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Analysis of Using Fleet Readiness Centers Vice Civilian Contractors for Aircraft Modification Work

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December 2008

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Becky Jones

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Fleet Readiness Center Southwest (FRCSW) conducts maintenance on various aircraft platforms. In addition to regular aircraft overhauls, FRCSW has the capacity to perform aircraft modifications, which are currently completed by contractors. This project examines why the FRC's are not getting more CH-53E modification work when they have the capacity and capability to complete the work. This project uses FRCSW as a case study to address the issue. Interviews were conducted with the heads of Multi-line Division within FRCSW in San Diego, California and the Commander of FRC's and the H-53 Assistant Program Manager for Logistics at Naval Air Systems Command (NAVAIR), Patuxent River, Maryland. The results of these interviews provided an assessment of the actions taken to reduce inefficiencies and non-value added activities and insight into how NAVAIR selects between contractors and FRC's to complete modification work. The data reveal that FRCSW has the capacity to complete modification work on CH-53 aircraft without schedule slippage. Also, a comparison of labor rate, schedule, and location of work, demonstrates how much more expensive FRCSW is and why NAVAIR chooses the lower cost contractor to complete modification work.

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ANALYSIS OF USING FLEET READINESS CENTERS VICE CIVILIAN CONTRACTORS FOR AIRCRAFT MODIFICATION WORK

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

Fleet Readiness Center Southwest (FRCSW) conducts maintenance on various aircraft platforms. In addition to regular aircraft overhauls, FRCSW has the capacity to perform aircraft modifications, which are currently completed by contractors. This project examines why the Fleet Readiness Centers (FRCs) are not getting more CH-53E modification work when they have the capacity and capability to complete the work. This project uses FRCSW as a case study to address the issue. Interviews were conducted with the heads of Multi-line Division within FRCSW in San Diego, California and the Commander of FRCs and the H-53 Assistant Program Manager for Logistics at Naval Air Systems Command (NAVAIR), Patuxent River, Maryland. The results of these interviews provided an assessment of the actions taken to reduce inefficiencies and non-value added activities and insight into how NAVAIR selects between contractors and FRCs to complete modification work. The data reveal that FRCSW has the capacity to complete modification work on CH-53 aircraft without schedule slippage. Also, a comparison of labor rate, schedule, and location of work, demonstrates how much more expensive FRCSW is and why NAVAIR chooses the lower cost contractor to complete modification work.

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I. INTRODUCTION

A. PURPOSE OF THIS STUDY

The purpose of this study is to analyze why the FRC's are not receiving more CH-53E modification work when they have the capacity and capability to complete the work.

B. BACKGROUND

The service life of the CH-53E is 54 months. At the end of 54 months, the aircraft goes out of a reporting status and into its respective FRC for a Planned Maintenance Interval (PMI) event. Once the PMI event is completed, the aircraft is sent back to the operational unit, and immediately enters into another period of maintenance to be fit with modifications. Currently, contractors complete modifications and as a result, the aircraft is unavailable for use for a longer period of time. Although FRCSW possesses the capabilities to conduct the aircraft modification in conjunction with the PMI event, this is not occurring for the majority of modifications being installed. For instance, FRCSW is conducting two modifications in conjunction with a PMI event. One modification involves the replacement of Kapton wiring inside the aircraft and the other modification removes and replaces the tail boom assembly.[1]

This project examines the CH-53 helicopter, for which FRCSW provides depot level maintenance. The cost NAVAIR incurs by having contractors perform the upgrades rather than FRCSW is reported. Also analyzed is whether a cost advantage by employing FRCSW for this function exists. In addition, the advantages to the fleet of having an aircraft back in the inventory sooner with all upgrades performed by FRCSW vice using contractors is examined. The authors traveled to FRCSW to gather data on how the multi-line operated and how they have improved on their processes. They also traveled to Patuxent River, Maryland to interview PMA-261 to ascertain its process for choosing contractors.

[1] Dave Kelly, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 11, 2008.

C. RESEARCH QUESTIONS

1. Primary Question

Is it in the best interest of the United States Marine Corps to utilize Fleet Readiness Centers to conduct more CH-53E modification work?

2. Secondary Question

Can the FRC's conduct modifications in conjunction with a PMI event in 180-day TAT?

II. FLEET READINESS CENTER SOUTHWEST

A. THE TRADITIONAL THREE LEVELS OF MAINTENANCE[2]

The organizational, intermediate, and depot levels of aviation maintenance are distinctive in organization, mission and concept. Listed below is a brief synopsis of each level's responsibility to the Naval Aviation Maintenance Program.

1. Organizational

Organizational level (O-level) is performed by an operating unit on a day-to-day basis in support of its own operations. The O-level's maintenance mission is to maintain assigned aircraft and aeronautical equipment in a Full Mission Capable (FMC) status while continually improving the local maintenance processes. While O-level maintenance may be done by intermediate (I-level) or depot level (D-level) activities, O-level maintenance is usually accomplished by maintenance personnel assigned to aircraft-reporting custodians.[3] Aircraft-reporting custodians are responsible for the administrative reporting and maintenance of weapons systems in their custody. Squadrons, such as, VFA-34, VF-101, HM-14, HSC-26 are examples of O-level activities (or units). These O-level activities are assigned aircraft, equipment, and personnel that provide direct support to the warfighter. These maintenance functions generally are grouped under the categories of inspections, servicing, handling, on-equipment repairs, preventive maintenance, and upkeep.[4]

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[2] Section A with minor modification is drawn directly from, F. R. Clemmons and, H. M. Falconieri, "Analysis of Fleet Readiness Center Southwest Concept Integration: New-Employee Orientation and Communications Process," (MBA Project, Naval Postgraduate School, 2007), 3-4.

[3] Naval Air Systems Command, "COMNAVAIRFOR INSTRCUTION 4790.2," Naval Aviation Maintenance Program (NAMP), vol. 1, Naval Air Systems Command, (February 1, 2005), http://logistics.navair.navy.mil/4790/library/VOL_1.pdf (accessed March 11, 2007).

[4] Ibid.

2. Intermediate

The I-level's mission is to enhance and sustain the combat readiness and mission capability of supported activities by providing quality and timely material support at the nearest location with the lowest practical resource expenditure.[5] I-level maintenance consists of on-and off-equipment material support. On-equipment maintenance is conducted on the aircraft/end-item. On-equipment maintenance includes the repair of installed engines, calibration of systems, or repair of support equipment. Off-equipment maintenance is conducted when the component/item is removed from the aircraft/end-item and repaired at the facility. Off-equipment maintenance includes the processing of aircraft components; incorporation of technical directives; provision of technical assistance; the manufacture of selected components, liquids, or gases; and performance of certain on-equipment repairs.[6]

3. Depot

The D-level's maintenance is performed at or by the Naval aviation industrial establishment to ensure continued flying integrity of airframes and flight systems during subsequent operational service periods. D-level maintenance is also performed on material requiring major overhaul of parts, assemblies, sub-assemblies, and end-items beyond the capability of I-level. D-level maintenance includes manufacturing parts, modifying, testing, inspecting, sampling, and reclamation.[7] D-level maintenance supports O-level and I-level maintenance by providing engineering assistance and performing maintenance beyond O-level and I-level capabilities.

[5] Naval Air Systems Command, "COMNAVAIRFOR INSTRCUTION 4790.2," Naval Aviation Maintenance Program (NAMP), vol. 1, Naval Air Systems Command, (February 1, 2005), http://logistics.navair.navy.mil/4790/library/VOL_1.pdf (accessed March 11, 2007).

[6] Ibid.

[7] Ibid.

B. UNITED STATES CODE TITLE 10[8]

Title 10 of the U.S. Code provides the legislative foundation for depot-level maintenance and the use of working capital funds for industrial type activities. The section of Subtitle A, Part IV of Chapter 148 sets the requirement for depot-level maintenance activities within the DoD. Sections 2460-2464, 2466-2467, 2469-2472 and 2474-2475, of Chapter 146 provide the elements of the legislation for depot-level maintenance activities. The sections of Chapter 146 are as follows.

- define depot-level maintenance
- establish the scope of work
- establish the studies and reports requirements
- encourage public-private competition
- establish the requirements for converting to and from contracting workforce
- establish the requirement to maintain core logistics capabilities
- limit the amount of depot maintenance that can be contracted to private industry
- set the standard for managing DoD civilian employees
- allow depot-level maintenance activities to compete for other federal agency work
- authorize the Secretary of Defense (SECDEF) to designate Centers of Industrial and Technical Excellence

Section 2563, Chapter 152 allows depot maintenance activities to perform work for private industry. Section 2687, Chapter 159 discusses base closures and realignments and section 2208, Chapter 131 discusses working capital funds.

Title 10 provides legal justification, restrictions, opportunities, and requirements for the military depot-level maintenance industry.

[8] Section B & C with minor modifications is drawn directly from, T. Curran and, J. J. Schimpff, "An Analysis of Factors Generating the Variance between the Budgeted and Actual Operating Results of the Naval Aviation Depot at North Island, California," (MBA Project, Naval Postgraduate School, 2008), 5-8.

By providing the Armed Forces with a critical capacity to respond to the needs of the Armed Forces for depot-level maintenance and repair of weapons systems and equipment, the depot-level maintenance and repair activities of the DoD play an essential role in maintaining the readiness of the Armed Forces.

C. BRAC 2005

There have been five Base Realignment and Closures (BRAC) rounds (in 1991, 1993, 1995, 1998 and 2005). BRAC 2005 was the driving force behind the reorganizing and restructuring of Naval Aviation Maintenance into what it is today.[9]

A comprehensive assessment in support of BRAC decisions revealed that the DoD maintained a 24 percent excess capacity in installations to support the future forces.[10] In his initial guidance to the DoD, then Secretary of Defense (SECDEF) Donald Rumsfeld directed the DoD leaders to reconfigure the current infrastructure into one, which maximizes both war fighting capability and efficiency.[11] As a result, five themes were developed:

- Support force transformation
- Rebase forces to address new threat, strategy, and force protection concerns
- Consolidate business-oriented support functions
- Promote joint and multi-Service basing
- Achieve savings (DoD, 2005)

The two themes the Naval Aviation Enterprise (NAE) directly supports are to consolidate business-oriented support functions and achieve savings through restructuring support functions and reduction of support personnel, land and facilities.[12] To support

[9] GAO Report, "Observations on Prior and Current BRAC Rounds," http://www.gao.gov/new.items/d05614 (accessed November 1, 2008).

[10] "Base Closure and Realignment Report Part 1 of 2: Results and Process, vol. 1," *Department of Defense*, Washington, D.C., 2005.

[11] Ibid.

[12] Ibid.

the two themes, NAE adopted the objectives of reducing the number of maintenance levels by integrating the depot-level maintenance and intermediate level-maintenance and moving the integrated maintenance closer to the most populated fleet areas.

BRAC 2005 reorganization and restructuring of depot-level and intermediate-level maintenance activities proposed the creation of six Fleet Readiness Centers (FRC) and 13 satellite FRC sites. Naval Aviation Depot (NADEP) North Island and the Aviation Intermediate Maintenance Department (AIMD) entities at North Island were realigned under FRC Southwest. Figure 1 shows the Naval Aviation Enterprise FRC layout as of April 2006.[13] As depicted in this figure, the concentrations of maintenance activities are located where the Navy's aviation assets are concentrated.

[13] J. Johns, "Naval Aviation Transformation Brief," Defense Supply Center Richmond, http://www.dscr.dla.mil/uuserweb/dscrl/alc.alc2006/ACL%202006%20Briefings/1%20(A-8.1)%20Services%20Senrio%20Panel%20John%20John.ppt#275.17.Slide17 (accessed December 15, 2007).

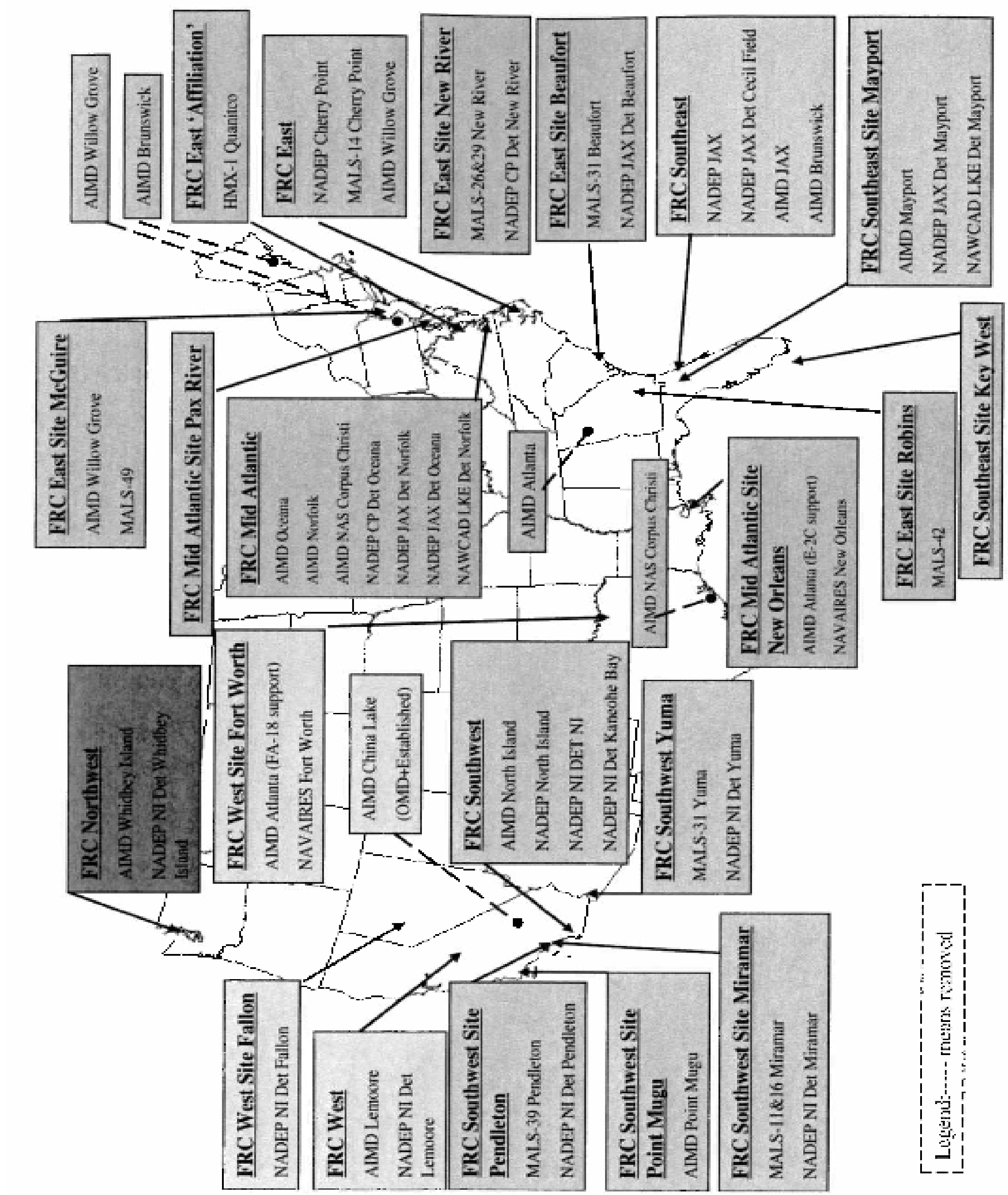

Figure 1. Naval Aviation Enterprise (NAE) Fleet Readiness Centers[14]

[14] J. Johns, "Naval Aviation Transformation Brief." Defense Supply Center Richmond, http://www.dscr.dla.mil/uuserweb/dscrl/alc.alc2006/ACL%202006%20Briefings/1%20(A-8.1)%20Services%20Senrio%20Panel%20John%20John.ppt#275.17.Slide17 (accessed December 15, 2007).

D. NADEP NORTH ISLAND[15]

The depot-level maintenance functions of FRCSW are nearly as old as Naval Aviation itself. In 1919, nine years after the start of Naval Aviation, the FRC began work as an Assembly and Repair Department of the Naval Air Station at North Island. In 1969, the Assembly and Repair Department was renamed the Naval Air Rework Facility (NARF). By 1987, the NARF was renamed the Naval Aviation Depot (NADEP) North Island.[16] As result of BRAC 2005, NADEP North Island was disestablished and realigned into FRC Southwest.[17]

Recognized as an innovator in depot-level maintenance by the Office of Naval Research's Best Manufacturing Practices Program, FRCSW is the Navy's primary west coast aircraft repair and modification facility for mission essential fighter and rotary wing aircraft for Navy and Marine Corps squadrons.[18] As of December 2007, FRCSW employed 4,371 people consisting of 3,494 civilian employees and 877 military personnel. The mission of the Fleet Readiness Center Southwest is:

> …CNAF's [Commander Naval Forces] West Coast Aircraft Repair D21 [Depot to Intermediate] facility specializing in the support of Navy and Marine Corps aircraft and related systems. Through partnerships with industry, other government agencies and supporting aerospace organizations, FRC Southwest, North Island repairs and overhauls aviation systems.[19]

FRCSW performs repair and modifications work on F/A 18 Hornets and Super Hornets, EA-6B Prowlers, E-2 Hawkeyes, C-2 Greyhounds, AV-8B Harriers, SH-60

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15 Section D with minor modifications is drawn directly from T. Curran and J. J. Schimpff, "An Analysis of Factors Generating the Variance between the Budgeted and Actual Operating Results of the Naval Aviation Depot at North Island, California," (MBA Project, Naval Postgraduate School, 2008), 5-8.

16 Best Manufacturing Practices, "Naval Aviation (NAVAIR) Depot, North Island – San Diego, CA: Best Practices," http://www/bmpcoe.org/bestpractices/internal/nadep/index.html (accessed November 20, 2007).

17 Joe Moore, "BRAC 2005; The New Integrated I&D Level Maintenance," http://www.av8.org/brac-05 (accessed November 1, 2008).

18 Ibid.

19 Fleet Readiness Center Southwest, "Homepage," http://www.frcsw.navy.mil/frcsw (accessed November 30, 2007).

Seahawks and HH/MH-60s, AH-1 Cobras, UH/HH Hueys, and CH-53 Sea Stallions. Additionally, FRCSW deploys Field Service Teams and Voyager Repair Teams to deployed aviation squadrons, ships, and installations worldwide. The Field Service and Voyager Repair Teams provide depot-level maintenance repair and modification for aircraft, aviation structures, aircraft components, aircraft carrier catapult and arresting gear systems, and aviation equipment and facilities on other ships.[20] In 2007, FRCSW deployed over 2,500 Field Service and Voyager Repair Teams, repaired and modified approximately 285 aircraft, and manufactured over 50,000 aircraft components.

1. FRCSW Programs[21]

The FRCSW receives aircraft, engines and a multitude of components from activities within the U.S., as well as forward deployed units, for maintenance, modification and repair needed from normal operations or battle related damage. Requests to manufacture new replacement items for components that can no longer be repaired, refurbished or are not commercially available are also received from fleet units as well as other DoD components. These demands are satisfied by the services provided through one or more of the following seven FRCSW programs.[22]

a. Components Program

The components program at FRCSW has the capabilities to repair and refurbish over 19,000 different types of Navy, Marine Corps aircraft components, supply systems and DoD assets. The Components Department existed as a program within the Depot prior to the merger. As a result of the FRC implementation, the AIMD repair capabilities and the Depot artisan (worker) skills are integrated into a single organization.

[20] Fleet Readiness Center Southwest, “Homepage,” http://www.frcsw.navy.mil/frcsw (accessed November 30, 2007).

[21] Section 1 with minor modifications is drawn directly from J. F. Montes, “Organizational Design Analysis of Fleet Readiness Center Southwest Components Department,” (MBA Project, Naval Postgraduate School, 2007), 7-10.

[22] Fleet Readiness Center Southwest, “Homepage,” http://www.frcsw.navy.mil/frcsw (accessed November 30, 2007).

The new organization has personnel, equipment and facilities specialized in the repair and refurbishment of Avionics, Aircraft Supports and Surfaces, Instruments and Generators, Landing Gear and Hydraulics components for units ashore and afloat.

b. E-2/C-2 Program

The E-2/C-2 Program is comprised of five groups that include 1) PMI One and Two for repair and refurbishing (PMI-1/2), 2) PMI-3/Service Life Extension Program (SLEP)/Rewire (C-2), 3) In-Service Repair (ISR), 4) Foreign Military Sales (FMS), and 5) E-2 Super Modules.

c. F/A-18 Program

The F/A-18 Program supports PMI-1/-2 Special Rework/Crash Damage Repair (SR/CD) and Center Barrel Replacement Plus (CBR+).

d. Manufacturing Program

The Manufacturing Program has machining, sheet metal fabrication, tube/hose/duct repair, foundry, welding and heat treatment capabilities that support the aircraft and helicopter rework programs as well as the overhaul of the LM2500 marine gas turbine engine used on surface naval ships. This department also manufactures and repairs over 150 different configurations of mobile VANS, large steel containers with special equipment that support deployed Marine Corps Units.

e. Engineering and Logistics Program

The Engineering and Logistics Program is part of the In-Service Support Center (ISSC) and consists of a full Materials Laboratory and the Navy Primary Standards Laboratory (NPSL). This program is responsible for developing the safest, most reliable and cost-effective engineering solutions needed to meet or exceed the repair, refurbishment and modifications requirement for products.

f. Multi-Line Program

The Multi-Line Program supports PMI-1/-2 for UH-1/HH-1 Huey, CH-53 Super Stallion, AH-1W Super Cobra and SH-60/MH-60/HH-60 Seahawk helicopters for the Navy and Marine Corps.

g. Field Service/Voyager Repair Program

The field Service/Voyager Repair Program is comprised of Voyager Repair teams, Field Service teams, paint/finish and surface/structural repair support for AV-8B Harrier aircraft in Yuma, Arizona.

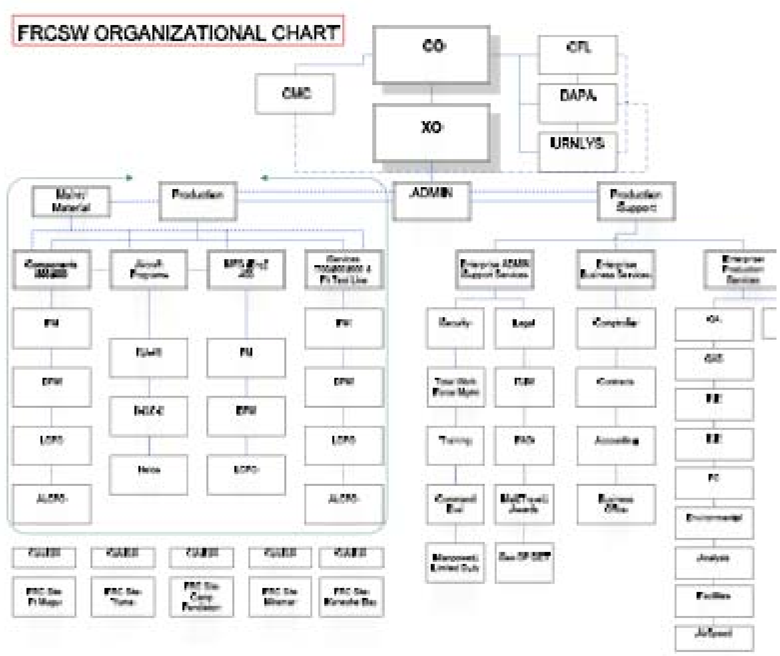

Figure 2. FRCSW Organization Chart.[23]

[23] Preliminary organizational chart provided by FRCSW Staff, July 2007.

III. AIRSPEED CONCEPT

A. PROBLEM IDENTIFICATION AND SOLUTION (ENTERPRISE AIRSPEED)

Recognizing the need to reduce the cost of doing business, improve productivity, and increase customer satisfaction, the Naval Air Systems Command (NAVAIR) implemented the "AIRSpeed" program. The program's intent was to create an environment of continuous process improvement, optimize maintenance and supply activities to meet operations, and eliminate sub-optimization by using a common set of industry proven tools.[24]

The AIRSpeed concept is not designed around available work hours. The schedule is what drives an airplane through the process, not the amount of workload.[25] The schedule is derived from the total number of airplanes that need to be completed during the year and the total number of workdays available. The process time is the same whether the amount of effort to complete the job is five hours or five hundred hours.[26] If there is additional work (hours) on the airplane that needs to be completed, the rate of effort is increased rather than the timeline. Productive effort can be increased when waste has been reduced. The tools FRCSW has used to achieve better efficiency are a mixture of Theory of Constraints (TOC), Lean, and Six Sigma. These tools focus attention on eliminating waste in processes and maintaining process control.

B. THEORY OF CONSTRAINTS

In the mid-80s, Dr. Elijahu Goldratt, developed TOC. This management tool focuses on reducing costs and improving productivity by identifying and removing

[24] Naval Aviation Enterprise, "Enterprise AIRSpeed," http://www.cnaf.navy.mil/airspeed (accessed August 15, 2008).

[25] Dave Kelly, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 11, 2008.

[26] Ibid.

"constraints" in a system. A constraint is a factor that limits an organization's ability to achieve its goal.[27] TOC allows the change process to employ five thinking process tools.

- Current Reality Tree: Using experienced and involved individuals, it identifies the root causes of a problem (what to change)
- Evaporating Cloud: Identifies a solution to the core problem and uncovers the factors that created the problem
- Future Reality Tree: Identifies what is missing from the proposed solution before implementing changes (what to change to)
- Prerequisite Tree: Identifies the intermediate steps and obstacles that need to be taken to reach the new goal or process (how to cause change)
- Transition Tree: Identifies the actions (implementation plan) needed to take, given the current situation, to achieve the intermediate goals (as identified in the Prerequisite Tree)[28]

TOC uses the terms bottleneck, drum, rope, and buffer to explain the output of a plant. The "drum" is essentially the bottleneck that paces the plant. Increase the drum and the bottleneck diminishes. Bottleneck idle time is reduced by having a "buffer," which is inventory that is in front of the bottleneck. The communication system within the plant is called the "rope." Inventory requirements at the bottleneck need to be communicated back to the material release point in order to control production. Remove bottlenecks and production increases.

The TOC Process can be broken down into five steps.

Step 1: Identify the constraint

Step 2: Focus on how to get more production at the constraint within the existing capacity limitations.

Step 3: Keep materials needed next from sitting idle in a queue at a non-constrained resource.

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[27] B. Motley, "Using Theory of Constraints (TOC) to Improve Quality, Cost and Productivity," *Defense Systems Management College*, June 2004.

[28] Ibid.

Step 4: If, after fully exploiting this process and it is still not possible to produce enough product to meet the demand, find other ways to increase capacity.

Step 5: Go back to step 1.[29]

There are multiple benefits to applying the TOC to a DoD program. For instance, TOC can help reduce cost and cycle time and it can help to improve quality, responsiveness, and performance.[30]

C. THE LEAN MODEL

The lean model is a systematic approach to identifying and eliminating waste (non-value-added activities) through continuous improvement by focusing on customer needs to deliver goods and services.[31] The lean model encompasses a set of principles, concepts, and techniques designed to pursue the elimination of waste continually while producing an efficient just-in-time production system that will deliver six things to customers.

- Exactly what they need
- When they need it
- In the quantity they need
- In the right sequence
- Without defects
- At the lowest possible cost[32]

Waste is anything other than the minimum amount of equipment, materials, parts, space, and the worker's time, which are absolutely essential to add value to the product.[33] Some common examples of waste in a plant are listed as follows.

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[29] B. Motley, "Using Theory of Constraints (TOC) to Improve Quality, Cost and Productivity," *Defense Systems Management College*, June 2004.

[30] Ibid.

[31] Dynamic Research Corporation and Clemson University, "Lean Pathways, Lean Overview of CVN Applications," *Navy MANTECH*, 2003.

[32] Ibid.

[33] Ibid.

- Overproduction
- Waiting
- Transportation of parts/material/tooling
- Non-value-added processing
- Excess finished inventory
- Defects
- Excess people motion
- Underutilized people
- Motion

The lean model is designed to start with the customer. First, internal and external customers need to be defined. Next, delivery needs to be on demand, where and when the customer wants the product. The Lean Model builds what is sold and supplies what is consumed. It is a system that is flexible in its responses and produces a balanced flow. Continuous improvement is the goal of Lean. The building blocks Lean relies on are as follows.

- TAKT time - the maximum amount of time allowed to produce a product in order to meet demand
- Pull/Kanban - a signaling system to trigger action
- Just-in-time (JIT) - an inventory strategy to improve the return on investment by reducing in-process inventory and its associated carrying costs
- Cellular/Flow - is the linking of manual and machine operations into the most efficient combination of resources to maximize value-added content
- Batch Reductions - meeting the customer's demands while at the same time reducing inventory carrying costs, work in progress, and lead or cycle time
- Quality at source - requires every employee to inspect their work, reducing defective products
- Quick Changeover - a process to reduce the amount of production time lost while a machine is down for changeovers
- Total Productive Maintenance (TPM) - is a methodology for proactive and progressive maintenance, which analyzes the overall equipment effectiveness

- Teams - innovative teams are able to accomplish more than an innovative individual. Cross-section teams engage all levels of the company and are able to respond to a broad spectrum of situations
- Standardized Work - enables a company wide communication of best practices. It also creates an environment that is flexible and able to new technologies and methods as they arise.
- Point Of Use Storage (POUS) - places material, tools, and equipment where and when it is needed in an orderly fashion
- Value Stream Mapping - involves drawing out schematics of processes in order to eliminate non-value added activities, reduce cycle time, enhance quality, and to increase affordability
- 5S - a way of organizing and managing the workspace and work flow with the intent to improve efficiency by eliminating waste and improving flow[34]

The lean model incorporates the 5S theory, which simply equates to good housekeeping. The 5Ss are Sorting (proper arrangement), Simplifying (orderliness), Sweeping (cleanliness), Standardize (cleanup) and Self-discipline (discipline).[35] Visual controls are a key ingredient in the building blocks of Lean. When walking into a place of work, proper Lean implementation should visually show the following.

- What the process is
- Who the customers and suppliers are
- What the deliverables are
- Where and what resources are being used in the process, and;
- An effective measurement system is in place

The purpose of visual controls are listed below.

- Show how to do the job (standard operations)
- Show how things are used
- Show where things are stored
- Control inventory storage levels
- Show production status

[34] RIMES, "What is a Lean Enterprise?" www.rimes.org (accessed October 1, 2008).

[35] Dynamic Research Corporation and Clemson University, "Lean Pathways, Lean Overview of CVN Applications," *Navy MANTECH*, 2003.

- Indicate when people need help
- Mistake-proof the operation[36]

The lean model principles are based on quality, cost and delivery. By creating a system, which is intolerant of production abnormalities, quality improves. Waste is minimized in production thus reducing cost and efficient delivery decreases lead times.[37] Lean production lines often use work cells to operate in a more efficient manner. A cell is a work center that incorporates everything required in order to process the product. Cells can create an environment for continuous flow manufacturing. Throughput is increased by utilizing cells. Figure 3 shows the worker in Part A having to move from raw materials (RM) in one station to subsequent stations to accomplish the task and have a finished good (FG). When tasks are organized into cells, as shown in Part B, efficiency results.

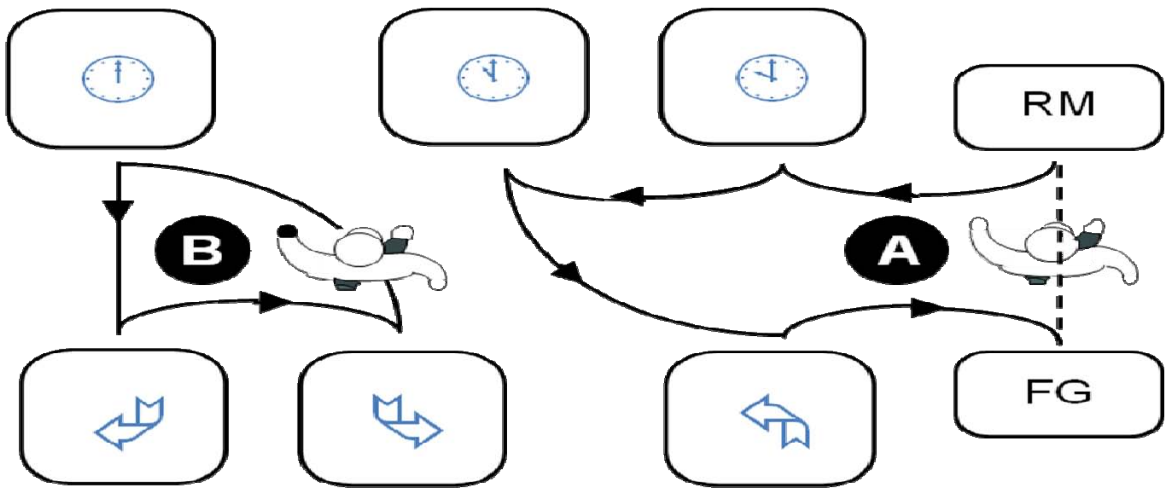

Figure 3. Cell Layout.[38]

[36] Dynamic Research Corporation and Clemson University, "Lean Pathways, Lean Overview of CVN Applications," *Navy MANTECH*, 2003.

[37] Ibid.

[38] Ibid.

1. Quick Hitters

Incorporating Lean tools in any organization can be a timely process. Many items, however, can be integrated quickly in order to enhance an operation and eliminate waste. Examples of this type of Lean engagement are called Quick Hitters. Quick Hitters are items that can be addressed quickly with little or no cost. Examples are listed as follows.

- Centralized Tooling
- Color coded parts
- Shelving labels
- Quality Matrix Charts
- Pick Lists
- Visual aids
- Machine Maintenance Log
- Parking Lots
- Training Manuals
- Internet/Interoffice email[39]

Lean eliminates waste within an organization, which not only increases the customer's satisfaction level, but also increases the bottom line for the organization. Lean principles enable individuals working on the floor the ability to implement their ideas for process improvement resulting in eliminating waste. This is good for management because it improves morale and productivity by providing the worker on the floor a sense of ownership in the process that said worker helped to create.

D. SIX SIGMA

Originally developed by Motorola, "Six Sigma" seeks to identify and remove the causes of defects and errors in manufacturing and business processes.[40] Defects are defined in the Six Sigma theory as anything that could lead to customer dissatisfaction.

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[39] Dynamic Research Corporation and Clemson University, "Lean Pathways, Lean Overview of CVN Applications," *Navy MANTECH*, 2003.

[40] J. Antony, "Pros and Cons of Six Sigma: An Academic Perspective," *Onesixsigma.com*, http://onesixsigma.com/node/7630 (accessed September 8, 2008).

By improving processes, organizations can reduce costs, keep customers satisfied and thus, increase the potential for profitability. The term Six Sigma comes from a field of statistics. The term Six Sigma process comes from the notion that if one has six standard deviations (sigma) between the mean of a process and the nearest specification limit, there will be practically no items that fail to meet the specifications.[41] Processes that operate with "Six Sigma quality" over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities or 99.9997 per cent efficiency.[42] Six Sigma evolved from years of quality control and improvement process methodologies, but differs from its predecessors in four distinct ways.

- A clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project
- An increased emphasis on strong and passionate management leadership and support
- A special infrastructure of "Champions," "Master Black Belts," "Black Belts," etc. to lead and implement the Six Sigma approach
- A clear commitment to making decisions on the basis of verifiable data, rather than assumptions and guesswork[43]

Fortune 500 companies, such as Honeywell International, and General Electric have adopted Six Sigma. Its usage in the DoD is growing in order to increase product reliability and reduce cycle time. AIRSpeed uses Six Sigma theory to try and improve the entire process by reducing the variation of multiple elements, inputs, and sub processes. This assumption is proven through a rigid and structured investigation methodology. The Six Sigma methodology includes five steps.

- Define**:** who is the customer and what are their problems? What are the key characteristics important to the customer and what processes support those characteristics?
- Measure**:** key characteristics are categorized, measurement systems are verified and data are collected

41 G. Tennant, *Six Sigma: SPC and TQM in Manufacturing and Services* (Gower Publishing, Ltd., 2001), 25.

42 Motorola University, "Six Sigma Dictionary," http://www.motorola.com/content.jsp?globalObjectId=3074-5804 (accessed September 8, 2008).

43 J. Antony, "Pros and Cons of Six Sigma: An Academic Perspective," *Onesixsigma.com*, http://onesixsigma.com/node/7630 (accessed September 8, 2008).

- Analyze**:** convert raw data into information that provides insights into the process. Identify the fundamental and most important causes of the defects or problems.
- Improve: develop solutions and make changes to the process. Results of changes are seen in the measurements.
- Control: the process is monitored to assure no unexpected changes occur[44]

E. COMPARISON OF THE THREE IMPROVEMENT PROGRAMS

Any number of techniques may be used to increase efficiency and effectiveness in production processes. Below is a summary of the three concepts used by FRCSW and selected strengths and weaknesses of each.

Program	Theory of Constraints	Lean	Six Sigma
Theory	Manage Constraints	Remove Waste	Reduce Variation
Application Guidelines	1. Identify Constraint 2. Exploit Constraint 3. Subordinate Processes 4. Elevate Constraint 5. Repeat Cycle	1. Identify Value 2. ID Value Stream 3. Flow 4. Pull 5. Perfection	1. Define 2. Measure 3. Analyze 4. Improve 5. Control
Focus	System Constraints	Flow Focused	Problem Focused
Assumptions	Emphasis on speed and volume. Uses existing systems. Process interdependence.	Waste removal will improve business performance. Many small improvements are better than systems analysis.	A problem exists. Figures and numbers are valued. System output improves if variation in all processes is reduced.
Primary Effect	Fast Throughput	Reduced Flow Time	Uniform Process Output
Secondary Effects	Less inventory/waste. Throughput cost accounting. Throughput-performance measurement system. Improved quality.	Less variation. Uniform output. Less inventory. New accounting system. Flow-performance measure for managers. Improved quality.	Less waste. Fast throughput. Less inventory. Fluctuation-performance measures for managers improved quality.
Criticisms	Minimal worker input. Data analysis not valued.	Statistical or system analysis not valued.	System interaction not considered. Processes improved independently

Table 1. Comparison of Improvement Programs.[45]

[44] P. D. Harnden, "Integrating Lean and Six Sigma and AIRSpeed within the NAVAIR 4.1 Organizational Improvement Efforts," (White Paper, Commonwealth Centers for High Performance Organizations, 2004).

[45] Ibid.

F. PITFALLS

AIRSpeed integration needs to be adopted and fostered by all levels within the organization. The tools that AIRSpeed utilizes (TOC, Lean, "Six Sigma") are building blocks that need to be continually reassessed in order to maintain the maximum amount of output a particular process/system can produce. The limits to AIRSpeed are that processes can only be improved to a certain level of efficiency and must be adapted differently depending on the system. Failure to achieve this will result in minimal impact to efficiency. In the case of FRCSW's multi-line, two workers may only utilize the aircraft cockpit at a time. Despite having multiple workers capable of working on the cockpit, the organization can do nothing to change the confines of the cockpit space. Therefore, efficiency is unlikely to increase any more than what has been achieved by keeping two people working in this space at one time.

IV. AIRSPEED INTEGRATION AT MULTI-LINE

A. ISSUES

FRCSW needed to review their processes because they were not meeting their customer's time requirements. They were taking too long and were inefficiently using resources, which ultimately increased costs. The CH-53E team, within the Multi-line division, agreed that they needed to a better job.

1. Customer Focused Requirements

The initial questions addressed in implementing the AIRSpeed transformation process were, "What does the customer expect?" and "how many aircraft does the customer want completed each year by the depot?" The answer to the question drives the production process. The math used within AIRSpeed was very simple. If the fleet requires 10 CH-53Es delivered each year from the Depot and there are 250 workdays available, then the multi-line division needed to produce a completed aircraft every 25 days.

2. Where to Start

Once the multi-line division identified their annual objectives and aircraft requirements, they studied how their current production line operated. The FRCSW multi-line division realized that before they could start Six Sigma, they needed to focus more on Lean. The Six Sigma concept does not work unless the processes under control. This became priority number one. FRCSW's multi-line personnel started to identify where they could apply Lean techniques to make tangible improvements. Their first step was to generate a value stream map of the CH-53E line from a 50,000-foot perspective. Simply put, they produced a flow chart that gave them the total picture of an aircraft overhaul process. Then, once they knew their output requirement, they designed a production process that would accomplish their goal.

3. Buy In

The AIRSpeed process needed artisan (skilled labor) buy-in from the beginning. The question that highlights this need is, "does management understand the detail of the shop floor processes better than the artisans doing the work?" The answer is 'no', management felt it was important to pull together the team of artisans with ideas for change, which would ultimately provide a better product for the customer. The artisans needed to know that the management chain would support the changes that were going to be made under the Lean Methodology. Artisans were asked about current work processes to determine if they were the most effective or efficient. Artisans were then encouraged to propose new ideas on making the operation more efficient and effective. Concurrently, management needed to resist the temptation to implement preconceived ideas of the solution before truly analyzing the problem and identifying the areas of waste. By allowing the workers to introduce ways in which to improve efficiency, they could increase the level of acceptance to a new process. When employees feel as though they have contributed to the creation of a process, then they are more apt to follow the process more closely, and in turn, ensure its continued success.[46]

B. LEAN IMPLEMENTATION AT FRCSW

The CH-53E program started practicing the lean theory in March of 2005. At that time, their turnaround time (TAT) for an aircraft was 380 days, (as evidenced from Figure 4), for aircraft X105.

[46] Section A with minor modifications is drawn directly from Keith Borror, "NADEP NI CH-53E PMI AIRSPEED PROGRESSION," *The Heavy Lift Quarterly*, December 2005, 12-14.

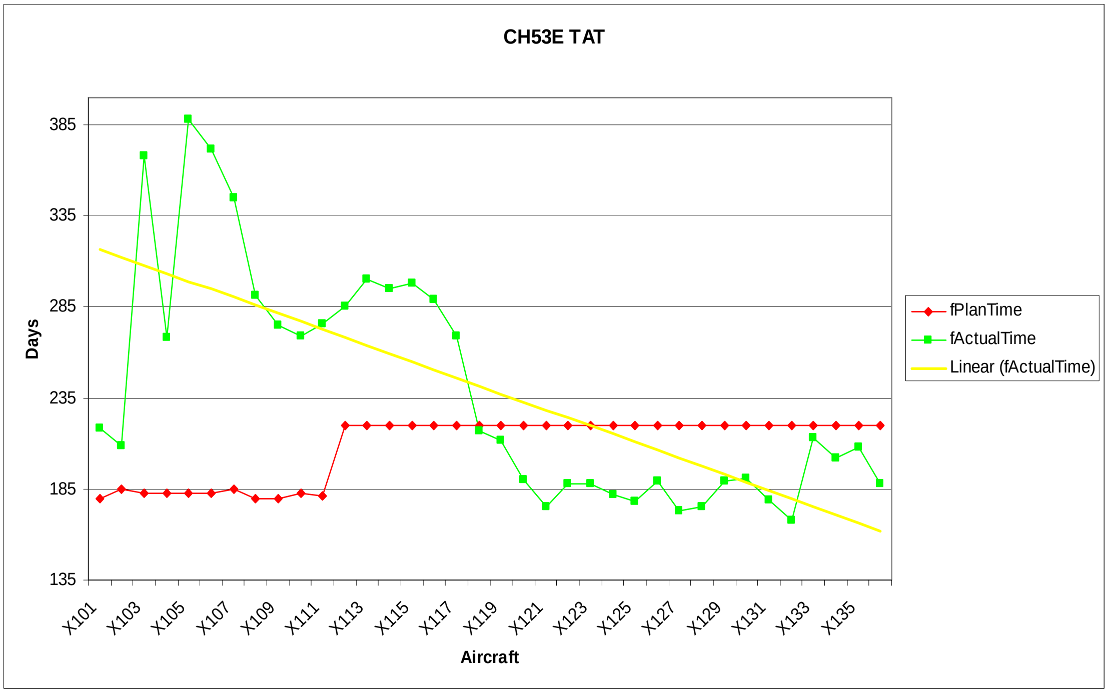

Figure 4. FY08 CH-53E Turnaround Time.[47]

FRCSW processes contained non-value added activities. This included time wasted waiting on the supply system. For example, parts were ordered when they were needed in the production process, rather them showing up when they were needed. Artisan time was wasted hunting for tools and parts within the hangar, rather than having the tools and parts organized and ready at that workstation.[48]

FRCSW started their Lean process by incorporating point-of-use tooling, point of use publications, pre-expendable bins (PEB), kits, standard workload, and cell development. These were the easiest processes to implement and demonstrated results quickly.[49]

47 FRCSW Multi-line, "FY08 AIRSpeed Initiatives," FRCSW PowerPoint 2008.

48 Ron Cobb, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 12, 2008.

49 Ibid.

1. Point of Use Tooling/Publications/Pre-expendable Bins

Points-of-use procedures are a Lean maintenance concept implemented at FRCSW in order to manage resources efficiently and reduce the man-hours not devoted to production. Prior to the introduction of this practice, an artisan may have had to leave the production line multiple times per day in order to return with a tool, publication, or part from a storage locker located some distance away from the work area. Each time the artisan stops working, he was forced into a non-value added activity. The man-hours away from the job add up, ultimately producing schedule delays. Point-of-use procedures places commonly used tools, publications, and parts in places close to the production line, where and when they are needed. This reduces the amount of time an artisan is not working. Additionally, point-of-use procedures allow for a centralized and controlled inventory system, which is easier to update and manage, further reducing delays.[50]

2. Kits

FRCSW developed kits in order to decrease their TAKT time and reduce the amount of time lost through unnecessary travel time by artisans. The kits contain all of the necessary parts, tools, nuts, and bolts required to complete a task. Kits are pre-delivered to the work area and are inventoried in order to ensure that all the necessary hardware is present. Table 2 lists an example. Kit A8RA is required to remove the auxiliary tanks and fins. If an artisan completes work early, it is then possible to request the next kit for the next job within the cell.[51]

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[50] Ron Cobb, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 12, 2008.

[51] Ibid.

Inflow								
CT	4				5			
Date	Mon 19 May				Tue 20 May			
Hour	2	4	6	8	2	4	6	8
A Mech	Remove Aux Tanks and Fins	Remove Batwing Panels	Remove L/H FWD & AFT Sponson Plumbing, Fuel Cell Panels & Covers		Remove R/H Sponson		Remove L/H Sponson	
	St Fl	St	St	Fl	St	Fl	St	Fl
	Kit A8RA / A8LA	Kit A8RA / A8LA	Kit A8L2 / A8L4 / A8L7		Kit A8R7		Kit A8L7	
B Mech	Remove IFR Probe		Remove L/H FWD & AFT Sponson Plumbing, Fuel Cell Panels & Covers		Remove R/H Sponson		Remove L/H Sponson	
	St	Fl	St	Fl	St	Fl	St	Fl
	Kit A102 / A207		Kit A8L2 / A8L4 / A8L7		Kit A8R7		Kit A8L7	

Table 2. Work Sequence Breakdown.[52]

Kits are put together and replenished by production control. Kits cut down on man hours and TAT. FRCSW estimates how much material (nuts, bolts, actuators) they need next year based on the frequency that they change parts this year. The FRCSW informs their suppliers, DLA and NAVICP, of how many parts are needed and the suppliers order them. This process ensures part availability when they are needed. TAKT time drives how many kits are needed and produced based on the consistent drumbeat of producing an aircraft every 35 days.[53]

3. Standard Work

Standard workloads or TAKT times are the maximum time allowed to produce a product to meet demand. To minimize surges and stagnation, workloads must be level loaded across the production line. FRCSW implemented standard work to prevent the schedule from moving unpredictably to increase TAT. FRCSW wanted to reduce delays in production and return completed aircraft to the customer on schedule. TAKT times are assigned to each cell based on the amount of time it takes work to be completed. For instance, an 18-day TAKT time is assigned for the disassembly phase for a CH-53E. Within that disassembly cell, a designated amount of work needs to be completed by each artisan per day. Table 2 listed such an example. Mechanics A and B are assigned

[52] FRCSW Multi-line, "CH-53 01 Disassembly, E&E, 18-day Work Sequence x-140," FRCSW Multi-line Excel Spreadsheet, 2008.

[53] Ron Cobb, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 12, 2008.

specific tasks each day throughout the entire phase. TAKT time drives the rate of effort. If the job requires more resources to be completed on time, then more resources should be directed toward that cell. This prevents schedule slippage.[54]

Currently, the United States Marine Corps (USMC) requires FRCSW to complete 12 PMI events per year on the 152 CH-53E in inventory. To maintain a constant schedule throughout the year, the Multi-line division negotiated that if the fleet could induct an aircraft every 35 days, then FRCSW could deliver a completed aircraft every 35 days. This TAT equates to 175-180 days to complete one aircraft PMI. Once Multi-line was able to shape their TAKT times, they were able to stay on schedule.[55]

4. Cell Development

Cell-based maintenance breaks up the production line into cells, which requires a certain amount of work to be completed each day. The airplanes move forward within a cell freeing up the cell for the next airplane. Airplanes move from one cell to another in a specified number of days that enables the production line to act as a fixed schedule.[56]

C. MULTI-LINE CELL DEVELOPMENT

To achieve a goal of a 180-day turnaround, FRCSW needed to identify the number of days an aircraft spends in each maintenance cell. By understanding what is necessary in each cell and eliminating the non-value added activities, FRCSW further refined the processes, thus reducing the TAKT time within each cell. The CH-53E line developed five working cells: Induction, Disassembly, Structures, Assembly, and Final Assembly. The PMI event incorporates work that needs to be accomplished in all five cells.[57] Table 4 in the Appendix shows a full PMI event schedule.

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[54] Dave Kelly, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 11, 2008.

[55] Ibid.

[56] Ibid.

[57] Ron Cobb, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 12, 2008.

1. Working Cell # 1 - Induction

Induction is the first cell through which an aircraft enters. An aircraft spends three days in induction where all the administrative work is conducted, for example, signing over the aircraft discrepancy book (ADB). The 180-day clock starts on the scheduled induction date. If an aircraft is late for induction, then the 175-180 day TAT could be extended from the originally scheduled date. Previously, late inductions drove the TAT to 210 days from the scheduled induction date. The multi-line division's newly gained efficiencies are still able to achieve a 170-180 day TAT despite late inductions.[58]

2. Working Cell # 2 - Disassembly

Disassembly is the next cell. An aircraft spends 15 days in this cell. Artisans disassemble the aircraft and send the structural parts of the aircraft to plastic media blast (PMB). PMB is part of the disassembly cell. PMB sprays plastic pellets against the aircraft to remove paint and corrosion. Since no hazardous waste was created, PMB is a more environmentally friendly technique than using standard primers or paint thinners. All of the loose gear that comes off the airplane then goes to the Examination and Evaluation (E&E) department. E&E x-rays the parts to detect cracks, fatigue, or failures in the component and upon receiving the results, determines the amount of rework that needs to be completed. Once E&E is complete with the loose gear, it returns to PMB. Table 2 shows an example of a standard day within the disassembly cell.[59]

3. Working Cell # 3 - Structures

An aircraft spends 18 days in the structures cell. Once the structural parts come back from PMB, they go to E&E. E&E determines the amount of rework necessary. The 18 TAKT time could be more or less depending upon the E&E findings. E&E produces an evaluation message stating how many days the structures rework requires. Most non-Operation Iraqi Freedom (OIF) CH-53E's enter the FRC PMI event needing

[58] Ron Cobb, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 12, 2008.

[59] Ibid.

approximately 12,000 hours of standard work. Those planes are estimated to have a TAT of 150-160 days. Aircraft returning from OIF come in needing 15,000 hours for a full PMI event, which means that the amount of effort directed at OIF aircraft is significantly greater than a non-OIF aircraft. OIF aircraft fly in a more corrosive environment, which degrades the airframe, rotors and engines. This degradation equates to more effort the FRC spends on that particular airframe. The majority of the effort spent on the OIF aircraft occurs typically in the metal shop. Cracks and corrosion drive up the cost of the OIF aircraft. Some examples of structural reworks are as follows.

- Flight control rod replacement/repair
- Airframe structural support, patching and repair
- Cleaning of internal and external airframe components, for example, removing sand from every crevice of the aircraft

Table 5 in the Appendix shows an eight-day Structures E&E cycle.

4. Working Cell # 4 - Assembly

The assembly cell is the next phase. The assembly cell takes 18 days, of which, seven days is spent in interior paint. While the aircraft is in interior paint, the mechanics start building up the sponsons and the tail pylon. Once the aircraft comes back from interior paint, the mechanics have 10 days to rebuild the aircraft. Since the sponsons and tail pylon are already completed, they may also be installed on the airframe.

5. Working Cell # 5 - Final Assembly

Final Assembly is the last cell, which takes 18 days. The first 11 days are spent putting finishing touches on the aircraft. The last seven days are spent in final paint where the entire exterior of the aircraft is painted. Once the aircraft is painted, it then goes to weight and balance and then on to the test line.

The test line is where maintenance pilots fly the aircraft to ensure that it performs to the specifications set forth in the Naval Aviation and Training Operations (NATOPS) Manual. Functional Check Flights (FCF) are conducted daily, testing various parts of the airframe for airworthiness. Some procedures conducted on an FCF flight are as follows.

- Engine set up
- Rotor alignment
- Autorotation
- Running landings
- Torque checks
- Rotor RPM checks

Prior to the integration of AIRSpeed into the multi-line, an aircraft spent 35 days on the test line. Since incorporating the 18-day TAKT time in each of the maintenance cells, the average aircraft now spends only 23 days on the test line. This equates to faster delivery of the finished product to the customer.[60]

D. BENEFITS OF AIRSPEED

The AIRSpeed process implemented by the multi-line three years ago has taken their 380-day TAT and reduced it to 157 days. Figure 4 shows Aircraft X118 through Aircraft X136 finishing in less than the planned time. This demonstrates the success AIRSpeed has had on FRCSW Multi-line. AIRSpeed creates predictability. Since the schedule is no longer variable than the rate of effort must be. AIRSpeed increases the rate of effort in order to meet the schedule. TAT was further reduced because FRCSW fit work packages into the amount of days that were available for each event. This increased the rate of effort dedicated toward a particular job. Essentially, FRCSW are working more products through the plant. In the past, FRCSW may have only had 10 mechanics, but under AIRSpeed, FRCSW may require 15. This addition of workers has decreased overtime. Paying 10 mechanics overtime actually became more expensive than 15 mechanics working a regular shift.

FRCSW has achieved impressive results due to point-of-use tooling, point of use publications, pre-expendable bins (PEB), kits, standard workload, and cell development. Figure 5 and 6 demonstrate the time gained from adopting lean techniques.

[60] Ron Cobb, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 12, 2008.

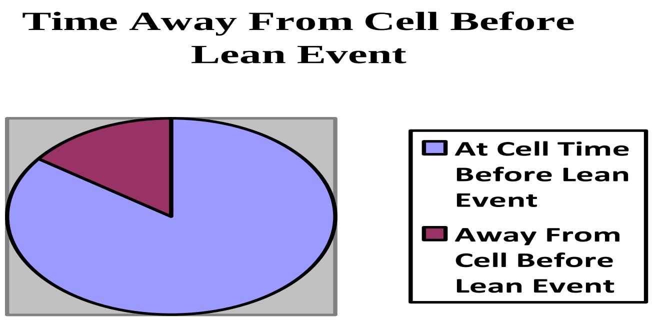

Figure 5. Artisan Time Off Aircraft is Waste.[61]

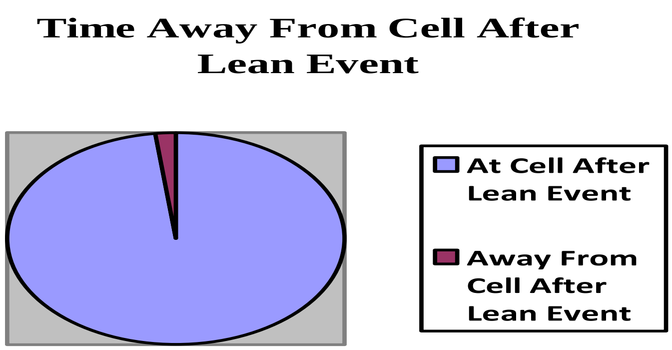

Figure 6. Reduced Off Aircraft Time After Lean.[62]

- 84.7 percent reduction in artisan walking distance for PEB
- 82.5 percent reduction in artisan walking distance for HAZMAT/Commodities
- 93.6 percent reduction in artisan walking distance for SE/IMRL Gear
- 84.2 percent reduction in artisan walking distance for Tooling
- 60.2 percent reduction in artisan walking distance for Technical Publications[63]

Industry competitors have even recognized the efficiencies that the FRC's have gained through AIRSpeed initiatives. An example of this is a contract that the program manager for the Navy H-60 program has with Raytheon. Raytheon makes the Forward

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[61] Keith Borror, "NADEP NI CH-53E PMI AIRSPEED PROGRESSION," *The Heavy Lift Quarterly*, December 2005, 12-14.

[62] Ibid.

[63] Ibid.

Looking Infrared (FLIR) System for the Navy's H-60. Raytheon has subcontracted Fleet Readiness Center Southeast (FRCSE) to complete ninety percent of the touch labor on the system installation.[64]

The addition of new and efficient processes at FRCSW Multi-line through AIRSpeed initiatives has directly resulted in eliminating their customers' concerns with regarding timeliness and cost.

[64] Paul Grosklags, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

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V. PROGRAM MANAGEMENT AIR VIEWPOINT

A. PROGRAM MANAGEMENT AIR (PMA)

NAVAIR is a United States Navy command, headquartered in Patuxent River, MD with military and civilian personnel stationed at eight principal continental United States sites and one site overseas.[65] NAVAIR is designed to provide unique engineering, development, testing, evaluation, in-service support, and program management capabilities to deliver airborne weapons systems that are technologically advanced and readily available. Using a full-spectrum approach, the command attempts to deliver optimal capability and reliability for the Sailor and the Marine.[66] NAVAIR's organizational structure is divided into six Program Executive Offices (PEO).

- PEO (A) Air ASW, Assault, & Special Mission Programs
- PEO (T) Tactical Aircraft Programs
- PEO (U&W) Unmanned Aviation & Strike Weapons
- PEO (JSF) Joint Strike Fighter
- AIR-1.0
- AIR-5.0[67]

Located within the six PEOs are aviation programs run by PMAs.

1. Program Managers Responsibilities

PMAs are responsible for full life cycle support for an aircraft from design to retirement.[68] PMAs have the responsibility of how money under their control is spent within their program. PMAs decide on what upgrades and overhauls will be done on the aircraft and who will do the work. The PMAs are responsible for submitting a budget for

[65] Naval Air Systems Command (NAVAIR), "NAVAIR Organization," Naval Air Systems Command, http://www.navair.navy.mil (accessed October 8, 2008).

[66] Ibid.

[67] Ibid.

[68] Paul Grosklags, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

their program, which becomes incorporated into the Program Objective Memorandum (POM). Funds requested within the POM are divided into specific line numbers. For instance, aircraft procurement -3 (APN-3) is used for purchasing aircraft. Many PMAs do not deal with APN-3 money because they are no longer procuring aircraft for their type/Model/series (TMS). PMAs may only be dealing with the operation and maintenance costs associated with the life cycle of the airframe. Overhauls and modifications generally fall into this category. Overhauls are conducted at the FRC as discussed previously. The money for modifications is delineated into two line numbers, APN-5 and APN-5I. APN-5 money is used to purchase modification kits and APN-5I money is used to pay for the installation of kits.[69]

2. Modification Plan

PMAs create a modification plan to retrofit all of their TMS aircraft. As an example, PMAs will buy kits with APN-5 dollars in 2008 and have them installed with APN-5I dollars in 2009. The number of kits purchased this year will equate to how many installs there will be the next year. However, many kits purchased the next year will equate to how many installs there are the year after that.[70] The modification plan drives the process of upgrading aircraft with newer systems. Each PMA has to discern the amount of installation dollars needed to have available for a particular modification, as well as, how to get it done efficiently.

3. PMA Constraints

One of the biggest constraints that PMAs face is when the dollar amount for the number of kits budgeted for one year does not equal the amount appropriated to install the kits in the subsequent year. For example, assume PMA budgets in 2008 for 24 kits to be installed in 2009, at a cost of $100 per hour. Assuming each kit requires 1,000 hours to be installed, $2.4 million are necessary to fund the installation in 2009. If the

[69] Section 1 is drawn directly from Henry Hess, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[70] Dave Kelly, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 11, 2008.

estimated cost of installation increases to $120 per hour, the PMA may only be able to afford to install 20 kits vice the original 24. Labor rates can change from year to year making it difficult to match APN-5 dollars with APN-5I dollars. It is also vital that PMAs get accurate estimates on the number of hours that a modification is going to require to budget appropriately.

4. Supplemental and Global War on Terrorism Money

After the attacks on September 11, 2001, President Bush requested a $20 billion package to fight the Global War on Terror (GWOT). Congress authorized $40 billion.[71] In addition to annual supplemental authorizations to finance the wars, many programs within DoD have been able to use GWOT money to finance projects that were not part of the POM.[72] PMAs at NAVAIR have had the ability to execute a number of modifications on their TMS aircraft using GWOT and supplemental dollars. If a particular modification could be linked to the GWOT or justified using supplemental money, than that modification would be funded and executed.[73] The supplemental authorization is being increasingly relied upon to fund recurring costs, which is not its original intent.

B. MODIFICATION PROCESS

As new technologies are developed, the need to incorporate them within existing systems increases. These modifications allow existing systems the ability to maintain leading edge capabilities without the need for replacing the entire system. The CH-53E has been in operation since 1981 and has undergone multiple upgrades from the original design.[74]

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[71] L.R. Jones and J.L. McCaffery, *Budgeting, Financial Management and Acquisition Reform in the U.S. Department of Defense* (Charlotte: Information Age Publishing Inc., 2008), 292.

[72] Ibid.

[73] Henry Hess, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[74] Wikipedia, "Ch-53E Super Stallion," http://en.wikipedia.org/wiki/CH-53E_Super_Stallion (accessed September 30, 2008).

1. Modification Kits

Once a modification is determined necessary to be introduced to the CH-53E, PMA-261 decides how many aircraft are going to get the modification. If PMA-261 decides to modify all of the airframes (152), then the piece parts are purchased from the Original Equipment Manufacturer (OEM), such as Bell. The money used to purchase kits originates from APN-5 appropriations and is usually entered into the POM in the year prior to execution. After the piece parts required to support the 152 CH-53E aircraft are received and inventoried, they are then sent to a kitting facility in Orange Park, FL. The OEM piece parts are then put into kits, and after a technical directive is issued, the kits are pushed into the field so that the aircraft can be modified.[75]

2. Completion of Modification Installations

After the kits are built and sent to the fleet, PMA-261 must determine who will perform the installation. A variety of contractors or the FRC may be used to perform the installations. Currently, PMA-261 uses contractors such as L3, BF Goodrich, as well as the FRCs for all CH-53E modifications. L3 is the primary contractor due to their low cost and their workers' familiarity with the airframe.[76]

3. Decision on Installer

The decision to determine who will be performing modification installations is a difficult one, which takes into account cost, schedule, and location of the work to be done. The best value to the customer (Program Office and the fleet) is the main concern when making the contract decision.[77] Once an initial determination is made of who will perform the work, PMA-261 will launch a Rough Order of Magnitude (ROM) to a

[75] Henry Hess, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[76] Ibid.

[77] Paul Grosklags, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

particular contractor or FRC to see how many hours it will take to complete a particular modification. The contractor or FRC will reply with an estimate, and if the PMA finds it acceptable, the PMA will contract the FRC or contractor.

Examining the contract with L3 as compared to FRCSW or FRCE, the differences in cost, schedule, and location were identified.[78] Labor rates, schedule, and location are the primary factors that guide the PMA in the decision process.

a. Labor Rates

The labor rate for L3 contractors is $52.00/hour for work completed in the field.[79] The FRCSW Multi-line labor rate is $84.38 and the FRCE labor rate is $94.52 for modification work.[80] L3 is cheaper than FRCSW and FRCE ($32.38 and $42.52, respectively), due in large part to not having any overhead costs associated with conducting modifications.[81] L3 is able to perform the required modification at the flight line or hangar at $52/hr because the fleet is responsible for paying the overhead. In contrast, the $84.38 FRCSW rate and $94.52 FRCE rate assumes the modification is performed at the FRC facilities in conjunction with a PMI event.

b. Schedule

Timing is crucial to the installation of modifications and becomes a major function in the decision-making process. Marine Corps CH-53E squadrons typically detach airplanes out to units, such as an Aviation Combat Element (ACE), which is part of a Marine Expeditionary Unit (MEU), or they may send a four-plane detachment to various locations around the world, such as the Horn of Africa. Non-deployed CH-53E squadrons operate with a minimal amount of aircraft. The PMA's goal is to maximize

[78] Henry Hess, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[79] Cameron Isaac, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[80] Ron Cobb, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, 12 August 2008.

[81] Ibid.

the amount of time the fleet has the aircraft in a reporting status. Between PMI events, the service life of the CH-53E is 54 months. At the end of 54 months, the aircraft go out of a reporting status and are sent to its respective FRC for a PMI event. If modifications between PMI events are needed, the modifications reduce the amount of training time usable within the service life because of the downtime required for the installation. Reducing the number of aircraft available for training puts an increased strain on the squadron and remaining aircraft. A balance is found in modifying aircraft and using them for operational commitments. Priority for modification work goes to aircraft that are part of a MEU or are deploying to a wartime theater. Aircraft currently deployed may receive their modifications once they return home.[82]

c. Location of Work

The location of the installation work is important in the decision-making process because moving an aircraft to and from a production location adds to the time it takes to complete the installation. If the aircraft has to be moved, it potentially adds one day for transport and one day for preparation before work can begin. This would occur if an aircraft was moved from the squadron to the FRC for modification work. If installations can be done on-site then an aircraft can be readied one day and worked on by contractors the next day.

C. SUMMARY

This chapter described the process of how modifications are budgeted, built, and installed. Through interviews, the variables affecting the PMA's decisions were determined with regard to modifications including the needs of the fleet, labor rates, schedule, constraints, and location of work. All of these factors must be considered when determining best value to the customer.

[82] Section b is a summary drawn directly from Henry Hess, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

VI. COMPARISON OF CONTRACTOR VS. FRCSW

A. FACTORS AFFECTING CHOICE OF PROVIDER

There are multiple factors to be considered when choosing among FRCs and civilian contractors. The decision must balance the cost and timing of work including where the work is accomplished. Additionally, perceptions regarding the provision of service by either FRCSW or contractors are relevant.

1. Labor Rates

Cost is the leading factor in the decision to use contractors for modification installations. The civilian contractor holds the advantage because a contractor may be able to quote a lower price. In the case of L3, approximately a $52/hour labor rate is set because they have few overhead costs related to the installations. This is a direct result of being able to conduct the modification work at the hangar where the aircraft are kept. [83] FRCs have higher overhead costs associated with their labor rates. FRCSW is approximately $84/hour and FRCE is approximately $94/hour. This results from having to do the work done at the FRC's location vice the aircraft's location.[84]

2. Schedule

The time in which the work is completed is important because the need for modification installations can vary from year to year. Civilian contractors hold an advantage in that they can go to the squadron when a modification is necessary. They also have the benefit of having skilled labor only performing modification work vice other maintenance work. This allows them to focus solely on improving their efficiency

[83] Henry Hess, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[84] Cameron Isaac, Interviewed by Bryan McKernan Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

in installing modifications. For example, L3 initially installed the Blue Force Tracker upgrade in two weeks. As L3 became more proficient with the installation, L3 reduced the installation time to seven days.[85]

Another advantage the contractor has over the FRC is that the contractor can potentially perform the modification on more than 24 aircraft per year. Each FRC is limited in that it can only do PMI events on 12 aircraft per year whereas the contractor is not limited. If a modification installation is included in the PMI event then this results in only 24 aircraft being available for upgrade in any given calendar year.

One advantage in using the FRC for installations is that the modification can be done concurrently with a PMI event. During the PMI event, the aircraft is out of service and may require 12,000 hours of work. If a modification is incorporated with this event, it may increase the hour's requirement to 14,000 hours. FRCSW's AIRSpeed initiatives have allowed the PMI event, no matter the hour's requirement, to be completed on schedule.[86] This means that an aircraft could be completed with all of the necessary upgrades in less than 180 days by increasing the resources used to complete the job. The aircraft comes out of the FRC and back to the fleet ready for operations. The aircraft does not need to be taken out of service for the modification once it is returned to the squadron.

3. Location of Work

The location of the modification installation affects both cost and schedule. By having the modification installation occur at an FRC, increased time is incurred to account for transporting the aircraft to and from the FRC. Additionally, since FRC's have a higher overhead rate than contractors who perform modification installations at the flight line, a higher labor rate will be paid to perform the installation at the FRC. The contractor has the advantage in that it is possible to use maintenance personnel from the

[85] Section 2 is a summary drawn directly from Henry Hess. Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[86] Dave Kelly, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 11, 2008.

squadron to ready the aircraft for modification work the day prior to contractor work beginning. The contractor can then complete the modification installation on the flight line and give the aircraft back to the customer in the same day. This process is repeated as the contractor moves from one aircraft to the next on the flight line.

4. Perceptions

Decision makers perceptions of different organizations affect how decisions are made.[87] On the one hand, the civilian contractors, particularly L3, are seen as particularly efficient and effective at PMA-261. Their ability to perform aircraft modifications in a timely and cost effective manner has helped them to be the preferred source for future aircraft modifications. On the other hand, Naval Aviation Depots (NADEPs) have been criticized for their inability to complete projects in a timely manner. The quality was never in question, but schedule slippage and cost overrun were seen as the norm.[88] When NADEPs became FRCs during the restructuring in 2005, those individuals who had experienced the problems with NADEPs, continued to have concerns.[89] The FRCSW Multi-line division contributed to these concerns, prior to AIRSpeed, by having an average completion time of greater than 300 days. Currently, FRCSW is completing aircraft in as little as 154 days.[90]

The use of contractors to execute modifications contributes to the concerns regarding the FRCs. Aircraft immediately going into a modification installation phase by L3 on the flight line after returning from the FRC reinforces the poor impression of FRCs. Some in the fleet may see it as the FRC not being competent enough to perform a modification installation. They individuals may not understand that it is less expensive to

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[87] Stephan P. Robbins, Organization Behavior: Perception and Individual Decision Making (Pearson Education Prentice Hall, 2008).

[88] Henry Hess, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[89] Paul Grosklags, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[90] Dave Kelly, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 11, 2008.

use the contractor to perform the upgrade. They only see the aircraft as unavailable for a longer period of time because the modification was not completed while the FRC was performing a PMI.[91]

Some individuals have also been told that the addition of modification work to a PMI event will cause the schedule to be delayed and the FRC will not be able to deliver the finished product on time.[92] The author's research shows that given the AIRSpeed initiatives performed at FRCSW, this belief is unfounded. By providing more resources for aircraft, the FRC can achieve the desired results without impacting the schedule.[93] Costs will be higher because the rate FRC charges is higher, but no additional work will be required when the aircraft is returned to the fleet.

An additional advantage to using the FRC for modification work is that they can become proficient on the latest upgrades to the aircraft and stay competitive with industry. Since the FRC is performing work on each CH-53E on or about every 54 months, FRCs need to know what new systems are being added to the aircraft and how those systems operate. This would help FRC to keep their completion time low because FRC artisans would already understand the new systems when a PMI event is scheduled.

[91] Dave Kelly, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 11, 2008.

[92] Henry Hess, Interviewed by Bryan McKernan, Naval Air Systems Command, Patuxent River, Maryland, September 30, 2008.

[93] Dave Kelly, Interview by Bryan McKernan and Erik Herrmann, Fleet Readiness Center Southwest, San Diego, California, August 11, 2008.

	Civilian Contractor	**Fleet Readiness Center**
COST	**Advantage**: $52/hour (no overhead)	**Disadvantage**: $84-$94/hour
	Advantage: Can do unlimited number of aircraft per year	**Disadvantage**: Can only work 24 aircraft per year
TIME	**Advantage**: They come to you	**Disadvantage**: Work done at FRC
	Advantage: Artisans working solely on modification	**Disadvantage**: Artisans responsible for entire aircraft
	Disadvantage: Only modification work is being done.	**Advantage**: modification can be done concurrently with PMI
	Disadvantage: Time aircraft spends out of service increased	**Advantage**: No additional out of service time when done with PMI event.
LOCATION OF WORK	**Advantage:** Can return modified aircraft to customer and begin work on next aircraft in same day.	**Disadvantage:** must complete entire PMI before returning aircraft to customer.
	Advantage: Can use labor of maintenance personnel to prep aircraft / less overhead for contractor.	**Disadvantage:** higher rate due to higher overhead costs.
PERCEPTION	**Advantage**: Confidence level high with respect to performance	**Disadvantage**: Confidence level still low due to poor performance before AIRSpeed
	Advantage: Confidence level high with respect to timeliness of modification	**Disadvantage**: Belief that modification work will increase schedule
		Disadvantage: Fleet concern because aircraft are out of service for PMI and separate modification work
		Advantage: Keeping work inside DoD keeps FRC up to date with new technologies

Table 3. Comparison of Contractor vs. FRC

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VII. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

The primary purpose of this project is to answer the question why are the FRCs not getting more CH-53E modification work when they have the capacity/capability to complete the work? This study also determines who is best suited and what the best process is to complete modification work on the CH-53 aircraft. FRCSW was the primary FRC studied along with labor rates from FRCE. PMA-261, APML, for the CH-53 program, was interviewed along with the Commander of all six FRCs. Cost, timing, location of work, and perception were the critical areas revealed from the author's research affecting the answer to the primary research question. Participants in the process have different views of how to best serve the customer. The purpose is to present recommendations on how to serve the customer best from an independent third party's viewpoint based on the analysis of the data gathered for this project.

Modifications occur at varying times during the year. As previously noted, the program office budgets for modifications annually. By analyzing costs and time schedules, PMA-261 determines the best value for the customer and then decides how best to begin modifying the aircraft. Ideally, the best time to modify an aircraft is when the fleet cannot use it for operations. This time period comes every 54 months when the aircraft is at an FRC for a PMI event. By modifying aircraft during the PMI event, the aircraft would come back to the fleet with the PMI and all necessary modifications completed. The modification could be conducted concurrently with the PMI event and while still meeting the 180-day TAT. This method eliminates the additional down time of the aircraft because an aircraft would not have to come out of a 180-day PMI at the FRC and then immediately enter into a modification phase on the flight line. One FRC per coast maintains the CH-53E aircraft. Both FRCs are capable of performing 12 PMI events per year for the CH-53 community. This means in any given year only 24 aircraft are available to receive the modification concurrent with a PMI event.

When using a contractor to complete the modification installation, such as L3, the squadron personnel ready the aircraft and then contractors come in and perform the modification work. The down time of the aircraft is the amount of time it takes the contractors to install the modification. The aircraft is then returned to the squadron days or weeks later with the new modification incorporated. This method may be preferred when the aircraft is not due for a PMI event, the modification is required immediately, and/or the contracted company can perform the work less expensively than the FRC.

B. PRIMARY QUESTION

1. Is It in the Best Interest of the United States Marine Corps to Utilize Fleet Readiness Centers to Conduct More CH-53E Modification Work?

Based on the data, FRCSW has achieved capacity/capability to complete modification work through AIRSpeed. The cost data, however, does not justify using FRCs to complete modification work when L3 is less expensive. Cost is a constraint in any program. However, if an aircraft is already out of service, then that would be the best time to install any new modifications available. From the author's perspective, as aviators, the money saved by using contractors does not make up for the time lost to the fleet.

C. SECONDARY QUESTION

1. Can the FRCs Conduct Modifications in Conjunction with a PMI Event in the 180-day TAT?

The results from the interviews conducted indicate that individuals who have previous experience with FRCs do not have confidence in the FRC's ability to produce aircraft in a timely manner. The idea of contracting FRCs to do simple or complex modifications is said to be more expensive and more time consuming. The cost issue cannot be disputed; the FRCs are more expensive. Time can be a factor in the PMA's review. Since 2005, FRCSW has reduced their TAT from 380 days to 180 days with the last few aircraft coming in at less than 160 days. Adoption of AIRSpeed is the driving factor in this accelerated TAT. Under AIRSpeed, time is not a factor; the rate of effort is. If more work needs to be done to complete a job on time then the rate of effort is increased. This was a key finding discovered in the research. The cost to conduct the modification at an FRC may be $30-$40 more expensive than using L3, but there is no additional time lost. Time lost to the fleet can have more of an impact than cost.

D. RECOMMENDATIONS

1. PMA's Need to Reexamine the FRC's Capabilities

The FRCs have come a long way in the past three years. It is evident from the research conducted that they are competitive with industry and industry is starting to recognize their abilities as mentioned in the Raytheon/FRCSE example. Benefits to keeping the work in house is that finished products are produced in a timelier manner and the knowledge base is reinforced within the DoD.

2. PMA-261 Should Have FRCSW and FRCE Install All Available Modifications in Conjunction with the 24 Annually Scheduled PMI Events

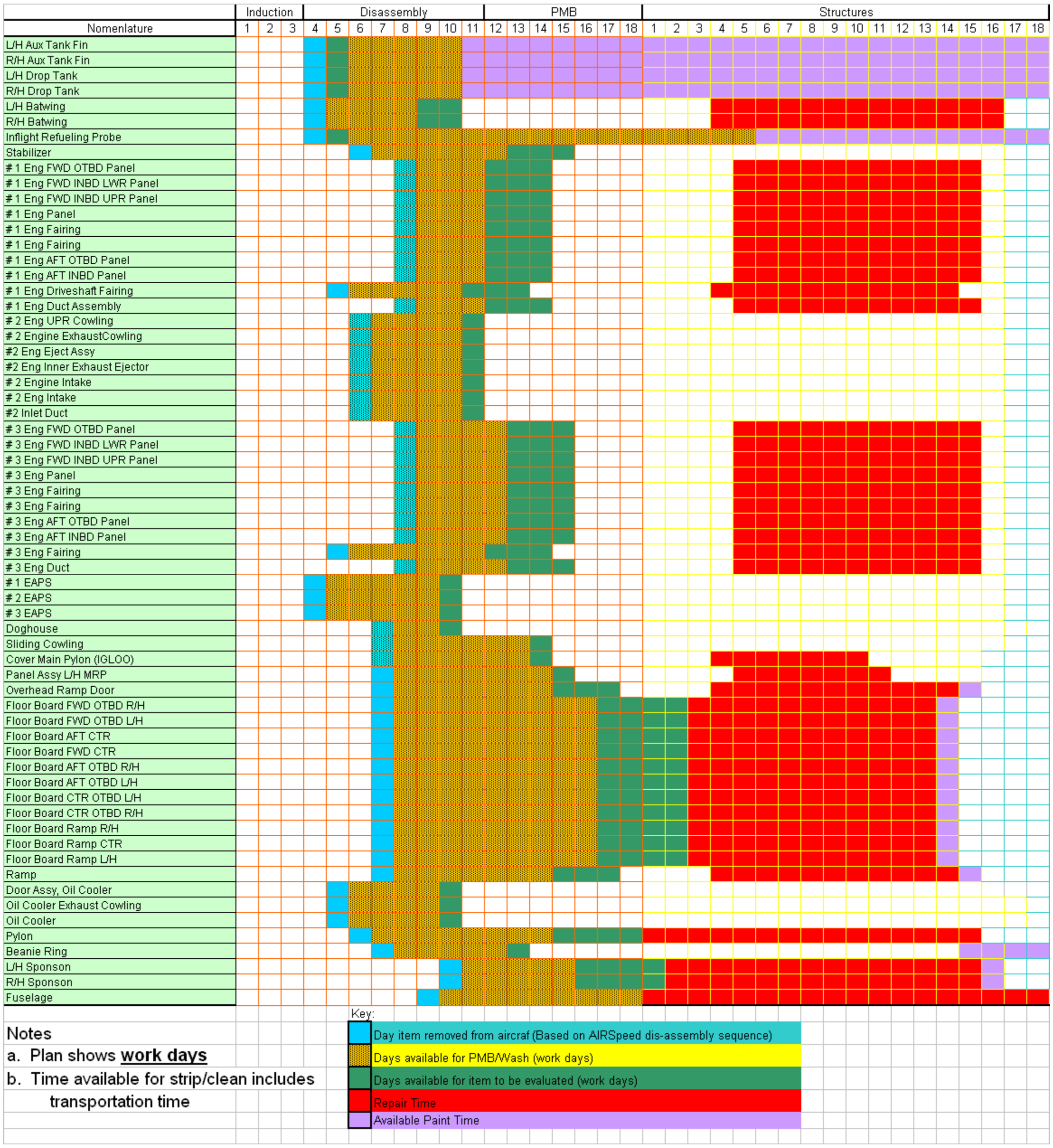
The fleet will be better served if all available modifications are conducted in conjunction with the scheduled PMI events. Since only 24 aircraft can be completed by FRC's in a given year, contractors should be utilized for the aircraft not undergoing a PMI.

E. FURTHER ANALYSIS QUESTIONS

1. What is the Cost to the Fleet to Have an Aircraft Out of Service for One Day?

The cost of an aircraft lost to modification work is difficult to quantify. Numbers of available aircraft are factored into training plans and arguably, more aircraft means more training. Costs of maintenance, personnel, available flight hours, and readiness are all factors that need to be calculated to determine the total cost to the fleet. The calculation of the aforementioned factors is beyond the scope of this study.

APPENDIX.


Induction
Disassembly
PMB
Structures
Nomenlature
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
L/H Aux Tank Fin
R/H Aux Tank Fin
L/H Drop Tank
R/H Drop Tank
L/H Batwing
R/H Batwing
Inflight Refueling Probe
Stabilizer
1 Eng FWD OTBD Panel
1 Eng FWD INBD LWR Panel
1 Eng FWD INBD UPR Panel
1 Eng Panel
1 Eng Fairing
1 Eng Fairing
1 Eng AFT OTBD Panel
1 Eng AFT INBD Panel
1 Eng Driveshaft Fairing
1 Eng Duct Assembly
2 Eng UPR Cowling
2 Engine ExhaustCowling
#2 Eng Eject Assy
#2 Eng Inner Exhaust Ejector
2 Engine Intake
2 Eng Intake
#2 Inlet Duct
3 Eng FWD OTBD Panel
3 Eng FWD INBD LWR Panel
3 Eng FWD INBD UPR Panel
3 Eng Panel
3 Eng Fairing
3 Eng Fairing
3 Eng AFT OTBD Panel
3 Eng AFT INBD Panel
3 Eng Fairing
3 Eng Duct
1 EAPS
2 EAPS
3 EAPS
Doghouse
Sliding Cowling
Cover Main Pylon (IGLOO)
Panel Assy L/H MRP
Overhead Ramp Door
Floor Board FWD OTBD R/H
Floor Board FWD OTBD L/H
Floor Board AFT CTR
Floor Board FWD CTR
Floor Board AFT OTBD R/H
Floor Board AFT OTBD L/H
Floor Board CTR OTBD L/H
Floor Board CTR OTBD R/H
Floor Board Ramp R/H
Floor Board Ramp CTR
Floor Board Ramp L/H
Ramp
Door Assy, Oil Cooler
Oil Cooler Exhaust Cowling
Oil Cooler
Pylon
Beanie Ring
L/H Sponson
R/H Sponson
Fuselage
Key:
Day item removed from aircraf (Based on AIRSpeed dis-assembly sequence)
Days available for PMB/Wash (work days)
Days available for item to be evaluated (work days)
Repair Time
Available Paint Time
Notes
a. Plan shows work days
b. Time available for strip/clean includes
transportation time

	Interior Paint	Assembly	Final Assembly	Final Paint
Nomenlature	1 2 3 4 5 6 7	8 9 10 11 12 13 14 15 16 17 18	1 2 3 4 5 6 7 8 9 10 11	12 13 14 15 16 17 18
L/H Aux Tank Fin				Installed on Fuselage
R/H Aux Tank Fin				
L/H Drop Tank				
R/H Drop Tank				
L/H Batwing				Installed on Fuselage
R/H Batwing				Installed on Fuselage
Inflight Refueling Probe				
Stabilizer				Installed on Fuselage
# 1 Eng FWD OTBD Panel				Installed on Fuselage
# 1 Eng FWD INBD LWR Panel				Installed on Fuselage
# 1 Eng FWD INBD UPR Panel				Installed on Fuselage
# 1 Eng Panel				Installed on Fuselage
# 1 Eng Fairing				Installed on Fuselage
# 1 Eng Fairing				Installed on Fuselage
# 1 Eng AFT OTBD Panel				Installed on Fuselage
# 1 Eng AFT INBD Panel				Installed on Fuselage
# 1 Eng Driveshaft Fairing				Installed on Fuselage
# 1 Eng Duct Assembly				Installed on Fuselage
# 2 Eng UPR Cowling				Installed on Fuselage
# 2 Engine ExhaustCowling				Installed on Fuselage
#2 Eng Eject Assy				
#2 Eng Inner Exhaust Ejector				
# 2 Engine Intake				Installed on Fuselage
# 2 Eng Intake				Installed on Fuselage
#2 Inlet Duct				Installed on Fuselage
# 3 Eng FWD OTBD Panel				Installed on Fuselage
# 3 Eng FWD INBD LWR Panel				Installed on Fuselage
# 3 Eng FWD INBD UPR Panel				Installed on Fuselage
# 3 Eng Panel				Installed on Fuselage
# 3 Eng Fairing				Installed on Fuselage
# 3 Eng Fairing				Installed on Fuselage
# 3 Eng AFT OTBD Panel				Installed on Fuselage
# 3 Eng AFT INBD Panel				Installed on Fuselage
# 3 Eng Fairing				Installed on Fuselage
# 3 Eng Duct				Installed on Fuselage
# 1 EAPS				Installed on Fuselage
# 2 EAPS				Installed on Fuselage
# 3 EAPS				Installed on Fuselage
Doghouse				Installed on Fuselage
Sliding Cowling				Installed on Fuselage
Cover Main Pylon (IGLOO)				Installed on Fuselage
Panel Assy L/H MRP				Installed on Fuselage
Overhead Ramp Door				Installed on Fuselage
Floor Board FWD OTBD R/H				Installed on Fuselage
Floor Board FWD OTBD L/H				Installed on Fuselage
Floor Board AFT CTR				Installed on Fuselage
Floor Board FWD CTR				Installed on Fuselage
Floor Board AFT OTBD R/H				Installed on Fuselage
Floor Board AFT OTBD L/H				Installed on Fuselage
Floor Board CTR OTBD L/H				Installed on Fuselage
Floor Board CTR OTBD R/H				Installed on Fuselage
Floor Board Ramp R/H				Installed on Fuselage
Floor Board Ramp CTR				Installed on Fuselage
Floor Board Ramp L/H				Installed on Fuselage
Ramp				Installed on Fuselage
Door Assy, Oil Cooler				
Oil Cooler Exhaust Cowling				Installed on Fuselage
Oil Cooler				Installed on Fuselage
Pylon				Installed on Fuselage
Beanie Ring				Installed on Fuselage
L/H Sponson				Installed on Fuselage
R/H Sponson				Installed on Fuselage
Fuselage	Interior Paint			Installed on Fuselage

Key:

- Day item removed from aircraf (Based on AIRSpeed dis-assembly sequence)
- Days available for PMB/Wash (work days)
- Days available for item to be evaluated (work days)
- Repair Time
- Available Paint Time

Notes

a. Plan shows **work days**

b. Time available for strip/clean includes transportation time

Table 4. Master Work Sequence Schedule Example

CT	1	2	3	4	5	6	7	8
A E & E	Evaluate Zone 3 of E/E phase Aircraft			Evaluate Zone 2 of E/E Phase Aircraft				
	St	Fi		St		Fi		
B E & E	Evaluate Zone 3 of E/E phase Aircraft			Evaluate Zone 2 of E/E Phase Aircraft				
	St	Fi		St		Fi		
C E & E	Evaluate Zone 2 of E/E phase Aircraft					Write Up & Issue Zone 2 Discrepancy Write Ups	Write Up & Issue Zone 2 & 3 Discrepancy Write Ups	Write Up & Issue Zone 2 & 3 Discrepancy Write Ups
	St		Fi			St Fi	St Fi	St Fi
D E & E	Evaluate Zone 5 of E/E Phase Aircraft				Write Up & Issue Zone 5 Discrepancies	Evaluate Zone 6 of E/E Phase Aircraft	Write Up & Issue Zone 6 Discrepancies	Evaluate Zone 9 of E/E Phase Aircraft
	St		Fi		St Fi	St Fi	St Fi	St Fi
E E & E	Evaluate Zone 5 of E/E Phase Aircraft				Write Up & Issue Zone 5 Discrepancies	Evaluate Zone 7 of E/E Phase Aircraft	Write Up & Issue Zone 7 Discrepancies	Evaluate Zone 9 of E/E Phase Aircraft
	St		Fi		St Fi	St Fi	St Fi	St Fi
F E & E	Evaluate Zone 1 of E/E Aircraft			Write Up & Issue Zone 1 Discrepancies	Evaluate Zone 8L of E/E Phase Aircraft	Evaluate Zone 8R of E/E Phase Aircraft	Write Up & Issue Zone 8L & 8R Discrepancy Write Ups	Write up & Issue Zone 9 Discrepancies
	St	Fi		St Fi	St Fi	St Fi	St Fi	St Fi
G E & E	LIAISON							

Table 5. Structures Examination & Evaluation 8-Day Sequence Example

Artisan	Target Flow	86	87	88	91	92	93	94	95
	CT	1	2	3	4	5	6	7	8
	Date	1-May	2-May	5-May	6-May	7-May	8-May	9-May	12-May
Sponsons		Sponson Barrel Nuts and Dump Pump	Sponson Liners		L/H Sponson Foam	Seal and Tape Sponson Liners		L/H FWD Fuel Bladder	L/H FWD Race Track Panel Breakaway Valves
		St Fi	St Fi		St Fi	St Fi		St Fi	St Fi
		A8L0, A8R0	A8L9, A8R9						A8L1, A8L3
		Sponson Barrel Nuts and Dump Pump	Sponson Liners		R/H Sponson Foam		Batwing Panels	L/H AFT Fuel Bladder	L/H FWD Race Track Panel Breakaway Valves
		St Fi	St Fi		St Fi		St Fi	St Fi	St Fi
		A8L0, A8R0	A8L9, A8R9				A8LA, A8RA		A8L1, A8L3
							Batwing Panels	R/H FWD Fuel Bladder	R/H FWD Race Track Panel Breakaway Valves
							St Fi	St Fi	St Fi
							A8LA,A8RA		A8R1, A8R3
								R/H AFT Fuel Bladder	R/H FWD Race Track Panel Breakaway Valves
								St Fi	St Fi
									A8R1, A8R3
A								Prep Oil Cooler	
								St Fi	
B					Prep Floorboards			Prep Oil Cooler	
					St Fi			St Fi	
C		Assemble Mixer	Prep TQ Tubes		Prep Floorboards		Build-Up Drive Shafts		
		St Fi	St Fi		St Fi		St Fi		
		A5C1	A101				A301		

98	99	100	101	102	105	106	107	108	109	
9	10	11	12	13	14	15	16	17	18	
13-May	14-May	15-May	16-May	19-May	20-May	21-May	22-May	23-May	27-May	
L/H FWD Scupper and Inner Supports	L/H FWD Plumbing		L/H Sponson Panels	Install L/H Sponson	L/H Fwd Probes and Level Sensor	L/H Dump System	L/H Gap Panels	Install L/H Batwing		
A8L2, A8L3	A8L1, A8L2					A8L7				
L/H AFT Scupper and Inner Supports	L/H AFT Plumbing		R/H Sponson Panels	Install L/H Sponson	L/H AFT Probes and Level Sensor		R/H Gap Panels	Install L/H Batwing		
A8L4, A8L3	A8L1, A8L4									
R/H FWD Scupper and Inner Supports				Install R/H Sponson	R/H Fwd Probes and Level Sensor			Install L/H Batwing		
A8R2, A8R3										
R/H AFT Scupper and Inner Supports				Install R/H Sponson	R/H AFT Probes and Level Sensor					
A8R4, A8R3										
	FWD and AFT Hook Supports	Igloo, Folding Doghouse, Sliding Doghouse, APP and Accesory Drive Shafts			Install Ramp	Tail Driveshafts and Sell Tunnel D/S Panels			Zone 9 Cowlings, Exhaust and Close Zone	
	A2C1	A5C3			A306	A3C3			A902, A903, A904	
	FWD and AFT Hook Supports	Igloo, Folding Doghouse, Sliding Doghouse, APP and Accesory Drive Shafts			Install Ramp	Tail Driveshafts and Sell Tunnel D/S Panels			#1 and #3 Engine Exhausts	
	A2C1	A5C3			A306	A3C3			A605, A705	
Input D/S Cowlings and Alignment						Input Drive Shafts and OTC Cowling		Zone 6 Nacelles and Close Zone		
A604, A5R1								A602, A605		

Table 6. Assembly 18-Day Sequence Example

Artisan	Target Flow	112	113	114	115	116	119	105	106	107	108	111
	CT	1	2	3	4	5	6	7	8	9	10	11
	Date	28-May	29-May	30-May	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	9-Jun	10-Jun	11-Jun
A		Fi	Clean and Sell Cockpit (St)	(Fi)	Clean / Sweep Zone 2 (St)	(Fi) A202		Grease Aircraft (St, Fi)	Purify Hyd Systems			
B		Zone 1 Panels and Seats (St) AIC1, AIL1, AIR1	(Fi)	Clean Zone 3 (St, Fi)	Clean / Sweep Zone 2 (St)	(Fi) A202		Grease Aircraft (St, Fi)	Jack and Cycle Operation (St)	(Fi)		Pylon Fold / Service Util. (St, Fi)
C		Zone 1 Panels and Seats (St) AIC1, AIL1, AIR1	(Fi)	Clean Zone 3 (St, Fi)	HYD Power / Leak Check (Util., No. 1, No. 2 Systems) (St)		(Fi)		Jack and Cycle Operation (St)	(Fi)		Pylon Fold / Service Util. (St, Fi)

Artisan	Target Flow	112	113	114	115	118	119	120
	CT	12	13	14	15	16	17	18
	Date	12-Jun	13-Jun	16-Jun	17-Jun	18-Jun	19-Jun	20-Jun
A		Fuselage To Final Paint						
B								
C								

Table 7. Final Assembly 18-Day Sequence Example

Inflow																												
CT	1				2				3				4				5				6				7			
Date																												
Hour	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8	2	4	6	8
A ASI	Open Fuel Panels	Press Indicator Checks		Work Mafs	Prep Main Rotor Blades	Install and Sell MRB		Bleed and Service MRH	Bleed and Service Ist Stage	Bleed and Service 2nd Stage	Bleed and Service Utility	Bleed and Service Eng Start	Flight Control Rig Check	Main Rotor Blade Angles		Tail Rotor Blade Angles	Stick Jumps	Safety Wire M/R Servos	Prep Engines For 4 PT Plots	PCR / Damper Bearing Check	Rig Engines		Check and Sell Blade Fold OP		Install Vibe Gear	Compass Swing	Paint Touch-U	
	St Fi	St	Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St	Fi	St Fi	St Fi	St	Fi
B ASI	Inspect Fuel System Security	Refuel Op Check		Work Mafs	Prep Main Rotor Blades	Install and Sell MRB		Bleed and Service MRH	Bleed and Service Ist Stage	Bleed and Service 2nd Stage	Bleed and Service Utility	Bleed and Service Eng Start	Flight Control Rig Check	Main Rotor Blade Angles		Tail Rotor Blade Angles	Stick Jumps	Roll Damp Check	Prep Engines For 4 PT Plots	PCR / Damper Bearing Check	Rig Engines	Deprez Engines	Check and Sell Blade Fold OP		Install Vibe Gear	Compass Swing	Paint Touch-U	
	St Fi	St	Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St	Fi
C Mech	Inspect Fuel System Security	Refuel Op Check		Work Mafs	Prep Main Rotor Blades	Install and Sell MRB		Sell Eng FOD Checks	Bleed and Service Ist Stage	Bleed and Service 2nd Stage	Bleed and Service Utility	Bleed and Service Eng Start	Flight Control Rig Check	Main Rotor Blade Angles		Tail Rotor Blade Angles	Stick Jumps	Balance Spring Check	Prep Engines For 4 PT Plots	PCR / Damper Bearing Check	Rig Engines	Deprez Engines	Check and Sell Blade Fold OP		Install Vibe Gear	Compass Swing	Paint Touch-U	
	St Fi	St	Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St	Fi
D Mech	Inspect Fuel System Security	Fuel Dump Check		APP Light Off	Prep Main Rotor Blades	Install and Sell MRB		Sell Eng FOD Checks	Bleed and Service Ist Stage	Bleed and Service 2nd Stage	Bleed and Service Utility	Bleed and Service M/L/G Struts	Sell and Install Fuel Panels	Main Rotor Blade Angles		Safety Wire Stops	Stick Jumps	Check NG / NF Adj	Prep Engines For 4 PT Plots	PCR / Damper Bearing Check	Rig Engines	Deprez Engines	Check and Sell Blade Fold OP		Install Vibe Gear	Compass Swing	Paint Touch-U	
	St Fi	St	Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St	Fi
E AVI	Inspect Fuel System Security	Fuel Dump Check		Install Loose Gear	Service MRH D/A	Install and Sell MRB		Sell Eng FOD Checks	Bleed and Service Ist Stage	Bleed and Service 2nd Stage	Bleed and Service Utility	Service Tires	Sell and Install Fuel Panels	Main Rotor Blade Angles		Safety Wire PCL's	COMM, NAV and ICS Checks	Transducer Checks	Accel / FAS Null	Hard Over Checks	Rig Engines	Deprez Engines	Check and Sell Flight Control		Install Vibe Gear	Compass Swing	Paint Touch-U	
	St Fi	St	Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St	Fi	St Fi	St Fi	St	Fi

8		9			10			11	12-17			18	
2 4	6 8	2	4	6 8	2	4	6 8	2 4 6 8	2	4 6	8	2 4	6 8
D & T	Tail Balance	Flat Track	Set Eng	Profile "A" Checks	Pull Samples	CAD Install	Document Closure	"Dash" 6 Sell	D & T	Track and Balance	Oil Samples	Sell Ferry Turn Around	Document Closure
St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi
D & T	Tail Balance	Flat Track	Set Eng	Profile "A" Checks	Pull Samples	Tail Blade Sealant	Update QA Test Data Book	"Dash" 6 Sell	D & T	MAD Cal	Oil Samples	Sell Ferry Turn Around	Document Closure
St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi
D & T	Tail Balance	Flat Track	Set Eng	Profile "A" Checks	Pull Samples	Tail Blade Sealant		"Dash" 6 Sell	D & T	120 Vibes	Oil Samples	Sell Ferry Turn Around	Document Closure
St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi		St Fi	St fi	St Fi	St Fi	St Fi	St Fi
D & T	Tail Balance	Flat Track	Set Eng	Profile "A" Checks	Pull Samples	Safety Wire PCRs		"Dash" 6 Sell	D & T	Eng Plots	Oil Samples	Sell Ferry Turn Around	Document Closure
St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi		St Fi	St Fi	St Fi	St Fi	St Fi	St Fi
D & T	Tail Balance	Flat Track	Set Eng	Profile "A" Checks	Pull Samples	Safety Wire PCRs		"Dash" 6 Sell	D & T	"B" Card	Oil Samples	Sell Ferry Turn Around	Document Closure
St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi		St Fi	St Fi	St Fi	St Fi	St Fi	St Fi

Inflow													
CT	8		9			10			11	12-17			18	
Date														
Hour	2 4	6 8	2	4	6 8	2	4	6 8	2 4 6 8	2	4 6	8	2 4	6 8
A ASI	D & T	Tail Balance	Flat Trac	Set Eng	ofile "A" Chec	Pull Samples	CAD Install	Document Closure	"Dash" 6 Sell	D & T	Track and Balance	Oil Samples	Sell Ferry Turn Around	Document Closure
	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi
B ASI	D & T	Tail Balance	Flat Trac	Set Eng	ofile "A" Chec	Pull Samples	Tail Blade Sealant	Update QA Test Data Book	"Dash" 6 Sell	D & T	MAD Cal	Oil Samples	Sell Ferry Turn Around	Document Closure
	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi
C Mech	D & T	Tail Balance	Flat Trac	Set Eng	ofile "A" Chec	Pull Samples	Tail Blade Sealant		"Dash" 6 Sell	D & T	120 Vibes	Oil Samples	Sell Ferry Turn Around	Document Closure
	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi		St Fi	St fi	St Fi	St Fi	St Fi	St Fi
D Mech	D & T	Tail Balance	Flat Trac	Set Eng	ofile "A" Chec	Pull Samples	Safety Wire PCRs		"Dash" 6 Sell	D & T	Eng Plots	Oil Samples	Sell Ferry Turn Around	Document Closure
	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi		St Fi	St Fi	St Fi	St Fi	St Fi	St Fi
E AVI	D & T	Tail Balance	Flat Trac	Set Eng	ofile "A" Chec	Pull Samples	Safety Wire PCRs		"Dash" 6 Sell	D & T	"B" Card	Oil Samples	Sell Ferry Turn Around	Document Closure
	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi	St Fi		St Fi	St Fi	St Fi	St Fi	St Fi	St Fi

Table 8. Test Line 18-Day Sequence Example

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