Constructing Program Management Offices for Major Defense Acquisition Programs: Factors to Consider

by Charlotte M. Farmer

B.S. in Chemical Engineering, May 1987, Tennessee Technology University
M.S. in Chemical Engineering, December 1994, University of Tennessee
M.S. in Business Administration, May 2000, University of North Carolina

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Dissertation directed by

Thomas A. Mazzuchi
Professor of Engineering Management and Systems Engineering and of Decision Sciences

Shahram Sarkani
Professor of Engineering Management and Systems Engineering

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Charlotte Mitcham Farmer

Dissertation Research Committee:

Thomas A. Mazzuchi, Professor of Engineering Management and Systems Engineering and of Decision Sciences, Dissertation Co-Director

Shahram Sarkani, Professor of Engineering Management and Systems Engineering, Dissertation Co-Director

Amirhossein Etemadi, Assistant Professor of Engineering and Applied Science, Committee Member

Ebrahim Malalla, Visiting Associate Professor of Engineering and Applied Science, Committee Member

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Dedication

The author wishes to dedicate this research to …

My super husband, who supported me through the doctoral degree process by taking on my chores. His abundance of gracious, constructive reviews speaks volumes to the depth of our love.

Our awesome children, Nia, Derel, and James, who have been steadfast in their encouragement and support by reviewing and editing my work.

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Abstract of Dissertation

Constructing Program Management Offices for Major Defense Acquisition Programs: Factors to Consider

Over the last two decades, assessments of major defense acquisition systems consistently cite program management office (PMO) effectiveness as a key factor for successfully producing weapon systems. Studies conducted across government, industry, and academia attribute PMO effectiveness to ideal organizational structure, relevant capabilities, and well-balanced skill mix among other PMO attributes. This research identifies key factors to consider when constructing systems integration organizational structures (SIOS) for large, complex programs. Unique organizational factors emerged from the analysis of 162 Major Defense Acquisition Programs (MDAPs) (including current and terminated systems, 1995-2016). Theoretically, these factors will help the program management scholars design a robust decision model that will guide selection of organizing constructs for MDAP PMOs. This research provides the methodology used to identify primary SIOS types, evaluate SIOS effectiveness, and identify core factors that help Program Managers select a SIOS that aligns with acquisition strategy. Program Managers can review SIOS type attributes and gain understanding of available SIOS configurations, the success rate and factors associated with a given SIOS type and understand the advantages and disadvantages of each option. While most SIOS types will work, probability of success can be improved by selecting the configuration that best suits the program factors.

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List of Acronyms

Acronym	Definition
ACAT	Acquisition Category
APB	Acquisition Program Baseline
DAG	Defense Acquisition Guidebook
DAU	Defense Acquisition University
DoD	Department of Defense
FAR	Federal Acquisition Regulations
FFRDC	Federally Funded Research Center
GAO	Government Accountability Office
INCOSE	International Council on Systems Engineering
IPT	Integrated Project Team or Integrated Product Team
LSI	Lead Systems Integrator
MDAP	Major Defense Acquisition Program
MOE	Measure of Effectiveness
MSC	Major Subordinate Command
NASA	National Air and Space Administration
OMB	Office of Management and Budget
PM	Program manager
PMO	Program Management Office
PMI	Project Management Institute
SDLC	System Development Lifecycle
SE	Systems Engineering

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SI	Systems Integration
SIOS	System Integration Organizational Structure
SOS	System of Systems
TRL	Technology Readiness Level
USD(AT&L)	United States Defense Acquisition, Technology and Logistics
USMC	United States Marine Corps
USAF	United States Air Force

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Glossary of Terms

Development start: The initiation of an acquisition program as well as the start of engineering and manufacturing development. This coincides with DOD's milestone B (DAU, 2013).

Program start: Date that generally coincides with DOD's former terminology for milestone I or DOD's current milestone A (DAU, 2013).

Production decision: The decision to enter the production and deployment phase, typically with low-rate initial production.

Initial capability: The initial operational capability—sometimes called first unit equipped or required asset availability (DAU, 2013).

Acquisition Program Baseline (APB) Breach: Thresholds establish "deviation limits" and define the cost, schedule, and performance trade-off space available to PMs. An acquisition program baseline breach occurs when the current estimate for a parameter exceeds the threshold value (i.e., the minimum acceptable requirement for a parameter) (DAU, 2013).

Project Size: Determined by life cycle cost, which is misleading if skewed by budget allocations to fund prototypes and low rate initial production.

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Acquisition Program: A directed, funded effort that is designed to provide a new, improved, or continuing weapon system in response to a valid operational need (DAU, 2013).

Acquisition Category I (ACAT I): An acquisition program initiated from a favorable Milestone I decision. ACAT IC and ACAT ID are designations for Major Defense Acquisition Programs (MDAP) with R&D threshold >$335M /PMC threshold > $2.135B PMC and different decision authorities; ACAT IC- Army Acquisition Executive (AAE) and ACAT ID- Under Secretary of Defense (Acquisition and Technology) (DAU, 2013).

Cluster Analysis: "Cluster analysis is an exploratory multivariate technique designed to uncover natural groupings of the rows in a data set. Useful in analyzing multivariate data], cluster analysis is a technique where no dependence in any of the variables is required. The object of cluster analysis is to divide the data set into groups, where the observations within each group are relatively homogeneous, yet the groups are unlike each other." (Xu and Wunsch, 2009).

Federally Funded Research Center (FFRDC): "Conduct research for the US Government…in accordance with U.S Code of Federal Regulations, Title 48, Part 35, Section 35.017."

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Project Success: Congruent with the Defense Acquisition Guide (2013), this study defines MDAP success as not exceeding the acquisition program baseline threshold for set parameters (i.e., cost, schedule, and functional performance) (DAU, 2013).

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Chapter 1: Introduction

1.1 Environmental Scan

Multiple sectors (e.g., Defense, infrastructure, enterprise systems, information technology, intelligence, and space exploration) employ megaprojects to deliver international space stations, hospitals, national border patrol, high-speed rail lines, and logistics systems for mammoth enterprises (Flyvbjerg, 2017). Megaprojects significantly impact the global economy as exhibited by ~$6-9 trillion per year spent globally (i.e., eight (8) percent of global GDP) (Shore & Cross, 2003; Greiman, 2013; Flyvbjerg, 2017). Given the substantial impact on the economy compounded with a plague of megaproject failures, a sound knowledge base surrounding megaproject management has never been more important (Flyvbjerg, Bruzelius, & Rothengatter, 2003). The multitude of studies focusing megaproject failure compelled the authors to join the discussion on strategies for megaproject success, gleaning success factors from literature so that they may be systemically pursued by major Defense acquisition programs (MDAP) (Merrow, 2011).

The Defense industry is a good empirical setting for this research because its wide-range of attributes avoids bias and may inform multiple industries. For example, products range from commodity items to niche items. Project teams are situated in multiple locations. Engineering and development are relatable to multiple industries. Most notable, the Defense sector provides a broad range of PMO performance. Congress has mandated that performance data be collected on MDAPs to determine if there is a breach of performance parameters (U.S. Government Accountability Office, 2003-2005, 2007-2017). As such, the preponderance of data lends itself to a quantitative study.

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1.2 Challenges

Though important in many fields, the development of mechanisms that help boost the chance of megaproject success is paramount in Defense. This research provides an empirical study that explores a relatively untouched area in the megaproject field - organization typology for major Defense programs. When project management offices (PMO) lack the appropriate organization structure, they struggle to efficiently deliver systems as evidenced by highly publicized cost growth and missed schedule targets (DAU, 2007). Large-scale, complex Defense systems (consisting of hardware, software, multiple military services, multiple suppliers, and a broad range of engineering disciplines) require robust PMO structures to execute across the acquisition lifecycle, typically spanning decades (Franke, 2001; Dillard, 2005; Ben-Ari & Chao, 2009). MDAP PMs need organizational factors to help select PMO organization structures that align with their mission. This practical need sparks scholarly interest in megaprojects as cornerstones for new organizational forms to deliver increasingly complex, integrated solutions (Franke, 2001; Ben-Ari & Chao, 2009; Söderlund, 2010). Given that there is no perfect PMO organization structure; the point of this research is not to derive a PMO structure panacea. DoD systems are much too complex for a one size fits all approach (Dillard & Nissen, 2007). Instead, this study considers enterprise context to help select the appropriate PMO organization structure (Turner, 2016).

1.3 Problem Summary

Department of Defense (DoD) acquisition of research, development, procurement, and support of weapon systems is widely known for large, complex programs governed by a myriad of federal regulations that specify how to accomplish the planning, review,

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execution, and oversight of Government acquisition programs (Schwartz, 2010). DoD procurement activities are governed by three sets of federal government regulations. The first set of regulations, which apply to the entire U.S. Federal Government, are found in the Federal Acquisition Regulation (FAR); the second set of regulations apply only to DoD and are found in the Defense Federal Acquisition Regulation Supplement (DFARS); the third set of regulations apply only to individual DoD Components and are found in component-unique FAR Supplements. Defense acquisition program management offices (PMOs) must adhere to these and other relevant regulations during program planning and execution (Schwartz, 2010).

Due in part to large systems and a host of rules associated with Defense acquisition, the programs responsible for DoD acquisition activities tend to reflect the kinds of formalized organizational forms that respond poorly to change (Dillard and Nissen, 2005). Arguably, one or more robust organizational approaches exist to develop and deliver weapon systems successfully in alignment with Acquisition strategy. However, which organizational form prevails? On what basis should acquisition leaders choose between competing organizational forms for systems integration?

When PMOs lack the appropriate organization structure, they struggle to efficiently deliver products, systems, or services as evidenced by highly publicized cost growth and missed schedule targets that plague acquisition programs (DAU, 2007). Large, complex Defense systems (consisting of hardware, software, multiple military services, multiple suppliers, and a broad range of engineering disciplines) require robust PMO structures to execute across the acquisition lifecycle, typically spanning decades (Dillard, 2005). Faced with building PMO organization structures, program managers (PM) who lead

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major Defense acquisition programs (MDAP) should prepare for the possibility of following organizational issues (DAU, 2007):

- Inadequate systems engineering (SE) processes to bridge participating organizations and provide clarity in SE functions
- Unsubstantiated PMO organization design for systems integration
- Vague roles and responsibilities within and across organization lines (e.g., suppliers, sub-systems)
- External and internal volatility (e.g., changes in PMs and priorities) throughout the system development lifecycle.

These issues have compelled the authors to explore how PMs might improve MDAP organizational efficiency through improved organization structures. PMs need organizational factors to help select PMO organization structures that best support their mission.

1.4 Research Significance

This research contributes theoretical and practical program management knowledge.

First, it adds to the PMO organization structure and program management body of knowledge by identifying additional factors that assist PMO structure selection. Second, this research contributes to a more comprehensive understanding of organizational configuration by adding to contextual knowledge of complex, mega programs. From a practical perspective, understanding how various PMO structures affect normative outcomes will help PMs define the ideal systems integration organization structure (SIOS) typology for MDAPs to achieve desired performance (Deutscher *et al.,* 2016).

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Integrating large, complex Defense systems (often consisting of hardware, software, multiple military services, multiple suppliers and a broad range of engineering disciplines) requires robust PMOs that evolve with each phase of the Defense acquisition life cycle. Building on theoretical results, practical guidance may be derived from the study of empirical data to construct robust program management organizations that design, develop, produce, and deploy complex systems (often consisting of hardware, software, multiple military organizations, multiple contractors, and a broad range of engineering disciplines). There is, of course, no such thing as an "ideal" structure for any organization. As such, guidance under the United States Department of Defense (DoD) Directive 5000.01 provides:

> "*There is no one best way to structure an acquisition program to accomplish the objective of the Defense Acquisition System. PMs shall tailor program strategies and oversight to fit the particular conditions of that program*" (DoD, 2007, 3).

Complex Defense programs are unique in that the government PMs hold ultimate program responsibility. Faced with designing PMO organizational structures, PMs who lead MDAPs face the following challenges:

- Inadequate systems engineering (SE) processes to bridge participating organizations and codify SE functions
- Unsubstantiated PMO organization structure for systems integration
- Vague roles and responsibilities of key stakeholders (e.g., PMO workforce, suppliers, sub-systems)
- PMO environmental volatility (e.g., frequent changes in funding and priorities)

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These problems have catalyzed exploration into how PMs might improve MDAP organizational effectiveness from a systems integration perspective.

1.5 Goal of Research

The project management body of knowledge needs organization design factors to guide selection of PMO organizational structures that best support their mission. The goal of this research is to 1) determine key factors that influence selection of systems integration organizational structures (SIOS); 2) determine the fundamental set of SIOS types for MDAPs; and, 3) develop a decision mechanism that guides PMs in constructing evolutionary PMOs. The results of this research should help answer the following questions:

- Is there a relationship between MDAP SIOS types and PMO effectiveness?
- What organizational factors exist to help select a SIOS configuration for MDAPs?

This research examines the integration of PMO functions and offers a robust set of organizational factors to guide PMO structure transformation as systems progress through each phase of the SDLC. Themes emerging from literature describe systems integration as a vital function responsible for *establishing interfaces* between components, systems, and system of systems (SoS); *integrating skills, knowledge, and activities* across military services and key entities (e.g., Defense contractors, sub-contractors, and federally funded research centers (FFRDCs)); *and, providing interoperable, cost-effective, timely solutions* that meet requirements toward developing complex technology (Farmer, Sarkani, Mazzuchi, 2014).

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1.6 Scope of Research

This research shares a promising approach to identifying organizational factors to consider when constructing PMOs for large programs that deliver complex systems. This research draws from the integration of organization contingency theory, PMO structure perspectives, and PMO performance perspectives. There have been previous attempts at integrating two of these three concepts

- Organization theory and PMO structure design theory in the commercial sector (Kerzner, 2013)
- PMO structure design theory and PMO performance principles in the federal sector (Thomas, 2009; Dillard and Nissen, 2005).

The approach taken in this research integrates all three concepts with focus on large, complex programs (having lifecycle cost greater than $250 million) in the Defense acquisition sector. The studies that have integrated these theories, do not close the gap on selecting organization structures for large, complex Defense programs. Hobday (2000) examined the impact of organization typology on effectiveness of producing complex, high value products; however, the case study narrowly focused on two products and two project typologies in one scientific medical equipment company. Dillard and Nissen (2007) studied Defense acquisition organizations; however, they focused on locating knowledge, responsibilities, and decisions. Componation, Youngblood, Utley, and Farrington (2008) offered a promising approach to help determine if a relationship exists between the success of NASA projects and the organization of NASA project teams. Treating PMOs as systems integration mechanisms, Thomas (2009) examined the impact of systems integration organizational

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models on project performance and offered an approach to help select PMO integration structures. While helpful, Thomas' (2009) work was limited to 80 predominantly aerospace projects (i.e., 68 NASA/12 DoD). As such, the capability gap remains for selecting PMO organization structures with consideration for MDAPs across all Defense sectors (air/missile, ground, sea, communications, and chemical/biological/nuclear).

This research offers two contributions. First, it adds to the PMO organization structure body of knowledge by identifying additional factors that assist PMO structure selection. Second, it contributes to a more comprehensive understanding of organizational configuration by adding to contextual knowledge of megaprojects relative to the Defense sector (Flyvbjerg & Turner, 2017).

From a practical perspective, the research helps Systems Engineering and program management professionals build understanding of how various PMO structures affect normative outcomes. It attempts to help define systems integration organization structure (SIOS) typology for MDAPs to achieve desired performance (Deutscher, Zapkau, Schwens, Baum, & Kabst*,* 2016).

1.7 Research Questions

DoD projects are too complex to articulate in a simple form for analysis. The authors therefore find it convenient to express these megaprojects in terms of several measurable and recorded attributes, including the SIOS and whether a megaproject was deemed successful or not. Once expressed in this manner, the attribute values may be analyzed to help determine which SIOS type in combination with other megaproject attributes lead to successful projects and which to unsuccessful projects. Thus, this framework reduces to a problem in cluster analysis (Ketchen et al*.,* 1997). Due to the limited data size and the

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number of permutations for different project attributes, it is possible that these results may be inconclusive for some attribute combinations. In utilizing this frame work, the research addresses the following research questions

1. Can a DoD megaproject be expressed in terms of a meaningful set of attributes?
2. Can these attributes be used to classify which SIOS type should be used for successful megaprojects?
3. Can these attributes be used to classify which SIOS type should be avoided to preempt unsuccessful outcome?

Congruent with the Defense Acquisition Guide (2013), this study defines MDAP success as not exceeding the acquisition program baseline threshold for set parameters (i.e., cost, schedule, and functional performance). Thresholds establish "deviation limits" and define the cost, schedule, and performance trade-off space available to PMs. An acquisition program baseline breach occurs when the current estimate for a parameter exceeds the threshold value (i.e., the minimum acceptable requirement for a parameter) (DAU, 2013).

1.8 Organization of Research

The literature review in Chapter 2 starts with exploration of organizational design theory as a baseline to help identify factors that generally influence the selection of organization. Organizational design research closes with focus on the program management office structure. Next, the chapter provides research of both program and project management scholarly literature combined with Federal Government studies for factors that influence program management performance.

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Chapter 3, *Research Methodology*, encompasses three major phases. The chapter leads with derivation of program management office organizational factors. Next, the chapter frames a database using the program management office organizational factors as key fields; and, populated the database with empirical MDAP data. Last, the chapter provides analysis of MDAP data to determine the impact of organizational structure and factors on program performance.

Chapter 4, *Analysis and Results*, summarizes analytical results and findings and concludes with validation of analysis.

Chapter 5, *Recommendations and Conclusion*, and offers recommendations for further research.

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Chapter 2: Literature Review

2.1 Introduction

As depicted in Figure 2-1, a focused review of literature relevant to this research garners elements of three broad bodies of knowledge- organization theory, PMO structure theory, and PMO performance theory. Organization theory, Section 2.2, provides a baseline for literature research to help identify factors that generally influence the selection of organization structures. Next, in Section 2.3, exploration of PMO structure theory narrows organization theory with focus on temporary organizations. Last, in Section 2.4, a review of PMO performance theory literature wraps-up research by exploring relationship between organization factors and program performance.

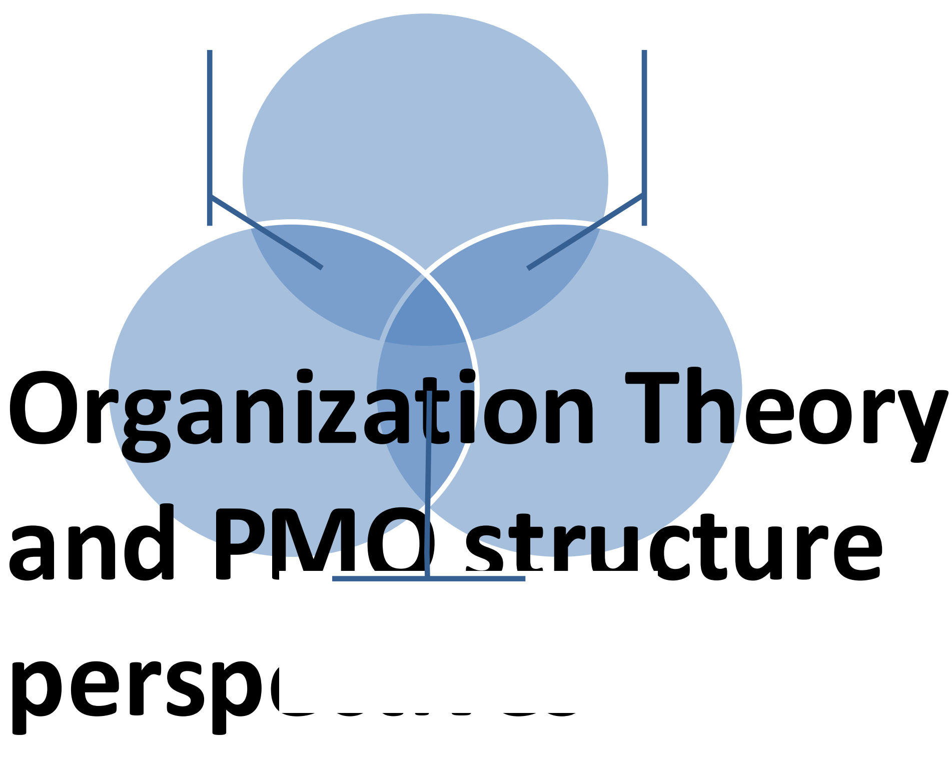

Figure 2-1: Literature Research Overview of Program Management Office Structure Design

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2.2 Organization Theory

Organizational theory relevant to this research diverges into multiple bodies of knowledge including but not limited to organization configuration, organization design, organization typology/structure, organization culture, business strategy, organizational change, process improvement, and accelerating operations (at the speed of X, where X represents production of various goods and services) (Fenton and Pettigrew, 2000). Collective, organization theory research conducted by Mintzberg (1993), Bradach (1996); Fenton and Pettigrew (2000); Snow *et al.* (2005); Jones (2013); Hatch and Cunliffe (2013); and, Maclean, Harvey, and Clegg (2016) convey the following emerging themes:

- Organizational Configuration- An organization's form should fit its environment
- Contingency Theory- A combination of factors (e.g., structure, strategy, systems, culture, skills, values, etc.) are critical to understanding an organization's effectiveness
- Organization Design- Organization design includes topology (term used interchangeably with structure) along with processes, practices, integrating mechanisms, knowledge, and governance
- Organization structure- There are multiple approaches to organizing; no best way exists
- System Integrators- An organization constitutes a complex system of inter-related capabilities which collectively impact effectiveness

These theoretical concepts are discussed below.

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2.2.1 Organizational Configuration

Organizational configurations are groupings of companies classified by common emerging themes such as archetypes, modes, typologies, and taxonomies (Fiss, 2007). Building on Ketchen's (1993) research, Payne's (2006) study of organization configurations examines correlations between strategy variables (price, R&D cost, production capacity, scope of work, distribution, operations capabilities) and structure variables (including organization size, geographic dispersion, contracting, vertical, and horizontal relationships, and confirms that industry context) that are integral to distinguishing successful from unsuccessful configurations.

2.2.2 Contingency Theory

Fenton and Pettigrew (2000) and several contemporaries (Donaldson, 2001; Baligh, 2006; Westerman, McFarlan, and Iansiti, 2006; Hunter, 2015) point toward contingency theory to explain the relationship between company structures and performance. Contingency theory posits that a well-functioning organization design requires alignment or fit among contingencies (e.g., leadership, knowledge sharing, information technology, incentives) (Burton *et al*., 2015).

Nissen and Burton (2011) extended contingency theory to account for the dynamic nature of organizations. Their research characterizes organization structures in terms of ruggedness, speed, maneuverability, and stability; and, suggests that agile organizations sacrifice robust performance capability for maneuverability (Nissen and Burton, 2011).

2.2.3 Organization Design

Organization design encompasses a sequence of work that aligns mission/vision, values/operating principles, strategies, goals/objectives, tactics, systems, organization

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structure, people, processes, culture, and performance measures to deliver required products/services per operating context (Stanford, 2007; Albert, 2010). Over the years, organization theory modernists have conducted a great deal of research relative to this research that 1) helps characterize organization designs in relation to technology and environmental, conflict, control, and culture characteristics (Hatch and Cunliffe, 2013); 2) relates organization design characteristics to performance measures (Hatch and Cunliffe, 2013); and, 3) relates organization design to designing systems and technologies (Brooks *et al.*, 2011).

2.2.4 Organization structure

The organization structure is one of several features (Short, Payne, and Kitchen, 2008) that may be adjusted during organization design (Brix and Peters, 2015). Several types of organization structures have emerged to keep pace with evolving business operations, system complexity, technology advances, globalization, and speed of commerce. The comprehensive study of organization structure conducted by Mintzberg (1993) serves as the baseline of organization structures types listed below:

- *Simple* – entrepreneurial and flat structures (Mintzberg, 1993; Hatch and Cunliffe, 2013; Jones, 2013)
- *Machine bureaucracy* – functional structures (Mintzberg, 1993; Stanford, 2007; Hatch and Cunliffe, 2013; Jones, 2013; Steiger *et al.,* 2014)
- *Professional bureaucracy* – several specialists (Mintzberg, 1993; Jones, 2013)
- *Divisional form* – strategic business unit, M-Form, centralized hierarchy by product, process, geographic/market, or customer (Mintzberg, 1993; Stanford, 2007; Hatch and Cunliffe, 2013; Jones, 2013; Zhou, 2013); Steiger *et al.*, 2014)

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- *Professional adhocracy* – project-based industries, matrixed/cross-functional organization with functional and product dimensions (Mintzberg, 1993; Stanford, 2007; Hatch and Cunliffe, 2013 Jones, 2013; Steiger *et al.*, 2014; Burton *et al.*, 2015)
- *Hybrid* – strategic alliances, joint ventures, multi-firm network, multinational corporations, geographic matrix, virtual, life-form, cluster, intermix (Galbraith, 2000; Snow, 2005; Siggelkow and Rivkin, 2005; Graetz and Smith, 2006; Hatch and Cunliffe, 2013; Jones, 2013; Thamhain, 2014)

2.2.5 Organizations as Systems Integrators

Systems theory together with complexity theory popularized network structures and amplified matrix structures that emphasize horizontal tasks, cross-unit collaboration, and focus on process (Stanford, 2007; Burton et al., 2015). Barki and Pinsonneault (2005) examined organizations as integrating entities building on Bradach's (1996) premise that balancing specialization with integration poses a challenge to organization design. Some organizational theorists note systems integration issues (e.g., interdependency and interactions) as inherent complexity due to persistent change in operational environments (Stanford, 2007). Comparing organizations to systems, Barki and Pinsonneault (2005) deduce that organization structures reflect the extent to which people, processes, and technologies of an organization are integrated.

Treating organizational structures as systems integration mechanisms, Rendon, et al. (2011) offer three options for structuring an SoS acquisition organization and describe the influence on SoS acquisition issues. Rendon et al.'s (2011) organizing options include designated individual program, separate government program, and Lead Systems

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Integrator (LSI). They posit, "An organizing option must be coupled directly with a contracting option to resolve SoS acquisition issues." (Rendon, Huynh, and Osmundson, 2011, 480). Rendon et al. (2011), recommend that system engineers have strict control in the PMO's SE organization.

SIOS selection focuses on acquisition authority; program management and systems integration (SI) authority; and, responsibilities between the government, industry, and non-profit organizations. This research identifies SIOS combinations that could be selected based on findings of six key studies that define program (or project) management and SI organizational options for complex government programs: Artto, Kulvika, Poskelab, and Turkulainen (2011); Thomas and Utley (2006); Friedman and Sage (2004); The Committee on Systems Integration for Project Constellation National Research Council (NRC) (2004); Dombrowski, Gholz, and Ross (2003); and Smiley (1992).

Artto et al.'s (2011) research on commercial innovation projects concludes that PMOs are integrative structures that coordinate processes across multiple organizational sub-units. According to Artto et al. (2011), organization design includes two major decisions 1) identifying and assigning tasks to sub-units, and 2) designing systems that achieve the mission. Artto et al. (2011) derived integration mechanisms from the cumulative research of Burns and Stalker (1961), Child (1972, 1973, 1975), Pierce and Delbecq (1977), Pugh et al. (1968, 1969), Galbraith (1973, 1977, 1994), Edstrom and Galbraith (1977), Adler (1995), Hage et al. (1971), Lawrence and Lorsch (1967), Tushman (1977), Barnard (1938), Grandori and Soda (1995). Artto et al.'s (2011) commercial PMO integrating mechanisms include:

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- *Vertical mechanisms* – Centralized decision-making governance entity, standardized/formalized procedures
- *Horizontal mechanisms* – Informal lateral mechanisms (cross-functional job rotation, informal lateral communication) and Formal lateral mechanisms (task forces, liaison and integrator roles, meeting arrangements, cross-functional teams, committees, and integrative units)
- *Information systems* – Complement vertical/horizontal integrating mechanisms transferring information both vertically and laterally across sub-units
- *Social mechanisms* – PMO environment and teaming style.

This research identifies SIOS types that could be selected based on findings of four key studies that define program (or project) management and system integration organizational options for complex government programs: Artto, Kulvika, Poskelab, and Turkulainen (2011); Thomas (2009); Friedman and Sage (2004); and, Ross, Dombrowski, and Gholz (2002).

2.3 PMO Structure Theory

While the PMO structure primarily depends on its function (Gellerman, 1991, 57) and the processes it executes (PMI, 2013); other considerations emerge from literature. Beyond function and processes, PMO structure research relevant to this research generally focus on,

- Functionality and processes (Gellerman, 1991; DAG, 2006; Rendon and Snider, 2008; INCOSE, 2013; PMI, 2013)
- Organization type (Turner and Müller, 2003; Modig, 2007)
- Context (Donaldson, 2001; Müller, Glückler, Aubry, 2013)

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- Systems Integration (Kerzner, 2013; DAU 2014)

2.3.1 Program Management Office Versus Project Management Office

According to Sanghera (2008, 34), "project management and program management are two different (but related) beasts." Pellegrinelli (2011) notes that while projects are components of programs, *project* management approaches and *program* management approaches are complements not substitutes. Partington et al.'s (2005) research validates that program management offices have qualitatively different approaches to work compared to project office counterparts. Simply put, programs and projects are different and should be addressed differently.

Acknowledging these differences, the Project Management Institute (PMI) and the International Project Management Association (IPMA) have expanded knowledge beyond the field of project management to include the management of programs, portfolios, and organizations that achieve their mission through projects, programs, and/or portfolios (Pellegrinelli, Partington, Hemingway, Mohdzain, and Shah, 2007). Expansive bodies of knowledge have emerged to advance the tenets of program management. The UK Office of Government Commerce (2003) drafted *Managing Successful Programmes* based on input from leading public and private practitioners, including professional bodies and leading consultancies. As of 2007, *Managing Successful Programmes* is the approved approach for managing programs throughout the UK public sector and is increasingly recognized throughout Europe (Pellegrinelli, Partington, Hemingway, Mohdzain, and Shah, 2007). Similarly, PMI added the *U.S. Department of Defense Extension to: A Guide to the Project Management Body of Knowledge* to address large, complex Defense programs (Defense Acquisition University, 2003).

Lycett et al. (2004) warn against treating programs as scaled-up projects. Supporting this premise, Hobbs and Aubry (2010) derived distinctive organizational categories from a study of 502 project and program offices world-wide – 1) project office, 2) project support office, 3) project management center of excellence, and 4) program (portfolio) management office. Given

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that managing a program is distinctly different from managing a project, it follows to reason that factors influencing the performance of *project* management offices may vary from factors influencing the success of *Program management office*s.

Similarities and differences between program management and project management are expected to carry through to similarities and differences in program management office and project management office constructs.

2.3.2 PMO Functionality and Processes

Given Gellerman's well known assertion that "form follows function," research started by identifying key PMO processes and responsible functional groups that should be considered during PMO organizational design (Gellerman, 1991, 57). Key PMO functional groups and associated processes emerging from literature fit into three major pillars: SE, Program Management, and Governance. Defining these PMO functions helps to form the building blocks for constructing organizational structures.

2.3.2.1 Systems Engineering Functionality

Given that the PMO serves as an integration mechanism, its core functionality is systems engineering. Systems engineering is the approach used by PMOs to integrate acquisition program lifecycle processes to achieve integrated systems designs. Per the Defense Acquisition Guidebook,

> *"Systems engineering is an interdisciplinary approach encompassing the entire technical effort to evolve and verify an integrated and total Lifecycle balanced set of system, people, and process solutions that satisfy customer needs. Systems engineering is the integrating mechanism across the technical efforts related to the development, manufacturing, verification, deployment, operations, support, disposal of, and user*

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training for systems and their lifecycle processes. System engineering develops technical information to support the program management decision-making process." (DAG, 2006, 74).

Supported by DoD Directive 5000.02 (2008), Friedman and Sage (2004) suggest imperative SE lifecycle phases (i.e., “Requirements Definition and Management, Systems Architecture Development, System/Subsystem Design, Systems Integration and Design, Validation and Verification, System Deployment and Post Deployment”) and supporting program processes (i.e., “Life Cycle Support, Risk management and System/Program Management”) (Friedman and Sage, 2004, 86).

Consistent with ISO/IEC 15288: 2002(E) – *Systems Engineering – System life cycle processes,* the International Council on Systems Engineering (INCOSE) provides a top-down enterprise view of PMO process categories including: Technical Processes, Agreement Processes, Organizational Project Enabling Processes, Tailoring Processes, and Project Processes (INCOSE, 2010). Considering Defense acquisition challenges, the Government Accountability Office (GAO) (2006) adds strategic planning and technology transition processes because deficiencies these processes often jeopardize cost and schedule outcomes (GAO, 2006).

2.3.2.2 Program Management Functionality

The Project Management Institute (PMI) *Program Management Standard* includes twelve overarching knowledge areas with 47 subordinate processes. The *Program Management Standard* (2013) program management knowledge areas currently include communications, cost, financial, integration, procurement, quality, stakeholder, risk, schedule, scope, human resources, and governance (PMI, 2013). Rendon and Snider

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(2008) add a phased contracting process to the program management list (including procurement planning, solicitation planning, solicitation, source selection, contract administration, and contract closeout) (Rendon and Snider, 2008).

2.3.2.3 Governance Functionality

Governance processes ensure that decision-making and program delivery activities focus on achieving program goals in a consistent manner, addressing appropriate risks and fulfilling stakeholder requirements (PMI, 2013). The need for governance tends to increase with the 1) acquisition of SoS' due to the increase in interface coordination and 2) implementation of evolutionary acquisition strategy due to additional reviews for multiple, parallel sprints (Ellman, 2009). Confirming this trend, GAO (2009) has observed new review boards being established to identify and mitigate technical risks and evaluate the impact of requirement changes on ongoing programs (GAO, 2009). PMs must establish an appropriate balance of governance practices and program execution demands.

Table 2-1 summarizes PMO functions and highlights a few core processes for each functional grouping.

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Table 2-1: Summary of PMO functions and representative core processes for each functional grouping

PMO Functions	Core Processes	References
Systems Engineering and Technology	• Stakeholder Requirements Definition Process • Requirements Analysis Process • Architectural Design Process • Implementation Process • Integration Process • Verification Process • Technology Transition Process • Validation Process • Operation Process • Maintenance Process • Disposal Process	GAO (2006), ISO/IEC 15288: 2002(E), INCOSE (2013)
Program Management	• Project Planning Process • Project Assessment Process • Project Monitoring and Control Process • Decision-Management Process • Risk and Opportunity Management Process • Configuration Management Process • Information Management Process • Performance Measurement Process • Tailoring Process • Stakeholder Management Process • Strategic Communications Process • Scope and Schedule Management Process	ISO/IEC 15288: 2002(E), INCOSE (2013), PMI (2010)
Business, Finance, and Analysis	• Strategic Planning Process • Budget Development and Analysis Process • Enterprise Environment Management Process • Investment Management Process • System Life Cycle Processes • Resource Management Process	ISO/IEC 15288: 2002(E), INCOSE (2013), PMI (2010), GAO (2006)
Governance and Resource Management	• Life Cycle Model Management Process • Infrastructure Management Process • Project Portfolio Management Process • Quality Management Process • Human Resource Management Process	ISO/IEC 15288: 2002(E), INCOSE (2013)
Acquisition	• Acquisition Process • Contracting and Procurement Process	INCOSE (2013)

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It is important to note that some PMOs may require all functions to accommodate systems that are in all four phases at the same time (e.g., when services spiral technology to theater as soon as it is feasible). Mature programs are often only in one phase, such as operations and support, while newer systems are only in concept and technology development (Army, 2013).

2.3.3 PMO Organization Type

The confluence of research on temporary organizations and project-based companies points toward flexible, flat, and networked structures to manage in dynamic, complex environments (Cleland and Gareis, 2006). Conventional PMO constructs (e.g., functional, matrix, and product-oriented typology) (Galbraith, 1973) are not always practical when engaging multiple, large sub-programs that involve a confederation of constituent enterprises to produce a complex SoS (Kerzner, 2013). Rendon *et al*. (2011) suggest structuring robust programs to enable adaptable, agile execution to deal with changes in a program's system of systems (SoS) environment. As such, PMs should fortify PMO structures with multi-disciplined, integrated product teams (or integrated project teams) (IPT) that evolve was needed (DAU, 2014). As a fortifying mechanism, varying types of IPTs may be used to bolster each of the organizational models. DAU (2014) indicates that each of these organizational structures supports the use of IPTs. In fact, DAU (2014) asserts that IPTs may be the basis on which to organize an entire PMO. When successful, IPTs integrate and concurrently apply all necessary processes to effectively and efficiently provide quality products. Typically, the program manager provides cross-functional individuals from PMO constituent elements (sections, divisions, and/or directorates) to IPTs of various types (DAU, 2014).

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In developing the PMO and SE organizational structure, the program manager and Systems Engineer should understand the developer's technical organizational design, functions, and contracting model (i.e., in-house vs. outsourced). In some cases, the program manager and Systems Engineer may organize multiple IPTs to align with the major products in the program's Work Breakdown Structure. In smaller programs, the SE organization may be organized as a single IPT. The program's SE processes should include all stakeholders to ensure the success of program efforts throughout the acquisition life cycle. For MDAPs, the program manager ensures that the PMO is structured to interface with the Working-Level Integrated Product Teams (SE WIPTs) to address DoD leadership concerns and interests. The program manager formally charters the SE WIPT, led by the Systems Engineer, to assist in developing and monitoring SE activities as documented in the program MDAP SE Plan. The SE WIPT includes representatives from USD(AT&L) and the component acquisition executive's organization, both Government and developer IPT leads from the program Systems Engineer, PEO Systems Engineer, SoS Systems Engineer, and Developer Systems Engineer. SE WIPTs (at the Pentagon/Service HQ level) and IPTs provide oversight and assistance to the program manager and facilitate program execution (DAG, 2013).

2.3.4 PMO Context

Consistent with contingency theory, consider company context (i.e., environment, technology, and scale of operation) when selecting PMO structure (Fenton and Pettigrew, 2000; Burton et al., 2015). Roberts (2007) explained that organizational design should adapt to environmental changes (in economic, political, legal, regulatory, social, and technological), strategy development, and organizational evolution to achieve better

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performance in an organization's context. Congruent with this precept, Hobbs and Aubry (2010) encourage multi-project programs to configure PMO organization structures given the context of their environment. The preponderance of research highlighted in Table 2-2 focuses on structures in the context of industry. Some researchers warn that achieving peak performance cannot be automatically assumed in any given industry context; investigators must also consider conflict amongst functional demands, structural design options, and the trade-offs (Deutscher *et al.*, 2015). Regardless, this research adds environmental context relative to the Defense sector.

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Table 2-2: Catalogue of PMO Organizational Studies found in literature (Part 1 of 4)

Theory	Theorists	P	Context	Factors found in literature																									
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Organization Theory	Fenton & Pettigrew, 2000	SP	Industry								x	x		x						x	x	x		x	x	x	x	x	
	Turner & Müller, 2003	IJPM	Industry											x						x	x	x					x		
	Tsoukas & Knudsen, 2003	O	Industry									x	x	x							x			x		x	x	x	
	Miller, Greenwood & Prakash, 2009	JMI	Industry									x												x					
	Hatch & Cunliffe, 2013	O	Industry									x	x	x							x	x		x	x	x	x	x	
	Maclean, Harvey & Clegg, 2016	AMR	Industry																					x		x	x	x	
Organization Configuration Theory	Goodman, 1970	HR	Industry			x	x			x	x	x	x	x	x	x	x		x	x	x	x		x	x	x	x	x	
	Bradach, 1996	HBS	Industry										x											x	x	x	x		
	Snow, *et al.,* 2005	SP	Industry										x									x		x	x	x	x		
	Fiss, 2007	AMR	Industry									x												x		x	x		
	Short, Payne & Ketchen, 2008	JOM	Industry																			x		x		x	x	x	
Organization Design Theory	Mintzberg, 1993	PH	N/A																			x		x		x	x	x	
	Gellerman, 1991	OD	Industry										x				x	x						x			x		
	Pettigrew, *et al* ., 2003	SP	Industry									x	x									x		x		x	x	x	
	Siggelkow & Rivkin, 2005	OS	Industry									x									x			x			x		x
	Graetz and Smith, 2006	IJSCM	Industry									x					x					x		x	x	x	x		x
	Kates & Galbraith, 2010	W	Industry									x					x					x		x	x	x	x	x	
	Alberts, 2012	OD	Industry									x												x					
	Jones, 2013	PI	Industry									x					x	x			x	x	x	x		x	x	x	
	Steiger, 2014	IJBM	Industry									x									x					x	x	x	
	Burton, Obel & Håkonsson, 2015	OD	Industry			x				x		x		x					x			x	x	x		x	x	x	

Legend of Publishers (P): AMR-Academy of Mgmt. Review, HBS-Harvard Business School Press, HR-Human Relations, IJBM- Intl. Journal of Business & Mgmt., IJPM- Intl. Journal of Project Mgmt., IJSCM-Intl. Journal of Strategic Change Mgmt., JMI- Journal of Mgmt. Inquiry, JOM-Journal of Mgmt., O- Oxford University Press, OD-Journal of Organization Design, OS- Organization Studies, PH- Prentice-Hall Publications, PI-Pearson Intl., SP-Sage Publications, W-Wiley Publishing

Legend of Factors: 1. Jointness, Not observed in literature, **2.**Foreign Military Sales, Not observed in literature, **3.**Project Size, **4.**Acquisition Strategy, **5.**International Cooperation, **6.**Project Duration, **7.**Project Location, **8.**Product Architecture, **9.**System Hierarchy, **10.**Available Resources, **11.**Governance, **12.**Critical Technology, **13.**Well Defined Requirements, **14.**Novel Technology, **15.**Complex Technology, **16.**Visibility, **17.**PM Experience with PMO, **18.**Stakeholder Communications, **19.**Business Operations Efficiency, **20.**Product Knowledge, **21.**Organization Context, **22.**Quality Management, **23.**Strategy, **24.**Structure, **25.**Culture, **26.**Agility

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Table 2-2: Catalogue of PMO Organizational Studies found in literature (Part 2 of 4)

				Factors found in literature																									
Theory	**Theorists**	**P**	**Context**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Contingency Theory	Donaldson, 2001	SP	Industry			x																x		x		x			x
	Barki & Pinsonneault, 2005	OS	Industry								x	x										x							
	Westerman, McFarlan & Iansiti, 2006	OS	Industry									x				x	x					x	x						
Design/ Performance Theory	Roberts, 2007	O	Industry																		x	x		x		x			
	Stanford, 2007	E	Industry									x		x							x	x	x	x		x	x	x	
	Aubry, Hobbs & Thuillier, 2009	MPB	Industry									x	x								x	x			x	x	x		
	Morris & Pinto, 2010	W	Industry																x	x	x		x						
	Csaszar, 2013	OS	Industry																			x		x		x	x		
Configuration/ Performance	Ketchen, Thomas & Snow, 1993	AMR	Industry								x	x									x	x	x	x		x	x		
	Ketchen, *et al.,* 1997	AMR	Industry														x	x						x			x		
	Payne, 2006	OS	Industry			x	x			x		x	x								x	x		x	x				
	Deutscherr, *et al* ., 2016	JBR	Industry																	x		x		x					
Structure/ Performance	Nissen & Burton, 2011	IEEE	Defense																					x			x		x
	Turkulainen & Ketokivi, 2013	OD	Industry									x										x		x			x		
	Worley, Williams & Lawler, 2014	W	Industry									x	x	x		x	x	x		x	x	x	x	x	x	x	x	x	x
	Hunter, 2015	OD	Industry									x					x	x			x	x		x		x	x	x	
Systems Thinking Theory	Sage & Cuppan, 2001	IKSM	Industry				x				x																		
	Dillard, 2005	ARJ	Defense				x					x		x			x	x		x	x	x		x		x	x		x
	Friedman & Sage, 2004	SE	Defense								x	x		x		x				x	x		x		x				
	Hobday, Davies & Prencipe, 2005	ICC	Industry				x				x	x	x			x	x	x		x		x	x	x	x	x	x		x
	Meier, 2008	PMJ	Defense				x						x				x			x	x								
	Frank, Sadeh & Ashkenasi, 2011	PMJ	Industry									x	x			x	x	x						x			x	x	x
	Kerzner, 2013	W	Industry			x			x	x			x						x	x									

Legend of Publishers (P): AMR-Academy of Mgmt. Review, E-Economist, IEEE-IEEE Transactions on Systems, JBR-Journal of Business Research, MPB-Intl. Journal of Managing Projects in Business, O- Oxford University Press, OD-Journal of Organization Design, OS- Organization Studies, SP-Sage Publications, W-Wiley Publishing

Legend of Factors: **1.**Jointness, Not observed in literature, **2.**Foreign Military Sales, Not observed in literature, **3.**Project Size, **4.**Acquisition Strategy, **5.**International Cooperation, **6.**Project Duration, **7.**Project Location, **8.**Product Architecture, **9.**System Hierarchy, **10.**Available Resources, **11.**Governance, **12.**Critical Technology, **13.**Well Defined Requirements, **14.**Novel Technology, **15.**Complex Technology, **16.**Visibility, **17.**PM Experience with PMO, **18.**Stakeholder Communications, **19.**Business Operations Efficiency, **20.**Product Knowledge, **21.**Organization Context, **22.**Quality Management, **23.**Strategy, **24.**Structure, **25.**Culture, **26.**Agility

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Table 2-2: Catalogue of PMO Organizational Studies found in literature (Part 3 of 4)

Theory	Theorists	P	Context	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
				Factors found in literature																									
PMO Theory	Van Der Merwe, 1997	IJPM	Industry										x	x													x		
	Andersen, Henriksen & Aarseth, 2007	JME	Industry			x						x	x	x							x	x			x		x		
	Pellegrinelli, *et al.* , 2007	IJPM	Industry									x		x				x		x	x	x		x	x	x	x	x	
	Aubry, *et al.* , 2010	IJPM	Industry			x		x	x	x	x	x	x	x					x	x	x	x	x	x	x	x	x	x	x
	Morris & Pinto, 2010	W	Industry								x	x		x			x	x	x		x	x		x	x	x	x		x
	Thamhain, 2014	W	Industry										x		x	x	x	x		x	x	x	x		x	x			
	Turner, 2016	R	Industry											x		x				x	x	x			x	x			
PMO Structure Theory	Galbraith, 1971	BH	Industry			x	x				x	x					x	x											
	Hobbs & Aubry, 2008	PMJ	Industry									x	x						x			x		x		x	x	x	
	Aubry, Hobbs & Thuillier, 2007	IJPM	Industry					x		x	x	x	x	x						x		x	x	x	x	x	x		x
	Aubry, Hobbs & Thuillier, 2008	IJPM	Industry														x	x		x		x	x	x		x	x	x	
	Hobbs, Aubry & Thuillier, 2008	IJPM	Industry									x	x	x			x	x	x		x	x	x	x	x	x	x	x	
	Miterev, Mancini & Turner, 2017	IJPM	Industry									x	x	x								x	x	x		x	x	x	
	Modig, 2007	IJPM	Industry									x									x	x		x			x		
	Müller, Glückler & Aubry, 2013	PMJ	Industry									x	x	x							x	x		x		x	x	x	
	van Donk & Molloy, 2008	IJPM	Industry									x						x			x	x		x		x	x	x	
Systems Thinking Theory	Sage & Cuppan, 2001	IKSM	Industry				x				x																		
	Dillard, 2005	ARJ	Defense				x					x		x			x	x		x	x	x		x		x	x		x
	Friedman & Sage, 2004	SE	Defense								x	x		x		x				x	x		x		x				
	Hobday, Davies & Prencipe, 2005	ICC	Industry				x				x	x	x			x	x	x		x		x	x	x	x	x	x		x
	Meier, 2008	PMJ	Defense				x						x				x			x	x								
	Frank, Sadeh & Ashkenasi, 2011	PMJ	Industry									x	x			x	x	x						x			x	x	x
	Kerzner, 2013	W	Industry			x			x	x			x						x	x									

Legend of Publishers (P): ARJ- Defense Acquisition Review Journal, BH-Business Horizons, ICC-Industrial and Corporate Change, IJPM- Intl. Journal of Project Mgmt., IKSM- Information Knowledge Systems Mgmt., JME-Journal of Mgmt. in Engineering, PMJ-Project Mgmt. Journal, R-Routledge, SE-Systems Engineering Journal,W-Wiley Publishing

Legend of Factors: **1.**Jointness, Not observed in literature, **2.**Foreign Military Sales, Not observed in literature, **3.**Project Size, **4.**Acquisition Strategy, **5.**International Cooperation, **6.**Project Duration, **7.**Project Location, **8.**Product Architecture, **9.**System Hierarchy, **10.**Available Resources, **11.**Governance, **12.**Critical Technology, **13.**Well Defined Requirements, **14.**Novel Technology, **15.**Complex Technology, **16.**Visibility, **17.**PM Experience with PMO, **18.**Stakeholder Communications, **19.**Business Operations Efficiency, **20.**Product Knowledge, **21.**Organization Context, **22.**Quality Management, **23.**Strategy, **24.**Structure, **25.**Culture, **26.**Agility

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Table 2-2: Catalogue of PMO Organizational Studies found in literature (Part 4 of 4)

				Factors found in scholarly journals																									
Theory	**Theorists**	**P**	**Context**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Program Management Complexity	Lyneis, Cooper & Els, 2001	SDR	Defense			x	x					x	x													x	x		x
	Dillard & Nissen, 2007	PMJ	Defense				x					x		x						x				x			x		
	Arttoa *et al.,* 2011	IJPM	Industry									x		x												x	x	x	
	Brady & Davies, 2014	PMJ	Industry			x				x		x	x	x		x	x	x			x	x			x		x	x	
Program Performance Theory	Farmer, Fritchman & Farkas, 2003	JOL	Defense				x																						x
	Bourne & Walker, 2005	TPM	Industry					x		x	x	x					x	x			x	x							
	Shenhar & Dvir, 2007	PMJ	Industry										x								x	x	x		x	x			x
	Aubry & Hobbs, 2011	PMJ	Industry									x	x	x							x	x		x	x	x	x	x	x
	Shenhar & Dvir, 2011	MIT	Industry													x			x	x	x		x			x		x	
	Wysocki, 2011	W	Industry			x							x	x		x	x	x		x					x	x			
	Levin, 2012	AP	Industry										x							x	x	x							
PMO Structure/ Performance	Cleland & Gareis, 2006	MH	Industry																	x	x	x					x		x
	Thomas, 2009	DD	NASA					x			x	x			x								x				x		
	Hobbs & Aubry, 2010	PMI	Industry			x			x	x	x	x	x	x					x	x	x	x		x	x	x	x	x	x
	Brooks, *et al* ., 2011	IEEE	Government									x		x				x		x	x		x	x		x	x		
	Shao & Müller, 2011	IJPM	Industry			x			x				x					x		x	x	x					x		
	Müller, Pemsel & Shao, 2015	PMJ	Industry											x						x	x						x		

Legend of Publishers (P): AP- Auerbach Publications, DD-Doctoral dissertation, IEEE-IEEE Transactions on Systems, IJPM- Intl. Journal of Project Mgmt., JOL- Air Force Journal of Logistics, MH- McGraw-Hill Professional, MIT- MIT Sloan Mgmt. Review, PMJ-Project Mgmt. Journal, SDR-System Dynamics Review, TPM-Team Performance Mgmt., W-Wiley Publishing

Legend of Factors: 1. Jointness, Not observed in literature, **2.**Foreign Military Sales, Not observed in literature, **3.**Project Size, **4.**Acquisition Strategy, **5.**International Cooperation, **6.**Project Duration, **7.**Project Location, **8.**Product Architecture, **9.**System Hierarchy, **10.**Available Resources, **11.**Governance, **12.**Critical Technology, **13.**Well Defined Requirements, **14.**Novel Technology, **15.**Complex Technology, **16.**Visibility, **17.**PM Experience with PMO, **18.**Stakeholder Communications, **19.**Business Operations Efficiency, **20.**Product Knowledge, **21.**Organization Context, **22.**Quality Management, **23.**Strategy, **24.**Structure, **25.**Culture, **26.**Agility

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2.3.5 Systems Integration

PMO organization structures (Thamhain, 2014), PMs (Kerzner, 2013), and cross-functional teams (Turner, 2016) serve as integrating mechanisms that (in varying degrees) aggregate and integrate people, processes, and technology to achieve an organization's mission (Farmer, Sarkani, and Mazzuchi, 2014). Integrating weapon systems as a SoS further complicates matters as multiple programs are dispersed in time across decades. The resulting mix of systems is a technological hodgepodge that often does not work or does not integrate well. This situation has raised questions among those charged with oversight of Defense procurement, particularly Congress (GAO, 2014).

Systems integration is a core technical, strategic, and organizational capability of complex Defense products. Hobday, et al. (2005) divide SI capability into multiple categories including platform SI (e.g., production, system assemblers), component SI (e.g., engineering development, component development), Architecture SI (e.g., trade-off studies, system definition), and weapon systems acquisition (Hobday, Davies, and Prencipe, 2005). Consistent with Hobday et al.'s commercial industry argument, SI strategy depends on the product; high-volume, low-tech products require a different level and type of SI capability along the SDLC than low-volume, complex systems (Hobday, Davies, and Prencipe, 2005).

Thomas (2009) attempts to address the "systems integration" gap in PMO structure theory by characterizing constructs for complex, high-tech projects. In agreement, Artto *et al*., (2011) recognizes PMOs as integrative structures that coordinate between sub-units. Further, Kerzner (2013) recommends the analysis of integrating devices (i.e., organization structure) before implementing a program. Friedman and Sage (2004) pose

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system acquisition integrating function alternatives between contractors, government, and/or shared responsibilities for systems engineering efforts. Given that integration is a core technical, strategic, and organizational capability in complex systems, this paper seeks to identify SIOS options for complex government programs (Hobday, Davies, and Prencipe, 2005). Fundamental SIOS types exist throughout the Defense acquisition environment including governance entities, integrated product teams, PMOs, and singular positions (e.g., PMs, LSIs, and Lead Systems Engineers).

2.4 PMO Performance Theory

PMO literature appears to fall into two categories: pragmatic and theoretical. In the first type of literature, researchers examine traditional program management success factors from a time-bounded, product development perspective (e.g., cost, schedule, risk, quality, and portfolio management) and try to identify, correlate, and explain the root causes for departure from baseline performance targets. These studies seek to survey stakeholder/end-user satisfaction, examine program baseline breaches, promulgate best practices, and/or share lessons learned (U.S. Government Accountability Office, 2003-2014; Bruner, 2002; Schwartz, 2010; Welby, 2010-2013). Congruent with Rhodes et al.'s (2009) study assessing leading indicators of program effectiveness, Shao and Müller's (2011) research expands program success criteria to include enterprise success (i.e., mission and strategy achievement), preparation for the future (e.g., new systems engineering capabilities and technology innovation), social effects (e.g., safety and security), and workforce development.

The second type of literature focuses on advancing program management office performance theory. Within this general area of literature resides a body of research that

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explores factors, which influence program management office functional composition and structure. Aubry et al. (2007, 331) account for organizational context by assessing performance “from the corporate down through to the portfolio and programme levels, and finally to the project level.”

Notable research on the relationship between organizational structure and program management office effectiveness has resulted in factors that influence program management office organizational structure selection. This body of research explores a broad population of organizations throughout commercial, government, military, and non-profit enterprises. Advancing this research, Thomas (2009) characterized the relationship between systems integration organizational models and project effectiveness (Kerzner, 1998; Brady, 2001; Ross, Dombrowski, and Gholz, 2002; Sosa, Eppinger, and Rowles, 2003; Friedman and Sage, 2004; Thomas, 2009).

The idea is to organize in a way that best enables the PMO to develop and deliver products/services given organizational factors that may impact PMO effectiveness. However, SIOS Optimization alone does not guarantee program success. The Defense Acquisition Structures and Capabilities Review (DASCR) Study, triggered by section 814 of the 2006 National Defense Authorization Act, tasked DAU to closely examine the structures and capabilities of each military department, Defense agency, and any other element of the DoD with an acquisition function. The study found that organizational structure change is not enough to offset other shortcomings (Lumb, 2008). The Section 814 study also found that “joint acquisition programs have problems with cost, schedule, and performance similar to single-service programs, but they are amplified by the multi-service and multi-agency environment” (Lumb, 2008, 19). The study of PMO

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performance theory relevant to this research boils down to critical success factors and PMO characteristics.

2.4.1 Critical success factors

Applying contingency theory to temporary organizations, project management researchers reveal factors that help select typology for PMO organizations (Aubry *et al.*, 2007, 2009). Pinto and Slevin's (1987) seminal work empirically derived ten critical project implementation success factors- project mission, top management support, project schedule/plans, client (i.e., end-user) consultation, personnel issues, technical tasks, client acceptance, monitoring and feedback, communication, and troubleshooting. Years later, Delano (1999) defined critical success factors for Defense PMOs including acquisition factors (e.g., well defined requirements, acquisition strategy, works well when fielded stability) and resource factors (e.g., program management skills, quality people, program manager responsibility and authority, total team concept). Shenhar *et al.* (2002) argue that success factors depend on contextual influence and assert that "different factors influence different kinds of projects." Their work resulted in 22 success factors independent of project characteristics. Müller and Turner (2007) support this view with their observation that project success rates vary by industry and complexity.

Using organization design theory as a backdrop, Morris and Pinto (2010) identify important factors for project success - powerful PMs, cross functional teams, effective internal and external communication, a powerful project leader, senior management support, and team tenure are critical to organizational effectiveness.

Exploring why project management offices change, Aubry et al. (2010) derived 35 factors that describe the context, scope, and nature of the transition of the project

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management office over time. Interestingly, some of these factors align with Thomas' (2009) research findings on factors that influence systems integration organizational model selection.

Comprehensive research of Müller and Jugdev (2012), underscores the significance of early work Pinto and Slevin (1987) contemporaries and provides a broader view of project success along four dimensions: project efficiency; impact on customers; business success; and strategic potential. Building on Müller and Jugdev (2012) and distilling the work of Fortune and White (2006) (who reviewed 63 success factor publications), Rolstadås *et al.* (2014) suggest that megaproject performance may be assessed (and modeled) with focus on five organizational aspects: structure, technologies, culture, social relations and networks, and interaction.

Adding systems engineering context, Frank *et al.* (2011) suggest success factors for engineering projects- "clearly defined objectives and requirements, top management support and involvement, proper planning, vendor and customer involvement and partnership, appropriate staff selection and training, the existence of the required technology, customer and end-user satisfaction, good control, monitoring and feedback, and high levels of communication and proper risk management." Building on these studies, several researchers have explored the human factor. Levin and Ward (2011) point to program manager competency as a factor that drives program outcomes. Similarly, PMI (2013), Kerzner (2013), and GAO (2015) link program knowledge to program effectiveness. Shao and Müller (2011) reinforce that program manager competence is a key success factor for programs. Demonstrating this perspective, PMI (2013) links the PM's role to program effectiveness. Shao and Müller (2011) broaden this perspective of

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program success criteria. Their research provided success criteria beyond stakeholder satisfaction and program efficiency (i.e., cost, schedule, quality, functionality) to include enterprise success (i.e., strategy achievement, follow-up mission), preparation for the future (e.g., new SE capabilities, technology innovation), social effects (e.g., safety), and the program team (e.g., workforce development).

Bridging project management and SE, Kerzner (1998, 2013) identified factors to consider when designing structures for project-based organizations. Kerzner's (2013) organizational factors appear to be congruent with Rhodes et al.'s (2009) SE indicators for assessing program and technical effectiveness. Later, Müller, Pemsel, and Shao (2015) add governance, leadership, and talent infrastructure to the list of factors that help explain project success.

2.4.2 PMO characteristics

Early on, Galbraith's (1971) seminal work contributed universal characteristics to consider when determining PMO typology – diversity of product lines, rate of change of the product line, interdependencies among subunits, level (or complexity) of technology, presence of economies of scale, and organization size. Expanding this perspective, Pinto and Slevin's (1988) research added prerequisite PMO attributes for successful strategic program management- grouping similar projects, structured and flexible decision making, effective communication, program alignment to strategic direction, organization design, setting and measuring goals, and program evaluation. Later, Shenhar and Dvir (2007) identified common characteristics of highly successful projects- innovation, clear requirements, highly qualified PM, top management support, revolutionary project culture, collaboration/coordination with outside organizations, maximizing existing

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knowledge, integrated development teams, rapid problem solving, adaptability to environmental changes, and team culture of partnership. In addition, Aubry *et al.* (2009) contributed project-based organizational attributes including agility, power, politics, and coexisting values. Congruent with Rhodes *et al.*'s (2009) study of leading indicators of program effectiveness, Shao and Müller's (2011) research expanded program success criteria to include enterprise success (i.e., mission and strategy achievement), preparation for the future (e.g., new systems engineering capabilities and technology innovation), social effects (e.g., safety and security), and workforce development.

Wysocki (2011) characterized PMO strengths as scalability and coordination ability to integrate multiple product teams, project schedules, and resources. While researchers seeking better ways to deal with organizational complexity, add project ambiguity, low predictability, increased risk, surprises, unfamiliar technology (Alberts, 2012). Alberts (2012) incorporates the need for organization designs that allow for speed, versatility, flexibility, adaptability, and innovativeness. Brady and Davies (2014) confirm that complexity influences the ability to achieve performance objectives.

Worley, Williams, and Lawler (2014) establish a connection between organization agility and performance for large corporations. They define organizational agility as the ability to change as needed to keep pace with environmental trends and disruptions (Worley *et al.*, 2014).

Most organization design research for complex Defense programs correlates organizational structures with program architecture – SoS, system, or component (Sosa, Eppinger, and Rowles, 2003). For example, Friedman and Sage (2003) pose three options for system acquisition organizational responsibilities:

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- *Contractor Responsibilities* – Prime SoS engineering (and integration) Contractor with responsibility for the total SE effort
- *Government Responsibilities* – Government integrator and Government SoS program manager with separate contractors for the engineering of each component system
- *Shared Responsibilities* – Independent contractor SoS integrator and SoS program manager with separate Government assigned contractors for the engineering of each component system.

Building on much of the aforementioned research, Thomas and Utley (2006) examined the effect of systems integration organizational model types on high-tech, complex government projects' effectiveness. Admittedly, their research stops short of *program* management organizations.

The balance of this Dissertation includes a review of research methodologies followed by discussion of analysis and relevant findings. Conclusions and suggestions for further research close the Dissertation.

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Chapter 3: Research Methodology

3.1 Overview

The Defense Industry was selected as a good empirical setting for this research because (1) it provides a wide-range of megaproject attributes for comparison across multiple industries; and, (2) it offers a sizeable dataset for analysis to support hypothesis testing. For example, hundreds of Defense products range from commodity high volume items to niche high value items. Project teams are situated in multiple locations. Engineering and development are relatable to multiple industries. And, the MDAP dataset features a broad range of megaproject performance dispositions.

Hypotheses emerging from the literature review in Section 2 help to shape the research methodology and are discussed below in Section 3.2. A review of the research methodology will follow the discussion of hypotheses.

3.2 Research Hypotheses

Explaining relationships between structures and contingencies warrants empirical studies (Dillard and Nissen, 2007). Consistent with this premise, Brooks, Carroll, and Beard's (2011) research findings suggest that empirical studies are critical for understanding developing sound organizational theory. Further, Miller, Greenwood, and Prakash (2009) advocate for continuing organizational theory research via empirical studies, they suggest future research that explores more types of organizations and contexts. And, recognizing organization designs as entities which function as systems of systems, they stress studying interdependencies among organization design elements. Per Brooks *et al*. (2011), avoid the assumption that organization design literature concepts directly apply to government enterprises. Per Deutscher *et al.* (2016), PMOs

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that align certain factors should outperform PMOs that do not. PMO attributes represent a complex cluster of factors that lead to success or failure.

Factors are interrelated with mutually dependent influences on program performance (Thomas, 2009). PMO organization factors for MDAPs have not been fully explored in literature. Citing opportunities to expand organizational theory, Short *et al.* (2008) make the case for additional research to explore concepts of fit. These considerations lead to the following hypothesis.

Hypothesis 1. Clusters emerging from distinct combinations of factors help to characterize MDAP structure types as destined for superior performance or destined for failure.

Researchers have sought to identify and explain relationships between factors that influence project-based organization structures (Van Der Merwe's, 1997; Thomas, 2009; Aubry, 2010). Over a decade ago, Lyneis, Cooper, and Els, (2001) asserted that projects continued to perform poorly despite multiple advances and substantial improvement efforts on tools and techniques because they did not account for the dynamic, complex nature of projects. Since then, several researchers have come on the scene to study project complexity, advance agile project management theory, and develop practical agile project management tools and techniques (e.g., the scaled agile framework- SAFe) (Brady and Davis, 2014; Nissen and Burton, 2011). Regardless, advances in environmental context remains a central theme. Pellegrinelli *et al.* (2007) stressed the importance and influence of context (e.g., structure, operations, etc.) on program performance. Per collective research, it stands to reason that the conditions leading to commercial project success via

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new agile methodologies do not guarantee success for Government projects. These considerations lead to the following hypothesis.

Hypothesis 2. MDAP organizational PMO selection factors influence program performance.

Ketchen's *et al.* (1997) research supports this study's basis of PMO organization structure, breadth of variables, sample populations, and study time frame. Though hotly debated, Ketchen *et al.* (1997) made the following discoveries about configurations – performance relationships:

- Inductively derived configurations will report a stronger relationship with performance than studies using deductively derived configurations.
- Broad sets of configurational variables will report a stronger relationship than studies using narrow sets.
- Single-industry samples will report a stronger relationship than studies using multi-industry samples.
- Longitudinal designs [5years>] will report stronger relationships than studies using cross-sectional designs."

3.3 Methodology Key Steps

The methodology undertaken includes determination of PMO organizational selection factors, empirical database development, MDAP cluster analysis, and PMO organization structure characterization. As depicted in Figure 3-1, The research methodology encompasses derivation of PMO organizational factors and effectiveness measures, empirical database development, MDAP cluster analysis, and PMO organization structure characterization. Each step is discussed below.

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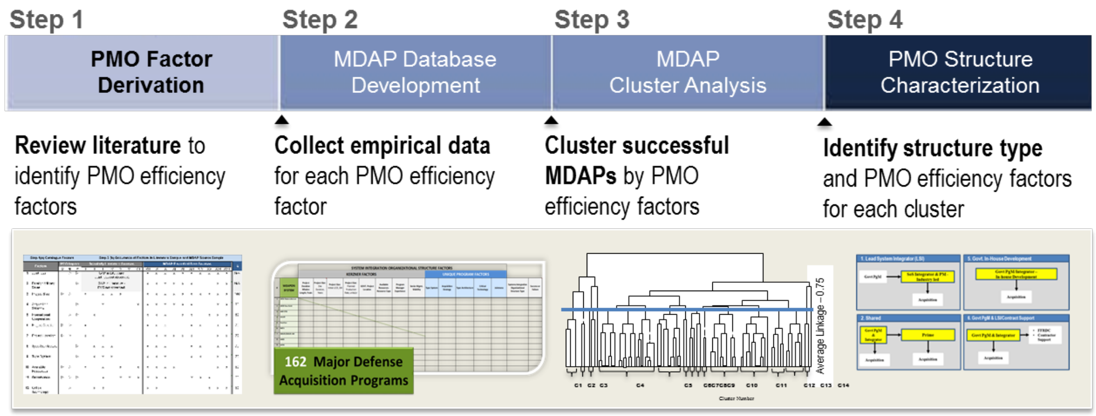

Figure 3-1: Methodology Key Steps and Outputs

3.4 PMO Factor Derivation

An exhaustive literature search was conducted to help identify factors associated with program effectiveness, systems integration, and PMO organization typology (Figure 3-2). This research also examined empirical data in the form of publicly available studies and independent Government reports to define factors that are "unique aspects" of MDAP organizational structures and determine relevant measures of effectiveness (MOEs) (e.g., Selected Acquisition Reports, DoD SE Annual Reports, DoDI 5000.02, DoDD 5000.01, GAO Assessments, and acquisition documents). GAO's (2013) weapon systems assessment along with redacted DoD Selected Acquisition Reports (SAR) helped to isolate organizational factors for effective complex Defense programs. Literature research details are available in Chapter 2.

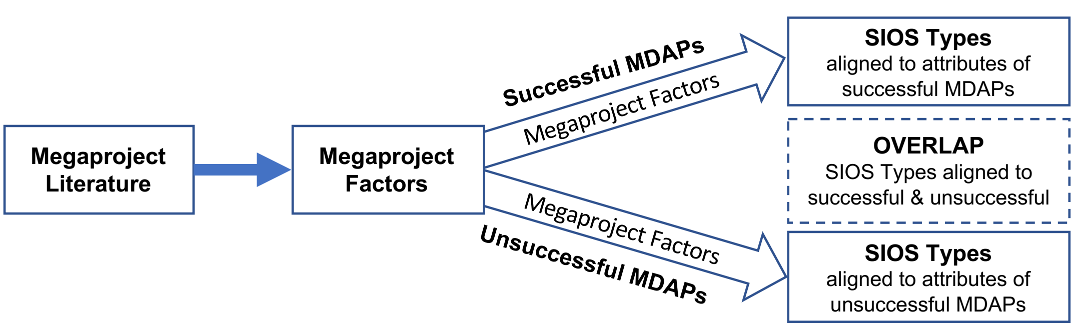

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Figure 3-2: Research framework

Factors extracted from scholarly megaproject-centric (i.e., large, complex projects and/or systems with lifecycle cost greater than $1 billion) literature are listed below (Table 3-1) in alignment with emergent themes relevant to this study – business context, strategy, technology, processes, human factors, organization, communication, complexity, project control (e.g., risk, cost, and quality management), and duration.

Table 3-1 Organizational Factors Found in Literature for Large, Complex Projects

Theme	Megaproject Organizational Factors	References
Business Model	Project Mission	[45],[46]
	Budgeting environment and financing	[13],[23]
	Political influence, policy changes	[3],[12],[46],[54]
	Product line diversity & rate of change, economies of scale	[1],[15],[50]
	Resource constraints/allocation	[10],[39],[45]
	International policy	[20],[54]
	Partnerships, Contracting practices	[39],[55]
	Stakeholder relationship management	[4]
	Shifting executive authority between Services	[46]
Strategy	Program alignment, Strategic measures, Clear priorities, Initial planning, Clear objectives and deliverables, Threat environment changes	[5],[45],[46],[49]
	Long-range/Strategic planning	[10],[13],[36],[39],[50]
Technology	Unfamiliar technology, changes in technology	[3],[11],[23][34],[35],[37],[39],[45],[46],[50]
	Innovation and clear requirements	[2],[6],[35],[48],[49],[50]
Processes	Decision making and program evaluation	[20],[31],[50]
	Knowledge management, rapid problem solving	[35],[38],[49]
	Process integration	[13],[50],[56]
Human Factors	Project Manager competency	[10],[26],[35],[39]
	Culture	[40],[47],[48],[50],[52],[54],[56]
	Team knowledge, skills, and experience	[5],[10],[20],[30],[39],[40],[48],[56]
	Integrated development teams, adaptability	[29],[34],[35],[42],[49],[50],[51],[55]
	Power, politics, and coexisting values	[9],[11]
	Top management involvement and support	[10],[19],[35],[44]
	Team member continuity	[23],[39]
Organization	Subunit interdependency	[23],[37],[39],[45]
	Similar project groupings and organization design	[38],[47]
	Internal and External collaboration/ coordination	[35]
	Agility, ruggedness, speed, versatility, flexibility, adaptability	[20],[28],[35],[40]
	Leadership and talent infrastructure	[13],[27],[34],[55],[56]
	Decision rights	[2]
	Network nodality	[3]
	Team/Organization Size, Team Recruitment	[23],[39],[45]
	Team Member and/or stakeholder co-location	[53]
	Geographic Dispersion, PMO Locations	[23],[39]
Communication	Effective internal and external communication	[10],[37],[44]
	Exponential stakeholder interfaces, stakeholder engagement and "buy-in", client consultation	[13],[18],[23],[32],[34],[38],[39],[40],[41],[45]
Complexity	Ambiguity, low predictability, increased risk, unfamiliar technology	[2],[18],[22],[35],[43]
	Structural, technical, directional, and temporal complexity	[2],[32],[34],[40]

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Theme	Megaproject Organizational Factors	References
	Management mechanisms	[14]
	Change management	[10],[16]
	Systems integration, interdependency, and management	[2],[3],[17],[37],[38],[50]
Project Control	Risk Identification and Management	[5],[8],[13],[18],[33],[37],[39],[45],[48]
	Cost Estimation and Management	[1],[8],[13],[37],[39],[46]
	Governance, scope/change management, monitoring and feedback	[5],[7],[13],[20],[22],[23],[24],[26],[37],[38],[39],[45],[48]
	Schedule Management	[1],[5],[13],[37],[39],[45]
Duration	Impact of time on long, complex project lifecycle	[1],[5],[13],[37],[39],[55]
Quality	Quality Management (Assurance and Control), Client Acceptance, and Troubleshooting	[1],[5],[10],[13],[23],[37],[39],[45],[50],[52],[56]

Legend: **[1]** Albert, *et al.*, 2017; **[2]** Alberts, 2012; **[3]** Alderman and Ivory, 2007; **[4]** Chan, Hu, & Shan, 2015; **[5]** Cooke-Davies, 2002; **[6]** Davies, Gann, & Douglas, 2009; **[7]** Flyvbjerg and Turner, 2017; **[8]** Flyvbjerg *et al.*, 2003; **[9]** Flyvbjerg, 2014; **[10]** Fortune and White, 2006; **[11]** Giezen, 2013; **[12]** Gil and Pinto, 2017; **[13]** Greiman, 2013; **[14]** Hass, 2009; **[15]** Hobday, 2000; **[16]** Jaafari, 2004; **[17]** Johnson, 2002; **[18]** Kardes, Ozturk,& Cavusgil, 2013; [**19]** Kerzner, 2013; **[20]** Lehtonen, 2014; **[21]** Levin and Ward, 2011; **[22]** Levitt and Scott, 2017; **[23]** Merrow, 2011; **[24]** Miller and Hobbs, 2005; **[25]** Morris and Pinto, 2010; **[26]** Müller and Turner, 2007; **[27]** Müller, Pemsel, & Shao, 2015; **[28]** Nissen and Burton, 2011; [**29]** Pau, Langeland, & Nja, 2014; **[30]** PMI, 2013; **[31]** Priemus, 2010; **[32]** Remington and Pollack, 2007; **[33]** Rolstadås, Hetland, Jergeas, & Westney, 2011; **[34]** Rolstadås, *et al.*, 2014; **[35]** Shenhar and Dvir, 2011; **[36]** Shenhar, Dvir, Levy, & Maltz, 2001; **[37]** Shenhar, *et al.*, 2002; **[38]** Söderlund, 2010; **[39]** Turner, 2016; **[40]** Van Marrewijk, Clegg, Pitsis, & Veenswijk, 2008; **[41]** Williams, Ferdinand, & Pasian, 2015; **[42]** Yazici, 2009; **[43]** Brady and Davies, 2014; **[44]** Clowney, 2016; **[45]** Pinto and Slevin, 1987; **[46]** DAU Smart Shutdown Guidebook, 2009; **[47]** Baughn & Finzel, 2009; **[48]** Componation et al., 2008; **[49]** Corea et al., 1998; **[50]** Franke, 2001; **[51]** Lake, 1992; **[52]** Papadales, 1989; **[53]** Patti, 1997; **[54]** Shore & Cross, 2003; [**55]** Thamhain, 2004; **[56]** Thamhain, 2011.

The study applied comparative analysis to derive MDAP PMO organizational factors. During the literature review, PMO structure selection factors that impact lifecycle cost, schedule, and/or systems acquisition process implementation were catalogued in Table 3-2. The occurrence of a factor in each journal article was noted. In a representative literature sample, a numerical consensus was determined as to the relative importance of each factor. For example, if a factor was mentioned in seven out of ten MDAP empirical data sources surveyed, it was given a value of 70% for comparison purposes.

Table 3-2: Ranking PMO Organizational Factors found in Empirical Data Sources

	PMO Impact			Occurrence of Factors in MDAP Data Sources									
Factors	C	S	P	1	2	3	4	5	6	7	8	9	*Count*
Jointness		>	>	x	x	x	x	x	x	x	x	x	9
Program Size (LCCE, #Units, $/Unit)	>	>			x	x	x	x	x	x	x		7
Acquisition Strategy			>	x	x	x	x	x	x	x			7
Foreign Military Sales			>		x	x	x	x	x	x		x	7
Available Resources	>	>		x	x	x	x	x				x	6
Governance	>	>	>	x	x	x	x			x	x		6
International Cooperative		>	>		x	x	x		x	x		x	6

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Program Duration	>	>			x	x	x			x	x		5
Program Location	>	>				x	x	x	x	x			5
Product Architecture			>		x	x	x			x	x		5
Systems Hierarchy			>		x	x	x			x	x		5
Critical Technology		>		x	x	x			x			x	5
Novel Technology		>	>	x	x	x			x			x	5
Well Defined Requirements	>	>	>		x		x			x			3
Organization Context			>	x				x					2
Visibility		>			x							x	2
Program Manager Experience		>		x	x								2
Product Knowledge		>		x	x								2
Quality Management	>	>	>	x									1
Stakeholder Communications		>			x								1

Legend: C-Cost, **S**-Schedule, **P**-Technical Performance
Data Sources: 1. U.**S**. Government ***Accountability*** Office Weapon Systems Assessment **Reports** 1995-2016, **2.** U.S. Military Department Annual Acquisition Guidebooks, **3.** U.S. Defense Operations, Test & Evaluation Annual Reports, **4.** DoD budget reports: RDT&E justification, **5.** U.S. Defense Inspector General Audit Reports, **6.** Deputy Assistant Secretary of Defense for Systems Engineering Annual Reports, **7.** U.S. Defense Systems of Systems Guide, **8.** U.S. Congressional Research Service Reports, **9.** Quadrennial Defense Reviews

Organizational factors ranking 50% or more were selected for further analysis - Acquisition Strategy, Program Duration, Foreign Military Sales, International Cooperative, Jointness, Novel Technology, Product Architecture, Program Location, Available Resources, Systems Hierarchy, and Program Size (i.e., LCCE, Unit Cost, and Product Quantity). Some factors ranking 50% or more (i.e., Governance and Critical Technology) were not included in analysis due to lack of variation across the MDAP data set. For example, it is assumed that all programs in the dataset develop critical technology and undergo equally rigorous Governance processes.

Factors with the highest percent citation in surveyed literature are briefly summarized along with their measure of efficiency. All measures stem from pre-established scales in the Defense literature. Employing established measurement scales serves to avoid questionable findings and unwarranted conclusions (Short et al., 2008).

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Only selected factors (i.e., acquisition strategy, foreign military sales, international cooperative, jointness, novel technology, product architecture, project size, program duration, PMO location, program resource availability, system hierarchy and SIOS Type) were used in analysis. Some factors (i.e., governance, critical technology, program manager experience with PMO, and visibility of upper-level management) were excluded because the values of their measures of effectiveness were essentially consistent across MDAPs. Case in point: the rigor of program manager selection suggests that MDAP PMs have the appropriate experience. Future studies should examine program manager turnover during program duration. The consequences of high frequency of program manager turnover can include poor decisions, slow decisions, and inaction that can lead to cost and schedule growth (Meier, 2008). Qualitatively, it has been asserted that having a stable program manager (and critical staff) should lead to better program performance (USD(AT&L), 2007). GAO (2008) assessed a subset of MDAPs and determined that PMs tended to change more frequently than prescribed by DoD policy (GAO, 2008).

Remaining factors are recommended for future research given that they require authoritative data sources beyond readily available sources. Factors for future consideration include stakeholder communications, business operations, quality management, and product knowledge. Knowledge deficits early in a program can cascade through design and production, leaving decision- makers with less knowledge to support decisions about when and how best to move into subsequent acquisition phases that commit more budgetary resources. A promising MOE for the product knowledge factor is defined by GAO's (2014) knowledge-based acquisition approach – "a cumulative process in which certain knowledge is acquired by key decision points before

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proceeding" (GAO, 2014, 23). Knowledge point 1: Resources and requirements match. Achieving a high level of technology maturity by the start of system development is one of several important indicators of whether this match has been made. This means that the technologies needed to meet essential product requirements have been demonstrated to work in their intended environment. Knowledge point 2: Product design is stable. This point occurs when a program determines that a product's design will meet customer requirements, as well as cost, schedule, and reliability targets. A best practice is to achieve design stability at the system-level critical design review, usually held midway through system development. Completion of at least 90 percent of engineering drawings at this point provides tangible evidence that the product's design is stable, and a prototype demonstration shows that the design is capable of meeting performance requirements. Knowledge point 3: Manufacturing processes are mature. This point is achieved when it has been demonstrated that the developer can manufacture the product within cost, schedule, and quality targets. A best practice is to ensure that all critical manufacturing processes are in statistical control—that is, they are repeatable, sustainable, and capable of consistently producing parts within the product's quality tolerances and standards—at the start of production.

3.5 MDAP Database Development

The Defense industry is a good empirical setting for this research because its wide-range of attributes avoids bias and may inform multiple industries. For example, products range from commodity items to niche items. Project teams are situated in multiple locations. Engineering and development is relatable to multiple industries. Further, the Defense sector provides a broad range of program performance. Congress has mandated

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that performance data be collected on programs of this size to determine if there is a breach of performance parameters (U.S. Government Accountability Office, 2017). As such, the preponderance of data lends itself to a quantitative study.

An MDAP database was built and populated with empirical data including 33 data fields (spread sheet columns) for each MDAP (n=162): Selected factors (14 fields), organization structure type (1 field), program performance (e.g., cost, schedule, and/or performance) (3 fields), program disposition (1 field), and lead military component (1 field). Other data fields were populated to provide additional context – program overview (1 field), contract types (1 field), prime contractor/ Lead Systems Integrator (1 field), MDAP type (1 field), Selected Acquisition Report baseline year (1 field), Selected Acquisition Report date (1 field), program milestone dates (3 fields), initial lifecycle cost estimate (LCCE) (1 field), unit quantity (1 field), program acquisition unit cost (1 field), and Program Manager contact information (1 field).

The data sample includes major DoD programs occurring between 1995 and 2015. The empirical data set was bounded by selecting MDAPs that have completed the Engineering and Manufacturing Development phase of the Defense systems acquisition lifecycle. Four MDAPs had not completed this phase (by June 2015) and were eliminated from the study leaving 162 MDAPs for analysis. As of September 2015, 62% of the MDAPs in this study were in-progress; 23% were closed with mission accomplished; and, 15% were terminated (DoD, 1995-2015). The MDAP dataset features multiple complex products that are developed by a variety of military components (36% Navy, 27% Army, 27% Air Force, and 10% DoD).

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Prior to analysis, measures of efficiency and data types (i.e., nominal, binary, ordinal, or continuous) were defined for selected factors. The data was then parsed to form two matrices (a matrix for successful MDAPs and a matrix for unsuccessful MDAPs) and standardized. The MDAP database was developed by creating a spreadsheet containing a column for each organizational factor. Table 3-3 identifies selected organizational factors and defines MOEs that are unique to MDAPs. Selected factors and associated MOEs are discussed further in Chapter 4 Results and Analysis.

Table 3-3: Defining Organizational Factors and Effectiveness Measures for MDAPs

Organizational Factor	Factor Definition Used for This Research	Data Classification and Measure of Effectiveness (MOE)
Available resources	Presence or absence of resource caps to depict the constraints on PMs across multiple organizations	Nominal Data: 1) Workforce, 2) Technical, 3) Cost, 4) Schedule, or 5) Resource Constraint combinations
Program Duration	Period of time between Milestones II and III; Engineering and Manufacturing Development Phase	Continuous Data: Years
Program Location	Location where authority and responsibility are delegated with End-Item Responsibility	Nominal data: 1) Government, 2) Industry, 3) Non-profit, 4) Government and Industry (2> locations responsible for system end item/product), or 5) Government and Non-profit (2> locations)
Program Size	a) total Product Quantity over a program's life b) product Unit Cost c) program lifecycle cost estimate-LCCE	Continuous Data: a) #Units b) $/Unit c) $Million
Acquisition Strategy	Acquisition strategies prescribed by DAG (2013)	Nominal Data: 1) Evolutionary, 2) Single-Step to Full Capability, or 3) Pre-Planned Product Improvement
Foreign Military Sales (FMS)	Did the MDAP have conduct FMS?	Binary Data: Yes or No
International Cooperative	Clearly defined international coalition?	Binary Data: Yes or No
Jointness	Combinations of DoD military services and international collaborators?	Ordinal Data: 1, 2, 3, or 4
Novelty	New technology with several systems integration unknowns?	Binary Data: Yes or No
System Hierarchy	INCOSE (2013) standard for systems architecture	Nominal Data: 1) System of Systems, 2) System, or 3) Component

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Organizational Factor	Factor Definition Used for This Research	Data Classification and Measure of Effectiveness (MOE)
Product Architecture	Major weapon systems classifications	Nominal Data: 1) Ground, 2) Weapon, 3) Air/Missile, 4) Communications, or 5) Chemical Biological Nuclear
SIOS Type	Type system integration organizational structure	Nominal Data: SIOS 1, SIOS 2, SIOS 3, SIOS 4, or SIOS 5

Other data added to the MDAP spreadsheet include SIOS Type and MDAP ABS breach disposition for cost, schedule, and performance.

Data was both qualitative and quantitative as demonstrated by the associated measures of effectiveness and performance categories that were used to populate the database for each MDAP. The sample population included Defense ACAT I programs, dating from (calendar year) 1995 through 2016 (AR&A/AM, 2016). Programs must have demonstrated at least five years of operation to be considered for this research.; so, programs during this period (i.e., 1995 – 2016) that started after 2009 were not included. The population is represented by a sample size of 162 programs. The sample data was derived from authoritative sources with publicly available data including SAR, Government Accountability Office (GAO) Weapon System Assessment Reports, DoD Systems Engineering Annual Reports, DoD Annual Budget Request Program Acquisition Cost by Weapon System, Congressional Research Service Reports, and Inspector General MDAP Audits. In some cases, Military Component Acquisition Guides (e.g., Army, Navy, Air Force) and Office of the Director, Operational Test & Evaluation Annual Reports were reviewed for background, context, and validation. Data collection is underway, and the database is currently being updated to include all 162 programs (DoD, 1995 – 2016).

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Reliance on redacted public data sources poses limitations due to knowledge gaps. Variation in performance data poses inaccuracies. Multiple data sources were sampled for each MDAP entry to mitigate these risks. MDAP samples were selected from the redacted summary of Defense ACAT I weapon systems (DoD Instruction 5000.02 ACATs - section 2430 of Reference (k)). SARs were the primary source of MDAP research data. For example, GAO observations on the overall changes in the size, cost, and cycle time of DoD's portfolio of MDAPs, were obtained and analysed cost, quantity, and schedule data from SARs and other information in the Defense Acquisition Management Information Retrieval (DAMIR) Purview system. Through discussions with DoD officials responsible for the DAMIR database and confirming selected data with program offices, GAO determined that the SAR data and the information retrieved from DAMIR were sufficiently reliable (GAO, 2004 – 2016). The SAR is considered a viable data source because the Secretary of Defense is mandated to submit SARs for MDAP Acquisition Category (ACAT) I program ($250M>) to Congress (Section 2432 of title 10, United States Code, "Selected Acquisition Reports").

3.6 Analysis Approach

Accounting for a mixture of quantitative and qualitative data types, this study employed both descriptive statistics and multivariate analysis. Descriptive statistics helped characterize the selected PMO organizational factors for the Defense program data set. Drawing insight from prior organization design research, cluster analysis was employed to group organizational factors into discrete classes aligned to specific PMO structures and to characterize MDAP performance for each classification (Ketchen et al., 1997).

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3.6.1 MDAP Cluster Analysis

Cluster analysis hinges on selecting an appropriate resemblance coefficient. Choosing the right resemblance coefficient is important because it drives the clustering algorithm that measures the similarity for each pair of MDAPs. Xu and Wunsch (2009) caution that there is "no conclusive, absolute" way to confirm the effectiveness of resemblance coefficients.

Choosing the measure of proximity is arbitrary and there are several approaches available. Some approaches include Euclidean Distance, Squared Euclidean Distance, Euclidean Sum of Squares, City Block Distance, Jukes-Canter Gene, and Gower's Similarity Coefficient (Thomas, 2009). This research uses Gower's (1971) coefficient as the measure of proximity since it has successfully been used for data sets containing mixed data types (Romesburg, 2004; Wishart, 2006; Xu & Wunsch, 2009; Thomas, 2009). After the proximity matrix was computed, then the cluster proximities were clustered using the unweighted pair-group method with arithmetic mean (UPGMA). Wishart's (2006) Clustan™ Graphics software was used to create resemblance matrices and subsequent hierarchical clusters for successful and unsuccessful MDAPs, respectively. The hierarchical clustering approach employed in this work builds a cluster hierarchy that is commonly displayed as a dendrogram. The horizontal axis of the dendrogram represents the distance (i.e., mean proximity) between clusters (Romesburg, 2004). The vertical axis represents the MDAPs and clusters.

Clusters (or sub-groups) or formed when the dendrogram is cut at certain levels. The height of the cut to the dendrogram (i.e., level of similarity) controls the number of clusters obtained. The dendrograms in this study were truncated into clusters at the 75%

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similarity level to form archetypical classes (sub-classes) of MDAP classifications. Seventy-five (75%) as appears to be the standard in published literature (Yang et al., 2017; de Mello, Da Silva, & Travassos, 2015; Amiri, Shariff, & Rashid, 2014; Beigi, Zamanizadeh, Razavi, & Zare, 2013).

Hierarchical cluster analysis was employed to produce a set of nominal scale factors that indicate the membership of each factor in each cluster (Lattin, Carroll, and Green, 2003). The cluster analysis process used to assess the SIOS type categories incorporated three basic steps- 1) selecting a proximity matrix, 2) selecting a cluster analysis technique, and 3) validating the clustering technique employed.

3.6.2 Proximity Matrix Selection

Cluster analysis hinges on selecting an appropriate resemblance coefficient. Choosing the right resemblance coefficient is important because it drives the clustering algorithm that measures the similarity for each pair of MDAPs. Take for example, classifying birds of prey. Researchers must choose a resemblance coefficient that excludes sharks, wolves, and some humans from mixing with eagles, hawks, buzzards, etc. Alas, no panacea exists. Xu and Wunsch (2009) caution that there is "no conclusive, absolute" way to confirm the effectiveness of resemblance coefficients.

Prior research confirmed that Gower's algorithm best approximates proximity for data sets that have a combination of quantitative and qualitative data (Rosemburg, 2004; Thomas and Utley, 2006; Thomas, 2009, Xu and Wunsch, 2009; Ketchen, 2013). As such, the Gower's General Resemblance Similarity Coefficient was selected as the proximity matrix for this research. Gower's coefficient S_{ih} was computed for each pair of MDAPs where two cases i and h were compared as follows:

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$$S_{ih} = \frac{\sum_j Wih_j Sih_j}{\sum_j Wih_j} \qquad (3.1)$$

where S_{ihj} is the contribution provided by the j^{th} variable; W_{ihj} is 0 or 1 depending upon whether or not the comparison is valid for the j^{th} variable; if differential variable weights are specified, it is the weight of the j^{th} variable or 0 if the comparison is not valid. Gower (1971) defines the value of S_{ihj} for ordinal and continuous variables as follows:

$$S_{ihj} = 1 - \frac{|X_{ij} - X_{hj}|}{r_j} \qquad (3.2)$$

where r_j is the range of values for the j^{th} variable. For continuous variables, S_{ihj} ranges between 1, for identical values $X_{ij}=X_{hi}$, and 0, for the two extreme values $X_{jmax} – X_{jmin}$. For a binary variable, Gower (1971) defines the component of similarity and the weight, where + denotes that attribute j is "present" and – denotes that attribute j is "absent". For nominal variables, $S_{ihj}=1$ if cases i and h have the same "state" for attribute j then $X_{ij} = X_{hj}$, or 0 if they have different "states" $X_{ij} \neq X_{hj}$ and $W_{ihj} = 1$ if both cases have observed states for attribute j, or zero if ether value is missing. Weight W_{ihj} for the comparison on the j^{th} variable is usually 1 or 0.

3.6.3 Cluster Analysis Selection

Hierarchical clustering was used to construct a tree-like, nested structure partition of **X**. Here, Xu and Wunsch (2009) give a simple mathematical description of hierarchical clustering. Given a set of input patterns **X** = $\{X_1, \ldots, X_j, \ldots, X_N\}$, where $X_j = (X_{j1}, X_{j2}, \ldots, X_{jd}) \in \Re$, with each measure X_{ji} called a feature (attribute, dimension, or variable), where $\Re$ represents the empirical data set for this research. For the purposes of this research, input patterns **X** would be the SIOS type while the measure X_{ji} would be the measures of effectiveness listed in Table 3-2 (Xu and Wunsch, 2009).

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The unweighted pair-group method with arithmetic averages (UPGMA) hierarchical cluster analysis was selected for cluster analysis given that it uses information about all pairs of distances between all pairs of cases uses information about all pairs of distances, not just the nearest or the furthest. For this reason, it is usually preferred to the single and complete linkage methods for cluster analysis (Haase, 2014).

Clustering methods differ in the way that proximity between any two clusters p and q is calculated. After the proximity matrix is computed, then the Cluster Proximities will be clustered using the unweighted pair-group method with arithmetic mean (UPGMA). With the UPGMA, the proximity S_{pq} between two clusters p and q is the average of the proximities between all pairs of cases, one case from each cluster:

$$S_{pq} = \frac{\sum_i \sum_h S_{ih}}{n_p n_q} \qquad (3.3)$$

Summation is for iεp; jεq; and $n_p n_q$ is the number of proximities. Average linkage combines the two clusters p and q for which the average between-cluster similarity is maximum; or the average between-cluster dissimilarity is minimum.

Romesburg's research (2004, 171-172), selected the Gower's General Resemblance Coefficient of Similarity over the following methods for analysing mixed data: 1) treating qualitative data as quantitative data (and vice versa), 2) conducting qualitative and quantitative analyses separately, and 3) forming a Combined resemblance matrix. Wishart's (2006) Clustan™ Graphics software was selected because it includes Gower's coefficient as a proximity option and enables analysis of mixed data-types.

Wishart's (2006) Clustan™ Graphics software was used to create resemblance matrices and subsequent hierarchical clusters (i.e., dendrograms) for successful and

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unsuccessful MDAPs, respectively. The dendrograms were cut into clusters at the 80% similarity level to form archetypical classes of MDAP classifications.

Table 3-4 summarizes the factor, data type, and transform used to perform the analysis. Only four factors were identified as quantitative. Transformation to z-scores was recommended for continuous data (Wishart 2006) in order to provide equal weight when computing the proximities.

Table 3-4: Factor Summary in Clustan™ Graphics software

Factor	Type	Transform
1. Acquisition Strategy	Nominal	none
2. Duration	Continuous	range
3. Foreign Military Sales	Binary	none
4. International Cooperative	Binary	none
5. Jointness	Ordinal	z-score
6. LCCE	Continuous	range
7. Novelty	Binary	none
8. Product Architecture	Nominal	none
9. Program Location	Nominal	none
10. Product Quantity	Continuous	range
11. Available Resources	Nominal	none
12. Systems Hierarchy	Nominal	none
13. SIOS Type	Nominal	none
14. Unit Cost	Continuous	range
15. Performance	Binary	none

3.6.4 Cluster Model Validation

This step requires the evaluation of several applicable cluster analysis approaches to ensure robustness of the selected cluster analysis tool. Robustness was evaluated by running the analyses by program title (alphabetical order) and running again with programs grouped by SIOS type. The results were checked for consistency.

The UPGMA cluster analysis was evaluated for consistency of data clustering along with the evaluation of the single linkage (SLINK), complete linkage (CLINK), weighted pair-group method using arithmetic averages (WPGMA), mean proximity, flexible and density

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cluster analysis methods to ensure robustness of the selected cluster analysis tool. Note that median, centroid, sum of squares, and increase in sum of squares are not applicable for use with Gower's proximity matrix (Thomas, 2009).

Effective evaluation standards and criteria are critically important to yielding confidence in the clustering results. According to Xu and Wunsch (2009), "validation criteria provide some insights into the quality of clustering solutions, but even choosing an appropriate criterion is a demanding problem" (Xu and Wunsch, 2009). Systems hierarchy (i.e., component, system, or SoS) served as our prominent clustering criterion followed by product architecture (i.e., air/missile, ground, communications, sea, or chemical, biological, nuclear) and so forth.

3.7 PMO Structure Characterization

In this last step, SIOS type and other factors were identified for each cluster. Examining MDAP clusters within each dendrogram revealed 1) predominant PMO organization structure type and MDAP systems; and, 2) common characteristics (or attributes) within each MDAP classification. This offers clues to researchers and practitioners who seek relevant factors to examine when selecting a PMO structure for a given system classification.

Thomas and Utley's (2006) study of High Technology Government Projects defined by the National Academies Aeronautics and Space (NAA&S) Board resulted in an assessment of eight specific SIO structure types: 1. LSI, 2. Shared SI, 3. Project Management and SoSI, 4. Joint Venture, 5. Government In-House Development Sl, 6. Government Project Management and SI, (with Contracted Support), 7. Industry-Led program management and Sl, and 8. FFRDC or Non-profit program management and SI. As of October 2010, Congress banned contractors from serving in the LSI role (Section

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802 of the National Defense Authorization Act (Pub. L. 110-181)). This legislation compromises the validity of Thomas and Utley's (2006) research where they identified eight SIOS types. As shown in Figure 3-3, five of the eight SIOS types featured Defense contractors and/or Federally Funded Research Centers (FFRDCs) in the LSI Role. Figure 3-3 illustrates functional relationships within each type of core SIO structures. A yellow-shaded box indicates organizations having LSI and program management responsibility. While military services may share the same acquisition mission, they tend to organize differently and use contractors in varying degrees to help achieve the mission (Lumb, 2008).

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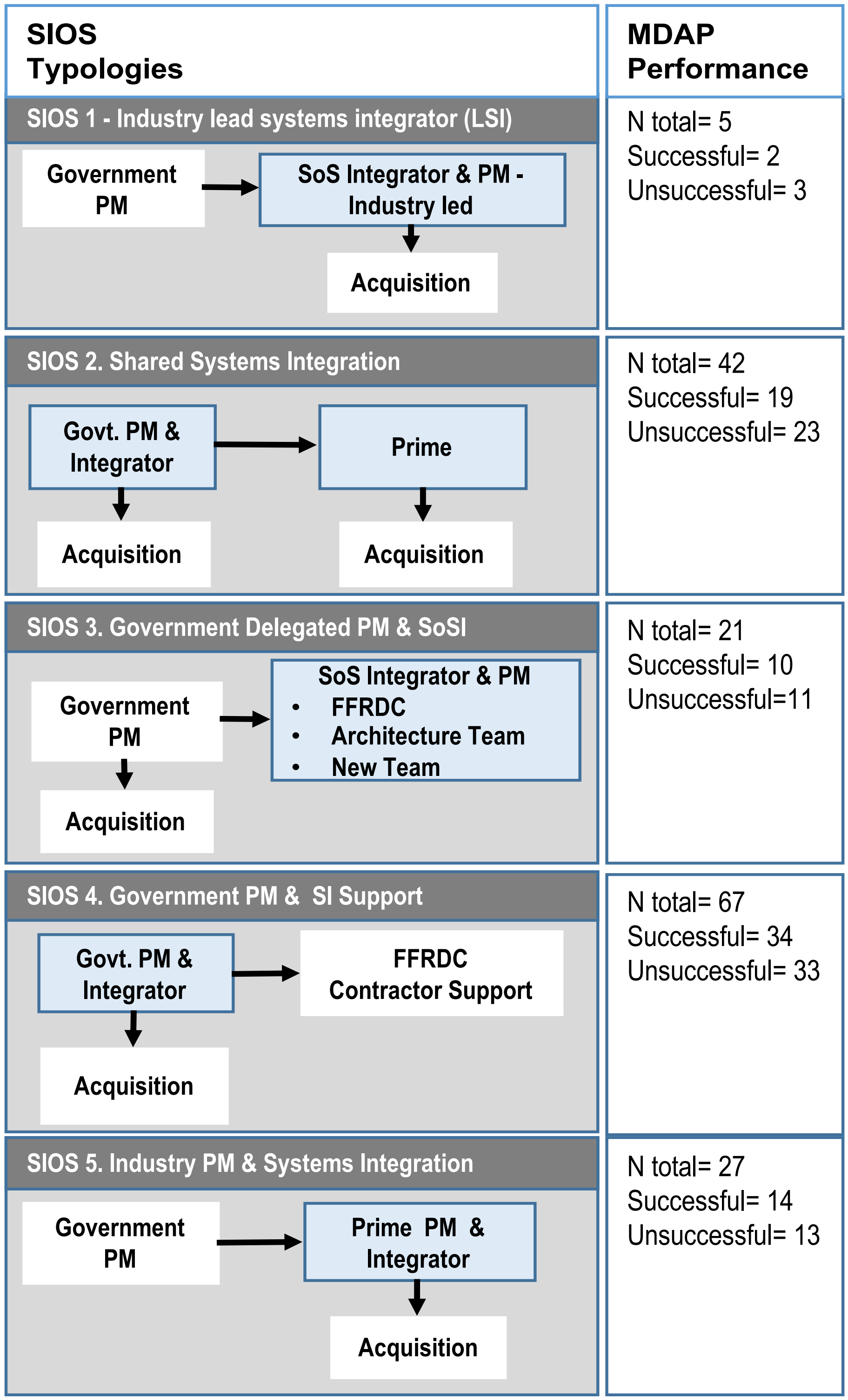

Figure 3-3: Summary of notional MDAP SIOS typology, PMO attributes, and MDAP performance

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Chapter 4: Results and Analysis

4.1 Data Collection

The empirical data sample included 162 major DoD programs with program lifecycle cost greater than $0.25 billion occurring between 1995 and 2016 (DoD Selected Acquisition Reports, 1995-2016). Program disposition varied across MDAPs in the data set. As of September 2016, 62% of the 162 MDAPs in this study were in-progress; 23% were closed with mission accomplished; and, 15% were terminated.

The Navy appears to manage most of programs in the MDAP data set followed Army, Air Force, and DoD, respectfully. While joint programs exist, only the lead organization is listed to simplify stratification. The MDAP dataset not only features multiple product types and multiple lead organizations, but also a wide range of program sizes. The MDAP data set contains products ranging from commodity items (exhibiting high volume and low product unit cost) to high tech items (exhibiting low volume and high product unit cost).

The MDAP empirical data set was bounded by selecting MDAPs that have completed Milestone II (i.e., Engineering and Manufacturing Development). Four MDAPs had not completed Milestone II (as of June 2016) and were eliminated from the study leaving 162 MDAPs for analysis. Prior to analysis, measures of efficiency and data types (i.e., nominal, binary, ordinate, or continuous) were defined for selected factors. The data was then parsed to form two matrices (a matrix for successful MDAPs and a matrix for unsuccessful MDAPs) and standardized. Table 4-1 summarizes successful and unsuccessful MDAPS.

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Table 4-1: Summary of Successful and Unsuccessful MDAPs, n=162

No APB Breach		Cost Breach	Schedule Breach	Technical Performance	Multiple APB Breaches
Abrams M-1A2	INCREMENT 1 E-IBCT	F-22	AEHF SV1-4, SV5-6	Comanche	FCS ***
AESA (RDT&E)	JAGM	ACS	Chem Demil CMA	GMLRS/GMLRS AW	NTW TBMD ***
AGM-154 JSOW BASELINE/BLU-108 + Unitary	JASSM - (ER)	Black Hawk Upgrade UH-60M	NAVSTAR GPS	JSTARS	RQ-4A/B Global Hawk MQ-4C /NATO AGS***
AGM-88E AARGM	JLTV	FBCB2	SBSS BLOCK 10	JTUAV	AAWS (Later JAVELIN)***
AH-64E Remanufacture (AB3)	Joint MRAP	FMTV	MP-RTIP	Crusader	ASDS***
AN/SQQ-89	JPATS	JCM	SFW	EFV	BMDS: ABL***
ATIRCM CMWS	JTRS WAVEFORM (RDT&E)	JDAM	Trident II Missile	ERM	TSAT (LEGACY) ***
ATIRCM QRC	KC-130J	MQ-9 UAS Reaper	WIN-T Inc 3	SSDS MK-1 Portion	JSIMS**
AWACS Blk 40/45 Upgrade	LAIRCM	DDG 51	SSN 774		NMD *
AWACS RSIP (E-3)	LHD-1	F-35 JSF Aircraft (SUB-PROGRAM)	BMDS: GMD		WIN-T Inc 1
B-1B CMUP	Longbow HELLFIRE	Patriot PAC-3	BMDS: SM-6		JLENS
B-2 EHF Inc 1	LPD 17	ASIP	C-130 AMP		MH-60S
B-2 EHF Inc 2	M109A7	LCS	Chem Demil-CMA		WGS
BMDS: RIM-66C SM-2	M2 BRADLEY	ADS (AN/WQR-3)	IDECM Blocks 4		Patriot/MEADS CAP - FIRE UNIT +Missile
BMDS: SM-3	MH-60R	AH-64E New Build (AB3)	JHSV		CJR COBRA JUDY REPLACEMENT
BMDS: THAAD	MM III GRP	AIM-9X Blk II	JTN		FAB-T
C-130J Hercules	MM III PRP	EA-18G	JTRS HMS		GBS
C-17A	MQ-4C BAMS UAS	KC-46A	JTRS NED		JPALS Inc 1A
C-5 AMP	MUOS	LHA 6	MQ-1C UAS Gray Eagle		JTRS GMR
C-5 RERP	NAS	MIDS-LVT JTRS	NPOESS		MQ-4C Triton
CH-47F	Navstar GPS IIIA	MQ-8 (Fire Scout)	SDB II		AOE
CH-53K	NESP AN/USC-38 - Navy EHF SATCOM (NESP)	SADARM	VTUAV		VH-71
Chem Demil-ACWA	NMT	ARH	AIM-120 AMRAAM		
CVN 21 (RDT&E)	P-8A MMA	ATACMS BAT	C-27J JCA		

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No APB Breach		Cost Breach	Schedule Breach	Technical Performance	Multiple APB Breaches
CVN-68	PIM	JTRS AMF	B-2 RMP		
DDG 1000 DD(X) (RDT&E)	PLS	LUH			
E-2C REPRODUCTION	RMS	CEC			
E-2D AHE	SBIRS High - Baseline (GEO 1-4, HEO 1-2, and Ground) GEO 5-6				
EELV	SDB I				
Excalibur	SMART-T				
F/A-18E/F	SSBN/SSGN				
G/ATOR	SSC				
GPS OCX	STRATEGIC SEALIFT Program SSP				
GSM PORTION OF CGS	T-45TS				
H-1 Upgrades	T-AKE				
HC/MC-130 Recap	TACTOM Tactical Tomahawk				
HIMARS	TWS				
IAMD	V-22				
IAV - STRYKER	WIN-T Inc 2				
IMS Scorpion					

*Notes: ***Cost, Schedule, and Technical Performance APB Breach, **Cost and Performance APB Breach, *Schedule and Performance APB Breach*

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As shown in the appendix, Table B-1, the database included the following data fields for each program: SIOS type (1), program performance (e.g., cost breach, schedule breach, and/or technical performance breach) (1), program disposition (e.g., completed, terminated, in-progress) (1), jointness (1), program milestone dates (e.g., Milestone I, II, III) (3), development duration (1), life cycle cost estimate (LCCE) (1), product quantity (1), product unit cost (1), program location (1), resource constraints (1), acquisition strategy (1), foreign military sales (1), novelty (1), international cooperation (1), systems hierarchy (1), and product architecture (1). Other data fields were populated to provide additional context – MDAP full name (1), lead military component (1).

4.2 Analysis

This research employed multi-variate analysis to account for a mixture of quantitative and qualitative data types. Descriptive statistics helped characterize the selected PMO organizational factors for the Defense program data set and examine the correlation between factors. Drawing insight from organizational design research, cluster analysis was employed to group organizational factors into discrete classes aligned to specific PMO structures and to characterize MDAP performance for each classification (Ketchen et al., 1997).

MDAP SIOS type selection serves as the central theme for summarizing results. Analytical results are categorized by MDAP SIOS type to convey confluence of factors within a given SIOS type. Characterization of PMO organization factors is discussed first and is followed by a review of PMO organizational efficiency relative to SIOS type and an assessment of SIOS type similarity, respectively.

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4.2.1 Characterization of PMO Organization Selection Factors

Characterization of MDAP organization factors is discussed first and is followed by a review of MDAP organizational efficiency relative to SIOS type and an assessment of SIOS type similarity, respectively.

Can a DoD megaproject be expressed in terms of a meaningful set of attributes? Yes. Findings reveal a few interesting differences regarding the PMO organization selection factors found in literature (Table 3-1) versus those derived from MDAP empirical data (Table 3-2). Further, this research supports the argument that megaproject performance may be analyzed by structure and technologies (Rolstadås et al., 2014); and, adds a few Defense specific factors- Foreign Military Sales and Jointness, that were missing in literature. The remainder of this section characterizes selected MDAP organization factors.

Factors with the highest percent citation in surveyed MDAP empirical data sources (from Table 3-2) are briefly summarized along with their measure of efficiency. All measures stem from pre-established scales in empirical Defense literature. Employing established measurement scales serves to avoid questionable findings and unwarranted conclusions (Short et al., 2008).

All MDAPs are high profile, have intense governance processes, and have knowledgeable PMs. Given the rigor of MDAP program manager selection, MDAP PMs generally have a high level of experience. Most MDAPs favor evolutionary acquisition strategy, develop critical technology, encompass complex systems of systems, and are co-located (DoD, 2016). Analysis of the MDAP data set (n=162) reveals program durations lasting ~ 20 years (average) with LCCE ranging from \$0.41 billion to \$338.95 billion.

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Some MDAPs produce as many as 271,202 units (systems or components) while others produce only one (1) unit over the entire program lifecycle.

SIOS Type. Recall, from the PMO organization theory discussion in the literature review above, that SIOS type selection is the central theme of the research. MDAP SIOS type was derived from triangulation of multiple empirical data sources including but not limited to annual DoD budget justification documentation, annual DoD weapon system test and evaluation reports, and select DoD Inspector General audits (DoD, 1995-2016). During analysis, MDAP SIOS type was classified as nominal data. Table 4-2 describes SIOS types resulting from literature search (Thomas, 2009; Friedman and Sage, 2004; Dombrowski *et al.,* 2003) and identifies the number of MDAPs in the data set with the given SIOS type. SIOS Type 1 PMO organization structure was used by only three percent (3%) of MDAPs undoubtedly due to U.S. legislation banning contractors from lead system integration roles (U.S. Congress, 2008). It stands to reason that SIOS Type 2 and SIOS Type 4 PMO organization structures would emerge with the highest frequency given the trend away from contractor lead system integration toward primary government responsibility. SIOS Types 3 and 5 feature government responsibility to lessor degrees.

Table 4-2: Systems integration organization structure (SIOS) description (n=162 MDAPs)

SIOS Type	Description	Number MDAPs
SIOS 1 - Industry LSI	Industry LSI responsible for end-to-end systems performance, performing program management, systems integration, and all acquisitions. Thomas (2009); Freidman and Sage (2004)	5
SIOS 2 - Shared systems integration	Both the Government and Prime perform acquisitions and share responsibility in the overall systems integration. Government responsible and accountable for program management and systems integration; Industry Prime responsible for delivering an end item to	42

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SIOS Type	Description	Number MDAPs
	the government. Thomas (2009); Freidman and Sage (2004)	
SIOS 3 - Government delegated program manager and system of systems integrator (SoSI)	Government responsible for program management and all acquisition, delegated program management and SoSI responsibility to Federally Funded Research Centers (FFRDC), an Industry team, or a new private organization formed specifically for this function. Thomas (2009); Friedman and Sage (2004); Dombrowski *et al*. (2003)	21
SIOS 4 - Government program manager and systems integrator/ contracted support	Government responsible for program management, systems integration, and acquisition, with contracted systems integration support from either an FFRDC or Industry support contractors. Thomas (2009); Friedman and Sage (2004); Dombrowski *et al*. (2003)	67
SIOS 5 - Industry program manager and systems integrator	Government responsible for overall program management, but delegates program management, systems integration, and acquisition responsibility Industry prime contractor. Thomas (2009); Friedman and Sage (2004)	27

MOE characterization in Table 4-3 indicates that all SIOS Types feature MDAPs that have produced Air/Missile, Sea, or Communications systems (or SoS) and cooperated internationally. Otherwise,

- SIOS Type 1 structures tend to feature low volume (~353 units), high LCCE ($47.445 billion) systems, ~19-year development, FMS, evolutionary acquisition, PMO on industry site, known technology.
- SIOS Type 2 structures tend to feature high volume (~13,541 units), low LCCE (~$9.385 billion) systems of systems, ~20-year development, FMS, evolutionary or planned improvement acquisition, multiple government-industry sites, and novel technology.

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- SIOS Type 3 structures tend to feature joint programs, low volume (~1,936 units), high LCCE (~$28.635 billion), ~25-year development, foreign military sales (FMS), evolutionary or planned improvement acquisition, multiple government-industry sites, and novel technology.
- SIOS Type 4 structures features same as SIOS Type 3 except for high volume (~11,135 units), low LCCE (~$9.605 billion), and ~25-year development.
- SIOS Type 5 structures features same as SIOS Type 3 except for low volume (~1,724 units), low LCCE (~$8.849 billion), and ~21-year development.

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Table 4-3: Descriptive statistics: PMO organizational factors measures of effectiveness by SIOS Type (n=162)

Factor	Measure of Effectiveness	SIOS 1	SIOS 2	SIOS 3	SIOS 4	SIOS 5	Total	Frequency
		Number of MDAPs, n=162						
Jointness	No- 1 Agency involved	4	41	17	54	24	**140**	86%
	Yes- 2 Agencies involved	1	1	3	5	2	**12**	7%
	Yes- 3 or more agencies	0	0	1	8	1	**10**	6%
Program Size: Life Cycle Cost	<$2,000 Million	1	13	4	15	8	**41**	25%
	2,000 - 10,000	2	18	8	33	11	**72**	44%
	10,000 - 18,000	0	6	2	10	4	**22**	14%
	18,000 - 26,000	0	2	1	1	3	**7**	4%
	26,000 - 34,000	0	1	1	2	0	**4**	2%
	34,000 - 42,000	0	2	1	3	0	**6**	4%
	$42,000 Million >	2	0	4	3	1	**10**	6%
Program Size: Total Product Volume	< 10 units	0	10	7	12	5	**34**	21%
	10 - 510	4	15	10	26	15	**70**	43%
	510 - 1,510	1	5	1	8	4	**19**	12%
	1,510 - 2,510	0	2	2	3	0	**7**	4%
	2,510 - 3,510	0	0	0	4	1	**5**	3%
	3,510 - 4,510	0	1	0	1	0	**2**	1%
	4,510 - 25,510	0	3	1	8	2	**14**	9%
	25,510 > Units	0	6	0	5	0	**11**	7%
Foreign Sales	Yes, foreign military sales	1	17	8	18	6	**50**	31%
	No, foreign military sales	4	25	13	49	21	**112**	69%
Acquisition Strategy	Evolutionary	4	19	8	40	10	**81**	50%
	Planned Improvement	1	15	9	19	15	**59**	36%
	Single Step	0	8	4	8	2	**22**	14%
International Cooperative	Yes, international partners	2	2	3	7	2	**16**	10%
	No, international partners	3	40	18	60	25	**146**	90%
Program Duration	<20 years	0	21	5	19	13	**58**	36%
	20 - 30 years	0	11	9	30	7	**57**	35%
	30 - 40 years	2	10	3	16	4	**35**	22%
	40 - 50 years	3	0	3	1	3	**10**	6%
	50 years >	0	0	1	1	0	**2**	1%
Location of Program	Industry (Ind)	3	0	4	4	9	**20**	12%
	Government (Gov)	0	7	2	19	3	**31**	19%
	Ind/Gov Co-Located	1	15	9	35	8	**68**	42%
	Ind/Gov (2 > Locations)	1	20	6	9	7	**43**	27%
Product Architecture	Air/Missile	4	22	9	30	17	**82**	51%
	Sea	0	3	7	4	4	**18**	11%
	Ground	0	4	1	8	1	**14**	9%
	Communications	0	12	4	24	5	**45**	28%
	Chemical,Biological,Nuclear	0	1	0	1	0	**2**	1%
	All (Air, Sea, Ground, Comm)	1	0	0	0	0	**1**	1%
System Hierarchy	Family of Systems	0	5	2	20	4	**31**	19%
	System of Systems	1	0	15	1	1	**18**	11%
	System	4	32	4	37	22	**99**	61%
	Component	0	5	0	9	0	**14**	9%
Available Resources	No Apparent Constraints	2	14	6	14	9	**45**	28%
	Cost constraint	1	13	10	20	10	**54**	33%
	Technology (Tech.) constraint	1	6	1	16	1	**25**	15%
	Schedule constraint	0	2	2	3	3	**10**	6%
	Schedule & cost constraints	1	5	1	4	2	**13**	8%
	Schedule & tech. constraints	0	0	0	5	0	**5**	3%
	Cost & Tech. constraints	0	1	1	2	0	**4**	2%
	Cost, Schedule, & Tech.	0	1	0	3	2	**6**	4%
Novel Technology	Yes, novel technology	1	23	13	27	17	**81**	0.5
	No, familiar technology	4	19	8	40	10	**81**	0.5

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Program Duration. This factor measures the period of performance between concept development and the date of program closure in the form of continuous data (i.e., years). Caution, program duration is subject to interpretation. In theory, development ends cleanly at production and fielding marks the hand-off to MSC components for sustainment. Systems are continually being upgraded and modified (Rigby and Harris, 1987). The system engineering lifecycle includes concept, development, production, utilization, support, and retirement; however, there are multiple interpretations and derivations by industry (INCOSE, 2010). The Defense industry follows four general phases for MDAPs including pre-Milestone I- analysis of alternatives, Milestone I-Technology Maturation and Risk Reduction, Milestone II- Engineering and Manufacturing Development/Developmental Testing, Operational Assessment, and Milestone III- Production and Deployment, Low Rate Production, Independent Operational Test and Evaluation, Operations and Support and Disposal (Schwartz, 2010). The program duration factor was treated as system development duration to ensure a consistent boundary for the measure of effectiveness. System development duration was calculated as the period between Milestone I start and Milestone II completion.

Analytical results, shown in Table 4-4, indicate that programs typically reach Milestone III within two decades give or take a decade. The broad distribution accounts for outliers such as short duration programs (e.g., terminated MDAPS) versus long duration programs (e.g., SIOS Type 2: 60> years and SIOS Type 5: 70> years). The duration spread in SIOS Type 3 programs exhibits less variation than the rest of the SIOS types. SIOS Types 1, 2, and 4 appear to be skewed below 30 years.

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Table 4-4: Descriptive statistics: MDAP program duration

	SIOS 1	SIOS 2	SIOS 3	SIOS 4	SIOS 5	Overall
Program Duration Factor, years						
Mean	19	20	25	25	21	23
Standard Deviation	14	11	15	9	13	11
Minimum	3	1	9	1	4	1
Median	24	21	26	26	22	24
Maximum	32	39	68	59	46	68

Program Size. This factor measures program size in the form of continuous data relative to total product volume over a program's life (# units), product cost ($/unit), and program lifecycle cost estimate-LCCE ($), respectfully. Future research should expand the measure of effectiveness for this factor to include production rate. Planned production rate accounts for variation in system type (e.g., high volume commodity systems like ground vehicles versus low volume high-tech systems like satellites). Ashton studies suggest, "size determines structure more than technology" (Fenton and Pettigrew, 2000). Per Table 4-5, analytical results show a wide distribution in program LCCE (minimum $413 million, median $4,731 million, maximum $338,950 million), product quantity (minimum 1 unit, median 172 units, maximum 271,202 units), and product unit cost (minimum $0.01 million/unit, median $31 million/unit, maximum $38,082 million/unit).

Table 4-5: Descriptive statistics: MDAP program size

	SIOS 1	SIOS 2	SIOS 3	SIOS 4	SIOS 5	Overall
Program Size Factor: Program Lifecycle Cost Estimate, $Million						
Mean	$47,445	$9,385	$28,635	$9,605	$8,849	$13,770
Standard Deviation	$68,405	$10,917	$65,790	$13,525	$13,435	$32,198
Minimum	$1,005	$648	$413	$529	$537	$413
Median	$6,811	$5,301	$6,321	$4,218	$3,844	$4,731
Maximum	$159,320	$41,506	$338,950	$67,622	$69,571	$338,950
Program Size Factor: Product Quantity, Total # Units						
Mean	353	13,541	1,936	11,135	1,724	8,294
Standard Deviation	645	41,111	5,311	45,634	4,900	35,142
Minimum	15	1	1	1	1	1
Median	32	223	76	195	86	172

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	SIOS 1	SIOS 2	SIOS 3	SIOS 4	SIOS 5	Overall
Maximum	1,500	241,890	26,552	271,202	21,102	271,202
Program Size Factor: Product Cost, $Million / Unit						
Mean	$2,221	$440	$2,720	$907	$398	$982
Standard Deviation	$4,698	$1,189	$5,407	$4,591	$729	$3,742
Minimum	$5.00	$0.03	$1.00	$0.01	$0.39	$0.01
Median	$89	$28	$169	$16	$53	$31
Maximum	$10,621	$7,071	$20,252	$38,082	$3,153	$38,082

All SIOS types had a large spread in program cost, product unit cost, and product quantity. SIOS Types 1 and 3 tended to have lower product quantity and high program cost while SIOS Types 2 and 5 tended to have higher product quantity and lower program cost. Overall, program size data was skewed above the mean for all SIOS types outliers observed for each program size sub-factor.

Acquisition Strategy. This research explores acquisition strategy that involves Defense Acquisition System (DAS) activities that are typically managed against cost, schedule, technical performance, and risk to develop and deliver systems for Warfighters (Moran, 2008). The Acquisition Strategy factor guides the evolution of PMO functions to accommodate shifting system capabilities and priorities at each milestone (Dillard, 2003). In addition to establishing PMO functions, the acquisition strategy essentially imprints the systems integration model (i.e., SIOS type) before the program is formalized and designates which SE functions are needed (DAG, 2013). The Defense Acquisition Guide recognizes three acquisition strategies - evolutionary, pre-planned product improvement, and single-step to full capability acquisition) (DAU, 2013). These acquisition strategies comprise the acquisition strategy measures of effectiveness and are classified as nominal data.

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Defense policy supports evolutionary acquisition for new systems development (Farmer, Fritchman, and Farkas, 2003, DAG, 2013) to boost program speed, flexibility, and agility among other things (Dillard, 2005). Theoretically, evolutionary acquisition delivers requirements by leveraging mature, quickly garnered technologies, then increasing the system's capabilities in subsequent increments over time. The objective is to balance needs and available capability with resources, and to put capability into the hands of the user quickly (Ellman, 2009). Evolutionary acquisition strategy essentially changes program structure by separating projects into smaller, less complex increments (Dillard, 2003).

Novak, et al. (2004) assert that system development integration is a crucial facet of evolutionary acquisition strategy requires effective cross-functional involvement across functional stove-pipes. Ellman (2009) adds that multiple, simultaneous development projects inherent in an evolutionary acquisition program require significantly more resources and reviews.

Roughly half of the systems in the data set have been produced using an evolutionary acquisition strategy while over a third have used pre-planned product improvement. Data indicates that 80% of MDAPs with SIOS Type 1 structures and 60% of MDAPs with SIOS Type 4 structures employ evolutionary acquisition strategy followed by SIOS Type 2 (45%). SIOS Type 5 (56% of MDAPs) structure predominantly uses pre-planned product improvement followed by SIOS Type 3 (43% of MDAPs).

Foreign Military Sales. The FMS factor is important to MDAP PMO organization design because FMS offices generally require duplicate, specialized organizational functions that are compartmentalized from the core PMO organization. While foreign

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military sales tend to be favored for boosting buying power, it is unclear if this factor will have a direct effect on program effectiveness prior to initial operational capability as measured by acquisition program baseline performance measures (DAU, 2012). The FMS factor assessment was based on the presence or absence of foreign sales. The measure of efficiency was classified as binary data (i.e., yes, no).

Roughly a third of MDAPs have duplicate program offices to manage foreign sales. Foreign sales are more prevalent in MDAPs with SIOS Type 2 structures (40%) followed by SIOS Type 3 (38%) and SIOS Type 4 (27%) structures.

International Cooperative. International cooperation complicates programs with multiple coalition stakeholders; but, it boosts efficiency by leveraging scarce program resources to obtain advanced technology from the global technology and industrial base (DAU, 2012). The measure of effectiveness for this factor is classified as binary data – the program either participated in an international coalition or it did not (i.e., yes, no). International Cooperation in AT&L has the potential to significantly improve interoperability for coalition warfare, to leverage scarce program resources, and to obtain the most advanced, state-of-the-art technology from the global technology and industrial base (International Cooperation in AT&L Handbook, 2012, Forward).

Very few MDAPs (10%) in the sampled set have participated in international cooperatives where two or more countries share technology and resources in the development of mutually beneficial systems. Of this small population, MDAPs with SIOS Type 1 structure stand out as participating in international cooperatives 67% of the time.

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Jointness. The Jointness factor impacts PMO organization SIOS type selection particularly for SoS architectures because possible integration mechanisms available for use across multiple DoD departments. Lumb (2008) sites the Section 814 Study finding that "joint acquisition programs have problems with cost, schedule, and performance like single-service programs, but they are amplified by the multi-service and multi-agency environment." The Jointness factor assessment was based on the number of DoD organizations participating involved a given program. The measure of efficiency was classified as ordinal data representing the level of jointness (i.e., the number partners including DoD, Army, Navy, USAF, USMC, and/or international cooperatives).

Similar to the International Cooperative factor, very few MDAPs (i.e., 13%) are developed by joint programs including two or more military service enterprises (i.e., USAF, Army, USMC, and/or Navy). Roughly 20% of MDAPs of SIOS Type 1 structures manage joint programs followed by 19% of MDAPs of SIOS Type 4 structures and 19% of Type 3 structures.

Novel Technology. Demonstrating technology maturity is a prerequisite for moving forward into system development, during which the focus should be on design and integration. A stable and mature design is also a prerequisite for moving forward into production, where the focus should be on efficient manufacturing. The Novel Technology factor supports PMO organization SIOS type selection because it influences the type of acquisition strategy (e.g., evolutionary acquisition strategy, pre-planned product improvement acquisition strategy, or single-step acquisition strategy), underpinning processes (e.g., spiral development process, incremental development processes, etc.), and risks associated with knowledge gaps. Similarly, Jones' research (2013) concludes

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that the technology and strategy determine organization structure. Systems designated as having novel technology are unconventional systems with little known technology. Programs that manage novel technology development are riskier and command more rigor in program management planning and governance. By contrast, systems designated as not having novel technology are merely upgrades to an existing design and are designated as low risk and suitable for conventional PMO mechanisms. Therefore, understanding the novelty of technology associated with a given program is fundamental to program planning and should also be a factor in selecting the SIOS type. The Novel Technology factor assessment was based on the presence or absence of unique technology. This data was classified as binary data.

Future research should study this MOE as ordinal data. Technology Readiness Levels (TRL) are graded definitions/descriptions of stages of technology maturity. They were originated by the National Aeronautics and Space Administration (NASA) and adapted by the DOD for use in its acquisition system. The Army and Air Force science and technology research organizations use them to determine when technologies are ready to be handed off from science and technology managers to product developers (GAO, 2014). PMs use TRLs as a method of estimating technology maturity of Critical Technology Elements (CTE) of a program during the acquisition process. TRL are based on a scale from 1 to 9 with 9 being the most mature technology. The use of TRLs enables consistent, uniform, discussions of technical maturity across different types of technologies. Decision authorities will consider the recommended TRLs when assessing program risk. The primary systems engineering objective is to gain sufficient technical knowledge to verify that the system solution(s) required technology is sufficiently mature

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before proceeding to Milestone II (DAG, 2013). Per TRL definitions in Table 4-6, components or sub-systems have reached TRL 6 or higher for approval to integrate in the system or system of systems.

Table 4-6: Definition of Technology Readiness Levels (DAG, 2013)

Level	Definition	DoD DAG Description
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5	Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.
6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness.
7	System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space.
8	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

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GAO best-practices work shows that a TRL 7, a technology prototype demonstration in a realistic environment, is the level of technology maturity that constitutes a low risk for starting a product development program. These technologies are referred to as fully mature by GAO. GAO Weapon System Assessments over the last decade served the source for TRL data. It should be noted that, in most cases, GAO did not validate the program offices' the determination of the demonstrated level of maturity (GAO, 2004-2016).

Half of the sampled MDAPs involve novel technology. Sixty-three percent (63%) of MDAPs with SIOS Type 5 structure build systems that require novel technology. In close second, 62% of MDAPs of SIOS Type 3 structures require novel technology followed by 55% of MDAPs of SIOS Type 2 structures.

System Architecture. Presumably, program organization structures vary with product type. For example, the program structure needed to produce a complex satellite is vastly different than that needed to produce a fleet of vehicles. Consistent with Hobday *et al.'s* (2005) commercial industry argument, system integration depends on the product type; high-volume, low-tech products require a different level and type of system integration capability than low-volume, complex systems. The MOE for this factor is classified as nominal data that represent product types – air/missile, communications, ground, and sea. This MOE offers practical implications for PMO structure; a SoS will have a program manager for each system and the level of complexity is expected to increase with the number of system interfaces.

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As shown in Table 4-7, Aircraft/missile systems dominate the product types across all SIOS types; communications products follow in distant second to aircraft/missiles. Seventy-five percent (80%) of SIOS Type 1 organizations develop aircraft or missiles followed by 63% of SIOS Type 5 organizations, 52% of SIOS Type 2, 45% of SIOS Type 4, and 43% of SIOS Type 3 type organizations.

Table 4-7: Product profile: type system and lead U.S. Defense organizations

	Number of MDAPS				
Product Type	Air Force	Navy	Army	DoD	Total
Air & Missile Systems	28	28	19	6	81
Communication Systems	16	11	12	6	45
Sea Systems	0	18	0	0	18
Ground Systems	0	1	12	1	14
Chemical, Biological, and Nuclear Systems	0	0	0	3	3
Air, Ground, and Communication Systems	0	0	1	0	1
Total	44	58	44	16	162

PMO Location. The Project Location factor measures the location where program authority and end-item responsibility reside in form of nominal data (i.e., Government, industry, both government and industry, or more than two locations). The location factor not only considers where the PMO resides, but also the number of PMOs operating simultaneously throughout the program lifecycle. Considering program integration, as location nodes increase, the level of communication complexity is expected to increase; thereby, jeopardizing efficiency of collaboration and coordination.

Most MDAPs (i.e., 69%) in the sample were co-located in industry and government locations. Twenty-six percent (26%) of MDAPs had multiple PMO co-location sites. Fewer SIOS types had MDAPs that were located exclusively in industry (12%) or

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government (19%). A few exceptions should be noted. SIOS Type 2 did not have MDAPS located exclusively in industry; and, SIOS Type 1 did not have MDAPs located exclusively in government.

Available Resources. This factor measures the presence or absence of resource caps in the form of nominal data (i.e., technical, cost, schedule) to depict constraints on PMs across multiple organizations. Our research indicates that MDAPs generally produce critical systems with some combination of resource limitations – challenging technologies, limited funding, limited staff, and aggressive timelines. The authors focused on cost, schedule, and technology constraints in this research. In future research, the measure of effectiveness for the Available Resources factor should be expanded to include workforce availability and capability. Rigby and Harris (1987), noted staffing resource levels as the most critical external influence; this finding from the late 1980's remains true in DoD as demonstrated by the level of service contracts associated with MDAPs. Workforce requirements were found to differ with program lifecycle phase (i.e., Milestone I, II, or III) and organizations were not entirely successful at adjusting staffing to reflect lifecycle changes (Rigby and Harris, 1987).

Research findings indicate that 28% of the MDAPs exhibited no apparent constraints. Cost constraints accounted for most resource constraints at 33% relative frequency followed by technology constraints at 15% and schedule constraints at 6%. Seventeen (17) percent of MDAPs experienced a combination of cost, schedule, and/or technology constraints.

System Hierarchy. The systems hierarchy factor influences the complexity of PMO design. Hobday, et al. (2005) divide system integration capability into multiple categories

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including platform system integration (e.g., production, system assemblers); component system integration (e.g., engineering development, component development); architecture system integration (e.g., trade-off studies, system definition); and, systems acquisition. It stands to reason that the high number of subordinate systems the higher the number of integration nodes and the higher the number of possible organization structures. The systems integrator for SoS and systems level programs require different approaches (Friedman and Sage, 2004; Dombrowski et al., 2002). Integrating systems of systems complicates matters as multiple programs are dispersed in time across decades. The resulting mix of systems is a technological hodgepodge that often does not work or does not integrate well. This situation has raised questions among those charged with oversight of DoD procurement, particularly United States Congress (DoD SoS Guide, 2014). The measure of effectiveness for this factor is classified as nominal data given that a program can produce a component, system, SoS, or family of systems.

The nature of the weapon system will influence other organizational factors. Each weapon system commands a unique approach to design, development, deployment, sustainment and in some cases acquisition strategy. For example, a mine-resistant ambush protected (MRAP) vehicle represents a SoS architecture type while a Trident II (D-5) Sea-Launched Ballistic Missile UGM 133A (Trident II Missile) is arguably a component given that it requires other components in a system to accomplish its purpose.

Fundamentally, most MDAPs (i.e., 61%) appear to develop systems vice components or systems of systems. MDAPs with SIOS Type 3 structures stand out as developing SoS’s. Results are highly debateable given that conventional wisdom on defining system hierarchy continues to evolve.

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4.2.2 MDAP Performance Working Definition

This research uses the DoD mechanism for measuring program performance due to its rigor and regulation. Pursuant to the Defense Acquisition Improvement Act of 19, the Packard Commission recommended that DoD “fully institutionalize baselining to improve program stability.” As such, Acquisition Program Baselines (APB) are required by Title 10, United States Code, Section 2435 (10 USC 2435) for Major Defense Acquisition Programs (MDAPs). APBs are governed by DoD Instruction 5000.2 and the Defense Acquisition Guidebook provide policies and procedures for APBs and reporting APB breaches for all ACAT IC&ID and ACAT IAM&IAC programs (DAU, 2013).

The APB is essentially a contract between the Program Manager and the DoD Milestone Decision Authority (MDA) documenting program performance, schedule, and cost goals (objectives). The APB provides a reference point for measuring program status and establishes the Program Manager’s trade space, where trade space considers:

- How is the system supposed to perform?
- When are critical events to occur?
- How much will it cost?

The APB defines the deviation limits (thresholds) beyond which the Program Manager may not exceed without authorization from the MDA. Per statutory requirements, all MDAP (ACAT I C/D) programs) must have APBs. Program Managers are compelled to comply and provide periodic APB updates because, no funds may be obligated after Milestone B for MDAPs without an approved an APB (unless waived by USD(AT&L)). For example, Program Managers must prepare APBs before System

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Development and Demonstration, Production and Development, and Full Rate Production.

The MDAP original baseline APB is prepared just before a program enters system development and demonstration or program initiation (whichever occurs later). Applying strict governance, the MDA determines whether to revise the APB. The current baseline may be revised only as the result of (1) a major program restructure that is fully funded and approved by the MDA; or, (2) a program deviation (breach), if the breach is determined to be beyond the Program Manager's control. Multiple APB revisions may not be authorized by the MDA to avoid a reportable breach. Program Managers must immediately notify the MDA of a deviation beyond threshold in any cost, schedule, or performance parameter. Baselines include

- Performance goals (Objectives and thresholds): key performance parameters (KPPs)
- Schedule goals (Objectives and thresholds): major milestone decision points, Initial Operational Capability, and other critical events
- Cost Goals (Objectives and Thresholds): RDT&E, procurement, MILCON, acquisition related operations & maintenance, program acquisition unit cost, average procurement unit cost, and other costs as determined by the MDA.

Per regulation, MDAP cost, schedule, and performance status is updated in Selected acquisition reports pursuant to 10 USC 2432.

Per Table 4-1, 79 out of 162 MDAPs in the data set successfully reached Milestone III (Production and Deployment) without an APB breach or termination. The remainder

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of the MDAPs in the data set experienced cost, schedule, and/or technical performance baseline breaches. Almost a third (i.e., 29.3%) of the failed MDAPs were terminated.

4.2.3 MDAP Performance Correlated with PMO Organization Selection Factors

Factors to consider when selecting SIOS types for major Defense programs are summarized and correlated in Table 4-8. Empirical Defense program data indicates that at least two factors should be added to the list of factors that were gleaned from megaproject literature; these factors include foreign military sales and jointness, respectively. This is not surprising given that these two factors are unique to the Defense data set.

Supporting Hypothesis 1, Table 4-8 indicates that most of the selected factors influence program performance with $p<0.05$ -- Program Duration (to reach manufacturing and deployment), Program Location, Available Resources, Acquisition Strategy, and Product Architecture appear to impact MDAP performance.

Correlation analysis indicates that MDAP SIOS type is related to program performance, prior studies suggest that it does impact a PMO's productivity, efficiency, and ability to focus on the mission (DAU, 2007). As such, analytical results are categorized by MDAP SIOS type to convey confluence of factors within a given SIOS type. Subsequently, MDAP SIOS type selection serves as the central theme for summarizing results. Characterization of PMO organization factors is discussed first and is followed by a review of PMO organizational efficiency relative to SIOS type and an assessment of SIOS type similarity, respectively.

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Table 4-8: Descriptive Statistics: Correlations of Selected Factors [a,b,c,d]

	Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1.	Acquisition Strategy	--													
2.	Duration	-.015	--												
3.	Foreign Military Sales	.023	.095	--											
4.	International Cooperative	-.005	.070	.137	--										
5.	Jointness	-.098	.013	.006	.085	--									
6.	LCCE	.101	.154	.075	.151	.218	--								
7.	Novelty	.896	.020	.027	-.041	-.164	.071	--							
8.	Product Architecture	.015	-.080	-.186	-.050	.034	-.058	-.022	--						
9.	Program Location	.125	.016	.148	-.005	.028	.124	.129	.116	--					
10.	Product Quantity	-.057	-.004	.154	-.038	.169	-.030	-.059	.017	.015	--				
11.	Available Resources	-.143	-.152	-.090	-.055	.032	-.076	-.177	-.090	-.081	-.056	--			
12.	Systems Hierarchy	-.214	.102	-.080	-.105	.119	.119	-.194	.105	-.019	.154	.077	--		
13.	SIOS Type	-.030***	.063***	-.122***	-.033***	.111***	-.112***	.016***	.030***	-.211***	-.055**	.069***	.091***	--	
14.	Unit Cost	-.068	.077	-.133	-.079	-.064	.157	-.102	.045	.027	-.061	-.008	.152	-.029**	--
15.	Performance	-.18***	-.29***	-.13***	-.11***	.05***	.04***	-.20***	-.05!!	.06**	-.02**	.38*	.003!	-.03***	.15**

a. N=162.

b. Values are Pearson correlation coefficients based on standardized values.

c. Correlation significance: !!p<0.9, !p<0.6, *p<0.05; **p<0.01; *** p<0.000001.

d. Did not include p-values for other variables because the scope of this research explores the influence of SIOS Type on MDAP performance.

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4.2.4 MDAP Performance Relative to SIOS Type

As summarized in Table 4-9, SIOS Type 1, SIOS Type 2, and SIOS Type 3 programs were more likely to have a program baseline breach (e.g., 60% of SIOS Type 1, 55% SIOS Type 2, and 52% SIOS Type 3 programs had a program breach). SIOS Type 4 and SIOS Type 5 programs were less likely to have a program baseline breach (e.g., 49% SIOS Type 4 and 48% SIOS Type 5 programs had a baseline breach).

Table 4-9: MDAP performance as indicated by Acquisition Program Baseline Breach, (n=162)

MDAP Performance Category	Number of MDAPs SIOS 1	SIOS 2	SIOS 3	SIOS 4	SIOS 5	Total
Success- no program breaches	2	19	10	34	14	**79**
Unsuccessful- program breacl						
• Cost	1	7	6	9	5	**27**
• Schedule	0	8	2	12	3	**24**
• Cost and schedule	0	4	1	6	2	**13**
• Technical	0	4	0	4	0	**8**
• Cost, schedule, and technical	2	0	1	1	3	**7**
• Cost and technical	0	0	1	0	0	**1**
• Schedule and technical	0	0	0	1	0	**1**

Analysis of successful MDAPs suggests that all MDAPs with SIOS Type 1 and SIOS Type 3 structures were delivered on schedule; other SIOS types fell near or below 80% on-time delivery. Findings indicate that 90% of MDAPs with SIOS Type 4 were delivered without a cost breach. MDAPs with other SIOS types fell near or below 80% delivery without a cost breach. There is evidence to suggest that all SIOS types except SIOS Type 4 successfully delivered programs without a technical breach. Ten percent (10%) of MDAPs with SIOS Type 4 structures experienced a technical breach. Successful programs (without a baseline breach) last longer than programs with a baseline breach. Intuitively, this makes sense given that terminated MDAPs standout in

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program duration analysis as outliers below 10 years (i.e., cost breach and schedule breach), skewed distribution below the mean (i.e., technical performance breach and cost/schedule/technical performance breach), and/or a single data point (i.e., schedule/technical breach).

4.2.5 Discussion of Cluster Analysis Results

This section provides discussion of cluster analysis results and is broken into three major parts: *Cluster Validation*, *Results from Cluster Analysis of Successful MDAPs* and *Results from Cluster Analysis of Unsuccessful MDAPs.* Refer to Section 3 for discussion of the cluster analysis approach used.

4.2.5.1 Cluster Validation

Resulting dendrograms from cluster analysis of successful MDAPs and unsuccessful MAPs are depicted in Figure 4-1.

Validation of cluster analysis using Jain and Dubes' (1988) cophenetic correlation coefficient (CPCC) indicates that the dendrogram (clustering output) shown in Figure 4-1 perfectly represents the respective resemblance matrix (clustering input). The resulting CPCC equalled 1.0 on a scale of -1.0 to 1.0, where -1.0 indicates poor fit and 1.0 indicates perfect fit. Bottom-line, in this case, clustering output can be trusted to help catalogue similar attributes for successful and unsuccessful MDAP SIOS types.

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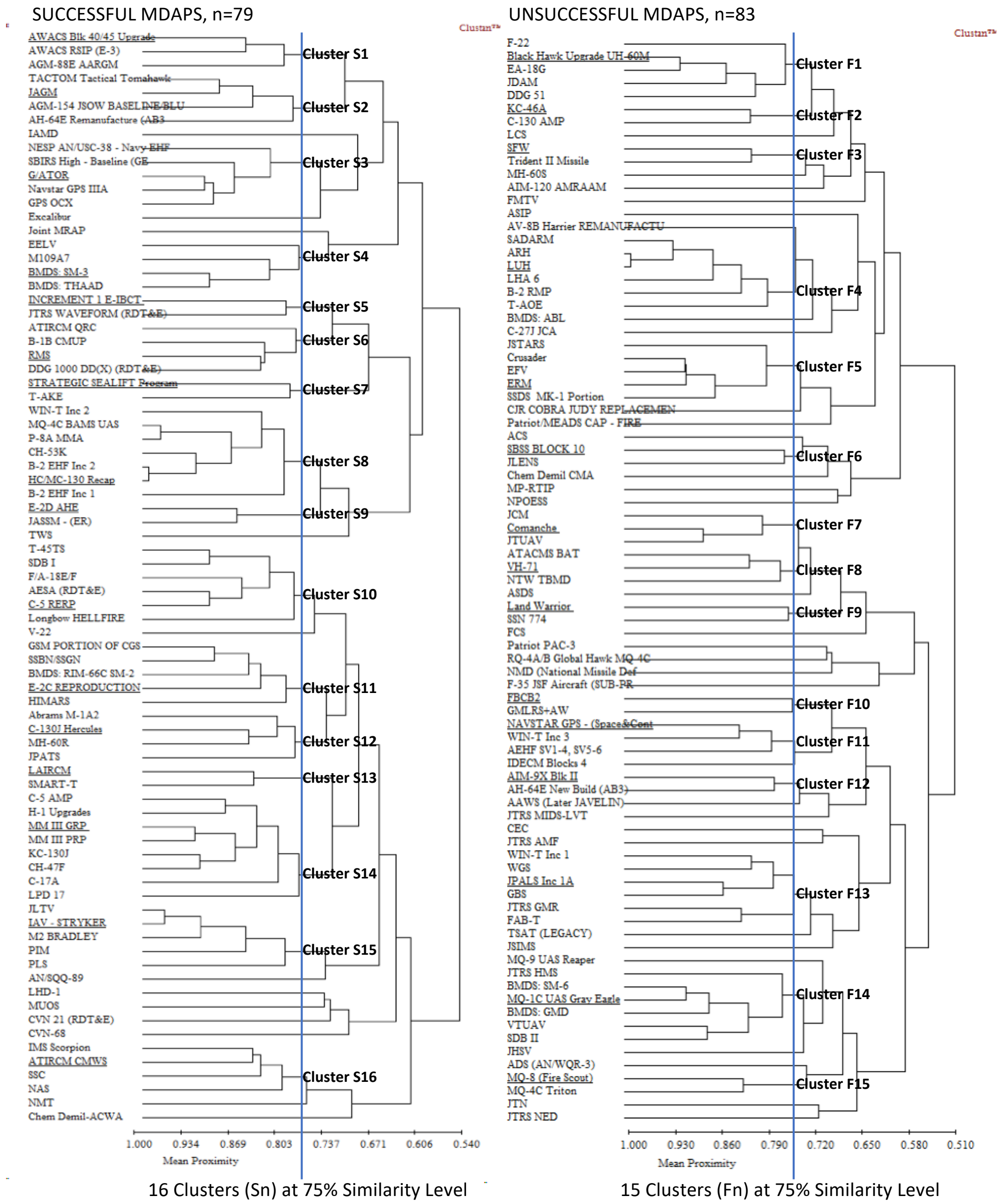

Figure 4-1: Cluster Analysis of Successful and Unsuccessful Major Defense Programs

4.2.5.2 Results from Cluster Analysis of Successful MDAPs

Can selected attributes be used to classify which SIOS type should be used for <u>successful</u> megaprojects? Yes. About half of MDAPs in the data set (i.e., 79 out of 162) successfully reached the Production and Deployment phase without an acquisition program baseline breach.

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Cluster analysis across 79 successful MDAPs (i.e., no acquisition baseline breach) revealed a dendrogram with 16 clusters at 75% level of similarity. Details of successful MDAPs located in clusters based on the similarity percentage are described in Table 4-10 using selected attributed and are summarized below in three major categories that characterize MDAP size and development duration.

Table 4-10: Successful MDAP attributes cluster characterization: 16 total clusters, 75% similarity level [S1-S5]

Successful MDAP Clusters, Sn	S_1	S_2	S_4	S_5
MDAP Count	3	4	4	2
SIOS Type, %				
SIOS 1	67	0	0	0
SIOS 2	0	25	0	100
SIOS 3	0	25	0	0
SIOS 4	33	50	100	0
SIOS 5	0	0	0	0
Duration, years				
Mean	31	32	25	14
St. Dev.	2	4	11	9
Min	28	29	11	8
Max	32	38	37	20
LCCE, $Million				
Mean	$ 1,924	$ 7,187	$ 23,957	$ 1,687
St. Dev.	$ 877	$ 4,892	$ 29,600	$ 590
Min	$ 1,005	$ 2,006	$ 4,308	$ 1,270
Max	$ 2,753	$ 13,760	$ 67,622	$ 2,104
Quantity, #Units				
Mean	661	4,463	585	2
St. Dev.	1,090	4,313	472	1
Min	31	639	163	1
Max	1,919	10,334	1,250	3
Program Location, %				
1-Industry	0	75	100	50
2-Government	0	0	0	50
3-Government/Industry	33	0	0	0
4-Gov./Industry (2>sites)	67	25	0	0
Resource Caps, %				
0-No evidence of caps	0	0	25	100
1-Cost cap	0	100	25	0
2-Schedule cap	100	0	0	0
3-Technology cap	0	0	0	0
4-Cost, Schedule	0	0	0	0
5-Cost, Schedule,&Tech	0	0	50	0

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Successful MDAP Clusters, Sn	S_1	S_2	S_4	S_5
6-Cost, Tech caps	0	0	0	0
7-Tech&Schedule caps	0	0	0	0
Acquisition Strategy, %				
1-Evolutionary	100	100	100	100
2-Planned Improvement	0	0	0	0
3-Single Step	0	0	0	0
Foreign Military Sales, %				
Yes	67	75	50	0
No	33	0	50	100
Novelty, %				
Yes	0	0	0	0
No	100	100	100	100
International Cooperative, %				
Yes	100	0	0	0
No	0	100	100	100
Jointness, %				
1-Primary Lead	100	75	100	100
2-Two Partners	0	25	0	0
3-Three Partners	0	0	0	0
4-Four Partners	0	0	0	0
Systems Hierarchy, %				
1-Component	0	0	100	100
2-System	0	0	0	0
3-System of Systems	0	25	0	0
4-Famliy of Systems	100	75	0	0
Product architecture, %				
1-Air/Missile	100	100	75	0
2-Sea	0	0	0	0
3-Chembionuclear	0	0	0	0
4-Land	0	0	25	50
5-Communication	0	0	0	50

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Table 4-10: Successful MDAP attributes cluster characterization: 16 total clusters, 75% similarity level [S6-S10]

Successful MDAP Clusters, Sn	S_6	S_7	S_8	S_9	S_{10}
MDAP Count	4	2	7	2	6
SIOS Type, %					
SIOS 1	0	0	0	0	0
SIOS 2	100	0	14	0	33
SIOS 3	0	50	0	0	0
SIOS 4	0	0	43	100	67
SIOS 5	0	50	43	0	0
Duration, years					
Mean	30	16	30	33	20
St. Dev.	10	18	7	6	15
Min	15	4	18	29	1
Max	39	29	36	38	41
LCCE, $Million					
Mean	$ 6,079	$ 6,507	$ 14,116	$ 12,408	$ 11,476
St. Dev.	$ 10,095	$ 6,155	$ 13,284	$ 11,381	$ 19,110
Min	$ 648	$ 498	$ 560	$ 4,360	$ 580
Max	$ 21,214	$ 6,860	$ 34,935	$ 20,456	$ 50,059
Quantity, #Units					
Mean	50	17	388	1,476	6,396
St. Dev.	34	4	782	1,981	10,011
Min	3	14	20	75	52
Max	83	20	2,156	2,877	24,070
Program Location, %					
1-Industry	0	0	0	0	100
2-Government	100	0	0	0	0
3-Government/Industry	0	0	100	100	0
4-Gov./Industry (2>sites)	0	100	0	0	0
Resource Caps, %					
0-No evidence of caps	50	100	14	0	83
1-Cost cap	50	0	0	50	17
2-Schedule cap	0	0	86	50	0
3-Technology cap	0	0	0	0	0
4-Cost, Schedule	0	0	0	0	0
5-Cost, Schedule,&Tech	0	0	0	0	0
6-Cost, Technology caps	0	0	0	0	0
7-Tech&Schedule caps	0	0	0	0	0
Acquisition Strategy, %					
1-Evolutionary	100	100	100	0	0
2-Planned Improvement	0	0	0	100	100

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Successful MDAP Clusters, Sn	S_6	S_7	S_8	S_9	S_{10}
3-Single Step	0	0	0	0	0
Foreign Military Sales,%					
Yes	25	0	0	0	33
No	75	100	100	100	67
Novelty, %					
Yes	0	0	0	100	100
No	100	100	100	0	0
International Cooperative, %					
Yes	0	0	0	0	0
No	100	100	100	100	100
Jointness, %					
1-Primary Lead	100	100	100	50	100
2-Two Partners	0	0	0	50	0
3-Three Partners	0	0	0	0	0
4-Four Partners	0	0	0	0	0
Systems Hierarchy, %					
1-Component	0	50	0	0	0
2-System	0	0	29	0	33
3-System of Systems	0	0	0	0	0
4-Famliy of Systems	100	50	71	100	67
Product Architecture,%					
1-Air/Missile	25	0	71	100	83
2-Sea	50	100	0	0	0
3-Chembionuclear	0	0	0	0	0
4-Land	0	0	0	0	0
5-Communication	25	0	29	0	17

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Table 4-10: Successful MDAP attributes cluster characterization: 16 total clusters, 75% similarity level [S11-S15]

Successful MDAP Clusters, Sn	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}
MDAP Count	5	4	2	8	5
SIOS Type, %					
SIOS 1	0	0	0	0	0
SIOS 2	100	100	0	0	0
SIOS 3	0	0	100	0	0
SIOS 4	0	0	0	0	80
SIOS 5	0	0	0	100	20
Duration, years					
Mean	19	26	15	33	27
St. Dev.	10	9	8	12	4
Min	6	16	9	11	22
Max	33	36	20	46	32
LCCE, $Million					
Mean	$ 2,430	$ 10,524	$ 692	$ 16,529	$ 13,245
St. Dev.	$ 1,714	$ 4,779	$ 394	$ 22,371	$ 11,332
Min	$ 797	$ 5,301	$ 413	$ 1,148	$ 1,237
Max	$ 4,358	$ 15,539	$ 971	$ 69,571	$ 31,108
Quantity, #Units					
Mean	137	584	143	308	13,055
St. Dev.	148	454	191	265	23,340
Min	4	168	8	10	582
Max	381	1,155	278	652	54,730
Program Location, %					
1-Industry	0	75	0	12.5	20
2-Government	100	25	50	25	80
3-Govt./Industry	0	0	0	0	0
4-Govt./Ind.(2>sites)	0	0	50	62.5	0
Resource Caps, %					
0-No evidence of caps	80	25	0	75	20
1-Cost cap	20	25	0	25	60
2-Schedule cap	0	0	0	0	0
3-Technology cap	0	25	0	0	0
4-Cost, Schedule	0	0	0	0	20
5-Cost, Sched,&Tech.	0	0	0	0	0
6-Cost, Tech. caps	0	25	0	0	0
7-Tech&Sched. caps	0	0	0	0	0
Acquisition Strategy, %					
1-Evolutionary	0	0	0	0	0
2-Planned Improvement	60	75	100	80	100
3-Single Step	40	25	0	20	0
Foreign Military Sales,					
Yes	20	100	100	37.5	20
No	80	0	0	62.5	80
Novelty, %					
Yes	100	100	100	100	100

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Successful MDAP Clusters, Sn	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}
No	0	0	0	0	0
International Cooperative, %					
Yes	0	0	0	20	0
No	100	100	100	80	100
Jointness, %					
1-Primary Lead	100	67	100	100	100
2-Two Partners	0	33	0	0	0
3-Three Partners	0	0	0	0	0
4-Four Partners	0	0	0	0	0
Systems Hierarchy, %					
1-Component	20	0	0	0	75
2-System	20	0	0	0	0
3-System of Systems	0	0	50	0	0
4-Famliy of Systems	60	100	50	100	25
Product Architecture, %					
1-Air/Missile	60	75	0	87.5	0
2-Sea	20	0	0	12.5	0
3-Chembionuclear	0	0	0	0	0
4-Land	20	25	0	0	100
5-Communication	0	0	100	0	0

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Table 4-10: Successful MDAP attributes cluster characterization: 16 total clusters, 75% similarity level [S16]

Successful MDAP Clusters, Sn		S_{16}
MDAP Count		4
SIOS Type, %		
SIOS 1		0
SIOS 2		0
SIOS 3		0
SIOS 4		100
SIOS 5		0
Duration, years		
Mean		17
St. Dev.		9
Min		5
Max		26
LCCE, $Million		
Mean	$	2,876
St. Dev.	$	1,588
Min	$	1,447
Max	$	4,765
Quantity, #Units		
Mean		1,201
St. Dev.		1,317
Min		73
Max		2,624
Program Location, %		
1-Industry		100
2-Government		0
3-Government/Industry		0
4-Gov./Industry (2>sites)		0
Resource Caps, %		
0-No evidence of caps		0
1-Cost cap		75
2-Schedule cap		0
3-Technology cap		25
4-Cost, Schedule		0
5-Cost, Schedule ,&Tech.		0
6-Cost, Technology caps		0
7-Tech&Schedule caps		0
Acquisition Strategy%		
1-Evolutionary		0
2-Planned Improvement		0
3-Single Step		100
Foreign Military Sales, %		
Yes		25
No		75
Novelty, %		
Yes		100
No		0

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Successful MDAP Clusters, Sn	S_{16}
International Cooperative, %	
Yes	25
No	75
Jointness, %	
1-Primary Lead	80
2-Two Partners	0
3-Three Partners	0
4-Four Partners	20
Systems Hierarchy, %	
1-Component	0
2-System	0
3-System of Systems	0
4-Famliy of Systems	100
Product Architecture, %	
1-Air/Missile	0
2-Sea	25
3-Chembionuclear	0
4-Land	0
5-Communication	75

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- ***Small, Rapid MDAP***. Clusters S5, S7, S11, S13, and S16 contain MDAPs that are small by comparison (<$3 billion LCCE) to the rest of the dataset, developed in less than 20years, and less than 150 units produced over the life of the project. There is no dominant SIOS type for this group of clusters. Both clusters S5 and S11 contain SOIS 2; S13 contains SIOS 3; and S16 contains SIOS 4. Cluster S7 contains both SIOS 3 and SIOS 5. The primary acquisition approach employed in clusters S5 and S7 is evolutionary acquisition; S11 and S13 contain planned improvement; and, S16 includes single step acquisition. All product architectures are included except chem/bio/nuclear systems. Cluster S5 includes ground and communications systems; S7 includes sea systems; S11 includes air/missile, sea, and ground; and, both S13 and S16 contains communications systems.
- ***Moderate Sized, Moderate Development Duration MDAP***. Clusters S3, S4, S10, S12, and S15 contain MDAPs that are moderate in size and speed by comparison to MDAPs in the rest of the dataset ($3.0-$10.0 billion LCCE, 20-29 years) with 150 - 1,200 units produced over the life of the project. SIOS 4 is the dominant SIOS type for this group of clusters. Clusters S3, S4, S10, and S15 contain SOIS 4 while S12 contains SIOS 2. The primary acquisition approach employed in S3 and S4 is evolutionary acquisition, clusters S10 and S12 contain planned improvement; and S15 includes single step acquisition. All product architectures are included except chem/bio/nuclear and sea. Cluster S3 includes communication systems; clusters S4, S10, and S12 contain air/missile systems; and S15 is ground systems.
- ***Large, Slow MDAP.*** Clusters S1, S2, S6, S8, and S14 contain MDAPs that are large and fast ($11.0> billion LCCE, 20-29> years) with 1,200> units produced over the

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life of the project. There is no dominant SIOS type for this group of clusters. Cluster S1 contains SIOS 1 and SIOS 4; cluster S2 includes SIOS 2, 3, and 4; cluster S6 contains SOIS 2, S8 contains SIOS 2, 4, and 5; and, S14 contains SIOS 5, exclusively. The primary acquisition approach employed in S1, S2, S6, and S8 includes evolutionary acquisition strategy; and, S14 includes planned improvement acquisition strategy. All product architectures are included except chem/bio/nuclear. Both S1 and S2 include air/missile; S6 includes air/missile, ground, and communications; S8 includes air and communication systems; and, S14 contains air/missile and sea.

Interestingly, 62% of clusters for successful MDAPs included a single SIOS type. Cluster S1 included programs with SIOS Type 1 structures; Clusters S5, S6, S11, and S12 were composed of MDAPs having only SIOS Type 2 structures; Cluster S13 included MDAPs with SIOS Type 3 structures; Clusters S3, S4, S9, and S16 were composed of MDAPs with SIOS Type 4 structures; and Cluster S14 included MDAPs with SIOS Type 5 structures.

Each individual cluster of successful MDAPs is presented in subsequent paragraphs. The individual summaries will include assessment of similar factors, detailed examples of project implementation of best practices and issues associated with the project management/systems integration implementation, and a summary of key findings.

Cluster S1 Analysis Summary: Table 4-11 identifies the MDAPs included in cluster S1. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

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Table 4-11: Cluster S1 MDAP Summary

Cluster	MDAPs in Cluster
S1	AGM-88E AARGM
S1	AWACS Block 40/45 Upgrade
S1	AWACS RSIP (E-3)

As shown in Table 4-12, Cluster S1 contains a combination of SIOS Type 1 and SIOS Type 4 structures. Cluster S1 includes MDAPs with LCCE ranging between $1,005 - $2,753 million and product quantity between 31 - 1,919 units over the life of the program. Similar, the MDAPs included in Cluster S1 were constrained by schedule urgency. Other similar factors included development duration range of 28 - 32 years; development of air/missile systems using conventional technology at multiple government and industry sites; international partners and foreign military sales; evolutionary acquisition strategy; and family of systems hierarchy.

Table 4-12: Cluster S1 Analysis Summary, n=3

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	31 years +/- 2 years
3. Foreign Military Sales	Yes
4. International Cooperative	Yes
5. Jointness	One (1) Organization
6. LCCE	$1,924 million +/- $877 million
7. Novelty	No
8. Product Architecture	Air/Missile
9. Program Location	Government/Industry (2> sites)
10. Product Quantity	661 +/- 1,090

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Variable	Measure of Effectiveness
11. Available Resources	Schedule constraint
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 1 and SIOS Type 4
14. Performance	Successful – No APB Breach

Cluster S2 Analysis Summary: Table 4-13 identifies the MDAPs included in cluster S2. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-13: Cluster S2 MDAP Summary

Cluster	MDAPs in Cluster
S2	AGM-154 JSOW BASELINE/BLU-108 + Unitary
S2	AH-64E Remanufacture (AB3)
S2	JAGM
S2	TACTOM Tactical Tomahawk

As shown in Table 4-14, dissimilar factors include SIOS Type and MDAP size. Cluster S2 contains a combination of SIOS Type 2, SIOS Type 3, and SIOS Type 4 structures. MDAP LCCE ranged between $2,006 - $13,760 million and product quantity ranged between 639 - 10,334 units over the life of the program. Similar, the MDAPs included in Cluster S2 were constrained by cost limitations. Other similar factors included development duration range of 29 - 38 years; development of air/missile systems using conventional technology at a primary industry site; foreign military sales; evolutionary acquisition; and family of systems hierarchy.

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Table 4-14: Cluster S2 Analysis Summary, n=4

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	32 years +/- 4 years
3. Foreign Military Sales	Yes
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$7,187 million +/- $4,892 million
7. Novelty	No
8. Product Architecture	Air/Missile
9. Program Location	Industry
10. Product Quantity	4,463 +/- 4,313
11. Available Resources	Cost constraint
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 2, SIOS Type 3, and SIOS Type 4
14. Performance	Successful – No APB Breach

Cluster S3 Analysis Summary: Table 4-15 identifies the MDAPs included in cluster S3. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-15: Cluster S3 MDAP Summary

Cluster	MDAPs in Cluster
S3	G/ATOR
S3	GPS OCX
S3	Navstar GPS IIIA
S3	NESP AN/USC-38 - Navy EHF SATCOM (NESP)

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Cluster	MDAPs in Cluster
S3	SBIRS High - Baseline (GEO 1-4, HEO 1-2, and Ground) GEO 5-6

As shown in Table 4-16, dissimilar factors include MDAP LCCE which range between $2,058 - $13,572 million and product quantity ranging between 1 - 507 units over the life of the program. Similar, the MDAPs included in Cluster S3 have SIOS Type 4 structures and were not constrained by resource caps. Other similar factors included development duration range of 19 - 25 years; development of communication systems using conventional technology at a primary industry site; no international partners or foreign military sales; evolutionary acquisition strategy; and, family of systems hierarchy.

Table 4-16: Cluster S3 Analysis Summary, n=5

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	22 years +/- 2 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$5,141 million +/- $4791 million
7. Novelty	No
8. Product Architecture	Communication
9. Program Location	Industry
10. Product Quantity	113 +/- 221
11. Available Resources	No resource constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 4

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Variable	Measure of Effectiveness
14. Performance	Successful – No APB Breach

Cluster S4 Analysis Summary: Table 4-17 identifies the MDAPs included in cluster S4. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-17: Cluster S4 MDAP Summary

Cluster	MDAPs in Cluster
S4	BMDS: SM-3
S4	BMDS: THAAD
S4	EELV
S4	M109A7

As shown in Table 4-18, dissimilar factors include MDAP LCCE which range between $4,308 - $67,622 million; product quantity ranged between 163 – 1,250 units over the life of the program; and, development duration ranged between 11 - 37 years. Similar, the MDAPs included in Cluster S4 have SIOS Type 4 structures and were simultaneously constrained by cost, schedule, and technology limitations. Other similar factors include development of air/missile components using conventional technology at a primary industry site; evolutionary acquisition; and, foreign military sales.

Table 4-18: Cluster S4 Analysis Summary, n=4

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	25 years +/- 11 years
3. Foreign Military Sales	Yes
4. International Cooperative	No
5. Jointness	One (1) Organization

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Variable	Measure of Effectiveness
6. LCCE	$23,957 million +/- 29,600 million
7. Novelty	No
8. Product Architecture	Air/Missile
9. Program Location	Industry
10. Product Quantity	585 +/- 472
11. Available Resources	Cost, Schedule, and Technology constraint
12. Systems Hierarchy	Component
13. SIOS Type	SIOS Type 4
14. Performance	Successful – No APB Breach

Cluster S18 Analysis Summary: Table 4-19 identifies the MDAPs included in cluster S5. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-19: Cluster S5 MDAP Summary

Cluster	MDAPs in Cluster
S5	INCREMENT 1 E-IBCT
S5	JTRS WAVEFORM (RDT&E)

As shown in Table 4-20, dissimilar factors include MDAP duration, product architecture, and program location. Development duration ranged between 8 - 20 years. Similar, the MDAPs included in Cluster S5 have SIOS Type 2 structures and were not constrained by resource caps. Other similar factors include component level hierarchy, conventional technology, evolutionary acquisition, LCCE, and product quantity. MDAP LCCE ranged between $1,270 - $2,104 million and quantity ranged between 1 - 3 units over the life of the program.

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Table 4-20: Cluster S5 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	14 years +/- 9 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$1,687 million +/- $590 million
7. Novelty	No
8. Product Architecture	50% Communication; 50% Land
9. Program Location	50% Industry; 50% Government
10. Product Quantity	2 +/- 1
11. Available Resources	No resource constraints
12. Systems Hierarchy	Component
13. SIOS Type	SIOS Type 2
14. Performance	Successful – No APB Breach

Cluster S6 Analysis Summary: Table 4-21 identifies the MDAPs included in cluster S6. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-21: Cluster S6 MDAP Summary

Cluster	MDAPs in Cluster
S6	ATIRCM QRC
S6	B-1B CMUP
S6	DDG 1000 DD(X) (RDT&E)
S6	RMS

As shown in Table 4-22, dissimilar factors include MDAP duration, LCCE, and quantity. Development duration ranged between 15 - 39 years. MDAP LCCE ranged

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between $648 - $21,214 million and quantity ranged between 3 - 83 units over the life of the program. Similar, the MDAPs included in Cluster S6 have SIOS Type 2 structures and were constrained by cost limitations. Other similar factors include family of sea systems, conventional technology, evolutionary acquisition, and Government site.

Table 4-22: Cluster S6 Analysis Summary, n=4

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	30 years +/- 10 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$6,079 million +/- $10,095 million
7. Novelty	No
8. Product Architecture	Sea
9. Program Location	Government
10. Product Quantity	50 +/- 34
11. Available Resources	Cost constraint
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 2
14. Performance	Successful – No APB Breach

Cluster S7 Analysis Summary: Table 4-23 identifies the MDAPs included in cluster S7. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4- 23: Cluster S7 MDAP Summary

Cluster	MDAPs in Cluster
S7	STRATEGIC SEALIFT Program SSP

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Cluster	MDAPs in Cluster
S7	T-AKE

As shown in Table 4-24, dissimilar factors include SIOS type, MDAP duration, and LCCE. Cluster S7 contains a combination of SIOS Type 3 and SIOS Type 5 structures. Development duration ranged between 4 - 29 years. MDAP LCCE ranged between $498 - $6,860 million. Similar, the MDAPs included in Cluster S7 were constrained by cost limitations. Other similar factors include family of systems hierarchy, conventional technology, evolutionary acquisition, location, and quantity. Product quantity ranged between 14 - 20 units over the life of the program.

Table 4-24: Cluster S7 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	16 years +/- 18 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$6,507 million +/- $6,155 million
7. Novelty	No
8. Product Architecture	Sea
9. Program Location	Government/Industry (2> sites)
10. Product Quantity	17 +/- 4
11. Available Resources	No constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 3 and SIOS Type 5
14. Performance	Successful – No APB Breach

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Cluster S8 Analysis Summary: Table 4-25 identifies the MDAPs included in cluster S8. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-25: Cluster S8 MDAP Summary

Cluster	MDAPs in Cluster
S8	B-2 EHF Inc 1
S8	B-2 EHF Inc 2
S8	CH-53K
S8	HC/MC-130 Recap
S8	MQ-4C BAMS UAS
S8	P-8A MMA
S8	WIN-T Inc 2

As shown in Table 4-26, dissimilar factors include SIOS type, MDAP duration, quantity, and LCCE. Cluster S8 contains a combination of SIOS Type 2, SIOS Type 3 and SIOS Type 4 structures. Development duration ranged between 18 - 36 years. MDAP LCCE ranged between $560 - $34,935 million. Product quantity ranged between 20 – 2,156 units over the life of the program. Similar, the MDAPs included in Cluster S8 were constrained by schedule urgency. Other similar factors include family of air/missile systems, conventional technology, evolutionary acquisition, and combined Government/Industry location.

Table 4-26: Cluster S8 Analysis Summary, n=7

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	30 years +/- 7 years
3. Foreign Military Sales	No

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Variable	Measure of Effectiveness
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$14,116 million +/- $13,284 million
7. Novelty	No
8. Product Architecture	Air/Missile
9. Program Location	Government/Industry
10. Product Quantity	388 +/- 782
11. Available Resources	Schedule constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 2, 4, and 5
14. Performance	Successful – No APB Breach

Cluster S9 Analysis Summary: Table 4-27 identifies the MDAPs included in cluster S9. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-27: Cluster S9 MDAP Summary

Cluster	MDAPs in Cluster
S9	E-2D AHE
S9	JASSM - (ER)

As shown in Table 4-28, dissimilar factors include SIOS type, MDAP duration, quantity, and LCCE. Cluster S9 contains a combination of SIOS Type 2, SIOS Type 3 and SIOS Type 4 structures. Development duration ranged between 29 - 38 years. MDAP LCCE ranged between $4,360 - $20,456 million. Product quantity ranged between 75 – 2,877 units over the life of the program. Similar, the MDAPs included in Cluster S9 have SIOS Type 4 structures and are simultaneously constrained by both schedule urgency and

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cost limitations. Other similar factors include family of air/missile systems, conventional technology, evolutionary acquisition, and combined Government/Industry location.

Table 4-28: Cluster S9 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	33 years +/- 6 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$12,408 million +/- $11,381 million
7. Novelty	Yes
8. Product Architecture	Air/Missile
9. Program Location	Government/Industry
10. Product Quantity	1,476 +/- 1,981
11. Available Resources	Schedule and Cost Constraint
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 4
14. Performance	Successful – No APB Breach

Cluster S10 Analysis Summary: Table 4-29 identifies the MDAPs included in cluster S10. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-29: Cluster S10 MDAP Summary

Cluster	MDAPs in Cluster
S10	AESA (RDT&E)
S10	C-5 RERP
S10	F/A-18E/F
S10	Longbow HELLFIRE

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Cluster	MDAPs in Cluster
S10	SDB I
S10	T-45TS

As shown in Table 4-30, dissimilar factors include SIOS type, MDAP duration, quantity, and LCCE. Cluster S10 contains a combination of SIOS Type and SIOS Type 4 structures. Development duration ranged between 1 - 41 years. MDAP LCCE ranged between $580 - $50,059 million. Product quantity ranged between 52 - 24,070 units over the life of the program. Similar, the MDAPs included in Cluster S10 were not constrained by resource caps. Other similar factors include family of air/missile systems, novel technology, planned improvement acquisition strategy, and located at one primary industry site.

Table 4-30: Cluster S10 Analysis Summary, n=6

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	20 years +/- 15 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$11,476 million +/- $19,110 million
7. Novelty	Yes
8. Product Architecture	Air/Missile
9. Program Location	Industry
10. Product Quantity	6,396 +/- 10,011
11. Available Resources	No resource constraints
12. Systems Hierarchy	Family of Systems

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Variable	Measure of Effectiveness
13. SIOS Type	SIOS Type 2 and SIOS Type 4
14. Performance	Successful – No APB Breach

Cluster S11 Analysis Summary: Table 4-31 identifies the MDAPs included in cluster S11. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-31: Cluster S11 MDAP Summary

Cluster	MDAPs in Cluster
S11	BMDS: RIM-66C SM-2
S11	E-2C REPRODUCTION
S11	GSM PORTION OF CGS
S11	HIMARS
S11	SSBN/SSGN

As shown in Table 4-32, dissimilar factors include MDAP duration, quantity, and LCCE. Development duration ranged between 6 - 33 years. MDAP LCCE ranged between $797 - $4,358 million. Product quantity ranged between 4 - 381 units over the life of the program. Similar, the MDAPs included in Cluster S11 have SIOS Type 2 structure and are not constrained by resource caps. Other similar factors include family of air/missile systems, novel technology, planned improvement acquisition strategy, and located at one primary government site.

Table 4-32: Cluster S11 Analysis Summary, n=5

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	19 years +/- 10 years
3. Foreign Military Sales	No

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Variable	Measure of Effectiveness
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$2,340 million +/- $1,714 million
7. Novelty	Yes
8. Product Architecture	Air/Missile
9. Program Location	Government
10. Product Quantity	137 +/- 148
11. Available Resources	No constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 2
14. Performance	Successful – No APB Breach

Cluster S12 Analysis Summary: Table 4-33 identifies the MDAPs included in cluster S12. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-33: Cluster S12 MDAP Summary

Cluster	MDAPs in Cluster
S12	Abrams M-1A2
S12	C-130J Hercules
S12	JPATS
S12	MH-60R

As shown in Table 4-34, dissimilar factors include MDAP duration, quantity, and LCCE. Development duration ranged between 16 - 36 years. MDAP LCCE ranged between $5,301 - $15,539 million. Product quantity ranged between 168 - 1,155 units over the life of the program. Similar, the MDAPs included in Cluster S12 have SIOS Type 2 structures and are simultaneously constrained by both cost and technology

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limitations. Other similar factors include family of air/missile systems, novel technology, planned improvement acquisition strategy, and located at one primary industry site.

Table 4-34: Cluster S12 Analysis Summary, n=4

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	29 years +/- 6 years
3. Foreign Military Sales	Yes
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$10,524 million +/- $4,779 million
7. Novelty	Yes
8. Product Architecture	Air/Missile
9. Program Location	Industry
10. Product Quantity	584 +/- 454
11. Available Resources	Cost and Technology Constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 2
14. Performance	Successful – No APB Breach

Cluster S13 Analysis Summary: Table 4-35 identifies the MDAPs included in cluster S13. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-35: Cluster S13 MDAP Summary

Cluster	MDAPs in Cluster
S13	LAIRCM
S13	SMART-T

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As shown in Table 4-36, dissimilar factors include MDAP duration, quantity, and LCCE. Development duration ranged between 9 - 20 years. MDAP LCCE ranged between $413 - $971 million. Product quantity ranged between 8 - 278 units over the life of the program. Similar, the MDAPs included in Cluster S13 have SIOS Type 3 structures and are not constrained by resource caps. Other similar factors include family of communication systems, novel technology, planned improvement acquisition strategy, and located at multiple government and industry sites.

Table 4-36: Cluster S13 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	15 years +/- 8 years
3. Foreign Military Sales	Yes
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$692 million +/- $394 million
7. Novelty	Yes
8. Product Architecture	Communication
9. Program Location	Government/Industry (2> sites)
10. Product Quantity	143 +/- 191
11. Available Resources	No resource constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 3
14. Performance	Successful – No APB Breach

Cluster S14 Analysis Summary: Table 4-37 identifies the MDAPs included in cluster S14. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

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Table 4-37: Cluster S14 MDAP Summary

Cluster	MDAPs in Cluster
S14	C-17A
S14	C-5 AMP
S14	CH-47F
S14	H-1 Upgrades
S14	KC-130J
S14	LPD 17
S14	MM III GRP
S14	MM III PRP

As shown in Table 4-38, dissimilar factors include MDAP duration, quantity, and LCCE. Development duration ranged between 11 - 46 years. MDAP LCCE ranged between $1,148 - $69,571 million. Product quantity ranged between 10 - 652 units over the life of the program. Similar, the MDAPs included in Cluster S14 have SIOS Type 5 structures and are not constrained by resource caps. Other similar factors include family of air/missile systems, novel technology, planned improvement acquisition strategy, and located at multiple government and industry sites.

Table 4-38: Cluster S14 Analysis Summary, n=8

Variable		Measure of Effectiveness
1.	Acquisition Strategy	Planned Improvement
2.	Duration	33 years +/- 12 years
3.	Foreign Military Sales	No
4.	International Cooperative	No
5.	Jointness	One (1) Organization
6.	LCCE	$16,529 million +/- $22,371 million

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Variable	Measure of Effectiveness
7. Novelty	Yes
8. Product Architecture	Air/Missile
9. Program Location	Government/Industry (2> sites)
10. Product Quantity	308 +/- 265
11. Available Resources	No resource constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 5
14. Performance	Successful – No APB Breach

Cluster S15 Analysis Summary: Table 4-39 identifies the MDAPs included in cluster S15. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-39: Cluster S15 MDAP Summary

Cluster	MDAPs in Cluster
S15	IAV - STRYKER
S15	JLTV
S15	M2 BRADLEY
S15	PIM
S15	PLS

As shown in Table 4-40, dissimilar factors include SIOS Type, MDAP duration, quantity, and LCCE. Cluster S15 contains a combination of SIOS Type 4 and SIOS Type 5 structures. Development duration ranged between 11 - 46 years. MDAP LCCE ranged between $1,148 - $69,571 million. Product quantity ranged between 10 - 652 units over the life of the program. Similar, the MDAPs included in Cluster S15 are constrained by cost limitations. Other similar factors include component level hierarchy, land-based

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product architecture, novel technology, planned improvement acquisition strategy, and located at one primary government site.

Table 4-40: Cluster S15 Analysis Summary, n=5

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	27 years +/- 4 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$13,245 million +/- $11,332 million
7. Novelty	Yes
8. Product Architecture	Land
9. Program Location	Government
10. Product Quantity	13,055 +/- 23,340
11. Available Resources	Cost constraint
12. Systems Hierarchy	Component
13. SIOS Type	SIOS Type 4 and SIOS Type 5
14. Performance	Successful – No APB Breach

Cluster S16 Analysis Summary: Table 4-41 identifies the MDAPs included in cluster S16. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-41: Cluster 16 MDAP Summary

Cluster	MDAPs in Cluster
S16	IMS Scorpion
S16	ATIRCM CMWS
S16	SSC
S16	NAS

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As shown in Table 4-42, dissimilar factors include MDAP duration, quantity, and LCCE. Development duration ranged between 5 - 26 years. MDAP LCCE ranged between $1,447 - $4,765 million. Product quantity ranged between 73 - 2,624 units over the life of the program. Similar, the MDAPs included in Cluster S16 have SIOS Type 4 structures and are constrained by cost limitations. Other similar factors include family of communication systems, novel technology, planned improvement acquisition strategy, and located at one primary industry site.

Table 4-42: Cluster S16 Analysis Summary, n=4

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	17 years +/- 9 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Organization
6. LCCE	$2,876 million +/- $1,588 million
7. Novelty	Yes
8. Product Architecture	Communication
9. Program Location	Industry
10. Product Quantity	1,201 +/- 1,317
11. Available Resources	Cost constraint
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 4
14. Performance	Successful – No APB Breach

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Single Branch Analysis Summary: Table 4-43 identifies successful MDAPs that did not join a cluster at the 0.75 similarity level. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-43: Single Branches MDAP Summary

Single Branches	MDAP
between cluster S2 and cluster S3	IAMD
between cluster S3 and cluster S4	Excalibur
between cluster S3 and cluster S4	Joint MRAP
between cluster S9 and cluster S10	TWS
between cluster S10 and cluster S11	V-22
between cluster S15 and cluster S16	AN/SQQ-89
between cluster S15 and cluster S16	LHD-1
between cluster S15 and cluster S16	MUOS
between cluster S15 and cluster S16	CVN 21 (RDT&E)
between cluster S15 and cluster S16	CVN-68
following Cluster S16	Chem Demil-ACWA
following Cluster S16	NMT

Per the dendrogram in Figure 4-1, as similarity decreases MDAPs which standout as single branches will merge into the cluster with closest proximity. For example, if similarity were reduced to 0.68, then IAMD would join cluster S3. If similarity were reduced to 0.72, then Joint MRAP would join cluster S4 and Excalibur would join cluster S3. MRAP is notably a singular success story across literature and is widely analyzed and referenced in the defense acquisition community as the model MDAP. However, it is not considered a realistic benchmark MRAP given that the program appeared to have high priority and unconstrained resources. If similarity were reduced to 0.69, then TWS

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would join cluster S9. If similarity were reduced to 0.74, then V-22 cluster S10. If similarity were reduced to 0.73, then AN/SQQ-89 would join cluster S15. If similarity were reduced to 0.73, then AN/SQQ-89 would join cluster S15. If similarity were reduced to 0.73, then LHD-1, MUOS, and CVN 21 (RDT&E) would form their own cluster with CVN-68 joining this new cluster if similarity is further reduced to 0.69. If similarity were reduced to 0.74, then NMT would join cluster S16. Chem Demil-ACWA would join cluster S16 if similarity were further reduced to 0.69.

4.2.5.3 Results from Cluster Analysis of Unsuccessful MDAPs

Can these attributes be used to classify which SIOS type should be avoided to preempt unsuccessful outcome? Yes. The other half of the MDAPs experienced cost, schedule, and/or technical performance baseline breaches. SIOS Type 1, SIOS Type 2, and SIOS Type 3 programs were more likely to have a program baseline breach (e.g., 60% of SIOS Type 1, 55% SIOS Type 2, and 52% SIOS Type 3 programs had a program breach). SIOS Type 4 and SIOS Type 5 programs were less likely to have a program baseline breach (e.g., 49% SIOS Type 4 and 48% SIOS Type 5 programs had a baseline breach).

Cluster analysis was also conducted for the set of unsuccessful MDAPs (i.e., programs experiencing an acquisition baseline breach). Cluster analysis across 83 unsuccessful MDAPs revealed 15 clusters at 75% level of similarity. Validation of cluster analysis with CPCC=1.0 indicates that the clustering output (shown in Figure 4-1) can be

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trusted to help catalogue similar attributes for unsuccessful MDAPs. Table 4-43 catalogues cluster characterization for quantitative and qualitative attributes, respectively.

Over sixty-seven percent (67%) of clusters for unsuccessful MDAPs included a single SIOS type. Clusters F2, F12, F14, and F15 included programs with SIOS Type 4 structures; Clusters F3, F6, F7, F10, and F11 were composed of MDAPs having only SIOS Type 2 structures; Cluster F9 included MDAPs with SIOS Type 3 structures. Note that SIOS Type 1 structure was not found in unsuccessful MDAP clusters (at 75% similarity).

Theoretically, MDAP attributes can be mapped to a given cluster as a starting point to determine the most likely SIOS type for success. In addition, there are also SIOS types to completely avoid for certain combinations of MDAP attributes. Knowing areas to avoid will certainly reduce the number of iterations in the path toward selecting the ideal SIOS type. Some caution is placed on using these findings as an indicator of MDAP SIOS type selection given that some Selected Acquisition Report data represented re-baselined schedules (DoD, 1995-2015).

Each individual cluster of unsuccessful (i.e., failed) MDAPs is presented in subsequent paragraphs. The individual summaries will include assessment of similar factors, detailed examples of project implementation of best practices and issues associated with the project management/systems integration implementation, and a summary of key findings.

Cluster F1 Analysis Summary: Table 4-44 identifies the MDAPs included in cluster F1. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

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Table 4-44: Cluster F1 MDAP Summary

Cluster	MDAPs in Cluster
F1	Black Hawk Upgrade UH-60M
F1	DDG 51
F1	EA-18G
F1	F-22
F1	JDAM

As shown in Table 4-45, dissimilar factors include SIOS type, MDAP duration, quantity, and LCCE. Cluster F1 contains a combination of SIOS Type 1, 2, 3, and 4 structures. Development duration ranged between 24 - 30 years. MDAP LCCE ranged between $6,442 - $91,234 million. Product quantity ranged between 77 – 241,890 units over the life of the program. Similar factors include family of systems, novel technology, and planned improvement acquisition.

Table 4-45: Cluster F1 Analysis Summary, n=5

Variable		Measure of Effectiveness
1.	Acquisition Strategy	Planned Improvement
2.	Duration	27 +/- 2 years
3.	Foreign Military Sales	80% Yes, 20% No
4.	International Cooperative	No
5.	Jointness	One (1) Military Service
6.	LCCE	$41,392 million +/- $32,672 million
7.	Novelty	Yes
8.	Product Architecture	80% Air/Missile
		20% Sea
9.	Program Location	80% Industry

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Variable	Measure of Effectiveness
	20% Multiple Industry and Government sites
10. Product Quantity	48,733 +/- 96,580
11. Available Resources	60% No evidence of constraints
	40% Cost constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	20% SIOS Type 1
	40% SIOS Type 2
	20% SIOS Type 3
	20% SIOS Type 4
14. Performance	Cost Breach

Cluster F2 Analysis Summary: Table 4-46 identifies the MDAPs included in cluster F2. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-46: Cluster F2 MDAP Summary

Cluster	MDAPs in Cluster
F2	C-130 AMP
F2	KC-46A

As shown in Table 4-47, dissimilar factors include MDAP duration, quantity, and LCCE. Development duration ranged between 11 - 27 years. MDAP LCCE ranged between $2,200 - $49,461 million. Product quantity ranged between 9 – 179 units over the life of the program. Similar factors include family of air/missile systems, novel technology, and planned improvement acquisition. The MDAPs included in Cluster F2 were SIOS Type 4 structures and were simultaneously constrained by both schedule urgency and technology limitations.

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Table 4-47: Cluster F2 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	19 years +/- 8 years
3. Foreign Military Sales	50% Yes, 50% No
4. International Cooperative	No
5. Jointness	One (1) Military Service
6. LCCE	$25,830 million +/- $23,630 million
7. Novelty	Yes
8. Product Architecture	Air/Missile
9. Program Location	Industry and Government
10. Product Quantity	94 +/- 85
11. Available Resources	Technology and Schedule constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 4
14. Performance	50% Cost Breach
	50% Schedule Breach

Cluster F3 Analysis Summary: Table 4-48 identifies the MDAPs included in cluster F3. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-48: Cluster F3 MDAP Summary

Cluster	MDAPs in Cluster
F3	SFW
F3	Trident II Missile

As shown in Table 4-49, dissimilar factors include MDAP duration, quantity, and LCCE. Development duration ranged between 15 - 33 years. MDAP LCCE ranged

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between $1,921 - $41,506 million. Product quantity ranged between 561 - 4,920 units over the life of the program. Similar factors include family of air/missile systems, novel technology, planned improvement acquisition, and one primary industry site. The MDAPs included in Cluster F3 were SIOS Type 2 structures and were simultaneously constrained by both schedule urgency and cost limitations.

Table 4-49: Cluster F3 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	24 years +/- 9 years
3. Foreign Military Sales	50% Yes, 50% No
4. International Cooperative	No
5. Jointness	One (1) Military Service
6. LCCE	$21,714 million +/- $19,792 million
7. Novelty	Yes
8. Product Architecture	Air/Missile
9. Program Location	Industry
10. Product Quantity	2,741+/- 2,180
11. Available Resources	Cost and Schedule constraints
12. Systems Hierarchy	50% System
	50% Family of Systems
13. SIOS Type	SIOS Type 2
14. Performance	Schedule Breach

Cluster F4 Analysis Summary: Table 4-50 identifies the MDAPs included in cluster F4. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

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Table 4-50: Cluster F4 MDAP Summary

Cluster	MDAPs in Cluster
F4	ARH
F4	B-2 RMP
F4	LHA 6
F4	LUH
F4	SADARM
F4	T-AOE

As shown in Table 4-51, dissimilar factors include SIOS Type, MDAP duration, quantity, and LCCE. Cluster F4 contains a combination of SIOS Type 4 and 5 structures. Development duration ranged between 5 - 35 years. MDAP LCCE ranged between $537 - $11,319 million. Product quantity ranged between 1 - 1,252 units over the life of the program. Similar, the MDAPs included in Cluster F4 were constrained by cost limitations. Other similar factors include family of air/missile systems, novel technology, and planned improvement acquisition.

Table 4-51: Cluster F4 Analysis Summary, n=6

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	15 years +/- 10 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Military Service
6. LCCE	$3,009 million +/- $3,770 million
7. Novelty	Yes

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Variable	Measure of Effectiveness
8. Product Architecture	Air/Missile
9. Program Location	83% Industry
	17% Greater than two (2) Industry and Government
10. Product Quantity	266 +/- 415
11. Available Resources	Cost constraints
12. Systems Hierarchy	17% Component
	83% Family of Systems
13. SIOS Type	33% SIOS Type 4
	67% SIOS Type 5
14. Performance	67% Cost Breach
	17% Schedule Breach
	16% Cost, Schedule, Technology Performance Breach

Cluster F5 Analysis Summary: Table 4-52 identifies the MDAPs included in cluster F5. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-52: Cluster F5 MDAP Summary

Cluster	MDAPs in Cluster
F5	Crusader
F5	EFV
F5	ERM
F5	JSTARS
F5	SSDS MK-1 Portion

As shown in Table 4-53, dissimilar factors include SIOS Type, MDAP duration, quantity, and LCCE. Cluster F5 contains a combination of SIOS Type 2 and SIOS Type 4

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structures. Development duration ranged between 8 - 38 years. MDAP LCCE ranged between \$669 - \$9,642 million. Product quantity ranged between 18 - 15,100 units over the life of the program. Similar factors include family of systems, novel technology, and planned improvement acquisition.

Table 4-53: Cluster F5 Analysis Summary, n=5

Variable	Measure of Effectiveness
1. Acquisition Strategy	Planned Improvement
2. Duration	18 years +/- 11 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Military Service
6. LCCE	\$3,890 million +/- \$3,148 million
7. Novelty	Yes
8. Product Architecture	40% Air/Missile
	20% Sea
	20% Land
	20% Communication
9. Program Location	60% Industry
	40% Government
10. Product Quantity	3,132 +/- 5,987
11. Available Resources	20% Cost constraints
	80% Schedule constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	20% Type 2
	80% Type 4
14. Performance	Technology Performance Breach

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Cluster F6 Analysis Summary: Table 4-54 identifies the MDAPs included in cluster F6. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-54: Cluster F6 MDAP Summary

Cluster	MDAPs in Cluster
F6	JLENS
F6	SBSS BLOCK 10

As shown in Table 4-55, dissimilar factors include LCCE and resource constraints. MDAP LCCE ranged between $918 - $2,646 million. Half of the MDAPs included in Cluster F6 were constrained by cost limitations. Similar, Cluster F6 contains SIOS Type 2 structures. Other similar factors include development duration (8 - 9 years), product quantity (1-2), family of systems, novel technology, and single step acquisition.

Table 4-55: Cluster F6 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Single Step
2. Duration	8.5 years +/- 0.5 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Military Service
6. LCCE	$1,782 million +/- $864 million
7. Novelty	Yes
8. Product Architecture	Communication
9. Program Location	50% Government 50% Industry and Government
10. Product Quantity	2 +/- 1
11. Available Resources	50% Cost constraints

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Variable	Measure of Effectiveness
	50% No evidence of constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 2
14. Performance	50% Schedule Breach
	50% Cost, Schedule, Technology
	Performance Breach

Cluster F7 Analysis Summary: Table 4-56 identifies the MDAPs included in cluster F7. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-56: Cluster F7 MDAP Summary

Cluster	MDAPs in Cluster
F7	Comanche
F7	JCM
F7	JTUAV

As shown in Table 4-57, dissimilar factors include LCCE, duration, and quantity. MDAP LCCE ranged between \$788 - \$39,319 million, development duration (3 - 25 years), and product quantity (9 - 48,815). Similar, Cluster F7 contains SIOS Type 2 structures. The MDAPs included in Cluster F7 indicate no evidence of resource constraints. Other similar factors include family of air/missile systems, evolutionary acquisition strategy, and one primary industry location.

Table 4-57: Cluster F7 Analysis Summary, n=3

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	15 years +/- 9 years

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Variable		Measure of Effectiveness
3.	Foreign Military Sales	No
4.	International Cooperative	33% Yes, 67% No
5.	Jointness	One (1) Military Service
6.	LCCE	$15,655 million +/- $16,915 million
7.	Novelty	No
8.	Product Architecture	Air/Missile
9.	Program Location	Industry
10.	Product Quantity	16,491 +/- 22,858
11.	Available Resources	No evidence of constraints
12.	Systems Hierarchy	Family of Systems
13.	SIOS Type	SIOS Type 2
14.	Performance	50% Cost Breach
		50% Technology Performance Breach

Cluster F8 Analysis Summary: Table 4-58 identifies the MDAPs included in cluster F8. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-58: Cluster F8 MDAP Summary

Cluster	MDAPs in Cluster
F8	ATACMS BAT
F8	NTW TBMD
F8	VH-71

As shown in Table 4-59, dissimilar factors include SIOS type, LCCE, duration, and quantity. Cluster F8 contains a combination of SIOS Type 1 and SIOS Type 5 structures. MDAP LCCE ranged between $2,430 - $6,811 million, development duration (3 – 12 years), and product quantity (28 – 1,500). Similar, the MDAPs included in Cluster F8

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have family of air/missile systems, evolutionary acquisition strategy, and one primary industry location.

Table 4-59: Cluster F8 Analysis Summary, n=3

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	7 years +/- 4 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	67% One (1) Military Service
	33% Two (2) Military Services
6. LCCE	\$5,331 million +/- \$2,051 million
7. Novelty	No
8. Product Architecture	Air/Missile
9. Program Location	Industry
10. Product Quantity	997 +/- 685
11. Available Resources	33% Cost constraints
	67% Technology constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	33% Type 1
	67% Type 5
14. Performance	33% Cost Breach
	67% Cost, Schedule, Technology Performance Breach

Cluster F9 Analysis Summary: Table 4-60 identifies the MDAPs included in cluster F9. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

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Table 4-60: Cluster F9 MDAP Summary

Cluster	MDAPs in Cluster
F9	Land Warrior
F9	SSN 774

As shown in Table 4-61, dissimilar factors include LCCE, duration, and quantity. MDAP LCCE ranged between $671 - $91,847 million, development duration (13 - 34 years), and product quantity (30 - 440units). Similar, Cluster F9 contains SIOS Type 3 structures, and, the MDAPs included in Cluster F9 have cost limitations. Other similar factors include family of air/missile systems, evolutionary acquisition strategy, and one primary industry location.

Table 4-61: Cluster F9 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	24 years +/- 11 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Military Service
6. LCCE	$46,259 million +/- $45,588 million
7. Novelty	No
8. Product Architecture	50% Sea 50% Land
9. Program Location	Industry
10. Product Quantity	235 +/- 205
11. Available Resources	Cost constraints
12. Systems Hierarchy	50% System of Systems

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Variable	Measure of Effectiveness
	50% Family of Systems
13. SIOS Type	SIOS Type 3
14. Performance	Schedule Breach

Cluster F10 Analysis Summary: Table 4-62 identifies the MDAPs included in cluster F10. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-62: Cluster F10 MDAP Summary

Cluster	MDAPs in Cluster
F10	FBCB2
F10	GMLRS+AW

As shown in Table 4-63, dissimilar factors include LCCE and quantity. MDAP LCCE ranged between $3,818 - $6,694 million and product quantity (43,936 – 90,068). Similar, Cluster F10 contains SIOS Type 2 structures, and the MDAPs included in Cluster F10 were simultaneously constrained by both cost limitations and schedule urgency. Other similar factors include short development duration (i.e., 5 years), family of systems, evolutionary acquisition strategy, and one primary government location.

Table 4-63: Cluster F10 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	5 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Military Service
6. LCCE	$5,256 million +/- $1,438 million

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Variable	Measure of Effectiveness
7. Novelty	No
8. Product Architecture	50% Air/Missile
	50% Communications
9. Program Location	Government
10. Product Quantity	67,002 +/- 23,066
11. Available Resources	50% Cost constraints
	50% Schedule constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 2
14. Performance	50% Cost Breach
	50% Technology Performance Breach

Cluster F11 Analysis Summary: Table 4-64 identifies the MDAPs included in cluster F11. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-64: Cluster F11 MDAP Summary

Cluster	MDAPs in Cluster
F11	AEHF SV1-4, SV5-6
	NAVSTAR GPS - (Space & Control +
F11	User Eqpt.)
F11	WIN-T Inc 3

As shown in Table 4-65, dissimilar factors include duration, LCCE, and quantity. Development duration ranged between 24 - 31 years, MDAP LCCE ranged between \$7,996 - \$17,890 million, and product quantity (6 - 3,513). Similar, Cluster F11 contains SIOS Type 2 structures. Other similar factors include family of communication systems and evolutionary acquisition strategy.

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Table 4-65: Cluster F11 Analysis Summary, n=3

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	28 years +/- 3 years
3. Foreign Military Sales	33% Yes, 67% No
4. International Cooperative	33% Yes, 67% No
5. Jointness	One (1) Military Service
6. LCCE	$13,323 million +/- $4,075 million
7. Novelty	No
8. Product Architecture	Communications
9. Program Location	67% Government
	33% Government and Industry
10. Product Quantity	1,184 +/- 1,647
11. Available Resources	50% Cost constraints
	50% No evidence of constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 2
14. Performance	Schedule Breach

Cluster F12 Analysis Summary: Table 4-66 identifies the MDAPs included in cluster F12. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-66: Cluster F12 MDAP Summary

Cluster	MDAPs in Cluster
F12	AH-64E New Build (AB3)
F12	AIM-9X Block II

As shown in Table 4-67, dissimilar factors include duration, LCCE, and quantity. Development duration ranged between 8 - 27 years, MDAP LCCE ranged between

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$2,485 - $4,336 million, and product quantity (56 - 6,000). Half of the MDAPs included in Cluster F12 were simultaneously constrained by both cost and technology limitations. Similar, Cluster F12 contains SIOS Type 4 structures. Other similar factors include family of communication systems and evolutionary acquisition strategy.

Table 4-67: Cluster F12 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	18 years +/- 10 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	50% One (1) Military Service 50% Two (2) Military Services
6. LCCE	$3,411 million +/- $926 million
7. Novelty	No
8. Product Architecture	Air/Missile
9. Program Location	50% Industry 50% Greater than two (2) Industry and Government
10. Product Quantity	3,028 +/- 2,972
11. Available Resources	50% No evidence of constraints 50% Cost and Technology Constraints
12. Systems Hierarchy	Family of Systems
13. SIOS Type	SIOS Type 4
14. Performance	Cost Breach

Cluster F13 Analysis Summary: Table 4-68 identifies the MDAPs included in cluster F13. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

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Table 4-68: Cluster F13 MDAP Summary

Cluster	MDAPs in Cluster
F13	FAB-T
F13	GBS
F13	JPALS Inc 1A
F13	JTRS GMR
F13	WGS
F13	WIN-T Inc 1

As shown in Table 4-69, dissimilar factors include SIOS type, duration, LCCE, and quantity. Cluster F13 contains a combination of SIOS Type 2 and 4 structures. Development duration ranged between 9 - 26 years, MDAP LCCE ranged between $1,103 - $4,820 million, and product quantity (8 - 11,030). Similar factors include communication hierarchy level and evolutionary acquisition strategy.

Table 4-69: Cluster F13 Analysis Summary, n=6

Variable		Measure of Effectiveness
1.	Acquisition Strategy	Evolutionary
2.	Duration	19 years +/- 6 years
3.	Foreign Military Sales	83% No, 17% Yes
4.	International Cooperative	No
5.	Jointness	67% One (1) Military Service
		33% Three (3) Military Services
6.	LCCE	$3,241 million +/- $1,538 million
7.	Novelty	No
8.	Product Architecture	Communications
9.	Program Location	50% Industry

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Variable	Measure of Effectiveness
	17% Government
	33% Industry and Government
10. Product Quantity	2,520 +/- 3,090
11. Available Resources	17% Cost constraints
	83% Technology constraints
12. Systems Hierarchy	33% Component
	67% Family of Systems
13. SIOS Type	33% SIOS Type 2
	67% SIOS Type 4
14. Performance	Cost, Schedule, and Technology
	Performance Breach

Cluster F14 Analysis Summary: Table 4-70 identifies the MDAPs included in cluster F14. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-70: Cluster F14 MDAP Summary

Cluster	MDAPs in Cluster
F14	BMDS: GMD
F14	BMDS: SM-6
F14	JTRS HMS
F14	MQ-1C UAS Gray Eagle
F14	SDB II
F14	VTUAV

As shown in Table 4-71, dissimilar factors include duration, LCCE, and quantity. Development duration ranged between 22 - 31 years, MDAP LCCE ranged between $3,156 - $66,972 million, and product quantity (1 - 271,202). A third of the MDAPs

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included in Cluster F14 exhibited no evidence of constraints; the majority of remaining MDAPs in Cluster F14 experienced schedule constraint others had a combination of cost, schedule, and technology constraints. Similar, Cluster F14 contains SIOS Type 4 structures. Other similar factors include component hierarchy level and evolutionary acquisition strategy.

Table 4-71: Cluster F14 Analysis Summary, n=6

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	29 years +/- 3 years
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	67% One (1) Military Service
	17% Two (2) Military Services
	16% Three (3) Military Services
6. LCCE	$11,162 million +/- $12,246 million
7. Novelty	No
8. Product Architecture	83% Air/Missile
	17% Communication
9. Program Location	Government and Industry
10. Product Quantity	48,295 +/- 106,821
11. Available Resources	33% No evidence of constraints
	50% Schedule constraints
	17% Cost, Schedule, and Technology Constraints
12. Systems Hierarchy	67% Component
	17% System
	16% Family of Systems

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Variable	Measure of Effectiveness
13. SIOS Type	SIOS Type 4
14. Performance	Schedule Breach

Cluster F15 Analysis Summary: Table 4-72 identifies the MDAPs included in cluster F15. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-72: Cluster F1 MDAP Summary

Cluster	MDAPs in Cluster
F15	MQ-4C Triton
F15	MQ-8 (Fire Scout)

As shown in Table 4-73, dissimilar factors include duration, LCCE, and quantity. Development duration ranged between 29 - 30 years, MDAP LCCE ranged between $3,061 - $15,268 million, and product quantity (70 - 126). Half of the MDAPs included in Cluster F15 exhibited cost constraints; the other half had a combination of schedule and technology constraints. Similar, Cluster F15 contains SIOS Type 4 structures. Other similar factors include air/missile component hierarchy level and evolutionary acquisition strategy.

Table 4-73: Cluster F15 Analysis Summary, n=2

Variable	Measure of Effectiveness
1. Acquisition Strategy	Evolutionary
2. Duration	29 years +/- 1 year
3. Foreign Military Sales	No
4. International Cooperative	No
5. Jointness	One (1) Military Service
6. LCCE	$9,165 million +/- $6,104 million

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Variable	Measure of Effectiveness
7. Novelty	No
8. Product Architecture	Air/Missile
9. Program Location	Industry
10. Product Quantity	98 +/- 18
11. Available Resources	50% Cost constraints
	50% Technology and Schedule constraints
12. Systems Hierarchy	Component
13. SIOS Type	SIOS Type 4
14. Performance	50% Cost Breach
	50% Cost, Schedule, Technology Performance Breach

Single Branch Analysis Summary: Table 4-74 identifies the unsuccessful MDAPs that did not join a cluster at the 0.75 similarity level. Formal MDAP names are available in the Appendix Table B-1 MDAP Database.

Table 4-74: Single Branches MDAP Summary for Unsuccessful MDAPs

Single Branches	MDAP
between cluster F2 and cluster F3	LCS
between cluster F3 and cluster F4	MH-60S
between cluster F3 and cluster F4	AIM-120 AMRAAM
between cluster F3 and cluster F4	FMTV
between cluster F3 and cluster F4	ASIP
between cluster F3 and cluster F4	AV-8B Harrier REMANUFACTURE
between cluster F4 and cluster F5	BMDS: ABL
between cluster F4 and cluster F5	C-27J JCA
between cluster F5 and cluster F6	CJR COBRA JUDY REPLACEMENT

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Single Branches	MDAP
between cluster F5 and cluster F6	Patriot/MEADS CAP - FIRE UNIT +Missile
between cluster F5 and cluster F6	ACS
between cluster F6 and cluster F7	Chem Demil CMA
between cluster F6 and cluster F7	MP-RTIP
between cluster F6 and cluster F7	NPOESS
between cluster F8 and cluster F9	ASDS
between cluster F9 and cluster F10	FCS
between cluster F9 and cluster F10	Patriot PAC-3
between cluster F9 and cluster F10	RQ-4A/B Global Hawk MQ-4C /NATO AGS
between cluster F9 and cluster F10	NMD (National Missile Defense)
between cluster F9 and cluster F10	F-35 JSF Aircraft (SUB-PROGRAM)
between cluster F11 and cluster F12	IDECM Blocks 4
between cluster F12 and cluster F13	AAWS (Later JAVELIN)
between cluster F12 and cluster F13	JTRS MIDS-LVT
between cluster F12 and cluster F13	CEC
between cluster F12 and cluster F13	JTRS AMF
between cluster F13 and cluster F14	TSAT (LEGACY)
between cluster F13 and cluster F14	JSIMS
between cluster F13 and cluster F14	MQ-9 UAS Reaper
between cluster F14 and cluster F15	JHSV
between cluster F14 and cluster F15	ADS (AN/WQR-3)
following Cluster F15	JTN
following Cluster F15	JTRS NED

Per the dendrogram in Figure 4-1, as similarity decreases MDAPs which standout as single branches will merge into the cluster with closest proximity. LCS is positioned

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between clusters F2 and F3; if similarity decreases to 0.68 then LCS would join the MDAPs that comprise clusters F1 and F2.

MDAPs MH-60S, AIM-120 AMRAAM, FMTV, ASIP, and AV-8B Harrier-Remanufacture are positioned between clusters F3 and F4. AV-8B Harrier-Remanufacture would join MDAPs in Cluster F4 if similarity decreases slightly to 0.74. If similarity is 0.70 then MH-60S and AIM-120 AMRAAM would join MDAPs in Cluster F3. At 0.66 similarity, ASIP would join MDAPs in Cluster F4. If similarity deceases to 0.63 then FMTV would join the MDAPs in clusters F2 and F3.

MDAPs BMDS-ABL and C-27J JCA are positioned between clusters F4 and F5. BMDS-ABL would join Cluster F4 at similarity of 0.72 and C-27J JCA would join Cluster F4 if reduced further to similarity of 0.69.

MDAPs CJR Cobra Judy Replacement, Patriot/MEADS CA/Fire Unit/Missile, and ACS are positioned between Cluster F5 and Cluster F6. If similarity were reduced to 0.74 then CJR Cobra Judy-Replacement would join MDAPs in Cluster F5. If similarity were reduced further to 0.69 then Patriot/MEADS CA/Fire Unit/Missile would join Cluster F5; however, ACS would join the MDAPs in Cluster F6.

MDAPs Chem Demil CMA, MP-RTIP, and NPOESS are positioned between Cluster F6 and Cluster F7. If similarity were reduced to 0.69 then Chem Demil CMA would join MDAPs in Cluster F6. MP-RTIP, and NPOESS would join Cluster F6 if similarity decreases to 0.67.

MDAP ASDS is positioned between Cluster F8 and Cluster F9. If similarity were reduced to 0.69 then ASDS would join Cluster F8.

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MDAPs FCS, Patriot PAC-3, RQ-4A/B Global Hawk, NMD, and F-35 JSF Aircraft are positioned between Cluster F9 and Cluster F10. MDAP FCS would join the MDAPs that comprise clusters F8 and F9 if similarity decreases to 0.65. Patriot PAC-3, RQ-4A/B Global Hawk, NMD, and F-35 JSF Aircraft would join the MDAPs that comprise Cluster F9 if similarity is further reduced to 0.62.

MDAPs IDECM Blocks 4 is positioned between Cluster F11 and Cluster F12. If similarity were reduced slightly to 0.74 then IDECM Blocks 4 would join Cluster 11.

MDAPs AAWS (later JAVELIN), JTRS MIDS-LVT, CEC, and JTRS AMF are positioned between Cluster F12 and Cluster F13. MDAPs AAWS (later JAVELIN) and JTRS MIDS-LVT would join the MDAPs that comprise Cluster F12 if similarity were reduced to 0.71. MDAPs CEC and JTRS AMF would join the MDAPs that comprise Cluster 13 if similarity decreases to 0.66.

MDAPs TSAT (LEGACY), JSIMS, and MQ-9 UAS Reaper are positioned between Cluster F13 and Cluster F14. MDAP TSAT (LEGACY) would join the MDAPs that comprise Cluster F13 if similarity is reduced to 0.72. MDAP MQ-9 UAS Reaper would join the MDAPs that comprise Cluster F14 if similarity is reduced to 0.71. MDAP JSIMS would join the MDAPs that comprise Cluster F13 if similarity is further reduced to 0.68.

MDAPs JHSV and ADS (AN/WQR-3) are positioned between Cluster F13 and Cluster F14. If similarity is reduced to 0.73 then MDAP JHSV would join the MDAPs that comprise Cluster F14 and MDAP ADS (AN/WQR-3) would join the MDAPs that comprise Cluster F15.

MDAPs JTN and JTRS NED follow Cluster F15. If similarity is reduced to 0.72 then they would join the MDAPs that comprise Cluster F15.

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A little over half of MDAPs in the data set (i.e., 83 out of 162) reached the Production and Deployment phase with an acquisition program baseline breach. Cluster analysis across 83 unsuccessful MDAPs (i.e., acquisition baseline breaches) revealed a dendrogram with 15 clusters at 75% level of similarity. Details of unsuccessful MDAPs located in clusters based on this similarity percentage are described in Table 4-75.

Table 4-75: Unsuccessful MDAP attributes cluster characterization: 15 total clusters, 75% similarity level [F1-F5]

Unsuccessful MDAP Clusters, Fn	F_1	F_2	F_3	F_4	F_5
MDAP Count	5	2	2	6	5
SIOS Type, %					
SIOS 1	20	0	0	0	0
SIOS 2	40	0	100	0	20
SIOS 3	20	0	0	0	0
SIOS 4	20	100	0	33	80
SIOS 5	0	0	0	67	0
Failure Category					
1- No Breach	0	0	0	0	0
2- Cost Breach	100	50	0	67	0
3- Schedule Breach	0	50	100	17	0
4- Technology Breach	0	0	0	0	100
5- Multiple Breach Types	0	0	0	16	0
Duration, years					
Mean	27	19	24	15	18
Standard Deviation	2	8	9	10	11
Minimum value	24	11	15	5	8
Maximum value	30	27	33	35	38
LCCE, $Million					
Mean	$ 41,392	$ 25,830	$ 21,714	$ 3,009	$ 3,890
Standard Deviation	$ 32,672	$ 23,630	$ 19,792	$ 3,770	$ 3,148
Minimum value	$ 6,442	$ 2,200	$ 1,921	$ 537	$ 669
Maximum value	$ 91,234	$ 49,461	$ 41,506	$ 11,319	$ 9,642
Quantity, #Units					
Mean	48,733	94	2,741	266	3,132
Standard Deviation	96,580	85	2,180	415	5,987
Minimum value	77	9	561	1	18
Maximum value	241,890	179	4,920	1,252	15,100
Program Location, %					
1-Industry	80	0	100	83	60
2-Government	0	0	0	0	40
3-Government/Industry	0	100	0	0	0
4-Gov./Industry (2>sites)	20	0	0	17	0

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Unsuccessful MDAP Clusters, Fn	F_1	F_2	F_3	F_4	F_5
Resource Caps, %					
0-No evidence of caps	60	0	0	0	0
1-Cost cap	40	0	0	100	20
2-Schedule cap	0	0	0	0	80
3-Technology cap	0	0	0	0	0
4-Cost, Schedule	0	0	100	0	0
5-Cost, Schedule, &Tech	0	0	0	0	0
6-Cost, Technology caps	0	0	0	0	0
7-Tech&Schedule caps	0	100	0	0	0
Acquisition Strategy, %					
1-Evolutionary	0	0	0	0	0
2-Planned Improvement	100	100	100	100	100
3-Single Step	0	0	0	0	0
Foreign Military Sales, %					
Yes	80	50	50	0	0
No	20	50	50	100	100
Novelty, %					
Yes	100	100	100	100	100
No	0	0	0	0	0
Intl. Cooperative, %					
Yes	0	0	0	0	0
No	100	100	100	100	100
Jointness, %					
1-One Organization	100	100	100	100	100
2-Two Partners	0	0	0	0	0
3-Three Partners	0	0	0	0	0
4-Four Partners	0	0	0	0	0
Systems Hierarchy, %					
1-Component	0	0	0	17	0
2-System	0	0	50	0	0
3-System of Systems	0	0	0	0	0
4-Famliy of Systems	100	100	50	83	100
Product Architecture, %					
1-Air/Missile	80	100	100	67	40
2-Sea	20	0	0	33	20
3-Chembionuclear	0	0	0	0	0
4-Land	0	0	0	0	20
5-Communication	0	0	0	0	20

Table 4-75: Unsuccessful MDAP attributes cluster characterization: 15 total clusters, 75% similarity level [F6-F10]

Unsuccessful MDAP Clusters, Fn	F_6	F_7	F_8	F_9	F_{10}
MDAP Count	2	3	3	2	2
SIOS Type, %					
SIOS 1	0	0	33	0	0

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Unsuccessful MDAP Clusters, Fn	F_6	F_7	F_8	F_9	F_{10}
SIOS 2	100	100	0	0	100
SIOS 3	0	0	0	100	0
SIOS 4	0	0	0	0	0
SIOS 5	0	0	67	0	0
Failure Category					
1- No Breach	0	0	0	0	0
2- Cost Breach	0	33	33	0	50
3- Schedule Breach	50	0	0	100	0
4- Technology Breach	0	67	0	0	50
5- Multiple Breach Types	50	0	67	0	0
Duration, years					
Mean	9	15	7	24	5
Standard Deviation	0	9	4	11	0
Minimum value	8	3	3	13	5
Maximum value	9	25	12	34	5
LCCE, $Million					
Mean	$ 1,782	$ 15,655	$ 5,331	$ 46,259	$ 5,256
Standard Deviation	$ 864	$ 16,915	$ 2,051	$ 45,588	$ 1,438
Minimum value	$ 918	$ 788	$ 2,430	$ 671	$ 3,818
Maximum value	$ 2,646	$ 39,319	$ 6,811	$ 91,847	$ 6,694
Quantity, #Units					
Mean	2	16,491	997	235	67,002
Standard Deviation	1	22,858	685	205	23,066
Minimum value	1	9	28	30	43,936
Maximum value	2	48,815	1,500	440	90,068
Program Location, %					
1-Industry	0	100	100	100	0
2-Government	50	0	0	0	100
3-Government/Industry	50	0	0	0	0
4-Gov./Industry(2>sites)	0	0	0	0	0
Resource Caps, %					
0-No evidence of caps	50	100	0	0	0
1-Cost cap	50	0	33	100	50
2-Schedule cap	0	0	0	0	50
3-Technology cap	0	0	67	0	0
4-Cost, Schedule	0	0	0	0	0
5-Cost, Schedule, & Tech	0	0	0	0	0
6-Cost, Tech. caps	0	0	0	0	0
7-Tech. & Schedule caps	0	0	0	0	0
Acquisition Strategy, %					
1-Evolutionary	0	100	100	100	100
2-Planned Improvement	0	0	0	0	0
3-Single Step	100	0	0	0	0
Foreign Military Sales,%					
Yes	0	0	0	0	100

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Unsuccessful MDAP Clusters, Fn	F_6	F_7	F_8	F_9	F_{10}
No	100	100	100	100	0
Novelty, %					
Yes	100	0	0	0	0
No	0	100	100	100	100
Intl. Cooperative, %					
Yes	0	33	0	0	0
No	100	67	100	100	100
Jointness, %					
1-One Organization	100	100	67	100	100
2-Two Partners	0	0	33	0	0
3-Three Partners	0	0	0	0	0
4-Four Partners	0	0	0	0	0
Systems Hierarchy, %					
1-Component	0	0	0	0	0
2-System	0	0	0	0	0
3-System of Systems	0	0	0	50	0
4-Famliy of Systems	100	100	100	50	100
Product Architecture, %					
1-Air/Missile	0	100	100	0	50
2-Sea	0	0	0	50	0
3-Chembionuclear	0	0	0	0	0
4-Land	0	0	0	50	0
5-Communication	100	0	0	0	50

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Table 4-75: Unsuccessful MDAP attributes cluster characterization: 15 total clusters, 75% similarity level [F11-F15]

Unsuccessful MDAP Clusters, Fn	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
MDAP Count	3	2	6	6	2
SIOS Type, %					
SIOS 1	0	0	0	0	0
SIOS 2	100	0	33	0	0
SIOS 3	0	0	0	0	0
SIOS 4	0	100	67	100	100
SIOS 5	0	0	0	0	0
Failure Category					
1- No Breach	0	0	0	0	0
2- Cost Breach	0	100	0	0	50
3- Schedule Breach	100	0	0	100	0
4- Technology Breach	0	0	0	0	0
5- Multiple Breach Types	0	0	100	0	50
Duration, years					
Mean	28	18	19	29	29
Standard Deviation	3	10	6	3	1
Minimum value	24	8	9	22	29
Maximum value	31	27	26	31	30
LCCE, $Million					
Mean	$ 13,323	$ 3,411	$ 3,241	$ 11,162	$ 9,165
Standard Deviation	$ 4,075	926	$ 1,538	$ 12,246	$ 6,104
Minimum value	$ 7,996	$ 2,485	$ 1,103	$ 3,156	$ 3,061
Maximum value	$ 17,890	$ 4,336	$ 4,820	$ 66,972	$ 15,268
Quantity, #Units					
Mean	1,184	3,028	2,520	48,295	98
Standard Deviation	1,647	2,972	3,090	106,821	0
Minimum value	6	56	8	1	70
Maximum value	3,513	6,000	11,030	271,202	126
Program Location,%					
1-Industry	0	50	50	0	100
2-Government	67	0	17	0	0
3-Government/Industry	33	0	33	100	0
4-Gov./Industry (2>sites)	0	50	0	0	0
Resource Caps, %					
0-No evidence of caps	33	50	0	33	0
1-Cost cap	0	0	17	0	50
2-Schedule cap	67	0	0	50	0
3-Technology cap	0	0	83	0	0
4-Cost, Schedule	0	0	0	0	0
5-Cost, Schedule & Tech	0	0	0	0	0

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Unsuccessful MDAP Clusters, Fn	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
6-Cost & Technology caps	0	50	0	0	0
7-Tech & Schedule caps	0	0	0	17	50
Acquisition Strategy, %					
1-Evolutionary	100	100	100	100	100
2-Planned Improvement	0	0	0	0	0
3-Single Step	0	0	0	0	0
Foreign Military Sales,%					
Yes	33	100	17	0	0
No	67	0	83	100	100
Novelty, %					
Yes	0	0	0	0	0
No	100	100	100	100	100
Intl. Cooperative, %					
Yes	33	0	0	0	0
No	67	100	100	100	100
Jointness, %					
1-One Organization	100	50	67	67	100
2-Two Partners	0	50	0	17	0
3-Three Partners	0	0	33	16	0
4-Four Partners	0	0	0	0	0
Systems Hierarchy, %					
1-Component	0	0	33	67	100
2-System	0	0	0	17	0
3-System of Systems	0	0	0	0	0
4-Famliy of Systems	100	100	67	16	0
Product Architecture, %					
1-Air/Missile	0	100	0	83	100
2-Sea	0	0	0	0	0
3-Chembionuclear	0	0	0	0	0
4-Land	0	0	0	0	0
5-Communication	100	0	100	17	0

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Chapter 5: Recommendations and Conclusion

5.1 Research Limitations

This research is limited to major defense acquisition programs; however, it is not evident that all cited foundational project performance literature was based solely on large programs (Cooke-Davies, 2002). In addition, there was not enough detailed MDAP data to examine variations in factors across the project lifecycle (DAU, 2013) or to examine the PMO organization typology below the lead systems integration level. It follows from cluster analysis that conclusions about proximity of observations can be drawn based on the level where the branches containing those observations are fused (in this case 75% similarity). While interpreting the dendrogram appears simple, interpretation is only as good as the level of insight and understanding of the objects being studied. This insight would be helpful in explaining the outliers observed in the dendrograms. "Non-clustered" outliers are indicated by lines that join at a distance greater than the cut-off value (i.e., greater than 75% level of similarity). This study identifies several MDAP outliers that would benefit from further analysis.

5.2 Conclusion

Making the case for megaproject importance, Flyvbjerg (2017) and contemporaries (Greiman, 2013; Li, Lu, Taylor, & Han, 2017) point to substantial impact on the global economy and our way of life. Yet, compared with established fields in engineering and management literature, megaproject management research is relatively sparse with a few classic texts being recognized roughly 13 years ago (Li et al., 2017). A theoretical perspective, this study seeks to advance the megaproject management body of knowledge by expanding understanding of PMO organization structure.

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At a more practical level, the authors strive to influence PMO organizational effectiveness. Pursuant to both objectives, organizational factors have been identified to assist in selecting PMO structures for large, complex Defense acquisition programs. From this research, the authors have learned that the PMO should support the overall organizational context.

This paper answers why and how organization selection factors impact PMO performance and goes beyond the description of selection factors found in literature. It provides convincing and ideally empirically substantiated explanations for real-life observations based on two decades of MDAPs. Megaproject success factors found in this empirical study of MDAPs both underscore and expand upon success factor dimensions found in organization performance and megaproject management performance research.

Grouping organizational factors into clusters provides clues that help select MDAP PMO organization structure types. These clues take into consideration both singularity and overlap between organizational factor measures of effectiveness values aligned to SIOS types. Attribute values within each MDAP classification enable future programs to determine which class they belong and approximate the most suitable PMO organization structure. Bottom-line, establishing the ideal SIOS type does not guarantee success.

Success rate was defined as the number of MDAPs without baseline breach divided by the total number of MDAPs for a given SIOS type. Analysis of 162 MDAPs (including closed, terminated, and in-progress programs) indicates that MDAPs with SIOS Type 3, 4, and 5 structures tend to be more successful than MDAPs with SIOS Type 1 and 2 structures. There were only five SIOS Type 1 programs identified, two of

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them failed miserably with baseline breaches in all three performance measures of effectiveness (i.e., cost, schedule, and technical performance).

5.2.1 SIOS Typology Recommendations

Cluster analysis of empirical MDAP data suggests SIOS types to select (and those to avoid) for given measures of effectiveness ranges for continuous data (e.g., program size and duration) and MDAP frequency (% MDAPs) for qualitative data (e.g., resource constraints, acquisition strategy, product architecture, program location, systems hierarchy, jointness, technology novelty, FMS, and international cooperatives). Recommendations for SIOS Type are based on the evidence of successful MDAPs for a given attribute. For example, if a SIOS Type has a high frequency of successful MDAPs for a given attribute, then that SIOS Type is recommended as a place to start when selecting PMO organizational structure for an existing or new MDAP.

As outlined in Tables 5-1 and 5-2, SIOS Type 4 emerges as the preferred typology given that it has been successfully employed across most MDAP attributes.

Available Resources: SIOS 4 offers the most realistic options for resource constraints with constraints across all fronts schedule constrains (urgent need), cost constraints (limited budget), and technology constraint (e.g., capability gaps, knowledge gaps and known uncertainties). SIOS 2, SIOS 3, and SIOS 5 do not appear to have a high level of MDAPs with resource constraints. Note that SIOS 2 also becomes an option when there are multiple, simultaneous constraints.

Acquisition Strategy: SIOS 4 is the place to start when using an evolutionary acquisition strategy. However, shift to SIOS 2, SIOS 3, or SIOS 5 if using a planned improvement strategy.

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Development Duration: While SIOS 4 offers the broadest ranges of development time (4 to 59 years), SIOS 3 (9 to 68 years) and SIOS 5 (4 to 46 years) are not far behind. Long develop durations may be attributed to long-lived programs that continually improve with emerging technology (e.g., Nuclear powered multi-mission aircraft carrier CVN-68 ships)

Program Size: Once again SIOS 4 offers the broadest range of LCCE, product quantity, and unit cost for successful MDAPs. Programs can range from an MDAP with a low volume - high cost SoS to an MDAP with high volume - low cost components. Start with SIOS 4 for MDAPs with high volume - low cost products and try SIOS 5 for low volume - high cost products.

Product Architecture: SIOS 4 has evidence of successful MDAPs across all product architectures (i.e., air/missile, land, sea, communications, and chemical, biological, nuclear). Just short of SIOS 4, SIOS 2 and SIOS 5 both have evidence of all product architectures accept chemical/biological/nuclear systems.

Program Location: Again, SIOS 4 has evidence of successful MDAPs across all program team locations. However, SIOS 3 or SIOS 5 are the place to start if the program team is primary operated in Industry. Try SIOS 2 first, if the program team is co-located across multiple government and industry sites.

Systems Hierarchy: Start with SIOS 4 if the MDAP includes a family of systems (FoS); but, quickly pivot to SIOS 3 if the MDAP involves a SoS and SIOS 5 if a singular system.

Jointness: SIOS 4 emerges as the SIOS type with the most evidence of successful joint programs. SIOS 3 serves as another option with evidence of a few successful joint programs.

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Novelty: While SIOS 4 has evidence of successful MDAPs with innovative technology, both SIOS 3 and SIOS 5 are clearly the place to start. The majority of MDAPs in SIOS 3 and SIOS 5 are systems with novel technology.

FMS: While SIOS 4 has evidence of successful MDAPs with FMS, SIOS 5 is clearly the place to start. SIOS 5 has the most evidence of successful MDAPs with FMS.

International Cooperatives: SIOS 4 has evidence of successful MDAPs with international collaboration. SIOS 5 is the only other option with evidence of successful MDAPs that have collaborated internationally.

As a quick example, assume that a program manager has to select a SIOS type for a new MDAP. The program manager should completely avoid SIOS Type 1. As of 2010 Legislation, it is illegal to use (Defense Authorization Bill (2008). (PL No: 110-181), Sec. 802. Lead Systems Integrators). If the program manager is responding to a joint (i.e., multiple, international enterprises) urgent need to rapidly develop a novel communication system with little knowledge of the underlying technology. It is clear from Table 5-2 that the program manager should avoid SIOS 3 and SIOS 5 typology because they both predominantly employ planned improvement acquisition strategy and the program manager requires the agility associated with evolutionary acquisition strategy. The program manager should also avoid SIOS 3 type structures because it falls in MDAP clusters of large, slow programs. While SIOS 4 structures appears to be popular for communication systems, the program manager should avoid it as well. Note that MDAP clusters containing SIOS 4 typology tend to fail when constrained by schedule and technology. Instead, per Table 5-1, the program manager should explore using SIOS 2

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type structures. MDAP clusters containing SIOS 2 have successfully developed novel technologies with speed and agility.

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Table 5-1: Recommended SIOS types to consider for MDAP attributes*

Selection Factor	Measure of Effectiveness (MOE)	SIOS Type 1 Industry PM/LSI $N_{\text{successful MDAP}}=2$	SIOS Type 2 Gov./Ind. Shared PM/SI/Acqn. $N_{\text{successful MDAP}}=19$	SIOS Type 3 Gov. PM/Acqn.; Delegated PM/SI $N_{\text{successful MDAP}}=10$	SIOS Type 4 Gov. PM/SI/ Acqn.; SI Support $N_{\text{successful MDAP}}=34$	SIOS Type 5 Gov. PM; Delegated PM/SI/Acqn. $N_{\text{successful MDAP}}=14$
Available Resources (Constraints)	No Apparent Constraints	50%	53%	60%	24%	65%
	Cost		32%	30%	41%	21%
	Technology	50%	5%	10%	20%	14%
	Schedule				6%	
	Schedule/Cost		5%		3%	
	Cost/Technology		5%		3%	
	Cost/Sched./Technology				3%	
Acquisition Strategy	Evolutionary	100%	42%	30%	53%	29%
	Planned Improvement		42%	50%	29%	64%
	Single Step		16%	20%	18%	7%
Development Duration	1 year - 68 years	32yrs	1yr – 38yrs	9.3yr – 68yrs	4yr – 59yrs	4yr – 46yrs
Program Size						
LCCE	$0.4B - $69.6B	$1.0B – $2.7B	$0.6B - $21.2B	$0.4B - $55.1B	$0.6B - $67.6B	$0.6B - $69.6B
Quantity	1unit - 10 units	31 – 32u	1u – 24,070u	1u – 10,334u	1u – 237,788u	10u – 2,857u
Unit Cost	$0.01 - $11,706 M/unit	$31 - $89M/u	$0.06 - $7,071M/u	$0.57 - $11,706M/u	$0.01 - $3,412M/u	$0.43 - $1,713M/u
Product Architecture	Air/Missile	100%	52%	30%	41%	64%
	Sea		16%	40%	3%	14%
	Ground		16%		21%	8%
	Communications		16%	30%	32%	14%
	Chem.Biological Nuclear				3%	
Program Location	Industry (Ind)			30%	2%	36%
	Government (Gov)		5%		24%	21%

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Selection Factor	Measure of Effectiveness (MOE)	SIOS Type 1 Industry PM/LSI $N_{successful\ MDAP}$ =2	SIOS Type 2 Gov./Ind. Shared PM/SI/Acqn. $N_{successful\ MDAP}$ =19	SIOS Type 3 Gov. PM/Acqn.; Delegated PM/SI $N_{successful\ MDAP}$ =10	SIOS Type 4 Gov. PM/SI/ Acqn.; SI Support $N_{successful\ MDAP}$ =34	SIOS Type 5 Gov. PM; Delegated PM/SI/Acqn. $N_{successful\ MDAP}$ =14
	Ind/Gov Co-Located	100%	37%	50%	62%	14%
	Ind/Gov (2 > Locations)		58%	20%	12%	29%
Systems Hierarchy	Family of Systems		16%	10%	32%	1%
	System of Systems			70%		1%
	System	100%	73%	20%	53%	98%
	Component		11%		15%	
Jointness	No - 1 Agency	100%	95%	80%	88%	100%
	Yes - 2 Agencies		5%		6%	
	Yes - 3> Agencies			20%	6%	
Novelty	Yes		58%	70%	47%	71%
	No	100%	42%	30%	53%	29%
FMS	Yes	50%	37%	30%	32%	71%
	No	50%	63%	70%	68%	29%
International Cooperative	Yes	100%			15%	14%
	No		100%	100%	85%	86%

(**Note: range provided for continuous data and frequency (%) provided for nominal, binary, and ordinal data)*

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Table 5-2: Summary of MDAP Attributes for Unsuccessful MDAPs by SIOS Type

Selection Factor	SIOS 1 N=3	SIOS 2 N=23	SIOS 3 N=11	SIOS 4 N=33	SIOS 5 N=13
Development Duration	3 – 24.4 years	3 - 38 years	13 - 42 years	35 years or less	5 -35 years
Program Size LCCE, Quantity, Unit Cost	6.8 – 159.3 billion, 15 – 1,500 units, or $5 – 10,621 million/unit	$0.78 - 41.5 billion, 1 - 241,890 units, or $0.1 - 2,347 million/unit	$0.51 - 338.9 billion>, 1 - 2,457units, or $2 - 20,252 million/unit	$0.53 - 49.5 billion, 1 - 271,202units, or $0.1 - 38,082 million/unit	$0.54 - 20.1 billion, 1 - 21,102 units, or $0.1 - 3,153 million/unit
Program Location	Industry or Government/Industry, +2 Sites	Industry or Government	Industry	Industry or Government/Industry	Industry
Resource Caps	None, Cost, Combination of Cost and Schedule	Combination of Cost, Technology, and Performance	Cost Constraint	Combination of Cost, Technology, and Performance	Cost Constraint or Technology Constraint
Acquisition Strategy	Evolutionary, Planned Improvement	Evolutionary, Planned Improvement, or Single Step	Evolutionary	Evolutionary, Planned Improvement	Evolutionary
Foreign Military Sales	No	Yes	No	Yes	No
Novelty	Yes or No	Yes or No	No	Yes or No	No
International Cooperation	No	No	No	No	No
Jointness	Yes	No	No	No	No
Systems Hierarchy	System of Systems, Family of Systems	Family of Systems	System of Systems, Family of Systems	Component, Family of Systems	Family of Systems
Product Architecture	Air/Missile, Combination of All	Air/Missile or Communication	Ground or Sea	Air/Missile or Communication	Air/Missile

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5.2.2 Recommendations for Future Research

Future research should explore the influence of additional time dependent factors (e.g., program manager turn-over, program organizational capability mix, etc.) on the selection of PMO organization structure types (Franke, 2001). Aubry et al.'s (2008) investigation presents empirical evidence that a snapshot of the PMO is insufficient to build understanding of the organization. And, Ketchen and Shook's (1996) examination of cluster analysis advocates incorporating time-series analysis into organizational configuration-performance relationship to any study of multiple time periods that uses cluster analysis. This helps explore varying lag times between configuration derivation and performance measurement (Ketchen & Shook, 1996). Lyneis et al. (2001) suggest that the major reason for continued PMO performance problems despite advances in PMO guidance, policy, tools and techniques is that while programs are complex, dynamic systems, most organization design concepts either view programs statically or take a myopic view.

Non-structural integration mechanisms offer potential for further study. Conventional PMO constructs (Galbraith, 1971) are not always practical when engaging multiple, large sub-projects that involve a confederation of constituent enterprises to produce a complex SoS (Kerzner, 2013). Future research should include human factors given that both project managers and multi-disciplined teams (or integrated project/product teams) fortify integration in PMO structures throughout the system lifecycle (Lake, 1992; Corea et al., 1998; Franke, 2001; DAU, 2014).

MDAP factors could be used to help design a robust decision model that will provide step-by-step guidance for constructing PMOs for large, complex Defense programs.

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This requires greater fidelity to characterize the relationship between system hierarchy as well as future research for the remaining factors that require authoritative data sources beyond readily available sources. Factors for future consideration include stakeholder communications, business operations, product knowledge, and quality management.

In addition, future research should examine organizational levels below the program management LSI. The conceptual organizational construct, depicted in Figure 5-1, serves as the foundation of multiple PMO organization structure derivatives that align functions to organizational factors such as acquisition strategy, product type, and system hierarchy (DAU, 2014).

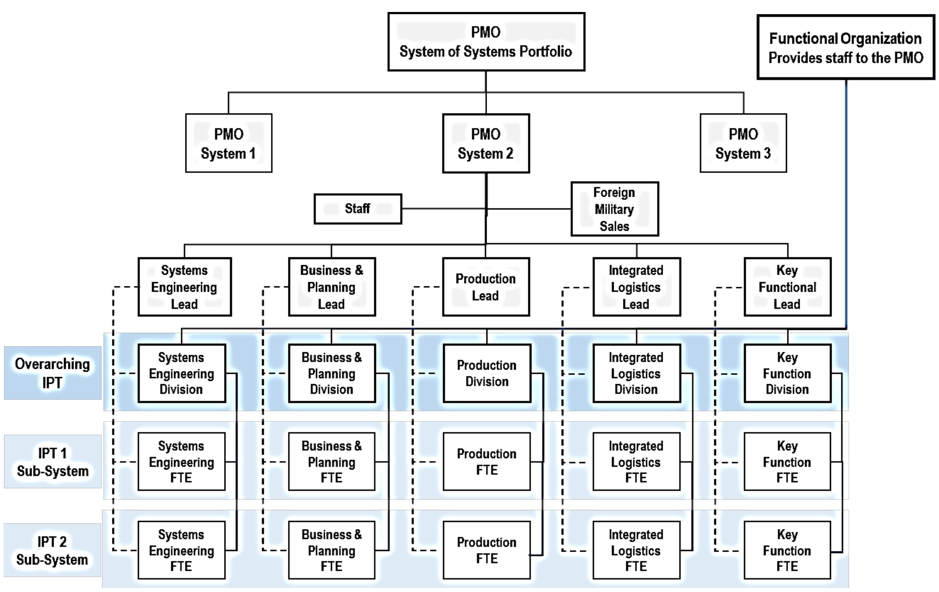

Figure 5-1. Foundational Organizational Construct for Major Acquisition Programs

Additional research is also warranted to identify unique factors that help select SIOS types for programs across multiple industries (e.g., health care, insurance, professional services, etc.). Lyneis, Cooper, and Els (2001) suggest that the major reason for continued PMO performance problems despite advances in PMO guidance, policy, tools

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and techniques is that while programs are complex, dynamic systems, most organization design concepts either view programs statically or take a myopic view. Variations in organization structure can often be attributed to the nature of the organizational mechanism used to deliver products and/or services (Lumb, 2008). The authors intend to identify unique factors for MDAPs and plan to use these factors to help design a robust decision model that will provide step-by-step guidance for constructing PMOs for large, complex Defense programs.

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Appendices

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APPENDIX A.

Data Sources and Collection Methodology

1. Office of the Under Secretary of Defense Acquisition, Technology, and Logistics Acquisition Resources and Analysis (ARA)/Acquisition Management (AM), Public Major Defense Acquisition Program (MDAP) List, Last Updated: October 25, 2012, http://www.acq.osd.mil/ara/am/mdap.html (As of May 31, 2014).
2. Selected Acquisition Reports (SAR) Summary Table, December 2012, http://www.acq.osd.mil/ara/am/sar/SST-2012-12.pdf (As of May 31, 2014). USC 2432: Selected Acquisition Reports, Text contains those laws in effect on July 28, 201. From Title 10-ARMED FORCES, Subtitle A-General Military Law, PART IV-SERVICE, SUPPLY, AND PROCUREMENT, CHAPTER 144-MAJOR DEFENSE ACQUISITION PROGRAMS, (As of July 29, 2018 http://uscode.house.gov/view.xhtml?req=granuleid:USC-prelim-title10-section2432&num=0&edition=prelim)Department of Defense (DoD) Systems Engineering FY2013 Annual Report, March 2014, Deputy Assistant Secretary of Defense Systems Engineering, www.acq.osd.mil/se (As of May 31, 2014), pp. 33-131.
3. Department of Defense (DoD) Systems Engineering FY2012 Annual Report, March 2013, Deputy Assistant Secretary of Defense Systems Engineering, www.acq.osd.mil/se (As of May 31, 2014), pp. 43-136.
4. **Selected Acquisition Reports, http://www.dod.mil/pubs/foi/logistics_material_readiness/acq_bud_fin/SARs.html (As of May 31, 2014).**

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SARs December 2012 - Army
AH-64E Apache New Build December 2012 SAR(PDF | 360 KB)
AH-64E Apache Remanufacture December 2012 SAR(PDF | 464 KB)
AMF JTRS December 2012 SAR(PDF | 490 KB)
CH-47F December 2012 SAR(PDF | 328 KB)
Excalibur December 2012 SAR(PDF | 344 KB)
FMTV December 2012 SAR(PDF | 412 KB)
GMLRS-GMLRS AW December 2012 SAR(PDF | 428 KB)
IAMD December 2012 SAR(PDF | 340 KB)
JLENS December 2012 SAR(PDF | 344 KB)
JTN December 2012 SAR(PDF | 396 KB)
JTRS HMS December 2012 SAR(PDF | 564 KB)
LUH December 2012 SAR(PDF | 276 KB)
MQ-1C Gray Eagle December 2012 SAR(PDF | 940 KB)
PAC-3 December 2012 SAR(PDF | 444 KB)
Patriot-MEADS CAP December 2012 SAR(PDF | 808 KB)
PIM December 2012 SAR(PDF | 408 KB)
UH-60M Black Hawk December 2012 SAR(PDF | 290 KB)
WIN-T Inc 2 December 2012 SAR(PDF | 376 KB)
WIN-T Inc 3 December 2012 SAR(PDF | 444 KB)
SARs December 2012 - Navy
AGM-88E AARGM December 2012 SAR(PDF | 348 KB)
AIM-9X Blk II December 2012 SAR(PDF | 392 KB)
CEC December 2012 SAR(PDF | 444 KB)
CH-53K December 2012 SAR(PDF | 408 KB)
CVN 78 December 2012 SAR(PDF | 610 KB)
DDG 51 December 2012 SAR(PDF | 476 KB)
DDG 1000 December 2012 SAR(PDF | 624 KB)
E-2D AHE December 2012 SAR(PDF | 1.25 MB)
EA-18G December 2012 SAR(PDF | 328 KB)
F-A-18E-F December 2012 SAR(PDF | 696 KB)
GATOR December 2012 SAR(PDF | 352 KB)
H-1 Upgrades December 2012 SAR(PDF | 968 KB)
IDECM December 2012 SAR(PDF | 604 KB)
JHSV December 2012 SAR(PDF | 916 KB)
JPALS Inc 1A December 2012 SAR(PDF | 488 KB)
JSOW December 2012 SAR(PDF | 676 KB)
KC-130J December 2012 SAR(PDF | 272 KB)
LCS December 2012 SAR(PDF | 412 KB)
LHA 6 December 2012 SAR(PDF | 448 KB)
LPD 17 December 2012 SAR(PDF | 548 KB)
MH-60R December 2012 SAR(PDF | 356 KB)
MH-60S December 2012 SAR(PDF | 924 KB)
MIDS December 2012 SAR(PDF | 704 KB)
MQ-4C Triton December 2012 SAR(PDF | 340 KB)

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MUOS December 2012 SAR(PDF | 388 KB)
NMT December 2012 SAR(PDF | 304 KB)
P-8A December 2012 SAR(PDF | 356 KB)
RMS December 2012 SAR(PDF | 364 KB)
SM-6 December 2012 SAR(PDF | 776 KB)
SSC December 2012 SAR(PDF | 348 KB)
SSN 774 December 2012 SAR(PDF | 468 KB)
Tactical Tomahawk December 2012 SAR(PDF | 324 KB)
Trident II Missile December 2012 SAR(PDF | 388 KB)
V-22 December 2012 SAR(PDF | 728 KB)
VTUAV December 2012 SAR(PDF | 344 KB)
SARs December 2012 - Air Force
AEHF December 2012 SAR(PDF | 948 KB)
AMRAAM December 2012 SAR(PDF | 532 KB)
AWACS Blk 40-45 December 2012 SAR(PDF | 288 KB)
B-2 EHF Inc 1 December 2012 SAR(PDF | 248 KB)
B61 Mod 12 LEP TKA December 2012_SAR(PDF | 296 KB)
C-130J December 2012 SAR(PDF | 628 KB)
C-5 RERP December 2012 SAR(PDF | 596 KB)
EELV December 2012 SAR(PDF | 352 KB)
FAB-T December 2012 SAR(PDF | 424 KB)
GBS December 2012 SAR(PDF | 320 KB)
GPS III December 2012 SAR(PDF | 1.20 MB)
GPS OCX December 2012 SAR(PDF | 632 KB)
HC-MC-130 Recap December 2012 SAR(PDF | 292 KB)
JASSM December 2012 SAR(PDF | 712 KB)
JDAM December 2012 SAR(PDF | 644 KB)
JPATS December 2012 SAR(PDF | 332 KB)
KC-46A December 2012 SAR(PDF | 324 KB)
MQ-9 Reaper December 2012 SAR(PDF | 500 KB)
NAS December 2012 SAR(PDF | 613 KB)
NAVSTAR GPS December 2012 SAR(PDF | 628 KB)
RQ-4A-B Global Hawk December 2012 SAR(PDF | 512 KB)
SBIRS High December 2012 SAR(PDF | 644 KB)
SDB II December 2012 SAR(PDF | 516 KB)
WGS December 2012 SAR(PDF | 468 KB)
SARs December 2012 - DoD
JLTV December 2012 SAR(PDF | 904 KB)
BMDS December 2012 SAR(PDF | 252 KB)
Chem Demil-ACWA December 2012 SAR(PDF | 488 KB)
F-35 December 2012 SAR(PDF | 724 KB)

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APPENDIX B.

MDAP Data Collection from Selected Acquisition Reports

This research assessed all 162 major defense acquisition programs in DOD's MDAP portfolio for our analysis of cost and schedule performance from 1995 – 2016. Major defense acquisition programs are those identified by DOD that require eventual total research, development, test, and evaluation (RDT&E) expenditures, including all planned increments, of more than $250 million, or procurement expenditures, including all planned increments, of more than $2.19 billion.

To develop observations, MDAP cost, schedule, and quantity data were obtained from DOD's December 2011 Selected Acquisition Reports (SAR). Through review of GAO Weapon Assessments and confirming selected data with program offices, the study determined that the SAR data were sufficiently reliable for our purposes. (GAO Page 155 GAO-13-294SP Assessments of Selected Weapon Programs).

SAR data is derived from the Defense Acquisition Management Information Retrieval Purview system (DAMIR) -- a DoD initiative that provides enterprise visibility to Acquisition program information. DAMIR streamlines acquisition management and oversight by leveraging web services, authoritative data sources, data collection, and data repository capabilities. DAMIR identifies various data sources that the Acquisition community uses to manage MDAP. DAMIR is the authoritative source for SAR, SAR Baseline, Acquisition Program Baselines (APB), and Assessments." (http://www.acq.osd.mil/damir/).

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Table B-1 MDAP Database (n=162)

MDAP	MDAP Full Name	MDAP LEAD	M/S I Year, Start	M/S II Year, Start	M/S III Year, Start	Initial LCCE $M	Product Quantity	Product Cost, $M/unit	SIOS Type	Schedule Breach	Performance Breach	Cost Breach	Disposition
AAWS (Later JAVELIN)	Advanced Anti-Tank Weapon System-Medium (Javelin), Close Combat Missile System– Medium (CCMS–M)	Army	May-86	Jun-89	Jun-94	$ 4,924.00	25,463	$ 0	6. Govt PM and SI	y	y	y	P
Abrams M-1A2	Abrams Tank Upgrade	Army	Jan-94	Jan-94	Jan-95	$ 7,794.20	1,155	$ 7	2. Shared PM and SI (Govt, Industry)	n	n	n	P
ACS	Aerial Common Sensor	Army	Jul-99	Terminated 2009	Terminated	$ 1,227.90	38	$ 32	2. Shared PM and SI (Govt, Industry)	n	n	y	T
ADS (AN/WQR-3)	AN/WQR-3 Advanced Deployable System (ADS) Buoy ADS (AN/WQR-3)	Navy	Oct-92	Terminated 2012	Terminated 2012	$ 528.80	1	$ 529	6. Govt PM and SI	n	n	y	T
AEHF SV1-4, SV5-6	Advanced Extremely High Frequency Satellite - BLOCK 1-4,5-6	Air Force	Apr-99	Sep-01	Jun-15	$ 14,082.80	6	$ 2,347	2. Shared PM and SI (Govt, Industry)	y	n	n	P
AESA (RDT&E)	APG-79 Active Electronically Scanned Array (AESA) Radar System(RDT&E)	Navy	Oct-98	Oct-00	Oct-04	$ 579.90	573	$ 1	6. Govt PM and SI	n	n	n	P
AGM-154 JSOW BASELINE/BLU-108	Joint Standoff Weapon - Baseline Variant and Unitary Warhead Variant	Navy	Jun-89	Apr-95	Dec-04	$ 5,873.00	10,334	$ 1	3. Non-Govt PM and SoS Integrator	n	n	n	p
AGM-88E AARGM	AGM-88E Advanced Anti-Radiation Guided Missile	Navy	Jun-03	Jun-03	Sep-08	$ 2,013.00	1,919	$ 1	6. Govt PM and SI	N	N	N	P
AH-64E New Build (AB3)	Apache Block IIIB New Build	Army	Jul-06	Jul-06	Sep-10	$ 2,484.50	56	$ 44	6. Govt PM and SI	N	N	y	P
AH-64E Remanufacture (AB3)	Apache Block IIIA Remanufacture	Army	Jan-96	Jul-06	Sep-10	$ 13,760.20	639	$ 22	6. Govt PM and SI	N	N	N	P
AIM-120 AMRAAM	AIM-120 Advanced Medium Range Air-to-Air Missile	Air Force	Nov-78	Sep-82	Apr-91	$ 20,133.00	16,253	$ 1	7. Industry PM & Systems Integrator	y	n	n	P
AIM-9X Blk II	AIM-9X Block II Air-to-Air Missile	Navy	Jan-04	Mar-07	Jun-11	$ 4,335.70	6,000	$ 1	6. Govt PM and SI	n	n	y	P
AMDR	Air and Missile Defense Radar (AMDR)	Navy	Sep-10	Oct-13	Sep-17	$ 5,192.60	22	$ 236	6. Govt PM and SI	N	N	N	P
AMPV	Armored Multi-Purpose Vehicle	Army	Oct-11	Dec-14	Jan-19	$ 12,467.01	3,198	$ 4	7. Industry PM & Systems Integrator	N	N	N	P
AN/SQQ-89	AN/SQQ-89A(V) Integrated Anti-Submarine Warfare (ASW) Combat Systems Suite	Navy	Jan-85	Jan-90	Jan-97	$ 4,141.50	91	$ 46	7. Industry PM & Systems Integrator	n	n	n	p
ARH	Armed Reconnaissance Helicopter	Army	Jun-04	Terminated 2009	Terminated	$ 536.70	1	$ 537	7. Industry PM & Systems Integrator	n	n	y	T
ASDS	Advanced Seal Delivery System (ASDS)	Navy	Jan-93	Terminated 2003	Terminated 2003	$ 737.70	1	$ 738	7. Industry PM & Systems Integrator	y	y	y	T
ASIP	Airborne Signals Intelligence Payload (ASIP	Air Force	Dec-02	Jan-05	Oct-10	$ 508.00	4	$ 127	3. Non-Govt PM and SoS Integrator	n	n	y	p
ATACMS BAT	Army Tactical Missile System (ATACMS) M39 Block 1- BAT	Army	Jan-91	Oct-95	Terminated	$ 2,430.20	1,462	$ 2	7. Industry PM & Systems Integrator	n	n	y	T
ATIRCM CMWS	Advanced Threat Infrared Countermeasure/Common Missile Warning System(CMWS) 219B	Army	Jun-96	Jun-96	Nov-03	$ 3,607.80	2,020	$ 2	6. Govt PM and SI	n	n	n	C
ATIRCM QRC	Advanced Threat Infrared Countermeasure/Common Missile Warning System - QRC 219C	Army	Jun-95	Sep-09	Oct-14	$ 1,006.60	83	$ 12	2. Shared PM and SI (Govt, Industry)	n	n	n	C
AV-8B Harrier REMANUFACTURE	AV-8B single seat Vertical/Short Takeoff and Land(V/STOL" strike aircraft REMANUFACTURE	Navy	Dec-73	Dec-76	Terminated	$ 2,169.10	74	$ 29	3. Non-Govt PM and SoS Integrator	n	n	n	T
AWACS Blk 40/45 Upgrade	Airborne Warning and Control System (AWACS) Block 40/45 Upgrade	Air Force	Jul-00	Jul-03	Jan-09	$ 2,753.10	31	$ 89	1. Industry LSI	N	N	N	P
AWACS RSIP (E-3)	Airborne Warning and Control System (AWACS) Upgrades (Includes AWACS RSIP (E-3))	Air Force	Mar-96	Mar-99	Jun-05	$ 1,005.10	32	$ 31	1. Industry LSI	n	n	n	P
B-1B CMUP	B-1B Lancer Conventional Mission Upgrade Program (CMUP)	Air Force	Oct-94	Oct-00	Mar-03	$ 647.70	60	$ 11	2. Shared PM and SI (Govt, Industry)	n	n	n	p
B-2 EHF Inc 1	B-2 Extremely High Frequency SATCOM and Computer Increment 1	Air Force	Mar-02	Feb-07	Feb-12	$ 559.70	20	$ 28	7. Industry PM & Systems Integrator	n	n	n	P
B-2 EHF Inc 2	B-2 Extremely High Frequency SATCOM and Computer Increment 2	Air Force	Mar-02	Feb-07	Mar-13	$ 1,796.70	20	$ 90	7. Industry PM & Systems Integrator	N	N	N	P
B-2 RMP	B-2 Radar Modernization Program (RMP)	Air Force	Oct-02	Aug-04	Dec-08	$ 1,225.10	20	$ 61	7. Industry PM & Systems Integrator	Y	N	N	C
B61 Mod 12 LEP TKA	B61 Modification 12 Life Extension Program (LEP) Tailkit Assembly (TKA)	Air Force	Jun-08	Nov-12	Apr-18	$ 1,451.80	890	$ 2	6. Govt PM and SI	N	N	N	P
Black Hawk Upgrade UH-60M	UH-60M Black Hawk Helicopter	Army	Mar-01	Mar-01	Mar-05	$ 28,860.60	1,375	$ 21	2. Shared PM and SI (Govt, Industry)	n	n	y	P
BMDS: ABL	ABL (Airborne Laser) - Ballistic Missile Defense System Technology Program	Air Force	Nov-96	Apr-01	Terminated	$ 3,545.50	2	$ 1,773	7. Industry PM & Systems Integrator	Y	Y	Y	T
BMDS: GMD	BMDS: Ground-Based Midcourse Defense (GMD)	DoD	Feb-95	Feb-96	Dec-02	$ 38,082.40	1	$ 38,082	6. Govt PM and SI	y	n	n	p

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BMDS: RIM-66C SM-2	Ballistic Missile Defense System: RIM-66C Standard Missile-2 Blocks III/IIIA/IIIB SM-2	Navy	Jan-84	Dec-86	Feb-92	$ 893.90	160	$ 6	2. Shared PM and SI (Govt, Industry)	n	n	n	P
BMDS: SM-3	Ballistic Missile Defense System: Aegis Ballistic Missile Defense Standard Missile-3 Block IB	DoD	Nov-00	Mar-07	Jan-09	$ 4,307.80	367	$ 12	6. Govt PM and SI	N	N	N	P
BMDS: SM-6	Ballistic Missile Defense System: Standard Missile-6 (SM-6) Extended Range Active Missile (ERAM)	Navy	Jun-04	Mar-06	Aug-09	$ 6,467.00	1,200	$ 5	6. Govt PM and SI	Y	N	N	P
BMDS: THAAD	Ballistic Missile Defense System: THAAD (Theater High Altitude Area Defense)	DoD	Jan-92	Oct-01	Jan-06	$ 16,813.50	1,250	$ 13	6. Govt PM and SI	N	N	N	P
C-130 AMP	C-130 Avionics Modernization Program (AMP)	Air Force	Jul-01	Aug-05	Terminated	$ 2,199.60	9	$ 244	6. Govt PM and SI	Y	N	N	T
C-130J Hercules	C-130J Hercules Transport Aircraft	Air Force	Jul-01	Aug-05	Jun-10	$ 15,539.30	168	$ 92	2. Shared PM and SI (Govt, Industry)	n	n	n	P
C-17A	C-17A- GLOBEMASTER III Advanced Cargo Aircraft Program.	Air Force	Nov-80	Feb-84	Jan-89	$ 69,570.80	223	$ 312	7. Industry PM & Systems Integrator	n	n	n	C
C-27J JCA	C-27J Joint Cargo Aircraft (JCA) Spartan	Air Force	n/a	n/a	Terminated 2013	$ 2,289.40	38	$ 60	7. Industry PM & Systems Integrator	y	n	n	T
C-5 AMP	C-5 AMP	Air Force	Jan-00	May-02	Oct-06	$ 1,147.90	80	$ 14	7. Industry PM & Systems Integrator	n	n	n	C
C-5 RERP	C-5 Reliability Enhancement and Re-engining Program	Air Force	Feb-00	Nov-01	Mar-08	$ 7,400.80	52	$ 142	6. Govt PM and SI	N	N	N	P
CEC	Cooperative Engagement Capability	Navy	May-95	May-95	Apr-02	$ 4,696.60	252	$ 19	7. Industry PM & Systems Integrator	n	n	y	P
CH-47F	CH-47F Improved Cargo Helicopter	Army	Dec-97	Dec-97	Nov-04	$ 14,387.00	532	$ 27	7. Industry PM & Systems Integrator	N	N	N	P
CH-53K	CH-53K Heavy Lift Replacement Helicopter	Navy	Nov-03	Dec-05	Feb-16	$ 28,524.40	200	$ 143	6. Govt PM and SI	N	N	N	P
Chem Demil CMA	Chemical Demilitarization-U.S. Army Chemical Materials Agency (Chem Demil-CMA) NEWPORT	DoD	Dec-96	Dec-96	Nov-00	$ 24,863.30	29,060	$ 1	2. Shared PM and SI (Govt, Industry)	y	n	n	C
Chem Demil-ACWA	Chemical Demilitarization-Assembled Chemical Weapons Alternatives	DoD	Jan-85	Jan-03	Dec-13	$ 10,653.40	3,136	$ 3	6. Govt PM and SI	N	N	N	P
CJR COBRA JUDY REPLACEMENT	COBRA JUDY REPLACEMENT	Navy	Oct-03	Oct-03	Sep-13	$ 1,714.20	1	$ 1,714	6. Govt PM and SI	y	n	y	C
Comanche	Comanche Reconnaissance Attack Helicopter (RAH-66)	Army	Jun-88	Apr-00	Terminated	$ 39,319.10	650	$ 60	2. Shared PM and SI (Govt, Industry)	n	y	n	T
Crusader	Crusader	Army	Oct-94	Terminated	Terminated	$ 4,286.30	480	$ 9	6. Govt PM and SI	n	y	n	T
CVN 21 (RDT&E)	CVN 21 CARRIER REPLACEMENT (2014)	Navy	Jun-00	May-04	Jul-07	$ 35,119.10	3	$ 11,706	3. Non-Govt PM and SoS Integrator	N	N	N	p
CVN 78 -(EMALS ?)	CVN 78 Gerald R. Ford Class Nuclear Aircraft Carrier	Navy	Jun-00	Apr-04	Mar-20	$ 39,775.10	3	$ 13,258	3. Non-Govt PM and SoS Integrator	N	N	N	P
CVN-68	CVN 68 Air Craft Carrier Nimitz-Class	Navy	Jan-68	Jan-68	#REF!	$ 6,265.80	1	$ 6,266	3. Non-Govt PM and SoS Integrator	n	n	n	p
DDG 1000 DD(X) (RDT&E)	DDG 1000 Zumwalt Class Destroyer	Navy	Jan-98	Mar-04	Jul-16	$ 21,214.20	3	$ 7,071	2. Shared PM and SI (Govt, Industry)	N	N	N	P
DDG 51	DDG 51 Arleigh Burke Class Guided Missile Destroyer	Navy	Jun-81	Dec-83	Oct-86	$ 91,234.40	77	$ 1,185	3. Non-Govt PM and SoS Integrator	N	N	Y	P
E-2C REPRODUCTION	E-2C REPRODUCTION - E-2C/D Hawkeye Airborne Early Warning Aircraft	Navy	Jul-00	Jun-03	Oct-10	$ 4,358.30	44	$ 99	2. Shared PM and SI (Govt, Industry)	n	n	n	p
E-2D AHE	E-2D Advanced Hawkeye Aircraft	Navy	Jun-03	Jun-03	May-09	$ 20,455.80	75	$ 273	6. Govt PM and SI	N	N	N	P
EA-18G	EA-18G Growler Aircraft	Navy	Aug-02	Dec-03	Jul-07	$ 13,084.20	135	$ 97	6. Govt PM and SI	N	N	Y	P
EELV	Evolved Expendable Launch Vehicle	Air Force	Dec-96	Jun-98	Feb-13	$ 67,622.40	163	$ 415	6. Govt PM and SI	N	N	N	P
EFV	Expeditionary Fighting Vehicle (EFV) [formerly Advanced Amphibious Assault (AAAV)]	Navy	Dec-00	Jul-08	Terminated	$ 3,329.60	20	$ 166	6. Govt PM and SI	N	Y	N	T
ERM	Extended Range Munition	Navy	Jul-96	Terminated 2008	Terminated	$ 1,521.40	15,100	$ 0	6. Govt PM and SI	n	y	n	T
Excalibur	Excalibur Precision 155mm Projectiles	Army	May-97	May-97	May-05	$ 1,697.80	7,852	$ 0	6. Govt PM and SI	N	N	N	P
F/A-18E/F	F/A-18E/F Super Hornet Aircraft	Navy	May-92	May-92	Jun-00	$ 50,058.60	552	$ 91	6. Govt PM and SI	N	N	N	C
F-22	F-22 Raptor Advanced Tactical Fighter Aircraft	Air Force	Oct-86	Jun-91	Mar-05	$ 67,337.00	188	$ 358	1. Industry LSI	n	n	y	C

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F-35 JSF Aircraft (SUB-PROGRAM)	F-35 Joint Strike Fighter Aircraft AIRCRAFT SUB-PROGRAM LIGHTNING II	DoD	Nov-96	Oct-01	Apr-19	$ 338,949.60	2,457	$ 138	3. Non-Govt PM and SoS Integrator	N	N	Y	P
FAB-T	Family of Beyond Line-of-Sight - Terminals	Air Force	Sep-02	Jan-09	Feb-14	$ 4,819.90	259	$ 19	6. Govt PM and SI	y	n	y	P
FBCB2	Force XXI Battle Command Brigade and Below	Army	Jan-06	Dec-10	Nov-11	$ 3,817.60	90,068	$ 0	2. Shared PM and SI (Govt, Industry)	N	N	Y	C
FCS	FUTURE COMBAT SYSTEMS	Army	May-00	May-03	Terminated	$ 159,320.20	15	$ 10,621	1. Industry LSI	y	y	y	T
FMTV	Family of Medium Tactical Vehicles	Army	May-87	May-87	Mar-93	$ 16,697.70	80,228	$ 0	2. Shared PM and SI (Govt, Industry)	N	N	Y	C
G/ATOR	Ground/Air Task Oriented Radar	Navy	Aug-05	Aug-05	Dec-13	$ 2,413.80	45	$ 54	6. Govt PM and SI	N	N	N	P
GBS	Global Broadcast Service	Air Force	Nov-97	Nov-97	Dec-03	$ 1,107.10	1,926	$ 1	6. Govt PM and SI	y	n	y	P
GMLRS/GMLRS AW	Guided Multiple Launch Rocket System/Guided Multiple Launch Rocket System Advanced Warhead	Army	Jul-98	Jul-98	Oct-03	$ 6,693.90	43,936	$ 0	2. Shared PM and SI (Govt, Industry)	N	Y	N	C
GPS OCX	Global Positioning System's Next Generation Operational Control System (GPS OCX)	Air Force	Feb-07	Nov-12	Oct-15	$ 3,412.40	1	$ 3,412	6. Govt PM and SI	N	N	N	P
GSM PORTION OF CGS	Common Ground System (CGS)	Army	Oct-95	Oct-96	Oct-97	$ 797.10	96	$ 8	2. Shared PM and SI (Govt, Industry)	n	n	n	C
H-1 Upgrades	H-1 Upgrades (4BW/4BN)	Navy	Oct-96	Oct-96	Sep-08	$ 12,724.40	353	$ 36	7. Industry PM & Systems Integrator	n	n	n	P
HC/MC-130 Recap	HC/MC-130 Recapitalization Aircraft	Air Force	Nov-96	Nov-08	Apr-10	$ 14,807.60	131	$ 113	7. Industry PM & Systems Integrator	N	N	N	P
HIMARS	High Mobility Artillery Rocket System	Army	Dec-99	Dec-99	Mar-03	$ 1,990.80	381	$ 5	2. Shared PM and SI (Govt, Industry)	n	n	n	C
IAMD	Integrated Air and Missile Defense	Army	Feb-06	Dec-09	Jun-15	$ 6,375.20	447	$ 14	3. Non-Govt PM and SoS Integrator	N	N	N	P
IAV - STRYKER	STRYKER: INTERIM ARMORED VEHICLE (IAV) Family of Stryker vehicles	Army	Aug-05	Aug-05	Aug-07	$ 16,280.00	4,536	$ 4	6. Govt PM and SI	N	N	N	P
IDECM Blocks 4	Integrated Defensive Electronic Countermeasures - BLOCK 4	Navy	May-08	Dec-09	Mar-12	$ 926.70	190	$ 5	6. Govt PM and SI	y	n	n	P
IMS Scorpion	Intelligent Munitions System-Scorpion	Army	May-06	May-06	Dec-11	$ 1,685.20	2,624	$ 1	6. Govt PM and SI	N	N	N	C
INCREMENT 1 E-IBCT	Increment 1 Early-Infantry Brigade Combat Team (E-IBCT)	ARMY	Jan-03	Jul-04	Dec-09	$ 1,269.60	3	$ 423	2. Shared PM and SI (Govt, Industry)	n	n	n	C
JAGM	Joint Air-to-Ground Missile	Army	Sep-08	Mar-12	Mar-16	$ 2,005.70	1,919	$ 1	6. Govt PM and SI	N	N	N	P
JASSM - (ER)	Joint Air-to-Surface Standoff Missile (ER)	Air Force	Jun-96	Jun-03	Jan-11	$ 4,360.00	2,877	$ 2	6. Govt PM and SI	N	N	N	P
JCM	Joint Common Missile	Army	Oct-01	Terminated 2004	Terminated	$ 6,858.80	48,815	$ 0	2. Shared PM and SI (Govt, Industry)	n	n	y	T
JDAM	Joint Direct Attack Munition	Air Force	Oct-93	Sep-95	Mar-01	$ 6,441.80	241,890	$ 0	2. Shared PM and SI (Govt, Industry)	n	n	y	P
JHSV	Joint High Speed Vessel	Navy	Apr-06	Oct-08	Dec-09	$ 2,178.30	10	$ 218	6. Govt PM and SI	Y	N	N	P
JLENS	Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System	Army	Aug-05	Aug-05	Jan-12	$ 2,645.80	2	$ 1,323	2. Shared PM and SI (Govt, Industry)	Y	n	Y	C
JLTV	Joint Light Tactical Vehicle (JLTV)	DoD	Dec-07	Aug-12	May-15	$ 31,108.20	54,730	$ 1	6. Govt PM and SI	N	N	N	P
Joint MRAP	Joint Mine Resistant Ambush Protected (MRAP) vehicle	Navy	Jan-07	Jan-07	Jan-07	$ 40,906.50	26,552	$ 2	6. Govt PM and SI	n	n	n	C
JPALS Inc 1A	Joint Precision Approach and Landing System Increment 1A	Navy	Jul-08	Jul-08	Nov-13	$ 1,102.80	37	$ 30	6. Govt PM and SI	y	n	y	P
JPATS	Joint Primary Aircraft Training System	Air Force	Jan-93	Aug-95	Dec-01	$ 5,301.20	752	$ 7	2. Shared PM and SI (Govt, Industry)	n	n	n	C
JSIMS	Joint Simulation System (JSIMS)	DoD	Jan-02	Sep-03	Terminated	$ 1,293.30	1	$ 1,293	6. Govt PM and SI	y	y	n	T
JSTARS	E-8 Joint Surveillance Target Attack Radar System (JSTARS)	Air Force	Jan-82	Aug-89	Oct-96	$ 9,642.00	18	$ 536	2. Shared PM and SI (Govt, Industry)	n	y	n	p
JTN	Joint Tactical Networks	Army	Jun-02	Jun-02	Oct-06	$ 2,084.30	1	$ 2,084	6. Govt PM and SI	y	n	n	P
JTRS AMF	Joint Tactical Radio System Airborne & Maritime/Fixed Station	DoD	Mar-08	Nov-09	Oct-15	$ 8,160.80	21,102	$ 0	7. Industry PM & Systems Integrator	N	N	Y	P

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JTRS GMR	Joint Tactical Radio System Ground Mobile Radio (JTRS-GMR)	DoD	Jan-97	Jun-02	Terminated	$ 4,374.10	11,030	$ 0	6. Govt PM and SI	Y	N	Y	T
JTRS HMS	Joint Tactical Radio System Handheld, Manpack, and Small Form Fit Radios	DoD	Apr-04	Apr-04	May-11	$ 10,191.10	271,202	$ 0	6. Govt PM and SI	y	n	n	P
JTRS NED	Joint Tactical Radio System Network Enterprise Domain	DoD	Jun-02	Jun-02	Dec-09	$ 1,992.60	1	$ 1,993	6. Govt PM and SI	Y	N	N	P
JTRS WAVEFORM (RDT&E)	Joint Tactical Radio System (JTRS) Waveforms, Cluster 1 and 5 and Airborne and Maritime/Fixed Stations (AMF)	DoD	Jun-02	Oct-02	Oct-07	$ 2,104.10	1	$ 2,104	2. Shared PM and SI (Govt, Industry)	N	N	N	P
JTUAV	Joint Tactical Unmanned Aerial Vehicles-JTUAV (close, medium and short range)	DoD	Jan-88	Jan-92	Terminated	$ 787.60	9	$ 88	2. Shared PM and SI (Govt, Industry)	n	y	n	T
KC-130J	KC-130J Transport Aircraft	Navy	Jun-92	Jun-92	Jun-96	$ 10,528.90	10	$ 1,053	7. Industry PM & Systems Integrator	n	n	N	P
KC-46A	KC-46A Tanker Modernization	Air Force	Feb-11	Feb-11	Aug-15	$ 49,460.60	179	$ 276	6. Govt PM and SI	n	n	y	P
LAIRCM	Large Aircraft Infrared Countermeasures (LAIRCM),	Air Force	Sep-01	Sep-01	Aug-02	$ 413.20	8	$ 52	3. Non-Govt PM and SoS Integrator	n	n	n	C
Land Warrior	Land Warrior	Army	Aug-94	Terminated 2004	Terminated	$ 671.40	440	$ 2	3. Non-Govt PM and SoS Integrator	n	n	n	T
LCS	Littoral Combat Ship AND MISSION PACKAGES (LCS MP)	Navy	May-04	Feb-11	Jan-12	$ 33,955.50	52	$ 653	3. Non-Govt PM and SoS Integrator	n	n	y	P
LHA 6	LHA 6 America Class Amphibious Assault Ship	Navy	Jul-01	Jan-06	Apr-16	$ 11,319.40	3	$ 3,773	6. Govt PM and SI	n	n	y	P
LHD-1	LHD 1 Wasp-Class Amphibious Assault Ship (AAS)	Navy	Jan-89	Jan-91	Jan-92	$ 10,001.00	8	$ 1,250	3. Non-Govt PM and SoS Integrator	n	n	n	C
Longbow HELLFIRE	MMW radar Longbow HELLFIRE-AGM-114L	Army	Jan-74	Jan-82	Jan-92	$ 2,509.30	12,905	$ 0	6. Govt PM and SI	n	n	n	p
LPD 17	LPD 17 San Antonio Class Amphibious Transport Dock	Navy	Jan-93	Jun-96	Apr-16	$ 18,842.30	11	$ 1,713	7. Industry PM & Systems Integrator	n	n	n	P
LUH	Light Utility Helicopter - uh-72A	Army	Mar-07	Mar-07	Jun-06	$ 1,809.30	315	$ 6	7. Industry PM & Systems Integrator	n	n	Y	C
M109A7	M109A7 Family of Vehicles	Army	Jun-07	Dec-08	Oct-13	7083.2	558	$ 13	6. Govt PM and SI	n	n	n	p
M2 BRADLEY	M2/M3 Bradley Fighting Vehicle Systems (FVS) Upgrade	Army	Jan-93	Jan-04	Jan-10	$ 9,695.20	2,568	$ 4	6. Govt PM and SI	n	n	n	P
MH-60R	MH-60R Multi-Mission Helicopter	Navy	Jul-93	Jul-93	Mar-06	$ 13,461.70	280	$ 48	2. Shared PM and SI (Govt, Industry)	n	n	n	P
MH-60S	MH-60S Fleet Combat Support Helicopter	Navy	Jul-98	Jul-98	Aug-02	$ 7,891.80	275	$ 29	2. Shared PM and SI (Govt, Industry)	y	n	y	C
MIDS-LVT JTRS	Multi-Functional Information Distribution System Joint Tactical Radio System	Navy	Dec-93	Dec-04	Dec-09	$ 3,336.20	6,233	$ 1	6. Govt PM and SI	n	n	y	P
MM III GRP	MINUTEMAN III Guidance Replacement Program (GRP)	Air Force	Jan-64	Aug-93	Mar-98	$ 2,427.70	652	$ 4	7. Industry PM & Systems Integrator	n	n	n	C
MM III PRP	MINUTEMAN III Propulsion Replacement Program (PRP)	Air Force	Jan-64	Jun-94	Oct-99	$ 2,601.80	601	$ 4	7. Industry PM & Systems Integrator	n	n	n	C
MP-RTIP	Multi-Platform Radar Technology Insertion Program (MP-RTIP)	Air Force	Oct-98	Oct-03	Oct-10	$ 1,303.80	1	$ 1,304	2. Shared PM and SI (Govt, Industry)	y	n	n	C
MQ-1C UAS Gray Eagle	MQ-1C Gray Eagle Unmanned Aircraft System	Army	Apr-05	Apr-05	Mar-11	$ 4,888.90	31	$ 158	6. Govt PM and SI	Y	n	n	P
MQ-4C BAMS UAS	MQ-4C Broad Area Maritime Surveillance Unmanned Aircraft System	Navy	Apr-08	Apr-08	Jan-13	$ 13,052.40	70	$ 186	6. Govt PM and SI	N	N	N	P
MQ-4C Triton	MQ-4C Triton Unmanned Aircraft System	Navy	Apr-08	Apr-08	Nov-14	$ 15,268.20	70	$ 218	6. Govt PM and SI	y	n	y	P
MQ-8 (Fire Scout)	MQ-8 (Fire Scout)	Navy	Jan-00	Jan-00	Nov-05	$ 3,060.60	126	$ 24	6. Govt PM and SI	N	N	Y	P
MQ-9 UAS Reaper	MQ-9 Reaper Unmanned Aircraft System	Air Force	Jan-02	Feb-04	Feb-08	$ 11,866.40	346	$ 34	2. Shared PM and SI (Govt, Industry)	n	n	y	P
MUOS	Mobile User Objective System	Navy	Sep-02	Sep-04	Aug-06	$ 7,133.80	6	$ 1,189	3. Non-Govt PM and SoS Integrator	N	N	N	P
NAS	National Airspace System	Air Force	Jul-92	Jul-95	Jun-05	$ 1,446.80	88	$ 16	6. Govt PM and SI	n	n	n	C
NAVSTAR GPS - (Space&Control +	NAVSTAR Global Positioning System Space and Control	Air Force	Jun-89	Feb-00	May-03	$ 7,995.80	33	$ 242	2. Shared PM and SI (Govt, Industry)	y	n	n	C
Navstar GPS IIIA	Navtar Global Positioning Satellite IIIA	Air Force	Mar-01	May-08	Jan-11	$ 4,250.80	8	$ 531	6. Govt PM and SI	n	n	n	P

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Table B-1 MDAP Database (n=162)

MDAP	MDAP Full Name	MDAP LEAD	M/S I Year, Start	M/S II Year, Start	M/S III Year, Start	Initial LCCE $M	Product Quantity	Product Cost, $M/unit	SIOS Type	Schedule Breach	Performance Breach	Cost Breach	Disposition
NESP AN/USC-38 - Navy EHF SATCOM	Navy Extremely High Frequency (EHF) Satellite Program	Navy	Jan-96	Jan-96	Oct-99	$ 2,057.90	507	$ 4	6. Govt PM and SI	N	N	N	P
NMD (National Missile Defense)	NMD (National Missile Defense)	DoD	Apr-96	Apr-96	Oct-99	$ 20,252.20	1	$ 20,252	3. Non-Govt PM and SoS Integrator	n	y	y	P
NMT	Navy (Advanced Extremely High Frequency) Multiband Terminal Satellite (formerly Navy Extremely High	Navy	Oct-03	Oct-03	Aug-10	$ 1,902.90	278	$ 7	6. Govt PM and SI	N	N	N	P
NPOESS	National Polar-Orbiting Operational Environmental Satellite System (NPOESS)	Air Force	Mar-97	Aug-02	Terminated 2011	$ 3,130.60	1	$ 3,131	6. Govt PM and SI	y	n	n	T
NTW TBMD	(Navy Theater Wide) Navy Area Theater Ballistic Missile Defense) [COMBINED WITH RDTE- 1994]	DOD	Mar-96	Oct-01	Terminated	$ 6,811.20	1,500	$ 5	1. Industry LSI	y	y	y	T
P-8A MMA	P-8A Poseidon Multi-Mission Maritime Aircraft	Navy	Mar-00	May-04	Aug-10	$ 34,935.00	122	$ 286	6. Govt PM and SI	N	N	N	P
Patriot PAC-3	Patriot Advanced Capability-3	Army	May-94	May-94	Oct-02	$ 11,007.30	1,354	$ 8	3. Non-Govt PM and SoS Integrator	n	n	y	C
Patriot/MEADS CAP - FIRE UNIT +Missile	Patriot/Medium Extended Air Defense System Combined Aggregate Program- MISSILE	Army	Jan-03	Aug-04	Nov-12	$ 9,666.90	1,528	$ 6	3. Non-Govt PM and SoS Integrator	y	n	y	P
PIM	Paladin Integrated Management	Army	Jul-98	Jun-07	Jun-13	$ 7,904.20	582	$ 14	6. Govt PM and SI	n	n	n	P
PLS	Palletized Load System (PLS) and PLS Extended Service Program (ESP) Armored Truck – Palletized Loading System	Army	Oct-09	Oct-09	Oct-09	$ 1,237.20	2,857	$ 0	7. Industry PM & Systems Integrator	n	n	n	p
RMS	Remote Minehunting System	Navy	Dec-99	Dec-99	May-14	$ 1,449.40	54	$ 27	2. Shared PM and SI (Govt, Industry)	N	N	N	P
RQ-4A/B Global Hawk MQ-4C /NATO	RQ-4A/B Global Hawk Unmanned Aircraft System	Air Force	Feb-94	Mar-01	Aug-11	$ 9,009.30	45	$ 200	3. Non-Govt PM and SoS Integrator	Y	Y	Y	P
SADARM	Sense and Destroy ARMor (SADARM) Rocket	Army	Jan-87	Mar-95	Terminated	$ 739.90	1,252	$ 1	6. Govt PM and SI	n	n	y	T
SBIRS High - Baseline (GEO 1-4,	Space Based Infrared System High (GEO 1-4, 5-6)	Air Force	Feb-95	Oct-96	Aug-01	$ 13,572.40	4	$ 3,393	6. Govt PM and SI	N	N	N	P
SBSS BLOCK 10	Space Based Space Surveillance (SBSS) Block 10 satellite,	Air Force	Feb-02	Sep-03	Nov-06	$ 917.70	1	$ 918	2. Shared PM and SI (Govt, Industry)	y	N	N	C
SDB I	Small Diameter Bomb I (SDB I)	Air Force	Aug-01	Oct-03	Sep-06	$ 1,476.90	24,070	$ 0	2. Shared PM and SI (Govt, Industry)	n	n	n	C
SDB II	Small Diameter Bomb Increment II	Air Force	May-06	Jul-10	Jan-14	$ 4,185.40	17,163	$ 0	6. Govt PM and SI	Y	N	N	P
SFW	Sensor-Fuzed Weapon	Air Force	Oct-84	Oct-86	Oct-95	$ 1,920.90	4,920	$ 0	2. Shared PM and SI (Govt, Industry)	Y	N	N	C
SMART-T	Secure Mobile Anti-Jam Reliable Tactical–Terminal (SMART–T)	Army	Jan-91	May-92	Feb-96	$ 971.00	278	$ 3	3. Non-Govt PM and SoS Integrator	n	n	n	p
SSBN/SSGN	nuclear- powered ballistic missile submarines (SSBNs) nuclear-powered guided-missile submarines SSGN (ohio classs)	Navy	Jan-11	Dec-11	Dec-11	$ 4,108.50	4	$ 1,027	2. Shared PM and SI (Govt, Industry)	n	n	n	P
SSC	Ship to Shore Connector Amphibious Craft	Navy	May-09	Jul-12	Nov-14	$ 4,764.60	73	$ 65	6. Govt PM and SI	N	N	N	P
SSDS MK-1 Portion	MK 1 - SSDS ship self defense system	Navy	Jan-87	May-95	Jan-98	$ 668.90	42	$ 16	6. Govt PM and SI	n	y	n	C
SSN 774	SSN 774 Virginia Class Submarine	Navy	Aug-94	Jun-95	Dec-08	$ 91,847.40	30	$ 3,062	3. Non-Govt PM and SoS Integrator	Y	N	N	P
STRATEGIC SEALIFT Program	STRATEGIC SEALIFT Program 19 large,medium-speed roll-on/roll-off (RO/RO) (LMSR) vessels, four classes natl steel shipbuilding co	Navy	Oct-93	Oct-93	Oct-02	$ 6,154.60	20	$ 308	3. Non-Govt PM and SoS Integrator	n	n	n	p
T-45TS	Naval Aviation Training Aircraft (Goshawk)	Navy	Oct-09	Oct-09	Oct-09	$ 6,828.20	223	$ 31	2. Shared PM and SI (Govt, Industry)	n	n	n	C
TACTOM Tactical Tomahawk	Tactical Tomahawk RGM-109E/UGM 109E Missile	Navy	Jun-98	Jun-98	Aug-04	$ 7,109.00	4,961	$ 1	2. Shared PM and SI (Govt, Industry)	n	n	n	P
T-AKE	T- AKE dry cargo/ammunition ship	Navy	#REF!	#REF!	#REF!	$ 6,859.50	14	$ 490	7. Industry PM & Systems Integrator	n	n	n	C
T-AOE	AOE Fast Combat Support Multi-Product Station Ship	Navy	Jan-96	Jan-96	Jan-96	$ 2,424.70	4	$ 606	7. Industry PM & Systems Integrator	Y	n	y	C
Trident II Missile	Trident II (D-5) Sea-Launched Ballistic Missile UGM 133A	Navy	Oct-77	Oct-83	Apr-87	$ 41,506.10	561	$ 74	2. Shared PM and SI (Govt, Industry)	y	n	n	P
TSAT (LEGACY)	Transformational Satellite Communications System (TSAT)	Air Force	Apr-99	Sep-01	TERMINATED 4/1/2009	$ 18,920.70	6	$ 3,153	7. Industry PM & Systems Integrator	Y	Y	Y	T
TWS	Night Vision Thermal Systems–Thermal Weapon Sight family	Army	Jan-81	Dec-90	Jun-98	$ 2,953.70	237,788	$ 0	6. Govt PM and SI	n	n	n	C
V-22	V-22 Osprey Joint Services Advanced Vertical Lift Aircraft	Navy	Dec-82	Apr-86	Oct-05	$ 55,061.80	459	$ 120	3. Non-Govt PM and SoS Integrator	n	n	n	P

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MDAP	MDAP Full Name	MDAP LEAD	M/S I Year, Start	M/S II Year, Start	M/S III Year, Start	Initial LCCE $M	Product Quantity	Product Cost, $M/unit	SIOS Type	Schedule Breach	Performance Breach	Cost Breach	Disposition
VH-71	VH-71 Presidential Helicopter Replacement Program	Navy	Jan-03	Terminated 10/1/2009	Terminated 10/1/2009	$ 6,750.20	28	$ 241	7. Industry PM & Systems Integrator	y	n	y	T
VTUAV	MQ-8 Vertical Takeoff and Landing Tactical Unmanned Aerial Vehicle Fire Scout	Navy	Jan-00	Jan-00	May-07	$ 3,156.80	175	$ 18	6. Govt PM and SI	y	n	n	P
WGS	Wideband Gapfiller Satellite (aka, Wideband Global SATCOM (WGS))	Air Force	Nov-00	Nov-00	Jan-09	$ 3,822.60	8	$ 478	2. Shared PM and SI (Govt, Industry)	y	n	y	P
WIN-T Inc 1	Warfighter Information Network-Tactical Increment 1	Army	Jul-03	Jun-09	May-11	$ 4,221.50	1,860	$ 2	2. Shared PM and SI (Govt, Industry)	Y	N	Y	C
WIN-T Inc 2	Warfighter Information Network-Tactical Increment 2	Army	Jun-07	Jun-07	Mar-10	$ 5,137.40	2,156	$ 2	2. Shared PM and SI (Govt, Industry)	n	n	n	P
WIN-T Inc 3	Warfighter Information Network-Tactical Increment 3	Army	Jul-03	Jul-03	May-16	$ 17,890.10	3,513	$ 5	2. Shared PM and SI (Govt, Industry)	y	n	n	P

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MDAP	Project Office Location	Available Resources	Acquisition Strategy	Foreign Military Sales	Novel Tech.	International Cooperative Program	Jointness	Systems Hierarchy	Product Architecture
AAWS (Later JAVELIN)	4)Gov. and industry (2> locations responsible	1) Cost cap	1)Evolutionary	Y	low	N	Army	System	Air/Missile
Abrams M-1A2	3)Government/Industry	1) Cost cap	2)Planned Improvement	Y	High	N	Army	System	Ground
ACS	2)Government	3) Technical/performance cap	3)Single Step	N	High	N	Army	System	Air/Missile
ADS (AN/WQR-3)	3)Government/Industry	3) Technical/performance cap	1)Evolutionary	N	low	N	Navy	SoS	Communication
AEHF SV1-4, SV5-6	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	1)Evolutionary	Y	low	N	USAF	System	Communication
AESA (RDT&E)	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	Navy	System	Communication
AGM-154 JSOW BASELINE/BLU-108	3)Government/Industry	1) Cost cap	1)Evolutionary	Y	low	N	Navy	SoS	Air/Missile
AGM-88E AARGM	2)Government	0) No evidence of cost, schedule, technical/	1)Evolutionary	Y	low	Y	Navy	System	Air/Missile
AH-64E New Build (AB3)	1)Industry	0) No evidence of cost, schedule, technical/	1)Evolutionary	Y	low	N	Army	System	Air/Missile
AH-64E Remanufacture (AB3)	1)Industry	1) Cost cap	1)Evolutionary	N	low	N	Army	System	Air/Missile
AIM-120 AMRAAM	4)Gov. and industry (2> locations responsible	3) Technical/performance cap	2)Planned Improvement	Y	High	N	Navy/USAF	System	Air/Missile
AIM-9X Blk II	3)Government/Industry	6) Cost, technical/ performance (CT) caps	1)Evolutionary	Y	low	N	Navy/USAF	System	Air/Missile
AMDR	3)Government/Industry	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	Navy	System	Communication
AMPV	3)Government/Industry	1) Cost cap	2)Planned Improvement	Y	High	N	Army	FOS	Ground
AN/SQQ-89	4)Gov. and industry (2> locations responsible	1) Cost cap	2)Planned Improvement	N	High	Y	Navy	SoS	Communication
ARH	3)Government/Industry	1) Cost cap	2)Planned Improvement	N	High	N	Army	System	Air/Missile
ASDS	3)Government/Industry	5) CST	1)Evolutionary	N	low	N	Navy	System	Sea
ASIP	3)Government/Industry	2) schedule cap	3)Single Step	Y	High	N	usaf	sos	Communication
ATACMS BAT	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	Army	System	Air/Missile
ATIRCM CMWS	3)Government/Industry	1) Cost cap	3)Single Step	Y	High	N	Army	System	Communication
ATIRCM QRC	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	1)Evolutionary	Y	low	N	Army	System	Communication
AV-8B Harrier REMANUFACTURE	1)Industry	1) Cost cap	2)Planned Improvement	N	High	Y	Navy	FOV	Air/Missile
AWACS Blk 40/45 Upgrade	1)Industry	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	Y	USAF	System	Air/Missile
AWACS RSIP (E-3)	1)Industry	3) Technical/performance cap	1)Evolutionary	Y	low	Y	USAF	System	Air/Missile
B-1B CMUP	4)Gov. and industry (2> locations responsible	1) Cost cap	1)Evolutionary	N	low	N	USAF	System	Air/Missile
B-2 EHF Inc 1	2)Government	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	USAF	System	Communication
B-2 EHF Inc 2	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	USAF	System	Air/Missile
B-2 RMP	1)Industry	1) Cost cap	2)Planned Improvement	N	High	N	USAF	System	Air/Missile
B61 Mod 12 LEP TKA	2)Government	4) cost, schedule	1)Evolutionary	N	low	N	USAF	FOS	Air/Missile
Black Hawk Upgrade UH-60M	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	Army	System	Air/Missile
BMDS: ABL	1)Industry	5) CST	2)Planned Improvement	N	High	N	USAF	FOS	Air/Missile
BMDS: GMD	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	DOD	FOS	Air/Missile
BMDS: RIM-66C SM-2	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	Navy	FOS	Air/Missile
BMDS: SM-3	3)Government/Industry	5) CST	1)Evolutionary	Y	low	N	DOD	FOS	Air/Missile
BMDS: SM-6	2)Government	7) Technical/performance and Schedule (TS) caps	1)Evolutionary	N	low	N	Navy	FOS	Air/Missile
BMDS: THAAD	3)Government/Industry	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	DoD	FOS	Air/Missile
C-130 AMP	2)Government	7) Technical/performance and Schedule (TS) caps	2)Planned Improvement	Y	High	N	USAF	System	Air/Missile
C-130J Hercules	3)Government/Industry	4) cost, schedule	2)Planned Improvement	Y	High	N	USAF	System	Air/Missile
C-17A	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	Y	USAF	System	Air/Missile
C-27J JCA	1)Industry	2) schedule cap	3)Single Step	N	High	N	Army/AirForce	System	Air/Missile
C-5 AMP	1)Industry	1) Cost cap	2)Planned Improvement	N	High	N	USAF	System	Air/Missile
C-5 RERP	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	USAF	System	Air/Missile
CEC	1)Industry	1) Cost cap	1)Evolutionary	N	low	N	Navy	System	Communication

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MDAP	Project Office Location	Available Resources	Acquisition Strategy	Foreign Military Sales	Novel Tech.	International Cooperative Program	Jointness	Systems Hierarchy	Product Architecture
CH-47F	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	Army	System	Air/Missile
CH-53K	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	Navy	System	Air/Missile
Chem Demil CMA	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	3)Single Step	N	High	N	DOD	Component	ChemBioNuclear
Chem Demil-ACWA	4)Gov. and industry (2> locations responsible	3) Technical/performance cap	3)Single Step	N	High	N	DOD	Component	ChemBioNuclear
CJR COBRA JUDY REPLACEMENT	4)Gov. and industry (2> locations responsible	2) schedule cap	3)Single Step	N	High	N	Navy	System	Air/Missile
Comanche	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	Army	System	Air/Missile
Crusader	3)Government/Industry	3) Technical/performance cap	2)Planned Improvement	N	High	N	Army	System	Ground
CVN 21 (RDT&E)	3)Government/Industry	0) No evidence of cost, schedule, technical/	3)Single Step	N	High	N	Navy	SoS	Sea
CVN 78 -(EMALS ?)	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	Navy	SoS	Sea
CVN-68	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	Navy	SoS	Sea
DDG 1000 DD(X) (RDT&E)	4)Gov. and industry (2> locations responsible	1) Cost cap	1)Evolutionary	N	low	N	Navy	System	Sea
DDG 51	3)Government/Industry	1) Cost cap	2)Planned Improvement	Y	High	N	Navy	System	Sea
E-2C REPRODUCTION	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	3)Single Step	N	High	N	Navy	System	Air/Missile
E-2D AHE	2)Government	1) Cost cap	2)Planned Improvement	N	High	N	Navy	System	Air/Missile
EA-18G	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	Navy	System	Air/Missile
EELV	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	USAF	FOS	Air/Missile
EFV	3)Government/Industry	3) Technical/performance cap	2)Planned Improvement	N	High	N	Navy	System	Sea
ERM	3)Government/Industry	3) Technical/performance cap	2)Planned Improvement	N	High	N	Navy	System	Air/Missile
Excalibur	2)Government	1) Cost cap	1)Evolutionary	Y	low	Y	Army	Component	Ground
F/A-18E/F	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	Navy	System	Air/Missile
F-22	1)Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	USAF	System	Air/Missile
F-35 JSF Aircraft (SUB-PROGRAM)	4)Gov. and industry (2> locations responsible	1) Cost cap	3)Single Step	Y	High	Y	Army/Navy/ USMC/ USAF	sos	Air/Missile
FAB-T	2)Government	4) cost, schedule	1)Evolutionary	N	low	N	USAF	FOS	Communication
FBCB2	4)Gov. and industry (2> locations responsible	1) Cost cap	1)Evolutionary	Y	low	N	Army	System	Communication
FCS	4)Gov. and industry (2> locations responsible	1) Cost cap	1)Evolutionary	N	low	N	Army	SOS	ALL
FMTV	4)Gov. and industry (2> locations responsible	1) Cost cap	3)Single Step	Y	High	N	Army	FOS	Ground
G/ATOR	3)Government/Industry	3) Technical/performance cap	1)Evolutionary	N	low	N	Navy	System	Communication
GBS	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	Army/Navy/Air Force/USMC	System	Communication
GMLRS/GMLRS AW	4)Gov. and industry (2> locations responsible	3) Technical/performance cap	1)Evolutionary	Y	low	N	Army	System	Air/Missile
GPS OCX	3)Government/Industry	2) schedule cap	1)Evolutionary	N	low	N	USAF	System	Communication
GSM PORTION OF CGS	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	Army	System	Ground
H-1 Upgrades	3)Government/Industry	1) Cost cap	2)Planned Improvement	N	High	N	Navy	System	Air/Missile
HC/MC-130 Recap	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	USAF	System	Air/Missile
HIMARS	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	3)Single Step	Y	High	N	Army	Component	Air/Missile
IAMD	1)Industry	1) Cost cap	1)Evolutionary	N	low	N	Army/Navy/ USMC/ USAF	SoS	Communication
IAV - STRYKER	4)Gov. and industry (2> locations responsible	1) Cost cap	2)Planned Improvement	N	High	N	Army	FOs	GROUND
IDECM Blocks 4	2)Government	0) No evidence of cost, schedule, technical/	1)Evolutionary	Y	low	NA	Navy	System	Communication
IMS Scorpion	3)Government/Industry	4) cost, schedule	3)Single Step	N	High	N	Army	System	Communication
INCREMENT 1 E-IBCT	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	Army	FOS	Ground
JAGM	3)Government/Industry	1) Cost cap	1)Evolutionary	Y	low	N	Army/Navy	System	Air/Missile
JASSM - (ER)	2)Government	3) Technical/performance cap	2)Planned Improvement	N	High	N	Navy/USAF	System	Air/Missile
JCM	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	Y	Army	System	Air/Missile

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JDAM	3)Government/Industry	1) Cost cap	2)Planned Improvement	Y	High	N	USAF	System	Air/Missile
JHSV	3)Government/Industry	3) Technical/performance cap	1)Evolutionary	N	low	N	Army/Navy	System	Sea
JLENS	2)Government	0) No evidence of cost, schedule, technical/	3)Single Step	N	High	N	Army	System	Communication
JLTV	4)Gov. and industry (2> locations responsible	1) Cost cap	2)Planned Improvement	N	High	N	DOD	FOV	Ground
Joint MRAP	3)Government/Industry	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	Navy/ USMC/ army	FOS	Ground
JPALS Inc 1A	3)Government/Industry	4) cost, schedule	1)Evolutionary	N	low	N	Navy	System	Communication
JPATS	3)Government/Industry	6) Cost, technical/ performance (CT) caps	3)Single Step	Y	High	N	Navy/USAF	System	Air/Missile
JSIMS	2)Government	7) Technical/performance and Schedule (TS) caps	1)Evolutionary	N	low	N	DoD	Component	Communication
JSTARS	4)Gov. and industry (2> locations responsible	1) Cost cap	2)Planned Improvement	N	High	N	USAF	System	Air/Missile
JTN	1)Industry	1) Cost cap	1)Evolutionary	N	low	N	Army/Navy/Air Force	FOS	Communication
JTRS AMF	4)Gov. and industry (2> locations responsible	1) Cost cap	1)Evolutionary	Y	low	N	Army/Navy/ USMC/ USAF	FOS	Communication
JTRS GMR	4)Gov. and industry (2> locations responsible	4) cost, schedule	1)Evolutionary	N	low	N	Army/Navy/ USMC/ USAF	FOS	Communication
JTRS HMS	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	Army/Navy/ USMC/ USAF	FOS	Communication
JTRS NED	3)Government/Industry	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	Army/Navy/ USMC/ USAF	Component	Communication
JTRS WAVEFORM (RDT&E)	4)Gov. and industry (2> locations responsible	1) Cost cap	1)Evolutionary	N	low	N	DoD	FOS	Communication
JTUAV	3)Government/Industry	5) CST	1)Evolutionary	N	low	N	DoD	System	Air/Missile
KC-130J	1)Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	Navy	System	Air/Missile
KC-46A	2)Government	7) Technical/performance and Schedule (TS) caps	2)Planned Improvement	N	High	N	USAF	System	Air/Missile
LAIRCM	1)Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	USAF	SoS	Communication
Land Warrior	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	Army	System	Ground
LCS	2)Government	6) Cost, technical/ performance (CT) caps	2)Planned Improvement	N	High	N	Navy	SoS	Sea
LHA 6	3)Government/Industry	1) Cost cap	2)Planned Improvement	N	High	N	Navy	System	Sea
LHD-1	3)Government/Industry	1) Cost cap	2)Planned Improvement	N	High	N	Navy	SOS	Sea
Longbow HELLFIRE	3)Government/Industry	1) Cost cap	2)Planned Improvement	Y	High	N	Army	Component	Air/Missile
LPD 17	1)Industry	0) No evidence of cost, schedule, technical/	3)Single Step	N	High	N	Navy	System	Sea
LUH	3)Government/Industry	1) Cost cap	2)Planned Improvement	N	High	N	Army	System	Air/Missile
M109A7	3)Government/Industry	5) CST	1)Evolutionary	N	low	N	Army	FOV	Ground
M2 BRADLEY	4)Gov. and industry (2> locations responsible	1) Cost cap	2)Planned Improvement	N	High	N	Army	System	Ground
MH-60R	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	Navy	System	Air/Missile
MH-60S	4)Gov. and industry (2> locations responsible	4) cost, schedule	2)Planned Improvement	Y	High	N	Navy	System	Air/Missile
MIDS-LVT JTRS	4)Gov. and industry (2> locations responsible	6) Cost, technical/ performance (CT) caps	1)Evolutionary	Y	low	N	Army/Navy/Air Force	System	Communication
MM III GRP	1)Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	USAF	System	Air/Missile
MM III PRP	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	USAF	System	Air/Missile
MP-RTIP	2)Government	4) cost, schedule	2)Planned Improvement	N	High	N	USAF	Component	Communication
MQ-1C UAS Gray Eagle	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	Army	FOS	Air/Missile
MQ-4C BAMS UAS	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	Navy	FOS	Air/Missile
MQ-4C Triton	3)Government/Industry	7) Technical/performance and Schedule (TS) caps	1)Evolutionary	N	low	N	Navy	FOS	Air/Missile
MQ-8 (Fire Scout)	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	Navy	FOS	Air/Missile
MQ-9 UAS Reaper	2)Government	3) Technical/performance cap	1)Evolutionary	Y	low	N	Army	FOS	Air/Missile
MUOS	3)Government/Industry	3) Technical/performance cap	3)Single Step	N	High	N	Navy	SoS	Air/Missile
NAS	3)Government/Industry	1) Cost cap	3)Single Step	N	High	Y	Army/Navy/Air Force	System	Communication
NAVSTAR GPS - (Space&Control +	4)Gov. and industry (2> locations responsible	3) Technical/performance cap	1)Evolutionary	N	low	y	USAF	System	Communication

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Table B-1 MDAP Database (n=162)

MDAP	Project Office Location	Available Resources	Acquisition Strategy	Foreign Military Sales	Novel Tech.	International Cooperative Program	Jointness	Systems Hierarchy	Product Architecture
Navstar GPS IIIA	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	USAF	System	Communication
NESP AN/USC-38 - Navy EHF SATCOM	3)Government/Industry	3) Technical/performance cap	1)Evolutionary	N	low	Y	Navy	Component	Communication
NMD (National Missile Defense)	4)Gov. and industry (2> locations responsible	1) Cost cap	1)Evolutionary	N	low	N	DoD	SoS	Air/Missile
NMT	3)Government/Industry	0) No evidence of cost, schedule, technical/	3)Single Step	Y	High	Y	Navy	Component	Communication
NPOESS	1)Industry	5) CST	3)Single Step	N	High	N	USAF	Component	Communication
NTW TBMD	3)Government/Industry	4) cost, schedule	1)Evolutionary	N	low	N	Army/Navy	System	Air/Missile
P-8A MMA	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	Army	FOS	Air/Missile
Patriot PAC-3	4)Gov. and industry (2> locations responsible	4) cost, schedule	1)Evolutionary	Y	low	N	Army/MDA	SoS	Air/Missile
Patriot/MEADS CAP - FIRE UNIT +Missile	4)Gov. and industry (2> locations responsible	3) Technical/performance cap	2)Planned Improvement	N	High	y	Army	SoS	Air/Missile
PIM	3)Government/Industry	2) schedule cap	2)Planned Improvement	N	High	N	Army	FOV	Ground
PLS	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	Army	fov	Ground
RMS	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	Navy	System	Sea
RQ-4A/B Global Hawk MQ-4C /NATO	2)Government	1) Cost cap	1)Evolutionary	Y	low	N	USAF	SoS	Air/Missile
SADARM	3)Government/Industry	1) Cost cap	2)Planned Improvement	N	High	N	Army	System	Air/Missile
SBIRS High - Baseline (GEO 1-4,	3)Government/Industry	1) Cost cap	1)Evolutionary	Y	low	N	USAF	System	Communication
SBSS BLOCK 10	4)Gov. and industry (2> locations responsible	1) Cost cap	3)Single Step	N	High	N	USAF	System	Communication
SDB I	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	USAF	Component	Air/Missile
SDB II	2)Government	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	Navy/USAF	Component	Air/Missile
SFW	3)Government/Industry	2) schedule cap	2)Planned Improvement	Y	High	N	USAF	Component	Air/Missile
SMART-T	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	Y	High	N	Army	System	Communication
SSBN/SSGN	4)Gov. and industry (2> locations responsible	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	Navy	System	Sea
SSC	3)Government/Industry	1) Cost cap	3)Single Step	N	High	N	Navy	System	Sea
SSDS MK-1 Portion	4)Gov. and industry (2> locations responsible	3) Technical/performance cap	2)Planned Improvement	N	High	N	Navy	System	Communication
SSN 774	3)Government/Industry	1) Cost cap	1)Evolutionary	N	low	N	Navy	SoS	Sea
STRATEGIC SEALIFT Program	1)Industry	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	Navy	fos	Sea
T-45TS	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	Navy	System	Air/Missile
TACTOM Tactical Tomahawk	3)Government/Industry	1) Cost cap	1)Evolutionary	Y	low	N	Navy	System	Air/Missile
T-AKE	1)Industry	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	Navy	System	Sea
T-AOE	3)Government/Industry	1) Cost cap	2)Planned Improvement	N	High	N	Navy	FOS	Sea
Trident II Missile	3)Government/Industry	2) schedule cap	2)Planned Improvement	N	High	N	Navy	System	Air/Missile
TSAT (LEGACY)	4)Gov. and industry (2> locations responsible	4) cost, schedule	1)Evolutionary	N	low	N	USAF	System	Communication
TWS	2)Government	0) No evidence of cost, schedule, technical/	1)Evolutionary	Y	low	N	Army	FOS	Communication
V-22	3)Government/Industry	0) No evidence of cost, schedule, technical/	2)Planned Improvement	N	High	N	Navy/ USMC/ USAF	System	Air/Missile
VH-71	3)Government/Industry	4) cost, schedule	1)Evolutionary	N	low	N	Navy	System	Air/Missile
VTUAV	2)Government	0) No evidence of cost, schedule, technical/	1)Evolutionary	N	low	N	Navy	System	Air/Missile
WGS	3)Government/Industry	4) cost, schedule	1)Evolutionary	Y	low	N	USAF	System	Communication
WIN-T Inc 1	2)Government	4) cost, schedule	1)Evolutionary	N	low	N	Army	System	Communication
WIN-T Inc 2	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	Army	System	Communication
WIN-T Inc 3	2)Government	3) Technical/performance cap	1)Evolutionary	N	low	N	Army	System	Communication

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APPENDIX C.

Characterization of full MDAP data set, n=162 MDAPs

Table C-1: Factors and Data Types Summary Table

Factor	Variable Type	Missing Value?	Min. Value	Max. Value	Range[1]	Data Mean	Std. Dev.
1. Acquisition Strategy	Nominal	None	1	3	3	n/a	n/a
2. Available Resources	Nominal	None	0	7	8	n/a	n/a
3. Critical Technology	Binary	None	0	1	2	n/a	n/a
4. Engineering & Manuf. Development Duration, years	Continuous	Yes[2] N=142	0.00	47.70	47.70	6.13	5.215
5. Foreign Military Sales	Binary	None	0	1	2	n/a	n/a
6. Human Systems Integration	Binary	None	0	1	2	n/a	n/a
7. International Cooperation	Binary	None	0	1	2	n/a	n/a
8. Jointness	Ordinal	None	1	4	4	n/a	n/a
9. Product Architecture	Nominal	None	1	6	6	n/a	n/a
10. Product Quantity	Continuous	None	1	271,202	271,201	8,294	35,142
11. Product Unit Cost, $Million	Continuous	None	$0.01	$38,082	$38,082	$988	$3,753
12. Program Cost, $Million	Continuous	None	$413	$338,950	$338,536	$13,770	$32,198

[1] Inclusive Range is used for Nominal and Binary data to demonstrate the size of the range in the sense of the NUMBER of values between the highest and lowest, inclusive such that Range(inclusive)=(XH-XL)+1.

[2] The sample size is n=142 for this factor because some programs in the MDAP data set were terminated during Engineering & Manufacturing Development.

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Factor	Variable Type	Missing Value?	Min. Value	Max. Value	Range[1]	Data Mean	Std. Dev.
13. Program Duration, years	Continuous	Yes[3] N=142	1.50	67.70	66.20	25.22	10.842
14. Program Location	Nominal	None	1	4	4	n/a	n/a
15. Program Manager Experience	Binary	None	0	1	2	n/a	n/a
16. Program Visibility	Binary	None	0	1	2	n/a	n/a
17. Technology Development Duration, years	Continuous	Yes[4] N=156	0.00	30.44	30.40	3.53	4.531
18. Novel Technology	Binary	None	0	1	2	n/a	n/a
19. Systems Hierarchy	Nominal	None	1	4	4	n/a	n/a

[3] The sample size is n=142 for this factor because program duration as reflected by mission life was not included for terminated programs in the MDAP data set.

[4] The sample size is n=156 for this factor because some programs in the MDAP data set were terminated during Technology Development.

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