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Schedule Risks Associated with Middle Tier Acquisition

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Schedule Risks Associated with Middle Tier Acquisition

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Abstract

Major defense acquisition programs take about 8 years to proceed from program initiation to an initial operational capability. Recent changes created Middle Tier Acquisition programs intended to deliver capabilities and products in less than 5 years.

This research defines schedule risk as the likelihood of exceeding a duration. We developed quantitative models to identify significant factors and relationships. This report summarizes our approach and presents modeled results associated with Middle Tier Acquisitions.

Program offices must concurrently adapt to both emergent guidance and programmatic realities. This research contributes to the understanding of the risks and opportunities associated with recent Middle Tier Acquisitions. The research results will be useful to program offices and acquisition leadership in executing current and future rapid acquisition programs.

Introduction

This research explored schedule-related risks and opportunities associated with implementing new rapid prototyping and fielding program authorities, modular open system architectures, and Agile development. We assessed schedule risks and opportunities associated with these innovations and identified programmatic modifications and measures to manage schedule growth.

Research Scope

Our research focused on quantifying the programmatic and system engineering–related schedule risks attributable to using rapid prototyping and fielding pathways, modular open systems architectures, and Agile acquisition practices. We developed quantitative models to identify significant factors and relationships. This report summarizes our approach and presents results associated with Middle Tier Acquisitions (MTAs).

The research applies to rapid prototyping and rapid weapon system MTA programs and specifically excludes programs intended to acquire services or defense business systems. It includes acquisition policy and management changes enacted in the 2016, 2017, and 2018 National Defense Authorization Acts (NDAAs) and the Department of Defense (DoD) and service guidance, governance, and execution strategies implementing these changes. The research findings may not be valid for programs beyond these innovations.

Research Questions and Objectives

1. What types of programs have delivered prototypes or fielded systems within 5 years?
2. What characterized innovative technologies and systems fielded within 5 years?
3. How do acquisition process innovations such as Agile development and modular open systems affect program schedule performance?

Research Objectives

1. To develop a program database from publicly available sources suitable for research.
2. To identify and quantify significant factors for rapid acquisition strategies and significant predictors of and risk factors associated with achieving schedule objectives.

This paper continues with a review of recent literature in the Literature Review. A methodology overview in Methodology describes datasets developed from publicly available sources and the quantitative methods used. Results and Analysis presents the results of quantitative analysis, and Conclusions and Future Work summarizes research results and suggests future opportunities.

Literature Review

Schedule is an outcome. Successful past approaches include incremental or evolutionary acquisition strategies, exemplified by Mortlock's (2019) case study, adopting or reusing existing technologies, and updating or modifying existing systems (Tate, 2016). We briefly review policy and highlight recent innovations and research, including open systems architectures, modularity, Agile development, and Middle Tier Acquisitions.

Rapid Acquisition Policies

Fox (2011) produced a comprehensive summary of defense acquisition reform efforts between 1960 and 2009 and chronicles the interplay between Congress, the DoD, and the defense industry. Significant changes included

- McNamara centralized acquisition authorities and introduced budgeting, programming, and requirements processes within the DoD.
- Laird and Packard instituted policies related to management by objective, decentralized execution, cost reforms, prototyping, identifying, and managing technical risks, and formalizing acquisition training.
- Increased accountability for results with congressional legislative initiatives such as the Nunn-McCurdy Amendment, Federal Acquisition Streamlining Act, and Clinger-Cohen Act.

Fox (2011) argued that DoD personnel did not have the expertise to implement and execute these reforms but emphasized the importance of congressional, DoD and industry leadership in creating these process and policy changes. Recent reforms starting with the 2016 National Defense Authorization Act increasingly emphasized speed of development and delivery. We will evaluate these reforms' effectiveness using publicly available data.

Middle Tier Acquisitions

Congress enacted Middle Tier Acquisition (MTA) processes in 2016 (NDAA, 2015, § 804). In 2019, the Office of the Under Secretary of Defense for Acquisition and Sustainment (OUSD[A&S]) issued a new policy directive, *Operation of the Middle Tier of Acquisition (MTA)* (Lord, 2019). This policy introduced two new acquisition paths, rapid prototyping and rapid fielding, which are structured for rapid start, including setting requirements or starting production within 6 months, and delivery of a prototype residual capability or completed fielding within 5 years of start (Lord, 2019). The services released their own middle acquisition references concurrent with DoD issuance.

The DoD introduced the Agile Acquisition Framework, bringing traditional acquisition, urgent acquisition, Middle Tier Acquisitions, software, business and services acquisitions into a common framework (Lord, 2020b). The DoD issued extensive acquisition policy revisions in 2020, including *The Defense Acquisition System* (Lord, 2020b), and *Operation of the Adaptive Acquisition Framework* (Lord, 2020b). The MITRE Corporation created a comprehensive website collecting the DoD and service acquisition executive policy and guidance (MITRE, 2019).

Contracting Innovations

Contracting strategies are critical to rapid acquisitions. The time from program start to contract award is in series with development and production. Most government acquisitions use contracts conforming to the Federal Acquisition Regulation (FAR). Several innovations exist to reduce procurement acquisition lead time, including

- *Modular* contracting, introduced by the Clinger–Cohen Act (Clinger–Cohen Act, 1996). The intent was reducing investment risk, product delivery times, and barriers to introducing new information technology (Office of Management and Budget [OMB], 2012). Modular contracting has expanded beyond information technology acquisitions to include software and hardware development and procurements (OUSD[A&S], 2019).
- *Agile* contracting adapts contract management to support *agile acquisition* processes. Pennington (2018) notes that inherently Agile attributes such as incomplete requirements, incremental deliverables, and acceptance criteria make for challenging procurements. Contracting officers predominantly use fixed-price type contracts to manage Agile procurements; key issues include setting quality standards, definitions of done, and appropriate risk sharing (Ellis et al., 2019).

Statutory alternatives to FAR contracts also reduce lead times, including Procurements for Experimentation (Procurement for Experimental Purposes, 1993), and Commercial Solutions Opening (NDAA, 2016, sec. 879). These simplify commercial item procurements for research and development. Other Transaction Agreements (Research Projects: Transactions other than Contracts and Grants, 1993) are legally binding agreements where generally contract- and grant-related Federal laws and regulations do not apply. There are three common types of other transactions – other transactions for prototypes, other transactions for research, and other transactions for production (Research Projects: Transactions other than Contracts and Grants, 1993).

Business Innovations

Several advisory panels provided specific recommendations for business process innovations. A recent example was the Section 809 Panel, which provided extensive recommendations intended to accelerate acquisition processes by leveraging commercial marketplaces and processes, simplifying acquisition regulations, changing resource allocation processes, and improving the acquisition workforce (Drabkin et al., 2016). The DoD implemented less than half of their recommendations as of January 2021.

The DoD and Congress created several funding processes designed to accelerate technology transitions from non-traditional performers (Office of the Under Secretary of Defense for Research and Engineering [OUSD(R&E)], 2020). For example, the DoD Rapid Innovation Fund was created by Congress in 2011 and expanded in 2018 to accelerate small business technology transition to the DoD (NDAA, 2011). It is structured to move small business technology into operational use or to an acquisition program within 24 months (OUSD[R&E], 2020). Congress did not appropriate funding for this activity in 2020.

The Defense Innovation Unit is a different effort, embedded in Silicon Valley and reporting to the Under Secretary of Defense for Research and Engineering (USD[R&E]). It is focused on transitioning commercial advanced technologies to the DoD and uses an extension of other transaction agreement authorities (NDAA, 2015, § 815) to fund development and transition. It recently expanded to other locations and provides market access and non-dilutive capital for non-traditional defense contractors (Defense Innovation Unit [DIU], 2020).

Rapid System Acquisitions

Arellano et al. (2015) analyzed two successful rapid acquisition programs and noted the importance of direct senior leadership involvement to successful rapid acquisitions. This support mandates schedule adherence, requires programs to accept more risk, and creates agility to bypass financial and bureaucratic obstacles.

Wong (2016) identified three long-term (replacement, expedited, or traditional) and three opportunistic (missed, new, or alternative) acquisition categories. In his analysis, rapid acquisition processes depend upon budget reprogramming for initial action, but quantities depend upon capability adoption and use proliferation (Wong, 2016). The recently introduced acquisition pathways or strategies emphasize accelerated demonstration of a prototype or fielding of a new capability and are consistent with Wong's (2016) opportunistic categories. Of note, Congress provided statutory relief allowing transfer of procurement funds to rapid fielding accounts (NDAA, 2016), further supporting Wong's (2016) analysis.

Following Wong (2016), rapid acquisitions are a response to an emergent need—an immediate investment. Van Atta et al. (2016) defined "accelerated acquisitions" as those with requirements urgency, requirements specificity, and technology availability. They noted that relatively few (18 of about 330 Major Defense Acquisition Programs [MDAPs] reviewed) programs met these criteria and resulted from emergent urgent needs. Nine of these 18 programs delivered a prototype or claimed initial operational capability (IOC) within 5 years of program start (Van Atta et al., 2016). Dougherty (2018) examined programmatic and objective differences between six current rapid acquisition offices, noting attributes reflecting flexibility in contracting, transition, and programmatic objectives.

Open Architectures

Initiatives such as *open system architectures* intend to minimize change costs[1] by encapsulating functions in modules, using interfaces conforming to consensus standards, and

[1] Congress directed DoD use of open systems, called Modular Open Systems Architectures (MOSA; 10 U.S.C. § 2446a, 2016). MOSA development strategies emphasize module-level competition, development, testing and deployment, with multiple competing open standards (Engebretson & Frey, 2017).

establishing processes to ensure architectural compliance (Firesmith, 2015). Watson et al. (2016) related design margin (what they called “excess capacity”) to the ability to evolve a military ground vehicle design over time. They found, given future requirements uncertainty, the optimal design in terms of cost and benefits of excess capacity was related to the expected design service life; also, excess capacity *was not cost-effective* when expected service lifetimes were *below a certain value* (Watson et al., 2016).

The implications are that system designs face a choice: produce systems designed for changeability over a long service life or in favor of sustained production of incrementally evolving systems with shorter system design lifetimes. We see examples of both choices today, such as the aircraft carrier (changing over a long life) and commercial computers.

Modularity

Modularity, like open systems architectures, is a design choice to reduce complexity or change system function or performance without creating a new system. It partitions product knowledge into distinct but related processes and products. Modularity allows companies to develop products faster and either protects or exposes company intellectual property (Baldwin & Henkel, 2015, p. 1641).

van Gent and Kassapoglou (2014) examined modularizing composite airframes and showed the effects on direct operating costs and fuselage weight with increasing modularity. They derived cost and weight values for specific flight load conditions and optimized structural designs. While cost and weight savings were achievable, they were reduced or lost at high modularity levels as modules became heavier (and more expensive; van Gent & Kassapoglou, 2014). Chadha et al. (2018) examined redesign of a representative missile using additive manufacturing processes to simplify system interfaces and expand the design space. Applying their redesign process to selected modules and components, they presented design changes improving reliability and manufacturability by reducing module part count, eliminating internal module interfaces, and optimizing module design. While improved, the redesigned missile still required flight certification (Chadha et al., 2018).

Agility and Agile Development

Agility has multiple meanings within the DoD; it may refer to software development, acquisition processes, or any changeable process or product. In 2017, the DoD had few programs using Agile software development methods.

Rosa et al. (2017) developed cost models for traditional (“waterfall”) and Agile software processes within the DoD. Notwithstanding a small Agile process dataset, they found that *product size* (source lines of code) is a valid measure of required effort and Agile methods were more productive than traditional (non-Agile) software development methods (Rosa et al., 2017, p. 36).

Nidiffer et al. (2014) described Agile programs as “implementation-driven,” meaning requirements are dependent on interactions and direct communications to establish short-term requirements, while traditional approaches focus on documented requirements. While Agile helps requirements validation, there still are specific issues such as contract modifications and managing non-functional requirements (Inayat et al., 2015). Adams (2017) identified DoD and non-DoD related factors affecting DoD Agile software development adoption, including contracting, requirements management, training and team organization. Schoeni (2015) found similar cultural barriers and identified regulatory constraints.

Rework is a significant shortcoming of Agile processes for physical systems, as it uses incremental function[2] delivery (OUSD[A&S], 2019). Cooper and Sommer (2016) proposed a hybrid development process, called Agile Stage-Gate, where Agile methods are applied within selected stages, such as studies and technology development, and gated with clear exit or “done sprint” criteria.

Haberfellner and Weck (2005) provide an excellent overview of Agile systems engineering in a series of illustrative case studies highlighting the systems engineering challenges of designing agility (speed of change) into real systems. They show that agility is valuable for long-lived systems when “significant switching costs exist coupled with substantial uncertainty[3] in the environment” (Haberfellner & Weck, 2005, p. 1463).

Islam and Storer (2020) developed a case study examining how safety-critical systems development conflicts with Agile development. While qualitative and from a single case, they identified three broad grounds of challenges: the influence of “waterfall-like” systems engineering processes on Agile teams, complex customer interactions, and conflicts between Agile process and regulatory standards, such as upfront design requirements for hazard analysis conflicting with incremental Agile design (Islam & Storer, 2020).

Production

DoD production (inventory) quantities for traditional acquisition programs are defined by requirements (Wicecarver, 2017), reducing incentives to produce more than contract requirements. Desai et al. (2007) considered the problem for commercial durable goods production and found inventory holding costs and durability incentivize lower inventory. Davis and Tate (2020) provide several examples of how acquisition quantities change over time and that systems change over time such that later production versions may be quite different than initial deliveries.

Physical system production at large scale requires extensive facilities. For example, in December 2019, Boeing and Airbus delivered 29 and 138 large commercial aircraft, respectively (Oestergaard, 2020). Boeing’s Everett production facility covers nearly 100 acres (Boeing, 2020), and Airbus has five final assembly lines world-wide (Airbus, 2020). Changing production demand may exceed a contractor’s capacity. In such cases, leader–follower production strategies may be useful.

Reconfigurable manufacturing systems reduce short-run production overhead and retooling costs by modularizing production processes for an intended parts family. Commercial modular production firms use mechanisms such as cost-sharing agreements, hedged delivery dates,[4] and premiums for early deliveries[5] to incentivize rapid acquisitions (Zhai et al., 2016), and spot and future markets can be created for premium demand purchases (Cai et al., 2020). Asghar et al. (2018) developed a multi-objective algorithm to optimize module (machine) sequencing and usage (scheduling) as production demands change (p. 4397). The research was specific for a part production line using programmable multi-axis milling machines. Efficient production sequencing minimized production downtime.

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[2] Function, also called story or story points.

[3] Examples include requirements or demand uncertainty.

[4] In this case, hedging consists of setting module delivery dates earlier than need dates, thus covering the module production process time uncertainty.

[5] Zhai et al. (2016) call these premiums “crashing money.”

The U.S. Air Force recently announced flight testing of a Next Generation Air Dominance prototype, developed using a “digital engineering[6]” based development process, asserting this to be a faster path to prototype demonstration than prior methods (Reim, 2020). The development time is not stated, but the program office was activated in October 2019, suggesting a short development cycle (Waldron, 2019).

Schedule Estimating–Related Research

Schedule risk has different definitions in the literature, ranging from the likelihood to achieve a predicted duration (Dubos et al., 2007) to an estimate of likelihood and consequence (Tao et al., 2017). Browning (1998) used causal loop representations to identify likely sources and consequences of schedule delays and showed how uncertainty drives risk. Thomas et al. (2014) extended earned value methods to estimate schedule risk within a detailed cost and schedule Monte Carlo simulation. Similarly, Wauters and Vanhoucke (2017) used machine learning techniques to simulate project schedule duration within an earned value methodology. Such simulations require detailed work project schedules and duration uncertainty distributions as inputs.

Jaifer et al. (2020) examined effort and time drivers for aerospace new product development and grouped them into complexity[7] and proficiency[8] categories, later adding uncertainty as a separate category following a subject matter expert survey. Jahr (2014) tried to quantify the effect of Agile project management on schedule relative to traditional program management processes. He developed a hybrid management process for software development using constrained activity-on-node graphs and ran an experiment comparing performance to scrum processes for modification and new product development. The teams using the modified process were able to outperform scrum teams in terms of schedule and cost growth for both new and modified software development (Jahr, 2014). This suggests that applying planning constraints and management can benefit Agile processes such as scrum-type software development.

Ingold (2014) noted that schedule durations for small software development efforts are approximately the cube-root of the planned effort in person-months, and the square root of planned effort for large efforts. He argued that Agile efforts tend to follow square root relationships and that while reducing schedule leads to cost growth, Agile processes are able to achieve schedules shorter than predicted by standard software cost estimating models (Ingold, 2014). He developed and calibrated an Agile schedule systems dynamic model with 12 qualitative schedule acceleration sub-factors that predicted schedule durations within a few percent (Ingold, 2014). His schedule-accelerating subfactors map to previously identified schedule factors (Riposo et al., 2014), and his people-related factors map to Jahr’s (2014) proficiency group.

Discussion and Summary

The literature provides an overview of program better practices and decisions associated with shorter schedules. These include

- Reducing requirements to meet capability and deliver something sooner
- Having a competent team and bounding the system by what is known and in use, including interfaces and standards

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[6] Also called a digital thread (Bone et al., 2019).

[7] Such as size, technical difficulty, and uncertainty.

[8] Examples include experience, communications, and process management competency.

- Starting with an existing or proven system to reduce development delays
- Adjusting work to retire schedule risk
- Having sponsorship from the top and using the resulting flexibility to overcome inevitable obstacles
- Segmenting integration risk

There is extensive literature on specific manifestations of rapid acquisitions, notably modularity and Agile software development; however, these are focused cases and provide lessons learned for program management offices. The literature shows extensive development in policies and process supporting rapid acquisitions.

Congress and the DoD instituted several process and statutory changes in recent years, such as Modularity, Agility, and Middle Tier Acquisitions. The DoD adopted these innovations to reduce program cycle times. There are few quantitative articles on the effects of modularity and Agility on schedule performance, and Middle Tier Acquisition programs as relatively new, [9] representing a significant research gap. We focused this paper on Middle Tier Acquisitions schedule risk and the following research hypothesis:

- Middle Tier Acquisition programs have lower schedule risk than traditional MDAPs.

Methodology

We defined the likelihood of exceeding a specified schedule duration as the *schedule risk*. We did not assess risk context, severity, or treatment, as these are program-dependent. In Figure 1, the *vertical red dashed line* indicates a schedule risk of about 0.9 (89.2%) that the schedule of a program in this dataset will exceed 60 months.

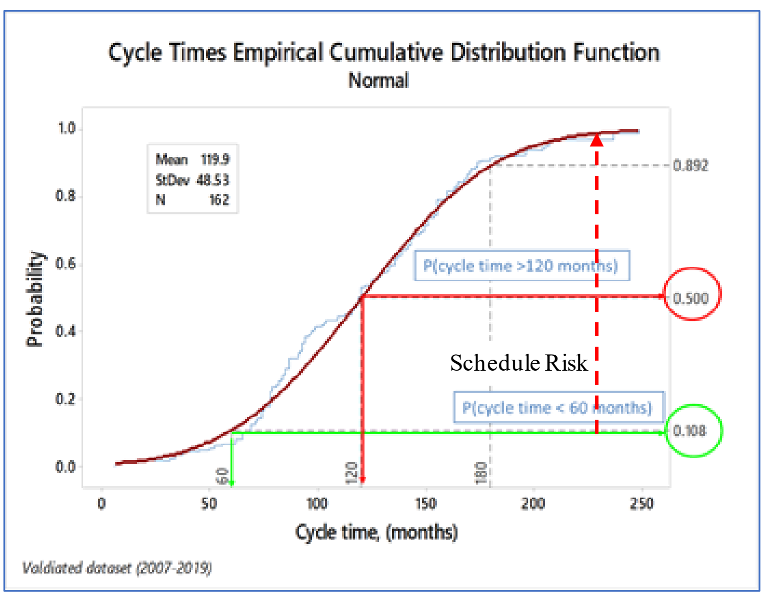

Figure 1. Estimation of schedule risk

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[9] Some quantitative information is in recent budget documentation. The Fiscal Year 2022 budget data was not released as of March 31, 2021.

The key assumption is that similar program types have similar schedule durations and risks—in this case, MDAPs. If true, then there is a 50% chance of a similar program's schedule exceeding 120 months, and about an 11% chance of exceeding 180 months.

Research Design Overview

We relied on several publicly available data sources for this research: the Government Accountability Office (GAO) annual weapon system assessments, the Director, Operational Test and Evaluation (DOT&E) Annual Reports, FPDS.gov, and usaspending.gov. We included the Fiscal Year 2019 through 2021 budget documentation to identify rapid acquisition programs. We compiled data into comma-separated variable files that are available upon request. Contract data was substantial; programmatic data was sparse. We manually validated the smaller datasets.

Budget data text searches were critical to labeling programs as modular, open systems, Agile development, Middle Tier, or Section 804 acquisitions, and claiming rapid fielding or rapid prototyping activities.

We used Microsoft and Adobe text search engines, R, Minitab, and SPSS to identify relevant programs and significant factors. We developed simplified schedule models in Minitab and ran Monte Carlo simulations to estimate schedule risk for the previously-labeled strategies. We performed additional modeling on Air and Missile system commodity types to identify and characterize influential variables and test model predictive performance.

Research Terms and Definitions

GAO and DOT&E 2020 reports and DoD budget documentation provided most of the research data. We searched for programs with the following text strings:

- *"Agile development."* This is commonly a software-dominated development and delivery process with incremental requirements elaboration, schedule-driven product delivery and acceptance. Searches included "Agile," "Agility," and "Agile software." Searching using "Agile development" provided good specificity to specific budget documents. An example of "Agile development" is the previously mentioned Air Force Air Operations Center Weapon System 10.2 (AOC-WS 10.2) replacement program.
- "*Modular system."* A modular system is often the product of a program with multiple components in development or production, with system function determined by the types of modules used to compose systems. Searches included "modular" and "modularity." An example of a modular system is the Army Field Medical Equipment.
- *"Middle Tier."* This is a program or project using Section 804 (Middle Tier Acquisition) pathways. Searches were also conducted using "Section 804," "MTA," "rapid fielding," and "rapid prototyping." Prior to the 2016 National Defense Authorization Act, the DoD used "Agile," "rapid fielding," and "rapid prototyping" within budget documentation descriptions of program plans and strategies. Examples include the Air Force Air-Launched Rapid Response Weapon (ARRW) and AOC-WS 10.2
- *"Open System."* Also known as Open System Architecture & Modular Open Systems Architecture Explicit Interfaces, standards, composition rules (structure) Often includes configuration management. Examples include the Air Force F-16 Modification of In-Service Aircraft and AOC-WS 10.2.

Results and Analysis

Text searches of budget documents between Fiscal Years 2010 and 2021 inclusive showed that Agile development and Modular system are more common in procurement documents, and Middle Tier and Open System are more common in research and development documents. Also, the Air Force has more activity related to Agile development and Middle Tier Acquisitions that the other services. Figure 2 shows these trends.

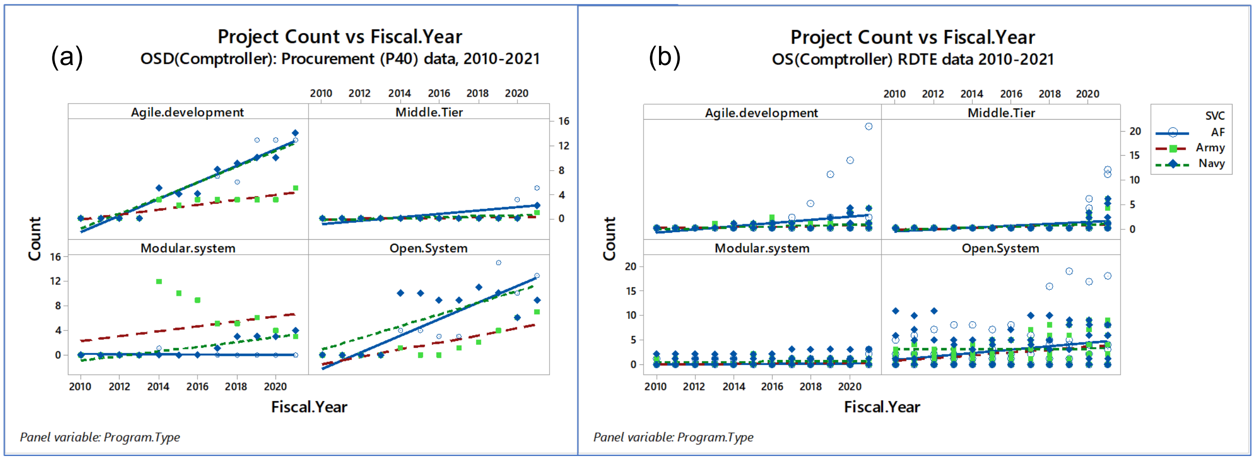

Figure 2. Term usage count summary by fiscal year

Figure 2 shows increasing overall usage trends for both procurement (Figure 2[a]) and research and development (Figure 2[b]). Agile development and open system activities are growing in all services. Open systems are a sustained emphasis in research and development, and Middle Tier Acquisition programs are a recent development.

Modeling Middle Tier Acquisition Program Schedule Duration

We used data from the GAO 2020 annual weapon systems assessment and added Fiscal Year 2020 and 2021 budget documents to create a dataset with program cycle times or schedules with programmatic factors and classification using the previous labels.

We found that modifications of existing systems were commonly occurring with modular systems and considered “modification” as a proxy for modular and open systems in the dataset.

Agile development programs did not always have a clear end date or planned initial operational capability date. The challenge is part of determining the “definition of done” (OUSD[A&S], 2020), essentially when the accumulated product value meets the customer requirement. This is normally a software development issue and may be in-service use, date of authority to operate, or another defined state. This definition problem exists in Agile development and Middle Tier Acquisition programs. We chose either the latest specified product delivery date or the last date in the budget submission.

We subsetted the data to consider Air (AIR) and Missile (MSL) commodity type programs. Figure 3 summarizes the cycle times by Agile (AGILE), MDAP, modification (MOD) and Middle Tier Acquisition (MTA.RP).[10]

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[10] All Middle Tier Acquisition programs in the dataset were rapid prototyping projects.

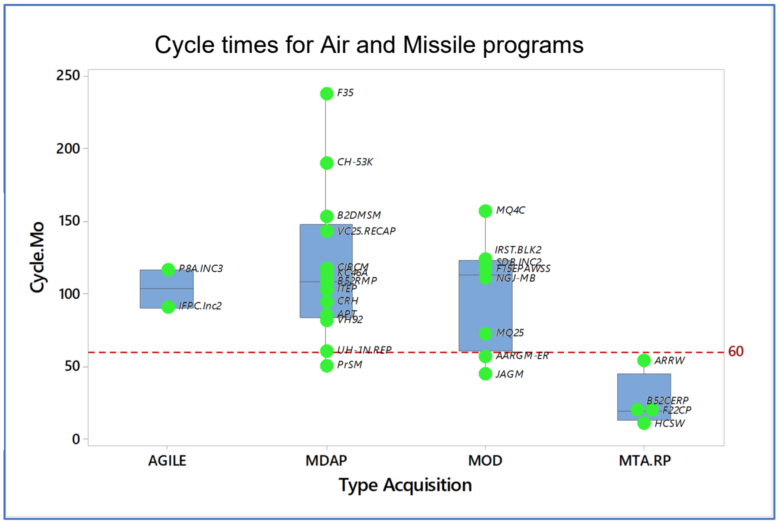

Figure 3. Cycle Times for AIR and MSL Programs (GAO, 2020)

Figure 3 highlights that Middle Tier Acquisition programs are so new that none have reported schedule growth resulting in durations greater than 5 years (60 months). It also shows that modifications of existing systems have a smaller range and lower median cycle time than an MDAP does. Random forest modeling identified the most important predictor variables: time since program start, change in the research and development budget, the natural log transforms of the research and development budget, and estimated unit cost.[11] We developed a multivariate regression, leaving out time since program start.[12] Table 1 summarizes the multivariate regression model that excluded time since program start.

Table 1. Cycle Time (Schedule) Regression Model Summary

Factor	Coefficient	Contribution	p-value	VIF
Intercept	1.6			
LN(R&D budget)	12.66	25.87%	0.000	1.13
PCT change (R&D)	37.74	20.32%	0.000	1.17
LN(Unit cost estimate)	4.97	6.75%	0.013	1.03
MTA = TRUE	-39.28	11.94%	0.000	1.03
S	**R-sq**	**R-sq(adj)**		**R-sq(pred)**
34.74	64.88%	61.90%		51.23%

We used a reduced version of this model as one estimator of Middle Tier Acquisition program schedule risk.

Predicting Schedule Risk for Middle Tier Acquisition Programs

We fitted polynomials to GAO cycle time (schedule) cumulative distributions for the four different program types.[13] These provide a simple estimate of schedule risk following the Figure

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[11] If not specified, then unit cost was total budget divided by planned buy.

[12] This was evaluated as reflecting the schedule growth of older programs in the dataset.

[13] The cumulative distributions could be modeled by a 3 parameter Weibull distribution. We developed algebraic models to allow schedule risk estimation using simpler tools.

1 approach. Most polynomials were quadratic or cubic, with R-squared values above 95%. The Middle Tier Acquisition distribution was best fit by a logarithmic equation:

$$P(> D) = 1 - \{0.4284 * \ln(D) - 0.8496\}, \tag{1}$$

where D is the schedule duration in months.

We ran three Monte Carlo simulations to estimate the likelihood of Middle Tier Acquisition programs exceeding 60 months. The first simulation (*normal data fit*) assumed normally distributed schedule durations with estimated upper (53 months) and lower (10 months) bounds and an estimated standard deviation. The second simulation (*regression model*) started with a regression model predicting schedule distributions from program budgets.[14] The third simulation (*Weibull data fit*) assumed schedules followed a Weibull distribution, with scale (49.7), shape (2.705), and a 0 threshold. Table 2 shows Middle Tier Acquisition program duration simulation schedule risk results at 5, 6, 7, and 8 years (60–96 months).

Table 2. Middle Tier Acquisition Schedule Risk Simulation Results

Simulation/Model	P(>60 months)	P(>72 months)	P(>84 months)	P(>96 months)
Normal data fit	2.7%	0.4%	0.19%	0%
Regression model	46.6%	25.4%	11.5%	4.3%
Weibull data fit	19.8%	7.2%	1.6%	0.2%
poly fit	9.6%	1.7%	0%	0%

The last row (*poly fit*) is the estimate for the GAO cumulative schedule distribution for comparison with the simulations. The normal data fit simulation estimated a duration less than zero 2.3% of the time; 2.7% is the schedule risk of duration exceeding 60 months. The other models predict some risk of exceeding 60 months. Regression model results suggest that larger budget (greater than $1 billion) programs will be more likely to exceed 60 months. No Middle Tier model or simulation predicted significant schedule risk beyond 96 months.

We modeled MDAP schedule risk as above. Table 3 summarizes MDAP schedule risk for the GAO data and a polynomial model.

Table 3. MDAP Schedule Risk Simulation Results

Simulation/Model	P(>60 months)	P(>120 months)
Monte Carlo simulation	88.7%	46.7%
Polynomial model	88%	46%

This shows that Middle Tier Acquisition (MTA) programs have less schedule risk than MDAPs at the same *absolute* schedule duration. However, the *schedule risk* of an MTA and an MDAP at the *same relative percent schedule completion are comparable.*

Conclusions and Future Work

The literature review provided an overview of program better practices and decisions associated with shorter schedules, including

- Reducing requirements to meet capability and deliver something sooner

[14] The regression model had a predicted R-squared of about 30%.

- Starting with proven technologies, interfaces, and standards
- Having a competent team and capable suppliers
- Adjusting work to retire schedule risk and segmenting integration risk
- Having a plan to get to contract award and production sooner

Middle Tier Acquisition programs can benefit from these practices and add policy limits on schedule durations, oversight, and stakeholder involvement to incentivize schedule adherence and lower schedule risk.

This research provides insight into the schedule risk of MTA programs. Simulations showed the likelihood that an MTA program will exceed its planned schedule is less than 20%. Simulations also predict that the schedule risk for MTA programs grows with larger total research and development budgets (MTAs with budgets greater than $1 billion are more likely to exceed 60 months).

Middle Tier Acquisition programs have less schedule risk than traditional MDAPs at the same absolute duration. For example, at 60 months after program start, the schedule risk for an MTA program should be less than 20% and over 80% for an MDAP, as the MDAP has years of schedule left, while the MTA is (should be) nearly completed.

The schedule risk estimation process is extensible to other rapid acquisition innovations. Future work should include replicating this effort using restricted datasets and program-level data, validating schedule risk predictions and predictor significance with observed program performance, and developing context and severity estimators.

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