4061-4070. Retrieved November 12, 2008, from http://ihome.cuhk.edu.hk/~b103313/Exetrain/lean agile or leagile.pdf

Mathaisel, D. F. (2005). A Lean Architecture for Transforming the Aerospace Maintenance, Repair and Overhaul Enterprise. *International Journal of*

Productivity and Performance Management. Retrieved July 10, 2008, from Massachusetts Institute of Technology Web site: http://web.mit.edu/dfxm/www/Pubs/Lean Enterprise Architecture IJPPM Jan 2005.pdf

Mattioda, D. D. (2002). USE OF CRITICAL CHAIN SCHEDULING TO INCREASE AIRCRAFT AVAILABILITY (Master's thesis, Air Force Institute of Technology, Wright-Patterson AFB, OH, 2002).

Nakata, D. (2005). *Can Safe Aircraft and MSG-3 Coexist in an Airline Maintenance Program?* Brochure]. EmpowerMX. Retrieved July 17, 2008, from http://www.sinex.com/whitepapers/CanSafeAircraft&MSG-3Coexist.pdf

Nakata, D. (2005). *Why Transition to a MSG-3 Based Maintenance Schedule?* [Brochure]. EmpowerMX. Retrieved July 17, 2008, from http://www.empowermx.com/whitepapers/MSG3.pdf

O'Neill, P. M., & Vandersall, S. P. (2008, Fall). Re-baselining Air Force Scheduled Maintenance for the C-5 Galaxy. *Exceptional Release*, *109*, 42-43,46.

Osborn, D. (2007, June 7). C-5 Isochronal inspections move to Dover AFB. In *Air Mobility Command News Release*. Retrieved January 4, 2009, from Air Mobility Command Web site: http://www.amc.af.mil/news/story.asp?id=123056246

Pike, J. (2006). C-5 Service Life. Retrieved September, 2008 from Global Security Web site: http://www.globalsecurity.org/military/systems/aircraft/c-5-serv.htm

Polomsky, R. D. (March, 2007). AIR MOBILITY COMMAND’S EN ROUTE SUPPORT INFRASTRUCTURE: A CONSTRUCT OF AIRCRAFT TYPE AND GEOGRAPHIC LOCATION UTILIZED TO ASSESS EN ROUTE AIRCRAFT LOGISTIC SUPPORT (Master's thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base, OH, 2007).

Ragsdale, C. T. (2007). *Spreadsheet Modeling & Decision Analysis: A Practical Introduction to Management Science* (5th ed.). Mason, OH: Thomson Higher Education.

Rahman, S.-U. (1998). Theory of Constraints: A Review of the Philosophy and Its Applications. I*nternational Journal of Operations and Production Management, 18*(4), 336. Retrieved July 17, 2008, from ABI Inform database: http://proquest.umi.com/ pqdweb?index=2&did=116359829&SrchMode=2&sid=1&Fmt=3&VInst=PROD &VType=PQD&RQT=309&VName=PQD&TS=1216753034&clientId=27547

Rahman, S.-U. (2002). Theory of Constraints Thinking Process Approach to Developing Strategies. I*nternational Journal of Physical Distribution & Logistics*

Management, 32(9/10), 809-828. Retrieved July 14, 2008, from ABI Inform database: http://proquest.umi.com/ pqdweb?index=0&did=277284841&SrchMode=2&sid=1&Fmt=6&VInst=PROD &VType=PQD&RQT=309&VName=PQD&TS=1216753034&clientId=27547

Rausand, M. (2004, March 19). *Chapter 9 Reliability of Maintained Systems, Part 3 Maintenance Planning and Optimization*. Lecture presented at Norwegian University of Science and Technology.

Rinehart, G. W. (2006, Winter). How the Air Force Embraced "Partial Quality" (and Avoiding Similar Mistakes in New Endeavors). *Air & Space Power Journal*. Retrieved July 17, 2008, from Air University Web site: http://www.airpower.maxwell.af.mil/airchronicles/apj/apj06/win06/rinehart.html

Russell-Walling, E. (2007). *50 Managment Ideas You Really Need to Know*. 21 Bloomsbury Square, London: Quercus Publishing Plc.

Smith, J. (2006, July 30). Operation Enduring Freedom: Maintenance Crews Critical to Operations. *News Blaze*. Retrieved from http://newsblaze.com/story/20060730083820nnnn.nb/topstory.html

Smith, P. E. (Summer, 2008). High Velocity Regionalized C-5 Aircraft Isochronal (HVRISO) Inspection Process. *The Exceptional Release*, 44-47.

Smith, P.E., Capt (2008, July 21). Request for Information about C-5 RISO Bases. E-mail communications and telephone conversation during week of 20 July with Capt Smith, 436 MXS/MXM, Dover AFB, DE. Message posted to AFIT E-mail server and archived in personal folder.

TO 00-20-1. Aerospace Equipment Maintenance Inspection, Documentation, Policies, and Procedures. Retrieved Jun 3, 2008, from Tinker AFB, OK Web site: http://www.tinker.af.mil/shared/media/document/AFD-061220-046.pdf

Wallace, K. TSgt (USAF) (2008, January 23). MXS's backline maintenance produces 'BIG' results . In *Dover Air Force Base* [Press release]. Retrieved September 7, 2008, from http://www.dover.af.mil/news/story.asp?id=123083257

What Does It Take To Keep Them Flying? (1999, September 8). *Aerosphere* [Aeronautics]. Retrieved October 9, 2008, from http://www.aerosphere.com/Magazine/AERONAUTICS/aeronautics.shtml

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Faced with eroding budgets, Air Mobility Command (AMC) is confronted with implementing simultaneous changes to its isochronal (ISO) inspection process for C-5 aircraft. C-5 inspection criteria will use a Maintenance Steering Group-3 (MSG-3) approach beginning in October, 2009. MSG-3 has been used successfully in civilian aviation since 1980 and AMC hopes to produce similar results. AMC is also consolidating the four docks presently in use to three high-velocity regionalized isochronal (HVRISO) docks. Centralized scheduling by AMC should utilize a dock selection method that minimizes both processing time and queue time when arriving aircraft cannot be immediately inducted into the servicing inspection dock. This study uses discrete-event simulation techniques to test the factors of dock consolidation, MSG-3 inspection times, and proposed dock selection methods at various levels. Using a designed experiment, the simulation examines the effects of each factor on aircraft availability. Regression analysis is applied to the simulation results to assess which factors have the greatest impact on processing and queue time.

15. SUBJECT TERMS

Simulation, Aircraft Availability, High-Velocity Regionalized Isochronal

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