DEPARTMENT OF DEFENSE
ENTERPRISE REQUIREMENTS AND ACQUISITION MODEL

THESIS

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AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

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Abstract

In support of senior leadership emphasis on improving early systems engineering and analysis, the Enterprise Requirements and Acquisition Model (ERAM) is a quantitative discrete-event process simulation model accounting for activities from early capability analysis through system fielding. The model begins with Air Force Space Command's (AFSPC) identification of a desired space capability early in the Joint Capabilities and Integration Development System (JCIDS) process through system development at Milestone-C (MS-C) of the acquisition system resulting in a probabilistic schedule distribution for a given concept. This model of the Department of Defense's (DoD) space capability development process provides decision making information for the Concept Characterization and Technical Description (CCTD) documents referenced during Analysis of Alternatives (AoA). The research focused on identifying activities and assigning historical distributions and probabilities at each decision point. Data was collected through analysis of applicable policy, instructions, and journal articles as well as interviews with subject matter experts (SME) from the Air Staff, AFSPC and the Space and Missile Systems Center (SMC). ERAM will be initially utilized at Aerospace Corporation's Los Angeles based space Concept Design Center (CDC) providing decision-makers insight into timeline estimations and probabilities of program success for various technical concepts based on historical comparisons. ERAM also has the potential to be used as a training tool for Air Staff, AFSPC and SMC personnel to better understand existing organizational interdependencies and required processes necessary to acquire a capability on schedule and within budget.

Acknowledgements

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I. Introduction

1.1 Background

The United States DoD's global military dominance has been achieved in part by its ability to maintain a technological advantage over its adversaries. As research and development efforts discover new technologies and potential military applications, three systems, the DoD JCIDS system, the Program, Planning, Budget and Execution (PPB&E) system and the acquisition system, function simultaneously and dependently on one another to continue evolving US military capabilities. This complex "system of systems" is governed by numerous statutes, policies, instructions and guides that establish a process framework outlining the activities involved and how they relate to one another. It requires significant experience, education and initiative to understand and successfully navigate the system as a requirements or acquisition professional. DoD weapon systems have significantly increased in complexity and interdependency in the past two decades with mandatory Key Performance Parameters (KPP) relating to net centricity, joint interoperability, as well as several others. According to a Government Accountability Office (GAO) report, programs such as Transformational Satellite Communications System (TSAT) and Space Radar were "among the most complex programs ever undertaken" (Nelson and Sessions 2006). DoD's ability to deliver within original cost and schedule estimates has diminished. In a GAO survey with an unspecified total number of MDAP PMs interviewed, "45 program managers (PM) responded that their program had been rebaselined one or more times for cost and schedule increases" (Nelson and Sessions 2006). Numerous senior DoD leaders have indicated that one of the reasons for this is due to insufficient and/or inaccurate data used to make early decisions to pursue material solutions; this recognition has placed new emphasis on improving early systems engineering analysis during capability gap analysis and requirements generation, pre-Materiel Development Decision (MDD) activities, and early acquisition activities pre MS-A. President Barack Obama released the National Space Policy of the United States of America on June 28, 2010, and stated, “Departments and agencies shall: Improve timely acquisition and deployment of space systems through enhancements in estimating costs, technological risk and maturity, and industrial base capabilities” (Obama, National Space Policy of the United States of America 28 June 2010). Secretary of Defense Gates made the following statement in his Defense Budget Recommendation Statement on 6 April, 2010,

> … Second, we must ensure that requirements are reasonable and technology is adequately mature to allow the department to successfully execute the programs…Third, realistically estimate program costs, provide budget stability for the programs we initiate, adequately staff the government acquisition team, and provide disciplined and constant oversight (SECDEF 2009).

In the Chief of Staff of the Air Force’s Vector dated 4 July, 2010, General Norton Schwartz’s fifth priority to recapture acquisition excellence states, “Ultimately, the health of the Air Force requires that we bring acquisition costs and timelines under much greater control and oversight.” In an effort to accomplish this, he states we must “Recapture a vision for aggressive science and technology (S&T) development, the rapid transition of innovative technology into operational capabilities, and harnessing aerospace technology to meet broader national security needs” (Schwartz 2010). In August, 2010, Lt Gen Shackelford (SAF/AQ) was the keynote speaker at the Air Force Systems Engineering conference and highlighted two specific challenges: the first addressed planning and “the lack of technical input to make informed decisions”. The second focused on execution and stated that “technical issues/risks aren’t discovered and addressed at the right time and at the right level” (Shanley 2011).

The President of the United States, the Secretary of Defense and senior Air Force officials have clearly recognized the need to improve the capability development, requirements validation and acquisitions within the DoD and have issued strategic guidance to tackle the challenge (Obama 28 June 2010, Secretary of Defense Gates 6 Apr 2009, Office of the Assistant Secretary of the Air Force 2009). One of the fundamental factors resulting in poor program performance is insufficient early systems engineering analysis and inaccurate Technology Readiness Assessments (TRA) in the requirements and acquisition systems. This has inevitably resulted in early program decisions being made based upon poor cost and schedule estimates (Shanley 2011).

In September, 2009, a doctoral dissertation, “Identifying Enterprise Leverage Points in Defense Acquisition Program Performance”, was published with the goal of characterizing the system of acquiring large, complex, socio-technological systems for the DoD (Wirthlin 2009). The research resulted in an in-depth analysis of the discrete events and products required for a typical aerospace defense program throughout the lifecycle, with emphasis placed on events prior to MS-C. Data about the events and products was gathered through analysis of existing policy and guidance (pre 2006) as well as numerous interviews with defense acquisition experts. Subsequently, this data was modeled and programmed using the Arena® software modeling tool, resulting in the first-ever discrete-event simulation of the entire defense acquisition model, albeit abstracted at a high level. For the purpose of this research, this version of the model will be referred to as the ERAM, version 1.0 (ERAM 1.0). ERAM 1.0 simulated various activities and events using probabilities for decision event outcomes and timeline distributions to determine likely overall program timelines as well as probabilities of successful program execution up to MS-C. The output is reflected by a probabilistic determination of likely program duration through approval of MS-C using Monte Carlo simulation techniques. ERAM 1.0 modeled a capability concept or idea entering the Major Command (MAJCOM) requirements process and simulated its path to termination. Additional implementation included decision points throughout the process flow to include determination of a successful design review, rework, funding checks and other events. The activities for discrete events incorporated triangular distributions for elapsed times. For example, timelines associated with affordability assessments, preparing for reviews, writing documents, all had probability distributions with a best case, worst case and most likely number of days, with the data elicited from various sources. These sequences of events with timeline probabilities and decision points as executed through the simulation delivered results enabling further analysis for decision-making. Accordingly, with additional refinement and enhancements this model has the potential to be used as a valuable data source for decision makers in forecasting a program's development and delivery schedules and life cycle costs (Wirthlin 2009).

In the Fall of 2010, the SMC, Development Planning branch (SMC/XR) sponsored further research and analysis on ERAM 1.0, focusing specifically on early space requirements and acquisition activities pre MS B (Figure 1). The model will be updated and enhanced to address these issues specifically.

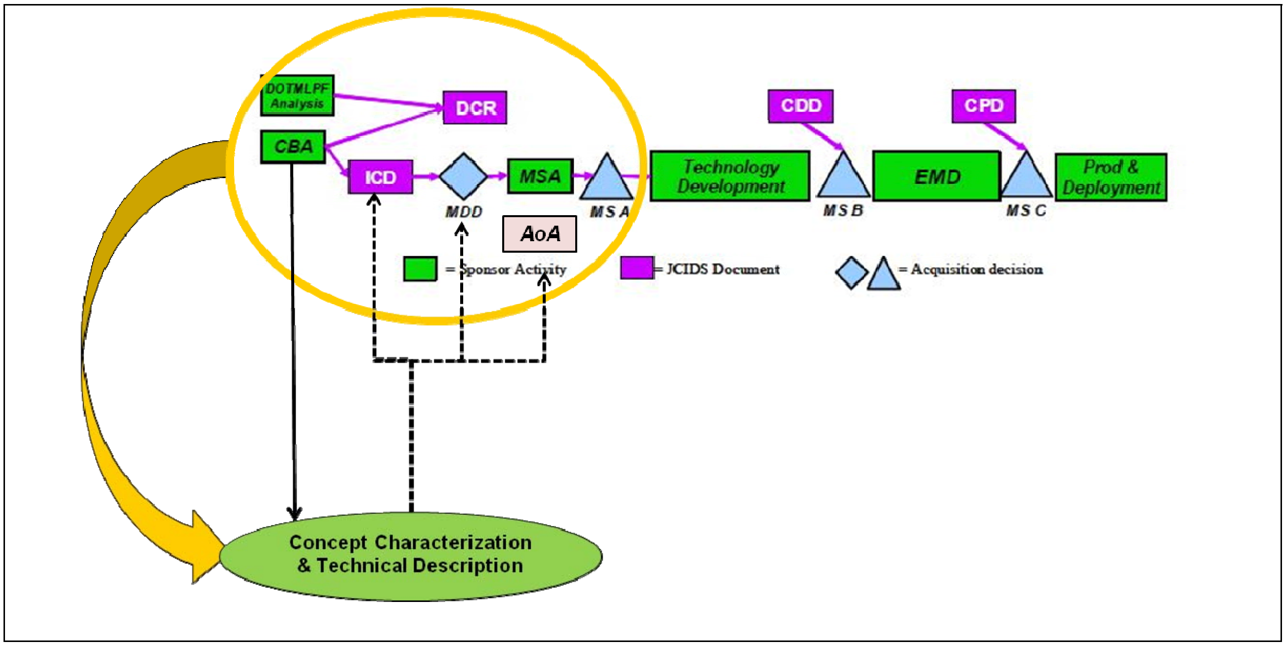


Figure 1: Requirements Generation Process (CJCS 2011)

Research data was collected through a series of interviews with space requirements and acquisition personnel from AFSPC Requirements directorate (AFSPC/A5), the Under Secretary of the Air Force, Acquisitions Science, Technology and Engineering (SAF/AQR) division and space acquisition program managers coupled with an analysis of updated requirements and acquisition guidance. The research approach resulted in several updated model versions, ERAM 1.1, 1.2, 2.0 and 2.1, highlighted and explained in Figure 2 and Table 1.

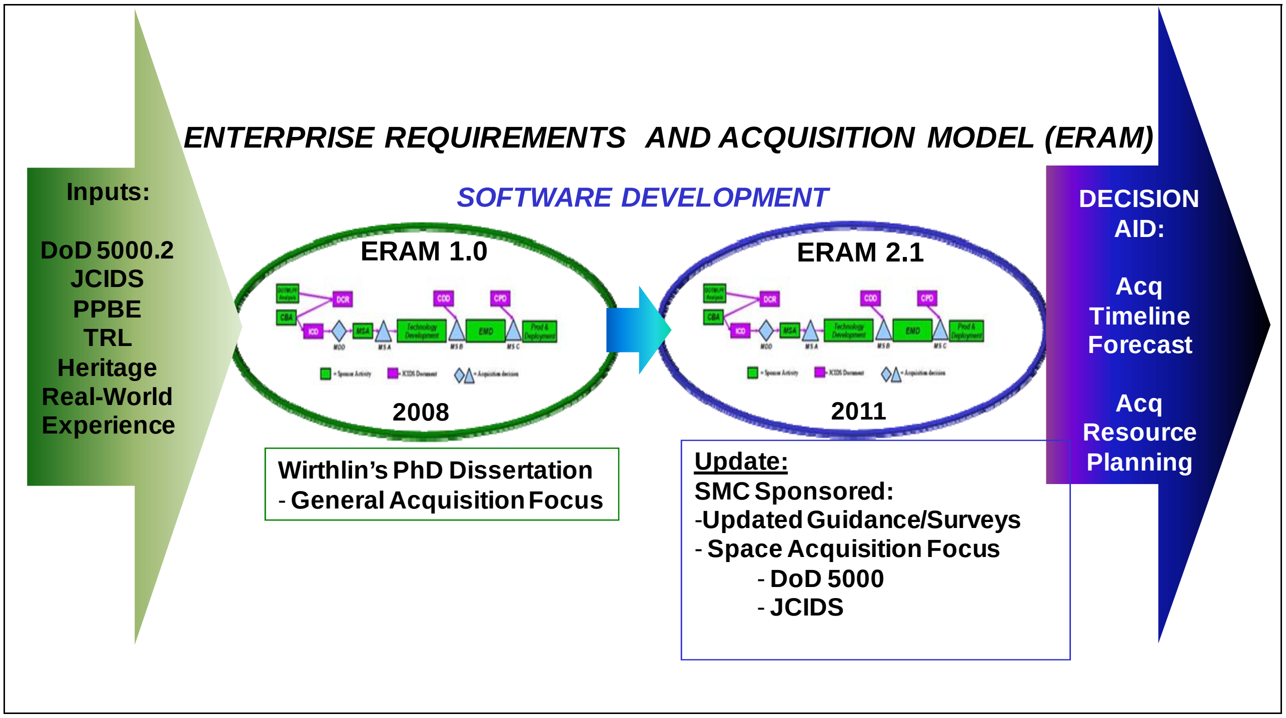


Figure 2: ERAM Evolution

Table 1: ERAM Versions

Model Version	Description
ERAM 1.0	Original model developed and published in Wirthlin's dissertation
ERAM 1.1	Incorporated updated changes from *Arena® and port* to *ExtendSim*© software
ERAM 1.2	Incorporated changes from DoDI 5000.02 May 2003 version to Dec 2008 version
ERAM 2.0	Incorporated model parameter adjustments to capability (i.e. SPO capability matrix)
ERAM 2.1	Incorporates early requirements development activities from JCIDS

First, ERAM 1.0 was ported to the ExtendSim® modeling software to support the installed software base of the sponsor. It then went through the iterations as mentioned in Table 1.

The main research focus spans ERAM 1.2 through ERAM 2.1 by making ERAM current with recent DoD Instruction 5000.02 (DoDI) updates and expanding the pre MS-B JCIDS processes to show how Development Planning (DP) and CCTD processes are integrated into the process of developing a new capability. The research found capabilities desired by the AFSPC can typically be categorized as either "evolutionary" or "revolutionary". Evolutionary capabilities are achieved through modification(s) or upgrade(s) to an existing system(s). In these instances, AFSPC performs its JCIDS requirements process and may reach back to the product center's system(s) program offices (SPO) for their DP. On the other hand, revolutionary capabilities are typically those that require the development of an entirely new system. For these DP activities, AFSPC reaches out to subject matter experts (SME) at SMC/XR. These revolutionary capabilities have the potential of moving out of SMC/XR and into a new SPO. Additionally, the research made inquiries into deviations from existing policy and methods of approval for these deviations. This served as a way to enrich the realism of the model's and subsequently, its usefulness for decision makers.

1.2 Problem Statement

President Obama states in the National Security Strategy for the United States of America,

> Cost-effective and efficient processes are particularly important for the DoD, which accounts for approximately 70 percent of all Federal procurement spending. We will scrutinize our programs and terminate or restructure those that are outdated, duplicative, ineffective, or wasteful. The result will be more relevant, capable, and effective programs and systems that our military wants and needs (Obama, National Security Strategy 2010).

Furthermore, from the National Defense Strategy (June 2008), Secretary of Defense Robert Gates states, "We also must continue to improve our acquisition and contracting regulations, procedures, and oversight to ensure agile and timely procurement of critical equipment and materials for our forces" (Gates, National Defense Strategy 2008).

Senior leader decisions with regards to future space programs must be based upon realistic and accurate cost and schedule estimates which historically have not existed. Sadly, cost overruns and schedule delays have become the norm in space acquisitions. National defense leadership has emphasized the importance of continuing to expand our role in space as well as increasing space capabilities in a costly and timely manner. *Currently, there is no existing capability or process to quickly and comprehensively develop the requirements and acquisition program details for large and complex space systems.* According to Dr. Peter Hantos and Nancy Kern of the Aerospace Corporation, "Pre MS-A Systems Engineering and Pre MS-B Software Engineering efforts are not comprehended in any estimation models" (Hantos and Kern 2011).

1.3 Implications

The primary purpose of this research was to update and modify ERAM 1.0 to ERAM 2.1 for SMC/XR to utilize as a tool to increase the fidelity of CCTDs. By improving the quality and viability of the data within these documents, Defense Acquisition Board (DAB) decisions regarding future space capabilities will be based on more accurate cost and schedule estimates resulting in decreased breaches and improved program performance.

Additionally, there are several other important implications that modeling the requirements and acquisition process delivers. ERAM in conjunction with this comprehensive report can aid requirements and acquisition professionals to better understand organizational relationships and provide a map of required activities based upon current directives and guidance, improving the likelihood of successfully maintaining program cost, schedule and performance objectives. The model could also help OSD and SAF personnel identify inefficiencies and disconnects within the vast number of current instructions, resulting in modification and simplification of current guidance. ERAM also provides detailed context to the well known, but too often incomprehensible, DAU acquisition "wall chart." This chart provides a high level picture of acquisition activities, but, lacks detail to effectively train acquisition professionals. By supplementing the "wall chart" with the ERAM framework, real world data can significantly improve the current training curriculum for acquisition personnel— possibly resulting in a “flight simulator” of the acquisition system. This training device could evolve into a more disciplined and rigorous training & evaluation system for acquisition personnel.

Chapter II (Literature Review) of this report will provide an overview of the key documents that heavily influenced the development of ERAM 1.2 through 2.1 and the findings included in this report. Chapter III (Methodology) describes the methods used to collect the data necessary to accurately update ERAM. Furthermore, it highlights the methodology for the research accomplished through interviews of subject matter experts and processes for making updates to the software model. Chapter IV (Results and Analysis) will consolidate the findings from the interviews and discuss how they were implemented into the model. Chapter V (Conclusions and Recommendations) summarizes the findings of this research effort and provides recommendations on additional research and policy changes that would benefit space acquisitions.

II. Literature Review

Research on the subject of DoD capability development required the review of more than 50 policy documents, official instructions, guidance, journal articles, and briefings. Table 2 highlights the eight major resources that are the seminal pieces of literature for this research. They were utilized to capture the essence of the space acquisition and requirements themes for making modeling decisions and acquisition observations for this research effort. However, these are but a small snapshot of the policy requirements that acquisition professionals will need to quickly process and internalize in order to develop requirements and acquisition program details for complex space systems. Wirthlin's dissertation (Resource #1 below) provides the foundation of this modeling effort. The remainder provides significant guidance in the ever-changing world of acquisition. Each of these resources is intended to aid in the background required for inputs into ERAM development. The foundation of Wirthlin's dissertation and the additional guidance provided in the literature review serve as the basis for the information which can be utilized for improved decision-making and closing the gap in acquisition knowledge. More details about each resource follow.

Table 2: Highlighted Literature Overview

	Resource
1)	Wirthlin, J. Robert. *Identifying Enterprise Leverage Points in Defense Acquisition Program Performance.*
2)	Gates, Robert M. *SECDEF MEMO. Department of Defense Efficiency Initiatives.* 16 Aug 2010.
3)	Carter, Ashton B. *USD/AT&L MEMO for Acquisition Professionals: Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending*. 14 Sep 2010.
4)	Assistant Secretary of the Air Force for Acquisition (SAF/AQ) *Early Systems Engineering Guidebook Version 1*.
5)	Loren, Jeff C (SAF/AQRE). *The ABCs of Concept Evolution: A Better-Informed Materiel Development Decision for USAF Programs.* 18 Nov 2010
6)	United States of America Congress. *Weapons Systems Acquisition Reform Act (WSARA) of 2009*
7)	Acquisition Improvement Plan (AIP) 4 May 2009
8)	Directive-Type Memorandum (DTM) 09-025 – Space Systems Acquisition Policy (SSAP)

Resource #1: Identifying Enterprise Leverage Points in Defense Acquisition Program Performance

Wirthlin's PhD dissertation simulated the acquisition "wall chart" using the Arena® software tool. It provides a thorough background of the acquisition process, the PPBE process, and the JCIDs process. Through reviewing literature and interviewing members of the DoD requirements and acquisition communities, this dissertation provides a candid view of many of the challenges and opportunities to bring an acquisition program to MS-C.

The fundamental research questions in the dissertation were the following: "How does the acquisition system work?" A follow up question was, "Why does the system behave the way that it does?" And finally, "Are there things that can be done to improve the system?" (Wirthlin 2009) Throughout the dissertation and model development, real world detailed examples were given on not only how the acquisition process should work according to policy and guidance, but also how MAJCOMs, Air Staff, or SPO personnel personalized the system to be more effective within their own areas of responsibility. ERAM 1.0, as developed in the Arena® simulation program, captured process steps, activities, and injected uncertainty to show additional realism. Although it captured various elements as discrete events, these were modeled with a triangular distribution of the number of days required to complete. Inputs to these discrete event activities were minimum, maximum and most likely number of days based on a user's actual experience and estimates. Alternative paths through the system or branching points were also identified with associated probabilities.   For example, one branching point was during a source selection. The probability of receiving a protest from a losing contractor was identified as 20%. ERAM 1.0 captured this probability and added an activity to account for the protest event.

ERAM 1.0 represents a predictive model of various detailed elements of the acquisition processes with their timelines and interdependencies along with several exploratory variants that include: Air Staff intervention; MAJCOM approval body(s) intervention; technical interventions; interventions at different design reviews; funding stability; etc.   By exploring these variants, and combining these adjustments over acquisition category (ACAT) I, II, and III level programs, conclusions were drawn regarding ways to improve program outcomes. An identical analysis approach will also be used in this new research by focusing on the SMC/XR processes in the development planning phase of acquisition.

The "meat" of the dissertation was certainly ERAM 1.0, its development, its results, and the verification and validation. The printed version of ERAM 1.0 in a readable format takes a roll of butcher block paper approximately 14 feet long. The main outputs include: where the process was terminated; the probability of reaching the exit points, and the number of days required to complete the process through MS-C and other areas. A concept or idea enters the model at the requirements shop. The exact method for a concept entering the requirements process is not specifically modeled in ERAM 1.0. It assumes an idea is introduced to the requirements organization and then proceeds forward. This is then carried forward and either terminates at various points along ERAM 1.0, or reaches MS-C. Innovative methods to account for the various unplanned taskings levied on a program were modeled using uncertainty events at a regular frequency.

> Uncertainty driven by political circumstances is artificially modeled by randomly generating a 'program review' where the finances, program management and other aspects of a program are 'reviewed' for potential cuts and/or changes. A set driver of uncertainty, also artificially driven, is named simply 'event happens' and is used to account for the stochastic nature of problems encountered in the execution of the development program, running the gamut from the impacts of 'known unknowns' to "unknown unknowns" (Wirthlin 2009).

Examples of these uncertain events could include some tasking from Air Staff to write a point paper defending their acquisition strategy. This is an out-of-cycle activity levied on the PM, which may or may not happen. So therefore, each "uncertainty event" captured the possibility of an unplanned activity path.

The dissertation and ERAM 1.0 lays the groundwork for observers to take a hard look at how policy changes impact the acquisition process. The insight gained from inserting realism into the acquisition "wall chart" or "horse blanket" can be enlightening to those wishing to understand the impact of certain decisions on the overall outcome of a program. The analogy of the "butterfly effect" is that a butterfly flapping its wings at one location could potentially create a major windstorm at another location. A small tweak to the acquisition process could have a major impact to the outcome. It has the potential to aid decision makers to understand how to resource their programs, provide more realistic expectations on program timelines, and in the future, provide "knobs" where critical process/program parameters could be modified to improve overall outcomes (sensitivity analysis).   A high-level view of this model is found in Figure 3.

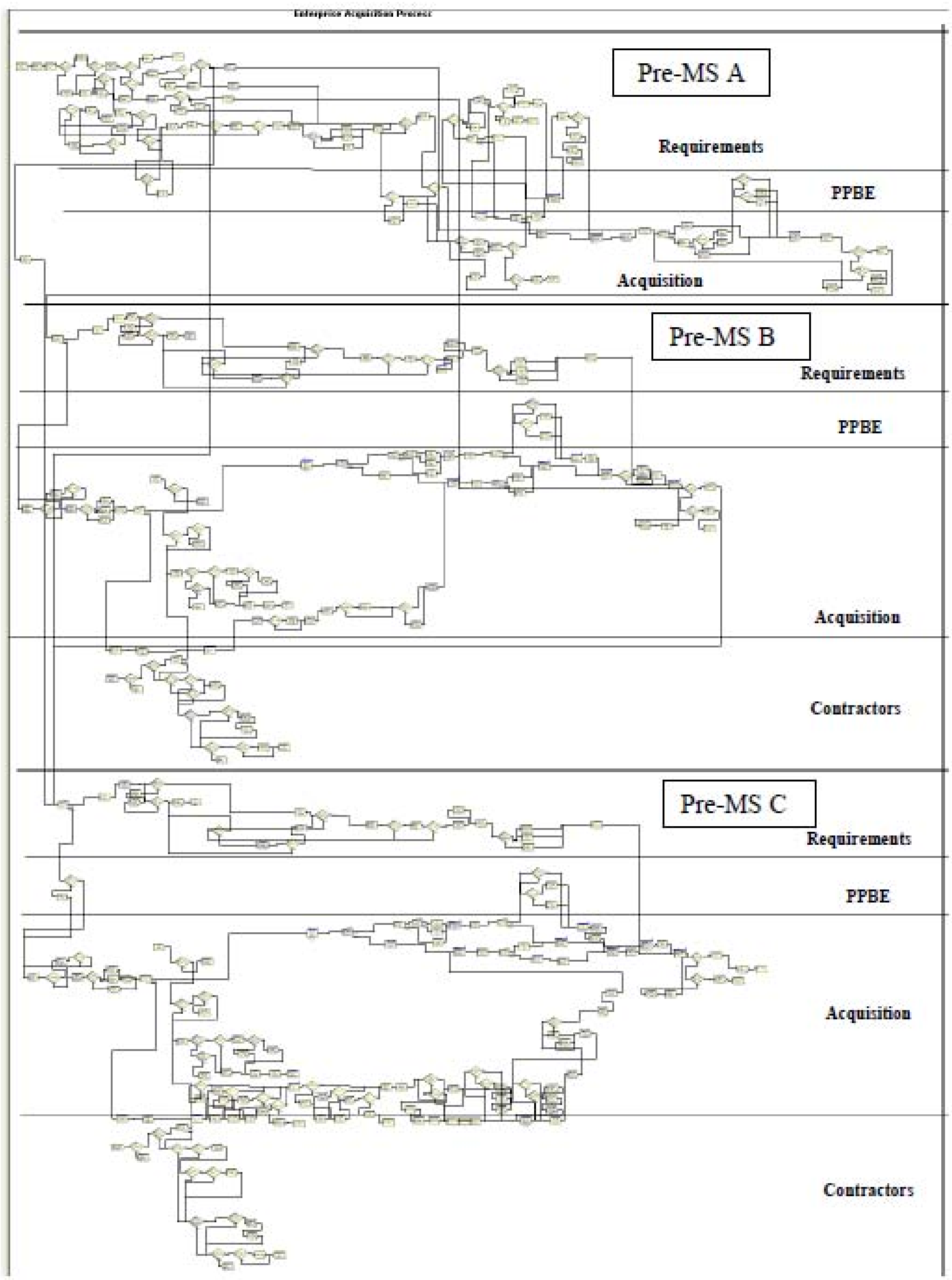


Figure 3: ERAM 1.0 Arena (Wirthlin 2009)

Resource #2: Department of Defense Efficiency Initiatives

Secretary of Defense Gates provided direction for eliminating excess costs in the DoD budget in a memo issued 16 August 2010. These efficiencies are intended to align the Defense budget with the overall intent to reduce the size of the federal budget. Some of these efficiencies include: "10% reduction in funding for service support contractors"; freezing the number of staff billets at several agencies including Office of the Secretary of Defense (OSD); 25% reduction in advisory studies; eliminate Assistant Secretary of Defense for Networks & Information Integration (ASD/NII) and J6 organizations; and "complete a comprehensive review of all Department-required oversight reports with the aim of reducing the volume by eliminating non-essential requirements" (OUSD/ATL 2010). This impacts the acquisition process in several ways such as extending activity timelines with a less experienced and minimally staffed workforce. Additionally, future iterations of the model could have activities eliminated if they are considered to be surplus oversight requirements. These efficiencies have the potential to provide benefit in reduced bureaucracy and an improvement in the ability of acquisition professionals to understand the requirements levied on them. All of these must be captured in ERAM.

Resource #3: Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending

This letter also provides several key directives to redirect $100B in defense spending by improving business practices and cutting lower priority spending initiatives. Secretary Carter stated: "To put it bluntly: we have a continuing responsibility to procure the critical goods and services our forces need in the years ahead, but we will not have ever-increasing budgets to pay for them. We must therefore strive to achieve what economists call productivity growth: in simple terms, to DO MORE WITHOUT MORE." (Carter 2010) Some key elements include the following: 1) At MS-A, the acquisition decision memorandum (ADM) will include affordability as a Key Performance Parameter (KPP); 2) Eliminate redundancies within portfolios; 3) Competitive Strategy required at all milestones; 4) Further insight into contractors Independent Research and Development (IRAD) investments; 5) Modify Nunn-McCurdy rules for special situations; etc. The independent cost estimates (ICE) will now be used to drive productivity into the programs and provide incentives. There will now be "should cost" and "will cost" estimates. Previously, only the "will cost" estimates were used. The "should cost" estimates will now be inserted into the process to incentivize leanness and efficiencies by the PM. If prices are negotiated less than the "will cost" and the program is executed as such, cost savings could be reallocated within programs to acquire other capabilities.

> "The metric of success for Should Cost management leading to annual productivity increases is annual savings of a few percent from all our ongoing contracted activities as they execute to a lower figure than budgeted. Industry can succeed in this environment because we will tie better performance to higher profit, and because affordable programs will not face cancellation." (Carter 2010)

Cost estimates through OSD will impact program flows and timelines. These cost drivers impact program timelines in the modeling and analysis as the OSD governing body for cost estimates adds additional checks and balance in the early systems engineering process. A fair criticism of space programs would be that the "will cost" estimates were not achieved suggesting the notion of "should cost" estimates as being without merit. However, with the added emphasis on cost estimation with more defined processes, the "should cost" will be a driving force in future acquisitions programs. Further research will determine if this new emphasis achieved its desired goals. As acquisition professionals are given the knowledge tools to execute their programs, they will be empowered to successfully navigate through the information and succeed. These must be accounted for and captured in ERAM.

Resource #4: Early Systems Engineering Guidebook

This guidebook is critical for this research project as it discusses the "meat" of the acquisition process prior to MS-A. It discusses the Capability Based Assessment (CBA), Concept Exploration and Refinement, AoA, the CCTD document, and the Materiel Solution Analysis phase.

> "A development and acquisition organization, typically XR, responsible for translating high-level system needs into more detailed system-level information. With the help of all stakeholders, they generate and analyze alternative system concepts, and provide balanced estimates of effectiveness, performance, cost, schedule, and risk to assist the stakeholders in selecting preferred concepts" (SAF/AQ 2009).

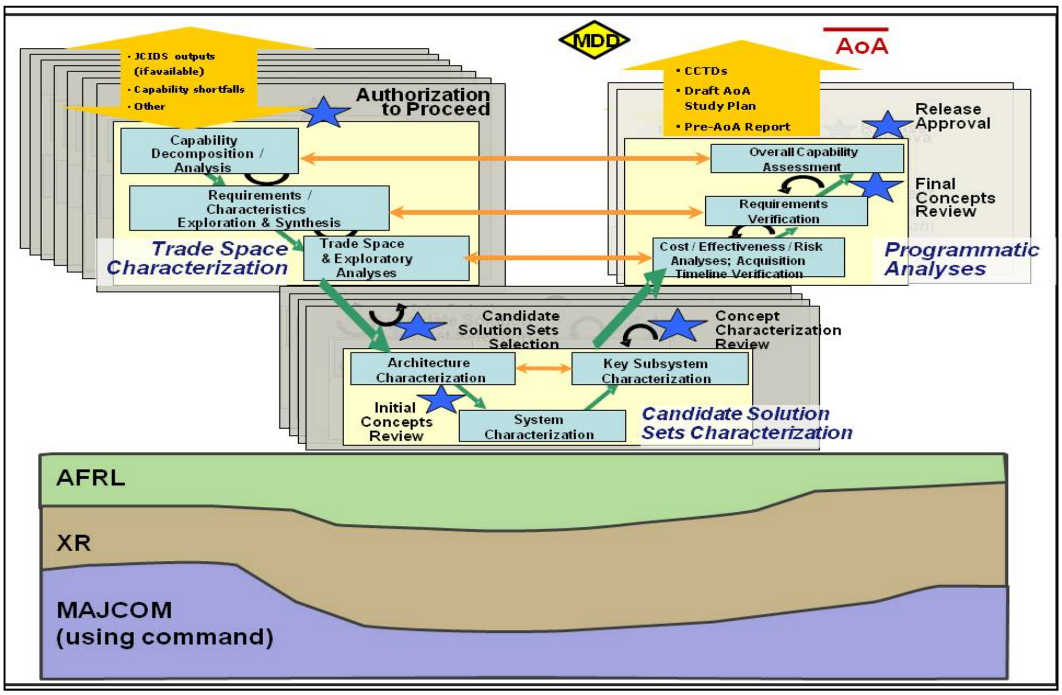


Figure 4: Early Systems Engineering Process (SAF/AQ 2009)

Figure 4 highlights the system engineering “V” with the associated organizational impacts throughout the process. Thorough early systems engineering efforts have the potential to close knowledge gaps. These CCTD processes are recommended as updates to ERAM in Version 2.1.

Resource #5: The ABCs of Concept Evolution: A Better-Informed Materiel Development Decision for USAF Programs

The Concept Initiation briefing addresses the MDD leading up to MS-A. It addresses the relationships between systems engineering, DP, S&T, and the CCTD. It acknowledges changes to the JCIDS that eliminated the Functional Solutions Analysis (FSA) and the Analysis of Material Alternatives (AMA) but the knowledge resulting from these types of studies is still required to support MDDs and MS-As. It discusses a paradigm shift where the shift is from technology focus to capability focus. Early systems engineering is critical to transform the technology into meeting a capability gap. CCTDs are becoming a critical element of the early systems engineering process to support MDDs and AoAs. (Loren 2010) Early systems engineering as updated in the model has the potential to impact later impacts to the process. Understanding these early system engineering impacts may reduce overall program cost as decision makers have the necessary knowledge. These references and activities need to be incorporated into ERAM.

Resource #6: Weapons Systems Acquisition Reform Act

WSARA updates Title 10 of the US Code in several areas to improve the acquisition process in DoD. For example, to improve the cost estimates for major defense acquisition programs (MDAP), a Director of Cost Assessment and Program Evaluation (CAPE) is directed to place an improved emphasis on cost estimation. Other events impacting the model include competitive prototyping requirements which impact acquisition and contracting strategies. This is related to the new adjustments to DoDI 5000.02 policy (US Congress 2009). Additional oversight has the potential to provide more accurate cost estimates with less of an impact for cost growth and program breaches. Although these cost estimates may add time early in the process, the PMs may have a more accurate assessment of their program This would potentially reduce later program inquiries from Congress or Headquarters personnel. More accurate program cost estimates aid in closing knowledge gaps for acquisition professionals. ERAM needs to explicitly model these changes and impacts.

Resource #7: Acquisition Improvement Plan

As a follow-up to WSARA, the Air Force made a commitment to improve various acquisition processes based on lessons learned from past acquisition programs with negative outcomes. Secretary Donley and General Schwartz stated: "This plan focuses our efforts and will serve as our strategic framework for the critical work of modernizing and recapitalizing our air, space and cyber systems" (SAF/AQ 2009). One of the goals is to improve the core workforce in the acquisition community. "To operate effectively, today's acquisition workforce must be supported by a human resource environment that recognizes the complexity of the acquisition mission and grooms professional journeyman as well as future leaders in all of the acquisition functional specialties" (SAF/AQ 2009). This is especially true as this research reports on observations by key personnel in the acquisition community on the requirements for knowledgeable team members. Additionally, this document identifies the need to improve the requirements generation process. "In the future, there will be acquisition involvement earlier in the Air Force requirements and development process and systems engineering techniques will be applied to assist in the tradeoffs that occur as part of the process" (SAF/AQ 2009). The key to this is in ensuring the constant collaboration with Headquarters, lead commands, and acquisition program offices.   These interpersonal relationships and collaboration will aid PMs to internalize all of the required information. Such changes will need to be accommodated in ERAM.

Resource #8: Space Systems Acquisition Policy

Ashton Carter, USD/AT&L, directed specific acquisition procedures for space programs. Some of these activities go above and beyond the standard DoDI 5000.02 guidance and impact the modeling development efforts in this research.

> "The Milestone Decision Authority (MDA) shall conduct a formal program assessment following the System Design Review (SDR) for space systems. The SDR provides an opportunity to assess satisfaction of user needs through functional decomposition and traceability of requirements from the initial capabilities document (ICD) to the contractor's functional baseline and system specification. An Independent Program Assessment (IPA) shall be provided to support the Pre-System Design Review Assessment (P-SDRA)." (Carter 2010)

These post review assessments with the MDA, to include optional IPA support, add activities with timeline distributions to the model. More importantly they impact the actual execution requirements levied on a SPO. This information is significant to this research as it modifies the DoDI 5000.02 guidelines specific to space programs. PMs are required to be prepared for these multiple MDA looks which are above and beyond standard MDA reviews.

Summary

This literature review demonstrates the ever-changing pockets of guidance and knowledge levied on acquisition professionals within DoD. All of the policy changes are intended to improve program execution. However, the number of policies and their frequency of change levy vast knowledge and training requirements. Wirthlin's dissertation showed the complexity of the knowledge network PMs are required to distill into something executable. Several policy documents and memos in this review showed the many nuances in oversight required at various stages in the process. Others attempt efficiency improvements in acquisition.

Early systems engineering was identified as a critical element in program improvement. Ultimately, all of these elements show areas where acquisition professionals need to quickly understand requirements and acquisition program details for complex space programs. Incorporating and addressing these elements in ERAM fills an important knowledge gap for both the researcher and practitioner of weapon system acquisition.

III. Methodology

The research team performed qualitative social science research with the objective of building and refining an existing quantitative discrete event simulation model to be utilized by SMC and SPO XR branches as a decision support tool during early concept analysis.

3.1 Research Scope

The focus of this research is to analyze and model the discrete events for Air Force space programs from capability gap analysis through MS-C of the acquisition system, more specifically, the early front-end area of capability gap analysis, requirements validation, DP and early acquisition. Focusing on the front end of ERAM 1.0 limited the literature reviews and key personnel interviews to OSD, Acquisition, Technology & Logistics (OSD/AT&L), Secretary of the Air Force, Acquisitions (SAF/AQ), AFSPC, SMC, the Aerospace Corporation and government support contractors. Although some of the discussion with key requirements personnel included the cyber and information technology (IT) domain, the modeling implementation remained focused on space capability requirements and programs.

The PPB&E and Test and Evaluation (T&E) processes were not expanded beyond what was previously developed in ERAM 1.0. PPB&E is the calendar driven funding process; the detailed formal budgeting process will be a topic left to future research to increase the fidelity of ERAM. Certain elements in the model have incorporated checks for available funding, ICE, and above-threshold cost increases, however, do not identify the specific activities and decision points as well as their duration distributions and probabilities, respectively. Uncertainty events which occur in the model may have ties to budget directives and decisions and will be based on out-of-cycle budget cut drills and other events gleaned from ERAM 1.0

Similarly, analysis of the T&E activities identified in ERAM 1.0 was not included in the scope of this research. Since it is such a critical and timely activity in any capability development, this is a prime topic for additional research, e.g. identify, document and update ERAM with the differences between aerospace and space T&E activities.

3.*2 Research Objectives*

At the beginning of the research effort, the following objectives were identified and agreed upon by both the customer (SMC/XR) as well as the research team (AFIT/ENV).

1) Review and update ERAM 1.0 (predominantly focused on post MS-B activities and generalized USAF acquisition processes) to ERAM 2.1 for space programs. These include:
   a. Implement corrections identified when transferring the model from *Arena*® to *ExtendSim*© modeling software (ERAM 1.1)
   b. Ensure updated DoDI 5000.02 representation and acquisition system processes (ERAM 1.2)
   c. Incorporate modeling parameter knobs to adjust certain model sensitivities, e.g. a SPO Experience matrix, ACAT, and technology readiness levels (TRL) (ERAM 2.0)
   d. Research and reflect, where applicable, capability gap analysis, JCIDS, and DP processes (ERAM 2.1)
2) Validate utility of the model and how it can be used in existing early requirements and acquisition processes
3) Identify additional research requirements for future versions of ERAM

3.3 Methodology

In order to achieve the objectives of this research, a five phase approach was established and is illustrated in Figure 5.

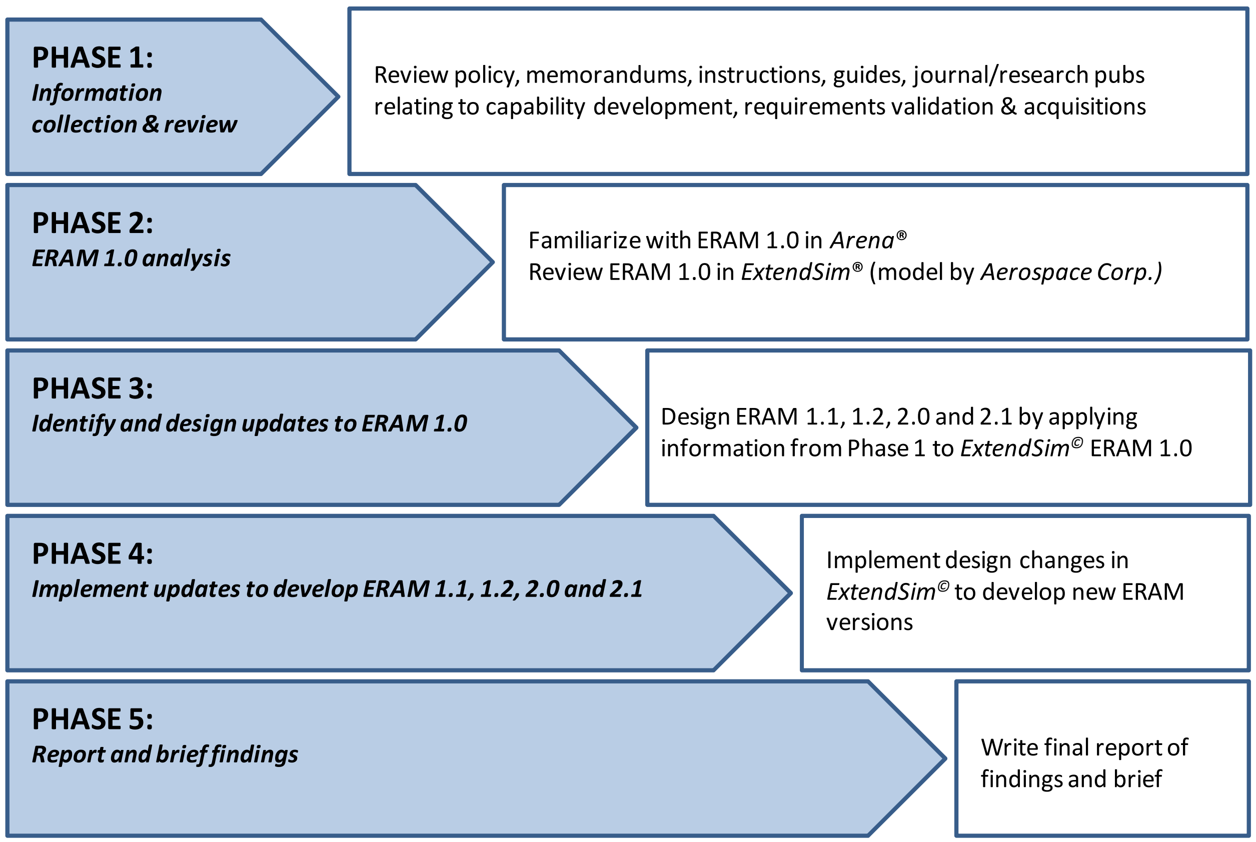


Figure 5: Group Research Project (GRP) Phased Approach

3.3.1 Phase 1

The first step was to review statutes, official DoD and Air Force regulations, instructions, guides and publications as well as applicable journal articles and research papers. Figures 6 and 7 provide a glimpse into the complexity and interdependencies of the policies and instructions.

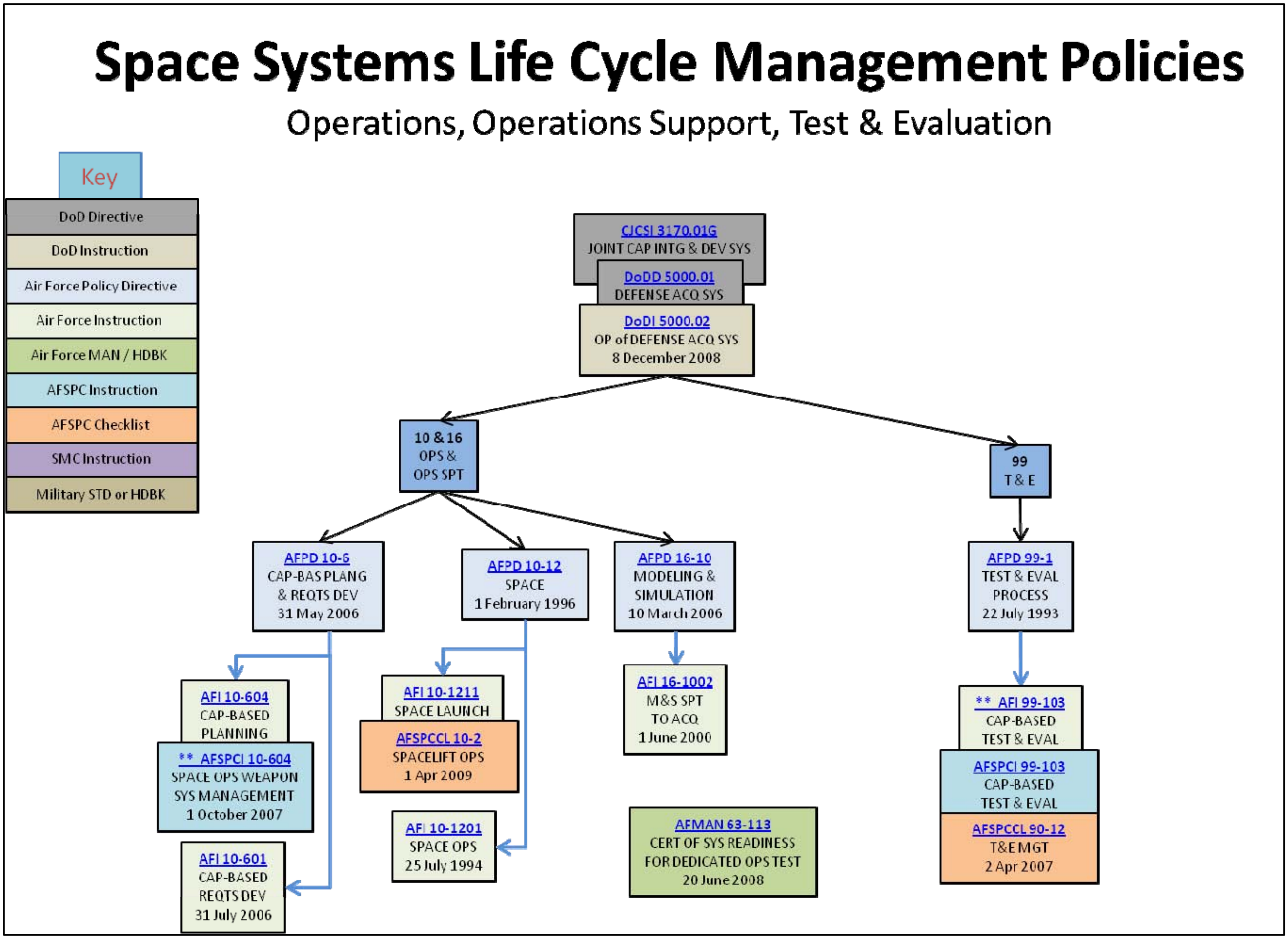


Figure 6: Ops/Ops Support/T&E (SMC/SLX 2011)

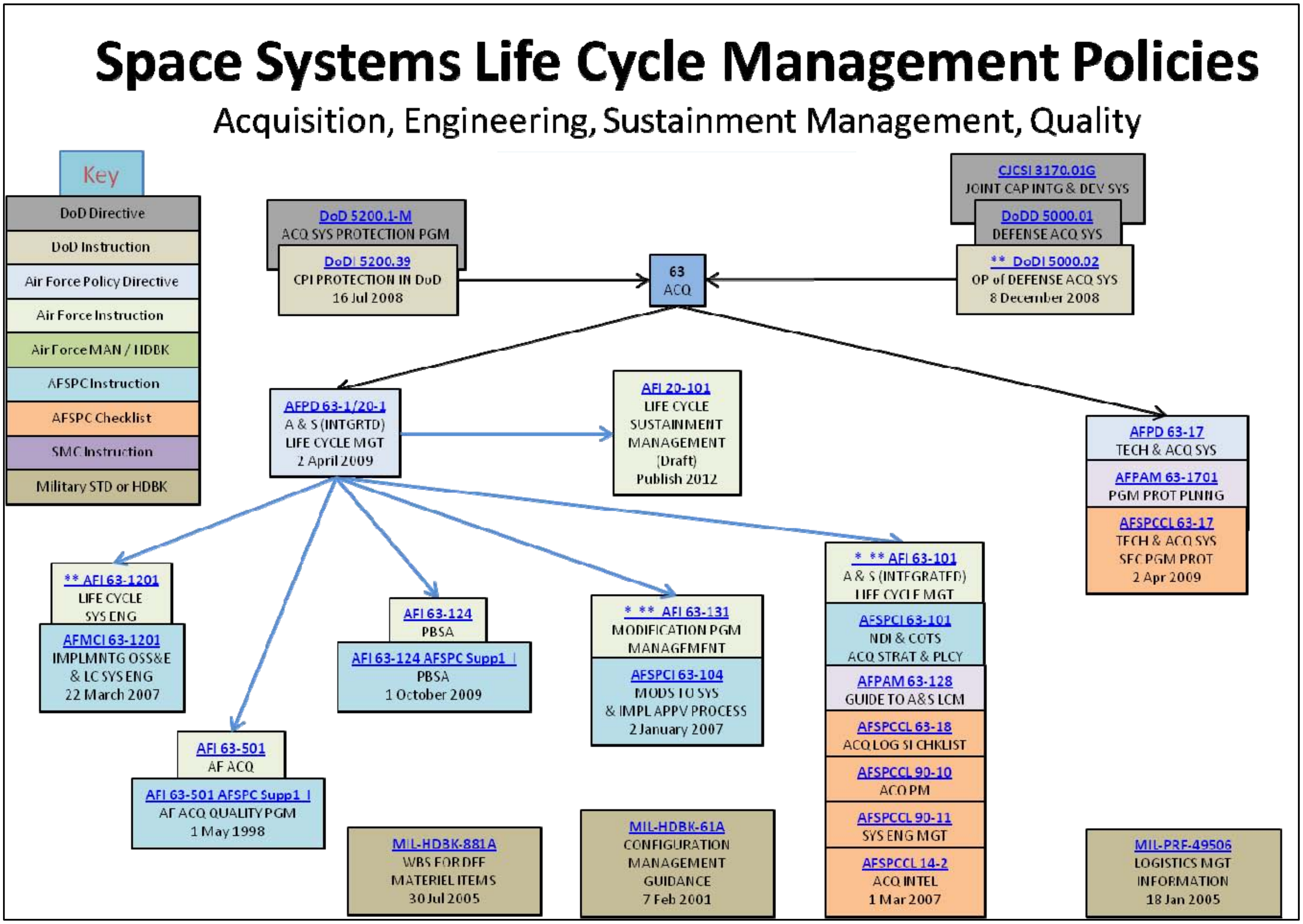


Figure 7: Acq/Eng/Sustainment Mngt/Quality (SMC/SLX 2011)

There are a significant number of references that establish the framework for how to develop and deliver new space capabilities. Figure 8 represents the primary sources of policy information utilized in this research effort, a subset of instructions from Figures 6 and 7, and what portion of the "system" they are most closely related to (vertical alignment). The challenge was identify the linkages between the activities and the various decision points that occur between capability gap analysis, requirement validation, DP, S&T activities and executing the acquisition.

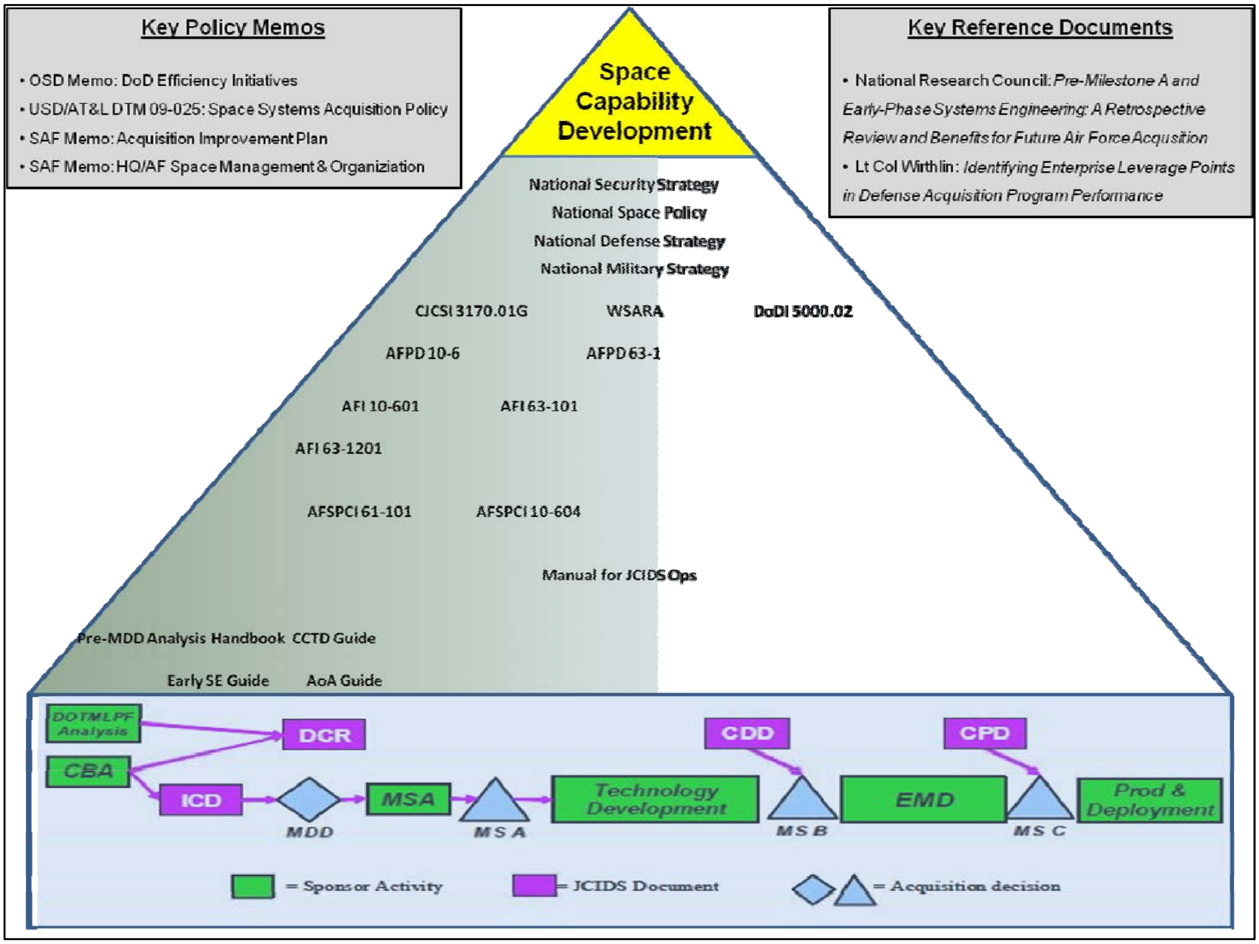


Figure 8: Pedigree of Guidance for Space Capability Development

The second step of phase one was to conduct interviews with SMEs familiar with capability gap analysis, requirements development and the acquisition process. These were semi-structured interviews using purposeful and snowball sampling. Purposeful sampling identified known SMEs (military, government civilians, Federally Funded Research & Development Contract personnel and support contractors) from SMC, AFSPC and SAF/AQ, each of which had significant experience in the acquisition and requirements career fields. The interviews provided a perspective from where the policy makers and senior leaders are most likely to impact timelines and coordination cycles on required acquisition documentation. "In sociology and statistics research, snowball sampling is a technique for developing a research sample where existing study subjects recruit future subjects from among their acquaintances" (Castillo 2009). Through the course of the interviews, additional names of SMEs were provided that could help answer specific questions regarding activities in several of the phases of the capabilities development system. Some of the questions asked include the following:

1) Describe what processes you've been involved with regards to space capability development (i.e. gap analysis, S&T, JCIDS documents, DP, and/or acquisitions) and with which program

2) Describe the specific activities and decision points for the processes you've been involved in from question 1.

3) What reviews and documentation were required for your program?

The complete list of representative questions can be found in Appendix C.

3.3.2 Phase 2

After completing phase one, the next step was to verify the current baseline program, ERAM 1.0, had been transferred correctly from *Arena*® to *ExtendSim*® software. Feedback was provided to SMC/XR's Aerospace software engineers with any discrepancies or recommended updates identified. The primary reason for transferring the system to *ExtendSim*® was to lower overall distribution costs; licensing for a wider distribution of *Arena*® versions of the modeling software would be cost prohibitive.

In addition to familiarizing themselves with ERAM 1.0 in *ExtendSim*®, the research team reviewed the associated doctoral dissertation, "Identifying Leverage Points in Defense Acquisition Program Performance" and met with the author on a regular basis to better comprehend the methodology used to create the ERAM 1.0 framework. The research team also participated in frequent meetings with the SMC/XR Aerospace team that implemented the *ExtendSim*® version of the model. A hardcopy of the ERAM 1.0 was printed out to help facilitate visualization of the process; it requires 9 large butcher paper sheets pasted together to form a single picture, as shown in the photograph in Figure 9 (the ninth page is behind Major Leach).

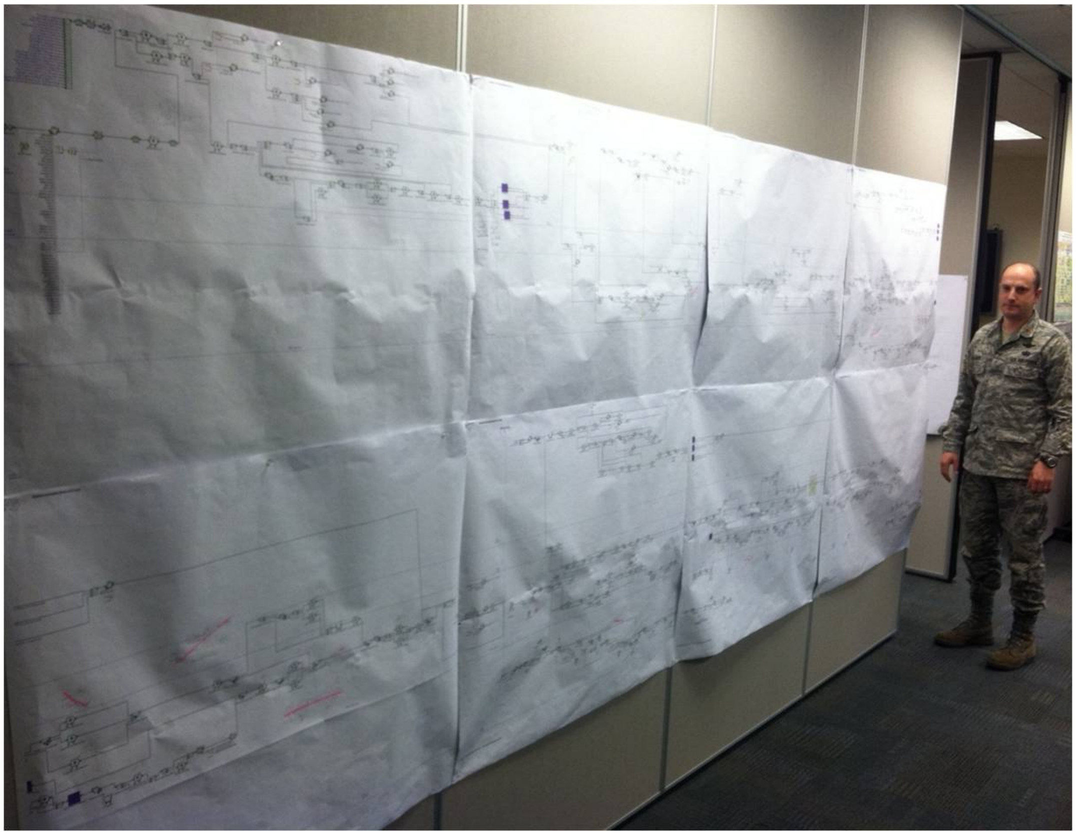


Figure 9: ERAM 1.0 Printout

In meetings with the Aerospace implementation team in Los Angeles, the printout was displayed in several locations to clarify portions of the model and identify where the various corrections and updates would occur. These updates would include developing the model triggers identified as an output of the AFSPC Integrated Planning Process (IPP), the JCIDS document development activities and DoDI 5000.02 activities.   Figure 10 is an example of one portion of ERAM close up to see individual elements.

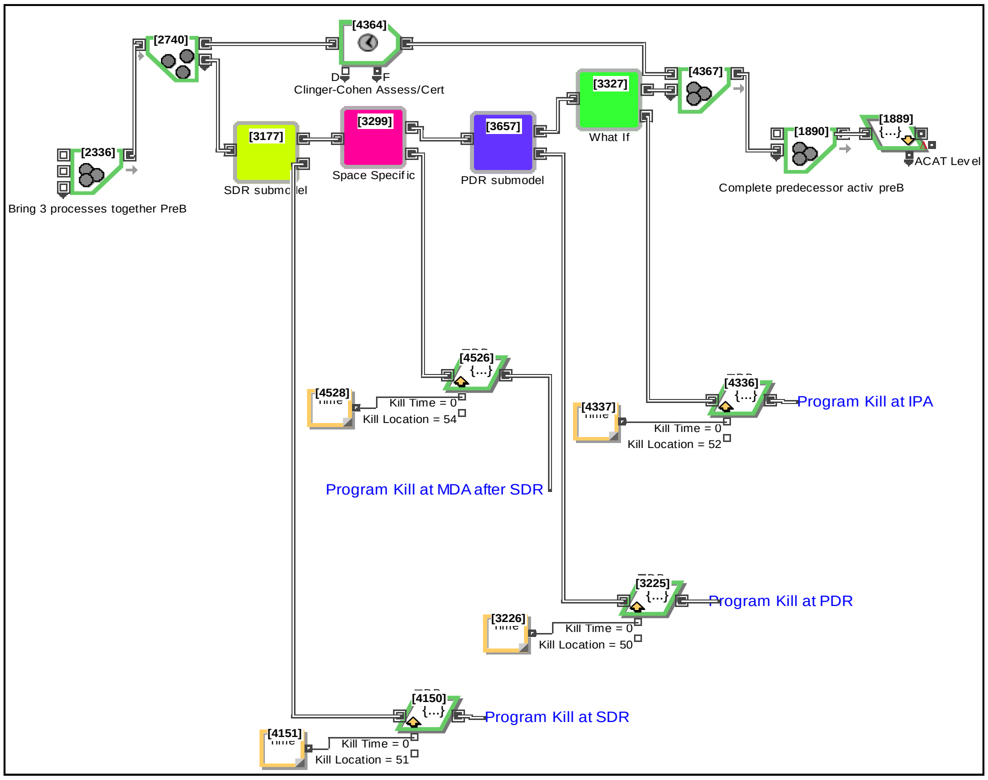


Figure 10: ERAM 1.0 Close Up View

For purposes of this discussion, five of the many *ExtendSim*® icons are described and illustrated in Figure 11. The "Event/Activity" icon is implemented with a time duration allowing a distribution to be selected. For this research, triangular distributions were implemented based on the data elicited from personnel. The "And Merge With Wait" waits for all the inputs to arrive before proceeding to the next event. The "Or" icon uses Boolean logic to proceed if either of the inputs occur. The "Decision Point" output is based on the likelihood of an event to occur. The probabilities of each event are entered into the properties of the icon.

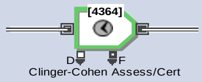
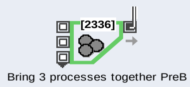
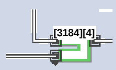
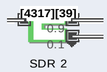
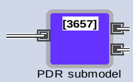
ExtendSim Icon	Function Name
 [4364] Clinger-Cohen Assess/Cert	Event/Activity
 [2336] Bring 3 processes together PreB	And Merge with Wait
 [3184][4]	Or
 [4317][39] SDR 2	Decision Point
 [3657] PDR submodel	Submodel

Figure 11: ExtendSim Icons

3.3.3 Phase 3

The third phase focused on determining how to update *ExtendSim*® software code from ERAM 1.0 in order to develop the coding implementation plans for ERAM 1.1, 1.2, 2.0 and 2.1. The research team identified required updates in collaboration with the SMC/XR Aerospace team by providing model design inputs via Microsoft Visio diagrams, Microsoft Word documents, teleconferences, in person meetings, plain text and *ExtendSim*® drawings.

For ERAM 1.1, while transferring the model from *Arena*® to *ExtendSim*©, the Aerospace Corporation and the research team identified several portions of the model (specific activities) that didn’t apply to space requirements and acquisitions or activities that hadn’t been included. Recommended coding changes were diagramed and validated by referencing the sources reviewed in phase one.

ERAM 1.2 design updates were identified by analyzing the updates that occurred between the March 2003 and December 2008 versions of the DoDI 5000.02. Additionally, design updates incorporating guidance from the DTM 09-025 SSAP were included.

ERAM 2.0 further improved the fidelity of the model by establishing parameters for the model that would adjust the outputs. Essentially, these are the settings or "knobs" that can be changed prior to running the model and include factors such as SPO Experience Level, ACAT level (for space programs, almost always ACAT-1D), TRL and what JCIDS documents may or may not exist. To model the human factors influence on a program, a SPO Experience Matrix was created that included acquisition experience level, resource availability, staff experience, external program support, etc. The user input of this matrix globally impacted certain ERAM activity distributions. The details of this will be discussed further in Chapter IV.

The final version, ERAM 2.1, incorporated the largest software update. This increased the fidelity of ERAM 1.0 by identifying and incorporating the activities that occur early in the capability development, to include user-selected JCIDS concepts options (following output of AFSPC IPP e.g. paper concept, Advanced Technology Demo (ATD), Joint Urgent Operational Need (JUON, others), as well as JCIDS and DP activities preceding MDD. Information for this update was gleaned from Chairman of the Joint Chief of Staff Instruction 3170.01G (CJCSI 3170.01G), CCTD Guide, the AoA Guide, Early Systems Engineering Guide and Pre-MDD Handbooks as well as through iterative discussions with SMEs located at AFSPC/A5 and SAF/AQRE. Document reviews guided the first draft of an activity diagram representing the flow of the early activities. Subsequent iterations of the diagram were updated based on feedback from AFSPC/A5 and SAF/AQ SMEs to validate the activity flow. Additionally, the SMEs assisted in defining timelines for activities within the model for most likely, worst and best case timelines for the activities as well as the decision point probabilities based on historical experience. Another valuable source of data was the Requirements and Management Plan (RAMP) initiative developed by AFSPC. This was a recently developed work breakdown structure (WBS) that identified all activities at AFSPC/A5 and was a useful tool for identifying best case timelines or policy-directed timelines for various discrete events within the JCIDS and acquisition processes. The AF/A5 website was also referenced and provided estimated coordination and approval timelines for achieving a Joint Requirements Oversight Council (JROC) approved ICD.

3.3.4 Phase 4

This phase involved implementing the ExtendSim® code design changes developed in phase three by leveraging an established collaborative working relationship between the research team and the SMC/XR Aerospace software engineers. With the required design changes developed in the previous phase, the software engineers made the necessary programming changes to ERAM 1.0. Various interactions and follow-up conversations were made to clarify programming inputs. After clarifying certain aspects of the code, the teams collaborated to provide one another feedback. When code was implemented, it was released for review with clarification questions. The research team answered the appropriate inquiries based upon policy, guidance, and interview notes.

3.3.5 Phase 5

At the conclusion of the effort of the first four phases, the results were captured in this research report. It includes notes from the interviews, information from the policy documents, elements of the programming code as well as general observations/opinions about space capability development. During the interviews, the researchers took notes, transcribed them, and then coded them or extracted common themes to incorporate into the report. Additionally, the literature review revealed other pertinent themes which were then incorporated. Results of the programming updates were included in their appropriate sections.

Another aspect of the research included reviews of other acquisition modeling activities. In the socialization of this research with various organizations, similar but not duplicate modeling efforts were discovered some of which were inspired by the methodology used by Wirthlin (2009). Many of the different developments were not known by the other parties. The following models and/or tools were reviewed: 1) Acquisition Process Model (APM) (http://acpo.crethq.com/acpo.htm); 2) Acquisition Document Development and Management (ADDM); and 3) RAMP. Further discussion of these is in Chapter V.

3.4 Assumptions

Development of space based technologies is outlined in the AFSPC Instruction 61-101 (AFSPCI 61-101), Space S&T Management (18 October 2007). This instruction documents the process of identifying and prioritizing which space science and technologies are worthy of investment in order to reach future strategic objectives and is executed through the AFSPC IPP. Figure 12 provides a summary of the activities flows of this process.

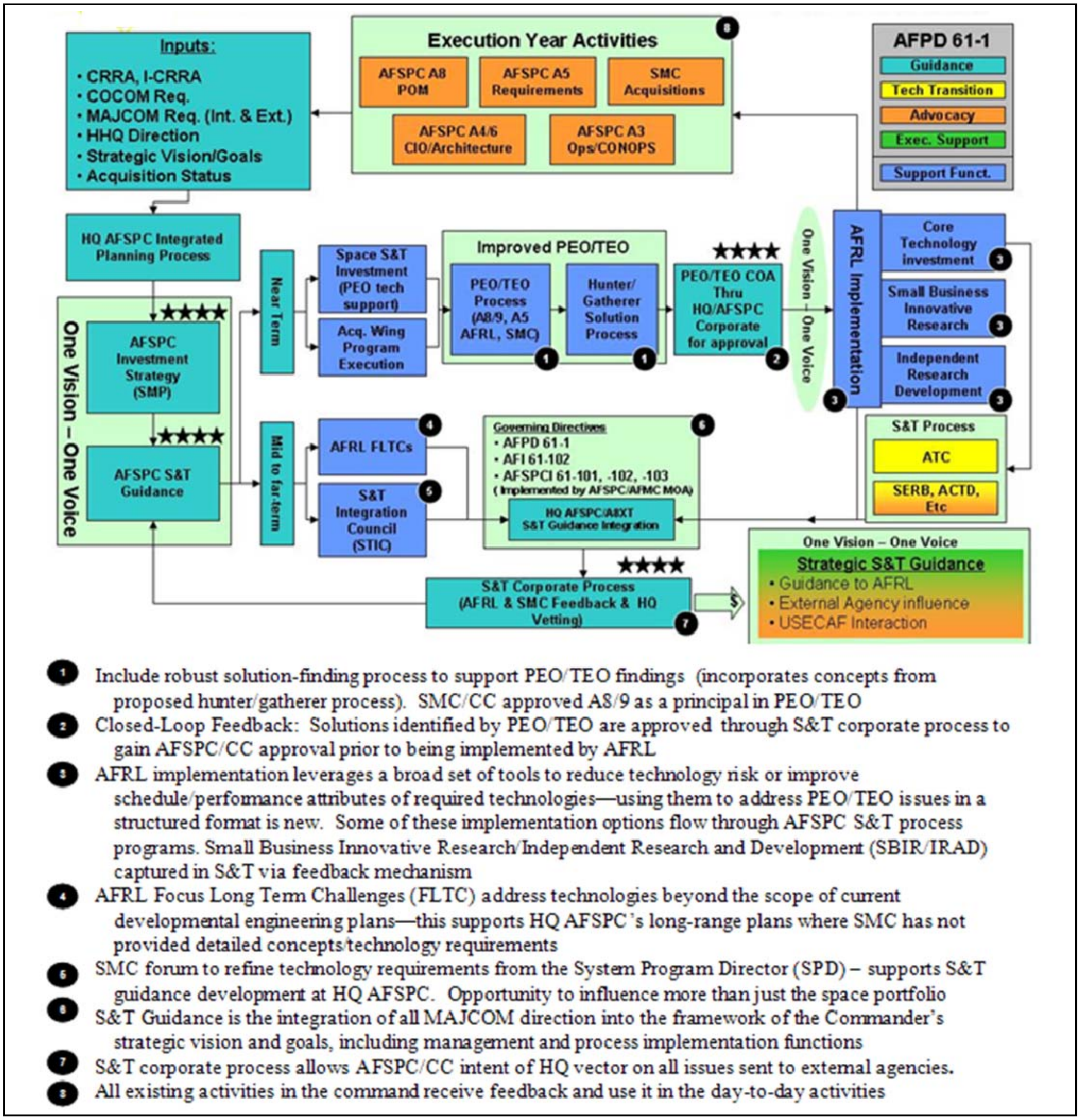


Figure 12: Major S&T Process Elements (AFSPC 2007)

Since the IPP is continually evaluating and selectively funding specific S&T activities that support identified Mission Area Architecture gaps and occurs in advance of concept consideration, this was not included in ERAM. It is a very important process, but doesn't fall within the scope of the objectives of this research.

3.5 Limitations

Despite research efforts to identify all sequential/parallel activities that occur early in capability gap analysis through MS-C of a program and the decision probabilities at the various junctions, as with all models, there are limitations to ERAM. Some of these are generic to all models while others are specific to ERAM. For example, modeling personalities and human behaviors is extremely difficult. Personalities can have a significant impact on interpersonal relationships which can have influence on the success of a program. If the PM has a positive relationship with the MDA, the likelihood of a positive review may be higher. This is highly subjective and a challenge to quantify in software code.

1) Generic modeling limitations include scope and schedule risks. The number of all the events of the acquisition and requirements processes could lead to several thesis and dissertations to improve model robustness. The researchers needed to limit the focus areas and allow for future research to continue improving ERAM. The schedule for this project was bounded by immovable schedule deadlines. Heldman notes: “When none of the constraints are negotiable—watch out” (Heldman 2005). Therefore, the scope had to be clear and adjustable as deadlines grew near and understanding of the model increased.

2) A significant common factor in all activities within capability analysis, requirement development/validation and executing the acquisition program is that all are heavily influenced by the personnel involved on the program. This is the human factors element that is extraordinarily difficult to accurately capture in the model. A sampling of these issues are identified in Table 3.

Table 3: Human Factors

Human Factor	Characteristic	Impact
Military Personnel	Turnover ~2-4 years	Loss of technical/contract/ program knowledge negatively impacting program
Elected Officials	Turnover ~2-4 years	Funding, strategic prioritites
Key Personnel	Leadership/Management/ Interpersonal Relationships	PM, CO, and JAG can each individually have drastic impacts on program performance
Senior Leaders (OSD, MDA, PEO/SP, AFSPC/CC, AFSPC/A5, SAF/AQ)	Turnover ~2-4 years	Program priority resulting in change in available resources, sponsorship
Govt support contractors	Quality and Technical Competency	Experience and qualifications can result in insufficient/inadequate program support
Federally Funded Research & Development Center (FFRDC) Contractors	Availability	Insufficient technical support impedes government's independent assessments
Industry Personnel	Management & Technical Performance	Profit versus schedule and cost prioritization

For instance, military personnel are rotating every 2-4 years. Space programs can easily last ten to fifteen years, implying there will be a significant turnover at the SPO all the way up to DoD senior decision makers. This turnover in personnel can be either very beneficial or detrimental to the original schedule, but, in either case adds significant variability to ERAM results. Certain key personnel positions in the requirements and acquisition system can significantly influence ERAM outputs. For example, in the acquisition system, the PM and contracting officers (CO) are critical positions to the execution of the program. The PM position is competitively managed by Air Force Personnel Command (AFPC) as a Materiel Leader. Strict qualification requirements are levied and a board of senior Air Force officers selects from qualified candidates to fill the positions. On the contrary, the CO is more often than not filled by who's available at that location; they are essentially a high demand, low density Air Force asset.

The CO may or may not be technically competent or have past performance qualifications to successfully support the schedule and cost constraints of the program.   Common feedback from interviewed PMs was that a CO's "can do" attitude or "can't do" attitude can critically impact schedule objectives. Additionally, the performance of industry personnel were difficult to model. Depending on the profitability of a program, it may or may not have the "all-star" personnel assigned to it.

ERAM 2.0 attempts to capture the impacts of these human factors by having a parameter that can be adjusted based upon the composition of the team. However, this does not fully capture the variability that people contribute to the system. The success or failure of a program is greatly impacted by the levels of education, motivation, acquisition experience, and personality of all team members, both on the government and industry teams. The column headings below relate to the human factor indicators in Table 3 as they impact the variables in experience and qualifications of the program office team.

Table 4: Acquisition Maturity Potential Matrix

Acquisition Maturity Potential Matrix						
	Senior Leadership Experience in position	Staff Experience in position	Senior Leadership Cohesiveness	Staff Certifications, Training and Motivations	External Program Support	Program Office Size
Level 0	Has less than 1 year experience	Has less than 1 year experience	Has not worked together	Staff has minimal Acquisition training; few if any certifications	No interest beyond MAJCOM	No formal program office yet
Level 1	Has 1 to 3 years experience	Has 1 to 3 years experience	Has worked together for less than 6 months	Staff has some Acquisition training & Certifications	Some interest	Less than 50% of authorized staffing Level
Level 2 Baseline	Has 3 to 5 years experience with Acq processes	Has 3 to 5 years experience with Acq processes	Has worked together for 1 year	All Staff has some Acquisition training & Level I Certifications	Senior leadership helping with Acq process	Between 50% and 70% of authorized staffing Level
Level 3	Has years of Acquisition Experience	Has years of Acquisition Experience	Has worked together for 1 to 3 years	Motivated, certified (some Level II) and trained staff	Senior leadership wants program to go	Greater than 70% of authorized staffing Level
Level 4	Has been steering program through Acq Process	Has been steering program through Acq Process	Has worked together for 3 to 5 years but not more	Highly motivated and trained staff (Certifications Levels I, II, and III as appropriate)	Senior leadership and congressional interest	Fully staffed to authorized staffing Level

ERAM 2.0 adds a global variable of acquisition capability into ERAM 1.2. Table 4 identifies areas where an ERAM user can identify the appropriate level to reflect the capabilities of the

SPO.   Appendix B documents the activities selected that will be impacted by this global variable. This variable has levels from 0 to 4 which modify the triangular distribution impact for the timelines of the discrete events.

3) Challenges in modeling the activities in the requirements process are found where the urgency for a capability receives various levels of advocacy from senior leadership. If a program is influenced a certain way, some of the modeled process could be waived or bypassed. However, through this research, no distinguishable pattern was found for waiving processes. Leadership may change which increases or decreases momentum behind a program. Programs could "sit on hold" for years while different political processes churn. On the other hand, urgent needs could enter the process at varying points. Although the rapid capability acquisition framework was designed for ERAM, further research is required to implement this process. Even when it is implemented, there will remain a level of uncertainty as to how personalities will influence this unique process.

4) This research approach did not add any further PPB&E activities to ERAM 1.0. Although there was a cost growth check during technology development, no further events were added to the model. This calendar driven process was also simulated at a certain level in ERAM 1.0 and to add further detail to that model would be outside the scope of this effort. It is left for further research to include higher fidelity modeling in this category.

5) The probability of the various triangular distributions on event timelines in later versions of ERAM is based on a small sample size due to the limited number of available personnel for interviews. Schedule constraints also limited access to SMEs in certain areas. Further research should increase the sample base and improve the fidelity of these distributions.

6) OSD has the authority to issue a Resource Management Decision (RMD) to a SPO directing specific actions for their program. This can occur at any time during a program. Since this is such an unpredictable event, this will be left for further research to determine the best model entry points. Examples of the RMD could include specifying an acquisition strategy, downward directed contracting methods, or other directives, all of which could significantly impact the timeline to reach MS-C.

7) PMs and other SPO personnel may have irregular tasking or requests from outside agencies. These events occur outside the regular flow of the process model. These irregular “firefighting” activities that acquisition personnel accomplish are partially modeled in uncertainty events which were included in the original ERAM and are also explained further in this research paper. However, due to the unpredictability of these events, they are not modeled explicitly for every possibility. The number of permutations or possibilities is too large to accomplish in this effort. The actual performance of any process depends on two factors: the amount of time spent working and the capability of the process used to do that work (Repenning and Sterman 2001). Figures 13 through 15 below shows how there is a balance needed between spending resources improving the process and the time spent working on the current activities. Two approaches are “Working Harder” and “Working Smarter”.

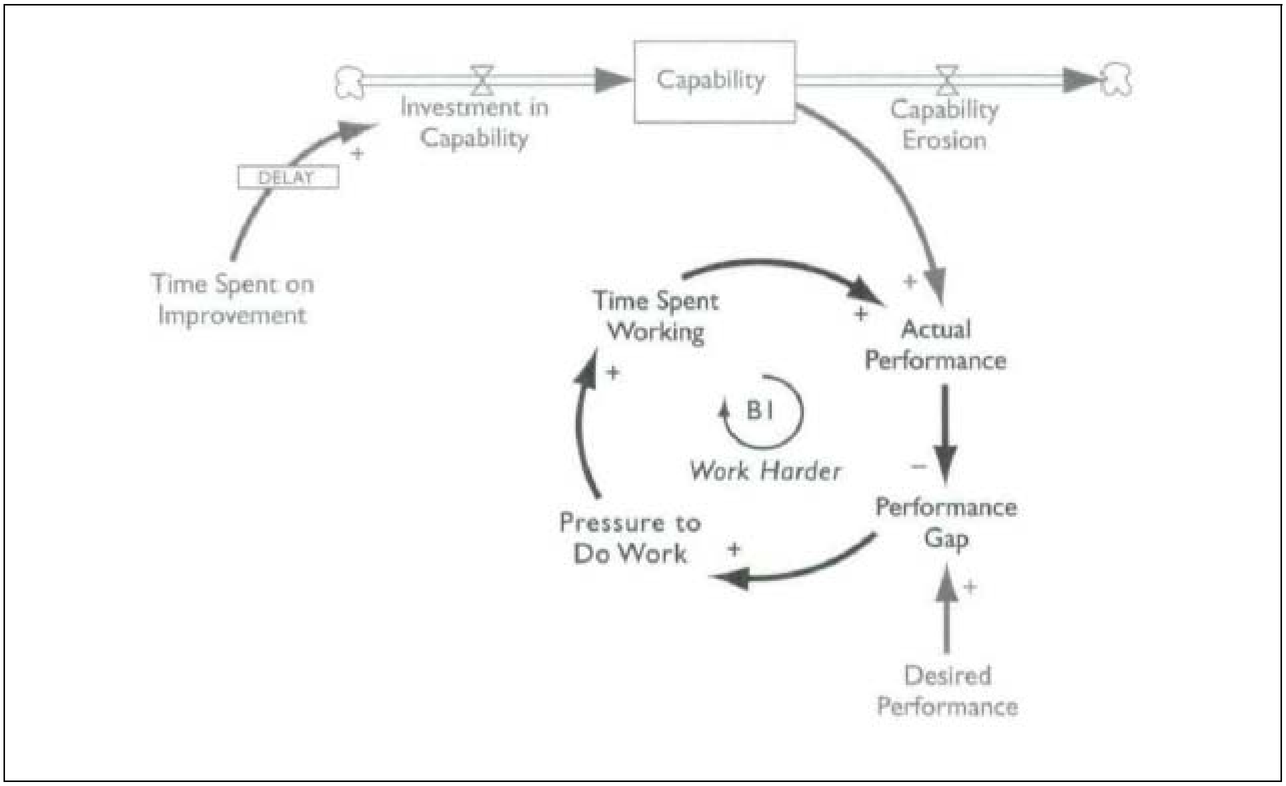


Figure 13: Work Harder Balance Loop (Repenning and Sterman 2001)

Figure 13 describes a process where an organization focuses on the current activities or "fires". Training and other improvement efforts are put on hold. In the Work Harder loop as performance expectations are not met, pressure to produce more increases which lengthens the time spent working. However, as an individual's time is maxed out working the current issues, this model demonstrates that long term performance decreases.

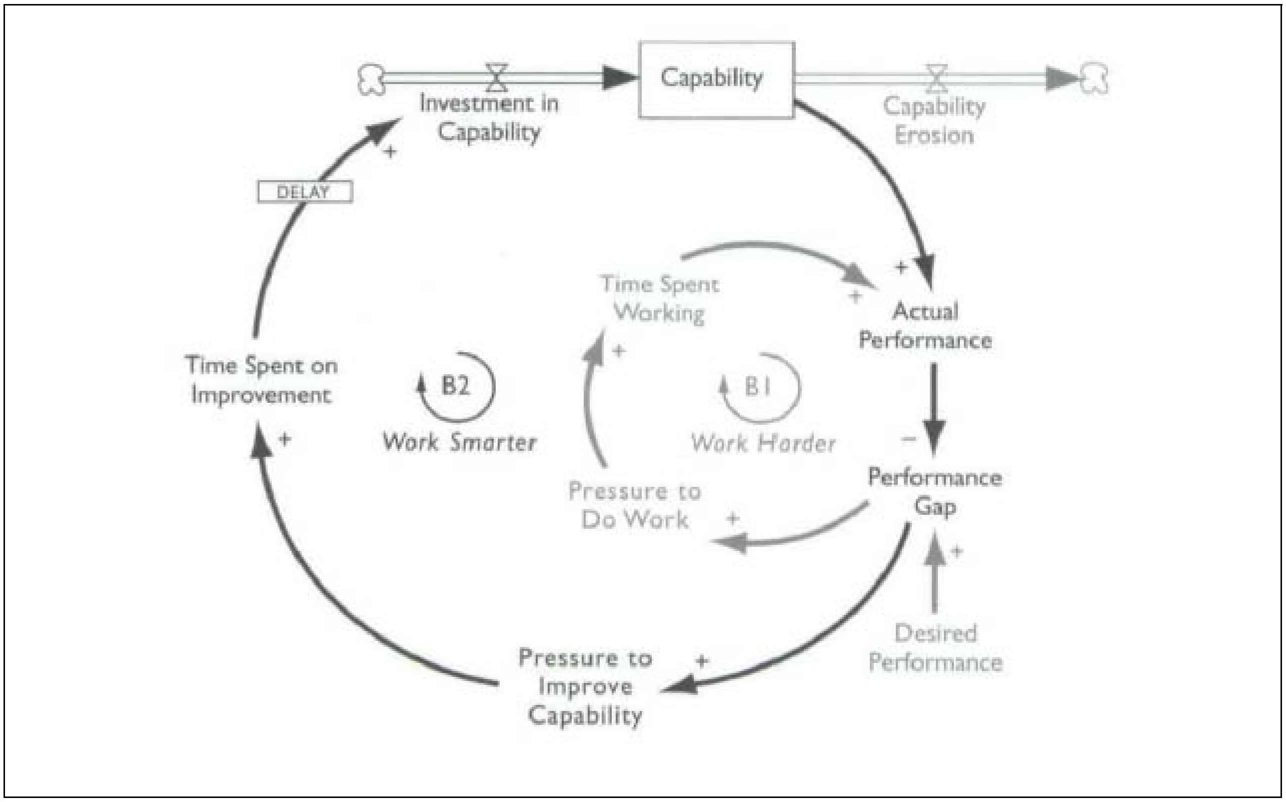


Figure 14: Work Smarter Balance Loop (Repenning and Sterman 2001)

Figure 14 shows a cycle of competing demands of working current issues and the pressure to improve overall capability. When the desired performance doesn't meet the current performance, time is invested in improving overall capability. If too much emphasis is placed in improving capability, actual performance decreases. If too much time is spent on improvement, resources are removed from actual current work requirements.

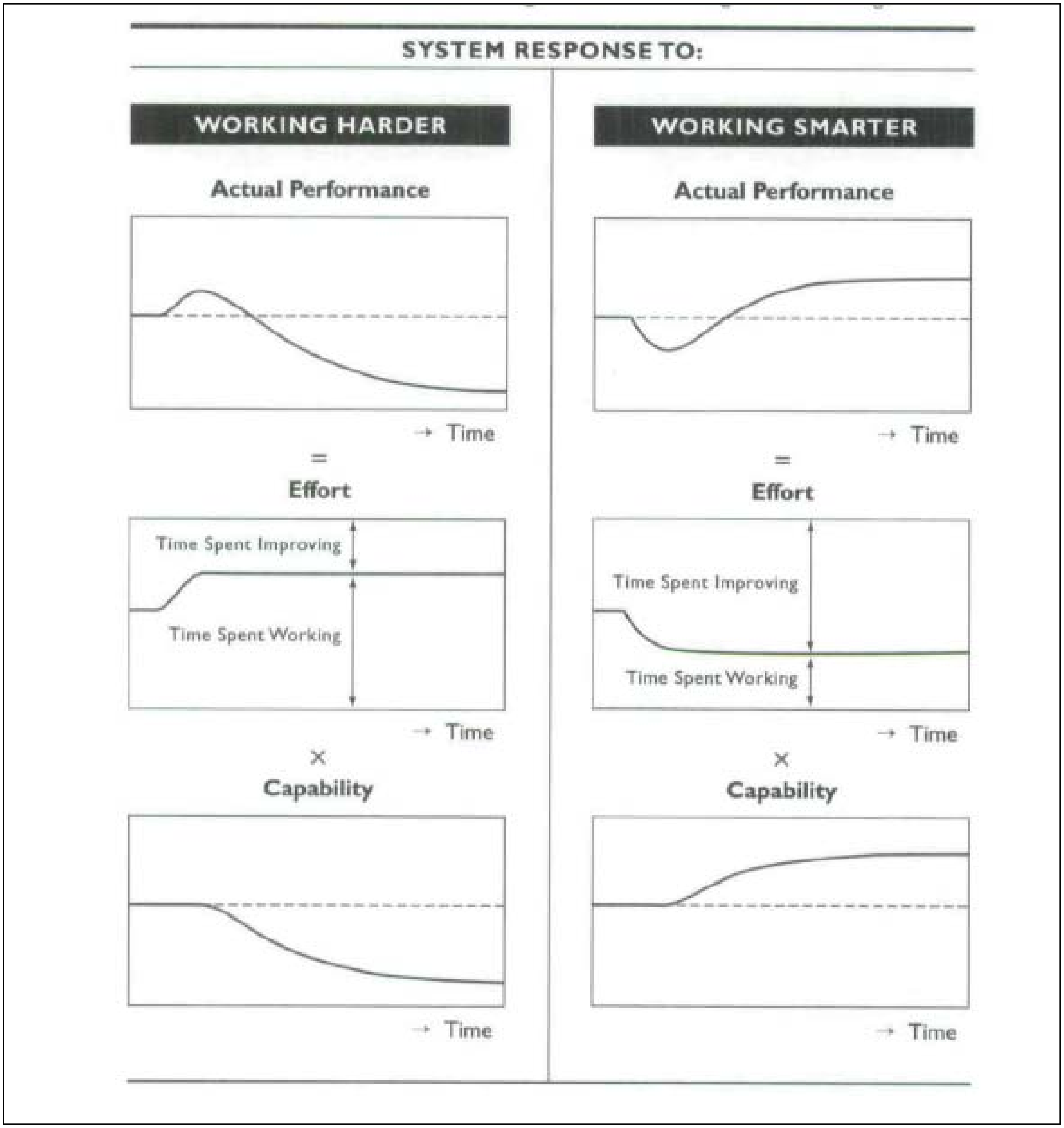


Figure 15: Simulations of Working Harder and Smarter Strategies (Repenning and Sterman 2001)

Care is needed in determining this balance. As seen in Figure 15, when the majority of the emphasis is spent on working current "fires" or issues, there is a net decrease in capability and performance. When there is a balance of time spent improving capability, there is a short term decrease in performance but it rebounds into an overall net increase in both capability and performance on the current tasks. As this balance is achieved, the uncertainty resulting from "firefighting" should reduce and predictability in productivity should increase. As the ever increasing demands on personnel in DoD acquisitions coupled with personnel decreases, it is challenging to anticipate a situation where it will be easy to strike the balance as military personnel only remain in their positions for a short period of time. If they invest in capability improvement, the net increases in capability will not be realized during their tenure. In fact, if they implement process improvements, they may be in the short term productivity "well" shown in Figure 15 (top right graphic). Understanding leadership and applying these human factors are considerations in modeling the acquisition process for ERAM.

8) The capability gap analysis, requirements development, JCIDS process and acquisition system change significantly every 10 years or less. The names of documents, processes, reviews, and others change frequently. Therefore, to find historical data upon which the outputs of ERAM are based upon was extraordinarily challenging, especially for space. Space programs take 10-15 years. Due to budget constraints, it appears that new program of record starts will be very rare. Current programs of record will be modified and upgraded in place of new starts. Thus the "fuzzy front end" of the requirements process could be iterations of existing programs returning to earlier parts of the acquisition process.

9) Most importantly, it's necessary to accept the fact that every capability development program is unique! Basing the development of a new capability on historical data is inherently flawed since the capability has never been developed and there are an infinite amount of unknown unknowns. ERAM generates a histogram based on data gathered from SMEs in space capability development, but, there is always the chance for an outlier. Just as the prediction of

future stock prices on the financial markets is impossible to do, so is the exact prediction of the schedule for defense capability development. ERAM is a tool to help scope the effort of the problem, but, in no way can guarantee what the realized schedule will be.

IV. Results and Analysis

4.1 Phase 1: Information Collection & Review

4.1.1 Interviews

The researchers obtained information through interviews of SMEs in the space development planning, requirements and acquisition fields. The interviews revealed opinions about problems with existing processes and policy from personal experience as well as specific experiences with process activities and associated timeframes. In an effort to consolidate and filter the large quantity of interview data, the data was coded into common themes resulting from the conversations. Twenty-three SMEs were contacted from SAF/AQ, United States Strategic Command (USTRATCOM), AFSPC, and SMC. Table 5 shows these themes in order from the most frequently discussed in these interviews. Interpretation of this qualitative data resulted in observations and recommendations for ERAM.

Table 5: Research Interview Themes

	Interview Themes	**% Discussed**
1)	SPO/MAJCOM/HHQ Interpersonal Relationships & PM Credibility	74%
2)	Direct Higher Headquarter (HHQ) Involvement	48%
3)	Requirements “creep”	30%
4)	PM Personnel Requirements	17%
5)	DP Funding	13%
6)	Requirements personnel Training	13%
7)	Senior Leadership Direction	9%
8)	Process Flexibility	9%

1) In discussions with PMs at SMC, some challenges identified in the process were that the MAJCOM had to have all their “i’s” dotted and “t’s” crossed until they would let users or HHQs get involved. This “coordination in a vacuum” proved cumbersome and introduced delays into the JCIDS process. When the PM was attempting to meet demands of leadership and perform a rapid acquisition, their experience was that the MAJCOM was not a willing partner

with the goal of speeding up the process. The PM related an analogy that the command lead was analogous to a pet dragon. He would need to be regularly fed, but had the capability to "breathe fire" on the program meaning the ability to significantly impede program progress. The PM had a program to execute with milestones and deadlines to meet, but this "fire breathing dragon" was a matter of bureaucracy difficult to overcome. HHQs was not receiving regular communication due to this challenge at command. PMs were working on balancing relationships with their command leads and HHQ. With the programs limited on staffing and funding at this level, they didn't have the schedule margin or breathing room to spend enough time thinking about the program's strategy.

Another PM's perspective was that the credibility of the PM is what determined the success of the program. By establishing credibility through continuous interactions, constant meetings via teleconference or in person, the program was able to maintain a continuous flow of communication and obtain approval on required documentation in a timely manner. Contrary to what was expected, this classified program completely followed the JCIDS and DoDI 5000.02 acquisition policy without seeking waivers. The program followed guidance from Dr. Ashton Carter's memo dated 14 Sep 2010 for greater efficiency and productivity in defense spending. This guidance included initiatives on affordability, improved cost management, and improved incentivizing of the industry partners. Due to the successful implementation of these measures, the credibility of the PM, and continuous communication practices, this program successfully completed the Defense Acquisition Board (DAB) in a record 41 minutes. Unlike many other space programs, this program had the luxury of hand selecting team members from the SPO to achieve an "all-star" team. The relationship with the SPO and the Program Element Monitor (PEM) was ideal. Each party understood their lanes of the road. Vigilant leadership established credibility and a well established line of communication with HHQs enabling this remarkable achievement.

According to other senior leaders and systems engineers at the center, the proposition that “acquisition is a team sport” was reinforced. The forging of relationships and constant situational awareness of programmatics among all levels was crucial to positive feedback and program success. Indeed, acquisition success was based on the people, their ownership in program success, and the continuous flow of information.

2) A PM identified where a RMD was issued by OSD in order to provide direction to a program. In this case, the RMD was issued to define the program’s acquisition strategy. This is an OSD document to direct a program when the Program Objectives Memorandum (POM) process doesn’t fix problems in the program. It “gets overwhelming fixing problems one year at a time”. Therefore, the process of maintaining levels of communication with HHQs helps to alleviate any misinformation with respect to the expectations of the program.

3) Systems engineering has received a large amount of press with respect to its ability to make or break a program’s performance. A challenge identified by members was the lack of disciplined configuration control of requirements and a clear understanding of how to manage the trade space between overarching system-level requirements and derived requirements. It is extremely difficult for a program manager and chief engineer to manage the technical performance of their program with a “moving target” of requirements. Even when key performance parameters (KPP) are defined and a capability development document (CDD) is signed and delivered to a SPO, requirements creep tends to continue to manifest itself in programs. These are not formal changes to the CDD, they are small changes such as e-mails that don’t get reviewed. The quandary is in how much direction the SPO can provide the contractor

within the scope of the contract without going through an often timely and costly formal engineering change process (ECP). There needs to be some level of control and tracking, but within the proper balance.

4) One PM's approach to balancing programmatic issues was to model the Commander's intent and delivered a PM's intent similar to the Joint Operations Planning Process. This delivered the message and maintained a focus within the members of the SPO. His recommendation was to limit a PM's team to no more than 40 people. This was the maximum amount a single leader could have to be effective and manage the "face time" of the subordinates to provide programmatic direction.

5) The S&T community within the DoD also weighed in on the acquisition process. Many good ideas are developed at the research labs in basic and applied research. As these ideas grow in technological maturity, the lead developer, whether it is the government sponsor or contractor will start to look for sponsorship and advocacy. However, it is extremely difficult in a constrained budget environment to obtain funding for new ideas. One member of the S&T community had been advocating for a program that maintained its priority just below the MAJCOM cut line. DP is never included in cost estimates. The Program Element (PE) or budget line for activities prior to MS-B is not consistently funded or defended during the PPB&E process and is often used as a source of funds to pay other bills. Therefore, these DP activities require sponsorship from an organization with some level of discretionary funding.

6) Continued conversations with MAJCOM personnel highlighted the results of changes and areas of emphasis from the AIP dated 4 May 2009. It states: "Requirements must be acquisition-friendly and produced in a format that is readily adaptable for use during source selection and throughout the acquisition process". The MAJCOM recognized that their

personnel needed to be trained in requirements management and development. Therefore, they developed a requirements certification program. This created a uniform methodology to grow requirements leads and meet the intent of the AIP.

7) AFSPC senior leaders desire the ability to quickly understand the impacts a single program may have across the space capability spectrum. This requires developing and actively maintaining a robust space systems architecture. As capability development program schedules deviate or requirements are modified, being able to identify the implications is currently a timely, costly and difficult challenge, at best.

One example of a challenging aspect of modeling the acquisition processes is the leadership and its influence on the program. According to one perspective, "senior leadership is the wildcard in the process". One program was tackling the multiple organizations vying for opportunities to manage it. It was led by two Program Executive Officers (PEO) responsible for different components of the overall program. With two programs reporting to different chains of command, it was extremely difficult to have any synergy in program execution. This program had an approved Operational Requirements Document (ORD) based on previous acquisition guidance. Nine subsequent CDDs were developed. Five years after ORD approval, the program was cancelled by SAF. The bottom line was that a large acquisition program should not be split between two centers and two PEOs for political purposes.

Although, small programs in theory would have less oversight from HHQ, there are some exceptions. Programs that fall under the Joint Capability Areas (JCA) deemed as "JROC Interest Items" will automatically be reviewed at the highest level. According to one requirements lead, that is "overkill". The JCAs categorized as a JROC Interest Items include: Command and Control (C2), Net Centric, and Intelligence, Surveillance and Reconnaissance (ISR). Therefore, JCIDS milestones for a small ACAT III level program at these JCAs would have several more months of time due to this level of interest. If the proposed capability is a JROC Interest Item, historically, another three months is required to get an ICD written and through the Air Force Requirements Oversight Council (AFROC). Cumulatively, an additional nine to twelve months is required to get a JROC approved ICD. Of note, nearly all space programs fall within the JROC Interest Item category.

8) One criticism of the JCIDS requirements model was the lack of flexibility. Those working in requirements for Information Technology (IT) or Cyber were confronting the challenges of accomplishing the various events of the JCIDS process while attempting to perform these in a rapid fashion in keeping up with the fast moving pace of IT. Senior leadership would perhaps question the slow pace of meeting JCIDS milestones in this cyber or IT environment. For example, if software or a piece of standard computer hardware needed to be upgraded it would require an AoA and other activities. The MAJCOM leads suggested that in the IT world, with the requirement to perform rapid technology refreshes, all of the JCIDS steps should be accelerated or eliminated. This would be able to significantly compress the timelines. The AoA could be replaced with a business case analysis which could be completed in less than a month with a small number of personnel. The MAJCOM lead said “I don’t want the process to be different. It needs leadership to be able to apply flexibility.”

JCIDS Process Inputs:

Of the 23 individual contacts 12 were able to provide input to validate ERAM 1.0 and provide updated information. A portion of the interviews was spent understanding organizational roles and responsibilities. From AFSPC/A5, it is SMC’s responsibility to develop materiel solutions in response to AFSPC’s validated shortfalls and gaps that are discovered in the

CBA. The CBA is a MAJCOM responsibility that is accomplished by an O-6 led Capability Team. The capability teams at AFSPC are identified in Table 6.

Table 6: AFSPC Capability Teams (AFSPC/CV 2010)

Primary Director	Capability Team
A5	Situational Awareness/Command & Control (SA/C2)
A3	Space Protection and Information Operations
A5	Missile Warning/Missile Defense (MW/MD)
A2	Battlespace Awareness/Technical Intel (BA/TI)
A3	Position, Navigation and Timing (PNT)
A5	MILSATCOM
A3	Launch, Ranges and Networks
A5	Operationally Responsive Space
A3	Training, Exercises and Evaluations
A3	Current Operations
A5	Policy and Integration
A8	Total Force Integration (TFI)
A3	Air Expeditionary Force (AEF)
A3	Cyber Warfare
A3	Cyber Operations
A6	Cyber Infrastructure
A3	Testing, Modeling & Simulation
A8	Nuclear Issues and Matters

These Capability Teams request space DP efforts from AFSPC/A5X on behalf of combatant commanders (COCOM) (i.e. Warfighter). AFSPC/A5X has a 30 day timeline to develop a proposal and provide it back to the Capability Team for approval. In addition to DP activities from the Capability Teams, AFSPC/A5X does an annual AF wide data call for DP proposals in early November (AFMC/A2/5 2010).

While accomplishing the DP activity, AFSPC can tap into technical SMEs through SMC/XR or directly through an existing SMC SPO. One of the products of DP from SMC is the CCTD. Ultimately, this early analysis focuses on determining if the Materiel Development Decision (MDD) Acquisition Decision Memorandum (ADM) should direct accomplishing a new Analysis of Alternatives (AoA). Depending on the urgency of the capability, either CYBER

SAFARI (6-9 months) or traditional (8-12 months) DP is accomplished. With an appropriate level of technical analysis and early systems engineering applied during the CCTD development, AoA activities should be reduced from 18-24 months to just 6-9 months. Of note, no space AoAs were accomplished in FY10; three space system MDDs are scheduled for FY11.

The process for developing a CCTD in the DP process is initiated by the MAJCOM. "Capability Teams will meet regularly and frequently and will address the full sets of issues (requirements, trade-offs, human resources, training, infrastructure, tactics and procedures) in defining, developing, fielding and operating a new capability. Capability Teams will be major contributors to the IPP and Corporate Processes" (AFSPC 2008). After an ICD was complete through the IPP, the MAJCOM A5 issued a DP request to the Center XR for a new concept, or to the Center SPO for an upgrade. The Center is given 30 days to provide a DP Proposal back to the MAJCOM. This DP action is in essence the development of a CCTD. These CCTDs can carry single or multiple concepts. The draft CCTD is expected approximately 8 months after start with the final completed by 12 months. The concepts from the CCTD studies are the "alternatives" used in an analysis of alternatives.

The document administrator at HQ/AF is A5RP. A5RP provides guidance on the standardized package that should be submitted for HHQ coordination. Typically, it takes approximately two months to have a document reach the A5RP chaired Requirements Strategy Review (RSR). This review essentially approves the pursuit of authoring the ICD for the capability under consideration. Once the RSR approves, the ICD can be drafted as quickly as one week by the High Performance Team (HPT), depending on the urgency and available resources. The draft ICD can be entered into internal (AFSPC) and external (SAF and OSD) coordination simultaneously with appropriate AFSPC senior leader approval to save time.

Coordination requires a minimum of three weeks. Upon completion of coordination, the document will be reviewed by the AFROC. In this example, the AFROC met three weeks after coordination and comment resolution. Another document that will be required is the AoA Study Guide. Based on previous examples, in this case, it only took one day to author this document. Of note, OSD/CAPE is responsible for approving this document for JROC Interest Items. The example that was discussed in the interview was being driven by AFSPC/A5 (Brigadier General) and was definitely unique. Other capability documents would likely take three times as long to work through this process.

From another AFSPC/A5 source, there are two ways capability development is kicked off: 1) downward directed, or 2) determining the needs of the warfighter. The most timely way to kickoff capability development is to tie the requirement to an existing/approved ICD, alleviating many of the early JCIDS activities since they were previously accomplished.

The CBA is heavily influenced by US Strategic Command (USTRATCOM)/J8 (representing warfighter needs), however, most of the analysis is accomplished by AFSPC with support from SMC. A CBA for a revolutionary capability (new system) will require six to twenty-four months while one for an evolutionary capability (upgrade an existing system) will take approximately three to six months.

From another AFSPC interview, the ICD requires one month to write and requires six to nine months for coordination and approval. The ICD may result in no action or kick off preparation for MDD and ADM. Policy requires that funding must be set aside to reach the next milestone. In the case of getting an ADM from the MDA at the MDD, this requires funding through MS-A.

Another valuable note from the AFSPC interviews was the fact that either AFSPC or USTRATCOM could sponsor an ICD. Should the combatant command sponsor the ICD, this relieves the AFSPC action officer from Air Force specific coordination activities (RSR and AFROC).

4.1.2 General Comments/Other Tools:

ADDM:

As the research team continued to detail the processes and activities at SMC, AFSPC and SAF/AQRE, it became apparent that other independent efforts with goals similar to that of ERAM were underway at AFSPC and ASC/XR. On 28 October, 2010, Mr. Blaise Durante, SAF/AQX, issued a memorandum with the subject of "Acquisition Document Development and Management Initiative". This was distributed to each of the Air Force PEOs as well as the Acquisition Center of Excellence (ACE) at SMC, Aeronautical Systems Center (ASC), Electronics Systems Center (ESC) and Air Armament Center (AAC). It summarized the purpose of ADDM and directed the following actions:

1) PEO: Identify the priority and timing for each of your program offices to begin utilizing ADDM and communicate that list with SAF/AQXI in order to establish the deployment and support schedule—complete within two weeks of the date of this memorandum;
2) PEO and ACE: Begin to use ADDM to identify and track acquisition milestone readiness status of acquisition programs in your portfolios;
3) PEO and ACE: Communicate ideas for improvement or enhancement of ADDM.

ASC/XR has been made aware of this initiative and is beginning to implement this tool (SAF/AQX 2010). Unlike ERAM, this tool focuses on the detailed tasks during execution and helps provide the program with document templates depending on where they are in the acquisition process. ERAM is a modeling tool that focuses on the overall process and providing early schedule analysis data to decision makers prior to MDD. Figure 16 shows some of the capabilities of translating DoDI 5000.02 into an executable roadmap. The roadmap is similar to Microsoft Project® to layout a program schedule. The SPO is then able to tailor the roadmap and document templates. ADDM enables the planning, tailoring, development, tracking, review and approval of milestone acquisition document content to successfully meet the next milestone decision date. Additionally it provides authoritative references, guidance, and instructions. It has the capability to dynamically generate documents based on most current data in system (ASC/XRCC 2010).

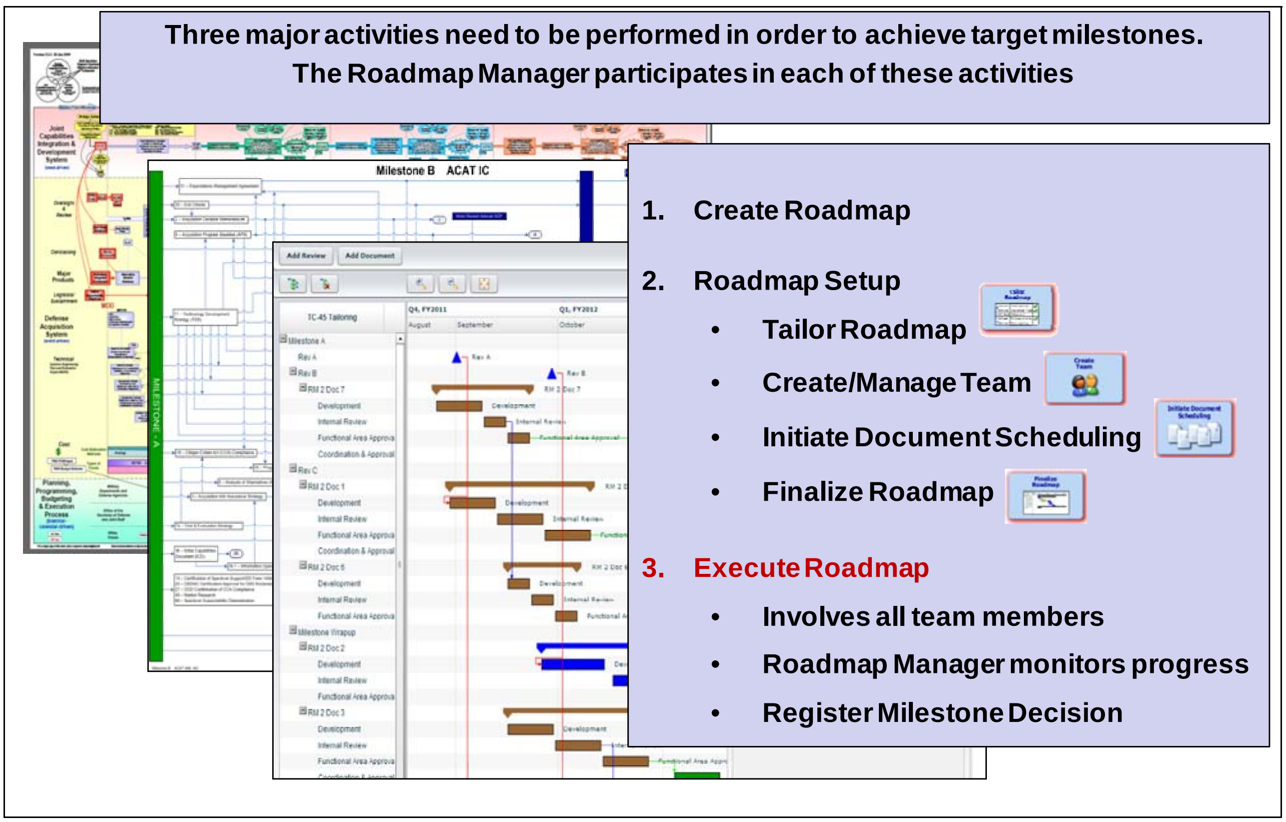


Figure 16: ADDM (ASC/XRCC 2010)

RAMP:

AFSPC/A5 has taken the initiative to develop a comprehensive space architecture that will enable better understanding of the interdependencies of all space capabilities and the impacts current acquisition programs may have on existing and/or planned capabilities. AFSPC acknowledged the need to identify requirements generation process improvements to bring the "speed of need to space & cyber acquisition". They identified nine root causes to these challenges which are: procedures, tribal knowledge, resources, process discipline, monitoring, quality assurance/quality control, requirements definition, poor correlation funding and requirements, and systems engineering issues. To work towards overcoming these challenges, they implemented a four-prong approach which is: process, knowledge infrastructure, organization, and people (Gilchrist 2011). RAMP's development contributes to these solutions. To accomplish this, the first step A5 accomplished was to develop an all inclusive WBS structure of all activities that occur at both AFSPC and SMC when developing a capability. RAMP documents requirements and acquisition at a top-level process and integrates with Microsoft Project®. This tool references guidance and policy. It allows the user to schedule activities, track resources and tailor their activities (Gilchrist 2011). Figure 17 shows this tailorable Microsoft Project ® schedule that is generated.

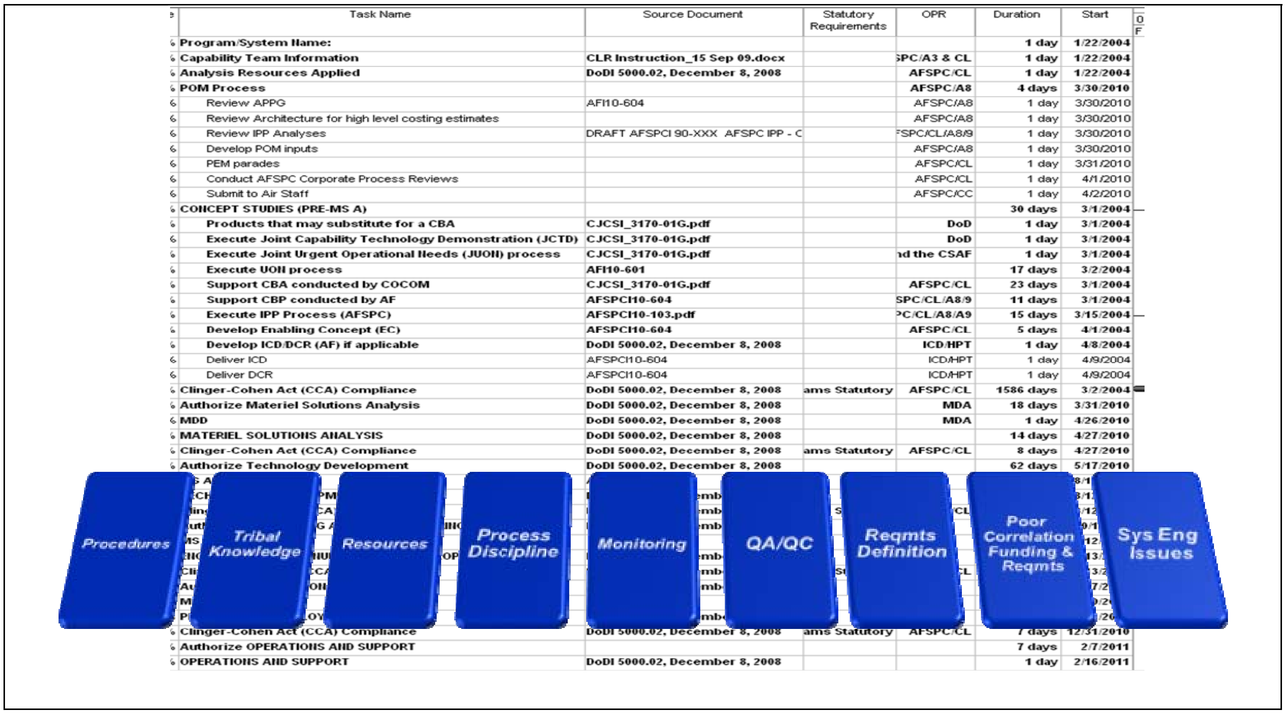


Figure 17: RAMP (Gilchrist 2011)

APM:

The Acquisition and Excellence and Change Office (SAF/AECO) developed another process model of the acquisition system. It is called the Acquisition Process Model (APM). The intent of APM provides the documented current state process in an interactive fashion. In 2009, the ACPO commissioned DSD Laboratories' Center for Reengineering and Enabling Technology (CRET) to develop the APM. The APM is a compilation of policy, instructions, and guidance for persons involved in the acquisition process. The APM accomplishes the following goals: Establishes standard definition and activities associated with AF Acquisition; provides an integration context for other external/related process models; provides the process input to Acquisition Enterprise Architecture and other Enterprise Architectures; provides a standard reference model for all stakeholders; and provides a common context for process improvement initiatives (AF/ACPO 2011). APM is an interactive tool to interface with various portions of the acquisition "wall chart". The user can "click" on each block to get further details on a particular portion of the acquisition process. Figure 18 shows an example of the interactive web page.

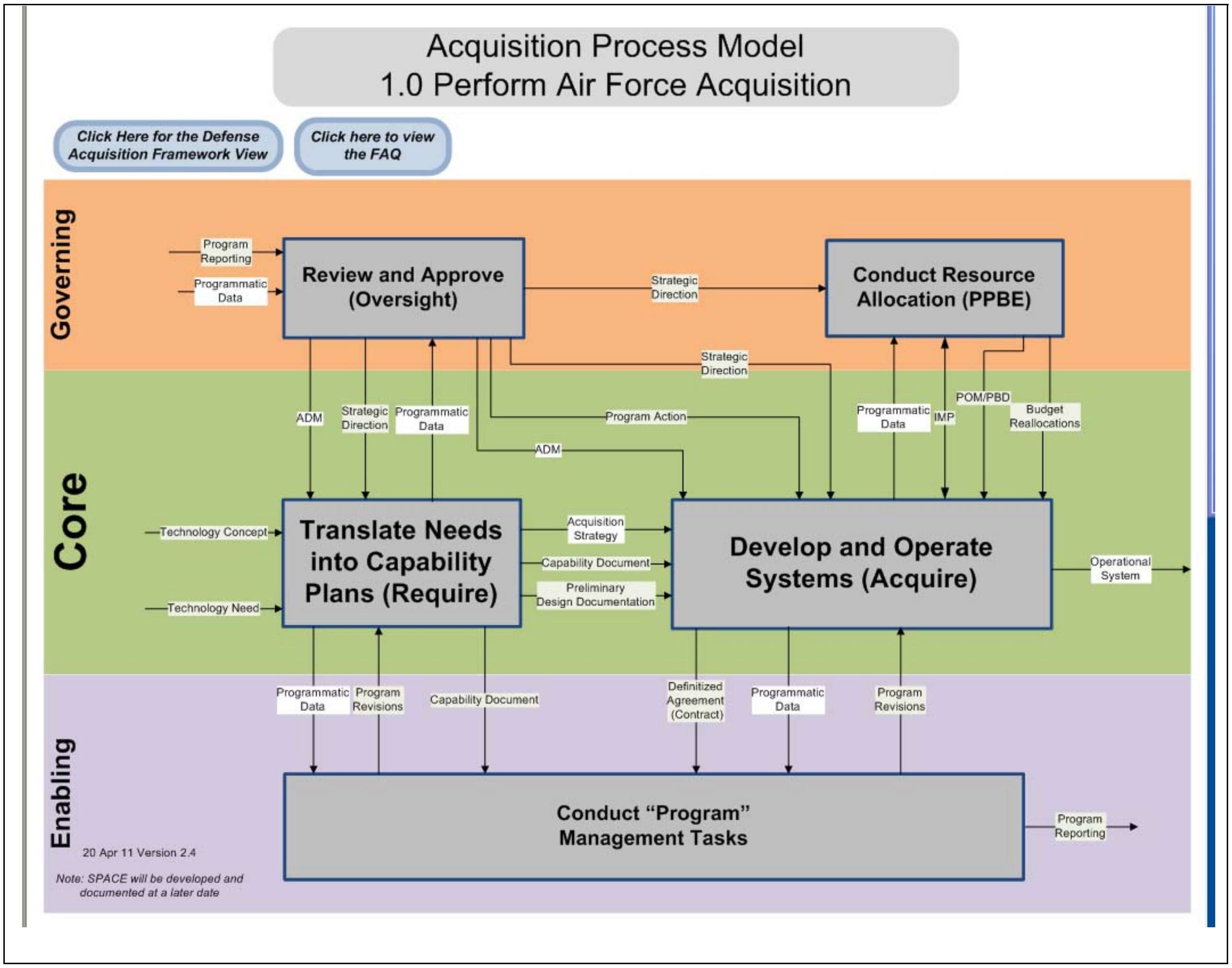


Figure 18: Acquisition Process Model (ACPO 2011)

Take-Away:

Although the objectives of each organization and their respective tools are unique, the data required to develop the respective tools may be shared. For example, ERAM is a simulation model that identifies key high-level activities and associated distributed times of these activities from capability gap analysis through Milestone C. It enhances CCTDs that will be used during the AoA when determining which Materiel Solution should be selected and pursued. Similarly, RAMP identifies all the activities and a specific time associated with each activity as well. ADDM is an acquisition tool that provides standardized templates of required acquisition documents, of which will be required at various points in ERAM and RAMP. APM provides an interactive repository of process guidelines and steps to aid acquisition professionals in their understanding of the acquisition processes. There appears to be great potential for these tools to collaborate together.

4.2 Phase 2: ERAM 1.0 Analysis

The Model

The probabilistic discrete event model developed by Wirthlin was modified with a space systems focus by implementing policy change updates (post 2006) and enhanced early activities by identifying the JCIDS and early systems engineering activities occurring during Material Solutions Analysis and Technology Development phases. The PPB&E process can significantly impact the execution of the programs, but, due to the dynamic and unpredictable nature of the defense budget, few updates were made in the model to reflect these activities. The model attempts to account for the budget variability by utilizing “funding check” nodes at a variety of places throughout the model. The core updates to the model were divided into two sections: 1) updates to DoDI 5000.02 since ERAM was first developed, and 2) additions based on the JCIDS process specific to AFSPC.

4.3 Phase 3: Identify and design updates to ERAM 1.0

ERAM 1.1

ERAM 1.1 focused on the changes required due to porting from Arena® to ExtendSim©. The Aerospace Software Engineers audited the software to ensure that the results from ERAM 1.1 were comparable to ERAM 1.0. The artifacts of running a new simulation software program generated a small number of changes. These specific changes were implemented and updated into ERAM 1.1 as the baseline for future changes. The validation and verification of this model is being conducted wholly by Aerospace and is outside the scope of this effort.

ERAM 1.2

Policy and guidance is constantly evolving based on the political climate, lessons-learned from existing or cancelled programs, funding constraints and others. The changes implemented in ERAM 1.2 reflect space acquisition policy updates currently being incorporated into DoDI 5000.02. Previous space policy documents and interim guidance have been rescinded while policy memos are serving as the interim guidance. Additionally, updates to DoDI 5000.02 since ERAM 1.0 are being incorporated into the model. Figure 19 describes specific DoDI 5000.02 updates to include the preliminary design review (PDR) moving prior to MS-B, with a placeholder for PDR occurring post MS-B, as required.

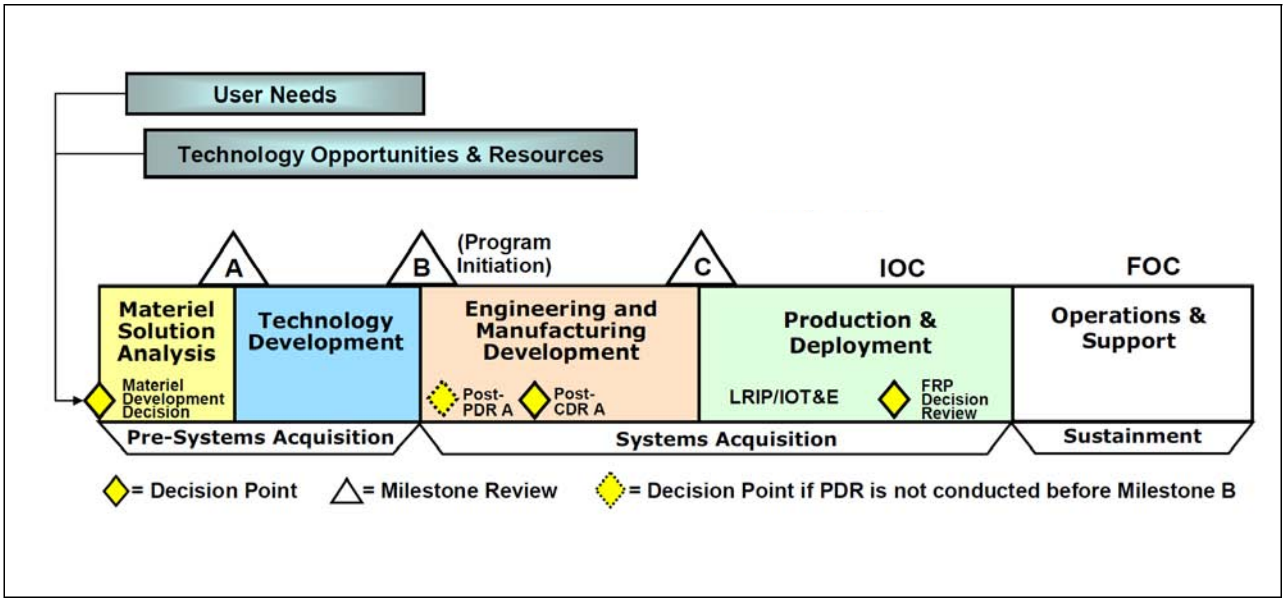


Figure 19: DoD 5000.02 Updates (OUSD/ATL 2008)

Figure 20 identifies the space specific acquisition process updates incorporated into the 2008 version of the DoDI 5000.02; ERAM 1.0 was based on the 2003 DoDI 5000.02 version. ERAM 1.2 added MDD, IPAs and Post SDR assessment. These IPAs were added to support MDA decisions.

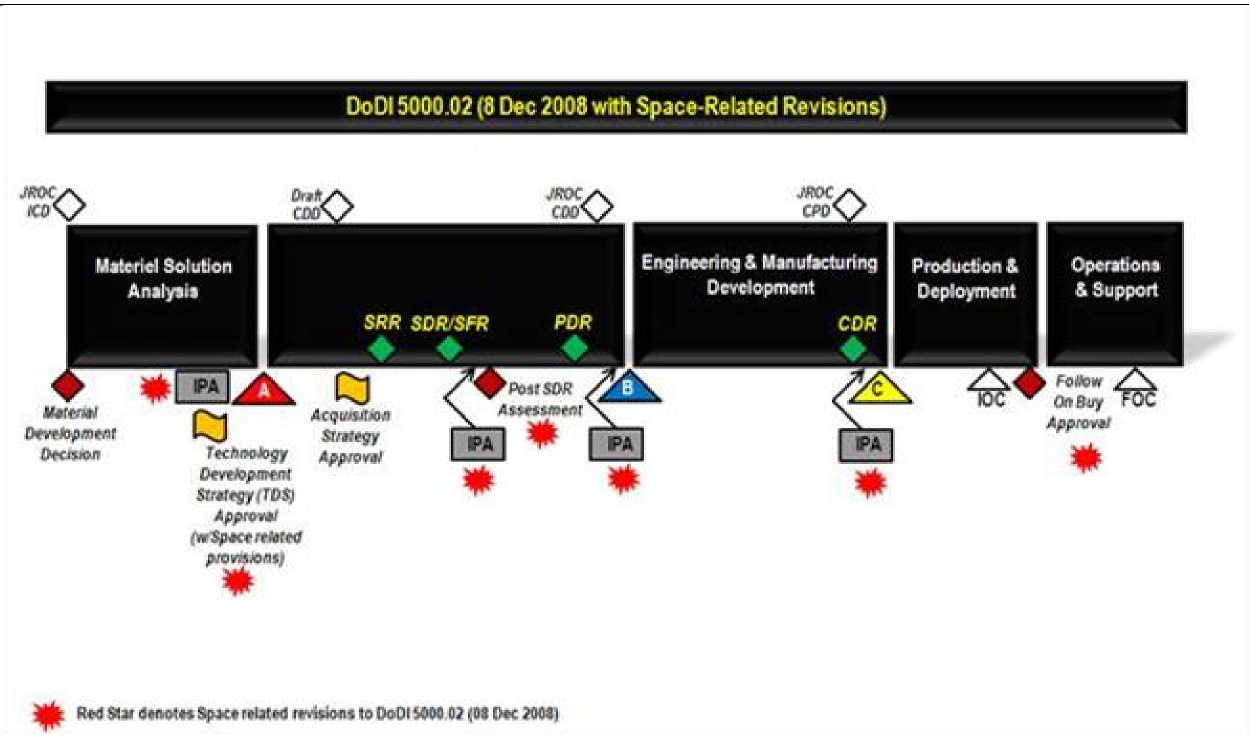


Figure 20: Space Acquisition Policy Updates to DoD 5000.02 (Skotte 2010)

ERAM 2.0

ERAM 2.0 focused on incorporating the changes from the SPO capability matrix. This was designed by instituting a human factors variable to be implemented as a global variable in various timed activities in ERAM. This was designed through discussions with the Aerospace design leadership and the researchers to determine impacted timelines. It was based on the collective understanding and knowledge of the researchers combined with learning from readings and interviews. Once these events were identified they were delivered to the design team to implement in ERAM 2.0. Recall that Table 4 showed the factors that determine the overall experience level of a program office which in turn changes timelines for processes in ERAM.

This global variable skews the triangular timeline distributions results from an aggregation of the above capabilities. It includes the number of years the senior leadership holds a position, the years of experience of the staff members, unit cohesion between the senior leaders and their subordinates, the formal certification training, support from external organizations, and the percentage of filled positions in the program office. The factors contribute to the aggregated global variable calculated and then applied to the impacted process activities (see Appendix B). The global variable has levels from 0 to 4 which determine how the triangular distribution of for the timelines of the discrete events is skewed.

ERAM 2.1

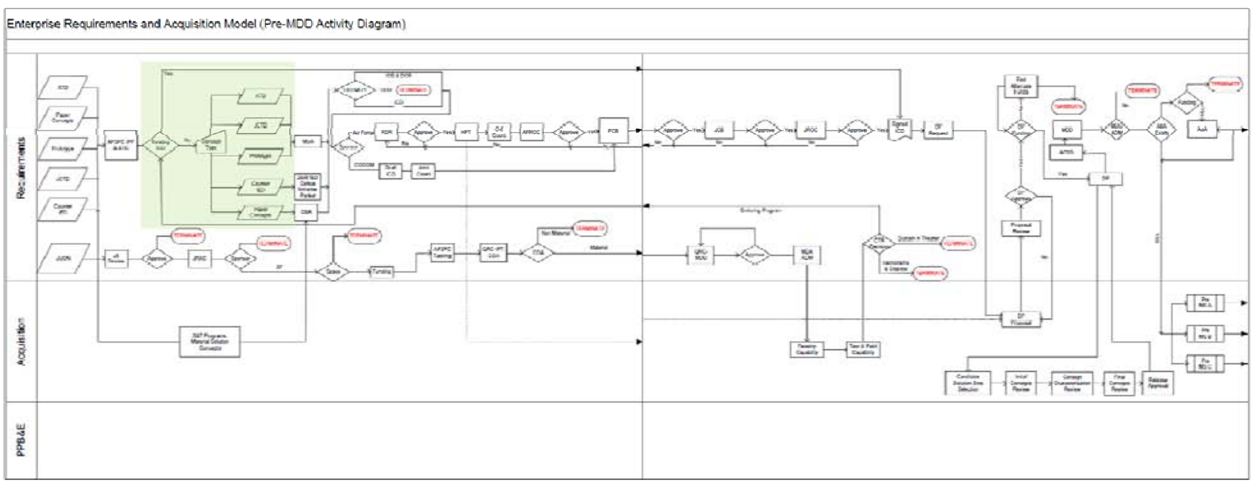


Figure 21: ERAM 2.2 Design

Figure 21 illustrates the activity diagram developed in Microsoft Visio that shows the basic activities involved between capability gap analysis up through conducting an AoA, post MDD. This diagram went through numerous iterations based upon feedback from both AFSPC and SAF/AQ personnel familiar with the processes. This is a collaborative representation of the processes, as everyone interviewed has varying opinions how S&T research, capability gap analysis, DP, JCIDS, CCTD and AoA processes occur and are interrelated. During this portion of the report, the activities and processes will be discussed and how they are intended to compliment other processes to deliver new defense capabilities. Additionally, the methods to determine the triangular distributions of time required for each activity and decision point probabilities will be discussed as well as the results of the analysis.

Strategic Discussion:

Before discussing the details of the various processes and organizational relationships, it's beneficial to look at the problem from the strategic level. Two common philosophies were discovered in discussions with personnel familiar with defense acquisitions and capability development: technology pull and technology push. The first is when the warfighter (COCOMs) identify a capability gap and request it be addressed by the respective MAJCOM—a *reactionary* response. The second method occurs when industry, universities or defense laboratories proactively market technologies and their potential capabilities to the MAJCOM, Joint Staff and/or Air Staff. This is referred to as technology push and addresses emerging threats (both theoretical and realized) that maturing technology may address—the *proactive* development of military applications. In the opinion of the authors, both are necessary, however, technology push is critical for the United States to continue to maintain its military superiority against all adversaries.

Expanding upon the concept of technology pull, a gap has been identified and has war fighter sponsorship, implying congressional and/or flag officer interest. Senior leader sponsorship is critical to navigate the DoD capability development process since there are numerous reviews and decision points where a concept can be shelved. The higher the rank of the sponsor, the less likely it will be shelved. The problem with this method is the JCIDS process is often not timely enough to adequately satisfy the urgency of the need. Hence, PPB&E, requirements management and acquisition activities often become jumbled and result in a chaotic work environment for each organization involved. Valuable early systems engineering activities are frequently rushed or neglected due to the time and cost associated, resulting in decisions being made on inaccurate or insufficient data that under estimate developmental and delivery costs and schedule.

In the instance of technology push, this embraces innovation and addresses emerging threats and/or capability gaps—the "what ifs". This method typically is much more difficult to find senior leader sponsorship since it is competing with realized threats (tech pull) and admittedly, has challenges making it from the research facilities into the JCIDS process to the acquisition centers. In theory, during technology fairs, demonstrations and exercises, the MAJCOMs, COCOMs, Joint Staff and Air Staff should be exposed to the maturing technology and its opportunities for military application—marketing opportunities for industry. If successfully marketed, the demonstrated technological advancements and their potential military application will trigger initiation into the JCIDS process by the MAJCOM.

Furthermore, technology push is critical for industry to continue to grow and post profits for shareholders. This research revealed it is a relatively ungoverned activity with lucrative potential. To take advantage of this opportunity, industry frequently hires retired military personnel with acquisition experience as "Business Development" managers. These persons are typically well networked within DoD staffs, knowledgeable on the capability gap analysis, requirements, acquisition and PPB&E systems and can be extremely valuable assets to companies since they are considered one of the catalysts that triggers the initiation of new MDAPs.

Having discussed the two philosophies with regards to how emerging technology is used to enhance existing capabilities and develop new capabilities, the next portion of the report will discuss the pre-MDD framework that was established for ERAM and how these two philosophies impact it.

Modeling Capability Gap Analysis

Significant time and effort was spent researching and understanding how the desire for a new space capability becomes a MDAP. A very simple and basic question proved challenging to answer: where are new ideas for military applications created and how are they formally inserted into the DoD requirements and acquisition system? There are both informal and formal S&T processes supporting AFSPC's responsibility to sustain existing capabilities and develop new ones. The formal process will be discussed first followed by a discussion of observations on the informal methods. Figure 22 circles the region of the framework under discussion in this section. It was necessary to understand this process, however, these activities and decision points were not modeled in ERAM as ERAM models an idea once it is in the "system".

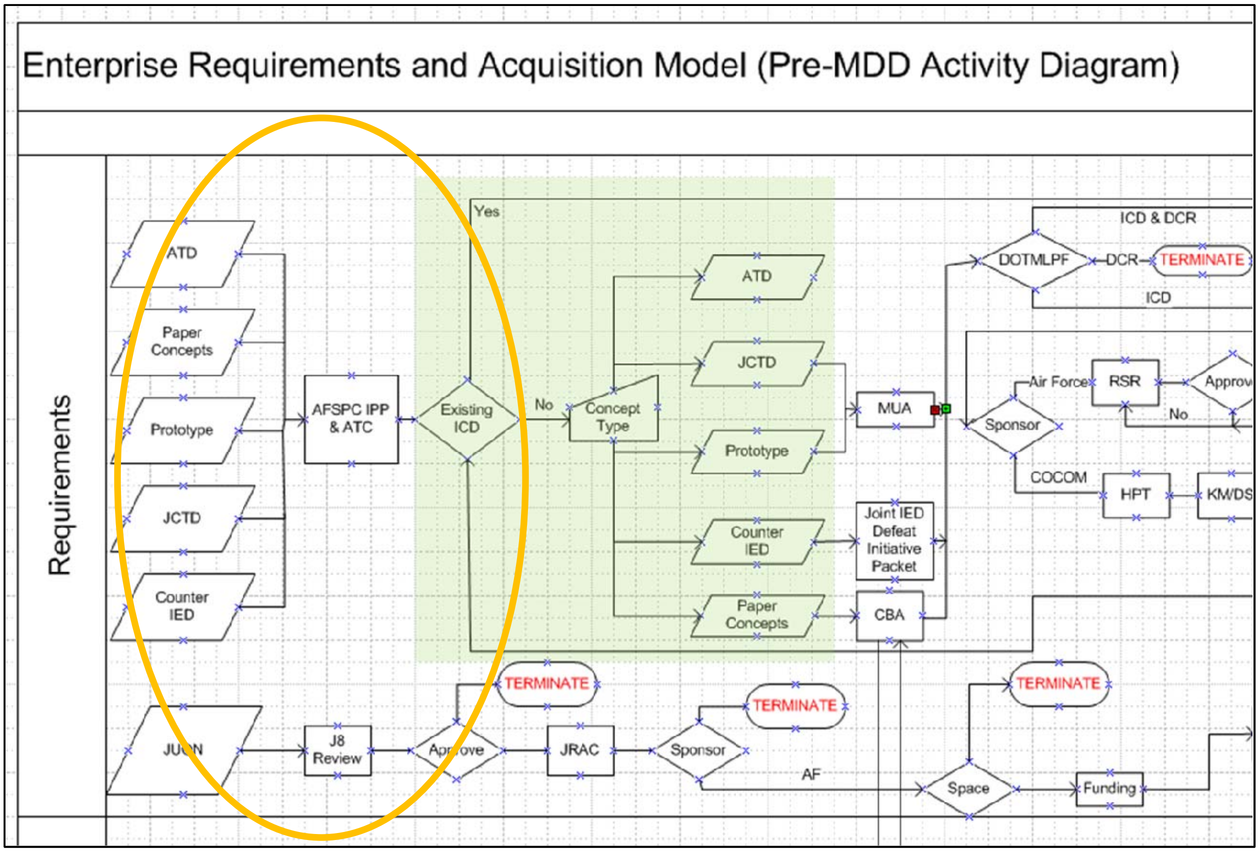


Figure 22: ERAM 2.1 Front End Design

S&T activities are formally governed by Air Force Policy Document 61-1 (AFPD 61-1), Management of Science and Technology, Air Force Materiel Command Instruction 61-102 (AFMCI 61-102), Advanced Technology Demonstration Technology Transition Planning, and AFSPCI 61-101, Space Science and Technology (S&T) Management. The space S&T program encompasses basic research, applied research and advanced technology development with the goal of maturing technologies that can be utilized by AFSPC to develop materiel solutions and eventually by the product centers to develop both evolutionary (upgrade existing systems to provide new capabilities) and revolutionary (new systems delivering new capabilities) systems. Interestingly, Air Force Materiel Command (AFMC), not AFSPC, develops space S&T POM recommendations (with inputs from Air Force Research Laboratory (AFRL) and each of the product centers) for investment strategies to focus on developing and maturing space technologies. Of note, AFRL is subordinate to AFMC, not AFSPC—this could be one of the reasons many of the interviewees for this research indicated there has historically been a problem with maturing space technology with the AFRL and transitioning it to space materiel solutions analysis and MDAPs at AFSPC and SMC, respectively. This organizational structure may also have limited or inhibited the robust establishment of space technology expertise within AFRL. Senior Air Force leaders may have recognized this issue; in 2010, the newly appointed AFRL commander had previous assignments as the Deputy Director of the National Reconnaissance Office (NRO) and prior to that was the Vice Commander of the SMC. But this remains a piecemeal fix with no permanent process in place to address the longer term issues.

How are AFSPC space capability and technology requirements communicated to the S&T community (AFRL, industry partners and academia)? According to AFSPCI 10-604, the AFSPC IPP is used:

> …to develop an executable Investment Strategy…Through the IPP, AFSPC identifies, defines and prioritizes needed capabilities, determines shortfalls that must be filled through modernization and transformation, assesses HIS requirements, and develops a fiscally and technologically achievable plan. The IPP follows phases known as FAA to determine, categorize and prioritize the basic functions the command must perform; FNA that identifies and prioritizes the capability shortfalls; FSA to assess possible materiel solutions to the shortfall; and Integrated Investment Analysis to determine the optimal force structure given resource constraints. Outputs required by the HQ AFSPC/A3/A5 in support of this AFSPCI include a capabilities needs list (shortfalls), an analysis of solutions and some initial MAJCOM-level FSA data for JCIDS and the results of IIA that include system roadmaps (out year funding profiles, IOCs, EOLs and other key milestones (AFSPC/A3F 2007).

One of the products of the IPP is the Strategic Master Plan (SMP). This document is intended to provide prioritized guidance to the labs with regards to what emerging space technologies require further research and development to meet the long term capabilities AFSPC is required to provide to the combat commands.

After reviewing the AFIs and AFSPCIs, the space S&T process was summarized and shared with AFSPC to confirm the research accurately depicted the process. Unfortunately, their response indicates that the processes outlined by the instructions are not current. This highlights a major problem for anyone involved in S&T and capability development. Implications include: 1) inability for formal training curriculum to be developed on the process since it's frequently changing, 2) inability for outside organizations to be able to read instructions to understand other organizations processes resulting in degraded inter-organizational processes, and 3) numerous conflicting interpretations of what the enterprise process should be according to individual organizations resulting in significant confusion. Not only does this occur at AFSPC, it is very likely that this occurs at SMC, SAF and OSD and is a problem throughout DoD.

The following is a summary of the changes in the original process outlined in the published instructions as explained by a source at AFSPC. AFSPC/A8X is responsible for the IPP. The IPP no longer produces a SMP (as the instruction indicates). In 2008, the IPP posted a classified Space Re-capitalization Plan (SRP), replacing the SMP. Recently, the SRP was replaced with the Service Core Functions (SCF). The Air Force SCF Master Plan 2010 is the most current version; it is Air Force wide and not specific to space. AFSPC/A8X is currently working on the AFSCP Core Function Master Plan for both space and cyberspace. Additionally, AFSPC/CC signed the classified 2011 Space S&T Guidance document.

Bottom line, the formal process is for AFSPC to provide prioritized guidance through the IPP to the S&T community on what capability gaps exist and possibly require additional investment in maturing technologies to achieve those capabilities. The S&T community includes defense laboratories, academia as well as industry partners. Theoretically, this guidance encourages them to invest in technologies and concepts that could potentially become MDAPs delivering advanced capabilities (this research effort did not substantiate this). Figure 23 summarizes the flow for S&T efforts to meet MAJCOM and COCOM capability needs.

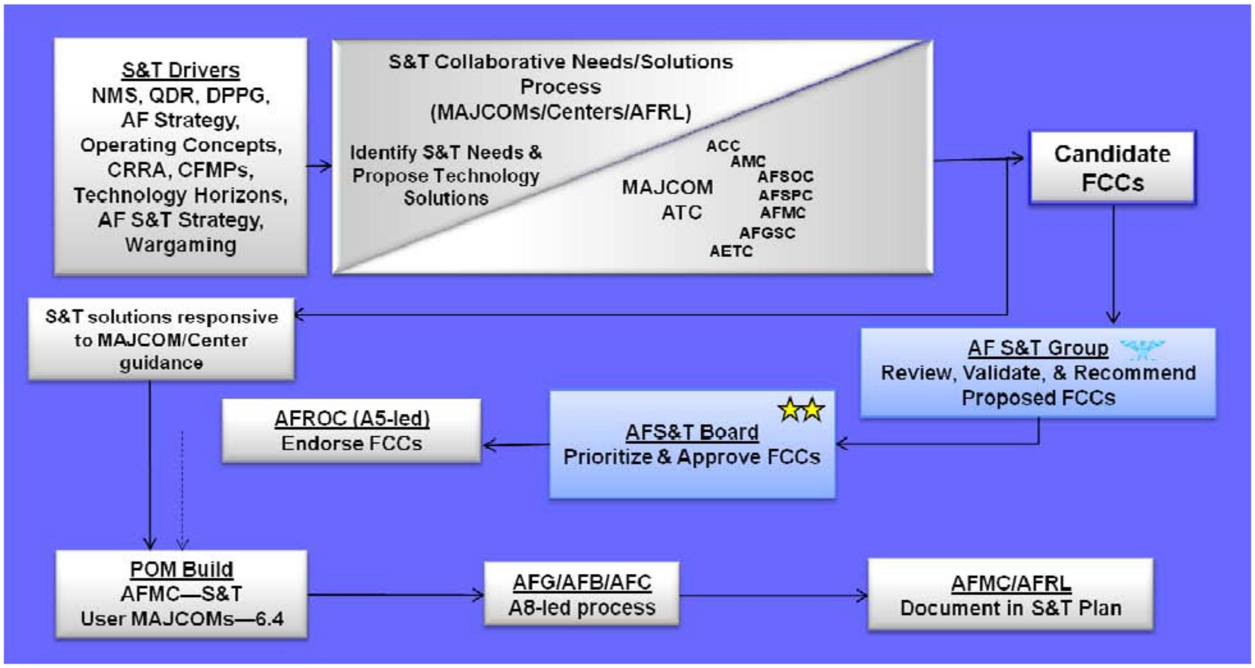


Figure 23: Science & Technology Process (Walker/Pawlikowski 2011)

Now that the basic S&T framework as defined by policy and instructions for formal capability analysis and technology development has been presented, it's appropriate to discuss the informal and undocumented processes. Interviews with SMC, AFSPC and informal discussions with defense industry members revealed that not all capabilities and concepts are "pulled" by AFSPC through the IPP. Rather, there is a more innovative method in which our industry partners, laboratories and academia "market" new concepts to DoD members. This can be as informal as a discussion during a game of golf about a cool and innovative idea to the actual demonstration of technology that delivers capabilities not considered by AFSPC.

ATD, Paper Concepts, Prototypes, Joint Capability Technology Demonstrations (JCTD) and Joint Improvised Explosive Device (IED) Defeat Initiatives are not all inclusive of the “capability development ideas” that the IPP is exposed to, but, represents a subset of what likely occurs. The official activity flow indicates that the IPP and the Applied Technology Council (ATC) determine what capabilities to pursue further. The quickest, and often time easiest, path is to find an existing, approved ICD that the capability would fall under (typically evolutionary). If there isn’t an existing ICD, then depending on how the proposed capability was injected into the IPP will determine the ERAM path that will result in a JROC approved ICD. The next section of this report will discuss the initial stages of ERAM as depicted in Figure 24 and how it tries to balance the “as is” of the process with the official process documentation.

Initial ERAM Activities

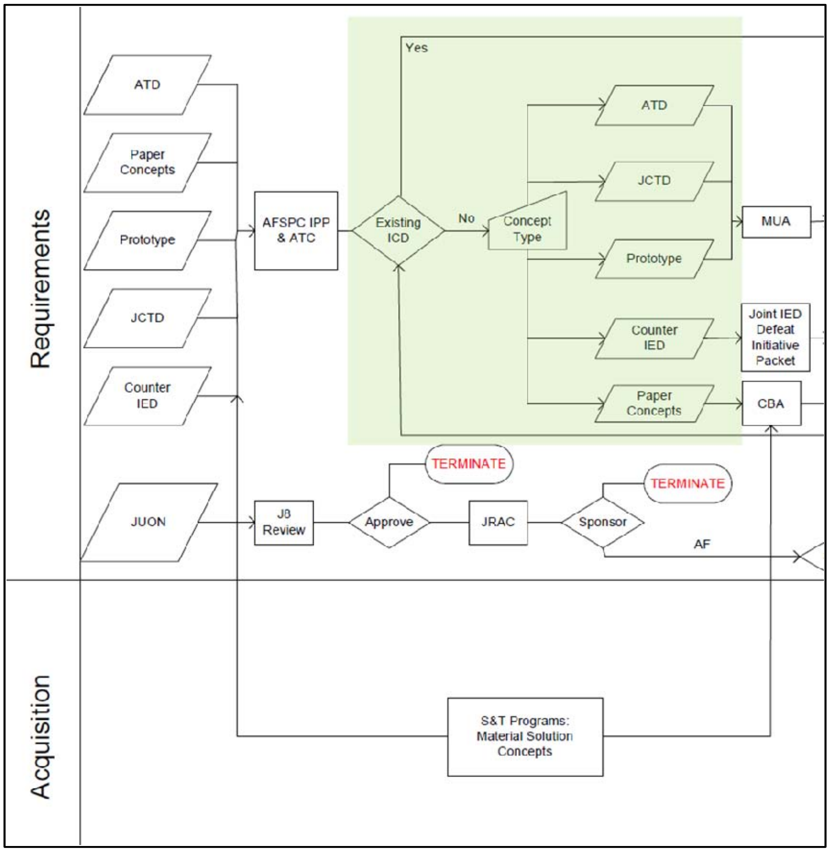


Figure 24: ERAM ICD Check

Once a capability gap has been identified or emerging/maturing technology has been successfully marketed to the DoD, the next phase begins with the JCIDS process. This can be initiated one of several ways: direction/request for a CBA by the responsible MAJCOM, a JCTD, a Prototype, a Joint IED Defeat Initiative (not discussed—see Manual for Operation of JCIDS for further information), a JUON or through the Advanced Technology Demonstrations (ATD).

At AFSPC, the IPP and ATC prioritize the capability gaps and based upon resource limitations (funding, manpower, etc.), determine a cutline with regards to which will be pursued further. For a given proposed capability above the cutline, the first step is to determine if there is an approved ICD already exists. If there is, this significantly reduces the amount of time to reach MDD. Without an ICD, JCIDS heavily influences subsequent activities.

If there is not an existing ICD, the type of capability and available technology will determine what JCIDS activity is accomplished. The CBA is the default activity. However, a Military Utility Assessment (MUA) is an alternative that can be accomplished for a prototype or JCTD. The Joint IED Defeat Initiative Transition Packet and JUONs are also approved alternatives to the CBA.

From the Manual for Operations of JCIDS, the analytical capability analysis is accomplished as a CBA. The purpose of a CBA is to "identify capability needs and gaps and recommends non-materiel or materiel approaches to address gaps." Additionally, "It [the CBA] becomes the basis for validating capability needs and results in the potential development and deployment of new or improved capabilities." Upon CBA completion, the report includes: 1) a description of the mission and military problem being assessed, 2) identification of the tasks to be completed to meet the mission objectives, 3) identification of the capabilities required, 4) an assessment of how well the current or programmed force meets the capability needs, 5) an assessment of operational risks where capability gaps exist, 6) recommendation for possible non-materiel solutions to the capability gaps, and 7) recommendations for potential materiel approaches (if required). Should a materiel approach be required, either AFSPC or a COCOM (for space, USTRATCOM) must sponsor the ICD to continue pursuing the capability development.

For prototypes and JCTDs, the MUA is accomplished at the completion of the demonstration and must have sufficient analytical data to be a suitable CBA replacement. It will be the basis for the ICD preparation and be a key reference document for the CDD and Capability Production Document (CPD).

A Joint IED Defeat Initiative Transition Packet is similar to the MUA in that it must provide sufficient analytic analysis to support the CDD and CPD. This is designed to streamline the development and fielding of the technology in support of current combat operations within US Central Command.

Another substitute for a CBA is when a COCOM submits a JUON. A JUON is defined as an urgent operational need identified by a combatant commander involved in an ongoing named operation. From JCIDS, “The scope of the combatant commander JUON will be limited to addressing urgent operational needs that: (1) fall outside of the established Service processes; and (2) most importantly, if not addressed immediately, will seriously endanger personnel or pose a major threat to ongoing operations” (CJCS 2011). The activity flow for JUONs will be discussed separately at the end of this section.

Not mentioned in JCIDS are the S&T activities that may result in a desired operational capability after the system has been developed and launched. A recent example of this occurred with Tactical Satellite-3 when it transitioned from an experimental demonstration to an operational asset (Air Force Magazine 2010). To account for these activities, ERAM incorporated an Advanced Technology Demonstration as a “user input” option. Similar to a prototype or JCTD, there will likely be a MUA or CBA equivalent report accomplished that documents the analytical utility of the technology and can be used to support the ICD, CDD and CPD, if required.

ICD Development & Approval

Upon completion of the CBA, MUA or ATD, the results will be documented and feed directly into the ICD, a doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) change recommendation (DCR) or both. If it is determined a materiel solution is not required and the capability can be met with existing capabilities, a DCR is written and ERAM terminates. However, if the CBA analysis results in the need for a materiel solution, then the process of writing an ICD begins. See Figure 25.

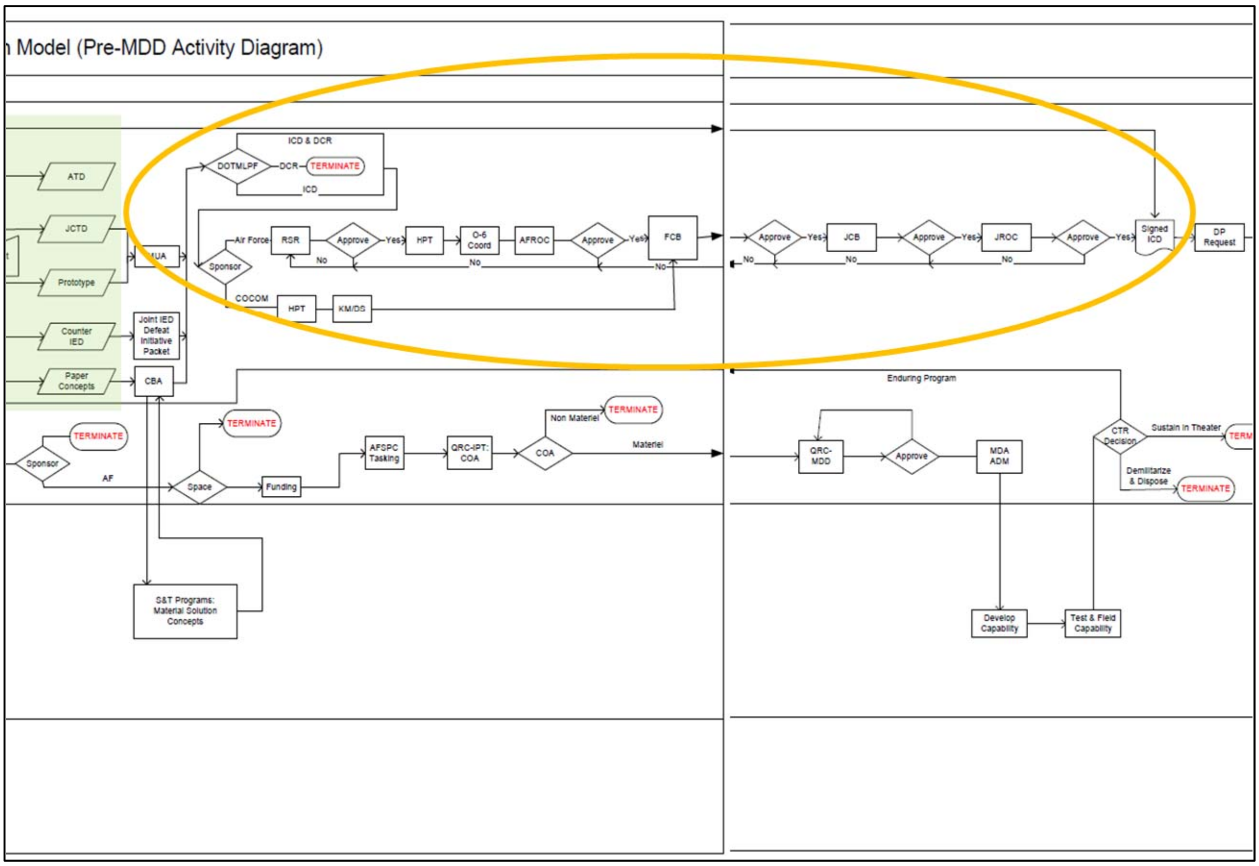


Figure 25: DOTMLPF Analysis

The first decision point after it has been determined an ICD is required is to determine who the sponsor is. For space, either USTRATCOM (COCOM) or AFSPC (MAJCOM) sponsors the ICD. If it is sponsored by the COCOM, this eliminates several Air Force specific requirements, as shown in the activity diagram. However, if the ICD is sponsored by the MAJCOM, the next activity is the RSR. The purpose of this review is for the sponsor (AFSPC) to identify the funding strategy for the Materiel Solution Analysis and Technology Development phases. As stated in AFI 63-101, prior to milestone approval, funding must be available and identified to reach the next milestone. In this case, funding must be available from JROC approval of the ICD through MS-A (SAF/AQ 2009).

Upon approval at the RSR, AF/A5RD establishes and facilitates a HPT with the objective of writing the ICD. The HPT is led by the sponsor (AFSPC) and ideally has 7-11 core members consisting of space SMEs from AFSPC, SMC, FFRDC and government support contractors. “This core team’s objective is to capture, articulate and document the operator’s requirements in minimum time, while achieving stakeholder buy-in” (AFSPC/A3F 2007). One advantage of the HPT is it facilitates simultaneous coordination with Air Force, Joint Staff, Service and Agency coordination. Failure to utilize the HPT results in sequential staffing of the document.

Once the ICD has been drafted by the HPT, it enters O-6 level coordination. For Air Force coordination, this is accomplished with the Information and Resource Support System (IRSS). The Knowledge Management/Decision Support (KM/DS) database is used for joint O-6 and flag officer coordination of JCIDS documents. This activity in the framework includes the time required to submit the document for coordination as well as time for review and comment resolution.

After document coordination and comment resolution is complete, the ICD is ready to be reviewed by the AFROC. This activity includes the lead time required to get on the AFROC agenda and complete the formal review. If approved by the AFROC, the document will proceed to the Gatekeeper, the J-8/Deputy Director for Requirements, for review and document designation.

The Gatekeeper will review all JCIDS documents regardless of ACAT, previous delegation decisions, or previous joint potential designator (JPD) decisions and assign a JPD. Possible JPDs are “JROC Interest”, “Joint Capabilities Board (JCB) Interest”, “Joint Integration”, “Joint Information” or “Independent”. Of the nine Joint Capability Areas (JCA), four of the areas automatically bin the capability as “JROC Interest”; from AFSPC sources, space almost always falls in one of these four JCAs. Table 7 from the Manual for Operation of JCIDS indicates the offices required to coordinate with depending on JPD assignment.

Table 7: Joint Staffing Matrix (CJCS 2011)

Table D-1. Staffing Matrix

Office	JROC Interest	JCB Interest	Joint Integration	Joint Information	Independent
Army	X	X	X	X	S
Navy	X	X	X	X	S
Air Force	X	X	X	X	S
Marine Corps	X	X	X	X	S
Joint Staff	X/C/E	X/C/E	C/E	X	
FCB Working Groups	L/S	L/S	L/S	L/S	L/S
Combatant Commanders	X	X	X	X	S
Other DOD Components	X	X	X	X	S
USD(AT&L)	X	X	X	X	
USD(P)	X	X	X	X	
USD(I)	X	X	X	X	
USecAF (DOD EA for Space)	X	X	X	X	S
ASD(NII)/CIO	X	X	X	X	
USD(P&R)	X	X	X	X	
USD(C)	X	X	X	X	
DOT&E	X	X	X	X	
Director, CA&PE	X	X	X	X	
DIA	X	X	X	X	
DISA	X	X	X	X	S
NGB	X	X	X	X	S
NGA	X	X	X	X	S
NSA	X	X	X	X	S
NRO	X	X	X	X	S
DNI/IRB	X	X	X	X	

L/S = lead/supporting FCB
S = Sponsor staffing only
X = Required staffing
C = Certification
E = Weapon Safety Endorsement

Figure 26 summarizes the flow of activities and timelines for a JPD of "JROC Interest" or "JCB Interest". This is essentially the detailed version of the circled ERAM activities in Figure 25. However, in ERAM 2.1, the model does not specifically identify each of the activities from Figure 26, but, rather incorporates all the times into the triangular distribution for each of the major reviews (Functional Capabilities Board (FCB), JCB and JROC).

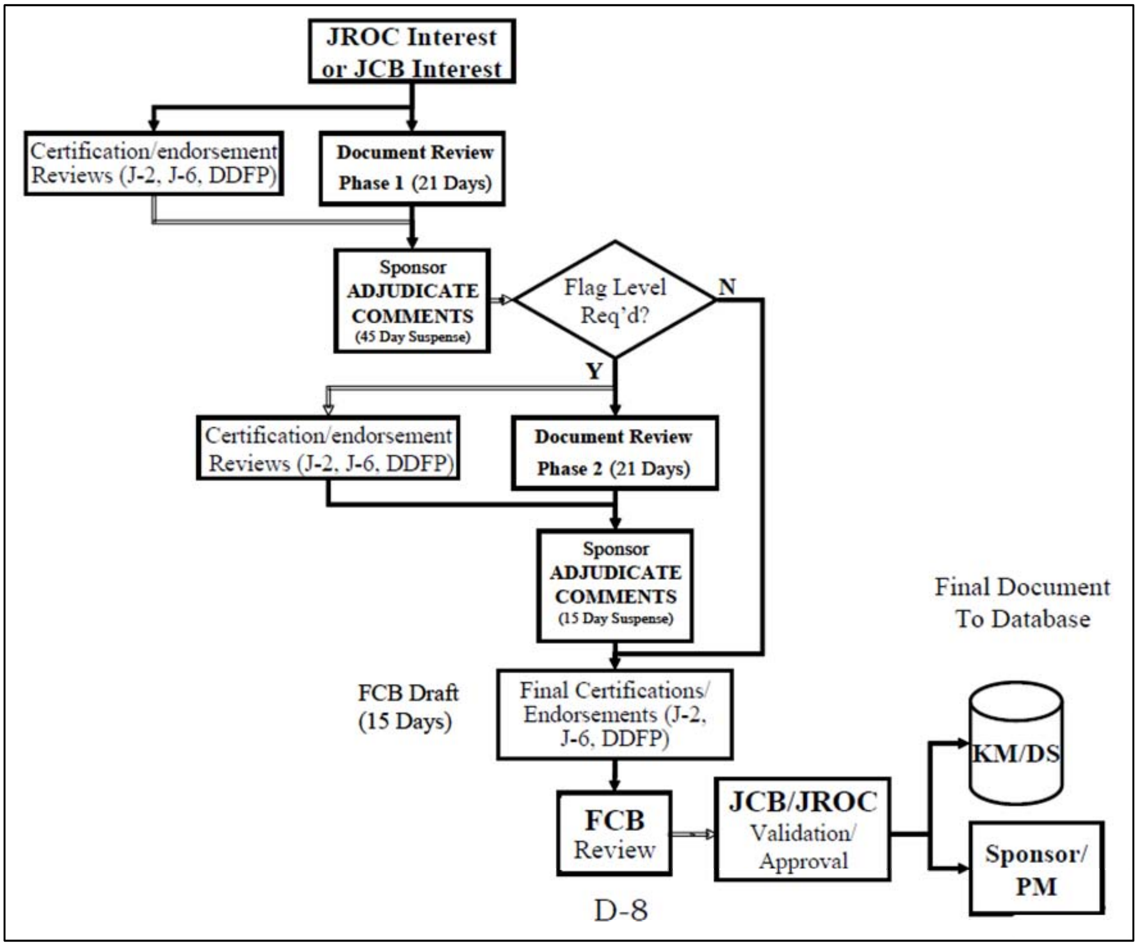
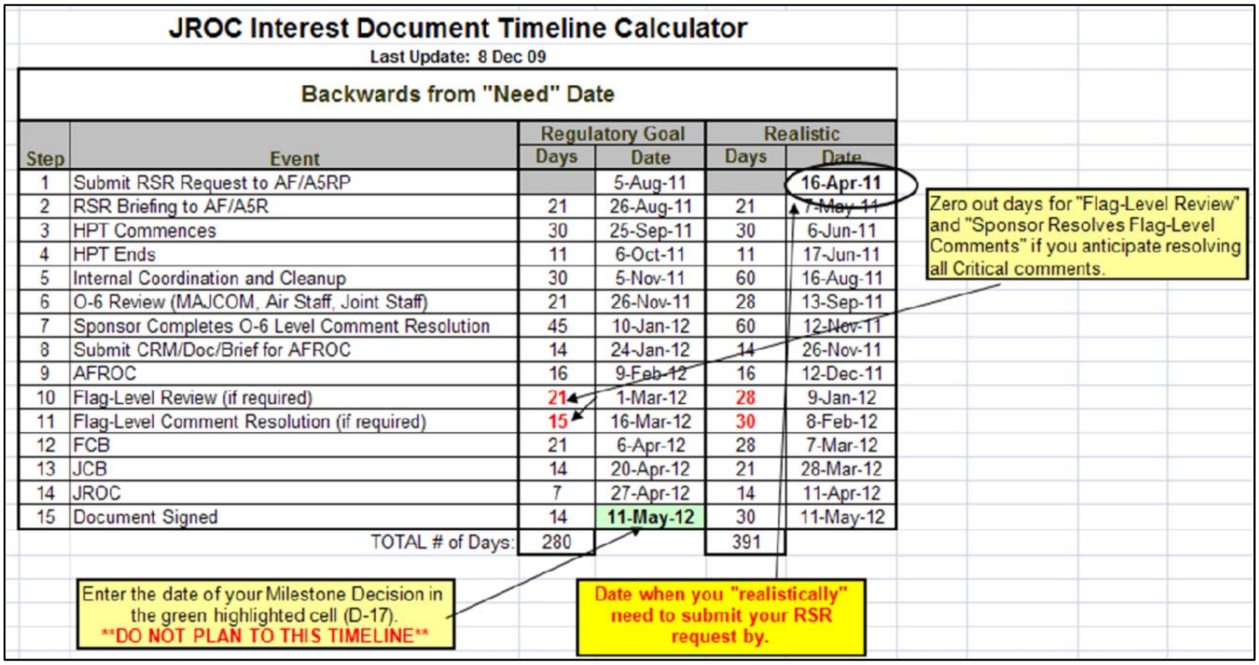


Figure 26: JROC Process (CJCS 2011)

The ERAM framework simplifies this process, but does account for all the time required to coordinate a document through the Joint Staff and have it approved. Figure 27 was a valuable source of data for ERAM activity times; it specified both regulatory and most likely times to staff a JCIDS "JROC Interest" document through the Joint Staff.



JROC Interest Document Timeline Calculator

Last Update: 8 Dec 09

Backwards from "Need" Date

Step	Event	Regulatory Goal Days	Regulatory Goal Date	Realistic Days	Realistic Date
1	Submit RSR Request to AF/A5RP		5-Aug-11		16-Apr-11
2	RSR Briefing to AF/A5R	21	26-Aug-11	21	7-May-11
3	HPT Commences	30	25-Sep-11	30	6-Jun-11
4	HPT Ends	11	6-Oct-11	11	17-Jun-11
5	Internal Coordination and Cleanup	30	5-Nov-11	60	16-Aug-11
6	O-6 Review (MAJCOM, Air Staff, Joint Staff)	21	26-Nov-11	28	13-Sep-11
7	Sponsor Completes O-6 Level Comment Resolution	45	10-Jan-12	60	12-Nov-11
8	Submit CRM/Doc/Brief for AFROC	14	24-Jan-12	14	26-Nov-11
9	AFROC	16	9-Feb-12	16	12-Dec-11
10	Flag-Level Review (if required)	21	1-Mar-12	28	9-Jan-12
11	Flag-Level Comment Resolution (if required)	15	16-Mar-12	30	8-Feb-12
12	FCB	21	6-Apr-12	28	7-Mar-12
13	JCB	14	20-Apr-12	21	28-Mar-12
14	JROC	7	27-Apr-12	14	11-Apr-12
15	Document Signed	14	11-May-12	30	11-May-12
	TOTAL # of Days:	280		391	

Figure 27: JROC Document Timeline Calculator (JROC 2009)

Post ICD – Pre MDD

Once the ICD has been approved by the JROC, this signifies the Joint Staff's validation of the need to fill a capability gap with a material solution. In the ERAM framework, the next formal activity is DP, as depicted in Figure 28.

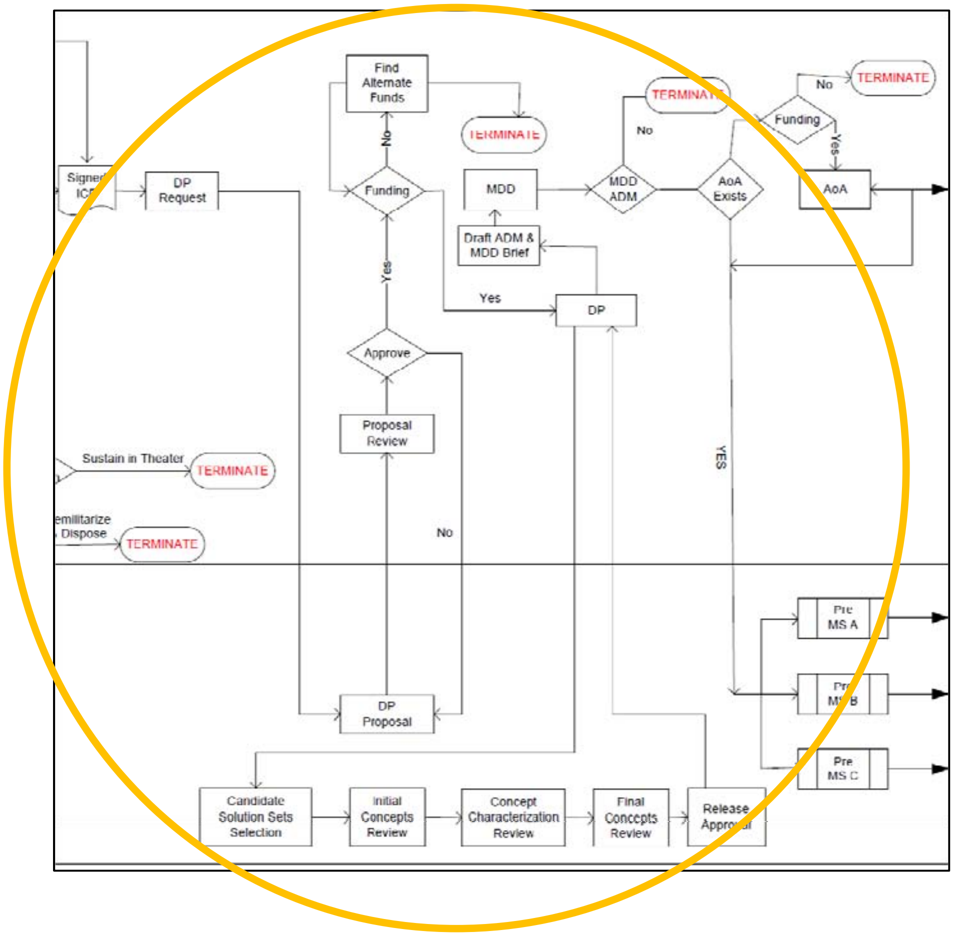


Figure 28: Early SE Design

According to AFI 63-101, “DP is the materiel, i.e., implementing command’s (AFMC and/or AFSPC), contribution to AF or AF-led capability planning. It is a collaborative process bridging warfighter-identified capability needs to planning for acquisition of materiel solutions.” Within ERAM, this activity begins following the approval of the ICD, however, in reality, DP can start as early as when the HPT is formed to draft the ICD; this helps jump start the activity and reduce overall time. AFSPC/A5 would begin organizing the DP team while the HPT drafts the ICD and it works through the Joint Staff coordination process and have begun coordinating with the appropriate personnel at SMC to get them up to speed. Additionally, in ERAM, DP activities at the Center are those required to generate the CCTD(s). In reality, this effort may continue through the Materiel Solution Analysis phase of the acquisition system, depending on the requirements of the capability and associated concept(s). Figure 29 from the DP Guide illustrates when this activity occurs while Figure 30 describes the detailed activities.

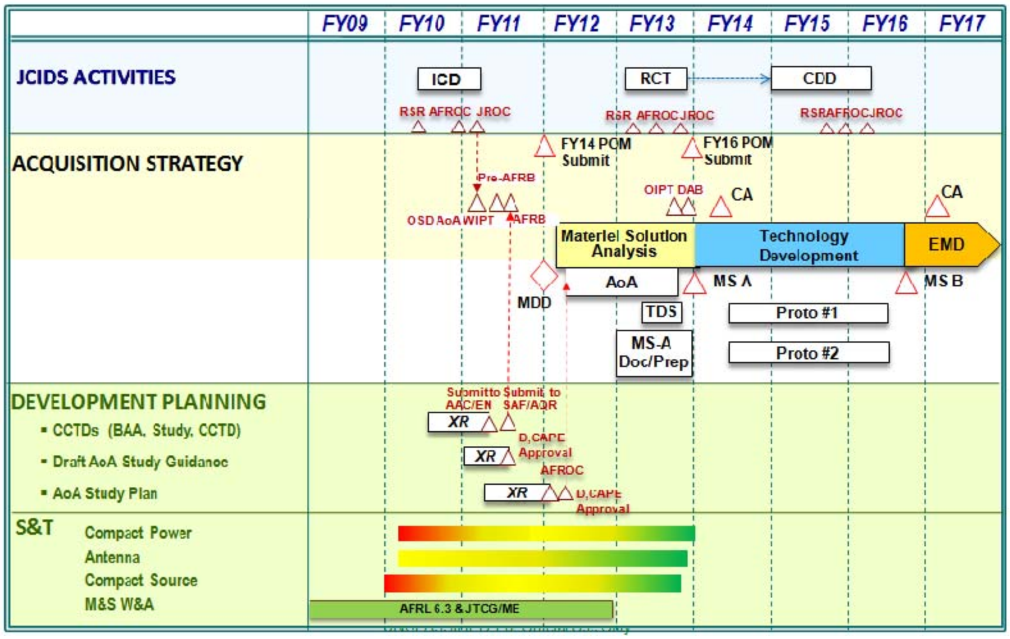


Figure 29: DP/JCIDS Process (AFMC/A2/5 2010)

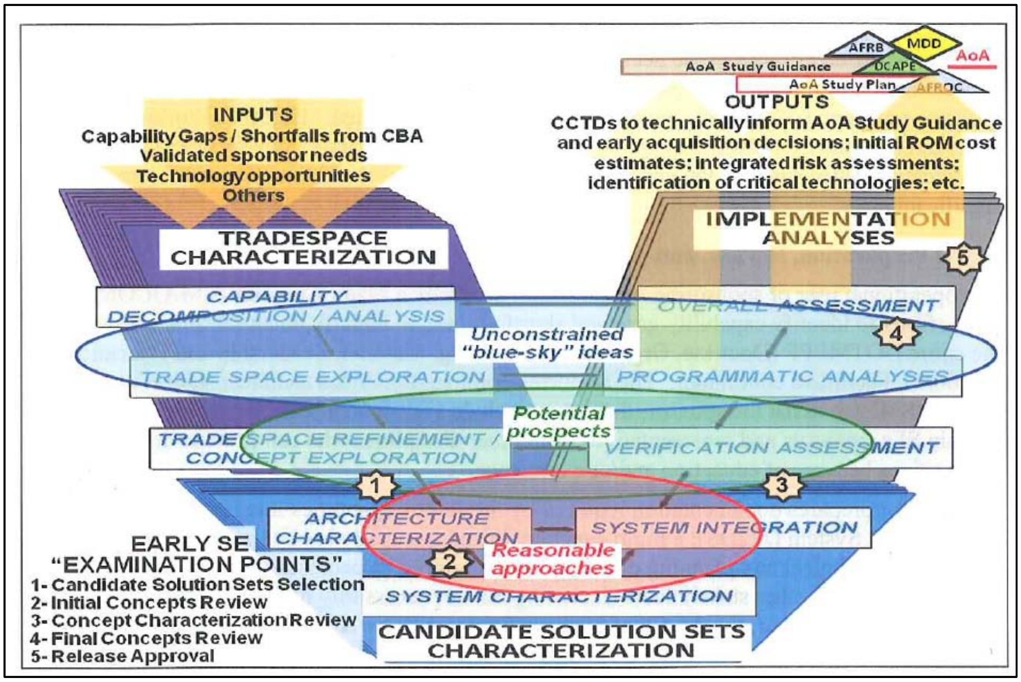


Figure 30: Early SE Process (SAF/AQ 2010)

According to the AFMC DP Guide, DP activities are led by AFSPC and/or either SMC/XR (revolutionary capability) or the existing SPO XR shops (evolutionary capability). They are responsible for providing technical support at the RSR, AFROC, JROC, Air Force Review Board (AFRB), MDD and AoA. The products that are being developed during this activity include the CCTDs, draft AoA Study Guidance and the AoA Study Plan. Policy requires the AoA Study Guide and Study Plan to be completed prior to MDD.

Based on discussions with AFSPC and to simplify the modeling of this process, in ERAM, the official DP request occurs following the approval of the ICD. This request is sent to either SMC/XR or to the SPO, depending on if the capability is revolutionary or evolutionary, respectively. SMC/XR or the SPO develops a proposal including number of resources and funding requirements for the effort and submits this to AFSPC for review. At this point, AFSPC will either approve the proposal as is or kick it back to SMC for re-work. If it is approved, AFSPC verifies funding is available; if it isn’t, they look for alternate funds. If alternate funds are not available, the effort is shelved. If funds are found, then the DP activities kick off. AFSPC and SMC work together to develop the CCTDs, the AoA Study Guide and the AoA Study Plan. In order to proceed with drafting the ADM and meeting the AFRB, at a minimum, the AoA Study Guide and Plan must be completed. The CCTDs necessary for the AoA effort ideally would be completed as part of the DP activity, but, will not hold up the MDD. According to AFSPC, there are very few official DP requests for space systems and all requests are approved and funded.

MDD

Upon completion of the DP, preparation activities for the MDD begin. The first activity following DP completion is the AFRB. According to AFI 63-101, paragraph 3.7.1.1, AFRBs are not conducted for services or space programs. After inquiring with SAF/AQR about this statement, clarification was given that Mr. Van Buren, SAF/AQ, has implemented the requirement for space programs to participate in the AFRB in advance of the MDD. This is to ensure the SAE has been coordinated with and is prepared to fully endorse the MDD to the MDA. ERAM has included this activity within the framework and model. The AFRB activity includes the time required to draft and coordinate the MDD briefing and ADM. From DoDI 5000.02, the purpose of the MDD is:

> When the ICD demonstrates the need for a materiel solution, the JROC shall recommend that the MDA consider potential materiel solutions. The cognizant MDA is determined as described in Enclosure 3. The MDA, working with appropriate stakeholders, shall determine whether there is sufficient information to proceed with a Materiel Development Decision. If the MDA decides that additional analysis is required, a designated office shall prepare, and the MDA shall approve, study guidance to ensure that necessary information is available to support the decision (OUSD/ATL 2008).

For space systems, the MDA is the Under Secretary of Defense, AT&L (USD/AT&L). Prior to meeting with the MDA, preparation activities are jointly shared by AFSPC and SMC. From the Pre-MDD Guidebook, the briefing team will present the JROC recommendation with regards to the ICD, and justify the business case identifying the affordability, viability of the materiel solution to address the gap(s). Additionally, they must justify why an Analysis of Alternatives is not required (if it is proposed not to do one) or present the AoA Study Plan and Study Guide.

At the conclusion of the MDD, the MDA will issue an ADM that includes signed AoA Study Guidance, authorizes an executive steering group to oversee the AoA (if required), identifies what phase of the acquisition system the program will enter (pre MS-A, MS-B or MS-

C), designates a lead service component (typically Air Force for space) and identifies expectations for the initial milestone review. The phase of the acquisition cycle that will be directed is technically reflected within the contents of the CCTD(s) and will be summarized in the AoA Study Guidance. These will document the maturity level of the technology required to fill the gap and recommend whether a materiel solutions analysis, technology development or engineering and manufacturing phase is appropriate for entry. It is possible for the ADM to approve entry into a later phase and give specific direction on additional requirements necessary (AFMC/OAS 2010).

Post MDD

Following the signing of the ADM at the MDD, a significant amount of logic was inserted into the model to determine the probabilities of where the capability would like be inserted into the acquisition system. The first attribute considered is whether the capability is evolutionary (upgrading an existing system in and existing SPO) or revolutionary (new system and a new SPO). If the system is revolutionary, it is assumed that an AoA must be accomplished. Depending on what type of system is being considered (JCTD, Prototype, ATD or Paper Concept) has unique probabilities for placement in the acquisition system. Since a JCTD, prototype and ATD are proven prototypes, it is much more likely that they will enter the system pre MS-B or pre MS-C. If the revolutionary system is a paper concept, following the AoA it is highly likely there will be technology development required and it will enter the system pre MS-A. If the system is evolutionary, the likelihood that a previously accomplished AoA may be used is high. Depending on if the system is a JCTD, prototype, ATD or paper concept will impact the probabilities of what phase of the acquisition system it will enter. For example, a paper concept will more than likely enter pre MS-A since technology development is likely required whereas a JCTD will likely be able to enter at pre MS-C since it is an upgrade to an existing system and the technology has been demonstrated. Table 8 summarizes the logic used within ERAM 2.1 for placement in the acquisition system following the MDD and AoA activity, if required.

Table 8: Acquisition System Insertion Logic

REVOLUTIONARY				EVOLUTIONARY					
* AoA is always accomplished				AoA Exists: 80%			AoA Required: 20%		
Pre MS-A	Pre MS-B	Pre MS-C		Pre MS-A	Pre MS-B	Pre MS-C	Pre MS-A	Pre MS-B	Pre MS-C
5%	75%	20%	JCTD	5%	20%	75%	5%	75%	20%
45%	50%	5%	Prototype	15%	75%	10%	45%	50%	5%
45%	50%	5%	ATD	15%	75%	10%	45%	50%	5%
100%	0%	0%	Paper Concept	95%	5%	0%	100%	0%	0%

With this logic established, ERAM 1.0 sufficiently identified the activities following the AoA and no additional framework was developed for this research effort. To validate the accuracy of the flow of the ERAM 2.1 framework, it was shared with several SMEs at the Air Staff, AFSPC and SMC. After approximately 11 iterations, the flow of the activity diagram was generally agreed upon. This is due in large part to the various interpretations that each SME had with regard to the "spirit and intent" of the process. The next portion of this phase was collecting the data for each activity and decision point.

ERAM uses triangular distributions of time for the activities while the decision points require percentages of occurrence for each outcome, the sum being 100%. This was both the most challenging portion of the research as well as the most critical, since it is the basis of ERAM outputs. There were two data sources available: 1) written documentation (policy, instructions and guides) and, 2) SMEs. The problem with the written documentation is too often, it didn't represent reality. There are nuances in the activities not accounted for in the policy timelines such as sufficient time for coordination and comment resolution. These nuances were captured during the interviews with the SMEs and explain the difference between policy and reality. A challenge to overcome with the SMEs was there were few that had been in positions for a significant period of time to be able to keep track of this type of information and answer specific questions. The processes and overarching guidance that currently exist have frequently changed in the past decade, making it difficult to answer questions on the process as it is modeled in ERAM. Additionally, JCIDS activities for space systems do not occur frequently enough to establish a well defined data set. Therefore, as required with other complex discrete modeling simulations, the research team leveraged heuristics of the SMEs and encouraged them to estimate times based on their expert opinions.

To begin data collection, two tables were built that followed the traditional space capability development path (not the JUON path). Table 9 included all the activities created in the ERAM 2.1 framework, including available published times (from policy and instructions). Additional columns were added to identify the least number of days required (best case), the most likely days required and the most days required (worst case). Table 10 identified all decision points in the framework, the possible outcomes and, based on heuristics and historical data, what percentage of time each outcome occurred. For decision analysis, policy and instructions do not provide this type of data—this was collected solely from SMEs. Both tables were shared with SMEs at the Air Staff, AFSPC and SMC with the request that they share their personal opinions on the times, all of which was based on historical data and experience with current processes.

Table 9: Pre MS-A ERAM Activity Timelines

ACTIVITY	PUBLISHED TIME (days)	LEAST (days)	MOST LIKELY (days)	MOST (days)
CBA	90-180 (JCIDS)	90 (evolutionary) 180 (revolutionary)	150 (evolutionary) 540 (revolutionary)	180 (evolutionary) 720 (revolutionary)
MUA		120	180	360
JUON		90	180	300
RSR		30	60	90
HPT	71	71	101	131
O-6 Coord	80	80	102	123
AFROC	52	14	74	120
Draft ICD		71	101	131
Joint Coord		80	102	123
FCB	21	21	28	42
JCB	14	14	21	35
JROC	21	21	44	65
DP Request		3	5	10
DP Proposal		30	45	90
Proposal Review		3	7	21
DP Rework		20	30	40
Find Alternate Funds		10	20	30
DP		240	360	720
Candidate Solution Sets Selection	CCTD Development Concurrent with DP Activity			
Initial Concepts Review				
Concept Characterization Review				
Final Concepts Review				
Release Approval				
AFRB		14	21	42
MDD		14	42	84
MDD Rework		30	90	180
AoA		180	360	720

The cells that are not shaded indicate data was provided from the SMEs based on their expert opinion for an ACAT ID space program. For those cells shaded in gray, the SMEs were unable to provide discrete answers; based on their own expert opinions, the authors estimated the time required for these activities. The following describes the activities in the ERAM 2.1 framework and the work associated with each activity:

CBA: AFSPC responsibility that requires 90-180 days for evolutionary systems and 180-720 days for revolutionary systems. Evolutionary systems are those that are upgrades to existing systems and have an established SPO; revolutionary systems are new systems and will require a new SPO.

MUA: 120-360 days to write an MUA and have it approved

JUON: the initial JUON framework was identified, however, event distributions were not obtained and require additional research efforts. Rather than discard the framework, it was assumed in the model coding that the comprehensive distribution of time for responding to a JUON is at least 90 days, most likely 180 days and at most, 300 days.

RSR: for AFSPC sponsored ICDs, AFSPC/A5X develops the RSR briefing (30-90 days), submits request to AF/A5RP for RSR 21 days (policy requirement) in advance of brief (JCS 2009)

HPT: the HPT takes 30 days (both regulatory goal and realistic) to establish the team and schedule the activity following RSR approval. Per policy, the HPT itself takes 11 days and another 30 days are scheduled for internal coordination and cleanup (60 days realistic). This results in 71 days total (policy) or 101 days (realistic) (JCS 2009).

O-6 Review: this activity includes both the O-6 review at the MAJCOM, Air Staff and Joint Staff as well as the time required to submit the comment resolution matrix (CRM), document and briefing. The expected time is 21 days for document review (policy), 28 days (realistic); 45 days for comment resolution (policy), 60 days (realistic); 14 days for submitting CRM, document and brief (policy and realistic). Therefore, policy goal total is 80 while realistically, it is 102 days (JCS 2009).

AFROC: this activity includes both the AFROC meeting and, if required, flag officer review and comment resolution. The AFROC requires 16 days to review documents (policy and realistic) and approve/disapprove. Should a critical comment be unresolved below the flag officer level, the flag officer review requires an additional 21 days (policy), 28 days (realistic). Flag officer comment resolution requires an additional 15 days (policy), 30 days (realistic). SAF/AQ sources indicated that rarely are flag officer review and comment resolution required, therefore, the AFROC activity in ERAM, the least number of days is 16, the most likely number of days requiring flag officer review and taking 74 days (realistic) and the maximum number of days is 120 (JCS 2009).

Draft ICD: similar to the HPT activity that occurs for Air Force sponsored ICDs, this is the activity that occurs when the ICD is sponsored by the COCOM. It incorporates time to establish the team, schedule the meeting and hold the meeting where the ICD will be drafted. Despite the fact that the COCOM sponsors this, much of the work is accomplished at AFSPC. Therefore, the same distributions from the HPT were used for this activity.

Joint Coord: similar to the O-6 Coord activity for Air Force sponsored ICDs, this is the COCOM sponsored activity for coordinating the drafted ICD. The distributions for O-6 Coord were used for this activity since they accomplish the same purpose.

FCB: this activity occurs 21 days (policy) after the AFROC activities, 28 days (realistic) (JCS 2009).

JCB: this activity occurs 14 days (policy) after the FCB, 21 days (realistic)

JROC: this activity occurs 7 days (policy) after the JCB, 14 days (realistic); 14 days (policy) to sign the document, 30 days (realistic) for a total of 21 days (policy) or 44 days (realistic).

DP Request: 3-10 days for AFSPC/A5 to draft a request for DP support tasked to SMC/XR or SPO XR (revolutionary or evolutionary capability, respectively).

DP Proposal: SMC/XR or SPO XR has 30 days to submit DP proposal to AFSPC, however, based on SME experience, this can take up to 90 days for the Center to accomplish.

Proposal Review: after the proposal is completed by SMC/XR or the SPO/XR, AFSPC reviews the proposal.

DP Rework: should the proposal not be approved and require changes, it is sent back to the originating XR branch for rework.

Find Alternate Funds: should funds not be immediately available for the DP effort, AFSPC will work to find alternate funds for the effort. In the unlikely event they are not found, the effort will terminate.

CCTD: this Center led activity occurs concurrently with the DP effort being accomplished by AFSPC. Specific activities include Candidate Solution Sets Selection, Initial Concepts Review, Concept Characterization Review, Final Concepts Review and Release Approval. This will be accomplished prior to the completion of the DP activity and is therefore not assigned duration distributions.

DP: this activity concludes when AFSPC receives the CCTDs from the Center; AFSPC develops the ICD briefing including “Level of Investment”, Affordability Assessment, JROC Recommendation, AoA Study Guidance and AoA Study Plan.

AFRB: this activity includes the number of days to draft the MDD briefing and the ADM and get SAE approval to proceed to the MDA.

MDD: this is the activity where the MDD briefing is presented and signature for the ADM is acquired.

MDD Rework: should the MDA not approve the ADM and require rework, this activity captures the time required for this effort.

AoA: the AoA activity may take as few as 180 days or up to 720 days to complete. If CCTDs are done with the appropriate level of technical analysis, according to DP SMEs at AFSPC and SMC, this should reduce the amount of time AoAs took in the past (12-24 months) to just 6-12 months, depending on the complexity of the system and available resources.

Table 10: ERAM Pre MS-A Capability Development Decision Probabilities

Decision	Outcome (Probability %)		
Existing ICD	YES (90)	NO (10)	
DOTMLPF	ICD and/or DCR (95)	DCR (5)	
RSR Approve	YES (50)	NO (50)	
AFROC	YES (60)	NO (40)	
FCB	YES (50)	NO (50)	
JCB	YES (75)	NO (25)	
JROC	YES (90)	NO (10)	
DP Approve	YES (99)	NO (1)	
DP Funding	YES (99)	NO (1)	
MDD ADM	YES (90)	NO (10)	
AoA Exists	YES (50)	NO (50)	
AoA Funding	YES (80)	NO (20)	
JUON Post Deployment	JCTD (90)	Theater Sustainment (5)	Demilitarize (5)

The probabilities in Table 10 were the most difficult to determine. Unique personnel characteristics such as rank/level of capability sponsorship, personality of SMC and AFSPC briefing team to gain HHQ buy-in, as well as the political environment all impact the probabilities of the outcome for a specific instance. In correspondence with the SMEs, they struggled to provide quantitative data (probabilities) to these questions. The notional probabilities are based on the expert opinions of the authors and further sampling is required to increase the fidelity of the data.

Rapid Capability Development

In addition to the traditional capability development methods discussed thus far, there also exists a more streamlined process for rapid capability development. CJCSI 3170.01G accounts for this process and defines it as a Joint Urgent Operational Need (JUON). Additionally, AFI 10-614 provides further instruction on this process. Based on the guidance documents as well as a SME from SAF/AQR, the initial framework for this process was modeled, however, the data for the activities and decision points was not acquired. This will be included as a recommended topic for future ERAM research.

Table 11 is a summary of the activities and decisions identified in the rapid capability development flow (JUON) for ERAM 2.1. Further research will be required to determine the distributions of times required for the activities as well as the probabilities associated with the decision points. The framework was derived from CJCSI 3170.01G, AFI 10-614 and an interview with a SAF/AQR SME. Rather than eliminate the initial framework, it remains for further research to be accomplished and a single distribution was assumed for all activities inclusively (see Table 9). Following the delivery of a capability in response to a JUON, three options are available and are denoted in the ERAM 2.1 framework as a CTR Decision. The system can be demilitarized and disposed of in theater, it can be sustained in theater and funded by the COCOM, or it may re-enter the JCIDS process as a JCTD. Table 10 indicates the probabilities the authors assumed for this decision point; further research is required to improve this portion of the model.

Table 11: JUON Activities and Decisions for Future Research

ACTIVITY		DECISION
J8 Review		J8 Approve
JRAC		Sponsor
Funding		Space
AFSPC Tasking		COA
QRC-IPT COA		MDD Approve
QRC MDD		CTR Decision
MDD ADM		
Development		
Test & Field		

4.4 Phase 4: Implement design updates to ERAM 1.1, 1.2, 2.0 & 2.1

ERAM 1.1

ERAM 1.1 was implemented by the Aerospace design team to make the required updates due to the requirements of the new simulation software. This effort was accomplished by the programmers in discussions with Wirthlin, the software modeling programmer for ERAM 1.0. These minor changes served as the ExtendSim® baseline for further, more significant model updates.

ERAM 1.2

Table 12: DoDI 5000.02 Model Change Summary

	Model Change
1	Move PDR to Pre-B, Add SDR (Uncertainty Flow)
2	Move PDR to Pre-B, Add SDR (Main Flow)
3	SDR Submodel
4	Space Specific Submodel
5	“What If” Submodel
6	Cost Growth Check

Table 12 summarizes the changes to ERAM 1.0 that resulted from applying updated space policy guidance. Table 12 describes the data entered into each activity model for the triangular distributions of the timeframes. Table 13 describes the probabilities for the decision points in the model for DoDI 5000.02 and space policy updates.

Table 13: DoDI 5000.02 Update Timelines

ACTIVITY	PUBLISHED TIME (days)	MINIMUM (days)	MOST LIKELY (days)	MAXIMUM (days)	Responsible Organization
Clinger-Cohen Act Compliance/Assessment	180	180	180	210	SPO
Rework from MDA		60	90	180	SPO
IPA Calendar Time		7	10	30	SPO
Cost Growth Check		14	30	60	SPO
Significant Change Notice	45	30	45	60	SPO
MDA Approval Process (Cost Growth)		60	70	90	MDA

Table 14: DoDI 5000.02 Decision Probabilities

Decision	Probability		
IPA Required	YES (65%)	NO (35%)	
MDA Approval (Post Design Review)	YES (65%)	NO/Rework (30%)	NO/Kill (5%)
SDR Success	YES (75%)	NO (25%)	
SDR 2 Success	YES (90%)	NO (10%)	
MDA Approval (Cost Growth Check)	YES (65%)	NO (35%)	

In reviewing the DoDI 5000.02 updated in 2008 and additional guidance memos, several areas were identified for updates in the model. One of the main areas of change was the movement of PDR prior to MS-B.

> When consistent with Technology Development Phase objectives, associated prototyping activity, and the MDA-approved Technology Development Strategy (TDS), the PM shall plan a PDR before MS-B. PDR planning shall be reflected in the TDS and shall be conducted for the candidate design(s) to establish the allocated baseline (hardware,

> software, human/support systems) and underlying architectures and to define a high-confidence design (OUSD/ATL 2008).

PDR in ERAM 1.1 occurs post MS-B as does System Design and Demonstration (SDD); PDR in ERAM 1.2 has PDR activities both before and after MS-B, with the latter optional. SDD is removed in ERAM 1.2 and replaced with a technology development identifier pre MS-B. Within the ExtendSim® modeling code, the PDR activity is triggered in an uncertainty event flow, as shown in Figure 31. This uncertainty event flow is an artificial way to introduce some randomness to how an entity progresses through the model. This uncertainty flow continuously checks random numbers to a probability distribution. If the number falls within the probability distribution, the event proceeds forward in the process flow. In ERAM 1.1, since the PDR was part of technology development, the contract association changed from 25% contract completion percentage. For PDR this percentage will be 80%. The trigger for these events is an uncertainty trigger which attempts to model various unpredictable events levied on the program office. It occurs about every 30 days based on a random generation of an event. It could be a funding cut drill or some other activity to defend their acquisition strategy. This is an out-of-cycle activity levied on the program manager, which may or may not happen. So therefore, this “uncertainty event” captured this unplanned activity path. Figure 31 demonstrates this uncertainty path for the PDR in the contractor’s swim lane which will be moved prior to MS-B. It checks the progress of the contract with contract length and time. If the uncertainty event levied on the program office occurs at a time where 80% or more of the contract has progressed sufficiently, the PDR is triggered. The PDR variable is set which kicks off the activities in Figure 32.

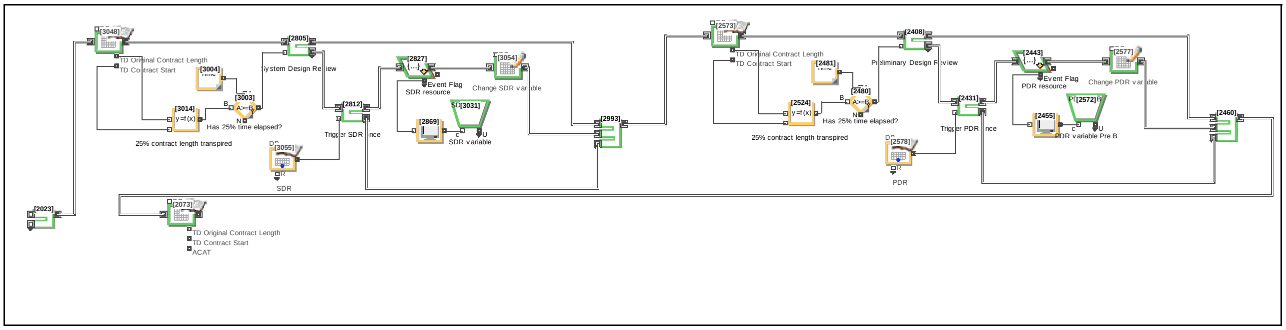


Figure 31: Move PDR to Pre-B, Add SDR (Uncertainty Flow)

Figure 32 occurs in the main acquisition swim lane. After the PDR event is triggered from the uncertainty event flow, approximately 80% of the technology development contract is complete and the SPO prepares for a down selection of competitive prototypes. Additionally, as indicated in Figure 31, a PDR failure will result in a rework cycle to for the contractor and SPO to make corrections and then go back for approval. This describes the original technology development activity prior to beginning testing. The original technology development had lower levels of scrutiny. However, the changes in the DoDI 5000.02 place a PDR toward the end of technology development and prior to MS-B. “The purpose of this phase is to reduce technology risk, determine and mature the appropriate set of technologies to be integrated into a full system, and to demonstrate critical technology elements (CTE) on prototypes.” (OUSD/ATL 2008). Figure 32 describes the addition of the SDR and PDR event flows prior to MS-B. It also adds the Clinger-Cohen Compliance Assessment and approval process which runs in parallel to those reviews in preparation for MS-B.

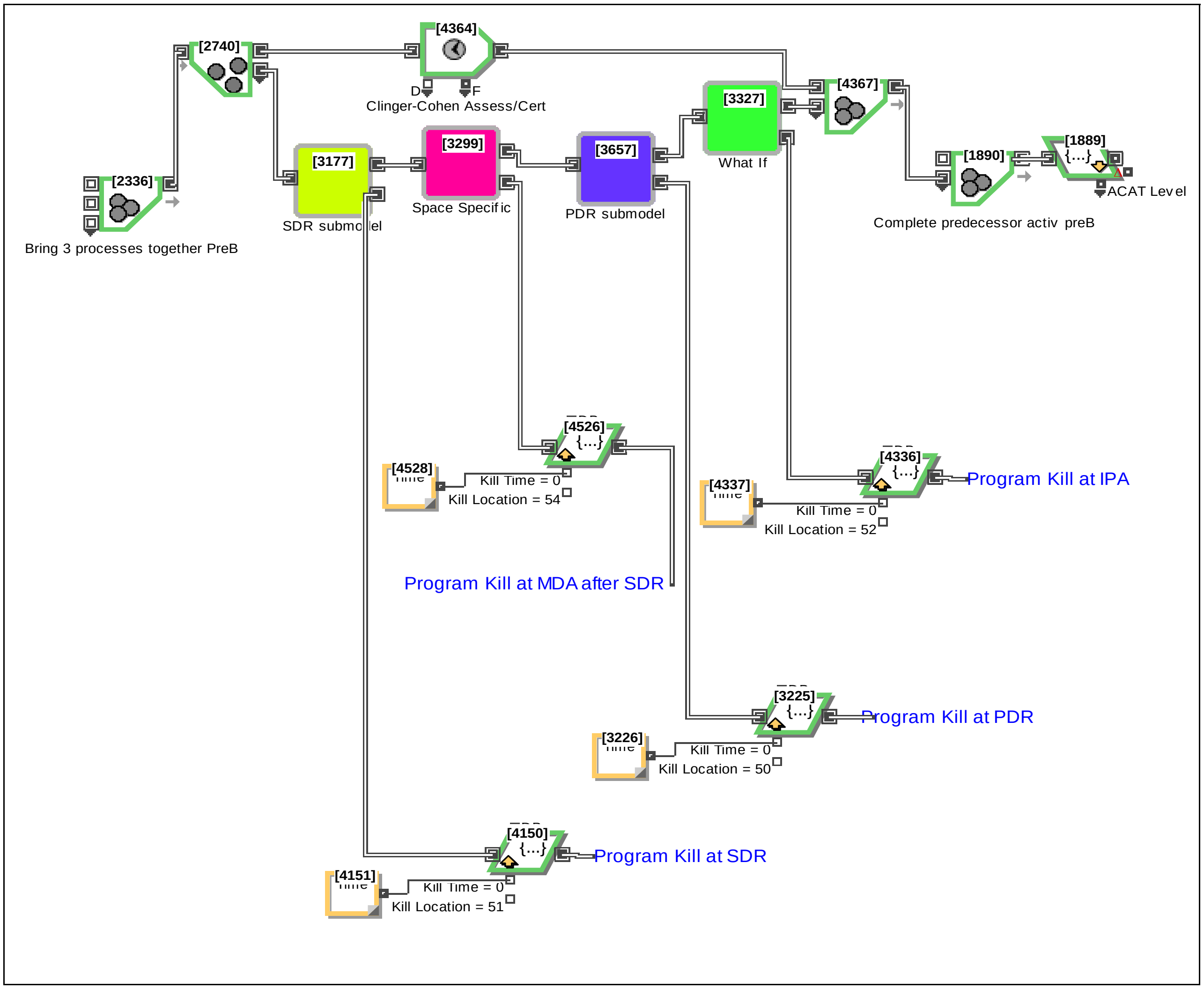


Figure 32: Move PDR to Pre-B, Add SDR (Main Flow)

A specific requirement for space systems directed by OSD/AT&L in DTM 09-025, Space Systems Acquisition Policy (18 October 2010) was that there would be a SDR early in acquisition "During the technology development phase, space system PMs shall conduct an SDR to ensure that the system's functional baseline is established and that the system has a reasonable expectation of satisfying the requirement of the ICD within the currently allocated budget and schedule" (Carter 2010). Figure 33 shows the implementation of the SDR process flow.

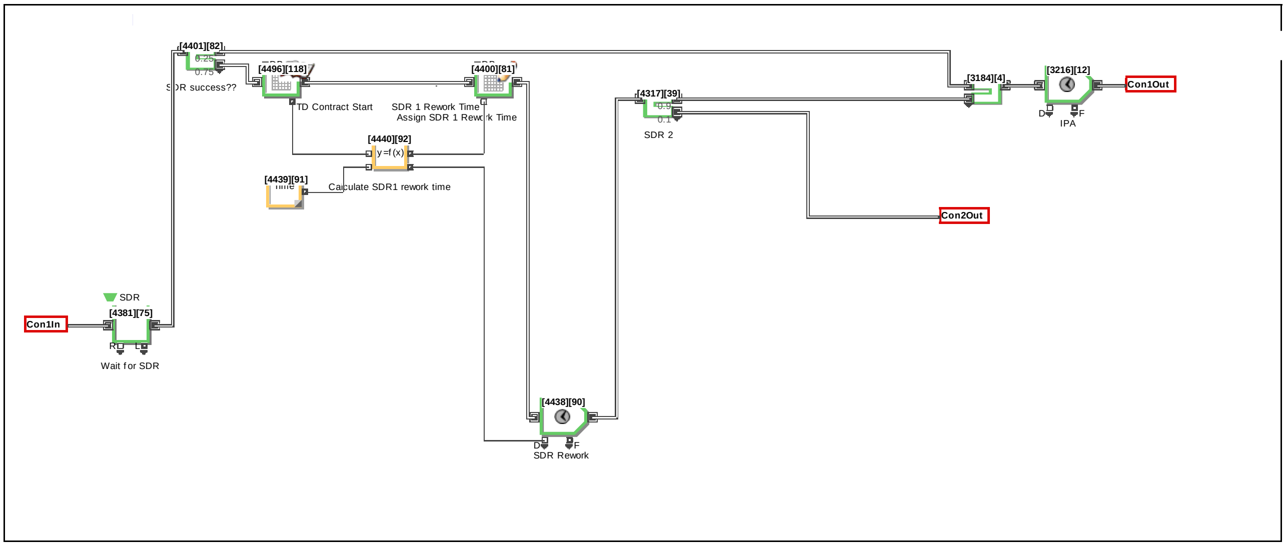


Figure 33: SDR Submodel

For SDR, the Space Specific sub-model in Figure 34 includes the IPA support of the Post SDR assessment. The "What IF" path was removed for SDR due to the fact that all SDRs include an IPA. Where there is a mandatory IPA immediately after the SDR, Figure 35 describes that activity's implementation. This illustrates an example of the process required for interacting between SMC/XR model developers and the authors of this report.

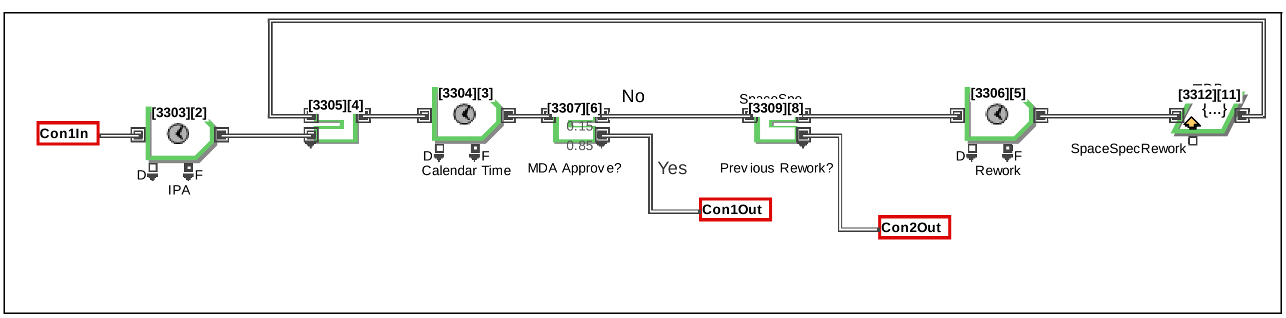


Figure 34: Space Specific Submodel

Figure 35 demonstrates a draft implementation of the "What IF" sub-model. This is a small portion of code that implements some of the activities described in the Space Systems

Acquisition Policy DTM. It describes additional activities to be associated with each review at the MDA level in addition to the typical milestone reviews. "The MDA shall conduct a formal program assessment following the SDR for space systems. The SDR provides an opportunity to assess satisfaction of user needs through functional decomposition and traceability of requirements from the ICD to the contractor's functional baseline and system specification. An IPA shall be provided to support the P-SDRA" (Carter 2010). The "What IF" sub-model checks to determine if an IPA is requested by the MDA. For SDRs, the IPA will always be required to support the MDA's post SDR assessment. For PDR and CDR, the MDA can decide whether or not to receive support from an IPA. Hence, the "What IF" sub-model performs that check following the particular review. If the MDA does not approve, there is a single rework cycle for the SPO to make corrections. For the PDR and CDR post assessments, the "What If" sub-model is included as a check to see if the MDA requests IPA support.

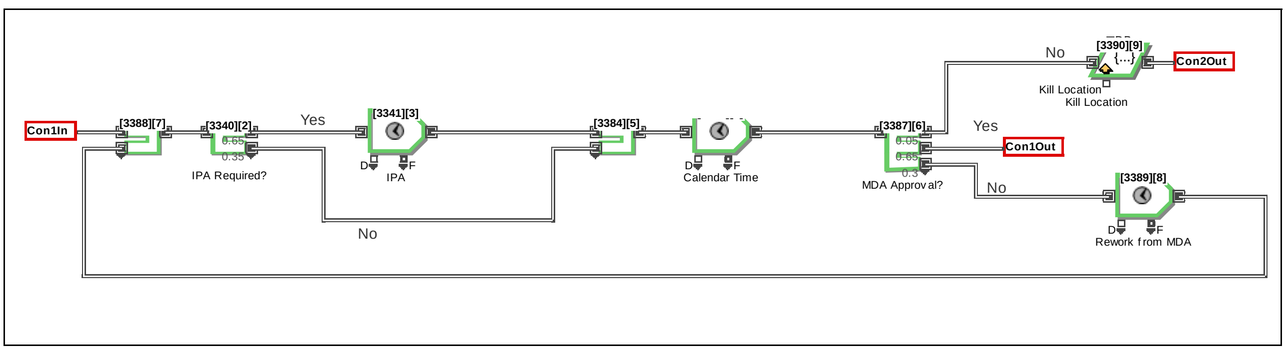


Figure 35: "What If" Submodel

MDA approval is needed after the affordability assessment if the cost growth is greater than 25% over the original estimate.

> "If, during Technology Development, the cost estimate upon which the MDA based the Milestone A certification increases by 25 percent or more, the PM shall notify the MDA of the increase. The MDA shall again consult with the JROC on matters related to program requirements and the military need(s) of the system. The MDA shall determine whether the level of resources required to develop and procure the system remains

consistent with the priority level assigned by the JROC. If not, the MDA may rescind the Milestone A approval if the MDA determines that such action is in the interest of national defense" (OUSD/ATL 2008).

This was implemented after the Affordability Assessment in the Pre MS-B activity. Figure 36 describes how the DoDI 5000.02 text was turned into a process flow diagram. This evolved into an implementation shown in Figure 37. Figure 38 shows how the Cost Growth Check sub-model was added into the main flow if the ExtendSim® implementation

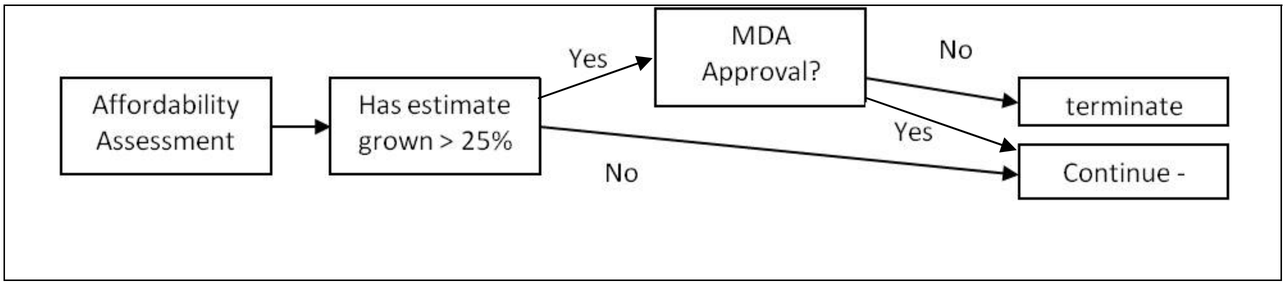


Figure 36: Notional Cost Growth Process Flow

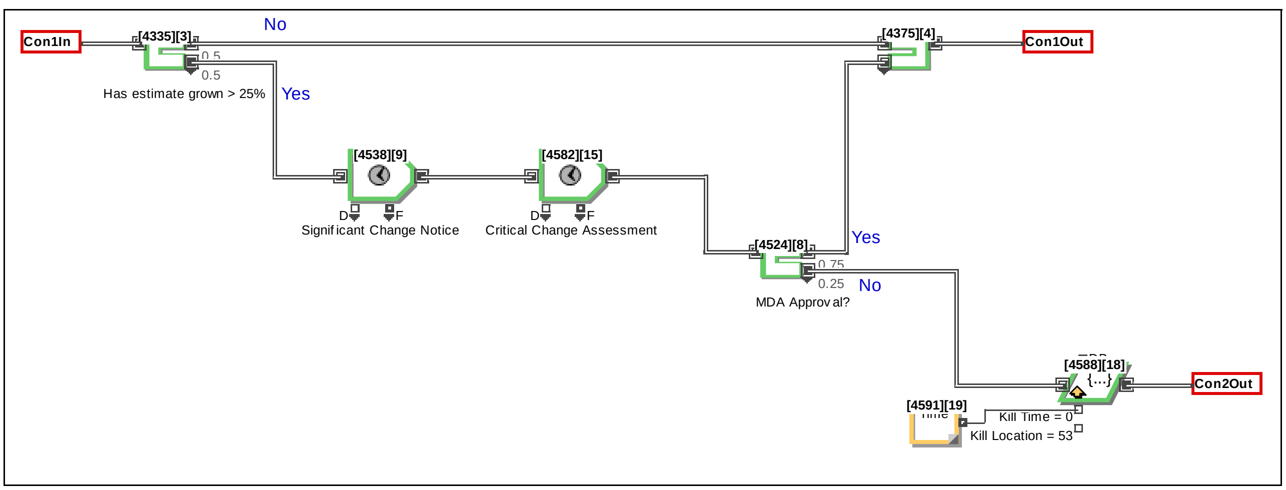


Figure 37: Cost Growth Check Submodel

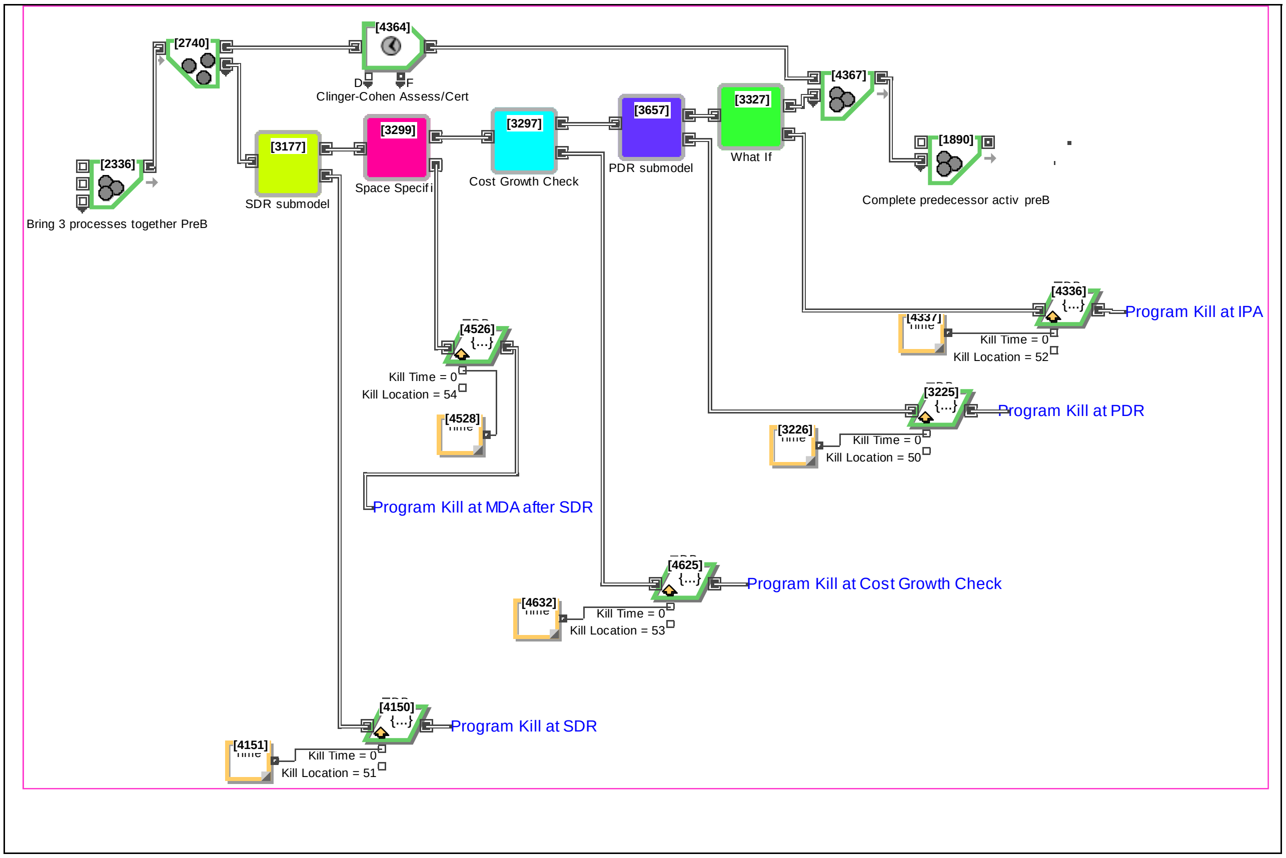


Figure 38: Cost Growth Check in Main Flow

Therefore, the above changes were implemented into ERAM 1.2 as a portion of the collaboration effort with SMC/XR. The DoDI 5000.02 guidance was checked to ensure that the independent cost estimate (ICE) activities in ERAM 1.2 accurately reflected the updates to the DoDI 5000.02. The structure of the flow did not change in the ICE portion. The Clinger-Cohen Act Acceptance/Review process was incorporated as a significant event. Additionally, the IPAs and Post-SDR/PDR/CDR assessments were added which have a significant impact on program timelines. They also add potential exit points to ERAM 1.2 with probabilities.

ERAM 2.0

ERAM 2.0 incorporated the global variable of acquisition capability into ERAM 1.2. Table 4 identifies areas where an ERAM user can identify the appropriate level to reflect the capabilities of the SPO. Appendix B documents the activities selected that will be impacted by this global variable. The global variable has levels from 0 to 4 which determine the triangular distribution impact for the timelines of the discrete events. Figure 39 shows a notional view of how the distributions will be impacted based on experience and staffing levels. The “y” axis shows the probabilities while the “x” axis shows the timelines in number of days. It suggests lower capability skews events longer, while higher capability skews the event to be completed in a more timely fashion. Level 2 is considered a baseline level which doesn’t skew activities as modeled in any direction.

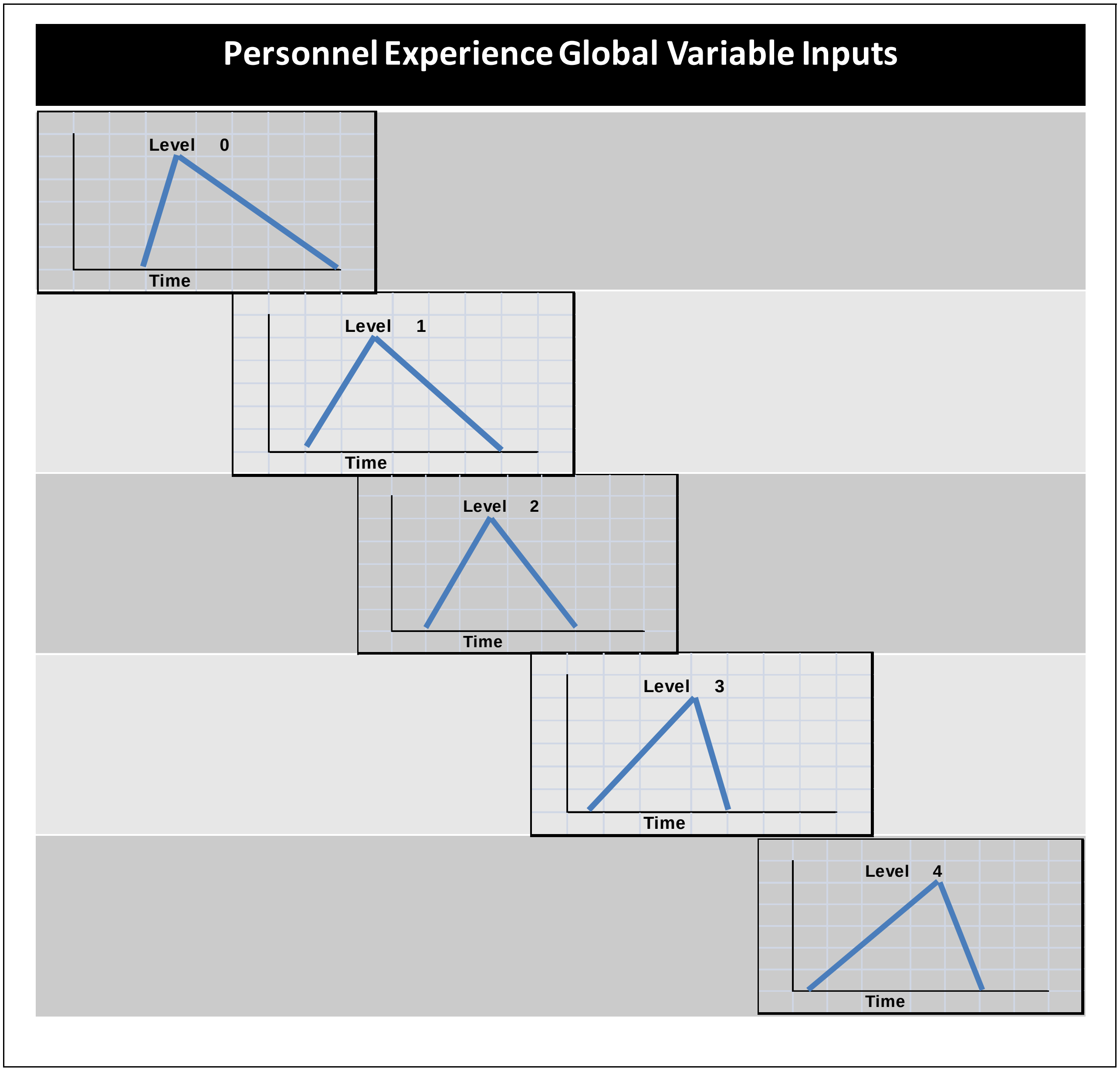


Figure 39: Notional Triangular Distribution Timeline Impacts

ERAM 2.1

In order to implement the JCIDS process in ERAM 1.2, several changes and additions were required. The Microsoft VISIO diagram that was reviewed with the requirements and acquisition personnel was compared with ERAM 1.2 to determine insertion points and changes. Table 14 outlines the activities recommended for implementation in ERAM 2.1.

Table 15: JCIDS Model Changes

	Model Changes
1	Add JCIDS Initiation
2	Add/Update JCIDS Concept Review Process
3	Add Development Planning Initiation
4	Add CCTD Development Process
5	Add/Update MDD Process
6	Update AoA Process
7	Add JUON Process

Figures 40 and 41 demonstrate how the model design was recommended to the Aerospace software engineers to fully implement the pre-MDD JCIDS activities. In Figure 40, the first column of activities represents potential sources of "ideas" for capabilities and/or concepts that are injected into the "AFSPC IPP & ATC". The "AFSPC IPP & ATD" at a given point in time will prioritize and select which capabilities to pursue further. The first step is to compare the capability against existing ICDs. If one exists, it by-passes the JROC ICD approval flow. However, if it requires a new ICD, depending on if the capability or technology is a paper concept, a prototype/JCTD or an ATD will determine which activity path it follows. Translating this to code, the "For existing Program" icon in Figure 41 becomes a user selected "pull-down menu" to choose ATD, Paper Concepts, or others.

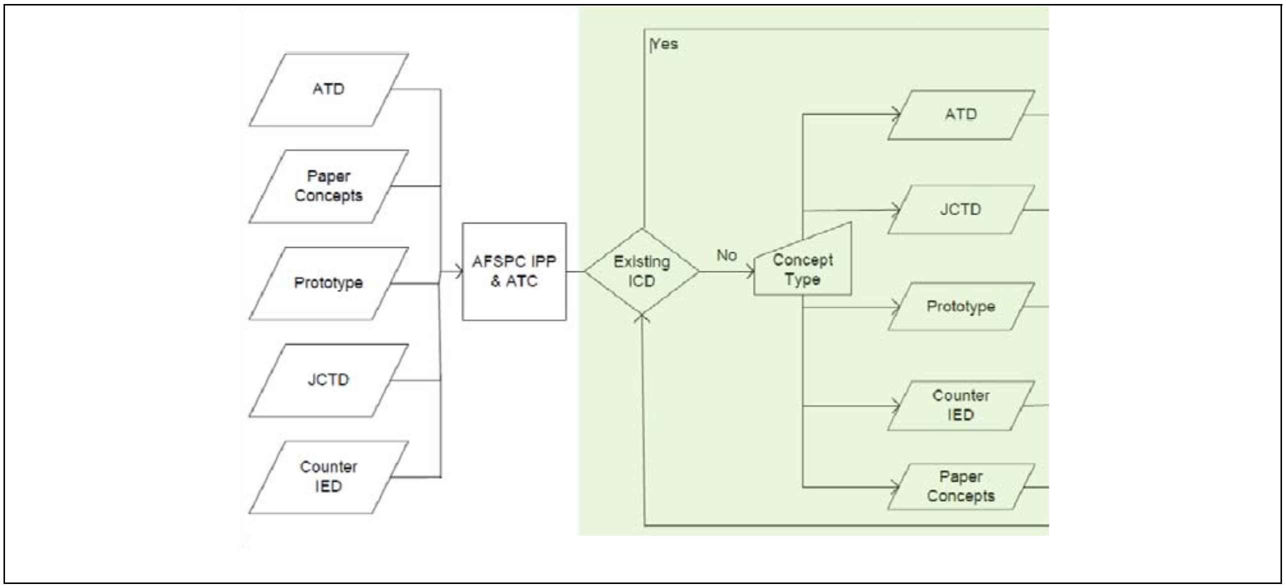


Figure 40: JCIDS Initiation

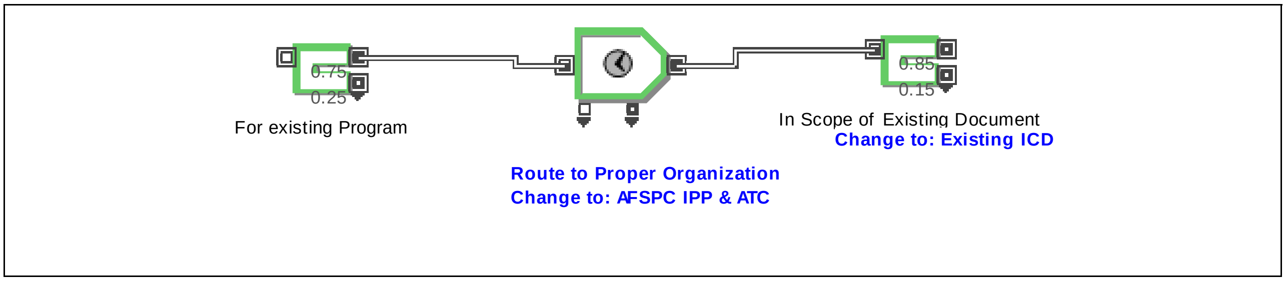


Figure 41: JCIDS Initiation ExtendSim Implementation

Figures 42 through 44 describe the concepts as they proceed through the CBA process. The concept then goes through a DOTMLPF decision. It follows separate paths based upon sponsorship from either AFSPC or USTRATCOM. If it is sponsored by USTRATCOM, it bypasses the Air Force specific processes. The implementation included reuse of existing code from the Joint Interest pre MS-B sub-model shown in Figure 43. A significant difference is that the USTRATCOM sponsored concept will bypass the AFROC and insert directly into the middle of the Joint Interest sub-model. The Functional Review Board in Figure 41 occurs in the Joint Interest sub-model.

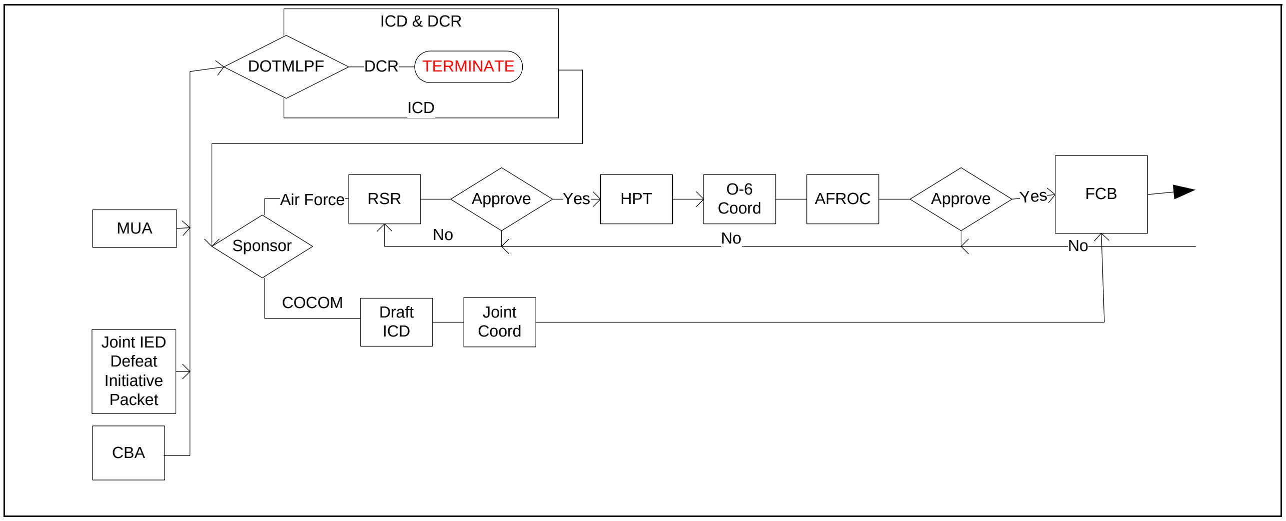


Figure 42: JCIDS Concept Review Process

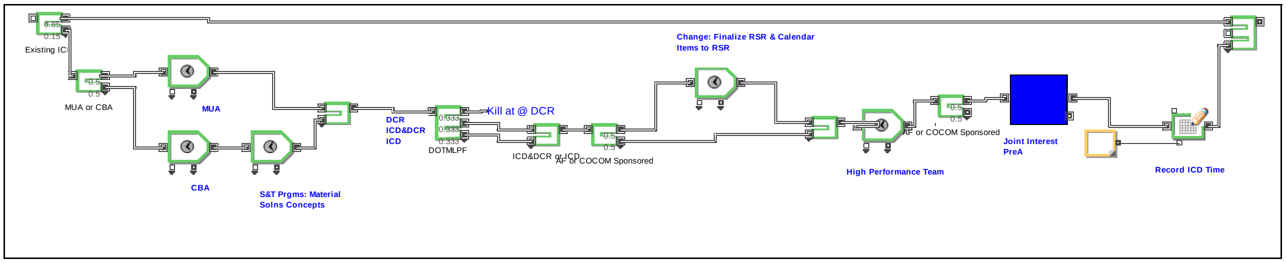


Figure 43: JCIDS Concept Review Process ExtendSim Implementation Part 1

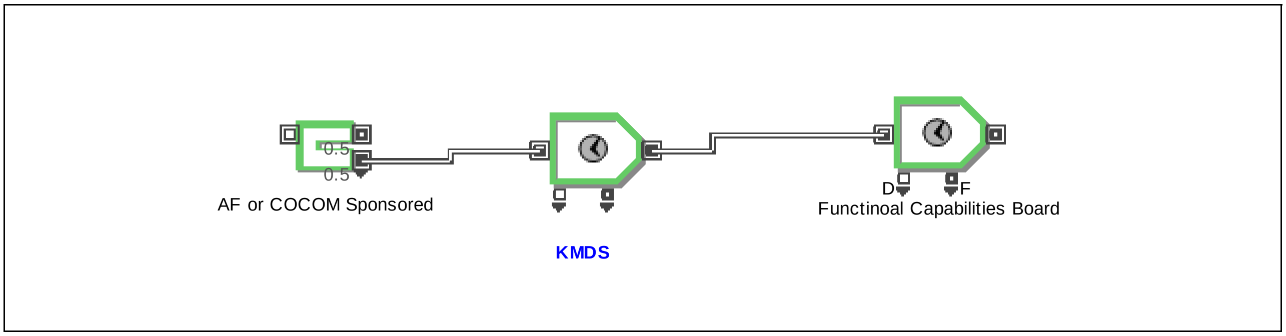


Figure 44: JCIDS Concept Review Process ExtendSim Implementation Part 2

Figures 45 and 46 describe the initiation of the DP process initiated after an ICD is approved. This AFSPC initiated processes sends the DP Request to SMC/XR or SPO for an existing program of record. This is then reviewed and processed through the AFSPC led prioritization process.

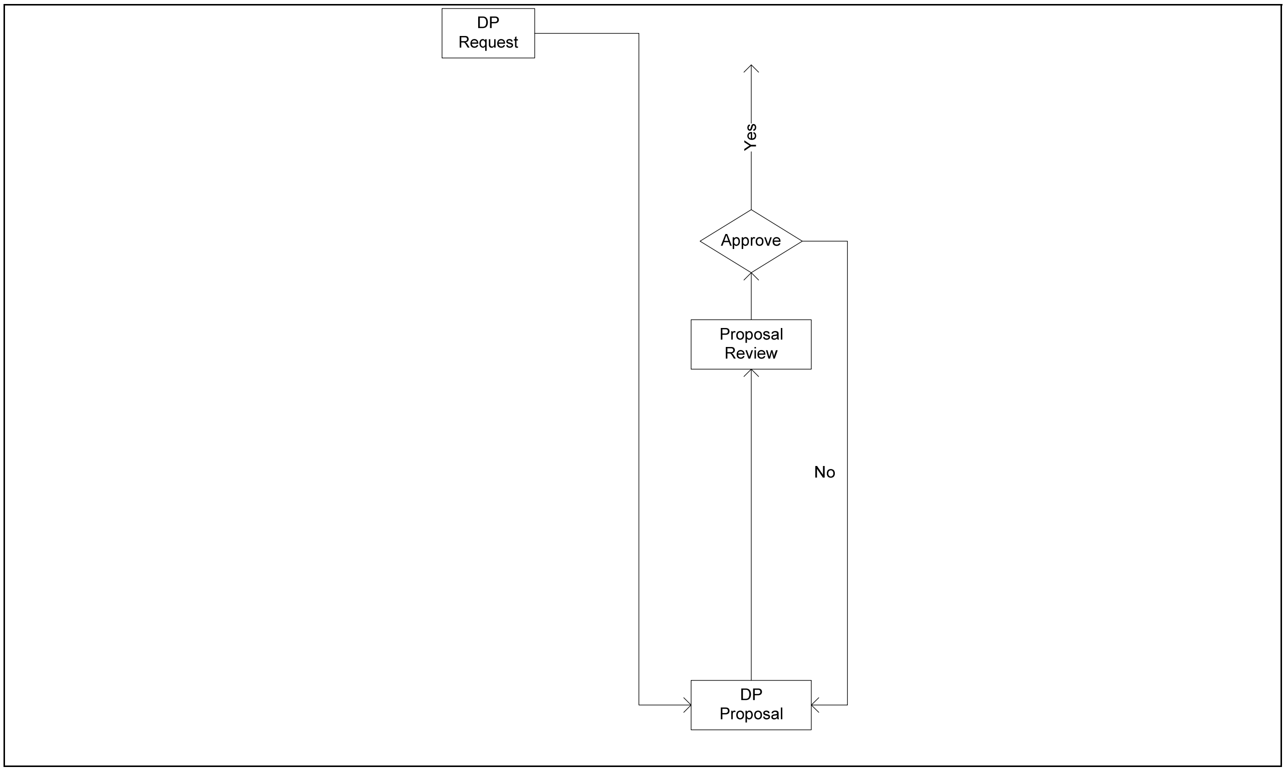


Figure 45: Development Planning Initiation

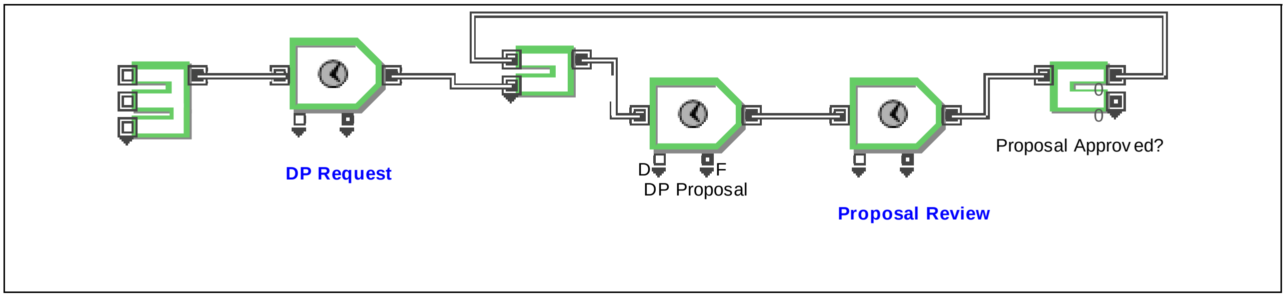


Figure 46: Development Planning Initiation ExtendSim Implementation

Figures 47 and 48 describe the various steps that SMC/XR or a SPO XR branch accomplishes as they complete the CCTD effort. The CCTD process owner accomplishes five phases, as shown in Figure 47. In the implementation in Figure 48, the five phases are executed sequentially as a substitute for the DP block. This is in concert with the intent of the designer. However, as the design team and the software engineers met, the 5 CCTD phases were aggregated back up to a single DP activity block.

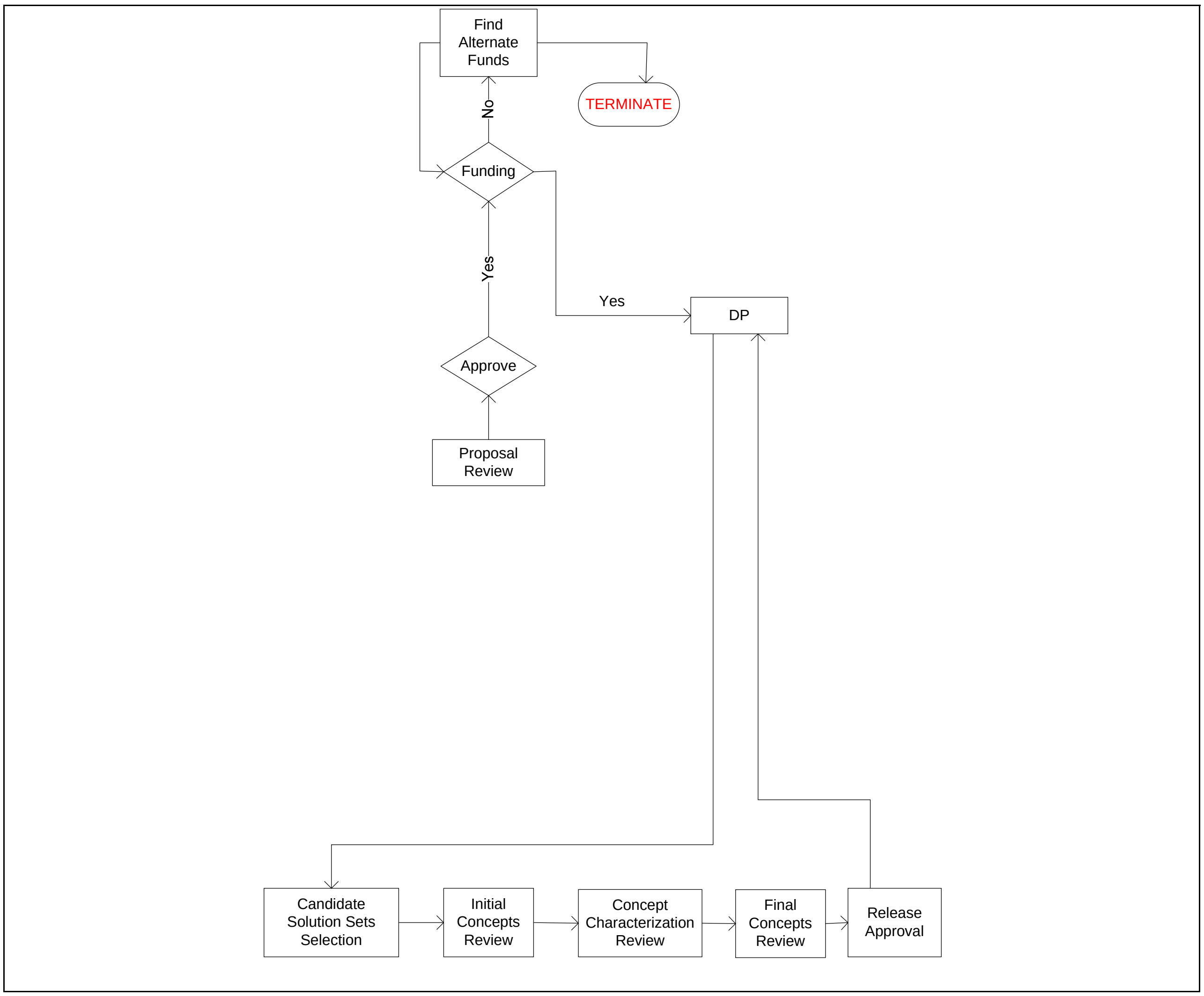


Figure 47: CCTD Development Process

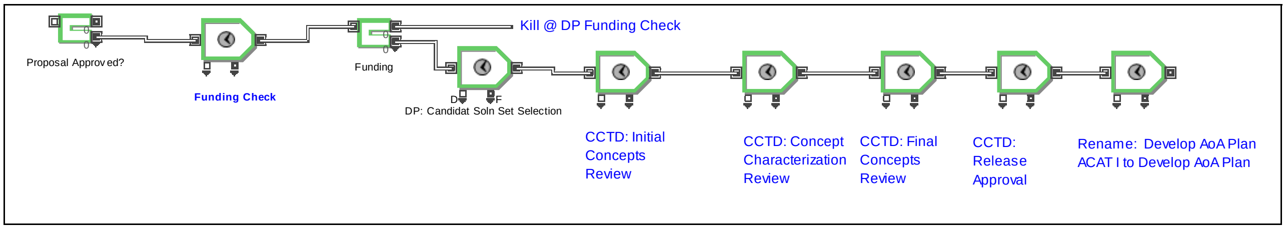


Figure 48: CCTD Development Process ExtendSim Implementation

Figures 49 and 50 describe how the MDD and approval were modeled. The ADM and MDD brief submitted to the MDD result in a decision which either terminates the program or sends it further down the process to begin an AoA. The implementation in Figure 50 reused existing ERAM 1.1 code and clarified the processes to include the AFRB.

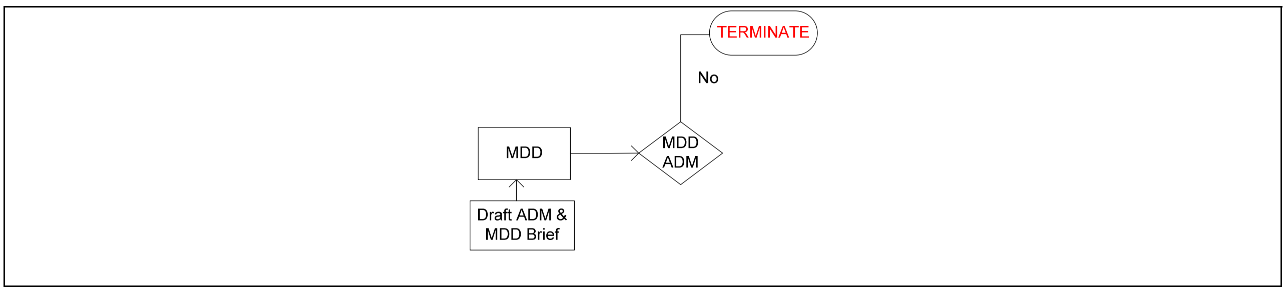


Figure 49: MDD Process

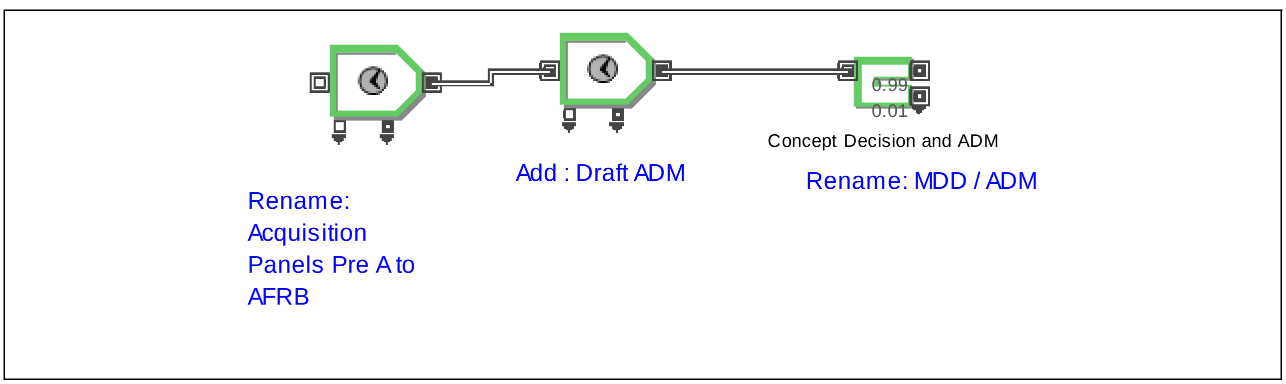


Figure 50: MDD Process ExtendSim Implementation

Figures 51 through 53 show the AoA design and implementation through the point the program is inserted into the acquisition process based on the ADM. Existing ERAM 1.1 code was reused which captured the detail of the AoA process through developing courses of action. In Figure 53, the different insertion points after a preferred concept is selected and the 3 way branch either continues in the pre MS-A, or jumps to pre MS-B or pre MS-C.

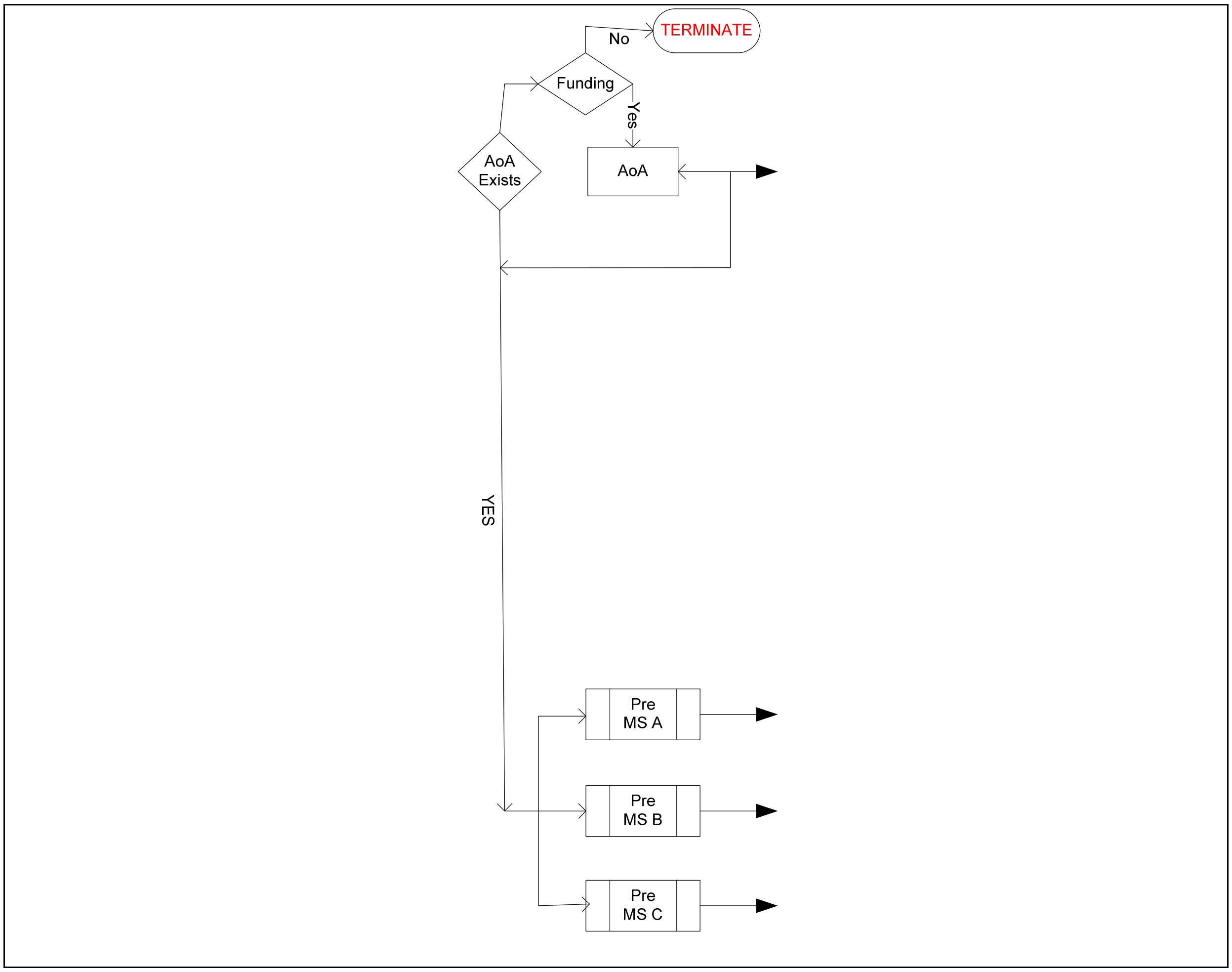


Figure 51: Analysis of Alternatives

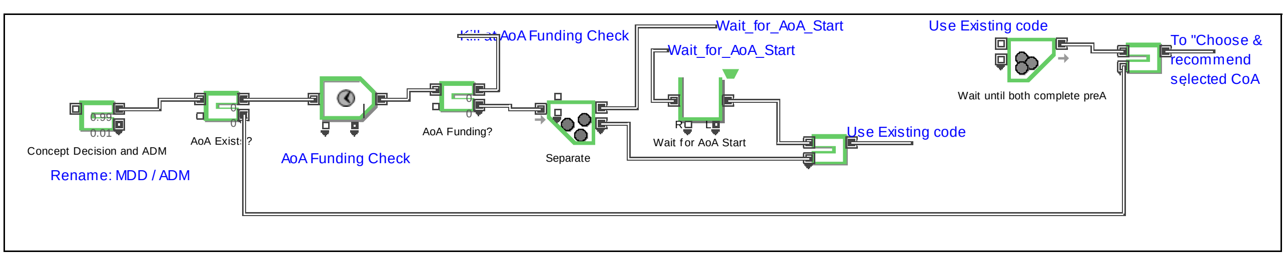


Figure 52: Analysis of Alternatives ExtendSim Implementation Part 1

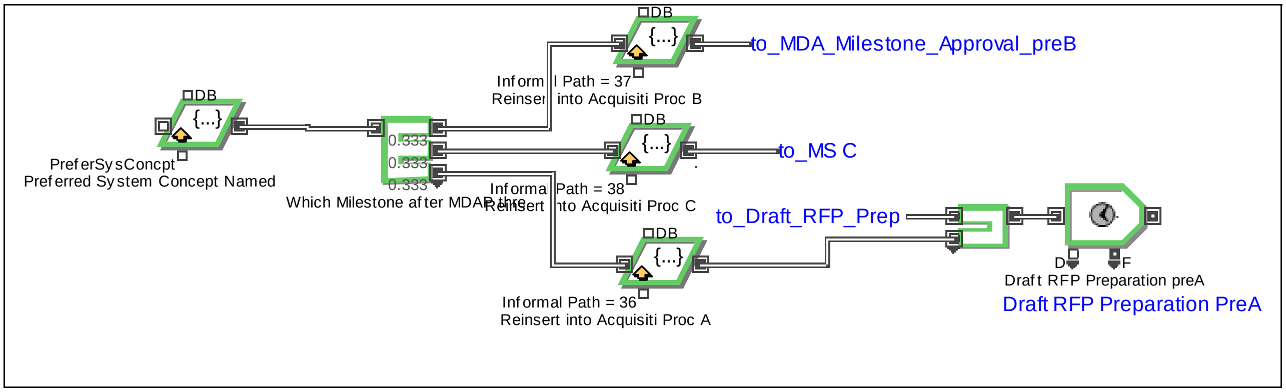


Figure 53: Analysis of Alternatives ExtendSim Implementation Part 2

Figures 54 through 57 show the separate JUON process. If the user selected menu in Figure 40 and 41 selects JUON, it follows the new path. This path ends at a fielded capability if it passes all of the review processes. The final decision results in a branching that selects whether or not it will become an enduring program and go into the official process, be disposed of or sustained exclusively in the theater of operations.

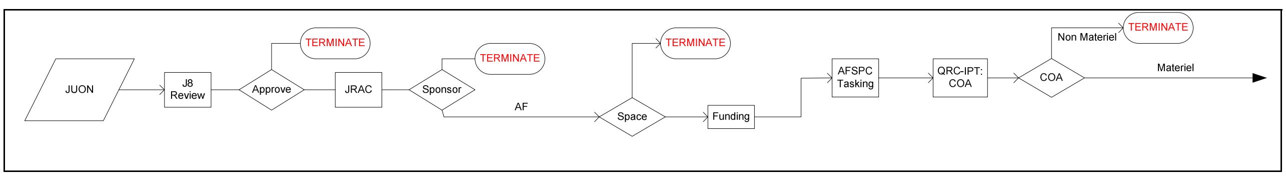


Figure 54: JUON Process Part 1

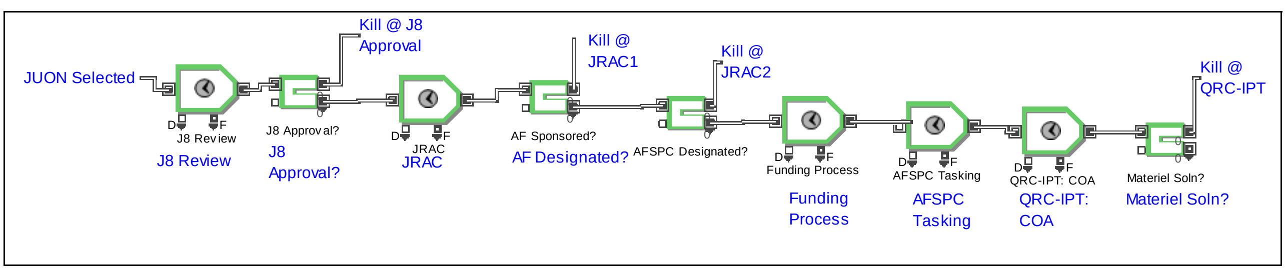


Figure 55: JUON Process Part 1 ExtendSim Implementation

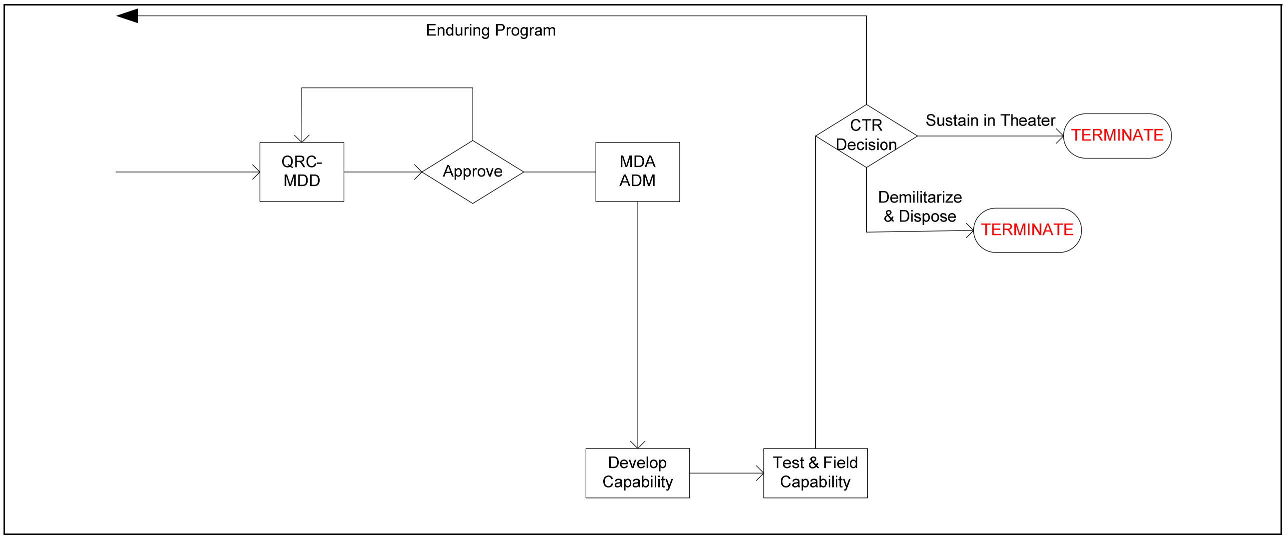


Figure 56: JUON Process Part 2

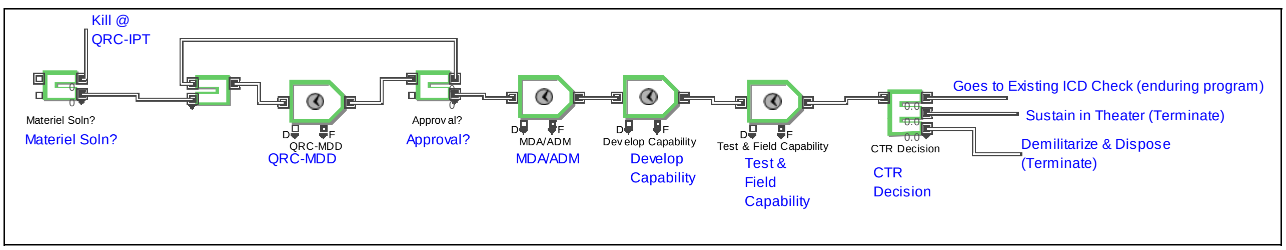


Figure 57: JUON Process Part 2 ExtendSim Implementation

4.5 Phase 5: Document and Report

At the conclusion of these interviews, modeling updates, document reviews, etc, the research team captured the data and documented the findings. These findings were also presented orally on multiple occasions for academic purposes and to satisfy the requirements of the sponsoring organization. A final review was conducted with the Aerospace software engineers to ensure they had obtained the required data for completing the model implementation.

V. Conclusion & Recommendations

5.1 Conclusion

Unfortunately, defense space acquisitions have earned a reputation of being notoriously over budget and behind schedule. Not surprisingly, Congressional and senior DoD leadership have recently focused efforts on identifying the root cause in order to improve program execution. As previously reported by the GAO, this research also found that many early space program decisions have been based on insufficient and/or inaccurate data with regards to schedule and cost estimates as well as technology maturity. In an abstract relationship, a DoD capability gap exists for its ability to properly estimate and execute the cost and schedule to deliver new capabilities.

In an effort to provide a solution to this capability gap, policy and statutory guidance has been updated in the past several years emphasizing the importance of early systems engineering, DP, and assessing technology maturity in advance of MS B. Tools such as ERAM, RAMP, ADDM and APM continue to gain attention as they provide insight into the acquisition system and help characterize the various decisions points and activity timelines. Through the process of updating ERAM for space acquisitions, the following are several valuable observations for potential contributions to the current challenges faced in space capability development:

1) ERAM provides a comprehensive early schedule estimate based upon existing government policy and instructions, a valuable piece of data currently missing. For a given concept, this data should be captured in the CCTD and properly assessed in the AoA prior to a materiel solution being selected.
2) ERAM provides insight into the extraordinarily complex process of developing space capabilities. A single model that comprehensively ties the multitude of processes and organizations outlined by DoD and AF policy, instructions, and guides has the

potential reducing and simplifying the process into an understandable and manageable process for requirements and acquisition personnel.

3) ERAM provides detailed context to the well known, but too often in comprehensible, DAU acquisition wall chart. The DAU wall chart provides a high level picture of the activities, but, lacks the detail to be an effective management tool. ERAM's activity diagram identifies the sequence of activities/decisions, the organizations responsible for them and estimated timelines for the activities, resulting in a management tool that empowers PMs to more effective.
4) ERAM could become the backbone of a training program for DoD and industry PMs providing detailed insight to current space acquisition policy and processes; a type of program management "flight simulator".
5) ERAM is an asset available for SMC/XR to utilize during DP efforts (developing CCTDs) for AFSPC with regards to "revolutionary" capabilities while existing SPO XR shops can leverage SMC/XR CCTD expertise and ERAM for AFSPC directed "evolutionary" capabilities DP.

At the beginning of this research effort, three objectives were established: update ERAM for space capability development in ExtendSim modeling software, verify and validate the model and lastly, provide recommendations for further research efforts (if required).

The first objective of updating ERAM in ExtendSim for space acquisitions was achieved; however, additional research remains in order to reach a version capable of providing usable data for CCTDs. Research efforts found that there is no single "correct" process that everyone agrees upon or one that can be designed from published guidance. The myriad of policy memos, instructions and guides are difficult to tie together into a single activity diagram; rather, they provide a framework that must be navigated uniquely for every program. Despite these challenges, a generally accepted framework has been designed and implemented as ERAM 2.1. Nevertheless, the authors used their own expertise and knowledge gained during this research to suggest notional data that can be refined later. Rather, the data generated by the authors is of high quality with reliable resources and meets the triangulation method of validation (Patton and Denzin, qtd. in Scharch, et al. 2011). This was accomplished through interviews with SMEs familiar with space capability development pre MS-A, analysis of existing policy and guidance governing capability development as well as comparing the model to current, real world pre MS-A space concepts. Objective three was met and documented in the "Recommendations" portion of this report.

5.2 Recommendations

With all of the uncertainty and variability within the DoD acquisition process, there will always be modeling opportunities to improve the fidelity. As Statistician George Box stated, "All models are wrong, but some are useful." (Box Vol 71) The following are several research topics that would continue to increase the utility of ERAM for space capability development:

1) PPB&E Activities/Decisions: More detailed research into modeling PPB&E Activities would add realism to the model. This calendar driven-process drives the funding available to program managers at various stages. Spring execution reviews and other events have the potential to remove funding from the program. This process exists in ERAM, but would be improved with further research.

2) T&E Activities/Decisions: Test and Evaluation as a significant portion of the acquisition community is a good candidate for research emphasis on future spirals of ERAM. It is included in the current version of ERAM but at a high level of abstraction. Coordination with the

Operational Test community is essential early in acquisition with Test and Evaluation Master Plans required at Milestone reviews.

3) ERAM Maintenance: In general terms, further research in probability distributions for activities and decision points would increase the fidelity of the model. Larger sampling of subject matter experts will further refine the spans of the distribution. Keeping up with the frequent policy changes will also add to the maintenance of ERAM.

4) Improve acquisition modeling efforts between SAF/AQ, AFMC, and the XR shops at ASC, ESC, AAC and SMC to reduce duplication of effort and maximize synergies between various models.

5) Analyze how the cost of early SE and increased quantitative analysis impact the overall performance (cost and schedule) of programs compared to previous programs with little early SE (utility analysis). These observations could then be folded into future versions of ERAM.

6) Further development and analysis of the rapid acquisition process (JUONs as well as other techniques).

In the process of identifying a comprehensive activity diagram that ties S&T, AFSPC capability gap analysis, JCIDS, DP and eventually the acquisition of a materiel solution, several general challenge areas with regards to space capability development are discussed:

Challenge #1: Inadequate Early Systems Engineering. Lack of early systems engineering results in a weak technical foundation for the system to be built upon and results in an increased number of risks and "unknown unknowns". Too often, the hard questions are pushed off to be addressed later in the program, resulting in costly schedule delays.

Proposed Solution: Improve early systems engineering analysis prior to MDD and MS-A approval. Early systems engineering will help identify and assess the risks associated with these questions before major program decisions occur, preventing more costly impacts further into the program. Recent guidance has directed this; however, implementation is still in progress. It is recommend that to overcome the challenges that remain 1) assign responsibility to a single organization, and 2) find/hire technically competent systems engineers to develop the space architecture, and 3) choose a single systems engineering software suite that is required for use by all services.

Challenge #2: Failure of the Government to Assess Technology Maturity. Poor technology maturity assessments prior to contract award results in costly schedule delays.

Proposed Solution: To accurately assess technology maturity levels, the government must improve its technical knowledge base and establish improved evaluation methods. Rather than accept ideas at face value as "good", proving the feasibility must be required. Improving the process for AFRL, universities and industry partners to prove military utility of hardware and software technologies in advance of contract award will likely significantly improve contract performance post Milestone B.

Challenge #3: Improper Distribution of Personnel. Developing new space capabilities and sustaining existing capabilities is indeed a challenging endeavor. In response, in the opinion of the authors, the number of personnel supporting HHQs appears to continue to increase, resulting in significant manpower (and associated costs) charged with developing new and improved policy and instructions. At the product centers, very few PMs can piece the policy architecture together or have the time to in order to make sense of how the multi-organizational process is designed to work.

Proposed Solution: First, reduce and consolidate the number of guidance documents. Ensure the documents are consistent with one another and establish a coherent process flow that doesn't require a genius to understand. After this is accomplished, second, reallocate the manpower positions supporting HHQ to support the personnel at the Centers. Third, with a portion of these resources, establish a rigorous formal training and *evaluation* program that qualifies personnel assigned to key positions. Current DAU training is insufficient; just as operators have formal training to learn how to operate their weapon system and understand technical orders, personnel involved in the acquisition system should be required to understand the acquisition system and associated instructions. In addition to initial training requirements, establish recurring training and evaluation programs that re-enforces and sustains the knowledge base. Fourth, with the remaining reallocated resources from HHQs, increase the number of technical positions at the Centers. It's the Centers that are responsible for early systems engineering, CCTD documents and executing programs on schedule and within cost and it's the Centers that have historically struggled.

Challenge #4: Lack of Process Discipline & Training. Individual organizations (AFSPC, SMC, AFRL, SAF, OSD, AFOTEC) all have their individual processes and procedures for fulfilling their responsibilities. With senior leadership within these organizations turning over approximately every two years, there is a good chance that those processes/products change every two years. This is not surprising since there are so many issues throughout the entire system. The intentions of these changes are positive, but the results have far reaching implications that aren't properly communicated/trained and difficult to absorb. This impairs the ability for other organizations dependent on that organization to understand how the process works. Additionally, it makes it extremely difficult to establish value added training curriculum since the material would become outdated more quickly than it could be approved.

Proposed Solution: Establish organizational process discipline. Should organizations choose to change processes that impacts other organizations in the "system", then there should be a formal change process. Part of the process would require outreach training to other organizations that rely on them for their own success/progress.

Challenge #5: Poor 6X Training & Evaluation Program. Acquisition personnel are required by law to take training courses offered by the Defense Acquisition University and maintain Continuous Learning Points. This training is insufficient and only scratches the surface with regards to how the acquisition system truly functions.

Proposed Solution: DoD and SAF need to establish a formal training and evaluation program for requirements and acquisition personnel. AETC is responsible for operational system qualification training for both intelligence, space and aerospace system operations. Additionally, the operational units have established formal evaluations to ensure the qualification and proficiency of the operators. The requirements and acquisition system is certainly different, however, establishing formal training and evaluation programs could enforce an in depth understanding of the processes and pay significant dividends to ensure personnel are knowledgeable and qualified. Additionally, this may serve as a forcing function to HHQ to reduce and simplify the policy guidance and instill process discipline throughout various organizations involved.

Challenge #6: Process Disconnects between MAJCOM & AFRL. The S&T process for focusing defense resources on maturing technologies for desired capabilities is disjointed from AFSPC and the JCIDS process.

Proposed Solution: AFSPC needs to improve its ability to communicate technology development requirements to AFRL. AFRL needs to improve their responsiveness to AFSPC on these efforts. At the same time, AFRL must also continue to provide AFSPC with ideas on emerging military technology applications so the classified capability development strategies can continue to evolve.

In conclusion, failure to for the Department of Defense to take actions to improve an inadequate space acquisition system threatens the United States supremacy in space as well as its national security. Adversaries are increasing their ability to develop technologies and field them at an alarming rate, closing the technology gap America has become accustomed to. From President Obama's National Security Strategy, "We will invest in the research and development of next-generation space technologies and capabilities that benefit our commercial, civil, scientific exploration, and national security communities, in order to maintain the viability of space for future generations." In a fiscally constrained environment, as the service responsible for space capabilities, the United States Air Force must tackle this challenge. ERAM is not the solution to the major problem, but can provide valuable context to the extraordinarily complex capability development system that requires significant reform.

APPENDIX A. List of Acronyms

ACAT	Acquisition Category
ACE	Acquisition Center of Excellence
ACPO	Acquisition Chief Process Office
ADM	Acquisition Decision Memorandum
ADDM	Acquisition Document Development and Management
AIP	Acquisition Improvement Plan
APM	Acquisition Process Model
ATD	Advanced Technology Demonstration
ASC	Aeronautical Systems Center
AAC	Air Armament Center
ACPO	Acquisition Chief Process Office
AFIT	Air Force Institute of Technology
AFMC	Air Force Materiel Command
AFMCI	Air Force Materiel Command Instruction
AFPC	Air Force Personnel Command
AFPD	Air Force Policy Document
AFRB	Air Force Review Board
AFROC	Air Force Requirements Oversight Council
AFRL	Air Force Research Laboratory
AFSPC	Air Force Space Command
AFSPCI	Air Force Space Command Instruction
AMA	Analysis of the Materiel Alternatives
ATC	Applied Technology Council
ASD/NII	Assistant Secretary of Defense for Networks Information & Integration
CDD	Capabilities Development Document
CBA	Capabilities-Based Assessment
CPD	Capability Production Document
CRET	Center for Re-engineering Technology
COCOM	Combatant Command
C2	Command and Control
CCTD	Concept Characterization and Technical Description
CDC	Concept Development Center
CO	Contracting Officer
CAPE	Cost Assessment & Program Evaluation
CTE	Critical Technology Element
DAB	Defense Acquisition Board
DAU	Defense Acquisition University
DoD	Department of Defense
DoDI	Department of Defense Instruction
DP	Development Planning
DTM	Directive Type Memorandum

ESC	Electronic Systems Center
ECP	Engineering Change Proposal
ERAM	Enterprise Requirements and Acquisition Model
FCB	Functional Capabilities Board
FFRDC	Federally Funded Research and Development Center
FSA	Functional Solutions Analysis
GAO	Government Accountability Office
GRP	Group Research Project
HPT	High Performance Team
HHQ	Higher Headquarters
IED	Improvised Explosive Device
ICE	Independent Cost Estimate
IPA	Independent Program Assessment
IRAD	Independent Research and Development
IRSS	Information and Resource Support System
IT	Information Technology
ICD	Initial Capability Document
IPP	Integrated Planning Process
ISR	Intelligence, Surveillance and Reconnaissance
JCB	Joint Capabilities Board
JCA	Joint Capability Area
JCIDS	Joint Capability Integration and Development System
JCTD	Joint Capability Technology Demonstration
JPD	Joint Potential Designator
JROC	Joint Requirements Oversight Council
JUON	Joint Urgent Operational Need
KPP	Key Performance Parameter
KM/DS	Knowledge Management/Decision Support
MAJCOM	Major Command
MDAP	Major Defense Acquisition Program
MDD	Materiel Development Decision
MS	Milestone
MDA	Milestone Decision Authority
MUA	Military Utility Assessment
NRO	National Reconnaissance Office
OSD/AT&L	Office of the Secretary of Defense, Acquisition, Technology & Logistics
ORD	Operational Requirements Document
PDR	Preliminary Design Review
P-SDRA	Pre-System Design Review Assessment
PE	Program Element
PEO	Program Executive Officer
PM&AE	Program Management & Acquisition Excellence
PM	Program Manager

POM	Program Objectives Memorandum
PPB&E	Program, Planning, Budget & Execution
RAMP	Requirements and Management Plan
RSR	Requirements Strategy Review
RMD	Resource Management Decision
S&T	Science & Technology
SAF/AECO	Secretary of the Air Force, Acquisition Excellence Change Office
SAF/AQ	Secretary of the Air Force, Acquisitions
SAF/AQRE	Secretary of the Air Force, Acquisitions Engineering & Technical Management Division
SCF	Service Core Functions
SMC/XR	SMC Development Planning Division
SMC	Space and Missile Systems Center
SRP	Space Re-capitalization Plan
SSAP	Space Systems Acquisition Policy
SMP	Strategic Master Plan
SME	Subject Matter Expert
SDD	System Design & Demonstration
SDR	System Design Review
SPO	System(s) Program Office
TDS	Technology Development Strategy
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TSAT	Transformational Satellite Communications System
USD/AT&L	Under Secretary of Defense, Acquisition, Technology & Logistics
USTRATCOM	United States Strategic Command
WSARA	Weapon System Acquisition Reform Act
WBS	Work Breakdown Structure

APPENDIX B. ERAM 2.0 Activities Impacted by Capability Matrix

Delay for protest
Delay for protest review PreB
Delay for protest review PreC
EOA rework and delay
MAJCOM approval PreA
AFROC Preparations PreA
AFROC Preparations independent document PreA
AFROC Preparation joint interest PreA
AFROC Document Review joint interest PreA
FCB and JCB joint interest PreA
AFROC Preparations independent document PreB
AFROC Preparations joint integration PreB
Final AFROC approval joint integrations PreB
AFROC Preparations joint interest PreB
AFROC Document Review joint interest PreB
FCB and JCB and JROC joint interest PreB
AFROC Preparations independent document PreC
AFROC Preparations joint integration PreC
Final AFROC Approval joint integration PreC
AFROC Preparations joint interest PreC
AFROC Document Review joint interest PreC
FCB and JCB and JROC joint interest PreC
MAJCOM Approval independent document PreA
MAJCOM A Letters and Coordination and Concur
MAJCOM A8 and RSR
MAJCOM Approval joint integrations PreA
MAJCOM Approval Later joint integration PreA
MAJCOM Approval joint interest PreA
MAJCOM Approval independent document PreB
MAJCOM A Letter and Coordinate and Concur PreB
MAJCOM A8 and RSR
MAJCOM Approval joint integration PreB
MAJCOM Approval Later joint integration PreB
MAJCOM Approval joint interest PreB
MAJCOM A Letter Coordination and Concur PreC
MAJCOM A8 and RSR PreC
MAJCOM Approval Independent document PreC
MAJCOM Approval joint integration PreC
MAJCOM Approval Later joint integration PreC
MAJCOM Approval joint interest PreC
SVR
DRR
SRR
MDA Milestone Approval PreB

MDA Milestone Approval PreC
MDA Milestone A Approval
RFP Release and Source Sel Pre-B

APPENDIX C. Sample Interview Questions

1) Describe your roles and responsibilities in the space acquisition processes.

2) What space programs do you have experience with?

3) Describe what processes you've been involved with regards to space capability development (i.e. gap analysis, S&T, JCIDS documents, DP, and/or acquisitions) and with which program

4) Describe the specific activities and decision points for the processes you've been involved in from question 3.

5) What reviews and documentation were required for your program?

6) In your opinion, was there a clearly identified sponsor (i.e. owner) for the documentation required for the reviews? If not, please describe the discrepancy.

7) What was the timeframe for approval on the required documentation? Which organizations were required for coordination? What obstacles needed to be overcome?

8) Have you experienced delays with your program? If so, what would you say was the primary driver of that delay?

9) When did the various reviews and other meetings occur in your program? Who was required to attend? What were the challenges that arose? How did you overcome those challenges?

10) If applicable, what waivers were applicable for moving your program forward? How did you obtain approval for those waivers?

11) In the future, as a framework of the activities from capability gap analysis through Materiel Development Decision is developed, would you be willing to review it and provide feedback for accuracy?

12) In reference to the previous question, would you be willing to provide data on the durations of the activities and probabilities for decision points?

13) Do you have any specific persons we should talk to at AFSPC, SAF/AQ, USD/AT&L, or other agencies?

14) Do you have anything else you would like us to consider with regards to modeling and reporting on the pre Milestone-B space acquisition activities?

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14. ABSTRACT
In support of senior leadership emphasis on improving early systems engineering and analysis, the Enterprise Requirements and Acquisition Model (ERAM) is a quantitative discrete-event process simulation model that accounts for activities from the identification of a desired space capability early in the JCIDS process through Milestone C of the acquisition system resulting in a probabilistic schedule distribution for a given concept. This model of the DoD's space capability development process will provide valuable decision making information for Concept Characterization and Technical Descriptions referenced during Analysis of Alternatives. The research focused on identifying activities, assigning historical triangular distributions and probabilities at each decision point. Data was collected through analysis of applicable policy, instructions, and journal articles as well as interviews with subject matter experts from the Air Staff, Air Force Space Command and the Space and Missile Systems Center. ERAM will be utilized at the Aerospace Concept Design Center providing decision-makers insight into timeline estimations and probabilities of success. ERAM has the potential to be used as a training tool for Air Staff, AFSPC and SMC personnel to better understand existing organizational interdependencies and required activities to successfully acquire a capability on schedule and within budget.

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