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Studying the Formulation of Incremental Development Approaches

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Abstract

The research surveys acquisition professionals for a recommended acquisition strategy for a typical acquisition program facing a milestone approval. This work provides insights into the importance of typical programmatic decision inputs (requirements, technology maturity, risk, urgency, and funding) to the formulation of an acquisition strategy. The research uses the Joint Common Missile (JCM) program and the subsequent Joint Air Ground Missile (JAGM) program as the basis. A questionnaire asks acquisition professionals to develop an acquisition strategy for the JCM program based on approved requirements, a technology risk assessment, and planned funding. The recommended strategies are compared to the actual strategy implemented in the JAGM program. The work highlights that once the program's cost and schedule parameters are planned, the program's only risk mitigation strategy is to delay desired capability to later increments. This research suggests that acquisition policy should require development programs to establish firm targets for cost and schedule and allow the services the ability to fit only what is affordable from a performance (requirements) perspective into the first increment of the program of record by delaying the achievement of some requirements to subsequent increments to allow more time for technology maturation.

Paper Keywords: critical thinking, decision-making, project management, acquisition strategy formulation

Introduction

Within U.S. defense acquisition, an evolutionary strategy with an incremental development approach is the preferred strategy for most acquisition programs (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)], 2007). The basic advantage over a single-step acquisition developmental approach is that the warfighter gets some capability sooner rather than waiting for full capability. Figure 1 outlines the basic advantage of the incremental approach versus a single-step approach, where the warfighter or user gets no capability until the end of a successful development. In contrast, using the incremental approach, the warfighter gets improved capability (over their existing level) in a shorter time period.

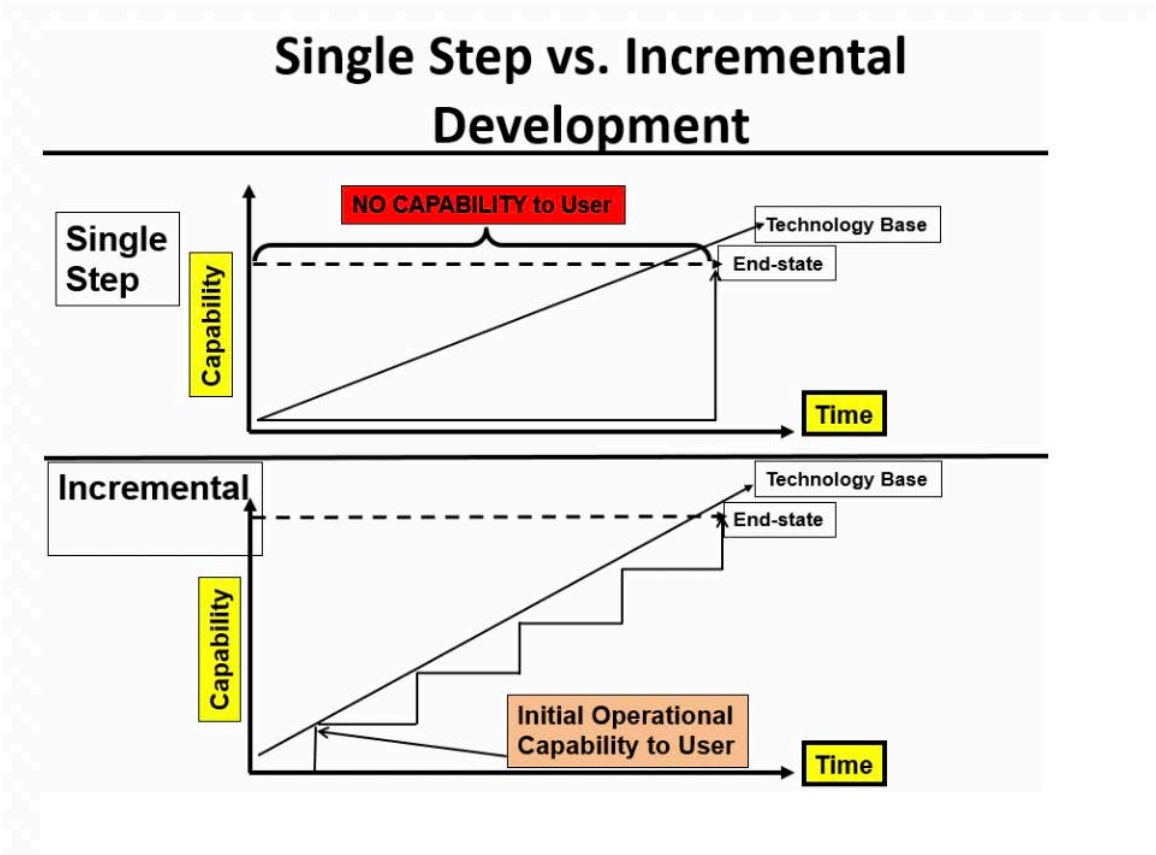

Figure 1. Single Step Versus Incremental Development Approach

But how hard is it for program managers (PMs) to recommend and implement this approach? This research studies how difficult it is for a PM to implement an evolutionary acquisition (EA) with an incremental development (ID) approach. The research focuses on analyzing the importance of typical program data, such as requirements, technology maturity, risk, and funding, as inputs to the PM decision-making process for determining a recommended acquisition strategy. The study goals are to provide insights into the unique challenges within the defense acquisition institution and provide acquisition policy reform recommendations. The work aligns with general research in the areas of project management, defense acquisition reform, strategic management, and organizational behavior. This research supports the 2018 National Defense Strategy approach to reform the Department of Defense (DoD) for greater performance and affordability (DoD, 2018) and also addresses the challenges of "enabling effective acquisition and contract management" highlighted in the 2018 DoD Inspector General (IG) report titled *Top Management Challenges: Fiscal Year 2018.*

According to DoD Directive (DoDD) 5000.01, *The Defense Acquisition System*, dated November 20, 2007, responsiveness is one of five policies that governs the defense acquisition system. Specifically, DoDD 5000.01 defines responsiveness as follows:

> Advanced technology shall be integrated into producible systems and deployed in the shortest time practicable. Approved, time-phased capability needs matched with available technology and resources enable evolutionary acquisition strategies. Evolutionary acquisition strategies are the preferred approach to satisfying operational needs. Incremental development is the preferred process for executing such strategies. (OUSD[AT&L], 2007)

The accompanying DoD Instruction (DoDI) 5000.02 (2008), *Operation of the Defense Acquisition System,* further expands on the use incremental development strategies. In fact, the words "incremental and/or increment(s)" appear more than 52 times in the approximately 100-page instruction (OUSD[AT&L], 2017). The DoDI 5000.02 recognizes the importance of a modular open systems approach (MOSA)—modular designs coupled with open business models—to successfully implement incremental development efforts. Figure 2 outlines a basic incremental development strategy across the five phases of the acquisition framework, from material solution analysis (MSA) to technology maturation and risk reduction (TMRR) to engineering and manufacturing development (EMD) to production and deployment (PD) to operations and support (OS). Key enablers for a successful implementation of an incremental development (ID) approach include time-phased requirements, MOSA, integrated test & evaluation (T&E), and sustainment strategies, as well as full funding for each increment.

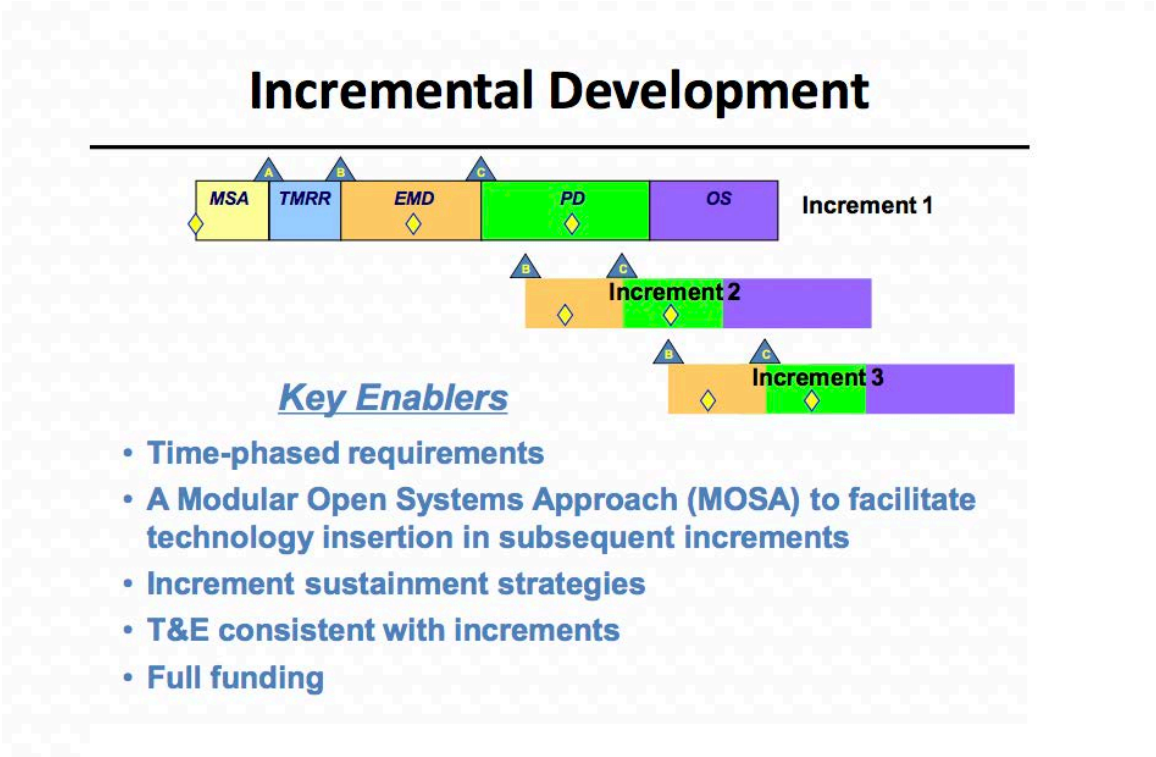

Figure 2. Standard Incremental Development Approach

The *Defense Acquisition Guidebook* (DAG) reinforces the DoDD 5000.01 and DoDI 5000.02 by mentioning "increment(s)" or "incremental" hundreds of times in this 1,230-page document (Defense Acquisition University [DAU], 2012). The DAG defines an *increment* as "a militarily useful and supportable operational capability that can be developed, produced, deployed, and sustained" (DAU, 2012). Furthermore, the recently approved Chairman of the Joint Chiefs of Staff Instruction (CJCSI) 5123.01H, dated August 31, 2018, which replaced the CJCSI 3170.01 series, continues the theme on the importance on time-phased requirements for the success of EA strategies and ID efforts (CJCS, 2015, 2018).

Despite the emphasis on ID approaches both in DoD acquisition and requirements policy documents and regulations, many program managers (PMs) struggle to successfully implement the preferred approach. The Government Accountability Office (GAO) and RAND reports continue to highlight the importance of EA and ID approaches as widely accepted

best practices in commercial industry. For example, a 2010 GAO report titled *Defense Acquisitions—Strong Leadership Is the Key to Planning and Executing Stable Weapons Programs* studied the stability of DoD major defense acquisition programs (MDAPs) and found that only 21% appeared to be stable (GAO, 2010). The GAO reported that stable MDAPs "pursued evolutionary or incremental acquisition strategies, leveraged mature technologies, and established realistic cost and schedule estimates that accounted for risk" (GAO, 2010). In many instances, defense acquisition programs that have incrementally fielded capabilities fall into the category of programs that have upgraded a very successful initial warfighting capability—that is, the future increments were never envisioned from the original requirements. The subsequent increments were natural upgrades to the initial capability and were a more affordable way of delivering increased capability to the warfighter rather than an expensive, new development effort.

This research focuses on programs that do not have time-phased requirements. In this situation, PMs use the inputs of urgency, resources (primarily funding), and technology maturity (primarily technology readiness levels and risk assessments) to try to develop a strategy to meet the warfighters' required needs and timelines, as well as being affordable for the service. Implementing an appropriate incremental development strategy requires strategic leadership and transparent information-sharing/decision-making as well as an understanding of the strategic environment, key stakeholders, change leadership, and organizational behavior.

The goal of this research is to examine the difficulty in developing an evolutionary acquisition strategy with an incremental development approach. The objectives include the following:

- Develop insights into the importance of typical programmatic decision inputs to the development of an acquisition strategy.
- Provide insights into how PMs can better develop acquisition strategies based on requirements, technology maturity, risk, urgency, and funding.
- Determine defense acquisition policy recommendations on how to better support the planning of successful incremental development acquisition strategies.

The research uses the Joint Common Missile (JCM) program and the subsequent Joint Air Ground Missile (JAGM) program as the basis to survey acquisition professionals. A questionnaire asks acquisition professionals to develop an acquisition strategy for the JCM program based on approved requirements, a technology risk assessment, and funding documents. These recommended strategies are compared to the actual strategy implemented in the JAGM program.

The primary research question is this: Can a PM or acquisition professional predict an effective acquisition strategy given typical programmatic decision inputs? The secondary research questions are the following:

- What is the most important factor in determining the recommended acquisition strategy?
- How can the decision input factors be changed to enable a PM or acquisition professional to recommend an appropriate, risk-based, knowledge-based, incremental development approach?

Background

The section reviews the background of both EA and ID and presents a historical review of how policy, regulations, and statutes have changed over time with respect to guidance on EA and ID for PMs. The seeds for significant acquisition reform were set in the 1980s. A 1986 RAND study titled *Improving the Military Acquisition Process* (Rich, Dews, & Batten, 1986) and *A Quest for Excellence: Final Report to the president by the President's Blue Ribbon Commission on Defense Management* (Packard; 1986; also known as the The Packard Report) outlined significant acquisition reform recommendations, many of which were later implemented. Groundbreaking legislation related to acquisition reform included the 1986 Goldwater–Nichols Department of Defense Reorganization Act, which reorganized the DoD and strengthened civilian authority in the DoD, the 1990 Defense Acquisition Workforce Improvement Act (DAWIA), the 1994 Federal Acquisition Streamlining Act (FASA), and the 1996 Federal Acquisition Reform Act (FARA). Although these transformational acts made no specific mention of EA or ID, they laid the groundwork for significant congressional involvement in acquisition reform (Goldwater–Nichols Department of Defense Reorganization Act, 1986; Defense Acquisition Workforce Improvement Act, 1990; Federal Acquisition Streamlining Act, 1994; Federal Acquisition Reform Act, 1996).

The National Defense Authorization Acts (NDAAs) have also had a significant impact on defense acquisition reform. The fiscal year (FY) 1996 NDAA specifically calls for the incremental acquisition of information technology and for the use of modular contracting.

Table 1 has a summary of the NDAAs from 1996 to 2017 with a count of the number of times the words "evolutionary," "increment," or "block" are referenced with respect to defense acquisition. The NDAAs from 1997 to 2002 do not mention the words "evolutionary," "incremental," or "block upgrades."

Table 1. NDAA Summary of EA and ID Word Use. Data From NDAAs Dated 1996–2017.

National Defense Authorization Act (NDAA)			
Fiscal Year	Total Page Count	Page Count of Title VIII - Acquisition Policy, Acquisition Management, and Related Matters	Uses of word "evolutionary" or "increment" or "block"
1996	519	10	40
1997	450	14	0
1998	450	22	0
1999	360	10	0
2000	466	16	0
2001	515	20	0
2002	384	18	0
2003	306	19	23
2004	436	20	1
2005	389	20	14
2006	423	32	16
2007	439	38	38
2008	602	70	48
2009	417	47	22
2010	656	23	16
2011	383	64	3
2012	566	45	49
2013	682	40	29
2014	494	13	14
2015	698	37	12
2016	585	80	52
2017	970	93	79

The FY2003 NDAA required extensive reporting to Congress on "evolutionary acquisition of major defense acquisition programs" while specifically addressing spiral development efforts (NDAA, 2003). Section 802 required the Secretary of Defense to submit a report to the congressional defense committees on major defense acquisition programs that follow the evolutionary acquisition process (NDAA, 2003). The FY2003 NDAA went on to define the term *evolutionary acquisition process* as "a process by which an acquisition program is conducted through discrete phases or blocks, with each phase or block consisting of the planned definition, development, production or acquisition, and fielding of hardware or software that provides operationally useful capability" (NDAA, 2003). The term "increment … means one of the discrete phases or blocks of such program" (NDAA, 2003). With respect to spiral development, the NDAA authorizes the Secretary of Defense to conduct major defense acquisition programs as spiral development programs, defining the "spiral development program, with respect to a research and development program" as "a program that is conducted in discrete phases or blocks, each of which will result in the development of fieldable prototypes; and will not proceed into acquisition until specific performance parameters, including measurable exit criteria, have been met" (NDAA, 2003).

The 2009 Weapon Systems Acquisition Reform Act (WSARA) reiterates the importance of time-phased requirements to the success of EA and ID approaches and states that "the process for developing requirements is structured to enable incremental, evolutionary, or spiral acquisition approaches, including the deferral of technologies that are not yet mature and capabilities that are likely to significantly increase costs or delay production until later increments or spirals" (WSARA, 2009).

Recent NDAAs have continued to emphasize the use of EA and ID approaches. The FY2015 NDAA refers to modular open systems approaches in acquisition programs and requires "that increments of acquisition programs consider the extent to which the increment will implement open systems approaches as a whole" (NDAA, 2015). Congress seemed to double down on this same concept in the FY2017 NDAA, which states that "major defense acquisition program[s] … be designed and developed, to the maximum extent practicable, with a modular open system approach to enable incremental development and enhance competition, innovation, and interoperability" (NDAA, 2017).

Clearly, over the years, Congress has included enough guidance on the application of EA and ID within DoD acquisition programs. In response to the statutory requirements and commercial industry best practices, the DoD acquisition community has gradually transformed its regulations, policies, and procedures. First, in the mid-1980s, EA using an ID approach was recognized as the best way to develop and deliver capabilities specifically for information technology like command and control systems which involved software-intensive development efforts. In 1987, the Defense Systems Management College (DSMC) published the *Joint Logistics Commander's Guidance for the Use of an Evolutionary Acquisition (EA) Strategy in Acquiring Command and Control (C2).* The guide encouraged

> consideration and use of an Evolutionary Acquisition (EA) strategy by the services in acquiring C2 systems. While this guidance is aimed specifically at the use of an EA strategy in acquiring Command and Control systems, the principles discussed may also be applicable to the acquisition of other kinds of systems. This EA strategy is of a character that the system is not required to have full capability when deployed, but will evolve to full capability through one or more incremental upgrades. Considered most broadly, EA consists of first sequentially defining, funding, developing, testing, fielding, supporting and evaluating increments of the system. (A'Hearn, Bergmen, & Hirsch, 1987)

The guide defines EA as both “adaptive and incremental,” requiring a description of the overall capability desired with a concept of operation. EA defines a “core or baseline” capability necessary with an architectural framework upon which to build future increments for the delivery of the final desired full capability. The core or baseline element should “enhance the user’s mission capability” and “be fielded quickly and sustained in its operational environment.” The subsequent increments improve on the baseline capability by developing the requirements for subsequent increments through periodic performance updates based upon the input of the “developer-user-tester-supporter team as they test and assess system operational use.” The EA plan “is essentially a baseline from which adjustments are made as dictated by the results of continuing feedback from tests and assessment of operational use” (A’Hearn et al., 1987).

The DoD 5000 series of regulations provide the basis for guidance to acquisition professionals, especially PMs. It is useful to study how the DoD 5000 series documents have evolved. In *DoD’s 5000 Documents: Evolution and Change in Defense Acquisition Policy,* Ferrara (1996) summarizes the changes in the DoD 5000 series from 1971 to 1993. Although not specifically focused on just EA or ID strategies, early versions of the documents laid the groundwork for later versions. It is interesting that the central themes of the original 1971 DoDD 5000.1 of “Centralized Policy, Decentralized Execution; Fly Before Buy; Streamlined Organizations; Limited Reporting Requirements; and Program Stability” remain relevant today (Office of the Director, Defense Research & Engineering [ODDR&E], 1971).

Table 2 summarizes the DoDD 5000.1 from 1971 through the still-valid 2007 version. Uses of the words “evolutionary,” “incremental,” or “block” upgrades first appear in the 1980s versions, gradually increase through the 1990s versions, and peak in the early 2000s versions.

Table 2. DoDD 5000.1 Summary of EA and ID Word Use. Data From DoDD 5000.1 Dated 1971, 1975, 1977, 1980, 1982, 1985, 1987, 1991, 1996, 2000, 2003, and 2007.

Department of Defense Directive (DoDD) 5000.1				
Revision Year	Total Page Count	Total Word Count	Uses of word "evolutionary" or "increment" or "block"	word density (total number of uses of words / total page count)
1971	7	1897	0	0.00000
1975	8	2308	0	0.00000
1977	15	3623	0	0.00000
1980	no data			
1982	no data			
1985	16	4808	1	0.00021
1986	15	5133	1	0.00019
1987	15	4425	2	0.00045
1991	35	14000	2	0.00014
1996	14	5734	4	0.00070
2000	15	4117	14	0.00340
2001	12	4220	14	0.00332
2003	8	3075	2	0.00065
2007	10	3210	3	0.00093

In the 1985 and 1986 versions, the DoDD 5000.1 encouraged PMs to "consider evolutionary alternatives" to reduce programmatic risk and not rely on solutions that push the technology envelope (Office of the Under Secretary of Defense for Research & Engineering [OUSD(R&E)], 1985a, 1986a). The 1987 version introduces the concept that the evolutionary strategy should be linked to the maturity of technologies (Office of the Under Secretary of Defense for Acquisition [OUSD(A)], 1987a).

The 1996 version further elaborates on the use of "non-traditional acquisition" and that incremental acquisition requires technology insertion. "Where appropriate, managers in the acquisition community shall make use of non-traditional acquisition techniques, such as Advanced Concept Technology Demonstrations (ACTDs), rapid prototyping, evolutionary and incremental acquisition, and flexible technology insertion" (Office of the Under Secretary of Defense for Acquisition and Technology [OUSD(A&T)], 1996).

The 2000 and 2001 versions have the most extensive use of the words "evolutionary," "incremental," and "block upgrades." The 2000 version builds upon the themes in the 1996 version, which linked evolutionary acquisition to the technology maturity, and also referenced the need for time-phased requirements. "Time-phased requirements are essential to evolutionary acquisition strategies and are strongly encouraged as a preferred approach to establishing and documenting operational needs" (OUSD[AT&L], 2000). For the first time, the DoDD clearly defined evolutionary acquisition in terms of "increments" or "blocks" of capability:

> Evolutionary Acquisition. To ensure that the Defense Acquisition System provides useful military capability to the operational user as rapidly as possible, evolutionary acquisition strategies shall be the preferred approach to satisfying operational needs. Evolutionary acquisition strategies define, develop, and produce/deploy an initial, militarily useful capability ("Block I") based on proven technology, time-phased requirements, projected threat assessments, and demonstrated manufacturing capabilities, and plan for subsequent development and production/deployment of increments beyond the initial capability over time (Blocks II, III, and beyond). In planning evolutionary acquisition strategies, program managers shall strike an appropriate balance among key factors, including the urgency of the operational requirement; the maturity of critical technologies; and the interoperability, supportability, and affordability of alternative acquisition solutions. (OUSD[AT&L], 2000)

It is interesting that the 2003 version of the DoDD emphasizes evolutionary strategies as the preferred approach but introduces "spiral development" as the preferred process and deletes references to increments or blocks (OUSD[AT&L], 2003).

The 2007 DoDD maintains nearly the same language as the 2003 version with the important change of replacing the word "spiral" with "incremental:"

> Responsiveness. Advanced technology shall be integrated into producible systems and deployed in the shortest time practicable. Approved, time-phased capability needs matched with available technology and resources enable evolutionary acquisition strategies. Evolutionary acquisition strategies are the preferred approach to satisfying operational needs**. Incremental development** is the preferred process for executing such strategies. (OUSD[AT&L], 2007)

In addition to the DoDD, the accompanying DoD Instruction (DoDI) 5000.2 evolved over time but not necessarily in lock-step with the directive updates. Table 3 tracks the use of the words "evolutionary," "increment," or "block" over the different versions of the DoDI.

Table 3. DoDI 5000.2 Summary of EA and ID Word Use. Data From DoDI 5000.2 Dated 1980, 1983, 1985, 1986, 1987, 1991, 1993, 2002, 2003, 2008, 2013, 2015, and 2017.

Department of Defense Instruction (DoDI) 5000.2				
Revision Year	Total Page Count	Total Word Count	Uses of word "evolutionary" or "increment" or "block"	word density (total number of uses of words / total page count)
1980	58	14056	2	0.00014
1983	34	no data	1	no data
1985	32	7035	1	0.00014
1986	34	7117	1	0.00014
1987	26	7958	0	0.00000
1991	345	92029	10	0.00011
1993	542	126858	32	0.00025
2002	193	46636	98	0.00210
2003	50	14958	52	0.00348
2008	80	28852	62	0.00215
2013	152	no data	40	no data
2015	154	61220	68	0.00111
2017	110	no data	52	no data

The 1991 DoDI issued by the USD(A), sees a spike in the use of the word "evolutionary" with reference to ID and preplanned product improvement approaches (OUSD[A], 1991). The 2002 DoDI 5000.02 combined guidance for major defense acquisition programs with major automated information systems and an associated spike in the use of the words "evolutionary" and "increment/s" and a large spike in the use of the term "block," especially for software-intensive IT systems (OUSD[AT&L], 2002). The 2003 DoDI 5000.02 specifies, "Evolutionary acquisition is the preferred DoD strategy for rapid acquisition of mature technology for the user" (OUSD[AT&L], 2003). The 2003 version also explains the two options for development approaches: spiral or incremental.

Similar to the DoDD 5000.01, the 2008 DoDI 5000.02 deletes references to spiral development and emphasizes incremental development and that each increment should deliver a militarily useful capability to the warfighter.

> Evolutionary acquisition is the preferred DoD strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements. The objective is to balance needs and available capability with resources, and to put capability into the hands of the user quickly.
>
> Evolutionary acquisition requires collaboration among the user, tester, and developer. In this process, a needed operational capability is met over time by developing several increments, each dependent on available mature technology. Technology development preceding initiation of an increment shall continue until the required level of maturity is achieved, and prototypes

of the system or key system elements are produced. Successive Technology Development Phases may be necessary to mature technology for multiple development increments.

Each increment is a militarily useful and supportable operational capability that can be developed, produced, deployed, and sustained. Each increment will have its own set of threshold and objective values set by the user. Block upgrades, pre-planned product improvement, and similar efforts that provide a significant increase in operational capability and meet an acquisition category threshold specified in this document shall be managed as separate increments under this Instruction. (OUSD[AT&L], 2008)

The 2013, 2015, and 2017 versions of the DoDI 5000.02 continue to emphasize incremental development approaches but no longer use the word "evolutionary." These instructions lay out typical schedule models for hardware-intensive, software-intensive, and hybrid development efforts.

Literature Review

Despite the emphasis of EA and ID within statutes, DoD regulations and directives, and acquisition reform initiatives, research in the area is limited primarily to case studies of acquisition programs. The following work basically observed the importance of incremental development approaches to reduce technical risk and speed delivery of capability to the warfighter.

- 1998, GAO report titled *Best Practices—Successful Application to Weapon Acquisitions Requires Changes in DOD's Environment* (GAO, 1998).
- 2003, feature article in *Computer* titled *Iterative and Incremental Development: A Brief History* (Larman & Basili, 2003).
- 2001, research on the application of EA within the DoD (Williams, 2001).
- 2003, GAO report titled *DoD's Revised Policy Emphasizes Best Practices, but More Controls Are Needed* (GAO, 2003b).
- 2003, GAO report titled *Best Practices: Better Acquisition Outcomes Are Possible if DoD Can Apply Lessons from the F/A-22 Program* (GAO, 2003a).
- 2005, GAO report titled *DoD Acquisition Outcomes—A Case for Change* (GAO, 2005a).
- 2005, GAO report titled *Opportunity to Reduce Risks in the Joint Strike Fighter Program With Different Acquisition Strategy* (GAO, 2005b).
- 2005, RAND report titled *Reexamining Military Acquisition Reform—Are We There Yet?* for the assistant secretary of the Army for acquisition, logistics, and technology (ASA[ALT]; Hanks, Axelband, Lindsay, Malik, & Steele, 2005).
- 2006, GAO report titled *Defense Acquisitions—Major Weapon Systems Continue to Experience Cost and Schedule Problems under DoD Revised Policy* (GAO, 2006).
- 2008, research titled *The Costs and Risks of Maturing Technologies, Traditional vs. Evolutionary Approaches* (Pennock & Rouse, 2008)
- 2009, a case study for the successful application of EA principles for management of the Navy's torpedo enterprise (Bussiere, Jester, & Sodhi, 2009).

- 2011, in *Defense Acquisition Reform 1960–2009: An Elusive Goal*, J. Ronald Fox (2011) writes,

  > **Evolutionary acquisition** is the preferred DoD strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing up front the need for future capability improvements. The objective is to balance needs and available capability with resources and to put capability into the hands of the user quickly. The success of the strategy depends on the phased definition of capability needs and system requirements and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability over time. (Fox, 2011)

- 2009, a study of two defense acquisition programs as case studies (Dillard & Ford, 2009).
- 2010, work by Bodner, Rahman, and Rouse (Bodner et al., 2010).
- 2014, RAND study titled *Prolonged Cycle Times and Schedule Growth in Defense Acquisition* (Riposo, McKernan, & Duran, 2014).
- 2014, GAO report titled *Agencies Need to Establish and Implement Incremental Development Policies* (GAO, 2014).
- 2016, GAO report titled *Agencies Need to Increase Their Use of Incremental Development Practices* (GAO, 2016).
- 2015, GAO report titled *Amphibious Combat Vehicle—Marine Corps Adopts an Incremental Approach* (GAO, 2015a).
- 2015, GAO report titled *Evolved Expendable Launch Vehicle—The Air Force Needs to Adopt an Incremental Approach to Future Acquisition Planning to Enable Incorporation of Lessons Learned* (GAO, 2015b).
- 2017, RAND study titled *Program Characteristics That Contribute to Cost Growth* (Lorell, Payne, & Mehta, 2017).
- 2017, GAO report to Congress on the Joint Strike Fighter (JSF) Program (GAO, 2017).

Acquisition Strategy Survey—Research Methodology and Data

The benefits of EA with an ID approach are well-documented commercial industry best practices for delivering customer products within performance, cost, and schedule constraints. With beginnings in software-intensive development efforts, the use of EA and ID naturally spread to hardware-intensive development efforts. However, as discussed, the successful application to DoD acquisition efforts is spotty at best. Directives, regulations, and statutes have given guidance on the application of EA and ID over a period of three decades. This research narrowly focuses on how PMs can more effectively apply EA with an ID approach to a development effort.

The JCM case study investigates how PMs develop an evolutionary acquisition strategy with an incremental development approach. The case study surveys acquisition professionals and asks them to develop an acquisition strategy using the actual JCM program decision input data. These proposed strategies are then compared to the Joint Air to Ground Missile (JAGM) program strategy subsequently executed by the Army and Navy.

Insights into the importance of various decision inputs to PMs will provide policy recommendations for the DoD to consider to better support PMs in developing the department's preferred strategy—EA with an ID approach. This research focuses on studying the original JCM decision inputs (requirements, funding, technology readiness, and risk assessments) to see if the JAGM strategy that was subsequently executed could have been predicted, thus avoiding a "lost decade" and possibly delivering capability to warfighters sooner.

Problem statement: It is incredibly difficult for the PMs to implement the DoD-preferred strategy of EA with an ID approach.

- **Primary objective**: Develop insights into the importance of typical programmatic decision inputs to the development of an acquisition providing insights into the following questions:
- **Primary question**: Can a program manager or acquisition professional predict an actual acquisition strategy implemented given typical programmatic decision inputs?
- **Secondary questions:**
    - What is the most important factor in determining the recommended acquisition strategy?
    - How can the decision input factors be changed to enable a program manager or acquisition professional to recommend an appropriate, risk-based, knowledge-based, incremental development approach?

The JCM case study focuses on a program that does not have requirements that are time-phased. Therefore, PMs use the inputs of resources (primarily funding) and technology maturity (primarily technology readiness levels and risk assessments) to try to develop a strategy to meet the warfighter's required needs and timelines as well as be affordable for the service. Implementing an appropriate incremental development strategy requires an understanding of the strategic environment, key stakeholders, change leadership, organizational behavior, strategic leadership, and decision-making.

The JCM program was a Joint (Army, Navy, Marine Corps) effort to replace Hellfire, Maverick, and aviation-launched, tube-launched, optically-tracked, wire-guided (TOW) missiles fired from both rotary wing (AH-64 Apaches, AH-1 Cobras, and MH-60 Seahawks) and fixed wing (F/A18 D/F Super Hornets) aircraft, initiated in the late 1990s. The JCM program had a successful Milestone B (MS B) in early 2005 with an approved capabilities development document (CDD) and awarded an Engineering and Manufacturing Development (EMD) contract. In late 2005, the JCM program was canceled. Ten years later, in 2015, the follow-on program, now renamed the Joint Air to Ground Missile (JAGM), emerged with a successful MS B and again awarded another EMD contract.

The acquisition strategy survey puts the participant in the shoes of a PM as they prepare for the approval of the JCM program of record to start EMD and asks for a recommendation of an appropriate strategy—single step or incremental—based on program requirements and constraints.

The baseline survey provides acquisition professionals with the actual JCM MS B data used by the PM, program management office (PMO), program executive offices (PEOs), service acquisition executives, and milestone decision authority (the defense acquisition executive who at the time was the USD[AT&L]). The survey data is consolidated into the important program information to include background program data, the draft acquisition program baseline, the service's affordability determinations, the independent

cost estimate, the risk assessment, and technology readiness levels (TRLs) of the critical technology elements (CTEs). Figure 3 outlines the general survey approach.

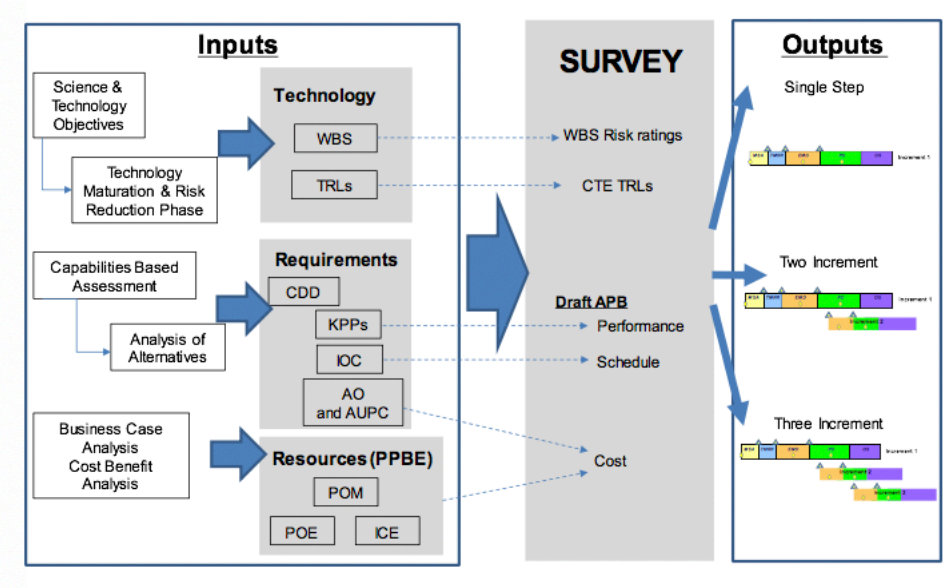

Figure 3. Acquisition Strategy Survey Approach

The inputs to the survey include three main areas: technology, requirements, and resources. The Army and Navy planned the JCM program for about a decade prior to the MS B or official designation of the program of record and start of the EMD phase. The science and technology communities matured the underlying missile technologies through science and technology (S&T) objectives and a technology maturation and risk reduction phase. A high-level government work breakdown structure (WBS) enabled a risk assessment for the JCM development effort as well as TRL determinations for the CTEs of the missile. As the same time as the missile technologies were being matured, the requirements generation system, formally named the Joint Capabilities, Development, and Integration System (JCIDS), completed both a capabilities-based assessment (CBA) and an analysis of alternative (AoA). The CBA and AoA supported the Joint Requirements Oversight Council (JROC) approval of the JCM capability development document (CDD), which contained key performance parameters (KPPs), initial operational capability (IOC) dates, acquisition objective (AO), and an average unit procurement cost (AUPC). Simultaneous to the technology maturation and requirements solidification, the resourcing plan for a JCM program was being worked on in the planning, programming, budgeting, and execution (PPBE) system. The JCM business case analysis supported the JCM program office estimate (POE), the Army and Navy program objective memorandum (POM) submissions, and an independent cost estimate (ICE).

The survey provides each individual data to make an informed recommendation on the most appropriate acquisition strategy. The survey participants make a recommendation to pursue a single-step development approach, a two-increment development approach, or a three-increment development approach based on the following programmatic data: the draft MS B acquisition program baseline, the WBS risk rating, and a CTE TRL for the three missile areas. The performance sections of the acquisition program baseline (APB) are the approved CDD KPPs. The schedule section of the APB came from the approved IOC date found in the CDD, and the cost section of the APB came from the approved AO and AUPC,

also found in the CDD. An ICE provided alternative schedule and cost constraints for survey participants to consider. Survey participants were then asked for the capabilities, cost, and schedule for their recommended acquisition strategy. The survey had boundary constraints with respect to performance, cost, and schedule. For example, with respect to performance, acquisition professionals only decided whether the desired KPP requirements were developed or delayed to a later increment. With respect to schedule and cost, the participants decided only whether to recommend the services' estimate or the ICE numbers.

The survey was intended to be taken by acquisition professionals in the DoD acquisition workforce. "The acquisition workforce is generally defined as uniformed and civilian government personnel, who are responsible for identifying, developing, buying, and managing goods and services to support the military" (Schwartz, Francis, & O'Conner, 2016). The size of the acquisition workforce has stabilized to approximately 150,000 total personnel (about 90% civilian and 10% uniformed personnel) across 14 distinct career fields that include engineering, contracting, life-cycle logistics, program management, production & quality management, test & evaluation, facilities engineering, business–financial management, information technology, auditing, science & technology management business–cost estimating, purchasing, and property (Schwartz et al., 2016).

As stated previously, the baseline survey used the following actual JCM MS B data for eight risk ratings and three TRL ratings:

- Critical Technology Element (CTE) TRLs:
  - Tri-mode seeker (s): 6
  - Multipurpose warhead (w): 6
  - Common motor (m): 6
- Risk ratings (RR) based on JCM WBS:
  - Tri-mode seeker (s): medium (m)
  - Multipurpose warhead (w): medium/high (m/h)
  - Common motor (m): medium (m)
  - Missile integration (i): medium/high (m/h)
  - AH-64 Apache platform integration (64): medium (m)
  - AH-1 Cobra platform integration (1): medium (m)
  - MH-60 Seahawk platform integration (60): medium (m)
  - F/A18E/F Super Hornet platform integration (18): medium (m)

[Note that the risk ratings had a range from low (l), low/medium (l/m), medium (m), medium/high (m/h) to high (h).]

The original JCM acquisition strategy recommended by the Army and Navy, supported by the warfighters, and approved by the DAE in the spring of 2005 after a successful MS B was a single-step development effort that included all the KPPs. The JCM program was later canceled as a program of record by the Office of the Secretary of Defense (OSD), and re-designated as a technology base effort (Wolfowitz, 2004). Eventually, the effort was renamed as the JAGM program. The JAGM program was approved as a program of record and successfully awarded an EMD contract after an MS B approval in 2015 (10 years after the first attempt for an EMD program of record). However, the capabilities to be delivered under the JAGM program were greatly reduced from the capabilities desired in the JCM program. Figure 4 displays the differences between the JCM and JAGM programs. The documented lessons learned emphasized the avoidance of extensive unprioritized requirements, multiple threshold platforms, and the fixed wing F18

platform in particular. The Army's and Navy's lessons applied to the JAGM effort emphasized an EA on the warfighter's highest priorities, reduced the threshold platforms, and leveraged the existing HELLFIRE missile warhead and motor to reduce risk, cost, and schedule.

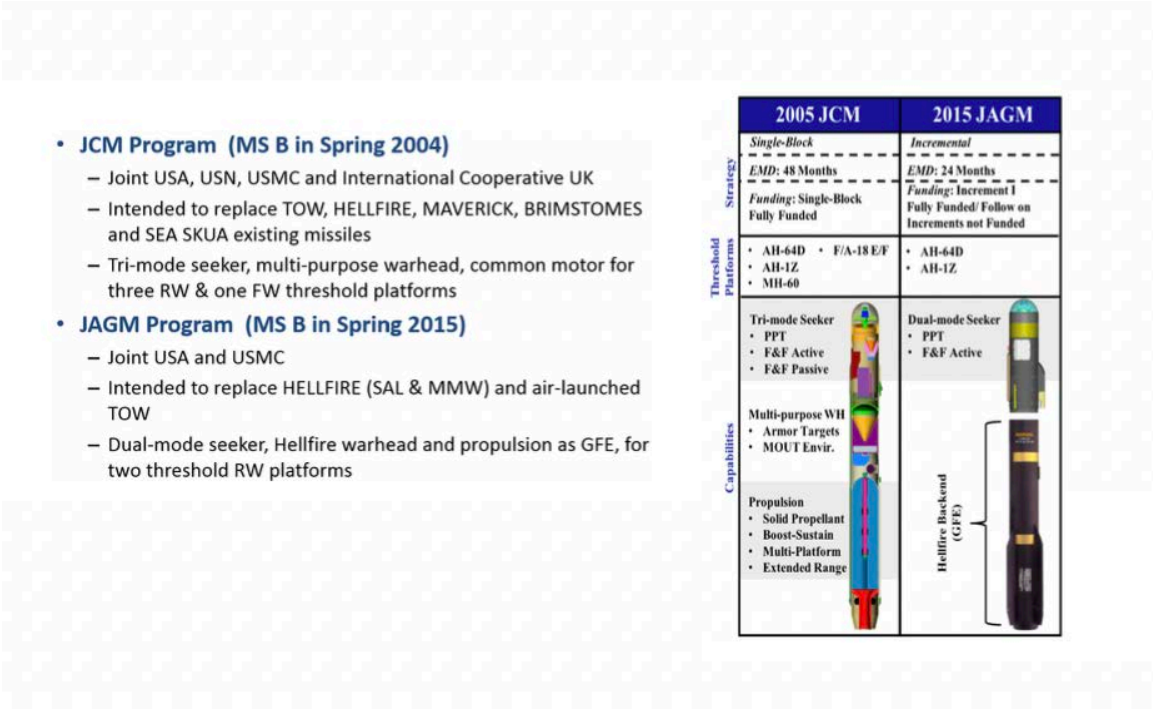

Figure 4. Acquisition Strategy Survey Approach
(Adapted from Gress, Kohtz, & Noll, 2018)

Data

The survey participants included 31 acquisition professionals representing a broad spectrum across the DoD, including active duty officers and government civilians from the Army, Navy, and Air Force. All the respondents were members of the acquisition workforce with various Defense Acquisition Workforce Improvement Act (DAWIA) acquisition certifications as well as graduate education degrees.

The baseline survey uses the actual JCM MS B data and asks survey participants to develop an appropriate acquisition strategy based on this data. Survey #1 results are presented in Table 4. We are interested in how many individuals predicted the JAGM strategy that was actually adopted based on the original JCM data. The first hypothesis was that the JAGM strategy would be nearly impossible for acquisition professionals to predict based on the pressures to deliver all KPPs by the required IOC with the cost constraints of the service-approved POE. Based on the nearly constant emphasis by senior leaders and Congress over many years on affordability and rapid acquisition, the second hypothesis was that acquisition professionals would reduce risk by maintaining the cost and schedule constraints in the draft APB and reduce programmatic risk by recommending delaying performance capabilities (pushing some KPPs to later increments). Given that an incremental strategy was recommended, the third hypothesis was that acquisition professionals would choose to delay capabilities associated with technologies with low TRL ratings and/or high risk ratings.

Table 4. Survey Data Results

		Seeker			Warhead		Propulsion		Platform				Schedule (EMD length)		Cost (AUPC)	
	Respondents (n)	Single Mode (NDI) TRL 9	Dual Mode	Tri-mode APB KPP TRL 6 Med Risk	Single (NDI) TRL 9	Multipurpose APB KPP TRL 6 Med/High Rsik	Single motor (NDI) TRL 9	Common APB KPP TRL 6 Med Risk	AH64 APB KPP	AH1 APB KPP	MH60 APB KPP	F18 APB KPP	48 months APB POE	72 or 144 months ICE	$108K or $120K APB POE	$153K ICE
	31															
Single Step	7		1	6	1	6	1	6	6	6	6	7	1	6	2	5
Two Increment Approach																
Increment I	13		8	5	7	6	3	10	12	11	10	5	7	5	8	4
Increment II				13		13		13	13	13	13	13	3	8	5	8
Three Increment Approach																
Increment I	11	4	5	2	8	3	10	1	10	8	6	5	9	2	7	4
Increment II			4	7	5	6	8	3	10	9	9	8	7	4	6	5
Increment III				11		11	1	10	10	9	9	10	7	4	6	5

Hypothesis #1: A low percentage of acquisition professionals would be able to predict the JAGM acquisition strategy from the JCM MS B data. For a sample size of 31, seven of 31 (23%) recommended a single step approach, 13 of 31 (42%) recommended two increments, and 11 of 31 (35%) recommended three increments. None (zero of 31, or 0%) of the respondents recommended an acquisition strategy even remotely close the JAGM strategy (dual mode seeker, COTS warhead, COTS motor, and integration of only AH64 and AH1 in first increment)—confirming hypothesis #1 that it is extremely difficult to predict a successful acquisition strategy based on typical MS B programmatic data.

Hypothesis #2: Most acquisition professionals would maintain the approved service cost and schedule constraints and chose to delay capability, given the JCM MS B data. For single-step acquisition, five of seven respondents (71%) chose the ICE recommended six-year schedule and $153,000 acquisition unit procurement cost (AUPC) with no capability increments, and two of seven (29%) of the respondents chose a four-year or 12-year schedule and $120,000 AUPC with no capability increments. For the first increment in two increment strategies, six of 13 (39%) recommended delaying some capability with a first increment schedule of six or 12 years with ICE recommended $153,000 AUPC, and seven of 13 (54%) recommended delaying some capability with a first increment schedule of 4four years and $120,000 AUPC. For the first increment in three increment strategies, seven of 11 (64%) recommended delaying some capability but maintaining the service approved four-year schedule and $108,000 AUPC. In summary, only 14 of 31 respondents (45%) decided to maintain the approved service cost and schedule constraints and incrementalize capability—disproving hypothesis #2.

Hypothesis #3: For those acquisition professionals that recommend an incremental approach, they would recommend delaying capabilities linked to technologies with low TRLs and/or high risk ratings. For the baseline survey, 24 of 31 (77%) recommended an incremental approach, with 13 recommending two increments and 11 recommending three increments. Of the 13 recommending a two increment approach, eight of 13 delayed seeker capability, seven of 13 delayed warhead capability, three of 13 delayed motor capability, and 11 of 13 delayed a platform to increment two. Of the 11 recommending a three increment approach, nine of 11 delayed seeker capability, eight of 11 delayed warhead capability, 10 of 11 delayed motor capability, and eight of 11 delayed a platform to later increments. For the baseline survey, the three CTEs had a TRL of 6, six risk areas were ranked as medium risk, and the warhead and integration were ranked as medium/high. These results neither confirm nor deny hypothesis #3 because the warhead was highlighted as higher risk, and 15 of 24 (63%) respondents pushed the multipurpose warhead to a later increment. However,

17 of 24 (71%) respondents pushed the seeker to a later increment despite the tri-mode seeker having the same TRL rating as the multipurpose warhead and a lower risk rating. The recommended approaches appear to be not entirely data-driven based on the CTE TRL and risk ratings.

Analysis of Results

The survey results are incredibly interesting. The results confirm what many acquisition professionals already know—it is extremely hard to predict the acquisition strategy actually implemented for a complex defense research and development effort. The inputs to the survey here are very typical of data that would be provided to the milestone decision authorities to approve acquisition strategies. Some might argue that more data is needed to make a truly informed decision; however, in reality, less data is normally available. In this case, the requirements were well established and supported by years of analysis with a set need date. The technologies needed to turn those requirements into capabilities for the warfighter had matured to the point that they were ready for integration, and the funding to support a program of record for a development and engineering work and procurement of missiles was aligned to the required need date. The PM triple constant of cost, schedule, and performance were all synchronized and set. However, the costs were underestimated while the technical risks (specifically the integration risks) were underappreciated, which led to a high-risk, un-executable program that was eventually canceled.

PMs basically have a few choices to reduce risk—either request more time and money for the effort as defined, or request a reduction in scope for the time and money available. Requesting more money or additional schedule for a development program that has been in the works for several years is unrealistic and would probably fall on deaf ears to service leaders who already approved the funding and the schedule to go along with that funding. The more likely choice to reduce risk would be to keep the cost and schedule constraints in place and recommend a reduction in scope or performance capability. This is a hard thing for the PM to recommend because the warfighter wants all of their required capability. This is where the benefits of an incremental development approach can help alleviate some concerns by delivering improved capability (albeit not full desired capability) in increments while the full capability is developed simultaneously. In this case, 71% recommended an incremental development approach—indicating good training and education of the acquisition workforce on the benefits of ID and EA. Additionally, the majority of acquisition professionals recommended delaying the capabilities associated with the higher risk.

Even though the majority of acquisition professionals recommended an ID approach, only 41% maintained the cost and schedule constraints. The majority of acquisition professionals believed that they not only had to reduce performance by delaying requirements, but they also had to recommend a longer schedule and request more funding. This puts the PMs in the difficult position of not being able to deliver on cost, schedule, or performance requirements. There is tremendous pressure on the PM to get the program approved as a program of record. This pressure must be balanced with the PM's risk of trying to execute a program with a high probability of encountering cost over-runs, schedule slips, and underperformance in delivering the proposed capabilities.

Future Research

Future work investigating the relative importance of TRL ratings versus risk ratings in determining the recommended strategy would shed light on the importance of these ratings. This effort centers on the question, "How can original JCM milestone data be changed to

have a greater percentage of acquisition professionals recommend a JAGM incremental approach?" Table 5 represents a design-of-experiments approach showing how the eight risk ratings and TRL ratings could vary over the 14 versions of the survey.

Table 5. Survey Descriptions

	Technology Readiness Level (TRL)			Risk Ratings (RR)							
Survey Number	Seeker (s)	Warhead (w)	Motor (m)	Seeker (s)	Warhead (w)	motor (m)	integration (i)	AH-64 Apache (64)	AH-1 Conbra (1)	MH-60 Seahawk	F/A18E/F (18)
Survey #1 - baseline	6	6	6	m	mh	m	mh	m	m	m	m
Survey #2 - seeker TRL	4	6	6	m	mh	m	mh	m	m	m	m
Surevy #3 - seeker RR	6	6	6	h	mh	m	h	m	m	m	m
Surevy #4 - seeker TRL & RR	4	6	6	h	mh	m	h	m	m	m	m
Survey #5 - warhead TRL	6	4	6	m	mh	m	mh	m	m	m	m
Survey #6 - warhead RR	6	6	6	m	h	m	h	m	m	m	m
Survey #7 - warhead TRL & RR	6	4	6	m	h	m	h	m	m	m	m
Survey #8 - motor TRL & RR	6	6	4	m	mh	h	h	m	m	m	m
Survey #9 - F18 platform RR	6	6	6	m	mh	m	mh	m	m	m	h
Survey #10 - MH60 platform RR	6	6	6	m	mh	m	mh	m	m	h	m
Survey #11 - motor TRL & RR and F18 RR	6	6	4	m	mh	h	h	m	m	m	h
Survey #12 - motor TRL/RR and F18/MH60 RRs	6	6	4	m	mh	h	h	m	m	h	h
Survey #13 - integration RR	6	6	6	m	mh	m	h	m	m	m	m
Survey #14 - JAGM	4	4	4	h	h	h	h	m	m	h	h

A comparison of the results between surveys #1–#4 would be undertaken to see if acquisition professionals recommend an incremental approach to the development of the tri-mode seeker in situations with a low seeker TRL and/or high seeker risk rating. Surveys #1 and #5–#7 would confirm the results of surveys #1–#4 by varying the warhead data rather than the seeker data. Similarly, surveys #8–#12 would study the missile motor as well as the platforms that would accept the missile. For example, the results of survey #9 would answer the question, "Did a higher percentage of acquisition professionals recommend delaying integration of the missile onto the F18 platform if the risk rating was high rather than medium?" Survey #13 would study the importance of the integration risk rating in relation to the CTE TRLs or CTE risk ratings. The results of this survey may indicate that the integration readiness level (IRL) has the same level of acceptance as TRLs and manufacturing readiness levels (MRLs) within acquisition policy. The results of survey #14 would confirm that acquisition professionals do indeed recommend an incremental approach at higher percentages when the TRLs are low and risk ratings are high. Survey #14 data input is set up to try to see if respondents recommended a JAGM strategy more than the baseline data in survey #1.

Conclusions/Recommendations

The work highlights the importance of the service affordability constraints in establishing the acquisition program's cost and schedule parameters in the acquisition program baseline. After cost and schedule constraints are set, the senior leaders, acquisition professionals, and warfighters must come together and agree on an incremental approach to deliver some capability as soon as possible to the warfighter and delay the full capability to later increments. If this struggle does not happen initially for a complex development program, then the program may never deliver capability because of the high risk of cancellation due to schedule slips and cost over-runs.

Once the program's cost and schedule parameters are planned, programmed, and budgeted in the service program objective memorandum, the program's only risk mitigation strategy is to delay desired capability to later increments. PMs must coordinate and balance the inputs from the science and technology, testing, and warfighter communities to recommend the integration of the least risky technologies for inclusion in the first increment of a new warfighting capability. Both the use of TRLs and risk ratings for the development of CTEs and integration risk ratings (along with an IRL) would help increase the chance of program success (defined in terms of improved fielded capability to warfighters).

In the case of the JCM program, the cost and schedule constraints indicated the need to recommend an incremental development approach and delay some capability to later increments. The JCM program was canceled after a successful MS B, and it took more than 10 years for the new JAGM program to successfully pass an MS B—this time with an incremental approach that leveraged existing government furnished equipment (GFE) components. Meanwhile, during this "lost decade," the warfighter got none of the desired capabilities required. The DoDD 5000.1 should mandate that programs of record establish hard cost and schedule caps for development efforts and then allow the services the ability to fit what is affordable from a performance (requirements) perspective into the first increment of the program of record by delaying the achievement of some requirements (even KPPs) to subsequent increments to allow more time for technology maturation. Warfighters would benefit from some capability increase, and acquisition programs would be less likely to fail due to cost over-runs and/or schedule slips.

The defense acquisition system must break the outdated concept of the PM's triple constraint of cost, schedule, and performance. The triple constraint unnecessarily ties the hands of the PMs and contributes to high program failure and no delivered capability. The bottom line is that if all three—cost, schedule, and performance—are set, then the program has a high risk of failure. If we allow the affordability to set the constraints of cost and schedule, which we must do in a public institution like defense acquisition, then flexibility in determining which requirements to pursue by allowing incremental development approaches would loosen the triple constraint stranglehold. In the end, the warfighter must determine if the first capability increment offers enough capability improvement over the current systems to warrant the investment of time and money. The current defense acquisition system incentivizes PMs to get through an improved milestone—oftentimes with a program that is un-executable in terms of cost, schedule, and performance and has a high risk of cancellation and failure. The system should incentivize fielded and delivered warfighter capability.

The following are specific defense acquisition policy recommendations as a result of this study:

- For major defense acquisition programs, especially development efforts, the DoDD5000.1 should continue to state the preferred approach as incremental development, but it should go further by requiring milestone decision authorities (MDAs) to justify any single-step acquisition, making incremental development the default strategy.
- The use of TRLs for specific component technologies is well entrenched in defense acquisition training for PMs, specifically the requirement for all competent technologies to be at TRL 6 for a Milestone B or entry to the engineering and manufacturing development (EMD) phase. However, TRLs alone do not provide sufficient information for PMs and MDAs to make well-informed choices on appropriate incremental strategies. Component technology TRLs should be augmented with risk ratings. Specifically, risk ratings should be medium or lower for all program-identified risks before proceeding into the EMD phase of the first increment.
- The integration risk should be specifically addressed at all milestone reviews, either through the program risk assessment or the introduction of an integration readiness level (IRL), similar to the TRL and MRL levels.
- The DoD should consider mandating that the program risk assessment, as well as TRL and MRL ratings, be performed independently from the program

management office and PM assessments. Similar to the requirement for an independent cost estimate (ICE) at a milestone review to compare to the program office estimate (POE), MDAs would have an independent program risk assessment and independent TRL, MRL, and IRL ratings in order to make more informed decisions.

This study focused on the challenges PMs have in formulating the DoD's preferred approach—an incremental development strategy. The conclusions and recommendations focus on acquisition policy changes to better optimize the implementation of incremental development strategies. The goal is to make the defense acquisition system more responsive to the warfighter by fielding improved capability as quickly as possible and reducing risk to the eventual delivery of the full required capability. A proposed extension of this research is a "new" area of research called "behavioral acquisition." Similar to behavioral finance that studies both economics and psychology within finance decision-making, behavioral acquisition would combine the study of program management, organizational dynamics, defense acquisition, and psychology within acquisition decision-making. A paradigm shift may be required within defense acquisition to realize the importance of research in behavioral acquisition. A solid understanding of how acquisition professionals critically think and make decisions/recommendations in the complex defense acquisition environment would lead to improved acquisition strategy planning and better acquisition program outcomes—specifically, delivered warfighter capability as soon as possible.

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