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# Enabling Early Sustainment Decisions

Application to F-35 Depot-Level  
Maintenance

John G. Drew, Ronald G. McGarvey, Peter Buryk

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RAND Project AIR FORCE

Prepared for the United States Air Force  
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## Preface

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The U.S. Air Force has long struggled to incorporate new weapon system logistics requirements and support system design considerations into its broader sustainment enterprise early in the acquisition process. Key decisions associated with support system design include whether contract or organic resources should be used to perform sustainment functions. This report develops an economic-based framework that can be used to make weapon system sustainment sourcing decisions as part of a sustainment enterprise posture planning process. The concepts presented here are intended to help the Air Force start thinking more strategically about sustainment posture planning and illuminate the advantages of an enterprise-wide view of sustainment management.

We demonstrate the use of this framework by applying it to a new weapon system, the F-35 Joint Strike Fighter, to identify depot maintenance strategies at the aircraft subsystem/technology level.

This analysis was conducted within the Resource Management Program of RAND Project AIR FORCE as part of the fiscal year (FY) 2012 project “Reducing F-35 Operations and Sustainment Costs.” The research was sponsored by the Director of Logistics in the Office of the Deputy Chief of Staff for Logistics, Installations, and Mission Support at Headquarters U.S. Air Force (AF/A4L).

This report should be of interest to Air Force secretariat and acquisition leaders and their staffs, as well as major command commanders and their staffs. It will also be of interest to logisticians, planners, operators, and employers of air and space weapon systems throughout the U.S. Department of Defense, especially those involved with acquisition, maintenance, and sustainment planning related to these systems and technologies.

This document is one in a series of RAND publications addressing Air Force sustainment planning issues. Related publications include the following:

- John Drew, Russell D. Shaver, Kristin F. Lynch, Mahyar A. Amouzegar, and Don Snyder, *Unmanned Aerial Vehicle: End-to-End Support Considerations*, MG-350-AF, 2005. This report examines the current support postures for unmanned aerial systems, such as Global Hawk and Predator. The authors conclude that there is a gap between traditional methods of determining logistics requirements and rapid acquisition processes. A balance is needed between providing a new capability rapidly and the resulting effects on the long-term support of that capability.
- Robert S. Tripp, Kristin F. Lynch, Daniel M. Romano, William Shelton, John A. Ausink, Chelsea Kaihoi Duran, Robert G. DeFeo, David W. George, Raymond E. Conley, Bernard Fox, and Jerry M. Sollinger, *Air Force Materiel Command Reorganization*

*Analysis*, MG-1219-AF, 2012. This congressionally mandated report examines the proposed reorganization of Air Force Materiel Command as required by the Defense Authorization Act for FY 2012. Specifically, it describes the current functional responsibilities, manpower authorization, and disposition in the proposed restructure. It also provides an independent assessment of how realignments would likely affect life-cycle management, weapon system sustainment, and support to the warfighter.

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## Summary

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The importance of strategic sourcing has been well recognized within the U.S. Air Force as the service continues to work toward a cost-effective sustainment enterprise. The goal of this analysis is to develop a set of criteria for support system design sourcing decisions that weapon system program offices can apply early in the acquisition cycle. The criteria will help determine whether the enterprise has the capability to sustain a system and, if not, whether it would be beneficial to develop that capability. If the new system can be routinely sustained within the Air Force, it may fit it into an existing enterprise structure and available capabilities (that could be expanded, if necessary).

The framework presented in this report addresses these sustainment planning challenges in several ways. First, the approach presented here provides a repeatable, analytically based decision tool that does not require a large amount of detailed data; we use historical Air Force repair data that are readily available and constantly archived. Second, this approach considers repair source decisionmaking in the context of the broader Air Force enterprise. That is, we examine large, complex “systems of systems,” such as fighter aircraft, from the perspective of technologies and subsystems, some of which are common across different aircraft. Finally, these concepts are potentially applicable to other aspects of sustainment planning, such as managing government-mandated repair sourcing mixes and informing other Air Force sustainment community responsibilities, including depot activation, sustaining engineering, supply chain management, and product support integration.

We demonstrate the use of this framework by applying it to a new weapon system, the F-35 Joint Strike Fighter (JSF), identifying depot maintenance strategies at the aircraft subsystem/technology level. As currently planned, the F-35 JSF is the largest aircraft acquisition program in the history of the U.S. Department of Defense (DoD). Its total acquisition and operating and support (O&S) cost is expected to exceed \$900 billion through 2065. Moreover, the F-35’s cost-per-flying-hour estimate increased by more than 80 percent (in constant dollars) from 2002 to 2010. To ensure that the affordability of the F-35 program is not threatened by continuing O&S cost growth, the Air Force is examining alternative strategies to reduce those costs. The Air Force, Navy, and Marine Corps, through the F-35 Joint Program Office, have determined that all depot-level repairs on the F-35 will have a core component. Having a core component means that the government will maintain the capability to perform some—but not necessarily all—repair work at a U.S. government facility.<sup>1</sup> Core decisions are made to protect the services so that, in an event of a natural disaster, war contingency, or disruption in

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<sup>1</sup> U.S. Department of Defense Instruction 4151.20, *Depot Maintenance Core Capabilities Determination Process*, January 5, 2007.

commercial-sector operations, the government will retain the capability to perform certain tasks. Air Force Materiel Command's Depot Operations Division (AFMC/A4D) has suggested that approximately 60 percent of the total depot maintenance workload for the F-35 falls into the core category.<sup>2</sup> Thus, although the U.S. government will retain the capability to perform the range of depot-level repairs, 40 percent of the workload—known as “above core”—can be considered for sourcing to an organic Air Force facility, another military service's facility, a foreign partner, or the private sector. DoD guidance states that above-core depot workloads should be assigned on the basis of a best-value determination.<sup>3</sup> But this guidance does not specify how to determine “best value.” To help fill this gap, this report presents an approach to determining best value when assigning above-core depot workloads.

In the longer term, this kind of analysis can help shape the future sustainment enterprise by giving the Air Force an opportunity to examine subsystems across weapon systems. In doing so, the Air Force needs to evaluate the effects of new or emerging technology on its subsystem strategies. By performing such a review across weapon systems and across technology types, the Air Force will be better positioned to identify the sustainment system that it would like to have in the future.

This framework can also inform decisions about other product support activities, such as supply chain management or sustaining engineering. For example, data from the framework can support decisionmaking when there are breaches of the congressionally mandated division of depot workload between commercial and government-owned providers (commonly referred to as “50/50”). Moreover, the framework could inform discussions between weapon system developers and the Air Force concerning engineering projections of reliability and maintainability parameters by providing a basis for comparison with data from legacy aircraft.

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<sup>2</sup> Discussions with AFMC/A4D personnel, April 12, 2012.

<sup>3</sup> U.S. Department of Defense, “Memorandum of Agreement on Joint Strike Fighter (JSF) Depot Source of Repair Assignment Process,” 2010.

## Acknowledgments

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Many people, both inside and outside the U.S. Air Force, provided valuable assistance and support for the initial concepts that became the foundation for this work and for our continuing engagement in this area. They are listed here with their rank and position at the time of our research. We thank Maj Gen Robert McMahon, former AF/A4L and the sponsor of our original enterprise posture planning work. We also thank Lt Gen Judith Fedder, AF/A4/7, and Maj Gen John Cooper, AF/A4L, for sponsoring this specific analysis and for their untiring support as we progressed. On their staffs, we owe special thanks to Guy Fowl, Lt Col Dave Seitz, and Col Kyle Matyi at AF/A4LY for their assistance throughout this research effort. We are grateful to Grover Dunn, AF/A4I, for his keen insights and suggestions, which helped focus our analysis. We also benefited from input from Deb Tune, SAF/IE, and Scott Reynolds and Mark Van Gilst, SAF/IEL.

We thank Lt Gen Bruce Litchfield, commander of the Air Force Sustainment Center, and Lt Gen C. D. Moore, commander of the Air Force Life Cycle Management Center, for sharing their feedback on our work. We also appreciate the feedback we received from Don Lucht at AFMC/A4D.

We could not have developed these concepts without the help and support of the staff from the major commands and the program offices. At Air Combat Command (ACC), we would like to thank Major General Dave Gillett, ACC/A4, for providing us with access to unit-level information. Without the tireless efforts of Rich Moore, Bob McCormick, Roger Moulder, and Sam Wright at AFMC/A8/9, the data analysis portion of this work would not have been possible. Their continued feedback as we progressed through the research was invaluable and made for a better end product. At the F-35 Joint Program Office, we are thankful for the help of Col Dave Morgan, Kim Fuller, Charlie Brown, and Ken Ziegler.

We are especially grateful for the assistance given to us by our Air Force Fellow Lt Col Jeff Meserve. His insights and understanding of sustainment strategies greatly enhanced our work.

Finally, at RAND, we are indebted to Robert Tripp and James Masters, whose insights on transaction cost accounting and deep knowledge of Air Force logistics led them to further develop the concepts described here. Kristin Lynch and Amy Maletic were also instrumental in developing these initial concepts, and we owe them a debt of gratitude. The knowledge and support of many of our colleagues also greatly enhanced our analysis. We would like to thank, in particular, Raymond Pyles, Michel Boito, and Tom Light for their related work on this subject and for sharing their knowledge and expertise with our team.

Finally, we benefited from the thoughtful reviews provided by Marc Robbins and Raymond Franck, which helped us improve the presentation of the analysis. The authors take full responsibility for any omissions or oversights in this report, however.





## Abbreviations

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|          |                                                                                                                                             |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------|
| ACC      | Air Combat Command                                                                                                                          |
| AF/A4L   | Director of Logistics, Office of the Deputy Chief of Staff for Logistics, Installations, and Mission Support, Headquarters U.S. Air Force   |
| AF/A4M   | Director of Maintenance, Office of the Deputy Chief of Staff for Logistics, Installations, and Mission Support, Headquarters U.S. Air Force |
| AFMC     | Air Force Materiel Command                                                                                                                  |
| AFMC/A4D | Air Force Materiel Command, Depot Operations Division                                                                                       |
| AFMC/A9A | Air Force Materiel Command, Studies and Analysis Division                                                                                   |
| DoD      | U.S. Department of Defense                                                                                                                  |
| ECM      | electronic countermeasure                                                                                                                   |
| FY       | fiscal year                                                                                                                                 |
| JSF      | Joint Strike Fighter                                                                                                                        |
| MDS      | mission design series                                                                                                                       |
| NIIN     | National Item Inventory Number                                                                                                              |
| O&S      | operating and support                                                                                                                       |
| OEM      | original equipment manufacturer                                                                                                             |
| PAF      | RAND Project AIR FORCE                                                                                                                      |
| R&M      | reliability and maintainability                                                                                                             |
| SME      | subject-matter expert                                                                                                                       |
| TAI      | total aircraft inventory                                                                                                                    |
| TCA      | transaction cost accounting                                                                                                                 |
| WUC      | work unit code                                                                                                                              |



## CHAPTER ONE

# Introduction

---

## Background and Purpose

The U.S. Air Force must sustain a sizable and diverse array of weapon systems. A good portion of these systems must be mission-capable at all times, ready to deploy quickly or support the day-to-day training activities that maintain Air Force readiness. Sustainment of weapon systems is expensive, however, accounting for about 70 percent of a system's total cost.<sup>1</sup> These costs have been rapidly growing. One estimate suggests that the current cost of Air Force sustainment activities now exceeds the total operating costs of such commercial companies as American Airlines and Delta Airlines.<sup>2</sup>

Some of these costs may stem from approaches used to make prior sustainment decisions. Often, the decision about whether to use organic or contractor support for the long-term sustainment of a weapon system is made within narrow organizational boundaries and does not consider the full range of capabilities in the enterprise to identify a more cost-effective option. Once made, such decisions can be difficult to reverse, thus locking the Air Force into a support process that may not be the most efficient or effective.

The importance of strategic sourcing is well recognized within the Air Force as it continues to work toward a cost-effective sustainment enterprise. The goal of the analysis presented in this report is to develop a set of criteria for support system design sourcing decisions that weapon system program offices can apply early in the acquisition cycle to help shape the sustainment enterprise. The criteria help determine whether the enterprise has the capability to sustain the system and, if not, whether it would be beneficial to develop the capability.

The criteria that we developed for this report are derived from economic literature and sourcing studies and can provide the Air Force with an opportunity to leverage core competencies and shape the logistics sustainment enterprise to be more efficient and effective. Standardizing sourcing criteria and enforcing their use can result in better integration and increased collaboration between organic and commercial support, and it can potentially reduce sustainment costs and increase organizational responsiveness and agility.<sup>3</sup> The framework

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<sup>1</sup> Ashton Carter, Under Secretary of Defense for Acquisition, Technology, and Logistics, "Pentagon Efficiency Initiatives," transcript of remarks at the Heritage Foundation, Washington, D.C., April 20, 2011.

<sup>2</sup> National Research Council, *Examination of the U.S. Air Force's Aircraft Sustainment Needs in the Future and Its Strategy to Meet Those Needs*, Washington, D.C.: National Academies Press, 2011, p. 1.

<sup>3</sup> See Robert S. Tripp, Kristin F. Lynch, Daniel M. Romano, William Shelton, John A. Ausink, Chelsea Kaihoi Duran, Robert G. DeFeo, David W. George, Raymond E. Conley, Bernard Fox, and Jerry M. Sollinger, *Air Force Materiel Command Reorganization Analysis: Final Report*, Santa Monica, Calif.: RAND Corporation, MG-1219-AF, 2012.

presented in this report addresses sustainment planning challenges in several ways. First, the approach presented here provides a repeatable, analytically based decision tool that does not require a large amount of detailed data; we use historical Air Force repair data that are readily available and constantly archived. Second, this approach examines repair source decisionmaking in the context of the broader Air Force enterprise. That is, we examine large, complex “systems-of-systems,” such as fighter aircraft, from the perspective of technologies and subsystems, some of which are common across different aircraft. Finally, we believe that these concepts are potentially applicable to other aspects of sustainment planning, such as managing government-mandated repair sourcing mixes and informing other Air Force sustainment community responsibilities, including depot activation, sustaining engineering, supply chain management, and product support integration.

## Application to the F-35

In fiscal year (FY) 2012 the Director of Logistics in the Office of the Deputy Chief of Staff for Logistics, Installations, and Mission Support at Headquarters U.S. Air Force (AF/A4L) sponsored the RAND Project AIR FORCE (PAF) project “Reducing F-35 Operations and Sustainment Costs.” As currently planned, the F-35 Joint Strike Fighter (JSF) is the largest aircraft acquisition program in the history of the U.S. Department of Defense (DoD). According to the December 2011 F-35 Selected Acquisition Report, the total acquisition cost to procure 2,457 F-35 aircraft across the USAF, Navy, and Marine Corps is \$331 billion, with total operating and support (O&S) costs of \$617 billion to operate the aircraft through 2065. (Both costs were computed using a base year of 2012.)<sup>4</sup> Moreover, the F-35 cost-per-flying-hour estimate increased by more than 80 percent (in constant dollars) between 2002 and 2010.

To ensure that the affordability of the F-35 program is not threatened by continuing O&S cost growth, the Air Force is examining alternative strategies to reduce these costs. Our fiscal year 2012 project focused on F-35 maintenance manpower and the maintenance of depot-level repairables because, as shown in Figure 1.1, these two categories account for 40 percent of the F-35’s O&S life-cycle cost estimate.<sup>5</sup> Our analysis of F-35 maintenance manpower is presented in another report.<sup>6</sup> The analysis contained in this report identifies criteria that can help the Air Force make sourcing decisions for F-35 depot maintenance.

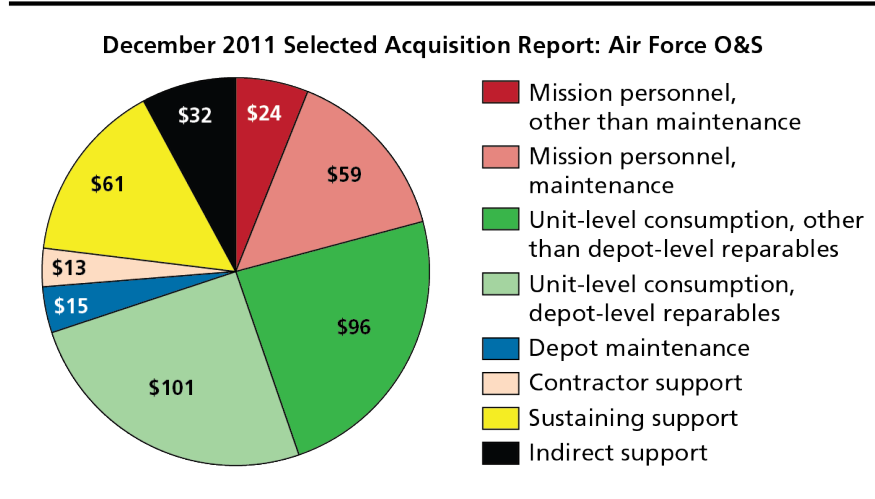
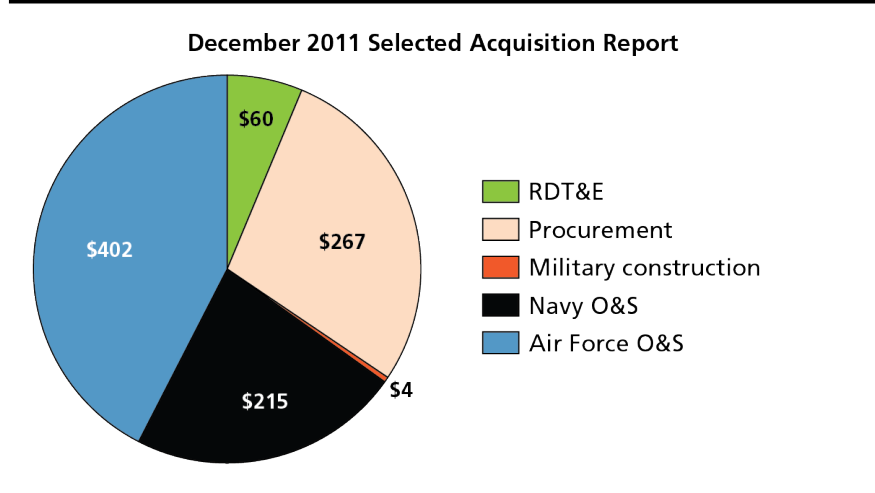
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<sup>4</sup> U.S. Department of Defense, *Joint Strike Fighter (F-35) Selected Acquisition Report*, December 31, 2011.

<sup>5</sup> The other large cost category in the O&S life-cycle cost estimate is unit-level consumption, excluding depot-level repairable maintenance. Aviation fuel is the largest component of this cost category.

<sup>6</sup> See Ronald G. McGarvey, James H. Bigelow, Gary Briggs, Peter Buryk, Raymond E. Conley, John G. Drew, Perry Shameem Firoz, Julie Kim, Lance Menthe, S. Craig Moore, William W. Taylor, and William A. Williams, *Assessment of Beddown Alternatives for the F-35*, Santa Monica, Calif.: RAND Corporation, RR-124-AF, 2013.

**Figure 1.1. F-35 Life-Cycle Cost Estimates**



NOTE: Costs are in base-year 2012 \$ billions. RDT&E = research, development, test, and evaluation.

RAND RR397-1.1

The Air Force, Navy, and Marine Corps, through the F-35 Joint Program Office, have determined that all depot-level repairs on the F-35 have a core component.<sup>7</sup> Having a core component means that the government will maintain the capability to perform some—but not necessarily all—repair work at a U.S. government facility.<sup>8</sup> Core decisions are made to protect the services so that, in an event of a natural disaster, war contingency, or disruption in commercial-sector operations, the government will retain the capability to perform certain tasks. Air Force Materiel Command’s Depot Operations Division (AFMC/A4D) has suggested that

<sup>7</sup> Email correspondence with an AFMC/A4D representative, April 17, 2012.

<sup>8</sup> U.S. Department of Defense Instruction 4151.20, *Depot Maintenance Core Capabilities Determination Process*, January 5, 2007.

approximately 60 percent of the total depot maintenance workload for the F-35 falls into the core category.<sup>9</sup> Thus, although the U.S. government will retain the capability to perform the range of depot-level repairs at its own facilities, 40 percent of the workload—known as “above core”—can be considered for sourcing to an organic Air Force facility, another military service’s facilities, a foreign partner, or the private sector. DoD guidance states that above-core depot workloads should be assigned on the basis of a best-value determination.<sup>10</sup> But this guidance does not specify how to determine “best value.” To help fill this gap, this report presents an approach to determining best value when assigning above-core depot workloads.<sup>11</sup>

## Organization of This Report

In Chapter Two, we describe ongoing Air Force sustainment initiatives, policy, and guidance, along with recent sourcing decisions and areas for potential improvement. We also review the economic theories associated with our framework. Chapter Three uses these theories to develop a framework for sourcing criteria, applying it to F-35 above-core depot workloads. Chapter Four presents conclusions and recommendations based on our research.

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<sup>9</sup> Discussions with AFMC/A4D personnel, April 12, 2012.

<sup>10</sup> U.S. Department of Defense, “Memorandum of Agreement on Joint Strike Fighter (JSF) Depot Source of Repair Assignment Process,” 2010.

<sup>11</sup> We recognize that, because the core workload determinations for the F-35 had already been performed at the time of this research, the scope of the analysis presented in this report does not address the full range of considerations necessary to “shape the logistics sustainment enterprise.” That said, we had an opportunity to apply our previously developed sustainment sourcing concepts to a weapon system (the F-35) for which the Air Force has not yet made sourcing decisions regarding the full range of sustainment activities. Subsequent research conducted by AFMC’s Studies and Analysis Division (AFMC/A9A) has taken the concepts presented in this report and applied them to a broader range of sustainment decisions for the KC-46. (See Air Force Material Command, *Studies and Analysis Division Annual Report*, Wright-Patterson AFB, Ohio, February 2013.)

## CHAPTER TWO

# TCA and Current Air Force Sustainment Efforts

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In 2008, the Director of Maintenance in the Office of the Deputy Chief of Staff for Logistics, Installations, and Mission Support at Headquarters U.S. Air Force (AF/A4M) asked PAF to develop recommendations to make the Air Force sustainment system more agile. At the time, the Air Force was acquiring the Predator and Global Hawk remotely piloted aircraft systems. AF/A4M leadership was concerned that the lengthy and data-intensive decision process imposed on Air Force acquisition programs was forcing sustainment decisions to be made late in the acquisition process.

If the Air Force had standard sustainment systems strategies for technology types, the common subsystems of each new acquisition could have been incorporated into the existing sustainment system. Then, only the new or unique technologies would have required new, detailed analysis for sustainment workload allocation determinations. However, PAF's analysis of historic acquisition programs showed that most programs made sustainment decisions in isolation. They sought to do what they perceived as best for their individual system and did not generally consider the effects on the Air Force's overall sustainment enterprise.

One finding that emerged from the early research suggested that the Air Force should develop an enterprise sustainment strategy at the product support group or technology subsystem level and develop the appropriate sustainment infrastructure. Then, the acquisition community would be directed to use this strategy for each applicable technology type or subsystem when making sustainment decisions for new weapon systems. History suggests that new aircraft systems generally act similarly to legacy aircraft systems at the technology/subsystem level. That is to say that landing gear performs like landing gear, radars perform like other radars, and jet engines act like jet engines. They do so until the underlying technology changes, such as if a system design or redesign were to employ active electronically scanned array radar or scramjet technologies. Some technology types, such as landing gear, will remain much like all other landing gear until the hydraulic systems in use are replaced by a radically new concept. In light of these observations, developing common sustainment strategies at the subsystem level makes logical sense.

If the Air Force were to develop such strategies, sourcing decisions could be made earlier in the sustainment planning process. In developing these strategies, key considerations would include who should do the work and where should it be done. There are multiple options for where the work could be done, ranging from a "blue suit" organization to some type of commercial operation or a blend of multiple sources. The answer could resemble today's air logistics complexes in AFMC's Air Force Sustainment Center. Or the best provider could be the original equipment manufacturer (OEM), some sort of competitive long-term contracted logistics



support, or a provider contracted through a performance-based logistics agreement. If the sustainment activity is more common, it could simply be purchased on the spot market whenever it is needed.

These options regarding who should do the work are presented in this report as being mutually exclusive, but that is only to make it easier to grasp the underlying concepts. The Air Force has had success with multisource strategies wherein some of the work may be done organically and some of it may be competed in an open market. This kind of competition through dual sourcing has, on some occasions, reduced cost and made for an effective sustainment solution. Thus, although for the sake of simplicity of presentation this report discusses mutually exclusive workload allocations, an actual implementation of these concepts would need to consider the costs and benefits of blended strategies.

In thinking about who should do the work, there are three primary considerations: cost minimization, the effectiveness of the solution, and risk mitigation.

## Transaction Cost Accounting

All organizations face fundamental choices about whether to conduct activities internally or contract with an external organization. Where robust markets exist, competition among potential external providers is expected to drive down prices. Economists Ronald Coase and Oliver Williamson won the Nobel Prize for their studies of how successful companies address the question of what to accomplish in-house and what to contract out.<sup>1</sup> Coase and Williamson identified a concept that they called “transaction cost accounting” (TCA). TCA is now a field of economics that addresses when outsourcing might be most beneficial and when the service or product might be best supplied by the firm itself—that is, insourced.<sup>2</sup> Given that the Air Force wants to take advantage of the commercial sector and pay the least amount possible for a high-quality service, a “transaction cost” approach offers helpful insight into these decisions.

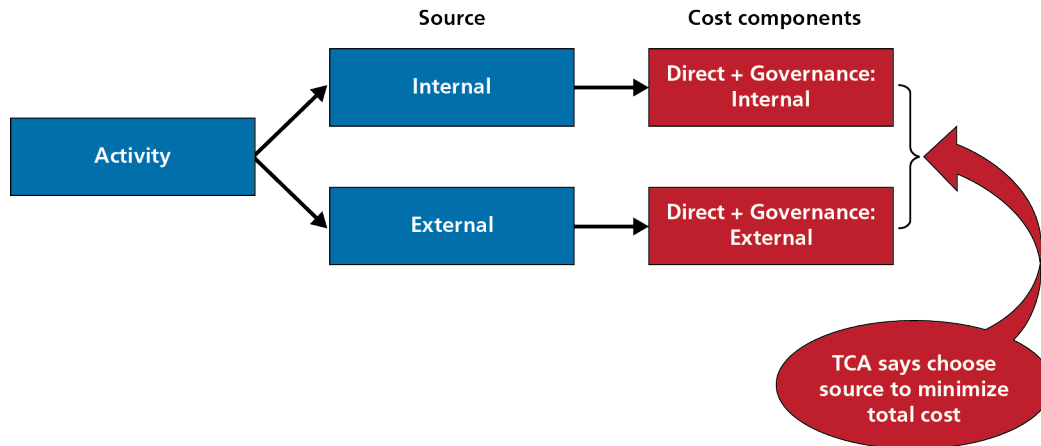
According to TCA, any activity can be done either internally or externally, as illustrated in Figure 2.1. When choosing a source to perform the activity, there are two cost components to consider: direct costs and governance costs. Coase and Williamson suggested that a successful company will not concentrate on only one cost category but, rather, will work to minimize the total costs of the activity.

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<sup>1</sup> Ronald H. Coase, “The Nature of the Firm,” *Economica*, Vol. 4, No. 16, November 1937; Oliver E. Williamson, and Sidney G. Winter, eds., *The Nature of the Firm: Origins, Evolution, and Development*, New York: Oxford University Press, 1993.

<sup>2</sup> This is a method that blends institutional economics, organizational theory, and contract law. It was developed by Ronald H. Coase and later expanded by Oliver E. Williamson in “Transaction-Cost Economics: The Governance of Contractual Relations,” *Journal of Law and Economics*, Vol. 22, No. 2, October 1979, and by George John and Barton A. Weitz in “Forward Integration into Distribution: An Empirical Test of Transaction Cost Analysis,” *Journal of Law, Economics, and Organization*, Vol. 4, No. 2, Autumn 1988.

**Figure 2.1. Application of Transaction Cost Accounting Sourcing Decisions**



SOURCES: Coase, 1939; Williamson, 1981.  
RAND RR397-2.1

Direct costs are the costs normally associated with a sourcing decision, such as manpower, facility, raw material, and utility costs. Some are easy to estimate, but others are less obvious. For example, in the context of government outsourcing, there remains disagreement about the accuracy of cost projections with respect to such categories as overhead rates. The government argues that its overhead rates incorporate more cost categories than do the rates a contractor charges for the same work. This, the government contends, is the source of disparity in the cost projections of these two types of providers. Understanding these differences is often a complex proposition.

Governance costs are even less well understood than direct costs. Governance costs are the comparative costs of planning, adapting, and monitoring task completion under different governance structures. They include such costs as the search for information to determine whether there are commercial entities capable of performing the required activity. Some amount of bargaining, decisionmaking, and contract writing is also necessary. Once the decision is made to use an external supplier, there must be some oversight to ensure that the sourcing organization (in our case, the Air Force) gets what it has agreed to pay for and that the providing organization gets paid for what it has supplied.

Considering the Air Force's spectrum of sourcing options, a purely organic decision is generally the most straightforward with respect to estimating total costs. Labor is directly controlled by the customer, either in the form of uniformed personnel or government civilians. Facilities are owned outright and can contribute to transportation costs, depending on the required logistics pipelines. Organic overhead rates are more transparent and can be measured more easily than outsourced options.

When outsourcing, the direct cost is generally the price paid; estimating the total cost is complicated by the need to identify governance costs for activities that are outsourced. Governance costs are not well described in most programs and, as a result, are often not

considered when cost comparisons are made. Typically, when comparing an activity being provided by one source—either internally or externally—the governance costs are considered only if the work is done internally because they factor into the overhead rates. But this is often not the case when the supplier is an external source.

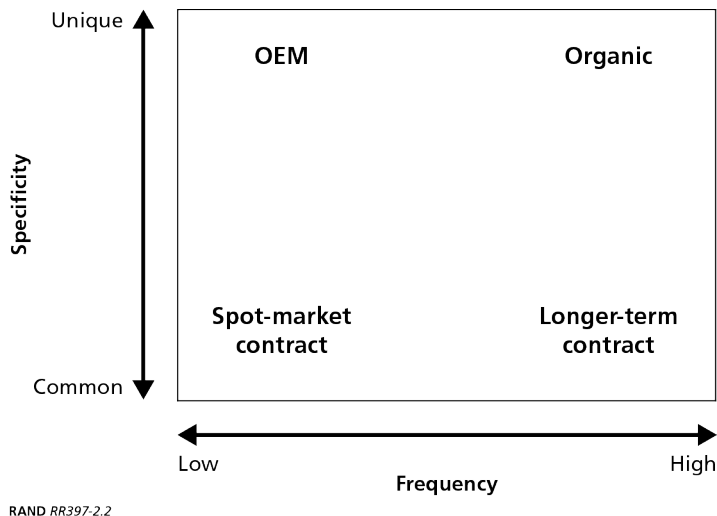
Even if they are well described, governance costs for externally sourced activities are difficult to estimate into the future. This information is easier to capture in retrospect. That is to say, after the work has been done, one can go back and determine how much time was spent searching for a company to do the work, reviewing bids, putting contracts in place, and conducting the requisite quality assurance to ensure that the organization is getting what it paid for. However, Coase and Williamson suggest that it is unnecessary to know the exact governance costs to make an optimal decision. Certain key characteristics of governance will drive the decision one way or another, and if these key characteristics are understood, specific governance cost data are not needed to make the decisions. The first key characteristic they cite is frequency of need: “How often do I need this activity, or how often am I going to have to accomplish this activity?” The other is asset specificity: “Is this a common activity that would be found in many organizations, or is this activity unique to my operation or to the company’s operation?”

Figure 2.2 provides a framework for thinking about how governance costs vary with the specificity and frequency of an activity. The x-axis represents frequency, with frequently occurring activities on the far right side and those that occur infrequently on the far left. The y-axis plots how specific an activity is, with activities that are very common at the bottom of the axis and unique activities at the top. The figure arrays four sources of support along the two axes: organic and three types of contracting (including OEM support). These categories represent the most efficient solutions for total cost minimization when direct costs are comparable across sources.<sup>3</sup> The specific location of any given activity is not exactly demarcated by fixed boundaries on the axes; organic support is generally located in upper right region, OEM is in the upper left, and so on. It is important to identify the position of each sourcing alternative *relative* to the others and to understand how changing specificity, frequency, or both can lead to different sourcing options.

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<sup>3</sup> We note that similar logic could be applied to direct costs when these costs are not comparable across sources. If an activity is unique to one organization, then that organization should be able to achieve all potential economies of scale associated with performing the activity in-house. However, given that there are fixed costs for developing the necessary capabilities, an activity that is performed infrequently may not provide sufficient return on investment to warrant in-house provision; if the OEM had to develop the necessary capabilities as a function of producing the weapon system, the direct costs might be minimized by assigning all such unique and low-frequency activities to the OEM. Activities that are common across organizations suggest that any individual organization cannot achieve the greatest potential economies of scale and thus should seek to outsource the activity.

**Figure 2.2. Conceptual Framework**



A unique activity that occurs frequently would be something that the Air Force would want to perform with organic assets. That is to say, if an activity is unique and the organization requires it frequently, no external provider could capture a greater economy of scale than the Air Force (due to uniqueness), and performing it in-house should yield a higher return on investment (due to high frequency). However, as that frequency declines and if the activity remains unique, it may be difficult for the Air Force to capture any return on investment for capital setup costs. Thus, our interpretation of Coase and Williamson would recommend leaving the activity with the OEM, which has likely already made the necessary capital investments to perform the work. As an activity moves from unique to more common, the decision shifts into the area that we call the “contracting range.” If the activity is both common and frequent, the organization should be able to negotiate a long-term contract and drive prices down significantly. However, if it is a common activity but not needed very frequently, there would be lower benefits to a long-term contract. In that case, the organization can contract for the activity on the spot market at the time of need.

These are “place-in-time” decisions, and they reflect how to think about an activity and then how source it. It is important to consider the temporal aspect of this kind of decision process. Economy of scale is an important consideration in determining a sourcing option, but it is only one of many. In taking time into account, two factors require consideration when thinking about the maintenance of Air Force components. The first is the longevity of the technologies, or what might be labeled the *firefly* effect: How long is the life of a technology? Second, are the technologies involved emerging? That is to say, is this a brand-new technology that the organization has never seen before? And then, even if it is an emerging technology and the organization has never seen it before, is it a quickly evolving technology or is it a more stable

one?<sup>4</sup> For example, compare propulsion and sensor technology. Propulsion is a fairly stable system: Metals are currently about as thin and strong as possible, engines run as hot as they are able, and most get as much thrust to weight as possible. There likely will not be significant changes in this technology until a new propulsion concept is developed. This knowledge suggests that the Air Force may be able to add a new system's engine to an existing engine workload for only the cost of any additional capacity required. Sensor and computing technology, on the other hand, are evolving very quickly. Chips work faster as their design is modified and refined and as the resolution of sensors continuously improves. An example would be the sensors in the multispectral ball mounted on the front of a Predator unmanned aerial system. Sensor technology in the ball is changing so rapidly that, as parts break, they tend to be replaced with newer, more capable components, so not much repair workload is generated.

Thus, it is important to determine whether a technology is a stable or a rapidly evolving one. If it is emerging but stable, then the Air Force may want to enter into an agreement to develop the repair capability if demand frequency is high and the technology is unique. But if it is a quickly evolving, unstable technology, it may become obsolete (or no longer fit into the Air Force's existing infrastructure) before the Air Force can buy tooling and equipment, build the necessary infrastructure, and hire the personnel to carry out repairs. So, the Air Force may be better off in the case of technologies like the sensor ball to leave the repair to the manufacturer until the technology matures. When thinking about specificity, considerations revolve around whether the part is common or unique. It may turn out that the part is unique today because the Air Force tends to be on the leading edge of technology. However, when examining the component, activity, or repair, it is necessary to ask whether future systems, other services, or foreign military partners will use it. It may turn out that what was thought to be specific to this program will be common in ten years. The converse of this view is the idea that a commercial capability will be available as long as the Air Force owns the weapon system. Typically, the Air Force keeps weapon systems much longer than the associated technologies remain commercially available. The KC-46 is an example. If the Air Force keeps the KC-46 as long as it has kept the KC-135, it is unrealistic to expect that any commercial variant of the KC-46 (i.e., the Boeing 767) will be in widespread use for as long as the Air Force's fleet.

Temporal considerations also apply when thinking about the frequency of an activity. Typically with Air Force systems, there is a learning curve in the repair process, with a high frequency of repair at the beginning of service life and declining frequency as the Air Force gains experience. It is important to consider the Air Force's frequency of need for a given activity and consider how that would influence today's thinking.

Addressing the temporal aspects of the decision process is part of identifying and mitigating risk; some of these factors pertain to today's risk and others to tomorrow's risk. It is common in

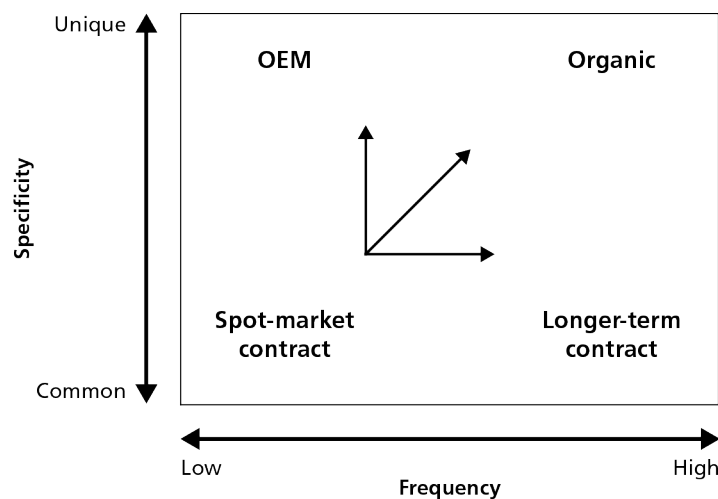
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<sup>4</sup> Charles H. Fine, *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, New York: Basic Books, 1999.

a new program for the focus to fall on today’s risk. But the Air Force must also think about future risks and what future risk-mitigation decisions can be made today to improve future support. A potential risk-mitigation strategy, in this case, would be securing key technical data rights early in a program’s life cycle—when there is price leverage—to retain the option to increase organic repair capabilities in the future if the fiscal, political, and economic environment warrants such a change.

To place these concepts in the military context, PAF researchers expanded Coase and Williamson’s work to include a third consideration of risk. Figure 2.3 is a visual representation of this concept. The three vectors in the decision space represent the potential effect of risk mitigation on repair sourcing decisions. Risk mitigation generally involves increasing the Air Force’s control of an item. That does not necessarily suggest that an item or activity must be performed with the Air Force’s organic capabilities. In-house sustainment carries its own risks. To sustain a system in-house, the Air Force must be able to maintain the repair capability and required competencies over time. This is complicated by the uncertainty of demand that stems, in part, from the unpredictability of war requirements. If it appears that frequency of an activity will rise, and if the component is common enough, an organization would not rely on a spot market indefinitely. In this case, establishing a longer-term contract relationship would be prudent. If an item is common but the organization is not sure how long it will need it or how long the item will remain common, that would suggest a need to go back to the OEM or procure technical data to bring the workload in-house. If the organization concludes that it might have underestimated frequency estimate and that it has been too confident about the commonality of an item, that would suggest a move to the organic arena. Decisionmakers need to weigh cost, effectiveness, and risk when making sustainment choices. These three dimensions of performance should be factored appropriately into the structure of the decision.

**Figure 2.3. Conceptual Framework with Risk Considerations**



RAND RR397-2.3



## CHAPTER THREE

# Application of the Framework to the F-35

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Given a basic understanding of the theory behind the framework, we now apply these concepts to F-35 sustainment decisions. This analysis focuses on a subset of sustainment activities—namely, the above-core depot maintenance workload for the F-35. As stated earlier, core decisions are made to protect the services so that, in the event of a natural disaster, war contingency, or disruption in commercial-sector operations, the U.S. government will have a capability that it owns and controls to perform certain workloads. In our view, core decisions are the primary way that the Air Force should identify risk and address risk mitigation. Because we think of core capabilities as risk mitigation, in this analysis, we assume that risk (except for the temporal considerations discussed in Chapter Two) has been addressed. Therefore, we do not discuss risk further in this report. Also, because the U.S. Air Force, Navy, Marines, and the F-35 Joint Program Office have determined that every repair on an F-35 has a core component, we set aside the fixed or sunk costs necessary to develop a repair capability. Because every repair has a core component, the government will necessarily bear the fixed or sunk costs to develop every repair capability. The remainder of this report discusses only the economic decision of where the above-core workload should be performed.

We began this analysis with an assessment of workload frequency. We first considered using contractor-provided F-35 reliability and maintainability (R&M) data. However, the Air Force's experience with contractor-provided R&M data early in a program has shown that those data are typically wrong, because they are early engineering estimates based on what an engineer anticipates is going to happen and not on data drawn from actual experience. Instead, we used actual R&M data for the Air Force's legacy fighter/attack aircraft, focusing on the A-10A, the F-15E, and the F-16C. We did not include data from the Air Force's most modern fighter platform, the F-22, because it is likely that initial system reliability issues would distort repair demands. For this reason, F-22 data are not good representations of expected future demands.<sup>1</sup>

For the legacy fleets, we examined ten years of historical depot repair demand data from a module in the Air Force's supply system, D085, as shown in Figure 3.1. We conducted this analysis at the National Item Identification Number (NIIN) level, which is a subset of the National Stock Number level. We then cross-referenced the D085 data with D200 data, another Air Force supply system data set, to determine the repair costs, to identify the source of repairs, and to link the NIINs to their five-digit work unit codes (WUCs). We looked at ten years of data because we wanted to normalize potential anomalies in repair demand over the sample period

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<sup>1</sup> As the Air Force gains experience with fifth-generation fighter aircraft, historical maintenance and reliability data from the program could better inform future sustainment decisions.



and ensure that modifications or individual depot-level repairs would not have an outsized effect on our results. By combining the D085 and D200 data and then linking them to their WUCs, we were able to establish frequency counts.

For specificity, we used the aircraft WUC manuals (“06” manuals) to identify subsystems at the two-digit WUC level. We then assigned each subsystem a specificity value between 0 and 1, with 0 representing shared commercial technology and 1 being military-specific technology unique to a single platform. The assignment of a specificity value was more subjective; we established initial estimates and then worked with Air Force subject-matter experts (SMEs) to fine-tune our assessments.

**Figure 3.1. Data Sources**

| Frequency<br>(Air Force-supplied, objective)                                                                                                                                                                                                                                                                                                                                   | Specificity<br>(RAND-generated, subjective)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• D085 data for LRU demand</li> <li>• D200 data for LRU unit repair costs, source of repair, and some work unit codes</li> <li>• All data span 10 years (2011–2002)</li> <li>• Linked NIIN to work unit codes using D085 inputs and Federal Supply Classification</li> <li>• Aggregated work unit codes at the 2-digit level</li> </ul> | <ul style="list-style-type: none"> <li>• Values can be changed with SME feedback</li> </ul> <div style="display: flex; align-items: center;"> <div style="writing-mode: vertical-rl; transform: rotate(180deg); margin-right: 5px;">Specificity</div> <div style="text-align: center; margin-right: 10px;">             1<br/>↑<br/>0           </div> <div> <p>Military-specific technology</p> <ul style="list-style-type: none"> <li>• Across Air Force MDS</li> <li>• Other services</li> <li>• Foreign military partners</li> </ul> <p>Shared commercial technology<br/>(across the spectrum of civilian aircraft platforms)</p> </div> </div> |

NOTE: LRU = line-replaceable unit. MDS = mission design series.

RAND RR397-3.1

Table 3.1 provides an example of how we gauged specificity. We took the entries from the F-15 WUC manual and assigned a specificity value to each major subsystem, ranging from a value of 1 for a subsystem that is unique to a single platform to 0 for a subsystem that is common with commercial platforms. Specifically, 0.8 represents a subsystem with *many* unique features that are shared among other fighter/attack aircraft. A value of 0.6 indicates that the subsystem has *some* unique features and is generally shared among other military aircraft. A value of 0.4 is a *common* subsystem on military aircraft. A value of 0.3 represents a common subsystem that is also shared among commercial platforms. For this set of subsystems, we did not assign a specificity value of less than 0.3 because we decided that even systems that closely resemble commercial versions still contained an element of military design and integration unique to the Air Force. We then refined these initial assessments based on inputs from SMEs at Headquarters U.S. Air Force and the major commands. The F-15E represented the most complex set of WUCs; therefore, the specificity values for these subsystems addressed the full range of systems we wanted to consider. Note that we assumed that each subsystem had an identical specificity value

across all three of the weapon systems in our study (the F-16C, the F-15E, and the A-10A). While further analysis may have allowed us to refine this assumption and identify variance in specificity across weapon systems, our SME interviews suggested that variances across fighter/attack aircraft should be minimal. (There may be less support for this assumption if we were considering very different platforms, such as heavy airlift versus fighters.)

**Table 3.1. Specificity Values Matrix by Two-Digit Work Unit Code**

| WUC | Nomenclature                   | Specificity Value |
|-----|--------------------------------|-------------------|
| 11  | Airframe                       | 1.0               |
| 55  | Malfunction Analysis/Recording | 1.0               |
| 76  | Penetration Aids/ECM           | 1.0               |
| 91  | Emergency Equipment            | 1.0               |
| 96  | Personnel                      | 1.0               |
| 97  | Explosive Devices              | 1.0               |
| 14  | Flight Controls                | 1.0               |
| 74  | Fire Control                   | 0.8               |
| 75  | Weapons Delivery               | 0.8               |
| 65  | Identify Friend or Foe         | 0.7               |
| 61  | HF Communications              | 0.6               |
| 62  | VHF Communications             | 0.6               |
| 63  | UHF Communications             | 0.6               |
| 71  | Radio Navigation               | 0.6               |
| 23  | Turbofan Power Plant           | 0.5               |
| 24  | Auxiliary Power Plant          | 0.4               |
| 41  | Environmental Control          | 0.4               |
| 42  | Electrical Power Supply        | 0.4               |
| 44  | Lighting                       | 0.4               |
| 51  | Flight Instruments             | 0.4               |
| 64  | Interphone                     | 0.4               |
| 13  | Landing Gear                   | 0.3               |
| 45  | Hydraulic/Pneumatic            | 0.3               |
| 46  | Fuel                           | 0.3               |
| 47  | Oxygen                         | 0.3               |
| 49  | Miscellaneous Utilities        | 0.3               |

NOTE: ECM = electronic countermeasure.

RAND RR397-T3.1

When we analyzed NIIN data, we found that about 20 percent of the legacy fighter/attack aircraft depot-level repairable items accounted for about 80 percent of demand. There were approximately 3,800 total NIINs with associated depot-level repair, as reflected in the last row of Table 3.2. Of those NIINs, 761 individual stock numbers constituted 84 percent of the total demand for repair. To keep our analysis tractable, we limited our application of the framework to the top 20 percent most-frequently repaired NIINs for each aircraft—304 from the F-15C, 208 from the F-15E, and 248 from the A-10A.

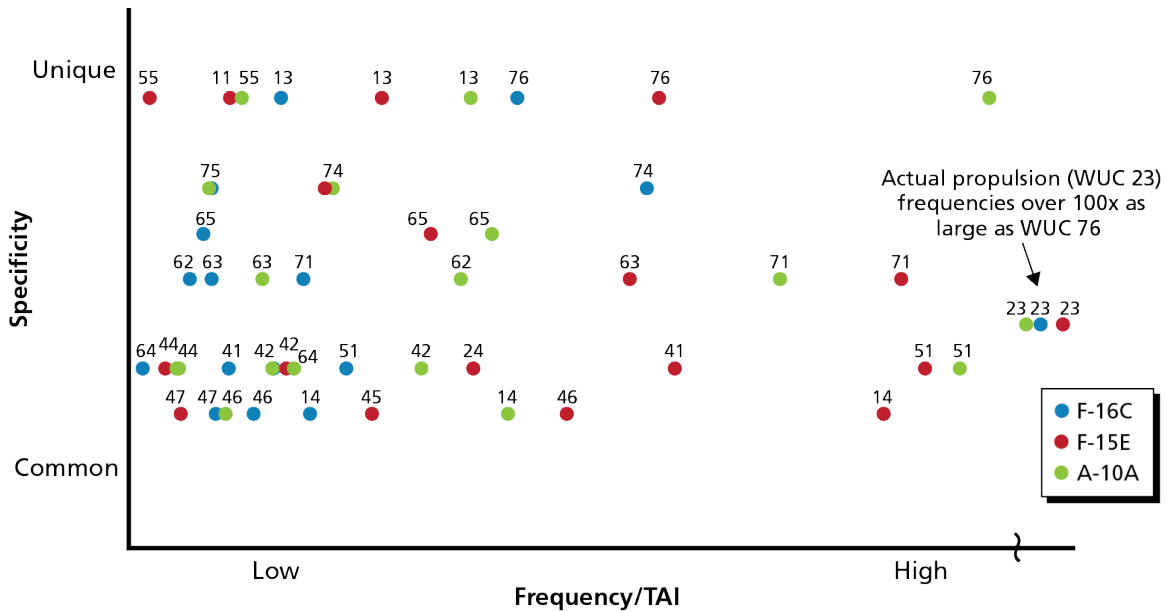
**Table 3.2. Depot-Level Repair Demand Frequency Count, by MDS**

| MDS   | Total NIINs | Number of NIINs Used (20%) | Total DRs | Number of DRs Used | % Total DRs |
|-------|-------------|----------------------------|-----------|--------------------|-------------|
| F-16C | 1,522       | 304                        | 868,282   | 733,558            | 84          |
| F-15E | 1,042       | 208                        | 558,225   | 490,174            | 88          |
| A-10A | 1,242       | 248                        | 336,312   | 271,943            | 81          |
| Total | 3,806       | 761                        | 1,762,819 | 1,495,675          | 84          |

RAND RR397-T3.2

To make the data easier to interpret, we aggregated repair work at the two-digit WUC, as shown in Figure 3.2. For example, we took all of a given aircraft’s NIINs associated with the jet engine (that is, WUC 23, propulsion) and consolidated the data for all repairs. We then normalized the repairs based on the size of the fleet (the total aircraft inventory, or TAI) to help account for differences in MDS inventories and allow for comparisons across platforms. Using both repair frequency values and the uniqueness values discussed previously, we then plotted each two-digit WUC for the F-16C (blue), F-15E (red), and A-10A (green). Note that there were no reported repair data for the F-16C’s WUC 55; therefore, no point is plotted for that subsystem. Additionally, there are several clusters of subsystems, such as WUC 74 and those in the lower left quadrant of the plot, where several platforms’ systems are covered by other points, so may be difficult to see that all three MDSs are represented.

**Figure 3.2. Results, by Two-Digit Work Unit Code and MDS**

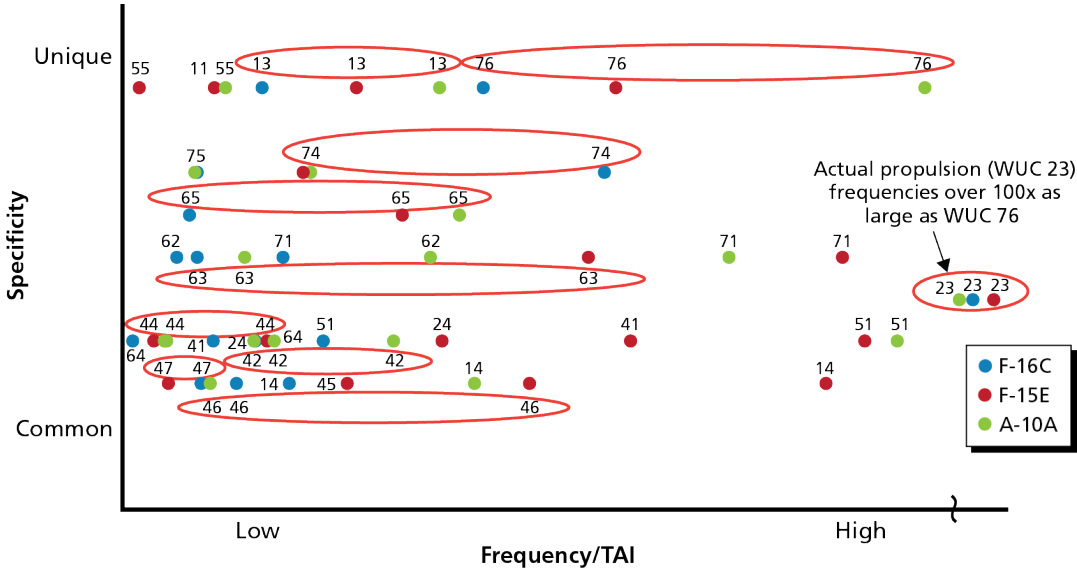


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This process begins to paint a much clearer picture. Because the frequency of repair for WUC 23 is approximately 100 times greater than the frequency of repair for WUC 76, the next most-frequently repaired subsystem, we place WUC 23 in the far right side of the figure, even though this is not an accurate representation of its position relative to the other subsystems. WUC 23 appears to have a very high frequency of repair because every fan blade or every component in an engine counts as an individual candidate for repair in the data system.

As indicated in Figure 3.3, normalizing WUCs by their TAI shows that that even though aircraft have different performance and reliability characteristics, major subsystems tend to act in a similar way. We highlight an illustrative set of groupings to show that—for the most part, like subsystems act similarly. This finding is consistent with the hypothesis we presented in Chapter Two that there would be some degree of common behavior for like subsystems across MDSs. That is to say, a landing gear for an F-16C (WUC 13) performs similarly to landing gear for an F-15E. Similarly, ECM systems and penetration aids (WUC 76) all act in a similar manner regardless of what airframe they are on. This is a significant finding, because it enables us to extrapolate repair behaviors of legacy systems onto future, similar systems of next-generation platforms, such as the F-35, for which the underlying technology has not significantly changed.<sup>2</sup>

**Figure 3.3. Model Results by Two-Digit Work Unit Code and MDS, with Like Subsystems Highlighted**

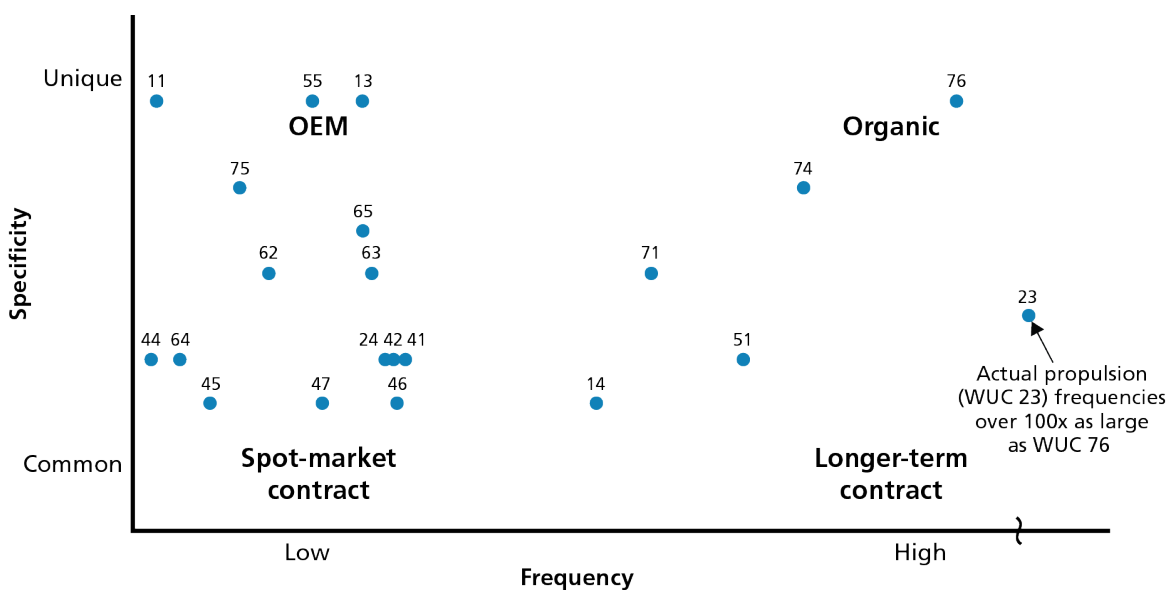


RAND RR397-3.3

<sup>2</sup> This is not a formal algorithm. For example, WUC 51 has two weapon systems displaying similar behaviors and one weapon system with significantly less repair demand. That said, the basic premise that legacy subsystems' behavior can be indicative of future subsystems' behavior holds true.

Given the finding that most subsystems behave in a similar manner across weapon systems, we then grouped the WUCs across the three legacy fighter/attack aircraft; Figure 3.4 presents a single point for each subsystem. This two-digit WUC-level grouping allows us to compare one subsystem with other subsystems, and we have superimposed the preferred source of work in the figure. This graphic demonstrates the concept of designing repair strategies with a system-centric view rather than one that is stovepiped and MDS-centric.

**Figure 3.4. Model Results by Two-Digit Work Unit Code, Pooled MDS Values**



RAND RR397-3.4

We emphasize that where any individual dot lies in the figure is not as important as its relative position: Where is one WUC plot on the axes compared with the others? WUCs closer to the upper right corner of the figure are more desirable workloads for organic provision than those in the lower left corner. Specifically, according to the data on these legacy fighter/attack aircraft, WUC 23 (propulsion) is more appropriate for organic repair than WUC 44 (utility lighting). Determining exactly how much workload the Air Force wishes to pursue will introduce other considerations, but the view provided by the figure can help the Air Force prioritize workloads, identifying which repairs are more advantageous and which are less desirable to perform organically from an enterprise perspective. It is important to point out that Figure 3.4 does not represent a single-source repair solution for all systems. Rather, it is an enterprise-level view of how the Air Force might think about sourcing decisions. In many cases, a split source of repair could be an efficient solution. For example, in Figures 3.2 and 3.3, the location of WUC 51 for the F-15E and A10A were tightly clustered far to the right, while the corresponding point for the F-16C was located relatively far to the left. Thus, the resulting single, pooled data point in Figure 3.4 is skewed downward and could drive sourcing decisions toward a different contracting

mechanism. With this phenomenon in mind, the Air Force should consider the specifics of each system and consider mixed repair source solutions where appropriate. Once the Air Force has determined its core requirements, it can then start thinking about which F-35 above-core workload it should perform with its organic capabilities. Figure 3.4 shows subsystems (e.g., WUCs 76, 23, 74) that might be good candidates for organic sourcing due to their high depot-level repair demand and high level of Air Force specificity. Conversely, the figure also points out those subsystems (e.g., WUCs 11, 44, 64) that do not generate substantial repair demands. In keeping with the framework, these systems might be candidates for outsourcing to some extent, depending on the Air Force’s strategic risk tolerance.

## Other Considerations

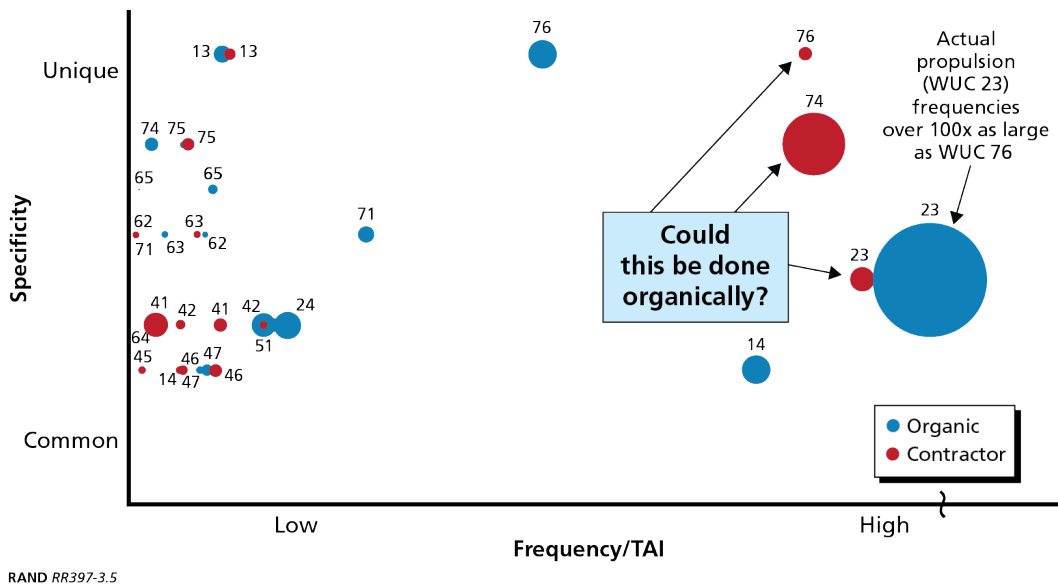
The previous discussion focused on sourcing decisions, applied our framework, and considered options for minimizing total costs based on such parameters as repair frequency and asset specificity. However, it is unrealistic for the Air Force to make these decisions while ignoring certain constraints, such as those on the amount of work that is legally allowed to be outsourced, a policy that is also known as “50/50.” This law states that no more than 50 percent of funds made available to a military department in a given fiscal year for depot-level maintenance and repair may be used to contract work to non-federal government personnel or facilities.<sup>3</sup> The analytic approach developed in this report can help leaders comply with 50/50 in a manner that provides the most benefit to the enterprise. This stands in contrast to the current approach, which appears to be more ad hoc. An analysis of a specific MDS or group of platforms (e.g., combat air forces, mobility air forces) also helps planners think strategically about which workloads for which subsystems should be reconsidered over time. As technologies mature and sustaining engineering improves subsystems’ performance, workloads that were originally performed organically may benefit from outsourcing due to diminishing demands. The reverse could also be true: Systems that generate addition repair demand later in their life cycles may be considered for insourcing to reduce governance costs while at the same time helping to satisfy statutory requirements like 50/50.

Figure 3.5 shows F-16C repair data only, in an attempt to demonstrate how the principles of specificity and frequency can help address other constraints—in this case, the 50/50 rule. To gain a better understanding and to visualize the multiple sources of repair that were actually used for a given two-digit WUC, we varied the color by source. Blue circles represent organic repair, and red circles represent contractor repair. The size of the circle denotes the total cost over ten years for the actual workload. Thus, WUC 23 is the biggest circle (and located in the far right of the figure), because the propulsion workload is the most significant in terms of cost.

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<sup>3</sup> U.S. Code, Title 10, Armed Forces, Section 2466, Limitations on the Performance of Depot-Level Maintenance of Material.

**Figure 3.5. Model Results for F-16C Only, Repair Cost Incorporated, In-Sourcing Candidates Highlighted**

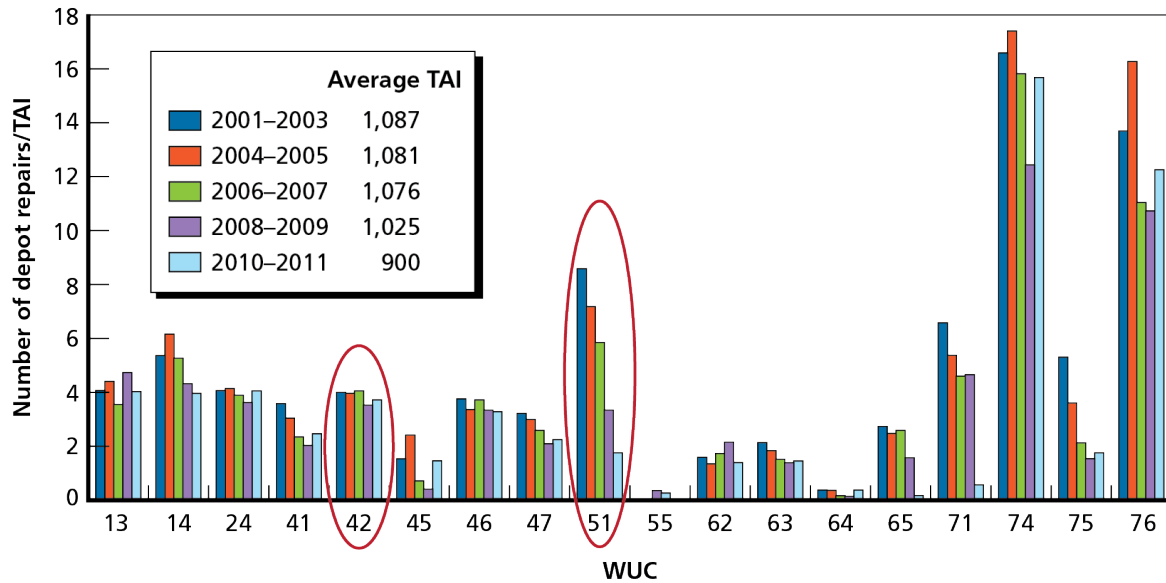


The figure shows that, today, some work on ECMs and penetration aids (WUC 76) is being done externally, as is most of the fire control (WUC 74) and some propulsion (WUC 23) workload. These decisions were made in the past and may have been valid at the time. But are they still valid today, given the subsystems’ relatively high frequency of repair and high level of specificity? Presenting the information in this manner suggests that those decisions may need to be revisited. Ultimately, there may be valid reasons for keeping the work in the commercial market. However, this kind of an analysis can highlight where the Air Force ought to look first for workloads to move in-house. If there are valid reasons to keep the repair of these WUCs in the commercial market, then the Air Force can begin to look to the red dots that are next closest to the upper right corner. The Air Force may want to examine the contractor repair portion of the landing gear systems (WUC 13) or flight control systems (WUC 14) to determine whether any of that work could be shifted to organic sources.

This approach provides an analytically based, repeatable process to help think through such constraints as 50/50.

As discussed previously, because these factors can change over time, a periodic review of the data could motivate changes in the enterprise strategy. The bars in Figure 3.6 represent the F-16C’s repair workload for a given WUC over two-year periods, normalized by the TAI. The data show that some subsystems, such as WUC 42 (electrical power supply), have remained fairly stable over time. Others, such as WUC 51 (flight instruments) have seen their workload decrease significantly over time. The Air Force could review this information and determine whether previous workload allocation decisions still make sense. If, for example, WUC 51 work is done organically, will there be a sustainable workload despite the drop in demand?

**Figure 3.6. F-16C Depot-Level Repair Demand, by Two-Digit Work Unit Code, Longitudinal**



RAND RR397-3.6

This analysis does not answer these questions. Rather, it identifies areas requiring further examination to inform the Air Force’s decision processes.





## CHAPTER FOUR

# Conclusions and Potential Extensions of This Analysis

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This report explained how we expanded the TCA concepts and developed a framework that draws on legacy aircraft data to inform F-35 above-core sustainment decisions. We have also shown how workload data can inform enterprise-level sustainment strategies. In the near term, this framework can help inform F-35 and KC-46 sourcing decisions.<sup>1</sup> It can also inform partnering/partnership discussions early in the acquisition cycle, when the Air Force is negotiating with the OEMs.

We recommend that the Air Force use this type of analytic framework to inform sourcing decisions. Strategic sustainment decisions are fundamentally economic decisions. Economy of scale is an important consideration in determining a sourcing option, but it is only one of many. The TCA-related literature suggests that key decisions about the sourcing of sustainment activities should be driven by the frequency, asset specificity, and risk associated with an acquired system. Decisions about who should perform specific functions should also take into account the rates of technological change of a weapon system's components, the economies of scale that can be achieved *across* weapon systems, and other considerations. Decisions should not be based on how any single system affects the enterprise.

In the longer term, this analysis can help shape the future sustainment enterprise. It gives the Air Force an opportunity to examine subsystems across weapon systems. In doing so, the Air Force needs to evaluate the effects of new or emerging technology on its subsystem strategies. By performing such a review across weapon systems and across technology types, the Air Force will be better positioned to identify the sustainment system that it would like to have in the future.

Although we focused on above-core depot workload in this analysis, the framework can be applied to other product support activities, such as supply chain management or sustaining engineering. More research would be needed to identify the appropriate metrics, measurement approach, and data sources, however.

The framework can also be used to inform the procurement of technical data rights—specifically, to help the Air Force determine where it should obtain technical data or negotiate rights to purchase data in the future, if necessary. In addition, the analytic approach can provide a

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<sup>1</sup> Based on this analysis, Air Force Materiel Command's Studies and Analysis Division initiated an internal study in late 2012 to support sourcing decisions for the KC-46. Staff examined legacy tanker MDSs and applied the framework to identify subsystems that were potential candidates for organic sourcing at Air Force depots. The result of this work is a tool that can be used by Air Force sustainment planners to help to prioritize spare parts purchased based on characteristics presented in this research. See Air Force Materiel Command, *Studies and Analysis Division Annual Report*, Wright-Patterson AFB, Ohio, February 2013, p. 5, for an example of a direct application of our framework.

prioritization scheme for the Depot Maintenance Activation Working Group as it identifies which workloads will be brought in-house and establishes the timing of these decisions (i.e., which workload should be brought in first, second, and so on). We argue that the subsystems in the upper right portion of our framework visualization are the higher-priority workloads when it comes to decisions about which work to bring in-house, and those in the lower left portion are lower-priority.

Another powerful use of the framework is to compare real-world legacy subsystem data with contractor-provided R&M projections for a new system. When a contractor says that a system is going to be 50-percent more maintainable than previous systems, it is possible to compare this projection to the Air Force's experience and be in a position to ask the contractor to validate its claims. This analysis would give the Air Force a much more informed basis on which to discuss R&M projections with the contractor.

We recognize that there are challenges to implementing this decision approach. For example, the Air Force will need to address personnel and training issues to enable system-wide analysis. The sustainment enterprise needs to provide its analysts with the appropriate logistics expertise to work with the acquisition community. One finding of Air Force's Logistics Requirements Traceability initiative was that logisticians with the appropriate training and competencies are not adequately involved in the identification and documentation of logistics requirements. One reason for this lack of involvement is that logisticians are not available in the right numbers or locations, or with the right competencies and skill sets, within the enterprise.<sup>2</sup>

In addition, roles, responsibilities, and authorities need to be defined for whoever is designated to oversee the enterprise vision and corresponding enterprise-level strategies. This question, while beyond the scope of this analysis, is worthy of future attention. Without a champion with corresponding responsibility and authority, these ideas will not move forward.

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<sup>2</sup> Mark Van Gilst, Office of the Assistant Secretary of the Air Force for Installations, Environment, and Logistics, "Enterprise ILCM Product Support and Related Efforts," briefing, August 26, 2009.

## Bibliography

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Air Force Instruction 10-601, *Capabilities-Based Requirements Development*, July 31, 2006.

Air Force Instruction 63-101, *Acquisition and Sustainment Life Cycle Management*, February 12, 2009.

Air Force Instruction 63-107, *Integrated Product Support Planning and Assessment*, November 10, 2004.

Air Force Instruction 90-901, *Operational Risk Management*, April 1, 2000.

Air Force Materiel Command, *Studies and Analysis Division Annual Report*, Wright-Patterson AFB, Ohio, February 2013.

Air Force Materiel Command Instruction 161-102, *Advanced Technology Demonstration Transition Planning*, May 30, 2006.

Air Force Policy Directive 20-5, *Air Force Product Support Planning and Management*, April 10, 2001.

Air Force Policy Directive 63-1, *Capability-Based Acquisition System*, July 10, 2003.

Carter, Ashton, Under Secretary of Defense for Acquisition, Technology, and Logistics, “Pentagon Efficiency Initiatives,” transcript of remarks at the Heritage Foundation, Washington, D.C., April 20, 2011. As of August 19, 2013:  
<http://www.heritage.org/events/2011/04/pentagon-efficiency?query=Pentagon+Efficiency+Initiatives:+Are+They+Enough+to=Stave+Off+More+Defence+Cuts>

Coase, Ronald H., “The Nature of the Firm,” *Economica*, Vol. 4, No. 16, November 1937, pp. 386–405.

Defense Acquisition University, “Air Force Acquisition-Sustainment Toolkit (ASTK),” web page, last updated June 6, 2013. As of August 19, 2013:  
<https://acc.dau.mil/CommunityBrowser.aspx?id=173329>

———, “Acquisition Sustainment (AS) Tool Kit Tutorial,” PowerPoint presentation, September 2008. As of August 19, 2013:  
<https://acc.dau.mil/CommunityBrowser.aspx?id=235028&lang=en-US>

- Drew, John G., Russell D. Shaver, Kristin F. Lynch, Mahyar A. Amouzegar, and Don Snyder, *Unmanned Aerial Vehicle: End-to-End Support Considerations*, Santa Monica, Calif.: RAND Corporation, MG-350-AF, 2005. As of August 19, 2013:  
<http://www.rand.org/pubs/monographs/MG350.html>
- Fine, Charles H., *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, New York: Basic Books, 1999.
- Headquarters, U.S. Air Force, *Unmanned Aircraft Systems Flight Plan 2009–2047*, Washington, D.C., May 18, 2009.
- John, George, and Barton A. Weitz, “Forward Integration into Distribution: An Empirical Test of Transaction Cost Analysis,” *Journal of Law, Economics, and Organization*, Vol. 4, No. 2, Autumn 1988, pp. 337–355.
- McGarvey, Ronald G., James H. Bigelow, Gary Briggs, Peter Buryk, Raymond E. Conley, John G. Drew, Perry Shameem Firoz, Julie Kim, Lance Menthe, S. Craig Moore, William W. Taylor, and William A. Williams, *Assessment of Beddown Alternatives for the F-35*, Santa Monica, Calif.: RAND Corporation, RR-124-AF, 2013. As of August 19, 2013:  
[http://www.rand.org/pubs/research\\_reports/RR124.html](http://www.rand.org/pubs/research_reports/RR124.html)
- National Research Council, *Examination of the U.S. Air Force’s Aircraft Sustainment Needs in the Future and Its Strategy to Meet Those Needs*, Washington, D.C.: National Academies Press, 2011.
- Tripp, Robert S., Kristin F. Lynch, Daniel M. Romano, William Shelton, John A. Ausink, Chelsea Kaihoi Duran, Robert G. DeFeo, David W. George, Raymond E. Conley, Bernard Fox, and Jerry M. Sollinger, *Air Force Materiel Command Reorganization Analysis: Final Report*, Santa Monica, Calif.: RAND Corporation, MG-1219-AF, 2012. As of August 19, 2013:  
<http://www.rand.org/pubs/monographs/MG1219.html>
- Tripp, Robert S., et al., *The Evolving Air Force Logistics Enterprise: A Vision and Next Steps*, Santa Monica, Calif.: RAND Corporation, forthcoming.
- U.S. Code, Title 10, Armed Forces, Section 2466, Limitations on the Performance of Depot-Level Maintenance of Material.
- U.S. Department of Defense, “Memorandum of Agreement on Joint Strike Fighter (JSF) Depot Source of Repair Assignment Process,” 2010.
- , *Joint Strike Fighter (F-35) Selected Acquisition Report*, December 31, 2011.
- U.S. Department of Defense Instruction 4151.20, *Depot Maintenance Core Capabilities Determination Process*, January 5, 2007.

- U.S. General Accounting Office, *Outsourcing DoD Logistics: Savings Achievable but Defense Science Board's Projections Are Overstated*, Washington, D.C., GAO/NSIAD-98-48, December 1997. As of August 19, 2013:  
<http://www.gao.gov/products/NSIAD-98-48>
- Van Gilst, Mark, Office of the Assistant Secretary of the Air Force for Installations, Environment, and Logistics, "Enterprise ILCM Product Support and Related Efforts," briefing, August 26, 2009.
- Walker, David M., U.S. Comptroller General, *Sourcing and Acquisition: Challenges Facing the Department of Defense*, testimony before the Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate, Washington, D.C.: U.S. General Accounting Office, GAO-03-574T, March 19, 2003. As of August 19, 2013:  
<http://www.gao.gov/products/GAO-03-574T>
- , *Defense Management: DoD Needs to Reexamine Its Extensive Reliance on Contractors and Continue to Improve Management and Oversight*, testimony before the Subcommittee on Readiness, Committee on Armed Services, U.S. House of Representatives, Washington, D.C.: U.S. Government Accountability Office, GAO-08-572T, March 11, 2008. As of August 19, 2013:  
<http://www.gao.gov/products/GAO-08-572T>
- Warren, David R., Director, Defense Management Issues, National Security and International Affairs Division, U.S. General Accounting Office, *Depot Maintenance: Air Force Faces Challenges in Managing to 50-50 Ceiling*, testimony before the Subcommittee on Readiness, Committee on Armed Services, U.S. Senate, Washington, D.C.: U.S. General Accounting Office, GAO/T-NSIAD-00-112, March 3, 2000. As of August 19, 2013:  
<http://www.gao.gov/products/GAO/T-NSIAD-00-112>
- Williamson, Oliver E., "Transaction-Cost Economics: The Governance of Contractual Relations," *Journal of Law and Economics*, Vol. 22, No. 2, October 1979, pp. 233–261.
- Williamson, Oliver E., and Sidney G Winter, eds., *The Nature of the Firm: Origins, Evolution, and Development*, New York: Oxford University Press, 1993.
- Wynn, Michael W., Secretary of the Air Force, "Codifying Service Acquisition Executive (SAE) and AFMC/CC Roles in Integrated Life Cycle Management," memorandum, Washington, D.C., June 6, 2007.

The U.S. Air Force has long struggled to incorporate new weapon system logistics requirements and support system design considerations into its broader sustainment enterprise early in the acquisition process. To help inform Air Force decisionmaking with regard to sustainment sourcing, RAND Project AIR FORCE researchers explored and adapted lessons from the transaction cost accounting literature. The result is a powerful economic-based framework that has three primary benefits when it comes to addressing sustainment planning challenges: It is a repeatable, analytically driven decision tool that does not require large amounts of data; it considers repair source decisionmaking in the context of the broader Air Force enterprise; and it is potentially applicable to other aspects of sustainment planning, such as managing government-mandated repair sourcing mixes and informing other Air Force sustainment community responsibilities. This report demonstrates how the framework can be used to select among depot maintenance strategies by applying it to the F-35 Joint Strike Fighter, the largest acquisition program in U.S. Department of Defense history. Although the U.S. government will retain the capability to perform the range of depot-level repairs for the F-35, 40 percent of the workload—known as “above core”—can be considered for sourcing to an organic Air Force facility, another military service’s facility, a foreign partner, or the private sector. The framework helps planners visualize program data and compare new acquisition programs with legacy Air Force systems. In this way, it offers the Air Force additional leverage in responding to technology developments and vetting contractors’ engineering, reliability, and maintainability projections for new weapon systems.



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