**AN ANALYSIS OF THE IMPACT OF DEFENSE ACQUISITION REFORMS**

**AND EXTERNAL FACTORS ON SCHEDULE GROWTH OF**

**DEFENSE WEAPON SYSTEMS**

THESIS

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## Abstract

The growth in the acquisition cycle time of large defense systems from what was planned (i.e., schedule growth) creates several issues for defense acquisition managers and policy makers. These issues include increased likelihoods of cancellations, changes in requirements, and delays in the fielding of improved combat capabilities and replacements for legacy systems, which have resulted in further cost and schedule growth. As a result, Congress, the DoD, and the individual military services implemented several major reforms to address the cost and schedule growth of weapon systems.

This research presents an empirical model of schedule growth to evaluate the impact of acquisition reform efforts, defense budget changes, unexpected inflation, and major contingency operations (war) on schedule growth of major weapon systems. A fixed-effects panel regression model was utilized to describe the schedule performance (using earned value data) of the major weapon system programs managed by the Army, Air Force, and Navy from 1980 to 2002. This research found that unexpected inflation results in increased schedule growth. In addition, the 2000 revision of the DoD 5000 series accounted for a reduction in schedule growth. The other examined acquisition reforms—the Packard Commission of 1986 and the 1993-1996 reform efforts [e.g., the Federal Acquisition Streamlining Act of 1994 and the Clinger-Cohen Act of 1996]—were not correlated with schedule growth. This lack of a relationship suggests these reforms were not fully internalized into the Department of Defense's acquisition process and appear to have not been successful at limiting schedule growth.

*To my wife*

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Michael P. Giacomazzi III

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# I. Introduction

## General Issue

In a recent study of 26 major Department of Defense (DoD) acquisition programs, the Government Accountability Office (GAO, 2006) found that the development costs of these programs increased by 37 percent and the acquisition cycle time increased by 17 percent. This growth in the cost and acquisition cycle time (schedule) of large defense systems creates several issues for defense acquisition managers and policy makers. Due to limited budgets, cost overruns lead to potential reductions in weapon system quantities and capabilities and increased budget instability in other programs where funds are taken in order to pay for the overruns (Czelusniak and Rogers, 1997:62). Similar issues arise due to schedule growth, including an increased likelihood of cancellation due to escalating costs and schedule delays (Pinto and Mantel, 1990:273). Additionally, a longer development schedule allows more opportunities to change (and add to) the technical requirements for the weapon system (Drezner and Smith, 1990:1). In the circumstances regarding a replacement weapon system, a growth in the schedule of this system also extends the planned life of the existing system(s) assuming there is a desire to maintain that war fighting capability (Reinertsen et al., 2002:8). As a result, additional operations and support costs are required to maintain the existing system or systems until the replacement system is fielded (Reinertsen et al., 2002:8).

**Specific Issue**

Congress, the DoD, and the individual military services implemented several major corporate reforms to address the cost and schedule growth of weapon systems (Hanks et al., 2005:xiv). These reforms usually involved the removal of time-consuming and costly requirements of the defense procurement process (Hanks et al., 2005:xiv). These major corporate reforms paved the way for and institutionalized numerous operational level actions to address one or more of the factors contributing to cost and schedule growth (Hanks et al, 2005:38). This research focuses on analyzing the schedule growth aspect.

Several researchers focused on identifying the numerous factors contributing to schedule growth that are addressed by the operational level actions of the acquisition reforms. These factors include technical risk (Cashman, 1995; Rodrigues, 2000), requirements stability (Dawkins, 1987; McNutt, 1998) and planned schedule duration (Drezner and Smith, 1990; McNutt, 1998). Other researchers evaluated the management initiatives implemented to address these factors of schedule growth, including prototyping (Tyson et al., 1992), incentive contracts (Tyson et al., 1992), and evolutionary acquisition (GAO, 2006). Other studies suggested cost and schedule growth of acquisition programs can be contributed to additional factors that are primarily external to the acquisition process. These factors include budget instability (McNutt, 1998), contingency operations (McNutt, 1998; Czelusniak and Rogers, 1997), and unexpected inflation (Smirnoff, 2006).

## Research Objective

While researchers (Christensen et al., 1998; Holbrook, 2003; Smirnoff, 2006) have assessed the impact of acquisition reforms on cost growth, there has yet to be an empirically rigorous study on the impact of reform efforts on schedule growth. Accordingly, the primary purpose of this research is to evaluate the effectiveness of acquisition reform efforts on limiting schedule growth of major DoD weapon systems. In order to isolate the influences of reforms, this research addresses the extent to which factors external to the acquisition process are related to schedule growth, specifically defense budget changes (budget instability), unexpected inflation, and major contingency operations.

## Scope & Methodology

To complete this research, data was collected from the Defense Acquisition Executive Summary (DAES) reports, which include programmatic and earned value data for the major acquisition programs for all of the services. More specifically, details pertaining to the schedule information of the various defense acquisition efforts and calculations of schedule growth were collected and analyzed. Currently, program initiation is marked by the entrance into the system development phase (GAO, 2006:6). Consistent with previous research, these major defense acquisition reforms are modeled as dummy variables (c.f., Smirnoff, 2006) reflecting (and beginning in) the year in which the reforms in the revisions to the DoD 5000 series of regulations reflecting the DoD's policy on defense acquisition.[1] The impact of the major defense acquisition reforms and

[1] Additional information, including rationale regarding the operationalizations utilized in this research, is provided in Chapter III.

the previously identified external factors on schedule growth are evaluated using panel regression consistent with the method described by Smirnoff (2006).

# II. Literature Review

This chapter examines the literature regarding schedule growth of Department of Defense (DoD) weapon systems. This chapter begins by describing the principal factors contributing to schedule growth. This section includes an exploration of several management initiatives implemented by the DoD to mitigate the risk and impact of many of these factors on a program's success. Then, this chapter describes several efforts initiated by the DoD and Congress to reform weapon system acquisition. This section also includes a review of the research analyzing the effectiveness of the reform efforts.

## Acquisition Reform

As a result of the cost and schedule growth of weapon systems, Congress and the DoD introduced several reforms to improve the efficiency and responsiveness of the defense acquisition process (including the laws, regulations, and training) (Hanks et al., 2005:xiv). These reforms traditionally involved streamlining requirements, speeding up processes, reducing overhead, and cutting paperwork in order to reduce the bureaucracy of defense procurement (Hanks et al., 2005:xiv). These large scale corporate reforms translated into numerous operational level actions to address one or more of the factors contributing to cost and schedule growth (Hanks et al, 2005:38). The following section examines these factors and several management initiatives (i.e. the operation level actions) to mitigate the risk and impact of these factors. An exploration of key acquisition reform efforts follows, which includes a discussion of the recommendations, mandated changes, and the research concerning the effectiveness of these corporate reform efforts.

## Factors Affecting Schedule Growth

While not as plentiful as the research on cost growth, there have been several studies regarding the factors affecting schedule growth.[2] While there are myriad potential factors contributing to schedule growth, it is beyond the scope of this research to address all of these factors.[3] Nonetheless, several key factors identified in the existing literature are discussed, including technical risk, requirement changes, and planned schedule duration.

### Technical Risk

Technical risk refers to both the maturity of the technology being incorporated into the weapon system and the technical complexity of the system's design (Cashman, 1995:73). The level of technical risk increases when the technology is less mature and when the design is more complex. This greater technical risk often corresponds with a greater probability and a greater number of technical problems encountered in the design and development of the components and systems (Cashman, 1995:74). As a result of the rework to address the technical issues, the programs experience schedule and cost growth (Drezner and Smith, 1990:23).

A study by Dawkins (1987) conveyed similar results regarding the influence of technical risk on schedule delays. Studying delays on forty-eight general building (instructional facilities, laboratories, aircraft hangars, office buildings, addition projects,

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[2] Most of the factors affecting schedule growth also contribute to cost growth, including requirements changes (Drezner et al., 1993), budget instability (Singleton, 1991), technical risk (Drezner et al., 1993), contingency operations (Czelusniak and Rogers, 1997), and planned schedule duration (Jarvaise et al., 1996). This chapter alludes to this relationship on several occasions.

[3] See Drezner and Smith (1990), Cashman (1995), and Monaco (2005) for an analysis of these additional factors contributing to schedule growth.

and warehouse facilities) construction contracts, Dawkins found technical difficulty in the design as the most significant factor for the delays of the construction projects (1987:66,69). The DoD's traditional strategy for acquiring major weapon systems has been to plan programs that would achieve a big leap forward in capability. This suggests that there is some inherent technical risk in most DoD weapon system programs because the needed technologies often are immature, where programs stay in development for years until the technologies are demonstrated (GAO, 2003:3). Rodrigues (2000:10) found that those programs allowed to advance further into system development despite low levels of technical maturity and unproven technologies suffered the effects of this high technical risk with increased costs and schedule slips.

### Requirement Changes

Requirement changes include increases or decreases in the specific capabilities of the system to be produced. These desired capabilities may change as a result of availability of a newer technology or changing circumstances, such as programmatic difficulties, availability of resources, and management direction. The inability to meet cost, schedule, or technical performance requirements often forces the acquisition program to suspend requirements, increase funding, or to delay the product (McNutt, 1998:102). For large DoD acquisition projects, if these changes concern the acquisition program baseline requirements, the schedule delay is exacerbated by the requirement to go through a similar level of review as the original milestone decision process (McNutt, 1998:102).

While not as influential as technical difficulty, Dawkins found that changes by the owner did influence delays of the construction projects significantly (1987:66,69). These owner changes are analogous to the requirement changes in DoD acquisition programs. McNutt (1998:276) found similar results regarding the relative impact of requirement changes on schedule slips. In a survey of 175 projects, requirement changes ranked third behind funding instability and technical problems as the reason for a development program to slip—accounting for approximately one quarter of the total average project slip of approximately two months per year (McNutt, 1998:276).

Planned Schedule Duration

A program with a longer development schedule has a greater probability of a schedule delaying event occurring, such as budget changes (McNutt, 1998), technical problems (Drezner and Smith, 1990), cost overruns (Jarvaise et al., 1996), and requirement changes (Drezner and Smith, 1990).

A study by Monaco, however, had conflicting results regarding the relationship between program duration and schedule growth (2005:76). He found the likelihood and magnitude of a schedule slip decreases as the development duration increases. The speculated rationale was there were greater opportunities to adjust to a problem in the program when the program had a longer planned development schedule (Monaco, 2005:106). Unlike the previous studies of schedule growth, Monaco restricted the analysis to more recent development programs (1990-2003) that were at least three years into their development phase.

**Management Initiatives**

Several management initiatives were instituted to mitigate the risk and impact these factors have on program success, specifically in terms of cost and schedule. The major acquisition reforms (described in greater detail below) institutionalized many of these management initiative as a part of their efforts to reduced cost and schedule growth. Many initiatives still remain in some form from their creation; whereas others faded away in favor of different management initiatives. For example, after 1965, the total package procurement (TPP) concept was utilized to reduce the cost risks born by the government by having contractors bid on the development, production, and support work under one fixed-price contract. TPP was intended to discourage the practice of contractors submitting low bids for development (in a competition) and then profiting under sole-source production contracts. During the early 1970s, however, a number of TPP programs had large cost overruns, which left some contractors in need of Government assistance (Tyson et al., 1992:II-2). Similar experiences occurred regarding fixed-price development contracts (Tyson et al., 1992:X-8). As a result, total package procurement was discontinued in favor of cost-plus-incentive-fee contracts that placed more risk on the government (Tyson et al., 1992:II-2).

These incentive contracts were designed to motivate the contractor to meet desired acquisition objectives while discouraging inefficiency and waste (FAR 16.401a). Incentive contracts usually include cost objectives, but can also include incentives for technical or schedule-related performance (FAR 16.401b). Tyson found development programs with incentive contracts experienced less schedule growth than those programs without incentive contracts (i.e. fixed-fee contracts) (Tyson et al., 1992:VI-3).

Another manner in which the government attempts to manage the risks of program is through the use of prototyping. Prototyping is designed to reduce technical risk by building and testing detailed pieces of hardware prior to any large-scale development (Tyson et al., 1992:V-1). These working models are used to demonstrate a concept, a specific design, or an operational objective. In order to reduce the potential for issues in development, potential design problems need to be identified and resolved as early as possible (Tyson et al., 1992:V-2). In an analysis of tactical aircraft and munitions from the 1960s to 1989, Tyson found no statistical difference between the development schedule growth of programs that were prototyped and those that were not (Tyson et al., 1992:V-3). Overall, prototyped programs took somewhat longer, but the differences may be due to technical complexity (Tyson et al., 1992:ES-5).

Advanced Concept Technology Demonstrations (ACTD) and Advanced Technology Demonstrations (ATD) are prototype efforts that are instrumental in the initiatives to reduce the acquisition cycle time of weapon systems. These experimental tools generated a second parallel acquisition process, which give war fighters the opportunity to assess prototype operational capability prior to formal program initiation (system development). The objective was to bridge the gap and improve the transition of Science and Technology (S&T) projects into the formal acquisition process (Vollmecke, 2004:7). As part of technology development, ACTDs and ATDs aim to increase the level of technical maturity of a technology prior to implementation into a weapon system.

The evolutionary acquisition approach relies upon the availability of mature technologies to field an operationally useful and supportable capability in as short a time as possible with the intent to deliver additional capability in the future (Sylvester and Ferrara; 2003:5-6). Evolutionary acquisition stresses an incremental approach to development, which capitalizes on the best mature technologies available at a given point in time. Evolutionary acquisition takes advantage of concurrent engineering and reduces acquisition cycle time by minimizing technical uncertainty at the start of the development program (Sylvester and Ferrara; 2003:8). The GAO identified this strategy of maturing a new technology to a high level of technology readiness prior to inclusion in a product as a commercial industry best practice and a major determinant of the success of new product launches (Best-Practices, 1999:3).

Evolutionary acquisition is a major shift from the single-step-to-full-capability acquisition strategy (grand design approach) used extensively for the past 30 years (Sylvester and Ferrara; 2003:8). The single-step-to-full-capability strategy involves an identified end state in terms of capability requirements, which the program would attain in one (usually lengthy) increment (Sylvester and Ferrara; 2003:8). Not surprisingly, in a 2006 study, the GAO contended the DoD was not effectively implementing the evolutionary approach by continuing to accept high levels of technology risk for programs entering into system design and development (GAO, 2006:12). Since 2000, thirteen of the eighteen programs initiated under the revised acquisition policy received approval to enter system development with immature technologies (GAO, 2006:14).

### Key Acquisition Reform Efforts

This section discusses the following acquisition reforms and their potential impact on schedule execution: the Packard Commission (1986), the National Performance Review (1993) and Federal Acquisition Streamlining Act of 1994, and the revision of the

DoD 5000 series in 2000.[4] These reforms serve as the basis for this research into the influence of acquisition reforms on schedule growth. In addition, the literature suggests the selected acquisition reforms were singular in their scope and potential impact on schedule execution. While additional reforms have been implemented that may have also impacted schedule growth, an analysis of these reforms is beyond the scope of this study.[5] The following section provides details regarding these reform efforts, including the recommendations and initiatives of these reforms, the implementation of these initiatives and recommendations, and studies evaluating the efficacy of these initiatives.

Packard Commission (1986)

In July 1985, President Reagan instituted the Blue Ribbon Commission on Defense Management (also known as the Packard Commission) to investigate issues pertaining to defense management and organization (Blue Ribbon Commission, 1986:27). In order to address the horror stories in the media of excessive prices for parts, test failures, and cost and schedule overruns, a task force was created to specifically address the military acquisition process (Munechika, 1997:12). In order to improve the defense acquisition system, which included improving cost and schedule performance by limiting overruns and reducing acquisition cycle time, the task force established a formula for action for the DoD to implement (Blue Ribbon Commission, 1986:15). The commission recommended stabilizing the programs, balancing cost and performance, using technology to reduce cost, streamlining acquisition organization and procedures,

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[4] Due to restrictions in the data obtained for this analysis (from 1980-2002), the revision of the DoD 5000 series in 2003 was excluded from this list of key acquisition reforms.

[5] For additional information on other acquisition reform efforts, see Reig (2000), Munechika (1997), Ferrara (1996), and Vollmecke (2004).

expanding the use of commercial products, increasing competition, and raising the quality of acquisition personnel (Blue Ribbon Commission, 1986:52-71).

Congress responded very enthusiastically to the Packard recommendations and, in short order, enacted the Defense Acquisition Improvement Act of 1986 (Ferrara, 1996:120). In addition, the DoD 5000 series was updated in 1987 to include the Packard Commission recommendations, including the new streamlined acquisition chain of command (Ferrara, 1996:120).

A study by McNutt (1998) assessed the impact of the Packard Commission's recommendations on schedule execution. Despite implementation by the DoD, he contended the recommendations on schedule execution were not widely internalized and appeared to have been unsuccessful (McNutt, 1998:50). His assessment relied on a visual analysis of the programmatic schedule data and interviews with government and contractor personnel in the Pentagon, program offices, and contractor facilities. A more empirical analysis is needed to confirm this assessment of the Packard Commission's impact on schedule performance.

Searle (1997), Christensen et al. (1999), and Smirnoff (2006) analyzed the impact of the Packard Commission recommendations on cost growth. The findings were inconsistent. Christensen et al. (1999:257) found that cost performance of defense contracts worsened in the period following the commission. In contrast, Smirnoff (2006:78) more recently concluded that cost performance improved as a result of the Packard Commission's recommendations. These inconsistent results might be attributed to the methods that were used to analyze the issue. Due to the size and complexity of the Department of Defense, a large acquisition reform effort would likely take some time to implement (Reig, 2000:38). In order to address this issue, one method has been for the researcher to identify a treatment date of when they considered reform efforts to be fully institutionalized in the DoD. Unfortunately, the researcher cannot be certain that this point in time accurately reflects when a reform is fully implemented. Searle (1997) and Christensen et al. (1999) used December 31, 1991 as a subjective treatment date for separating the data into pre- and post-reform. That is, this date represented their assessment of when the Packard recommendations were fully institutionalized in the DoD. They utilized statistical tests of the difference between population means of the two periods to assess the efficacy of the Packard Commission (Searle, 1997:65).

Even if there were no uncertainty around a treatment date, the principal concern with their studies is the absence of external (control) variables, such as changes in defense budgets, inflation, or war, might have biased the results of these studies (Smirnoff, 2006:20). Christensen et al. identified this bias as a potential threat to the internal validity of their study (1999:262). That is, these acquisition reform efforts might have resulted in less cost growth, but this relationship could be observed using their method due to the influence of external, environmental factors.

In order to address the shortcomings of the previous studies, Smirnoff (2006) utilized panel regression to evaluate the impact of acquisition reform efforts and several environmental variables on cost growth. The use of panel regression allowed for a more robust analysis of these factors compared to the use of subjective treatment dates and statistical tests of the difference between two means, because it showed the relative importance of each variable and its contribution to cost growth in a dynamic situation (Smirnoff, 2006:5). Additionally, Smirnoff used the panel regression results to statistically determine the lag structure (i.e. treatment dates) for the implementation of the acquisition reform efforts instead of developing a subjective treatment date. Because the reform efforts address many of the common factors of both cost and schedule growth, an empirical evaluation of schedule growth utilizing a method similar to Smirnoff (2006) may yield similar results after controlling for external factors. Specifically, whether the implementation of the acquisition reforms stemming from the Packard Commission reduced schedule growth.

### 1993-1996 Reform Efforts

Initiated in March 1993 and led by then-Vice President Gore, the National Performance Review (NPR) performed a detailed look at all government activities to find areas for improvement (GAO-NPR, 1999:3). The initial NPR report contained 384 recommendations spanning all aspects of government operations, including federal procurement. The report identified the need for the DoD to eliminate regulatory burden, simplify procurement, and rely more on the commercial market (Rogers and Birmingham, 2004:39).

The Federal Acquisition Streamlining Act of 1994 (FASA) codified many of the NPR's recommendations. The FASA was devised to overhaul the cumbersome and complex procurement system of the federal government. To this end, the act significantly modified or eliminated over 225 existing statutes (Holbrook, 2003:17-18). The overarching themes of the FASA included a preference for moving to commercial contracting methods, transitioning the procurement process to an electronic basis, eliminating non value-added requirements, and eliminating paperwork burdens in the procurement cycle (Cooper, 2002:16). The Clinger-Cohen Act of 1996 further advanced the changes made by FASA, providing additional opportunities for the DoD to further streamline and reduce non-value added steps in the acquisition process (Holbrook, 2003:19).

The National Performance Review (1993), the FASA (1994), and Clinger-Cohen Act (1996) led to a wave of acquisition management initiatives, including variations of the previously mentioned management initiatives (e.g. evolutionary acquisition, program stability, advanced concept technology demonstration). Hanks et al. (2005:38) identified 46 such initiatives that were initiated between 1994 and 1996. In their examination of these acquisition management initiatives, Hanks et al. grouped these reform initiatives into five themes:

- Rationalizing and improving the industrial base
- Streamlining
- Civilian-military integration
- Logistics transformation and total life-cycle system management
- Reducing fraud, waste, and abuse (Hanks et al., 2005:122-124)

More than half of these acquisition management initiatives focused on ways to streamline the acquisition process, which often meant relaxing some of the controls established in the 1980s to guard against fraud, waste, and abuse (Hanks et al., 2005:16).

Most of these initiatives were instituted in the 1996 revision of the DoD 5000 series. The 1996 version reflected how the acquisition system responded to the changing global environment since the end of the Cold War. Due to the uncertainty of where and when threats to the United States could come, the acquisition system needed the flexibility to be able to respond very quickly (Ferrara, 1996:123). The 1996 version instituted Advanced Concept Technology Demonstrations in order to infuse new technology into the process (Ferrara, 1996:123).

Integrated Product Teams (IPTs) were also institutionalized under this revision. The purpose of IPTs was to breakdown the barriers between different organizations and acquisition disciplines and to encourage integrated solutions to management problems (Ferrara, 1996:123). The 1996 revisions also added the management concept of cost as an independent variable, which involves making cost more of a constraint and less of a variable. As a result, tradeoffs were made between performance requirements and life-cycle costs in order to meet cost objectives (Hanks et al., 2005:92). Additionally, the revision included strategies to reduce expensive testing, in terms of time and money, through the use of modeling and simulation. Finally, the 1996 revision significantly reduced the amount of paperwork as compared to the previous (1991) version by canceling numerous previously mandated report formats (Ferrara, 1996:127).

Similar to the studies of the effectiveness of the Packard Commission's recommendation, studies on the impact of the 1993-1996 reform efforts yielded conflicting results. The National Performance Review (NPR) claimed its efforts to reinvent the government generated $137 billion in savings between 1993 and 2000 (GAO-NPR, 1999:1). A study by the GAO contended this number was exaggerated, because the NPR figure took credit for all of an agency's savings (compared to a baseline) over that time period, even the savings resulting from separate reform initiatives that were consistent with the NPR principles of reinventing government (GAO-NPR, 1999:1-2). Due to the complexity and time required, the GAO did not calculate the actual savings that were solely attributable to the NPR recommendations (GAO-NPR, 1999:1). These studies did not assess the impact of the NPR recommendations on schedule growth.

Smirnoff found the passing of the FASA corresponded with reduced cost growth regardless of contract type (2006:73). Holbrook contended the FASA and the Clinger-Cohen Act did not have an impact on cost growth; however, he utilized a subjective treatment date of December 31, 1997, for his analysis and did not control for the potential influence of any external factors (2003:91). As a result, his study suffers from the same limitations as those found in the studies by Searle (1997) and Christensen et al. (1999) on the impact of the Packard Commission recommendations on cost growth.

As a result of the focus by researchers on cost growth--specifically the effectiveness of DoD policies and reform initiatives on controlling cost growth--there has yet to be a study assessing the impact of the NPR, FASA, or the Clinger-Cohen Act on schedule growth. Many of these acquisition reform initiatives were aimed at addressing the underlying causes of cost and schedule growth, such as reducing the technical risk and ensuring requirements stability, that add unplanned work to the development effort. As a result, an empirical analysis of the impact of these acquisition reform efforts on schedule growth may produce results consistent with the studies concerning cost growth.

### DoD 5000 Revision (2000)

The 2000 revision codified many of the initiatives that were developed under the wave of acquisition reform efforts in the mid-to-late 1990s but not yet integrated into the DoD 5000 series. One of the more significant initiatives, in terms of its potential influence (assuming proper implementation) on schedule performance, was evolutionary acquisition. The 2000 revision made evolutionary acquisition the preferred DoD strategy for rapid acquisition of mature technology for the user (Hawthorne, 2003:np).

Due to the relatively recent focus on evolutionary acquisition and challenges in implementing the strategy (GAO, 2006), there has yet to be an empirical evaluation of the impact of evolutionary approaches on DoD weapon systems acquisition. However, the success of commercial efforts using a similar approach suggests evolutionary acquisition, when properly implemented, may provide its theoretical benefits (GAO, 2006:1).[6]

**External Factors (Control Variables)**

In addition, the existing literature suggests several factors that are primarily external to the defense acquisition process. In order to alleviate the omitted variable issues in the previous studies of acquisition reforms and cost growth, external factors are included as control variables in this research of the efficacy of acquisition reform efforts to limit schedule growth. The following section details the external factors affecting schedule growth and the corresponding research of these factors.

Budget Instability

A program's requirements are often modified as a result of adjustments to the program's budgets (current and projected) (McNutt, 1998:188). The schedule of planned work to be performed on a program assumes a certain amount of funding across numerous years. When this funding is altered, the program is faced with a decision to reduce requirements or to obtain additional funding in another (typically later) year and stretch out the program. Technical performance requirements, however, are less likely to be changed than the length of the schedule (McNutt, 1998:188). In a 1998 survey of 205 personnel at the Pentagon and various program offices, 113 stated that the schedule was more likely to change than performance requirements; whereas, only 46 stated

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[6] On October 30, 2002, a memorandum issued by Paul Wolfowitz, the then-Undersecretary of Defense for Acquisition, Technology and Logistics, cancelled the current DoD 5000 series of regulations (Rogers and Birmingham, 2004:46). An interim guidance was put in place until the revised DoD 5000 series was issued in 2003, which is the current version. Several of the key initiatives implemented in the 2000 revision remained, specifically evolutionary acquisition.

performance requirements would more likely change—a statistically significant difference (McNutt, 1998:287-288). A similar statistically significant difference existed in the tradeoff of cost and schedule where the schedule was more likely to be extended (McNutt, 1998:288).

In addition, McNutt (1998:276) surveyed government and contractor personnel at the Pentagon, program offices, and contractor facilities representing 175 projects. Results indicated that funding instability was the primary reason for a development program to slip—accounting for one month of the total average project slip of approximately two months per year (McNutt, 1998:276). Although there were some limitations with McNutt's method (i.e., it was a retrospective look that could be influenced by errors in recall), the individuals that were surveyed were closer to the projects than outsiders. Additionally, the individuals involved in the study were those that would be updating higher headquarters and Congress on the program's status.

Contingency Operations

Existing research has conflicting results concerning the influence of contingency operations on schedule growth, depending on the immediacy of the need for the weapon system. One side suggests the needs of contingency operations require systems, especially those in or near production, to be fielded sooner so that the capability is available to the war fighters (McNutt, 1998:40). As a result, those weapon systems identified as requirements for contingency operations are expected to have less (or negative—fielded prior to original plan) schedule growth.

The other side addresses those programs not specifically required or hastened due to contingency operations. Czelusniak and Rodgers found that Congressional decisions to shift funds to near-term priorities external to these programs (e.g. unplanned contingency operations) accounted for up to one-half of the cost growth in major weapons systems (1997:59). Their analysis, however, did not extend into the effects on schedule growth. The expectation is that the funding needs related to contingency operations (including the accelerated programs) contribute to budget instability in the programs not identified as contingency requirements. This budget instability leads to schedule growth as previously discussed. Therefore, the analysis of the influence of budget instability on schedule growth would necessitate accounting for the instability resulting from contingency operations.

Unexpected Inflation

Cost estimates for major programs span the entire life cycle of the program from initiation to disposal, which can last for numerous decades into the future. The development phase of these programs alone spans numerous years. These cost estimates included an estimate of inflation provided by the OSD Comptroller. If inflation is unexpectedly high in a given year then that forecasting error could contribute to cost overruns. There has yet to be an analysis of the impact of unexpected inflation on schedule growth; however, an analysis has been performed concerning cost growth.

A study by Smirnoff (2006:64) did not find a statistically significant relationship between unexpected inflation and cost overruns of procurement or development contracts. Additionally, the lack of a relationship between unexpected inflation and cost overruns may be due to the tradeoffs of reduced performance requirements or extended schedules.

**Summary**

This chapter examined the principal factors affecting schedule growth of Department of Defense (DoD) weapon systems. This chapter reviewed the major acquisition reforms with the scope and potential to impact schedule execution of defense acquisition efforts, which included a review of the research that assessed the efficacy of these reforms. Additionally, the literature identified funding instability, unexpected inflation, and contingency operations as external factors potentially contributing to schedule growth. This research on the efficacy of acquisition, however, has primarily been focused on cost growth. This research provides the lacking empirical analysis of the influence of the acquisition reform efforts and external factors on schedule growth.

# III. Data and Methods

This chapter details the methods used in this research, including a discussion of the operationalization of variables, the data analyzed, and the analytical techniques utilized in order to address the purpose of this research. More specifically, this chapter discusses the empirical model that was developed, and data that was collected, to evaluate the efficacy of acquisition reform efforts on limiting schedule growth of major DoD weapon systems. This model also addresses the influence of factors external to the acquisition process on schedule growth, including changes in defense budgets, unexpected inflation, and contingency operations.

The relationships between the dependent variable (schedule growth of DoD weapon systems) and the independent variables (acquisition reforms, contingency operations, unexpected inflation rates, and budget changes) is evaluated using panel regression. In addition to the discussion of the variables and the corresponding data, this chapter discusses the advantages of the use of panel regression in cross-sectional time-series analysis.

## Programs

This research evaluates the schedule growth of major defense acquisition programs (MDAPs) that are categorized as acquisition category (ACAT) I programs. These programs are designated as ACAT I programs due to their estimated cost exceeding a threshold or due to special interests (by the DoD or Congress) in the program (DoD5000.2, 2003:np). This cost threshold is currently $355 million in fiscal year (FY)

1996 constant year dollars for system development or $2.135 billion in FY 1996 constant dollars for production (DoD5000.2, 2003:np). That is, if the estimated expenditures for the program exceed either of those thresholds, the acquisition program is considered an MDAP and categorized by the milestone decision authority as an ACAT I program. Highly sensitive, classified programs (as determined by the Secretary of Defense) are not included among the MDAPs due to their sensitive nature (DoD5000.2, 2003:np). These programs receive special designations and are reported separately. As a result, this research excludes classified programs from the analysis and concentrates on the ACAT I major defense acquisition programs. Each of the military services is represented among the major defense acquisition programs. Among these MDAPs are joint programs, which are designated by the lead service for the joint program, such as the Air Force being the lead service for the Joint Direct Attack Munitions (JDAM) program.

As a result of being designated an ACAT I major defense acquisition program, these programs are required to submit quarterly submissions of the program's status into the Defense Acquisition Executive Summary (DAES) database. The DAES database includes Earned Value Management (EVM) data based on information supplied to the government by the performing contractor. EVM allows the government and contractors to monitor the status of programs with regard to contract costs and schedule by comparing the actual cost for work performed, the budgeted cost for work performed, and the budgeted cost for work scheduled. Due to the validation of the EVM accounting systems by the government, the data produced by these systems is considered to be valid (Searle, 1997:42). The period of analysis utilized in this research is from 1980 to 2002.[7]

This resulting sample DAES database is separated based on service and phase of the program—research and development (R&D) or procurement (proc.). The number of entries corresponding to a specific contract's EVM data is presented in the table below. An excerpt from the DAES database, a list of programs, and the number of contract entries per program is provided in Appendix A.

**Table 1: Number of Contract Entries in Sample DAES Database**

| | Air Force | Army | Navy | Total |
|---|---|---|---|---|
| R&D - Contract Entries | 1,998 | 1,194 | 1,303 | 4,495 |
| Proc. - Contract Entries | 2,172 | 792 | 2,893 | 5,857 |

## Measures

### Outcome (Dependent Variable)

Schedule Growth

For the purposes of this research, schedule growth is defined and measured using a modified version of percent schedule variance based on the *Earned Value Management Gold Card* (2007).[8] The following formula is used to calculate these values for percentage schedule growth of both development and production contracts:

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[7] This research utilizes the DAES database utilized in Smirnoff (2006), which extended from 1970 to 2002. This database, however, did not include data for one of the dependent variables (unexpected inflation) prior to 1980 due to the unavailability of inflation estimates. In order to mitigate any potential confusion with a discussion of varying beginning dates, this research focuses all discussions/graphical presentations on the time period from 1980 to 2002.

[8] The actual calculation for schedule variance according the EVM Gold Card is BCWP-BCWS, which results in negative values reflecting undesired circumstances. In this research, the variables were switched to allow for positive values to reflect percent schedule variance (also referred to as schedule growth throughout this study). This adjustment allows for easier interpretation and analysis of the empirical model coefficients.

% Schedule Growth for service *i* in year *t* =

$$\frac{\left(\sum BCWS_{i,t} - \sum BCWP_{i,t}\right)}{\sum BCWS_{i,t}} * 100 \qquad (1)$$

where: BCWS = Budgeted Cost for Work Scheduled
BCWP = Budgeted Cost for Work Performed

This equation aggregates the values by year, service, and program phase for all of the DAES contracts entries/years from 1980-2002. The next chapter presents a visual representation of the schedule growth for both development and production contracts.

A potential limitation of this operationalization of schedule growth is that it does not decipher between legitimate delays caused by DoD decisions, such as changing requirements, and delays caused by contractor performance. The majority of the delays, however, cannot be attributed to contractor actions, such as when the DoD calls for performance requirements that represent a high technical risk or when the government (either Congress or the DoD) chooses to shift financial resources creating funding instability (Drezner and Smith, 1990:35; McNutt, 1998:275). Despite the source of the delay, the issues resulting from schedule growth remain, including an increased probability of cancellation (Pinto and Mantel, 1990:273) and costs associated with maintaining existing systems (Reinertsen et al., 2002:8).

**Antecedents (Independent Variables)**

Acquisition Reform

The acquisition reforms that are studied in this research include the Packard Commission, the 1993-1996 reforms (NPR, FASA, and the Clinger-Cohen Act), and the

2000 revision of the DoD 5000 series of regulations. In accordance with previous research, these reforms are coded as dummy variables with a “1” indicating the presence of the reform (Smirnoff, 2006:28-29). This research utilizes the year in which the DoD revised its DoD 5000 series of regulations as the first year of the presence of these reforms. A common thread throughout the selected reforms is that the DoD 5000 series was revised soon after these acquisition reform efforts were codified (e.g., the Clinger-Cohen Act) or the study recommendations published (e.g., the Packard Commission). These revisions point to changes in acquisition policy made by the DoD as a result of these major reform efforts, which would affect all of the current programs including the major defense acquisition programs.

In accordance with this coding scheme, the Packard Commission recommendations are coded as “1” from 1987 to 1995. The 1987 date reflects when the DoD revised its acquisition policy (DoD 5000 series) to incorporate the recommendations. The 1993-1996 reforms and corresponding management initiatives were integrated into the 1996 revision of the DoD 5000 series; as a result, these reforms are coded as “1” from 1996 to 2002. In addition, these reforms superseded many of reform initiatives/recommendations of the Packard Commission, which is why the Packard Commission ends at 1995. Finally, the 2000 revision of the DoD 5000 series is coded as “1” from 2000 to 2002 (the last year of analysis in this research).

## External Factors

Budget Instability

This research utilized the actual procurement and development budgets as a proxy measure for budget instability. Budget instability was measured by utilizing the constant year budget figures detailed in Chapter 6 of the National Defense Budget Estimates for 2006 (also known as the *FY2006 Greenbook*). The budget information in this report was collected for each service (Air Force, Army, Navy), for each appropriation (research and development and procurement), and for each year of the analysis (1980-2002). A visual representation of the resulting values is presented in Appendix B.

Contingency Operations

This research codes contingency operations as a binary (dummy) variable, in which the values of "1" correspond to the existence of major combat operations (war) in a given year to account for the influence of the contingency operations on schedule growth of major defense acquisition programs. These major combat operations are more likely to impact major defense acquisition programs, either through budget instability as suggested by Czelusniak and Rogers (1997) or through the needs of combatant commanders hastening programs in order to support the contingency operations as suggested by McNutt (1998). Therefore, for the time period of 1980 to 2002, the identified major contingencies (where the war dummy variable is coded as "1") were Desert Storm/Shield and the Global War on Terror (Smirnoff, 2006:29).

Unexpected Inflation

The OSD Comptroller provides estimates of future inflation rates that the cost estimators incorporate into their estimates for major defense programs. These estimates of future inflation rates are presented in Chapter 5 of the National Defense Budget Estimates section included in the annual President's Budget submission. This research measures unexpected inflation as the difference between actual inflation and expected inflation for the year the funding was used (Smirnoff, 2006:31). The following formula is used to calculate the values for unexpected inflation:

$$\text{Unexpected Inflation} = \text{Inflation}_{actual} - \text{Inflation}_{estimated} \qquad (2)$$

For example, the expected inflation rate for the DoD in 1980 was 5.9 percent, but the actual inflation rate for 1980 was 11.7 percent. As a result, there was 5.8 percent of unexpected inflation for 1980. This level of unexpected inflation was calculated for each year from 1980-2002 to correspond with the span of the schedule growth data. A visual representation and a table of the calculated unexpected inflation values are included in Appendix B.

**Analysis**

The influence of the major defense acquisition reforms and the external factors (budget instability, contingency operations and requirements, and unexpected inflation) on schedule growth is empirically evaluated using panel regression. Panel regression is utilized to analyze an independent variable across groups with respect to multiple time periods. In terms of this research, the groups represent each service and the time periods correspond to the years 1980-2002.

Panel (data) analysis provides several benefits when compared to other possible analytical methods, such as multivariate regression analysis of cross-sectional data. Panel regression provides the ability to control for omitted variables. The bias resulting from omitted variables is typically an issue with multivariate analysis. This issue stems from unknown variable or variables affecting the dependent variable, which leads to biased estimations (regression results) (Kennedy, 2003:302). The issue of omitted variables represented the principle limitation in the previous studies of acquisition reforms and cost growth (Christensen et al., 1999; Holbrook, 2003). The ability of panel regression to control for these omitted variables is a key benefit to this analytical method. In addition, the combining of cross-sectional and time-series data creates more observations for statistical testing and produces more variability, which makes the panel model more robust to multicollinearity (Kennedy, 2003:302).

This research utilizes a fixed-effects specification for the panel model consistent with that utilized by Smirnoff (2006). Fixed-effects panel regression assumes there are nominal time-series impacts on the dependent variable, but more cross-sectional effects (Armstrong, 2006:34). Smirnoff's study similarly evaluated the impact of acquisition reforms and additional (economic) variables on major defense acquisition programs using a fixed-effects panel model; however, his analysis focused on the impacts on cost growth.

**Summary**

This research empirically evaluates the influence of defense acquisition reforms and external factors (budget instability, contingency operations, and unexpected inflation) on schedule growth of major defense acquisition programs between 1980 and 2002. This chapter described the how the dependent variable (schedule growth percentage) and independent variables were operationalized and measured, including the corresponding rationale. In addition, a description of the key source of information pertaining to the major defense acquisition programs, the Defense Acquisition Executive Summary (DAES) reports, was presented. Finally, this chapter described the analytical method that was utilized to analyze the relationship between the independent variables and schedule growth. The results of the panel analysis are presented in the next chapter.

# IV. Analysis and Results

## Chapter Overview

This chapter presents the analysis performed in order to address the purpose of this research. The first section includes details regarding the theoretical models utilized to analyze the collected data. Following that section, the results of these empirical models are presented, including a discussion of the key findings. This discussion includes addressing the findings that yielded results contrary to the expected (based on previous research) and the variables that were more significant (statistically and in the magnitude of the coefficients) than the other variables.

## Theoretical Model

The existing research suggests the below theoretical model for evaluating the relationship of the previously discussed factors on schedule growth:

$$\text{Schedule Growth (\%)} = \text{f}\begin{pmatrix}\text{Budget Stability, Unexpected Inflation,} \\ \text{Acquisition Reforms, War}\end{pmatrix} \tag{3}$$

The data concerning these variables were collected and coded according the methods described in the previous chapter. As mentioned previously, a cross-sectional fixed-effects panel model was utilized for this analysis. The general form of this panel model, where *i* represents the service and *t* represents the year, is:[9]

[9] An alternate model specification included the percent change in the budget variables. This specification, however, created challenges in the interpretations of the findings, specifically in the applications of the coefficients to real-world examples. As a result, the actual budgetary figures were utilized. In addition, the total budget for each service was excluded due to its high correlation with both the development and procurement budgets, which are the primary sources of funding for major acquisition programs.

$$\text{Schedule Growth (\%)}_{i,t} = \alpha + \alpha_i + \beta_1\text{*R\&D Budget}_{i,t} + \beta_2\text{*Procurement Budget}_{i,t} + \beta_3\text{*Unexpected Inflation}_{i,t} + \beta_4\text{*Packard}_{i,t} + \beta_5\text{*90s Reforms}_{i,t} + \beta_6\text{*2000 Revision}_{i,t} + \beta_7\text{*War}_{i,t} + e_{i,t} \quad (4)$$

This panel model includes the aforementioned cross-sectional fixed-effects to account for the service specific characteristics in the sample data. In addition, several other considerations were addressed in the modeling process. In order to minimize the possibility for spurious correlations, the dependent variable (percent schedule growth) was tested for stationarity using the augmented Dickey-Fuller test for each panel (service). The results of these tests (in Appendix C) suggest the existence of a stationary process.[10]

Another consideration tested for in the panel models was autocorrelation, which can bias the regression results. Specifically, it can lead to an upward bias in the estimates of the statistical significance of coefficient estimates (Schmidt, 2003:223). In order to address this issue, a first-order autocorrelation component was included in the empirical models.[11]

An additional concern for the models was heteroskedasticity (non-constant variance in the residuals), which can also bias the standard errors of the parameter estimates (Schmidt, 2003:247). In order to mitigate the potential heteroskedasticity, the residuals were 'White-washed' using White's heteroskedasticity-consistent variance-covariance matrix (White, 1980) to obtain robust standard errors.

[10] Additional tests of stationarity corroborated these results, specifically the Levin, Lin and Chu test for a common unit root.
[11] The Durbin-Watson statistic test was utilized to test for autocorrelation. In all of the models, the Durbin-Watson statistic increased such that the value was closer to two (the mean value for the Durbin-Watson statistic). As a result, the inclusion of an AR(1) component decreased the uncertainty that autocorrelation is not present.

## Panel Model Results

This section presents and interprets the model results, including a discussion of differences between the anticipated and realized impacts (specifically, the direction) of each variable. Two models were developed to determine the impact of the acquisition reform efforts and the external variables on schedule growth—one for schedule growth of development programs and one for schedule growth of production programs.

## Model 1: Schedule Growth of Development Contracts

As mentioned in Chapter II, most of the research concerning schedule growth addresses the growth in the development phase of the acquisition process. The dependent variable in this model is the average annual schedule variance (in percentage terms) per service for the development programs in the DAES database from 1980 to 2002. This variable is depicted in Figure 1 below. The schedule growth values for the Navy have two distinct peaks in the mid-1980s and the early-1990s. Both the Army and the Air Force have peaks in the late-1980s (and 1990).

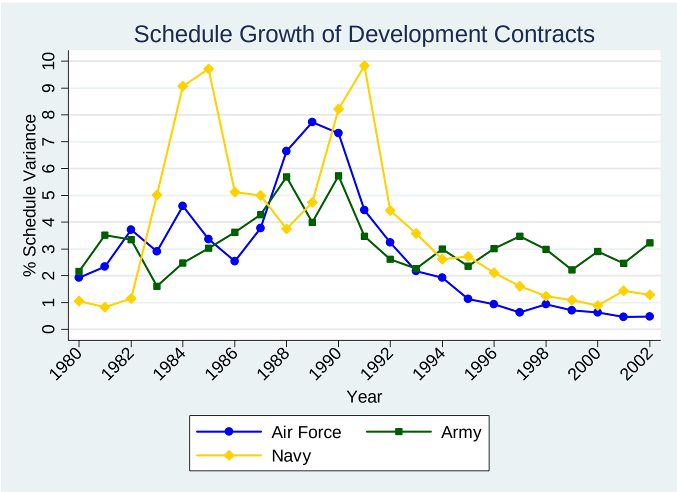


**Figure 1: Schedule Growth of Development Contracts (1980-2002)**

**Table 2: Regression Results for Schedule Growth of Development Contracts**

| Development Schedule Growth Panel Model | | |
|---|---|---|
| Fixed-effects Regression | | |
| Robust Standard Errors | | |
| Group Variable(i): Service | | |
| Variable | Coefficient | t-Statistic |
| C | -1.039 | -0.962 |
| R&D Budget (CY06 $B) | 0.160 | 0.677 |
| Proc. Budget (CY06 $B) | 0.094 † | 1.652 |
| Unexpected Inflation | 0.413 *** | 2.794 |
| Packard | 0.393 | 0.453 |
| 90s Reforms | -0.370 | -0.310 |
| 2000 Revision | -1.048 † | -1.398 |
| War | 1.074 † | 1.418 |
| AR(1) | 0.537 *** | 4.359 |
| F-statistic | 12.118 *** | |
| Number of Obs | 66 | |
| Number of Groups | 3 | |
| R-squared | 0.688 | |
| Adjusted R-squared | 0.631 | |
| Durbin-Watson stat | 1.670 | |

***statistical significance at 0.01 level,
** 0.05 level, * 0.10 level, † 0.20 level

The results of the panel model are presented in Table 2 above.[12] The first variables of interest concern the research and development and procurement budgets. Changes in the research and development budget do not have a statistically significant relationship with the schedule variances (used to measure schedule growth) of the development contracts. On the other hand, procurement budgets have a positive, statistically significant relationship with schedule growth of development contracts. The magnitude of this relationship (as measured by the coefficient), however, is not very

[12] This research first evaluates the contemporaneous conditions by not including any lagged variables; however, alternative model specifications including lags were also examined to see the impacts of their inclusion in the model. The optimal lag lengths determined by the lowest the Akaike Information Criterion (AIC) were three years for the budget variables, Packard, and the 1990s reforms. The 2000 revision had a one year lag and war had no lag. All of the same variables as in the original specification were statistically significant to at least the 0.20 level except unexpected inflation became no longer statistically significant.

large. The results suggest a 10 billion dollar (constant year 2006) increase in the service's procurement budget would increase schedule growth by only about one percent. This considerable amount of budget growth represents an approximate sixty percent increase in the procurement budget for the Army based on the mean for the sample.

Unexpected inflation has a positive, highly statistically significant relationship with schedule growth of development contracts. The results state a one percent value for unexpected inflation (such as if inflation was estimated to be 2.5 percent but actually was 3.5 percent) would increase schedule growth of development contracts by four-tenths of a percent, holding all other variables constant.

Two of the four binary (dummy) variables have a statistically significant relationship with schedule growth in this specified model, including major contingency operations (war) and the 2000 revision of the DoD 5000 series of regulation concerning the DoD acquisition process. The results indicate major contingency operations (and the corresponding large deployments and budget impacts) increase schedule growth on development contracts by a little over one percent. In addition, the 2000 revision resulted in an approximate one percent reduction in schedule growth. Both of these variables agree with the theorized impacts based on the existing research. On the other hand, the other two variables representing the presence of the reform efforts did not have statistically significant relationships.[13]

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[13] An alternate model specification utilizing percent change in the budget variables did yield a slightly statistically significant (to the 0.20 level) for both the 90's reforms and war. War has roughly the same coefficient as in the original specification (1.16) and the 90's reforms has a fairly large negative coefficient of -2.05 (see Appendix E for results). However, the budget variables and unexpected inflation were no longer significant to even the 0.20 level and the overall model lost explanatory power.

The evaluation of schedule variances in dollar terms is not as useful as the evaluation of cost variances (used often in cost overrun/growth research). That is, it does not necessarily imply an impact to the overall program schedule (in terms of completion dates and changes in program length/duration) of the same magnitude as the calculated schedule variance.[14]

**Model 2: Schedule Growth of Production Contracts**

The dependent variable in this model is the average annual schedule variance (in percentage terms) per service for the production programs in the DAES database from 1980 to 2002. This variable is depicted in Figure 2 below.

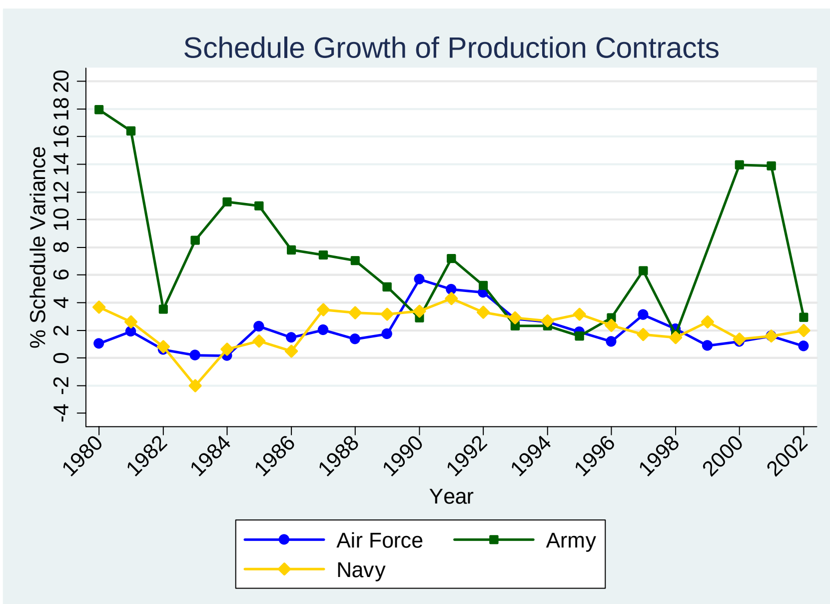


**Figure 2: Schedule Growth of Production Contracts (1980-2002)**

[14] The one instance it does is if the schedule variance refers only to the efforts on the program's critical path. The actual impact to the program's schedule may be either more or less than calculated percentage schedule growth depending on what planned efforts of the program had yet to be completed.

The values appear to vary more for the production contracts than the development contracts, especially for the Army. This fluctuation is primarily the result of the low number of production contract entries for the Army in the DAES database (an average of 34 per year versus 94 for the Air Force and 125 for the Navy).[15]

The results of the panel model are presented in Table 3 below. Unlike the model for development schedule growth, none of the budget variables have a statistically significant relationship with production schedule growth. Conversely, unexpected inflation remains statistically significant in the procurement contracts model with a greater magnitude positive relationship with schedule growth than in the development

**Table 3: Regression Results for Schedule Growth of Production Contracts**

Procurement Schedule Growth Panel Model
Fixed-effects Regression
Robust Standard Errors
Group Variable(i): Service

| Variable | Coefficient | t-Statistic |
|---|---|---|
| C | 4.386 * | 1.680 |
| R&D Budget (CY06 $B) | -0.079 | -0.393 |
| Proc. Budget (CY06 $B) | 0.023 | 0.423 |
| Unexpected Inflation | 0.783 * | 1.807 |
| Packard | -0.468 | -0.394 |
| 90s Reforms | -1.207 | -0.811 |
| 2000 Revision | -1.020 † | -1.327 |
| War | 0.726 | 1.028 |
| AR(1) | 0.475 *** | 2.890 |
| F-statistic | 8.348 *** | |
| Number of Obs | 64 | |
| Number of Groups | 3 | |
| R-squared | 0.612 | |
| Adjusted R-squared | 0.538 | |
| Durbin-Watson stat | 2.212 | |

***statistical significance at 0.01 level,
** 0.05 level, * 0.10 level, † 0.20 level

[15] The lower number of entries for the Army is likely the result of having fewer major acquisition programs in production in general and even fewer programs receiving earned value data, which is often not obtained on fixed-price production contacts.

contracts model. The results indicate a one percent level of unexpected inflation would lead to a 0.78 percent increase in schedule variances on production contracts, holding all other variables constant.

Only one of the four binary (dummy) variables has a statistically significant relationship with schedule growth in this specified model, which is the 2000 revision of the DoD 5000 series of regulation concerning the DoD acquisition process. [16] The 2000 revision resulted in a one percent reduction in schedule growth, which agrees with the theorized impact based on the existing research. On the other hand, the other two variables representing the presence of the reform efforts did not have statistically significant relationships. In addition, the dummy variable representing the major contingency operations (i.e., war) did not have a statistically significant relationship with schedule growth of procurement contracts.

**Summary**

This chapter described the analysis used to evaluate the impact of acquisition reform efforts and other, external factors on schedule growth of major defense acquisition programs (MDAP). The panel model was first described in general terms. Then, the regression results of the empirical models were presented and discussed. The models evaluated schedule growth for both development and production contracts of the MDAPs. The next chapter furthers the evaluation of the empirical results and their possible policy implications.

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[16] An alternate model specification akin to the one described in the development panel model was also generated for the production contracts. The only variables to become statistically significant in this revised specification were the war dummy variable and the percent change in the development budget (significant to the 0.20 level). Both unexpected inflation and the 2000 revision dummy variable remained consistent in both the magnitude of the coefficient and the level of statistical significance.

# V. Conclusions and Recommendations

## Chapter Overview

This chapter further examines the results from Chapter IV through their application to the research objectives identified in the introduction (Chapter I). That section is followed by a discussion of the major findings of this research. Finally, recommendations for future research are presented.

## Research Objectives

The primary purpose of this research was to perform an empirically rigorous study of the impacts of acquisition reform efforts and other, external factors on acquisition schedule growth that was lacking in the existing literature. Entries from the DAES database representing both development and production contracts for all three services from 1980 to 2002 were utilized to build an empirical (panel) model in order to evaluate the effectiveness of acquisition reform efforts on limiting schedule growth in the development of major DoD weapon systems. In order to isolate the influences of the reforms, this research addressed the extent to which factors external to the acquisition process are related to schedule growth, specifically defense budget changes (budget instability), unexpected inflation, and contingency operations.

## Discussion of Results and Research Objectives

This section applies the results from Chapter IV to the research objectives, including a discussion of potential conclusions concerning the objectives based on the results of the empirical models. The combined results of both panel models—the development contracts model and the production contracts model—are shown in Table 4 below.

**Table 4: Results of the Panel Models**

| Development Schedule Growth Panel Model | | | Procurement Schedule Growth Panel Model | | |
|---|---|---|---|---|---|
| Variable | Coefficient | t-Statistic | Variable | Coefficient | t-Statistic |
| C | -1.039 | -0.962 | C | 4.386 * | 1.680 |
| R&D Budget (CY06 $B) | 0.160 | 0.677 | R&D Budget (CY06 $B) | -0.079 | -0.393 |
| Proc. Budget (CY06 $B) | 0.094 † | 1.652 | Proc. Budget (CY06 $B) | 0.023 | 0.423 |
| Unexpected Inflation | 0.413 *** | 2.794 | Unexpected Inflation | 0.783 * | 1.807 |
| Packard | 0.393 | 0.453 | Packard | -0.468 | -0.394 |
| 90s Reforms | -0.370 | -0.310 | 90s Reforms | -1.207 | -0.811 |
| 2000 Revision | -1.048 † | -1.398 | 2000 Revision | -1.020 † | -1.327 |
| War | 1.074 † | 1.418 | War | 0.726 | 1.028 |
| AR(1) | 0.537 *** | 4.359 | AR(1) | 0.475 *** | 2.890 |

***statistical significance at 0.01 level, ** 0.05 level, * 0.10 level, † 0.20 level

Budget Instability

This research did not obtain results consistent with the previous research that suggests reduction in budgets (a proxy for budget instability) would lead to a schedule slip (and therefore, schedule growth) (McNutt, 1998:276). McNutt's study addressed schedule impacts of development programs identified through the use of a survey instrument (vice contractual data) and the budget stability referred to the program's development budget. In addition, his research examined programs of varying sizes and not just the major weapon systems (as in this research). This research did not find that changes in a service's research and development budget impacts schedule growth of either procurement or development contracts. This lack of a relationship is perhaps the result of major defense development programs tending not to have their development budgets dramatically reduced unless the program is terminated.[17]

Changes in the procurement budget, however, do appear to have a statistical relationship with schedule growth for development programs. While the literature does not address procurement budget stability as a source of development schedule growth, a possible explanation may that increased production budgets likely correspond to larger acquisition programs (including development) that are more complex (and likely more costly). These larger, more complex development programs are more likely to experience schedule growth (Rodrigues, 2000:10). While the changes in the procurement budget may capture this potential relationship with schedule growth, a more appropriate measure that is not included in the empirical model that may explain this relationship is technical complexity (or technical maturity).

Unexpected Inflation

While Smirnoff (2006) did not find a statistical relationship between unexpected inflation and cost overruns, the postulated rationale was that the lack of a relationship may be due to tradeoffs of reduced performance requirements or extended schedules. Based on the results of the empirical result, the latter appears to be the case. This research found that unexpected inflation impacts schedule growth in both development and production contracts. That is, when faced with a level of inflation greater than the forecasted amount (a positive value for unexpected inflation), both development and

[17] The same cannot be said regarding production budget profiles, which are often significantly larger than the development budgets and change more dramatically as a result of reduced quantities to procure and/or due to other (often political) factors.

production programs experience increased schedule growth. For example, one percent level of unexpected inflation would result in a 0.4 percent increase in schedule growth for development contracts and 0.8 percent increase for procurement contracts, holding all other variables constant. This increase in schedule growth signifies an increase in work that was not accomplished as planned. This level of schedule variance in the contracts likely corresponds to an extension in the program's schedules (such as, completion and milestone dates) to perform the missed work.

Contingency Operations (War)

The existing research presents conflicting theories on the potential impact of major contingency operations on schedule growth. One side suggests contingency operations require systems to be fielded sooner, especially those in or near production, so that the capability is available to the war fighting personnel (McNutt, 1998:40). The other side suggests contingency operations drive funding needs that contribute to budget instability in the programs not identified as contingency requirements (Czelusniak and Rogers, 1997:59). While the war dummy variable was not statistically significant in the procurement contracts model, it was significant in the development contracts model. In this model, the existence of a major contingency operation increased schedule growth on development contracts by a little over one percent. Therefore, the results of the production model agree with the theory presented in Czelusniak and Rogers (1997) that the budget instability generated by contingency operations leads to worsened program performance in terms of schedule growth. In addition, while a handful of programs may be fielded sooner than expected in order to support contingency operations, the majority of programs are not.[18]

Acquisition Reform Efforts

After accounting for the impacts of changes in the defense budget, unexpected inflation, and contingency operations on schedule growth, the results were primarily inconclusive regarding the impact of the acquisition reforms efforts on schedule growth. The existing research suggests the reforms utilized in the empirical model had the greatest potential to impact schedule execution. These acquisition reforms include the Packard Commission (1986), the National Performance Review (1993) and Federal Acquisition Streamlining Act of 1994, and the revision of the DoD 5000 series in 2000.

This research did not find a statistical relationship between the implementation of the Packard Commission's recommendations and initiatives and schedule growth of either production or development contracts. Similar inconclusive results were obtained regarding the implementation of the 1990s reform efforts in the 1996 revision of the DoD 5000 series. The 2000 revision of the DoD 5000 series, which included several initiatives aimed at controlling cost and schedule (specifically, evolutionary acquisition), has a

[18] This assertion is made based on a visual examination of the schedule milestones contained in the Selected Acquisition Reports (SARs) of the major defense acquisition programs from 1997 to 2005. Programs that require quicker fielding tend to have this reduced duration from the initiation of the program. As a result, the corresponding reports would not indicate a reduction in schedule, because the reduced schedule is the baseline for that program. For example, the schedule for the Army's Stryker program is perceived to have been advanced due to contingency requirements. The first SAR reflecting the approved program based on the Milestone II Review (in Nov 2000) already has a combined development/production (low rate initial production) decision with a threshold date of January 2003 for the first unit equipped. The actual first unit equipped date was actually later in March 2003. If the program had been advanced, it would be expected that this date would be sooner than initially planned and definitely before the threshold date. This, however, is not the case.

statistically significant relationship with schedule growth of both development and procurement contracts.  Furthermore, this research found the 2000 revision reduced development schedule growth by 1.05 percent and procurement schedule growth by 1.02 percent.  This result agrees with the research suggesting the potential benefits of some of the initiatives implemented in the 2000 revision, particularly evolutionary acquisition, which places greater emphasis on controlling requirements and fielding more mature technologies versus lengthy developments involving new and/or unproven technologies (GAO, 2006:1).

The lack of a relationship with schedule growth for the bulk of the reform efforts likely indicates these reforms were not effective at limiting scheduling growth; however, they also did not result in increased schedule growth.  This inefficiency at limiting schedule growth may be due to the shortfalls in the policies enacted as part of these reforms, but more likely are from not fully implementing the recommendations and initiatives into the DoD acquisition processes.  McNutt contended that, despite implementation by the DoD, the recommendations of the Packard Commission on schedule execution were not widely internalized and appeared to have been unsuccessful (1998:50).  The results imply that this might have been the case not only for the Packard recommendations but also for subsequent reform efforts.

### Significance of Research

This study fills the void in the existing literature of an empirically rigorous study of the factors contributing to schedule growth.  In particular, several studies have examined the impacts of reform efforts/initiatives on cost overruns (Christensen et al., 1998; Holbrook, 2003; Smirnoff, 2006), but none have yet to study the impacts on schedule growth. Similar deficiencies exist in the literature concerning the impact of unexpected inflation and contingency operations (war) on schedule growth. As a result, this research can form the basis for future research involving empirical analyses of the schedule execution of defense weapon system programs.

**Recommendations for Future Research/Policy Considerations**

Based on the results of this research, this section presents a few policy considerations concerning schedule growth of major defense acquisition programs. The first policy consideration is for greater resources to be devoted to forecasting inflation, considering its significant impact on schedule growth in both development and procurement efforts. The second policy consideration concerns accounting for the effects of contingency operations (war) on development schedule growth in the costs for future contingency operations. These costs may be calculated using the cost-of-delay analysis method in McNutt (1998) that considers the additional operations and sustainment costs for the additional time the system to be replaced has to remain in service and multiplier (or efficiency) costs/savings that are lost due to the delay in the fielding of a weapon system/capability. The final consideration is to place greater emphasis on the implementation of the recommendations and initiatives set forth in the acquisition reforms. A 2006 GAO study supported this assessment, pointing to the issue of the DoD allowing programs to enter into system development with immature technologies as a sign that the DoD had yet to fully institutionalize the revised (evolutionary) acquisition approach (2006:12).

Recommendations for future research follow two general paths: performing a similar analysis using a different dataset and examining different factors to see their impact on schedule growth. Future research concerning the first group includes utilizing the same method on individual program data using either earned value data (as per this study) in the DAES reports or using schedule milestones found in the Selected Acquisition Reports (SARs). This type of analysis allows for greater evaluation of schedule impacts based on type of weapon system and other programmatic characteristics. In addition, the existing dataset can be expanded to more recent years to discern any changes in the results while allowing for an analysis of more recent phenomena, such as changes in the organizational structure of Air Force program offices (System Wings, Program Executive Officer consolidation/movement).

Additionally, other studies can utilize a similar method to evaluate the impact of other factors on schedule execution. The other factors could include personnel characteristics, including education level, acquisition training, and the number in a given job (e.g., cost analysis). Another possible study concerns the evaluation of the common assumption that schedule growth leads to cost growth or vice versa. Finally, a study could be performed comparing the earned value data in the DAES to that of the schedule milestone data (in month/year form) found in the schedule section in either the DAES or SAR reports. This study will analyze to what extent changes in the earned value data are reflected in the current estimates for completion of schedule milestones.

# Appendix A: Summary of DAES Data

## Example Entries

Table 5 below provides an example of a few entries in the DAES database. The specific areas utilized in this research were the year, budgeted cost for work performed (BCWP), and budgeted cost for work scheduled (BCWS). The sample entries reflect the DAES entries corresponding to the May 25, 2002, DAES submissions for those programs.

**Table 5: DAES – Sample Entries**

| SUBMITDATE | Contract ID | Service | Program Name | ACWP | BCWP | BCWS | BAC | Program Phase |
|---|---|---|---|---|---|---|---|---|
| 5/25/2002 | F0862698C0027 | Air Force | AMRAAM (AIM-120A) | 135.2 | 128.9 | 130.2 | 179.8 | Development |
| 5/25/2002 | DAAH0199C0121 | Army | ATACMS BLK II | 130.4 | 115.6 | 123.7 | 124.6 | Production |
| 5/25/2002 | DAAH0199C0154 | Army | ATACMS BLK II | 122.1 | 102 | 106.3 | 132 | Development |
| 5/25/2002 | N0001997C0069 | Navy | Cooperative Engagement Capability (CEC) | 93.3 | 95.7 | 96.1 | 107.9 | Development |
| 5/25/2002 | N0002499C5110 | Navy | Cooperative Engagement Capability (CEC) | 131.1 | 132.2 | 132.8 | 149.9 | Development |
| 5/25/2002 | N39997993754 | Navy | DD(X) Destroyer | 140 | 137.4 | 141.5 | 172.4 | Development |
| 5/25/2002 | N0002496C2304 | Navy | DDG 51 | 935.8 | 850.5 | 858.1 | 926.7 | Production |
| 5/25/2002 | N0002496C2305 | Navy | DDG 51 | 1067.7 | 968.3 | 979.6 | 1021.1 | Production |
| 5/25/2002 | N0002497C5178 | Navy | DDG 51 | 432.8 | 448 | 452.1 | 772.2 | Production |
| 5/25/2002 | N0002498C2306 | Navy | DDG 51 | 831.2 | 747.7 | 780.6 | 1849.7 | Production |
| 5/25/2002 | N0002498C2307 | Navy | DDG 51 | 865.9 | 851 | 912.4 | 2599.7 | Production |
| 5/25/2002 | F0470197C0044 | Air Force | GBS | 186.2 | 186.8 | 187.3 | 187.9 | Development |
| 5/25/2002 | F3365701C4600 | Air Force | Global Hawk Unmanned aerial Vehicle | 7.9 | 8 | 8.2 | 83.7 | Development |
| 5/25/2002 | F3365701C4601 | Air Force | Global Hawk Unmanned aerial Vehicle | 3.5 | 3.5 | 3.4 | 90.3 | Production |
| 5/25/2002 | DAAH0198C0033 | Army | GMLRS Upgrade Missile | 125.2 | 122.9 | 124.9 | 135.6 | Development |
| 5/25/2002 | F0863500C0101 | Air Force | JDAM | 27.4 | 29.5 | 29.9 | 0 | Development |
| 5/25/2002 | F0862696C0002 | Air Force | Joint air to surface Standoff Missile (JASSM) | 312.5 | 295.8 | 299.6 | 334.3 | Development |
| 5/25/2002 | N0001995C0120 | Navy | Joint standoff weapon (JSOW) | 198.2 | 190.6 | 191.5 | 203.2 | Development |
| 5/25/2002 | F1962800C0023 | Air Force | JSTARS | 108.5 | 123.1 | 122.2 | 207.3 | Production |
| 5/25/2002 | F1962897C0001 | Air Force | JSTARS | 293.7 | 336.8 | 337.4 | 358.1 | Production |
| 5/25/2002 | F1962898C0003 | Air Force | JSTARS | 143.7 | 168.9 | 169.3 | 202.3 | Production |
| 5/25/2002 | F0470100C0006 | Air Force | Navistar Global Positioning system (GPS) II Modern | 50.5 | 49.8 | 49.5 | 51.2 | Development |
| 5/25/2002 | F0470196C0025 | Air Force | Navistar Global Positioning system (GPS) II Modern | 152 | 144 | 154 | 443 | Development |
| 5/25/2002 | N0002496C5337 | Navy | SM 2 (BLKS I-IV) | 80.4 | 78 | 78.4 | 82.1 | Production |
| 5/25/2002 | N0001998C0177 | Navy | Tactical Tomahawk Missile | 347.8 | 346.6 | 346.9 | 307.1 | Development |

## Programs

The following tables list the major defense acquisition programs comprising the dataset analyzed in this research.[19] Table 6 lists the Army programs and the number of contract entries in the overall DAES data. Table 7 lists the Air Force programs. Table 8 lists the Navy programs.

**Table 6: Army Programs**

| Program Name | Number of Contract Entries: Research & Development | Number of Contract Entries: Procurement |
|---|---|---|
| ABRAMS Tank M1/M1A1 | 11 | 35 |
| ADDS | 27 | 41 |
| Advanced Threat Infrared Countermeasures | 25 | 0 |
| AFATDS (ATCCS) | 49 | 0 |
| AH-64 Apache | 25 | 97 |
| Army TACMS | 65 | 0 |
| ASAS (ATCCS) Block IIB III | 32 | 17 |
| ATACMS BLK II | 94 | 10 |
| BFVS A3 Upgrade | 29 | 0 |
| BFVS M2 M3 (Bradley Fighting Vehicle | 4 | 47 |
| CH-47 Improved Cargo Helicopter (CH-47F) | 13 | 0 |
| CH-47D Chinook | 1 | 0 |
| Comanche Reconnaissance Attack Helicopter (RAH-66) | 37 | 0 |
| COPPERHEAD | 0 | 5 |
| CSSCS | 0 | 21 |
| FAAD C2I | 61 | 0 |
| FAAD NLOS Fiber Optic Guided-Missile | 7 | 0 |
| FBCB2 | 0 | 3 |
| GMLRS Upgrade Missile | 13 | 0 |
| IAV (Stryker) | 6 | 0 |
| Javelin | 30 | 24 |
| JSTARS Common Ground Station (CGS) | 26 | 0 |
| Laser Hellfire | 28 | 58 |
| Longbow Apache FCR | 73 | 0 |
| Longbow Hellfire | 0 | 21 |
| M1A2 Abrams Upgrade | 10 | 0 |
| MCS IV | 23 | 0 |
| MLRS | 45 | 4 |
| MLRS-TGW | 40 | 0 |
| PATRIOT | 72 | 120 |
| Patriot PAC-3 | 91 | 9 |
| PERSHING II | 21 | 69 |
| ROLAND | 0 | 20 |
| RPV (AQUILA) | 68 | 0 |
| SADARM | 71 | 16 |
| SCAMP | 10 | 0 |
| SGT YORK GUN (DIVAD) | 0 | 31 |
| SINCGARS | 36 | 0 |
| STINGER | 29 | 56 |
| STINGER RMP | 0 | 56 |
| TACIT RAINBOW (JGL) | 3 | 0 |
| TOW 2 | 19 | 0 |
| UH-60A/L Black Hawk | 0 | 32 |

[19] As mentioned in Chapter III, the earned value data detailed in the DAES entries for these programs were accumulated for the year and added with the other programs for that service in that specific year.

# Table 7: Air Force Programs

| Program Name | Number of Contract Entries: Research & Development | Procurement |
|---|---|---|
| ACM | 35 | 31 |
| AFATDS | 2 | 0 |
| ALCM | 8 | 24 |
| AMRAAM (AIM-120A) | 92 | 83 |
| ASAT | 66 | 10 |
| ATS | 20 | 0 |
| B-1 CMUP-DSUP | 2 | 0 |
| B-1B | 110 | 255 |
| B-1B CMUP | 58 | 0 |
| B-2A | 5 | 10 |
| C-130 Avionics Modernization Program ((C-130 AMP) | 2 | 0 |
| C-17A | 128 | 99 |
| CSRL | 14 | 9 |
| DMSP | 40 | 136 |
| DSCS III A&B | 21 | 15 |
| DSP | 87 | 207 |
| E-3 AWACS RSIP | 59 | 0 |
| E-3A | 0 | 33 |
| EF-111A | 0 | 9 |
| EJS | 13 | 0 |
| F-22A Raptor | 91 | 0 |
| F-15 | 15 | 62 |
| F-16 | 37 | 130 |
| GBS | 17 | 0 |
| GLCM | 12 | 11 |
| Global Hawk Unmanned aerial Vehicle | 1 | 1 |
| Inertial Upper Stage | 0 | 14 |
| IR Maverick | 9 | 34 |
| I-S/A AMPE | 13 | 0 |
| JDAM | 30 | 0 |
| JGL Tacit Rainbow | 27 | 0 |
| Joint air to surface Standoff Missile (JASSM) | 16 | 0 |
| Joint Primary training aircraft (JPATS) (T-45) | 24 | 64 |
| Joint Tactical Information Distribution System | 25 | 0 |
| JSIPS CIGSS | 9 | 0 |
| JSTARS | 79 | 102 |
| KC-135R | 0 | 42 |
| MARK XV IFF | 33 | 0 |
| MILSTAR | 32 | 17 |
| Minuteman III Guidance replacement Program (MMIII | 38 | 21 |
| Minuteman III Propulsion replacement program (MMII | 22 | 31 |
| Navistar Global Positioning system (GPS) II Modern | 84 | 98 |
| OTH-B (Radar) | 0 | 52 |
| Peacekeeper | 198 | 494 |
| PLSS | 17 | 0 |
| Rail Garrison | 48 | 0 |
| Sensor Fused Weapon | 28 | 50 |
| Small ICBM | 234 | 0 |
| SMART-T | 20 | 0 |
| Space based infra red surveillance system (SBIRS) | 25 | 0 |
| SRAM T AGM 131A/B | 17 | 0 |
| T-46A | 24 | 10 |
| Titan IV | 11 | 18 |

## Table 8: Navy Programs

| Program Name | Number of Contract Entries: Research & Development | Number of Contract Entries: Procurement |
|---|---|---|
| 5-INCH GUIDED PROJECTILE | 9 | 0 |
| A-12 | 9 | 0 |
| Aim-9X Short range air to air missile | 21 | 0 |
| AN/BSY-1 | 63 | 0 |
| AN/BSY-2 | 26 | 0 |
| AN/SQQ-89 | 53 | 87 |
| AN-APG-79 Active Electronically Scanned Array Radar | 2 | 0 |
| AOE 6 | 0 | 73 |
| ASPJ (AN/ALQ-165) | 0 | 33 |
| AV-8B Harrier II | 10 | 7 |
| C/MH-53E | 7 | 0 |
| CG 47 Aegis Cruiser | 0 | 153 |
| Cooperative Engagement Capability (CEC) | 39 | 14 |
| CVN 68 | 0 | 66 |
| DD(X) Destroyer | 3 | 0 |
| DDG 51 | 28 | 433 |
| E-2C Computer Upgrade | 63 | 0 |
| EMSP | 12 | 0 |
| F/A-18 C/D | 21 | 37 |
| F/A-18 E/F Super Hornet | 69 | 60 |
| F-14D | 0 | 6 |
| FDS | 60 | 0 |
| FFG-7 | 0 | 28 |
| HARM (NAVY) | 27 | 5 |
| Joint standoff weapon (JSOW) | 52 | 9 |
| JTIDS (NAVY) | 15 | 0 |
| LAMPS MKIII | 21 | 5 |
| LCAC | 0 | 155 |
| LHD-1 | 0 | 151 |
| LPD-17 | 0 | 45 |
| LSD 41 CARGO VAR | 0 | 26 |
| LSD 41 Class CV | 0 | 24 |
| MCM 1 | 0 | 31 |
| MH-60R | 62 | 6 |
| MH-60S | 9 | 0 |
| MHC 51 | 0 | 112 |
| MIDS-LVT | 43 | 0 |
| MK 48 ADCAP | 0 | 46 |
| MK 50 Torpedo | 38 | 33 |
| NATO PHM | 1 | 11 |
| Navy Area TMBD | 66 | 4 |
| NSSN New Attack Sub | 63 | 104 |
| P-7A | 6 | 0 |
| PHALANX CIWS (MK-15) | 0 | 6 |
| Phoenix (AIM-54C) | 0 | 16 |
| ROTHR | 3 | 0 |
| SEA LANCE | 26 | 0 |
| SEALIFT | 0 | 123 |
| SIDEWINDER (AIM-9L) (Navy) | 2 | 0 |
| SIDEWINDER (AIM-9M) (Navy) | 1 | 0 |
| SM 2 (BLKS I-IV) | 29 | 69 |
| SPARROW (AIM-7M) (Navy) | 0 | 14 |
| SSN 688 Attack Sub | 35 | 203 |
| T-45TS | 16 | 5 |
| TACTAS | 1 | 1 |
| Tactical Tomahawk Missile | 14 | 0 |
| T-AGOS | 0 | 20 |
| T-AO 187 OILER | 0 | 26 |
| Tomahawk R/UGM-109 | 65 | 114 |
| TRIDENT II MSL | 79 | 187 |
| TRIDENT II SUB | 0 | 154 |
| TRIDENT SUB | 0 | 19 |
| USMC H-1 Upgrades | 17 | 0 |
| V-22 Joint services advanced vertical lift aircraft | 117 | 88 |
| Virginia Class Sub SSN 774 | 0 | 84 |

**Appendix B: Summary of Independent Variables and Summary Statistics**

**Procurement and Development Budgets**

Figures 3 and 4 below show the procurement and development budgets for the Army, Air Force, and Navy between 1980 and 2002. These budget figures reflect the Total Obligation Authority values detailed in Chapter 6 of the National Defense Budget Estimates for 2006 (also known as the *FY2006 Greenbook*). The values presented throughout this study are in billions of [constant] fiscal year 2006 dollars.

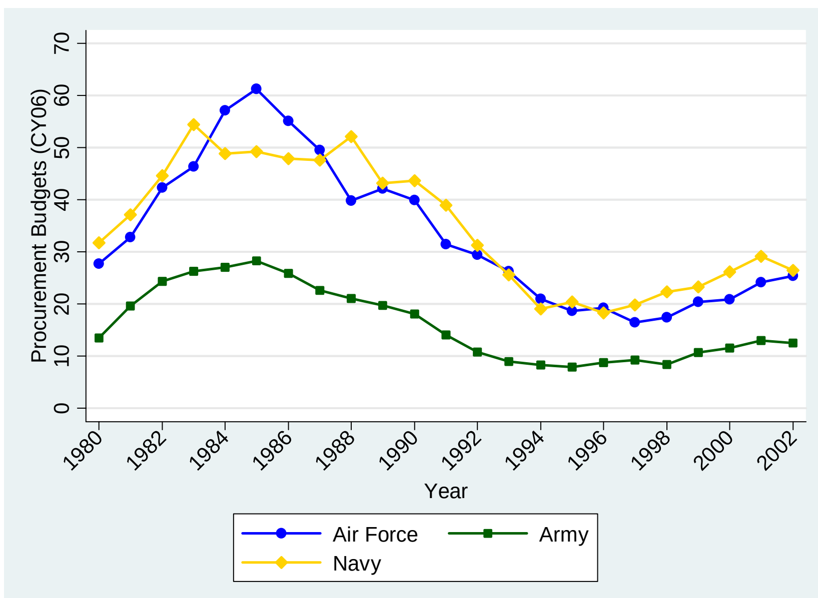


**Figure 3: Procurement Budgets from 1980-2002 (CY06 $B)**

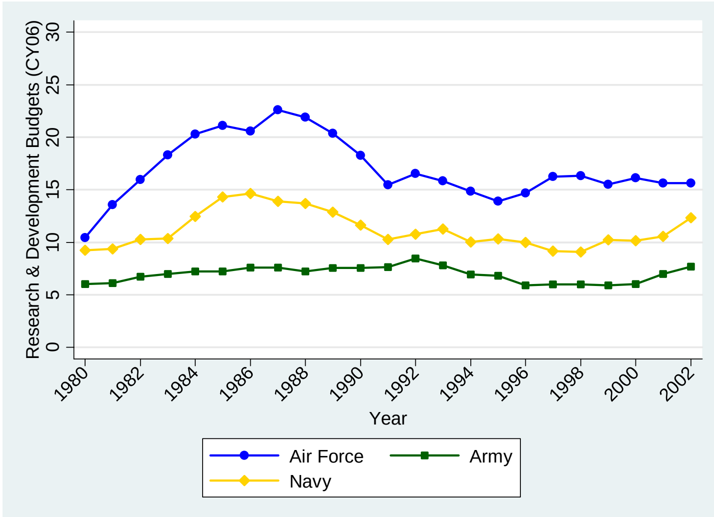


**Figure 4: Research & Development Budgets from 1980-2002 (CY06 $B)**

## Unexpected Inflation

The estimates of future inflation rates are presented in Chapter 5 of the National Defense Budget Estimates section included in the annual President's Budget submission. Figure 5 depicts the levels of expected inflation and actual inflation for each year from 1980 to 2002. Table 9 provides the calculated values for unexpected inflation for that time period.

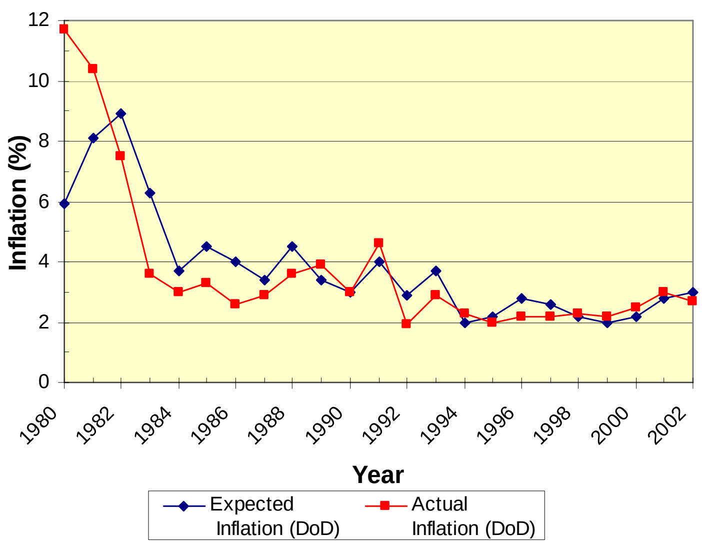


**Figure 5: Expected and Actual Inflation Rates from 1980-2002**

**Table 9: Unexpected Inflation from 1980-2002**

| Year | Expected Inflation (DoD) | Actual Inflation (DoD) | Unexpected Inflation |
|---|---|---|---|
| 1980 | 5.9% | 11.7% | 5.8% |
| 1981 | 8.1% | 10.4% | 2.3% |
| 1982 | 8.9% | 7.5% | -1.4% |
| 1983 | 6.3% | 3.6% | -2.7% |
| 1984 | 3.7% | 3.0% | -0.7% |
| 1985 | 4.5% | 3.3% | -1.2% |
| 1986 | 4.0% | 2.6% | -1.4% |
| 1987 | 3.4% | 2.9% | -0.5% |
| 1988 | 4.5% | 3.6% | -0.9% |
| 1989 | 3.4% | 3.9% | 0.5% |
| 1990 | 3.0% | 3.0% | 0.0% |
| 1991 | 4.0% | 4.6% | 0.6% |
| 1992 | 2.9% | 1.9% | -1.0% |
| 1993 | 3.7% | 2.9% | -0.8% |
| 1994 | 2.0% | 2.3% | 0.3% |
| 1995 | 2.2% | 2.0% | -0.2% |
| 1996 | 2.8% | 2.2% | -0.6% |
| 1997 | 2.6% | 2.2% | -0.4% |
| 1998 | 2.2% | 2.3% | 0.1% |
| 1999 | 2.0% | 2.2% | 0.2% |
| 2000 | 2.2% | 2.5% | 0.3% |
| 2001 | 2.8% | 3.0% | 0.2% |
| 2002 | 3.0% | 2.7% | -0.3% |

## Summary Statistics

Table 10 below provides the summary statistics for the continuous variables utilized in this research. The values reflect the entire range of data from 1980 to 2002 for all three services. The amount of schedule growth appears to vary more in procurement contracts, including values reflecting periods where the programs of one service were ahead of schedule on average for that year (that is, a negative schedule growth value).

**Table 10: Summary Statistics**

| | Obs. | Mean | Median | Maximum | Minimum | Std. Dev. |
|---|---|---|---|---|---|---|
| R&D Schedule Growth (percent) | 69 | 3.25 | 2.91 | 9.84 | 0.47 | 2.20 |
| Proc. Schedule Growth (percent) | 68 | 3.76 | 2.60 | 17.94 | -2.01 | 3.86 |
| R&D Budget ($ billion) | 69 | 11.70 | 10.35 | 22.61 | 5.89 | 4.60 |
| Procurement Budget ($ billion) | 69 | 28.09 | 25.64 | 61.31 | 7.90 | 14.06 |
| Unexpected Inflation (percent) | 69 | -0.08 | -0.30 | 5.80 | -2.70 | 1.57 |

## Appendix C: Tests for Stationarity of Dependent Variable

In order to minimize the possibilities for spurious correlations, the dependent variable used in the panel regression model must be stationary. In this research, the dependent variables are the schedule growth percentages of procurement and development contracts in the DAES database for each service in each year. The Augmented Dickey-Fuller Test was utilized in this study to test for the presence of a unit root; the values are Tables 11 and 12 below. All of the p-values for the tests are less than $\alpha=0.05$, except for that of the Air Force's research and development contracts, which has a p-value less than $\alpha=0.15$. This value might have impacted some of the findings in this research; however, the value is still relatively low and the other two services had lower (more ideal) p-values. This is confirmed in the Levin, Lin and Chu test for common unit root test (values in Table 13) with both the procurement and development contract entries having p-values less than $\alpha=0.05$. As a result, the null hypothesis (of a unit root) can be rejected and it can be concluded that the schedule growth data reflect a stationary process.

**Table 11: Augmented Dickey-Fuller Test Results for Development Contracts**

| Percent Schedule Growth - Research & Development Contracts | | | | | |
|---|---|---|---|---|---|
| Dickey-Fuller Test for Unit Root | | | | | |
| | | | Z(t) has t-distribution | | |
| | Number of Obs | Test Statistic | 1% Critical Value | 5% Critical Value | 10% Critical Value |
| **Z(t)-Air Force** | 22 | -1.076 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.1474** | | | |
| **Z(t)-Army** | 22 | -2.877 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0047** | | | |
| **Z(t)-Navy** | 22 | -1.81 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0427** | | | |

**Table 12: Augmented Dickey-Fuller Test Results for Procurement Contracts**

| Percent Schedule Growth - Procurement Contracts | | | | | |
|---|---|---|---|---|---|
| Dickey-Fuller Test for Unit Root | | | | | |
| | | | Z(t) has t-distribution | | |
| | Number of Obs | Test Statistic | 1% Critical Value | 5% Critical Value | 10% Critical Value |
| **Z(t)-Air Force** | 22 | -2.233 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0186** | | | |
| **Z(t)-Army** | 20 | -3.147 | -2.552 | -1.734 | -1.33 |
| **p-value for Z(t) =** | | **0.0028** | | | |
| **Z(t)-Navy** | 22 | -2.482 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.011** | | | |

**Table 13: Common Unit Root Test Results for Schedule Growth**

| Levin, Lin & Chu Test for Common Unit Root | | | |
|---|---|---|---|
| | Number of Obs | Test Statistic | Prob. |
| R&D Contracts | 64 | -1.68588 | 0.0459 |
| Proc. Contracts | 58 | -3.44782 | 0.0003 |

## Appendix D: Tests for Stationarity of Continuous Independent Variables

In addition to testing for stationarity of the dependent variable, unit root tests (same as in Appendix C) were also performed on the continuous independent variables (budgets and unexpected inflation) utilized in this research. The results of the individual Augmented Dickey-Fuller Tests are provided in Tables 14-16. Unexpected inflation has very significant test statistics for both the individual and common unit root tests, indicating a stationary process. In addition, the research and development budgets appear to reflect a stationary process (p-values less that $\alpha$=0.10 for the individual unit root tests and around $\alpha$=0.10 for the common unit root test). The procurement budgets appear to have a greater possibility for a non-stationary process with p-values around $\alpha$=0.20. The transformation of the budgets into percentage change from previous year seems to correct any issues with non-stationarity in both the procurement and development budgets. That is, the p-values for both the individual and common unit root tests are less than $\alpha$=0.01. The results of these tests for the transformed budget variables are provided in Tables 18-20. In accordance with this adjustment, regression results utilizing these transformed budget variables are provided in Appendix E.

### Table 14: Augmented Dickey-Fuller Test Results for Development Budgets

| Research & Development Budget (CY06 $B) | | | | | |
|---|---|---|---|---|---|
| Dickey-Fuller Test for Unit Root | | | | | |
| | | | Z(t) has t-distribution | | |
| | Number of Obs | Test Statistic | 1% Critical Value | 5% Critical Value | 10% Critical Value |
| **Z(t)-Air Force** | 22 | -2.371 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0139** | | | |
| **Z(t)-Army** | 22 | -1.651 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0572** | | | |
| **Z(t)-Navy** | 22 | -1.497 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.075** | | | |

**Table 15: Augmented Dickey-Fuller Test Results for Procurement Budgets**

| Procurement Budget (CY06 $B) | | | | | |
|---|---|---|---|---|---|
| Dickey-Fuller Test for Unit Root | | | | | |
| | | | Z(t) has t-distribution | | |
| | **Number of Obs** | **Test Statistic** | **1% Critical Value** | **5% Critical Value** | **10% Critical Value** |
| **Z(t)-Air Force** | 22 | -0.817 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.2119** | | | |
| **Z(t)-Army** | 22 | -0.754 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.2299** | | | |
| **Z(t)-Navy** | 22 | -0.804 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.2153** | | | |

**Table 16: Augmented Dickey-Fuller Test Results for Unexpected Inflation**

| Unexpected Inflation (%) | | | | | |
|---|---|---|---|---|---|
| Dickey-Fuller Test for Unit Root | | | | | |
| | | | Z(t) has t-distribution | | |
| | **Number of Obs** | **Test Statistic** | **1% Critical Value** | **5% Critical Value** | **10% Critical Value** |
| **Z(t)-Air Force** | 22 | -6.01 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0** | | | |
| **Z(t)-Army** | 22 | -6.01 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0** | | | |
| **Z(t)-Navy** | 22 | -6.01 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0** | | | |

**Table 17: Common Unit Root Test Results for Budgets & Unexpected Inflation**

| Levin, Lin & Chu Test for Common Unit Root | | |
|---|---|---|
| | **Test Statistic** | **Prob.** |
| Development Budget (CY06 $B) | -1.248 | 0.106 |
| Procurement Budget (CY06 $B) | -0.762 | 0.223 |
| Unexpected Inflation (%) | -7.315 | 0.000 |

**Table 18: Augmented Dickey-Fuller Test Results for Percent Change of Development Budgets**

| Percent Change - Research & Development Budget | | | | | |
|---|---|---|---|---|---|
| Dickey-Fuller Test for Unit Root | | | | | |
| | | | Z(t) has t-distribution | | |
| | Number of Obs | Test Statistic | 1% Critical Value | 5% Critical Value | 10% Critical Value |
| **Z(t)-Air Force** | 22 | -2.664 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0075** | | | |
| **Z(t)-Army** | 22 | -3.277 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0019** | | | |
| **Z(t)-Navy** | 22 | -3.059 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0031** | | | |

**Table 19: Augmented Dickey-Fuller Test Results for Percent Change of Procurement Budgets**

| Percent Change - Procuremnt Budget | | | | | |
|---|---|---|---|---|---|
| Dickey-Fuller Test for Unit Root | | | | | |
| | | | Z(t) has t-distribution | | |
| | Number of Obs | Test Statistic | 1% Critical Value | 5% Critical Value | 10% Critical Value |
| **Z(t)-Air Force** | 22 | -2.589 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0088** | | | |
| **Z(t)-Army** | 22 | -2.72 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0066** | | | |
| **Z(t)-Navy** | 22 | -3.141 | -2.528 | -1.725 | -1.325 |
| **p-value for Z(t) =** | | **0.0026** | | | |

**Table 20: Common Unit Root Test Results for Percent Change of Budgets**

| Levin, Lin & Chu Test for Common Unit Root | | |
|---|---|---|
| | Test Statistic | Prob. |
| % Change - R&D Budget | -3.874 | 0.0001 |
| % Change - Proc. Budget | -2.769 | 0.0028 |

## Appendix E: Alternative Specification for Panel Model

This section provides regression results for the schedule growth panel models utilizing a slightly altered specification for the models, which can be found in Table 21. That is, percent change of the budget variables were used in place of the constant year 2006 dollar figures utilized previously (in the body of this study). This altered specification results in fewer statistically significant variables in the model for schedule growth of development contracts. In addition, the development model explains less of the variation in the schedule growth data (an adjusted r-squared value of 0.568 versus 0.631). On the other hand, the procurement model has more statistically significant variables and the revised model explains more of the variation in the schedule growth data (from 0.538 to 0.555).

**Table 21: Alternative Model Specification Regression Results**

| | Schedule Growth Panel Models | | | |
|---|---|---|---|---|
| | Development | | Procurement | |
| Variable | Coefficient | t-Statistic | Coefficient | t-Statistic |
| C | 4.436 *** | 3.353 | 3.943 *** | 4.586 |
| % Change - R&D Budget | -4.6E-05 | -0.002 | 0.039 † | 1.380 |
| % Change - Proc. Budget | 0.0087 | 0.717 | 0.022 | 1.004 |
| Unexpected Inflation | 0.269 | 0.912 | 0.841 * | 1.878 |
| Packard | -0.542 | -0.453 | -0.192 | -0.212 |
| 90s Reforms | -2.049 † | -1.549 | -1.247 | -1.145 |
| 2000 Revision | -0.777 | -1.160 | -1.365 † | -1.391 |
| War | 1.160 † | 1.531 | 0.930 † | 1.602 |
| AR(1) | 0.631 *** | 4.813 | 0.500 *** | 3.222 |
| F-statistic | 9.554 *** | | 8.867 *** | |
| Number of Obs | 66 | | 66 | |
| Number of Groups | 3 | | 3 | |
| R-squared | 0.635 | | 0.626 | |
| Adjusted R-squared | 0.568 | | 0.555 | |
| Durbin-Watson stat | 1.652 | | 2.206 | |
| Fixed-Effects | Yes | | Yes | |
| Robust Standard Errors | Yes | | Yes | |

***statistical significance at 0.01 level, ** 0.05 level, * 0.10 level, † 0.20 level

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# Vita

Captain Michael Giacomazzi was born in Oxford, England. In 1998, he graduated from the Maine School of Science and Mathematics in Limestone, Maine. Afterward, he enrolled in the [then] College of Commerce and Business Administration at the University of Illinois: Urbana-Champaign where he was also a Cadet in the Air Force Reserve Officer Training Corps Detachment 190. He graduated with a Bachelor of Science in Finance in May 2002 and received his commission the same month. He was assigned to Wright-Patterson Air Force Base, Ohio, where he worked as a Financial Manager for the B-1 Systems Group until 2005. In August 2005, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology, to obtain his Master's Degree in Cost Analysis. Upon graduation, Captain Giacomazzi will be assigned as a Cost Analyst in the MILSATCOM Systems Wing, Los Angeles Air Force Base, California.

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**14. ABSTRACT**

Schedule growth of major defense acquisition programs creates several issues, including increased likelihoods of cancellations, changes in requirements, and delays in the fielding of improved combat capabilities and replacements for legacy systems. As a result, Congress, the DoD, and the individual military services have implemented several major reforms to address the cost and schedule growth of weapon systems. This research presents an empirical model of schedule growth to evaluate the impact of acquisition reform efforts, defense budget changes, unexpected inflation, and major contingency operations (war) on schedule growth of major weapon systems. A fixed-effects panel regression model was utilized to describe the schedule performance (using earned value data) of the major weapon system programs from 1980 to 2002. This research found that unexpected inflation results in increased schedule growth. In addition, the 2000 revision of the DoD 5000 series accounted for a reduction in schedule growth. The other examined acquisition reforms—the Packard Commission of 1986 and the 1993-1996 reform efforts (e.g., the Federal Acquisition Streamlining Act of 1994 and the Clinger-Cohen Act of 1996)—were not correlated with schedule growth. This lack of a relationship suggests these reforms were not fully internalized into the Department of Defense's acquisition process and appear to have not been successful at limiting schedule growth.

**15. SUBJECT TERMS**

Schedule growth, schedule variance, weapon systems, Packard, FASA, Clinger-Cohen, NPR, DoD 5000, acquisition regulation, inflation, acquisition reform, Defense budget, funding instability, EVMS, DAES, econometric modeling, panel model, time series analysis, cross-sectional, longitudinal

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