GLOBAL PERSISTENT ATTACK:

A SYSTEMS ARCHITECTURE, PROCESS MODELING,

AND RISK ANALYSIS APPROACH

Group Research Project

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AFIT/ISE/ENV/08-J04

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Wright-Patterson Air Force Base, Ohio

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AFIT/ISE/ENV/08-J04

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GROUP RESEARCH PROJECT

Presented to the Faculty

Department of Engineering and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Engineering

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June 2008

AFIT/ISE/ENV/08-J04

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AFIT/ISE/ENV/08-J04

Abstract

This research developed a defendable and traceable Global Persistent Attack (GPA) risk analysis methodology and designed integrated architectural products based on GPA and Battlespace Awareness (BA) concepts of operation. The detailed architecture illustrates the commonality of capabilities and associated activities along with their critical relationships within Global Persistent Attack (GPA). The additional insight provided will allow the Air Force (AF) to better understand and quantify essential capabilities with associated activities to improve the decisions during the development of the future force construct.

In order to accomplish risk identification and analysis, a Process Sequence Model (PSM) was developed to display the logical sequencing necessary for conducting GPA operations. Each activity and decision point was given a nodal probability of success and evaluated using Monte Carlo simulation to determine the overall mission probability of success. Sensitivity analysis was also accomplished to identify the capabilities most critical to the success of GPA operations. The identification of critical capabilities is essential to the proper development of the fiscally constrained force structure with respect to minimizing risk. Systems Engineering (SE) methodology and tools provide a structured, traceable process for identifying the critical relationships required to sustain the GPA concept. This insight will provide Air Combat Command (ACC) an improved decision making process to ensure the objectives of the national defense strategy can be attained while minimizing risk associated with the fiscally constrained force structure.

Dedication

To our families and friends

Acknowledgments

We would like to acknowledge our research advisors, Maj Jeff Havlicek and Dr. Dennis Strouble. Their insight and direction were appreciated. Very special thanks to Lt Col John Colombi and Maj Sonia Leach whose expertise and valuable inputs were essential to the completion of this research project. It was their guidance and support throughout this effort that made this project meaningful.

We are also appreciative to Maj Robert “Ding” Chavez and the ACC/A5S division for their candid feedback and time provided to ensure this research project was an invaluable and insightful endeavor.

Special thanks to Lynn Curtis for all her help and administrative support which was crucial to putting all the pieces of the research together.

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I. Introduction

The Air Force has sustained combat operations for the last 17 years with no end in sight. Enduring such relentless operations can be very costly and damaging to an organization's force structure and assets. Yet, despite these difficult and challenging times, Air Force supremacy has prevailed. Keen foresight and continual transformation has allowed the Air Force to predict requirements and prepare for future challenges within a dynamic environment. Guided by insightful strategy, the Air Force has projected and managed its force structure adequately to achieve the desired effects of the National Military Strategy-prescribed Full Spectrum Dominance (FSD). In order to continue to meet future challenges, the Air Force, along with its Joint partners, has established a very logical and structured process to determine what the Strategic Responsive Force (SRF) will require in the future; however, budgetary constraints place fiscal limits on the acquisition of the required capabilities identified to meet future challenges. As a result, a Fiscally Constrained Force (FCF) is constructed balancing risk and desired capability.

Based upon military strategy and senior leadership direction, the Combat Air Force (CAF) Flight Plan provides a methodology which outlines force construct requirements based upon expert opinion and assessments along with doctrinal guidance. In order to identify requirements and develop a force presentation, a thorough review and evaluation of current strategy documents in context with the existing and forecasted threat environment is accomplished. Based on the strategic environment and documentation review, Combatant Commander (COCOM) potential objectives and desired effects are identified and validated. Desired effects are linked to CAF required capabilities and supported by Concept of Operations (CONOPS), Capabilities Review and Risk Assessment (CRRA), Master Capabilities List (MCL), Universal Joint Task List (UJTL) and other publications (1, 8). The resulting force presentation construct is then evaluated using desired effects and projected capabilities against the entering assumptions associated with defense strategy and defense planning scenarios (DPS).

The purpose of this research project is to develop additional integrated architecture products for the Global Persistent Attack CONOPs in order to provide a defendable and traceable force construct risk analysis process. Providing a more detailed architecture will illustrate the commonality of activities/capabilities along with their critical relationships within the Global Persistent Attack (GPA) concept. The architectural products were developed in accordance with the Department of Defense Architecture Framework (DoDAF) version 1.5 six-step architecture development process. With a data-centric approach, "the architecture facilitates decision making by conveying the necessary information to the decision maker for the decision at hand as well as enabling the reuse of architecture information for additional needs" (2, 3-1). The additional insight provided will allow the Air Force to better understand and quantify essential capabilities with associated activities to improve the decisions during the development of the future force presentation construct. With Global Persistent Attack as the proof of concept, the research project was tasked with three deliverables:

- OV-2 Operational Node Connectivity Description for GPA
- OV-5 Operational Activity Model for GPA
- Develop a methodology that quantifies the process of meeting desired capabilities while minimizing risk within a fiscally constrained environment

The architecture additions to the GPA CONOPS will enable more comprehensive and traceable approaches to risk identification and management during the force construct development.

In order to accomplish risk identification and analysis, a Process Sequence Model (PSM) was developed to display the logic necessary for a generic GPA mission. Each activity and decision point was given a nodal probability of success and evaluated using Monte Carlo simulation to determine the overall mission probability of success. Sensitivity analysis was also accomplished to determine which activities and decision points were the most influential on the overall capability. This process enabled the identification of the capabilities most critical to the success of GPA operations. The identification of critical capabilities is essential to the proper development of the fiscally constrained force structure with respect to minimizing risk. Furthermore, critical capabilities that have a low probability of success coupled with severe consequences of failure may be identified as capability gaps or shortfalls mandating additional review or evaluation. In conclusion, Systems Engineering (SE) methodology and tools provide a structured, traceable process for identifying the critical relationships required to sustain the GPA capability concept. This insight will provide Air Combat Command (ACC) an improved decision making process to ensure the objectives of the national defense strategy can be attained while minimizing risk associated with the fiscally constrained force structure.

II. Background

> The fundamental requirements for the force structure and capabilities of the Air Force reside in the national strategic guidance documents, which describe the objectives the United States Armed Forces are expected to achieve; the current and future environment in which they are expected to operate; and unique capabilities that the Air Force contributes to joint warfighting (3, iii).

Influence of National Strategy

Derived from the highest level, the National Defense Strategy (NDS) builds from the National Security Strategy (NSS) by defining strategic-level objectives for the nation's defense. The most current NDS, released in 2005, provides direction and emphasis by designating specific national objectives:

- Secure the United States from direct attacks
- Secure strategic access and retain global freedom
- Strengthen alliances and partnerships
- Establish favorable security conditions (4, 1).

The Quadrennial Defense Review (QDR), DoD 5100.1 series, Transformational Planning Guidance (TPG) and several other strategic documents have been developed in support of the NSS to provide essential guidelines necessary to steer the strategic planning, budgeting, and decision-making process towards achieving the desired national objectives. For instance, the QDR provides the perspectives of senior civilian and military leaders and outlines a roadmap as to where the military will place its emphasis in the future. The QDR also delineates key objectives and capabilities necessary for the Department of Defense to achieve national objectives. These upper level principles and guidelines establish the foundation for the Department of Defense on how to plan, decide, and act upon key decisions about the military's future acquisitions, capabilities and force construct. According to the 2005 NDS, the US military must focus its operations and capabilities on developing an active, layered defense allowing for continual iterations to adapt to current and emerging threats. Formulated to utilize a capabilities-based approach, the US defense is able to identify and prioritize competing capabilities along with making substantial consideration to the risk associated with the resource and operations tradeoffs being made to achieve the desired capability (4, 11-14). This guidance provides the baseline and necessary context for Air Combat Command, Strategy, Concepts, and Doctrine (ACC/A5S) division to champion the Concept of Operations (CONOPS) for GPA and Global Strike (GS). Utilizing an effects-based capability approach that revolves around AF CONOPS and strategic vision, ACC/A5S is tasked to provide recommendations to senior leadership about the necessary direction of a future force construct by developing the Air Force Strategic Master Plan (SMP). Figure 2.1 below demonstrates the hierarchy of strategic guidance that influences the AF SMP. A significant portion of the ACC/A5S decision making process involves the identification and handling of risk associated with the design choices and capability trade-offs.

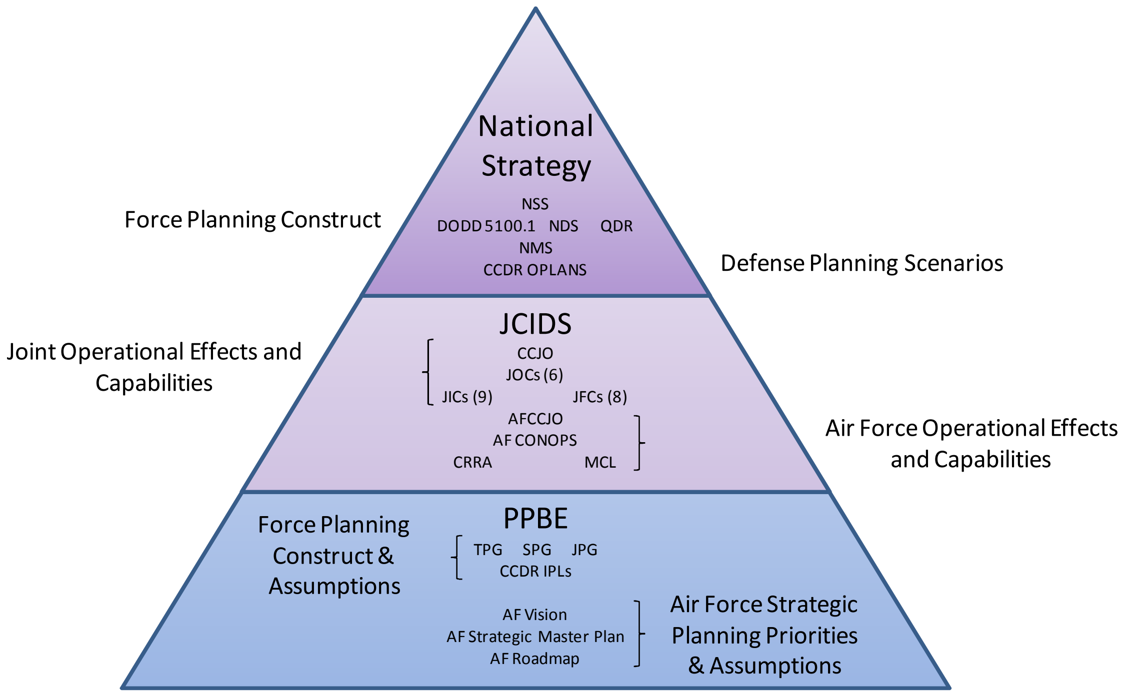

Figure 2.1. Strategic Guidance for AF SMP Development

Joint Integration

To further focus military planning and decision-making efforts and to reinforce the capabilities-based approach, the Capstone Concept on Joint Operations (CCJO) provides essential guidance and direction for the integration of joint concepts. The CCJO is the overarching concept of the Joint Operations Concept (JOpsC) family that provides guidance and direction to the development of future joint capabilities. The main purpose of the CCJO is to encourage joint force development by providing a foundation for how the Joint Force should operate in the future.

Following the CCJO on the JOpsC family hierarchy is the Joint Operational Concept (JOC). The JOCs describe and determine the necessary concepts of how the joint force will conduct operations in support of national military objectives. The JOCs facilitate in categorizing and steering force development through the identification of operational-level objectives and essential capabilities required to implement the joint concepts and achieve the overall desired end state. In addition, JOCs supply the operational context for the Joint Functional Concepts (JFC) and the Joint Integrating Concepts (JIC). The Joint Functional Concepts (JFC) provides guidance on how operations will be executed across the full Range of Military Operations (ROMO) and identifies the essential capabilities necessary to create the desired effect necessitated by the JOC. Next in line are the Joint Integrating Concepts (JIC) which focuses on capabilities and operations at the operational and tactical levels of command, while still accounting for strategic guidance. JICs are more narrowly focused descriptions of the desired capabilities in order to identify necessary fundamental tasks, conditions, and standards. The JOpsC family is fundamental to the national defense planning, decision making, and budgeting process. These concepts provide a crucial foundation for identifying what future capabilities should be prioritized and emphasize where the focus of efforts should be placed when confronted with design trade-offs. JOpsC family development is a cyclical process organized and structured to optimize concept writing, assessment, and revision efforts and allows the incorporation of necessary transformations based upon changing threats and technologies.

Over a three year period, the revision of CCJO, JOCs, JFCs and JICs are staggered to eliminate duplicative efforts, incorporate recent lessons learned and assessment results, and allow for a logical flow of release and production (see Figure 2.2 below).

	Jan 2005	Jun 2005	Jan 2006	Jun 2006	Jan 2007	Jun 2007	Jan 2008	Jun 2008	Jan 2009	Jun 2009	Jan 2010	Jun 2010
CCJO Revision		CCJO 2.0						CCJO 3.0				
JOC Writing/Revision				JOC 2.0						JOC 3.0		
JFC Writing/Revision						JFC 2.0						JFC 3.0
JIC Writing												
Transformation Roadmaps		TRs		TRs		TRs		TRs		TRs		TRs
Quadrennial Defense Reviews (QDRs)			QDR								QDR	
Defense Planning Scenarios												
JCD&E CPlan		CPlan				CPlan				CPlan		
JCSG	Feb/ May	Aug/ Nov	Feb/ May	Aug/ Nov	Feb/ May	Aug/ Nov	Feb/ May	Aug/ Nov	Feb/ May	Aug/ Nov	Feb/ May	Aug/ Nov

Dark Gray Box = Writing & Revision   Black Lined Box = Ongoing Activity   Text = Activity as stated or dated

Figure 2.2. Joint Operations Concept Revision Cycle. (5, A-3)

This continuous cycle allows for the joint documents to adapt and adjust to recent developments and proceedings. In addition, the JOpsC family revision process includes continuous defense planning scenario development, annual publication of joint and Service transformation roadmaps, QDRs, biennially produced Joint Concept Development and Experimentation Campaign Plans (JCD&EC), and quarterly Joint Concept Steering Group (JCSG) meetings (5, A-3).

It should be noted that there are several other strategic publications and documents that govern and provide direction for the military forces. The ones highlighted in this research paper present some of the key publications that drive the evolution and influence the decisions made during defense force structure development. Strategic-level guidance sets the foundation for how the military transforms and projects the force construct required for current and future years. As a result, the national strategy documentation is always the starting point from which ACC/A5S begins its decision making process of determining the capabilities required for GPA and the force construct required to achieve the military's end state objectives.

Air Force CONOPS

To bridge the gap from the Joint Operating Concepts to the primary Air Force mission areas and capabilities, the Air Force develops and relies on Concepts of Operations (CONOPS). AF CONOPS communicate the necessary air and space capabilities required to achieve the desired end state effects in accordance with national strategy and objectives. Currently, the Air Force maintains seven CONOPS: Global Persistent Attack (GPA), Global Strike (GS), Global Mobility (GM), Space and Command, Control, Communication, Computer, Intelligence, Surveillance and Reconnaissance (S&C4ISR), Homeland Defense (HLD), Nuclear Response (NR), and Agile Combat Support (ACS). This research project focused on the GPA concept (which incorporates almost every AF capability) since ACC/A5S develops a majority of the Strategy Responsive Force (SRF) and Fiscally Constrained Force (FCF) to support the GPA prescribed capabilities.

CAF Strategy

National, Department of Defense, and Air Force strategy and guidance influence two key AF planning documents: the CAF Flight Plan and the ACC Strategic Master Plan (SMP). Both products are strategic in nature but have different purposes and scope (1, 2). The ACC SMP is developed for actions within the next 3-5 years, whereas the CAF Flight Plan contends with forecasting requirements 12-15 years beyond the next Future Year Defense Programs (FYDP). Both plans are critical to AF planning and Program Objective Memorandum (POM) submissions; however, the focus of this research will be on the CAF Flight Plan based upon research tasking. The 2007 CAF Flight Plan establishes four main objectives:

- Provide clear direction for CAF/USAF programming actions that support the Nation's warfighting requirements
- Integrate CAF-related critical AF planning initiatives (CONOPS, system roadmaps, recapitalization, rotation constructs, etc.)
- Establish and articulate long-range requirements and resource constrained options with associated risk
- Determine specific near-term and medium-term decisions necessary to achieve the force structure options (6,2)

These objectives establish the baseline for the Air Force to develop a Strategy Responsive Force (SRF) and Fiscally Constrained Force (FCF). The SRF is the force construct that achieves national objectives with minimal risk under an unconstrained, yet realistic budget. The FCF is a fiscally constrained force construct that balances national objectives with associated risk based on calculated design and planning trade-offs.

The methodology for the CAF Flight Plan entails four phases: I) Requirements and Force Presentation, II) Effects-based modules, III) Integration and Annexes, and IV) Publishing and Outreach (1, 7). Phase I involves a thorough absorption of all current and relevant national strategy guidance and documentation to fully understand significant areas of concern. It is crucial that planners understand and are able to apply the current strategic guidance to the planning and decision making process. Concurrently with publications review, essential CAF operational effects and capabilities are derived and validated. Within the last decade, direction has been for planners to focus on effects-based capabilities instead of system-based capabilities to ensure thorough integration and cross-cutting implications are incorporated. This approach helps ensure coverage of the entire spectrum of essential CAF capabilities. Phase I also involves the establishment of entering assumptions for force presentation construct and considerations for alterations in organizational concepts (1, 8).

According to ACCI 90-105, Phase II of the CAF Flight Plan methodology involves three steps: develop the Force Structure framework, create the vision force (recently changed to the Strategy Responsive Force), and build the cost-constrained force (recently changed to the Fiscally Constrained Force). After substantial document and assessment reviews, the force structure framework categories are built on the primary operational effects required to execute the AF CONOPS (1, 8). Currently, ACC has decided to use four groups or modules: Air and Surface, Information/Cyberspace, Battlespace Awareness, and Agile Combat Support. These four modules provide the basis for operational effects and capabilities necessary to cover the full spectrum of warfare (6, 07). To ensure the incorporation of updated strategy changes and calculated projections based on current events and assessments, the CAF Flight Plan is revised every other year (see Figure 2.3 below).

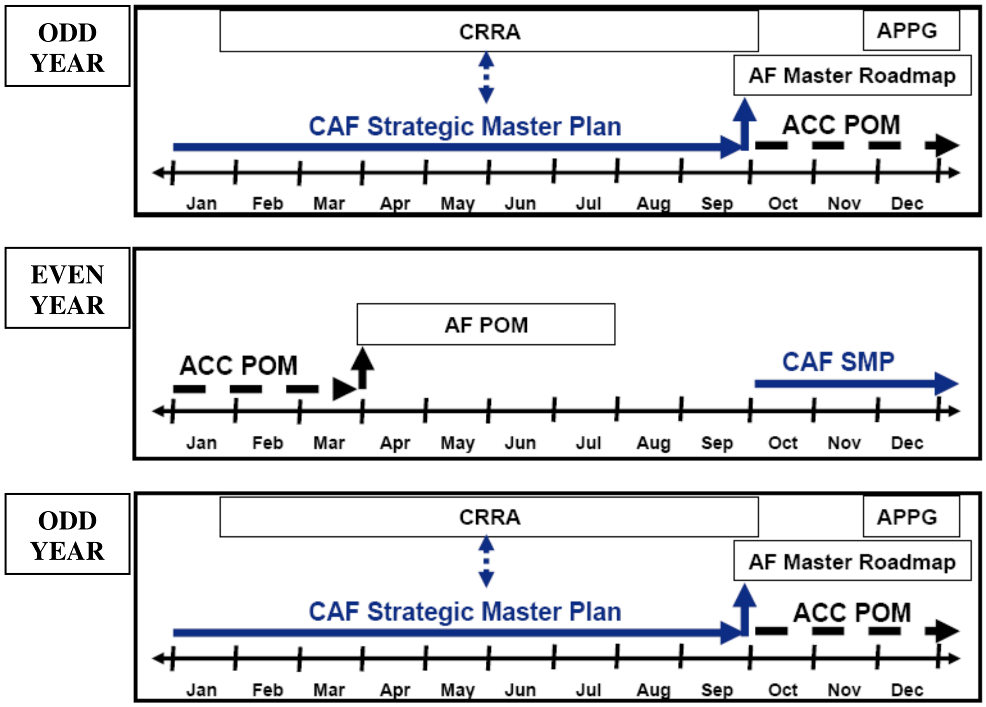

Figure 2.3. CAF SMP Timeline (7, 9)

The framework for the Strategy Responsive Force (SRF) development is accomplished by categorizing operational effects into effects-based modules. In addition, review and evaluation of recapitalization requirements and key acquisitions help link resources to necessary capabilities (7, 7-16). Based upon this framework, the SRF force construct is developed with cost analysis and forecasting incorporated to ensure a realistic, fiscally "unconstrained" budget limitation exists. It is the fiscally constrained guidance from Congress that warrants the development of a Fiscally Constrained Force (FCF). As mentioned earlier, ACC/A5S uses iterative analysis to determine acceptable force capability levels, incurred risk acceptance, and cost expenditures. To ensure capability coverage is complete, ACC/A5S categorizes systems into capability modules which are considered mutually exclusive. Once a system is used for a capability, the system is not considered for another capability despite having the ability to do so if tasked. For example, once a bomber platform is grouped into the Long Range Strike (LRS) capability, it will not be considered as a Close Controlled Strike (CCS) asset even though it could potentially provide that capability.

Once the force construct is built, ACC/A5S reviews and evaluates any shortfalls or capability gaps identified from the CRRA to ensure the SRF and FCF contain viable solutions and have identified the risk associated with those decisions. Despite the heavy reliance of the Process Sequence Models use during the CRRA process, one problem noted by ACC/A5S is that a PSM does not adequately identify sufficiency of a capability required to accomplish the objectives (8, Mar 08). For instance, if the expectations are that a next generation fighter is four times more capable than a legacy fighter, a common error is reducing the required numbers by a multiple of four. This reduction in requirements may seem reasonable on the surface; however, this approach fails to consider requirements spread across several geographically separated areas of operations. To address this limitation, ACC/A5S relies on judgment and results from the Modeling and Simulation (M&S) office to account for and adjust sufficiency requirements (8, Mar 08).

The force construct process involves several Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities (DOTMLPF) reviews to evaluate trade-offs and risk associated with the force structure decisions. Solutions are identified and forwarded in accordance with DoD guidance. Due to limited manpower with Systems Engineering (SE) and Operational Research backgrounds along normal turnover rates, ACC/A5S does not utilize SE products or tools during the force construct building process. Currently, the GPA CONOPS features a High-Level Operational Concept Graphic (OV-1), and a limited representation of an Operational Activity Model (OV-5). Current guidance is somewhat conflicting concerning architecture products. Air Force Instruction (AFI) 10-2801, Air Force Concept of Operations Development, requires CONOPS architecture developers to:

- Maintain top-level architectures, including activity models that document how sequenced Master Capabilities Library (MCL) capabilities and tasks combine to achieve desired AF CONOPS effects.
- Maintain more detailed architectures and mission-level activity models, consistent with the top-level CONOPS activity models, supporting analysis of high-interest areas selected by AF CONOPS Champions and Flight Leads
- Maintain close liaison with AF CONOPS Flight Leads to ensure architectures appropriately reflect the CONOPS (9, 8).

Air Force Policy Directive (AFPD) 10-28, however, states that architecture and interacting command relationships necessary to execute the operating concept are to be developed "as required".

Risk

The NDS initiates the emphasis for decision makers to manage risk based upon four risk areas:

- **Operational** – risks associated with the current force executing the strategy successfully within acceptable human, material, financial, and strategic costs

- **Future challenges –** risks that are associated with the Department of Defense's capacity to execute future missions successfully against an array of prospective future challengers
- **Force management**- risks associated with managing military forces fulfilling the missions described in the NDS
- **Institutional –** risks associated with the capacity of new command, management, and business practices (4, 14)

To comply with DoD risk management policy, ACC/A5S accomplishes a quantitative and qualitative analysis when developing the CAF force construct. For qualitative assessment, capabilities are divided into four modules: air and surface, information/cyberspace, battlespace awareness, and agile combat support. Each module has an assigned lead based upon expertise. With ACC/A5S as the integration team lead, assessment is provided applying the team's perception on how well the strategy will be able to accomplish the intended objectives based on the presumed acquisition of capability. Quantitative analysis is accomplished by evaluating the difference in capability between two forces measured by an ACC-created Capabilities Analysis Tool (CAT) in terms of time of campaign for a decisive win and attrition. (8, Mar 08). ACC/A5S has indicated that utilizing additional quantitative methods would be beneficial in their force construct projection and risk analysis.

Utilizing expert judgment, statistical data, and modeling and simulation, ACC/A5S determines the likelihood of failure and associated consequence for each decision made within the development of the 2025 force construct. Risk handling is accomplished through a combination of transference, mitigation, avoidance, and acceptance. Once a force construct is developed, ACC/A5S briefs the ACC Commander (COMACC) of their methodology, assumptions, and projected force construct, and highlights the risk associated with significant decision points. Ultimately, the senior leadership makes the final decisions on the force construct. Their decisions are based upon their staff's recommendations balanced with their acceptable level of risk. Since risk posture can be fluid, it is impossible to put absolute values on what is acceptable. Often times, a typical response from senior leadership when asked how much risk is acceptable leads to "I will know it when I see it." (8, Mar 08).

Capabilities Review and Risk Assessment (CRRA)

In 2003, the United States Air Force initiated the Capabilities Review and Risk Assessment (CRRA) process to analyze current and future capabilities, determine critical capabilities and shortfalls, and identify and assess risk associated for each of the AF CONOPS against a specific set of DoD-approved scenarios. The CRRA presents a means to provide traceability from strategic guidance down to the system level. The most recent CRRA was accomplished in 2007. It selected 18 baseline missions to analyze across a cross-section of environments, including two Major Combat Operations (MCOs). More detail on the methodology can be found in Appendix A of the 2007 CRRA. Of concern to our research is the methodology of how the CRRA was accomplished to ensure key capabilities and shortfalls were identified properly in order to prioritize budgeting for key capabilities under a constrained budget with limited resources.

Preparation for the 2007 CRRA began with a thorough review and examination of strategic guidance documents, Operational Assessments, Integrated Priority Lists (IPLs), Air Force Vision 2025, and other relevant publications. (10, A3) JOpsC family publications, Master Capability Library (MCL), and previous CRRA reports were also reviewed to establish a baseline of where the focus and emphasis should be placed for the revised assessment and review.

One tool that was relied upon to accomplish the 2007 CRRA was the Process Sequence Model (PSM). Very similar in layout and nature to a Function Flow Block Diagram (FFBD), PSMs were used to highlight essential activities and decisions points. Within a PSM, key decisions and activities were organized in logical order, and the critical nodes were then identified and evaluated by Air Force Subject Matter Experts (SMEs). Once key activities or decision points were identified, SMEs would place a statistical probability of success on individual activities within the overall operation. Critical activities that scored high in terms of overall mission impact were labeled as potential capability shortfalls. The SMEs provided three values relating to the estimated Probability of Success [*P(s)*]. The three values were based on the most likely, low, and high *P(s)* values between zero and one. Each decision point and activity node was evaluated separately with the assumption that each node was independent of all others. In addition to the *P(s)* values, SMEs provided values for the consequences severity level associated with mission failure. These values were then used to develop a PSM consequence distribution for each COCOM affected by the PSM (10, App A).

Using Monte Carlo analysis, an overall *P(s)* distribution for the PSM mission area was calculated based upon the nodal *P(s)* distributions within the logic framework of the PSM. The risk assigned to each PSM mission area was based upon a pre-determined percentile of the consequence distribution reported in the overall PSM *P(s)* distribution.

Senior AF leadership determined to report the 50th percentile of the consequence distribution based upon the desired level of risk tolerance. The 50th percentile is a statement of risk neutrality. In addition to this analysis, marginal and sensitivity calculations were accomplished to identify key nodes that incorporated a greater marginal impact on risk. Nodes that returned a significantly higher level of sensitivity to the overall risk level were considered as possible risk drivers where shortfalls or capability gaps may exist (10, App A).

The use of PSMs provided a format that could easily be repeated and defended for the staffers that build and use the diagrams; however, against good SE practices, little to no traceability is shown when transitioning from strategy and guidance review directly to designing PSMs. Also, no official DoD guidance exists to standardize PSMs. Without documented standards, the development of PSMs can vary making it difficult for an outsider to understand and integrate with other related products. Standardized guidance for developing PSMs in accordance with an integrated architecture would provide the decision maker a framework to conduct analysis in identifying capability and supportability shortfalls, identify and determine additional alternatives, and determine associated resource implications with traceability to strategic objectives (11, 7).

Global Persistent Attack

Global Persistent Attack is the persistent and sustained operations required to maintain air, space, surface, information and battlespace dominance. GPA capitalizes on persistent synchronized precision strikes, either kinetic or non-kinetic, and information operations to influence the enemy's ability to act driving them into such a disadvantaged position that continued resistance is futile or impossible (3, 3). GPA requires the utilization of all elements to cover the full spectrum of warfare. While accomplishing missions, strategic to tactical, the JFC will be responsible for incorporating and synchronizing GPA capabilities and associated assets to produce synergistic effects. As with all the other CONOPS, GPA's success is often contingent upon the integration and capabilities provided from all the other AF CONOPS. However, the authors of this research paper have decided to decompose the GPA capability into five activities: Achieve Battlespace Dominance, Achieve Surface Dominance, Achieve Air and Space Dominance, Achieve Information/Cyberspace Dominance and Provide Enabling Capabilities. This decomposition is based upon the GPA CONOPS and is very similar to the ACC module structure.

Battlespace Dominance activities include those associated with Command and Control (C2), Intelligence, and Surveillance and Reconnaissance which are responsible for providing the critical tasking and battlespace awareness necessary to achieve desired effects. The Information/Cyberspace Dominance activity is broken down into Electronic Warfare, Network Warfare and Influence Operations activities. Dominance in these activities allow for forces to attack the adversaries' information and decision making process while securing and defending their own information and decision-making networks (3,6).

By first achieving Battlespace Awareness and Information/Cyberspace Dominance, forces obtain decision-making superiority providing a significant advantage over the enemy. Decision superiority – the process of making decisions better and faster than an adversary – is essential to executing a strategy based on speed and flexibility. Decision superiority requires new ways of thinking about acquiring, integrating, using and sharing information. Battlespace Awareness, combined with responsive command and control systems, supports dynamic decision-making and turns information superiority into a competitive advantage adversaries cannot match. The ability of the future force to establish an “unblinking eye” over the battle-space through persistent surveillance will be key to conducting effective joint operations. Future ISR capabilities will be designed to collect information that will help decision makers mitigate surprise and anticipate potential adversary actions.

Information/Cyberspace Dominance is critical to the GPA concept by establishing supremacy in all areas of the global information domain including both offensive and defensive operations to attack and defend information and decision making capabilities. Key to the information/cyberspace dominance functions are the operations designed to influence the electromagnetic spectrum as well as the analog and digital portions of the battlespace. Electronic warfare operations consisting of electronic attack, electronic protection, and electronic warfare support provide the means by which dominance in the electromagnetic spectrum can be attained. Network warfare operations consist of network attack, network protection, and network warfare support and enable the ability to attack adversary networks while simultaneously defending friendly networks. Influence operations such as psychological operations, military deception, operations security, counterintelligence, counter-propaganda, and public affairs contribute to the ability to affect behaviors and protect operations by achieving effects across the cognitive domain (3, 13-14).

To accomplish the desired effects, Force Application functions of Surface Dominance and Air and Space Dominance allow forces to conduct operations without interference by the opposing forces in each respective domain. Air and Space dominance requires the activities of Air-to-Air Supremacy, Space Supremacy and Suppression of Enemy Air Defenses (SEAD). Surface Dominance operational activities include Long Range Strike (LRS), Close Controlled Strike (CCS), Intra-theater Strike (ITS), and Special Operations (SO). A significant challenge for the military will be to accomplish these activities while operating from across the globe or from austere, clandestine forward-deployed locations. The changing political scene may cause current and potential allies to suddenly deny basing rights for US forces/assets. Additional friction may also come from the absence of an easily-definable enemy and uncertain coalition composition. The challenges are addressed by having the capability to neutralize an adversary's anti-access strategies, allowing follow-on persistent forces to deploy and respond quickly and globally to neutralize fleeting and emerging high-value targets, to include Time-Sensitive Targeting (TST) while having the necessary infrastructure and technology to support continuous operations. Ensuring effective GPA capability though Air, Space, and Surface Dominance will be critical to achieving the desired outcome.

Other difficulties may arise when attempting to gain and maintain access for operations. The GPA capability requires forces to conduct operations with persistence and minimal deterrence. The anti-access problem is two dimensional based upon political uncertainty and physical threat. Political uncertainty includes access rights such as over-flight and staging. The physical threat consists of actual efforts taken by the enemy to deny basing in theater, or entry into their airspace, through use of various advanced defensive weapons systems. The complexities associated with the anti-access problem deemed it necessary for the Air Force to develop the Global Strike CONOPS to directly address them. The purpose of the GS concept is to execute the operations necessary to gain access to the battlespace for the persistent application of force within GPA. Once anti-access threats are defeated, GS assets transition to the new GPA mission focus while maintaining access.

Another challenge to GPA operations stems from the target array which has transitioned from a fixed, fielded force to a series of fleeting and emergent targets. Our adversaries employ strategies such as dispersing their critical systems into sensitive areas with high collateral damage potential, or in deeply buried bunkers or tunnels. Successful resolution of any crisis requires careful preparation of the battlefield. Planning, coordination, and execution of US government agencies must be an ongoing effort throughout all phases of a crisis.

Lastly, to effectively achieve the GPA desired effects, enabling capabilities are necessary to provide the foundation from which GPA operations can be conducted. Essential enabling capabilities for GPA include: Personnel Recovery (PR), Net-Centric Infrastructure, Responsive Space Operations, Airbase Opening Operations, Agile Combat Support (ACS), Positioning, Navigation and Timing (PNT), and Global Mobility (GM).

Success in PR is crucial to sustaining the morale, cohesion, and operational performance of friendly forces while simultaneously denying the enemy a potential intelligence source. A robust, secure, net-centric communication infrastructure is a critical enabler for GPA operations across all domains. The capability associated with Responsive Space Operations is vital to ensuring globally responsive support to meet time-critical needs associated with evolving situations.

Airbase Opening Operations are essential for developing the required infrastructure to sustain combat operations, while ACS provides the necessary mission support to sustain joint and coalition forces. GM enables rapid projection and application of GPA forces through deployment, sustainment, augmentation, and redeployment globally. Air refueling and airlift are the key capabilities within GM necessary for supporting the full range of military operations. PNT is critical to the all-weather precision strike capability of GPA operations providing the necessary abilities to navigate the battlespace and acquire and engage targets with the required synchronization to achieve the desired effects.

The GPA CONOPS encompasses the spectrum of capabilities applicable across the range of military operations to meet the challenges associated with the future global environment. In order to meet future challenges, the GPA CONOPS provides guidance for the development, acquisition, and sustainment of capabilities necessary to achieve the desired effects of information superiority, freedom to maneuver, and persistent engagement. Although the GPA CONOPS identifies the full range of capabilities to meet the challenges associated with an uncertain future, "the success of political, military, economic, social, infrastructure, and information activities throughout all phases of conflict will shape or dictate the capabilities required to accomplish GPA missions" (3, 4).

III. Methodology

This research focused on providing the Air Force (Air Combat Command in particular), an improved methodology to optimize the future force structure capable of meeting the needs of the national defense strategy under fiscally constrained guidance while minimizing risk. In order to fully address the issue, a systematic approach was employed to ensure the overall process was logical, repeatable and, more importantly, accountable by providing detailed traceability throughout the process.

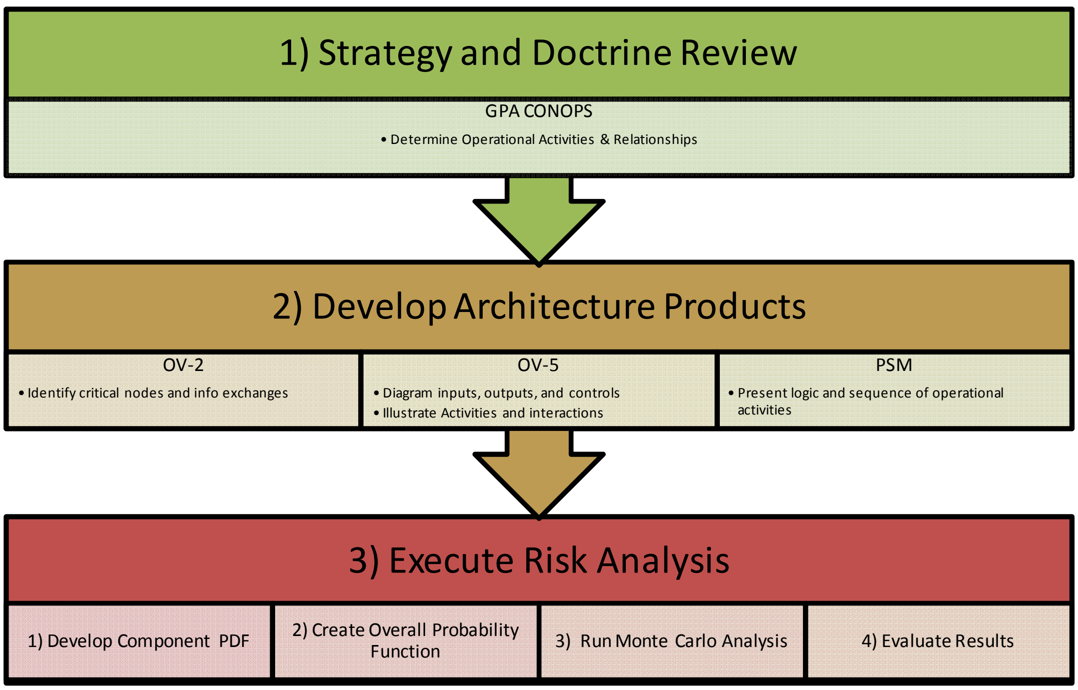

Figure 3.1. GRP Methodology

Figure 3.1 provides a pictorial view of our process. The first step of the methodology required a thorough review and understanding of the boundaries and depth of the GPA CONOPS to lay the foundation from which this research project could develop an analysis process for quantifying risk associated with the limitations presented by a fiscally constrained environment. The second step involved developing key architectural products to determine the required operational activities and their relationships outlined in the GPA CONOPS. To achieve this end, a graphical depiction of the key operational nodes that indicate the key players and necessary interactions or exchanges of information required to conduct the operational activities within GPA was developed in the form of an Operational Node Connectivity Description (OV-2). This product provided the means by which information exchange requirements could be tracked; however, the OV-2 did not depict the physical connectivity between the nodes.

In order to fully understand the connectivity between the operational nodes and the operational activities within them, an Operational Activity Model (OV-5) was developed. This product provided the necessary information to describe the capabilities, operational activities, and the input/output flows between activities.

Although the OV-2 and OV-5 products provided information about the interconnectivity and interdependence of the capabilities and operations within the GPA concept, they did not provide the necessary dependency logic needed to capture risk. Many different types of products can be used to model sequencing logic; however, due its prevalence and familiarity within the Air Force strategic planning process, a Process Sequence Model (PSM) format was selected as proof of concept for this methodology. A PSM was developed to model the logic of activities within the GPA CONOPS based upon the find, fix, target, track, engage, and assess construct (F2T2EA). This product was used as the primary tool for analyzing risk.

The third step was to define a process that could quantify risk and account for several different scenarios and alterations. In order to accomplish this, a probability distribution function (PDF) was applied to each activity and key decision node within the

GPA PSM representing the node's probability of success [*P(s)*] based upon a hypothetical SRF Construct. A Monte Carlo simulation was then used to determine the overall *P(s)* distribution for the GPA mission. The resulting information provided by the overall GPA *P(s)* distribution based upon the nodal PDFs was then used to quantify risk. Lastly, a sensitivity analysis was accomplished to identify key nodes or decision points that have the greatest effect on the overall *P(s)*. The identification of critical activities provided additional insight as to what capabilities require risk management and detailed analysis. The risk analysis process was then repeated varying the nodal PDFs to represent fiscal constraint limitations. The resulting information was compared to the original results for the SRF construct to determine the level of increased risk due to fiscal constraints.

Defining the Scope of the Operational Concept

The scope of this research was determined to exist at the operational architecture level. Enterprise architectures allow for improved decision making for human resource utilization, deployment of assets, warfighter investments, and identification of the boundaries and functional responsibilities. Mission area architectures allow for the management of capabilities within and across mission areas to improve investment decisions. "They provide roadmaps and descriptions of future or desired end states" (2, 3-1). The grand scope of the GPA concept also mandated analysis at the operational level. A high level approach was necessary to ensure a comprehensive evaluation of all essential activities and operations involved within GPA. Depending upon the scenario, the scope of GPA operations can involve just about every AF capability.

The GPA CONOPS provided the foundation from which the operational activities were defined along with their interrelationships. It included information exchange requirements as well as the outputs or desired effects of each activity. The operational representation of the GPA capability was developed using DODAF v1.5 guidance and products.

Functional Decomposition

A thorough analysis of the GPA CONOPS provided a detailed understanding of what entities, activities, and relationships were necessary to perform GPA operations. This understanding was used as the foundation to develop the architectural products for the GPA concept. Based upon the GPA CONOPS, all activities were decomposed as required within the formats of OV-2 and OV-5 products to provide a detailed architectural view of the required operations and capabilities.

Operational Node Connectivity Description (OV-2)

Adhering to DODAF v1.5 guidance, an OV-2 Operational Node Connectivity diagram was developed. The OV-2 provides an easy-to-read graphical display of the operational nodes with needlines connecting the nodes indicating information exchange requirements (12, 4-10). Based upon the GPA CONOPS, four primary nodes were identified: C4ISR, Combat Air Forces, Cyber Command, and Combat Support (See Figure 3.2 below).

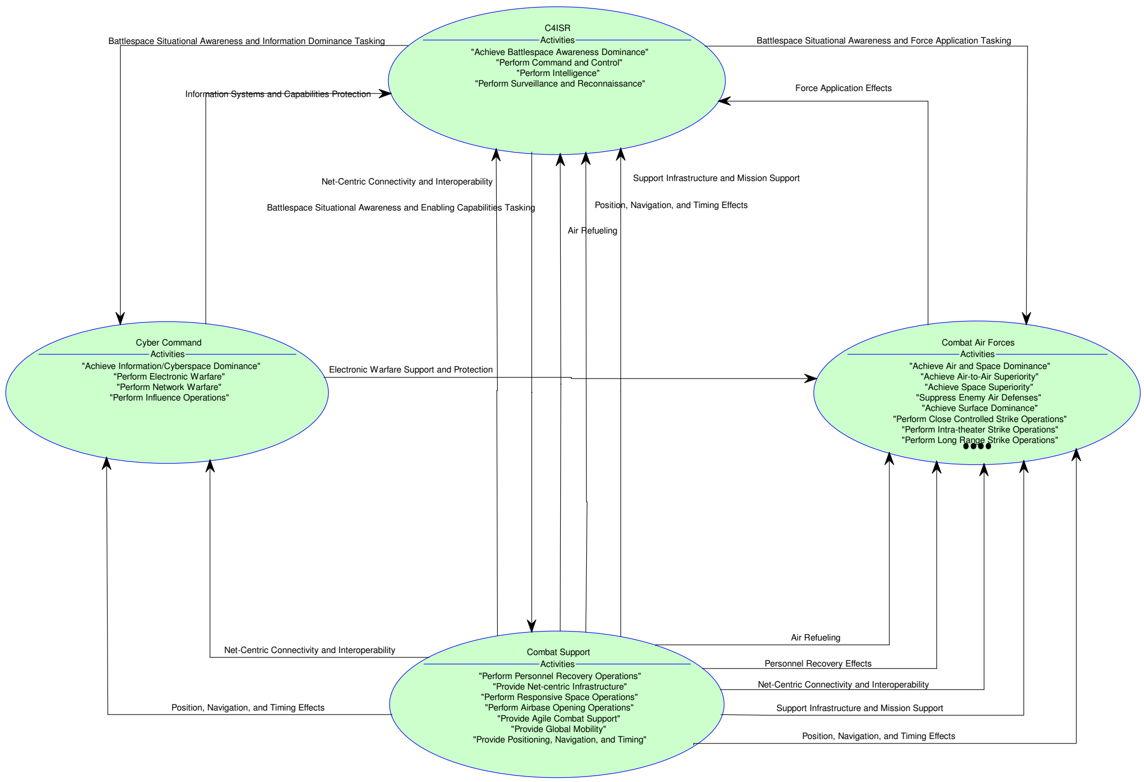

Figure 3.2. GPA OV-2

Operational Activity Model (OV-5)

The OV-5 Operational Activity Model was developed to demonstrate the relationship between the key operational activities involved within GPA. The OV-5 Activity Hierarchy was created to be used as a quick reference to easily identify where each capability existed in the GPA hierarchical activity structure. The GPA CONOPS was the primary source for establishing the decomposition of the GPA activities (See Figure 3.3 below).

The OV-5 Activity Hierarchy was then used to develop the Operational Activity Model. Additionally, the five main activities represented in the activity hierarchy were color coded to easily identify the associated activities represented in the PSM.

Comparing the color-coded PSM to the OV-5 allowed for an easy identification of what activities occurred frequently within the mission sequencing logic.

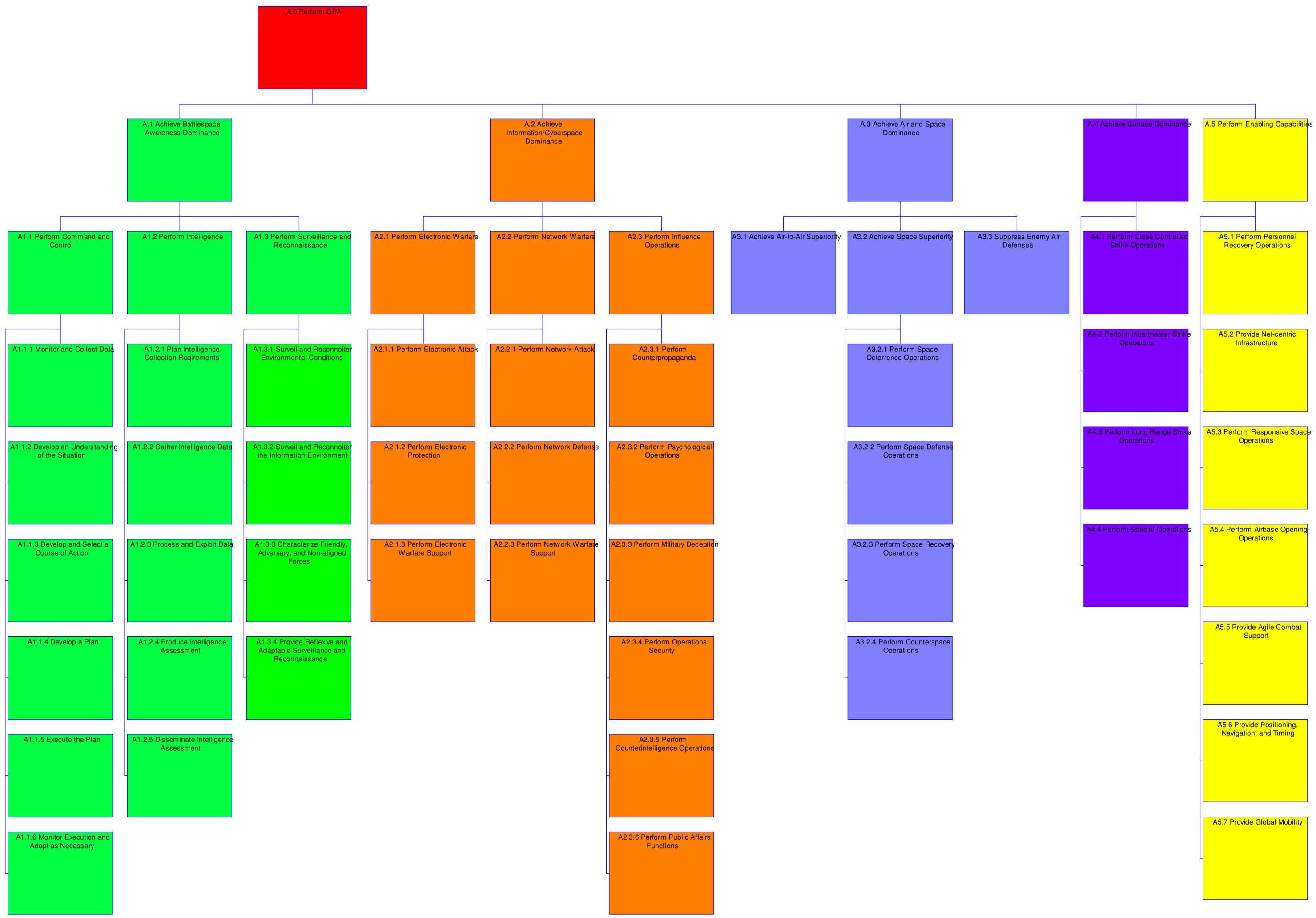

Figure 3.3. GPA OV-5 Activity Hierarchy

"The OV-5 is a key product for describing capabilities and relating capabilities to mission accomplishment" (12, 4-40). The OV-5 is a very powerful SE tool that can be used to:

- Clearly delineate lines of responsibility for activities when coupled with an OV-2
- Uncover unnecessary operational activity redundancy
- Make decisions about streamlining, combining or omitting activities
- Define opportunities or operational activities and their interactions
- Provide the necessary foundation for depicting activity sequencing and timing
- Identify critical mission threads and operational information exchanges (12, 4-40)

As one of the primary deliverables in this research project, the OV-5 was the cornerstone of the research project. See Appendix A for a better view of each OV-5 diagram. The OV-5 was utilized to establish traceability from the GPA CONOPS to the PSM. The essential activities depicted in the OV-5 also provide the basis for acquiring operational systems (mechanisms) used to develop the future force construct. This product presented the baseline for critical entities and their relationships. It is important to note that the decomposition of the GPA concept was accomplished down to a level that achieved the objectives of this research project. Further decomposition could be accomplished for a more in-depth view of each of the activities; however, the scope of this research project did not require a more in-depth analysis beyond what was necessary to quantify risk at the operational level.

Logical Sequencing Model

A Process Sequencing Model (PSM) was developed and used to represent the logic and sequencing of a generalized GPA mission. Building off the activities identified in the OV-5, the logic and sequencing of those activities and decisions points were placed in a PSM format. The PSM uses a format similar to a Function Flow Block Diagram (FFBD). This type of model is valuable in showing the traceability of actions in a scenario and the sequence of activities that form the basis for defining and understanding the key factors that impact or are required to accomplish the overall capability (12, 4-68). The PSM format was selected over the strictly defined DoDAF OV-6C format because PSMs are currently used by HQ AF. Applying an existing and familiar PSM format to this methodology should present AF planners with a more usable and familiar process. In addition, several scenarios have already been developed and approved for use in the CRRA process, and more importantly, the PSM database is easily accessible to AF planners which allows for standardization and minimal duplication of effort.

To show proof-of-concept that AF planners could utilize PSMs in the database, the Global Power PSM, dated Jun 2007 and located on the Air Force Knowledge Now Website, was used as a starting point for the creation of the GPA PSM. The Global Power PSM was adapted and modeled using ARENA discrete event simulation software to ensure GPA activities and relationships were incorporated. Although ARENA can be used to perform simulation analysis, this research project used ARENA as a tool for developing the model for visualization purposes only. The OV-2 and OV-5 were used as the foundations to ensure traceability and standardization of essential GPA activities. After incorporating GPA activities into the model, the necessary logic and sequencing were analyzed and evaluated for accuracy and validity. For easy identification, each activity was color coded in accordance with the OV-5 Activity Hierarchy criterion (See Figure 3.4 below).

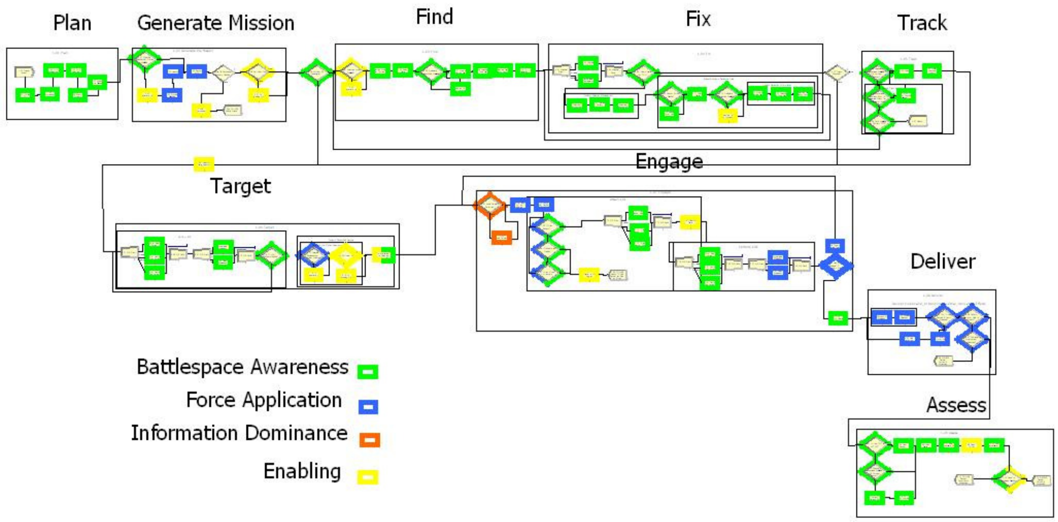

Figure 3.4. GPA PSM Diagram

The color coding of the PSM allowed for easy identification of categorized activities. The illustrated model also displayed where the critical nodes and decision points were located during the sequence of the GPA process. With the easy identification of the critical nodes, the linked activities can then be properly acknowledged and appropriately prioritized as essential activities required for accomplishing GPA operations. In addition, a traceability matrix was created to further define the relationships as well as provide a map of traceability between the GPA OV-5 operational activities and the nodes used to create the GPA PSM. The matrix showing this detailed mapping can be found in Appendix C.

Probability and Sensitivity Analysis

Similar to the CRRA process but different in outcome objectives, the PSM was used for risk identification and assessment. After the GPA PSM was completed, probability distribution functions (PDF) were assigned to each activity node and decision point. A triangular distribution was used for each component PDF. Further analysis could provide more accurate PDFs to be used in future evaluations. The PDFs were created using values for the lowest, highest and most likely $P(s)$ based upon Subject Matter Expert (SME) judgment, historical data, and other relevant assessments. Once the PDFs were created for each node and decision point, the development of an overall probability equation was required to model the sequencing logic within the PSM.

Supported by reliability modeling equations, the overall probability equation was developed based on the Process Sequence Model logic structure and calculated using Crystal Ball software. The PSM was divided into nine modules for analysis: Plan (1.01), Generate Mission (1.02), Find (1.03), Fix (1.04), Track, (1.05), Target (1.06), Engage (1.07), Deliver (1.08), and Assess (1.09). The $P(s)$ distribution of each module of the PSM was calculated based on the decisions and activities within it. For example, the 1.02 Generate Mission module is composed of smaller activities and decisions (see Figures 3.5 and 3.6 below).

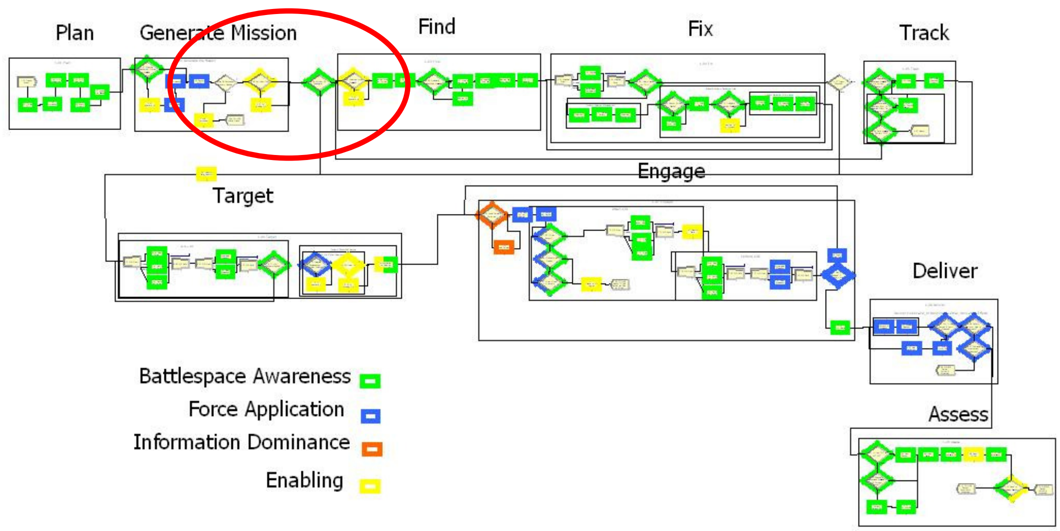

Figure 3.5. GPA PSM Logic Sequence

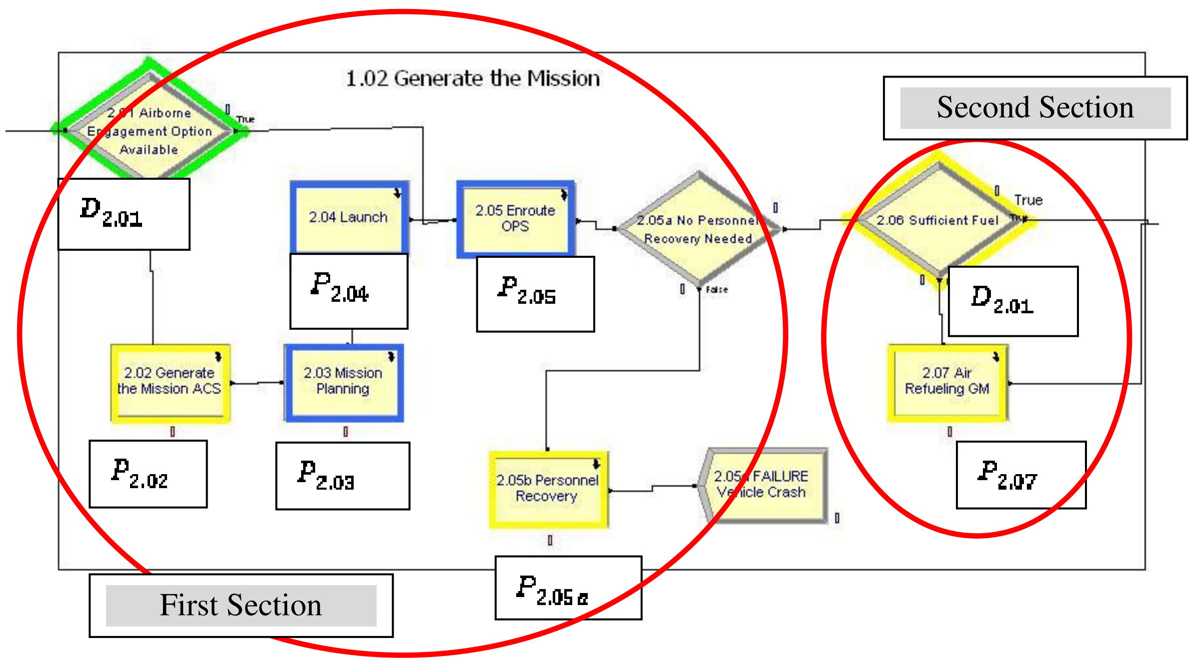

Figure 3.6. Generate the Mission Probability Components

Based upon reliability modeling, the PDFs for the components were appropriately combined resulting in a modular probability using Microsoft Excel. Under the same principle, the modular probabilities were then combined to create the overall probability.

For example, the probability for the 1.02 Generate Mission module was calculated as follows:

If $D_{2.01} = \mathit{True}$ then

$P_{1.02\,first\ section} = P_{2.05}P_{2.05a}$

If $D_{2.01} = \mathit{False}$ then

$P_{1.02\,first\ section} = P_{2.02}P_{2.03}P_{2.04}P_{2.05}P_{2.05a}$

Smaller decision node branches were calculated as simple probabilities in order to simplify the logic in the Excel spreadsheet used in Crystal Ball. In the above case, the personnel recovery branch is a simple probability. Once the probability of the first section was determined, the second section consisting of the air refueling step was taken into account to calculate the overall Generate Mission Segment probability as follows:

If $D_{2.06} = \mathit{True}$ then

$P_{1.02} = P_{1.02\,first\ section}$

If $D_{2.06} = \mathit{False}$ then

$P_{1.02} = P_{1.02\,first\ section}P_{2.07}$

Each step of the PSM was calculated in a similar fashion according to the sequencing logic modeled. A few decision nodes were placed outside of the individual F2T2EA modules in order to determine whether or not certain steps were required for each PSM run. For example, if the Battlespace Awareness was adequate during a mission, the Find (1.03), Fix (1.04), and Track (1.05) probabilities were not calculated in the overall GPA probability. As a result, the Find, Fix, and Track probabilities were grouped together to simplify the logic. This is represented by the following logic and calculations:

If $D_{2.08} = \textit{True}$ (BA is adequate) then

$$P_{1.01-1.05} = P_{1.01}P_{1.02}$$

If $D_{2.08} = \textit{False}$ (BA not adequate) then

$$P_{1.01-1.05} = P_{1.01}P_{1.02}P_{1.03-1.05}$$

For some missions, the additional Assess step may not be required; therefore, the Target (1.06), Engage (1.07), Deliver (1.08), and Assess (1.09) steps were grouped together as follows:

If $D_{2.08} = \textit{True}$ (Assess needed) then

$$P_{1.06-1.09} = P_{1.06}P_{1.07}P_{1.08}$$

If $D_{2.08} = \textit{False}$ (Assess not needed) then

$$P_{1.06-1.09} = P_{1.06}P_{1.07}P_{1.08}P_{1.09}$$

Using the module groupings discussed above, the overall GPA P(s) was then calculated using the following equation:

$$P_S = P_{1.01-1.05}P_{1.06-1.09}$$

The overall probability equation with the nodal PDF values was entered into an Excel spreadsheet for compatibility with Crystal Ball software. The Crystal Ball software was then used to accomplish the Monte Carlo simulations required to produce the overall GPA *P(s)* distributions. For simplicity reasons, the probability values assigned to each node and decision point were assumed to be independent with no correlation to the others.

The nodal PDF values used for this research are located in Appendix D. To obtain the overall PDF of the GPA success, outcomes for each component were drawn from the component PDFs and combined based on the reliability structure function. The process was replicated 100,000 times using Crystal Ball to perform a Monte Carlo simulation which calculated the overall GPA probability of success. An example output from the Crystal Ball Monte Carlo simulation is provided in Figure 3.7.

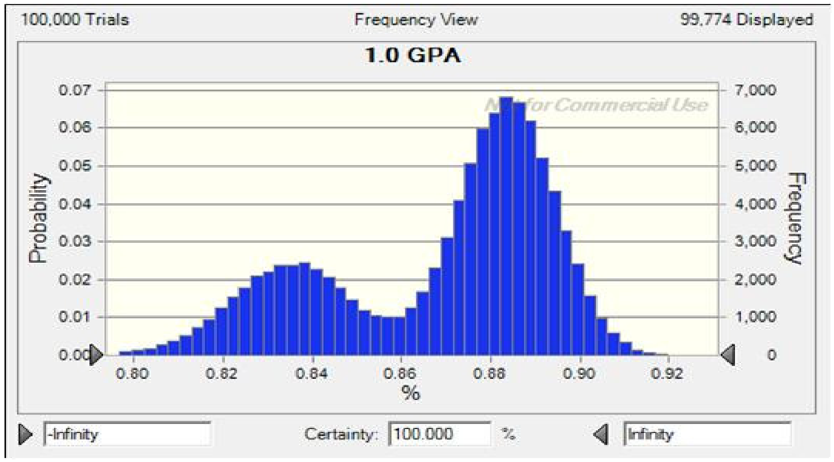

Figure 3.7. Example PSM Monte Carlo Results

Again, the resulting GPA *P(s)* distributions were used to quantify the risk associated with each force construct and associated capability levels represented by the PDFs within the PSM. The GPA *P(s)* distribution provides quantifiable risk analysis information such as the sample mean ($\bar{x}$) and sample standard deviation (s) that can be used for comparison. These values can be used to quantify the risk associated with the given force construct. The mean *P(s)* value can provide an estimate of the average success rate but cannot be used without consideration of all other values. For instance, the mean does not provide a measure for how much the distribution is expected to vary from the average value and can be extremely misleading for multimodal distributions. The standard deviation provides the measure of the expected deviation from the mean. A larger standard deviation implies a higher level of outcome uncertainty. A more complex analysis than simply comparing the mean and standard deviation may be required depending upon the type of distribution results. Chapter 4 will address considerations for multimodal distributions and provide more complex distribution analysis techniques to deal with various distribution results.

In order to capture the change in the level of risk associated with limitations due to fiscal constraints, the nodal PDFs were adjusted to reflect the reduction in capabilities for specific areas represented by the FCF construct. The reduction in capability represented by each PDF is based upon reduced overall capability and/or insufficiency within that capability. A list of the modified PDF values along with a detailed description of each node and decision point is located in Appendix D. The analysis process was then repeated to produce an overall *P(s)* distribution for the FCF. Parametric analysis of SRF and FCF was compared to highlight the changes in the expected value and standard deviation. The changes in these values were used to quantify the increase in risk due to fiscal limitations.

Finally, for both the SRF and FCF constructs, a sensitivity analysis was conducted within Crystal Ball to determine the critical capabilities/nodes within the GPA PSM. This analysis had to be conducted for each force construct independently because changes to the nodal PDFs impact the sensitivity. The sensitivity analysis produces a Tornado chart (see Figure 3.8 below) that quantifies the overall *P(s)* distribution sensitivity to each node and rank orders each node based upon descending level of sensitivity. The nodes that present the highest levels of sensitivity are the critical nodes/capabilities associated with the GPA concept for a given force construct. This information allows decision makers a path by which efforts can be focused. For instance, the identification of critical capabilities facilitates an analytical decision process for determining possible capability tradeoffs for improving the overall probability of success or determining the most critical nodal PDFs for SME estimation precision. Figure 3.8 highlights the “Is BA Adequate” decision node within the GPA PSM using SRF nodal PDFs as the most critical node to the overall success. Chapter 4 will discuss the implications of this finding in detail.

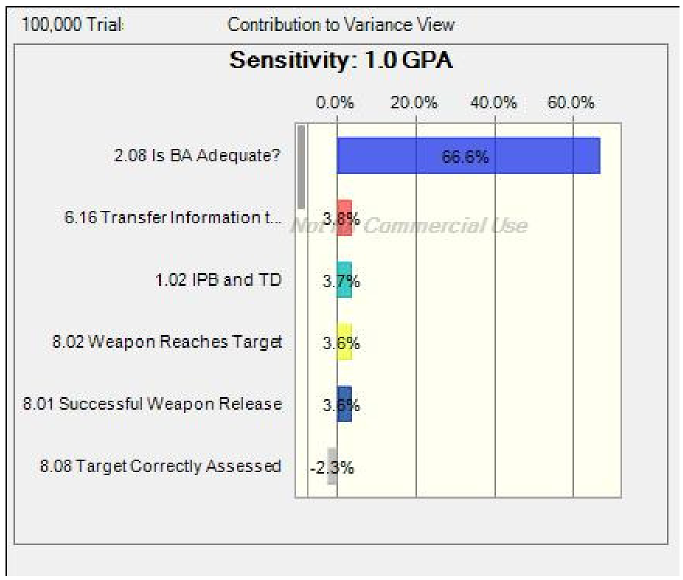

Figure 3.8. Sensitivity Analysis Tornado Chart

The final output distribution from the Monte Carlo analysis also provides quantitative data which can be used for additional analysis. Additionally, results from the campaign level simulation can be used to further refine the component PDF values for a higher fidelity risk assessment. It is important to note that the PSM methodology discussed here is a risk analysis process for developing the future force structure to meet the requirements of the GPA CONOPS.

Deliverables

This research focused on providing the Air Force an improved methodology to optimize the future force structure capable of meeting the needs of the national defense strategy under fiscally constrained guidance while minimizing risk. The OV-2 and OV-5 products provide the necessary foundation for tracking information exchange requirements between the key operational nodes identified within the GPA CONOPS as well as the connectivity and interdependence of the GPA operational activities. The PSM provides the necessary logic needed to analyze and quantify risk associated with the capabilities provided by the force construct. Appendices A and B detail the development of these products and Chapter 4 applies this project's risk assessment methodology to analyze and quantify the different levels of risk associated with two force constructs representing the SRF and FCF.

IV. Analysis and Results

The purpose of this research project was to provide the Air Force and Air Combat Command, in particular, an improved methodology to optimize the future force structure capable of meeting the needs of the national defense strategy under fiscally constrained guidance while minimizing risk. This chapter will step the reader through the various phases of the risk analysis process applied to a hypothetical SRF and FCF as defined by the authors in order to demonstrate the usefulness of this methodology to future force planning and budgeting considerations.

Strategy Responsive Force Analysis

The nodal *P(s)* PDFs for the SRF construct were based upon obtaining the required capabilities of a hypothetical force structure to meet future strategic objectives outlined in national level strategic guidance. The PDF parameter settings developed by our team for each node in the SRF are located in Appendix D. Monte Carlo trials were accomplished using Crystal Ball to draw from these nodal *P(s)* distributions to achieve the overall GPA PSM *P(s)* distribution. Figure 4.1 displays the overall GPA *P(s)* distribution for the SRF construct as defined by this research project.

Sensitivity analysis was also conducted using Crystal Ball to highlight the nodes within the GPA PSM that have the greatest impact on the overall GPA *P(s)* distribution. Figure 4.2 displays the sensitivity analysis results in the form of a tornado chart. The "Is BA Adequate?" decision node was the most critical to the overall success of GPA operations with an overwhelming 79% of the sensitivity to the overall *P(s)* distribution.

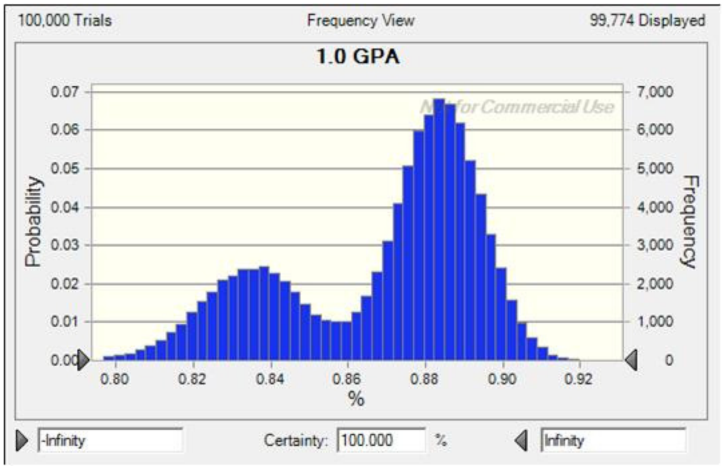

Figure 4.1. Overall Strategy Responsive Force *P(s)* Distribution

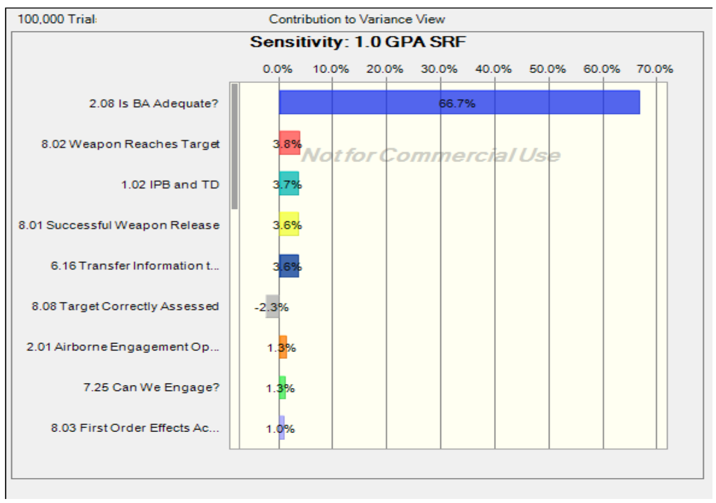

Figure 4.2. Strategy Responsive Force Sensitivity Analysis Results

The sensitivity analysis highlights the key reason for the bimodal distribution results demonstrated by Figure 4.3. The "Is BA Adequate?" decision node is a critical point in the logic and is controlled by the C4ISR activities prior to hostilities. The OV-5 decomposition of Achieve Battlespace Awareness Dominance outlines the necessary activities associated with C2, Intelligence, and Surveillance and Reconnaissance along with their interdependence. Part of the Intelligence cycle is dedicated to generating products associated with the Intelligence Preparation of the Battlespace (IPB).

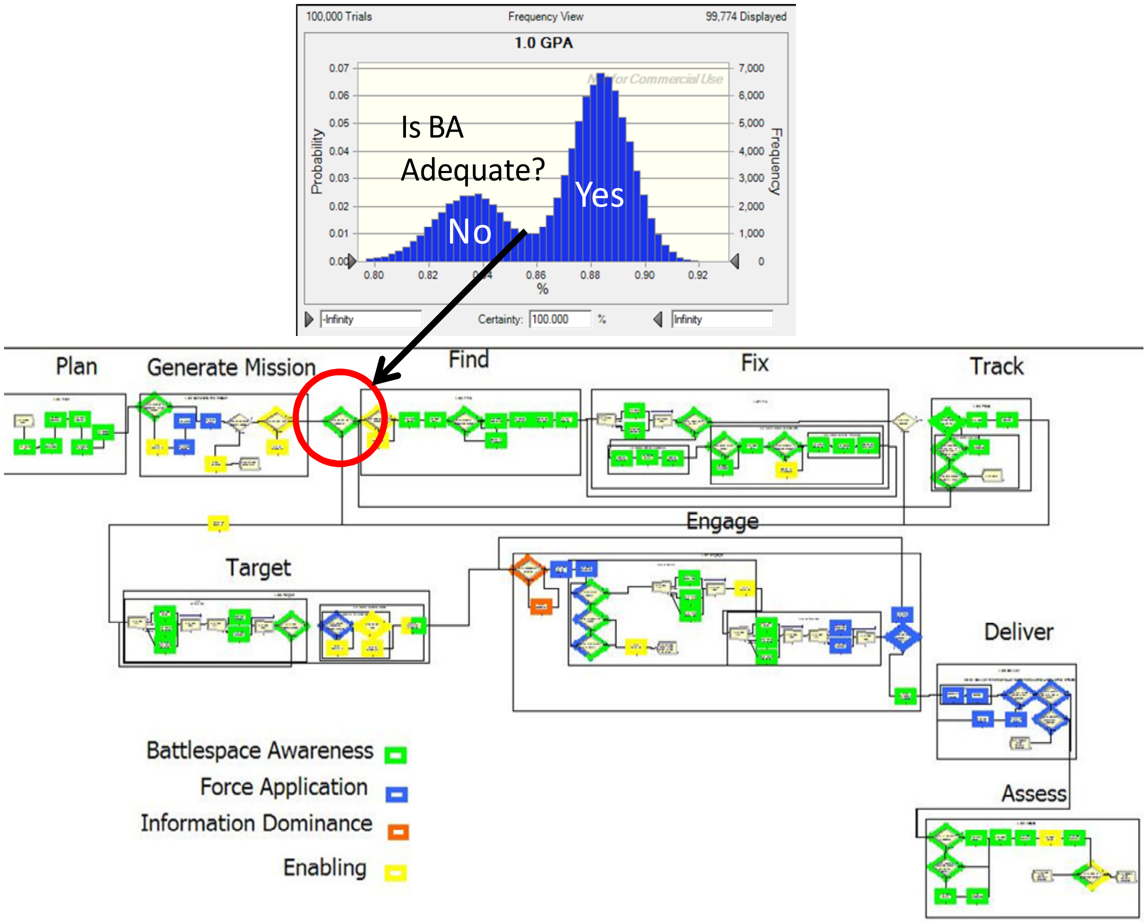

Figure 4.3. Highlighted Critical Decision Node within GPA PSM for SRF

The IPB includes the designation of key strategic targets with the required information to engage them. Targets that are identified and located with sufficient fidelity before hostilities begin and prior to the F2T2EA GPA process allow the GPA logic to skip the Find, Fix, and Track segments and proceed directly to the Target segment; therefore, the *P(s)* value for the "Is BA Adequate?" decision node controls the logic gates. The bimodal distribution demonstrates that if BA is not adequate, the resulting *P(s)* distribution shifts to the left. A simple analysis of the bimodal distribution's sample mean ($\bar{x}$) and sample standard deviation (*s*) for quantification of risk can be deceptive; therefore, additional analysis was performed by running the Monte Carlo simulation twice using the values of one and xero for the “Is BA Adequate?” decision node probability to highlight the expected changes in the overall *P(s)*. The results demonstrated by Figure 4.4 provide risk quantification associated with IPB capabilities.

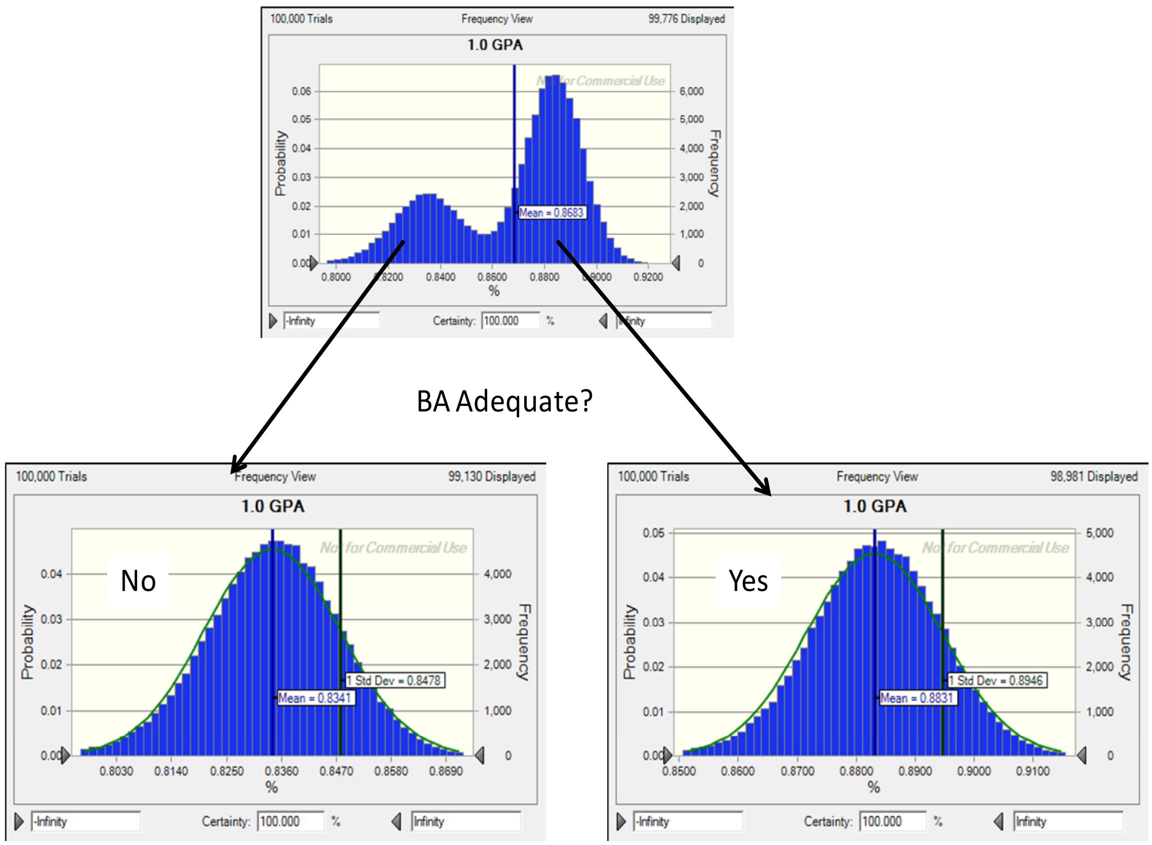

Figure 4.4. Effects of Adequate BA on GPA SRF *P(s)*

The GPA *P(s)* distribution representing the target sets for which sufficient intelligence for target engagement can be gathered prior to the execution of the F2T2EA process results in a distribution which fits a Normal distribution with a sample mean $(\bar{x})$ of 0.88 and sample standard deviation (s) of 0.0115. If intelligence information is not sufficient for engagement, the logic requires the process to execute the Find, Fix, and

Track segments which produces a Normal *P(s)* distribution with a sample mean ($\bar{x}$) of 0.83 and a sample standard deviation (s) of ± 0.0137. These results demonstrate an increase in the mean *P(s)* for GPA operations of five percent when adequate BA can be obtained prior to the F2T2EA process. The increase in the standard deviation for the distribution associated with inadequate BA also demonstrates an increased level of risk due to the increased range of mission success. As demonstrated, the standard deviation value provides valuable insight when attempting to minimize downside risk. A larger standard deviation implies increased risk. Table 4.1 summarizes the SRF risk analysis results.

SRF *P(s)* Distribution Results	Sample Mean ($\bar{x}$)	Sample Standard Deviation (s)	Best Curve Fit (Distribution Type/ K-S Value)
Bimodal SRF Results	0.87	N/A	Beta / .074
Is BA Adequate? = Yes	0.88	± 0.0115	Normal / .02
Is BA Adequate? = No	0.83	± 0.0137	Normal / .0166

Table 4.1. SRF Risk Analysis Summary Table

Targets that allow gathering sufficient engagement information prior to the F2T2EA process are typically associated with fixed targets. Scenarios that involve a significant amount of mobile or fleeting targets will result in a decreased *P(s)* associated with the increased emphasis on Finding, Fixing, and Tracking the targets within a dynamic environment. Campaign level analysis will require a lower probability value to be placed in the "Is BA Adequate?" decision node in order to accurately represent the increasingly dynamic environment associated with ongoing campaign level operations; however, the sensitivity analysis highlights the effectiveness of applying the appropriate capabilities to properly prepare the battlespace prior to hostilities. This observation is further reinforced by the second most sensitive node, IPD and TD activity, identified by the sensitivity analysis.

The sensitivity analysis also highlighted the critical nodes of Transfer Information to the Selected Strike Asset, Successful Weapon Release, and Weapon Reaches Target. The criteria used to develop the PDFs associated with each of these nodes are additional areas for capability and sufficiency research by SMEs. It is important to note, however, that any changes to the nodal PDFs and/or decision node probabilities will affect the sensitivity analysis as demonstrated in the following FCF analysis. In order to fully comprehend the effects of different PDFs due to various capability and sufficiency levels, a corresponding sensitivity analysis must be accomplished with every Monte Carlo simulation.

Fiscally Constrained Force Analysis

The FCF construct was represented by reducing specific nodal *P(s)* PDFs based upon reduced effectiveness due to decreased capabilities and/or lack of sufficiency. As proof of concept, this research project reduced the relevant nodal *P(s)* PDFs based upon fiscal constraint limits associated with three capability areas identified by ACC A5S as key risk areas. (see Figure 4.5 below) Two additional capability areas were modified based upon the top five acquisition priorities listed in Lt General Stephen Lorenz's brief "Lorenz on Leadership" (13, 8).

The first capability area addressed as a risk concern was associated with slipping the modernization of C2ISR platforms which would affect the *P(s)* PDFs associated with several PSM nodes linked to Battlespace Awareness (6, 22). Table 4.2 summarizes the modifications to the FCF nodal PDFs due to the reduced capabilities associated with slipping C2ISR modernization programs.

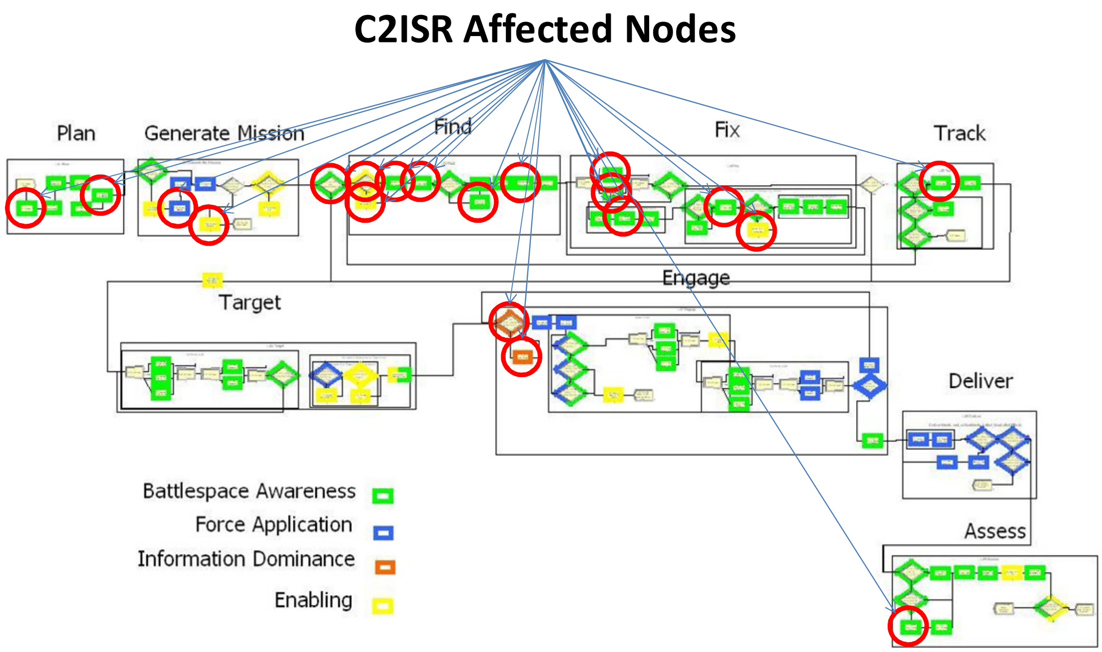

Figure 4.5. C2ISR Affected Nodes

Node	Description	SRF			FCF C2ISR		
		Min	Most	Max	Min	Most	Max
1.02	IPB and TD	0.980	0.990	1.000	0.900	0.940	0.950
1.07	Conduct Ops Planning	0.990	0.995	1.000	0.970	0.985	0.990
2.03	Mission Planning	1.000	1.000	1.000	0.980	0.995	1.000
2.05a	Personnel Recovery	0.999	0.999	0.999	0.960	0.980	0.990
2.08	Is BA Adequate?		0.700			0.500	
3.01	Collection Asset Available?		0.700			0.500	
3.02	Generate the Mission ACS	0.990	0.995	1.000	0.950	0.980	0.990
3.03	Position Collection Asset at Position Location	0.990	0.995	1.000	0.980	0.995	0.990
3.04	Collect Data	0.990	0.995	1.000	0.980	0.990	0.995
3.06	Transfer Collection Info to Processing Station	0.995	0.998	1.000	0.990	0.993	0.995
3.09	Transfer Collection Data Analysis Results to C2 Element	0.995	0.998	1.000	0.990	0.993	0.995
4.02	Combat ID CID TOI	0.980	0.990	1.000	0.970	0.990	0.995
4.03	Targetable Coordinates Available	0.980	0.990	1.000	0.970	0.990	0.995
4.07	Feasible Retask Options Exist	0.990	0.995	1.000	0.985	0.995	1.000
4.11	Collect Data	0.990	0.995	1.000	0.980	0.990	0.995
4.13	Transfer Collection Info to Processing Station	0.995	0.998	1.000	0.990	0.993	0.995
5.02	Collect	0.995	0.998	1.000	0.980	0.990	0.995
7.01	Ability to Avoid/Defeat Detection		0.850			0.750	
7.02	Avoid/Defeat Engagement	0.990	0.995	1.000	0.950	0.970	0.980
9.03	Feasible Retask Options Exist	0.980	0.990	1.000	0.980	0.990	0.995

Table 4.2. C2ISR PDF Modifications

The second capability area addressed by this research project's FCF reflected concerns about closing the F-22 line after Lot 9 which would jeopardize fleet sustainment and Air Dominance capabilities (6, 21). Table 4.3 lists the FCF nodal PDFs modified to incorporate F-22 fiscal limitations. Cutting or slipping the F-35 program would severely limit air-to-surface capabilities specifically in high threat scenarios. According to ACC A5S, campaign simulation results indicate an increase in MCO attrition and time when F-35 fiscal limitations are modeled (6, 21). Fiscal constraints associated with the F-35 program were addressed by modifying the nodal PDFs listed in Table 4.4.

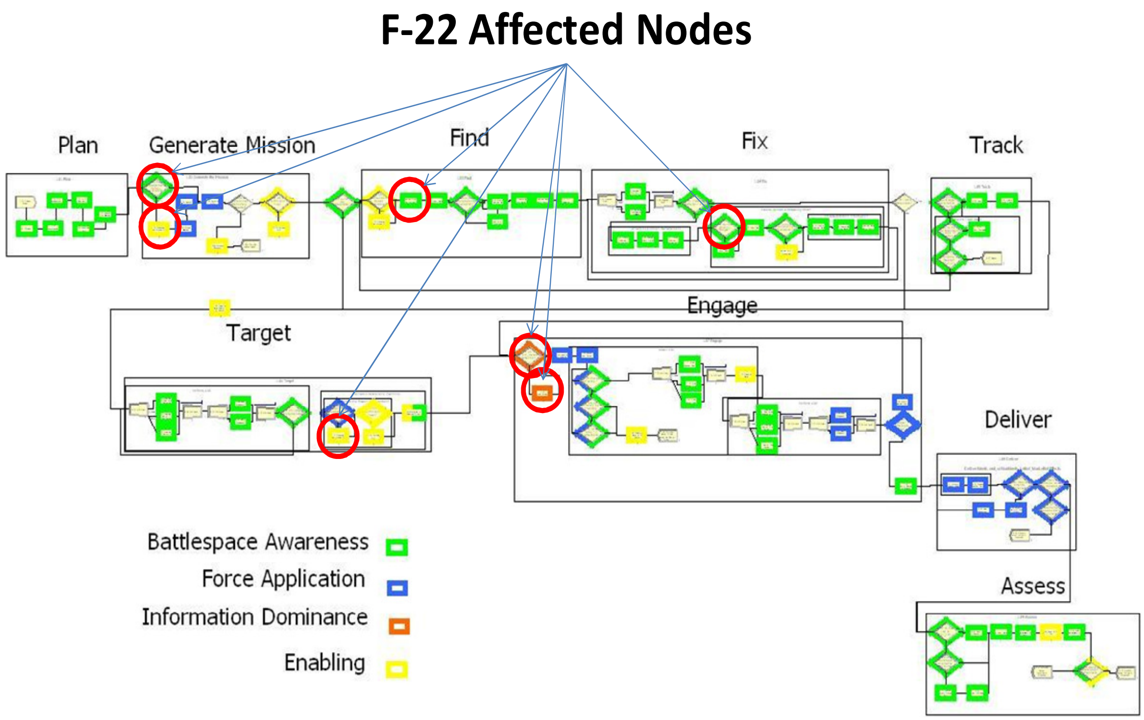

Figure 4.6. F-22 Affected Nodes

Node	Description	SRF			FCF F22		
		Min	Most	Max	Min	Most	Max
2.01	Airborne Engagement Option Available?		0.500			0.450	
2.02	Generate the Mission ACS	1.000	1.000	1.000	0.980	0.990	1.000
3.03	Position Collection Asset at Position Location	0.990	0.995	1.000	0.970	0.985	0.990
4.09	Sensor Within Range?		0.500			0.450	
6.13	Generate the Mission ACS	0.990	0.995	1.000	0.970	0.980	0.990
7.01	Ability to Avoid/Defeat Detection		0.850			0.700	
7.02	Avoid/Defeat Engagement	0.990	0.995	1.000	0.950	0.970	0.980

Table 4.3. F-22 PDF Modifications

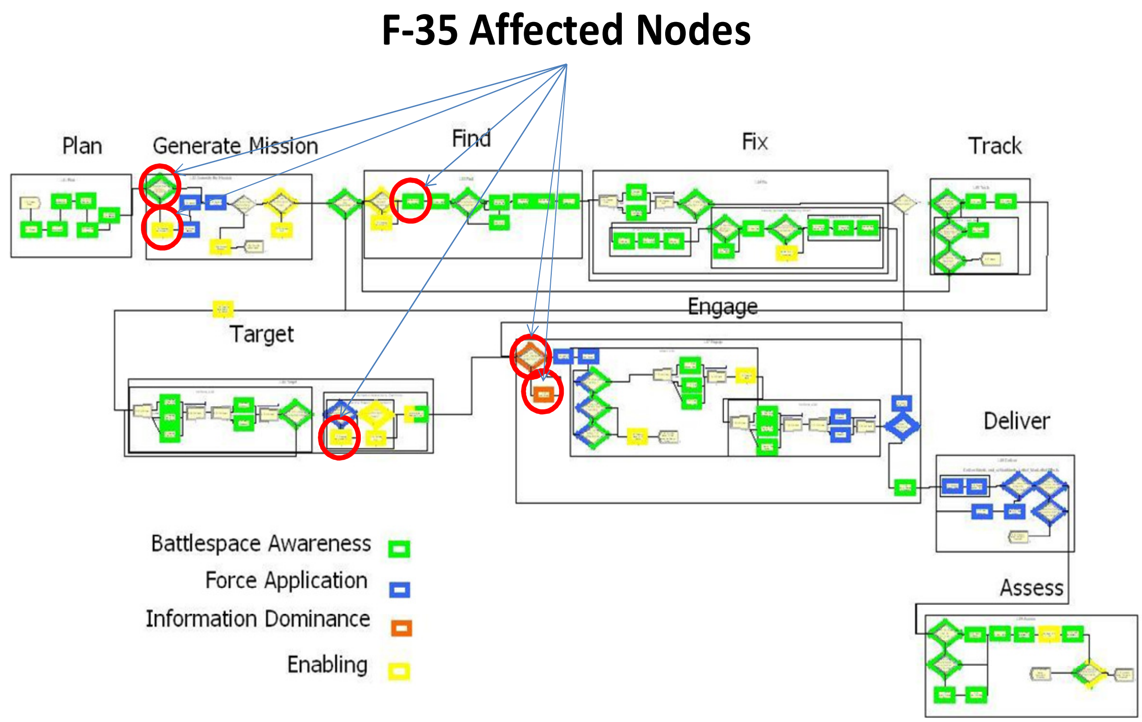

Figure 4.7. F-35 Affected Nodes

Node	Description	SRF			FCF F-35		
		Min	Most	Max	Min	Most	Max
2.01	Airborne Engagement Option Available?		0.500			0.450	
2.02	Generate the Mission ACS	1.000	1.000	1.000	0.980	0.990	1.000
3.03	Position Collection Asset at Position Location	0.990	0.995	1.000	0.970	0.985	0.990
6.13	Generate the Mission ACS	0.990	0.995	1.000	0.970	0.980	0.990
7.01	Ability to Avoid/Defeat Detection		0.850			0.700	
7.02	Avoid/Defeat Engagement	0.990	0.995	1.000	0.950	0.970	0.980

Table 4.4. F-35 PDF Modifications

The fourth capability area modified for the FCF in this research project addresses the Agile Combat Support air refueling enabling capability described within the GPA CONOPS. Cutting or slipping program efforts to develop a new tanker capability to replace the older KC-135 tanker fleet will significantly impact the necessary air refueling capabilities critical to successful GPA operations. Table 4.5 summarizes the changes in the PSM nodal PDFs based upon fiscal limitations affecting air refueling capabilities. Failing to develop a new long range bomber to replace legacy systems was the final capability limitation affected by fiscal constraints addressed by this research project's FCF. Table 4.6 lists the modified PDF values for the PSM nodes affected by reduced long range strike capabilities.

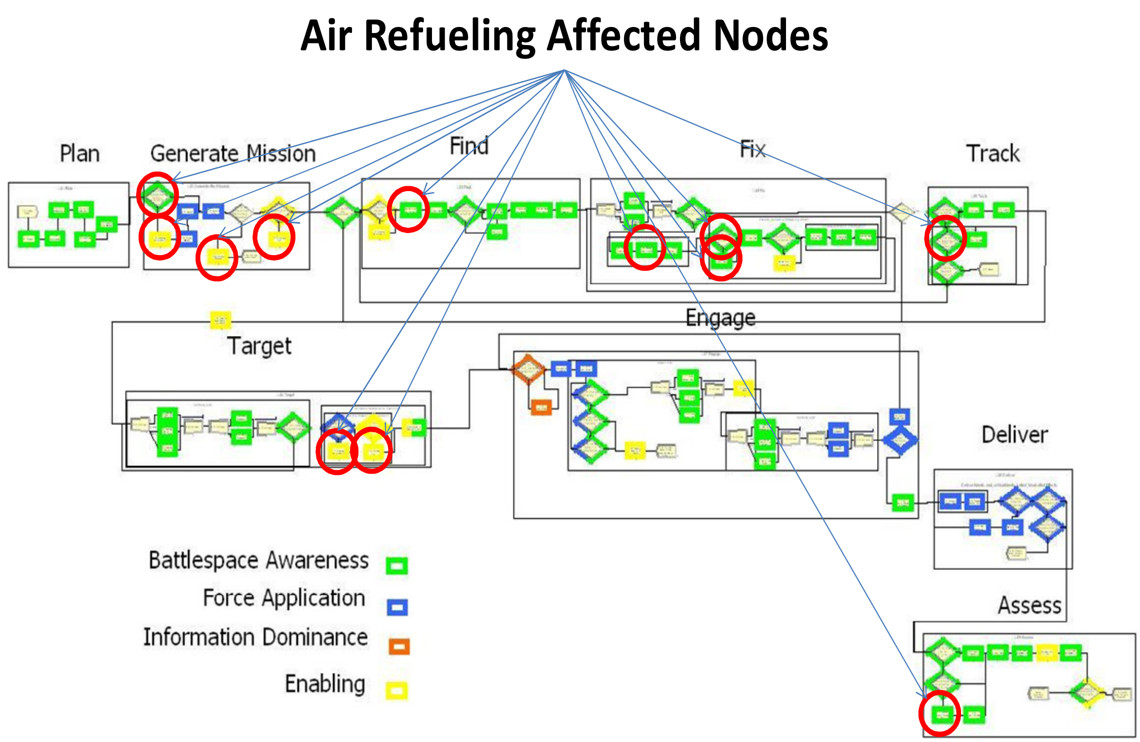

Figure 4.8. Air Refueling Affected Nodes

Node	Description	SRF			FCF Air Refueling		
		Min	Most	Max	Min	Most	Max
2.01	Airborne Engagement Option Available?		0.500			0.450	
2.02	Generate the Mission ACS	1.000	1.000	1.000	0.980	0.990	1.000
2.05a	Personnel Recovery	0.999	0.999	0.999	0.970	0.980	0.990
2.07	Air Refueling GM	0.990	0.995	1.000	0.850	0.920	0.950
3.03	Position Collection Asset at Position Location	0.990	0.995	1.000	0.970	0.985	0.990
4.07	Feasible Retask Options Exist	0.990	0.995	1.000	0.985	0.995	1.000
4.09	Sensor Within Range?		0.500			0.450	
4.10	Relocate Platform_Redirect Sensor	0.990	0.995	1.000	0.980	0.990	0.995
5.04	Coverage Options Exist to Maintain Track for Duration of Exec?		0.800			0.750	
6.13	Generate the Mission ACS	0.990	0.995	1.000	0.970	0.980	0.990
6.15	Air Refueling GM	0.990	0.995	1.000	0.850	0.920	0.950
9.03	Feasible Retask Options Exist	0.980	0.990	1.000	0.980	0.990	0.995

Table 4.5. Air Refueling PDF Modifications

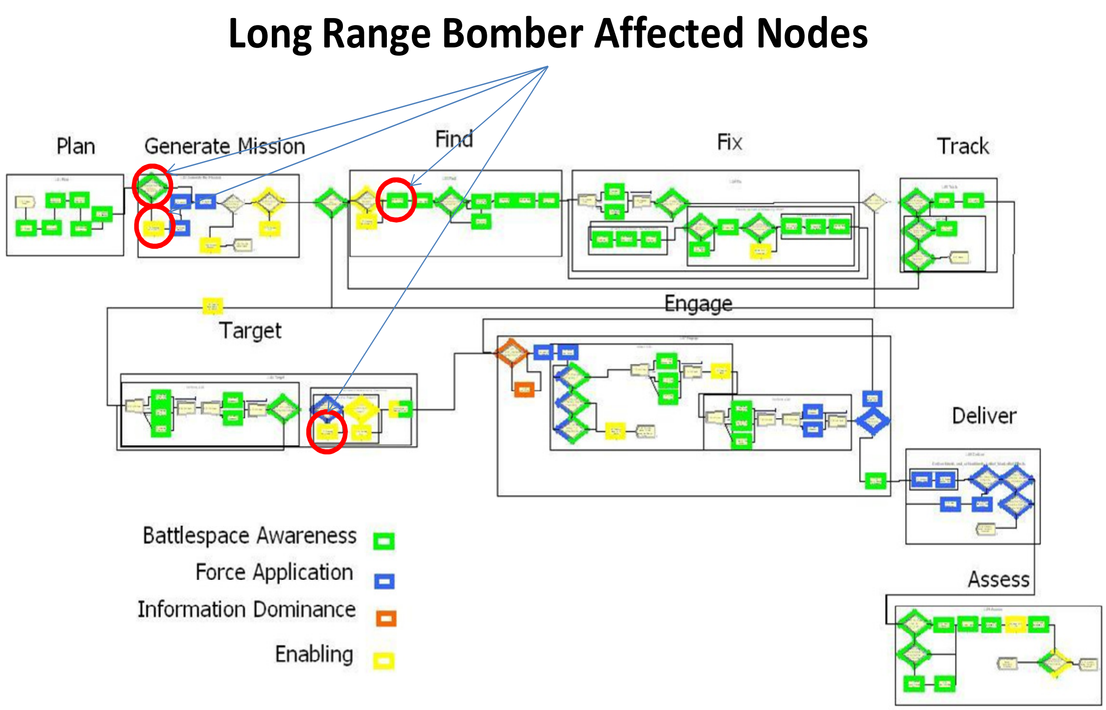

Figure 4.9. Long Range Bomber Affected Nodes

Node	Description	SRF			FCF Bomber		
		Min	Most	Max	Min	Most	Max
2.01	Airborne Engagement Option Available?	0.500			0.450		
2.02	Generate the Mission ACS	1.000	1.000	1.000	0.980	0.990	1.000
3.03	Position Collection Asset at Position Location	0.990	0.995	1.000	0.970	0.985	0.990
6.13	Generate the Mission ACS	0.990	0.995	1.000	0.970	0.980	0.990

Table 4.6. Long Range Bomber PDF Modifications

As shown by tables 4.2 through 4.6, each of the fiscal limitations was evaluated independently as to how it would affect each PSM nodal *P(s)* PDF. The combined effect of the fiscal limitations was then determined by comparing the independent evaluations and further modifying the nodal PDF values affected by multiple constraints. Table 4.7 summarizes the combined results of all *P(s)* PDF modifications used for the FCF risk analysis.

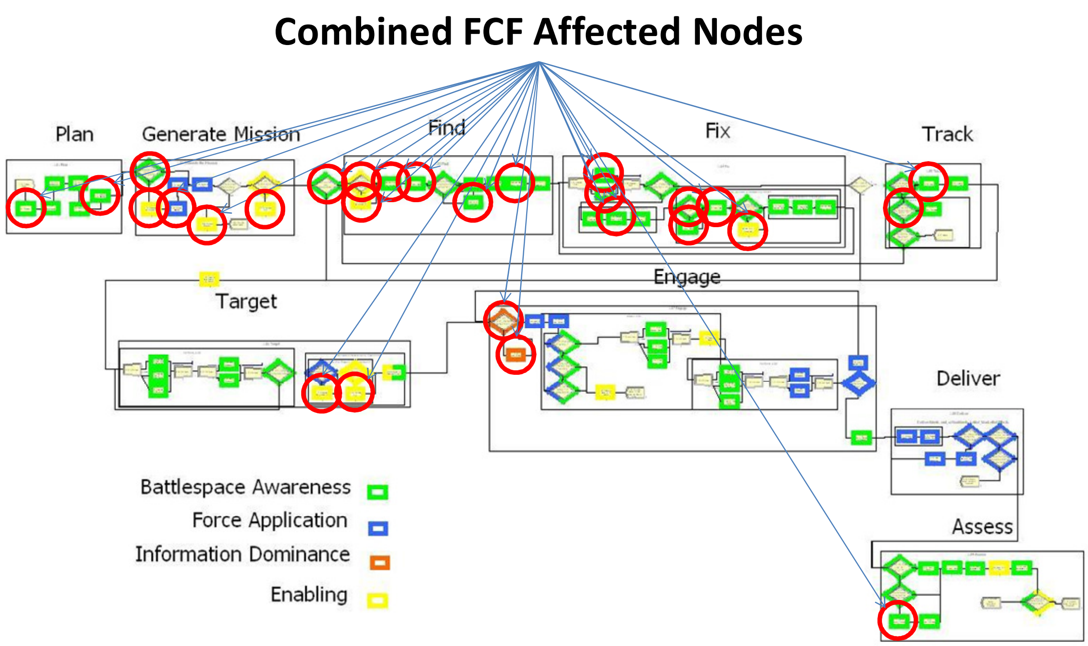

Figure 4.10. Combined FCF Affected Nodes

Node	Description	SRF			FCF Combination		
		Min	Most	Max	Min	Most	Max
1.02	IPB and TD	0.980	0.990	1.000	0.900	0.940	0.950
1.07	Conduct Ops Planning	0.990	0.995	1.000	0.970	0.985	0.990
2.01	Airborne Engagement Option Available?		0.500			0.300	
2.02	Generate the Mission ACS	1.000	1.000	1.000	0.950	0.970	0.980
2.03	Mission Planning	1.000	1.000	1.000	0.980	0.995	1.000
2.05a	Personnel Recovery	0.999	0.999	0.999	0.950	0.970	0.990
2.07	Air Refueling GM	0.990	0.995	1.000	0.850	0.920	0.950
2.08	Is BA Adequate?		0.700			0.500	
3.01	Collection Asset Available?		0.700			0.500	
3.02	Generate the Mission ACS	0.990	0.995	1.000	0.950	0.980	0.990
3.03	Position Collection Asset at Position Location	0.990	0.995	1.000	0.950	0.980	0.990
3.04	Collect Data	0.990	0.995	1.000	0.980	0.990	0.995
3.06	Transfer Collection Info to Processing Station	0.995	0.998	1.000	0.990	0.993	0.995
3.09	Transfer Collection Data Analysis Results to C2 Element	0.995	0.998	1.000	0.990	0.993	0.995
4.02	Combat ID CID TOI	0.980	0.990	1.000	0.970	0.990	0.995
4.03	Targetable Coordinates Available	0.980	0.990	1.000	0.970	0.990	0.995
4.07	Feasible Retask Options Exist	0.990	0.995	1.000	0.980	0.990	0.995
4.09	Sensor Within Range?		0.500			0.400	
4.10	Relocate Platform_Redirect Sensor	0.990	0.995	1.000	0.980	0.990	0.995
4.11	Collect Data	0.990	0.995	1.000	0.980	0.990	0.995
4.13	Transfer Collection Info to Processing Station	0.995	0.998	1.000	0.990	0.993	0.995
5.02	Collect	0.995	0.998	1.000	0.980	0.990	0.995
5.04	Coverage Options Exist to Maintain Track for Duration of Exec?		0.800			0.750	
6.13	Generate the Mission ACS	0.990	0.995	1.000	0.950	0.970	0.980
6.15	Air Refueling GM	0.990	0.995	1.000	0.850	0.920	0.950
7.01	Ability to Avoid/Defeat Detection		0.850			0.500	
7.02	Avoid/Defeat Engagement	0.990	0.995	1.000	0.850	0.900	0.950
9.03	Feasible Retask Options Exist	0.980	0.990	1.000	0.980	0.990	0.995

Table 4.7. Combined FCF *P(s)* PDF Modifications

The FCF consisting of the modified *P(s)* PDFs in Table 4.7 was evaluated by accomplishing a Monte Carlo simulation using Crystal Ball to provide an overall GPA *P(s)* distribution similar to the process used for the SRF. The resulting FCF *P(s)* distribution is presented in Figure 4.11.

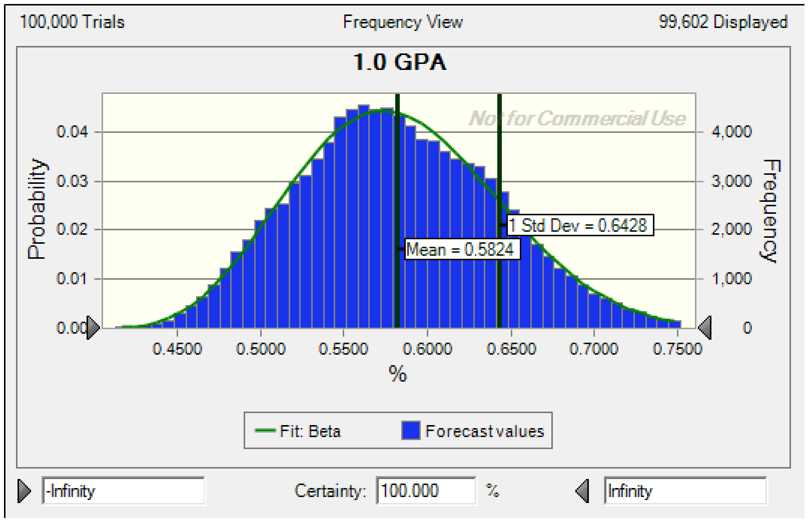

Figure 4.11. Overall FCF *P(s)* Distribution

The subsequent sensitivity analysis of the FCF highlighted the critical nodes that had the greatest effect on the overall *P(s)* distribution (see Figure 4.12 below). Again, the "Is BA Adequate?" decision node was identified as having the greatest sensitivity; however, the "Ability to Avoid/Defeat Detection" decision node was also highlighted as having the significant impact on the overall GPA *P(s)* distribution based on the FCF limitations.

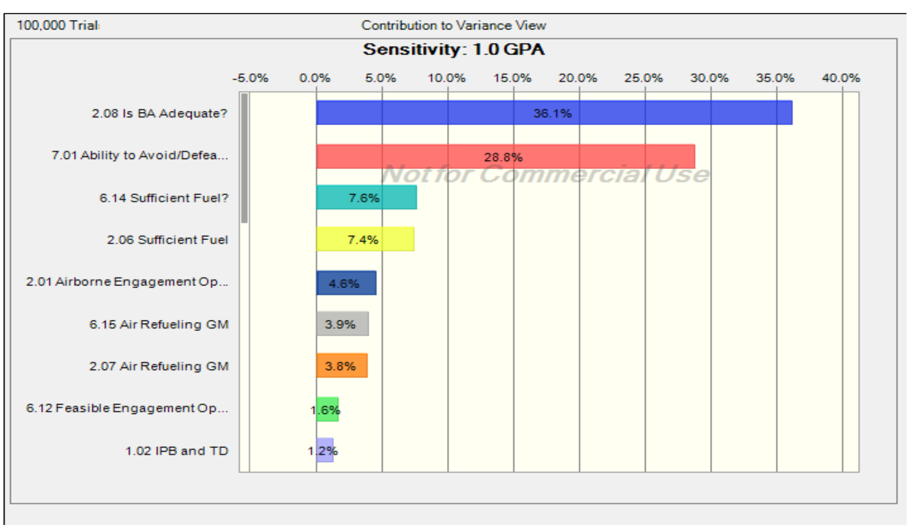

Figure 4.12. Combined FCF Sensitivity Analysis by Node

The sensitivity analysis results presented by Figure 4.12 provides insight into which nodes within the PSM had the greatest impact on the overall *P(s)* distribution and should be most thoroughly studied by SMEs. In order to fully understand the sensitivity of the overall GPA *P(s)* distribution to each individual capability constraint, the nodal sensitivity values were grouped by capability area. Figure 4.13 provides a graphical depiction of the *P(s)* distribution sensitivities to each capability constraint represented in the FCF. The resulting analysis identified the C2ISR capability as the most critical to the overall success of GPA operations, based on our notional component data.

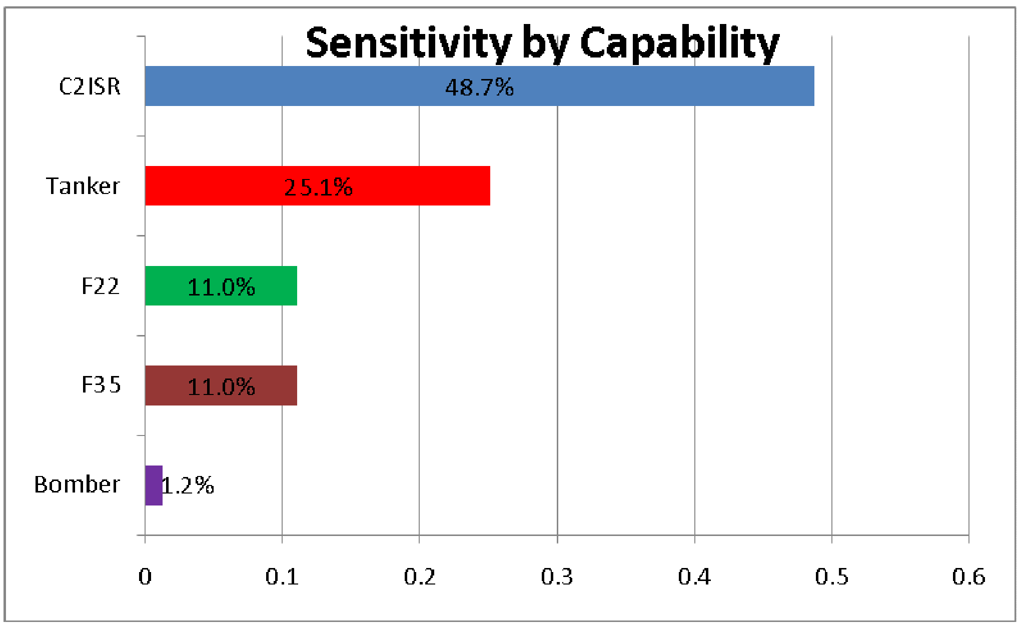

Figure 4.13. Combined FCF Sensitivity Analysis by Capability

The sensitivity analysis of the FCF once again identified the “Is BA Adequate?” decision node as the most critical to the overall *P(s)* distribution results; therefore, additional Monte Carlo simulations were accomplished to isolate the different distribution results based upon the sequencing path determined by the “Is BA Adequate?” decision. Figure 4.14 below provides the results.

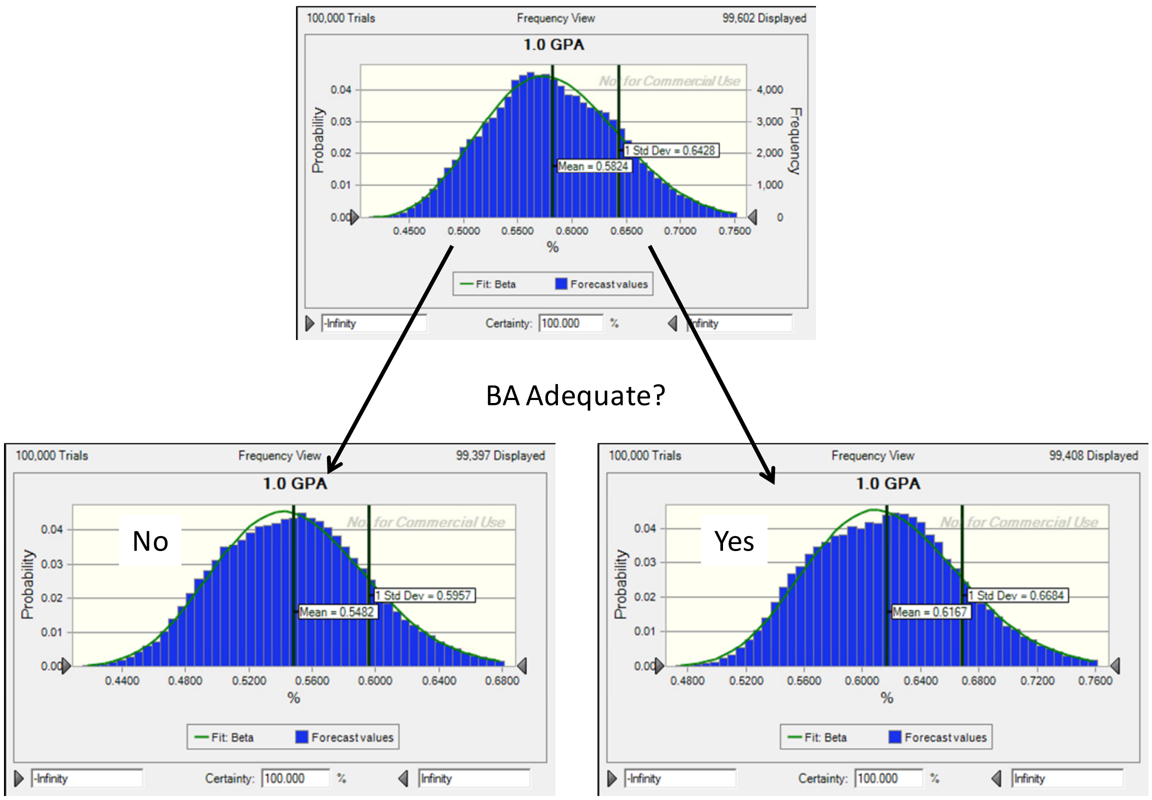

Figure 4.14. Effects of Adequate BA on GPA FCF *P(s)*

The GPA *P(s)* distribution representing the target sets for which sufficient intelligence for target engagement can be gathered prior to the execution of the F2T2EA process results in a distribution with a sample mean ($\bar{x}$) *P(s)* of 0.62 and sample standard deviation (*s*) of 0.0497. If intelligence information is not sufficient for engagement, the sequencing logic requires the process to execute the Find, Fix, and Track segments which produces a *P(s)* distribution with a mean *P(s)* of 0.55 and S of 0.0475. These results demonstrate an increase in the mean *P(s)* for GPA operations of approximately seven percent when adequate BA can be obtained prior to the F2T2EA process. The standard deviations for the distributions, however, were not significantly different. Table 4.8 summarizes the FCF risk analysis results.

FCF *P(s)* Distribution Results	Sample Mean ($\bar{x}$)	Sample Standard Deviation (s)	Best Curve Fit (Distribution Type/ K-S Value)
FCF Results	0.58	± 0.0604	Beta(7.3, 13.4) / .0065
Is BA Adequate? = Yes	0.62	± 0.0497	Beta(13.3, 33.9) / .0115
Is BA Adequate? = No	0.55	± 0.0475	Beta(15.6, 45.0) / .0091

Table 4.8. FCF Risk Analysis Summary Table

The FCF sensitivity analysis also identified the critical decision node of "Ability to Avoid/Defeat Detection" as having the second greatest impact on the overall FCF *P(s)* This decision node determines whether or not the PSM is required to execute the Avoid/Defeat Engagement activity. The constraints associated with the F-22, F-35, and C2ISR all impacted the PDF values for both these nodes. As a result, the combined effects of these constraints caused an increased number of simulation runs to execute the Avoid/Defeat Engagement activity which contained a significantly lower *P(s)* PDF than that of the SRF (see Table 4.7). The "Sufficient Fuel?" decision nodes and the Air Refueling activity nodes were also identified as critical capability areas that need greater emphasis within the constraints of the FCF.

Analysis of Individual Constraints

In order to quantify the effects of each individual constraint represented in the FCF, an independent risk analysis was conducted for each fiscal constraint. The analysis was accomplished by performing Monte Carlo simulations for each individual fiscal constraint using only the nodal PDF modifications directly impacted by that particular fiscal constraint.

C2ISR Analysis Results

In order to isolate the effects of the C2ISR capability constraints on the overall GPA *P(s)* distribution, a modified FCF analysis was accomplished. The C2ISR constraints were based upon slipping the modernization of the C2ISR capabilities including delaying the purchasing of key ISR and communication capabilities. Figure 4.5 highlights the nodes within the PSM directly impacted by the constraints associated with the C2ISR capability limitations. Table 4.2 lists the modified nodal PDF values used for the C2ISR risk analysis. The nodal PDF values for the nodes not listed in Table 4.2 contain the PDF values used for the SRF analysis and are listed in Appendix B. Figure 4.15 displays the resulting overall *P(s)* distribution.

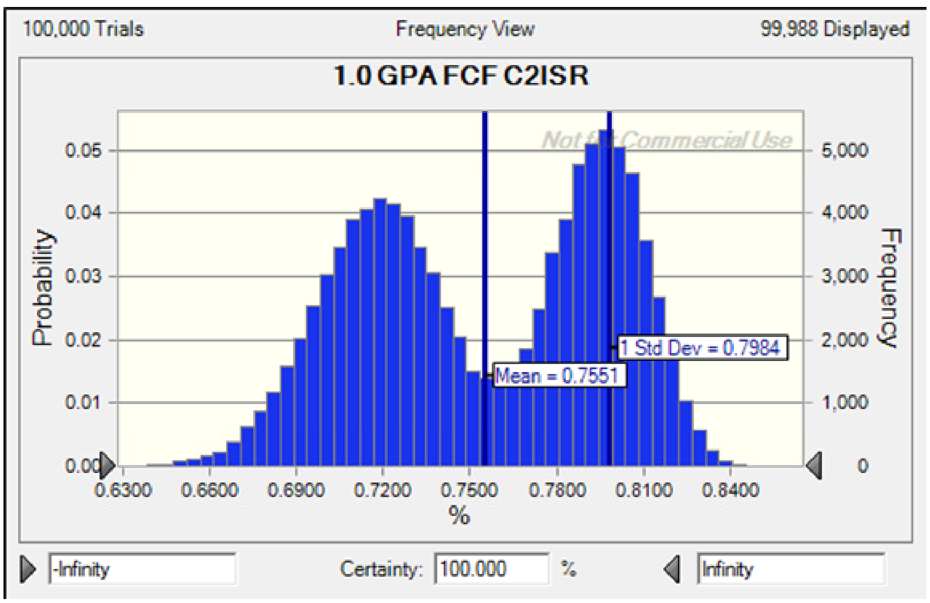

Figure 4.15. C2ISR FCF *P(s)* Distribution

The bimodal distribution is once again a result of the "Is BA Adequate?" decision node similar to the SRF results. The sensitivity analysis results shown in Figure 4.16 identify the "Is BA Adequate?" decision node as having the greatest impact on the overall *P(s)* distribution. The bimodal characteristic of the distribution does not allow presenting the mean and standard deviation as a viable quantification of risk without further analysis. As a result, two subsequent Monte Carlo simulations were accomplished to highlight the changes in the *P(s)* distribution based upon whether or not BA was adequate (see Figure 4.17 below).

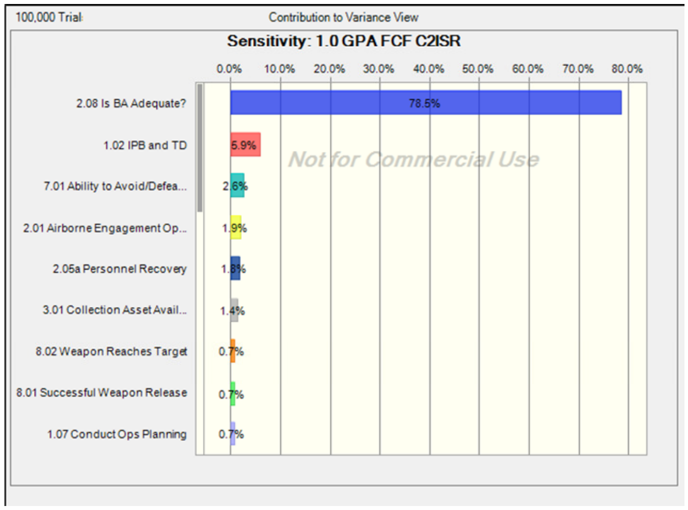

Figure 4.16. C2ISR FCF Sensitivity Analysis Results

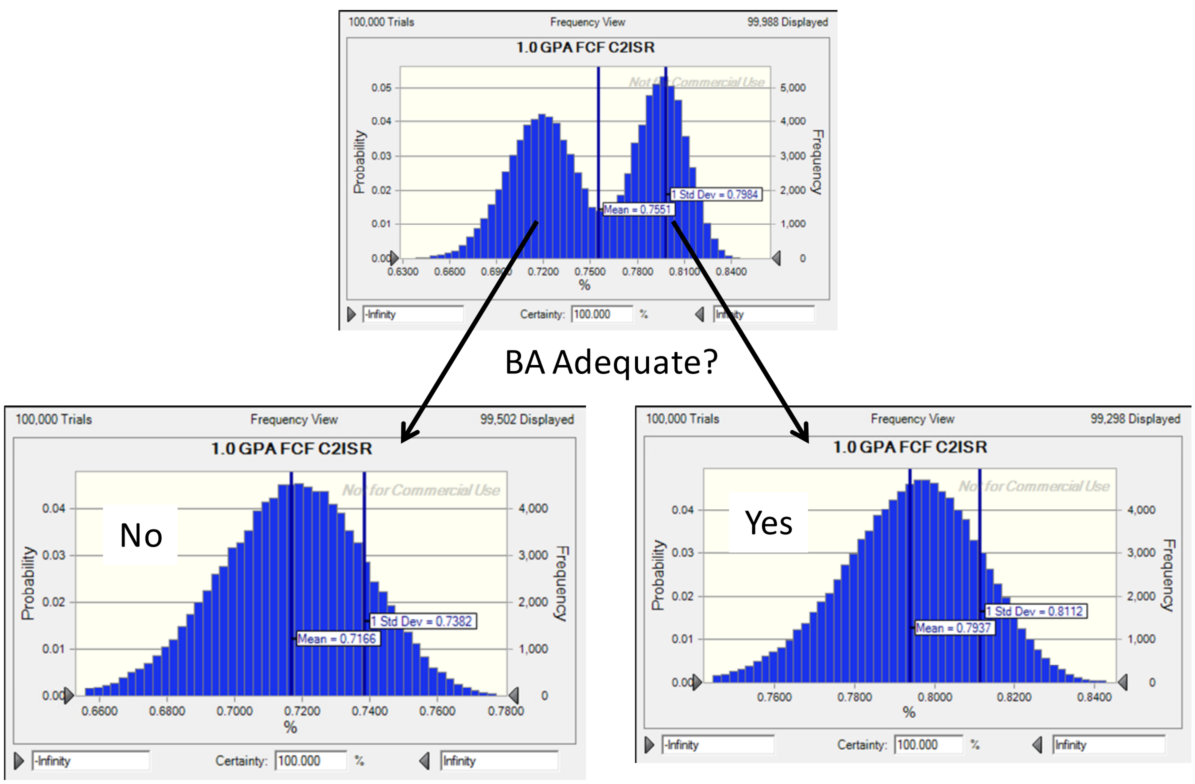

Figure 4.17. Effects of Adequate BA on GPA C2ISR FCF *P(s)*

The resulting *P(s)* distributions for the effects of adequate BA provide information that can be used to quantify the risk associated with the C2ISR capability constraints in terms of the mean *P(s)* and standard deviation values. Table 4.9 summarizes the C2ISR FCF risk analysis results and demonstrates an increase in the mean *P(s)* of approximately eight percent when BA is adequate. Also, the increase in the standard deviation value when BA is not adequate implies increased risk due to the increased range over which the distribution values are expected to fall.

C2ISR FCF *P(s)* Distribution Results	Sample Mean ($\bar{x}$)	Sample Standard Deviation (*s*)	Best Curve Fit (Distribution Type/ K-S Value)
C2ISR FCF Results	0.76	N/A	Beta / .0604
Is BA Adequate? = Yes	0.79	± 0.0175	Weibull / .0073
Is BA Adequate? = No	0.72	± 0.0216	Beta / .0028

Table 4.9. C2ISR FCF Risk Analysis Results Summary

F-22 Analysis Results

The F-22 FCF constraints reflected concerns about closing the F-22 line after Lot 9 which would jeopardize fleet sustainment and future Air Dominance capabilities due to lack of sufficiency in assets. Figure 4.5 highlights the nodes within the PSM directly impacted by the constraints associated with the F-22 sufficiency limitations. Table 4.2 lists the modified nodal PDF values used for the F-22 risk analysis. The nodal PDF values for the nodes not listed in Table 4.2 contain the PDF values used for the SRF analysis and are listed in Appendix B. Figure 4.18 below displays the F-22 FCF *P(s)* distribution based upon the F-22 constraints.

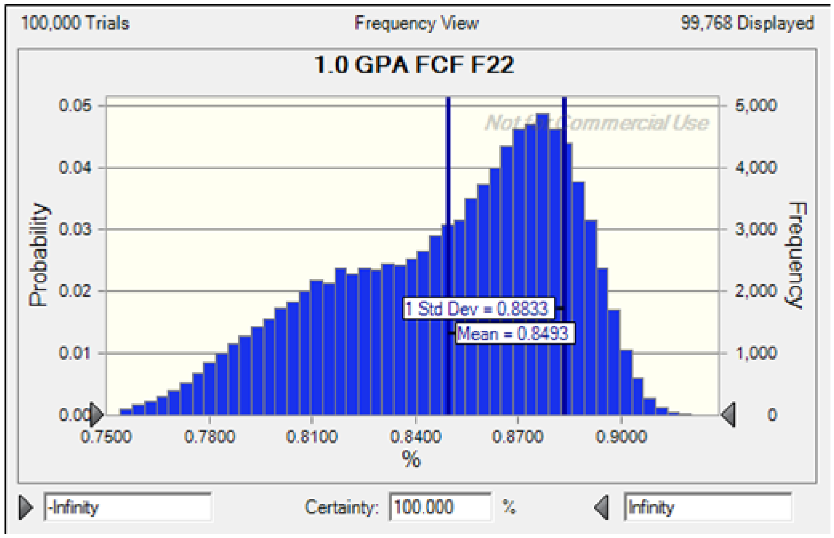

Figure 4.18. F-22 FCF *P(s)* Distribution

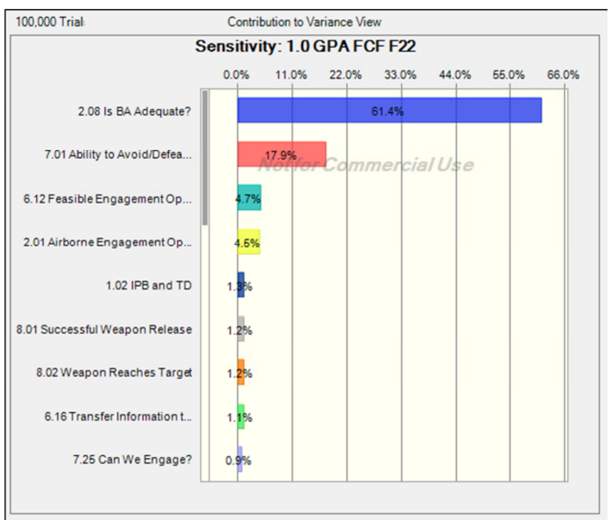

Figure 4.19. F-22 FCF Sensitivity Analysis Results

Once again, the sensitivity analysis identified the "Is BA Adequate?" decision node as having the greatest impact on the overall *P(s)* distribution; however, the second most sensitive node listed was the Ability to Avoid/Defeat Detection decision node (see Figure 4.19 above). The Avoid/Defeat Detection decision node consists of the probability that the asset will not have to take evasive maneuvers for self protection from adversary threat systems. The probability of success is scenario dependent and accounts for threats, ingress routing, asset stealthiness, on-board defensive systems, off-board jamming support, etc. Both Air-to-Air and Surface-to-Air threats are considered, and for high level analysis of campaign operations, fighter sweep and escort support operations play a significant factor. The probability of success of this decision node was reduced from 0.85 to 0.70 to represent a lack of sufficiency in stealthy fighter sweep and escort support assets.

The Avoid/Defeat Detection decision node was listed as having the second greatest impact on the overall $P(s)$ distribution due mainly to the increased percentage of simulation runs required to execute the Avoid/Defeat Engagement activity node which was also modified to reflect the reduced sufficiency of F-22s. The PDF for this activity is also scenario dependent similar to the Avoid/Defeat Detection decision node and, therefore, affected in a similar manner. Lack of fighter sweep and escort support assets increases the probability that strike assets will have to engage and defeat airborne threats in addition to surface threats. The Avoid/Defeat Engagement PDF for the SRF used a triangular distribution with a minimum of 0.99, maximum of 1.0, and most likely of 0.995. The modified PDF based upon lack of sufficiency used a triangular distribution with a minimum of 0.95, maximum of 0.98, and most likely of 0.97.

Additional Monte Carlo simulations were also accomplished to isolate the different modes created by the "Is BA Adequate?" node similar to the analysis accomplished for the SRF (see Figure 4.20 below). The resulting distributions once again provided information that could be used to quantify risk associated with the F-22 sufficiency constraints. Table 4.10 below summarizes the F-22 FCF risk analysis results.

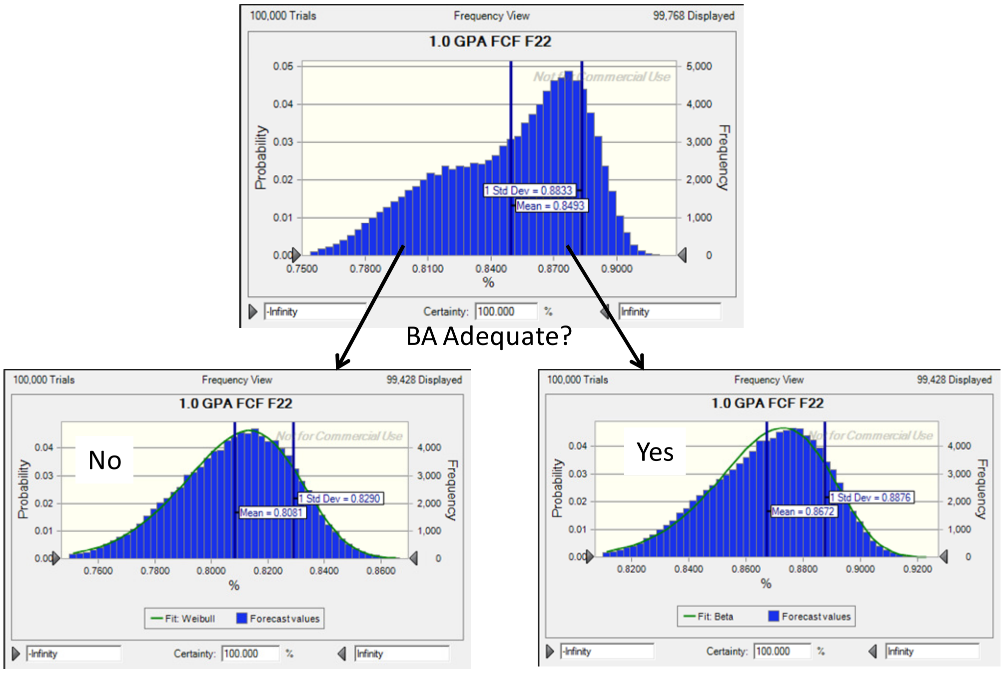

Figure 4.20. Effects of Adequate BA on GPA F-22 FCF *P(s)*

F-22 FCF *P(s)* Distribution Results	Sample Mean ($\bar{x}$)	Sample Standard Deviation (*s*)	Best Curve Fit (Distribution Type/ K-S Value)
F-22 FCF Results	0.85	N/A	Beta / .045
Is BA Adequate? = Yes	0.87	± 0.0204	Beta / .0105
Is BA Adequate? = No	0.81	± 0.0209	Weibull / .0065

Table 4.10. F-22 FCF Risk Analysis Results Summary

F-35 Analysis Results

The F-35 constraints were based upon concerns that cutting or slipping the F-35 program would severely limit air-to-surface capabilities specifically in high threat scenarios. Figure 4.5 highlights the nodes within the PSM directly impacted by the constraints associated with not having F-35s assets available in sufficient numbers to fulfill the air-to-surface capability requirements. Table 4.2 lists the modified nodal PDF values used for the F-35 risk analysis. The nodal PDF values for the nodes not listed in Table 4.2 contain the PDF values used for the SRF analysis and are listed in Appendix B.

Figure 4.21 displays the overall *P(s)* distribution results based upon the lack of F-35 assets.

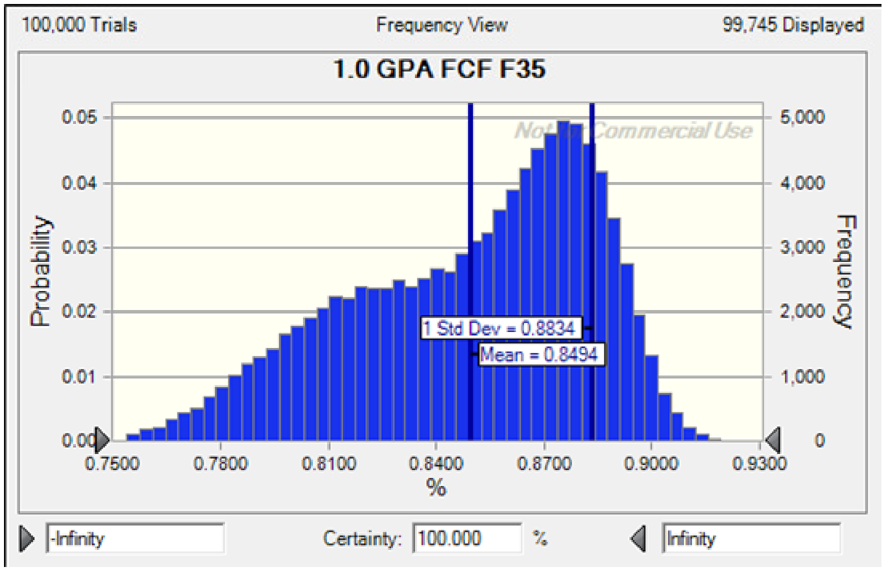

Figure 4.21. F-35 FCF *P(s)* Distribution

The sensitivity analysis of the F-35 FCF presented results similar to that of the F-22 FCF analysis with the "Is BA Adequate?" decision node listed as having the greatest impact on the overall *P(s)* distribution. The Ability to Avoid/Defeat Detection decision node was also listed like in the F-22 FCF sensitivity analysis as having the second greatest impact on the overall success of GPA operations due mainly to the increased number of simulations required to execute the Avoid/Defeat Engagement activity. Both the Ability to Avoid/Defeat Detection decision node and the Avoid/Defeat Engagement activity node were modified due to the reduced number of stealthy assets capable of avoiding or defeating specific air-to-air and surface-to-air threat systems.

Due to the bimodal distribution characteristics caused by the "Is BA Adequate?" decision node, the F-35 FCF *P(s)* distribution results required further analysis to isolate the effects of adequate BA. As a result, additional Monte Carlo simulations were once again accomplished using values of zero and one for the *P(s)* of the "Is BA Adequate" decision node (see Figure 4.23).

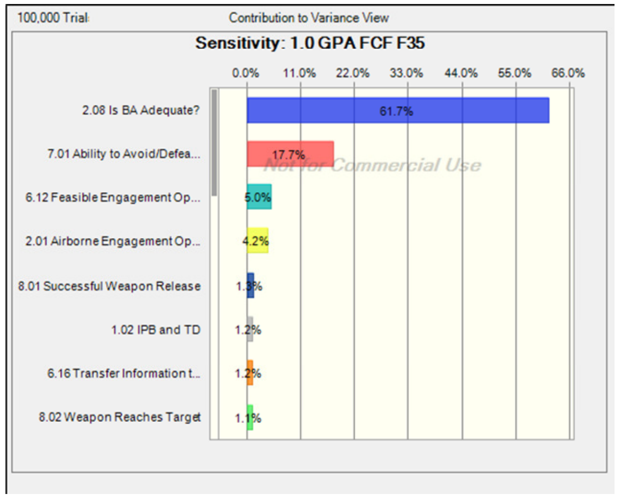

Figure 4.22. F-35 FCF Sensitivity Analysis Results

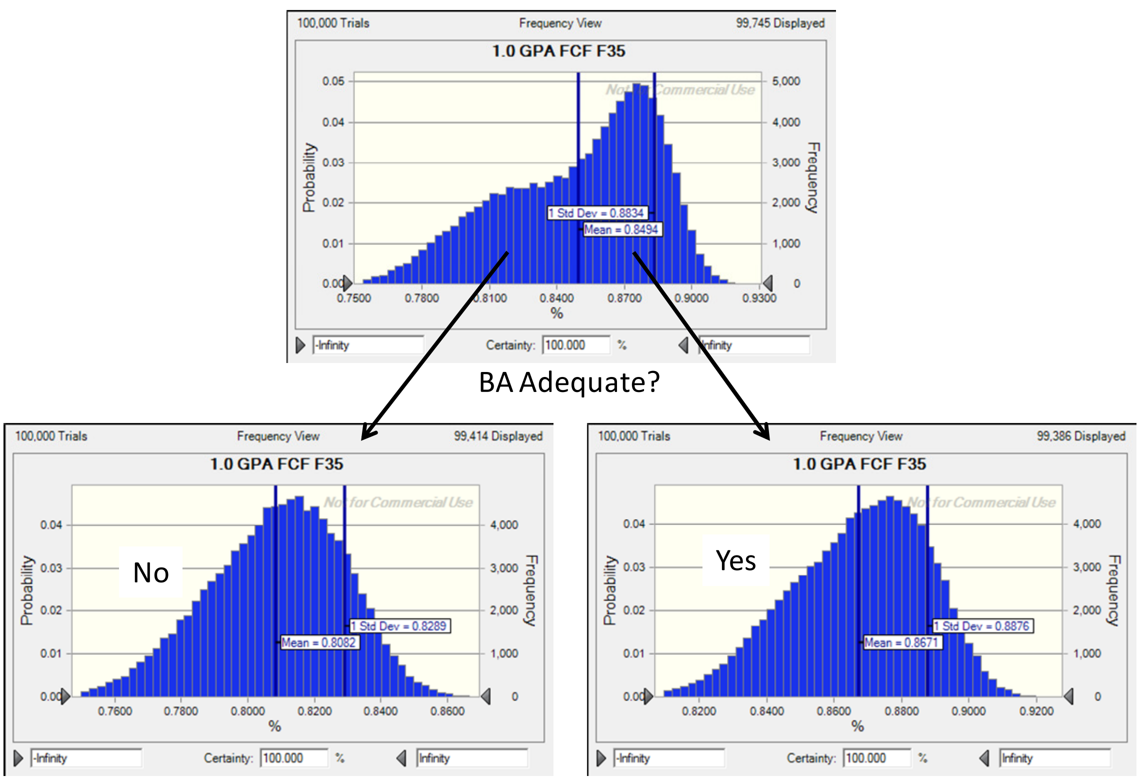

Figure 4.23. Effects of Adequate BA on GPA F-35 FCF *P(s)*

The resulting distributions provided sufficient information to quantify risk associated with the F-35 constraints. Table 4.11 summarizes the risk analysis results for the F-35 FCF.

F-35 FCF *P(s)* Distribution Results	Sample Mean ($\bar{x}$)	Sample Standard Deviation (*s*)	Best Curve Fit (Distribution Type/ K-S Value)
F-35 FCF Results	0.85	N/A	Beta / .023
Is BA Adequate? = Yes	0.87	± 0.0203	Beta / .0117
Is BA Adequate? = No	0.81	± 0.0208	Weibull / .0071

Table 4.11. F-35 FCF Risk Analysis Results Summary

Air Refueling Analysis Results

Cutting or slipping program efforts to develop a new tanker capability to replace the older KC-135 tanker fleet will significantly impact the necessary air refueling capabilities critical to successful GPA operations. Figure 4.5 highlights the nodes within the PSM directly impacted by the constraints associated with diminishing air refueling capabilities, and Table 4.2 lists the modified nodal PDF values used for the air refueling risk analysis. Again, the remaining nodal PDF values not listed in Table 4.2 contain the values used for the SRF analysis. Figure 4.24 displays the overall *P(s)* distribution results based upon a decreased air refueling capability due to slipping or cutting the program efforts to develop a new tanker.

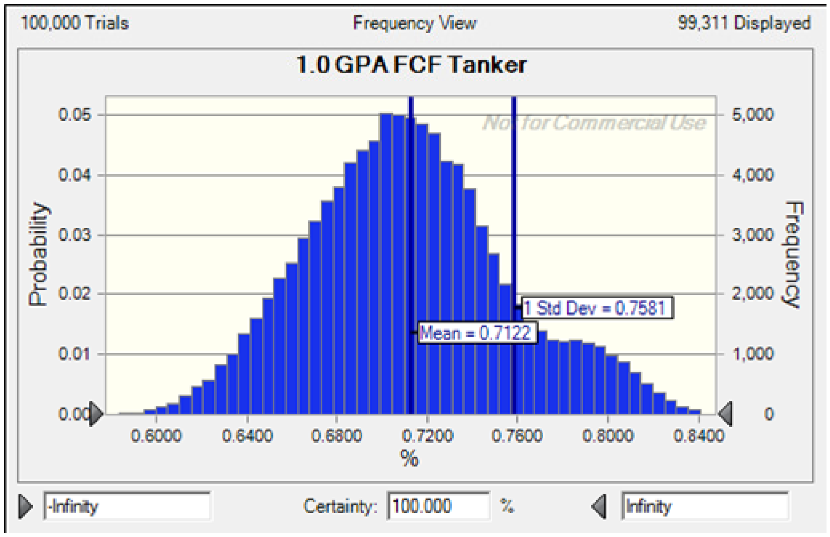

Figure 4.24. Tanker FCF *P(s)* Distribution

The “Is BA Adequate?” decision node was once again listed as having the greatest sensitivity when a sensitivity analysis was conducted for the Tanker FCF; however, the constraints associated with a decreased air refueling capability increased the impact of the air refueling activity on the overall GPA *P(s)* distribution. The two “Sufficient Fuel?” decision nodes (nodes 2.08 and 6.14) determine the likelihood that the required assets must refuel before continuing with the remaining F2T2EA process. These decision nodes determine the weight on the overall GPA *P(s)* that air refueling operations will possess. For instance, specific campaign scenarios may have limited forward basing options requiring a significant strain on air refueling capabilities. In this case, the PDF for the likelihood of having sufficient fuel to complete the mission without requiring air refueling assets should be low in order to force a higher number of outcomes within the Monte Carlo simulation through the air refueling loop. In order to remain consistent for a valid comparison between the SRF and Tanker FCF *P(s)* distributions, the “Sufficient Fuel?” decision node values were not modified because they are scenario dependent.

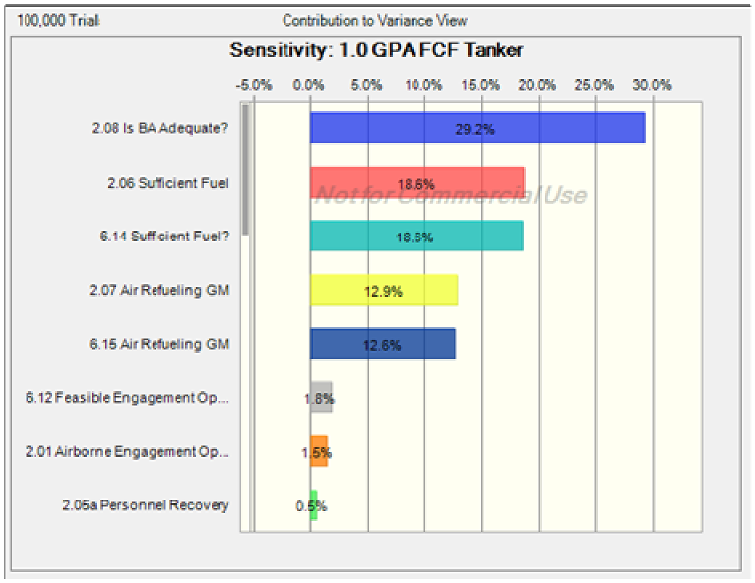

Figure 4.25. Tanker FCF Sensitivity Analysis Results

The modifications to the Air Refueling GM activities (nodes 2.07 and 6.15) are the reasons for the increase in sensitivity to the “Sufficient Fuel?” decision nodes. As previously stated, no changes were made to the “Sufficient Fuel?” decision nodes between the SRF and Tanker FCF; therefore, the percentage of simulation runs executing the air refueling activities remained the same between the two force constructs. The nodal PDFs for the Air Refueling GM activities, however, were modified to reflect the decreased air refueling capability due to the lack of a new tanker replacement for the aging current systems. The PDF values were reduced from a range of 0.99 to 1.0 for the SRF to 0.85 to 0.95 for the Tanker FCF.

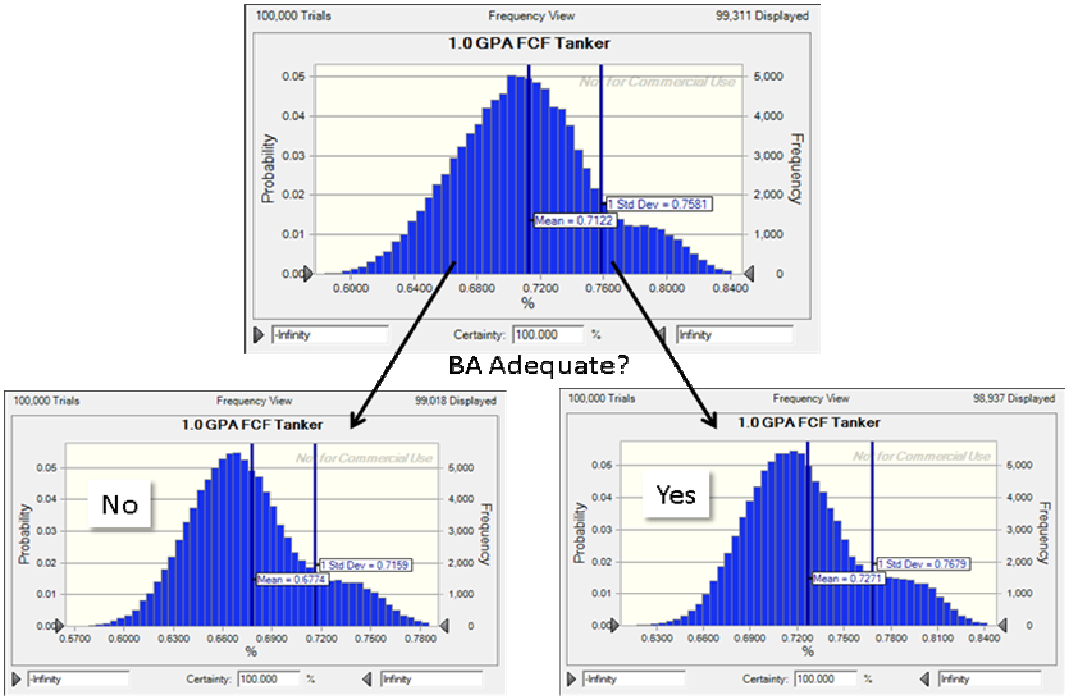

Figure 4.26. Effects of Adequate BA on GPA Tanker FCF *P(s)*

Once again, in order to isolate the effects of adequate BA prior to the F2T2EA process, additional Monte Carlo simulations were accomplished using values of zero and one for the *P(s)* of the "Is BA Adequate" decision node (see Figure 4.26). The distributions for the GPA Tanker FCF *P(s)*, however, still demonstrate bimodal characteristics that can be explained by the "Sufficient Fuel?" decision nodes. The *P(s)* values for the "Sufficient Fuel?" decision nodes are scenario dependent and did not change between the SRF and FCF constructs; however, the values determine the percentage of simulation runs that must execute the Air Refueling GM activities which were modified based upon the reduced air refueling capability. If sufficient fuel is available, the *P(s)* is unaffected by the reduced air refueling capabilities; however, if sufficient fuel is not available, the modifications to the Air Refueling GM PDFs have a significant impact on the overall *P(s)* distribution. The amount of outcomes within each mode is directly proportional to the *P(s)* values used for the "Sufficient Fuel?" decision nodes. Additional Monte Carlo simulations were accomplished to isolate the effects of the "Sufficient Fuel?" decision nodes. Figure 4.27 provides the results of the additional analysis and Table 4.12 summarizes the results of the Tanker FCF risk analysis.

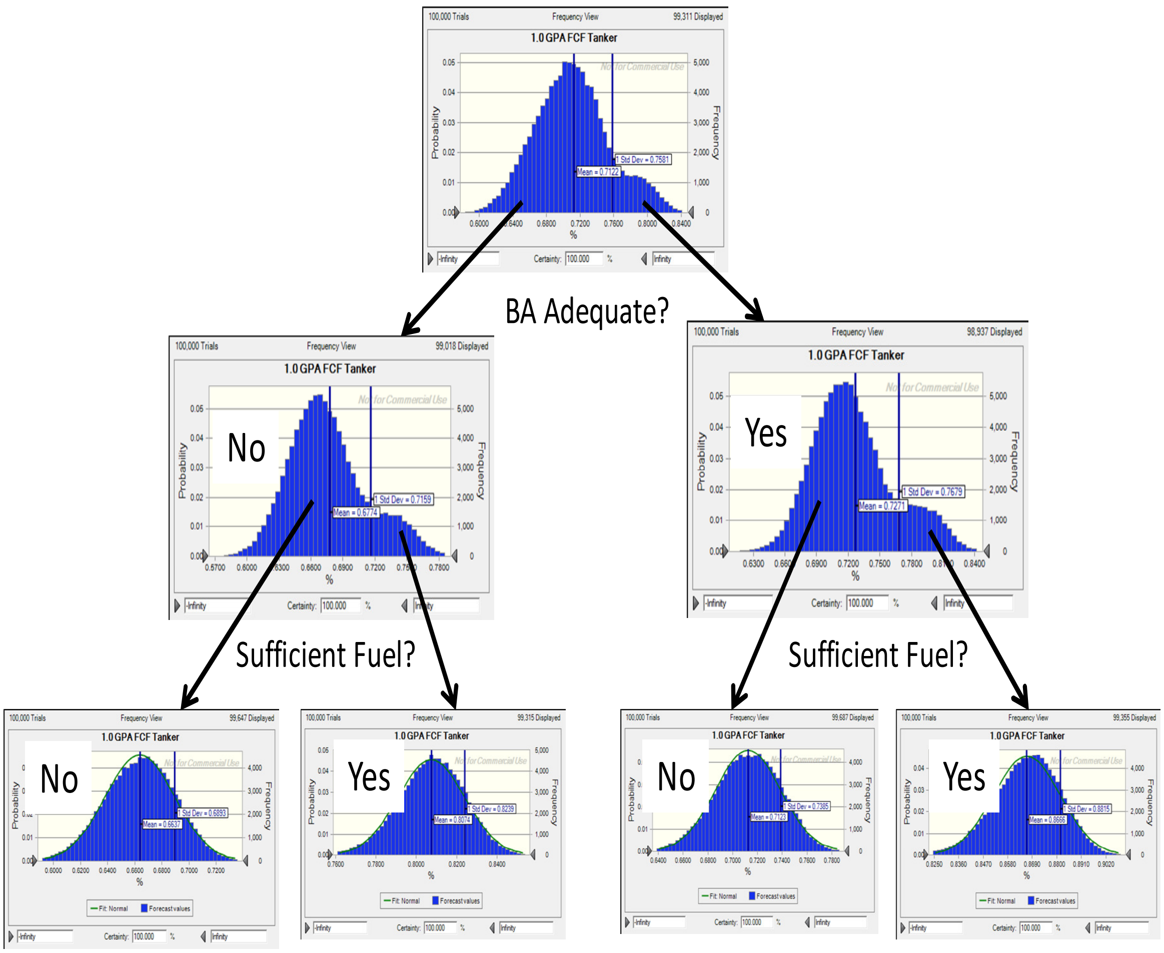

Figure 4.27. Effects of Sufficient Fuel on Tanker FCF *P(s)* Distribution

Tanker FCF $P(s)$ Distribution Results		**Sample Mean ($\bar{x}$)**	Sample Standard Deviation (s)	Best Curve Fit (Distribution Type/ K-S Value)
Tanker FCF Results		**0.71**	N/A	Gamma / .0192
Is BA Adequate? = Yes		**0.73**	± 0.0408	Beta / .0258
Is BA Adequate? = No		**0.68**	± 0.0385	Beta / .0219
BA Adequate = Yes	Sufficient Fuel = Yes	**0.87**	± 0.0149	Weibull / .0083
BA Adequate = Yes	Sufficient Fuel = No	**0.71**	± 0.0262	Beta / .0023
BA Adequate = No	Sufficient Fuel = Yes	**0.81**	± 0.0165	Weibull / .0082
BA Adequate = No	Sufficient Fuel = No	**0.66**	± 0.0256	Beta / .0016

Table 4.12. Tanker FCF Risk Analysis Results Summary

Long Range Bomber Analysis Results

Failing to develop a new long range bomber to replace legacy systems was the fifth fiscal constraint analyzed by this research project. Figure 4.5 highlights the nodes within the PSM directly impacted by the constraints associated with Long Range Bomber capabilities. Table 4.2 lists the modified nodal PDF values used for the Long Range Bomber risk analysis. Figure 4.28 displays the overall *P(s)* distribution results based upon a decreased long range strike capability due to the lack of a replacement for aging legacy systems.

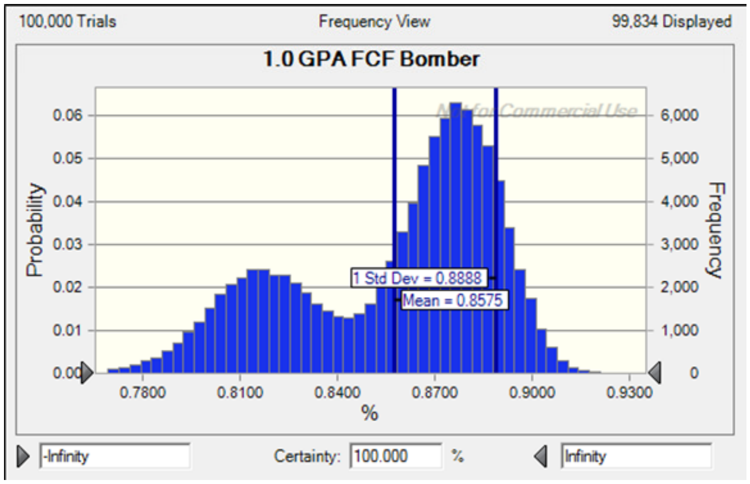

Figure 4.28. Long Range Bomber FCF *P(s)* Distribution

The sensitivity analysis of the Long Range Bomber FCF once again highlighted the "Is BA Adequate?" decision node listed as having the greatest impact on the overall *P(s)* distribution demonstrated by the bimodal distribution in Figure 4.28. The "Airborne Engagement Option Available?" decision node was modified for the Long Range Bomber FCF based upon decreased capabilities associated with long range strike asset availability. The reduction in the *P(s)* associated with this node increased the number of simulations required to execute the Generate the Mission ACS activity. The PDF values for this activity were also reduced due to a lack of sufficiency in long range strike assets. As a result, the sensitivity analysis for the Long Range Bomber FCF listed the "Airborne Engagement Option Available?" decision node as having a significant impact on the overall *P(s)* distribution.

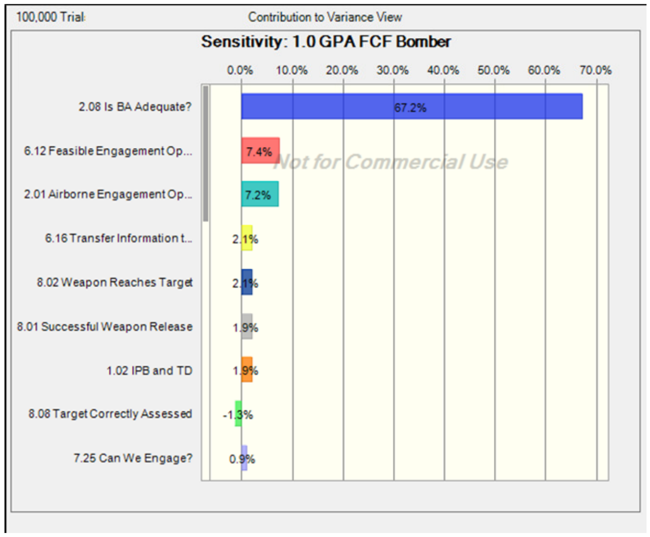

Figure 4.29. Long Range Bomber FCF Sensitivity Analysis Results

Again, the bimodal distribution results due to the "Is BA Adequate?" decision node required additional Monte Carlo simulations to isolate the effects of adequate BA. Figure 4.30 displays the effects of adequate BA on the Long Range Bomber FCF *P(s)* distribution. Table 4.13 summarizes the risk analysis results for the Long Range Bomber FCF.

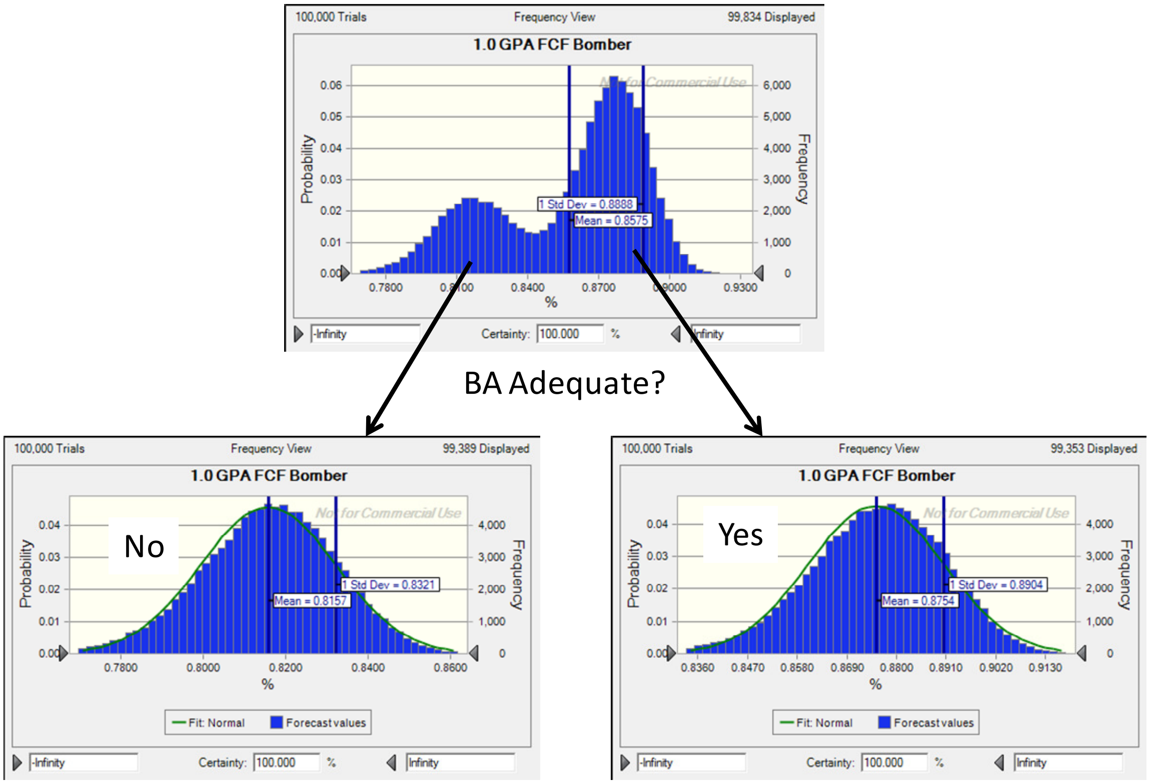

Figure 4.30. Effects of Adequate BA on GPA Long Range Bomber FCF *P(s)*

Bomber FCF *P(s)* Distribution Results	Sample Mean ($\bar{x}$)	Sample Standard Deviation (*s*)	Best Curve Fit (Distribution Type/ K-S Value)
Bomber FCF Results	0.86	N/A	Beta / .0604
Is BA Adequate? = Yes	0.88	± 0.0150	Normal / .0217
Is BA Adequate? = No	0.82	± 0.0164	Normal / .0158

Table 4.13. Long Range Bomber FCF Risk Analysis Results Summary

Comparing SRF and FCF Risk Analysis Results

The quantification of the increased risk associated with the FCF can be obtained by comparing the Monte Carlo simulation outputs for the two force constructs. Although the previous independent analysis of each force structure provided information for quantifying risk associated with the given force presentations, the results fail to capture the increased risk of the FCF without a direct comparison to the results of the SRF analysis.

Comparing the resulting SRF and FCF *P(s)* distributions provides a quantifiable and defendable measure of the increased risk associated with the FCF. Figure 4.31 provides a direct comparison of the GPA *P(s)* distributions for both the SRF and FCF.

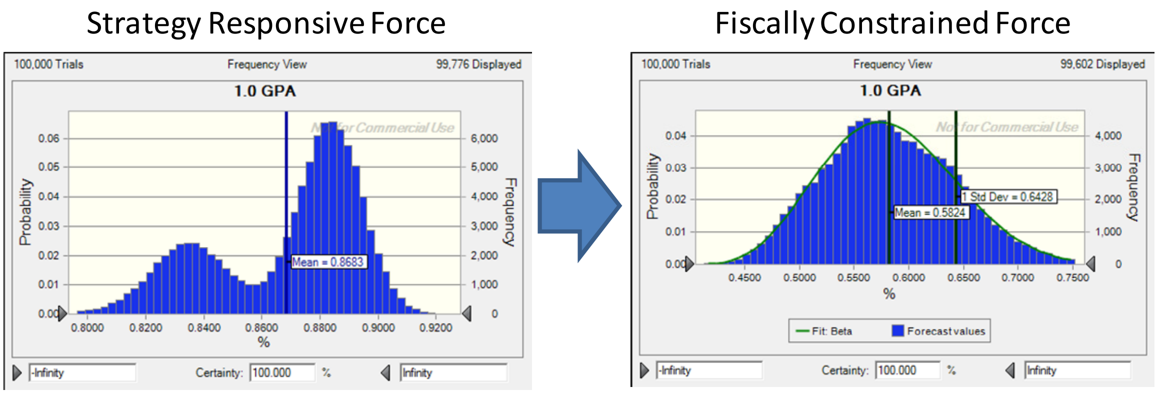

Figure 4.31. SRF and FCF *P(s)* Comparison for Risk Quantification

The bimodal distribution results for the SRF due to the "Is BA Adequate?" decision node does not allow for a direct comparison of the mean *P(s)* and standard deviation values between the two force constructs without further explanation. In order to quantify the increased risk using the mean and standard deviation values, the effects of adequate BA must be isolated. Figure 4.32 provides a comparison between the SRF and FCF with consideration for the adequate BA decision node.

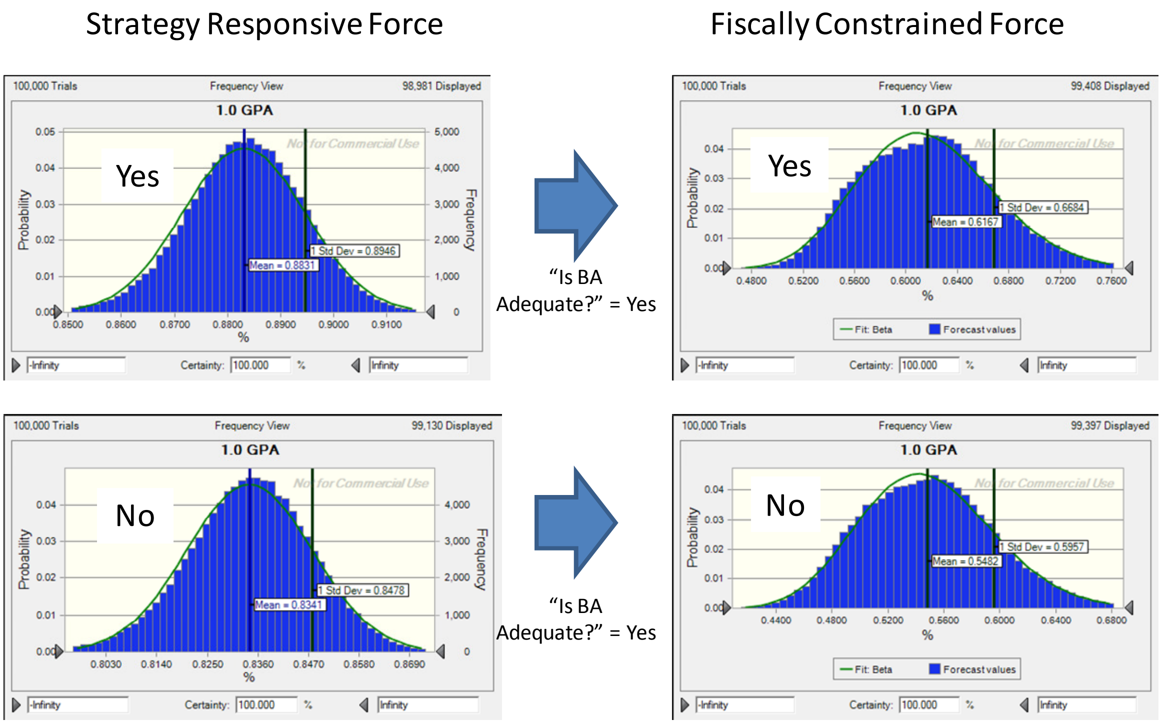

Figure 4.32. SRF and FCF Risk Analysis Comparison Considering Adequate BA Effects

Table 4.15 provides a summary comparison of the risk analysis results between the SRF and FCF constructs. The values listed in Table 4.14 can be used to quantify the increased risk associated with the FCF compared to the SRF. Directly comparing the mean *P(s)* values for the overall results can provide insight into the decrease in the expected level of success for the FCF; however, the mean *P(s)* value for the SRF can be misleading due to the bimodal distribution characteristics. In fact, the mean *P(s)* value for the SRF rarely occurs in the distribution. The actual results are dependent upon the sequencing path determined by the “Is BA Adequate?” decision node. In this case, if BA is adequate, the mean *P(s)* is expected be 0.88; whereas, if BA is inadequate, the mean *P(s)* is expected to be 0.83. Therefore, a direct comparison of the mean *P(s)* and standard deviation values with consideration to the adequacy of BA prior to the F2T2EA process is a much more accurate measure of the increased risk associated with the FCF construct.

P(s) Distribution Results	Sample Mean ($\bar{x}$)		Sample Standard Deviation (*s*)		Best Curve Fit (Distribution Type/ K-S Value)	
	SRF	FCF	SRF	FCF	SRF	FCF
Overall Results	0.87	0.58	N/A	± 0.0604	Beta / .074	Beta / .0065
Is BA Adequate? = Yes	0.88	0.62	± 0.0115	± 0.0497	Normal / .02	Beta / .0115
Is BA Adequate? = No	0.83	0.55	± 0.0137	± 0.0475	Normal / .06	Beta / .0091

Table 4.14. SRF and FCF Risk Analysis Comparison

Given that BA is adequate prior to the F2T2EA process, the constraints associated with the FCF construct can be expected to reduce the average probability of success for GPA operations approximately 26 percentage points while quadrupling the standard deviation from that of the SRF. The change in the range of expected *P(s)* values due to the increased size of standard deviation value for the FCF is important when considering a worst case risk aversion scenario in which the *P(s)* of GPA operations could decrease up to 38 percent given adequate BA. If BA is not adequate prior to the F2T2EA process requiring the Find, Fix, and Track segments of the sequencing logic to be executed, the average FCF probability of success is expected to be 28 percentage points less than that of the SRF, once again increasing the standard deviation about four times that of the SRF.

Using Risk Analysis and Sensitivity Results During Capability Tradeoff Decisions

The sensitivity analysis of the FCF construct along with the independent risk analyses of the individual constraints provide critical information for improving the capability tradeoff decision process. Figure 4.13 rank orders the impact of each of the fiscal constraints represented in the FCF on the overall GPA *P(s)* distribution. Based upon the sensitivity analysis, the C2ISR constraints have the greatest impact followed by the F-22 and F-35 sufficiency limitations. The risk analyses of each constraint independently support the sensitivity results. Tables 4.15 and 4.16 compare the effects of each constraint independently to the SRF risk analysis results. For the same reasons previously discussed, the effects of the "Is BA Adequate?" decision node had to be considered for a direct comparison of the mean *P(s)* and standard deviation values.

P(s) Distribution Results	Sample Mean ($\bar{x}$)					
	SRF	FCF				
		C2ISR	F-22	F-35	Tanker	Bomber
Overall Results	0.87	0.76	0.85	0.85	0.71	0.86
Is BA Adequate? = Yes	0.88	0.79	0.87	0.87	0.73	0.88
Is BA Adequate? = No	0.83	0.72	0.81	0.81	0.68	0.82

Table 4.15. SRF and Individual Constraint Mean *P(s)* Comparison

P(s) Distribution Results	Sample Standard Deviation (*s*)					
	SRF	FCF				
		C2ISR	F-22	F-35	Tanker	Bomber
Overall Results	N/A	N/A	N/A	N/A	N/A	N/A
Is BA Adequate? = Yes	± 0.0115	± 0.0175	± 0.0204	± 0.0203	± 0.0408	± 0.0150
Is BA Adequate? = No	± 0.0137	± 0.0216	± 0.0209	± 0.0208	± 0.0385	± 0.0164

Table 4.16. SRF and Individual Constraint Standard Deviation Comparison

Based upon the values contained within Tables 4.15 and 4.16, the air refueling constraints have the greatest individual impact on the overall GPA *P(s)* distribution followed closely by the C2ISR limitations. Again, the results of the individual constraint analyses reconfirm the combined FCF sensitivity analysis results categorized by capability (see Figure 4.13). This information is critical when determining possible capability tradeoffs for optimizing the FCF construct to meet fiscal limitations. For example, the information presented for the FCF modeled within this research project could be used to justify slipping the new Long Range Bomber development in order to increase capability or sufficiency levels within the other four constraint areas addressed. According to the analysis presented, the reduction in the Long Range Bomber capability reduces the expected mean GPA *P(s)* by only one to two percentage points while the Tanker and C2ISR constraints have a much greater impact in the range of 10 to 15 percentage points.

Summary of Risk Analysis Results

This chapter detailed the risk analysis process applied to a hypothetical SRF and FCF as defined by the authors in order to demonstrate the usefulness of this methodology to future force planning and budgeting considerations. To this end, the risk methodology provided quantifiable risk measures for both the SRF and FCF and compared the results in order to isolate the increased risk associated with fiscal constraints. In addition to measuring the change in risk between the SRF and FCF, the analysis process highlighted critical decision nodes and capabilities within each construct that impacted the overall GPA *P(s)* the greatest. The identified critical capabilities provide essential information to planners when conducting capability tradeoff analysis. As a result, the risk methodology presented by this research project provides the Air Force with a tool to perform trade studies of operational risk to future force structure capable of meeting the needs of the national defense strategy under fiscally constrained guidance.

V. Conclusion

Attempting to build a future force construct that meets national security objectives under strict fiscal constraints while minimizing operational risk presents many challenges. The tradeoff decisions between desired capabilities can have lasting and significant impacts on the effectiveness of national defense and security strategies. Guided by senior leadership insight and direction, key decisions are routinely made during the planning, budgeting and acquisitions processes to ensure the military force construct maintains and sustains its capability to achieve national defense objectives outlined in national defense strategy documents. Comprehensive planning and risk analysis is necessary for decision makers to be knowledgeable about critical capabilities and their interdependencies and relationships to make informed decisions. A quantifiable and repeatable methodology which provides a thorough understanding of critical capabilities along with their associated risk facilitates better decisions concerning the development of a force construct while minimizing risk associated with fiscal constraints.

This research project demonstrated the power and insight of a detailed, integrated GPA architecture. A well-designed architecture can provide decision makers and planners a method for identifying the essential activities, relationships, and information exchanges required for the successful development of a concept of operations or system. More importantly, architecture provides a format that is repeatable, traceable, and defendable that can be used from the highest level concepts down to the physical details.

This research project also presented a structured methodology that quantifies risk associated with the development of a force construct to meet national defense objectives. In order to accomplish the risk analysis, the decomposition of the operational activities, relationships, and information exchanges was performed to provide a solid framework for understanding the necessary capabilities outlined in the GPA CONOPS. The identification of the logic required to meet objectives highlighted the critical activities and key decision points. Applying probability of success PDFs to each node within the PSM representing the capabilities of different force constructs and running Monte Carlo simulations allowed for the quantification of risk associated with each force construct as well as the identification of specific risk drivers. Comparing the results of the risk analysis for different force constructs highlights the increased or decreased risk associated with varying capabilities.

Architecture Application

Architecture development and integration is a continual process. It is vital that the GPA architecture presented by this research project be continually built upon and modified by integrating its development into the entire AF enterprise architecture framework. Continuous improvements to the integrated architecture will ensure a thorough understanding of the capabilities associated with GPA and its critical activities. In order to fully realize the benefits of the GPA architecture, changes to the current guidance and usage of architectural products may be required. Currently, the force construct process does not involve any reliance on the GPA architecture, but instead relies on the intuition and expertise of the planners to incorporate current strategy and senior leadership guidance to develop an optimized future force construct balancing capability and cost.

Involvement of architecture will provide the necessary traceability of strategic concepts down to the technical and physical levels associated with future force constructs and budgeting. This traceability will provide insight to others and a medium to highlight changes to required activities and their relationships as conceptual changes occur. Figure 5.1 illustrates the force construct development areas that would benefit from using the researchers' suggested architectural products and risk analysis process.

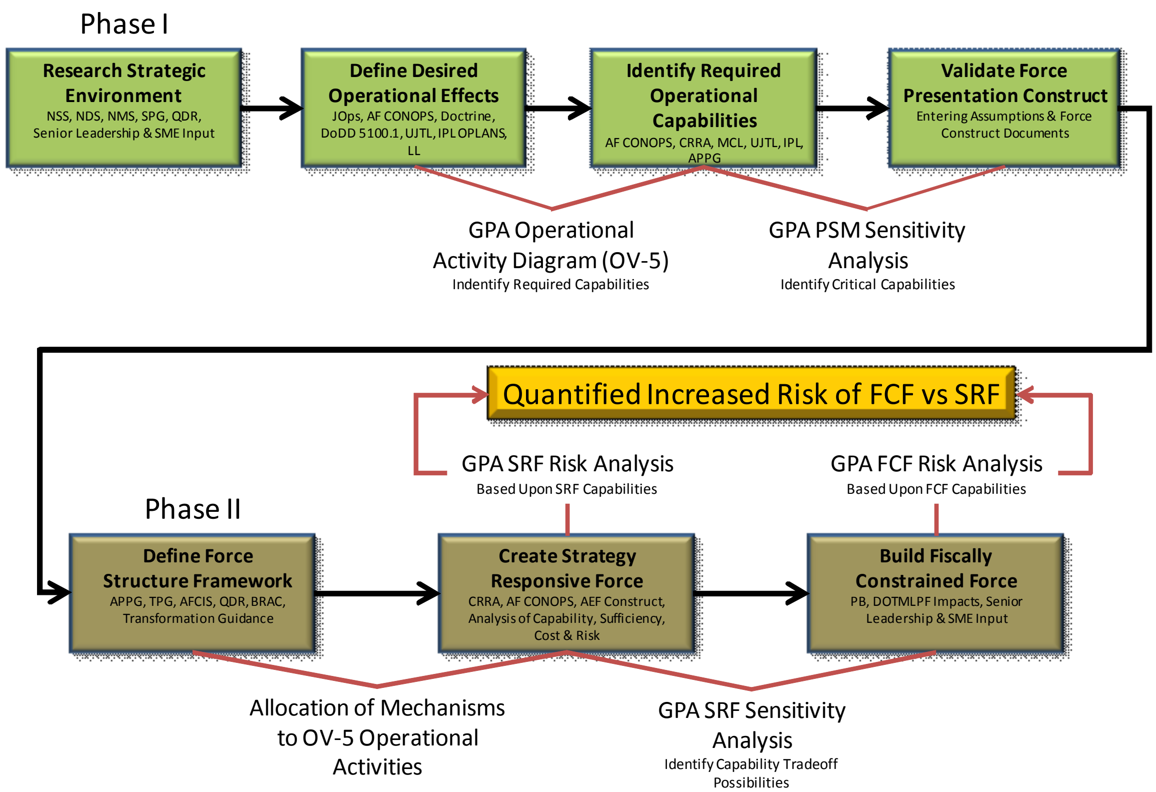

Figure 5.1. Suggested Force Structure Development Process

The application of the OV-5 architecture into the force construct process will assist in identifying required capabilities when planners transition from defining the desired operational effects to the identification of the required operational capabilities. The OV-5 can be used as a quick reference for understanding the relationships between GPA capabilities allowing for a more complete comprehension of the overall GPA concept. Using this knowledge, planners can then incorporate the mechanisms that perform the operational activities within the OV-5 diagram to ensure consistency and sufficiency when creating the force construct.

The application of the PSM for risk analysis will provide planners a quantitative means of capturing risk associated with various force constructs. The PSM sensitivity analysis can first be incorporated into the force structure development process once the planners have identified the required operational capabilities and are in the process of validating the force presentation construct. The sensitivity analysis can be used to identify the activities most in need of examination for Phase II of the development process.

Once the Strategy Responsive Force (SRF) is created, the risk analysis methodology can be used to quantify risk based upon the constraints associated with the SRF capability levels. The constraints are represented by developing probability density functions (PDFs) reflecting the force construct capability levels for each node within the PSM. A subsequent sensitivity analysis of the SRF will identify the critical capabilities that have the greatest impact on variation to the GPA probability of success. These critical capabilities can then be used as a foundation for capability tradeoff possibilities when developing the Fiscally Constrained Force (FCF). The risk analysis methodology can then be applied to the FCF to quantify the risk associated with the new fiscal constraints. Comparing the risk analysis results of the SRF to the FCF will allow a quantification of the increased risk associated with fiscal constraints.

Risk Analysis to Develop Force Structure

Mapping systems to functions is key to understanding how the sensitivity analysis can be used in developing an adequate force structure to meet strategic objectives. For example, this sensitivity analysis highlighted the “Is BA Adequate?” decision node as the most critical node in the overall GPA *P(s)* distribution for the SRF. Specific systems that perform the operational tasks associated with developing BA defined within the OV-5 activity diagram can be mapped to the nodes within the PSM to demonstrate how increases in capability or sufficiency based upon system allocation affect the overall GPA *P(s)*. Varying the value of the “Is BA Adequate?” decision node *P(s)* produces a graphical depiction of how the mean value for GPA success is a function of the “Is BA Adequate?” decision node (see Figure 5.2 below).

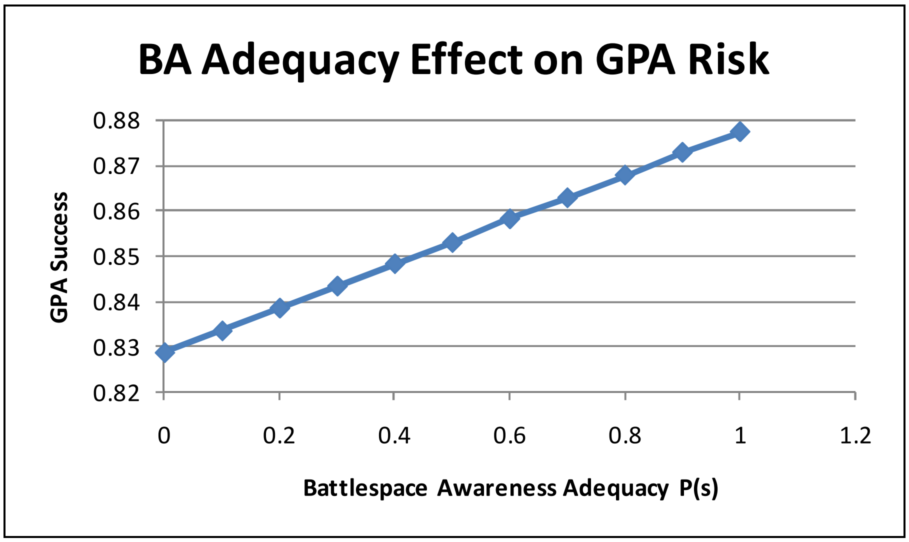

Figure 5.2. GPA Success versus “Is BA Adequate?” Decision Node *P(s)*

The risk analysis process developed for this research project addresses the risks associated with capability levels. Allocating systems to capabilities allows direct mapping of systems to overall GPA *P(s)* via the relationships identified in this research project. Once a system to capability relationship is determined, that relationship can be used to provide increased fidelity in the nodal *P(s)* PDFs within the GPA PSM as well as map system sufficiency or capability directly to GPA *P(s)*. The majority of the system-to-capability mapping is left for subsequent efforts.

The application of the risk analysis methodology presented by this research project to developing force constructs is an iterative process. First, performing a Monte Carlo simulation using the GPA PSM with objective nodal *P(s)* PDFs to achieve an overall GPA *P(s)* distribution enables the identification of critical nodes and capabilities within the GPA process via sensitivity analysis. The identification of the critical nodes and capabilities provides a starting point for developing a force construct to achieve strategic objectives by highlighting areas for emphasis that might provide the greatest return per dollar investment. Once a Strategy Responsive Force construct is developed, the nodal *P(s)* PDFs within the PSM can be modified to reflect the actual capabilities of the SRF identified in campaign model simulation results. Performing a subsequent Monte Carlo simulation and sensitivity analysis of the GPA PSM provides a GPA *P(s)* distribution that can be used to quantify the risk associated with the SRF.

The critical capabilities and nodes identified by the sensitivity analysis can also be used when making tradeoff decisions based upon fiscal constraints. As previously stated, the most sensitive capabilities and nodes provide the greatest “bang for the buck” when conducting tradeoff analysis. Once the FCF is determined, the nodal *P(s)* PDFs within the GPA PSM can be modified to reflect the actual capabilities of the FCF. A subsequent Monte Carlo simulation and risk analysis will provide a GPA *P(s)* distribution that can be used to quantify the risk associated with the FCF. Comparing the resulting SRF and FCF *P(s)* distributions enables a quantifiable and defendable measure for presenting the increased risk associated with the FCF versus the SRF.

Systems Engineering Lessons Learned

The military has made a significant improvement in architectural development and use within the past several years; however, work still remains to ensure a truly comprehensive and integrated architecture. The installation of the DoD Architecture Repository System (DARS) is an internet-access location that provides a place to store and view architectural products. Unfortunately, the DARS webpage is not user friendly and comes with several restrictions as to what access and privileges a user may have. The limited accessibility and lack of intuitive mapping prevents users from gaining knowledge and contributing to existing products. In addition, several architectural products are stored locally or placed on a variety of different portals, such Air Force Knowledge Now. This lack of centralization places significant additional barriers to the knowledge and access of existing architectural products.

Another contributing factor to the lack of architectural use and development is the limited background and training in systems engineering, operations research, and risk analysis possessed by decision makers. Key decision makers and planners have little to no experience or training with architectural products or risk analysis. Lack of understanding and familiarity may have serious consequences when decisions are made without full comprehension of all contributing factors. Requiring familiarization training on key system engineering and risk analysis tools and methodology would greatly benefit those placed in positions to make key decisions about the future of Air Force capabilities and force posture. Assignment of officers who demonstrate these skills to key staff positions should be supported by Air Force Personnel Center.

Future Recommendations

This research project has provided a constructive and beneficial methodology for AF planners to use during the force construct development. Time and manning limitations prevented this research to continue on into further developments. Several future endeavors can perhaps make this research even more beneficial. Incorporating the optimization function available with Crystal Ball software would be extremely informative and helpful in determining the optimal combinations of design choices. This optimization function would be very beneficial in determining the best "bang for the buck" when constraints are applied to several capabilities. Another recommendation for addition value to this research project would be to incorporate mechanisms to the GPA Operational Activity Model (OV-5). Detailed mapping of mechanisms would allow further insight to system capability and sufficiency. Lastly, continued analysis and refinement of the GPA nodal and decision point probability density functions (PDF) will be required to ensure a usable risk assessment product. The refinement of PDF values can be advanced through the results of campaign analysis, subject matter expert judgment, and other relevant assessments. Continued accuracy and support of the PDFs will only improve the power of the risk analysis methodology to become more insightful and reliable.

Appendix A. GPA Architecture Diagrams and Descriptions

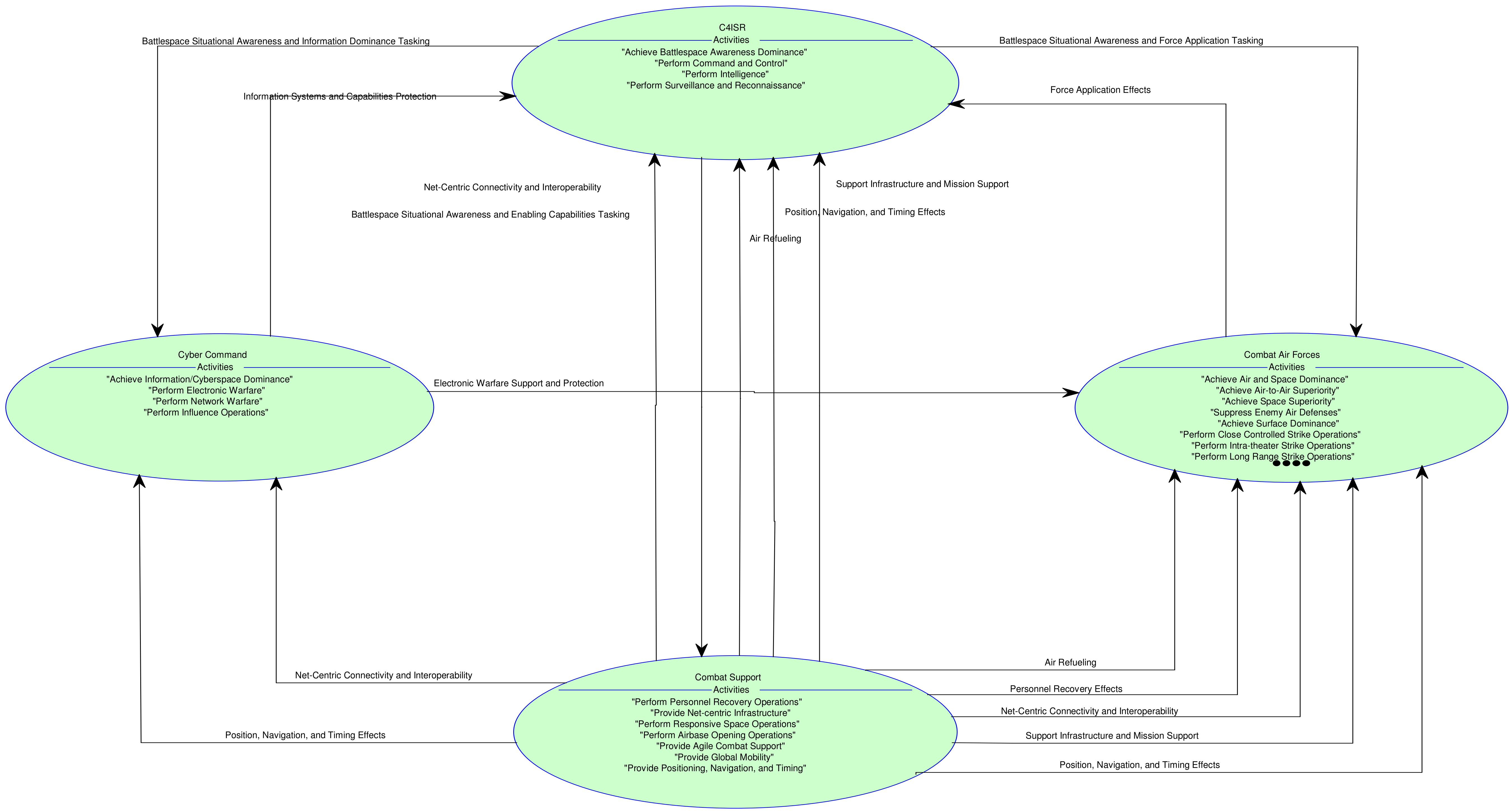

Figure A.1. GPA OV-2 Node Connectivity Diagram

Operational Node Connectivity Description (OV-2) Development

The Operational Node Connectivity Description (see Figure A.1) graphically depicts the operational nodes that play a key role in the architecture with needlines that represent the necessary interactions to conduct the corresponding operational activities of the OV-5. The OV-2 is intended to track the information exchange requirements from specific operational nodes to others, but does not depict the physical connectivity between the nodes. An operational node is an element within the architecture that produces, consumes, or processes information. Needlines document the requirement to exchange information between the nodes, but does not indicate how the information transfer is implemented (12, 4-10). Four operational nodes were identified within GPA based upon functional grouping: C4ISR, Cyber Command, Combat Air Forces, and Combat Support.

The C4ISR node consists of the functional grouping that provides the operational level command and control for GPA along with the required battlespace situational awareness to conduct operations and make decisions. The role of C4ISR is to provide supreme knowledge and understanding of the operational area's environment, factors, and conditions that enables timely, relevant, comprehensive, and accurate assessments in order to successfully apply combat power, protect the force, and/or complete the mission. The supreme knowledge and understanding of the operational area is represented by the Battlespace Situational Awareness needline from C4ISR to the other three operational nodes of Cyber Command, Combat Air Forces, and Combat Support. The command and control activities within the C4ISR node also provide the requisite tasking and guidance to the other three nodes.

The Cyber Command operational node represents the functional groups associated with maintaining supremacy in all areas of the global information domain allowing friendly forces the ability to attack adversaries' information and decision making while simultaneously securing and defending friendly information and decision making. This capability is represented by the Information Systems and Capabilities Protection and Electronic Warfare Support and Protection needlines from Cyber Command to the C4ISR and Combat Air Forces nodes respectively. The Information Systems and Capabilities Protection needline provides the required protection of friendly information against adversary efforts to destroy, disrupt, corrupt, or usurp it. It includes the effects of operational security and network defense efforts. The Electronic Warfare Support and Protection needline provides the necessary means to protect personnel, facilities, and equipment from the effects of enemy electronic warfare efforts to degrade, neutralize, or destroy friendly combat capability and the required information for other electronic warfare decisions such as threat avoidance, targeting and homing.

The Combat Air Forces operational node combines the operational activities associated with Air, Space, and Surface Dominance functions. Air and Space Dominance functions include those activities associated with gaining and maintaining supremacy in the air and space battle of one force over another. This supremacy permits the conduct of operations by the former and its related land, sea, air and space forces at a given time and place without interference by the opposing force. Surface Dominance functions include those activities associated with gaining supremacy in the surface battle which permits freedom of operations at a given time and place without interference by the opposing force. The key information output from the Combat Air Forces node are the effects associated with the application of force. This is represented by the needline Force Application Effects from the Combat Air Forces node to the C4ISR node. This information is used by the C4ISR node as input to the decision cycle and serves to update and refine the battlespace situational awareness picture. This results in a cyclical exchange of information between the C4ISR node and the Combat Air Forces node that continually builds upon itself until the overall strategic, operational, or tactical objectives are attained. For example, initial Force Application taskings from the Command and Control element within the C4ISR node result in effects that are subsequently used to develop follow-on taskings within the decision and targeting cycle.

The Combat Support operational node consists of those elements and activities that provide the capabilities that support but do not directly achieve the desired effects of Air and Space, Surface, Battlespace Awareness, and Information/Cyberspace dominance. The Combat Support node provides the required Net-Centric Connectivity and Interoperability, Support Infrastructure and Mission Support, and Position, Navigation, and Timing needlines for all three other operational nodes. In addition, the Combat Support node specifically provides the necessary Personnel Recovery Effects needline to the Combat Air Forces node. The Combat Support node provides the foundation from which all other nodes are able to operate.

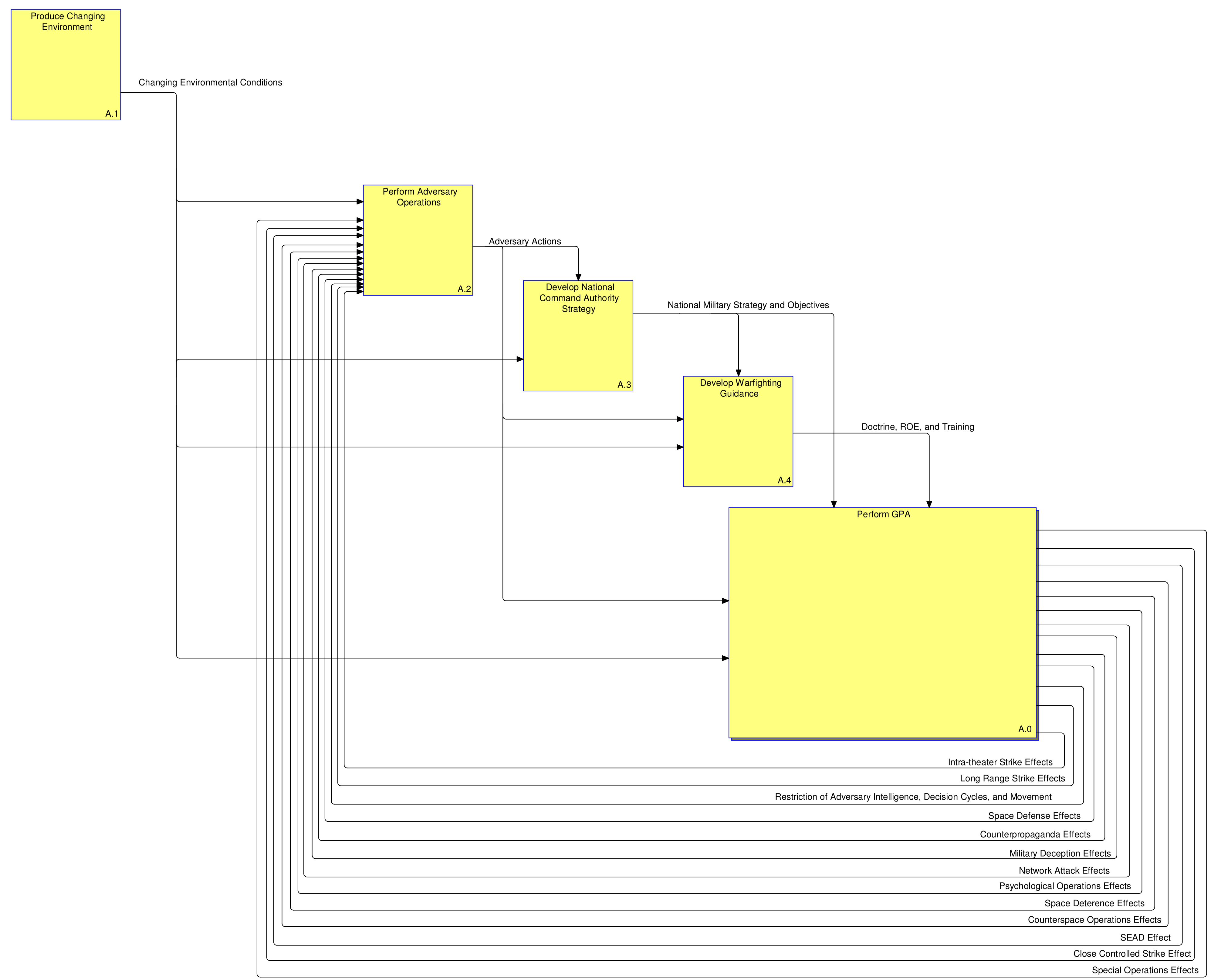

Figure A.2. GPA Context Diagram

Operational Activity Model (OV-5) Development

The Operational Activity Model describes the operations that are normally conducted in the course of achieving a mission or business capability. It describes capabilities, operational activities, input and output (I/O) flows between activities, and I/O flow to/from activities that are outside the scope of the architecture. The OV-5 is a key product for describing capabilities and relating capabilities to mission accomplishment. A capability can be defined by one or more sequences of activities, referred to as operational threads or scenarios. A capability may be further described in terms of the attributes required to accomplish the set of activities (such as the sequence and timing of operational activities or materiel that enable the capability) in order to achieve a given mission objective (12, 4-40). An OV-5 consists of a hierarchy of activities related by Inputs, Controls, Outputs, and Mechanisms (ICOMs). The GPA OV-5 Activity Diagram only utilizes the inputs, controls, and outputs. The integrated dictionary, AV-2 in Appendix E, supports the OV-5 by describing each ICOM and Activity. The mechanisms that enable each of these activities can be derived from the architecture in later System View (SV) products.

Perform Global Persistent Attack Functions Context Diagram

GPA is the application of effects-based campaign planning to achieve National Military Strategy (NMS) prescribed Full Spectrum Dominance. NMS and the associated objectives control the application and execution of GPA. In order to develop the activity diagram pertaining to the internal functions of GPA, the relationship between GPA and the external systems that influence it had to be determined (see Figure A.2). Four external systems were determined to interact with or influence the activities of GPA serving to provide inputs and controls that drive its internal activities. First, the Changing Environmental Effects serves as a critical input to GPA operations and represents the conditional state of the environment within the operational areas and areas of interest. This includes the air, land, sea, and space environments as well as the weather, terrain, electromagnetic and information environments associated with each. The environmental condition defines the context within which all operations are conducted and is a critical input to the decision cycle. Adversary Actions trigger the Develop National Command Authority Strategy activities that result in the National Military Strategy and Objectives. Adversary Actions also serve as direct inputs to the Develop Warfighting Guidance activities as well as those activities performed within GPA. As previously stated, GPA is the application of effects-based campaign planning to achieve NMS objectives.

The Develop Warfighting Guidance activity encompasses the activities of all government agencies that belong to the Department of Defense to include the major Services of the Army, Navy, Air Force, Marines, and Coast Guard. Activities within the Develop Warfighting Guidance include those responsible for the development, dissemination, and oversight of Doctrine, Organization, Training, Leadership, Personnel, and Facilities (DOTLPF). The DoD construct is driven by the NMS and associated objectives. As it pertains to GPA, the Develop Warfighting Guidance operational activity provides guidance through Doctrine, Rules of Engagement (ROE), and training.

The outputs of GPA are those effects associated with the GPA activities of applying persistent precision strike and information operations to influence, manipulate, or dismantle an opponent's ability to act, both physically and psychologically. The GPA Contextual Diagram graphically depicts those effects as inputs to the Perform Adversary Operations activity which influence future Adversary Actions. This demonstrates the cyclic nature of the operating context.

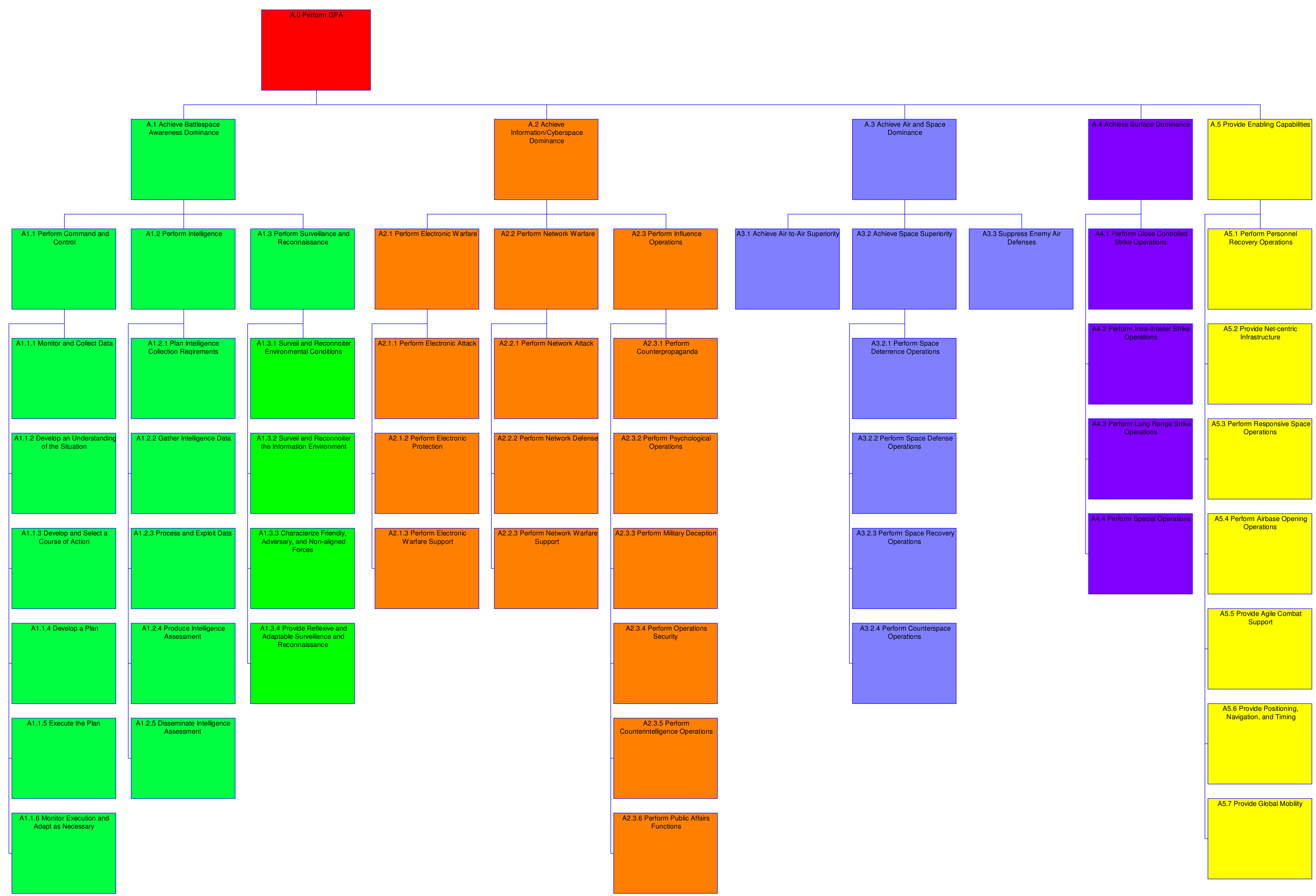

Figure A.3. GPA Activity Hierarchy

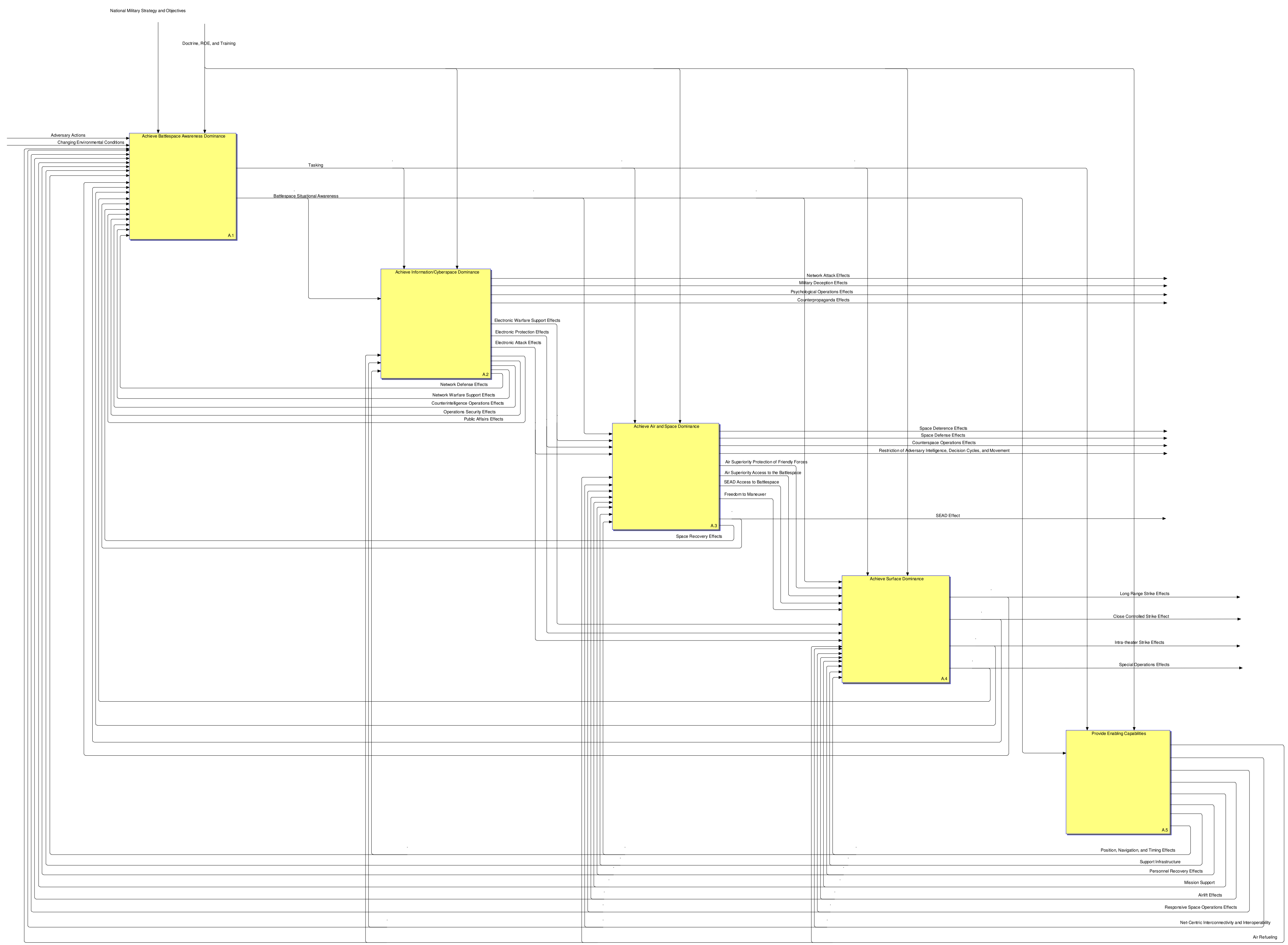

Figure A.4. GPA A0 Activity Diagram

Perform Global Persistent Attack Hierarchy and (A0) Diagrams

The development of the Perform GPA Activity Hierarchy and Diagram (see Figures A.3 and A.4) is based primarily upon the Air Force Global Persistent Attack CONOPS. The activity names and descriptions for the A0 diagram were derived from the GPA CONOPS defined operational effects of Air and Space Dominance, Surface Dominance, Battlespace Awareness Dominance, and Information/Cyberspace Dominance and include the Enabling Capabilities that support but do not directly contribute to those effects. The critical operational capabilities defined by the GPA CONOPS are those that directly contribute to the operational effects. The decomposition of each of the A0 operational activities encompasses those defined critical operational capabilities based upon the preponderance of support they provide to a capability area even though they may simultaneously support other capability areas.

The GPA CONOPS was developed to describe the Air Force vision for the joint employment of Air Force air and space capabilities, coupled with information/cyberspace dominance, as instruments of national power in support of NMS. The Joint Operations Concepts (JOC) serve a roughly similar role for the Joint Staff and joint requirements process as the AF CONOPS do for the Air Force – the translation of strategy into operational capability requirements (3, 1). As a result, required activities that were not directly addressed or defined by Air Force CONOPS or Air Force publications were taken from applicable joint concepts and joint publications during functional decomposition. This serves to reinforce the link between national strategy, Joint Operations, and Air Force capabilities.

The interrelationship between each of the operational activities is crucial to determining the influence each activity has upon the others. The Tasking and Battlespace Situational

Awareness outputs from Achieve Battlespace Awareness Dominance are critical to the successful accomplishment of all other operational activities. Tasking provides guidance for directing forces in the execution of effects-based operations in support of the Command and Control determined course of action. Battlespace Situational Awareness provides the information necessary for understanding the environment, factors, and conditions critical to the successful application of combat power, force protection, or completion of the mission.

The outputs of Information/Cyberspace Dominance provide the effects necessary for allowing friendly forces the ability to attack adversaries' information and decision making while simultaneously securing and defending friendly information and decision making. The effects of Operational Security, Network Defense and Network Warfare Support are inputs into Achieve Battlespace Awareness Dominance and serve to protect the information networks vital to the operations and activities within BA. Network Warfare Support information is also required by command and control for immediate decisions involving network warfare operations and can be used to produce intelligence or provide targeting for electronic or destructive attack. The effects of Counterintelligence and Public Affairs also provide input into the decision cycle within the BA functional area. The outputs of Electronic Warfare (Electronic Warfare Support Effects, Electronic Attack Effects, and Electronic Protection Effects) stemming from within the Information/Cyberspace Dominance functional activities provide vital input to the Force Application functional activities of Air and Space and Surface Dominance. All three help provide protection for friendly forces by influencing the electromagnetic spectrum to the advantage of friendly forces. Network Attack Effects, Psychological Operations Effects, Military Deception Effects, and Counterpropaganda Effects directly impact the external Perform Adversary Operations activity to influence future adversary actions.

The purpose of the Achieve Air and Space Dominance activity is to contribute to full spectrum dominance by providing supremacy in the air and space battle over the adversary. This supremacy permits the conduct of operations by friendly forces at a given time and place without interference by the opposing force. The outputs from this activity directly support the Surface Dominance activities by providing the required protection of friendly forces that permits battlespace access and freedom of maneuver. Other functions within Air and Space Dominance directly impact the Adversary through Space Deterrence and Defense Effects, Counterspace Operations Effects, and Restriction of Adversary Intelligence, Decision Cycles, and Movement. The effects of SEAD directly impact the opposing force but also feed back into the BA functions to be considered within the Command and Control decision cycle. Space Recovery Effects are integral to the Intelligence, Surveillance, and Reconnaissance capabilities to collect the necessary information needed for Battlespace Awareness Dominance.

The purpose of the Achieve Surface Dominance activity is to contribute to full spectrum dominance by providing supremacy in the surface battle which permits the conduct of operations by friendly forces at a given time and place without adversary interference. Key to achieving the required supremacy are the effects generated by the critical operational capabilities within Surface Dominance of Long Range Strike, Close Controlled Strike, Intra-theater Strike, and Special Operations. These effects directly influence adversary actions and also feed into the Battlespace Awareness functional activity as input into the Command and Control decision cycle.

As previously stated in the OV-2 discussion, the Provide Enabling Capabilities activity provides the foundation for all other operational activities. The key enabling capabilities outputs are those associated with the Position, Navigation, and Timing Effects, Support Infrastructure, Mission Support, Airlift and Air Refueling Effects, Responsive Space Operations Effects, and Net-centric Interconnectivity and Interoperability. All of these outputs provide critical support input into the other functional activities defined at the Perform GPA A0 decomposition level. Personnel Recovery Effects are critical to the Force Application functions in sustaining the morale, cohesion, and operational performance of friendly forces as well as key inputs to the Command and Control decision cycle.

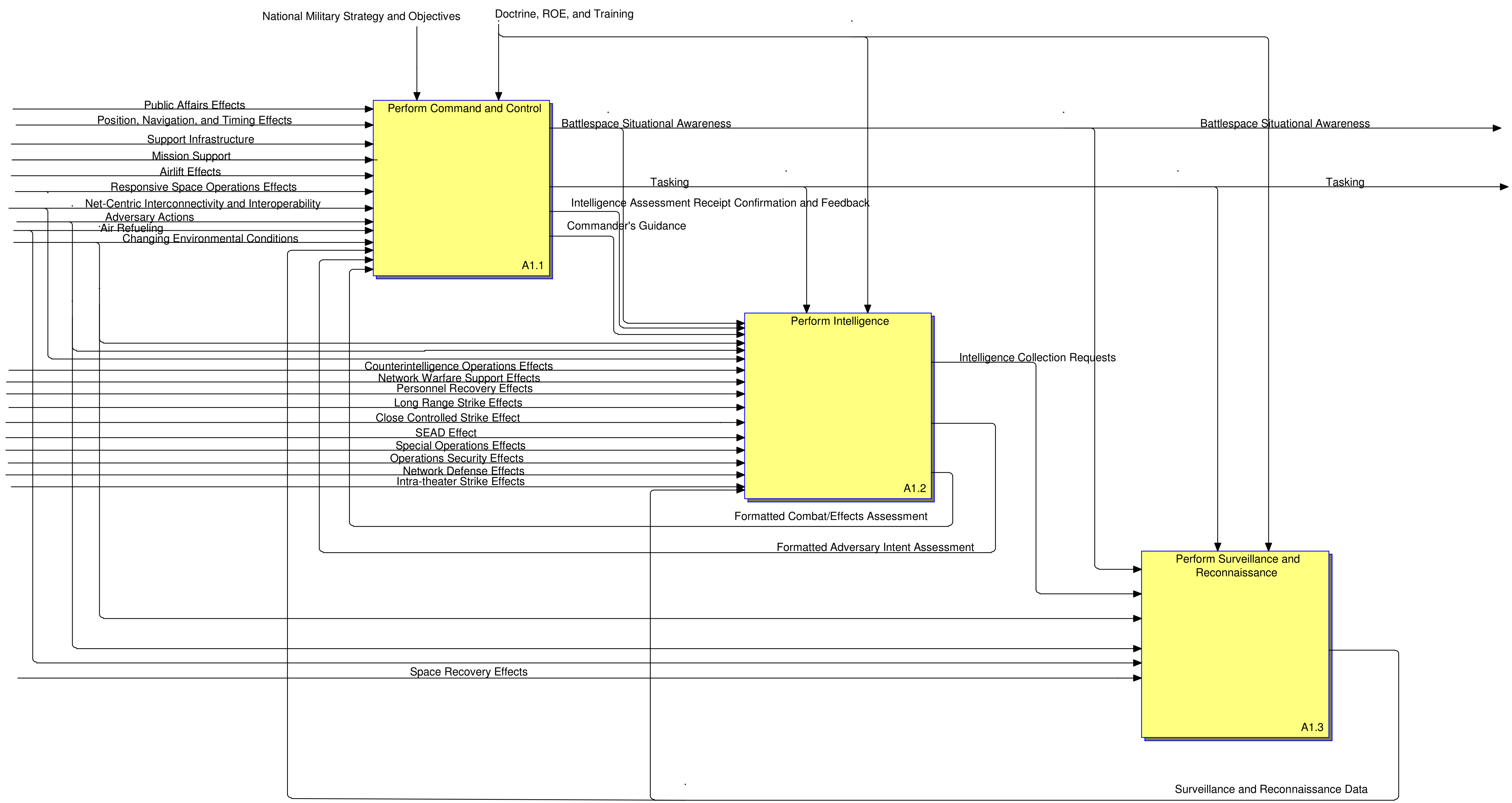

Figure A.5. Achieve Battlespace Awareness Dominance (A1) Activity Diagram

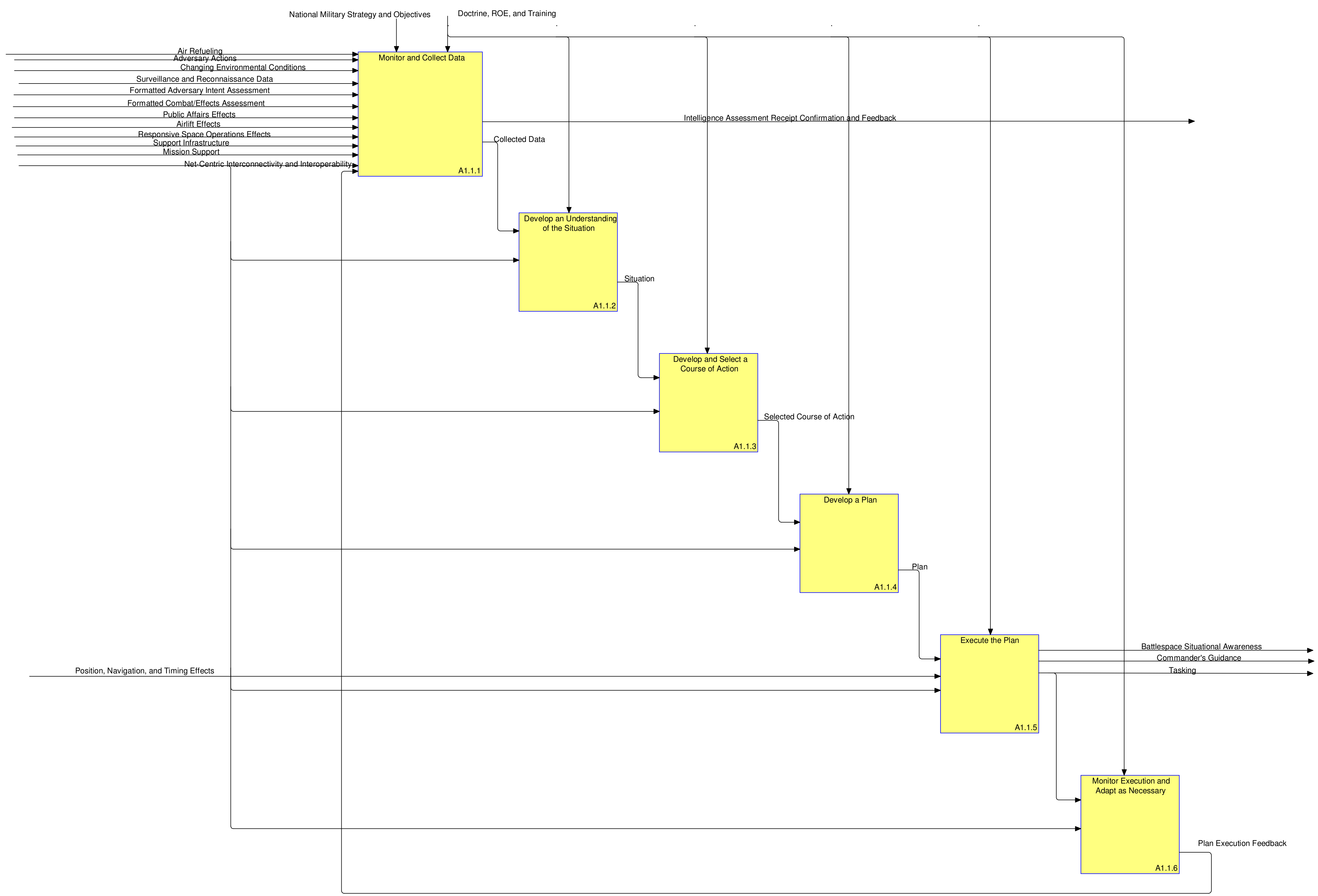

Figure A.6. Perform Command and Control (A1.1) Activity Diagram

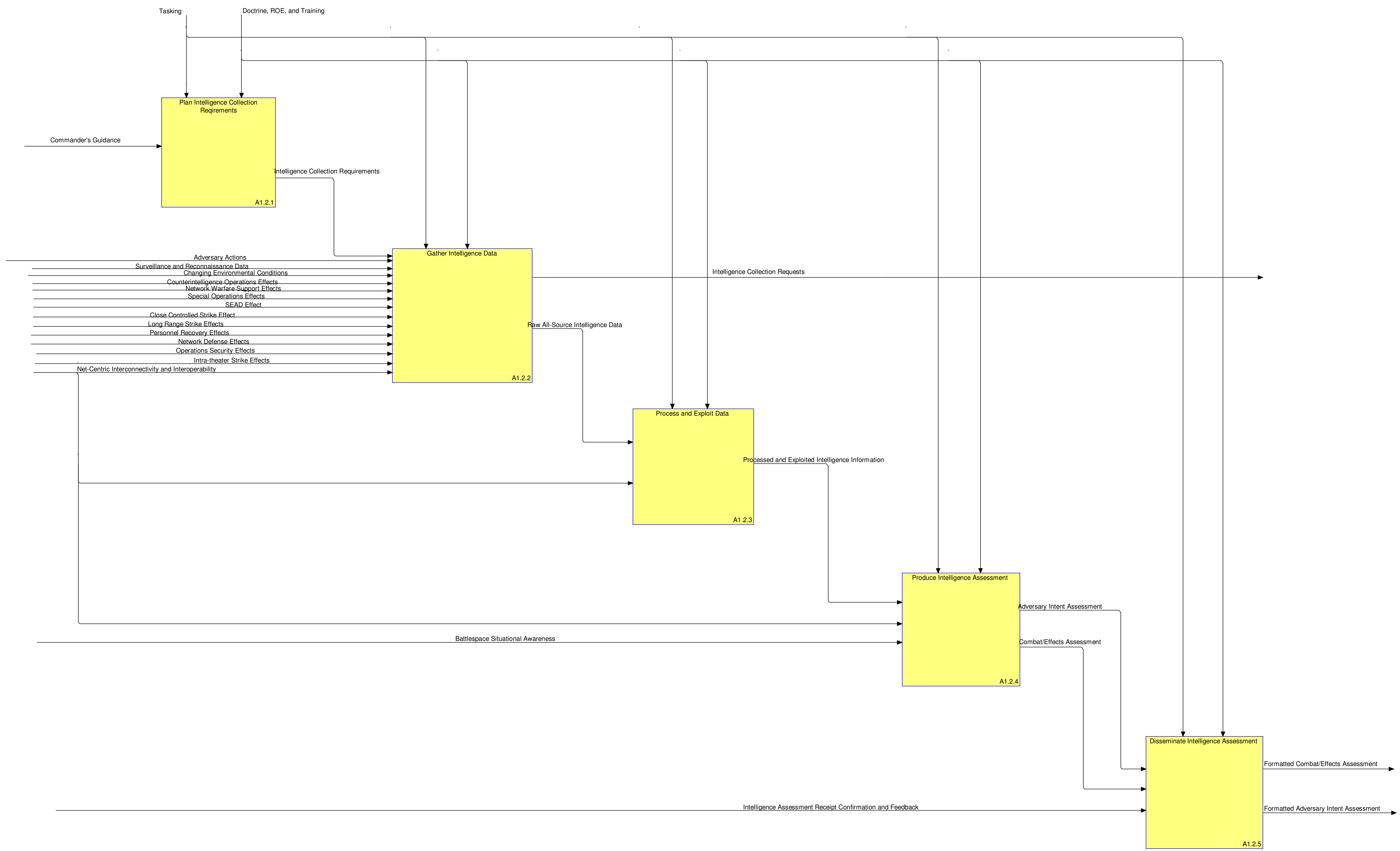

Figure A.7. Perform Intelligence Operations (A1.2) Activity Diagram

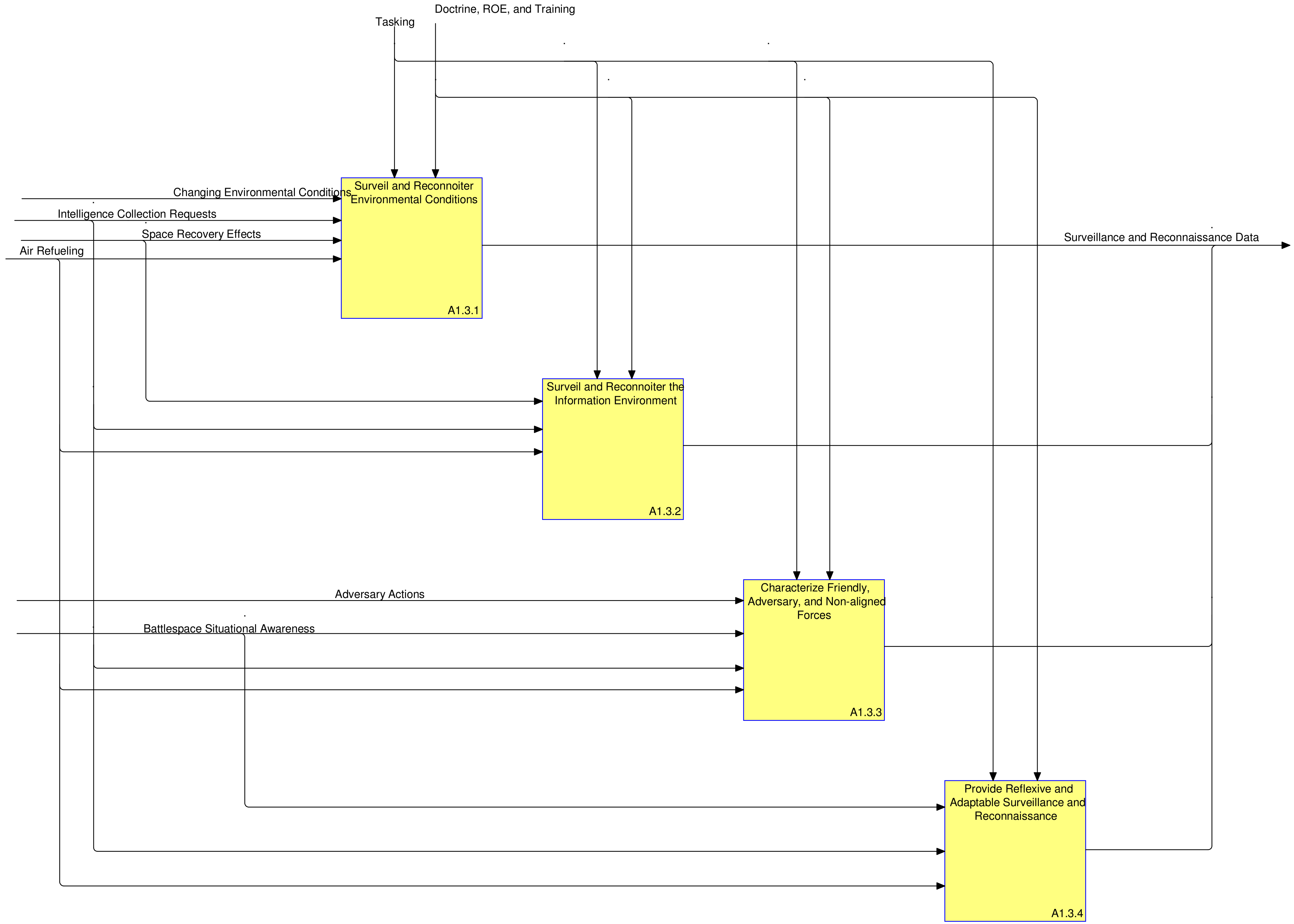

Figure A.8. Perform Surveillance and Reconnaissance (A1.3) Activity Diagram

Achieve Battlespace Awareness Dominance (A1) Diagram

Figure A.5 shows the decomposition of the Achieve Battlespace Awareness Dominance activity. These activities were grouped based upon functional areas defined by the GPA CONOPS necessary to accomplish the mission. The overall purpose of the Achieve Battlespace Awareness Dominance activity is to gain supreme knowledge and understanding of the operational environment, factors, and conditions in order to facilitate timely, relevant, comprehensive, and accurate assessments necessary for the successful application of combat power, force protection, and/or completion of the mission. As a result, the operational activities required to meet this goal were grouped into the Perform Command and Control, Perform Intelligence Operations, and Perform Surveillance and Reconnaissance activities.

Figure A.9 from the Air Force C4ISR CONOPS provides an alternate view of the interaction between the elements of C2, Intelligence, Surveillance, and Reconnaissance in the form of the Observe, Orient, Decide, and Act (OODA) concept. This graphic highlights the key activities of the OODA concept and how each activity within the Achieve Battlespace Awareness Dominance is related. Although current architectures predominately executes the OODA loop in the sequential manner represented by Figure 4.6, the enabling capabilities inherent in a robust net-centric infrastructure will allow the sequential OODA loop to be overcome by one that is more dynamic. Commanders and warfighters will have on-demand access to actionable intelligence information to make timelier, effective decisions (14, 14). The OV-5 representation of the Perform Battlespace Awareness Functions does not represent time dependence or imply sequence of actions. It simply provides a hierarchy of activities related by ICOMs and is not limited by sequential logic.

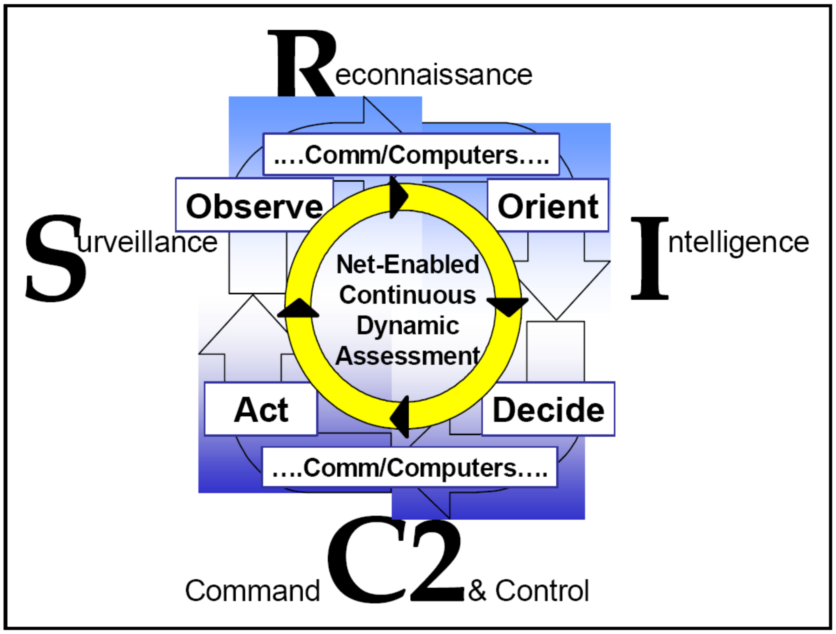

Figure A.9. OODA Loop/C4ISR Relationship (14, 12)

The Perform Command and Control activity is crucial to the entire GPA concept because it encapsulates the ability to monitor and assess the battlespace and direct forces in the execution of Effects Based Operations in any threat environment. In order to accomplish its mission, Command and Control must first receive overall mission guidance in the form of National Military Strategy and Objectives as well as Doctrine, ROE, and Training. This information, represented as a control to C2 Activities, guides the C2 decision process. In order to develop a course of action represented by the Tasking output, the C2 activities must first receive and monitor information. This requires additional taskings within the BA functions context to the Perform Intelligence Operations and Perform Surveillance and Reconnaissance activities in order to attain the required information necessary to develop effective decisions. The resulting information received from the Intelligence, Surveillance, and Reconnaissance (ISR) activities is fused to form the Battlespace Situational Awareness picture.

Decomposition of the C2 activities (see Figure A.6) demonstrates the decision process model used to develop a course of action, execute it, and assess its effects for input into future decisions. This process was outlined in the Joint Command and Control Functional Concept dated February 2004. The basic C2 functions include 1) Monitor and Collect Data, 2) Develop an Understanding of the Situation, 3) Develop and Select a Course of Action, 4) Develop a Plan, 5) Execute the Plan, and 6) Monitor Execution and Adapt as Necessary (15, 12).

This basic C2 process is the systematic execution of the functions required to recognize what needs to be done and to ensure the appropriate actions are taken. It is a cyclic process (Figure A.10) that continues until the desired end state objectives are met.

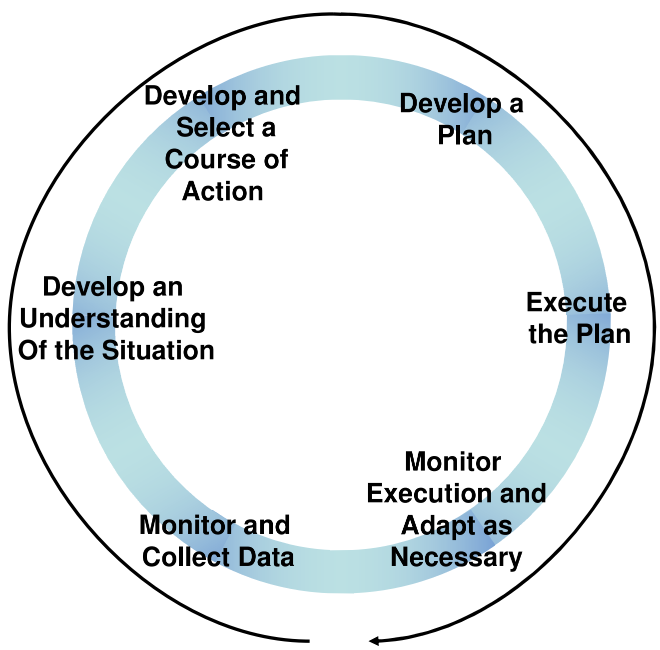

Figure A.10. Basic C2 Functions and Process (15, 12)

An initial picture or impression of the operational environment is developed by observing the situation and orchestrating the collection of different types of information from different sources. The collected information is then used to develop an initial understanding of the situation by putting it into the operational context, thus creating situational awareness. This situational awareness results from the ability to arrange disparate facts into a logical and understandable construction that facilitates the development of a course of action and allows the communication of complex information to others quickly and easily (15, 13).

Developing and selecting a course of action in a structured or analytic decision-making process consists of developing several alternatives, assessing the alternatives, and then selecting the best one. In the case of well-understood or rapidly unfolding situations, the decision is made quickly, with little consideration of developing or assessing alternative courses of action. Once a course of action is selected, a plan must be developed as to how the course of action is to be executed. The plan is then executed in the form of a tasking order coupled with the associated commander's guidance and required Battlespace Situational Awareness. Monitoring the execution of the plan allows the commander to observe the results of the selected course of action and adapt as the process starts again (15, 13).

Each decision and the courses of action they direct help to shape the operating environment. They help to establish the boundaries within which subsequent decisions and actions will take place. Multiple C2 process loops are working in parallel at different speeds and different levels of command, all having a greater or lesser impact on the others. This requires that the C2 system possess an effective means to coordinate the decisions to ensure mission success. The decision process also needs to be executed with sufficient tempo and quality to give the commander the advantage to operate within the adversary's decision cycle. These two requirements necessitate the enabling capability associated with net-centric interconnectivity and interoperability. The need to achieve precise effects within complex and uncertain operating environments makes the coordination of decisions and selected courses of action critical (15, 13).

The purpose of the Perform Intelligence Operations activity is to produce and provide the analytical products required to conduct Effects Based Operations and Assessment. This is a key element of Predictive Battlespace Awareness (PBA), which allows commanders to anticipate future events and adversary courses of action to be used in the C2 decision process. The decomposition of the Perform Intelligence Operations activity (Figure A.7) was developed using the *Joint Publication 2-01: Joint and National Intelligence Support to Military Operations* and the *Commander's Handbook for Joint Battle Damage Assessment* and mirrors the cyclic intelligence process outlined in both (see Figure A.11 below). The five activities composing Perform Intelligence Operations were determined to be Plan Intelligence Collection Requirements, Gather Intelligence Data, Process and Exploit Data, Produce Intelligence Assessment, and Disseminate Intelligence Assessment.

Intelligence correlates and fuses all sources of data, patterns of enemy activity, environmental conditions, and relevant events to assess the operating environment and predict adversary intent and actions. Intelligence operations begin with the identification of a need for intelligence regarding all relevant aspects of the battlespace to include the adversary. These needs are identified by the commander through the tasking order from C2 in conjunction with the commander's guidance and formalized as intelligence requirements early in the planning process. The critical pieces of intelligence the commander must know by a particular time to plan and execute a successful mission are identified as Priority Intelligence Requirements (PIRs). PIRs are identified at every level and are based on guidance obtained from the mission statement, commander's intent, and the end state objectives. These PIRs are represented in the activity diagram by the Intelligence Collection Requirements ICOM. The intelligence requirements provide the basis for intelligence operations and are prioritized based on customer inputs during the planning and direction portion of the intelligence process (16, III-2).

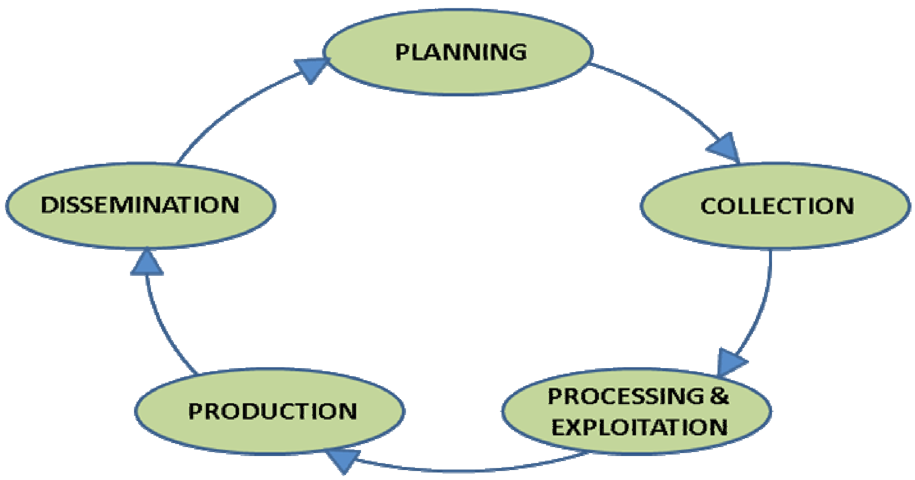

Figure A.11. Intelligence Process (16, III-2)

The Gather Intelligence Data activity involves tasking appropriate collections assets and/or resources to acquire the data and information required to satisfy collection objectives. This is represented by the ICOM Intelligence Collection Requests to the Perform Surveillance and Reconnaissance Functions activity and includes the identification, coordination, and positioning of required assets and/or resources (16, III-2). The intelligence data gathered is then fused into the Raw All-source Intelligence Data for processing and exploitation.

Through processing and exploitation, the collected data is transformed into information that can be readily disseminated and used by intelligence analysts to produce multidiscipline intelligence products. Processing and exploitation requirements are also prioritized and synchronized in accordance with the commander's PIR. The analysis and production of intelligence information involves integrating, evaluating, analyzing, and interpreting information from single or multiple sources into a finished intelligence product represented as the Adversary Intent and Combat/Effects Assessments ICOMs (16, III-3). The dissemination portion of the intelligence process involves properly formatting the intelligence assessments such that they can be disseminated to the requester and used in the decision-making and planning processes. Based upon continual evaluation of intelligence operations, activities, and products in combination with user feedback, actions should be initiated as required to improve the overall performance of intelligence operations.

The Perform Surveillance and Reconnaissance activity was decomposed in accordance with the Air Force Space & C4ISR CONOPS and consists of the activities: Surveil and Reconnoiter Environmental Conditions, Surveil and Reconnoiter the Information Environment, Characterize Friendly, Adversary, and Non-aligned Forces, and Provide Reflexive and Adaptable surveillance and Reconnaissance (see Figure A.8). The purpose of the Surveillance and Reconnaissance activity is to persistently collect data on the air, land, sea, space and cyber environments and continuously characterize all friendly, adversary, and non-aligned forces and relevant low-signature human activity.

All activities within Surveillance and Reconnaissance are controlled by the tasking requirements and guided by doctrine, ROE, and training. As indicated by the activity diagram, each activity is independent of the others and works in parallel to provide the desired information to fulfill the required collection objectives. The intent of the activity Surveil and Reconnoiter

Environmental Conditions is to persistently collect data across the physical domain to include the air, land, sea, and space mediums. This data consists of both natural phenomena and unnatural events such as CBNRE actions and space debris. This collection of data provides the foundation from which the impact of environments on operations can be ascertained and allows the identification of militarily significant changes to all environments. Detection of unnatural environmental events may also contribute to the assessment of adversary activity and intent (14, 18).

The intent of the Surveil and Reconnoiter the Information Environment is to persistently collect data on information systems that will detect changes to complex information networks, effectively characterize targets, and improve weaponeering. The Characterize Friendly, Adversary, and Non-aligned Forces activity consists of the ability to find, fix, track, and assess specific elements within the battlespace. This information is essential to enabling the targeting and C2 processes (14, 19).

The intent of the Provide Reflexive and Adaptable Surveillance and Reconnaissance activity is to conduct timely S&R tailored specifically to meet the time-critical needs of C2 and intelligence. This capability specifically addresses the agile characteristic for joint force operations outlined in the *Capstone Concept for Joint Operations* and mirrored in the *Air Force C4ISR CONOPS* to provide persistent surveillance in response to operational priorities and time-critical events (17, 20). Articulation of operational priorities, cross-cueing, and re-tasking are inherent to this capability requiring sophisticated guidance for collection management. (14,19).

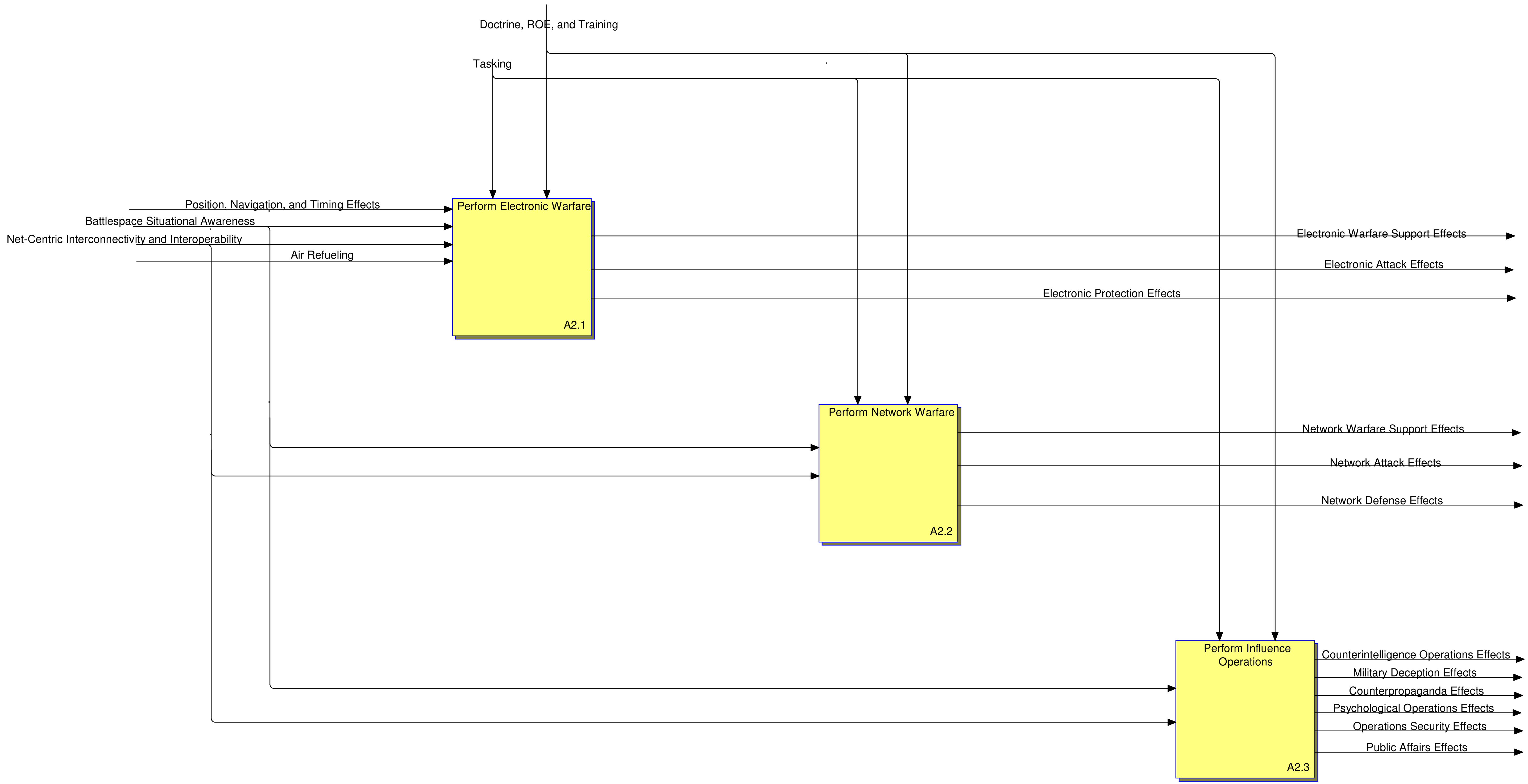

Figure A.12. Achieve Information/Cyberspace Dominance (A2) Activity Diagram

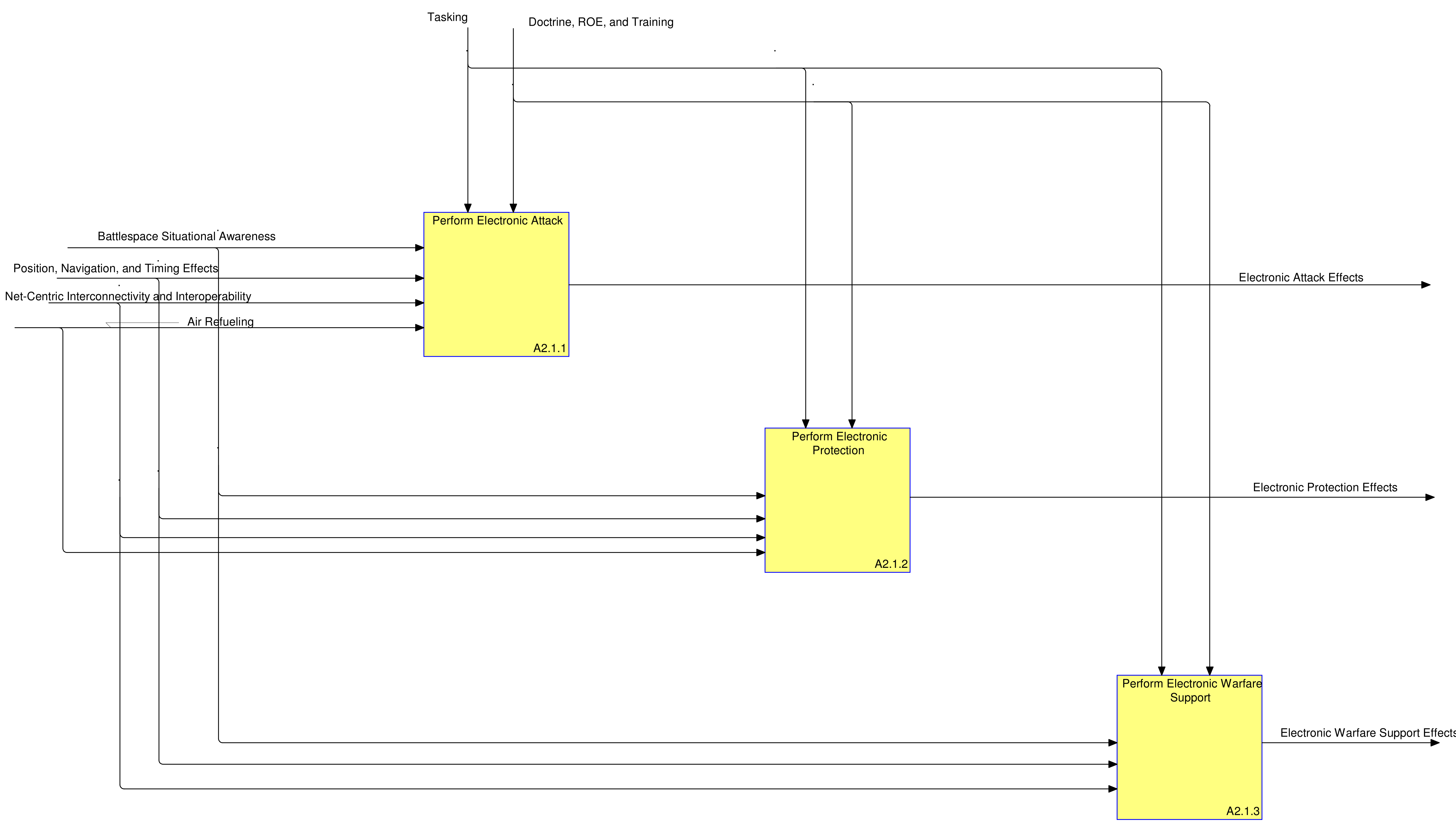

Figure A.13. Perform Electronic Warfare (A2.1) Activity Diagram

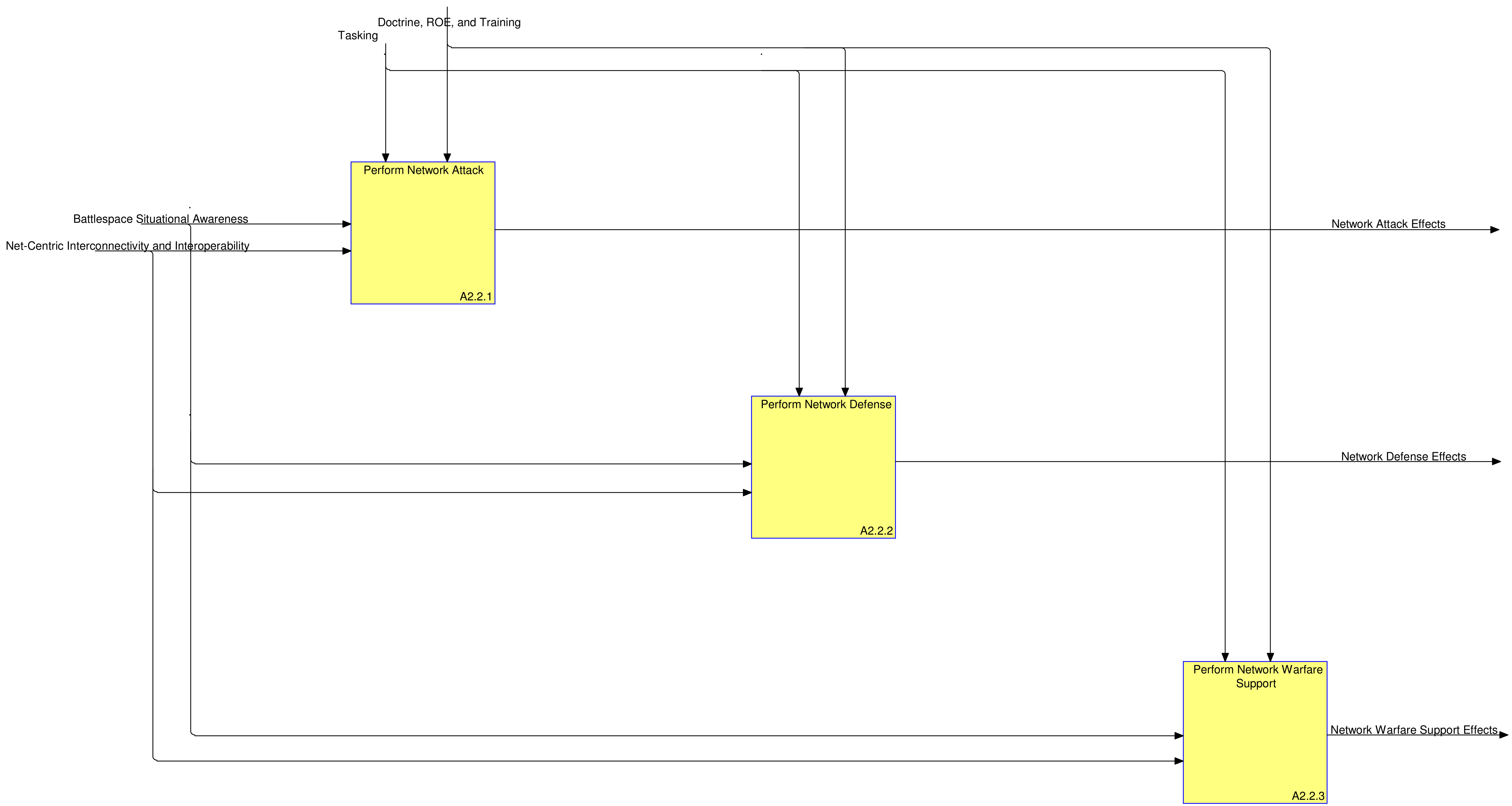

Figure A.14. Perform Network Warfare (A2.2) Activity Diagram

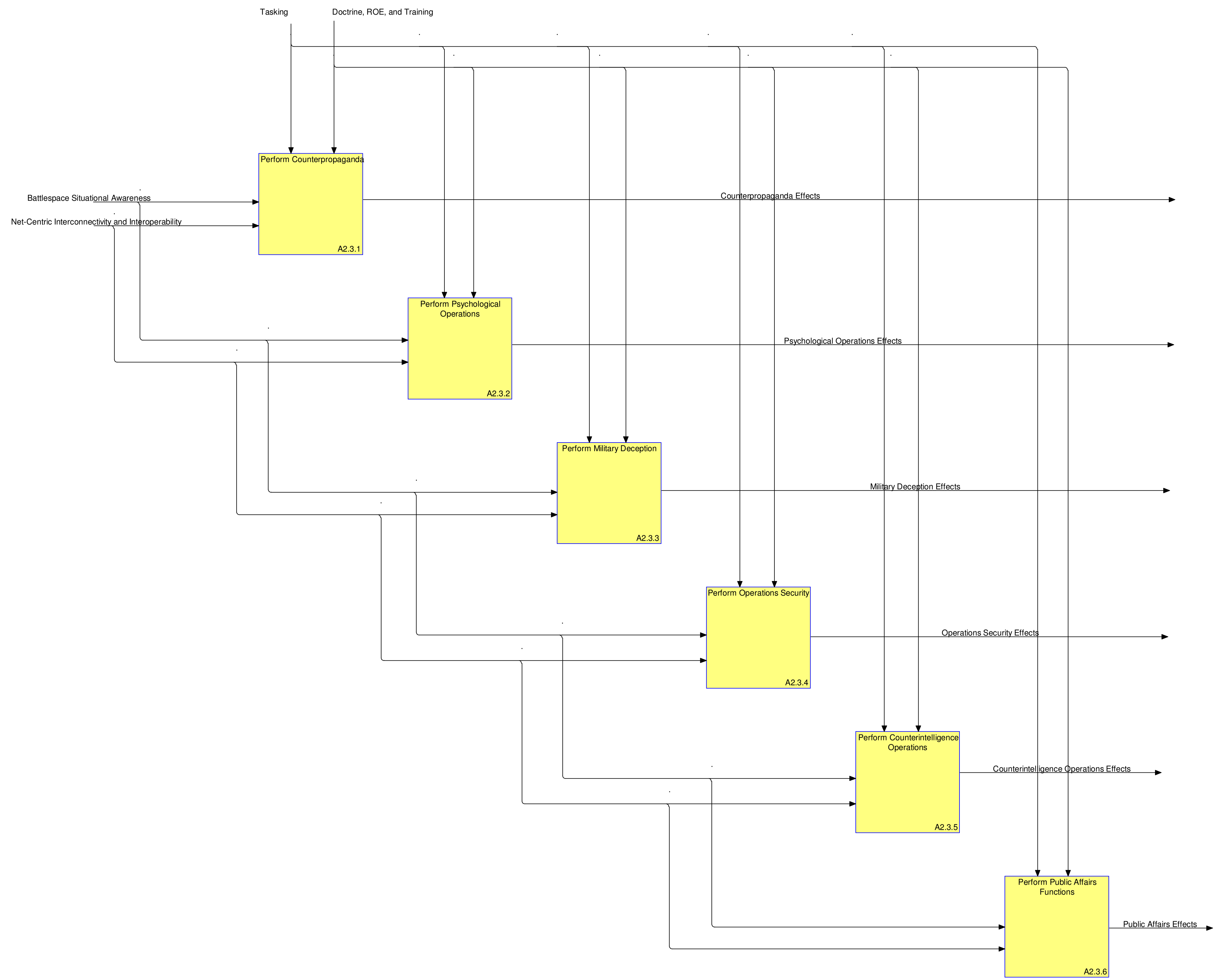

Figure A.15. Perform Influence Operations (A2.3) Activity Diagram

Achieve Information/Cyberspace Dominance (A2) Diagram

Figure A.12 shows the decomposition of the Achieve Information/Cyberspace Dominance activity. These activities were grouped based upon functional areas defined by the GPA CONOPS necessary to accomplish the mission. The overall purpose of the Achieve Information/Cyberspace Dominance activity is to provide supremacy in all areas of the global information domain allowing friendly forces the ability to attack adversaries' information and decision making while simultaneously securing and defending friendly information and decision making (3, 6). The activities that compose Information/Cyberspace Dominance are Perform Electronic Warfare, Perform Network Warfare, and Perform Influence Operations.

Once again, all activities that compose the Information/Cyberspace Dominance functional activities are controlled by tasking and guided by doctrine, ROE, and training. Battlespace Situational Awareness and Net-centric Interconnectivity and Interoperability are key inputs and enablers for each of the activities. Electronic warfare activities include the ability to attack adversary electromagnetic operations and defend friendly operations to gain dominance in the electromagnetic spectrum. The key effects from the Perform Electronic Warfare activity are those associated with the Electronic Attack and Electronic Protection Effects as well as the Electronic Warfare Support Effects. Electronic Attack Effects are the effects caused by the use of electromagnetic energy, directed energy, or antiradiation weapons to attack personnel, facilities or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability. Electronic Protection Effects are the effects of passive and active means taken to protect personnel, facilities, and equipment from any effects of friendly or enemy employment of electronic warfare that degrade, neutralize, or destroy friendly combat capability. Electronic

Warfare Support Effects consists of the information required for decisions involving electronic warfare operations and other tactical actions such as threat avoidance, targeting, and homing (3, 13). Electronic warfare support data can be used to produce signals intelligence, provide targeting for electronic or destructive attack, and produce measurement and signature intelligence. The decomposition of Perform Electronic Warfare is shown in Figure A.13.

The decomposition of Perform Network Warfare is shown in Figure A.14. The Perform Network Warfare activity includes the ability to attack adversary networks and defend friendly networks by maintaining dominance in the analog and digital portions of the battlespace. The military capabilities of network warfare are network attack, network defense, and network warfare support which produce the displayed key outputs of Network Attack Effects, Network Defense Effects, and Network Warfare Support Effects. Network Attack Effects consist of the effects from the employment of network-based capabilities to destroy, disrupt, corrupt or usurp information resident in or transiting through networks. These effects directly impact adversary functional activities by disrupting and/or influencing their decision cycle. Network Defense Effects are the effects resulting from the employment of network-based capabilities to defend friendly information resident in or transiting through networks against adversary efforts to destroy, disrupt, corrupt or usurp it. Network Warfare Support Effects consists of the information required for immediate decisions involving network warfare operations that can be used to produce intelligence, or provide targeting for electronic or destructive attack (3, 31-32). All of these effects are critical to the success of Battlespace Awareness activities and are supported by the Net-centric Infrastructure enabling capability.

The goal of Perform Influence Operations includes the ability to affect behaviors, protect operations, communicate commander's intent, and project accurate information to achieve the desired effects across the cognitive domain. The military capabilities of influence operations are psychological operations (PSYOP), military deception (MILDEC), operations security (OPSEC), counterintelligence (CI) operations, counterpropaganda operations and public affairs (PA) operations. The outputs of this activity reflect these key capabilities and are represented in its decomposition (Figure A.15).

PSYOPs are defined as the operations to convey selected information and indicators to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behavior of foreign governments, organizations, groups, and individuals. More specifically, PSYOPs effects are measured by the extent as to which foreign attitudes and behaviors are induced or reinforced such that they are favorable to the originator's objectives. MILDEC are the actions executed to deliberately mislead adversary military decision makers as to friendly military capabilities, intentions, and operations, thereby causing the adversary to take specific actions (or inactions) that will contribute to the accomplishment of the friendly mission (18, 341).

OPSEC effects are measured by the level of success associated with the process of identifying critical information and subsequently analyzing friendly actions attendant to military operations and other activities. The analysis is used to (1) identify those actions that can be observed by adversary intelligence systems; (2) determine indicators hostile intelligence systems might obtain that could be interpreted or pieced together to derive critical information in time to be useful to adversaries; and (3) select and execute measures that eliminate or reduce to an acceptable level the vulnerabilities of friendly actions to adversary exploitations (19, 397). The effects of CI operations are measured by the level of success associated with gathering information and accomplishing activities conducted to protect against espionage, other intelligence activities, sabotage or assassinations conducted by, or on behalf of, foreign governments or elements thereof, foreign organizations or foreign persons, or international terrorist activities (19, 128). Counterpropaganda effects are the effects from the activities to identify and counter adversary propaganda and expose adversary attempts to influence friendly populations' and military forces' situational understanding (3, 28). The effects of public affairs consist of the influences on the operational environment of the activities to communicate unclassified information about Air Force activities to Air Force, domestic, and international audiences (18, 4).

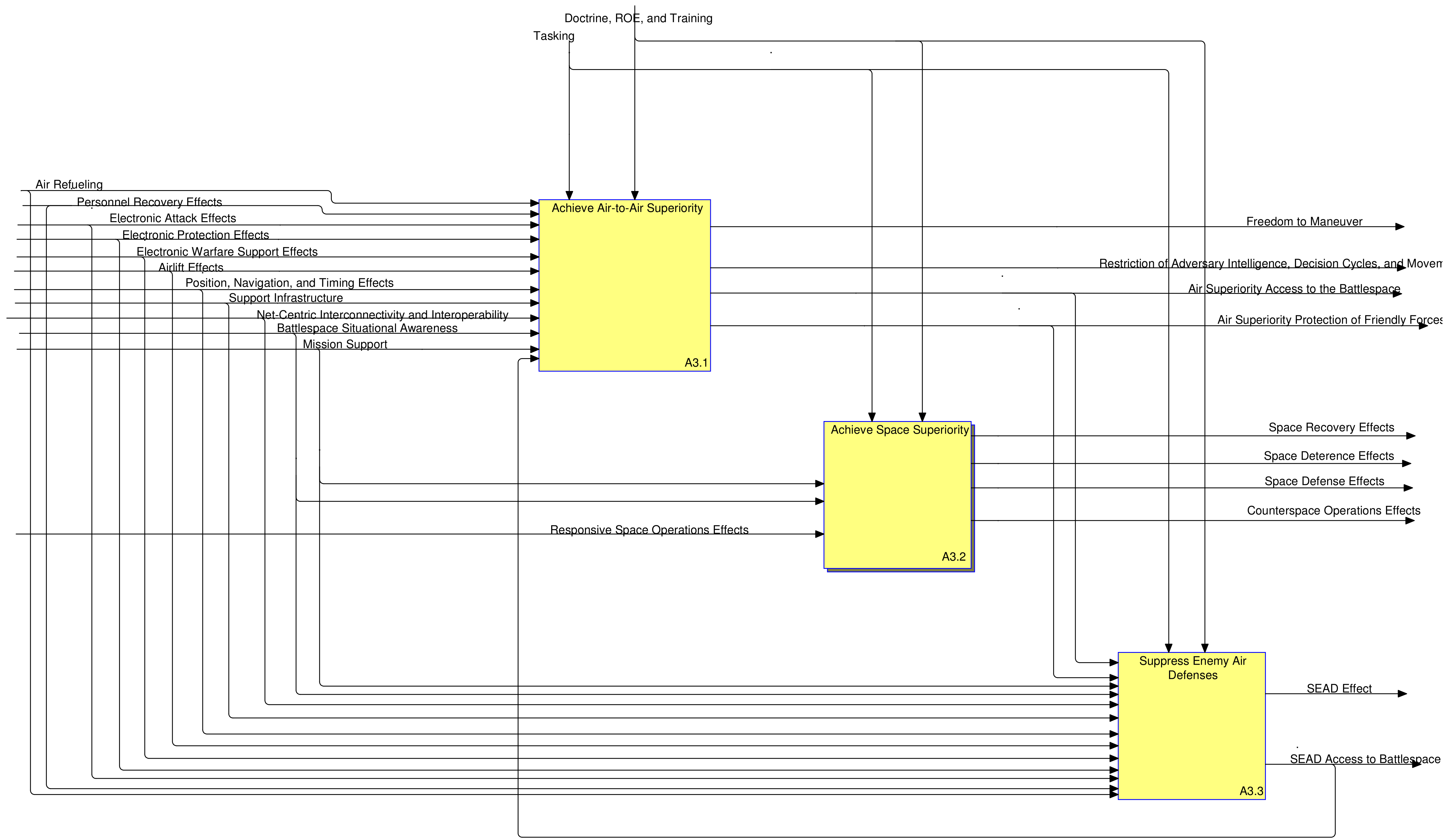

Figure A.16. Achieve Air and Space Dominance (A3) Activity Diagram

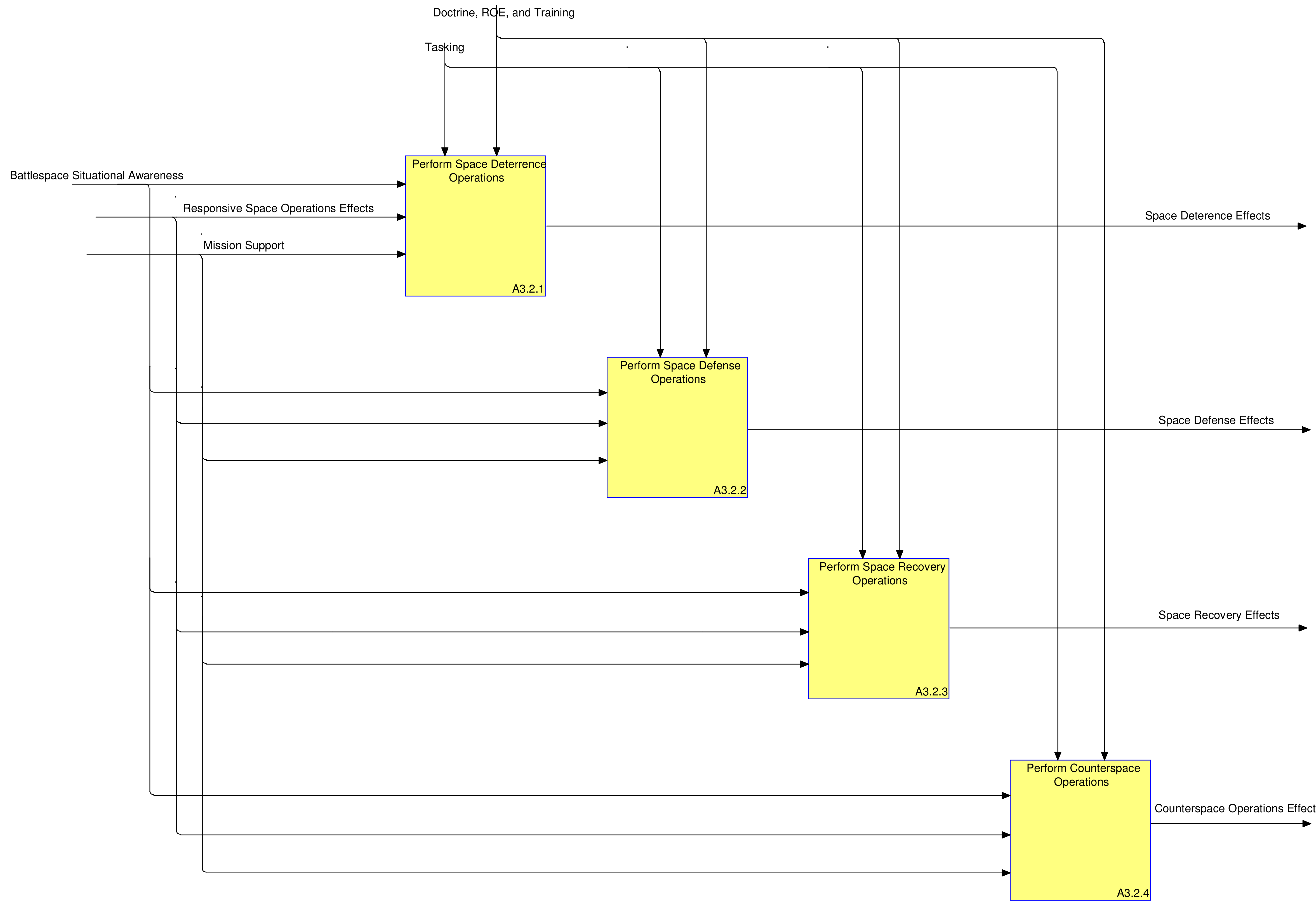

Figure A.17. Achieve Space Superiority (A3.2) Activity Diagram

Achieve Air and Space Dominance (A3) Diagram

The purpose of the Achieve Air and Space Dominance activity is to gain supremacy in the air and space battle to permit the conduct of operations by land, sea, air and space forces at a given time and place without interference by the opposing force (3, 6). The decomposition of this activity (Figure A.16) was derived from the GPA CONOPS functional grouping. The activities that compose Achieve Air and Space Dominance are Achieve Air-to-Air Supremacy Functions, Achieve Space Superiority Functions, and Suppress Enemy Air Defenses.

Consistent with all other activities within GPA, the operations are controlled by tasking and guided by doctrine, ROE, and training. The Achieve Air-to-Air Superiority activity includes the ability to neutralize or destroy any airborne threat by employing airborne assets possessing a superior kill chain (3, 10). The critical effects resulting from this activity allow access to the battlespace and freedom of maneuver by protecting friendly forces from adversary air threats. These effects are critical to the success of other Force Application activities, specifically those that reside in the Achieve Surface Dominance activity. In addition, Air-to-Air Superiority serves to restrict adversary intelligence gathering, decision cycles, and movement. Each of these effects is represented by the corresponding outputs within the activity diagram.

The Suppress Enemy Air Defenses (SEAD) activity includes the ability to neutralize, destroy, or temporarily degrade surface-based enemy air defenses by destructive and/or disruptive means. SEAD enables joint/coalition forces to engage the entire enemy integrated air defense system (IADS) in order to provide critical access openings in time and space. This is represented by the SEAD Access to Battlespace output in the activity diagram. Airborne electronic attack, advanced standoff weapons, stealth, speed, countermeasures and other

Information Operations contribute to the SEAD capability (3, 11). Additionally, key to the success of SEAD operations is the ability to accurately locate and identify emitters, especially those associated with mobile threat systems. This ability forms a cyclic relationship with the capabilities used for developing Battlespace Situational Awareness. Accurate information from Battlespace Situational Awareness facilitates locating and identifying these types of emitters. In turn, that information is then fed back into the Battlespace Awareness functions in order to update situational awareness information and influence future decisions.

In order to facilitate success in gaining Air-to-Air Superiority and performing SEAD functions, a significant number of inputs must be received as demonstrated by the diagram. Although each input is critical to the success of these activities, none is more critical than the Battlespace Situational Awareness input provided by the Achieve Battlspace Awareness Dominance activity.

The purpose of the Achieve Space Superiority activity is to dominate an adversary's space forces in order to permit the conduct of operations by land, sea, air, and special operations forces at a given time and place without prohibitive interference from the opposing force. The vantage point of space provides the ultimate high ground from which to conduct C4ISR missions (3, 10). The decomposition of this activity (Figure A.17) consists of Perform Space Deterrence Operations, Perform Space Defense Operations, Perform Space Recovery Operations, and Perform Counterspace Operations.

Space Deterrence operations consist of those activities designed to deter adversaries from attacking US military, civil, and commercial space capabilities. Space Defense operations are those activities for the purpose of defending US military, civil and commercial space capabilities. Space recovery operations are those operations that recover or restore space capabilities if they are lost. Offensive counterspace operations implement measures to deceive, disrupt, deny, degrade, and destroy an adversary's on-orbit assets, ground nodes, and/or communication pathways (3, 11). As demonstrated by the diagram, each of these activities is performed independently; however, each activity may indirectly affect the others. For example, the ability to conduct offensive counterspace operations may serve as a deterrent to adversary aggression. Key inputs to these activities include Responsive Space Operations Effects from the associated enabling capability as well as the required mission support framework. Again, Battlespace Situational Awareness is a required input to achieve the desired effects for each activity.

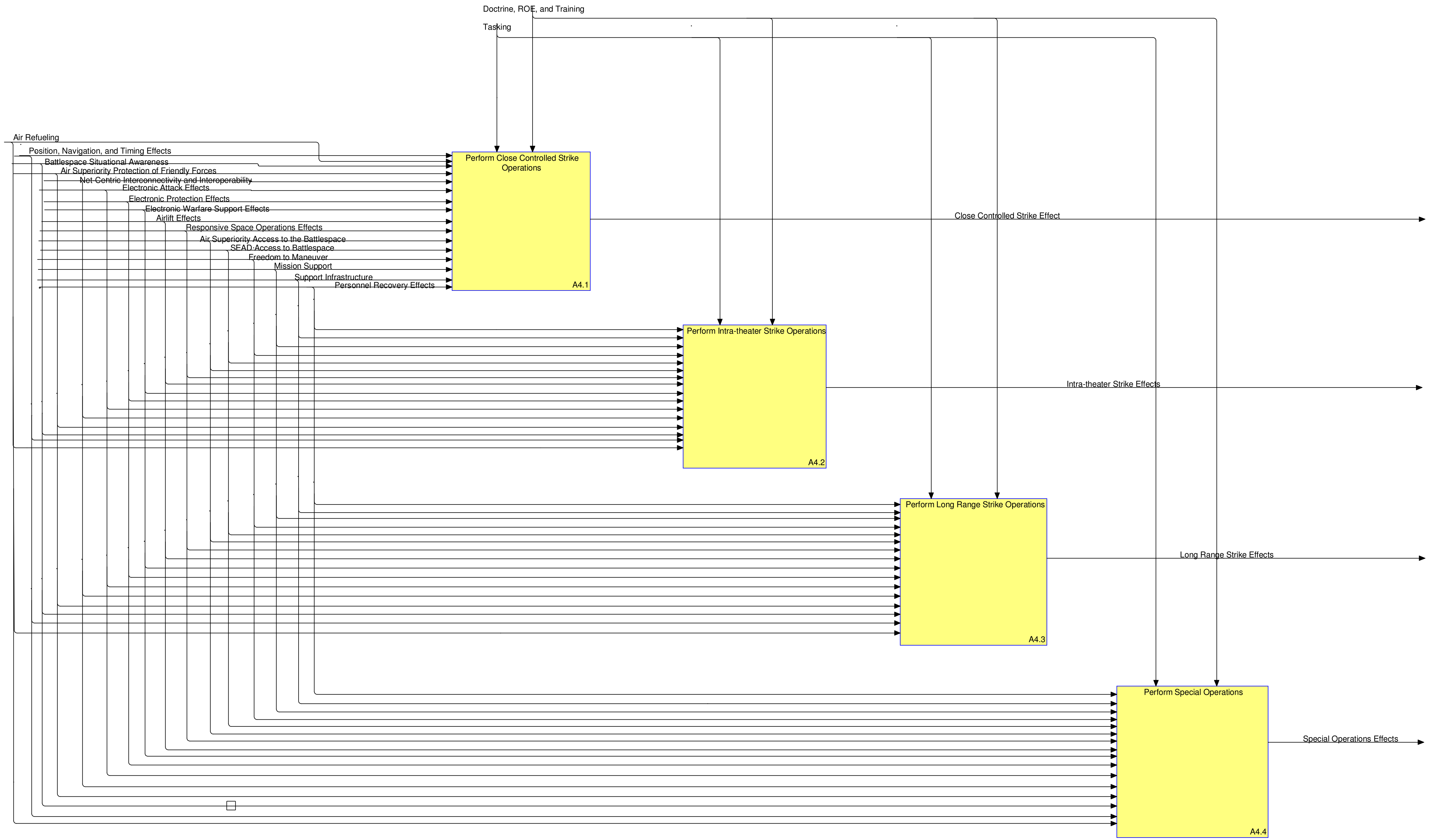

Figure A.18. Achieve Surface Dominance (A4) Activity Diagram

Achieve Surface Dominance (A4) Diagram

The Achieve Surface Dominance activity is critical to achieving the NMS prescribed Full Spectrum Dominance as one of the four pillars. The goal of the Surface Dominance functional activity is similar to that of Air and Space Dominance with respect to the surface battle. In other words, the Achieve Surface Dominance activity is dedicated to gaining supremacy in the surface battle in order to permit the conduct of friendly operations at a given time and place without adversary interference (3, 6). Again, the functional decomposition of this activity was derived from the functional grouping resident in the AF GPA CONOPS and consists of Perform Close-controlled Strike Operations, Perform Intra-theater Strike Operations, Perform Long Range Strike Operations, and Perform Special Operations (Figure A.18). Each of the activities is controlled by tasking and guided by doctrine, ROE, and training. The key outputs are the effects associated with each activity that directly influence adversary activities.

Close-controlled Strike Operations consist of the ability to perform persistent, precise, time-sensitive attacks, day or night, in adverse weather in all land and littoral environments against fixed or mobile targets. This ability is combined with the ability to communicate rapidly with surface forces. Typical missions within the Close Controlled Strike functional activity are those associated with Combat Search and Rescue (CSAR), terminal guidance operations (TGO), and close air support (CAS) (3, 11).

Intra-theater Strike Operations include the ability to conduct air-to-surface operations within a joint operations area or geographic theater in all weather, day or night, and anti-access environments against fixed and/or mobile targets. This activity also includes the ability to carry at least a medium payload to execute precise, point-and-shoot, dynamic targeting, time-sensitive and networked attacks, and to provide deep strike command and control. This activity provides a critical, robust, rapid, flexible and persistent attack capability against high value targets (HVTs). Typical missions within this activity are those associated with air interdiction (AI), offensive counterair (OCA), strike coordination and reconnaissance (SCAR), and strategic attack (SA) (3, 11).

Long-Range Strike (LRS) Operations include the ability to conduct inter-theater, long endurance, high payload air-to-surface, and surface-to-surface operations (to include capabilities that transit space) against significant and/or high value and time-sensitive targets to neutralize an adversary's forces or critical vulnerabilities rapidly, precisely, and overwhelmingly. LRS operations provide a deep, rapid strike capability on adversary forces, leadership, strategic resources, C4ISR systems, anti-satellite weapons, ballistic and cruise missiles, and CBRNE weapons and storage sites. LRS capabilities are used to perform operations such as SA, AI, and OCA (3, 12).

Special Operations provide the ability to conduct operations in hostile, denied, or politically sensitive environments to achieve military, diplomatic, informational, and/or economic objectives employing military capabilities for which there is no broad conventional force requirement or there is no force available (3, 12). Special Operations are used to conduct missions such as direct action (DA), Special Reconnaissance, Unconventional Warfare (UW), and Foreign Internal Defense (FID) (3, 12).

The activities that compose Achieve Surface Dominance are the primary means by which the Air Force delivers kinetic and non-kinetic effects against adversary targets to achieve campaign objectives. Each of the activities requires a number of inputs critical to their success.

These inputs originate from a variety of different activities within the GPA concept and demonstrate the dependencies between them. The OV-5 activity models combined with the OV-2 operational node diagram highlights those dependencies.

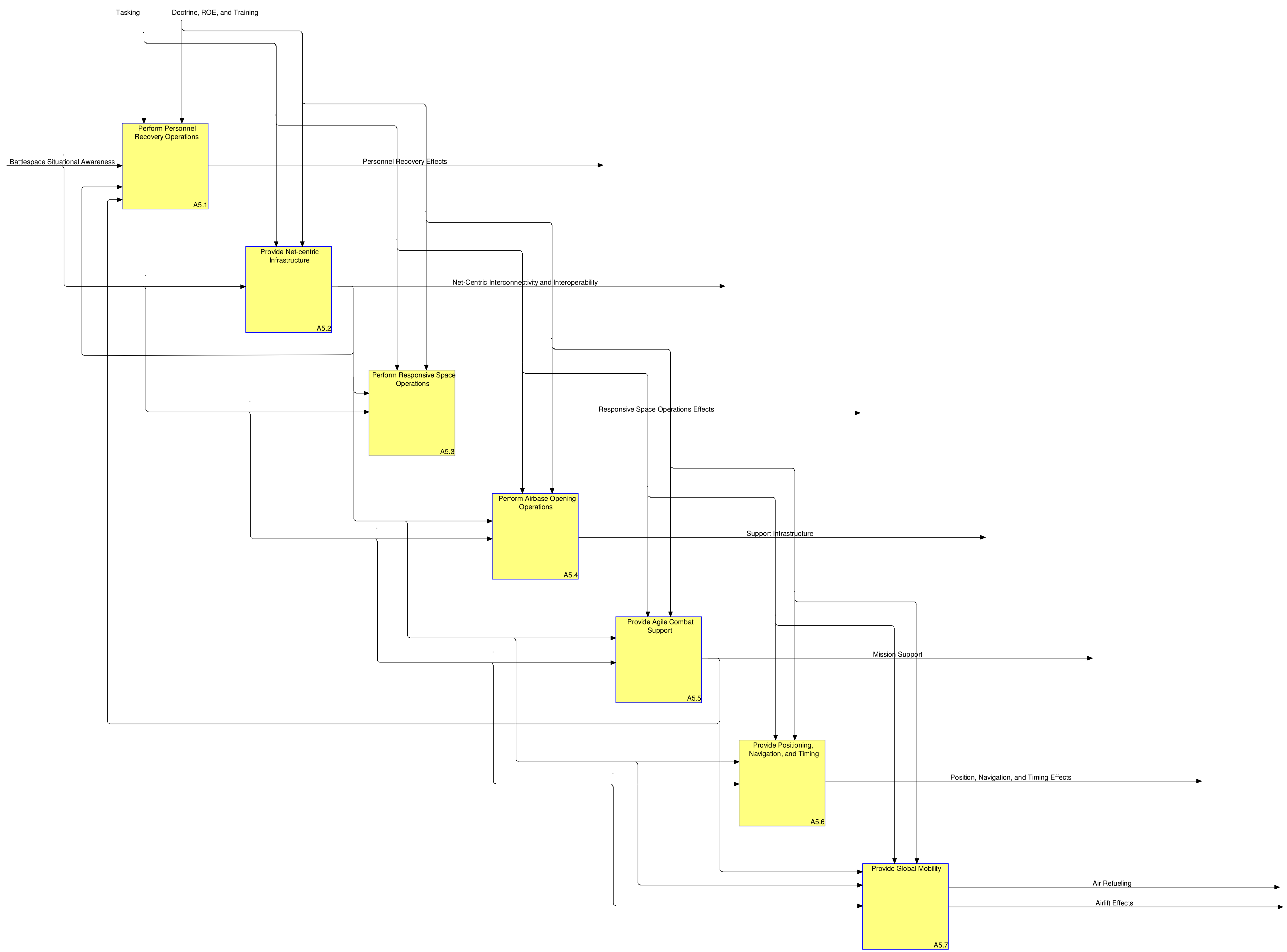

Figure A.19. Provide Enabling Capabilities (A5) Activity Diagram

Perform Enabling Capabilities (A5) Diagram

Underlying the four pillars of Full Spectrum Dominance are the Enabling Capabilities. The Provide Enabling Capabilities consists of those capabilities that support but do not directly achieve the desired effects of air and space, ground, battlespace awareness, and information dominance (3, 14). These capabilities are critical to the overall success of the GPA concept and often drive Air Force and MAJCOM strategic planning efforts. Figure A.19 shows the decomposition of the Provide Enabling Capabilities activity in accordance with the GPA CONOPS.

The Perform Personnel Recovery Operations includes the ability to report, locate, support, recover, and reintegrate isolated personnel across the spectrum of military operations in order to preserve critical combat resources and deny the enemy a potential intelligence source. This capability is a key element in sustaining the morale, cohesion, and operational performance of friendly forces (3, 14).

The Provide Net-centric Infrastructure includes the ability to provide human and technical interconnectivity and interoperability to all users (3, 14). This capability is extremely critical to all operations within GPA and provides the foundation from which C2 decisions can be made and disseminated based upon access to information and capabilities resident within the infrastructure.

The Provide Responsive Space Operations activity includes the ability to be responsive at the strategic, operational, and tactical levels to meet time-critical needs and evolving situations, including the capability of on-demand space asset deployment and operations (3, 14). The effect of this activity is a key input into both the Space Superiority functions as well as the Surveillance and Reconnaissance functions.

Perform Airbase Opening Operations consist of the ability to assess, plan, reconfigure, modify, build, and maintain a manageable infrastructure capable of supporting combat mission requirements. The infrastructure includes, but is not limited to, airfield, aviation fuel, weapons delivery and storage, and utility/communications grids (3, 14-15).
Agile Combat Support (ACS) is one of the seven major Air Force CONOPS outlining the ability to sustain joint and coalition forces to enable the application of persistent force. ACS capabilities include all elements of forward base-support structure and are essential for providing rapid assessment, base set-up and defense, C2, mission generation, and supporting Air Expeditionary Task Forces (3, 15). The Mission Support output in the diagram consists of the abilities to generate the mission and support the mission and forces. Requirements to generate the mission include the ability to accomplish maintenance and configuration, payload preparation, launch and recovery, and fuel support. Supporting the mission and forces encapsulates the ability to maintain effective capacities of mission support for the duration of the operation to include the distribution of materiel when and where needed.

Positioning, Navigation, and Timing (PNT) includes the ability to support the battlespace navigation by friendly forces as well as target acquisition, engagement and precision strike of adversary targets regardless of weather conditions. This capability also facilitates planning, execution, and synchronization of information networks (3, 15).
Global Mobility operations consist of those that provide rapid projection and application of GPA forces through deployment, sustainment, augmentation and redeployment globally to support the full range of military operations. The two key outputs from the Perform Global Mobility activity are Air Refueling and Airlift. Air Refueling includes

the ability to transfer fuel to airborne joint and allied aircraft during deployment/redeployment and combat operations. The air refueling capability is a force extender for GPA operations by enabling operational maneuver over strategic and operational distances and tactical maneuver throughout a regional combatant commander's area of responsibility. Airlift permits GPA operations by providing the means by which materiel and personnel are moved over strategic distances. It allows GPA to maintain a small forward footprint with time definite delivery of reachback forces (3, 15-16).

Each of the activities within the Provide Enabling Capabilities activity is also controlled by tasking and guided by doctrine, ROE, and training. The key inputs to all these activities are Battlespace Situational Awareness and Net-centric Interconnectivity and Interoperability; however, some of the activities such as Global Mobility and Personnel Recovery also require the additional input of Mission Support due to the complexity and size of their operations. Again, the enabling capabilities provide the foundation from which GPA operations can be executed and are critical to their level of success.

Appendix B. Process Sequence Model (PSM) Development

In order to quantify risk in accordance with the objectives of this research project, a tool had to be developed that outlined the sequence logic associated with the activities highlighted by the OV-5. The OV-5 models the static structure of the architecture activities and their relationships, but does not address the dynamic behaviors associated with the sequencing and timing aspects within the architecture. DoDAF Version 1.5 addresses the dynamic nature of the modeled architecture through the use of OV-6 products. The OV-6a is the Operational Rules Model that specifies the constraints associated with the operational activities. At the mission or operational level, the OV-6a rules may consist of doctrine, guidance, and rules of engagement (ROE). The OV-6b is the Operational State Transition Description that graphically depicts how operational nodes or activities respond to various events by changing states. The OV-6b can be used to describe the explicit sequencing of operational activities by relating states, events, and actions. The OV-6c provides a sequenced examination of the information exchanges between operational nodes as a result of a particular scenario in the form of an event-trace diagram. This product allows the tracing of actions in a scenario or critical sequence of events that can be used by itself or in conjunction with the OV-6b to describe the dynamic behavior of the operational thread (12, 4-52; 4-68).

The Process Sequence Model (PSM) is similar to the OV-6c product. A PSM depicts the chronological activity flow of Air Force mission areas in a format developed specifically for use in the Air Force CRRA analytical process. This product provides the mechanism by which the CRRA process is responsive, repeatable, and defendable (10, 4.1). This research project builds upon the PSM methodology instead of developing DoDAF OV-6 architectural products due to Air Force decision-makers' familiarity with PSMs as part of the decision-making process. The

PSM methodology and format is an Air Force approved product for use in decision analysis that meets this research project's requirements for risk assessment.

HQ A5XC has constructed several PSMs depicting Air Force critical mission areas; however, in order to apply risk analysis to the activities associated with the GPA CONOPS, a PSM had to be developed that captured GPA critical activities. As a result, the A5XC Global Power PSM was modified to reflect the GPA process and capabilities using the same Find, Fix, Track, Target, Engage, and Assess (F2T2EA) construct (see Figure B.1 below).

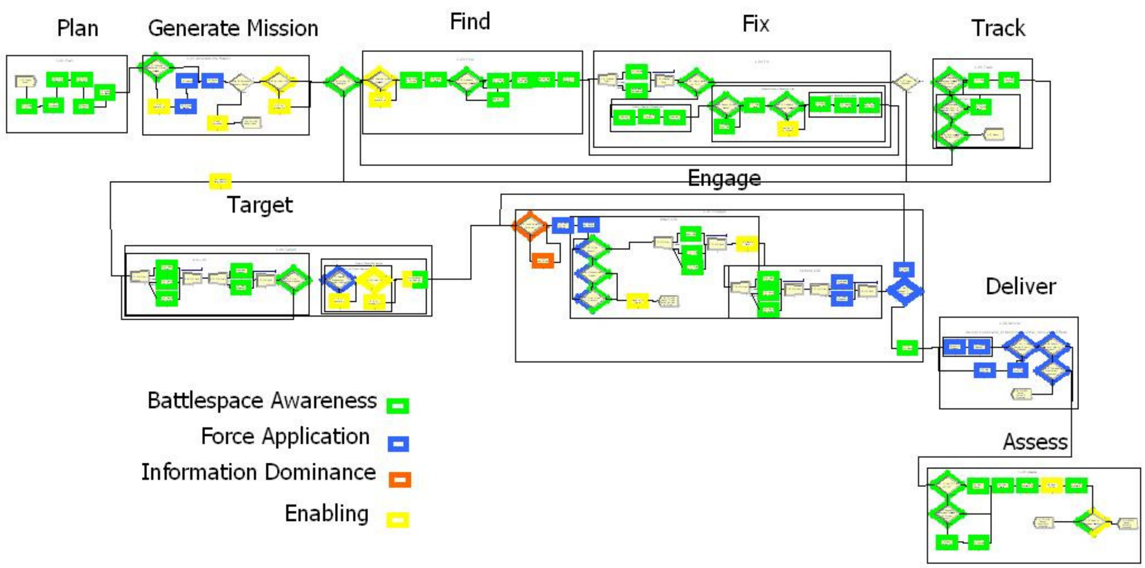

Figure B.1. GPA PSM Diagram

GPA PSM Plan Segment

As shown in Figure B.1, the GPA PSM was divided into sections related to operational activities (rectangles) and decision nodes (diamonds) that combined to meet specific objectives within the process sequencing. The reader will also notice other modeling blocks within the PSM specific to ARENA software necessary to perform the proper sequencing logic; however, these additional modeling blocks provide no input to the overall *P(s)* distribution calculations.

The first section specifically addresses those capabilities and processes necessary to plan the mission (see Figure B.2 below). The nodes within the Plan process include the activities demonstrated by the OV-5 decomposition of Perform C2 Functions and Perform Intelligence Functions.

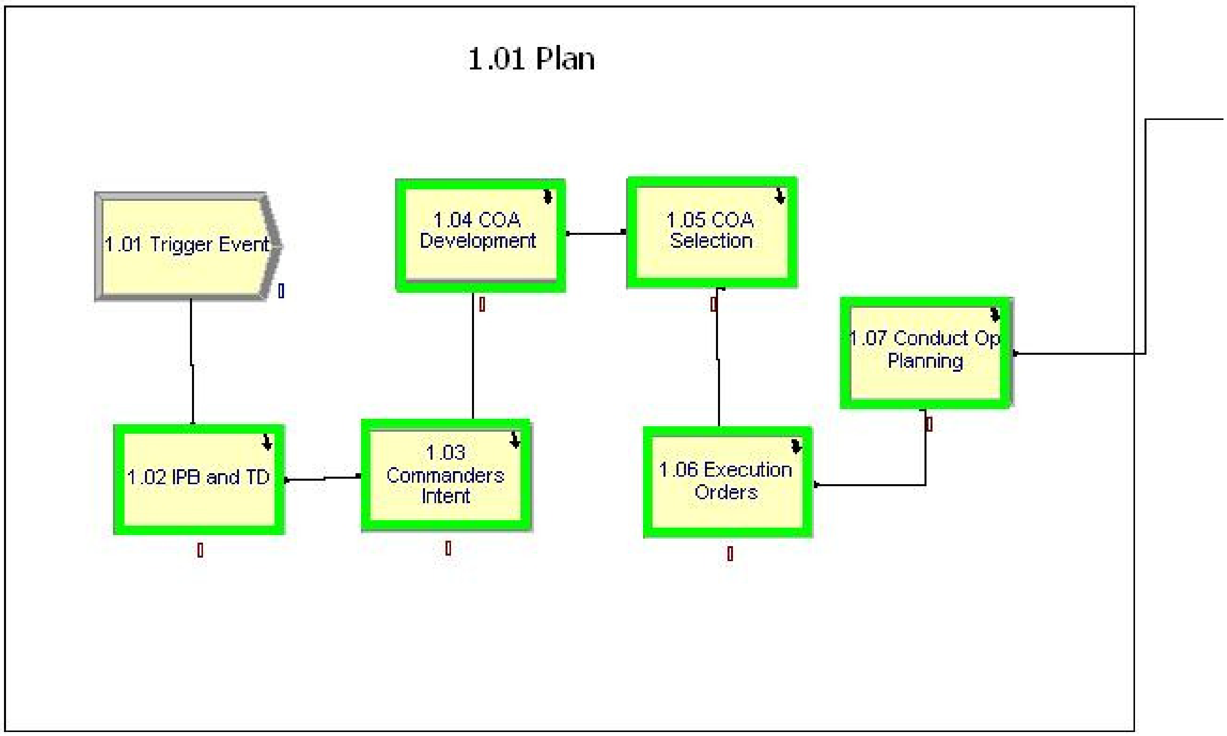

Figure B.2. GPA PSM Plan

Intelligence Preparation of the Battlespace (IPB) and Target Designation (TD) are processes within the Perform Intelligence Functions that provide the necessary information to support the C2 decision process. The Commander's Intent, Course of Action (COA) Development, COA Selection, Execution Orders, and Conduct Operational Planning nodes mirror the activities of the OV-5 C2 decision process (Perform C2 Functions).

GPA PSM Generate the Mission Segment

Generate the Mission segment consists of those activities and decisions necessary for generating the mission to include accomplishing mission planning, maintenance and configuration, payload preparation, launch and recovery, and fuel support (see Figure B.3 below).

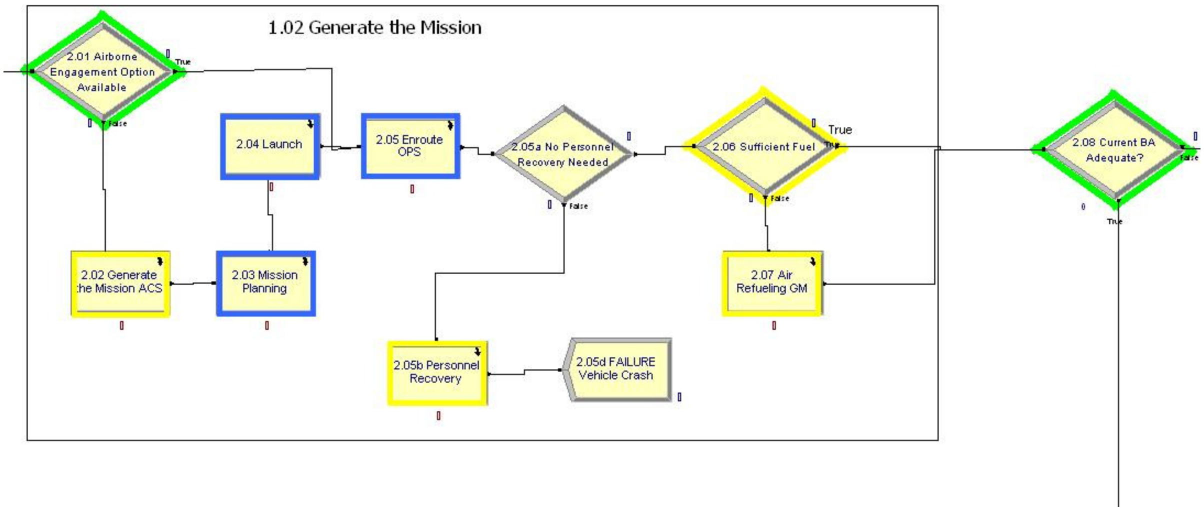

Figure B.3. GPA PSM Generate the Mission

The first decision node within the Generate Mission section answers the question as to whether or not an airborne engagement option is available that meets the needs of the mission and can be tasked in a timely manner. This includes the availability and accuracy of the data necessary to make this decision. This node should include such considerations as the availability of the strike assets, the availability of support assets or surface assets if needed, A/C type, A/C number, location, mission support requirements, SCL, fuel state, etc. It should also take into account personnel and systems available to complete this task including the time needed for completion (10, 110). If the decision node is true, the process jumps to the Enroute Operations activity. If it is determined to be false, the process continues to the Generate the Mission (ACS) activity that addresses the sortie generation process to support the engagement requirement. This activity is evaluated as a separate PSM within the Agile Combat Support functionality for the CRRA process due to its internal complexities (10, 110). This methodology allows for a general evaluation of this activity based upon ACS enabling capabilities as well as a more detailed evaluation using the HQ A5XC Generate the Mission PSM. If it is determined that the enabling capabilities are available to generate the mission within the GPA process required timeline for a given scenario, this activity should be evaluated within the GPA PSM using a *P(s)* of 1. Depending upon the level of analysis, however, this activity may require a more detailed evaluation or a different *P(s)* distribution. A specific, time-critical mission analysis with fleeting target opportunities and no available airborne engagement options may require a different *P(s)* PDF more representative of the ability to generate a mission within time constraints. This methodology, however, is focused on evaluating this activity on a broader, higher level that more closely mirrors campaign level operations with ACS enabling capabilities and GPA operations established and ongoing.

The Mission Planning activity is evaluated based upon the probability that the mission is properly planned and coordinated to include the quality of the plan as well as the process and systems used to produce it. Again, this activity should normally be given a *P(s)* value of 1 unless specific mission planning shortfalls can be identified. Evaluating this activity for specific missions requiring newer weapon systems without proven mission planning support systems may require a modified *P(s)* PDF.

The launch activity addresses the reliabilities inherent in the involved weapon systems to start, taxi, and takeoff. Again, this activity should normally be given a *P(s)* of 1 unless known system or maintenance problems exist such as with aging aircraft or unproven systems. Using a

P(s) of 1 is justified for most cases because the number of aircraft generated is typically based upon successfully launching a sufficient number of assets to complete the mission with consideration to the expected number of ground aborts. If time-critical mission requirements necessitate launch time constraints, an adjusted PDF may need to be evaluated in order to capture limitations or reliability concerns with the involved systems. For large scale operations in a high level analysis, this node must consider all required weapon systems for mission completion. Enroute operations address the probability that the required weapon systems will be able to continue the mission to the target. The probability function for this activity includes the system reliabilities of in-flight operations.

The Personnel Recovery decision node determines whether or not a manned asset for the mission will need recovery in case of a vehicle accident. The functional activity is the likelihood of a recovery mission successfully extracting personnel from the scene of the downed asset. The functional activity is performed by the enabling capability for Personnel Recovery.

The Sufficient Fuel decision node determines the likelihood that the required assets must refuel before commencing with the engagement process. This decision node determines the weight on the overall GPA *P(s)* that air refueling operations will possess. For instance, specific campaign scenarios may have limited forward basing options requiring a significant strain on air refueling capabilities. In this case, the PDF for the likelihood of having sufficient fuel to complete the mission without requiring air refueling assets should be low in order to force a higher number of outcomes within the Monte Carlo simulation through the air refueling loop. High level analysis for large operations should also normally use a PDF that forces a preponderance of the sequencing logic to include air refueling operations.

GPA PSM Find Segment

Before entering the Find segment (see Figure B.4 below) of the sequencing logic, the Current Battlespace Awareness Adequate decision node must be addressed. This node addresses the probability associated with having sufficient information previously collected and analyzed to Track the target and proceed directly to the Target segment. The PDF associated with this node should typically consist of lower values in high level, large operations analysis to account for the need to continually update Battlespace Awareness information based upon ongoing events. The lower PDF values will force more outcomes through the Find, Fix, and Track portions of the PSM sequencing logic.

The Find segment within the GPA PSM construct consists of the activities and decision nodes necessary to conduct the relevant ISR operations described in the OV-5. The Collection Asset Available node is the probability that a collection asset is available and capable of the desired collection requirements negating the need to generate a new mission. If an asset is not available, a new mission must be generated via the Generate the Collection Mission activity, otherwise, the sequencing logic continues to Position Collection Asset at Collection Location.

The Generate the Collection Mission activity addresses the probabilities associated with the C4ISR mission generation process to support the dictated collection requirements within the necessary timeframe. The CRRA process uses the ACS PSM for airborne assets to determine the *P(s)* PDF for this activity. Again, leveraging existing PSMs to generate higher fidelity PDF distributions for complex activities increases the value and validity of the overall results. If this is not possible or desired, SME judgment for high level analysis may be sufficient.

The Position Collection Asset activity uses a *P(s)* PDF to estimate the probability that the collection asset can successfully get into position to collect the required intelligence information. Considerations for this activity include, but are not limited to, the repositioning of assets and/or sensors, refueling requirements, threat avoidance, range of collection sensor, and survivability. Different threat environments will dictate different PDFs.

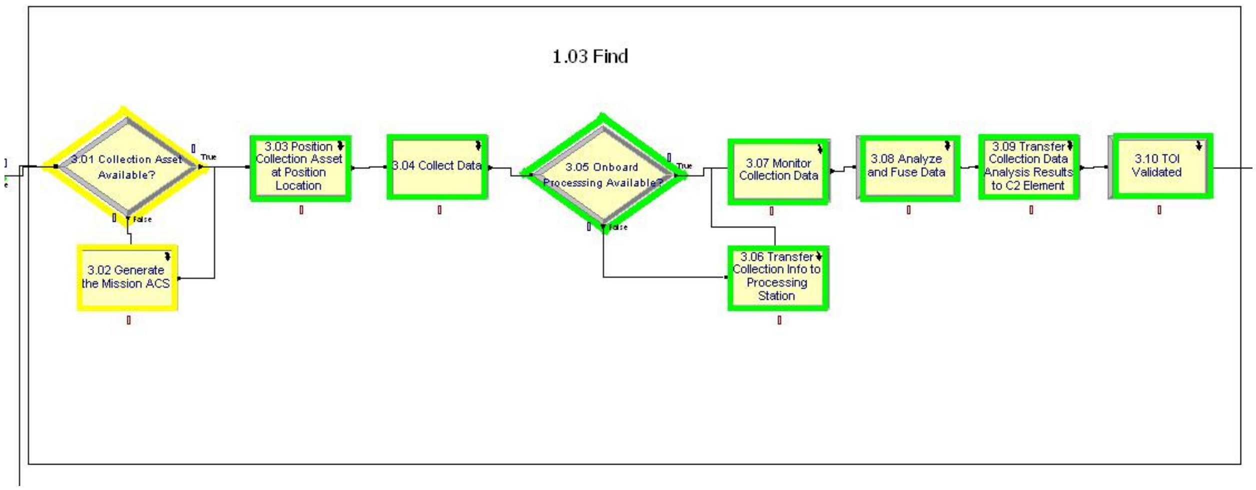

Figure B.4. GPA PSM Find Segment

The Collect Data activity is the probability that the collection asset is able to collect the required data to locate the target. This activity may include multiple sensor types and modes as well as the full range of intelligence sources such as MASINT, HUMINT, SIGINT, ELINT, etc. for high level analysis. Specific scenarios may also dictate changes in the PDF values based upon weather conditions in the area of operations.

The Onboard Processing Available decision node differentiates between the sensors/sources that can process data onboard and those that must send data through the intelligence processing cycle. The *P(s)* associated with this decision node should reflect the ratio of collection sensors/sources that have this capability to those that do not. The ratio should also include considerations to the amount and type of data typically collected. For instance, a pure ratio for collection sensor types may fail to capture the collection distribution requirements placed upon each sensor. In other words, a pure ratio for collection sensor types assumes that each sensor bears an equal amount of the collection requirements. For most scenarios, this assumption is not accurate.

If onboard processing of data is not available, the sequencing logic requires the transference of collected data to the appropriate location for processing in accordance with the Transfer Collection Info to Processing Station activity. This *P(s)* PDF for this activity is the probability that the collected data is successfully transmitted to the appropriate processing location including considerations such as time, bandwidth, and other communication restrictions.

Monitor Collection Data, Analyze and Fuse Data, and Transfer Collection Data Analysis to C2 Elements represent the respective intelligence functions described within the Perform Intelligence Functions activity of the OV-5 decomposition of Battlespace Dominance. The *P(s)* PDFs for these activities must accurately represent the ability to process and exploit incoming data, analyze and fuse the exploited data, and disseminate the intelligence products to the proper locations such as the C2 element and warfighter.

The TOI Validated activity is the probability that the target is validated by the C2 element. This includes the C2 element successfully evaluating the TOI against typical validating criteria (i.e. ROE, Commander's Intent, etc.) and the time needed to complete the task. Computer issues (in the C2 element) that may affect the success of this task must be taken into consideration as well as the line of command that this information must proceed through before a decision can be made (10, 112).

GPA PSM Fix Segment

The Fix segment of the GPA PSM (see Figure B.5 below) addresses the sequenced actions and decisions required to determine whether or not a given target meets the validation criteria to be considered a properly characterized target. The first two activities are considered to operate in parallel for *P(s)* evaluation. A validated target can possess sufficient information to obtain Combat ID (CID) or have targetable coordinates that will not require CID. The Combat ID TOI activity node is the probability that the C2 element has sufficient information to obtain CID considering ROE, target types, and sensors available. Targetable Coordinates is the probability that sufficient information, systems, and training are available to derive actionable coordinates and elevation. Success in either of these activities allows for the continuation of the sequencing logic to the Attain Sufficient Fidelity Data to Characterize TOI decision node.

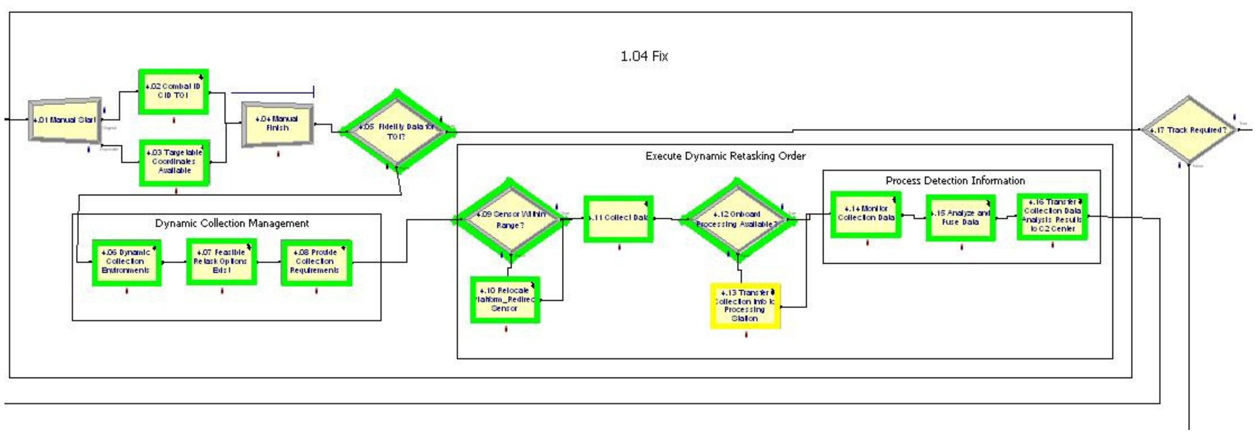

Figure B.5. GPA PSM Fix Segment

Evaluation node 4.04 is the probability that the target meets validation criteria to be considered a characterized target. The success of this node is based on the combination of the *P(s)* in nodes 4.02 and 4.03 evaluated in parallel. If the resulting *P(s)* value for this node equals or exceeds a specific value (0.95 nominal value for this research project), this node is evaluated as "yes" and the sequencing logic continues to the Track Required decision node. Otherwise, the sequencing logic proceeds to the Dynamic Collection Management, Retasking, and Processing sequence outlined.

The Dynamic Collection Management activity addresses the probability that an appropriate sensor can be tasked to collect the required information in a timely manner. This probability is captured through the determination of collection requirements, feasibility of retasking options, and providing collection requirements. The Determine Collection Requirements activity consists of the probability that the data collection requirements are properly defined within the time constraints dictated by mission requirements. The Feasible Retask Options Exist node consists of the probability that a sensor can be feasibly retasked to collect the required information taking into account the available assets and expected demand each asset must meet. The Provide Collection Requirements node is the probability that the controlling authority for collection assets successfully receives the collection requests as outlined in the OV-5.

All nodes within the Execute Dynamic Retasking Order sequence except the first decision node have previously been discussed and should be evaluated with extra consideration for the relevant time constraints based upon the location in the GPA sequencing process for these operations. The Sensor within Range decision node is the only node not previously discussed and addresses the probability that an appropriate sensor is within range to perform the retasking functions.

GPA PSM Track Segment

The Track Required decision node prior to entering the GPA PSM Track Segment (see Figure B.6 below) is the probability that the target requires tracking. This is particularly important for High Value Targets that are mobile. The *P(s)* PDF for this node should account for the number of fixed targets versus mobile/fleeting target types in order to place the required emphasis on the tracking segment for this risk analysis process. The PDF for this node should vary based upon the scenario and adversary capabilities.

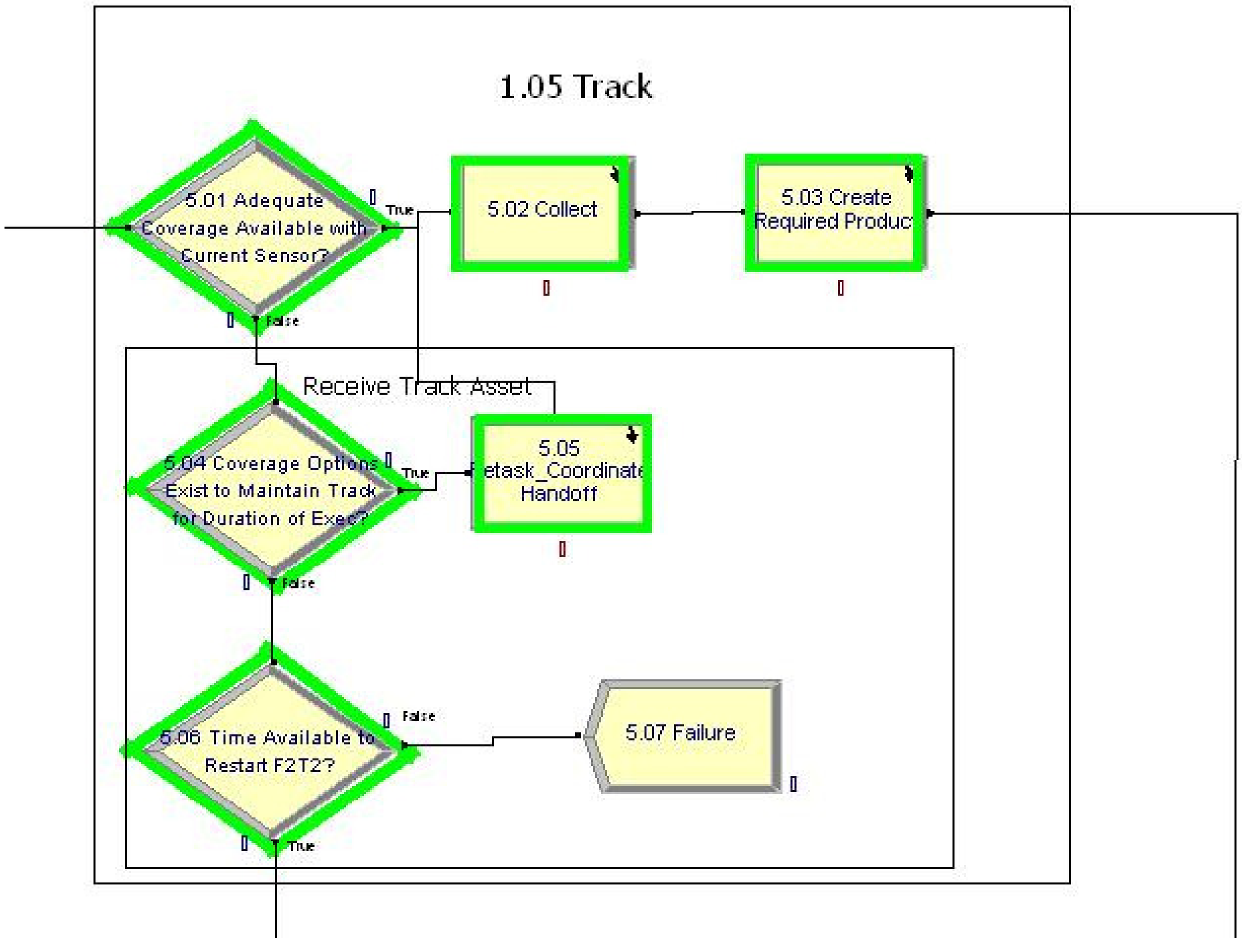

Figure B.6: GPA PSM Track Segment

The first decision node within the track segment answers the question as to whether or not adequate coverage is available with current sensors to adequately track the target. If so, the process sequence continues to the collect activity that has previously been discussed. If not, the sequence logic addresses the probability that an appropriate track asset is available and assigned in a timely manner to collect the required track information. The first decision node within Receive Track Asset addresses the probability as to whether or not another collection asset is available for retasking that could provide the desired collection requirements. If so, the Retask / Coordinate Handoff activity is accomplished. The PDF for this activity addresses the probability that a successful handoff occurs. If another asset is not available for retasking, the decision node Time Available to Restart F2T2 determines whether or not the mission continues by looping back to the find segment or is terminated. The *P(s)* for this node should provide a reasonable estimate of the number of expected time-critical targets requiring tracking in the scenario versus the number of targets that are not time-critical or do not require tracking such as fixed targets.

The Create Required Product node that completes the tracking segment consists of the probability that a usable product is created from the collected data. This PDF should consider the time, processes, and systems used within the Perform Intelligence Functions OV-5 activity to produce and disseminate an intelligence product deemed timely and usable by the customer (C2 and/or warfighter).

GPA PSM Target Segment

The Perform Collateral Damage Estimate (CDE) section within the Target segment (see Figure B.7 below) is addresses the probability that the C2 element is able to estimate the collateral damage necessary to engage the target. This segment is expanded to more detailed nodes 6.02 through 6.11. The PDFs associated with each of the nodes within the Perform CDE section needs to consider target characteristics (mobile, fixed, CCD, etc.), environment (weather, urban, rural, etc.), and force application asset capabilities.

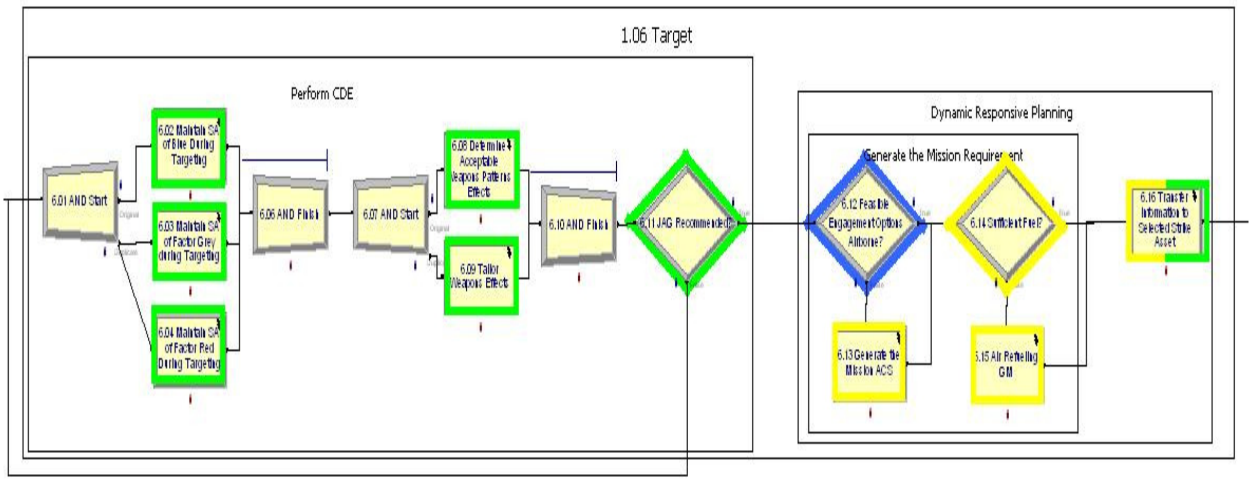

Figure B.7. GPA PSM Target Segment

The Maintain Situational Awareness (S/A) of Blue, Factor Grey, and Factor Red During Targeting nodes are executed simultaneously; however, the *P(s)* PDFs are evaluated in serial. In other words, each of the nodes must be successful in order to continue with the targeting process. The *P(s)* PDFs for each node represent the probabilities that the C2 element is able to maintain the required level of S/A on the respective blue, factor grey, and factor red forces to ensure CD is acceptable in accordance with ROE.

The Determine Acceptable Weapons Pattern Effects and Tailor Weapons Effects nodes are also evaluated in serial although they are graphically represented in parallel. Again, the parallel presentation merely demonstrates that both processes are occurring simultaneously, but both must be successful to continue the targeting process. The Determine Acceptable Weapons Pattern Effects node addresses the probability that accurate weapons effect patterns can be determined within acceptable CD limits. The Tailor Weapons Effects is the probability that weapons effects can meet target requirements also considering acceptable CD limits. Considerations for the developed PDFs must include capabilities to vary fusing and yield as well as flexibility in weapons selections. The Jag Recommended decision node addresses the legal requirements associated with the targeting process.

The Dynamic/Responsive Planning section within the Target segment consists of the Generate the Mission Requirements subsection combined with the Transfer Target Information to Selected Strike Asset node. The Generate the Mission Requirements subsection is the probability that the engagement option selected can be generated in a timely manner. This section is expanded to more detail beginning with the Feasible Engagement Options Airborne decision node which represents the probability that an airborne option is available that meets the mission requirements for weapons, CD, and timeliness. Considerations for this node include the availability and accuracy of necessary data to make the decision and the availability of strike assets and required support assets. If this node is successful, the process continues to the Sufficient Fuel node previously discussed in the Generate the Mission section. If an airborne option is not available, the process branches to the Generate the Engagement Mission activity node. The CRRA process evaluates this node through a separate PSM provided by the ACS for airborne assets, C4ISR and GM. This node represents the ability of the mission generation process to meet the mission requirements (10, 119). This node, however, can be given a *P(s)* PDF based upon SME judgment for generic force construct risk analysis.

The final activity node within the Target segment of the GPA PSM is the Transfer Target Information to Selected Strike Asset node which is the probability that the C2 element is able to successfully transmit the required target information to the selected asset. This evaluation considers restrictions associated with the Net-Centric Infrastructure enabling capabilities such as bandwidth and other communication limitations. The availability of the GIG to required assets via the Link or other means is an important factor in determining the *P(s)* PDF for this node.

GPA PSM Engage Segment

The Engage segment (see Figure B.8 below) begins with the Avoid / Defeat Detection decision node which consists of the probability that the asset will not have to take evasive maneuvers for self protection from adversary threat systems. The *P(s)* PDF is scenario dependent and accounts for threats, ingress routing, asset stealthiness, on-board defensive systems, off-board jamming support, etc. Both Air-to-Air and Surface-to-Air threats must be considered. For high level analysis of campaign operations, fighter sweep and escort support operations must also be considered along with electronic warfare operations. For high threat scenarios using advanced air defense systems, the associated PDF for this node should be lower than that of a scenario implementing older technologies. The selected PDF, however, should be adjusted to be representative of acquired capabilities to counter the more advanced threat systems when used to analyze the risks associated with future force constructs.

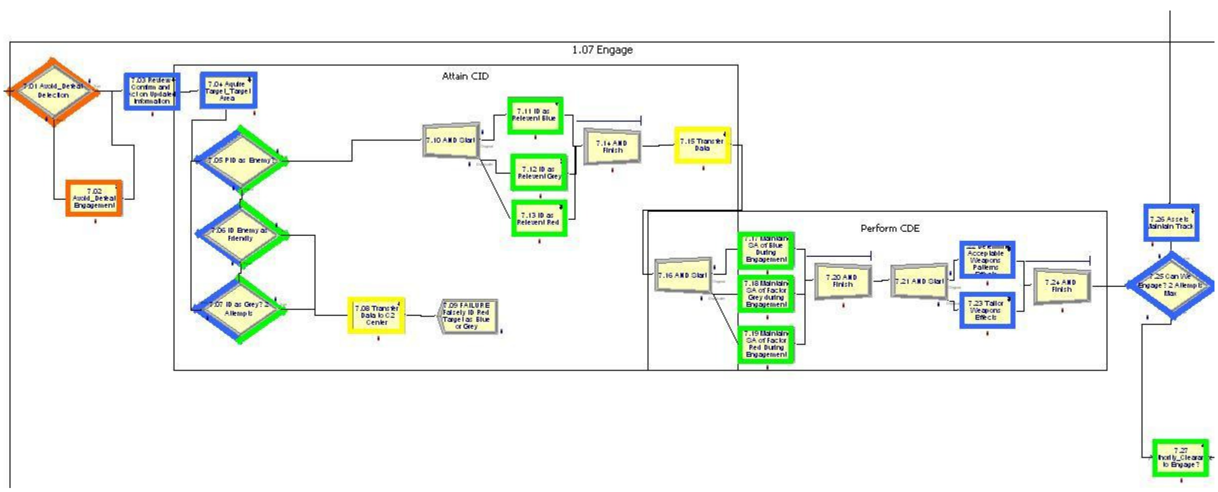

Figure B.8. GPA PSM Engage Segment

If it is determined that the asset will not have to take evasive maneuvers to defeat threat systems, the sequencing logic steps to the Review, Confirm, and Act on Updated Information activity. This activity represents the probability that the asset is able to review, confirm, and act on updated information and guidance with respect to target characteristics, ROE, LOAC, etc. This node does not include CDE and CID which are evaluated separately. If it is determined that the asset will have to take evasive maneuvers, the sequencing logic steps to the Avoid/Defeat Enemy Engagement activity which consists of the probability that the asset will be able to successfully avoid or defeat enemy engagement. The *P(s)* PDF for this node is also scenario dependant and heavily reliant on the tactics, stealthiness, and jamming capabilities inherent with the strike asset and support package. The aggressiveness and competency of adversary forces also significantly influence the *P(s)* of this node.

The Acquire Target activity node is the probability the asset is successful in acquiring the target and should consider target characteristics, environment, and asset capabilities. Target characteristics such as mobility and CCD techniques would reduce the *P(s)* associated with this node if insufficient capabilities are available to counter them. Also, environmental conditions consisting of weather as well as urban versus rural target locations are major factors for developing a PDF representative of the capabilities associated with this node.

The PID as Enemy decision node is the probability that the target can be positively identified as an emitting or non-emitting enemy in accordance with ROE constraints. The *P(s)* PDF for this node includes considerations for the full spectrum of target types and can be refined based upon specific scenarios. For example, a specific scenario that employs weapons against target coordinates may not require PID if the target has previously been confirmed as a valid target. This node includes both air-to-air and air-to-surface engagement options and must be evaluated with respect to all available capabilities for PID. A high level campaign analysis needs to consider the full spectrum of engagement options and associated requirements, air-to-air and air-to-surface. This node includes autonomous ID capabilities if dictated by the scenario.

If PID as Enemy is successful, the sequencing logic proceeds to the ID as Relevant Blue, Grey, and Red activities performed simultaneously to enhance battlespace situational awareness. The probabilities associated with these activities address the capabilities to actively or passively identify and track all relevant blue, grey, and red forces for situational awareness and fratricide reduction. The capabilities include utilizing off-board systems to perform ID and transmitting the information to the shooter including the integration of capability into systems and multi-source correlation of information to mitigate associated risks (fratricide, etc).

If PID as Enemy results is a false output, the sequencing logic steps to the ID as Friendly decision node which is defined as the probability of falsely identifying an enemy target as friendly. Again, the PDF for this node must consider all capabilities used to PID targets along with the associated limitations to include possible ambiguities. If this node is determined to be false, the next decision node consists of the probability of falsely identifying an enemy target as grey using the same considerations. If either of the ID as Friendly or ID as Grey decision nodes is determined to be true, the resulting information is transferred to the C2 center and the PSM fails. If the ID as Grey decision node is false, the identification process is repeated as required. The CRRA process limits this ID loop to a maximum of two attempts (10, 122).

Assuming the PID as Enemy decision node is true and the following CID process is successful, the Transfer Data activity is executed. The *P(s)* PDF for this node is defined as the probability that the appropriate data is sent and received to the force application platform in order to make informed shoot/no-shoot decisions. For a limited scenario analysis where the ID process is accomplished autonomously, the *P(s)* for this node should be 1.0; otherwise, the *P(s)* PDF should be representative of the conglomeration of scenarios in which PID would be required.

Following the CID process, the PSM logic repeats the CDE process previously discussed. The next decision node, Can We Engage, is the probability that an engagement is possible given the target characteristics. Assuming CDE is acceptable, the probability of this node addresses target engagement limitations due to target motion, etc. In other works, the selected strike asset may not have the capabilities to engage a moving target and must therefore continue to track the target until it has stopped. Considerations for this node include scenarios in which a mobile target that is being tracked is not able to be engaged while in motion and subsequently maneuvers to an area where CDE is no longer met. In this case, the PSM fails.

The last activity node within the Engage segment is the Authority/Clearance to Engage activity which consists of the probability that a clearance to engage the target is successfully understood, processed, and acted upon. The PDF associated with this node is extremely dependent upon the communication network within the C2 structure.

GPA PSM Deliver Segment

The Deliver segment (see Figure B.9 below) of the GPA PSM addresses the probability that the kinetic or non-kinetic means of achieving the desired effects is successfully employed and the target is adequately neutralized. The Employ Weapon node is divided into the probability that the weapon is successfully released and the probability that it is guided to the correct target. These nodes do not address the effects of the weapon, which are addressed later.

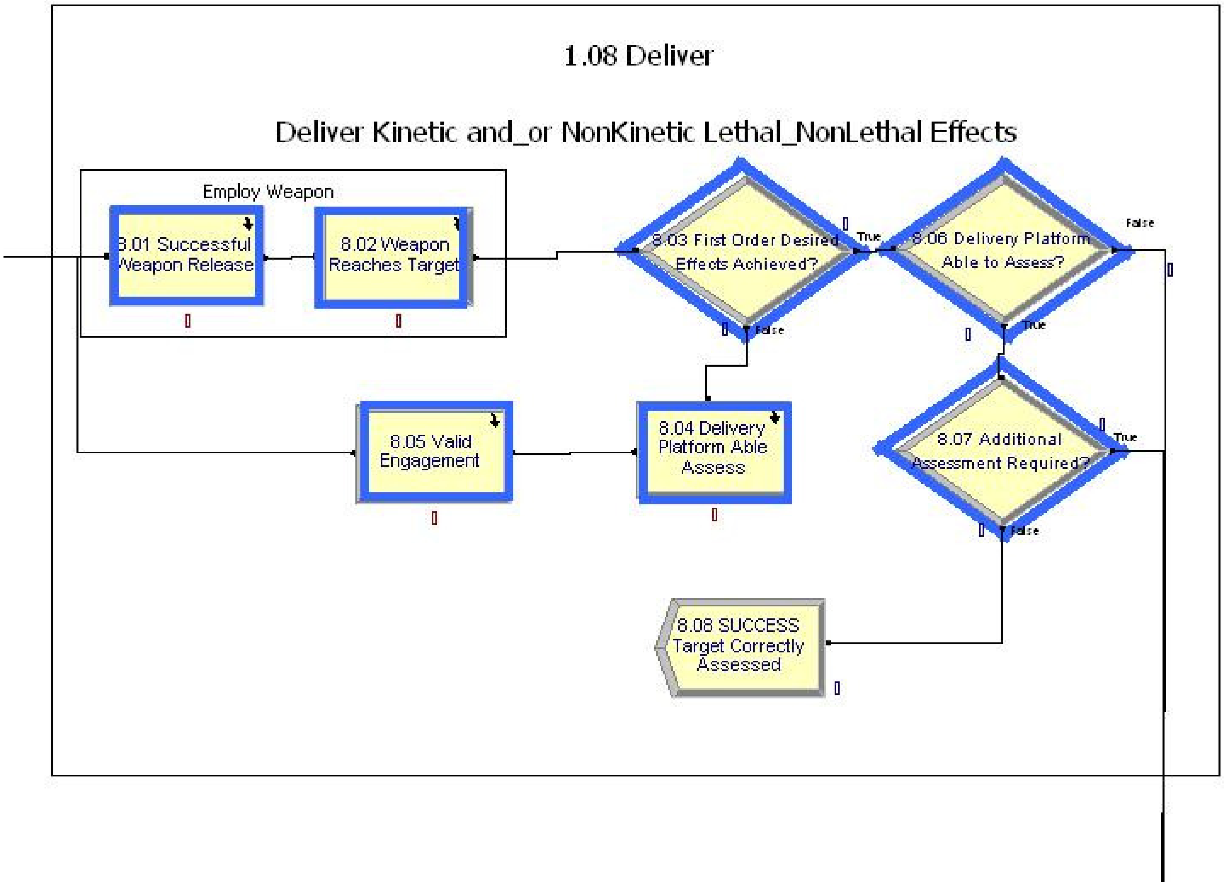

Figure B.9. GPA PSM Deliver Segment

The Successful Weapon Release node is the probability that the weapon is successfully released considering mechanical reliability, threat, target type, weather, and aircrew workload within the scenario. Sources for developing the PDFs for this node include JMEM/JWS and Air-to-Ground Weapon System Evaluation Program (A/G WSEP) data. The Weapon Reaches Target node specifically addresses the probability that the weapon successfully reaches the intended target. Again, reliable sources for developing this PDF include JMEM/JWS and A/G WSEP data.

The decision node First Order Desired Effects Achieved consists of the probability that the weapon achieves the desired first order weapon effects assuming the weapon was successful in reaching the intended target. This node also assumes that weaponeering was accomplished correctly based upon previous nodes. This node should take into account weapon fuze reliability with respect to mission package versus single ship operations. Evaluating this node should consider mission planning and weaponeering considerations that typically dictate multiple weapons per target to offset fuze reliability concerns. In other words, the *P(s)* PDF should not be purely based upon single fuze reliability data, but should represent the increased reliability based upon multiple weapons and fuzing techniques designed to increase the *P(s)* JMEM/JWS should be used whenever possible.

If the first order desired effects are not achieved, the process sequence logic allows a re-attack loop if the strike asset is able to autonomously asset that the desired effects were not achieved. As a result, the next activity node, Delivery Platform Able to Assess, is the probability that the strike asset is able to autonomously assess the weapons effects. If this activity is successful, the logic steps to the Valid Engagement node which is the probability that the engagement is still valid for re-attack considering the threats, fuel, payload, target type, etc. If a re-attack option exists, the logic repeats the Employ Weapon process.

Assuming that the first order desired effects are achieved, the next decision node, Delivery Platform Able to Assess, represents the probability that the strike asset is able to autonomously assess the weapons effects real time and successfully communicate that information to the C2 element. This node must consider the myriad of engagement tactics and capabilities to include large standoff ranges. Some target sets such as HVTs within heavily defended operational areas require significantly larger standoff ranges for strike asset survivability dictating the requirement for National level effects assessment. A high level campaign analysis should consider the number of HVTs requiring standoff capabilities during the initial phases of the conflict versus the number of close range tactical engagement operations during the following persistent force application period that allow for strike asset assessment. This proportionality should be represented in the applied *P(s)* PDF. If this node is false, the PSM sequence continues to the Assess segment. If this node is true, the next decision node, Additional Assessment Required, determines whether or not the strike asset BDA consists of sufficient fidelity to meet requirements. Again, if this node is false, the PSM sequence continues to the Assess segment. If the node is true, the PSM successfully terminates.

GPA PSM Assess Segment

The last segment of the GPA PSM, Assess Segment (see Figure B.10 below), begins with the Is the Target a HVT / TST decision node. This node consists of the percentage of the time the target meets HVT / TST requirements to warrant immediate collection (10, 130). Again, campaign analysis should consider the percentage of targets listed on the HVT list versus the number of expected targets within the campaign operations. If this node is assessed as false, the next activity, Task Sensor, addresses the probability that an appropriate sensor can be tasked in a timely manner to collect the required information given defined collection requirements (10, 130). If, however, the target meets HVT / TST requirements, the next decision node addresses the probability that adequate coverage is available with current sensors. This *P(s)* PDF should consider the percentage of time the assets most likely to achieve “Fix” for the various types of targets within the scenario will be in position during the deliver and assess phases to collect the required information. If the current sensor is capable collecting the required information, the process continues to Collect Data.

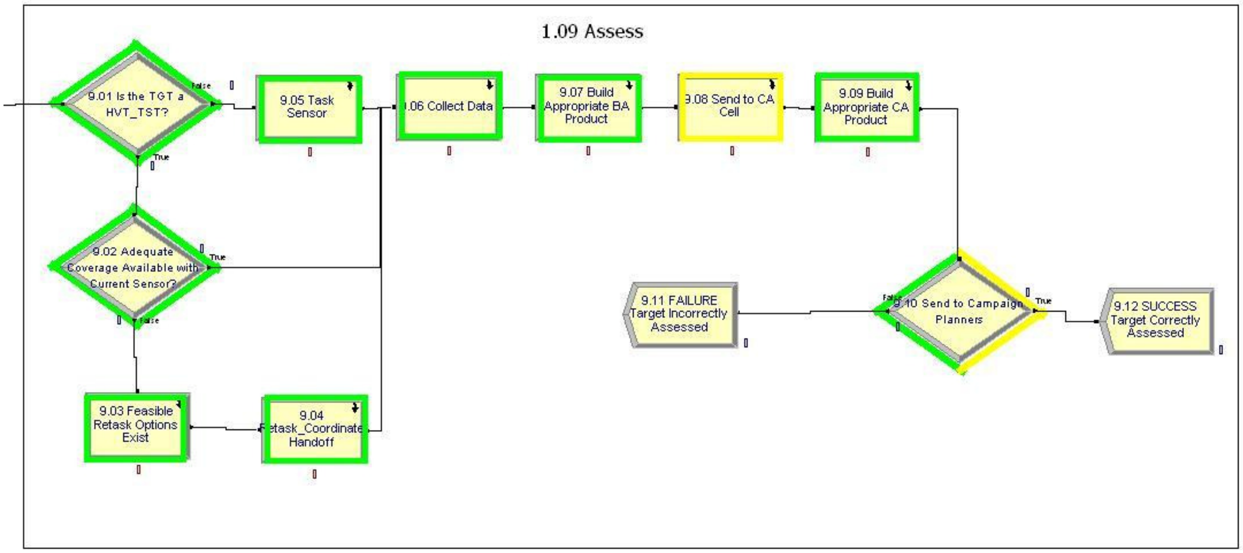

Figure B.10. GPA PSM Assess Segment

If the current sensor does not have adequate coverage to collect the required information, the next activity node, Feasible Re-task Options Exist, addresses the probability that a sensor re-task option exists that can fulfill the particular collection request considering the total demands the available collection assets must meet. If a sensor is available for re-tasking, the Re-task/Coordinate Handoff activity addresses the probability that the collection asset successfully receives the re-tasking information necessary to accomplish the collection requirements. This node captures the ability of the C2 element to manage collection assets (10, 130).

The Collect Data activity node is the probability the collection asset is able to collect the required data to support combat assessment with sufficient fidelity. The Build Appropriate Battlespace Awareness (BA) product consists of the probability that a useful product can be created from the collected data to support combat assessment. The Send to Combat Assessment Cell is the probability that the appropriate Combat Assessment Cell receives the assessment products and measures the effectiveness of the communication network within the Battlespace Awareness Dominance functions outlined in the OV-5. The Build Appropriate Combat

Assessment (CA) product captures the ability of the Intelligence element to produce assessments adequate for use in the decision process by decision makers. Finally, the Send to Campaign Planners decision node addresses the probability that the Intelligence dissemination process and communication networks can successfully send the CA products to the appropriate decision makers at all levels to include tactical, operational, and strategic.

The general scope and operational division of this PSM construct using the F2T2EA format facilitates application to various levels of analysis. As demonstrated by this research project, this PSM can be utilized for high level force construct risk analysis. On the other hand, the PSM can be applied to a much lower level of abstraction for conducting risk analysis for specific scenarios and missions. The following table (Table B.1) provides a quick reference for nodal descriptions.

GPA Process Sequence Model		
Node	**Name**	**Description**
1.02	IPB and TD	The probability that pre-conflict and on-going IPB and TD are adequate to support timely operations within scenario context in order to allow for rapid transition of intelligence into executable targets.
1.03	Commander's Intent	The development of a concise expression of the purpose of the operation and the desired end state that serves as the initial impetus for the planning process.
1.04	COA Development	The probability that COAs are developed in a timely manner to support operations.
1.05	COA Selection	The probability that a COA is selected in order to accomplish the mission.
1.06	Execution Orders	The probability that an EXORD is transmitted and received by the C2 element.
1.07	Conduct Ops Planning	The probability that the ATO and theater collection plan are produced, transmitted and received.
2.01	Airborne Engagement Option Available?	The probability that there is an airborne option available that meets the needs of the mission (weapons requirements, CD restrictions, timeliness etc.) and can be tasked in a timely manner.
2.02	Generate the Mission ACS	The ability of the sortie generation process to support the engagement requirement for this target.
2.03	Mission Planning	The probability that the mission is planned and coordinated.
2.04	Launch	The probability that the aircraft starts, taxis and takes off.
2.05	Enroute Ops	The probability that the strike asset transitions from takeoff to FENCE-IN and is capable of continuing the mission to the target.
2.05	Personnel Recovery	
2.06	Sufficient Fuel	This node determines the likelihood that the engagement asset selected must refuel before it can engage the target.
2.07	Air Refueling GM	The probability that the A/C successfully and sufficiently receives air refueling.
2.08	Is BA Adequate?	The probability that sufficient information has been previously collected and analyzed in order to Track this TOI.
3.01	Collection Asset Available?	Probability that a collection asset is available and capable of desired collection (negating need to generate a new mission).

3.02	Generate the Mission ACS	The ability of the mission generation process to support the collection requirement for this TOI. This includes the time it takes to generate the mission that is designated to Find this target.
3.03	Position Collection Asset at Position Location	The probability that the collection asset can successfully get into position to collect on the TOI.
3.04	Collect Data	The probability that the collection asset collects data to locate the TOI.
3.05	Onboard Processing Available?	This is a branch node that differentiates between sensors/sources that can process their data Near Real Time onboard and sensors/sources that must send their data to a processing station.
3.06	Transfer Collection Info to Processing Station	The probability that collection data is successfully transmitted to an appropriate processing station and received.
3.07	Monitor Collection Data	The probability that analysts processes and exploits the incoming collection data on the TOI in a timely manner.
3.08	Analyze and Fuse Data	The probability that the collection data is accurately correlated/fused/integrated etc. with other information sources to produce a TOI in a timely manner.
3.09	Transfer Collection Data Analysis Results to C2 Element	The probability that the TOI information is transmitted and received by the appropriate C2 element or warfighter.
3.10	TOI Validated	The probability that the TOI is validated by the C2 element.
4.02	Combat ID CID TOI	The probability that the C2 element has sufficient information to obtain CID.
4.03	Targetable Coordinates Available	The probability that the C2 element can attain targetable coordinates.
4.05	Fidelity Data for TOI?	The probability that this TOI meets the validation criteria necessary to be considered a characterized target, given PID, CID and mensurated coordinates all of sufficient fidelity.
4.06	Dynamic Collection Requirements	The probability that data collection requirements are defined.
4.07	Feasible Retask Options Exist	The probability, given that the particular collection request is successfully assessed and compared to all other requests to determine that a feasible retask sensor option exists for this TOI.
4.08	Provide Collection Requirements	The probability that the collection authority successfully receives the collection requests.
4.09	Sensor Within Range?	The probability that an appropriate sensor is within range to perform this retask.
4.10	Relocate Platform_Redirect Sensor	The probability that the collection asset is successfully able to relocate to the position needed or redirect its field of view to satisfy this retasking request.

4.11	Collect Data	The probability that the collection asset collects data to CID the TOI.
4.12	Onboard Processing Available?	The probability that the sensor can autonomously process the collected data to provide actionable and timely information.
4.13	Transfer Collection Info to Processing Station	The probability that collection data is successfully transmitted to an appropriate processing station and received.
4.14	Monitor Collection Data	The probability that analysts processes and exploits the incoming collection data on the TOI in a timely manner.
4.15	Analyze and Fuse Data	The probability that the collection data is accurately correlated/fused/integrated etc. with other information sources to produce a TOI in a timely manner.
4.16	Transfer Collection Data Analysis Results to C2 Center	The probability that the TOI information is transmitted and received by the appropriate C2 element or warfighter.
4.17	Track Required?	The probability that the target requires tracking.
5.01	Adequate Coverage Available With Current Sensor?	The probability that the asset that fixed the target is able to continuously track the TOI.
5.02	Collect	The probability that the collection asset collects data to track the TOI.
5.03	Create Required Product	The probability that the product is created from collected data to track the TOI.
5.04	Coverage Options Exist to Maintain Track for Duration of Exec?	Probability that a collection asset is available and capable of desired collection (negating need to generate a new mission).
5.05	Retask/Coordinate Handoff	The probability that the handoff occurs.
5.06	Time Available to Restart F2T2?	The probability that there is time to restart F2T2 when TOI tracking is lost.
5.08	Transfer Data Analysis to C2 Center	The probability that the TOI information is transmitted and received by the appropriate C2 element or warfighter.
6.02	Maintain SA of Blue During Targeting	Probability that the C2 element maintains S/A on Blue, real time, during targeting to ensure CD is acceptable and meets ROE.
6.03	Maintain SA of Factor Grey during Targeting	Probability that S/A is maintained on Grey, real time, during targeting to ensure CD is acceptable and meets ROE.
6.04	Maintain SA of Factor Red During Targeting	Probability that S/A is maintained on Red, real time, during targeting to ensure CD is acceptable and meets ROE.
6.08	Determine Acceptable Weapons Patterns Affects	The probability that accurate weapons effect patterns can be determined within acceptable collateral damage.

6.09	Tailor Weapons Effects	The probability that weapons effects can be tailored to meet target requirements while considering acceptable collateral damage.
6.11	JAG Recommended?	The probability that the target planning meets legal requirements.
6.12	Feasible Engagement Options Exist?	The probability that there is an airborne option available that meets the needs of the mission (weapons requirements, CD restrictions, timeliness etc.) and can be tasked in a timely manner.
6.13	Generate the Mission ACS	The ability of the mission generation process to support the collection requirement for this TOI. This includes the time it takes to generate the mission that is designated to Find this target.
6.14	Sufficient Fuel?	This node determines the likelihood that the engagement asset selected must refuel before it can engage the target.
6.15	Air Refueling GM	The probability that the A/C successfully and sufficiently receives air refueling.
6.16	Transfer Information to Selected Strike Asset	The probability that the C2 element is able to successfully send the required target information on the TOI to the selected asset, and that the asset successfully receives the information.
7.01	Ability to Avoid/Defeat Detection	The probability that the platform, even if detected by any available means, will not have to take evasive maneuvers to self protect.
7.02	Avoid/Defeat Engagement	The probability that the platform, when detected by any available means, is able to successfully avoid or defeat enemy engagement.
7.03	Review Confirm and Act on Updated Information	The probability that the asset is able to review, confirm, and act on updated information and guidance.
7.04	Aquire Target/Target Area	The probability that the asset is successful in acquiring the target/target area.
7.05	PID as Enemy	The probability of positively identifying emitting or non-emitting TOI as enemy.
7.11	ID Relevent Blue	The probability of actively or passively identifying and tracking blue forces for the purpose of enhanced battlespace situational awareness and reduced fratricide.
7.12	ID as Relevent Grey	The probability of actively or passively identifying and tracking grey forces for the purpose of enhanced battlespace situational awareness and reduced fratricide.
7.13	ID as Relevent Red	The probability of actively or passively identifying and tracking red forces for the purpose of enhanced battlespace situational awareness and reduced fratricide.

7.15	Transfer Data	The probability that the appropriate data is sent and received to the FA platform in order to make informed shoot/no-shoot decisions.
7.17	Maintain SA of Blue During Engagement	Probability that the strike asset maintains S/A on Blue, real time, during engagement to ensure CD is acceptable and meets ROE.
7.18	Maintain SA of Factor Grey During Engagement	Probability that the strike asset maintains S/A on Grey, real time, during engagement to ensure CD is acceptable and meets ROE.
7.19	Maintain SA of Factor Red During Engagement	Probability that the strike asset maintains S/A on Red, real time, during engagement to ensure CD is acceptable and meets ROE.
7.22	Determine Acceptable Weapons Patterns Effects	The probability that accurate weapons effect patterns can be determined prior to release within acceptable CDE parameters.
7.23	Tailor Weapons Effects	The probability that weapons effects can be tailored to meet target requirements while considering acceptable collateral damage within a real time/near real time dynamic environment.
7.25	Can We Engage?	The probability that the engagement is possible. This node is intended to capture the difference in procedure, success, and timeliness.
7.26	Assets Maintain Track	The probability that the current FA asset is able to maintain track on the target until it either stops or is in a location where the CDE restrictions are lifted. The process does not move forward until one of these two conditions are fulfilled
7.27	Authority/Clearance to Engage?	The probability that a clearance to engage the target is successfully understood, processed, and acted upon.
8.01	Successful Weapon Release	The probability that the weapon is released successfully (comes off/out of the platform). A part of the score is mechanical reliability, but this node also takes into account other variables such as threat, target type, weather, etc as defined in the scenario in order to consider pilot workload for the overall probability.
8.02	Weapon Reaches Target	The probability that the weapon successfully reaches its target (no interruptions). This node includes acquisition and guidance of data link, survivability of passive/active enemy actions, weather etc..
8.03	First Order Effects Achieved?	The probability that the weapon used against the target achieves the desired first order weapon effects as intended.
8.04	Delivery Platform Able Assess	The probability that the strike asset is able to autonomously assess desired weapon effects real time.
8.05	Valid Engagement	The probability that the engagement is still valid for reattack. Considerations should include threats, fuel, payload, target type etc.

8.06	Can delivery Platform Assess?	The probability that the strike asset is able to autonomously assess desired weapon effects real time.
8.07	Additional Assessment Required?	The probability that National level assessment is still required, even though the strike asset is capable of real-time BDA, but additional data is needed.
8.08	Target Correctly Assessed	This is a termination node that is not scored. All TOI that end here have been correctly assessed, and have completed the kill chain. This could include targets that are correctly assessed as having not achieved the desired weapons effects, but have still completed the kill chain.
9.01	Is the TGT a HVT_TST?	The Percentage of the time the target meets HVT/TST requirements to warrant immediate collection.
9.02	Adequate Coverage Available with Current Sensor?	The percentage of the time the asset, that fixed the target, is able to continuously track the TOI.
9.03	Feasible Retask Options Exist	The probability, given that the particular collection request is successfully assessed and compared to all other requests to determine that a feasible retask sensor option exists for this TOI.
9.04	Retask/Coordinate Handoff	The probability that the handoff occurs.
9.05	Task Sensor	The probability that data collection requirements are defined and an appropriate sensor can be tasked against the TOI in a timely manner.
9.06	Collect Data	The probability that the collection asset collects data to support combat assessment at all levels.
9.07	Build Appropriate BA Product	The probability that the product is created from collected data to support combat assessment.
9.08	Send to CA Cell	The probability that the appropriate Combat Assessment Cell receives the Battlespace Awareness products.
9.09	Build Appropriate CA Product	The probability that Combat Assessment products are adequate to inform decision makers at all levels.
9.10	Target Correctly Assessed	This is a termination node that is not scored. All TOI that end here have been correctly assessed, and have completed the kill chain. This could include targets that are correctly assessed as having not achieved the desired weapons effects, but have still completed the kill chain.
* Probability descriptions taken from CRRA 2007 PSMs.		

Table B.1. PSM Nodal Descriptions

Appendix C. OV-5 to PSM Traceability Matrix

OV-5 to PSM Traceability Matrix		PSM Nodes	Plan						Generate										Find									
OV-5 Operational Activities			2.02 IPB and TD	2.03 Commanders Intent	2.04 COA Development	2.05 COA Selection	2.06 Execution Orders	2.07 Conduct Ops Planning	3.01 Airborne Engagement Option Available?	3.02 Generate the Mission ACS	3.03 Mission Planning	3.04 Launch	3.05 Enroute Ops	3.05a No personnel Recovery Needed?	3.05b Personnel Recovery	3.06 Sufficient Fuel?	3.07 Air Refueling GM	3.08 Current BA Adequate?	4.01 Collection Asset Available?	4.02 Generate the Mission ACS	4.03 Position Collection Asset at Position Location	4.04 Collect Data	4.05 Onboard Processing Available?	4.06 Transfer Collection Info to Collection Station	4.07 TCI Validated	5.02 Monitor Collection Data	5.03 Analyze and Fuse Data	5.04 Transfer Collection Data Analysis Results to C2 Element
Battlespace Awareness Dominance	C2	Monitor and collect data	x																			x	x	x		x		x
		Understanding the situation	x						x					x		x		x	x						x		x	
		Develop and select COA		x	x	x															x				x			
		Develop a plan			x						x																	
		Execute a plan					x					x	x															
		Monitor and adapt as necessary		x				x							x	x									x	x	x	
	Intel	Plan Intelligence Collection Requirements	x			x		x													x							
		Gather Intelligence Data	x				x	x													x	x						
		Process and Exploit	x																								x	
		Produce Intelligence Assessment	x																						x		x	
		Disseminate Intelligence Assessment		x	x																							x
	SR	Surveill and Reconnoiter Environmental Conditions	x																		x	x						
		Surveill and Reconnoiter the Information Environment																			x	x						
		Characterize Friendly, Adversary, and Non-Aligned Forces																									x	
		Provide Reflexive and Adaptive Surveillance and Reconnaissance																			x	x			x			x
Information & Cyberspace Dominance	Electronic Warfare	Electronic Attack																										
		Electronic Protection																			x			x				x
		Electronic Warfare																										
	Network Warfare	Network Attack																										
		Network Defense						x																x				x
		Network Warfare Support						x																x				x
	Influence Operations	Counterpropaganda		x				x			x																	
		Psychological Operations		x				x			x																	
		Military Deception		x				x			x																	
		Operations Security		x				x			x																	
		CounterIntelligence Operations		x				x			x																	
		Public Affairs Operations		x				x			x																	
Air & Space Dominance	Air-to-Air Superiority																				x							
	Space Superiority	Space Deterrence	x																x		x	x				x		
		Space Defense	x																x		x					x		
		Space Recovery Operations	x																x		x							
		Counterspace Operations	x																x		x							
	Suppression of Enemy Air Defense																				x							
Surface Dominance	Close Controlled Strike										x	x	x															
	Intra-theater Strike										x	x	x															
	Long Range Strike										x	x	x															
	Special Operations										x	x	x															
Enabling Capabilities	Personnel Recovery														x													
	Nec-centric Infrastructure		x					x		x	x	x	x					x	x					x				x
	Responsive Space Operations																		x		x	x		x		x		x
	Airbase Opening									x										x								
	Agile Combat Support							x		x	x						x			x				x				x
	PNT									x	x	x	x				x			x	x	x						
	Global Mobility									x		x	x				x			x								

OV-5 to PSM Traceability Matrix

Track (with 10.04)

OV-5 Operational Activities			5.01 Adequate Coverage Available with Current Sensor?	5.02 Collect	5.03 Create Required Product	5.04 Coverage Options Exist to Maintain Track for Duration of Execution?	5.05 Retask_Coordinate Handoff	5.06 Time Available to Restart F2T2?	10.04 Transfer Data Analysis to C2 Center
Battlespace Awareness Dominance	C2	Monitor and collect data		X					X
		Understanding the situation	X			X		X	
		Develop and select COA	X				X	X	
		Develop a plan			X		X	X	
		Execute a plan					X	X	
		Monitor and adapt as necessary							
	Intel	Plan Intelligence Collection Requirements	X		X			X	
		Gather Intelligence Data		X					
		Process and Exploit							
		Produce Intelligence Assessment							
		Disseminate Intelligence Assessment							X
	SR	Surveill and Reconnoiter Environmental Conditions		X					
		Surveill and Reconnoiter the Information Environment		X					
		Characterize Friendly, Adversary, and Non-Aligned Forces							
		Provide Reflexive and Adaptive Surveillance and Reconnaissance		X					X
Information & Cyberspace Dominance	Electronic Warfare	Electronic Attack							
		Electronic Protection							
		Electronic Warfare							
	Network Warfare	Network Attack							
		Network Defense							X
		Network Warfare Support							X
	Influence Operations	Counterpropaganda							
		Psychological Operations							
		Military Deception							
		Operations Security							
		CounterIntelligence Operations							
		Public Affairs Operations							
Air & Space Dominance	Air-to-Air Superiority		X	X				X	
	Space Superiority	Space Deterrence							
		Space Defense							
		Space Recovery Operations							
		Counterspace Operations							
	Suppression of Enemy Air Defense		X	X				X	
Surface Dominance	Close Controlled Strike								
	Intra-theater Strike								
	Long Range Strike								
	Special Operations								
Enabling Capabilities	Personnel Recovery								
	Nec-centric Infrastructure		X			X	X	X	X
	Responsive Space Operations			X		X			X
	Airbase Opening								
	Agile Combat Support								X
	PNT			X		X			
	Global Mobility								

Target

OV-5 Operational Activities			6.02 Maintain SA of Blue During Targeting	6.03 Maintain SA of Factor Grey During Targeting	6.04 Maintain SA of Factor Red During Targeting	6.08 Determine Acceptable Weapons Patterns Effects	6.09 Tailor Weapons Effects	6.11 JAG recommened?	6.12 Feasible Engagement Options Airborne?	6.13 Generate the Mission ACS	6.14 Sufficient fuel?	6.15 Air Refueling GM	6.16 Transfer Information to Selected Strike Asset
Battlespace Awareness Dominance	C2	Monitor and collect data											X
		Understanding the situation	X	X	X	X		X	X		X		X
		Develop and select COA						X					
		Develop a plan				X	X						
		Execute a plan					X						
		Monitor and adapt as necessary						X	X				
	Intel	Plan Intelligence Collection Requirements											
		Gather Intelligence Data											
		Process and Exploit											
		Produce Intelligence Assessment											
		Disseminate Intelligence Assessment											X
	SR	Surveill and Reconnoiter Environmental Conditions											
		Surveill and Reconnoiter the Information Environment											
		Characterize Friendly, Adversary, and Non-Aligned Forces						X					
		Provide Reflexive and Adaptive Surveillance and Reconnaissance											
Information & Cyberspace Dominance	Electronic Warfare	Electronic Attack											
		Electronic Protection											
		Electronic Warfare											
	Network Warfare	Network Attack											
		Network Defense											X
		Network Warfare Support											
	Influence Operations	Counterpropaganda											
		Psychological Operations											
		Military Deception											
		Operations Security											
		CounterIntelligence Operations											
		Public Affairs Operations											
Air & Space Dominance	Air-to-Air Superiority		X	X	X				X				
	Space Superiority	Space Deterrence											
		Space Defense											
		Space Recovery Operations											
		Counterspace Operations											
	Suppression of Enemy Air Defense								X				
Surface Dominance	Close Controlled Strike												
	Intra-theater Strike												
	Long Range Strike												
	Special Operations												
Enabling Capabilities	Personnel Recovery												
	Nec-centric Infrastructure												X
	Responsive Space Operations												X
	Airbase Opening									X			
	Agile Combat Support									X	X	X	
	PNT		X	X	X	X	X			X		X	X
	Global Mobility									X		X	

Engage

OV-5 Operational Activities			7.01 Avoid_Defeat Detection?	7.03 Review Confirm and Act on Updated Information	7.04 Acquire Target_Target Area	7.05 PID as Enemy?	7.06 ID Enemy as Friendy?	7.07 ID as Grey?	7.08 Transfer Data to C2 Center	7.11 ID as Relevent Blue	7.12 ID as Relevent Grey	7.13 ID as Relevent Red	7.15 Transfer Data	7.17 Maintain SA of Blue During Engagement	7.18 Maintain SA of Grey During Engagement	7.19 Maintain SA of Red During Engagement	7.22 Determine Acceptable Weapon Pattern Effects	7.23 Tailor Weapons Effects	7.25 Assets maintain track	7.26 Can we engage?	7.27 Authority_Clearance to Engage?
Battlespace Awareness Dominance	C2	Monitor and collect data				X	X	X	X				X								
		Understanding the situation				X	X	X		X	X	X		X	X	X				X	X
		Develop and select COA																		X	X
		Develop a plan																			
		Execute a plan																			X
		Monitor and adapt as necessary																			
	Intel	Plan Intelligence Collection Requirements																			
		Gather Intelligence Data																			
		Process and Exploit																			
		Produce Intelligence Assessment																			
		Disseminate Intelligence Assessment							X				X								
	SR	Surveill and Reconnoiter Environmental Conditions																			
		Surveill and Reconnoiter the Information Environment																			
		Characterize Friendly, Adversary, and Non-Aligned Forces																			
		Provide Reflexive and Adaptive Surveillance and Reconnaissance							X				X								
Information & Cyberspace Dominance	Electronic Warfare	Electronic Attack	X																		
		Electronic Protection	X																		
		Electronic Warfare	X																		
	Network Warfare	Network Attack	X																		
		Network Defense							X				X								
		Network Warfare Support							X				X								
	Influence Operations	Counterpropaganda																			
		Psychological Operations																			
		Military Deception																			
		Operations Security																			
		CounterIntelligence Operations																			
		Public Affairs Operations																			
Air & Space Dominance	Air-to-Air Superiority		X		X	X	X	X		X	X	X		X	X	X			X		
	Space Superiority	Space Deterrence																			
		Space Defense																			
		Space Recovery Operations																			
		Counterspace Operations																			
	Suppression of Enemy Air Defense		X		X									X	X	X			X		
Surface Dominance	Close Controlled Strike			X	X												X	X	X		
	Intra-theater Strike			X	X												X	X	X		
	Long Range Strike			X	X												X	X	X		
	Special Operations			X	X												X	X	X		
Enabling Capabilities	Personnel Recovery																				
	Nec-centric Infrastructure			X					X				X								
	Responsive Space Operations																		X		
	Airbase Opening																				
	Agile Combat Support								X				X								
	PNT		X		X	X	X	X		X	X	X		X	X	X	X	X	X		
	Global Mobility																				

Deliver

OV-5 Operational Activities			8.01 Successful Weapon Release	8.02 Weapon Reaches Target	8.03 First Order Desired Effects Achieved?	8.04 Delivery Platform Able Assess	8.05 Valid Engagement	8.06 Delivery Platform Able to Assess?	8.07 Additional Assessment Required?
Battlespace Awareness Dominance	C2	Monitor and collect data						X	
		Understanding the situation			X				X
		Develop and select COA							
		Develop a plan							
		Execute a plan							
		Monitor and adapt as necessary							
	Intel	Plan Intelligence Collection Requirements							
		Gather Intelligence Data							
		Process and Exploit							
		Produce Intelligence Assessment							
		Disseminate Intelligence Assessment							
	SR	Surveill and Reconnoiter Environmental Conditions							
		Surveill and Reconnoiter the Information Environment							
		Characterize Friendly, Adversary, and Non-Aligned Forces							
		Provide Reflexive and Adaptive Surveillance and Reconnaissance							
Information & Cyberspace Dominance	Electronic Warfare	Electronic Attack							
		Electronic Protection							
		Electronic Warfare							
	Network Warfare	Network Attack							
		Network Defense							
		Network Warfare Support							
	Influence Operations	Counterpropaganda							
		Psychological Operations							
		Military Deception							
		Operations Security							
		CounterIntelligence Operations							
		Public Affairs Operations							
Air & Space Dominance	Air-to-Air Superiority					X			
	Space Superiority	Space Deterrence							
		Space Defense							
		Space Recovery Operations							
		Counterspace Operations							
	Suppression of Enemy Air Defense					X			
Surface Dominance	Close Controlled Strike		X	X		X	X		
	Intra-theater Strike		X	X		X	X		
	Long Range Strike		X	X		X	X		
	Special Operations		X	X		X	X		
Enabling Capabilities	Personnel Recovery								
	Nec-centric Infrastructure								
	Responsive Space Operations								
	Airbase Opening								
	Agile Combat Support								
	PNT		X	X		X	X	X	
	Global Mobility								

Assess

OV-5 Operational Activities			9.01 Is the TGT a HVT_TST?	9.02 Adequate Coverage Available with Current Sensor?	9.03 Feasible Retask Options Exist	9.04 Retask_Coordinate Handoff	9.05 Task Sensor	9.06 Collect Data	9.07 Build Appropriate BA Product	9.08 Send to CA Cell	9.09 Build Appropriate CA Product	9.10 Send to Campaign Planners
Battlespace Awareness Dominance	C2	Monitor and collect data						X		X		X
		Understanding the situation	X	X	X	X						
		Develop and select COA			X	X	X					
		Develop a plan							X			
		Execute a plan										
		Monitor and adapt as necessary										
	Intel	Plan Intelligence Collection Requirements					X		X			
		Gather Intelligence Data						X				
		Process and Exploit										
		Produce Intelligence Assessment									X	
		Disseminate Intelligence Assessment								X		X
	SR	Surveill and Reconnoiter Environmental Conditions						X	X			
		Surveill and Reconnoiter the Information Environment						X	X			
		Characterize Friendly, Adversary, and Non-Aligned Forces										
		Provide Reflexive and Adaptive Surveillance and Reconnaissance			X			X				X
Information & Cyberspace Dominance	Electronic Warfare	Electronic Attack										
		Electronic Protection										
		Electronic Warfare										
	Network Warfare	Network Attack										
		Network Defense								X		X
		Network Warfare Support								X		X
	Influence Operations	Counterpropaganda										
		Psychological Operations										
		Military Deception										
		Operations Security										
		CounterIntelligence Operations										
		Public Affairs Operations										
Air & Space Dominance	Air-to-Air Superiority				X							
	Space Superiority	Space Deterrence										
		Space Defense										
		Space Recovery Operations										
		Counterspace Operations										
	Suppression of Enemy Air Defense				X							
Surface Dominance	Close Controlled Strike											
	Intra-theater Strike											
	Long Range Strike											
	Special Operations											
Enabling Capabilities	Personnel Recovery											
	Nec-centric Infrastructure			X		X	X			X		X
	Responsive Space Operations				X		X	X	X		X	X
	Airbase Opening											
	Agile Combat Support								X	X		X
	PNT											
	Global Mobility											

Appendix D. Detailed Risk Analysis

Node	Description	SRF			FCF Combination		
		Min	Most	Max	Min	Most	Max
1.02	IPB and TD	0.980	0.990	1.000	0.900	0.940	0.950
1.03	Commander's Intent	1.000	1.000	1.000	1.000	1.000	1.000
1.04	COA Development	1.000	1.000	1.000	1.000	1.000	1.000
1.05	COA Selection	1.000	1.000	1.000	1.000	1.000	1.000
1.06	Execution Orders	0.990	0.995	1.000	0.990	0.995	1.000
1.07	Conduct Ops Planning	0.990	0.995	1.000	0.970	0.985	0.990
2.01	Airborne Engagement Option Available?		0.500			0.300	
2.02	Generate the Mission ACS	1.000	1.000	1.000	0.950	0.970	0.980
2.03	Mission Planning	1.000	1.000	1.000	0.980	0.995	1.000
2.04	Launch	0.990	0.995	1.000	0.990	0.995	1.000
2.05	Enroute Ops	0.990	0.995	1.000	0.990	0.995	1.000
2.05	Personnel Recovery	0.999	0.999	0.999	0.950	0.970	0.990
2.06	Sufficient Fuel		0.100			0.100	
2.07	Air Refueling GM	0.990	0.995	1.000	0.850	0.920	0.950
2.08	Is BA Adequate?		0.700			0.500	
3.01	Collection Asset Available?		0.700			0.500	
3.02	Generate the Mission ACS	0.990	0.995	1.000	0.950	0.980	0.990
3.03	Position Collection Asset at Position Location	0.990	0.995	1.000	0.950	0.980	0.990
3.04	Collect Data	0.990	0.995	1.000	0.980	0.990	0.995
3.05	Onboard Processing Available?		0.500			0.500	
3.06	Transfer Collection Info to Processing Station	0.995	0.998	1.000	0.990	0.993	0.995
3.07	Monitor Collection Data	0.990	0.995	1.000	0.990	0.995	1.000
3.08	Analyze and Fuse Data	0.990	0.995	1.000	0.990	0.995	1.000
3.09	Transfer Collection Data Analysis Results to C2 Element	0.995	0.998	1.000	0.990	0.993	0.995
3.10	TOI Validated	0.980	0.990	1.000	0.980	0.990	1.000
4.02	Combat ID CID TOI	0.980	0.990	1.000	0.970	0.990	0.995
4.03	Targetable Coordinates Available	0.980	0.990	1.000	0.970	0.990	0.995
4.05	Fidelity Data for TOI?		4.02*4.03			4.02*4.03	
4.06	Dynamic Collection Requirements	1.000	1.000	1.000	1.000	1.000	1.000
4.07	Feasible Retask Options Exist	0.990	0.995	1.000	0.980	0.990	0.995
4.08	Provide Collection Requirements	0.995	0.998	1.000	0.995	0.998	1.000
4.09	Sensor Within Range?		0.500			0.400	
4.10	Relocate Platform_Redirect Sensor	0.990	0.995	1.000	0.980	0.990	0.995
4.11	Collect Data	0.990	0.995	1.000	0.980	0.990	0.995
4.12	Onboard Processing Available?		0.500			0.500	
4.13	Transfer Collection Info to Processing Station	0.995	0.998	1.000	0.990	0.993	0.995
4.14	Monitor Collection Data	0.995	0.998	1.000	0.995	0.998	1.000
4.15	Analyze and Fuse Data	0.995	0.998	1.000	0.995	0.998	1.000
4.16	Transfer Collection Data Analysis Results to C2 Center	0.995	0.998	1.000	0.995	0.998	1.000
4.17	Track Required?		0.200			0.200	

Node	Description	SRF			FCF Combination		
		Min	Most	Max	Min	Most	Max
5.01	Adequate Coverage Available With Current Sensor?		0.800			0.800	
5.02	Collect	0.995	0.998	1.000	0.980	0.990	0.995
5.03	Create Required Product	0.995	0.998	1.000	0.995	0.998	1.000
5.04	Coverage Options Exist to Maintain Track for Duration of Exec?		0.800			0.750	
5.05	Retask/Coordinate Handoff	0.995	0.998	1.000	0.995	0.998	1.000
5.06	Time Available to Restart F2T2?	0.900	0.900	0.900	0.900	0.900	0.900
5.08	Transfer Data Analysis to C2 Center	0.995	0.998	1.000	0.995	0.998	1.000
6.02	Maintain SA of Blue During Targeting	0.995	0.998	1.000	0.995	0.998	1.000
6.03	Maintain SA of Factor Grey during Targeting	0.995	0.998	1.000	0.995	0.998	1.000
6.04	Maintain SA of Factor Red During Targeting	0.995	0.998	1.000	0.995	0.998	1.000
6.08	Determine Acceptable Weapons Patterns Affects	0.995	0.998	1.000	0.995	0.998	1.000
6.09	Tailor Weapons Effects	0.995	0.998	1.000	0.995	0.998	1.000
6.11	JAG Recommended?		1.000			1.000	
6.12	Feasible Engagement Options Exist?		0.800			0.800	
6.13	Generate the Mission ACS	0.990	0.995	1.000	0.950	0.970	0.980
6.14	Sufficient Fuel?		0.100			0.100	
6.15	Air Refueling GM	0.990	0.995	1.000	0.850	0.920	0.950
6.16	Transfer Information to Selected Strike Asset	0.980	0.990	1.000	0.980	0.990	1.000
7.01	Ability to Avoid/Defeat Detection		0.850			0.500	
7.02	Avoid/Defeat Engagement	0.990	0.995	1.000	0.850	0.900	0.950
7.03	Review Confirm and Act on Updated Information	0.995	0.998	1.000	0.995	0.998	1.000
7.04	Aquire Target/Target Area	0.995	0.998	1.000	0.995	0.998	1.000
7.05	PID as Enemy	0.990	0.995	1.000	0.990	0.995	1.000
7.11	ID Relevent Blue	0.995	0.998	1.000	0.995	0.998	1.000
7.12	ID as Relevent Grey	0.995	0.998	1.000	0.995	0.998	1.000
7.13	ID as Relevent Red	0.995	0.998	1.000	0.995	0.998	1.000
7.15	Transfer Data	0.995	0.998	1.000	0.995	0.998	1.000
7.17	Maintain SA of Blue During Engagement	0.995	0.998	1.000	0.995	0.998	1.000
7.18	Maintain SA of Factor Grey During Engagement	0.995	0.998	1.000	0.995	0.998	1.000
7.19	Maintain SA of Factor Red During Engagement	0.995	0.998	1.000	0.995	0.998	1.000
7.22	Determine Acceptable Weapons Patterns Effects	0.995	0.998	1.000	0.995	0.998	1.000
7.23	Tailor Weapons Effects	0.995	0.998	1.000	0.995	0.998	1.000
7.25	Can We Engage?		0.990			0.990	
7.26	Assets Maintain Track	0.995	0.998	1.000	0.995	0.998	1.000
7.27	Authority/Clearance to Engage?	0.990	0.995	1.000	0.990	0.995	1.000
8.01	Successful Weapon Release	0.980	0.990	1.000	0.980	0.990	1.000
8.02	Weapon Reaches Target	0.980	0.990	1.000	0.980	0.990	1.000
8.03	First Order Effects Achieved?		0.990			0.990	
8.04	Delivery Platform Able Assess	0.990	0.995	1.000	0.990	0.995	1.000
8.05	Valid Engagement	0.990	0.995	1.000	0.990	0.995	1.000
8.06	Can delivery Platform Assess?		0.980			0.980	
8.07	Additional Assessment Required?		0.200			0.200	
8.08	Target Correctly Assessed		0.196			0.196	
9.01	Is the TGT a HVT_TST?		0.100			0.100	
9.02	Adequate Coverage Available with Current Sensor?		0.900			0.900	
9.03	Feasible Retask Options Exist	0.980	0.990	1.000	0.980	0.990	0.995
9.04	Retask/Coordinate Handoff	0.995	0.998	1.000	0.995	0.998	1.000
9.05	Task Sensor	0.995	0.998	1.000	0.995	0.998	1.000
9.06	Collect Data	0.995	0.998	1.000	0.995	0.998	1.000
9.07	Build Appropriate BA Product		1.000			1.000	
9.08	Send to CA Cell	0.995	0.998	1.000	0.995	0.998	1.000
9.09	Build Appropriate CA Product		1.000			1.000	
9.10	Target Correctly Assessed	0.999	0.999	0.999	0.999	0.999	0.999

Appendix E. AV-2 Integrated Dictionary

Achieve Air and Space Dominance – [Operational Activity] - Supremacy in the air and space battle of one force over another which permits the conduct of operations by the former and its related land, sea, air and space forces at a given time and place without interference by the opposing force.

Achieve Air-to-Air Superiority – [Operational Activity] - Includes the ability to neutralize or destroy any airborne threat by employing airborne assets possessing a superior kill chain including first look, first shot, and first kill. Ref GPA CONOPS

Achieve Battlespace Awareness Dominance – [Operational Activity] - Supreme knowledge and understanding of the operational area's environment, factors, and conditions, to include the status of friendly and adversary forces, neutrals and noncombatants, weather and terrain, that enables timely, relevant, comprehensive, and accurate assessments, in order to successfully apply combat power, protect the force, and/or complete the mission.

Achieve Information/Cyberspace Dominance –[Operational Activity] - Supremacy in all areas of the global information domain allowing friendly forces the ability to attack adversaries' information and decision making while simultaneously securing and defending friendly information and decision making.

Achieve Space Superiority – [Operational Activity] **-** Includes the ability to dominate an adversary's space forces that permit the conduct of operations and its related land, sea, air, and special operations forces at a given time and place without prohibitive interference by the opposing force.

Achieve Surface Dominance – [Operational Activity] - Supremacy in the surface battle of one force over another which permits the conduct of operations by the former and its related land, sea, air and space forces at a given time and place without interference by the opposing force.

Adversary Actions – [ICOM Arrow] - Actions of the adversary that influence the situation and subsequent decision cycles.

Adversary Intent Assessment – [ICOM Arrow] - Unformatted assessment of adversary intent.

Airlift Effects – [ICOM Arrow] - The level of success in the ability to provide rapid projection and application of GPA forces through deployment, sustainment, augmentation and redeployment globally to support the full range of military operations.

Air Refueling – [ICOM Arrow] – The capability to refuel aircraft in flight, which extends presence, increases range, and serves as a force multiplier. ref JP 1-02

Air Superiority Access to the Battlespace – [ICOM Arrow] - The degree to which access to the battlespace is achieved without prohibitive interference from the opposing force.

Air Superiority Protection of Friendly Forces – [ICOM Arrow] - The degree to which friendly forces are able to conduct operations within a specified area without interference from the opposing force.

Battlespace Situational Awareness – [ICOM Arrow] - Awareness of the environment, factors, and conditions that must be understood to successfully apply combat power, protects the force, or completes the mission. This includes the air, land, sea, space and the included enemy and friendly forces, facilities, weather terrain, the electromagnetic spectrum, and the information environment within the operational areas and areas of interest. ref GPA CONOPS

Changing Environmental Conditions – [ICOM Arrow] - Conditional state of the environment within the operational areas and areas of interest. This includes air, land, sea, and space as well as the weather, terrain, electromagnetic, and information environment.

Characterize Friendly, Adversary, and Non-aligned Forces – [Operational Activity] - Intent: Find, fix track, and assess elements within the battlespace including the what, where, when and why associated with critical forces/actors and materiel. This capability includes characterizing things that are problematic such as CBRNE, hardened and deeply buried targets, forces employing CC&D, mobile forces, and blue force situation awareness. It also provides essential information to enable the targeting and C2 processes.

Close Controlled Strike Effect – [ICOM Arrow] - The degree of success associated with the ability to perform persistent, precise, time sensitive attacks, day or night, in adverse weather in all land (including urban ops) and littoral environments against fixed or mobile targets, combined with the ability to communicate rapidly with surface forces. ref GPA CONOPS

Collected Data I- [ICOM Arrow] - Includes data about the environment, factors, and conditions that must be understood to successfully apply combat power, protect the force, or complete the mission.

Commander's Guidance – [ICOM Arrow] - Guidance provided in the form of objectives associated with selected courses of action.

Counterintelligence Operations Effects – [ICOM Arrow] - The level of success associated with gathering information and accomplishing activities conducted to protect against espionage, other intelligence activities, sabotage or assassinations conducted by, or on behalf of, foreign governments or elements thereof, foreign organizations or foreign persons, or international terrorist activities.

Counterpropaganda Effects – [ICOM Arrow] - Effects from the activities to identify and counter adversary propaganda and expose adversary attempts to influence friendly populations and military forces situational understanding.

Counterspace Operations Effects – [ICOM Arrow] - Level of success in deceiving, disrupting, denying, degrading, and/or destroying an adversary's on-orbit assets, ground nodes, and/or communication pathways.

Course of Action – [Operational Activity] - Once the commander gains an understanding of the situation, the commander decides on a course of action. Deciding on a course of action in structured or analytic decision making consists of developing several alternatives, assessing the alternatives and then selecting the best one. In the case of well-understood or rapidly unfolding situations, the decision is made quickly, with little consideration of developing or assessing alternative courses, in a more intuitive decision making style.

Develop a Plan – [Operational Activity] - Develop a plan to execute the selected course of action.

Disseminate Intelligence Assessment – [Operational Activity] - Properly formatted intelligence products are disseminated to the requester, who integrates the intelligence into the decision-making and planning processes. In the case of threat warning alerts essential to the preservation of life and/or vital resources, such information must be immediately communicated directly to those forces, platforms, or personnel identified at risk so the appropriate responsive action can be taken once such notification has been acknowledged.

Develop Warfighting Guidance – [Operational Activity] - Consists of all government agencies that belong to the Department of Defense to include the major Services of the Army, Navy, Air Force, Marines, and Coast Guard. Functions within the DoD include those responsible for the development, dissemination, and oversight of Doctrine, Organization, Training, Leadership, Personnel, and Facilities (DOTLPF). As it pertains to GPA, the DoD operational activity provides guidance through Doctrine, Rules of Engagement (ROE), and training.

Doctrine, ROE, and Training – [ICOM Arrow] - Doctrine, Rules of Engagement (ROE), and Training guide execution of functions.

Electronic Attack Effects – [ICOM Arrow] - The effects caused by the use of electromagnetic energy, directed energy, or anti-radiation weapons to attack personnel, facilities or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability. ref GPA CONOPS

Electronic Protection Effects – [ICOM Arrow] - The effects of passive and active means taken to protect personnel, facilities, and equipment from any effects of friendly or enemy employment of electronic warfare that degrade, neutralize, or destroy friendly combat capability. ref GPA CONOPS

Electronic Warfare Support Effects – [ICOM Arrow] - Information required for decisions involving electronic warfare operations and other tactical actions such as threat avoidance, targeting, and homing. Electronic warfare support data can be used to produce signals intelligence, provide targeting for electronic or destructive attack, and produce measurement and signature intelligence. ref Joint Pub 1-02

Execute the Plan – [Operational Activity] - Execute the plan, to include providing direction and leadership to subordinates. The decision process needs to be executed with sufficient tempo and quality to give the commander the advantage to operate within the adversary's decision cycle.

Formatted Adversary Intent Assessment – [ICOM Arrow] - Prediction of adversary intent based upon the correlation and fusion of all sources of data, patterns of enemy activity, environmental conditions and relevant events pertaining to the operating environment.

Formatted Combat/Effects Assessment – [ICOM Arrow] - Assessment of both kinetic and non-kinetic engagement in order to provide timely/real-time battle damage and strike effectiveness information. Effects assessment determines whether engagements have derived the desired effects as well as predicting how neutralizing a target influences an adversary's future actions.

Freedom to Maneuver – [ICOM Arrow] - The degree to which land, sea, and air forces at a given time and place are able to conduct operations without prohibitive interference by the opposing force.

Gather Intelligence Data – [Operational Activity] - The collection portion of the intelligence process involves tasking appropriate collection assets and/or resources to acquire the data and information required to satisfy collection objectives. Collection includes the identification, coordination, and positioning of assets and/or resources to satisfy collection objectives.

Intelligence Assessment Receipt Confirmation and Feedback – [ICOM Arrow] - Confirmation of receipt of intelligence assessment and feedback as to the value and usability of the information.

Intelligence Collection Requests – [ICOM Arrow] - Prioritized collection requests for surveillance and reconnaissance.

Intelligence Collection Requirements – [ICOM Arrow] - Prioritized requirements for collection requests of collection of intelligence data.

Intelligence – [Operational Activity] - Includes the ability to produce and provide the analytical products required to conduct Effects Based Operations, Effects Based Assessments, and a key element of Predictive Battlespace Awareness (PBA), which allows commanders to anticipate future events and adversary courses of action. ref GPA CONOPS

Intra-theater Strike Effects – [ICOM Arrow] - The degree of success associated with the ability to conduct air-to-surface operations within a joint operations area or geographic theater in all weather, day or night, and anti-access environments against fixed or mobile targets; includes the ability to carry at least a medium payload, and execute precise, point-and-shoot, dynamic targeting, time-sensitive and networked attacks, and to provide deep strike command and control. ref GPA CONOPS

Long Range Strike Effects – [ICOM Arrow] - The degree of success in the ability to conduct inter-theater, long endurance, high payload air-to-surface, and surface-to-surface operations (to include capabilities that transit space) against significant and/or high value and time-sensitive targets to neutralize an adversary's forces or critical vulnerabilities rapidly, precisely, and overwhelmingly. ref GPA CONOPS

Military Deception Effects – [ICOM Arrow] - Effects of actions executed to deliberately mislead adversary military decision makers as to friendly military capabilities, intentions, and operations, thereby causing the adversary to take specific actions (or inactions) that will contribute to the accomplishment of the friendly mission. ref JP 1-02

Mission Support – [ICOM Arrow] - The level to which joint and coalition forces can be sustained enabling the application of persistent force.

Monitor Execution and Adapt as Necessary – [Operational Activity] - Monitoring the execution of the plan allows the commander to observe the results of the decisions and to adapt as the process starts again.

Monitor and Collect Data – [Operational Activity] - A commander develops an initial picture or impression of the operational environment by observing the situation and orchestrating the collection of different types of information from different sources.

National Military Strategy and Objectives – [ICOM Arrow] - GPA is the application of effects-based campaign planning to achieve National Military Strategy (NMS) prescribed Full Spectrum Dominance. NMS and the associated objectives control the application and execution of GPA.

Net-Centric Interconnectivity and Interoperability – [ICOM Arrow] - The degree of human and technical interconnectivity and interoperability to all users.

Network Attack Effects – [ICOM Arrow] - The effects of the employment of network-based capabilities to destroy, disrupt, corrupt or usurp information resident in or transiting through networks. ref GPA CONOPS

Network Defense Effects – [ICOM Arrow] - The effects from the employment of network-based capabilities to defend friendly information resident in or transiting through networks against adversary efforts to destroy, disrupt, corrupt or usurp it.

Network Warfare Support Effects – [ICOM Arrow] - Information required for immediate decisions involving network warfare operations. Network Warfare Support data can be used to produce intelligence, or provide targeting for electronic or destructive attack.

Operations Security Effects – [ICOM Arrow] - The level of success associated with the process of identifying critical information and subsequently analyzing friendly actions attendant to military ops and other activities to (1) identify those actions that can be observed by adversary intelligence systems; (2) determine indicators hostile intelligence systems might obtain that could be interpreted or pieced together to derive critical information in time to be useful to adversaries; and (3) select and execute measures that eliminate or reduce to an acceptable level the vulnerabilities of friendly actions to adversary exploitations. ref JP 1-02

Perform Airbase Opening Operations – [Operational Activity] - Includes the capability to assess, plan, reconfigure, modify, build, and maintain a manageable infrastructure capable of supporting combat mission requirements.

Perform Close Controlled Strike Operations – [Operational Activity] - Includes the ability to perform persistent, precise, time sensitive attacks, day or night, in adverse weather in all land (including urban ops) and littoral environments against fixed or mobile targets, combined with the ability to communicate rapidly with surface forces.

Perform Command and Control– [Operational Activity] - Includes the ability to monitor and assess the battlespace and to direct forces in the execution of Effects Based Operations (EBO) in any threat environment. ref GPA CONOPS

Perform Counterintelligence Operations – [Operational Activity] - Information gathered and activities conducted to protect against espionage, other intelligence activities, sabotage or assassinations conducted by, or on behalf of, foreign governments or elements thereof, foreign organizations or foreign persons, or international terrorist activities. ref Joint Pub 1-02

Perform Counterpropaganda – [Operational Activity] - Activities to identify and counter adversary propaganda and expose adversary attempts to influence friendly populations and military forces situational understanding.

Perform Counterspace Operations – [Operational Activity] - Offensive counterspace capabilities implement measures to deceive, disrupt, deny, degrade, and destroy an adversary's on-orbit assets, ground nodes, and/or communication pathways.

Perform Electronic Attack – [Operational Activity] - Electronic Attack (EA) includes but is not limited to self-protection countermeasures and Airborne Electronic Attack (AEA). AEA gives friendly forces the ability to counter target sets susceptible to EA non-kinetically. AEA's system-of-systems approach allows warfighting commanders to use a variety of alternatives to counter EA targets and support the other GPA critical capabilities. ref JP 1-02

Perform Electronic Protection – [Operational Activity] - Electronic Protection (EP) includes the actions taken to protect friendly forces from the effects of enemy and friendly EW employment. A key element of EP is frequency management and deconflicting the friendly application of EA. ref JP 1-02

Perform Electronic Warfare – [Operational Activity] - Includes the ability to attack adversary electromagnetic operations and defend friendly operations to gain dominance in the electromagnetic spectrum. ref JP 1-02

Perform Electronic Warfare Support – [Operational Activity] -Electronic Warfare Support (ES) capabilities support threat avoidance, targeting, and homing. ref JP 1-02

Perform Influence Operations – [Operational Activity] - Include the ability to affect behaviors, protect operations, communicate commander's intent, and project accurate information to achieve the desired effects across the cognitive domain. The military capabilities of influence operations are psychological operations (PSYOP), military deception (MILDEC), operations security (OPSEC), counterintelligence (CI) operations, counterpropaganda operations and public affairs (PA) operations.

Perform Intra-theater Strike Operations – [Operational Activity] - Includes the ability to conduct air-to-surface operations within a joint operations area or geographic theater in all weather, day or night, and anti-access environments against fixed or mobile targets; includes ability to carry at least a medium payload, and execute precise, point-and-shoot, dynamic targeting, time-sensitive and networked attacks, and to provide deep strike command and control.

Perform Long Range Strike Operations– [Operational Activity] - Includes the ability to conduct inter-theater, long endurance, high payload air-to-surface, and surface-to-surface operations (to include capabilities that transit space) against significant and/or high value and time-sensitive targets to neutralize an adversary's forces or critical vulnerabilities rapidly, precisely, and overwhelmingly.

Perform Military Deception – [Operational Activity] - Actions executed to deliberately mislead adversary military decision makers as to friendly military capabilities, intentions, and operations, thereby causing the adversary to take specific actions (or inactions) that will contribute to the accomplishment of the friendly mission. MILDEC will not intentionally target or mislead the US public, Congress, or the news media. Ref Joint Pub 1-02

Perform Network Attack – [Operational Activity] - The employment of network-based capabilities to destroy, disrupt, corrupt or usurp information resident in or transiting through networks. Networks include telephony and data services networks. ref AFDD 2-5

Perform Network Defense – [Operational Activity] - The employment of network-based capabilities to defend friendly information resident in or transiting through networks against adversary efforts to destroy, disrupt, corrupt or usurp it.

Perform Network Warfare – [Operational Activity] - Includes the ability to attack adversary networks and defend friendly networks by maintaining dominance in the analog and digital portions of the battlespace. The military capabilities of network warfare are network attack, network defense, and network warfare support.

Perform Network Warfare Support – [Operational Activity] - Actions tasked by or under direct control of an operational commander to search for, intercept, identify, and locate or localize sources of access and vulnerability for the purpose of immediate threat recognition, targeting, planning, and conduct of future operations. NS provides information required for immediate decisions involving network warfare operations. NS data can be used to produce intelligence, or provide targeting for electronic or destructive attack. ref AFDD 2-5

Perform Operations Security – [Operational Activity] - A process of identifying critical information and subsequently analyzing friendly actions attendant to military ops and other activities to (1) identify those actions that can be observed by adversary intelligence systems; (2) determine indicators hostile intelligence systems might obtain that could be interpreted or pieced together to derive critical information in time to be useful to adversaries; and (3) select and execute measures that eliminate or reduce to an acceptable level the vulnerabilities of friendly actions to adversary exploitations. ref Joint Pub 1-02

Perform Personnel Recovery Operations – [Operational Activity] - Includes the ability to report, locate, support, recover, and reintegrate isolated personnel across the spectrum of military operations, preserving critical combat resources while denying the enemy a potential intelligence source.

Perform Psychological Operations – [Operational Activity] - Planned operations to convey selected information and indicators to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behavior of foreign governments, organizations, groups, and individuals. The purpose of psychological operations is to induce or reinforce foreign attitudes and behavior favorable to the originator's objectives. (Joint Pub 1-02) Air Force PSYOP is an operational discipline that leverages Air Force core competencies and the psychological effects of air, space, and information/influence operations to shape and exploit the psychological vulnerabilities of the adversary to the advantage of US forces and objectives.

Perform Public Affairs – [Operational Activity] - Operational activities that communicate unclassified information about Air Force activities to Air Force, domestic, and international audiences. The capabilities they give the warfighter include: providing counsel and guidance about the public information environment; enhancing airman morale and readiness; gaining and maintaining public support for military operations; and communicating US resolve in a manner that provides global influence and deterrence. ref AFDD 2-5.4

Perform Responsive Space Operations – [Operational Activity] - Includes the ability to be responsive at the strategic, operational, and tactical levels to meet time-critical needs and evolving situations.

Perform Space Defense Operations – [Operational Activity] - US Air and Space forces must defend US military, civil and commercial space capabilities if an adversary attacks.

Perform Space Deterrence Operations – [Operational Activity] - Air and Space forces must deter adversaries from attacking US military, civil, and commercial space capabilities.

Perform Space Recovery Operations – [Operational Activity] - Includes the capability to recover US military, civil and commercial space capabilities if lost.

Perform Special Operations – [Operational Activity] - Includes the ability to conduct operations in hostile, denied, or politically sensitive environments to achieve military, diplomatic, informational, and/or economic objectives employing military capabilities for which there is no broad conventional force requirement or there is no force available.

Personnel Recovery Effects – [ICOM Arrow] - The degree of success in the ability to report, locate, support, recover, and reintegrate isolated personnel across the spectrum of military operations, preserving critical combat resources while denying the enemy a potential intelligence source. ref GPA CONOPS

Plan – [ICOM Arrow] - Detailed plan on how to execute the selected course of action.

Plan Execution Feedback – [ICOM Arrow] - Feedback from the monitoring of the plan execution that will be used in the development of follow-on decision cycles.

Plan Intelligence Collection Requirements – [Operational Activity] - intelligence operations begin with the identification of a need for intelligence regarding all relevant aspects of the battlespace, especially the adversary. These intelligence needs are identified by the commander and all joint force staff elements, and are formalized by the J-2 as intelligence requirements early in the planning process. Those critical pieces of intelligence the commander must know by a particular time to plan and execute a successful mission are identified as the commander's PIRs. PIRs are identified at every level and are based on guidance obtained from the mission statement, the commander's intent, and the end state objectives. Intelligence requirements provide the basis for current and future intelligence operations, and are prioritized based on consumer inputs during the planning and direction portion of the intelligence process. The J-2 provides the focus and direction for collection requirements to support the combatant command or subordinate joint force.

Position, Navigation, and Timing Effects – [ICOM Arrow] - The level of the ability to support the battlespace navigation by friendly forces as well as target acquisition, engagement and precision strike of adversary targets regardless of weather conditions. This capability also facilitates planning, execution, and synchronization of information networks. ref GPA CONOPS

Process and Exploit Data – [Operational Activity] - Once the data that might satisfy the requirement is collected, it undergoes processing and exploitation. Through processing and exploitation, the collected raw data is transformed into information that can be readily disseminated and used by intelligence analysts to produce multidiscipline intelligence products. Relevant, critical information should also be disseminated to the commander and joint force staff to facilitate time-sensitive decision making. Processing and exploitation time varies depending on the characteristics of specific collection assets. For example, some ISR systems accomplish processing and exploitation automatically and in near simultaneity with collection, while other collection assets, such as HUMINT teams, may require substantially more time. Processing and exploitation requirements are prioritized and synchronized with the commander's PIR.

Processed and Exploited Intelligence Information – [ICOM Arrow] - Collected intelligence data that has been processed and exploited to be presented in a usable form for analysis.

Produce Intelligence Assessment – [Operational Activity] - The analysis and production portion of the intelligence process involves integrating, evaluating, analyzing, and interpreting information from single or multiple sources into a finished intelligence product. The demands of the modern battle require intelligence products that anticipate the needs of the commander and are timely, accurate, usable, complete, relevant, objective, and available.

Provide Agile Combat Support– [Operational Activity] - Includes the ability to sustain joint and coalition forces, which enables the application of persistent force.

Provide Enabling Capabilities – [Operational Activity] - Operational capabilities that support but do not directly achieve the desired effects of air and space, ground, battlespace awareness, and information dominance. These GPA capabilities drive AF and MAJCOM strategic planning efforts and link to the Air Force Master Capability Library (MCL).

Provide Global Mobility – [Operational Activity] - Includes the ability to provide rapid projection and application of GPA forces through deployment, sustainment, augmentation and redeployment globally to support the full range of military operations.

Provide Net-centric Infrastructure – [Operational Activity] - Includes the ability to provide human and technical interconnectivity and interoperability to all users.

Provide Positioning, Navigation, and Timing – [Operational Activity] - Includes the ability to support the battlespace navigation by friendly forces as well as target acquisition, engagement and precision strike of adversary targets regardless of weather conditions. This capability also facilitates planning, execution, and synchronization of information networks.

Provide Reflexive and Adaptable Surveillance and Reconnaissance – [Operational Activity] - Intent: Conduct timely S&R tailored specifically to meet the needs of C2 and particular facets of the intelligence question under investigation or provide needed information. The S&R architecture must be capable of agilely adapting itself to provide persistent surveillance in response to operational priorities and time-sensitive requirements. Articulation of operational priorities, cross-cueing, and re-tasking are inherent to this capability.

Psychological Operations Effects – [ICOM Arrow] - Effects of the operations to convey selected information and indicators to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behavior of foreign governments, organizations, groups, and individuals. Specifically, the extent as to which foreign attitudes and behaviors are induced or reinforced such that they are favorable to the originator's objectives.

Public Affairs Effects – [ICOM Arrow] - The effects of operational activities that communicate unclassified information about Air Force activities to Air Force, domestic, and international audiences.

Raw All-Source Intelligence Data – [ICOM Arrow] - Collected all-source intelligence data that has not been processed.

Responsive Space Operations Effects – [ICOM Arrow] - The degree of success associated with the ability to be responsive at the strategic, operational, and tactical levels to meet time-critical needs and evolving situations.

Restriction of Adversary Intelligence, Decision Cycles, and Movement – [ICOM Arrow] - The degree to which adversary intelligence gathering capabilities, decision cycles, and movement are restricted

SEAD Access to Battlespace – [ICOM Arrow] - The degree to which air forces are able to conduct operations in a given area of operations free of interference from surface threats.

SEAD Effect – [ICOM Arrow] - The degree to which surface-based enemy air defenses are neutralized, destroyed, or temporarily degraded by destruction and/or disruptive means.

Selected Course of Action – [ICOM Arrow] - Course ft action to be executed in order to achieve the desired objectives given the current situation.

Situation – [ICOM Arrow] - Well defined assessment of the current situation and associated factors.

Space Defense Effects – [ICOM Arrow] - Level of success in defending US military, civil and commercial space capabilities if an adversary attacks.

Space Deterrence – [ICOM Arrow] - Effects Level of success in deterring adversaries from attacking US military, civil, and commercial space capabilities.

Space Recovery Effects – [ICOM Arrow] - Level of success in the capability to recover US military, civil and commercial space capabilities if lost.

Special Operations Effects – [ICOM Arrow] - The degree of success in the ability to conduct operations in hostile, denied, or politically sensitive environments to achieve military, diplomatic, informational, and/or economic objectives employing military capabilities for which there is no broad conventional force requirement or there is no force available. ref GPA CONOPS

Support Infrastructure – [ICOM Arrow] - Level of infrastructure capable of supporting combat mission requirements.

Suppression of Enemy Air Defenses – [Operational Activity] - Includes the ability to neutralize, destroy, or temporarily degrade surface-based enemy air defenses by destruction and/or disruptive means. ref GPA CONOPS

Surveil and Reconnoiter Environmental Conditions – [Operational Activity] - Intent to persistently collect data on the air, land, sea, and space mediums. Such data will include both natural phenomena, as well as unnatural events such as CBRNE actions and space debris. The capability must be mature enough to offer the foundation from which to clearly ascertain the impact of the environments on operations and immediately identify militarily significant changes to all environments. Detection of unnatural environmental events may also contribute to assessment of hostile activity/intent and impacts on friendly capabilities. ref GPA CONOPS

Surveil and Reconnoiter the Information Environment – [Operational Activity] - Persistently collect data on information systems. This capability will detect changes to complex information networks, effectively characterize targets, improve weaponeering, monitor execution, mature measures of effectiveness, and assure information systems to directly enable friendly operations.

Surveillance and Reconnaissance Data – [ICOM Arrow] - Data on air, land, sea, space, and cyber environments used to continuously characterize all friendly, adversary, and non-aligned forces and relevant low-signature human activity that includes people, soft vehicles, small buildings, and occasional armored vehicles.

Surveillance and Reconnaissance – [Operational Activity] - Includes the ability to persistently collect data on the air, land, sea, space, and cyber environments, and to continuously characterize all friendly adversary, and non-aligned forces and relevant low-signature human activity. ref GPA CONOPS

Tasking – [ICOM Arrow] - Guidance for directing forces in the execution of Effects Based Operations in support of the determined course of action.

Understanding of the Situation – [Operational Activity] - Once the information is collected; commanders then develop an initial understanding by putting it into a context, thus creating situational awareness. The context is created by deducing patterns of interaction among the various factors in the operational environment. These patterns are the result of a combination of the commander's previous experience and own intuition. They assist the commander to arrange disparate facts into a logical and understandable construction that helps the commander to both deduce a course of action and communicate complex information to others quickly and easily.

Appendix F. Acronyms

ACC Air Combat Command

ACC/A5S – Air Combat Command/Strategy, Concepts and Doctrine Division

ACS Agile Combat Support

AF Air Force

AFI Air Force Instruction

AFPD Air Force Policy Directive

AI Air Interdiction

BA Battlespace Awareness

C2 Command and Control

CAF Combat Air Force

CAT Capabilities Analysis Tool

CBNRE Chemical Biological Nuclear Radiological Explosive

CCJO Capstone Concept on Joint Operations

CCS Close Controlled Strike

CI Counterintelligence

CID Combat Identification

COA Course of Action

COCOM Combatant Commander

COMACC Commander, Air Combat Command

CONOPS Concept of Operations

CRRA Capabilities Review and Risk Assessment

CSAR Combat Search and Rescue

DA Direct Action

DoD Department of Defense

DoDAF Department of Defense Architecture Framework

DOTMLPF Doctrine Organization Training Materiel Leadership Personnel Facilities

DPS Defense Planning Scenarios

F2T2EA Find Fix Track Target Engage Assess

FCF Fiscally Constrained Force

FFBD Function Flow Block Diagram

FID Foreign Internal Defense

FSD Full Spectrum Dominance

FYDP Future Year Defense Program

GPA Global Persistent Attack

GM Global Mobility

GS Global Strike

HLD Homeland Defense

HVT High Value Targets

IADS Integrated Air Defense System

ICOM Input Control Output Mechanism

I/O Input/Ouput

IPL Integrated Priority List

ISR Intelligence Surveillance Reconnaissance

ITS Intra-theater Strike

JCD&EC Joint Concept Development and Experimentation Campaign

JCIDS Joint Capabilities Integration and Development System

JCSG Joint Concept Steering Group

JIC Joint Integrating Concept

JFC Joint Functional Concept or Joint Force Commander

JOC Joint Operational Concept

JOpsC Joint Operations Concept

LRS Long Range Strike

M&S Modeling and Simulation

MAJCOM Major Command

MCL Master Capability List

MCO Major Combat Operations

MILDEC Military Deception

NCW Network Centric Warfare

NDS National Defense Strategy

NMS National Military Strategy

NSS National Security Strategy

NR Nuclear Response

OCA Offensive Counterair

OODA Observe Orient Decide Act

OPSEC Operations security

OV-1 High-level Operational Concept Graphic

OV-2 Operational Node Connectivity Description

OV-5 Operational Activity Model

PA Public Affairs

PBA Predictive Battlespace Awareness

$P_c(s)$ Probability of component success

PDF Probability Distribution Function

PIR Priority Intelligence Requirements

POM Program Objective Memorandum

$P_o(s)$ Probability of overall success

PNT Positioning Navigation and Timing

PPBE Planning Programming Budgeting and Execution

PR Personnel Recovery

P(s) Probability of Success

PSM Process Sequence Model

PSYOP Psychological Operations

ROE Rules of Engagement

ROMO Range of Military Operations

S&C4ISR Space Command Control Communication Computers Intelligence Surveillance Reconnaissance

SA Strategic Attack

SCAR Strike Coordination and Reconnaissance

SE Systems Engineering

SEAD Suppression of Enemy Air Defense

SME Subject Matter Expert

SMP Strategic Master Plan

SO Special Operations

SRF Strategy Responsive Force

SV Systems View

TD Target Designation

TGO Terminal Guidance Operations

TOI Target of Interest

TPG Transformational Planning Guidance

TST Time Sensitive Targetting

UJTL Universal Joint Task List

UW Unconventional Warfare

QDR Quadrennial Defense Review

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Vita

Major John Eller, USAF

Major Eller graduated Valedictorian from Canyon High School in Canyon, Texas, in 1990. He earned his Bachelor of Science Degree in Aeronautical Engineering from the United States Air Force Academy in 1995. Major Eller was selected to attend pilot training at Columbus AFB, Mississippi, from which he graduated in September 1996.

In August 1997, Major Eller completed the F-16 training course at Luke AFB and was assigned to the 80th Fighter Squadron at Kunsan AB, Republic of Korea. Following his tour in Korea, Major Eller was assigned to the 78th Fighter Squadron at Shaw AFB, South Carolina, until being selected to attend the United States Air Force F-16 Weapons Instructor Course at Nellis AFB, Nevada. He graduated in December 2001 and was assigned to the 389th Fighter Squadron at Mountain Home AFB, Idaho. In May 2004, Major Eller was assigned to the 86th Fighter Weapons Squadron at Eglin AFB, Florida, where he served as the Weapons Flight Commander and Chief of Weapons and Tactics for the USAF Air-to-Ground Weapons System Evaluation Program.

In June 2007, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduating with a Masters of Science in Systems Engineering, he will be assigned to HQ AF/TE at the Pentagon where he will be the Chief of Fighter Operations.

His awards include the Meritorious Service Medal with one oak leaf cluster, Air Medal with four oak leaf clusters, Air Force Commendation Medal with one oak leaf cluster, and other unit deployment and campaign medals and awards.

Major Brian Hazel, USAF

Major Brian Hazel graduated from Brunswick High School in Brunswick, Ohio in 1989. For one year, he went to the New Mexico Military Institute on a Falcon Foundation Scholarship before being accepted into the Unite States Air Force Academy. Upon receiving a Bachelor's of Science in Environmental Engineering, he was commissioned on 1 Jun, 1994.

His first training assignment was for Specialized Undergraduate Navigator Training, where received his Navigator Rating in Oct 1995. Upon completion of Electronic Warfare School and B-1B RTU, he was assigned to the 37th Bomb Squadron located at Ellsworth Air Force Base, South Dakota. After only a few months as an operational Weapons System Officer, he was selected for Specialized Undergraduate Pilot Training at Columbus AFB. Upon receiving his Aviator Rating in Oct 1998, he completed A/OA-10 FTU at Davis-Montham AFB and was assigned to the 81st Fighter Squadron in Spangdahlem Air Base, Germany. His next assignment took him to Sheppard AFB as a T-38A Flight Instructor. In March 2005, he was assigned to the 25th Fighter Squadron located at Osan Air Base, Korea and once again flying the A/OA-10.

In June 2007, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduating with a Masters of Science in Systems Engineering, he will be assigned to the 590th Flying Training Squadron where he will be a Flight Instructor for the T-38C Pilot Instructor Training (PIT) program.

His awards include the Meritorious Service Medal, Aerial Achievement Medal, Air Force Commendation Medal among other unit deployment and campaign awards.

Brendan Rooney, Civilian USAF

Brendan Rooney graduated from Brighton High School, in Brighton, Michigan in 1994. Upon graduating he attended Kettering University in Flint, Michigan where he received a B.S. in Manufacturing Systems Engineering in 1998. He then attended the University of Michigan where he received a M.S. in Aerospace Engineering.

His first professional job was as a student co-op with General Motors 1994-1998. While with GM he worked on CAD design, car body testing, vibration modal analysis, and welding engineering for car bodies. He also worked on solving car quality problems during several car startups of some major General Motors vehicles such as the Grand Prix and Corvette. As a fulltime engineer from 1998-1999 he worked in quality engineering for GM.

In 2001 Brendan started his aerospace career at the NAVAIR Weapons division in China Lake, California. While at NAVAIR he worked on Ramjet inlet design, CFD gridding for Pulse Detonation Engines, and in the Trident Testing office.

In 2002 he transferred to the Aerospace Systems Design & Analysis branch in the Aeronautical Systems Center(ASC/XRE) at Wright Patterson Air Force Base in Dayton, Ohio. While there he worked in the Hypersonics and Space Access group modeling the impact of reusable launch vehicle design on operability and designs for hypersonic inlets. He was involved in several major projects assessing technology impact on launch vehicle operability.

In June 2007, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduating with a Masters of Science in Systems Engineering, he will be assigned back to ASC/XRE working on propulsion designs ranging from subsonic to hypersonic engines.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No.*

1. REPORT DATE (DD–MM–YYYY)	2. REPORT TYPE	3. DATES COVERED *(From — To)*
10–06–2008	Master's GRP	Jun 2007 — Jun 2008

4. TITLE AND SUBTITLE	
Global Persistent Attack: A Systems Architecture, Process Modeling, and Risk Analysis Approach	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 08ENY118
John Eller, Maj, USAF Brian Hazel, Maj, USAF Brendan Rooney, Civ, USAF	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way WPAFB OH 45433-7765	8. PERFORMING ORGANIZATION REPORT NUMBER AFIT/ISE/ENV/08-J04
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) HQ ACC/A5SC POC: Lt Col Brian Farrar; Comm:757-764-7053 (DSN 574) 204 Dodd Blvd Suite 202 Langley AFB VA 23665-7773	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This research developed a defendable and traceable Global Persistent Attack (GPA) risk analysis methodology and designed integrated architectural products based on GPA and Battlespace Awareness (BA) concepts of operation. The detailed architecture illustrates the commonality of capabilities and associated activities along with their critical relationships within Global Persistent Attack (GPA). In order to accomplish risk identification and analysis, a Process Sequence Model (PSM) was developed to display the logical sequencing necessary for conducting GPA operations. Each activity and decision point was given a nodal probability of success and evaluated using Monte Carlo simulation to determine the overall mission probability of success. Sensitivity analysis was also accomplished to identify the capabilities most critical to the success of GPA operations. The identification of critical capabilities is essential to the proper development of the fiscally constrained force structure with respect to minimizing risk. Systems Engineering (SE) methodology and tools provide a structured, traceable process for identifying the critical relationships required to sustain the GPA concept. This insight will provide Air Combat Command (ACC) an improved decision making process to ensure the objectives of the national defense strategy can be attained while minimizing risk associated with the fiscally constrained force structure.

15. SUBJECT TERMS

Global Persistent Attack, Risk Analysis, Process Sequence Model, Monte Carlo Simulation, Sensitivity Analysis, Strategic Responsive Force, Fiscally Constrained Force

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Jeffrey Havlicek, Maj, USAF
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (Include Area Code)
U	U	U	UU	245	(937) 255-3355 X3348; e-mail: Jeffrey.havlicek@afit.edu