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FACTORS INFLUENCING TIMELINES ON NON-COMPETITIVE ACQUISITIONS GREATER THAN $500 MILLION

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December 2018

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The purpose of our research is to develop a procurement administrative lead time (PALT) prediction model for sole-source contract awards greater than $500 million at Air Force Life Cycle Management Center. The scope of our research is confined to PALT, which is the number of days between solicitation release and contract award. Our research team uses an ordinary least squares regression to model the relationship among our response variable, PALT, and 12 explanatory variables. Based on our results, we found five statistically significant variables and their effects—sign and magnitude—on PALT. The model accounts for 90.05% of the variation in PALT. Accurately predicting a schedule provides commanders and decision-makers with the ability to make better strategic business decisions to support the warfighter. Further research recommendations include externally validating our prediction model against other populations; testing variables excluded from this research, such as human factors and technological risk; and estimating individual phases within the contract award process.

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FACTORS INFLUENCING TIMELINES ON NON-COMPETITIVE ACQUISITIONS GREATER THAN $500 MILLION

ABSTRACT

The purpose of our research is to develop a procurement administrative lead time (PALT) prediction model for sole-source contract awards greater than $500 million at Air Force Life Cycle Management Center. The scope of our research is confined to PALT, which is the number of days between solicitation release and contract award. Our research team uses an ordinary least squares regression to model the relationship among our response variable, PALT, and 12 explanatory variables. Based on our results, we found five statistically significant variables and their effects—sign and magnitude—on PALT. The model accounts for 90.05% of the variation in PALT. Accurately predicting a schedule provides commanders and decision-makers with the ability to make better strategic business decisions to support the warfighter. Further research recommendations include externally validating our prediction model against other populations; testing variables excluded from this research, such as human factors and technological risk; and estimating individual phases within the contract award process.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADAS(C)	associate deputy assistant secretary of the Air Force for contracting
AFB	Air Force base
AFFARS	Air Force Federal Acquisition Regulation Supplement
AFLCMC	Air Force Life Cycle Management Center
AFLCMC/PK	Air Force Life Cycle Management Center Contracting Directorate
AFMC	Air Force Materiel Command
AFNT	Air Force negotiation team
APB	acquisition program baseline
BBP	Better Buying Power
BLUE	best linear unbiased estimator
CAA	clearance approval authority
CI	confidence interval
CO	contracting officer
CPR	cost performance report
DAS(C)	deputy assistant secretary of the Air Force for contracting
DAU	Defense Acquisition University
DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
DPAP	Defense Procurement and Acquisition Policy
EB	Armament Directorate
EMD	engineering and manufacturing development
FAR	Federal Acquisition Regulation
FFRDC	federally funded research and development center
FMS	foreign military sales
FY	fiscal year
GAO	Government Accountability Office
IOC	initial operational capability
ISR	intelligence, surveillance, and reconnaissance
MDA	milestone decision authority
MDAP	major defense acquisition program

MDD	materiel development decision
MSA	materiel solutions analysis
MS A	Milestone A
MS B	Milestone B
MS C	Milestone C
NDAA	National Defense Authorization Act
NDS	National Defense Strategy
NSS	National Security Strategy
O&S	operations and support
OLS	ordinary least squares
P&D	production and deployment
PALT	procurement administrative lead time
PAR	presidential aircraft recapitalization
PEO	program executive officer
PNM	price negotiation memorandum
PPNM	preliminary price negotiation memorandum
RAND	Research and Development Corporation
RDT&E	research, development, test, and evaluation
RFP	request for proposal
RSS	residual sum of squares
SASC	Senate Armed Services Committee
SCCO	senior center contracting official
SMC	Space and Missiles Systems Center
TMRR	technology maturation and risk reduction
WI	Intelligence, Surveillance, and Reconnaissance and Special Operations Forces Directorate
WK	Tanker Directorate
WL	Mobility Directorate
WV	Presidential Aircraft Recapitalization Directorate
WW	Fighters and Bombers Directorate
WPAFB	Wright Patterson Air Force Base
UCA	undefinitized contract action

USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics

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I. INTRODUCTION

In today's environment of evolving adversarial threats, advancing technology, continuing budgetary pressures, and changing security concerns, acquisition leaders must make more informed management decisions to deliver needed capabilities to the warfighter. The increasing complexity, cost, and sophistication of defense systems warrant a greater need for the most accurate schedule estimations (Schwartz, 2014). Accurately predicting a schedule is challenging, but it provides commanders and decision-makers with a more realistic expectation of when a capability to support warfighter needs will be delivered. Our study seeks to identify factors that affect timeline from solicitation[1] release to contract award for sole-source acquisitions[2] greater than $500 million; understand the effect—both sign and magnitude—of these factors on the timeline; and create a forecasting model that predicts the timeline for similar contract actions. The forecasting model uses Air Force Life Cycle Management Contracting Directorate's (AFLCMC/PK) historical contract data to estimate each explanatory variable's effect on the timeline for a subset of the acquisition[3] life cycle, the contract award process. The contract award process begins at solicitation, or request for proposal (RFP), release and ends at contract award. We refer to the number of days that the contract award process takes as *procurement administrative lead time* (PALT). As it currently stands, no previous research for the Air Force predicts the PALT for sole-source acquisitions greater than $500 million; therefore, this study is the first attempt to create such a model.

A. PURPOSE STATEMENT

AFLCMC/PK created a standard PALT for sole-source acquisitions between $50 and $500 million using historical PALT data. AFLCMC/PK has not created this same timeline, or examined the contextual factors, for sole-source acquisitions greater than $500 million. We examined factors that may affect PALT based on literature, subject matter

[1] Defined in Appendix.

[2] Defined in Appendix.

[3] Defined in Appendix.

expertise, and experience. By understanding factors that significantly drive PALT, AFLCMC/PK can forecast the PALT of sole-source acquisitions more accurately; find ways to expedite the PALT by improving significant factors; allocate manpower and resources more efficiently and effectively in the contract award process; decrease the procurement lead time; and ultimately, deliver capabilities to the warfighter in a timelier manner.

B. RESEARCH QUESTION

The questions guiding this research are as follows: What are the primary contextual factors that influence the PALT (i.e., the number of days from the date that the contracting officer[4] [CO] releases the solicitation, or RFP, to the date that the CO awards the resulting contract[5]), and what are these factors' effects—sign and magnitude—for sole-source acquisitions greater than $500 million?

C. RESEARCH SCOPE

The scope of this research is limited to predicting the PALT for a sole-source acquisition greater than $500 million. This scope specifically eliminates consideration of all schedule factors associated with procurement planning and solicitation planning prior to the solicitation and contract administration and contract close out after contract award.[6]

D. BENEFIT OF STUDY

The Advisory Panel on Streamlining and Codifying Acquisition Regulations[7] identified a system that is time-sensitive as one of five essential features of the future acquisition system in their Volume 1 Report (Department of Defense [DoD], 2018). The

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[4] Defined in Appendix.

[5] Defined in Appendix.

[6] Six phases of contract management include procurement planning, solicitation planning, solicitation, source selection, contract administration, and contract close out (R. Rendon, email to authors, November 6, 2018).

[7] The Fiscal Year 2016 National Defense Authorization Act (FY2016 NDAA) required the secretary of defense to establish a panel charged with reviewing regulations and creating ways of "streamlining and improving the efficiency and effectiveness of the defense acquisition process and maintaining defense technology advantage" (FY2016 NDAA, 2015).

report states that a culture that prioritizes processes over the mission and a system that fails to promote quantifying opportunity and manpower costs are two problems that lengthen acquisitions. These problems hinder the current system from being time-sensitive. The Section 809 Panel (2018) specifically identifies legislation directing the DoD to study PALT as "evidence of the desire for the DoD to account for delays at many process points" (p. 10). There are several benefits to understanding underlying factors affecting and accurately predicting the PALT for sole-source acquisitions above $500 million.

Understanding the number of days that the contract award process takes can improve AFLCMC/PK planning. AFLCMC/PK can optimize resources by allocating labor more efficiently and reducing the number of manpower hours spent on each contract action. Strategic resource allocation adds capacity through organizational optimization and provides more value for U.S. taxpayer dollars because the workforce can perform other tasks. Accurately predicting the PALT also creates a benchmark to measure, and subsequently improve, performance. By understanding the factors affecting PALT, AFLCMC/PK can create measures to reduce unnecessary delays in the process and decrease PALT. Furthermore, decreasing the PALT allows contractors to begin performance earlier and creates an opportunity to develop, produce, and field capabilities faster.

E. ORGANIZATION OF REPORT

This report is divided into six chapters. Chapter I includes the introduction, purpose, research question, scope, and benefits.

In Chapter II, we discuss the importance of schedule in defense acquisitions and summarize previous defense acquisition literature and research on factors that affect acquisition schedules.

In Chapter III, we explain the methodology we used to conduct our research, in detail, so that future researchers can replicate our findings and improve our model. We describe the sample and our data collection procedures, explain the operationalization of response and explanatory variables, and specify our prediction model.

In Chapter IV, we present the results of our regression model, including the results of various statistical tests we conducted to ensure our model is as robust as possible.

In Chapter V, we discuss the results and interpretations of our regression outputs in detail. We analyze the statistically significant and statistically nonsignificant explanatory variables in comparison to our initial hypotheses at the beginning of our study. We also explain why our results are meaningful.

Finally, in Chapter VI, we discuss the limitations of our research, provide recommendations for further research, and answer our research questions.

II. LITERATURE REVIEW

In this chapter, we examine previous studies and literature on schedule management within the defense acquisition environment. First, we define schedule within defense acquisition and describe the PALT process. Next, we discuss the importance of defense acquisition schedules in recent legislation, strategy documents, and Congressional testimonies. Then, we discuss problems caused by inaccurate schedule estimates from previous research. Lastly, we discuss previously identified factors that significantly influence acquisition schedules and the relationship between these factors and the ones within our model.

A. SCHEDULE

As defined by the Defense Acquisition University, a schedule is

> the process [that] examines all program activities and their relationships to each other in terms of realistic constraints of time, funds, and people, i.e., resources. In program management practice, the schedule is a powerful planning, control, and communications tool that, when properly executed, supports time and cost estimates, opens communications among personnel involved in program activities, and establishes a commitment to program activities and costly element of defense acquisition procurement. (DoD, 2001, p. 1)

Figure 1 displays the generic life-cycle model for a hardware-intensive major defense acquisition program (MDAP). The generic model consists of six phases, three milestone decisions, and four additional decisions.

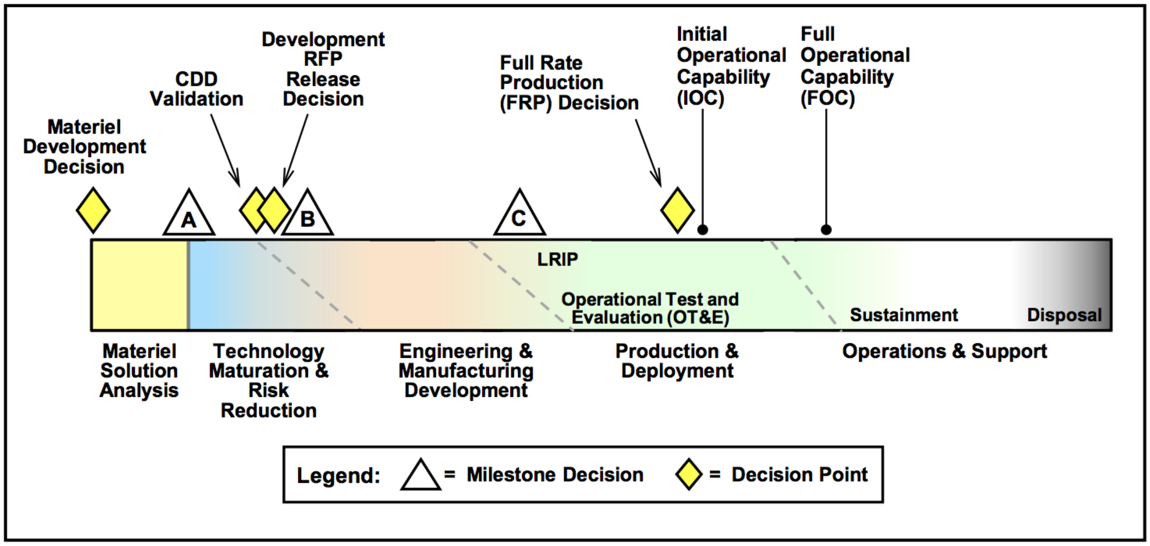

Figure 1. Hardware Intensive Program Generic Model.
Source: DoD (2017).

The six phases from start to finish are Materiel Solution Analysis (MSA), Technology Maturation and Risk Reduction (TMRR), Engineering and Manufacturing Development (EMD), Production and Deployment (P&D), Operations and Support (O&S), and Disposal. The seven decisions from start to finish are the Materiel Development Decision (MDD); Risk Reduction Decision or Milestone A (MS A); Capability Development Document Validation; Development RFP Release Decision; Development Decision or Milestone B (MS B); Low-Rate Initial Production or Limited Deployment Decision, called Milestone C (MS C); and Full Rate Production Decision. The MDD initiates the acquisition process, but MS B initiates an acquisition program unless the program enters the acquisition life cycle directly at MS C (Department of Defense [DoD], 2017). The program manager (PM) must develop an acquisition program baseline (APB), and the Milestone Decision Authority (MDA) must approve the APB prior to initiating a program.

The APB establishes an MDAP's cost, schedule, and performance requirements and serves as the baseline for tracking and reporting program status during the program increment or life (DoD, 2017). The term *program schedule* refers to the approved APB schedule. Negative schedule deviations from the APB delay delivery and are known as schedule overruns or schedule slips. Congress, leaders within the Executive Branch, and academia primarily focus on these negative program schedule deviations, rather than PALT, because this deviation means that the defense acquisition workforce and contractor delivered a capability later than planned.

The contract award process is a subset of the acquisition life cycle. Sole-source acquisitions may occur at any point in the program life cycle, but the majority of sole-source acquisitions greater than $500 million at AFLCMC occur after MS B. AFLCMC's standard process for sole-source contract awards organizes the process for sole-source acquisitions into six high-level activities or phases:

- Phase 1.0—Release of RFP (Letter/Formal) to Receipt of Adequate Proposal (Qualifying Proposal),[8]
- Phase 2.0—Fact Finding and Evaluation,
- Phase 3.0—Business Clearance,[9]
- Phase 4.0—Negotiations,
- Phase 5.0—Contract Clearance,[10] and
- Phase 6.0—Contract Award (V. Fry, personal communication, March 8, 2018).

Figure 2 shows a more detailed diagram of AFLCMC's process. For the purpose of data collection, we defined the end of each phase as the completion of the following outputs:

- Phase 1.0—Receipt of Adequate Proposal (Qualifying Proposal),

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8 Defined in Appendix.

9 Defined in Appendix.

10 Defined in Appendix.

- Phase 2.0—Preliminary Price Negotiation Memorandum,[11]
- Phase 3.0—Signed Business Clearance,
- Phase 4.0—Date of Considered Negotiated,
- Phase 5.0—Signed Contract Clearance, and
- Phase 6.0—Contract Award.

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[11] According to FAR 15.406-3, "The contracting officer shall document in the contract file the principal elements of the negotiated agreement. The documentation (e.g., price negotiation memorandum (PNM)) shall include the following:

(1) The purpose of the negotiation.

(2) A description of the acquisition, including appropriate identifying numbers (e.g., RFP No.).

(3) The name, position, and organization of each person representing the contractor and the Government in the negotiation.

(4) The current status of any contractor systems (e.g., purchasing, estimating, accounting, and compensation) to the extent they affected and were considered in the negotiation.

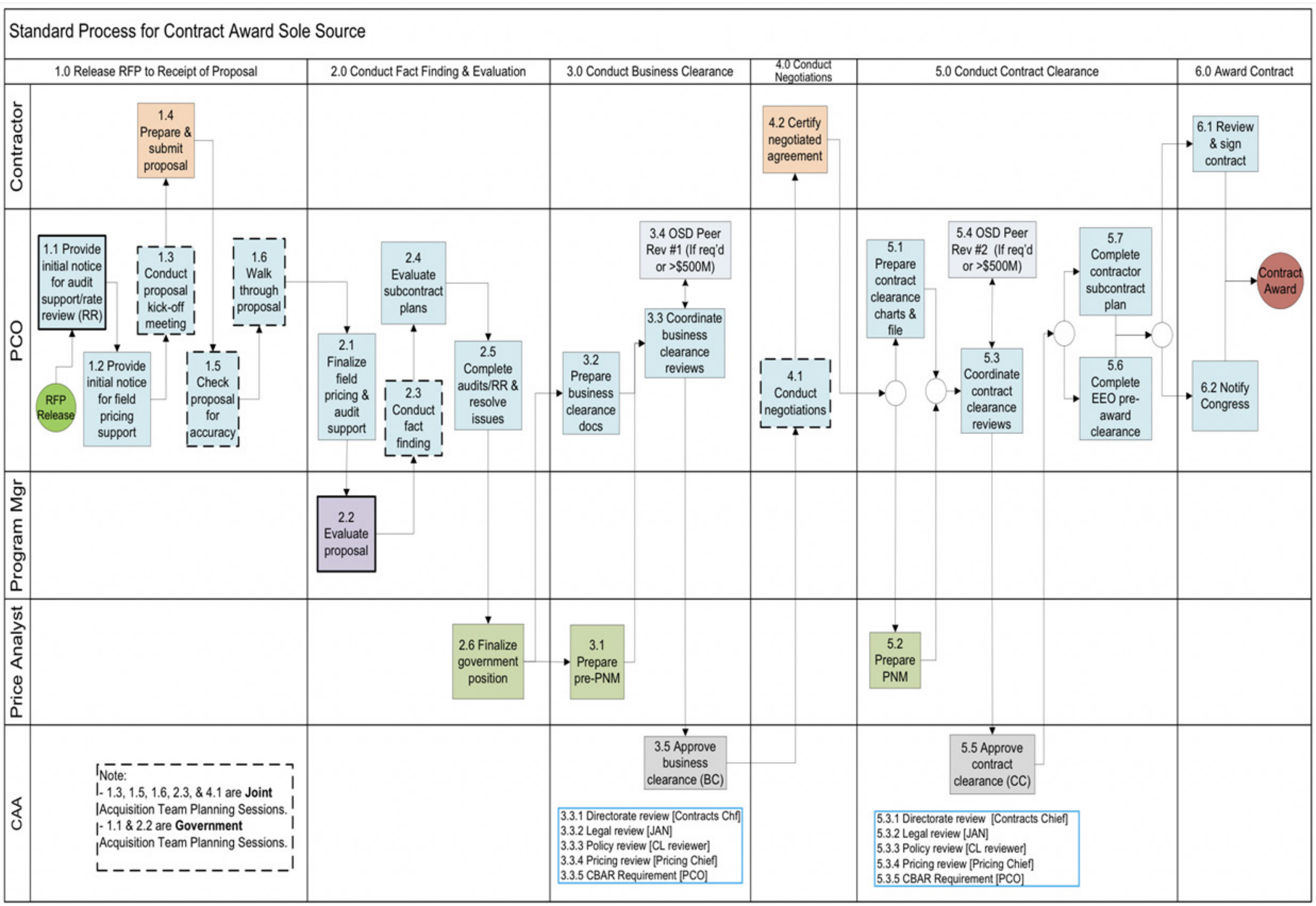
(5) If certified cost or pricing data were not required in the case of any price negotiation exceeding the certified cost or pricing data threshold, the exception used and the basis for it.

(6) If certified cost or pricing data were required, the extent to which the contracting officer --

(i) Relied on the cost or pricing data submitted and used them in negotiating the price;

(ii) Recognized as inaccurate, incomplete, or noncurrent any certified cost or pricing data submitted; the action taken by the contracting officer and the contractor as a result; and the effect of the defective data on the price negotiated; or

(iii) Determined that an exception applied after the data were submitted and, therefore, considered not to be certified cost or pricing data (2018)."



Source: V. Fry, personal communication, March 8, 2018.

Figure 2. AFLCMC's Detailed Process Flow Chart.

B. IMPORTANCE OF SCHEDULE IN DEFENSE ACQUISITION

The vision of the Federal Acquisition System is to "deliver on a ***timely basis*** the best value product or service to the customer, while maintaining the public's trust and fulfilling public policy objectives" (FAR 1.102(a)). Defense acquisition professionals must continuously deliver capabilities and weapon systems to its customer, the warfighter, with affordability and speed to "retain overmatch—the combination of capabilities in sufficient scale to prevent enemy success—and to ensure that America's sons and daughters will never be in a fair fight" (Trump, 2017, p. 28). According to Under Secretary Ellen Lord, the under secretary of defense for acquisition and sustainment, the Department of Defense delivers the best weapon systems in the world; however, the countries that pose the greatest threat to national security surpass the speed at which it delivers those systems, eroding the United States' overmatch (*DoD Acquisition Reform Efforts*, 2017).

Leadership within the Legislative and Executive Branches and Department of Defense—the Senate Armed Services Committee (SASC), President Donald Trump, Secretary of Defense James Mattis, Secretary of the Air Force Heather Wilson, Undersecretary Ellen Lord, and combatant commanders—universally recognize and support the need to reform the defense acquisition system for speed, as evidenced by a concerted effort to address acquisition speed. The ubiquity of reform and speed in legislation, strategy documents, and testimonies proves the importance of schedules, both PALT and program schedule, to our national security and national defense.

Recent legislation from the last three fiscal years (FY) reflects Congress' attention to defense acquisition reform. The National Defense Authorization Acts (NDAA) for FY2016, FY2017, and FY2018 contain an average of 82 provisions related to acquisition reform, compared to an average of 47 provisions in the previous 10 NDAAs (Schwartz & Peters, 2018). NDAA provisions related to speed include

- increasing the use of rapid acquisition authorities,
- authorizing the secretary of defense to waive provisions of acquisition law or regulation, and

- requiring the secretary of defense to create an advisory panel to review defense acquisition regulations for ways to "streamlining and improving the efficiency and effectiveness of the defense acquisition process and maintaining defense technology advantage." (FY2016 NDAA, 2015)

In addition to recent legislation, strategy documents from the president of the United States and Secretary of Defense echo the need for defense acquisition reform.

The Trump administration released its first National Security Strategy (NSS)[12] on December 18, 2017, which begins by describing a new hyper-competitive and geopolitical operating environment. The strategic vision of the 2017 NSS responds to this increasing political, economic, and military competition by putting America first and focusing on four pillars of national interest: (1) "protect the American people, the homeland, and the American way of life", (2) "promote American prosperity", (3) "preserve peace through strength", and (4) "advance American influence" (Trump, 2017, p. 4). Defense acquisitions fall under the third pillar. Although the United States military remains the strongest in the world, many defense systems cost more than expected, take longer than planned, and do not always deliver the full promised capability; therefore, the ability to efficiently modernize existing systems and procure new ones is important (Baldwin & Cook, 2015; Trump, 2017). The United States must improve its acquisition processes and policies to increase readiness and lethality in today's dynamic security environment and, ultimately, preserve peace through strength.

The 2018 National Defense Strategy (NDS) outlines Secretary Mattis' strategic approach to support President Trump's four pillars of national interest. The 2018 NDS emphasizes a need to reform acquisition processes and policies to promote greater performance and affordability. The DoD previously implemented several acquisition reforms to combat cost overruns, schedule delays, and performance shortfalls, yet federal

[12] The NSS is a congressionally mandated document that communicates the current administration's strategic vision to the American people, its allies and partners, and federal agencies. The 2017 NSS also discusses the nation's strategic direction—challenges, goals, and objectives—to guide federal departments, agencies, and other governmental organizations in executing their core function while adhering to the direction provided.

agencies still face significant challenges in procuring and managing major defense acquisitions (Government Accountability Office [GAO], 2018). For example, federal agencies still use outdated management practices, struggle to integrate and adapt to change, and fight bloated bureaucracies (Trump, 2017). This bureaucratic approach fosters a culture that minimizes risk above all else and prioritizes "exceptional performance at the expense of providing timely decisions, policies, and capabilities to the warfighter" (Mattis, 2018, p. 10). The current system and approach prove to be unresponsive to warfighter needs.

Secretary Wilson and Under Secretary Lord testified before the SASC on DoD acquisition reform efforts on December 7, 2017. They concurred with President Trump and Secretary Mattis' concern that the pace of capability delivery threatens national security. Secretary Wilson (2017) stated that the Air Force must deliver capabilities faster than ever "to prevail against rapidly innovating adversaries" (p. 1). According to Secretary Wilson (2017),

> the acquisition enterprise is currently optimized for industrial-age procurement of large weapons systems with extensive requirement development, military specifications and resultant long acquisition timelines. We must shift to align with modern industry practices in order to get cost-effective capabilities from the lab to the warfighter faster. (p. 3)

Under Secretary Lord focused on procurement lead time [PALT] in her testimony before the SASC, stating that reducing the time required to award contracts is a priority. Under Secretary Lord concluded that the DoD could reduce procurement lead time by up to 50% of the current timeline, which will significantly reduce costs while simultaneously accelerating the required time to field new capabilities (*DoD Acquisition Reform Efforts*, 2017). She initiated six pilot programs to test the DoD's contracting agility and demonstrate the DoD's ability to responsibly reduce PALT, including two AFLCMC sole-source acquisitions: C-130J retrofit kits and Japanese Global Hawk (DoD Acquisition Reform Efforts, 2017). Under Secretary Lord set an interim goal of 210 days for the procurement lead time of these six pilot programs, but would like to eventually decrease that procurement lead time to 180 days (DoD Acquisition Reform Efforts, 2017).

The remarks made by our nation's leadership within the Legislative and Executive Branches indicate the need for acquisition enterprise reform and highlight prioritizing speed as a key element. These sentiments are not new, and parties interested in defense acquisition have emphasized faster acquisitions for decades. This emphasis and interest motivated subsequent studies on the problems caused by inaccurate schedule estimates and schedule overruns.

A 1998 dissertation written by U.S. Air Force Major Ross McNutt discussed six distinct, negative impacts of weapons system schedule delay:

- "Systems [are] not ready when needed" (p. 39). McNutt identified 17 specific weapons systems that began development at least five years prior to Operation Desert Storm but were not delivered until after the war. Seven of these systems provide capabilities that would have met critical needs.
- "Systems [are] not meeting current needs when fielded" (p. 41). New MDAPs take nearly 10 years to develop. Operational environments and threats constantly change, so the specific threat(s) a program was meant to address may no longer exist by the time the U.S. fields the system.
- "New systems [are] fielded with dated technology" (p. 41). McNutt recognized that weapons systems were delivered to the field without the most current technologies, due to an exponential technological growth paired with elongated development times. We still experience exponential technological growth in today's environment; therefore, the same impact of elongated schedule or schedule delay exists.
- "Slow response to new or emerging threats" (p. 43). The United States developed the AIM-9X in response to the Soviet Archer AA-11, which the Soviets developed in 1985. The AIM-9X did not reach initial operational capability (IOC) until November of 2003 ("AIM-9X," 2003). This long development time left U.S. fighter aircraft without the specific defense capability it needed for 18 years.
- "Slow response to known safety problems" (p. 43). McNutt mentioned two systems designed to mitigate and resolve safety issues. The slow

development of these systems led to multiple aircraft accidents and collisions that were avoidable.

- “Effects of development time on cost” (p. 44). McNutt stated that the as development time increases, program costs increase: ACAT I programs that take seven years to complete cost $1.2 billion on average, programs that take from seven to 14 years cost $1.8 billion on average, and programs that take longer than 14 years cost $3.6 billion on average. Note: RAND adjusted these dollar values in terms of program base-year dollars to remove the effects of inflation.

McNutt (1998) also discussed the influence of the RFP’s expected or desired program schedule on the contractor’s proposed schedule. He stated, “A contractor’s primary consideration in proposing a project’s schedule is the program office’s desired schedule. The company’s development capabilities are given much less consideration” (McNutt, 1998, p. 237). In other words, contractors simply propose the government-provided schedule back to the government to win the contract, regardless of the development requirements or contractor’s capabilities (McNutt, 1998). The program office’s interpretation of available funding, rather than development requirements or any other consideration, primarily affects the expected program schedule. This may cause schedule slips when funding constraints, development requirements, and contractor capabilities are not considered holistically.

Although McNutt’s study focused on development times in weapons system acquisition, the six impacts of long acquisition schedules still exist, and the process begins with PALT. The importance of acquiring and fielding relevant, current, and reliable technology to the warfighter on a timely basis remains unchanged through the years.

C. DEFENSE ACQUISITION SCHEDULE PREDICTIVE FACTORS

In this section, we summarize and consolidate previous studies and reports on defense acquisition schedules so that we can better understand factors that affect schedules. Since this is the first attempt to develop a multiple regression model that predicts the PALT of a sole-source acquisition greater than $500 million, we need to understand the similarities and differences between previously conducted research and our research. To understand the similarities and differences, the summaries of each study or report include the researchers' purpose, the definition of the examined schedule, the population of interest and sample, the estimation procedure or analysis framework, the hypothesized factors that affect schedules, and the results of their research. Table 1 consolidates the sample and data, dependent variable(s), results, and significant independent variables of the literature examined in our literature review.

Table 1. Consolidation of Literature Review

Citation	Sample & Data	Dependent Variable	Results/Significant Independent Variables
1. Drezner and Smith (1990)	Data collected from 10 programs across all services with a variety of acquisition strategies and schedule outcomes. All have Milestone I dates post-1970	Original schedule plan and deviation from plan. *We focus on the original schedule plan factors for this report.*	**Lengthen Original Plan:** Competition, Prototyping, Joint Management, and Program Complexity **Shorten Original Plan:** Concurrency, Funding Adequacy, Separate Contracting, and Service Priority
2. MacKinnon (1992)	Analyzed 834 Naval Air Weapon Center contracts > $25K awarded between 1989 and 1991	Procurement Administrative Lead Time (PALT)	Contract Type, Contract Value, and Contract Description
3. Cashman (1995)	Descriptive study looking at Cost Performance Reports from 22 Air Force weapons system programs valuing between $40 million to $10 billion in EMD phase. All dated between 1981 to 1994.	Schedule problems, in terms of frequency and variance (dollar value and work days), within large defense system development efforts	**Top 3 factors in terms of frequency:** Technical Problems, Subcontractor Late, Late Data **Top 3 factors in terms of dollar variance:** Technical Problems, Subcontractor Late, and Design Changes **Top 3 factors in terms of work days:** Subcontractor Late, Manufacturing Problems, Technical Problems
4. McNutt (1998)	Survey based data collection, received 317 respondents across ACAT I, II, and III programs that characterized a sufficient representation of aerospace development efforts initiating between 1970 to 1998. Cost ranged between $140M to $2.1B in their respective year's dollar values.	Factors influencing initial schedule development. Impact of initial schedule development on the contracting process.	**Top factors influencing initial schedule development:** User's Desired Delivery Schedule, Expected Development Funding, Expected Production Funding **Impact on contracting process:** Initial development schedule is the primary driver for contracted schedule
5. Monaco and White (2005)	Comparative Literature Review of 12 studies dating between 1987 and 2002	Predictive schedule drivers from literature	Technical Issues (Maturity/difficulty/complexity), Competition, Contract Type, Prototyping
6. Riposo, McKernan, and Duran (2014)	Comparative Literature Review of studies dating between the 1960s to 2014	Schedule growth and slippage factors from literature	Requirements Development, Generation, and Management, Managing Technical Risk, Resource Allocation, Defense Acquisition Management, Other (delays in obtaining data)
7. Jimenez, et. al (2016)	Collected data from 56 Selected Acquisition Reports of defense acquisition programs dating back to 1950s	Schedule prediction from the end of Milestone B to IOC	Total RDT&E Funding at MS B start, Percentage of RDT&E Funding at MS B start, Modification vs new program, MS B Start dated 1985 or later

1. Drezner and Smith (1990)

Drezner and Smith (1990) listed three research objectives: determining whether acquisition program durations are increasing, identifying and understanding the factors that affect acquisition program durations, and providing recommendations to decrease acquisition program durations. They measured program duration from the start of Milestone I[13] to the "delivery of the first operationally configured production article to the user" (Drezner & Smith, 1990, p. v).

Drezner and Smith (1990) selected 10 systems and subsystems programs that started Milestone I after 1970. They wanted a diverse sample, so the programs they selected vary in program characteristics, acquisition strategies, schedule outcomes, schedule durations, and lead services. They prioritized studying a smaller sample in greater detail over studying a larger sample in less detail to understand the factors that affect program length better and measure program length more consistently. One limitation of their research is the selected sample size limits the applicability of their findings to their population.

Drezner and Smith (1990, p. viii) created a general model to represent program length and frame their analysis:

$$\text{Actual Program Length} = \text{Length of Original Plan} + \text{Deviation from Plan} \qquad (1)$$

Drezner and Smith (1990) identified 16 factors that potentially affect actual program length and categorized each factor under one of three categories: factors that affected the estimated length of the original plan, factors that caused deviations from the original plan, and factors that affected the estimate of the original plan and caused deviations of the original plan. The researchers hypothesized that six of the 16 factors affected the estimated length of the original plan, five of the 16 factors caused deviations from the original plan, and five of the 16 factors did both (Drezner & Smith, 1990).

Out of the 11 factors that Drezner and Smith analyzed, they identified nine as significant in affecting the original plan. Competition, Prototype Phase, Joint Management,

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[13] Defined in Appendix.

and Program Complexity tended to lengthen schedules; Concurrency, Funding Adequacy, Separate Contracting, and Service Priority tended to shorten schedules; and External Guidance could either lengthen or shorten the schedule depending on the actual guidance (Drezner & Smith, 1990). They did not find any evidence that Technical Difficulty or Concept Stability affected the original plan (Drezner & Smith, 1990).

Of the 10 factors that the researchers identified as potentially causing a deviation from the original plan, eight caused a deviation. The eight factors were External Guidance, Program Complexity, Technical Difficulty, Concept Stability, Contractor Performance, External Event, Funding Stability, and Major Requirements Stability. Each of the eight factors tended to cause a schedule slip or delay the schedule. The researchers did not find any evidence that Joint Management or Program Manager Turnover caused a deviation to the original plan (Drezner & Smith, 1990).

Our research is similar to Drezner and Smith's second research objective: identifying and understanding factors that affect schedules, but our research differs because our primary objective is to estimate a schedule with each factor's effect—sign and magnitude. They did not study the magnitude of their factors' effects. Our schedule and population are also subsets of the schedule and population examined in this study.

2. MacKinnon (1992)

MacKinnon's (1992) thesis objective was to develop a forecasting model that predicts both the cost and lead-time (PALT) of awarding a contract. He defined PALT as the number of days from an approved acquisition requirements package to an awarded contract (MacKinnon, 1992).

MacKinnon (1992) analyzed the PALT of 834 contracts greater than $25,000 awarded by the Naval Air Weapon Center, China Lake, California between 1989 and 1991. He developed an estimation model using 559 contracts awarded in 1989 and 1990 and validated his model using 275 contracts awarded in 1991 (1992).

The response variable is PALT, and he transformed PALT by taking the natural logarithm. He identified five factors that potentially explain PALT:

- Contract Type: fixed price or cost-reimbursable;
- Contract Value: in dollars and transformed by squaring the natural logarithm of dollar value;
- Contract Description: service, supply, or research and development;
- Competitive Nature: competitive or sole-source; and
- Complexity Score in points. Complexity score is the difficulty in processing that individual contract action based on variables such as contract value, contract type, justifications and approval required, and number of RFP amendments (MacKinnon, 1992).

MacKinnon (1992) fit the full model using each variable and every possible interaction, and then sequentially eliminated each variable that was not statistically significant at alpha = 0.10. The final model explained approximately 27.4% of the variation in PALT. MacKinnon found that a significant relationship between PALT and Contract Type, Contract Value, and Contract Description existed.

3. Cashman (1995)

The objectives of Cashman's (1995) thesis were to identify the reasons for schedule problems, to quantify the frequency and severity of each identified reason, and to demonstrate that the identified reasons commonly exist in large Air Force system development programs. He used a descriptive study to research reasons for schedule problems. He did not focus on determining the causal relationships of schedule delays.

Cashman (1995) researched the schedule of 22 Air Force programs—including aircraft, missile, aircraft equipment, aircraft upgrade, and simulator programs—in the EMD phase from 1981 to 1994 with contract values from $40 million to greater than $10 billion. Cost performance reports (CPRs) provided all the data for his analysis. Contractors delivered CPRs to the program office monthly on major defense acquisition programs and CPRs contained the reasons for and severity of schedule problems. In his sample, contractors reported 549 instances of schedule problems (Cashman, 1995).

Cashman (1995) sorted the reasons for schedule problems into 20 categories; however, we are particularly interested in the *contracting* and *subcontractor late* categories from this study. He further separated the *contracting* category into four subcategories:

- selecting subcontractors,
- awarding subcontractor contracts,
- processing purchase orders, and
- terminating subcontractors.

Cashman found that *Contracting* delayed schedule in nine of the 22 EMD programs.

Cashman (1995) separated the *subcontractor late* category into three subcategories:

- late deliveries that impacted the prime contractor's activities,
- late deliveries by lower-tier subcontractors (a subcontractor's subcontractor) that impacted a subcontractor's activities, and
- slow progress by a subcontractor that prevented the subcontractor from meeting its planned schedule.

Subcontractor late delayed schedule in 17 of the 22 EMD programs (Cashman, 1995).

Cashman (1995) compared the 20 categories in three dimensions to quantify the importance of each category in terms of frequency and severity—frequency, total schedule variance ($), and total schedule variance (workdays)—to meet the study's second objective. *Contracting* ranked number five and four in both severity categories, total schedule variance ($) and total schedule variance (work days) respectively *Subcontractor late* ranked number two in frequency, two in total schedule variance ($), and one in total schedule variance (work days) respectively. The top three factors in terms of frequency were Technical Problems, Subcontractor Late, and Late Data. The top three factors in terms of dollar variance were Technical Problems, Subcontractor Late, and Design Changes. Lastly, the top three factors in terms of workdays were Subcontractor Late, Manufacturing Problems, and Technical Problems (Cashman, 1995).

4. McNutt (1998)

The initial research questions from McNutt's (1998) dissertation were as follows: How are schedules determined? How does the initial schedule impact the development of the contractor's schedule and subsequently, the contracted schedule? And how does the initial and contracted schedule impact the actual development schedule?

McNutt conducted an exploratory, survey-based research study utilizing three different surveys to answer these questions. He sent the surveys to 905 potential respondents, and these respondents "were identified as the Program Offices, the defense contractors, and the Pentagon" (McNutt, 1998, p. 144). McNutt (1998) received 317 responses across ACAT I, II, and III programs showing a sufficient representation of aerospace development efforts initiated from 1970 to 1998. The cost of these efforts ranged between $140 million to $2.1 billion in their respective year's dollar values (McNutt, 1998).

McNutt (1998) used a variety of methods to analyze the data collected from the surveys with the goal of identifying the factors and their influence on program schedules. He discussed the visual inspection of the distribution of the raw data, which showed that more times than not the data did not fall on a normal distribution curve; this finding limited the amount of statistical analysis that could be conducted on the data. Therefore, McNutt conducted a variety of statistical tests on the data that did not rely on the assumption of normally distributed data, such as the Wilcoxon Signed Rank test, which analyzed and presented the interval scale data (McNutt, 1998). McNutt established statistical groupings for the different variables into four parts: development of a program's initial schedule, effects of the initial schedule on the contracting phase, schedule-related incentives from all stakeholders, and the effects of a program's initial schedule and the contracted schedule on the development schedule (McNutt, 1998). For the purposes of this study, we only focused on the first two categories of his findings as they relate more closely to our research.

McNutt (1998) found that the initial schedule is driven mostly by "funding-related constraints" (p. 218). The initial schedule development is primarily influenced by the user's desired delivery schedule, the expected development funding, and the expected production funding. Furthermore, expert judgment is used to consider the other constraints in the initial schedule development (McNutt, 1998).

As discussed previously in this chapter, McNutt (1998) found that the contracted schedule was primarily driven by the initial schedule developed and presented to contractors. This, based on McNutt's (1998) assessment, was driven by the lack of incentives given to the contractor to deviate from the government-provided schedule. These findings may suggest that negotiations surrounding schedule would not be a significant driver for PALT because the deviation between the contractor's proposal and the government's initial schedule are, according to McNutt, exceedingly similar across the data.

5. Monaco and White (2005)

Monaco and White's report (2005) provided an overview of factors that cause schedule variances from previous descriptive and inferential statistical studies. They reviewed 12 studies conducted from 1987 to 2002 and highlighted common factors that affect schedule. The most common predictive schedule drivers in acquisition literature were technical issues, such as technical maturity, technical difficulty, and technical complexity; competition; prototyping; and contract type.

In addition to the study conducted by Monaco and White, in 2011, the Government Accountability Office (GAO) conducted a study on space acquisitions to investigate continuing cost and schedule growth. While our population excludes space acquisitions, these large system acquisitions are of comparable scope and magnitude to the programs analyzed by our team. The GAO (2011b) assessed the billions of dollars in cost growth, schedule slippage, and increased technical risk. The GAO (2011b) report mentioned that a nine-year schedule slip left the military open for capability gaps and increased costs. The GAO (2011b) stated that the DoD had a longstanding tendency to begin space programs prior to maturing technologies to the required technology readiness level. Reaching an appropriate technology readiness level prior to program initiation reduces cost, schedule, and performance risks.

Furthermore, the GAO's 2017 annual defense major weapons system acquisition assessment discussed the current trends in the DoD across 78 programs. The report discussed the adverse effects on cost and schedule that carried through to subsequent phases of the acquisition when systems started without fully mature technologies (GAO, 2017). The GAO (2017) discussed the process of “fully maturing technologies prior to system development start” (p. 1) as an enterprise best practice that should be incorporated into future acquisitions. Technology maturation, technology risk, and technology readiness are all factors that repeat throughout reports and acquisition literature.

6. Riposo, McKernan, and Duran (2014)

Riposo, McKernan, and Duran’s report (2014) summarized the sources of excessive cycle-time and schedule growth from defense acquisition literature and presented possible opportunities to shorten individual program schedules. The researchers’ purpose, however, was not to critically analyze the validity of the findings in acquisition literature. The researchers studied literature from government, academia, and non-profit analytic sources to understand the cause of schedule growth and increased cycle-times and ways to address it.

Riposo et al. (2014) identified three main reasons for schedule growth: difficulty of managing technical risk, difficulty of fulfilling initial assumptions or expectations, and funding instability. The researchers explained that schedule growth frequently stemmed from managing technical risk in areas such as “program complexity, immature technology, [and] unanticipated technical issues" (Riposo et al., 2014, p. 18). They suggested “using incremental fielding and evolutionary acquisition (EA) strategies, developing derivative products, and using mature or proven technology” to manage or reduce technical risk (Riposo et al., 2014, p. xii).

Riposo et al. (2014) found that the difficulty of fulfilling initial assumptions or expectations such as schedule estimates, risk control, system requirements, and performance assumptions led to schedule growth. Ambitious and overly optimistic were two characterizations associated with schedule growth, and the researchers stated that ambitious schedules “blind[ed] decision-makers to the need to make early, informed trade-offs, and they set up programs for later criticism over schedule growth” (Riposo et al., 2014, p. 59). They recommended using improved schedule estimates but claimed that schedule-estimating methodologies are not well developed and the extent of schedule-estimating skills is limited (Riposo et al., 2014).

Riposo et al. (2014) also described how funding instability led to schedule growth. Fiscal constraints and stagnant, or even decreasing, budgets force programs to compete for funding, which leads to funding instability and ultimately, schedule growth. In 2010, former Under Secretary of Defense for Acquisition, Technology, and Logistics (USD AT&L) Ashton Carter initiated Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending (BBP 1.0). In BBP 1.0, he stated that

> the leisurely 10–15 year schedule of even the simplest and least ambitious Department programs not only delays the delivery of needed capability to the warfighter, but directly affects program cost. As all programs compete for funding, the usual result is that a program settles into a level-of-effort times the length of the program. Thus, a one-year extension of a program set to complete in 10 years can be expected to result in 10 percent growth in cost as the team working on the project is kept on another year. Yet managers who run into a problem in program execution generally cannot easily compromise requirements and face an uphill battle to obtain more than their budgeted level of funding. The frequent result is a stretch in the schedule. (Carter, 2010, p. 4–5)

Riposo et al. (2014) identified overly demanding requirements at program initiation and requirements changes during performance as two factors that affect the schedule. Additionally, the GAO (2011a) expressed concerns about the complexity of changing requirements and cost and schedule growth:

> While changing requirements creates instability and, therefore, can adversely affect program outcomes, it is also possible that some programs experiencing poor outcomes may be decreasing program requirements in an effort to prevent further cost growth. … Programs with changes to performance requirements experienced roughly four times more growth in research and development costs and three to five times greater schedule delays compared to programs with unchanged requirements. Similarly, programs with increases to key system attributes—lower level, but still crucial requirements of the system—experienced greater, albeit less pronounced, cost growth and schedule delays than other programs. (p. 14)

Riposo et al. (2014) stressed that creating an appropriate or optimal schedule and executing that schedule require balancing various complexities and interrelated factors, such as technological maturity, complexity, and budget. These factors stem from sources both internal and external to the government. Riposo et al. (2014) detailed potential ways to improve schedule management based on acquisition literature. Those most closely pertaining to this report include but are not limited to

- Requirement generation improvements: provide "stable and realistic initial requirements, especially at the engineering level," (p. xiii) improve collaboration between the program offices and customers, and increase "proper management of flexible requirements" (p. xiii);
- Technical risk improvements: increase use of mature/demonstrated technology, prototype more frequently, increase concurrency in programs with low technical risk, employ more "agile methods that easily respond to changes in software development" (p. 38), increase use of commercial items, and reduce the complexity of designs where able; and
- Resource allocation improvements: use stable funding and adequate test funds when able (Riposo et al., 2014, p. 16)

Due to the nature of the internal and external factors present in government acquisition, unpredictability will always play a role in schedule growth. To the best extent possible, all factors should be analyzed and weighted properly when examining and approximating schedule growth.

7. Jimenez (2016)

The objective of Jimenez's (2016) study was to develop a multiple regression model that predicts the schedule from the end of Milestone B (MS B), which is the Development Decision, to IOC, which is the point that the system is deployable and provides a capability to the warfighter, in months (Jimenez, 2016).

Jimenez (2016) created a database populated with Selected Acquisition Report[14] data for 330 defense acquisition programs dating back to the 1950s. The database included

[14] Defined in Appendix.

defense programs from the Air Force, Army, Navy, and Marines. Jimenez's sample size included 56 programs. He excluded space programs, programs that did not have both an MS B and an IOC date in the database, programs that did not have RDT&E funding data for at least one year prior to MS B, and programs that did not have clear Milestone A[15] start and end dates and funding data (Jimenez, 2016). He randomly split the sample of 56 programs into a validation pool of 11 programs and a regression model pool of 45 programs. Jimenez identified 26 pre-MS B factors that potentially predict post-MS B schedules to include in his model and used a mixed direction stepwise regression to identify significantly significant factors and estimate the statistically significant factors' effects (Jimenez, 2016).

Jimenez (2016) found four statistically significant factors. The first factor is RDT&E Funding (in millions of dollars) at MS B Start, which is the raw total of RDT&E funds allocated to the program prior to MS B. The second factor is the Percentage of RDT&E Funding at MS B Start, which is the percentage of RDT&E funds allocated to the program prior to MS B. The third factor is Modification—whether the program is a modification to a pre-existing weapons system. The fourth factor is 1985 or later for MS B Start—or whether the program started MS B in 1985 or later.

Jimenez's (2016) model explained 42.9% of the variation in timelines. He found that the strongest prediction variable, at 31% contribution to the model, is the percentage of RDT&E funds allocated to the program prior to MS B. Similar to Jimenez, the purpose of our research is to develop a multiple regression model to predict schedule. Our population of interest and estimated schedule differ from Jimenez's population and schedule because both our schedule and population are subsets of his.

D. SUMMARY

In summary, defense acquisition schedules, especially negative deviations from APBs, continually draw attention from Congress, the president, secretary of defense, service secretaries, combatant commanders, and academia. Parties interested in defense

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[15] Defined in Appendix.

acquisitions seek to improve schedule estimations, decrease cycle-times, and deliver capabilities faster. Based on our literature review, we collected data on factors such as contract value, contract type, external events or outside influences, mission type, and number of subcontractors. Other factors in our study came from subject matter expertise and experience in contracting.

Technological difficulties such as risk, maturation, and readiness are recurring factors that lengthen program schedules in acquisition literature. From literature, it is evident that technical readiness is not only pertinent post-award through TMRR, EMD, and P&D, but also important during the solicitation and contract award phases. Although literature frequently cites technical difficulties, risk, maturation, and readiness as factors affecting program schedule, we decided not to include these as factors in our specified model. While these technical difficulties may affect contractor performance and program schedules, the relationship between technical difficulties and PALT are unclear. Additionally, although literature states competition requirements lengthen schedules, our study's scope is limited to sole-source acquisitions and excludes competitive acquisitions; therefore, we did not include competition requirements as a factor in our prediction model. In Chapter VI, we recommend researchers include these factors in future studies.

III. METHODOLOGY

The purpose of this chapter is to describe the procedures used to conduct our research in detail. First, we describe the population, sample data, and method of collecting the sample data. Second, we explain our operationalization of the response variable and explanatory variables. Third, we specify the preliminary model. Lastly, we provide the estimation procedure.

A. POPULATION AND SAMPLE

Our unit of analysis is AFLCMC non-competitive contract actions greater than $500 million at the final business clearance. We chose to include actions greater than $500 million at business clearance, rather than at the receipt of an adequate proposal, because the clearance approval authority (CAA) changes at that threshold. The deputy assistant secretary of the Air Force for contracting (DAS[C]) or associate deputy assistant secretary of the Air Force for contracting (ADAS[C]) acts as the CAA for actions greater than $500 million (Air Force Federal Acquisition Regulation Supplement [AFFARS] 5301.9001(f)(1)).[16] If the proposal is greater than $500 million, but the Air Force negotiation team's negotiation objective is less than $500 million, the CAA is the senior center contracting official[17] (SCCO) at the operating location (AFFARS 5301.9001(f)(2)).

The population includes all AFLCMC non-competitive contract actions greater than $500 million awarded after October 1, 2013, and includes contract actions from Wright-Patterson Air Force Base (WPAFB) OH, Eglin AFB FL, Hanscom AFB MA, Hill AFB UT, and Robins AFB GA. The population includes Program Executive Officer (PEO) requirements for Agile Combat Support; Armament; Business and Enterprise Systems; Command, Control, Communications, Intelligence and Networks; Digital; Fighters and Bombers; Intelligence, Surveillance, Reconnaissance and Special Operations Forces;

[16] The threshold changed from $500 million to $1 billion on October 1, 2018.

[17] Defined in Appendix.

Mobility; Presidential Aircraft Recapitalization; and Tankers and non-PEO requirements for services.

Our team collected all the data for this analysis and created a new database. The sample size of our database is 26 contract actions. AFLCMC awarded all the sample contract actions between October 1, 2013, and February 6, 2018. We travelled to WPAFB to collect data from contract files for Mobility and Tanker actions from May 14 to May 18, 2018. Additionally, our team used electronic copies of Preliminary Price Negotiation Memorandums (PPNM) and/or Price Negotiation Memorandums[18] (PNM) to collect data

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[18] "The contracting officer shall document in the contract file the principal elements of the negotiated agreement. The documentation (e.g., price negotiation memorandum (PNM)) shall include the following:

(1) The purpose of the negotiation.

(2) A description of the acquisition, including appropriate identifying numbers (e.g., RFP No.).

(3) The name, position, and organization of each person representing the contractor and the Government in the negotiation.

(4) The current status of any contractor systems (e.g., purchasing, estimating, accounting, and compensation) to the extent they affected and were considered in the negotiation.

(5) If certified cost or pricing data were not required in the case of any price negotiation exceeding the certified cost or pricing data threshold, the exception used and the basis for it.

(6) If certified cost or pricing data were required, the extent to which the contracting officer --

(i) Relied on the cost or pricing data submitted and used them in negotiating the price;

(ii) Recognized as inaccurate, incomplete, or noncurrent any certified cost or pricing data submitted; the action taken by the contracting officer and the contractor as a result; and the effect of the defective data on the price negotiated; or

(iii) Determined that an exception applied after the data were submitted and, therefore, considered not to be certified cost or pricing data.

(7) A summary of the contractor's proposal, any field pricing assistance recommendations, including the reasons for any pertinent variances from them, the Government's negotiation objective, and the negotiated position. Where the determination of a fair and reasonable price is based on cost analysis, the summary shall address each major cost element. When determination of a fair and reasonable price is based on price analysis, the summary shall include the source and type of data used to support the determination.

(8) The most significant facts or considerations controlling the establishment of the prenegotiation objectives and the negotiated agreement including an explanation of any significant differences between the two positions.

(9) To the extent such direction has a significant effect on the action, a discussion and quantification of the impact of direction given by Congress, other agencies, and higher-level officials (i.e., officials who would not normally exercise authority during the award and review process for the instant contract action).

(10) The basis for the profit or fee pre-negotiation objective and the profit or fee negotiated.

(11) Documentation of fair and reasonable pricing" (FAR 15.406-3(a), 2018).

for all contract actions in the sample. We used AFLCMC/PK's Contract Action Tracker for the start and end dates of each phase.[19]

B. OPERATIONALIZATION OF VARIABLES

This section describes the variables in our model, how we categorized or measured each variable, and how we transformed the variable, if applicable.

1. Response Variable

The dependent variable is the predicted PALT for sole-source acquisitions greater than $500 million, measured in days. If the contracting officer issued an undefinitized contract action[20] (UCA), we defined the contract award as the date that the CO signed the contract resulting from the definitization[21] of all terms and conditions. We transformed the response variable by taking the natural logarithm of the PALT: Ln(PALT). The logarithmic transformation of PALT quantifies the approximate percent change in PALT resulting from a change in the explanatory variables, which makes the results more meaningful and allows users of this model to understand the associations with the explanatory variables more intuitively. The logarithmic transformation also accounts for non-linear relationships between the explanatory variables and response variable.[22]

a. Predicted Procurement Administrative Lead Time (Regression Output)—PALT

This variable states the predicted PALT for a sole-source acquisition greater than $500 million based on the model's explanatory variables in Ln(Days). Table 2 provides the descriptive statistics of Ln(PALT) in our sample, and Figure 3 depicts the graph of Ln(PALT) for each observation.

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[19] If the start date of a specific phase did not match the end date of the previous phase, we edited the start date of that specific phase to match, so that we did not miss or double count any days.

[20] Defined in Appendix.

[21] Defined in Appendix.

[22] The logarithmic transformation of the response variable allows the regression model to represent a linear relationship between time and our predictor variables. This transformation satisfies the Ordinary Least Squares assumption that the regression model is linear in parameters (i.e., regression coefficients).

Table 2. Ln(PALT) Descriptive Statistics

Mean	6.5807
Standard Error	0.1109
Median	6.5220
Mode	5.6560
Standard Deviation	0.5653
Sample Variance	0.3196
Kurtosis	-0.0650
Skewness	-0.5049
Range	2.2272
Minimum	5.2257
Maximum	7.4530
Sum	171.0975
Count	26

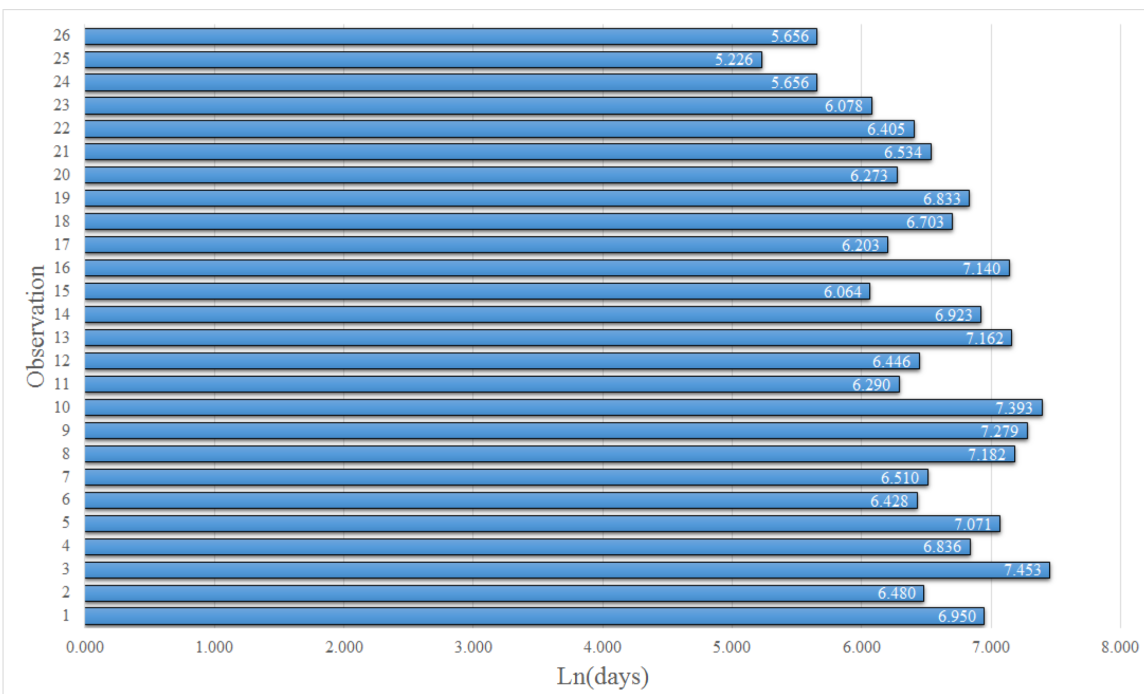

Figure 3. Timeline of Sample Observations

There are three contract actions for Non-PEO requirements. All three of these contract actions are for Federally Funded Research and Development Center[23] services awarded to non-profit contractors. The timeline for these observations was at least 1.5 standard deviations shorter than the mean timeline for all observations (i.e., 412 days shorter than the mean).[24]

2. Candidate Explanatory Variables

This section explains the candidate explanatory variables for the multiple regression model in terms of how we categorized, found, and/or measured each explanatory variable. We chose candidate explanatory variables based on inputs from subject matter experts and literature.

Users of our model must input a value for each explanatory variable to estimate PALT. An Air Force negotiation team (AFNT) estimates PALT prior to RFP release; however, the AFNT will not know the value of all explanatory variables at the time of RFP release. Therefore, the AFNT must estimate values for explanatory variables that are unknown at the time of RFP release. The following sections identify the phase that the AFNT should know the value of each explanatory variable, if the variable value is unknown at RFP release.

a. Proposed Price (Price)—Continuous Variable

This continuous variable gives the contractor's proposed price. We found this information in the contractor's proposal, PPNM, or PNM. We transformed the proposed price by taking the natural logarithm: Ln(Price). The relationship between time and price is non-linear, so the logarithmic transformation of price allows the model to satisfy the Ordinary Least Squares (OLS) assumption that the model is linear in parameters for price. The AFNT will not know this value until the contractor submits a qualifying proposal (end

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[23] Defined in Appendix.

[24] The mean is 6.5807, and the standard deviation is 0.5653. We calculated 412 days by taking the difference between the exponentiation of Euler's number by the mean (e^6.5807) and the exponentiation of Euler's number by the difference between the mean and the standard deviation multiplied by 1.5: (e^6.807) - (e^(6.807-1.5*(0.5653))).

of Phase 1.0). Based on MacKinnon's (1992) thesis, our hypothesis is that a positive relationship between Price and PALT exists.

Table 3 contains the descriptive statistics for Ln(Price) in our sample.

Table 3. Ln(Price) Descriptive Statistics

Mean	21.0284
Standard Error	0.1548
Median	20.8001
Mode	21.0859
Standard Deviation	0.7894
Sample Variance	0.6232
Kurtosis	0.4702
Skewness	1.0254
Range	2.9474
Minimum	20.0556
Maximum	23.0030
Sum	546.7383
Count	26

b. Undefinitized Contract Action (UCA)—Categorical (Binary) Variable

This categorical variable identifies whether the contracting officer issued a UCA to the contractor in order for the contractor to commence work immediately or if the contracting officer negotiated the terms and conditions prior to the contractor commencing work (standard buy). There are two categories:

- yes, the action is a UCA (1); and
- no, the action is a standard buy (0).

The AFNT knows this variable prior to RFP release. Of the 26 observations within our sample, 11 are UCAs.

We hypothesize that a positive relationship exists between UCA and PALT because the DoD and Air Force have experienced difficulties with meeting definitization timelines. The DFARS requires the CO to definitize a UCA within 180 days of issuing the UCA but allows up to a 180-day extension after the receipt of a qualifying (adequate) proposal. Former Director, Defense Procurement and Acquisition Policy (DPAP) Claire Grady stated in testimony before the House Armed Services Committee that despite the DFARS definitization timeline requirements, there were 11 FMS UCAs that were not definitized after 730 days (*Assessing the DoD's Execution of Responsibilities in the U.S. FMS Program*, 2016). The GAO (2015) examined the Air Force's use of UCAs and found that the Air Force did not meet the definitization timelines for seven of the nine UCAs reviewed by the GAO. Headquarters Air Force Materiel Command (AFMC)/A9 analyzed and compared AFLCMC's standard PALT of 365 days for contracts valued between $50 and $500 million to the PALT of contracts that AFLCMC awarded from 2009 to 2017 between these dollar values. AFMC/A9 found that AFLCMC awarded 154 contracts late (i.e., the PALT exceeded 365 days), 50 of the 154 contracts awarded late started as UCAs, and the PALT of 26 of these 50 contracts that started as UCAs exceeded 730 days (V. Fry, personal communication, May 7, 2018).

c. Is the Date of Initial Proposal and Date of Adequate Proposal the Same (Adq_Prop)—Categorical (Binary) Variable

This categorical variable identifies whether the date of the contractor's initial proposal and the date of an adequate proposal are the same. There are two categories: yes (1) or no (0). We used AFLCMC/PK's Contract Action Tracker for the dates of initial proposal and adequate proposal. The dates are the same for 15 observations and different for 11 observations. The AFNT will know this variable after the contracting officer reviews the contractor's initial proposal (Phase 1.0).

If the dates of the initial proposal and adequate proposal are the same, we expect that PALT will decrease, (i.e., a negative relationship between Adq_Prop and PALT), if Adq_Prop is yes (1). Phase 1.0 ends with the receipt of an adequate proposal, so any delay of the contractor submitting an adequate proposal delays the rest of the sole-source contract award process and extends the PALT. Under Secretary Lord identified the receipt of an adequate proposal within 60 days as one way to reduce PALT (*DoD Acquisition Reform Efforts*, 2017). The GAO's (2015) report on the Air Force's use of UCAs stated that Air

Force contracting officials assert that the lack of an adequate proposal is the most common cause of definitization timeline delays.

d. Number of Proposed Major Subcontractors and Major Inter/Intra-Work Transfer Orders /Agreements (Major_Subs)—Continuous Variable

This continuous variable identifies the number of major subcontractors proposed by the prime contractor and the number of divisions (transfers) within the corporation performing a major portion work for the prime contractor. We defined Major_Subs as subcontractors or transfers[25] that exceed the threshold at FAR 15.404-3(c)(1). The current threshold is $13.5 million. The threshold prior to October 1, 2013, was $12.5 million.[26] We collected this data from the contractor's proposal, the PPNM, or PNM. The PPNM and PNM contain the proposed prices of subcontractors and transfers in the cost element summary, typically under subcontract costs or material costs. The AFNT will know this value after the contractor submits an adequate proposal (end of Phase 1.0).

We expect a positive relationship between Major_Subs and PALT. Prime contractors request and evaluate subcontractor proposals and negotiate and award subcontracts. The AFNT evaluates subcontractor proposals and negotiates subcontractors as a cost element of the prime contractor's proposal. As the number of subcontractors increases, we expect the PALT to increase.

Table 4 and Table 5 contain the descriptive statistics and tabulation of Major_Subs. Of the 26 observations in the sample, 22 observations have at least one major subcontractor or transfer, and four had no major subcontractors or transfers. Three of the four observations that had no proposed major subcontractors or transfers were for federally funded research and development center (FFRDC) services, which the Air Force awarded to non-profit contractors.

[25] We included transfers only if the prime contractor submitted a proposal or a discrete number of hours for that transfer. If the prime contractor multiplied any portion of their costs by a cost estimating relationship for their proposed transfer price, we did not include that transfer in our number of Major_Subs.

[26] The Air Force did not award any of the contract actions in our sample prior to October 1, 2013; however, the increased threshold applied only to acquisitions started after October 1, 2013 (i.e., contract actions with an RFP Release Date after October 1, 2013).

Table 4. Major Subcontractor and Transfer Descriptive Statistics

Mean	6.3462
Standard Error	1.5571
Median	4
Mode	0
Standard Deviation	7.9395
Sample Variance	63.0354
Kurtosis	13.1937
Skewness	3.2192
Range	40
Minimum	0
Maximum	40
Sum	165
Count	26

Table 5. Major Subcontractor and Transfer Tabulation

Range	Frequency	Percent
0	4	15.38
1	2	7.69
2	2	7.69
3	3	11.54
4	3	11.54
6	3	11.54
7	1	3.85
8	2	7.69
11	4	15.38
13	1	3.85
40	1	3.85
Total	26	100

e. Aggressiveness of the Government's Objective Position (Obj_Position)—Continuous Variable

This continuous variable identifies the percentage point change between the contractor's total proposed dollar amount and AFNT's total objective dollar amount:

(Contractor total proposed dollar amount - AFNT total objective dollar amount) /
(Contractor total proposed dollar amount) * (100) (2)

We collected this data from the PPNM. The AFNT will know this value after evaluating the contractor's proposal (end of Phase 2.0/start of Phase 3.0).

We expect a positive relationship between Obj_Position and PALT. In general, a larger percentage point difference between the AFNT's and contractor's positions will shrink the zone of possible agreement and increase the length of negotiations (Phase 4.0).

Table 6 contains the descriptive statistics of Obj_Position.

Table 6. Objective Position Descriptive Statistics

Mean	13.6593
Standard Error	1.4440
Median	13.4515
Mode	16.9380
Standard Deviation	7.3631
Sample Variance	54.2151
Kurtosis	0.131
Skewness	0.4033
Range	29.9820
Minimum	0
Maximum	29.9820
Sum	355.1430
Count	26

f. The Number of Times Delta Clearance is Required (Range)—Continuous Variable

This continuous variable identifies the number of times the AFNT required a delta business clearance. The CAA approves a clearance value, which is the dollar amount that the AFNT must negotiate at or below to complete negotiations. If the AFNT and contractor do not agree to a price under the cleared amount, the AFNT must conduct a delta business clearance with the CAA to request a higher clearance amount (i.e., negotiation range or range). The preferred source of whether the AFNT required a higher range is "Tab 59 - Clearance Review & Approval Documentation" of the contract file; however, we did not have access to all the contract files. When we did not have access to the contract file, we used information from the “Business Clearance/Pre-Negotiation Authorization” paragraph in the PNM. The AFNT will not know this variable until the AFNT and contractor complete negotiations (end of Phase 4.0).

We expect a positive relationship between Range and PALT. The AFNT and contractor may not agree to a price below the cleared amount for various reasons, such as changed requirements or no zone of possible agreement. Regardless of the reason, the AFNT regresses from Phase 4.0 to Phase 3.0 and must receive a higher clearance amount, which requires additional reviews and/or briefings.

Table 7 and Table 8 contain the descriptive statistics and tabulation of Range. Of the 26 observations in the sample, 17 observations required at least one delta business clearance, and nine observations required zero delta business clearances.

Table 7. Range Descriptive Statistics

Mean	1.0769
Standard Error	0.2213
Median	1
Mode	1
Standard Deviation	1.1286
Sample Variance	1.2738
Kurtosis	0.6032
Skewness	1.1043
Range	4
Minimum	0
Maximum	4
Sum	28
Count	26

Table 8. Range Tabulation

Range	Frequency	Percent
0	9	34.62
1	11	42.31
2	2	7.69
3	3	11.54
4	1	3.85
Total	26	100

g. *Foreign Military Sales Requirement (FMS)—Categorical (Binary) Variable*

This categorical variable identifies whether the contract action includes Foreign Military Sales (FMS) requirements (1) or not (0). The PPNM and PNM contain a "Description of Current Procurement: Program/Item/Service Identification" paragraph that identifies whether the contract action contained FMS requirements. The requirements document also indicates whether the requirement includes FMS requirements. The AFNT knows this variable prior to RFP release. Within our sample, 12 observations contained FMS requirements, and 14 did not contain FMS requirements.

We expect a positive relationship between FMS and PALT based on analysis by AFMC/A9 and testimony from Claire Grady, former Director, DPAP. AFMC/A9 found that AFLCMC awarded 154 contracts, valued between $50 and $500 million, late, which means that the PALT exceeded AFLCMC's standard PALT of 365 calendar days (V. Fry, personal communication, May 7, 2018). According to AFMC/A9, FMS requirements accounted for 61 contracts and 39 of the 154 contracts awarded late; AFLCMC awarded 39 of 61 contracts for FMS requirements late; and the PALT exceeded more than 730 days for 23 of these FMS contracts. In her testimony before Congress, Grady stated that she was looking at ways to decrease the acquisition cycle-time of FMS and cited several areas of improvement including the requirements for certified cost or pricing data, use of UCAs, different contract types, and offset agreements (*Assessing the DoD's Execution of Responsibilities in the U.S. FMS Program*, 2016). She explained that offsets are agreements between the contractor and foreign government for business expenses that the contractor would not incur in contracts without FMS requirements; that the DoD is not a party to these offset agreements; and that offsets are a significant source of delay.

h. Non-Profit Contractor (Non_Profit)—Categorical (Binary) Variable

This categorical variable identifies whether the contract awardee is a non-profit contractor (1) or not (0). The AFNT knows this variable prior to RFP release. Three observations are non-profit contractors, and 23 are not. We expect a negative relationship between Non_Profit and PALT because the AFNT and contractor do not need to negotiate profit or fee, which should decrease the proposal preparation, evaluation, and negotiation time.

i. Program Executive Officer (PEO)—Categorical Variable

This variable indicates the PEO portfolio that each individual contract action falls under, not the individual serving as the PEO. There are seven different PEO portfolios in our sample: Armament (EB), ISR (WI), Tanker (WK), Mobility (WL), PAR (WV), Fighters and Bombers (WW), and Non-PEO. The AFNT knows this variable prior to RFP release.

WI, WK, and WV each contained one observation, and Non-PEO contained three observations within our sample. We grouped WI, WK, WV, and Non-PEO into one category, Other, due to the low number of observations within each of these PEOs. WL and WW contain seven observations each, and EB and Other contain six observations each. Table 9 shows the tabulation of PEO.

Table 9. PEO Tabulation

PEO	Frequency	Percent
EB	6	23.08
Other	6	23.08
WL	7	26.92
WW	7	26.92
Total	26	100

We used deviation coding instead of dummy coding for PEO because deviation coding compares the outcomes of each individual group to the mean of all groups, rather than comparing each individual group to a specified level within the group (Cohen, Cohen, West, & Aiken, 2003). It is more useful for us to compare all four levels of PEO to the mean, rather than comparing Other, WL, and WW to EB. We also used unweighted effects, rather than weighted effects because the number of observations within each category are relatively similar. Table 10 shows the coding system for PEO. The Level of PEO column indicates the PEO responsible for the observation, and the EB, WL, and WW columns display the value for each respective variable within our regression model. For example, if the PEO responsible for a contract action is Other, then the values of the explanatory variables EB, WL, and WW, will each be -1.

Table 10. PEO Deviation Coding

	Explanatory Variable		
	EB	**WL**	**WW**
Level of PEO	Level 2 vs. Mean	Level 3 vs. Mean	Level 4 vs. Mean
1 (Other)	-1	-1	-1
2 (EB)	1	0	0
3 (WL)	0	1	0
4 (WW)	0	0	1

We expect a relationship between PEO and PALT to exist, based on AFMC/A9's analysis and variables other researchers used in their studies. AFMC/A9 identified that differences in the number and percentage of contracts awarded late exist between PEOs, but AFMC/A9 did not analyze the length of delays (V. Fry, personal communication, May 7, 2018). The programs under each PEO also differ by technical complexity and program complexity. The number of critical technologies and testing required for programs differs by weapon system, such as armament versus fighters and bombers.

j. Previous Acquisition Data Available for Cost/Pricing Comparison (History)—Categorical (Binary) Variable

This categorical variable identifies whether previous acquisition data was available to the AFNT in order to perform a meaningful cost or pricing comparison. There are two categories:

- yes, the AFNT had previous acquisition data (1); or
- no, the AFNT did not have previous acquisition data (0).

We collected this data from the PPNM or PNM. The PPNM and PNM have a previous buy paragraph that describe similar purchases in the past and whether the AFNT can use data from those purchases for a cost or price comparison. The AFNT will know this value prior to RFP release. Within our sample, 17 observations have previous acquisition history that allows the AFNT to make a meaningful cost or price comparison with the current buy, and nine do not.

We expect a negative relationship between History and PALT. Previous acquisition history provides data that the contractor can use to create bases of estimates and prepare proposals, data that the AFNT can use to evaluate proposals, and data that both sides can use in negotiations.

A peculiarity in the data is that the PNMs of the three observations with the shortest timelines stated that the AFNT could not perform a meaningful price comparison with previous buys. These three observations were contract actions awarded to non-profit contractors for FFRDC requirements.

3. Explanatory Variables Correlation Matrix

Table 11 shows the correlation matrix for our response variable and explanatory variables and identifies the degree of multicollinearity between our explanatory variables. Multicollinearity becomes problematic when explanatory variables in a multiple regression model can linearly predict another explanatory variable accurately. Multicollinearity is a problem if the correlation value between explanatory variables is greater than 0.8 (Mason & Perreault, 1991). The highest absolute value of any of the correlations is 0.6286 and between History and WL. Since the value is less than 0.8, multicollinearity is not problematic.

Table 11. Explanatory Variables Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.00												
2	-0.03	1.00											
3	0.72	-0.24	1.00										
4	-0.20	-0.03	-0.21	1.00									
5	-0.19	0.30	-0.10	-0.06	1.00								
6	0.37	0.30	-0.13	-0.37	0.04	1.00							
7	-0.18	-0.12	0.15	0.06	0.41	0.15	1.00						
8	0.34	-0.15	0.61	-0.30	-0.05	-0.22	0.08	1.00					
9	0.61	0.59	-0.31	0.07	-0.29	0.22	-0.24	-0.33	1.00				
10	-0.70	-0.32	0.23	-0.11	0.20	-0.01	0.41	0.57	-0.53	1.00			
11	0.39	-0.31	0.50	-0.28	0.19	0.08	0.39	0.28	-0.53	0.48	1.00		
12	0.61	-0.26	0.39	0.16	0.21	-0.08	0.29	0.39	-0.53	0.48	0.46	1.00	
13	0.21	-0.37	-0.30	0.03	0.22	-0.20	0.27	0.02	-0.50	0.48	0.63	0.15	1.00

KEY

	Variable	Mean	Standard Deviation
1	PALT	6.58	0.57
2	Price	21.03	0.15
3	UCA		
4	Adq_Prop		
5	Major_Subs	6.35	1.56
6	Obj_Position	13.66	1.44
7	Range	1.08	0.22
8	FMS		
9	Non_Profit		
10	EB		
11	WI		
12	WW		
13	History		

C. MODEL SPECIFICATION

Equation 3 specifies our multiple linear regression model with each of the previously explained candidate explanatory variables. Ln(PALT) is the response variable.

$$\ln(PALT) = \beta_0 + \beta_1 \ln(Price) + \beta_2(UCA) + \beta_3(Adq\_Prop) + \beta_4(Major\_Subs) + \beta_5(Obj\_Position) + \beta_6(Range) + \beta_7(FMS) + \beta_8(Non\_Profit) + \beta_9(EB) + \beta_{10}(WL) + \beta_{11}(WW) + \beta_{12}(History) + \epsilon_i \quad (3)$$

D. ESTIMATION PROCEDURE

We used an ordinary least squares (OLS) regression to estimate the model. An OLS estimation regression is commonly used to specify prediction models because OLS "seeks to minimize the sum of the squared differences between the observed and predicted squares of Y" (Cohen et al., 2003, p. 124).

E. SUMMARY

This chapter outlines our research methodology. We summarize the population and sample data, detail our process of data collection, and explain our response and candidate explanatory variables in detail. We provide our preliminary regression model and estimation procedure. In the next chapter, we introduce the results and interpretation of our model.

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IV. RESULTS

A. SUMMARY OF RESULTS

Our research team uses an OLS regression to model the relationship between our response variable, PALT, and 12 explanatory variables using STATA 15 software. We used previous research and subject matter expertise to guide the development of our model. Given that heteroscedasticity can affect the validity or power of our statistical tests when using OLS regression, we employ heteroscedasticity-consistent (robust) standard errors to reduce the effects of heteroscedasticity (Hayes & Cai, 2007).[27] Table 12 shows the results of our regression model. The model (Equation 3) was significant ($F(12, 13) = 33.44$, $p < .05$), and the changes in the explanatory variables explained 95.19% of the variance in the response variable (R-squared = 0.9519). The adjusted R-squared = 0.9005 and is adjusted based on the number of explanatory variables used in our model. The $\beta_0 = 5.43$ is the regression constant, or intercept, and represents the estimated Ln(PALT) of a hypothetical non-competitive contract action greater than $500 million with no influencing factors, that is, all $X_i = 0$ ($\beta_0 = 5.43$, $t(13) = 2.73$, $p = .017$). The root-mean-square error[28] (RMSE) of 0.17 shows how accurately the model predicts the response variable. The full regression equation is

$$\text{Ln(PALT)} = \beta_0 + \beta_1\text{Ln(Price)} + \beta_2(\text{UCA}) + \beta_3(\text{Adq\_Prop}) + \beta_4(\text{Major\_Subs}) + \beta_5(\text{Obj\_Position}) + \beta_6(\text{Range}) + \beta_7(\text{FMS}) + \beta_8(\text{Non\_Profit}) + \beta_9(\text{EB}) + \beta_{10}(\text{WL}) + \beta_{11}(\text{WW}) + \beta_{12}(\text{History}) + \epsilon_i$$

[27] The violation of the homoscedasticity assumption, also known as heteroscedasticity, assumes that the residual variances are not constant across all the explanatory variables in our model.

[28] Defined in Appendix.

Table 12. Results of Regression Model

Linear Regression		Number of Observations			=		26
		F(12, 13)			=		33.44
		Prob > F			=		0
		R-squared			=		0.9519
		Root MSE			=		0.1720
Ln(PALT)	**Coeff.**	**Robust Std. Error**	**t**	**P>t**	**(95% Conf. Interval)**		
Price	0.0316	0.1000	0.32	0.756	-0.1837		0.2469
UCA	0.3341	0.1118	2.99	0.010	0.0926		0.5755
Adq_Prop							
Y	-0.0406	0.0926	0.926	0.668	-0.2407		0.1594
Major_Subs	0.0172	0.0069	0.007	0.028	0.0022		0.0322
Obj_Position	-0.0004	0.0081	0.008	0.966	-0.0178		0.0171
Range	0.0477	0.033	0.033	0.173	-0.0237		0.1191
FMS							
Y	0.4379	0.1509	2.9	0.012	0.1120		0.7638
Non_Profit							
Y	-0.6119	0.2867	-2.13	0.052	-1.2313		0.0075
EB	-0.3322	0.0821	-4.05	0.001	-0.5096		-0.1549
WL	0.0908	0.0706	1.29	0.221	-0.0617		0.2433
WW	0.2341	0.0686	3.41	0.005	0.0859		0.3822
History							
Y	0.1047	0.0902	1.16	0.266	-0.0901		0.2997
_cons	5.4305	1.9857	2.73	0.017	1.1407		9.7203

In regression analysis, an explanatory variable is statistically significant when the p-value is less than alpha (α = significance level of 0.05). Alpha is the probability of a Type I error. A Type I error is an "error of rejecting the true null hypothesis or, less formally, finding things that are not there" (Cohen et al., 2003, p. 182). Our model estimated the effects—sign and magnitude—of 12 explanatory variables and five were statistically significant—UCA, Major_Subs, FMS, EB, and WW. We further discuss the effect of each explanatory variable in Chapter V.

1. Chow Test

The Chow Test determines whether “subsets of coefficients in two regressions are equal [or not]” (Chow, 1960, p. 591). We used the Chow Test to determine whether our predictor variables have different effects on different subgroups of our sample: contract actions with and contract actions without FMS requirements. If the effects are different, we should separate contract actions with and without FMS requirements into two different populations. If the effects are not different, we may include the two subgroups in the same population. The null hypothesis is that our predictor variables have the same effects on the different subgroups within our sample. Equation 4 is the Chow Test equation.

$$\text{Chow} = \frac{(RSS_P - (RSS_1 - RSS_2))/k)}{(RSS_1 + RSS_2)/(N_1 + N_2 - 2k)}, \text{ where} \quad (4)$$

P: Pooled group (Group 1 + Group 2)

[Group] 1: contract actions without FMS requirements

[Group] 2: Contract actions with FMS requirements

RSS_P = 0.3845 (Used RSS from non-robust estimator model)

RSS_1 = 0.1277

RSS_2 = 0.0454

K: Number of predictor variables in pooled group = 12

N_1: Number of observations in Group 1 = 14

N_2: Number of observations in Group 2 = 12

Chow test statistic = 0.2910

F-critical (.05, 12, 2) = 19.4125

Since the Chow test statistic is less than the F-critical and does not fall in the rejection region, we fail to reject the null hypothesis, which means that there is no evidence that the predictor variables have different impacts on different subgroups within our sample. Thus, we do not need to separate these two subgroups into different populations and we can keep sole-source acquisitions with and without FMS requirements in the same population.

2. Breusch-Pagan Test

The OLS assumption of homoscedasticity states that the variance in the error term is constant; and the violation of homoscedasticity is known as heteroscedasticity. The Breusch-Pagan Test detects any linear form of heteroscedasticity by testing the null hypothesis to determine whether error variances are equal. Cohen et. al. (2003) stated that the "failure of homoscedasticity assumption may not be serious enough to invalidate tests of statistical significance, but it still could invalidate actual prediction if based on the assumption of equal error throughout the distribution" (p. 96). Therefore, it is important to address heteroscedasticity because it biases the standard errors, which leads to biases in test statistics and confidence intervals (CI). Figure 4 shows a plot of the residuals against the fitted values. The residual-versus-fitted plot shows an uneven distribution, which necessitates a formal test for heteroscedasticity in STATA.

The Breusch-Pagan Test resulted in a chi-square of 3.50 indicating that heteroscedasticity was present (chi2 (1) = 3.50; Prob > chi2 = 0.0613). A large chi-square indicates that heteroscedasticity is present. We use heteroscedasticity-consistent (robust) standard error estimators to reduce the effects of heteroscedasticity, thereby addressing the violation of the OLS assumption that standard errors are identically distributed.

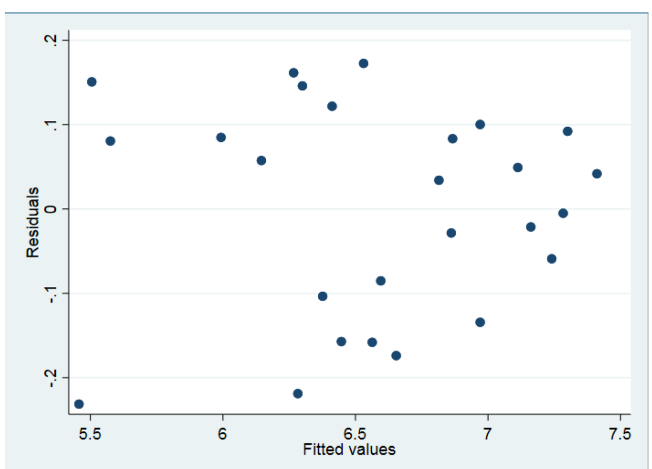

Figure 4. Residuals versus Fitted Plot

V. DISCUSSION

The purpose of this chapter is to discuss the results of our regression model and their interpretations. First, we present and analyze the results of the five statistically significant explanatory variables. Next, we discuss the explanatory variables that we hypothesized affected PALT but were not statistically significant. We also explain the methods of hypothesis testing (i.e., Type I and Type II error) and the explanatory power as it pertains to our regression model. Lastly, we discuss why our results are meaningful.

A. DISCUSSION OF RESULTS

1. Interpretation of Statistically Significant Explanatory Variables

In specifying the regression model, we used 12 explanatory variables to predict PALT. Five of the 12 explanatory variables were statistically significant, which confirms that a relationship between the explanatory variable and the response variable exists. We can also conclude, with 95% confidence, the lower and upper limit of how small and how large the effect size of the population might be in estimating PALT. The sign and magnitude of each effect is given by its beta coefficient, β_i. Each of the beta coefficients indicates an effect of the explanatory variables while holding all other explanatory variables in the equation constant. We discuss and analyze each statistically significant explanatory variable in the following paragraphs.

a. Undefinitized Contract Action (UCA)—Categorical (Binary) Variable

The explanatory variable, UCA, is statistically significant, where $\beta_2 = 0.3341$ is the estimated regression coefficient for UCA, such that a contract action determined to be a UCA is associated with a 33.41% increase in PALT ($\beta_2 = 0.3341$, $t(13) = 2.99$, $p = .010$). As expected, UCA is positively related to PALT; and based on this model, we are 95% confident that the percentage increase in PALT is between 9.26% and 57.55%. This result supports the claims in literature that the difficulties in definitizing UCAs indeed increase PALT.

b. Number of Proposed Major Subcontractors and Major Inter/Intra-Work Transfer Orders/Agreements (Major_Subs)—Continuous Variable

The explanatory variable, Major_Subs, is statistically significant, where β_4 = 0.0172 is the estimated regression coefficient for Major_Subs, such that each additional major subcontractor is associated with a 1.72% increase in PALT (β_4 = 0.0172, t(13) = 0.007, p = .028). As expected, Major_Subs is positively related to PALT; and based on this model, we are 95% confident that the percentage increase in PALT is between 0.22% and 3.22%.

c. FMS Foreign Military Sales Requirement (FMS)—Categorical (Binary) Variable

The explanatory variable, FMS, is statistically significant, where β_7 = 0.4379 is the estimated regression coefficient for FMS, such that a contract action determined to be an FMS requirement is associated with a 43.79% increase in PALT (β_7 = 0.4379, t(13) = 2.9, p = .012). As expected, FMS, is positively related to PALT; and based on this model, we are 95% confident that the percentage increase in PALT is between 11.20% and 76.38%.

d. Armament (EB)—Categorical Variable

The explanatory variable, EB, is statistically significant, where β_9 = -0.3322 is the estimated regression coefficient for EB, such that a contract action categorized as EB is associated with a 33.22% decrease in PALT (β_9 = -0.3322, t(13) = -4.05, p = .001). As expected, EB, is negatively related to PALT, and based on this model, we are 95% confident that the percentage decrease in PALT is between -50.96% and -15.49%.

e. Fighters and Bombers (WW)—Categorical Variable

The explanatory variable, WW, is statistically significant, where β_{12} = 0.2341 is the estimated regression coefficient for WW, such that a contract action categorized as WW is associated with a 23.41% increase in PALT (β_{12} = 0.2341, t(13) = 3.41, p = .005). As expected, WW, is positively related to PALT; and based on this model, we are 95% confident that the percentage decrease in PALT is between 8.59% and 38.22%.

2. Interpretation of Nonsignificant Explanatory Variables

Our study has a small sample size of 26 observations, and we include 12 explanatory variables in our model. Cohen et al. (2003) stated that "the greater the number of [explanatory variables], the lower the power of the test on each [explanatory variable]" (p. 186). When the statistical power of a study is low, there is a reduced chance of detecting an explanatory variable's true effect, making it difficult to derive a meaningful and accurate interpretation of the explanatory variable. Drawing statistical inferences on an explanatory variable may result in a Type I or Type II error. A Type I error is an "error of rejecting the true null hypothesis or, less formally, finding things that are not there" and a Type II error is an "error of failing to reject a false null hypothesis and failing to find things that are there" (Cohen et al., 2003, pp. 182–183). If an explanatory variable is nonsignificant, then our sample data provides no evidence that the effect of the explanatory variable on PALT is different from zero in the population. We discuss and analyze each statistically nonsignificant explanatory variable with the understanding that our data does not substantiate a statistically significant relationship, even though one may exist.

a. Proposed Price (Price)—Continuous Variable

The explanatory variable, Price, where $\beta_1 = 0.0316$ is the estimated regression coefficient ($\beta_1 = 0.0316$, $t(13) = 0.32$, $p = .756$), was in the expected positive direction in relation to PALT. However, our data offered no support for this relationship.

b. Is the Date of Initial Proposal and Date of Adequate Proposal the Same (Adq_Prop)—Categorical (Binary) Variable

The explanatory variable, Adq_Prop, where β_2= -0.0406 is the estimated regression coefficient ($\beta_2 = -0.0406$, $t(13) = 0.926$, $p = .668$), was in the expected negative direction. We hypothesized that PALT would decrease if the initial proposal and adequate proposal date were the same, but our data does not substantiate this relationship.

c. Aggressiveness of the Government's Objective Position (Obj_Position)—Continuous Variable

The explanatory variable, Obj_Position, where β_5 = -0.0004 is the estimated regression coefficient (β_5 = -0.0004, t(13) = 0.008, p = .966), had an estimated effect opposite of our hypothesis. We hypothesized that a larger percentage point difference between the AFNT and contractor positions would increase the length of negotiations, thereby increasing PALT.

d. The Number of Times Delta Clearance is Required (Range)—Continuous Variable

The explanatory variable, Range, where β_6 = 0.0477 is the estimated regression coefficient (β_6 = 0.0477, t(13) = 0.033, p = .173), was in the expected positive direction in relation to PALT. However, our data offered no support that PALT would increase.

e. Non-Profit Contractor (Non_Profit)—Categorical (Binary) Variable

The explanatory variable, Non_Profit, where β_8 = -0.6119 is the estimated regression coefficient (β_8 = -0.6119, t(13) = -2.13, p = .052), was in the expected negative direction in relation to PALT. However, our data offered no support that PALT would decrease.

f. Mobility (WL)—Categorical Variable

The explanatory variable, WL, where β_8 = -0.6119 is the estimated regression coefficient (β_{10} = 0.0908, t(13) = -2.13, p = .052), was in the positive direction in relation to PALT. We did not have a specific hypothesis for WL and wanted to test its effect on PALT.

g. Previous Acquisition Data Available for Cost/Pricing Comparison (History)—Categorical (Binary) Variable

The explanatory variable, History, where β_{12} = 0.1047 is the estimated regression coefficient (β_{12} = 0.1047, t(13) = 1.16, p = .266), had an estimated effect opposite of our hypothesis. We hypothesized that the availability of previous acquisition history would decrease PALT.

3. Why Results Are Meaningful

The coefficient of determination, also known as R-squared, is the percent of variance explained by our model. The value of R-squared ranges from 0% to 100%, and the model is interpreted as a "perfect fit" at 100%. Cohen et al. (2003) states that a "value of R-squared closer to [100%] generally implies a 'good' model" (p. 85). The value of the adjusted R-squared (adjusted R-squared = 90.05%) corrects for the sample size and the total number of factors estimated in our model. According to Cohen et al. (2003), our model would be considered a "good" model when compared against the baseline (i.e., the average). Therefore, we can rely on our model—its data, results, and analysis—to provide valuable insight on factors that affect PALT.

Our model provided objective measures of relationships between our response variable and explanatory variables. Instead of relying on experience and intuition, we have data that informs us (1) if a factor affects PALT and (2) if so, by how much. With this information and knowledge, acquisition leaders, commanders, and decision makers can improve business decisions and management trends in order to "deliver on a ***timely basis*** the best value product or service to the customer, while maintaining the public's trust and fulfilling public policy objectives" (FAR 1.102(a)). While immediate changes are never guaranteed, key stakeholders can now ask themselves, "What actions can we take with this data?" and "What can we do better and how?"

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VI. LIMITATIONS, RECOMMENDATIONS FOR FURTHER RESEARCH, AND CONCLUSION

In this chapter, we discuss the limitations of our study, provide recommendations for further research, and answer our research questions.

A. RESEARCH LIMITATIONS

The primary limitation of our research was the availability and amount of data on sole-source acquisitions greater than $500 million—our data set was limited to only 26 observations. We exercised our judgment, with the aid of our advisors, on specifying a model that could substantiate our results given a small sample size.

In specifying our model, we had to limit the number of explanatory variables based on our sample size. Even though our team brainstormed over 30 explanatory variables that we thought could have a significant impact on PALT, mathematically, we could not include more predictors than observations. Some of these factors required proxies that were difficult to quantify and measure, such as the level of expertise on the technical evaluation team. Consequently, our team was unable to determine user-friendly and easily measurable metrics for these factors making them unusable until we find an appropriate proxy.

Another limitation of a small sample size is that it decreases the estimation's level of certainty. Small sample sizes often result in broader CIs, which are not as precise compared to a larger sample size. A broader CI is more likely to include zero, increasing the risk for insignificant beta coefficients. Furthermore, we were unable to externally validate our model against a population such as the Space and Missiles Systems Center (SMC), the different military branches, and the DoD. Ultimately, we need a larger pool of observations to validate or refine our model.

B. RECOMMENDATIONS FOR FURTHER RESEARCH

Based on our research and our limitations discussed above, we have several recommendations for further research. First, we recommend additional research to externally validate the model to the population or refine the model. This includes creating a validation pool from the population as defined in Chapter III and testing the model within that pool. From there, based on the results of the test, the model would be strengthened or could be adjusted.

Additionally, further external validity could be proven by creating a validation pool including acquisitions greater than $500 million from organizations outside of AFLCMC, such as SMC. Once the validation pool has been created and the model tested against it, depending on the results, we would recommend adjusting and re-testing the model, thus strengthening the results through widening the population and subsequently, the sample size. We would also recommend including acquisitions from sister services across the DoD into the population and sample data set, and following similar research as discussed above to ensure external validity and future utilization of the model in these different organizations.

Another area of research is estimating the number of days in each phase of the contract award process. Phases 1.0 (Release of RFP to Receipt of Adequate Proposal) and 2.0 (Fact Finding and Evaluation) accounted for nearly two-thirds of the entire PALT in our sample. Understanding the significant factors that affect these two phases and those factors' effects will help AFLCMC/PK identify management focus areas to decrease the PALT of their acquisitions.

Our research primarily focused on the process of the buyer, or government, side of an acquisition. Future researchers can investigate the seller, or contractor, side of the acquisition and the interaction between the two sides. The seller is responsible for the deliverable in Phase 1.0 and this phase takes longer than any other phase, on average. Taking steps to decrease the time that Phase 1.0 takes can significantly decrease the PALT.

Last, we recommend that future researchers study the effects of both human factors and technical risk and maturation factors, as discussed in Chapter II, on PALT. Human factors include areas such as the experience of the AFNT and their capacities, the turnover rate of key personnel on the negotiations team, and potential political influences on the acquisition. Technical risk and maturation factors could be such things a projected post-award schedule that does not account for the time required for technology to keep up with the development of the weapon system. It is difficult to find appropriate proxies that represent these factors well, and it is harder to assume linear relationships between these factors and timelines, thus it is difficult to include them in regression analysis. Regardless of this difficulty, our team sees the importance of the inclusion of these factors in literature and therefore recommends this further research.

C. CONCLUSION

From our research, we found that the primary contextual factors that influence PALT are UCA, Major_Subs, FMS, EB, and WW. Each of these factors were statistically significant and affected PALT in the direction we hypothesized. The resulting beta coefficients (i.e., magnitude) for these five factors made sense based on subject matter expertise, experience, and literature.

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APPENDIX. DEFINITIONS

Acquisition: “the acquiring by contract with appropriated funds of supplies or services (including construction) by and for the use of the Federal Government through purchase or lease, whether the supplies or services are already in existence or must be created, developed, demonstrated, and evaluated. Acquisition begins at the point when agency needs are established and includes the description of requirements to satisfy agency needs, solicitation and selection of sources, award of contracts, contract financing, contract performance, contract administration, and those technical and management functions directly related to the process of fulfilling agency needs by contract” (FAR 2.101, 2018).

Business clearance: “for competitive acquisitions, approval to issue the solicitation. For noncompetitive contract actions, approval to begin negotiations” (AFFARS 5301.9000(c), 2018).

Contract: “a mutually binding legal relationship obligating the seller to furnish the supplies or services (including construction) and the buyer to pay for them. It includes all types of commitments that obligate the Government to an expenditure of appropriated funds and that, except as otherwise authorized, are in writing. In addition to bilateral instruments, contracts include (but are not limited to) awards and notices of awards; job orders or task letters issued under basic ordering agreements; letter contracts; orders, such as purchase orders, under which the contract becomes effective by written acceptance or performance; and bilateral contract modifications. Contracts do not include grants and cooperative agreements covered by 31 U.S.C. 6301, *et seq*” (FAR 2.101, 2018).

Contract clearance: “for noncompetitive contract actions, approval by the clearance approval authority to award a contract or contract modification/contract action” (AFFARS 5301.9000(e)(3), 2018).

Contracting officer: “a person with the authority to enter into, administer, and/or terminate contracts and make related determinations and findings. The term includes certain authorized representatives of the contracting officer acting within the limits of their authority as delegated by the contracting officer. ‘Administrative contracting officer (ACO)’ refers to a contracting officer who is administering contracts. ‘Termination contracting officer (TCO)’ refers to a contracting officer who is settling terminated contracts. A single contracting officer may be responsible for duties in any or all of these areas” (FAR 2.101, 2018).

Definitization: “the agreement on, or determination of, contract terms, specifications, and price, which converts the undefinitized contract action to a definitive contract” (DFARS 217.7401(c), 2018).

Federally Funded Research and Development Centers (FFRDCs): "activities that are sponsored under a broad charter by a Government agency (or agencies) for the purpose of performing, analyzing, integrating, supporting, and/or managing basic or applied research and/or development, and that receive 70 percent or more of their financial support from the Government; and—

(1) A long-term relationship is contemplated;

(2) Most or all of the facilities are owned or funded by the Government; and

(3) The FFRDC has access to Government and supplier data, employees, and facilities beyond that common in a normal contractual relationship" (FAR 2.101, 2018).

Milestone I: "the start of the demonstration and validation phase. This marks the beginning of the period where contractor(s) and the service management office prepare designs and perform hardware testing in preparation for full development" (Drezner & Smith, 1990, p. 8).

Qualifying proposal: "a proposal containing sufficient data for the DoD to do complete and meaningful analyses and audits of the—

(1) Data in the proposal; and

(2) Any other data that the contracting officer has determined DoD needs to review in connection with the contract" (DFARS 217.7401(c), 2018).

Risk Reduction Decision: also called Milestone A by DoD, "is an investment decision to pursue specific product or design concepts, and to commit the resources required to mature technology and/or reduce any risks that must be mitigated prior to decisions committing the resources needed for development leading to production and fielding" (DoD, 2017).

Root Mean Square Error (RMSE): the standard deviation of the regression and a lower value of RMSE indicates better fit.

Selected Acquisition Report: "provides the status of total program cost, schedule, and performance to Congress; provides program unit cost and unit cost breach information for a specific program" (DoD, 2017).

Senior Center Contracting Official (SCCO): "an individual serving in the position of Director of Contracting within AFMC (to include AFICA/CC) and at SMC who reports directly to the Center Commander. SCCO duties and responsibilities may also be performed by the Deputy Director of Contracting, Assistant Director of Contracting, the Technical Director/Assistant to the Director of Contracting, and the AFICA Executive Director, as well as the Director of Contracting at Eglin Air Force Base (AFB), Hanscom AFB, Hill AFB, and Robins AFB and the Deputy Director of Contracting, Assistant Director of Contracting, and the Technical Director/Assistant to the Director of Contracting at Eglin AFB, Hanscom AFB, Hill AFB, and Robins AFB" (AFFARS 5302.101, 2018).

Sole-source acquisition: “a contract for the purchase of supplies or services that is entered into or proposed to be entered into by an agency after soliciting and negotiating with only one source” (FAR 2.101, 2018).

Solicitation: “any request to submit offers or quotations to the Government. Solicitations under sealed bid procedures are called ‘invitations for bids.’ Solicitations under negotiated procedures are called ‘requests for proposals.’ Solicitations under simplified acquisition procedures may require submission of either a quotation or an offer” (FAR 2.101, 2018).

Undefinitized contract action: “any contract action for which the contract terms, specifications, or price are not agreed upon before performance is begun under the action. Examples are letter contracts, orders under basic ordering agreements, and provisioned item orders, for which the price has not been agreed upon before performance has begun. For policy relating to definitization of change orders, see DFARS 243.204-70” (DFARS 217.7401(d), 2018).

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