

Challenging the Sacred Assumption: A Call for a Systemic Review of Army Aviation Maintenance

A Monograph

by

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Abstract

Challenging the Sacred Assumption: A Call for a Systemic Review of Army Aviation Maintenance, by COL Richard A. Martin, USA, 39 pages.

In 2016, the Army Chief of Staff directed the formation of the Holistic Aviation Assessment Task Force (HAATF) to review all aspects of Army Aviation. The HAATF followed the 2013 Aviation Restructuring Initiative (ARI) that sought to maximize and protect the aviation modernization budget. The HAATF focused on leadership, readiness, training, maintenance and sustainment policy, and resources, to ensure the Combat Aviation Brigades were capable of operating in complex environments around the globe. ARI and the HAATF were the latest in a series of comprehensive reviews of Army Aviation over the past 20 years. Typically, these reviews are initiated by a significant shift in Army budgets and are focused on force structure, training, equipping and sustainment. Each study intends to optimize the force structure to achieve a balance between the modernization and operational budgets. Since 1994, Army Aviation force structures, training resources, available equipment and aircraft have changed significantly. Yet, none of these studies has produced the long-term efficiencies or affordability promised. The reason for this failure is the one thing that has not changed; how the Army maintains its aircraft.

The research analyzed the cause of the Army's consistent failures by studying the four most recent studies. Through a simple review, it became clear that while the studies varied slightly their results were very similar. More importantly, no study pursued any systemic analysis of the larger maintenance system. To find new, innovative ways to solve Army Aviation's problems of affordability, the data suggests that the Army must finally consider a systemic analysis of the larger maintenance system. This systemic analysis requires the Army to first challenge its basic maintenance assumption that the maintenance process remains valid. By changing the way Army Aviation views its maintenance process, the enterprise can objectively evaluate the merits of a new approach. This new approach, as described in the HAATF, requires a philosophy of Reliability Centered Maintenance (RCM) and a methodology similar to the civilian industry best practice of Maintenance Steering Group-3 (MSG-3). Together, RCM and MSG-3 provide the best opportunity to significantly reduce Army Aviation's operational costs. Beginning this transition to RCM will enable Army Aviation to develop an affordable and sustainable Future Vertical Lift aircraft.

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Introduction

Every assumption we hold, every claim, every assertion, every single one of them must be challenged

—GEN Mark Milley, “Radical Change is Coming: General Mark Milley Not Talking About Just Tinkering Around the Edges”

In January 2016, following several high-profile fatal aviation accidents, the Army Chief of Staff, General Mark Milley, directed Lieutenant General Kevin Mangum to conduct a review of all aspects of Army Aviation, including leadership, readiness, training, maintenance and sustainment policy, and resources.¹ Among aspects reviewed, readiness had the highest priority. Lieutenant General Mangum’s Holistic Aviation Assessment Task Force (HAATF) intended to ensure that aviation commands were ready and capable of operating in complex environments around the globe. General Milley charged the HAATF to determine the requirements needed to ensure Army aviation remained trained to operate as an integral maneuver force on the battlefield.

Milley called for the HAATF when the Army was in the midst of its latest Aviation Restructuring Initiative (ARI). The ARI of 2013 required the Army to divest older aircraft, change formations and organizational structures, and adjust total aircrew flight hours, in addition to other cost saving measures. Yet, even with ARI, Army Aviation still faced a potential two-billion dollar cut to its modernization budget. Cuts due, in part, to the Army’s need to shift funds to readiness, operations and maintenance.² These budget decisions came at a time when Army and congressional leaders were deeply concerned that reductions in the overall defense budget

¹ Holistic Aviation Assessment Task Force (HAATF), "Regaining Decisive Action Readiness," 2016, Washington, DC, i. (hereafter cited as Holistic Aviation Assessment Task Force).

² Richard Whittle, "Army Aviation Budget Plunges Earthward," *Breaking Defense*, February 9, 2016, accessed November 15, 2016, <http://breakingdefense.com/2016/02/army-aviation-budget-plunges-earthward/>.

had created risks in the operational and modernization budgets³. The approved ARI structure and unit organization were to remain in place, thus Milley instructed the HAATF to focus on other key areas to find “solutions that will enable Aviation to provide a cost-effective and sustainable combined arms maneuver capability.”⁴ General Milley emphasized cost effectiveness and sustainability because it was doubtful the Army could continue to afford the aviation force it desperately needed if aviation continued to operate in the same manner as it had for more than a decade.

Among many findings and recommendations, the HAATF identified several critical problems within the Army Aviation sustainment community that inhibited Army Aviation’s ability to operate efficiently, or what LTG Mangum referred to as operating at best value. Most significantly, the final HAATF report observed that Army aviation was not able to assess or see itself when it came to understanding the actual costs of aviation operations and sustaining aircraft. This blindness was due, in part, to Army Aviation’s scheduled maintenance system. That system continued to lag behind the maintenance systems of the other Services and civilian counterparts. The HAATF recommended Army Aviation improve the proficiency of its maintenance mechanics and clarify two-level maintenance within aviation units. Additionally, the HAATF recommended Army Aviation determine the accuracy and validity of the aviation readiness and reliability metrics.⁵ Unfortunately, many of the HAATF findings, and subsequent recommendations, were not new. Previous Army studies, spanning two decades, had made similar recommendations.

The 2013 ARI and the HAATF are just two of six large-scale Army Aviation studies undertaken since 1994. Nearly every study had been spurred by budgetary concerns, specifically

³ National Commission of the Future of the Army NCFA, "Report to the President and the Congress of the United States," January 28, 2016, Washington, DC.

⁴ Holistic Aviation Assessment Task Force (HAATF), i.

⁵ *Ibid.*, iii.

concern for proposed cuts in modernization budgets or the need to find savings in the operational budgets that could be shifted to modernization, or both. Just as predictably, the studies all ended with similar recommendations designed to optimize the force structure to achieve a balance between the modernization and operational budgets. In nearly every case, the Army responded by eliminating aircraft, changing unit force structure, and reducing personnel end-strength. In more than one study, the Army canceled large aviation acquisition and modernization programs because of increasing, unsustainable costs. Yet each study failed to achieve the promised long-term cost savings. After several decades and multiple studies, the bottom line remains that Army aviation has failed to find innovative ways to reduce its growing costs. Thus, to explain why has Army Aviation failed to achieve the required economies and long-term affordability it is necessary to explain why the past efforts have failed, and then define an alternative.

To explain Army Aviation's consistent failure requires an analysis of the four most recent studies to identify the common parameters of each study; i.e.; the rationale for each study and each study's approach, assumptions and recommendations. A simple review of previous aviation studies revealed that while three studies varied slightly in their approach, they shared similar results. Common among these studies were the recurring recommendations for changing maintenance doctrine, unit organizations, and maintenance materiel improvements. Among maintenance materiel, Army Aviation continued to emphasize expanding the use of Condition Based Maintenance (CBM) sensors. The past studies highlight that the Army continues to assume that its current maintenance management process is valid. In spite of the rising costs associated with sustaining an aging fleet of aircraft, the Army insists it is doing the necessary maintenance, the right way. No study, however, pursued any systemic analysis of the larger maintenance system. Therefore, the data drawn from the studies suggests that the Army must finally consider a systemic analysis of the larger maintenance system to find new solutions to the problems of affordability.

The HAATF was the lone exception in aviation studies. The HAATF challenged elements of the current preventative maintenance system and suggested elements that could form an alternative system of maintenance. The HAATF identified Reliability Centered Maintenance (RCM) and the use of Maintenance Steering Group-3 (MSG-3) as a methodology with which to design a more cost-effective aviation maintenance system. As stated in the HAATF report, the Army Aviation Enterprise is not guided by a clearly defined Reliability Centered Maintenance (RCM) strategy.⁶ Army Regulation 750-1, *Army Material Maintenance Policy* states:

RCM is the process that Capability Developers (CAPDEVs) and Material Developers (MATDEVs) use to determine the most effective approach to maintenance. RCM involves identifying actions that, when taken, will reduce the probability of failure and which are the most cost effective. It seeks the optimal mix of condition-based actions, interval (time-based or cycle-based) actions, failure finding, or run-to-failure approach.⁷

However, Army Aviation's guiding maintenance manuals, including Technical Manual 1-1500-328-23, *Aeronautical Equipment Maintenance Management Policies and Procedures* continue to prescribe a preventative approach, with no discussion or focus on condition-based or run-to-failure actions.

In the civil aviation industry, as well as other industrial applications, RCM is gaining prominence as a philosophical approach to maintenance. RCM evolved from an airline industry effort to provide maximum aircraft reliability at a predictable cost without compromising safety. Although the HAATF report does not endorse embracing RCM as a philosophy, it recommended using a civilian aviation industry "best-practice" known formally as Maintenance Steering Group-3 (MSG-3). MSG-3 is a Federal Aviation Administration (FAA) approved RCM-focused process used to design a holistic maintenance program, with a proven record of reducing operating and sustainment costs. MSG-3 is not a maintenance program in and of itself but is a methodology for developing a comprehensive maintenance program for new or modified aircraft. Civilian aviation

⁶ Holistic Aviation Assessment Task Force (HAATF), 80.

⁷ Army Regulation (AR) 750-1, *Army Materiel Maintenance Policy* (Washington, DC: Army Publication Directorate, 2013), 92

firms as well as other military services successfully employ RCM and MSG-3 at considerable cost savings. The other agencies are gaining these cost savings and efficiencies without reducing reliability and airworthiness, or increasing risk to aircrews and commanders. Simple data analysis suggests an RCM approach to maintenance, employing MSG-3 may possess the greatest potential for achieving significant maintenance savings for Army Aviation.

In light of the past failures and the HAATF recommendations, it is past time for the Army to challenge its basic maintenance assumption and evaluate the merits of RCM and MSG-3. The first step in this process was to describe the context and outcomes of the previous aviation studies. These studies revealed the recurring assumptions within Army Aviation regarding its maintenance management processes. Next, it was necessary to describe how the data could be viewed differently in order to propose how a systemic analysis might be accomplished. RCM and the history of MSG-3 provided the concepts that when applied produced a different understanding of the Army Aviation maintenance system. Understanding the basics of MSG-3, as well as examples of success from civil aviation and other Department of Defense efforts ultimately illuminated the realm of possibilities within Army Aviation.

How We Got Here: The Aviation Branch's History with Studying Sustainment Costs

In April 1983, Army Aviation became the 15th basic branch of the United States Army. The timing was excellent because the Army had just started fielding the first UH-60A Blackhawks and was only a year away from receiving its first AH-64A Apaches. The Army validated the operational requirements, funded the research and development and ultimately produced these aircraft in just over seven and ten years respectively. The Army has not had similar acquisition success since, which has caused new problems for aviation leaders. Building new aircraft is expensive, but maintaining an aging fleet is even more so. While the purchase of a \$30 million helicopter is a significant cost, this accounts for only thirty percent of the total life-

cycle cost of the aircraft. The largest financial burden is in the actual owning and sustaining of each aircraft.⁸ Operations and Sustainment (O&S) is the accounting classification for what the Army spends on maintaining a major weapons system. Speaking before an Association of the US Army panel in January 2014, the former Commanding General of the Army's Aviation and Missile Life-Cycle Management Command (AMCOM) lamented the increasing costs of sustaining aging fleets of aircraft. Major General Collyar stated, "Sustainment costs are eating away at Army aviation and new approaches are needed to rein the costs in."⁹

Managing increasing sustainment costs while investing in future aircraft is a constant tension within the Aviation branch's portfolio. Finding balance between the development or acquisition costs and the O&S costs typically requires a compromise between numbers of airframes procured, organizational structure and personnel and training costs. As budgets decline, this tension increases and requires further adjustments to the aviation force. These adjustments in Aviation force structure usually begin with a comprehensive, Army-level study.

Between 1993 and 2013, the Army conducted six comprehensive aviation studies, in an attempt to find the optimal mix of aviation formations and organizations to obtain the greatest value from the Aviation branch's capabilities. To put these studies in perspective, consider that army aviation branch undertook a major restructuring to correct Army of Excellence deficiencies, and to offset the significant force reductions that followed Operation Desert Storm.¹⁰ Just over ten years after fielding the UH-60 and the AH-64, the Army Aviation Restructuring Initiative (ARI) sought to remove legacy aircraft from the force, including the AH-1 Cobra, the UH-1 Iroquois

⁸ Ashton Carter, "Pentagon Efficiency Initiatives. Remarks Given at the Heritage Foundation," 2011, Washington, DC.

⁹ David Vergun, "Taming Sustainment Costs Key to Keeping Army Aviation Aloft," *Army News Service*, January 15, 2014, accessed August 23, 2016, <https://www.army.mil/article/118276/>.

¹⁰ Dr. James W. Williams, *A History of Army Aviation: From Its Beginnings to the War on Terror* (Lincoln, NE: iUniverse, 2005), 319.

and the OH-58A/C Kiowa. By restructuring aviation formations, reducing the total number of aircraft in the force and cutting other costs, Army Aviation was able to protect its continued investment in the future RAH-66 Comanche and the AH-64D Longbow modernization programs.¹¹ Nevertheless, by the end of the 1990s, the Army still struggled with modernization and operational costs, eventually fielding fewer aircraft than authorized levels in aviation units.¹² Thus were the struggles in the Army of Excellence aviation brigade. The Army's transition to modular organizations in 2001 created even more problems for the Aviation force.

Modular Aviation: Thorough Studies, Faulty Logic

The Army's transition to modular brigade organizations renewed the scrutiny of aviation formations and costs. In January 2001, a Defense Daily article described potential cuts to the aviation force structure to save on the aviation branch's transformation costs. The costs of aviation branch's modernization plan continued to climb through the 1990s and reached a tipping point. The Army had to figure out how to pay the three-billion-dollars required to modernize the aviation fleet by replacing aging aircraft with newer, more sophisticated aircraft with significantly higher operating costs. Given the 2001 force structure and budget constraints, the planned modernization was unaffordable, and considered out of balance.¹³ Army aviation needed to balance its long-term aviation modernization costs with the training and sustainment costs required to meet the needs of the future force.

Just two years later, the newly appointed Army Chief of Staff, General Peter Schoomaker directed a new top-to-bottom review of Army Aviation to provide recommendations for an aviation force optimized for the then current force structure and future joint fight, and capable of

¹¹ Frances Lussier and Black Shaun, *A CBO Study: An Analysis of US Army Helicopter Programs* (Washington, DC: Congressional Budget Office, 1995), xii.

¹² Williams, 319.

¹³ Williams, 321.

operating with a shorter logistics tail.¹⁴ In response to GEN Schoomaker's directive, the Aviation branch created the Army Aviation Task Force (AATF). The AATF assessed aviation forces, including force structure, training requirements, equipment and organizations "to develop a new Army Aviation Master Plan that [was] joint, feasible, and affordable." The AATF in turn published the Comprehensive Review of Army Aviation Modernization (hereafter the Comprehensive Review) that sought to provide a full analysis of Army Aviation by using the Joint Capabilities Integration Development System analysis model of Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities (DOTMLPF).

Sustainment costs were an important factor in forming the AATF. In its sustainment analysis, the Comprehensive Review found that the current phase maintenance system was labor and parts intensive, often resulting in additional maintenance requirements through parts breakage during inspections and maintenance actions.¹⁵ The Comprehensive review went further to state that Army Aviation had no clear, unified vision on how to reduce the scheduled maintenance burden because each aircraft Program Manager (PM) pursued a scheduled maintenance program unique to his aircraft, built upon the Army's legacy three-levels of maintenance.¹⁶ Unfortunately, this was the limit of the AATFs analysis of the scheduled maintenance program. The final comprehensive review did not make any recommendations to change or modify the schedule maintenance program.

The AATF's failure to study the maintenance program further was due to one key, flawed assumption that limited the AATF's focus. The AATF assumed that the existing maintenance management concept remained valid.¹⁷ Because the AATF assumed that the bigger process was

¹⁴ TRADOC Army Aviation Task Force (AATF), *Comprehensive Review of Army Aviation Modernization* (Washington, DC: US Army Training and Doctrine Command, 2003).

¹⁵ *Ibid.*, 74.

¹⁶ TRADOC Army Aviation Task Force (AATF), 90.

¹⁷ TRADOC Army Aviation Task Force (AATF), 66.

fine, in spite of its own findings, the AATF did little to define or explore what GEN Schoomaker meant by a shorter logistical tail. In the portion of the Comprehensive Review's report labeled *Shorten Logistics Tail*, the AATF stated:

This objective is equally fundamental and important to the transformation of Army Aviation. While the tasking to the Aviation Sustainment team was to 'shorten the logistics tail', there is an implied task to improve maintainer efficiency, and increase aircraft availability while reducing operations and sustainment costs, the ultimate objective of the strategy should lead to a reduced logistics tail.

Choosing an indirect approach to addressing sustainment, the Comprehensive Review focused solely on predictive reporting, effective utilization of resources, effective process designs and concepts, an improve distribution system.¹⁸

The AATF made recommendations it thought would reduce the overall maintenance burden while keeping the existing maintenance management processes intact, yet adopting Condition Based Maintenance for a two-level maintenance organization. Developing Condition Based Maintenance, as recommended, meant developing processes to perform maintenance based upon evidence of need, which differed considerably from the then current preventative process the AATF felt remained valid. Changing aviation maintenance to a two-level maintenance system, more in line with the Army's ground-centric maintenance process, did nothing to provide a unifying vision for aviation maintenance, much less reduce the maintenance and parts demands of the current phased maintenance process.

Each of the AATF's recommendations required Army Aviation to change significantly Army regulations, doctrine and organization, in order to implement CBM fully. Clearly, the existing maintenance management concepts, including its structures and systems, were not valid. In making recommendations to improve maintenance processes, parts tracking and distribution, and other elements within the concept of sustainment, the AATF failed to recognize that all of

¹⁸ Ibid., 67.

their recommendations were in fact interconnected elements within a larger maintenance system. One element cannot be corrected or changed without affecting the entire management process.

In the end, the AATF transformed the core of the aviation force from the Army of Excellence Aviation Brigade into the modular Combat Aviation Brigade (CAB). The Comprehensive Review reduced the operational force by forty-two aircraft and over 2100 personnel¹⁹. It also cancelled the beleaguered and controversial Comanche program, after a sunk cost of nearly eight billion dollars²⁰. Though it recommended some changes to aviation maintenance organizations and material solutions, the study did little to codify how to reduce the logistics tail in the near term. Nevertheless, the Army Chief of Staff accepted the final AATF recommendations. Six years later, little had changed in Army aviation maintenance.

In May of 2009, facing new strategic environments and growing constraints on spending within the aviation branch portfolio, then Lieutenant General JD Thurman announced that the Army needed to conduct another study, called the Aviation Study II, to ensure the branch maintained its overmatch and capability over the enemy.²¹ In 2009, in the midst of combat operations in Iraq and Afghanistan, the Army felt that it did not have enough Aviation to meet its global demands, and had to find ways to resource more capability in its operational force.

Published in February 2010, the stated purpose of the Aviation Study II was very similar to that of the 2003 Comprehensive review. Aviation Study II stated, "Army Aviation must optimize current assets to continue to support [Army Force Generation] and maintain relevance as a capability-based maneuver arm, optimized for the Joint Fight with a more efficient logistics

¹⁹ TRADOC Army Aviation Task Force (AATF), 27-28.

²⁰ Todd Harrison, *Defense Modernization Plans through the 2020s: Addressing the Bow Wave* (Washington, DC: Center for Strategic and International Studies, 2016), 4.

²¹ Ann Roosevelt, "Army Launching Aviation Study II, General Says," *Defense Daily*, May 06, 2009, accessed November 14, 2016, <http://www.defensedaily.com/army-launching-aviation-study-ii-general-says-2/>.

tail.”²² However, because of significant time restrictions on the team, Aviation Study II did not conduct the same in-depth analysis as in the 2003 Comprehensive Review, and simply carried forward the same assumptions and recommendations. Just as with the first study, Aviation Study II assumed that the existing maintenance management concepts still remained valid. Aviation Study II did not establish any effective goals, discernable metrics or new recommendations to actually shorten the logistics tail of Army aviation.

Unfortunately, with no new analysis or recommendations, the problematic and burdensome phased-maintenance described in the first Comprehensive review would continue. Aviation Study II recommended the Army continue its efforts on formalizing and defining two-level maintenance and continue to incorporate condition-based maintenance, but the goal of defining and actually shortening the logistics tail remained elusive and undefined.²³ Aviation Study II went even further, assuming that current aircraft readiness funding would continue. Therefore, Aviation Study II did not meet its goal of finding new “ways to increase the efficiency and effectiveness of aviation sustainment operations.”²⁴

One key difference between Aviation Study II and the 2003 Comprehensive Review is the final recommendations that required significant growth in the aviation portfolio. After cancelling the Comanche program in 2003, the 2009 report required Army Aviation to increase the total aviation force by nearly 100 aircraft and 4000 soldiers to meet the operational demands. Just as had been the case in the 2003 study, Aviation Study II ended with the termination of another ill-fated acquisition program, the ARH-70 Arapaho, at a sunk cost of over \$500 million. Cancellation of the ARH-70 Arapaho meant that the existing fleet of OH-58D aircraft on hand

²² Daniel Ball and Ellis Golson, *Army Aviation Study-II* (Fort Rucker, AL: US Army Aviation Center of Excellence, 2010), 1.

²³ *Ibid.*, 144.

²⁴ James D. Thurman, "Memorandum for Vice Chief of Staff, US Army Regarding Army Aviation Readiness Review Findings," 2011, Ft. McPherson, GA.

would continue to age and the Army would need to pay the considerable sustainment costs of a Service Life Extension Program (SLEP). Both the Comprehensive Review and the Aviation Study II highlighted the tendency to manage costs by adjusting modernization programs and operational force structure. Yet, no one questioned whether changing the “valid” maintenance process, which accounts for the largest proportion of Army Aviation’s budget, could provide more efficient logistics and garner more of the needed cost savings.

Sequestration: A New Sense of Urgency

Barely three years following the 2010 Aviation Study II recommendations, the assumption that funding would continue proved to be wrong, Army Aviation faced a new, more urgent budgetary and force structure crisis. In 2013, prior to the enactment of the 2011 Budget Control Act, Army Aviation accounted for approximately 18 to 20 percent of the Army’s Research, Development, Test and Evaluation (RDT&E) and procurement budget, as well as over 20 percent of the Army’s training budget.²⁵ When the sequester took effect on March 1, 2013, Army Aviation faced a 20 percent reduction in funding in the near term budget years (nearly \$6.7 billion), and a potential 40 percent reduction out to fiscal year 2020.²⁶ Sequestration intended to make proportional cuts across the board affecting every major program. If enacted in full, Army Aviation faced further decline in investment in modernization as well as massive cuts to the current operational force. Following the earlier changes in Aviation programs, cuts of this magnitude would be disastrous to the Army’s ability to meet current and future aviation requirements.

Trying to avoid the extraordinarily risky salami slicing of the Aviation portfolio, Army aviation leaders presented an alternative plan for accommodating their share of the cost cutting

²⁵ Gian Gentile et al., *The Army's 2013 Aviation Restructure Initiative: Summary of Research for the National Commission on the Future of the Army* (Santa Monica, CA: RAND, 2015), 39; National Commission of the Future of the Army NCFA, 103.

²⁶ National Commission of the Future of the Army NCFA, 82.

impacts from sequestration. The new 2013 version of Aviation Restructuring Initiative sought to “place force structure and modernization programs on a fiscally sustainable path, rebalancing capabilities across the regular Army and reserve components, and preserve many of the Army’s most modern and capable systems as possible.”²⁷ Among the several controversial recommendations, Army aviation elected to divest older aircraft systems, including the OH-58D Kiowa Warrior (KW). Divesting the OH-58Ds allowed Army Aviation to save three billion dollars on the OH-58DF Cockpit and Sensor Upgrade program (CASUP) as well as seven billion dollars in long-term sustainment for an OH-58D Service Life Extension Program (SLEP).²⁸ A second, and even more controversial decision, was to consolidate all AH-64 Apache aircraft in the Regular Army, leaving none in the reserve component. The decision by the Department of the Army staff served as a way to accommodate the budget limits, maintaining a reasonable level of wartime capacity and a sustainable modernization program. Critics of ARI argued that the OH-58D had the highest readiness rates in the Army, at a much lower cost, averaging \$1,400 dollars per flight hour. In the same period, the average AH-64D flight hour cost over \$3200 per hour²⁹. By increasing the number of AH-64s in the active force, critics felt that they Army would be increasing its overall sustainment costs.³⁰

Though fiscally necessary, ARI incurred significant operational risk. With the divestiture of the OH-58D Kiowa Warrior, and other legacy aircraft, the operational force was left with three

²⁷ Gentile et al.

²⁸ Ibid., 12.

²⁹ *Operations & Sustainment Visual Analysis Tool (OSVAT) for Operating and Support Management Information System (OSMIS)* (Washington, DC: Deputy Assistant Secretary of the Army for Cost and Economics, 2014). Based upon 2013 aviation data collected from OSMIS.

³⁰ In the 2015 National Defense Authorization Act (NDAA), the Congress wanted “to ensure that we can provide the right Army, trained and equipped to meet the demands of the future.” National Commission of the Future of the Army NCFA, 1. The Army plan to increase the number of AH-64s in the active force by removing AH-64s from the National Guard, came to the attention of congressional leaders and was contentious. The Congress established the National Commission on the Future of the Army (NCFA), in large part to decide whether to proceed with the transfers as directed by the Aviation Restructure Initiative.

main types of aircraft: the AH-64 D/E, CH-47F and UH-60 series. These aircraft were in just ten regular Army Combat Aviation Brigades. Additionally, the cost of divesting old aircraft and transferring aircraft between units created additional strain on limited OPTEMPO dollars. When ultimately approved by the Department of Defense in January 2014, the final version of ARI effectively saved significant costs for Army aviation and kept the modernization programs in tact but at the expense of three active component Combat Aviation Brigades (CAB) and the loss of 334 aircraft in the total force.³¹ This was now the smallest, leanest aviation force the Army could afford, in terms of both fiscal constraints and operational risk. ARI protected the top two Aviation modernization priorities: the Improved Turbine Engine Program (ITEP) and the Future Vertical Lift (FVL) program. However, the current fleet of aircraft will age faster and serve much longer than originally intended, risking an exponential rise in sustainment costs.

Each of the prior studies and restructuring plans met its specific goal to protect operational capability of the aviation force or protect investments in the modernization budget. However, every four to five years, with the unpredictable nature of defense spending and budgets, the Army continues to ask the same questions again, trying to find ways for Aviation to address growing sustainment costs. If ITEP and FVL are to avoid the same fate as the Comanche, ARH-70 Arapaho and the OH-58DF, Army Aviation must finally find ways to reduce its overall costs. The HAATF is the first study to offer a glimpse at a different solution.

³¹ Gentile et al., 14. The NCFR recommended retaining one CAB in Korea and 4 AH-64D battalions in the NG. Implementing these recommendations would not have led to additional funding, placing additional stress on Army Aviation's O&S budgets.

Challenge the Sacred Assumption: The Maintenance Purpose and Process Must Change

Prior to the HAATF, every analysis reduced the tension between Army Aviation's modernization budgets and its O&S budgets through trades offs in platforms, force structure or by cancelling large programs. Army Aviation is now at a critical point. To maximize the current fleet's capabilities, the Army needs to invest in the development and acquisition of ITEP. Even with ITEP, and the programmed incremental block upgrades to the UH-60, AH-64 and CH-47 fleets, this series of airframes will serve well past 60 years; the CH-47 will serve for more than 100 years! Quite literally, Army aviation cannot afford to incur more risk to its modernization. Further reducing purchases and changing contracts will cost even more in the long term.³² Because of previous program failures, the current rotary wing fleet is aging faster than the Army can replace it. Thus, Army Aviation cannot risk another program failure like that of the Comanche or Arapaho. FVL must succeed if there is to be an Army Aviation capability in the future. Divesting more aircraft and unit structure is too risky in the near term, given that the National Commission on the Future of the Army recommended keeping one of the CABs destined for divestiture to meet the global demands. Aviation leaders argue that aircrews need to fly more, because they are not getting the training they need to maintain the levels of proficiency required for the full range of military operations they may face. In short, Army Aviation cannot find additional savings in force structure or modernization. Instead, it must find savings from the total cost of operating the current force.

³² Jen Judson, "Lawmakers Move to Restore Army Aviation Budget Cuts," *Defense News*, April 26, 2016, accessed October 1, 2016, <http://www.defensenews.com/story/defense/land/army-aviation/2016/04/26/lawmakers-move-restore-army-aviation-budget-cuts/83354172/>.

Prior Studies: A Different Perspective

Unfortunately, as the HAATF stated, Army Aviation cannot demonstrate what the current budgets are buying in terms of readiness. The operational readiness rates of Army aircraft have averaged below Army standard for 16 years, yet costs are increasing. This data demonstrates there is no correlation between increased spending and an increased readiness rate.³³ A 2011, Congressional Budget Office Report indicates the Army aviation is not alone. Across the Department of Defense, given the rising O&M spending, the services cannot “clearly identify the relationship between the department’s O&M spending and the readiness of military units.”³⁴

Clearly many of the proposed solutions from previous aviation studies did not have a beneficial effect. According to the HAATF, CBM has not produced a significant enough return on investment to stand up to scrutiny. Additionally, the maintainers in the force continue to be frustrated with the maintenance procedures and manuals that have not been updated and do not fit well with two-level maintenance. In general, the same cumbersome and expensive maintenance practices criticized over multiple studies remain in place today.

The cause for this is the faulty underlying assumption that the current maintenance management process remains valid. In his book, *System Thinking: Managing Chaos and Complexity: A Platform for Designing Business Architecture*, Dr. Gharajedaghi claims the “implicitness of the underlying assumptions prevents actors from questioning their validity; therefore, the defaults usually remain unchallenged and become obsolete.”³⁵ Believing for so long in the validity of the current maintenance process is why the Army’s efforts to create necessary savings have failed.

³³ Holistic Aviation Assessment Task Force (HAATF), 70.

³⁴ Adebayo Adedeji, *Linking the Readiness of the Armed Forces to Dod's Operation and Maintenance Spending* (Washington, DC: Congressional Budget Office, 2011), 2.

³⁵ Jamshid Gharajedaghi, *Systems Thinking: Managing Chaos and Complexity: A Platform for Designing Business and Architecture*, 3rd Burlington, MA ed. (Burlington, MA: Morgan Kaufmann, 2011).

If viewed from this different perspective, the data from the multiple aviation studies suggests an alternative interpretation of how to reduce Aviation sustainment costs. Finding new ways to reduce the operations and sustainment costs of Army Aviation may require challenging the decades-old assumption that the current maintenance process is valid. By assuming that the current maintenance process may need to change in order to reduce the financial cost of a flight hour, Army Aviation can conduct a *systemic* review and redesign of the entire maintenance process. This is the first step in fundamentally changing Army Aviation sustainment.³⁶

Systems Thinking: Systematic vs. Systemic

For decades, Army Aviation believed that the maintenance process remained valid, thus the same recommendations surfaced repeatedly from study to study. Aviation leaders thought they could solve the problem of the large logistics tail by improving the efficiency of Army soldiers, embracing and investing in CBM, and adopting two-level maintenance. Yet, study after study indicated that little or nothing improved, because the aviation community failed to see how each of these efforts connected to a larger, detailed maintenance system. Thinking about CBM, doctrine, unit organization, or soldier training independently is an example of what Dietrich Dorner's describes as *systematic* thinking. In his book, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations*, Dorner describes systematic thinking as the using mini-systems as a way of dealing with a "sequence of problems that [have] to be solved one at a time."³⁷ Within the larger aviation maintenance system, this way of thinking is inherently flawed.

The persistent recommendation to invest in CBM is an example of one mini-system. Army Aviation pursued CBM as means of predicting impending failure on certain key components of select aircraft. When initially conceived, it was not a fleet wide, standard Army

³⁶ Holistic Aviation Assessment Task Force (HAATF), iii.

³⁷ Dietrich Dorner, *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations* (New York, NY: Merloyd Lawrence, 1996), 86.

program. Because CBM was implemented to solve a single problem, with a loosely defined requirement, data collected through CBM Data Source Collectors (DSCs) remains largely unanalyzed. Few, if any, maintenance procedures changed to incorporate the formal use of CBM sensors. Additionally, as the HAATF recognized, Army aviation maintenance schools still did not teach CBM procedures, further reducing the efficiency of soldiers once they arrive in a maintenance unit.³⁸ Army systematic thinking, focusing only on the mini-systems of CBM, failed to see how developing and fielding CBM solutions affected the larger maintenance system, including training and doctrine development. Though CBM has evolved, it remains a point of contention in terms of cost versus benefit within Army Aviation.³⁹

Thinking of the larger maintenance system, and how CBM interacts with each of its subcomponents including training and doctrine, is systemic thinking. Systemic thinking considers the entire maintenance process as one whole system, and seeks to understand how one element affects every other. The whole aviation maintenance system has a unique structure, function and process, that would be fundamentally altered if it were to shift from doing preventative-style maintenance to doing maintenance on evidence of need (CBM). Thus, in order to make the logistics tail shorter or more efficient, it is necessary to understand the entire system including the linkages and interactions of each of its sub-elements, including required maintenance tasks, needed parts, data system, and soldiers' skills. None of these elements can be adjusted independently without thinking of the larger system, and without creating second and third order consequences that have to be managed, interpreted and adjusted. Each of these sub-elements affect the cost of maintenance within Army Aviation.

³⁸ Holistic Aviation Assessment Task Force (HAATF), 98. The final report only discussed basic familiarity on certain maintenance tasks. However, the lack of any CBM training in the Aviation schools was a finding made by the HAATF team.

³⁹ *Ibid.*, 80.

New Thinking: New Goals

Thinking systemically requires clearly defined goals or a concept of what success is or looks like. Neither the Comprehensive Review nor Aviation Study II defined what a “shortened” or “efficient” logistics tail looked like. The previous studies did not create a goal such as reducing some specific numbers of parts, reducing maintenance man-hour requirements or even specific cost reductions. Dorner states that “[i]f we have no criteria based on the specification of our goals to help us set priorities, we will choose the most obvious problems or the one that we already know how to solve.”⁴⁰ This lack of goals leads to repair service behavior, losing track of the larger whole and focusing on fixing the small known malfunctions.⁴¹ This is how multiple studies focused primarily on CBM, two-level maintenance and increasing the efficiency of soldiers. Yet the Army has little to show for it.

The 2016 HAATF was the first study to call for Army to find ways to operate at best value, and to “see ourselves” by being capable of linking our fiscal costs to accurate indicators of readiness. Best value, according to LTG Mangum, was maximizing the capability and capacity of current assets available, at a known and predictable cost. If Army leaders assume that maintenance process must change to find cost savings, then a systemic analysis is possible. The first step in that analysis is to define modest, measurable goals for reducing costs and increasing readiness. Under similar circumstances, the United States Air Force conducted a study to reduce O&S by ten percent on the C-5 A/B fleet of aircraft, while increasing readiness by at least four percent.⁴² The chosen means for the US Air Force to reach these measurable goals was RCM and MSG-3.

⁴⁰ Dorner, 63.

⁴¹ *Ibid.*, 59-63.

⁴² Donald A. Van Patten, "Transforming the Aircraft Inspection Process," *Air Force Journal of Logistics* 34, no. 1&2 (2010): 102.

A Different Way: Reliability Centered Maintenance and Maintenance Steering Group-3

A Brief History of RCM and MSG-3

The significant costs of aviation, whether military or civilian, is nothing new. Beginning in the 1960s, the civilian aviation industry attempted to find savings in the maintenance costs of the Boeing 747. An Air Transport Association (ATA) task force known as the Maintenance Steering Group (MSG) initiated a study to understand how aviation maintenance occurred. The MSG “looked for opportunities to increase aircraft availability and reduce maintenance costs, while not compromising safety.”⁴³ Within a decade, the second MSG task force expanded the research to develop a larger programmable inspection logic that could be used to develop initial minimum scheduled maintenance and inspection recommendations for new aircraft and new engines and multiple aircraft throughout the civilian aviation industry.⁴⁴ In 2006, the ATA task force became the Maintenance Programs Industry Group (MPIG), while the logic framework they produce is still known as MSG.

The first two variants of the MSG logic focused on failures of individual items, including engines, and not the entire aircraft as a whole system. Though they garnered considerable savings, the first two versions “did not factor in operating performance data as the aircraft matured nor did they establish intervals for the preventative tasks.”⁴⁵ These versions were very parts-driven, bottom-up and process oriented.⁴⁶ Ultimately, the inefficiencies of the first versions

⁴³ Lorenz Jessen and Brian Jenkins, "MSG-3 in the Helicopter World," *Helicopter Maintenance Magazine*, 2011.

⁴⁴ Federal Aviation Administration Advisory Circular 121-22C, *Maintenance Review Boards, Maintenance Type Boards, and Oem/Tch Recommended Maintenance Procedures* (2012), 5

⁴⁵ Van Patten, 98.

⁴⁶ Integraph, *Maintenance Steering Group-3 (MSG-3)-Based Maintenance and Performance-Based Planning and Logistics (Pbp&L) Programs: A White Paper* (Huntsville, AL: 2006), 2.

of MSG did not have the economic benefit for new, more advanced aircraft. With increasing fuel prices throughout the 1970s, as well as material costs for these newer aircraft, air carriers needed to evaluate the costs versus benefits of maintaining necessary levels of equipment reliability without sacrificing safety and airworthiness.⁴⁷ This was the beginning of a reliability centered philosophical approach to maintenance.

The concept of Reliability Centered Maintenance became an overarching philosophy for maintenance programs beginning in 1978.⁴⁸ At the heart of RCM is the idea of ensuring maximum availability of a given system or platform at all times, by using a decision logic "to determine what actions need to be accomplished to ensure the availability of physical assets, in their specific operating context, when needed by the operator or user."⁴⁹ This counters the typical idea of conducting general maintenance tasks based upon a cyclical hourly or calendar-based schedule.

Embracing RCM as a better way of thinking about maintenance, the ATA updated its documents to define clearly a methodology that is used to develop more efficient, task-oriented maintenance and inspection process and required intervals. Published in 1979, this third iteration of logic was called MSG-3.⁵⁰ Many use RCM and MSG interchangeably. RCM is a way of thinking, or philosophy of maintenance. MSG-3 is not the full aircraft maintenance program in and of itself, but a guideline to build a larger maintenance system for a fleet of aircraft.

Since its acceptance within the civil aviation industry, the RCM approach has spread into other industries. In his article, "RCM: Gateway to a World Class Maintenance Program", Anthony Smith describes several preventative maintenance (PM) themes recurring throughout the

⁴⁷ Richard W. Anderson, "Air Carrier Revisions to MSG-3," *Logistics Spectrum* Apr-Jun 2002, no. 36 (2002): 30.

⁴⁸ *Ibid.*

⁴⁹ *Integrgraph*, 2.

⁵⁰ *Ibid.*

manufacturing industry. The themes are: the program is the same as it has been for years, thus it must be good; the PM programs are reactive; downtime incurred by a PM program is too high and costly. These are similar themes in Army aviation maintenance. Smith describes that many PM programs typically focus on keeping a plants machinery in 100% working, serviceable condition, largely because that is the way it has always been. In this view, the costs of maintenance are seen as a necessary, sunk cost of operations Maintenance managers begin to chase the status report, thus, the equipment status becomes the end in itself.⁵¹

In Smith's analysis, typical PM programs' focus on maintaining equipment at certain measurable readiness level may appear logical, but it may foster unnecessary problems "such as promoting a tendency to treat all equipment as equally important and creating conservative or premature maintenance actions. Many times, PM tasks are intrusive actions and can lead to errors and re-work as often as 50% of the time."⁵² The Comprehensive Review and the HAATF report make similar claims regarding the Army Aviation's preventative-style maintenance. While the percentages may vary, the results are very similar. In Army aviation maintenance, many of the well-intentioned inspections and services actually induce excessive downtime. For example, in the CH-47 fleet between 72-75 percent of Not Mission Capable (NMC) time is attributed to scheduled, process-oriented, preventative maintenance.⁵³

Smith challenges maintenance program developers to abandon the notions of preserving equipment in lieu of developing maintenance practices that preserve function first. Thinking of the equipment as a means to the end, versus the end in itself, maintenance leaders can approach maintenance differently, by asking a few key questions:

⁵¹ Anthony Smith, "Rcm: Gateway to a World Class Maintenance Program," *Rock Products* 103, no. 5 (May 2000): 44.

⁵² Ibid.

⁵³ Kenneth Hessler and Donald Ketron, *Ch-47f Nmc Rates: Scheduled Vs. Unscheduled Maintenance Creep* (Redstone Arsenal, AL: US Army Research, Development and Engineering Command (RDECOM), 2015).

Is all equipment equally important?
Is it less costly to deliberately run some equipment to failure before acting?
Is it necessary to maintain an item just because it is accessible?

Embracing RCM: The Key to Change

Current Army maintenance policy says that if a system or component is installed on an aircraft it must be fully mission capable (FMC). Otherwise, the aircraft is considered partly mission capable (PMC) or Not Mission Capable (NMC). In many cases, Army aircraft are reporting PMC for subsystems not deemed critical, at the current time, by a commander. These PMC reports range from simple items, such as blade de-ice kits on UH-60s and cargo hooks on CH-47s to more complex and expensive Fire Control Radars (FCR) on AH-64s. At best, aircraft with these conditions would be reported PMC. At worst, these aircraft are NMC because maintenance personnel are actively trying to troubleshoot, repair or replace components to fix the faults.

Each of the aircraft in the above examples has a lot of function available for training and combat operations, and may fully meet the capabilities required by a commander. However, the current standards and reporting mechanisms make it very hard to recognize these capabilities at the strategic levels of the Army. Current reporting mechanisms require caveats and explanations to describe reality. More importantly, these maintenance actions consume significant amounts of time and financial resources, while providing relatively little in return. The HAATF recognized these challenges and recommended the Army determine more appropriate metrics for measuring the readiness of aviation combat power.⁵⁴

How the Army defines and measures aircraft readiness is where it may make a significant philosophical change. As stated earlier, Army Aviation maintenance is currently designed to preserve the life-cycle of aircraft. By adapting Army Aviation maintenance to an RCM-style approach, an approach focused on preserving and providing maximum function, many of these

⁵⁴ Holistic Aviation Assessment Task Force (HAATF), 73.

challenges can be solved. Smith's RCM-style logic questions above cannot be applied directly to Army aviation maintenance. However, the questions can be worded to fit the aviation situation better while preserving Smith's RCM logic. Thus, these questions might be posed:

1. Is it necessary to maintain every subsystem on the aircraft at 100% fully mission capable, or can the command assume risk on certain systems for a period of time, while not degrading maximum mission capacity?
2. Are there systems on an aircraft, that are not flight or mission critical, that will actually cost less, in time or money, to replace later, because the procedures are intrusive and time consuming? Would it be more efficient to delay replacing these items at a service interval, without affecting critical mission capability?
3. Is the maintenance task to be performed ensuring, maximizing or extending capability, or is it simply being done because of a pre-determined time cycle?

Answering RCM related questions such as these allows for an adjustment in the stated purpose of aviation maintenance. Ultimately an RCM philosophy will reorient the maintenance process toward preservation and/or maximization of the aircraft's capability to meet the operational requirements of the commander. RCM as a guiding philosophy will cause neither an atrophy in maintenance capability or capacity, nor more "hangar queens" of old. Instead, it will allow leaders to drive their maintenance efforts and focus the limited resources on items that maximize capabilities. As suggested in the HAATF, a way to accomplish this is through a top-to-bottom analysis using a systemic logic, like that found in MSG-3.

The MSG-3 Methodology: The Basics

The Federal Aviation Administration's (FAA) Advisory Circular (AC) 121-22C is the most current guide to for developing the scheduled or interval maintenance requirements for derivative or newly type-certified aircraft and engines that require FAA airworthiness approval.⁵⁵ When an OEM decides to develop a new, or update a current aircraft maintenance program, they form working groups to analyze an aircraft's systems and determine what minimum maintenance actions are required for a safe and reliable aircraft. The effectiveness of MSG-3 is in its top-down

⁵⁵ Federal Aviation Administration Advisory Circular 121-22C, 1.

systems approach in understanding possible failures, and the criticality of those failures, through a Failure Modes, Effects and Criticality Analysis (FMECA) of components and structures on the aircraft.

The first step of the systems analysis is the identification of Maintenance Significant Items (MSI) and reliability data for each component and system on the aircraft. Engineers then conduct a failure analysis of these MSIs to understand their criticality in the event of failure. The criticality assessment uses a Yes/No logic asking a series of questions:

1. Is the occurrence of the functional failure evident to the operating crew during the performance of normal duties? (YES/NO)
2. Does the functional failure or secondary damage resulting from the functional failure have a direct adverse effect on operating safety? (YES/NO)
3. Does the combination of a hidden functional failure and one additional failure of a system related or backup function have an adverse effect on operating safety? (YES/NO)
4. Does the functional failure have a direct adverse effect on operating capability? (YES/NO)

The answers to these Yes/No questions are what drives the development of maintenance tasks, through a causal analysis. Each failure is scrutinized to understand whether maintenance actions such as lubrication, inspection, functional check, or restoration would identify or correct the failure. Beyond developing maintenance tasks, the thoroughness of the analysis helps establish a baseline of reliability expectations for components of the aircraft. In her article “Understanding MSG”, Charlotte Adams states “[i]f MSG-3 analysis shows that a certain functional failure would jeopardize operational safety, and couldn’t be rectified by any of the hierarchy of standard tasks within the specified logic, then redesign of the item in question would be mandatory.”⁵⁶ This analysis establishes a baseline of reliability with every part on the aircraft.

What makes MSG-3 different from earlier versions is how it evaluates the aircraft as a whole system, and its systemic view of the loss of specific functions or capabilities on the

⁵⁶ Charlotte Adams, "Understanding MSG-3 ", accessed Jan 29, 2017, http://www.aviationtoday.com/am/repairstations/Understanding-MSG-3_33062.html.

aircraft. MSG-3 considers the failures that are evident in a system, as well as other possible hidden failures to ultimately identify three consequences of a loss of function (safety, operational, and economic). Knowing the impacts of a failure, whether upon safety, operational or economic, the MSG-3 logic then leads to understanding the cause of the failure before defining the types of maintenance tasks and required intervals, if any, to prevent the failure before it occurs. Through its logical analysis processes, MSG-3 focuses on identifying the effects of a failure instead of finding the failure in itself.⁵⁷

Adams further described how previous versions of MSG led to unnecessary tasks and an increased possibility of inducing errors and damage to aircraft. MSG-1 and 2 focused on parts and part failure rates, considered only one failure in the decision logic and did not identify any tasks. It was process-oriented rather than task-oriented.⁵⁸ Earlier versions of MSG focused on processes, based upon hard time or perceived condition and focused primarily on finding and replacing faulty parts.⁵⁹

The results of the MSG-3 analyses are published in a Maintenance Review Board Report (MRBR). MRBRs are approved by the FAA, and describe the minimum maintenance requirements for airworthiness. The MRBR is used by the OEM and each operator to develop his own maintenance programs and systems in more detail.⁶⁰ Each owner and operator of an aircraft or fleet of aircraft, whether an airline or private operator, develops his own maintenance program to support his operational requirements. These operators, applying their own lessons learned and best practices, contribute back to industry through the iterative process of MSG-3.

⁵⁷ Adams.

⁵⁸ Ibid.

⁵⁹ Anderson, 30.

⁶⁰ DanburyKline, "A Summary Guide to MSG-3," 2012, accessed Jan 29, 2017, http://danburykline.co.uk/DKWP/?page_id=1898.

The iterative and collaborative nature of MSG-3 is arguably its most important feature. According to the FAA advisory circular, “. . . the MRBR is intended to be an up-to-date, dynamic document, the OEM/ type-certificate holder (TCH), Industry Steering Committee (ISC) and the MRB chairperson should annually conduct a joint MRBR review to determine any need for a revision.”⁶¹ This means that at multiple points throughout an aircraft’s lifecycle, a working group convenes to analyze the traceability of certain tasks, maintenance intervals, and reliability data to ensure that the necessary maintenance is performed without decreasing reliability or increasing risk.

The MSG-3 process does not dictate the means to collect safety and reliability data. This remains within the purview of the operators and the maintenance process they develop for their fleet of aircraft. In the case of Army Aviation, the investment in CBM DSCs already installed on the aircraft may offer an exceptional means to collect this necessary data to inform an MRBR. As stated earlier, much of the data collected via DSCs thus far remains unanalyzed. Instead, using an MRBR, or a related process adapted for Army Aviation’s needs permit tasks to be traced, and provide required intervals and required reliability data on an annual or semi-annual basis. The analysis of reliability and maintenance data would help the Army regularly update Reliability, Availability and Maintainability metrics, as well as optimize maintenance tasks required to maximize Time-on-Wing for significant aircraft components.⁶²

Some critics argue there are limits to applying MSG-3 within the rotary wing community because MSG-3 was designed for fixed wing aircraft. Maintaining rotary wing aircraft poses unique challenges because of the structural and flight component differences caused by the dynamic nature of helicopter mechanics,⁶³ However, MSG-3 as a methodology, is readily

⁶¹ Federal Aviation Administration Advisory Circular 121-22C, 27.

⁶² Holistic Aviation Assessment Task Force (HAATF), 78, 81.

⁶³ Thierry Dubois, "Reinventing a Standard," *Aviation Week & Space Technology*, September 3, 2012, 2012, 93.

adaptable to the rotary wing aircraft as evidenced by an industry committee of Bell helicopter, Eurocopter, Sikorsky, and Agusta/Westland, who are developing a purely rotorcraft version of MSG-3. While the maintenance actions and intervals may be different, the goal of operating safe, reliable aircraft at an affordable cost is the same. Just as in the civilian fixed wing community, the civilian rotary wing enterprises seek to have profitable helicopter operations, high availability and low operating costs. Helicopter downtime, whether planned or unplanned, means lost revenue.⁶⁴ In the Army, it means a loss of combat capability.

Examples of Success- Lessons Learned from Applying MSG-3

Through multiple evolutions over the last forty years, MSG has helped the civilian aviation industry to solve many of the same problems Army Aviation still faces. Earlier versions were parts and process driven processes, which directed unnecessary tasks that induced further errors into the aircraft systems. For the Boeing 747-100, the initial MSG processes reduced the maintenance man-hour requirements to sixty-six thousand hours of maintenance per twenty thousand flight hours, compared to four million maintenance man-hours for the less complicated DC-8. In their MSG-3 whitepaper, Intergraph uses the DC-8 and DC-10 for another illustrative comparison. Without an MSG logic, the DC-8 had over 330 items for scheduled overhaul as part of its regular maintenance process. The DC-10, after using the MSG logic has only seven. The DC-10's engines no longer required overhaul. In turn, the demand for spare engines and replacement parts dropped by fifty percent and labor requirements shrank. These gains in efficiencies helped to reduce overall maintenance costs by as much as thirty percent.⁶⁵ Looking through the lens of the previous Army studies, this would surely qualify for a reduced logistics tail.

⁶⁴ Karen Wilhelm, "Retooling the MSG-3 Mro Standard for Rotorcraft" ABD Online, 2014, accessed December 20, 2016, <http://www.abdonline.com/news-analysis/rotorcraft/retooling-the-msg-3-mro-standard-for-rotorcraft/#.WFmeIvnafIU>.

⁶⁵ Intergraph, 2.

Another example of the successful use of MSG is Southwest Airlines. In 2010, operating a fleet of 447 aircraft, Southwest achieved a remarkable ninety-seven percent availability rate for the year. This equates to executing their entire flight schedule of more than 3000 flights with only 435 of their aircraft.⁶⁶ The potential of MSG in the civilian rotary wing industry is just as promising. Bell successfully launch the Bell 429, the world's first helicopter with a maintenance program developed using MSG-3. In some cases, some rotary wing maintenance experts credit MSG-3 for reducing costs by twenty percent. For rotary wing aircraft operators, like Army Aviation, who fly significant amounts of hours, spreading maintenance tasks over time, as opposed to packaging into a multitask checks with longer down time would be a significant operational benefit.⁶⁷

Within the Department of Defense, the US Air Force is demonstrating the promise of MSG-3 on military aircraft. In 2010, faced with ever-shrinking budgets, the Air Force's Program Budget Decision (PBD) 716 reduced the Air Force's maintenance and inspection manpower by more than 400 billets. Beyond manpower reductions, the Air Force faced the significant challenge of meeting the growing maintenance requirements on an aging aircraft fleet with the reduced in funding and fewer personnel, while still meeting global demands. With the aging fleet, Air Force leaders needed to improve aircraft availability and decrease the cost of maintenance. Developing the Aircraft Availability Improvement Program (AAIP), the Air Force established the goal of increasing availability by twenty percent while reducing costs by ten percent. As Colonel Donald Van Patten described, the US Air Force faced the reality it "cannot increase aircraft availability and decrease operating costs without revamping the current inspection process."⁶⁸ There were several key factors driving the Air Force to this realization, including the aging fleet of aircraft

⁶⁶ Van Patten, 102.

⁶⁷ Dubois, 93.

⁶⁸ Van Patten, 96.

(especially cargo aircraft), increased inspection and other age-related maintenance increasing downtime, dwindling budgets and the ever-increasing operating costs.

Partnering with the Intergraph Corporation, the Air Force used the MSG-3 methodology to develop new scheduled maintenance program for the C-5 A/B fleet of aircraft, to determine the feasibility of increased availability at a reduced cost, without compromising safety. Their initial goal was to increase inspection intervals when possible, extend the time between structural inspections to align with other major intervals, accomplish aircraft systems inspections at [Programmed Depot Maintenance] and nest inspections into a hierarchical process to gain efficiencies.⁶⁹ The results were significant. The home station inspections went from every 105 days to every 160 days; minor isochronal inspections went from fourteen months to sixteen months. The time to complete the inspections went from greater than thirty days to an average of fourteen days. Major isochronal inspections increased from every twenty-eight months to every forty-eight months taking a maximum of thirty days to complete.⁷⁰ Beyond increasing maintenance intervals, the cost savings are the most encouraging aspect. With an initial goal of saving at least ten percent, the Air Force's initial returns indicate a cost savings of more than thirty percent, even while improving fleet performance from fifty-three percent in FY 09 to nearly sixty-eight percent in just four years (FY13). With an initial investment of seven million dollars, it took nearly eight years for the US Air Force to adopt MSG-3 on the C-5 A/B fleet. The Air Force is applying its lessons learned toward other aircraft including the F15 and KC-135. The US Air Force expects it to take a minimum of four years to develop the MSG-3 standards for the F-15. Nevertheless, the Air Force still expects to develop a new maintenance program for the F-

⁶⁹ Scott Wrigley, *MSG-3 Deployment on a C-5 Galaxy* (730th Aircraft Sustainment Group, 2014), 3.

⁷⁰ *Ibid.*, 4.

15 much faster than the eight years it took for the C5.⁷¹ Van Patten's analysis indicates the Air Force stands to gain a net savings of \$37 million and \$41 million for each aircraft respectively.⁷²

The Realm of Possibilities: Applying MSG-3 in Army Aviation

The previous Army studies display striking similarities between the Air Force and Army's budgetary and force structure challenges. Both of the military departments struggled with maintenance costs, force structure reductions and operational requirements that stressed the forces to their limits. Only the Air Force has thus far completed a department wide review to increase availability and reduce costs with clearly defined goals and measures of success. Within the Army, the only organization thus far to embrace the potential of RCM and the current version of MSG-3 is the Army's Program Manager for the Cargo Helicopter (PM-Cargo). PM Cargo is using MSG-3 to redesign the scheduled maintenance program for the CH-47F Block I helicopter.

The latest version of CH-47 aircraft is the CH-47F, Block I. Its maintenance program is based upon the legacy CH-47D. The CH-47 fleet Non-Mission Capable for Maintenance (NMC-M) average for Fiscal Years 2014 and 2015 was over twenty-one percent. This average is well below the Department of the Army standard of ten percent.⁷³ Most of this downtime, over seventy percent, was due to scheduled maintenance services.⁷⁴ The scheduled services alone make it nearly impossible for units and commanders to meet Army readiness standards.

These readiness statistics are indicative of the extensive challenges with the preventative maintenance of the latest CH-47F. While many of the mechanical systems are similar, between

⁷¹ Ibid., 12.

⁷² Van Patten. Van Patten describes an initial investment of \$10 million per aircraft type. Amortized across the F-15 and KC-135 fleets of 482 and 530 aircraft respectively, this equates to an investment of just under \$21K and \$19K for the F-15 and KC-135. Assuming a modest savings of just 10% per aircraft equates to \$47.3M and \$41.4M respectively. Counting for the initial investment, this generates a net savings of \$37.3M and \$31.4M.

⁷³ Army Regulation (AR) 700-138, *Army Logistics Readiness and Sustainability* (Washington, DC: Army Publication Directorate, 2004), 29

⁷⁴ Hessler and Ketron.

the CH-47D and 74F models, the electronics and sub-systems are vastly different. The more modern CH-47F has more on-board prognostic and diagnostic systems available to the maintainers. Yet the current maintenance process which was carried forward from the legacy aircraft does little to maximize their use. PM-Cargo recognized this latency in the CH-47 scheduled maintenance program and initiated an MSG-3 effort to expand inspection intervals and increase availability without incurring risks to reliability and safety.

PM-Cargo contracted with the OEM (Boeing) to conduct a top to bottom assessment of the Block 1 aircraft. Using the most current version of the MSG-3 methodology, PM-Cargo established a new engineering baseline for the CH-47F and developed an Optimized Scheduled Maintenance Program (OSMP). The OSMP can serve as the maintenance framework for CH-47F for the next twenty years. The most important aspect of this analysis, and subsequent framework is its cyclical nature. Using an Interface Control Document (ICD), PM-Cargo will establish internal processes to evaluate and adjust maintenance tasks and intervals regularly, based upon input from the field and collected CBM data. Similar to the civilian MRBR, the data collected will inform the Reliability, Availability and Maintainability analysis required to ensure the aircraft are meeting the Army's operational demands. Therefore, this maintenance framework for the CH-47F will be updated regularly throughout the aircraft's life-cycle.

PM-Cargo invested an initial \$11.6 million. One international partner that purchased US CH-47s contributed an additional \$1 million. PM-Cargo contracted with the OEM for three years to develop the new OSMP. When amortized across the final acquisition objective of 449 aircraft, this investment equates to nine-thousand dollars per year per aircraft, or a total of \$28 thousand per aircraft. PM-Cargo's published goal for this study is a two to four percent increase in readiness and modest O&M cost savings. Using these measures of performance as a benchmark, the possible savings to the Army are incredible.

In 2013, the Army averaged \$369 thousand per CH-47F, per year in maintenance costs. Were it possible for the PM Cargo to achieve a modest ten percent reduction in maintenance

costs, the potential savings is \$36 thousand per aircraft. Given the CH-47F fleet of 449 aircraft, this equates to more than \$16 million a year. However, if the Army were able to achieve savings similar to the Air Force's thirty percent reduction in maintenance costs, the Army could save over \$49 million per year. While the Air Force boasted a more than ten percent increase in readiness within four years, a more moderate success would still be significant within Army Aviation. If PM-Cargo meets its goal of just a four percent increase in maintenance readiness, the CH-47F would easily exceed the minimum readiness standards. Saving a minimum of \$16 million in one year would more than recover the costs of the MSG-3 study. More importantly, if fully adopted, could save the Army over \$60 million for the remainder of one budget cycle. More importantly, this savings is for just one of the Army's three major rotary wing platforms. Similar success across the AH-64 and UH-60 fleets would garner even more significant savings.

Conclusion

For more than two decades, Army Aviation has struggled to find the most cost effective balance between maintaining an operational force structure to meet aviation requirements and protecting the investments in aircraft modernization. In 2014, facing declining budgets and total force reductions, Army aviation made its most significant force structure and aircraft fleet decisions to date in order to keep Army aviation affordable and on track for modernization. Army Aviation leaders have elected to divest the OH-58D and to invest in the incremental modernization of the CH-47, UH-60 and the AH-64, until the vision of Future Vertical Lift is realized. Those decisions mean the CH-47 will be flown in the US Army inventory for over 100 years, and the UH-60 and AH-64 will each serve for more than sixty years. Each of these MDS will far exceed their original intended life-cycle. Already the majority of these airframes are old and stressed, and even with incremental improvements, remanufacturing and recapitalization processes, they will continue to get older and more difficult to maintain. Typically, with aging aircraft comes a corresponding increase in the maintenance costs needed to keep them flying.

More problematic is that these cuts and changes are very similar to the past two decades worth of studies that indicate Army Aviation consistently uses force structure, airframes and personnel are the budget elements with which Army Aviation manages increasing operational and sustainment costs. Yet, none of the four major studies from 2003 until 2014 achieved the desired cost savings. After analyzing these studies, the data shows the reason for these constant failures is that none of the previous studies recommended any changes to the larger maintenance management system. In spite of calls to shorten the logistics tail of Army Aviation, the studies show that Army Aviation never considered a systemic analysis of the whole of Army Aviation sustainment.

In order to begin a systemic analysis, Army Aviation must challenge its own assumption that its current maintenance management processes remain valid. The data from past studies, and the fact that sustainment costs continue to consume a significant portion of the operational budget, clearly indicate that the assumption has no empirical support. When viewed from a different perspective, the maintenance processes must change to find the needed cost savings and efficiencies. Changing the maintenance process requires establishing realistic goals that clearly define success within the new maintenance system.

Changing the maintenance process is what the 2016 HAATF meant when it claimed that Army Aviation must make fundamental changes to reduce the costs of maintenance.⁷⁵ The HAATF was the first study to identify a potential way to change by suggesting a thorough analysis on the merits and benefits of RCM and the use of a methodology such as MSG-3. The current guiding regulations within the Army's maintenance enterprise describe the role RCM plays in developing maintenance programs, yet every program throughout the Army Aviation Enterprise remains preventative in its approach. A disconnect remains between Army policy and the larger aviation maintenance system.

⁷⁵ Holistic Aviation Assessment Task Force (HAATF), 69.

For more than thirty years, the concepts of RCM and MSG-3 evolved within the civil aviation industry and leading industrial maintenance organizations. Evolving significantly since the early 1970s, MSG-3 has a proven record of increasing reliability and reducing costs without compromising aviation safety standards. Nearly ten years ago, the US Air Force recognized the potential of MSG-3 within its large cargo fleet of aircraft and used the methodology to find significant savings and to increase reliability within the C5-A/B fleets. Because of its initial success, the US Air Force is expanding its MSG-3 programs to other airframes including the F15.

Though some elements within Army Aviation recognize the potential of RCM and MSG-3, the larger enterprise still requires convincing. Using the most current version of MSG-3, the on-going efforts of PM-Cargo offer the most promising glimpse at the potential financial savings to be achieved by conducting a top-to-bottom review of each aircraft. If fully implemented, the CH-47 study offers potential net savings between \$16 and \$60 million within a five-year budget cycle. Though that study is not complete, the data suggests that the savings will more than pay for the cost of the study. More importantly, the data suggest that an MSG-3-style maintenance system offers the best chance for Army aviation to reduce the maintenance costs for all its aging aircraft.

To adopt RCM and incorporate MSG-3 requires a change in aviation maintenance philosophy. In effect, embracing RCM requires changing a long-standing organizational culture to meet the challenges facing Army Aviation sustainment. These changes will not be easy, quick or inexpensive. But, one thing that is clear, the aviation community literally cannot afford to wait. The fielding of the UH-60 and the AH-64 were significant milestones for Army Aviation, but the branch has not enjoyed similar success since. The two greatest examples of the Aviation Branch's fielding shortcomings are the RAH-66 Comanche and the Armed Reconnaissance Helicopter (ARH), neither of which ever went into Low Rate Initial Production (LRIP). In both cases, the Army significantly oversold the sustainability and underestimated the maintenance burden, which

led to the cost overruns.⁷⁶ If the Army is to avoid making similar mistakes with the FVL program, now is the time for the cultural changes that can inform the CAPDEVs and MATDEVs as they design the FVL from the ground up. These efforts today will go a long way to ensure that the Army fields a next generation vertical lift aircraft that is affordable and sustainable into the future.

⁷⁶ US General Accounting Office, *Comanche Helicopter: Program Needs Reassessment Due to Increased Unit Cost*, by GAO National Security and International Affairs Division, CONGRESS 1992 Cong., GAO/NSAID-92-204 (Washington, DC: US General Accounting Office, 1992), 3.

Bibliography

- Adams, Charlotte. "Understanding MSG-3" Last modified 2009. Accessed Jan 29, 2017.
http://www.aviationtoday.com/am/repairstations/Understanding-MSG-3_33062.html.
- Adedeji, Adebayo. *Linking the Readiness of the Armed Forces to Dod's Operation and Maintenance Spending*. Washington, DC: Congressional Budget Office, 2011.
- Anderson, Richard W. "Air Carrier Revisions to MSG-3." *Logistics Spectrum* Apr-Jun 2002, no. 36 (2002): 2.
- Army Regulation (AR) 700-138, *Army Logistics Readiness and Sustainability*. Washington, DC: Army Publication Directorate, 2004.
- Army Regulation (AR) 750-1, *Army Materiel Maintenance Policy*. Washington, DC: Army Publication Directorate, 2013.
- Ball, Daniel and Ellis Golson. *Army Aviation Study-II*. Fort Rucker, AL: US Army Aviation Center of Excellence, 2010.
- Carter, Ashton. Pentagon Efficiency Initiatives. Remarks Given at the Heritage Foundation, Washington, DC.
- DanburyKline. "A Summary Guide to MSG-3." (2012). Accessed Jan 29, 2017.
http://danburykline.co.uk/DKWP/?page_id=1898.
- Dorner, Dietrich. *The Logic of Failure: Recognizing and Avoiding Error in Complex Situations*. New York, NY: Merloyd Lawrence, 1996.
- Dubois, Thierry. "Reinventing a Standard." *Aviation Week & Space Technology*, September 3, 2012, 2012.
- Federal Aviation Administration Advisory Circular 121-22C. *Maintenance Review Boards, Maintenance Type Boards, and OEM/TCH Recommended Maintenance Procedures*. 2012.
- Gentile, Gian, Joshua Klimas, Celeste Ward Gventer, Stephanie Young, R. William Thomas, Michael E. Linick, Raphael S. Cohen, Jennifer Kavanagh, Todd Nichols, Jerry M. Sollinger, and Zachary J. Steinborn. *The Army's 2013 Aviation Restructure Initiative: Summary of Research for the National Commission on the Future of the Army*. Santa Monica, CA: RAND, 2015.
- Gharajedaghi, Jamshid. *Systems Thinking: Managing Chaos and Complexity: A Platform for Designing Business and Architecture*. 3rd Burlington, MA ed. Burlington, MA: Morgan Kaufmann, 2011.
- Harrison, Todd. *Defense Modernization Plans through the 2020s: Addressing the Bow Wave*. Washington, DC: Center for Strategic and International Studies, 2016.
- Hessler, Kenneth and Donald Ketron. *Ch-47F NMC Rates: Scheduled Vs. Unscheduled Maintenance Creep*. Redstone Arsenal, AL: US Army Research, Development and Engineering Command (RDECOM), 2015.
- Holistic Aviation Assessment Task Force (HAATF). *Regaining Decisive Action Readiness*, Washington, DC: June, 2016.
- Integrgraph. *Maintenance Steering Group-3 (MSG-3)-Based Maintenance and Performance-Based Planning and Logistics (Pbp&L) Programs: A White Paper*. Huntsville, AL, 2006.

- Jessen, Lorenz and Brian Jenkins. "MSG-3 in the Helicopter World." *Helicopter Maintenance Magazine* 2011.
- Judson, Jen. "Lawmakers Move to Restore Army Aviation Budget Cuts." *Defense News* (April 26, 2016 2016). Accessed October 1, 2016. <http://www.defensenews.com/story/defense/land/army-aviation/2016/04/26/lawmakers-move-restore-army-aviation-budget-cuts/83354172/>.
- Lussier, Frances and Black Shaun. *A CBO Study: An Analysis of Us Army Helicopter Programs*. Washington, DC: Congressional Budget Office, 1995.
- Maze, Rick. "Radical Change Is Coming: Gen. Mark A. Milley Not Talking About Just Tinkering around the Edges." Association of the United States Army Articles. Last modified December 13, 2016. Accessed December 19, 2016. <https://www.ausa.org/articles/radical-change-coming-gen-mark-milley-not-talking-about-just-tinkering-around-edges>.
- National Commission of the Future of the Army NCFA. Report to the President and the Congress of the United States, Washington, DC: January 28, 2016.
- Operations & Sustainment Visual Analysis Tool (OSVAT) for Operating and Support Management Information System (Osmis)*. Washington, DC: Deputy Assistant Secretary of the Army for Cost and Economics, 2014.
- Roosevelt, Ann. "Army Launching Aviation Study II, General Says." *Defense Daily* 242, 25 (May 06 2009). Accessed November 14, 2016. <http://www.defensedaily.com/army-launching-aviation-study-ii-general-says-2/>.
- Smith, Anthony. "RCM: Gateway to a World Class Maintenance Program." *Rock Products* 103, no. 5 (May 2000): 44-45.
- Thurman, James D. Memorandum for Vice Chief of Staff, US Army Regarding Army Aviation Readiness Review Findings, Ft. McPherson, GA. 2011.
- TRADOC Army Aviation Task Force (AATF). *Comprehensive Review of Army Aviation Modernization*. Washington, DC: US Army Training and Doctrine Command, 2003.
- US General Accounting Office. *Comanche Helicopter: Program Needs Reassessment Due to Increased Unit Cost*, CONGRESS 1992 Cong, by Division, GAO National Security and International Affairs. GAO/NSAID-92-204, 1992.
- Van Patten, Donald A. "Transforming the Aircraft Inspection Process." *Air Force Journal of Logistics* 34, no. 1&2 (2010): 12.
- Vergun, David. "Taming Sustainment Costs Key to Keeping Army Aviation Aloft." *Army News Service* (January 15, 2014). Accessed August 23, 2016. <https://www.army.mil/article/118276/>.
- Whittle, Richard. "Army Aviation Budget Plunges Earthward." *Breaking Defense* (February 9, 2016). Accessed November 15, 2016. <http://breakingdefense.com/2016/02/army-aviation-budget-plunges-earthward/>.
- Wilhelm, Karen. "Retooling the MSG-3 Mro Standard for Rotorcraft." 2014. Accessed December 20, 2016. <http://www.abdonline.com/news-analysis/rotorcraft/retooling-the-msg-3-mro-standard-for-rotorcraft/#.WFmeIvnaFIU>.
- Williams, Dr. James W. *A History of Army Aviation: From Its Beginnings to the War on Terror*. Lincoln, NE: iUniverse, 2005.
- Wrigley, Scott. *MSG-3 Deployment on a C-5 Galaxy*. 730th Aircraft Sustainment Group, 2014.