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Acquisition Strategy Formulation: Evolutionary/Incremental Development Approach

23 August 2019

Dr. Robert F. Mortlock, Professor of the Practice

Graduate School of Business and Public Policy

Naval Postgraduate School

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Abstract

This research fits in a new area of research called "behavioral acquisition" and studies the difficulty that acquisition professionals have in implementing the Department of Defense's preferred acquisition approach—incremental development. 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 the importance of the Service affordability constraints in establishing the acquisition program's cost and schedule section of the acquisition program baseline. Once the program's cost and schedule parameters are planned, programmed, and budgeted, the program's only risk mitigation strategy is to delay desired capability to later increments. This research suggests that acquisition policy should mandate that programs of record establish firm targets for cost and schedule in development efforts, 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. This work also questions the outdated concept of the program manager's (PM's) triple constraint of cost, schedule, and performance. The triple constraint unnecessarily ties the hands of the PMs and contributes to program failures in the form of schedule slips, cost over-runs, and no delivered capability. The recommended acquisition policy changes better optimize the implementation of incremental development strategies with the goal of making 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.

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Acknowledgement

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Table of Contents

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List of Figures

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List of Tables

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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.

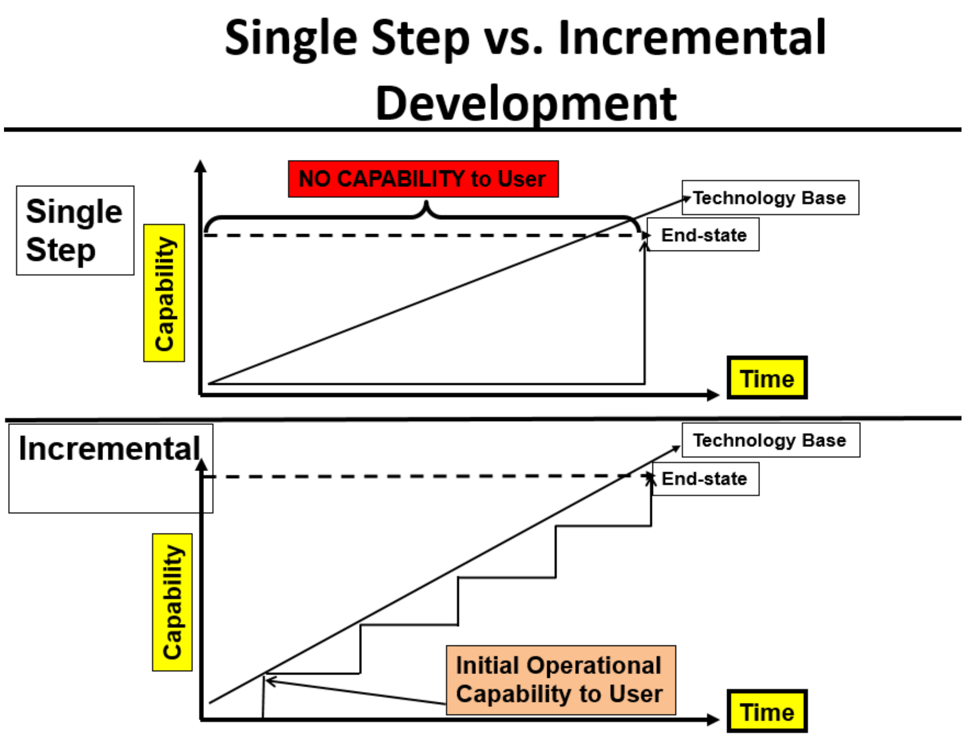

Figure 1. Single Step Versus Incremental Development Approach

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, *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.

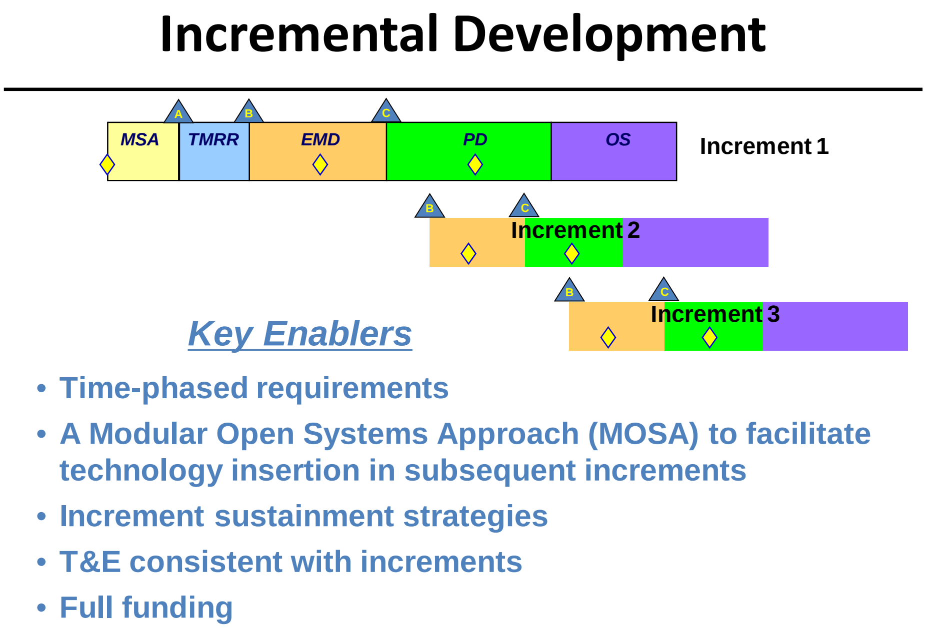

Figure 2. Standard Incremental Development Approach

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: 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?

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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* does not specifically mention EA or ID, but does outline the following broad recommendations to improve the acquisition process:

- Improve the process of formulating requirements for needed operational capabilities.
- Make early development more austere.
- Separate critical subsystem development from platform development and use “maturational development.”
- Encourage austere prototyping.
- Improve the transition from full-scale development to production through “phased acquisition.”
- Focus more attention on upgrading fielded weapon systems.
- Place much emphasis on plant modernization and production flexibility.
- Continuously evaluate acquisition policy changes (Rich, Dews, & Batten, 1986).

Later that same year, the Packard Commission also focused on acquisition reform. *A Formula for Action: A Report to the President on Defense Acquisitions, Blue Ribbon Commission on Defense Management* (also known as the The Packard Report) outlined significant acquisition reform recommendations, many of which were later implemented, to include the following: formation of Defense Acquisition Executive (DAE), Component Acquisition Executive (CAE), and Program Executive Officers (PEOs); use of technology to reduce cost; emphasis on prototyping and early operational testing; formation of the Defense Acquisition Board (DAB) and Joint Requirements Oversight Council (JROC); use of multi-year procurement and commercial-off-the-shelf (COTS) technologies; emphasis on competition; and a focus on the quality of acquisition personnel (Packard, 1986). Ground-breaking 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 for information technology and for the use of modular contracting:

> Under modular contracting, an executive agency's need for a system is satisfied in successive acquisitions of interoperable increments. Each increment complies with common or commercially accepted standards applicable to information technology so that the increments are compatible with other increments of information technology comprising the system.

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 FY03 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 report shall, at a minimum, address the following matters: (1) The manner in which the Secretary plans to establish and approve, for each increment of an evolutionary acquisition process—(A) operational requirements; and (B) cost and schedule goals. (2) The manner in which the Secretary plans, for each increment of an evolutionary acquisition process—(A) to meet requirements for operational testing and live fire testing; (B) to monitor cost and schedule performance; and (C) to comply with laws requiring reports to Congress on results testing and on cost and schedule performance. (3) The manner in which the Secretary plans to ensure that each increment of an evolutionary acquisition process is designed—(A) to achieve interoperability within and among United States forces and United States coalition partners; and (B) to optimize

> total system performance and minimize total ownership costs by giving appropriate consideration to—(i) logistics planning; (ii) manpower, personnel, and training; (iii) human, environmental, safety, occupational health, accessibility, survivability, operational continuity, and security factors; (iv) protection of critical program information; and (v) spectrum management. (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 NDAAs from 2004 to 2009 do not contain major acquisition reform policy changes with respect to EA but do reference increments and blocks of specific programs and efforts.

The 2009 Weapons 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).

The FY2010 NDAA included language specifically for the acquisition of information technology systems. The NDAA states that "the Secretary of Defense shall develop and implement a new acquisition process for information technology systems," which includes the following policies and procedures for the acquisition of information technology: "early and continual involvement of the user; multiple, rapidly executed increments or releases of capability; early, successive prototyping to support an evolutionary approach; and a modular, open-systems approach" (NDAA, 2010).

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,

> A major defense acquisition program that receives Milestone A or Milestone B approval after January 1, 2019, shall 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.

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 the following characteristics for C2 systems that make an EA approach well suited: primarily information systems, software dominant, inability to define detailed requirements for full desired capability up-front, well-defined architecture, need to define process to handle external interfaces, and protocols for future interoperability requirements. Derived from these characteristics, 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 DoD Directive 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 and gradually increase in use through the 1990s versions and peaking 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 [OUSDRE], 1985a, 1986a). The 1987 version introduces the concept that the evolutionary strategy should be linked to the maturity of technologies, specifically,

> Consider evolutionary alternatives in parallel with the need for advanced technology insertion so as to strike the most appropriate balance between development and/or production risk and the risk associated with failing to counter the threat. Commensurate with risk, such approaches as developing separate alternatives in high-risk areas; using early funding to design in reliability and support characteristics; reducing lead time through concurrency; using competitive prototyping of critical components; combining acquisition phases and making use of evolutionary acquisition procedures. (Office of the Under Secretary of Defense for Acquisition [OUSD(A)], 1987a)

Interestingly, the guidance is not just limited to information technology, C2 systems, or software development efforts.

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). The scope, performance capabilities, and timing of subsequent increments shall be based on continuous communications between the requirements, acquisition, intelligence, and budget communities. 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. To facilitate evolutionary acquisition, program managers shall use appropriate enabling tools, including a modular open systems approach to ensure access to the latest technologies and products, and facilitate affordable and supportable modernization of fielded assets. Sustainment strategies must evolve and be refined throughout the life cycle, particularly during development of subsequent blocks in an evolutionary strategy. (OUSD[AT&L], 2000)

The 2001 DoDD furthers amplifies the use of evolutionary strategies as the preferred approach in combination with time-phased requirements:

> Validated time-phased requirements generation is an evolutionary approach to specifying operational requirements in an incremental manner over time matched with projected threat assessments and

> available technology. 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], 2001)

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:

> 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. Spiral development is the preferred process for executing such strategies. (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 USD(A), sees a spike in the use the word "evolutionary" with reference to ID and preplanned product improvement approaches.

> Alternative acquisition strategies include evolutionary acquisition and preplanned product improvement. (1) Evolutionary acquisition is an approach in which a core capability is fielded, and the system design has a modular structure and provisions for future upgrades and changes as requirements are refined. An evolutionary acquisition strategy is well suited to high technology and software intensive programs where requirements beyond a core capability can generally, but not specifically, be defined. This approach is described in Joint Logistics Commanders Guidance, "Evolutionary Acquisition, An Alternative Strategy for Acquiring Command and Control (C2) Systems." (2) Preplanned product improvement is a phased approach that incrementally satisfies operational requirements in order to address the cost, risk, or relative time urgency of different elements of the system being developed. With this approach, selected capabilities are deferred so that the system can be fielded while the deferred element is developed in a parallel or subsequent effort. (OUSD[A], 1991)

The 2002 DoDI 5000.02 combined guidance for major defense acquisition program with major automated information systems and an associated spike in the use of the words "evolutionary" and "increment/s" and large spike in the use of the term "block," especially for software-intensive IT systems.

> When a program has time-phased requirements and utilizes an evolutionary acquisition strategy, each block shall have a set of parameters with thresholds and objectives specific to the block. An evolutionary acquisition strategy must be based on time-phased requirements, consisting of an initial block of capability, and some number of subsequent blocks necessary to provide the full capability required. Plans for competition must be tailored to the nature of each block, and the relationship of the successive blocks to each other. For example, if each block adds a discrete capability in a segregable package to a pre-established modular open system architecture, it may be possible and desirable to obtain full and open competition for each block. If each successive block enhances capability by building on its predecessor, such that it is necessary that the supplier of the first block also create the next block, then competition for the initial block may establish the sole source for subsequent blocks. (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. Figure 3 is the first time a draft, high-level, visual description appears to describe EA with ID approach.

> Evolutionary Acquisition
>
> 3.3.1. 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 consistent and continuous definition of requirements, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept.
>
> 3.3.2. The approaches to achieve evolutionary acquisition require collaboration between the user, tester, and developer. They include:
>
> 3.3.2.1. Spiral Development. In this process, a desired capability is identified, but the end-state requirements are not known at program initiation. Those requirements are refined through demonstration and risk management; there is continuous user feedback; and each increment provides the user the best possible capability. The requirements for future increments depend on feedback from users and technology maturation.
>
> 3.3.2.2. Incremental Development. In this process, a desired capability is identified, an end-state requirement is known, and that requirement is met over

time by developing several increments, each dependent on available mature technology. (OUSD[AT&L], 2003)

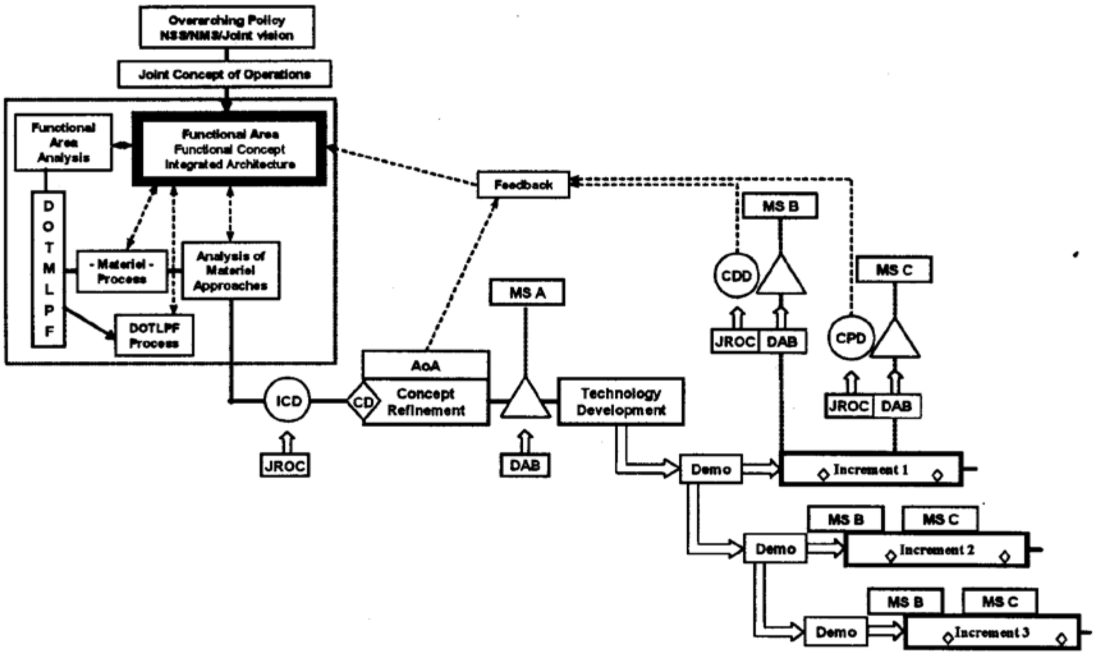

Figure 3 . 2003 DoDI 5000.02 Evolutionary Strategy With Incremental Development (OUSD[AT&L], 2002)

Similar to the DoDD 5000.01, the 2008 DoDI 5000.02 deletes references to spiral development and emphasizes incremental development, and that each incremental should deliver a militarily useful capability to the warfighter, as depicted in Figure 4.

> 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 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.
>
> 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)

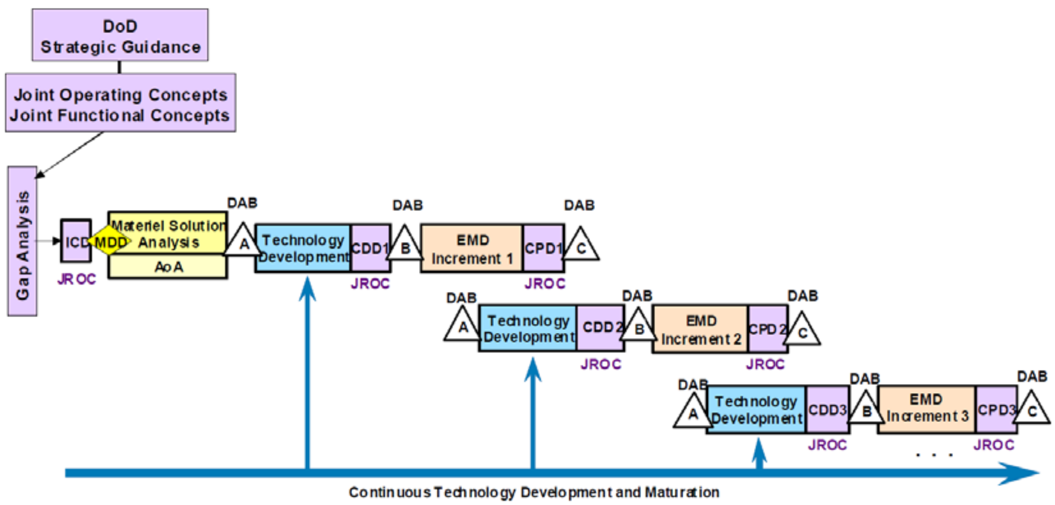

Figure 4. 2008 DoDI 5000.02 Evolutionary Strategy With Incremental Development (OUSD[AT&L], 2008)

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. Figure 5 is the model schedule for an “Incrementally Deployed Software Intensive Program” (OUSD[AT&L], 2017).

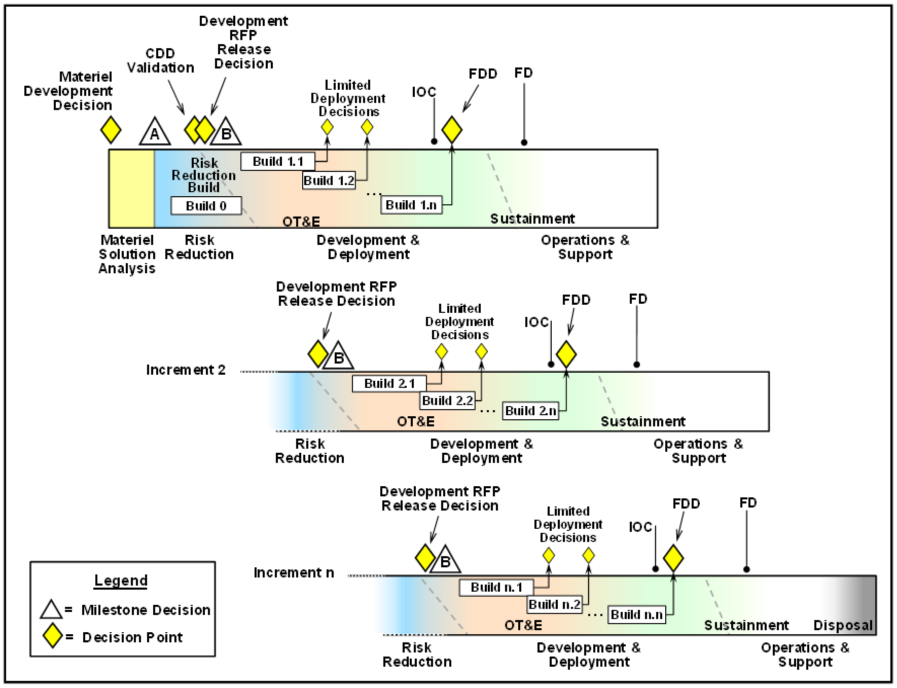

Figure 5. 2017 DoDI 5000.02 Incrementally Deployed Software Intensive Program (OUSD[AT&L], 2017)

Figure 5 is

> a model that has been adopted for many Defense Business Systems. It also applies to upgrades to some command and control systems or weapons systems software where deployment of the full capability will occur in **multiple increments** as new capability is developed and delivered, nominally in 1- to 2-year cycles. The period of each **increment** should not be arbitrarily constrained. The length of each **increment** and the number of deployable increments should be tailored and based on the logical progression of development and deployment for use in the field for the specific product being acquired. (OUSD[AT&L], 2017)

Figure 6 lays out the typical schedule model for a "Hybrid Program (software dominant)" (OUSD[AT&L], 2017).

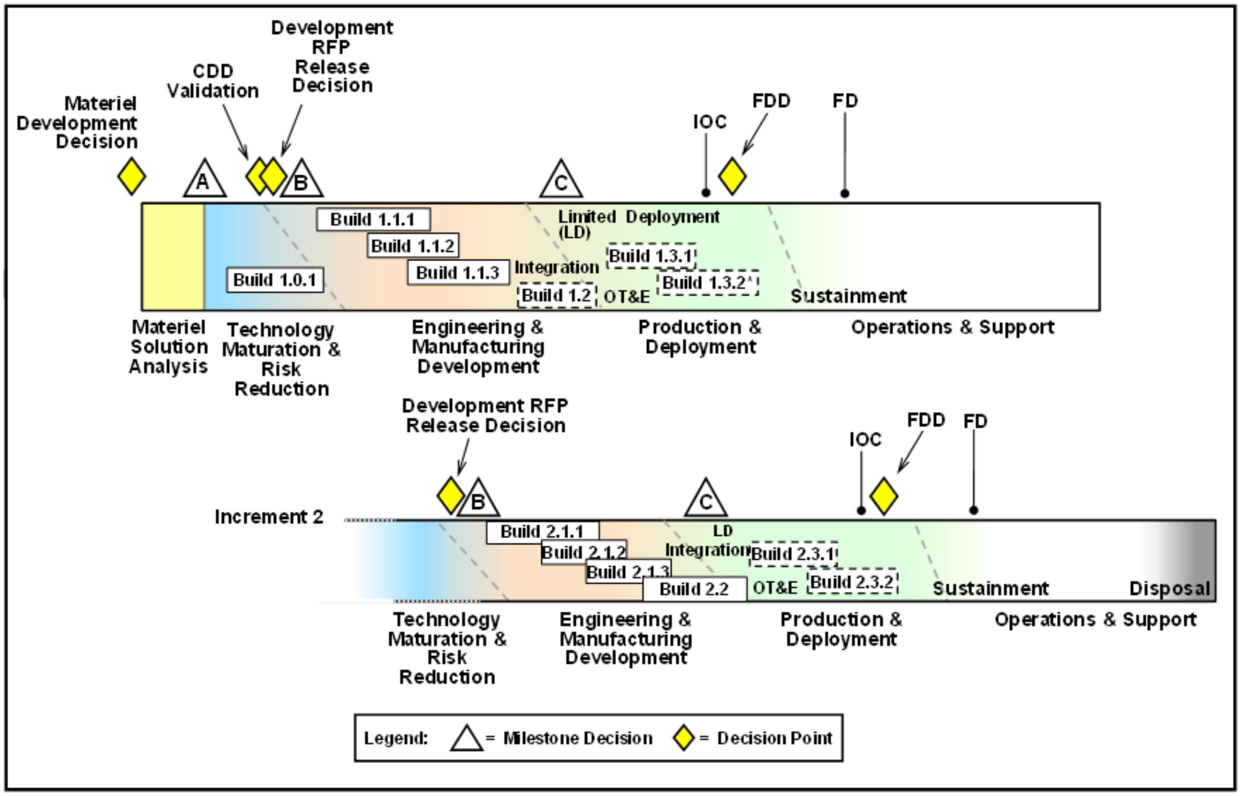

Figure 6. 2017 DoDI 5000.02 Hybrid Program (Software Dominant)

(OUSD[AT&L], 2017)

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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.

In 1998, a GAO report titled *Best Practices: Successful Application to Weapon Acquisitions Requires Changes in DOD's Environment* recommends that risk reduction within the DoD follow commercial practices of "using demonstrations of technology and incremental or evolutionary product developments." Furthermore, the GAO (1998) referenced the Defense Science Board recommendation that "emphasizes incremental technology advancement, coupled with much shorter product development cycle times." The GAO (1998) highlighted the National Center for Advanced Technologies' call for a

> new culture that relies on an affordable, incremental approach that could reduce product development cycle times by 3 to 5 years. The new culture features an incremental approach to performance, with a threshold or minimum performance for the initial battle group with incremental upgrades and requirements that would be managed through cost tradeoffs to keep performance and cost in balance, avoid grand designs, and mitigate risk.

A feature article in *Computer* in 2003 by Larman and Basili titled "Iterative and Incremental Development: A Brief History" explained that even though some view agile methods or evolutionary development as relatively new concepts, the software development community had recognized the value of iterative and incremental development (IID) for decades, as far back as the 1950s. The authors noted that a great variety of EA and IID approaches exist, but they all avoid "signal-pass sequential, document-driven, gated-step approach," often referred to in DoD standards as the waterfall model (Larman & Basili, 2003). Early practice of the IID approach in the 1970s with IBM working on DoD space and avionics systems and the command and control (C2) system for the U.S. Trident submarine involved "feedback-driven refinement with customer involvement and clearly delineated iterations" (Larman & Basili, 2003).

> In 1976, Tom Gilb published *Software Metrics* (coining the term), in which he discussed his IID practice—evolutionary project

management—and introduced the terms “evolution” and “evolutionary” to the process lexicon. This is the earliest book we could find that had a clear IID discussion and promotion, especially of evolutionary delivery. (Larman & Basili, 2003)

The application of the IID approach to software-intensive systems continued through the 1980s. The “spiral model” was also introduced as an alternative to the DoD standard single-pass waterfall model with integration and testing as the last phase. Despite the success and widespread use of the IID approach in the commercial sector and despite significant failures in acquiring software-based systems, the DoD standards still required the “strict, document-driven, single-pass waterfall model” (Larman & Basili, 2003).

Larman and Basili continued with the following:

> The DoD was still experiencing many failures with “waterfall-mentality” projects. To correct this and to reemphasize the need to replace the waterfall model with IID, the Defense Science Board Task Force on Acquiring Defense Software Commercially, chaired by Paul Kaminski, issued a report in June 1994 that stated simply, “DoD must manage programs using iterative development. Apply evolutionary development with rapid deployment of initial functional capability.”
>
> Consequently, in December 1994, Mil-Std-498 replaced 2167A. An article by Maj. George Newberry summarizing the changes included a section titled “Removing the Waterfall Bias,” in which he described the goal of encouraging evolutionary acquisition and IID: Mil-Std-498 describes software development in one or more incremental builds. Each build implements a specified subset of the planned capabilities. The process steps are repeated for each build, and within each build, steps may be overlapping and iterative.
>
> In 2000, DoD replaced Mil-Std-498 with another software acquisition standard, DoD 5000.2, which again recommended adopting evolutionary acquisition and the use of IID: There are two approaches, evolutionary and single step [waterfall], to full capability. An evolutionary approach is preferred. … [In this] approach, the ultimate capability delivered to the user is divided into two or more blocks, with increasing increments of capability … software development shall follow an iterative spiral development process in which continually expanding software versions are based on learning from earlier development. (Larman & Basili, 2003)

Williams studied the application of EA within the DoD. Williams found that despite several acquisition programs laying the groundwork for the application of EA, the use was not widespread at the time, with further education and training required in the PM and contract management acquisition workforce. The following areas were fundamental to the successful implementation of an EA approach: rigorous configuration management of increments, open systems architecture, maintaining competition in procurement for all increments, early and continuous feedback and involvement, and the avoidance of inflated requirements (Williams, 2001).

In 2003, the GAO reported to Congress on defense acquisitions in the *DoD's Revised Policy Emphasizes Best Practices, but More Controls Are Needed*. The GAO found that the DoD had adopted lessons learned from successful commercial companies by adopting a knowledge-based approach, specifically evolutionary acquisition with time-phased incremental development in accordance with the requirements in section 802 of FY2003 NDAA (GAO, 2003b). Also in 2003, the GAO's *Best Practices: Better Acquisition Outcomes Are Possible If DoD Can Apply Lessons from the F/A-22 Program* report used a case study approach with the F/A-22 program to illustrate "what can happen when a major acquisition program is not guided by the principles of evolutionary, knowledge-based acquisition" with incremental development—basically failing to delivery capability or delivery capability greater than the original cost and schedule estimates (GAO, 2003a). The GAO concluded that

> an evolutionary environment for developing and delivering new products reduces risks and makes cost more predictable. While the customer may not receive an ultimate capability initially, the product is available sooner, with higher quality and reliability, and at lower, more predictable cost. Improvements are planned for future generations of the product. (GAO, 2003a)

The GAO (2003a) recommended avoiding what they refer to as the "Big Bang" acquisition approach, or step-step acquisition, which is pictorially represented in Figure 7.

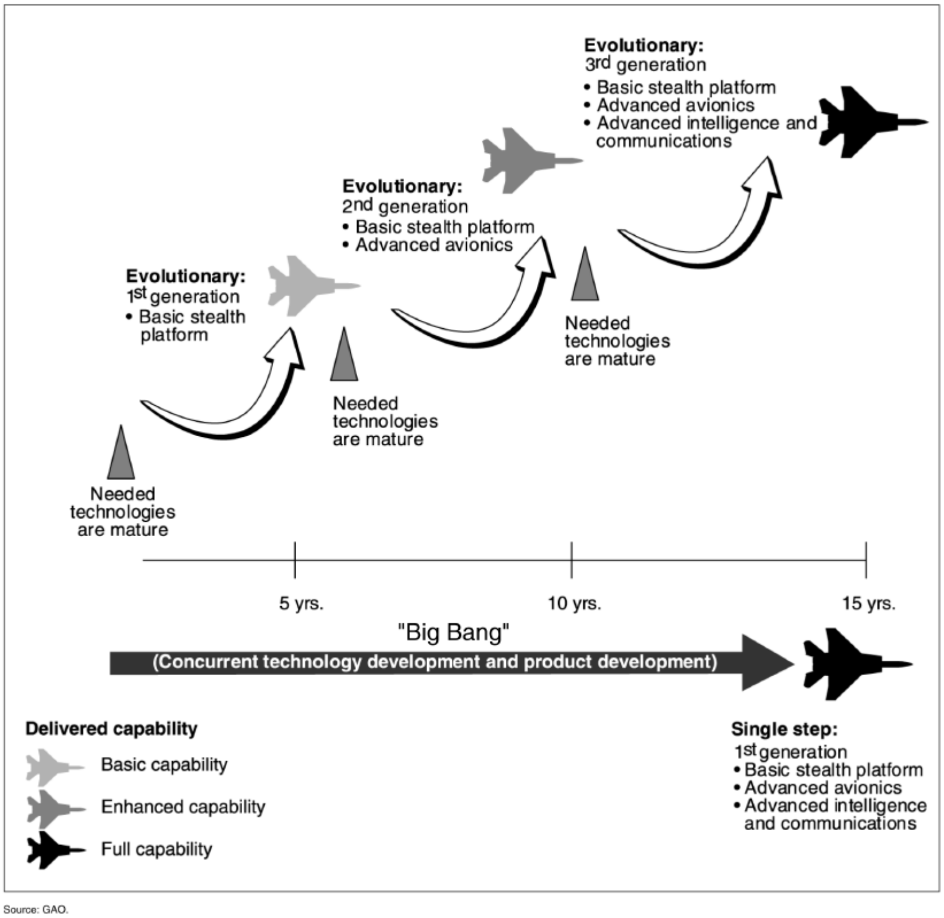

Figure 7. The GAO Comparison of Evolutionary and Big Bang Approaches (GAO, 2003a)

Following up on its earlier reports and at the height of military operations in Iraq and Afghanistan, in *DoD Acquisition Outcomes—A Case for Change*, the GAO reported to Congress that the DoD has been slow to fully adopt commercial industry's standard of knowledge-based acquisition:

> This knowledge-based approach results in evolutionary—that is, incremental, manageable, predictable—development and inserts several controls to help managers gauge progress in meeting cost, schedule, and performance goals. But DOD is not employing the knowledge-based approach, discipline is lacking, and business cases are weak. (GAO, 2005a)

The GAO (2005a) continues, saying that "a result of this knowledge-based process is evolutionary product development, an incremental approach that enables developers to rely more on available resources rather than making promises about unproven technologies."

The GAO continued its case study on the Joint Strike Fighter (JSF) with a report in 2005 entitled *Opportunity to Reduce Risks in the Joint Strike Fighter Program With Different Acquisition Strategy*, concluding that

> The program's current acquisition strategy does not follow a knowledge-based, evolutionary approach as dictated by best practices and DOD policy. The best practice is to establish an incremental—or evolutionary—approach to meet these needs by delivering increasingly better performance over time as funding and technologies permit and provide specific knowledge about the system at key decision points in the acquisition process. Successful commercial companies use an evolutionary acquisition approach where new products are developed in increments based on available resources. (GAO, 2005b)

Refer to Figure 8.

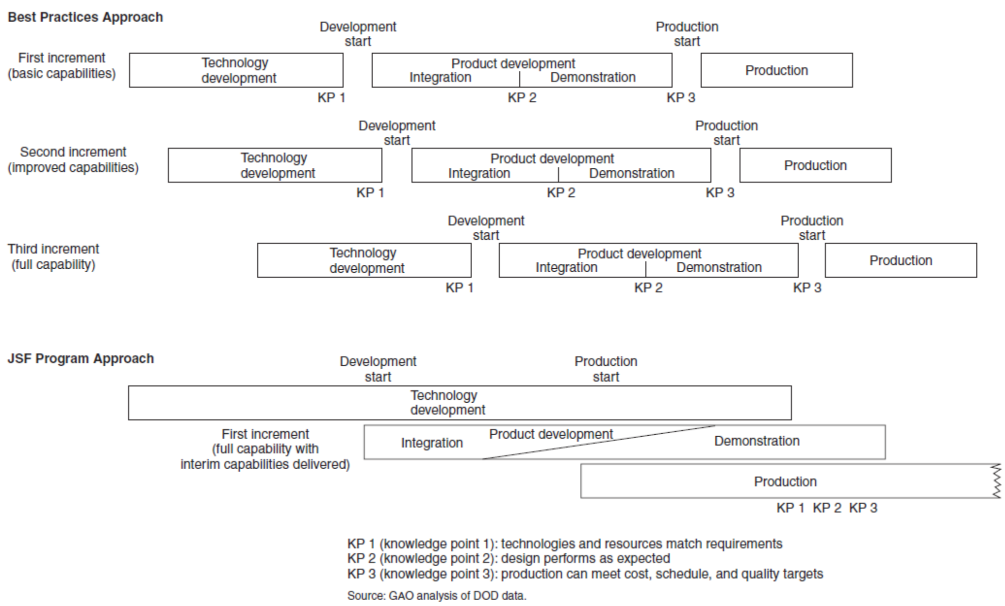

Figure 8. The GAO Comparison of the JSF Acquisition Approach Compared With Best Practices Approach for an Evolutionary, Knowledge-Based Acquisition Approach (GAO, 2005b)

In 2005, RAND published *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). The evolutionary acquisition was listed as one of 63 separate acquisition reform initiatives with the acquisition enterprise (Hanks et al., 2005). The acting ASA(ALT) at the time, Kenneth Oscar, highlighted that the “move to greater use of ‘evolutionary acquisition’ (the AR initiative that encourages PMs to acquire systems in ‘blocks’ or ‘increments’ to reduce technical risk and meet delivery schedules) will be a good thing for the Army” (Hanks et al., 2005).

In 2006, the GAO reported in *Defense Acquisitions—Major Weapon Systems Continue to Experience Cost and Schedule Problems under DoD Revised Policy* that

> poor execution of the revised acquisition policy is a major cause of DOD’s continued problems. DOD frequently bypasses key steps of the knowledge-based process outlined in the policy, falls short of attaining key knowledge, and continues to pursue revolutionary—rather than evolutionary or incremental—advances in capability… An evolutionary product development process defines the individual increments on the basis of mature technologies and a feasible design that are matched with firm requirements. Each increment should be managed as a separate and distinct acquisition effort with its own cost, schedule and performance baseline. An increment that excludes one of these key elements puts an extra burden on decision makers and provides a weak foundation for making development cost and schedule estimates. The knowledge-based, evolutionary approach in our model is intended to help reduce development risks and to achieve better program outcomes on a more consistent basis. (GAO, 2006)

The GAO continued, “In our case studies of nine acquisition programs initiated under the revised policy, we found only one program—the Small Diameter Bomb—that satisfied all of the criteria of an evolutionary approach” (GAO, 2006; refer to Table 4).

Table 4 . The GAO Assessment of Program Acquisition Strategies for GAO's Nine Case Studies (GAO, 2006)

Programs in GAO's case study	Claim to be evolutionary?	Meet evolutionary criteria?	Greater than 30% cost growth or more than 1-year schedule slip
Future Combat System	Yes	No	Yes
Global Hawk (RQ-4B)	Yes	No	Yes
Joint Strike Fighter	Yes	No	Yes
Aerial Common Sensor	Yes	No	Yes
Multi-Mission Maritime Aircraft	Yes	No	No
Small Diameter Bomb	Yes	Yes	No
E-2 Advanced Hawkeye	No	No	No
Expeditionary Fighting Vehicle	No	No	Yes
Multiplatform Radar Technology Insertion Program	No	No	No

Sources: DOD (data); GAO (analysis and presentation).

Pennock and Rouse (2008), in their work titled "The Costs and Risks of Maturing Technologies, Traditional vs. Evolutionary Approaches," used computational modeling of the DoD technology development process, system acquisition process, and the technical progress model to answer the question of whether "it is more cost effective to mature technologies within the R&D system or within an acquisition program?" (Pennock & Rouse, 2008). The researchers found that an EA approach has the potential to improve performance of deployed systems, but

> lower operating costs for the defense acquisition system are not automatic. While each individual program should be less expensive under evolutionary acquisition policies, the faster acquisition cycle-time means that development, production, and deployment costs are incurred more frequently. This may overwhelm any cost savings from managing technology development more efficiently … acquisition cycletime can be used to control the costs of an evolutionary policy without reverting to a traditional approach that employs immature technology. A requirement for mature technologies can be consistently imposed with the next acquisition cycle beginning only when it is affordable. (Pennock & Rouse, 2008)

The authors emphasized that an EA approach in which the technologies are matured outside the program will only work well if early-stage and middle-stage technologies are well-funded from an R&D perspective (Pennock & Rouse, 2008).

> There are definite benefits to the better management and development of new technologies implied in evolutionary acquisition. A well-managed

> technology portfolio leads to the development of technology options, which creates the flexibility to maximize the ability of acquired systems to meet emerging threats. Traditional programs, through their early commitment to particular approaches and technologies, sacrifice some of this flexibility. The outstanding question raised is whether the increased flexibility created by evolutionary acquisition comes at additional cost. What this study revealed is that net cost savings are not automatic. Additional research is required to determine under what circumstances they are possible. (Pennock & Rouse, 2008)

In April 2009, Bussiere, Jester, and Sodhi presented a case study for the successful application of EA principles for management of the Navy's torpedo enterprise. The researchers highlighted the importance of modular open system architecture (MOSA) design and stressed that "evolutionary updates via incremental development, modular design updates, technology refreshes, technology insertions" all come into play (Bussiere et al., 2009).

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)

Dillard and Ford published an article in October 2009 in the *Acquisition Research Journal* that highlighted the risks of EA with an ID approach under certain instances. The authors studied two defense acquisition programs as case studies and concluded,

> Mutable products with costless production, continuous requirements, low maintenance, or time criticality may be more likely to reap advantages from evolutionary approaches. Products that are nearly immutable, have binary requirements for key capabilities, require man-rating, or are maintenance-intensive may not be best candidates for incremental development. (Dillard & Ford, 2009)

These conclusions are consistent with the fact that the principles of successful applications of EA and ID approaches have their roots in development efforts of software-intensive information systems. These are the same characteristics that defined the C2 systems in early guides, acts, regulations, and directives as ideal EA and ID candidates.

Further work by Bodner, Rahman, and Rouse in 2010 found that

> acquisition programs are under pressure to deliver increasingly complex capability to the field without the cost growth associated with recent programs. Evolutionary acquisition was adopted to help reduce system cost (through the use of mature technologies) and to improve system performance (through faster deployment of incremental capability). While the ultimate verdict is not yet in on this decision, our previous simulation-based results have demonstrated that evolutionary acquisition can deliver improved capability more quickly than traditional acquisition, but that cost may actually increase over that of traditional acquisition. This is due to the overhead resulting from more frequent system deployment and update cycles. Are there other factors that can help reduce the cost of evolutionary acquisition? This paper investigates the role of system modularity and production level in the cost of evolutionary acquisition. Modularity typically imposes upfront costs in design and development, but may result in downstream savings in production and sustainment (including deployment of evolutionary new capability). (Bodner et al., 2010)

This work is particularly insightful as the emphasis switches from a comparison of development costs to the more important questions of affordability, using total ownership costs or total lifecycle costs as a better gauge for the Services about the true benefits of delivering capabilities.

In a 2014 RAND study titled *Prolonged Cycle Times and Schedule Growth in Defense Acquisition*, the authors comprehensively studied schedule growth within major defense acquisition programs. A literature review revealed that

> the most commonly cited recommendations for reducing cycle time and controlling schedule growth are strategies that manage or reduce technical risk. Some of those recommendations include using incremental fielding or evolutionary acquisition (EA) strategies; developing derivative products (rather than brand-new designs); using mature or proven technology (i.e., commercial, off-the-shelf components). (Riposo, McKernan, & Duran, 2014)

The authors opine that

> incremental fielding and EA are acquisition strategies that have been employed as a way to speed fielding and control technical risks. They aim to provide some initial operationally useful capabilities more quickly than processes that use a single step to acquire a capability. EA achieves this goal through incremental improvements, which are less demanding than those typically seen through the traditional process.
>
> Because it uses incremental (rather than single-step) technological improvements, incremental fielding is cited as one possible model to consider for software-intensive programs (Interim DoDI 5000.02, 2013). Conceptually, it should reduce technical risk substantially by incorporating technologies only after they are sufficiently mature or can be accommodated.
>
> Such concerns may have led to the de-emphasis on EA for hardware-intensive systems since the prior DoDI 5000.02 (2008). Of course, future upgrades to systems can be employed to insert new technologies into systems. It should be noted here that while incremental fielding should theoretically reduce technical risk and improve schedule performance in specific programs, these improvements do not necessarily translate to accelerated deployment of all desired technologies to the field. Technology must be developed before it can be deployed, and incremental fielding simply recognizes that it is best to insert technology when it is ready rather than forcing it to be ready by fiat. Determining the maturity and operational utility of new technologies prior to Milestone B (when a full-fledged program is established) could save the department time and money. These savings could be achieved not necessarily by reducing time and money spent on fielded systems, but by avoiding significant investments in established programs based on technologies that are not yet ready for incorporation in a system. This cost avoidance could, in turn, free up funds for programs that employ mature technologies and could be accelerated if they had more resources. Unfortunately, analysts have pointed out that placing restrictions on performance expectations and technology insertion in acquisition programs—as encouraged under an EA approach—can run counter to the military's desire to achieve and sustain a competitive edge over its adversaries (Arena et al., 2006). Current processes such as affordability constraints and Configuration Steering Boards (Interim DoDI, 2013; Kendall, 2013) indicate a willingness to make such trades. (Riposo et al., 2014)

With respect to information technology (IT), the GAO continued to recommend more widespread acceptance of incremental development policies. In a 2014 GAO report titled *Agencies Need to Establish and Implement Incremental Development Policies* and again in a 2016 GAO report titled *Agencies Need to Increase Their Use of Incremental Practices,* the GAO studied software development projects across federal agencies and found significant shortcomings with respect to adherence to the OMB guidance mandating delivery of functionality every six months as reported on the IT Dashboard (GAO, 2014, 2016).

In April 2015, the GAO issued a report entitled *Amphibious Combat Vehicle—Marine Corps Adopts an Incremental Approach* about the Marine Corps effort following the cancelation of the EFV program amid affordability concerns.

> The Marine Corps has adopted a new ACV acquisition approach consisting of three concurrent efforts that emphasize the requirement for improved protection from threats such as improvised explosive devices in the near term with improved amphibious capabilities over time. The first of the three efforts, the Assault Amphibious Vehicle (AAV) Survivability Upgrade Program, plans to upgrade legacy AAV protection and mobility. The second effort subdivides into two increments, ACV 1.1 and ACV 1.2. ACV 1.1 is a continuation of a previously suspended Marine Personnel Carrier program that intends to provide enhanced protected land mobility and limited amphibious capability. Testing on the ACV 1.1 will inform the development of the ACV 1.2, with the intent that the ACV 1.2 will demonstrate improved amphibious capability and at a minimum, achieve parity with the legacy AAV. The third effort, referred to as ACV 2.0, focuses on technology exploration to attain high water speed capability. Results of this high water speed research are intended to further inform the development of a replacement for the AAV fleet. (GAO, 2015a)

The GAO (2015a) concludes that

> the Marine Corps' incremental approach for the ACV acquisition is consistent with best practices and can increase the likelihood of success. The adoption of an incremental approach has helped the program progress towards achieving the balance—that is sought in accordance with best practices—between customer needs and resources (e.g., technologies, cost, and schedule).

As further evidence that the application of an incremental development approach is warranted across a wide spectrum of acquisition efforts, the GAO recommended in a 2015 report entitled *Evolved Expendable Launch Vehicle—The Air Force Need to Adopt an Incremental Approach to Future Acquisition Planning to Enable Incorporation of*

Lessons Learned that "when planning for the next phase of competition for launches, the Air Force use an incremental approach to the next acquisition strategy to ensure that it does not commit itself to a strategy until data is available to make an informed decision" (GAO, 2015b).

A 2017 RAND study, *Program Characteristics That Contribute to Cost Growth*, compared Air Force Major Defense Acquisition Programs and analyzed six programs that experienced extreme cost growth (Lorell, Payne, & Mehta, 2017). The study found two main common characteristics:

- premature approval of Milestone (MS) B

  − insufficient technology maturity and higher integration complexity than anticipated

  − unclear, unstable, or unrealistic requirements

  − unrealistic cost estimates
- suboptimal acquisition strategies and program structure

  − adoption of acquisition strategies and program structures that lacked adequate processes for managing risk through incrementalism or through provision of appropriate oversight and incentives for the prime contractor

  − use of a combined MS B/C milestone is based on the assumption that little or no RDT&E is required but has often been linked to an underestimation of required development work and often led to excessive concurrency between development and production phases. (Lorell et al., 2017)

The study also analyzed four programs without extreme cost growth with a key recommendation being to "embrace incremental strategies with comprehensive and proven implementation strategies" (Lorell et al., 2017).

> The essence of incremental acquisition strategies is breaking down complex, technologically challenging programs into smaller, less complex, more manageable discrete sequential segments. Our finding that the lower cost-growth MDAPs were all relatively less complex tends to confirm the importance of this strategy. When possible, large, complex programs incorporating cutting edge technologies and challenging system-integration issues should probably be separated into smaller, less-complex subcomponents, unless urgent requirements or the technological and design configuration of the system make such an approach unfeasible. Without reducing programmatic and technological complexity through the use of smaller-phased sequential segments, large challenging programs may be more likely to experience extreme

> cost growth. Effective implementation of incremental acquisition strategies can be challenging, particularly in determining the precise content of each increment. Nonetheless, this approach appears to hold out the promise of reducing developmental and integration complexities and risks that may lead to substantial cost growth later in programs. The Air Force needs to continue to experiment with incremental strategies, as well as novel contracting methods and incentives and other approaches to encourage contractors to control cost growth. (Lorell et al., 2017)

In the summer of 2017, the GAO reported to Congress that the Joint Strike Fighter (JSF) Program was implementing an incremental acquisition approach with "plans to take an incremental, knowledge-based approach that will develop Block 4 capabilities in four increments. … This approach is consistent with DOD policy and acquisition best practices and thus facilitates transparency and oversight" (GAO, 2017).

> The baseline development program is separated into mission systems software blocks. Block 3F is the last block of the baseline development program and is the foundation for Block 4. Block 4 is expected to be developed and delivered in four increments—currently referred to as 4.1, 4.2, 4.3, and 4.4. The first increment of Block 4 will primarily be software, as well as some new capabilities and correct deficiencies of nine capabilities carried over from the current development program such as the prognostics health management system down-link and communication capabilities. Program officials expect increments 4.1 and 4.3 to be primarily software updates, while increments 4.2 and 4.4 will consist of more significant hardware changes. (GAO, 2017)

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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 Department of Defense to consider to better support PMs in developing the Department's preferred strategy—evolutionary acquisition with an incremental development 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 being 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 cancelled. 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 9 outlines the general survey approach.

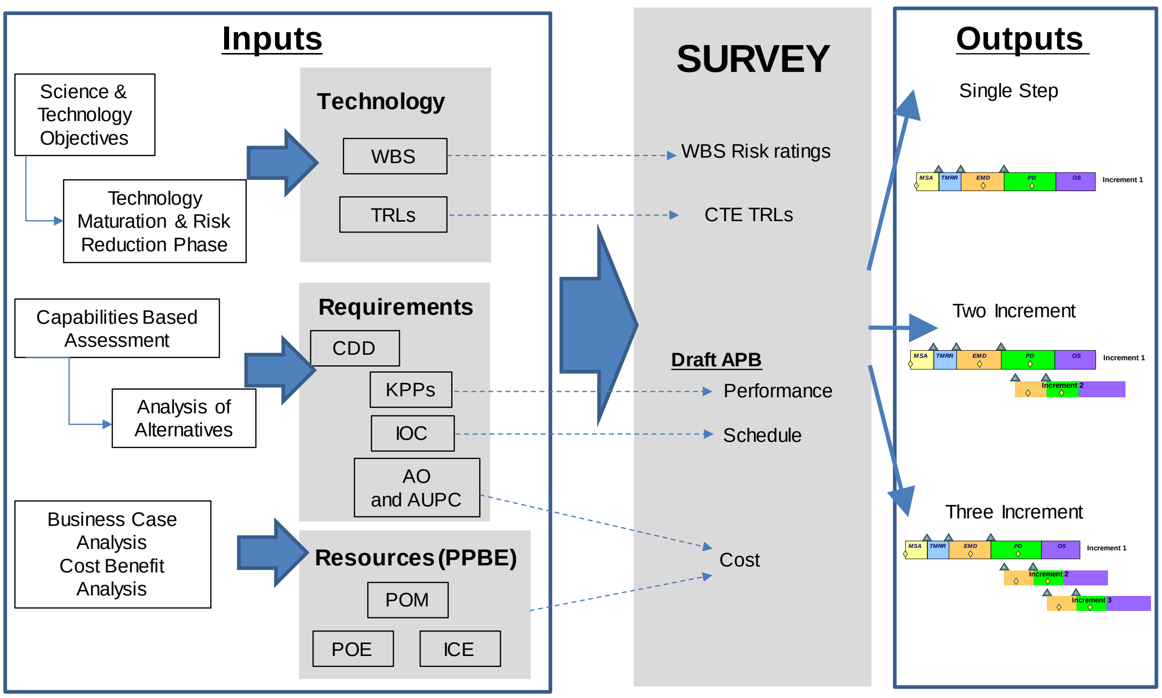


Figure 9 . Acquisition Strategy Survey Approach

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 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. Appendix I contains the baseline survey distributed to acquisition professionals.

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 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 manager, 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 cancelled 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 a 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 10 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. Appendices II and III summarize the JCM and JAGM program histories, respectively.

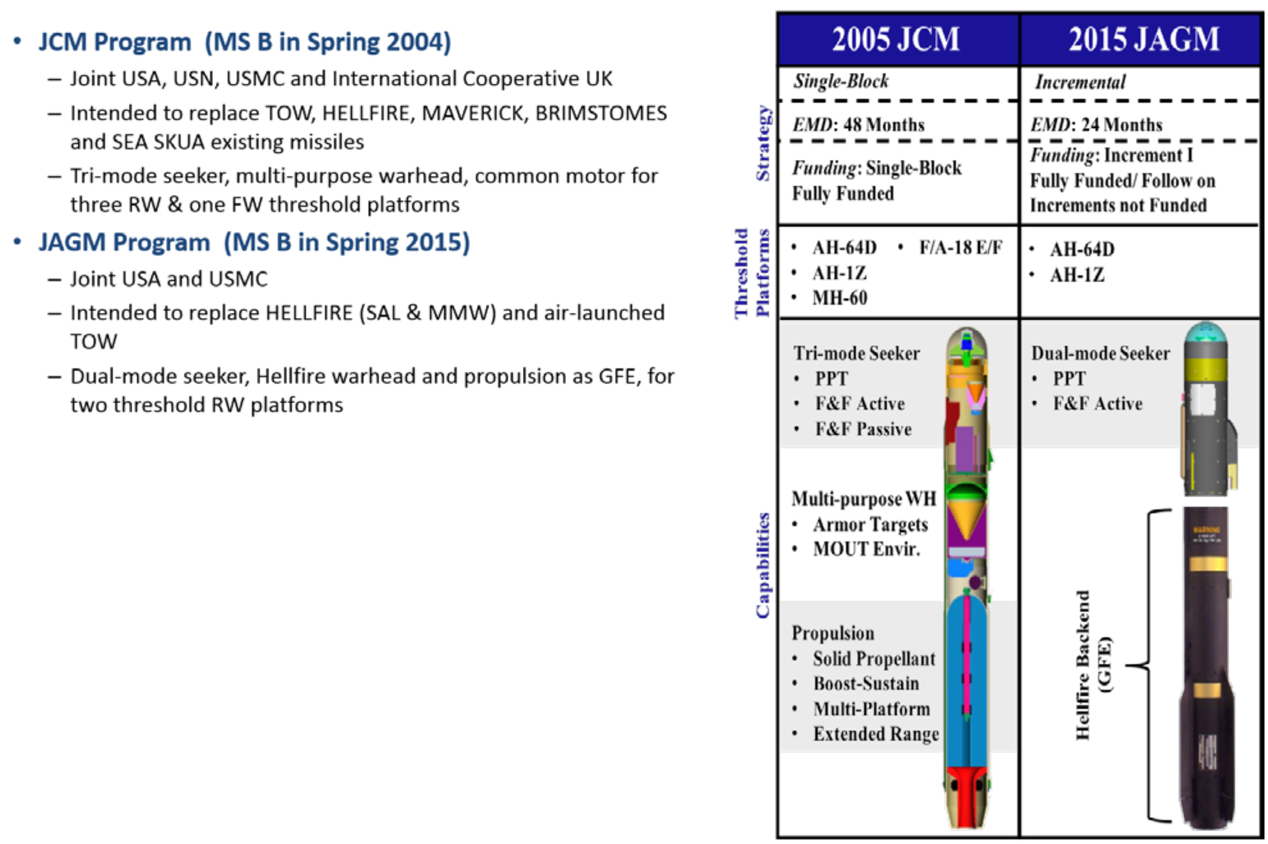


Figure 10. Acquisition Strategy Survey Approach (Adapted from Gress, Kohtz, & Noll, 2018)

Data

The survey participants included 31 acquisition professionals representing a broad spectrum across the Department of Defense, 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 5. 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 schedules 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 5 . Survey #1 Data Results

		Seeker			Warhead		Propulsion		Platform				Schedule			Cost - (AUPC)		
	Respondents (n)	Single Mode (COTS)	Dual Mode	Tri-mode	Single (COTS)	Multipurpose	Single motor (COTS)	Common	AH64	AH1	MH60	F18	48 months	72 months	144 months	$108K	$120K	$153K
	31																	
	7		1	6	1	6	1	6	6	6	6	7	1	5	1		2	5
	13																	
Increment I			8	5	7	6	3	10	12	11	10	5	7	4	1	3	6	4
Increment II				13		13		13	13	13	13	13	3	7	1	1	4	8
	11																	
Increment I		4	5	2	8	3	10	1	10	8	6	5	9	1	1	7		4
Increment II			4	7	5	6	8	3	10	9	9	8	7	2	2	4	2	5
Increment III				11		11	1	10	10	9	9	10	7	1	3	4	2	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, 7 of 31 (23%) recommended a single step approach, 13 of 31 (42%) recommended two increments, and 11 of 31 (35%) recommended three increments. None (0 of 31, or 0%) of the respondents recommended an acquisition strategy even remotely close to 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, 5 of 7 respondents (71%) chose the ICE recommended 6-year schedule and $153,000 acquisition unit procurement cost (AUPC) with no capability increments, and 2 of 7 (29%) of the respondents chose a 4-year or 12-year schedule and $120,000 AUPC with no capability increments. For the first increment in two increment strategies, 6 of 13 (39%) recommended delaying some capability with a first increment schedule of 6 or 12 years with ICE recommended $153,000 AUPC, and 7 of 13 (54%) recommended delaying some capability with a first increment schedule of 4 years and $120,000 AUPC. For the first increment in three increment strategies, 7 of 11 (64%) recommended delaying some capability but maintaining the Service approved 4-year schedule and $108,000 AUPC. In summary, only 14 in 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, 8 of 13 delayed seeker capability, 7 of 13 delayed warhead capability, 3 of 13 delayed motor capability, and 11 of 13 delayed a platform to increment two. Of the 11 recommending a three increment approach, 9 of 11 delayed seeker capability, 8 of 11 delayed warhead capability, 10 of 11 delayed motor capability, and 8 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 cancelled.

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 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 incremental development 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 6 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 6. 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 cancelled after a successful MS B, and it took more than 10 years for the new JAGM program to successfully pass a 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 revising the current nine TRL and 10 MRL ratings to five levels in order to simplify the levels. A simplification of the TRLs and MRLs, as well as integration of IRLs, would expand the understanding and use beyond just acquisition professionals. Five standard TRL, MRL, and IRL ratings should be defined to align with the programs' materiel development decision (MDD), MS A, MS B, MS C, and full rate production (FRP) decision reviews.
- 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 focuses on highlighting the difficulty PMs have in recommending an executable 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.

Appendix I. Actual Baseline Survey

Acquisition Strategy Survey

NAVAL POSTGRADUATE SCHOOL

Graduate School of Business and Public Policy

Consent to Participate in Research

You are invited to participate in a research study entitled Acquisition Strategy Development Case Study—Joint Common Missile (JCM) Acquisition Program. The purpose of the research is to analyze the importance of typical program data as inputs to the program manager decision-making process for determining a recommended acquisition strategy. This research will provide insights into how program managers can better develop acquisition strategies based on requirements, technology, risk, urgency, and funding. The goal of the research is to develop informed acquisition reform policy recommendations to better meet warfighter expectations.

If you consent to participate, your survey responses will be collected and analyzed. Your participation in this study is strictly voluntary. Deciding not to participate will not adversely affect your status as a student or government employee. There is a minimal risk of breach of confidentiality. All efforts, within reason, will be made to keep your personal information in your research record confidential but total confidentiality cannot be guaranteed.

If you have any questions or comments about the research, or you experience an injury or have questions about any discomforts that you experience while taking part in this study please contact the Principal Investigator, Dr. Robert F. Mortlock, 832-656-2672, rfmortlo@nps.edu.

I have read the information provided above. I understand that by agreeing to participate in this research I do not waive any of my legal rights.

☐ I consent to allow use of my survey responses for research.

☐ I do not consent to allow use of my survey responses for research.

Survey #1

Administrative Data

Please provide some basic information about your experience as an acquisition professional.

Mark the circles that apply:

Rank (select highest rank in which you served)

- ○ Flag Officer / SES
- ○ O6 / GS-15
- ○ O5 / GS-14
- ○ O4 / GS-13 or Below

Service (select the best that applies – this includes active duty or govt civilian service)

- ○ Army
- ○ Navy
- ○ Air Force
- ○ USMC
- ○ USCG
- ○ Other

Experience (select all the positions in which you served – more than one may apply)

- ○ PEO / DPEO (held actual position)
- ○ PEO Staff/Organization
- ○ O6 PM / DPM (held actual position)
- ○ O6 PMO Staff
- ○ O5 PM / DPM (held actual position)
- ○ O5 PM Staff
- ○ Service HQ ACQ Staff
- ○ Other Acquisition related organization (i.e., Contracting, T&E, Logistics, Material Command, RDECOM, etc.)

Credentials (select all that apply)

- ○ SSC Graduate
- ○ Senior ACQ Course Graduate
- ○ DAWIA PM Level III
- ○ DAWIA PM Level II
- ○ DAWIA PM Level I
- ○ Acq Workforce Mem
- ○ PMP Certified
- ○ MBA
- ○ NPS Graduate Degree
- ○ MS in PM
- ○ DAWIA certified in other than PM career field (i.e., Contracting, T&E, Engineering, etc.)
- ○ Other graduate degree

Instructions:

You are currently the PM for the Joint Common Missile (JCM) following the Materiel Development Decision (MDD) to begin development of a materiel solution.

TASK:

Thoroughly read and analyze the JCM background, constraints, and strategy options. Choose the best strategy option and support your selection by answering the follow-up questions for the section you chose.

CONDITION:

Given the JCM Key Performance Parameters (KPPs), previously completed risk assessment, budgetary environment, and JCM program timeline constraints, complete the survey in a classroom environment.

STANDARD:

Choose the best JCM strategy option based on your assessment of the program constraints. Answer the follow-up questions to explain your choices.

SITUATION

You are preparing for a Milestone (MS) B decision to enter Engineering & Manufacturing Development (EMD) and award competitive EMD contracts. The JCM program is an Acquisition Category-1D (ACAT-1D) program with planned MS B in 6 months.

BACKGROUND

The JCM program just finished a very successful 3-year Technology Maturation & Risk Reduction (TMRR) phase, which met all exit criteria in which all critical technology elements (CTE) were assessed at technology readiness level (TRL) 6. Successful Science & Technology Objectives (STO) efforts by Research Development & Engineering Command (RDECOM) proceeded the TMRR phase. Comprehensive analysis during the TMRR phase underpinned the requirements for the JCM program. The capabilities based assessment (CBA) documented the need for JCM, along with an approved initial capabilities document (ICD). An approved analysis of alternatives (AoA) solidified the Joint Requirements Oversight Council (JROC) approved capability development document (CDD) requirements, including the key performance parameter (KPP) thresholds/objectives.

The user has an operational and logistical need for development of the JCM to replace the Hellfire, Maverick, and aviation-launched TOW missiles for the Army and Navy. The services desire increased range, capability, force protection, and a decreased logistic footprint. The current platforms and accompanied missiles are as follows:

- Army AH-64 Apache fires multiple versions of the Hellfire missile with either precision point (PP) targeting using laser designation or fire & forget (active) targeting using millimeter wavelength (MMW) radar and separate warheads for different target sets. The Hellfire Average Unit Procurement Cost (AUPC) averages $58.2K–$115.6K.
- USMC AH-1Z Cobra fires all versions of the Hellfire missiles and TOW missiles with wire guided targeting. The TOW AUPC averages $63.7K - $92.5K.
- Navy MH-60 Seahawk fires all versions of the Hellfire missiles and TOW missiles.
- Navy F/A-18 E/F Super Hornet fires Maverick missiles with either PP or fire & forget (passive) targeting using Infrared (IR) with separate warheads for different target sets. The Maverick AUPC averages $179.0K.

All current missiles have single-mode seeking capability only, with separate warheads. A single JCM is capable of replacing more than a dozen variants of HELLFIRE, Maverick, and TOW missiles.

The current draft JCM acquisition strategy (AS) outlines a four-year EMD phase that meets the warfighter required initial operational capability (IOC) dates and has support from the warfighting community, the Services' requirements communities, the Service Chiefs, and Service Acquisition Executives.

DRAFT ACQUISITION PROGRAM BASLINE (APB): The following performance, schedule, and cost data outlines the constraints applied to the JCM program.

PERFORMANCE: The JCM CDD has recently been JROC approved. The CDD KPPs formed the basis for the performance section of the APB.

CDD Performance Requirements			
#	KPP	Threshold/ Objective	Performance
1	Targeting	T=O	Precision Point (Laser Designated / Guided)
			Fire & Forget – Active (Radar Designated / Guided)
			Fire & Forget – Passive (IR Designated / Guided)
2	Combat Effectiveness	T=O	Anti-Tank (T90)
			MOUT (Personnel behind Triple Brick & Concrete Walls)
3	Range	T=O	Rotary Wing (RW): 16 KM
			Fixed Wing (FW): 28 KM
4	Interoperability (Platform)	Threshold	AH-64D (Apache), AH-1Z (Cobra), F/A-18 (E/F), MH-60R (Seahawk)
		Objective	UAVs, JSF, UK airframes
#	Additional Attributes	Threshold/ Objective	Performance
1	Physical Dimensions	Threshold	Weight:108 lbs.
		Objective	Weight: 90 lbs.
		T=O	Length: 70 Inches

SCHEDULE

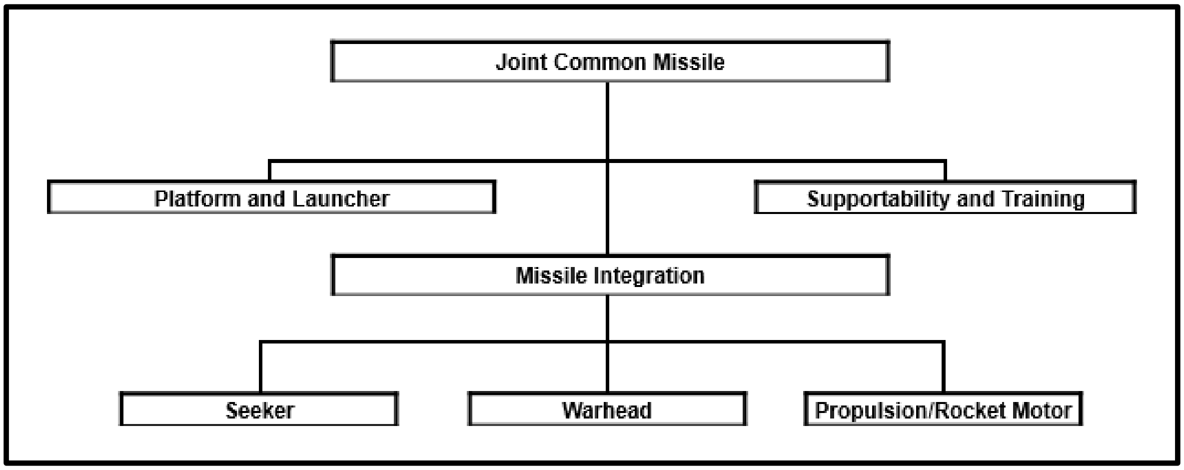
The JROC-approved CDD documented an Initial Operational Capability (IOC) for the JCM at MS B + 5 years (60 months) based on the urgency of the need, the CBA, and the AoA results. The EMD phase has been planned for 4 years (48 months). The schedule part of the APB has the following significant events: CDR at MS B + 2 years (24 months), MS C at MS B + 4 years (48 months), and IOC at MS B + 5 years (60 months).

COST

The JROC-approved CDD specified an acquisition objective (AO) for the JCM of 63,978 missiles to be procured for the Army and Navy. Cost estimates from Service affordability leads have determined an AUPC of $108K (with multi-year contract vehicle) and $120K (without multi-year contract vehicle). The program has been incorporated into the approved Services' POM positions and Services have certified that JCM is fully funded. The JCM Joint Cost Proposal (JCP) has been approved and the Army and Navy fully funded a 48-month EMD with Research Development Test & Evaluation (RDT&E) funding and a 10-year Production & Deployment (P&D) with procurement funding.

WORK BREAKDOWN STRUCTURE

The JCM has the following simplified work breakdown structure (WBS) that highlights critical technology elements of the system design. Each part of the WBS can be directly traced to CDD KPP requirements.



RISK ASSESSMENT

The program's integrated product team (IPT) conducted a thorough risk assessment (RA) approved by the appropriate Army and Navy leadership. The following RA documents the current near-term risk level for the JCM at MS B and the projected risk level at MS C assuming the development as well as test & evaluation progress as planned for each critical technology element.

Risk 1: Seeker—The JCM must employ precision point, fire & forget passive, and fire & forget active targeting capability (linked to KPP 1) that requires the development of a tri-mode seeker. A tri-mode seeker requires the integration of hardware and software for real time acquisition and tracking of targets in each of the three seeker modes. Additionally, the seeker dome must be able to transmit radiation for the millimeter wave radar, infrared signature, and laser designations. The seeker must prevent the radar penetration of other radar bands in the operational environment, which complicates the dome design and material usage.

Risk 2: Warhead—The JCM must defeat a wide array of targets (linked to KPP 2) that requires the development of a multipurpose warhead and fuse. The warhead technology is highly complex because each target requires different engagement mechanisms to achieve the required lethality.

JCM Integrated System Risk		
Risk	MS B	MS C
Integrated System	Med/High	Med/Low

Platform and Launcher		
Risk	MS B	MS C
AH-64D	Med	Low
AH-1Z	Med	Low
F/A-18E/F	Med	Med/Low
MH-60	Med	Med/Low

Supportability and Training		
Risk	MS B	MS C
Sup/Tng	Med	Low

Missile Integration		
Risk	MS B	MS C
Msl Integ	Med / High	Med/Low

Seeker		
Risk	MS B	MS C
Tri-mode seeker & dome	Med	Low

Warhead		
Risk	MS B	MS C
Multi-purpose warhead & fuze	Med / High	Med/Low

Rocket motor		
Risk	MS B	MS C
Propulsion	Med	Low

LEGEND	
Risk Level	Color
High	
Med / High	
Med	
Med / Low	
Low	

Survey 1

Risk 3: Propulsion/Rocket Motor—The JCM must be fired from both rotary wing and fixed wing aircraft (linked to KPP 3). The boost and sustain technology requires high turn down ratios to adjust the propulsion nozzle in order to achieve rotary and fixed wing ranges. The JCM will require a turn down ration of approximately double that of existing missiles from current platforms. In addition, the wide range of environmental conditions as well as vibration and shock constraints for both rotary and fixed wing platforms is hard to address in a single common motor.

Risk 4: Missile Integration—The tri-mode seeker, multi-purpose warhead, and common rocket motor system requires intensive software synchronization.

Risk 5: Platform Integration—The missile must integrate with the on-board fire control systems for each of the service platforms (linked to KPP 4). In addition, the JCM must be shipboard compatible.

TECHNOLOGY READINESS LEVELS

As stated in the background information, the JCM program successfully transitioned through a multi-year STO effort and a three-year TMRR phase with multiple vendors demonstrating competitive prototypes through experimentation, extensive modeling & simulation, and early warfighter demonstrations. The JCM program stakeholders collectively agreed that the following critical technology elements assessed at the following technology readiness levels (TRLs):

- Tri-mode Seeker – TRL 6
- Multipurpose Warhead – TRL 6
- Common Rocket Motor – TRL 6

INDEPENDENT COST ESTIMATE

The Cost Analysis Improvement Group (CAIG) estimated the JCM EMD phase to be from 72 to 144 months. The CAIG estimated the JCM most likely AUPC as $153K. These estimates are based on cost estimating relationships from analogous previous service missile efforts for the development of dual-mode seekers. The CAIG Independent Cost Estimate (ICE) raises some affordability concerns based on the draft APB AUPC and execution concerns from the possible cost and schedule APB breaches.

--------------------------------------END OF PROGRAM DATA-------------------------------------

SURVEY

The section below requires you to select cost, schedule, and performance options based off the JCM program data above. Each section addresses a different acquisition strategy from which you can choose. After completing the initial question of acquisition strategy choice (Single Step, Incremental with Two Increments, or Incremental with Three Increments), you will in turn answer questions corresponding to one of the three sections and justify your position.

SITUATION SUMMARY

You are finalizing the MS B decision documentation for final staffing in preparation for a planned MS B in six months. The Army and Navy warfighting communities have been actively involved in the STO efforts and TMRR phases and are enthusiastic champions for the JCM. Additionally, the Army and Navy requirements communities got the JCM CDD JROC approved and underpinned with a comprehensive CBA and AoA. As a result, both the Army and Navy acquisition executives and Service chiefs support the JCM program, and each Service fully funded JCM in the POM and deemed the program affordable. As a Joint, ACAT-1D, pre-major defense acquisition program (MDAP), the milestone decision authority (MDA) is the Defense Acquisition Executive (DAE).

Based on the JCM situation outlined and the program information provided, what is your recommended Acquisition Strategy for the JCM program?

A. Single Step Acquisition Strategy (Section 1)
B. Incremental Acquisition Strategy with Two Increments (Section 2)
C. Incremental Acquisition Strategy with Three Increments (Section 3)

Note: Upon your selection, please complete your designated section. There is no need to complete more than one section.

SECTION 1: SINGLE STEP ACQUISITION

1. **Performance:** Select the capabilities of the JCM that you will develop.

Seeker

- Single Mode (commercial off-the-shelf (COTS)) Specify which mode (only one):
  - Precision Point (PP)
  - F&F active
  - F&F passive
- Dual-Mode Specify which two modes (only one):
  - PP and F&F active
  - PP and F&F passive
  - F&F active and F&F passive
- Tri-Mode (KPP)

Warhead

- Single (COTS) Specify from which missile:
  - Hellfire
  - TOW
  - Maverick
- Multi-Purpose (KPP)

Propulsion

- Single Motor (COTS) Specify from which missile:
  - Hellfire
  - TOW
  - Maverick
- Common Motor (KPP)

Platform Integrated

- AH-64 (KPP)
- AH-1Z (KPP)
- F/A-18 (KPP)
- UH-60 (KPP)

a. If you did not select to develop a capability that delivers a required KPP, how do you propose to get JROC/Service relief to support a MS B in six months? (Select all that apply)
   - Does not apply because all KPPs developed
   - Request a configuration steering board to get KPP relief
   - Start the process to change the CDD KPPs

b. If you did not select to develop a capability that delivers a required KPP, select the primary reason for that decision. (Select all that apply)
   - Does not apply because all KPPs developed
   - Seeker TRL
   - Warhead TRL
   - Propulsion/rocket motor TRL
   - Seeker risk
   - Warhead risk
   - Propulsion/rocket motor risk
   - Missile integration risk
   - AH-64 integration risk
   - AH-1Z integration risk
   - F/A-18 integration risk
   - UH-60 integration risk

2. **Schedule:**
   - Based off the program information, select the length of EMD phase appropriate for your strategy. (Select one)
     - 48 Months (4 years) *(Draft APB based on CDD IOC and POM)*
     - 72 Months (6 years) *(Low CAIG ICE Estimate)*
     - 144 months (12 years) *(High CAIG ICE Estimate)*
     - Other (Specify) ________Months
   - Select the best reason for the length of the EMD phase you chose. (Select all that apply)
     - Supports the warfighter required IOC approved in the CDD
     - Specified in draft APB
     - Supported in Service POM funding positions and in the JCP
     - Supported by the low CAIG ICE analysis
     - Supported by the high CAIG ICE analysis
     - Supported by the risk assessment or TRL levels
     - Supported by the performance capability development strategy

3. **Cost:**
   - Select the system AUPC appropriate for your strategy. (Select one)
     - $108K *(Draft APB based on CDD and JCP with Multi-Year Contract)*
     - $120K *(Draft APB based on CDD and JCP without Multi-Year Contract)*
     - $153K *(CAIG ICE estimate)*
     - Other (Specify) $________
   - Select the best reason for the JCM AUPC you chose. (Select all that apply)
     - Specified in the CDD
     - Specified in draft APB
     - Specified in the JCP
     - Specified in the CAIG ICE
     - Supported by the AUPC of current missiles
     - Supported by the risk assessment or TRL levels
     - Supported by the performance capability development strategy

4. Indicate the importance (from not very important to very important) of the following reasons for your recommended performance, cost, and schedule selections.

- Planned MS B in six months (program risk for not starting the program as planned)

  ☐ not very important ☐ moderately important ☐ significantly important

- Army and Navy warfighting community support for the JCM capability

  ☐ not very important ☐ moderately important ☐ significantly important

- JROC approved CDD specifying KPPs and IOC

  ☐ not very important ☐ moderately important ☐ significantly important

- CDD KPPs underpinned by comprehensive AoA

  ☐ not very important ☐ moderately important ☐ significantly important

- STO and TMRR efforts maturing critical technologies to TRL 6 levels

  ☐ not very important ☐ moderately important ☐ significantly important

- CBA documenting the need for a JCM to fill capability gaps

  ☐ not very important ☐ moderately important ☐ significantly important

- Service approved Joint Cost Position and full funding a Service POM submission

  ☐ not very important ☐ moderately important ☐ significantly important

- JCM Risk assessment

  ☐ not very important ☐ moderately important ☐ significantly important

SECTION 2: INCREMENTAL APPROACH WITH TWO INCREMENTS:

1. **Performance:** Based on the requirements, select the capabilities of the JCM that you will develop in this strategy.
   a. Select all that apply for **Increment I**.

Seeker

- o Single Mode (commercial off-the-shelf (COTS)) Specify which mode (only one):
  - o Precision Point (PP)
  - o F&F active
  - o F&F passive
- o Dual-Mode Specify which two modes (only one):
  - o PP and F&F active
  - o PP and F&F passive
  - o F&F active and F&F passive
- o Tri-Mode (KPP)

Warhead

- o Single (COTS) Specify from which missile:
  - o Hellfire
  - o TOW
  - o Maverick
- o Multi-Purpose (KPP)

Propulsion

- o Single Motor (COTS) Specify from which missile:
  - o Hellfire
  - o TOW
  - o Maverick
- o Common Motor (KPP)

Platform Integrated

- o AH-64 (KPP)
- o AH-1Z (KPP)
- o F/A-18 (KPP)
- o UH-60 (KPP)

   b. If you did not select to develop a capability that delivers a required KPP in Increment I, select the primary reason for that decision. (Select all that apply)
   - o Does not apply because all KPPs developed
   - o Seeker TRL
   - o Warhead TRL
   - o Propulsion/rocket motor TRL
   - o Seeker risk
   - o Warhead risk
   - o Propulsion/rocket motor risk
   - o Missile integration risk
   - o AH-64 integration risk
   - o AH-1Z integration risk
   - o F/A-18 integration risk
   - o UH-60 integration risk

c. Select all that apply for **Increment II**.

Seeker
- o Single Mode (commercial off-the-shelf (COTS)) Specify which mode (only one):
  - o Precision Point (PP)
  - o F&F active
  - o F&F passive
- o Dual-Mode Specify which two modes (only one):
  - o PP and F&F active
  - o PP and F&F passive
  - o F&F active and F&F passive
- o Tri-Mode (KPP)

Warhead
- o Single (COTS) Specify from which missile:
  - o Hellfire
  - o TOW
  - o Maverick
- o Multi-Purpose (KPP)

Propulsion
- o Single Motor (COTS) Specify from which missile:
  - o Hellfire
  - o TOW
  - o Maverick
- o Common Motor (KPP)

Platform Integrated

c. AH-64 (KPP)
d. AH-1Z (KPP)
e. F/A-18 (KPP)
f. UH-60 (KPP)

- o If you did not select to develop a capability that delivers a required KPP in Increment II, select the primary reason for that decision. (Select all that apply)
  - o Does not apply because all KPPs developed
  - o Seeker TRL
  - o Warhead TRL
  - o Propulsion/rocket motor TRL
  - o Seeker risk
  - o Warhead risk
  - o Propulsion/rocket motor risk
  - o Missile integration risk
  - o AH-64 integration risk
  - o AH-1Z integration risk
  - o F/A-18 integration risk
  - o UH-60 integration risk

c. If you did not select to develop a capability that delivers a required KPP in Increment II, how do you propose to get JROC/Service relief to support a MS B in six months? (Select all that apply)
- o Does not apply because all KPPs developed in Increment II
- o Request a configuration steering board to get KPP relief
- o Starr the process to change the CDD KPPs

2. **Schedule:**
    a. Based off the program information, select the length of each EMD phase appropriate for your strategy.

Increment I (select one)
- o 48 months (4 years): *based on CDD/POM*
- o 72 months (6 years): *low CAIG estimate*
- o 144 mon (12 years): *high CAIG estimate*
- o Other (specify) ___________months

Increment II (select one)
- o 48 months
- o 72 months
- o 144 months
- o Other (Specify) _______months

    b. Select the best reason for the lengths of the EMD phases you chose. (Select all that apply)
    - o Supports the warfighter required IOC approved in the CDD
    - o Specified in draft APB
    - o Supported in Service POM funding positions and in the JCP
    - o Supported by the low CAIG ICE analysis
    - o Supported by the high CAIG ICE analysis
    - o Supported by the risk assessment or TRL levels
    - o Supported by the performance capability development strategy

3. **Cost**

    a. Select the program AUPC appropriate for each increment.

Increment I (select one)
- o $108K *(based on JCP with multi-year)*
- o $120K *(based on JCP without multi-year)*
- o $153K *(CAIG ICE estimate)*
- o Other (specify) $_______

Increment II (select one)
- o $108K
- o $120K
- o $153K
- o Other (Specify) $_______

    b. Select the best reason for the JCM AUPC you chose. (Select all that apply)
    - o Specified in the CDD
    - o Specified in draft APB
    - o Specified in the JCP
    - o Specified in the CAIG ICE
    - o Supported by the AUPC of current missiles
    - o Supported by the risk assessment or TRL levels
    - o Supported by the performance capability development strategy

This strategy would require a year delay in program start to align requirements and funding to include receiving service approval to delay MS B, getting JROC CDD change approval, and realigning the services' Program Objective Memorandum (POM) submission and the JCP.

4. Indicate the importance (from not very important to very important) of the following reasons for your recommended performance, cost, and schedule selections.

a. Planned MS B in six months (program risk for not starting the program as planned)

☐ not very important ☐ moderately important ☐ significantly important

b. Army and Navy warfighting community support for the JCM capability

☐ not very important ☐ moderately important ☐ significantly important

c. JROC approved CDD specifying KPPs and IOC

☐ not very important ☐ moderately important ☐ significantly important

d. CDD KPPs underpinned by comprehensive AoA

☐ not very important ☐ moderately important ☐ significantly important

e. STO and TMRR efforts maturing critical technologies to TRL 6 levels

☐ not very important ☐ moderately important ☐ significantly important

f. CBA documenting the need for a JCM to fill capability gaps

☐ not very important ☐ moderately important ☐ significantly important

g. Service approved Joint Cost Position and full funding a Service POM submission

☐ not very important ☐ moderately important ☐ significantly important

h. JCM Risk assessment

☐ not very important ☐ moderately important ☐ significantly important

SECTION 3: INCREMENTAL APPROACH WITH THREE INCREMENTS

1. **Performance:** Based on the requirements, select the capabilities of the JCM that you will develop in this strategy.

    a. Select all that apply for **Increment I**.

Seeker

- o Single Mode (commercial off-the-shelf (COTS)) Specify which mode (only one):
    - o Precision Point (PP)
    - o F&F active
    - o F&F passive
- o Dual-Mode Specify which two modes (only one):
    - o PP and F&F active
    - o PP and F&F passive
    - o F&F active and F&F passive
- o Tri-Mode (KPP)

Warhead

- o Single (COTS) Specify from which missile:
    - o Hellfire
    - o TOW
    - o Maverick
- o Multi-Purpose (KPP)

Propulsion

- o Single Motor (COTS) Specify from which missile:
    - o Hellfire
    - o TOW
    - o Maverick
- o Common Motor (KPP)

Platform Integrated

- o AH-64 (KPP)
- o AH-1Z (KPP)
- o F/A-18 (KPP)
- o UH-60 (KPP

    b. If you did not select to develop a capability that delivers a required KPP in Increment I, select the primary reason for that decision. (Select all that apply)

    - o Does not apply because all KPPs developed
    - o Seeker TRL
    - o Warhead TRL
    - o Propulsion/rocket motor TRL
    - o Seeker risk
    - o Warhead risk
    - o Propulsion/rocket motor risk
    - o Missile integration risk
    - o AH-64 integration risk
    - o AH-1Z integration risk
    - o F/A-18 integration risk
    - o UH-60 integration risk

c. Select all that apply for **Increment II**.

Seeker

- Single Mode (commercial off-the-shelf (COTS)) Specify which mode (only one):
  - Precision Point (PP)
  - F&F active
  - F&F passive
- Dual-Mode Specify which two modes:
  - PP and F&F active
  - PP and F&F passive
  - F&F active and F&F passive
- Tri-Mode (KPP)

Warhead

- Single (COTS) Specify from which missile:
  - Hellfire
  - TOW
  - Maverick
- Multi-Purpose (KPP)

Propulsion

- Single Motor (COTS) Specify from which missile:
  - Hellfire
  - TOW
  - Maverick
- Common Motor (KPP)

Platform Integrated

c. AH-64 (KPP)
d. AH-1Z (KPP)
e. F/A-18 (KPP)
f. UH-60 (KPP)

d. If you did not select to develop a capability that delivers a required KPP in Increment II, select the primary reason for that decision. (Select all that apply)

- o Does not apply because all KPPs developed
- o Seeker TRL
- o Warhead TRL
- o Propulsion/rocket motor TRL
- o Seeker risk
- o Warhead risk
- o Propulsion/rocket motor risk
- o Missile integration risk
- o AH-64 integration risk
- o AH-1Z integration risk
- o F/A-18 integration risk
- o UH-60 integration risk

e. Select all that apply for **Increment III**.

Seeker

- Single Mode (commercial off-the-shelf (COTS)) Specify which mode (only one):
  - Precision Point (PP)
  - F&F active
  - F&F passive
- Dual-Mode Specify which two modes:
  - PP and F&F active
  - PP and F&F passive
  - F&F active and F&F passive
- Tri-Mode (KPP)

Warhead

- Single (COTS) Specify from which missile:
  - Hellfire
  - TOW
  - Maverick
- Multi-Purpose (KPP)

Propulsion

- Single Motor (COTS) Specify from which missile:
  - Hellfire
  - TOW
  - Maverick
- Common Motor (KPP)

Platform Integrated

e. AH-64 (KPP)
f. AH-1Z (KPP)
g. F/A-18 (KPP)
h. UH-60 (KPP)

f. If you did not select to develop a capability that delivers a required KPP in Increment III, select the primary reason for that decision. (Select all that apply)

- o Does not apply because all KPPs developed
- o Seeker TRL
- o Warhead TRL
- o Propulsion/rocket motor TRL
- o Seeker risk
- o Warhead risk
- o Propulsion/rocket motor risk
- o Missile integration risk
- o AH-64 integration risk
- o AH-1Z integration risk
- o F/A-18 integration risk
- o UH-60 integration risk

g. If you did not select to develop a capability that delivers a required KPP in Increment III, how do you propose to get JROC/Service relief to support a MS B in six months? (Select all that apply)

- o Does not apply because all KPPs developed in Increment III
- o Request a configuration steering board to get KPP relief
- o Start the process to change the CDD KPPs

2. Schedule:

a. Based off the program information, select the length of EMD phase by increment appropriate for your strategy.

Increment I (select one)
- o 48 Months *(CDD/POM)*
- o 72 Months *(low CAIG)*
- o 144 Months *(high CAIG)*
- o Other (specify__months)

Increment II (select one)
- o 48 Months
- o 72 Months
- o 144 Months
- o Other (specify__months)

Increment III (select one)
- o 48 Months
- o 72 Months
- o 144 Months
- o Other (specify__months)

b. Select the best reason for the lengths of the EMD phases you chose. (Select all that apply)

- o Supports the warfighter required IOC approved in the CDD
- o Specified in draft APB
- o Supported in Service POM funding positions and in the JCP
- o Supported by the low CAIG ICE analysis
- o Supported by the high CAIG ICE analysis
- o Supported by the risk assessment or TRL levels
- o Supported by the performance capability development

3. Cost

a. Select the program AUPC appropriate for each increment of your strategy.

Increment I (select one)
- o $108K *(JCP w/ my)*
- o $120K *(JCP w/o my)*
- o $153K *(CAIG)*
- o Other (Specify $)

Increment II (select One)
- o $108K
- o $120K
- o $153K
- o Other (Specify $)

Increment III (select one)
- o $108K
- o $120K
- o $153K
- o Other (Specify $)

b. Select the best reason for the JCM AUPC you chose. (Select all that apply)

- o Specified in the CDD
- o Specified in draft APB
- o Specified in the JCP
- o Specified in the CAIG ICE
- o Supported by the AUPC of current missiles
- o Supported by the risk assessment or TRL levels
- o Supported by the performance capability development strategy

This strategy would require a year delay in program start to align requirements and funding to include receiving service approval to delay MS B, getting JROC CDD change approval, and realigning the services' Program Objective Memorandum (POM) submission and the JCP.

4. Indicate the importance (from not very important to very important) of the following reasons for your recommended performance, cost, and schedule selections.

a. Planned MS B in six months (program risk for not starting the program as planned)

☐ not very important ☐ moderately important ☐ significantly important

b. Army and Navy warfighting community support for the JCM capability

☐ not very important ☐ moderately important ☐ significantly important

c. JROC approved CDD specifying KPPs and IOC

☐ not very important ☐ moderately important ☐ significantly important

d. CDD KPPs underpinned by comprehensive AoA

☐ not very important ☐ moderately important ☐ significantly important

e. STO and TMRR efforts maturing critical technologies to TRL 6 levels

☐ not very important ☐ moderately important ☐ significantly important

f. CBA documenting the need for a JCM to fill capability gaps

☐ not very important ☐ moderately important ☐ significantly important

g. Service approved Joint Cost Position and full funding a Service POM submission

☐ not very important ☐ moderately important ☐ significantly important

h. JCM Risk assessment

☐ not very important ☐ moderately important ☐ significantly important

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Appendix II. Joint Common Missile (JCM) Description (Adapted from Gress, Kohtz, & Noll, 2018)

The Army and Navy conducted a capabilities-based assessment to identify numerous capability gaps where current assets could not achieve an overmatch. An in-depth analysis of alternatives (AoA) scrutinized the eight different capability gaps (Sleevi & Mount, 2003):

1. Destroy targets that were either time-sensitive or mobile in urban or complex terrain.
2. Destroy covered targets at extended ranges with minimal collateral damage.
3. Effectively counter battlefield effects of typical obscurants such as smoke or fires.
4. Communicate and designate weapons systems effectively in complex or mountainous terrain.
5. Avoid susceptibility to enemy counterattack due to long exposure time of effective shots on target.
6. Attain logistics simplicity in using a single missile with different seeker types and targeting capabilities instead of using multiple missiles.
7. Target high-speed water craft and other non-traditional targets with the array of legacy air-to-ground missions.
8. Overcome low cloud ceilings and adverse weather (Sleevi & Mount, 2003).

These capability gaps highlighted the importance of a solution capable of effectively operating in complex terrain and targeting a multitude of targets. A new air-to-ground missile provided a materiel solution to counter each of these capability gaps. A joint missile provided an overall reduction in the logistic footprint for the services, and the missile required a multipurpose seeker and warhead with a propulsion system to provide the capability over a large range (Sleevi & Mount, 2003).

As a result of these capability gaps, in October 2001, the JCM program began to provide a joint missile for rotary and fixed-wing platforms of the Army, Navy, and Marine Corps, and the target sets ranged from tanks and watercraft to bunkers and buildings (Joint Attack Munition Systems Project Office, 2016). The overarching goal of the JCM program was to use a modular open system for upgrades, obtain missile commonality, and reduce the logistic requirements to decrease life-cycle costs (Common Missile Project Office, 2003). The Services identified a need for "an extended range, precision guided, air-to-surface weapon providing both precision point target and fire-and-forget capability to be employed against targets in day, night, obscured battlefield, and adverse weather conditions" (Common Missile Project Office, 2003, p. iv). The operational need required a materiel solution that employed multiple advanced technologies. The significant capability gaps provided the reason to develop an advanced weapons system such as the JCM.

The JCM program was the first to become a program of record within the DoD's new capabilities-driven Joint Capabilities and Integration and Development System (JCIDS) process in early 2003. The U.S. Army was the lead service, alongside the U.S. Navy, U.S. Marine Corps, and the British Army Air Corps. The JCM Program Management Office (PMO) personnel assisted the Army and Navy requirement lead offices to develop the Initial Capabilities Document (ICD), analysis of alternatives (AoA), and Capabilities Development Document (CDD). The Joint Requirements Oversight Council (JROC) approved pursuing a materiel solution to the capabilities gap outlined in the JCM ICD. The AoA quantified performance measures and requirements for the CDD, later validated by the JROC (Mortlock, 2005).

Five key performance parameters (KPPs) outlined the critical requirements that the users developed for the missile system. The KPPs listed in the CDD were targeting capability, combat effectiveness/reliability, missile range, interoperability, and carrier/shipboard operability (Joint Requirements Oversight Council [JROC], 2004). The requirements were critical during all contractor design, development, fabrication, testing, and qualifying of the JCM (JROC, 2004).

The users required that the JCM contain three separate targeting methods. Precision point targeting (PPT), fire and forget (F&F) (passive), and F&F (active) were the three targeting methods. The targeting capability requirement quantifies hit probabilities for each of the targeting methods within a threshold and objective range. The PPT targeting method utilizes the JCM's seeker to identify, track, and guide the missile toward a friendly designated laser spot. This method enables multiple targeting platforms to use appropriate laser guidance for a single JCM missile to target. The F&F (passive) targeting method uses infrared (IR) identification and tracking capabilities within the seeker. A target's IR signature is used to help guide the missile towards the intended hit point. This targeting method allows for JCM use during low ceiling and adverse weather conditions. The F&F (active) targeting method uses radar guidance from hardware affixed to the launch platform. The launching platform's radar identifies, tracks, and guides the single JCM missile to the intended target (JROC, 2004).

The combat effectiveness/reliability KPP quantifies requirements for specific types of single-shot kill probabilities and defines different walled target types. The single-shot kill probabilities are broken into objective and threshold levels for T90 variant tank targets and Military Operations on Urban Terrain (MOUT)–type walls. The KPP requirement separated the MOUT wall targets into two types of material based on objective and threshold requirements. "Brick over Block" was designated as the threshold criteria, and "Triple Brick" material was designated as the objective criteria (JROC, 2004).

The missile range KPP outlined the minimum and maximum ranges required by the missile. The requirement separates both the minimum and maximum ranges into fixed-wing and rotor-wing launch platform categories. Minimum range requirements help to support targeting and firing on close-in targets likely found in an urban environment. Maximum range requirements allow launch platforms to engage targets at higher speeds.

Interoperability encompassed the last two KPPs. The interoperability requirement identifies specific aircraft types at the threshold and objective levels. The threshold platforms were American rotor and fixed-wing type aircraft. The AH-64D Apache, AH-1Z Cobra, F/A-18 E/D Hornet, and MH-60R Seahawk made up the list of threshold aircraft. The objective platforms included more American rotor/fixed-wing aircraft as well as UK platforms. The final KPP ensures the JCM is compatible and capable of carrier/shipboard operations without detracting from other surrounding naval operations.

The JCM PMO developed the WBS into three levels (Army Test and Evaluation Command, 2003; refer to Figure 11). The JCM's first level encompasses the JCM Integrated System, which branches off into the missile Platform & Launcher, and Supportability & Training. The second level of the WBS breaks out the major elements of the defense materiel item. The JCM's second level centers around Missile Integration and is tied directly to the JCM Integrated System. Integrated Flight Simulation branches off Missile Integration. The third level of the WBS identifies major subordinate elements of each second level major element. The JCM's third level breaks down the missile subsystems into Seeker Integration and its separate components, Warhead, Propulsion, and Guidance & Control.

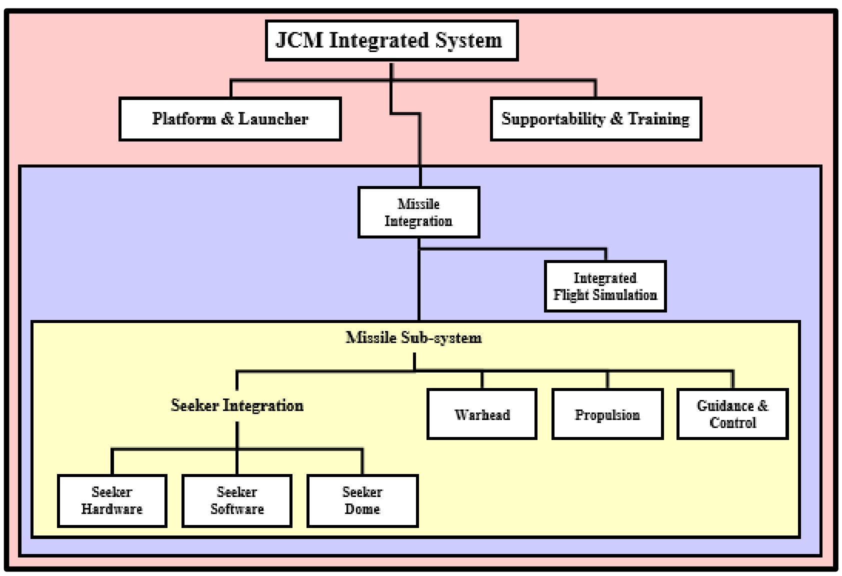

Figure 11 . JCM Work Breakdown Structure

The Army and Navy conducted a thorough risk assessment to determine the program's high-risk technologies in June 2003. The initial risk assessment illustrates the WBS traceability of requirements to the risk level of each critical technology element (Figure 5; Army Test and Evaluation Command, 2003). Since the main components of the weapon system were the seeker, warhead, and propulsion system, the most critical technologies of the program aligned with those areas. The three most critical technology elements were the seeker integration, propulsion turn down ratios, and the multipurpose warhead's low length/diameter (Common Missile Project Office, 2003).

Figure 13 highlights the outcome of the 2003 in-depth risk assessment. A collection of nearly 70 technical experts, acquisition professionals, and users conducted a four-day risk assessment lockdown at Aberdeen Proving Ground to assess the JCM risk (Army Test and Evaluation Command, 2003). Prior to the lockdown meeting, the risk assessment participants conducted internal assessments from each stakeholder's perspective. The intent of the assessments prior to the lockdown was to enable consensus building at lockdown, and establish conditions for the risk assessment at Aberdeen Proving Ground.

The risk assessment focused on each component and subcomponent area of the JCM, and the structure of the overall risk assessment aligned with the WBS levels. The first level was the JCM integrated system risk; the second level focused on platform and launcher interoperability, supportability and training, and missile integration; and the third level provided an analysis of each missile subsystem and integrated flight simulation. Risk assessments on each component and subcomponent identified the change in expected risk levels over the course of the program. The lockdown participants utilized the Army Materiel Systems Analysis Activity (AMSAA) methodology to determine the likelihood of a component's or subcomponent's technology's ability to mature (Army Test and Evaluation Command, 2003). For example, if the component or subcomponent technology is developed and mature, then the rating for the risk likelihood of occurrence would be low. The consequence rating of a component's and subcomponent's risk follows the DoD methodology of determining the impact on cost, schedule, and performance. A low rating has a minimal impact while a high rating has an unacceptable impact on the program's cost, schedule, and performance. The intersection of these two ratings gives the integrated rating for each component's or subcomponent's risk level according to the risk assessment guide shown in Figure 12.

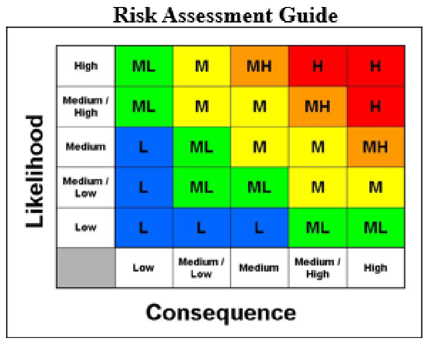

Figure 12. Risk Assessment Guide Matrix

(Army Test and Evaluation Command, 2003)

As a result, the ratings ranged from low to high at critical milestones throughout the program. The lockdown participants determined how the component and subcomponent risk would burn down during the program's life through events such as test and evaluation and modeling and simulation. The lockdown output follows the initial risk determination in 2003 through MS C and reflects the overall JCM WBS structure by component and subcomponent (see Figure 13). Initial assessments identified the warhead and missile integration as having the highest impact on the overall system integration risk. This in-depth risk assessment provided a useful illustration of the risk assessment by component and subcomponent. As a result, all stakeholders obtained a shared understanding, and the assessment remained a critical input for building the JCM's acquisition strategy and test & evaluation strategy.

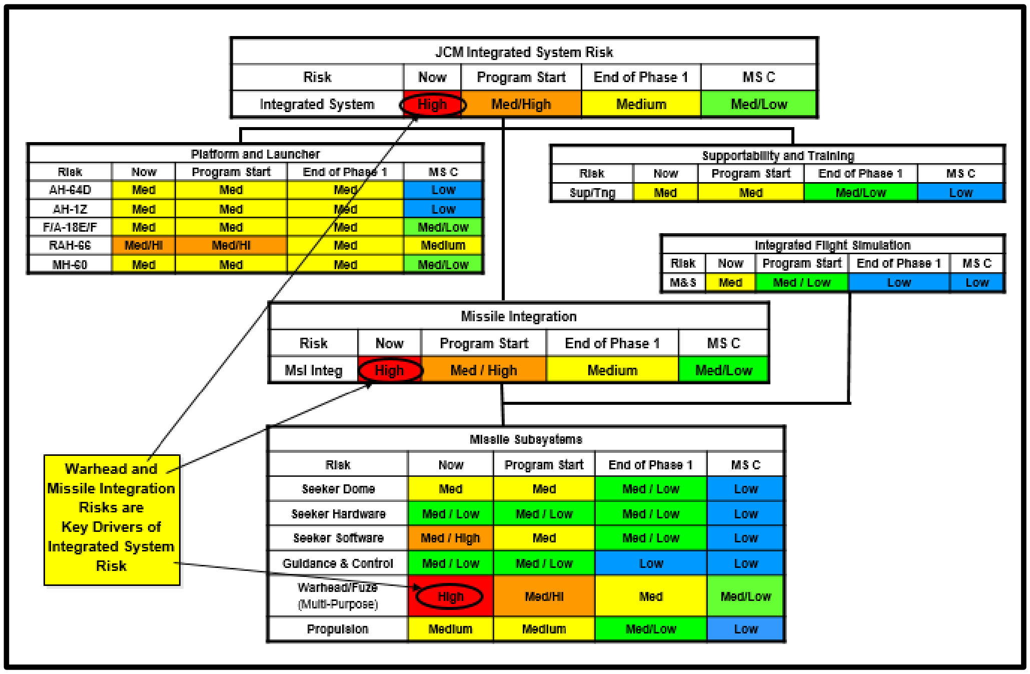

Figure 13. JCM Risk by WBS Level

(Army Test and Evaluation Command, 2003)

During the JCM MS B brief, the JCM Program Office identified six major program risks, which are displayed in Figure 14 (Joint Common Missile Program Office, 2004). The seeker encompasses the JCM's requirement to operate in three different modes. The modes include the ability for precision point targeting, F&F (passive), and F&F (active). The seeker risks were broken down into two critical technology elements, which were the seeker dome and seeker software. Propulsion turn down ratios related to the missile's ability to change propulsion geometry for a boost and sustain phase. These firing phases were necessary to fire the missile from both fixed and rotary-wing platforms at different ranges. Multipurpose warhead fuse technology was critical because the missile needed to hit an array of targets from a T-90 tank to a triple brick wall in a MOUT environment. In addition, the length and diameter of the warhead could have a significant impact on the missile's ability to penetrate armor or buildings (Common Missile Project Office, 2003).

The two remaining risks were missile integration and platform integration. The missile integration focused on the software's ability to control the flight and operation of the missile for its intended target. Platform integration was critical because the

JCM needed to fire from fixed and rotary-wing platforms from the Army, Navy, and Marine Corps (Joint Common Missile Program Office, 2004).

The program office's risk assessment made the following assessments based on technology maturity and integration difficulty. The multipurpose warhead fuze and missile integration were medium/high risk with a likelihood of occurrence rating of 3 and consequence of 5. The propulsion technology was a medium risk with a likelihood of 2 and consequence of 4. Platform integration and seeker software were medium risks with a likelihood of 3 and consequence of 4. The seeker dome was a medium risk having a likelihood of 4 and consequence of 3. See the JCM risk assessment in Figure 14, which provides a visual representation of the program office risk assessment prior to MS B (Joint Common Missile Program Office, 2004).

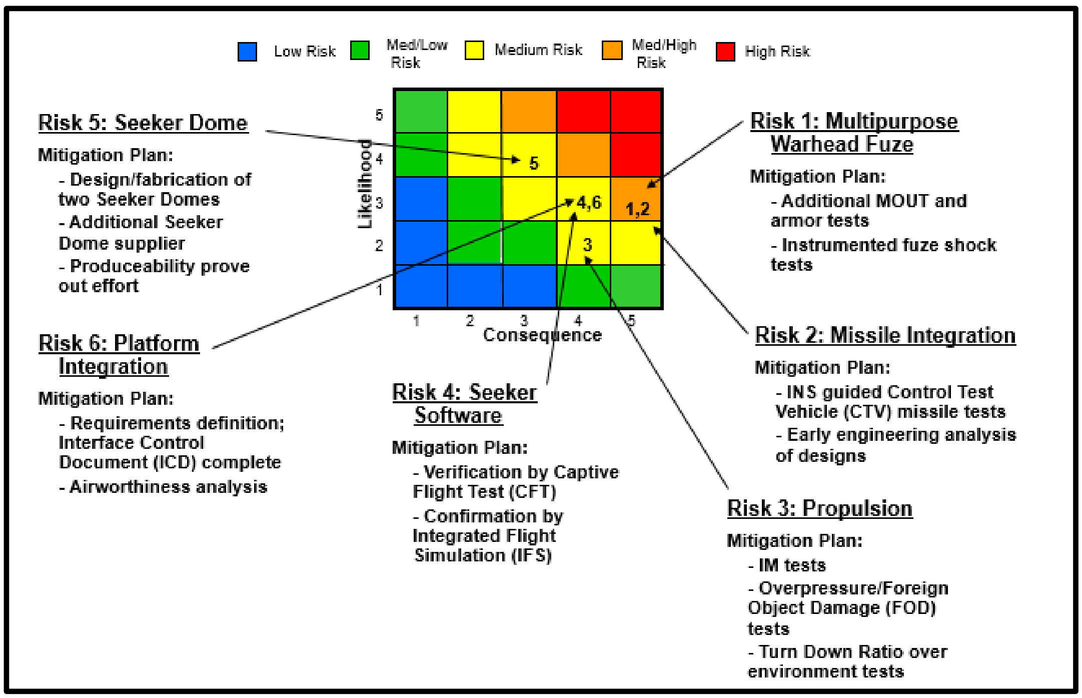

Figure 14. JCM Program Risk

(Joint Common Missile Program Office, 2004)

Technology readiness levels (TRLs) are necessary for a program to assess maturity of critical technology elements. Programs need a TRL of 6 to demonstrate system readiness prior to MS B. An independent technology assessment by the Office of the Secretary of Defense Science & Technology subject matter experts determined that the multipurpose warhead, seeker, and propulsion technology elements were at a TRL 6 before MS B based on a successful competitive technology development phase (Joint Common Missile Program Office, 2004).

Before the JCM became a program of record, several constraints were placed in the CDD that affected cost and schedule elements of the program. The CDD, approved April 12, 2004, outlined the user's need of achieving a target initial operational capability (IOC) in 2009 (JROC, 2004). The target IOC played to the favor of the joint cost proposal (JCP), as it estimated the engineering and manufacturing development phase to be 48 months long (Gregory, 2004). Furthermore, the CDD discussed program affordability in terms of the acquisition unit procurement cost (AUPC). Using the JCP as a baseline, the CDD identified the JCM AUPC to be $108,000 with a multiyear contract vehicle and $120,000 without a multiyear contract vehicle (JROC, 2004).

The Cost Analysis Improvement Group (CAIG) approved an independent cost estimate (ICE) for the JCM MS B review the same month the CDD was approved. In it, the CAIG estimated the development phase to be 74 months and having the potential to increase as high as 147 months, a difference of 39% with the JCP. AUPC estimates were also higher at $153,000, a difference of approximately 22% with the JCP (Burke, 2004). Despite the ICE, the JCM APB cost and schedule estimates were based on the JCP.

The program acquisition strategy report (ASR) outlined the design and development plan of the JCM in accordance with the then-current DoDI 5000.02 dated May 12, 2003 (Common Missile Project Office, 2003). Approved in September 2003, the ASR identified the JCM program as having an overall EA approach through the use of increments. Increment 1 was to provide full performance threshold capability as noted in the CDD. As a result, the ASR's primary focus was on the first increment of capability. A second increment that forecasted the development of an anti-radiation homing (ARH) variant had been identified but was not detailed (Common Missile Project Office, 2003). The program office planned to achieve full capability by using existing technologies and maturing them to meet the needs of established KPPs. Furthermore, a combination of Cost-Plus Incentive Fee (CPIF), Fixed-Price Incentive Fee (FPIF), and Firm-Fixed Price (FFP) contract types were templated to incentivize contractors and manage cost/risk sharing opportunities between the government and the prime contractor.

The JCM was designed to be a modular system and structured to maximize commonality among rotary and fixed-wing applications (Common Missile Project Office, 2003). Focused on the first increment of capability, the PMO used a multi-phased acquisition approach by planning for two development phases within the program's system development and demonstration (SDD) phase. The first phase of SDD concentrated on mitigating component risk by incorporating a combination of testing and design reviews. This phase was templated to last 12 to 14 months and would be considered successful upon completion of seeker design verification, meeting control test vehicle (CTV) test objectives on track missile design, development of a system design interface control document, and a completed preliminary design review (PDR) (Common Missile Project Office, 2003). The subsequent phase was templated to last 36 months. The SDD phase focused on the integration of JCM subcomponents into the overall system and intended to demonstrate the system's ability to meet all CDD requirements. However, in the first quarter of fiscal year (FY) 2005, the JCM program was terminated while in the first phase of SDD (Joint Attack Munition Systems Project Office, 2015).

Appendix III. Joint Air-to-Ground Missile Description (Adapted from Gress, Kohtz, & Noll, 2018)

Program Budget Decision (PBD) 753 terminated the JCM program in the first quarter of fiscal year (FY) 2005 due to budget constraints. The JROC instructed the JCM Project Management Office (PMO) to continue maturing key technology with Lockheed Martin and plan to restart the program in FY 2007 (Joint Attack Munition Systems Project Office, 2016). Prior to 2007, the PMO and Lockheed Martin completed a preliminary design review (PDR) and conducted a controlled test vehicle flight, along with more than 3,500 hours of hardware and software testing, and more than 1,000,000 integrated flight simulation runs on missile prototypes. The JCM PMO and the Aviation Rockets and Missiles PMO merged to form the Joint Attack Munition Systems (JAMS) PMO in FY 2007. Soon after formation, the JAMS office began writing the acquisition strategy (AS) for a new acquisition category (ACAT) 1 program called the JAGM (Joint Attack Munitions Systems Project Office, 2016).

The JAGM PMO continued developing key technologies from 2008 to 2010. The JAGM PMO based development of key technologies on the same requirements that outlined the need for JCM production. The JAGM CDD, approved in January 2013, differs from the JCM CDD by outlining a program that has an incremental requirement following an EA approach to reach full capability through three increments (JAGM Product Office, 2014). The CDD states the JAGM strategy

> addresses Increment-One capabilities for the JAGM. Increment-Two will address increases in range, possible inclusion of limited Imaging InfraRed (IIR) for terminal guidance/hit point selection, and other items as technology/schedule can accommodate. Increment-Three will provide full tri-mode seeker capabilities for active and passive engagements as well as an increase in range. (JROC, 2012, p. 14)

The JAGM CDD contains the same KPPs as the JCM and includes targeting capability, combat effectiveness/reliability, range, interoperability, and carrier/shipboard operability with sustainability (materiel availability) as the only new KPP included in the JAGM CDD (JROC, 2012). The biggest differences between the

JCM and JAGM KPPs were the inclusion of increments that separated the different threshold requirements for each KPP. Multiple parameters changed from a threshold element in the JCM program to objective level elements for the JAGM.

The targeting capability KPP changed only slightly by identifying the specific differences between the F&F active and passive requirements. Threshold values in Increments 2 and 3 and the Objective values contain F&F passive threshold values against stationary targets only. Increment 1 only contains a precision point targeting and F&F (active) seeker capability.

Combat effectiveness/reliability requirements included in-flight reliability threshold and objective values. The Increment 1 threshold includes initial fielding and system maturity values for the in-flight reliability, with Increments 2 and 3 containing the same values. The objective value increases the reliability. The other requirements in the combat effectiveness/reliability KPP are the same parameters with different threshold values spread over the different increments and objective elements.

Range requirements for Increment 1 reduced the maximum rotary-wing range to 8km instead of 16km in the JCM CDD. Increment 2 maximum range changed to "greater than 8km," with Increment 3 improving to 16km. Fixed-wing ranges are not required for the JAGM except for the Objective values because of the changes to the Interoperability KPP.

The interoperability KPP contained the biggest changes between the JCM and JAGM. The AH-64D Apache and AH-1Z Cobra helicopters are the only two aircraft identified as platforms for firing the JAGM in all Increment threshold values. The F/A-18 E/F Hornet and MH-60R Seahawk moved to the other Objective level aircraft so that Increments 1–3 are for the two rotary-wing aircraft only.

Carrier/shipboard operability requirements stayed the same, and the last KPP for JAGM that is new is the sustainability (materiel availability) requirement. The KPP describes a required percentage of missiles operationally capable of performing an assigned mission at a given time, based on materiel condition. Increment 1 establishes the same threshold values for Increments 2 and 3, with the Objective level increasing the percentage required.

In 2010, the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA[ALT]) review team conducted a technology readiness assessment (TRA) to review the technology maturity following TD phase. The review team determined that the TRL for the new rocket motor, warhead, and tri-mode seeker/guidance section were either a 5 or 6. The prototype technology of the original JCM requirements were too immature, which could impact the program's cost and schedule. Therefore, the program office utilized trade space evaluations to develop an alternative materiel solution with using the Hellfire Romeo backend with a multi-mode seeker for two rotary-wing aircraft.

The program AS, approved on October 2014, outlines the EMD phase and low rate initial production LRIP strategy for Increment 1 of the JAGM program. Like the JCM, the JAGM AS identifies the use of an EA approach through the delivery of capabilities in increments. Comparatively, Increment 1 for the JAGM was not designed to provide full threshold capability, but rather to establish a modular system capable of receiving future upgrades. The EMD phase of Increment 1 sought to mate a multi-mode seeker with the backend of the Hellfire missile. The conclusion to use government furnished equipment (GFE) resulted from multiple trade space evaluations identifying the use of the Hellfire Romeo backend as the most economical materiel solution. Furthermore, Increment 1 focused on system modularity, which facilitated the use of a Modular and Open Systems Architecture (MOSA) to accommodate future increments with the ability to insert technology (JAGM Product Office, 2014).

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Acquisition Research Program
Graduate School of Business & Public Policy
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net