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THESIS

TECHNOLOGY INSERTION CONSIDERATIONS FOR COMPLEX SYSTEM OF SYSTEMS DEVELOPMENT

by

Lasumar (Mark) Aragon

September 2008

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13. ABSTRACT (maximum 200 words)

The Future Combat Systems (FCS) is a system of systems, comprised of 14 individual systems, all connected via a common network with the Soldier as the centerpiece. The Army has recognized that evolutionary acquisition enables the rapid fielding of FCS technologies as they mature to meet warfighter requirements. It has implemented the Spin-out plan to leverage FCS R&D efforts to insert new capabilities into the Current Force. Complex system of systems development, however, requires more robust approaches to ensure effective and efficient delivery of new capabilities to the warfighter such that he can immediately take advantage of the full capabilities the new system offers. Integrating a Modular Open Systems Approach to acquisition ensures the seamless insertion of newly acquired systems into existing systems and facilitates insertion of future envisioned systems. The System Structure methodology provides a framework for engineering a system and is used to integrate the evolutionary acquisition process and the modular open systems approach for a tailored framework that addresses the needs and requirements of the FCS program and contribute to Army Modernization Strategy overall. The integration of evolutionary acquisition and MOSA within a sound systems engineering framework results in an insertion strategy that is responsive and flexible with the greatest benefit to the end user of the resulting products.

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TECHNOLOGY INSERTION CONSIDERATIONS FOR COMPLEX SYSTEM OF SYSTEMS DEVELOPMENT

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ABSTRACT

The Future Combat Systems (FCS) is a system of systems, comprised of 14 individual systems, all connected via a common network with the soldier as the centerpiece. The Army has recognized that evolutionary acquisition enables the rapid fielding of FCS technologies as they mature to meet warfighter requirements. It has implemented the Spin-out plan to leverage FCS research and development efforts to insert new capabilities into the Current Force. Complex system of systems development, however, requires more robust approaches to ensure effective and efficient delivery of new capabilities to the warfighter so that he can immediately take full advantage of the new system's capabilities.. Integrating a Modular Open Systems Approach to acquisition ensures the seamless insertion of newly acquired systems into existing systems and facilitates insertion of future envisioned systems. The system structure methodology provides a framework for engineering a system, and is used to integrate the evolutionary acquisition process and the modular open systems approach for a tailored framework that addresses the needs and requirements of the FCS program and contributes to Army Modernization Strategy overall. The integration of evolutionary acquisition and MOSA within a sound systems engineering framework results in an insertion strategy that is responsive and flexible with the greatest benefit to the end user of the resulting products.

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LIST OF ACRONYMS AND ABBREVIATIONS

AIS	Automated Information Systems
AoA	Analysis of Alternatives
ARCIC	Army Capabilities Integration Center
ASN	Assistant Secretary of the Navy
BCT	Brigade Combat Teams
CBA	Capability Based Assessments
CDD	Capability Development Document
CJCSM	Chairman of Joint Chief of Staff Manual
CJCSI	Chairman of Joint Chief of Staff Instruction
CONOPS	Concept of Operations
CPD	Capability Production Document
DAB	Defense Acquisition Board
DAG	Defense Acquisition Guidebook
DAS	Defense Acquisition System
DoD	Department of Defense
DoDD	Department of Defense Directive
DODI	Department of Defense Instruction
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities
EA	Evolutionary Acquisition
EIA	Electronics Industry Alliance
FCS	Future Combat Systems
FFID	Future Force Integration Division
ICD	Initial Capabilities Document
ICS	Integrated Computer System
IPPD	Integrated Product and Process Development
ITAB	Information Technology Acquisition Board
IWS	Information Warfare Systems
JCIDS	Joint Capabilities Integration and Development System
JOpsC	Joint Operations Concept
JROC	Joint Requirements Oversight Council
JTRS-GMR	Joint Tactical Radio System – Ground Mobile Radio
MDA	Milestone Decision Authority
MGV	Manned Ground Vehicles

MOSA	Modular Open Systems Approach
MULE	Multifunctional Utility/Logistics and Equipment
NLOS-LS	Non Line of Sight Launch System
OA	Open Architecture
OPNAV	Office of the Chief of Naval Operations
OSJTF	Open Systems Joint Task Force
PART	Program Assessment and Review Tool
PEO	Program Executive Office
PPBS	Planning, Programming, Budgeting System
R&D	Research and Development
RGS	Requirements Generation System
SE	Systems Engineering
SOSCOE	System of Systems Common Operating Environment
SYSCOM	Systems Command
TRAC	TRADOC Analysis Center
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicle
UGS	Unmanned Ground Systems
UGV	Unmanned Ground Vehicles

EXECUTIVE SUMMARY

The Future Combat Systems (FCS) is the Army's first full-spectrum modernization in nearly 40 years. It is a system of systems, comprised of 14 individual systems, all connected via a common network with the soldier as the centerpiece. FCS is envisioned as a modular system adaptable to the "full-spectrum" of operations to meet the current requirements. Additionally, it is expected to meet the requirements of the Future Force and future operations. The Army has implemented a Spin-out plan for the rapid delivery of maturing FCS technologies to the warfighter to ensure that the warfighter is consistently equipped with state-of-the-art capabilities. Each Spin-out will be inserted into legacy systems and fielded FCS systems until entire FCS Brigade Combat Teams are fielded and the Army continues its path to modernization.

This thesis focuses on the delivery of newly acquired systems to the warfighter and the considerations that must be accounted for in order to effectively and efficiently insert them into the current force systems while, at the same time, allowing for functional adjustments to envisioned future large-scale, complex systems of systems. The Acquisition Strategy Considerations, as outlined in the Defense Acquisition Guidebook (DAG), are used as the basis for constructing the general framework for new technology insertion, with specific focus on Systems Engineering (SE), Evolutionary Acquisition (EA) and the Modular Open Systems Approach (MOSA) to acquisition, to achieve a specific program's (in this case, FCS's) objectives. This thesis examines the application of systems engineering methodology to integrate evolutionary acquisition and MOSA to develop a framework for seamless insertion of new technology. It further examines the implications of applying these approaches to large and complex systems, similar to FCS, enabling an overall objective such as continuous force modernization.

Within the scope of this thesis, successful insertion is defined as the delivery of new capabilities to the warfighter such that capabilities are efficiently integrated with legacy systems without the need for major modifications. Additionally, new capabilities must also allow for the ease of future changes and/or upgrades to the system. The insertion of new capabilities must keep pace with technology maturity and evolving

requirements and threats, allowing for the rapid deployment of capabilities, minimizing the risk of obsolescence and ensuring that the warfighter is always equipped with state-of-the-art technology. This requires acquisition and insertion processes that exhibit flexibility and responsiveness in support of these requirements. Flexibility enables the system process to adapt to changing requirements and evolving threats. Responsiveness enables it to rapidly transition maturing technologies into capabilities to meet warfighter requirements. Finally, application of sound systems engineering practices to integrate and implement varying system processes ensures the delivery of a system that is capable, upgradeable, affordable and supportable throughout its planned life cycle.

The Army has recognized that evolutionary acquisition enables the rapid fielding of FCS technologies as they mature. It has implemented the Spin-out plan to leverage FCS R&D efforts to insert new capabilities into the Current Force. Evolutionary acquisition minimizes the acquisition process time to enable a quick transition from science and technology to capabilities that the warfighter can use. It also minimizes the risks of technology obsolescence ensuring that warfighters are equipped with state-of-the-art capabilities, maintaining the advantage over evolving and ever-changing threats in current and future operations. Evolutionary acquisition and the spiral process, however, do not sufficiently address the insertion of newly acquired technology and ensuring that the right capabilities are acquired to meet warfighter requirements. Evolutionary acquisition primarily addresses the acquisition phase of a system's life cycle. Complex system of system development and continuous modernization programs, such as FCS, require a more robust approach that encompasses the system's entire life cycle from requirements development to disposal. The insertion strategy, therefore, must be an integral part of program and system design from concept to deployment.

Utilizing a Modular Open Systems Approach to acquisition ensures the seamless insertion of newly acquired systems into existing systems and facilitates insertion of future envisioned systems. MOSA manages the interfaces between systems thereby ensuring interoperability between all the systems within a complex system of systems. An open architecture design further promotes seamless insertion thus enabling the execution of an evolutionary acquisition strategy.

The system structure methodology provides a framework for engineering a system. The system structure methodology is the top-down development and bottom-up realization of requirements using accepted processes for engineering systems in DoD acquisition programs. This framework is used for integration of evolutionary acquisition process and the modular open systems approach to tailor the framework to address the needs and requirements of the FCS program and contribute to Army Modernization Strategy overall.

Similar to the acquisition strategy, the insertion strategy must be tailored according to the specific program. Acquisition strategy goals and objectives can be utilized to develop the insertion strategy concurrently. Insertion strategy must be considered at the beginning of a program to determine the feasibility of the processes to be employed. The integration of evolutionary acquisition and MOSA within a sound systems engineering framework results in an insertion strategy that is responsive and flexible with the greatest benefit to the end user of the resulting products.

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I. INTRODUCTION

> The Army intends to remain the preeminent landpower on earth, dominant across the full spectrum of operations, now and in the future, to meet our enduring contract with the American people to defend freedom.[1]

A. PURPOSE AND SCOPE

The Future Combat Systems (FCS) is the Army's first full-spectrum modernization in nearly 40 years. The urgent needs of the current fight required that the Army accelerate transformation. The Army is in the midst of an ongoing process of transformation with a broad mandate to change across many domains. FCS Brigade Combat Team (BCT) is the material solution for the future force and is the Army's principal modernization strategy that is the embodiment of the modular force, a modular system designed for "full-spectrum" operations [2]. Due to the immensity and complexity of FCS, systems studies can be conducted to examine and evaluate a variety of issues from requirements development, technology maturity, and testing and evaluation. This thesis, however, focuses on the delivery of newly acquired systems to the warfighter and the considerations that must be accounted for in order to effectively and efficiently insert it into the current force systems while at the same time allowing for functional adjustments to envisioned future large scale complex systems of systems. The Acquisition Strategy Considerations, as outlined in the Defense Acquisition Guidebook (DAG), are used as the basis for constructing the general framework for new technology insertion with specific focus on Systems Engineering (SE), Evolutionary Acquisition (EA) and the Modular Open Systems Approach (MOSA) to acquisition, to achieve a specific program's (in this case, FCS's) objectives.

The Army has recognized that evolutionary acquisition is the fastest and surest way to field FCS technologies and modernize the Army. The Navy has made concerted efforts to implement open architecture in support of the development of systems that are affordable, operationally effective and suitable and can be a timely solution to satisfy user needs. This thesis proposes the application of a systems engineering framework to integrate evolutionary acquisition and MOSA to develop an insertion strategy that facilitates seamless insertion of new technology. The integration of these three considerations shall result in a system process that is flexible and responsive to enable the rapid fielding of maturing technologies, adjust to changing requirements due to changing threats, and capable of accommodating future upgrades without costly modifications to fielded systems.

Within the scope of this thesis, successful insertion is defined as the delivery of new capabilities to the warfighter such that capabilities are efficiently integrated with legacy systems without the need for major modifications. Additionally, new capabilities must also allow for the ease of future changes and/or upgrades to the system. The insertion of new capabilities must keep pace with technology maturity and evolving requirements and threats to rapidly deploy capabilities, minimizing the risk of obsolescence and ensuring that the warfighter is always equipped with state-of-the-art technology. This requires acquisition and insertion processes that exhibit flexibility and responsiveness in support of these requirements. Flexibility enables the system process to adapt to changing requirements and evolving threats. Responsiveness enables it to rapidly transition maturing technologies into capabilities to meet warfighter requirements. Finally, application of sound systems engineering practices to integrate and implement varying system processes ensures the delivery of a system that is capable, upgradable, affordable and supportable throughout its planned life cycle.

There are three key processes in the Department of Defense (DoD) that must work in concert to deliver the capabilities required by the warfighters: the requirements process; the acquisition process; and the Planning, Programming, Budgeting, and Execution (PPBE) process (Figure 1). To produce weapon systems that provide the capabilities our warfighters need, these three processes must be aligned to ensure consistent decisions are made [3]. Each process is summarily discussed to provide an overview of the DoD's decision support system to acquire new or modified materiel. Due to the scope of this thesis, analysis of DoD's decision support system is focused primarily on the requirements and acquisition process. These processes are then applied to the Army's modernization strategy via FCS (BCT) and the accelerated fielding of select capabilities (also called Spin-outs) to examine the evolutionary acquisition of a complex system.

Chapter I of this thesis describes DoD's decision support systems, FCS and the challenges inherent in inserting new technology in order to implement complex system of systems design. Chapter II summarily discusses the policies and regulations applicable to the three DoD decision support processes. Chapter III describes acquisition strategy considerations to facilitate seamless insertion of newly acquired systems. More specifically, systems engineering, evolutionary acquisition and the modular open systems approach are described. Chapter IV describes the application of the three considerations and FCS implications to the seamless integration of future Spin-outs. Chapter V is the conclusions and recommendations.

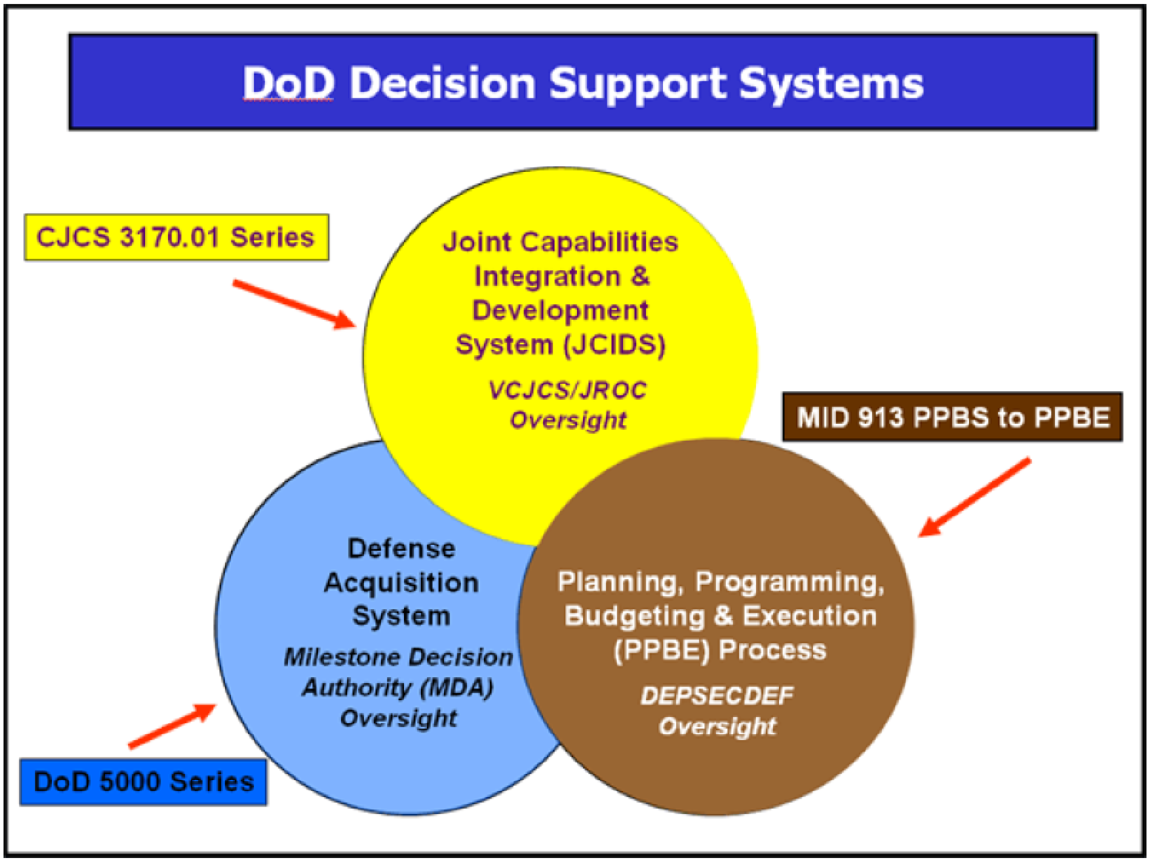

Figure 1. DoD Decision Support Systems. From [3]

B. BACKGROUND: WHAT IS FCS?

The FCS concept is designed to be part of the Army's Future Force, which is intended to transform the Army into a more rapidly deployable and responsive force that differs substantially from the large division-centric structure of the past. The Army is reorganizing its current forces into modular brigade combat teams, each of which is expected to be highly survivable and the most lethal brigade-sized unit the Army has ever fielded. FCS-equipped brigade combat teams will change the way the Army fights wars. Using sensors connected via network allows for improved communications and unmatched situational awareness enabling the Army to preemptively kill the enemy before they strike military or civilian targets. The Army is implementing its transformation plans at a time when current U.S. ground forces continue to play a critical role in the ongoing conflicts in Iraq and Afghanistan. It has instituted plans to spin out selected FCS technologies and systems to current Army forces to meet current operational requirements [4].

Fundamentally, the FCS concept is to replace size and quantity with superior information—allowing soldiers to see and hit the enemy first rather than to rely on heavy armor to withstand a hit. This solution attempts to address a mismatch that has posed a dilemma to the Army for decades: the Army's heavy forces had the necessary firepower needed to win but required extensive support and too much time to deploy while its light forces could deploy rapidly but lacked firepower and armor. The Future Force will be better organized, staffed, equipped, and trained for prompt and sustained land combat, ensuring the Army's continued domination over evolving and sophisticated threats. Although it is to be offensively oriented, FCS (BCT) will be capable of executing full spectrum operations from asymmetric and stability operations to humanitarian relief operations. The Army envisions a new way of fighting that depends on networking the force, which involves linking people, platforms, weapons, and sensors seamlessly together in a system-of-systems [4].

FCS (BCT) is the material solution for the future force and is the Army's principal modernization strategy that is the embodiment of the modular force, a modular system designed for "full-spectrum" operations. It will network existing systems, systems already under development, and systems to be developed to meet the requirements of the Army's Future Force. It will be adaptable to traditional warfare as well as complex, irregular warfare in urban terrains, mixed terrains such as deserts and plains, and restrictive terrains such as mountains and jungles. It can also be adaptable to civil support, such as disaster relief. It is a joint (across all the military services) networked (connected via advanced communications) system of systems (one large system made up of 14 individual systems, the network, and most importantly, the soldier) connected via an advanced network architecture that will enable levels of joint connectivity, situational awareness and understanding, and synchronized operations heretofore unachievable (Figure 2) [2].

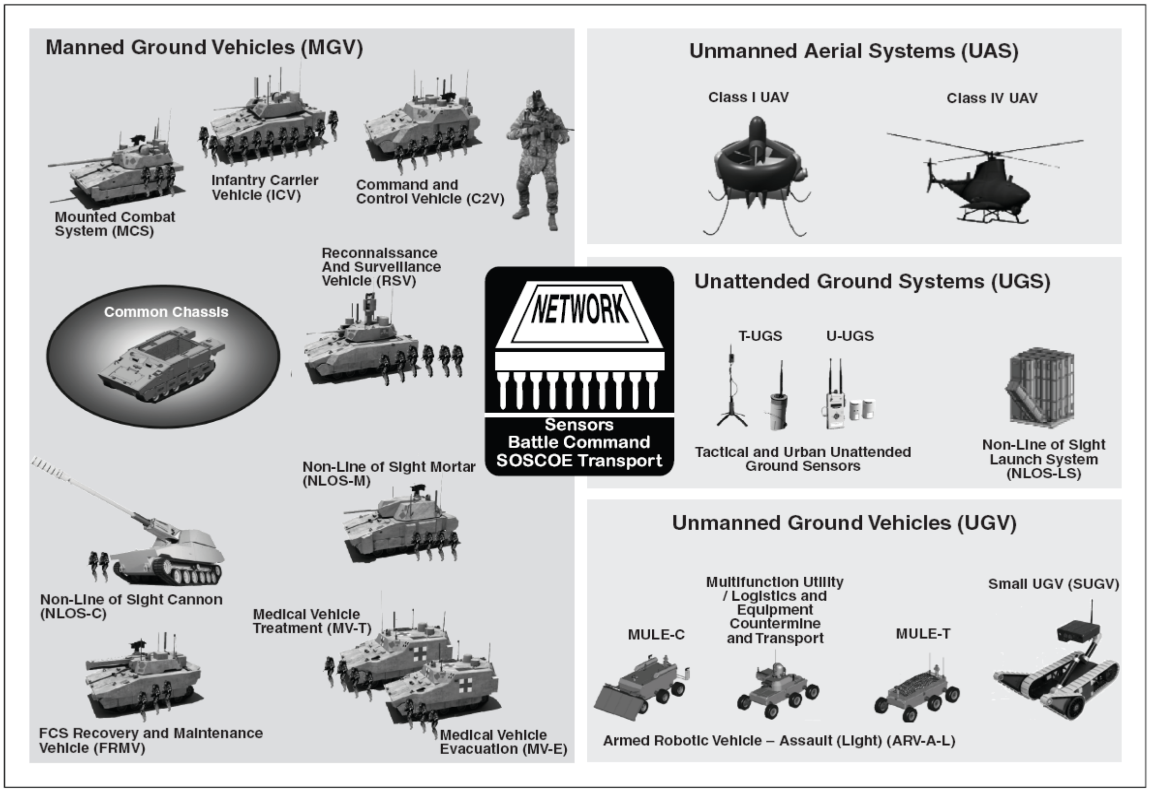

Figure 2. FCS Core Systems. From [4]

FCS (BCT) is using evolutionary acquisition to develop, field and upgrade FCS (BCT) throughout its life cycle. Since 2004, FCS has been working an accelerated delivery schedule of selected hardware and software to the Current Force. The Army is accelerating fielding of select FCS (BCT) capabilities (called Spin-outs) to reduce operational risk to the Current Force. Spin-outs are providing early capability in force protection, networked fires, expanded battle space, and battle command and have begun testing in 2008. Just as the emerging FCS (BCT) capabilities enhance the Current Force, the Current Force's operational experience informs the FCS (BCT) program, further mitigating future development challenges, force management, and institutional risks. In addition to the current Spin-outs, the Chief of Staff of the Army, in December 2007, directed the FCS Program to accelerate evaluation schedules for the Small Unmanned Ground Vehicle robot and the Class 1 Unmanned Aerial Vehicle [2].

Spin-out 1 consists of B-kits for Abrams, Bradley and HMMWV platforms, Tactical and Urban Sensors and Non Line of Sight-Launch System (NLOS-LS). B-kits provide increased situational awareness and communications through advanced network and communication settings. Spin-out 1 B-Kits include Joint Tactical Radio System Ground Mobile Radio (JTRS-GMR), Integrated Computer System (ICS), and System of System Common Operating Environment (SOSCOE). Tactical and Urban sensors placed in urban settings (by soldiers) and in tactical environments will increase situational awareness by providing real-time battlespace information over the network. These act as “eyes and ears” on the battlefield—thus allowing more Soldiers in the fight—with better situational awareness. NLOS-LS provides rapidly deployable and networked-linked stand off munitions launch capability that is currently not available within the Army. FCS Spin-out technology will reach operational brigades in 2010 timeframe. Spin-out 1 will be fielded to current force units at a rate of 6 per year until all of the Army’s 76 Brigade Combat Teams have been fielded with FCS capabilities. By 2015, the Army force structure will include one Brigade Combat Team (BCT) equipped with all FCS (BCT) core systems and additional Brigade Combat Teams with embedded FCS (BCT) capability [2].

C. ARMY MODERNIZATION AND FCS OBJECTIVES

As previously mentioned, FCS is at the core of Army modernization. It is envisioned to address the urgent needs of the current fight while, at the same time, accelerating transformation to prepare the future force. The 2008 Army Modernization Strategy document encompasses FCS in two of the four elements to methodically deliver needed capabilities to the warfighter. Figure 3 illustrates the four elements of Army modernization.

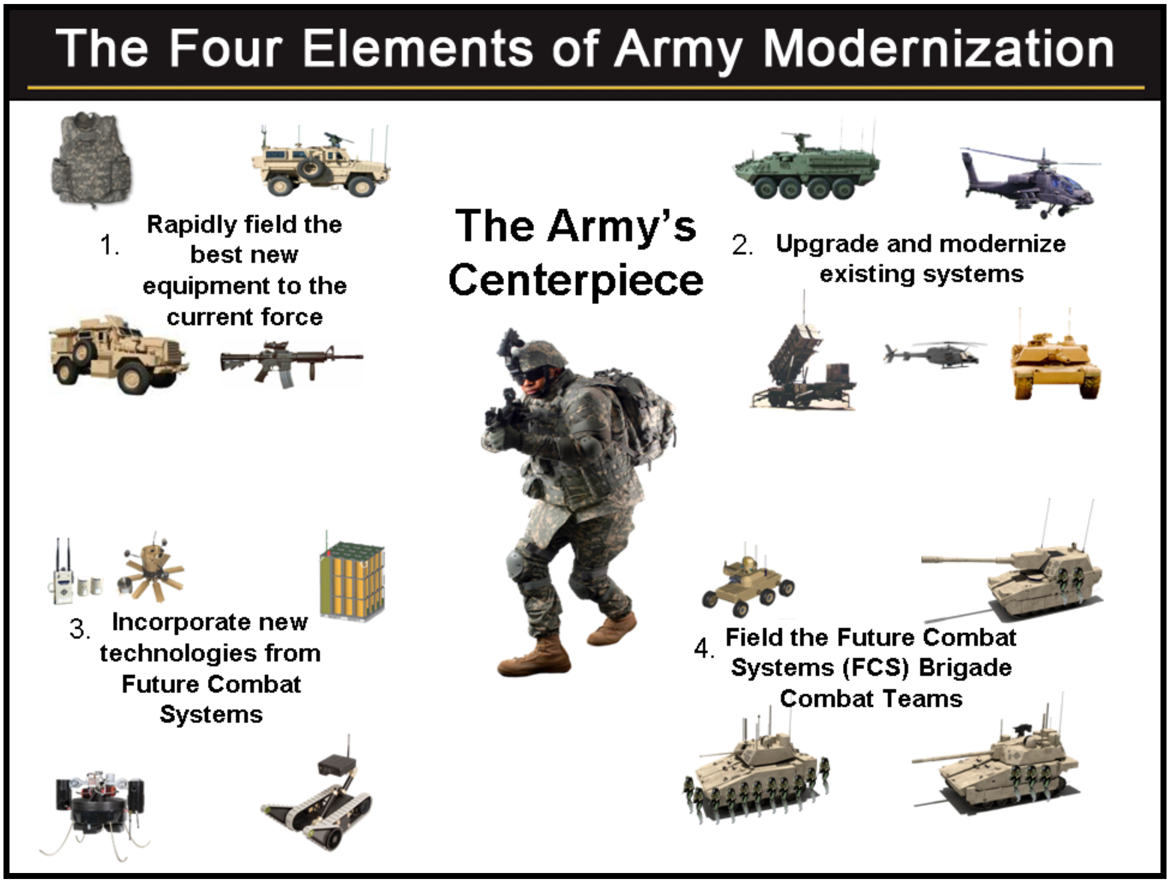

Figure 3. The Four Elements of Army Modernization. From [5]

Element number 3 of Army Modernization above drives research and development (R&D), rapid fielding and the modernization program through delivery of the latest capabilities via the Spin-outs. Incorporating these Spin-outs enables the Army to exploit and leverage new capabilities sooner rather than later, eventually modernizing legacy Army equipment and ultimately achieving the fourth element of Army Modernization, which is the fielding of FCS BCT. To achieve this goal, FCS components must exhibit characteristics that facilitate such a transition. The following excerpt describes the Army vision for FCS:

The Army is transforming into a networked Modular Force that is agile, globally responsive and sustainable. FCS is the core of this effort. FCS is designed to provide the Soldiers and leaders who engage the enemy with the situational awareness required for a decisive advantage in combat. Networked Battle Command and sensors will enhance the ability of platoons and companies to see the enemy and engage with precision. This is accomplished by providing Soldiers with Battle Command and sensor capabilities similar to those currently resident in brigade and division headquarters. The FCS BCT will be an integrated combat formation employing a system of systems approach to deliver the capabilities the Army needs. Fielding FCS will be fulfilling the Army's vision for the future by integrating full spectrum capabilities in its systems [5].

FCS requires a modular system designed to conduct "full-spectrum" operations. It needs to operate with existing systems as well as systems already under development and future systems to be developed to meet the requirements of the Army's Future Force. Additionally, the Army has established a number of key tenets it wanted to achieve with the FCS program. These key tenets were listed in the GAO report referenced in [6] and are as follows:

- create opportunity for best of industry to participate;
- leverage government technology base to maximum extent;
- associate ongoing enabling efforts with LSI-led activity;
- maintain a collaborative environment from design through life cycle;
- achieve, as a minimum, commonality at subsystem/component level;
- design/plan for technology integration and insertion;
- maintain and shape the industrial base for the future;
- retain competition throughout future force acquisition;
- ensure appropriate government involvement in procurement processes;
- achieve consistent and continuous definition of requirements;

- maintain and shape government acquisition community;
- achieve program affordability—balance performance and sustainment;
- ensure a "one team" operating with partnership and teamwork.

The key tenets listed above establish the objectives that the Army wanted to achieve in executing this program. Most of the tenets listed above describe process objectives; however, several translate into desired system combat capability such as modularity due to commonality at the subsystem/component level and designing for technology integration and insertion. These tenets provide insight into the Army's vision of FCS and its strategy to develop and field its complex system of systems. The Army has clearly stated that the preferred acquisition strategy in support of achieving their objectives is evolutionary acquisition [2]. This acquisition strategy is inline with DoD policies and guidelines. Evolutionary acquisition and the spiral process, however, do not sufficiently address the insertion of newly acquired technology and ensuring that the right capabilities are acquired to meet warfighter requirements. Evolutionary acquisition primarily addresses the acquisition phase of a system's life cycle. For complex system of system development and for continuous modernization programs, such as FCS, require a more robust approach that encompasses the system's entire life cycle from requirements development to disposal (i.e., cradle-to-grave). The following section describes FCS challenges that the program may encounter in executing the Army's preferred acquisition strategy.

D. FCS CHALLENGES

As with many endeavors, there are several challenges that must be overcome in order for the Army to achieve its objectives as described above.

1. Technology is changing rapidly. The transition of technology into new materiel systems and its acquisition must be capable of supporting rapid changes. The acquisition process has been revised considerably to support that objective. A similar

process for insertion must be developed that has the flexibility to accommodate these rapid changes to allow for seamless and effective insertion of new systems to current systems with respect to doctrine, organization, training, materiel, leadership, personnel and facilities (DOTMLPF). The inability to keep pace with changing technology, oftentimes result in the underutilization of new capabilities and results in costly modifications to fielded systems in order to effectively insert newly acquired capabilities.

2. Evolving requirements. The primary objective of Defense acquisition is to acquire systems that satisfy warfighter requirements and improve mission capability and operational support in a timely manner. End user involvement early in the acquisition process contributes to addressing warfighter needs. The challenge, however, is that in current and, possibly, future operations, the warfighter is faced with evolving threats that in turn change warfighter requirements. The process for delivery of new capabilities must keep pace with these evolving requirements while maintaining the flexibility to respond to urgent needs. In an evolutionary acquisition environment, requirements, technology, and capabilities can change several times throughout the program life cycle, which can significantly affect the end product. Integration challenges occur when the processes do not accommodate some degree of flexibility in the design and implementation of a system of systems.

3. Obsolescence and technology maturation risk. The warfighter constantly requires new capabilities as threats evolve and adapt. The time that a system spends in development and acquisition must constantly be minimized to reduce obsolescence risks. At the same time, however, sufficient technology maturity must be considered to ensure that the capabilities are technically feasible prior to entering into production.

In summary, technology continues to develop rapidly. To capitalize on cutting edge capabilities, capabilities must transition from concept to reality as fast as technology evolves. At the same time, warfighters are faced with evolving threats, which constitute evolving requirements. Effective and efficient insertion of capabilities into the current force enables the warfighter to fully capitalize on the capabilities that new technology provides. When technology is delayed in any phase of the development or acquisition process (Figure 4), it increases the risk that the system delivered to the warfighter is obsolete and irrelevant to current operations. Additionally, process iteration is inherent in conducting systems engineering. It is even more palpable in complex system of systems development. Anticipating and managing changing requirements at the beginning of the process while ensuring the delivery of end products that are relevant and capable of meeting these requirements is the difficulty inherent in complex system of systems development. The insertion strategy framework must therefore be flexible and responsive to the needs of the end user as well as the changing technology to enable the achievement of the Army's objectives for FCS and overall Army Modernization.

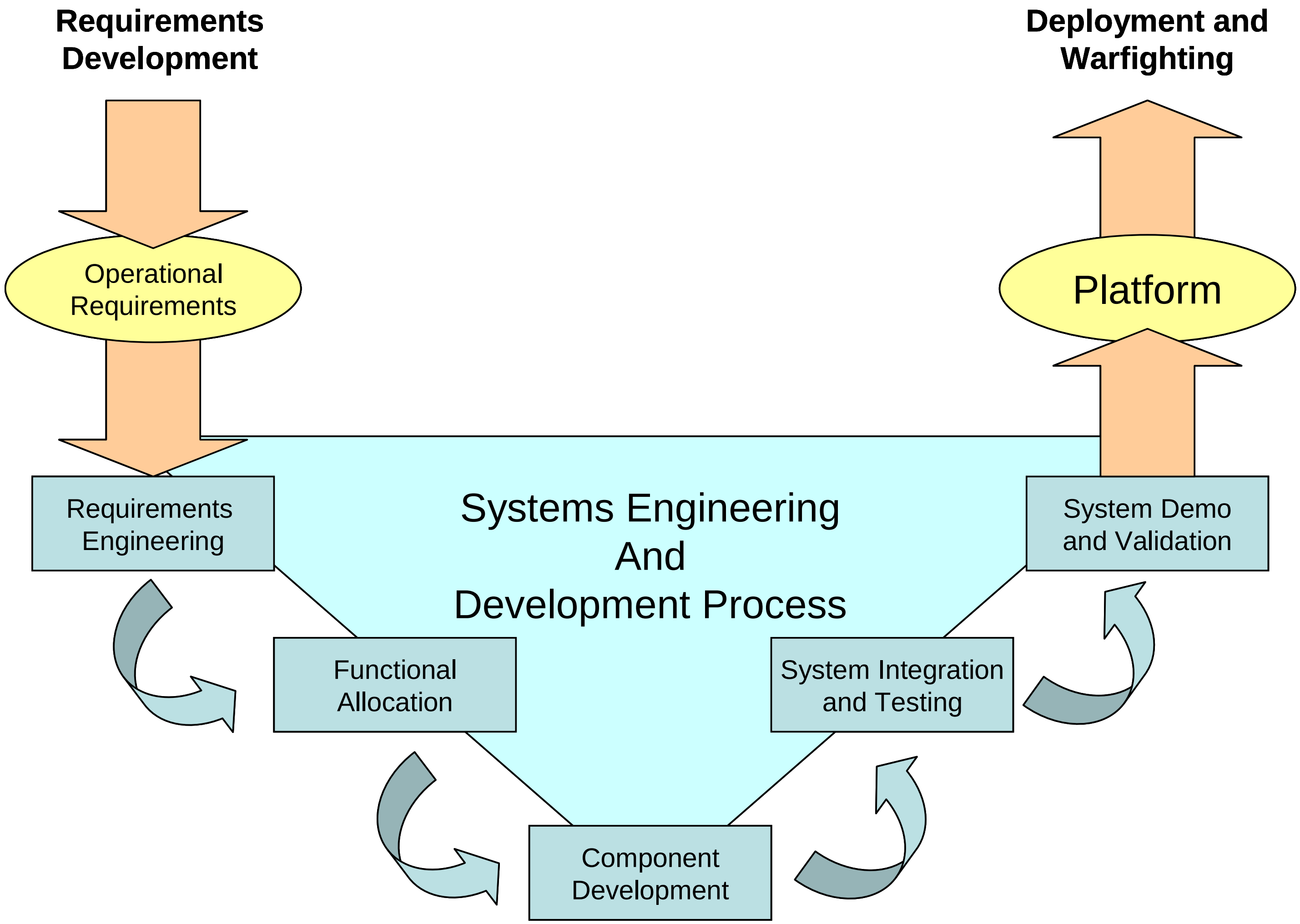

Figure 4. Systems Engineering and Development Process. From [7]

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II. LITERATURE REVIEW

A. INTRODUCTION

As the primary question for this thesis addresses the construction of a general framework for effective and efficient insertion of newly acquired systems into current systems, a large portion of the published works reviewed are joint publications and regulations manuals. The Joint Capabilities Integration and Development System (JCIDS), the Defense Acquisition System (DAS), and the Planning, Programming, and Budgeting System (PPBS) form the Department of Defense's three principal decision support processes for transforming the military forces according to the future DoD vision. Together, the three systems provide an integrated approach to strategic planning, identification of needs for military capabilities, systems acquisition, and program and budget development. Each process has its own set of guidelines and publications. Each process stage is summarily discussed to underline their significance to insertion and integration of the new system in the later phases of the program life cycle.

B. JOINT CAPABILITIES INTEGRATION AND DEVELOPMENT SYSTEM (JCIDS) PROCESS

With the Joint Staff's publication of CJCSM 3170.01 and CJCSI 3170.01C in June 2003, JCIDS replaced the Requirements Generation System (RGS). RGS used a mission needs approach to identify the warfighter's operational requirements. Each service generated their own requirements according to their needs, which oftentimes duplicated other services' requirements, and resulted in a lack of overall joint coordination. JCIDS is based on a joint concepts-centric capabilities identification process that focuses on the Joint Force. Figure 5 illustrates the differences between RGS and JCIDS. For the reasons discussed in the previous chapter, JCIDS's top-down approach to requirements generation poses unique challenges for the service component in the later phases of system development. This section establishes how JCIDS is linked to the acquisition process and its relevancy to technology insertion.

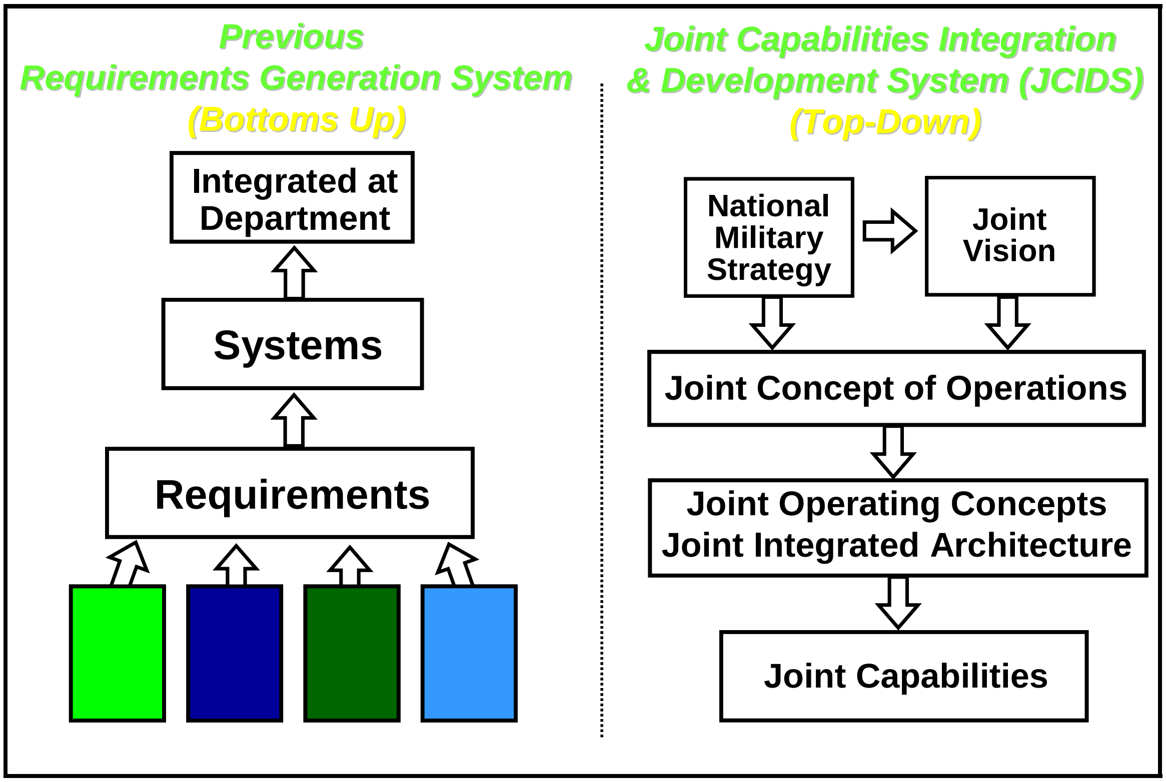

Figure 5. Requirement Generation Changes. From [8]

1. Top Down Capabilities Identification Methodology

The JCIDS process is one component of DoD's three principal decision support processes for transforming the military forces to support the national military strategy and the defense strategy. It implements a top-down methodology using joint concepts that identifies and describes shortcomings and redundancies in warfighting capabilities. The Joint Operations Concepts (JOpsC) are developed from top-level strategic guidance, providing a top-down baseline for identifying future capabilities. New capability requirements, materiel or non-materiel, must relate directly to capabilities identified through the JOpsC. Concept of Operations (CONOPs) may indicate short-term capability needs. CONOPs allow the joint community to adjust or divest current capabilities by providing the operational context needed to justify or modify current programs. The process flows from national level and strategic guidance through the concepts as shown in Figure 6. As they are developed, the JOpsC, and if necessary Service concepts, will provide the conceptual basis for the Capability Based Assessments (CBAs) to answer these questions by identifying capabilities, gaps, and redundancies as well as potential non-materiel and materiel approaches to addressing the issues. A CBA may also be based on a combatant command, Service, or Defense agency CONOPs. The CBA process is described in CJCSM 3170.01 Series, "Operation of the Joint Capabilities Integration and Development System."

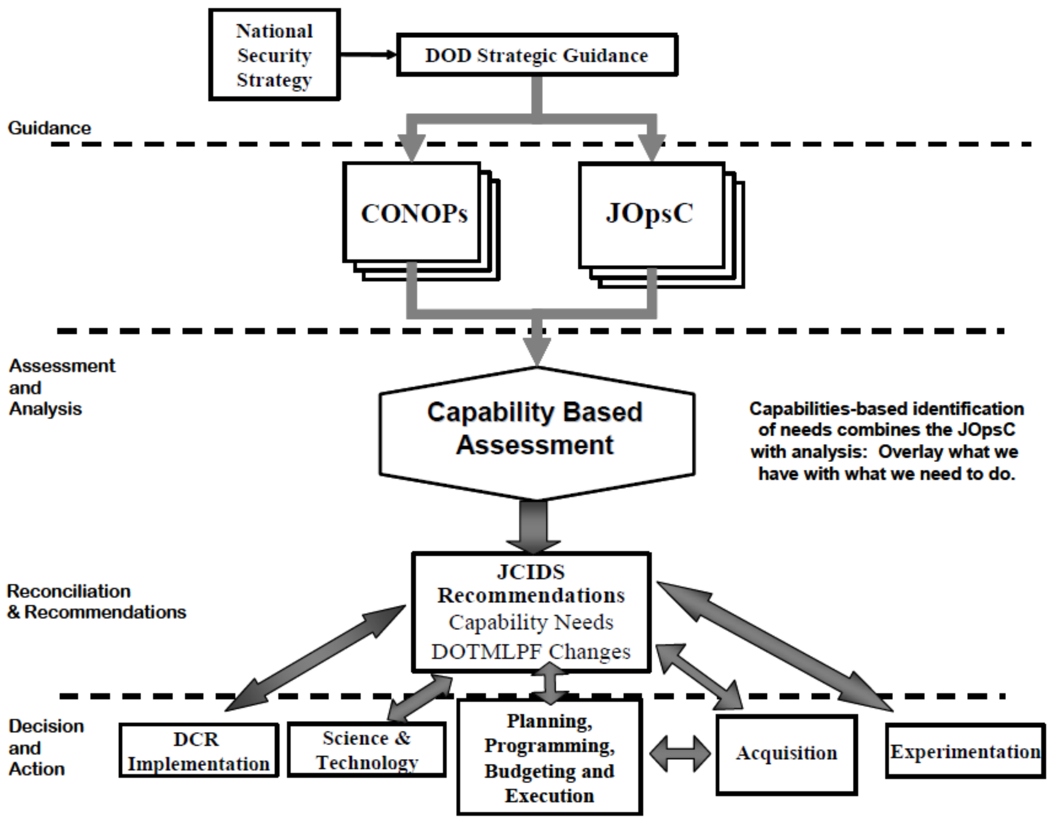

Figure 6. Top Down Capability Need Identification Process. From [9]

2. JCIDS Link to the Acquisition Process

As discussed in the previous section, JCIDS is based on a series of top-down analyses derived from national-level and strategic guidance. JCIDS identifies capability gaps and assesses the associated risks to determine if a materiel and/or non-materiel solution is required to address these gaps. The link between JCIDS and the acquisition process is established only when a materiel solution is recommended via an Initial Capabilities Document (ICD). Once a program is into the acquisition process, JCIDS continue to provide inputs at key points during the acquisition process to guide the subsequent development, production and testing of the program as shown in Figure 7.

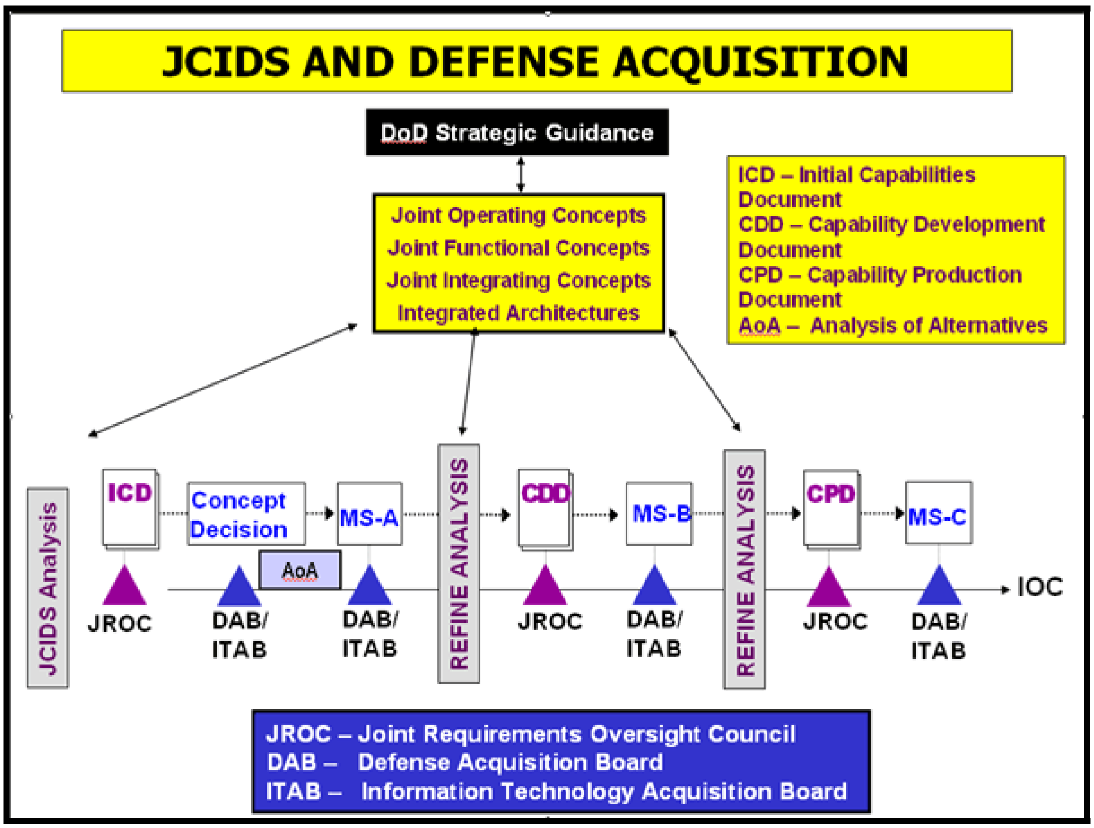

Figure 7. JCIDS and Defense Acquisition. From [3]

C. DEFENSE ACQUISITION SYSTEM

The Defense Acquisition System exists to manage the nation's investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces. The investment strategy of the Department of Defense shall be postured to support not only today's force, but also the next force, and future forces beyond that. The primary objective of Defense acquisition is to acquire quality products that satisfy user needs with measurable improvements to mission capability and operational support, in a timely manner, and at a fair and reasonable price [10].

Department of Defense Directive (DoDD) 5000.1, The Defense Acquisition System, provides management principles and mandatory policies and procedures for managing all acquisition programs. This directive applies to all DoD components and the policies contained within apply to all acquisition programs.

Department of Defense Instruction (DoDI) 5000.2, Operation of the Defense Acquisition System, establishes a framework for translating mission needs and technology opportunities based on approved mission needs and requirements, into stable, affordable, and well-managed acquisition programs that include weapon systems and automated information systems (AISs).

The Defense Acquisition Guidebook (DAG) provides a reference source for program managers in support of their management activities for their respective programs. This guidebook complements DoDD 5000.1 and DODI 5000.2 by providing best practices that can be tailored for each program.

D. PLANNING, PROGRAMMING, BUDGETING AND EXECUTION (PPBE) PROCESS

The purpose of the PPBE process is to allocate resources within the Department of Defense. The Secretary of Defense establishes policies, strategy, and prioritized goals for the Department, which is subsequently used to guide resource allocation decisions that balance the guidance with fiscal constraints. Within the scope of this thesis, it is assumed that funding has been allocated to the service component. Considerations applicable to successful technology insertion are limited to the nature and timing of funding based on the PPBE process. In evolutionary acquisition, the first increment of capability is fully funded at program initiation. Subsequent increments are funded dependent on the type of development, incremental or spiral. For incremental development, the end-state capability is defined and the acquisition strategy defines the funding for each increment of capability. In a spiral development, only the first increment is firmly defined. The precise end-state capabilities are not known at program initiation; therefore, each increment requires a management approach to define the exact capabilities as well as how it will be funded.

III. ACQUISITION STRATEGY CONSIDERATIONS

A. INTRODUCTION

DoD Instruction 5000.2 requires an approved acquisition strategy at program initiation. The acquisition strategy guides program execution through the entire program life cycle. The strategy covers development, testing, production, and life-cycle support. The development of the acquisition strategy incorporates several considerations in support of the Defense Acquisition System's primary objective to ensure the acquisition of quality products that satisfy user needs with measurable improvements to mission capability and operational support, in a timely manner. The Defense Acquisition Guidebook (DAG) lists the principal considerations associated with developing the acquisition strategy.

The same considerations are useful to apply in development of the insertion strategy. Not all of these considerations apply to every program in developing the acquisition strategy or the insertion strategy for a specific program. The program manager tailors the acquisition strategy for each individual program. The insertion strategy, therefore, must also be tailored to ensure an effective and efficient transition to the warfighter. Systems Engineering, Evolutionary acquisition (EA), and Modular Open Systems Approach (MOSA) are the three principal considerations that significantly contribute to the seamless insertion of newly acquired technology. Table 1 lists the principal considerations associated with developing the acquisition strategy.

Acquisition Strategy Considerations	Acquisition Approach	Modular Open Systems Approach
	Best Practices	
	Business Considerations	Product Support
	Capability Needs Summary	Program Structure
	Environment, Safety, Occupational Health	Relief, Exemption, and Waiver
	Human Systems Integration	Research and Technology Protection
	Information Assurance	
	Information Technology	Resource Management
	Integrated Test and Evaluation	Risk Management
		Systems Engineering
	Interoperability	

Table 1. Acquisition Strategy Considerations. From [3]

B. SYSTEMS ENGINEERING

DoD policy and guidance dictate the application of a systems engineering approach to achieve an integrated, balanced system solution. DoD Directive 5000.1 requires:

> *Acquisition programs shall be managed through the application of a systems engineering approach that optimizes total system performance and minimizes total ownership costs. A modular open-systems approach shall be employed, where feasible [10].*

The Defense Acquisition System recognizes the benefits that SE contributes to the management of acquisition programs. Its policies and guidance support SE methodology to achieve acquisition program objectives. The following describes SE and its applicability to the acquisition process:

> *Systems engineering is the overarching process that a program team applies to transition from a stated capability need to an operationally effective and suitable system. Systems engineering*

encompasses the application of systems engineering processes across the acquisition life cycle (adapted to each and every phase) and is intended to be the integrating mechanism for balanced solutions addressing capability needs, design considerations and constraints, as well as limitations imposed by technology, budget, and schedule. The systems engineering processes are applied early in concept definition, and then continuously throughout the total life cycle.

Balanced system solutions are best achieved by applying established systems engineering processes to the planning, development, and implementation of a system or system-of-systems acquisition in an Integrated Product and Process Development framework [3].

Just as the acquisition strategy is required to employ SE, development of the insertion strategy using SE enables a total system life cycle approach. A total system life cycle approach encompasses every system phase from requirements generation, concept development, acquisition, testing and validation, and ultimately system insertion and deployment. Applying SE from a "cradle-to-grave" perspective enables more seamless transitions as systems progress through its life cycle because transition considerations are accounted for early in system design.

Systems engineering is an interdisciplinary approach or a structured, disciplined, and documented technical effort to simultaneously design and develop systems products and processes to satisfy the needs of the customer. Systems engineering transforms needed operational capabilities into an integrated system design through concurrent consideration of all Lifecycle needs. As systems become larger and more complex, the design, development, and production of a system or system-of-systems require the integration of numerous activities and processes. Systems engineering is the approach to coordinate and integrate all acquisition Lifecycle activities.

Systems engineering provides a systematic set of processes to help coordinate and integrate activities throughout the life cycle of the system. Systems engineering offers a technical framework to enable sound decision making relative to trade studies among system performance, risk, cost, and schedule. The successful implementation of proven, disciplined systems engineering processes results in a total system solution that is:

—Robust to changing technical, production, and operating environments;
— Adaptive to the needs of the user; and
—Balanced among the multiple requirements, design considerations, design constraints, and program budgets [3].

The following sections discuss a top-level view of a systems engineering framework. This framework is applied using Naval Systems Engineering processes to tailor the framework for the purposes of this thesis. The *Naval Systems Engineering Guide* provides insight into how the Naval Systems Engineering processes fit into the overall EIA-632 systems engineering framework. The guide added Navy policies and procedures to describe the procedural steps with respect to Navy programs. Similarly, Army policies and procedures can be added for applicability to the FCS program. The processes, however, remain applicable to the Army because they are derived from accepted practices used for engineering systems in DoD acquisition programs.

1. Process Relationships

The processes of this SE approach have been organized into five distinct groups: Acquisition & Supply, Technical Management, System Design, Product Realization, and Technical Evaluation. The processes are applicable to the engineering or reengineering of the end products that make up a system, as well as the development of enabling products required to provide life-cycle support to system end products [11]. The appropriate processes are applied recursively and iteratively to define the system products of the system hierarchy and then to implement and transition the system products to the end user or the warfighter. Figure 8 shows the relationships between the processes of this SE approach.

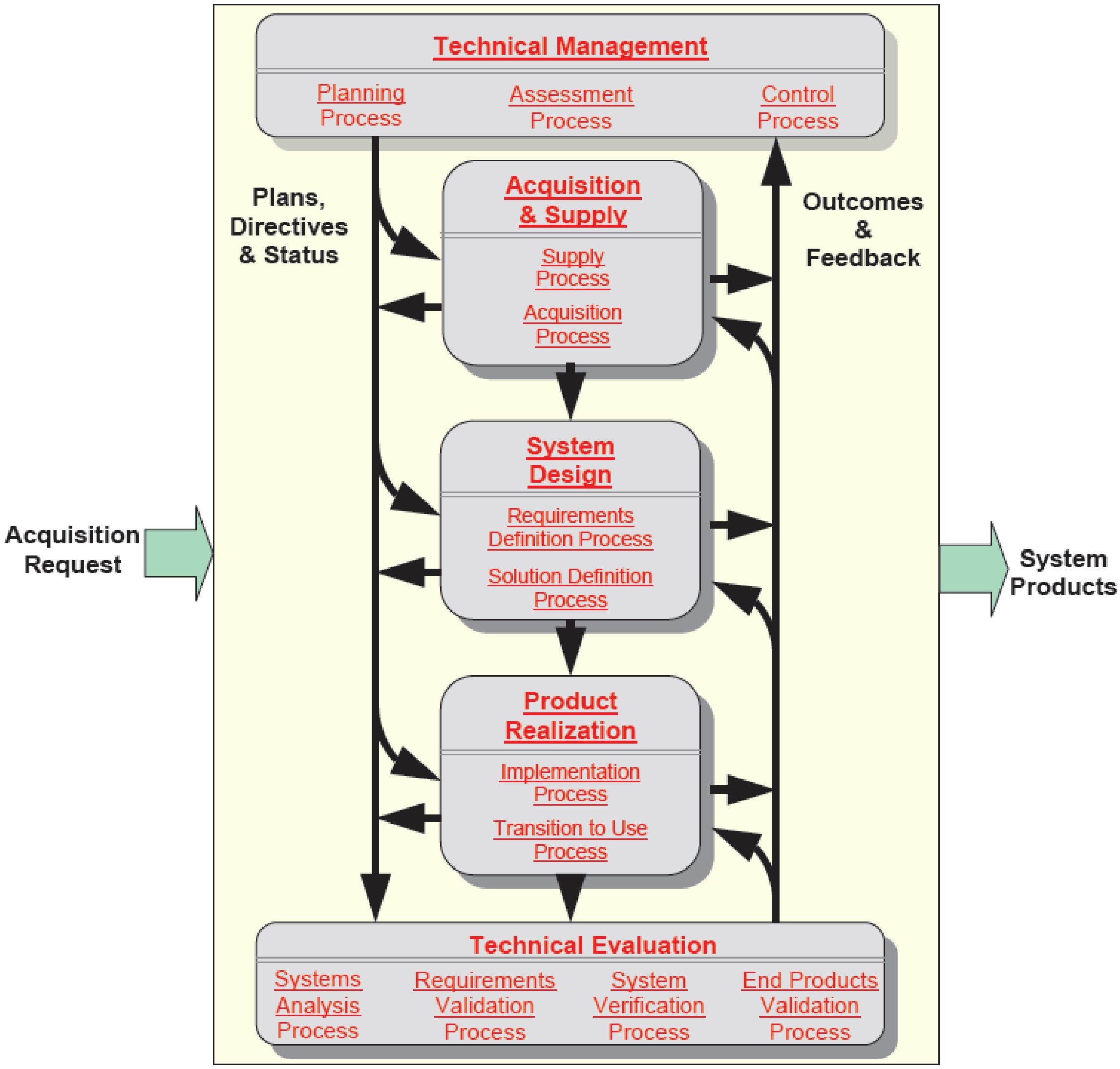

Figure 8. Relationship of processes for engineering a system. From [11]

Each of the processes has sub-processes that are the accepted practices used for engineering systems in DoD acquisition programs. The 33 sub-processes describe the tasks associated with each sub-process. Many of the associated tasks are concurrent and highly iterative, and have interactive dependencies that lead to alteration of previously established technical requirements. The program manager must therefore decide which of the processes apply to his specific program and which of the sub-processes apply to the processes selected. Furthermore, he must define appropriate tasks for each of the selected sub-processes; and establish methods and tools to support task implementation [11]. Every sub-process details the preceding processes, required inputs, entry criteria, specific tasks, outputs, exit criteria and the next processes upon completion. Figure 9 below shows the 33 sub-processes for engineering a system and Figure 10 shows the systems engineering process timeline as it applies to the DoD life-cycle.

SUPPLY SUB-PROCESSES
1 – Product Supply

ACQUISITION SUB-PROCESSES
2 – Product Acquisition
3 – Supplier Performance

PLANNING SUB-PROCESSES
4 – Process Implementation Strategy
5 – Technical Effort Definition
6 – Schedule and Organization
7 – Technical Plans
8 – Work Directives

ASSESSMENT SUB-PROCESSES
9 – Progress Against Plans and Schedules
10 – Progress Against Requirements
11 – Technical Reviews

CONTROL SUB-PROCESSES
12 – Outcomes Management
13 – Information Dissemination

REQUIREMENTS DEFINITION SUB-PROCESSES
14 – Acquirer Requirements
15 – Other Stakeholder Requirements
16 – System Technical Requirements

SOLUTION DEFINITION SUB-PROCESSES
17 – Logical Solution Representations
18 – Physical Solution Representations
19 – Specified Requirements

IMPLEMENTATION SUB-PROCESSES
20 – Implementation

TRANSITION TO USE SUB-PROCESSES
21 – Transition to Use

SYSTEMS ANALYSIS SUB-PROCESSES
22 – Effectiveness Analysis
23 – Trade-off Analysis
24 – Risk Analysis

REQUIREMENTS VALIDATION SUB-PROCESSES
25 – Requirements Statements Validation
26 – Acquirer Requirements Validation
27 – Other Stakeholder Requirements Validation
28 – System Technical Requirements Validation
29 – Logical Solution Representations Validation

SYSTEM VERIFICATION SUB-PROCESSES
30 – Design Solution Verification
31 – End Product Verification
32 – Enabling Products Readiness

END PRODUCTS VALIDATION SUB-PROCESSES
33 – End Products Validation

Figure 9. The 33 sub-processes for engineering a system. From [11]

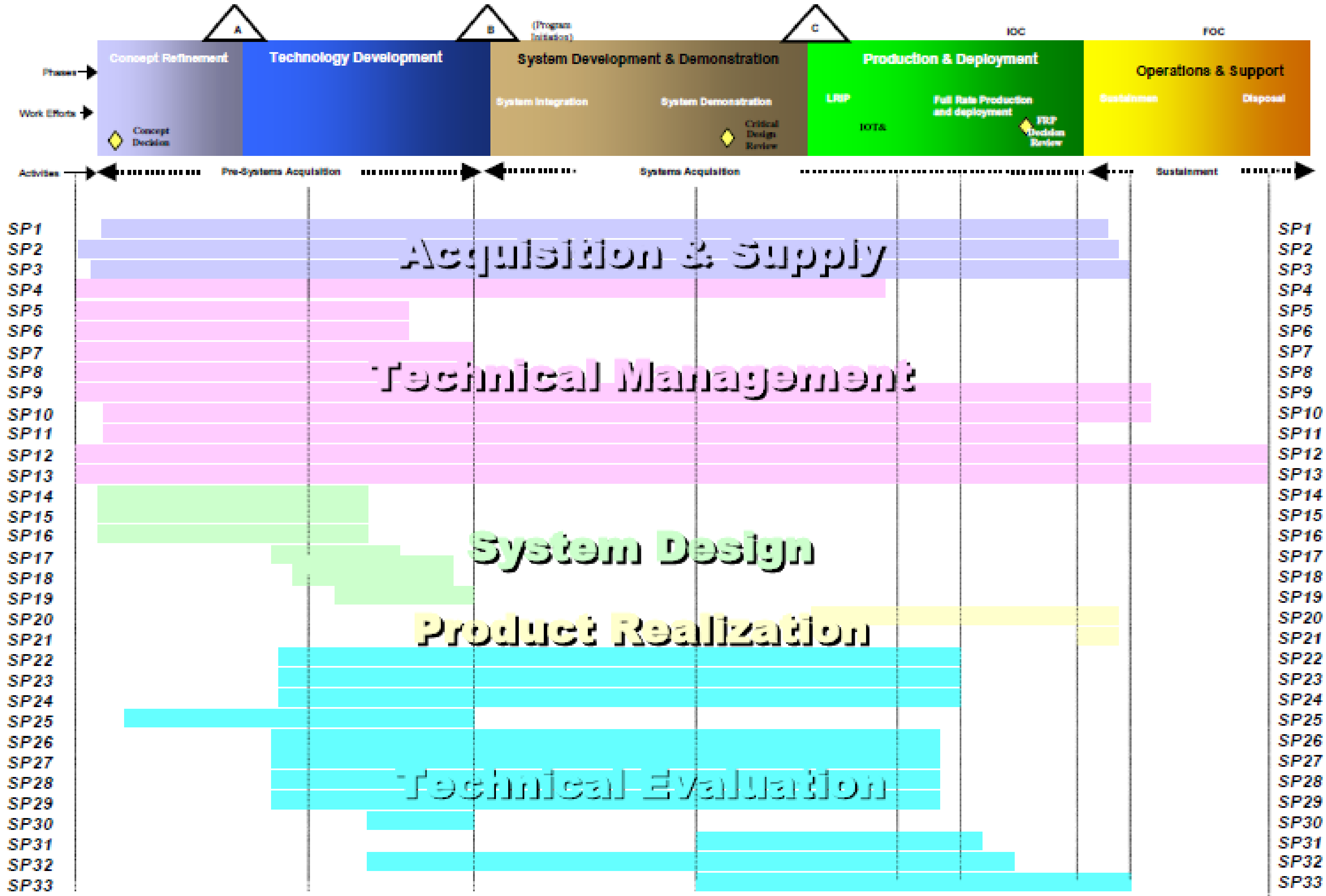

Figure 10. Systems engineering process timeline. From [11]

2. Process Application: Top-Down Development

This section describes key concepts for application of the processes described above to the engineering or reengineering of a system. The system structure concept serves as the framework for the engineering of a system. It is the top-down development and bottom-up realization of requirements using accepted processes for engineering systems in DoD acquisition programs. The system consists of both the end products to be used by an acquirer for an intended purpose and the set of enabling products that enable the creation, realization, and use of an end product, to an aggregation of end products. The system is the object for which warfighter and stakeholder requirements are defined using the Requirements Definition Processes. Figure 11 shows the relationship between these system elements.

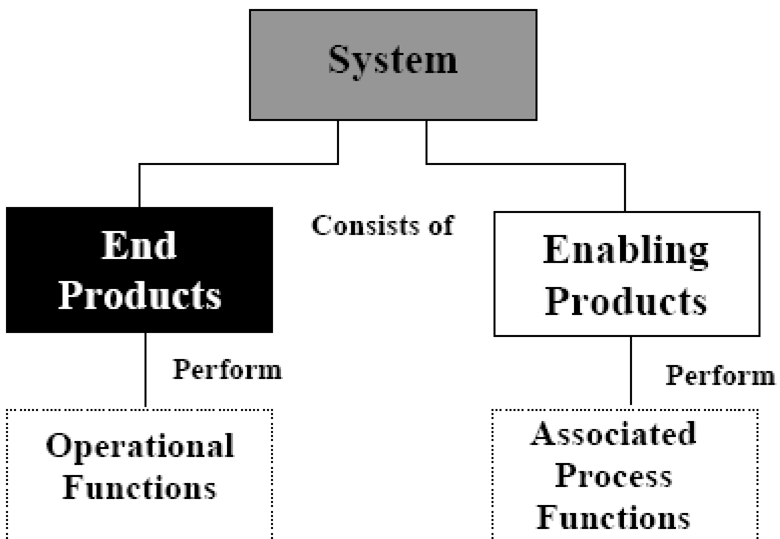

Figure 11. System concept. From [11]

Enabling products are used to perform the associated process functions of the system – develop, produce, test, deploy, and support the end products; train the operators and maintenance staff of the end products; and retire or dispose of end products that are no longer viable for use. Both the end products and the enabling products are either developed or reused, as appropriate [11]. The system forms the basis for a larger structure called a building block where the processes discussed in the previous section are applied. Figure 12 shows the building block and its associated enabling products. The enabling products shown in Figure 12 are not all inclusive. Enabling products may be added or removed according to program specifications.

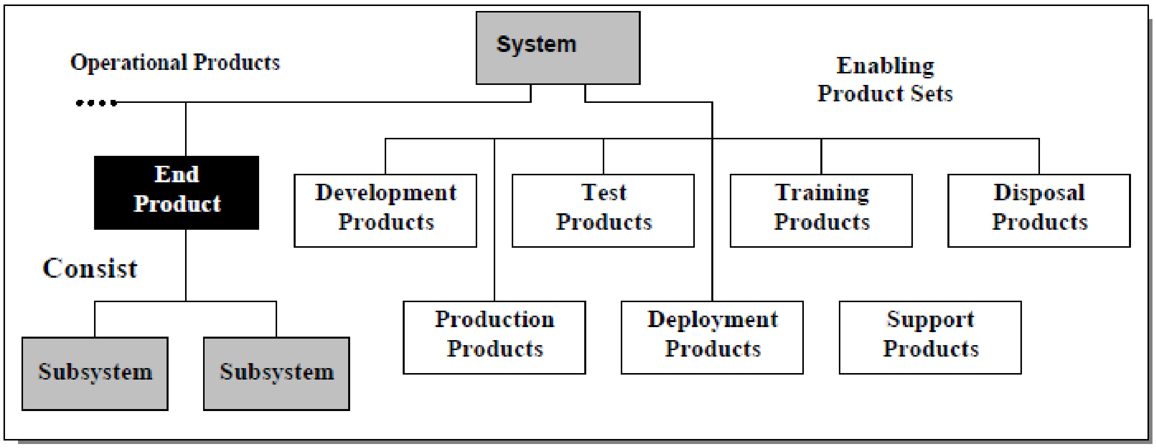

Figure 12. Building block and associated enabling products. From [11]

Building blocks form the system structure. Each subsystem of the end product becomes the system for the next lower layer. The layering of building blocks continues until the end products can be implemented, or the end product requirements can be satisfied by an existing product or it can be acquired from a supplier. The top building block contains the end product that must satisfy the end user's requirements. Figure 13 shows the relationships between the subsystems and the lower tiered building blocks. Figure 14 shows an example of a system structure.

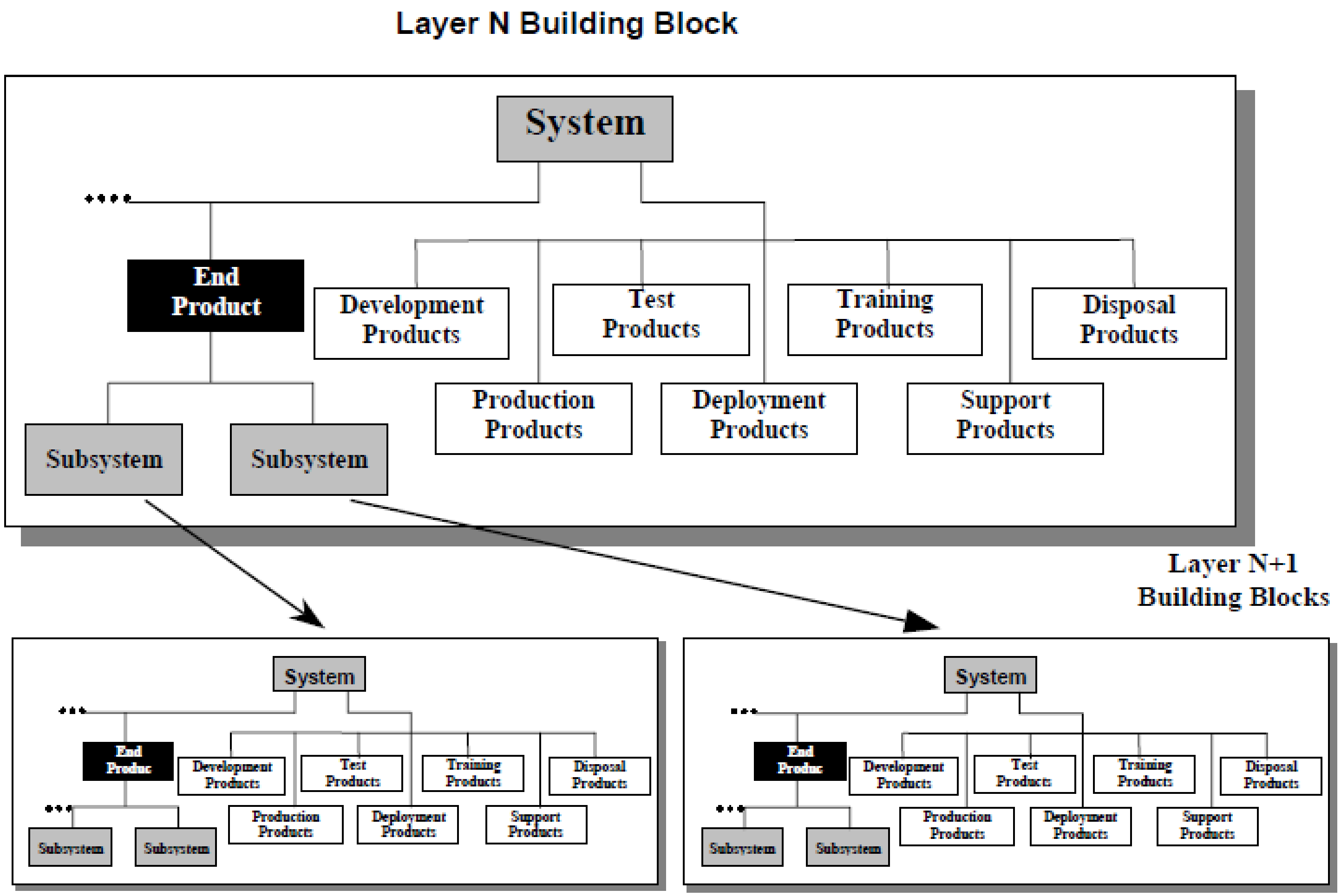

Figure 13. Building block relationships. From [11]

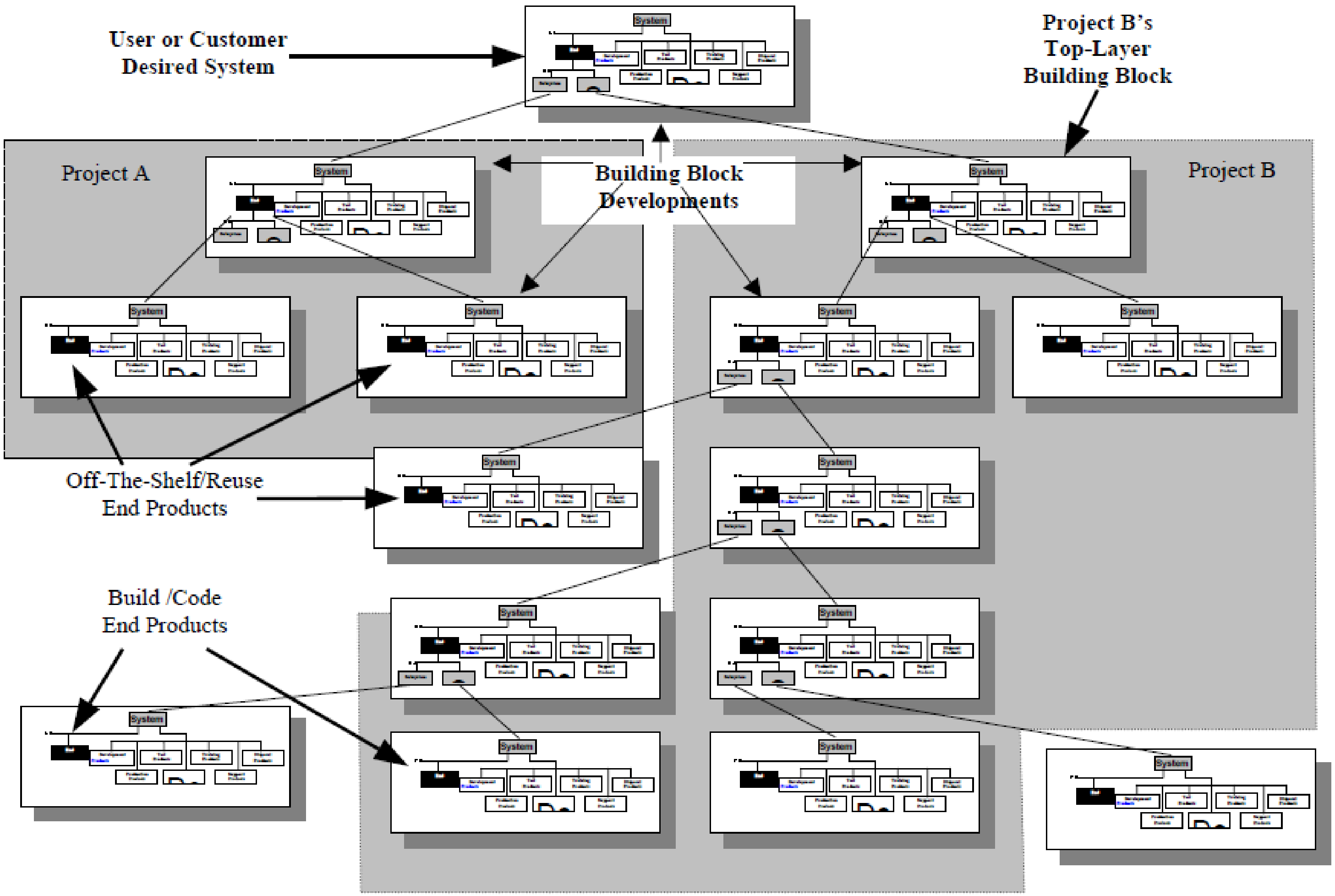

Figure 14. Example system structure. From [11]

The implication of the system structure described above is a top-down development approach. Requirements are flowed down each layer to ensure satisfaction of top-layer customer requirements. The inputs to each building block include the assigned requirements from the building block above it and the other stakeholder requirements that will influence the building block development. Once specified end products are defined sufficiently by specifications, product realization processes are initiated. The following section describes the product realization process and the ultimate delivery of the product to the end user.

3. Process Application: Bottom-up Realization

Bottom-up realization of the end product starts when the end products are sufficiently defined by specifications. Bottom-up realization includes Product Realization and End Product Validation processes. Additionally, the processes involved in the delivery of the product to the end user are included as the terminating phase of this bottom-up approach. The product realization processes can occur at any layer of the system structure so long as the end products are sufficiently defined. The main purpose for a bottom-up approach is to discover variances and design anomalies at the lowest layer of development possible. If these end product defects are not corrected at the lowest level possible, they may get overlooked and may show up at the top layer end product verification and validation. It would become increasingly difficult to trace and correct defects in an aggregation of end products. Figure 15 depicts the top-down development layered approach and Figure 16 depicts the bottom-up realization process for a program.

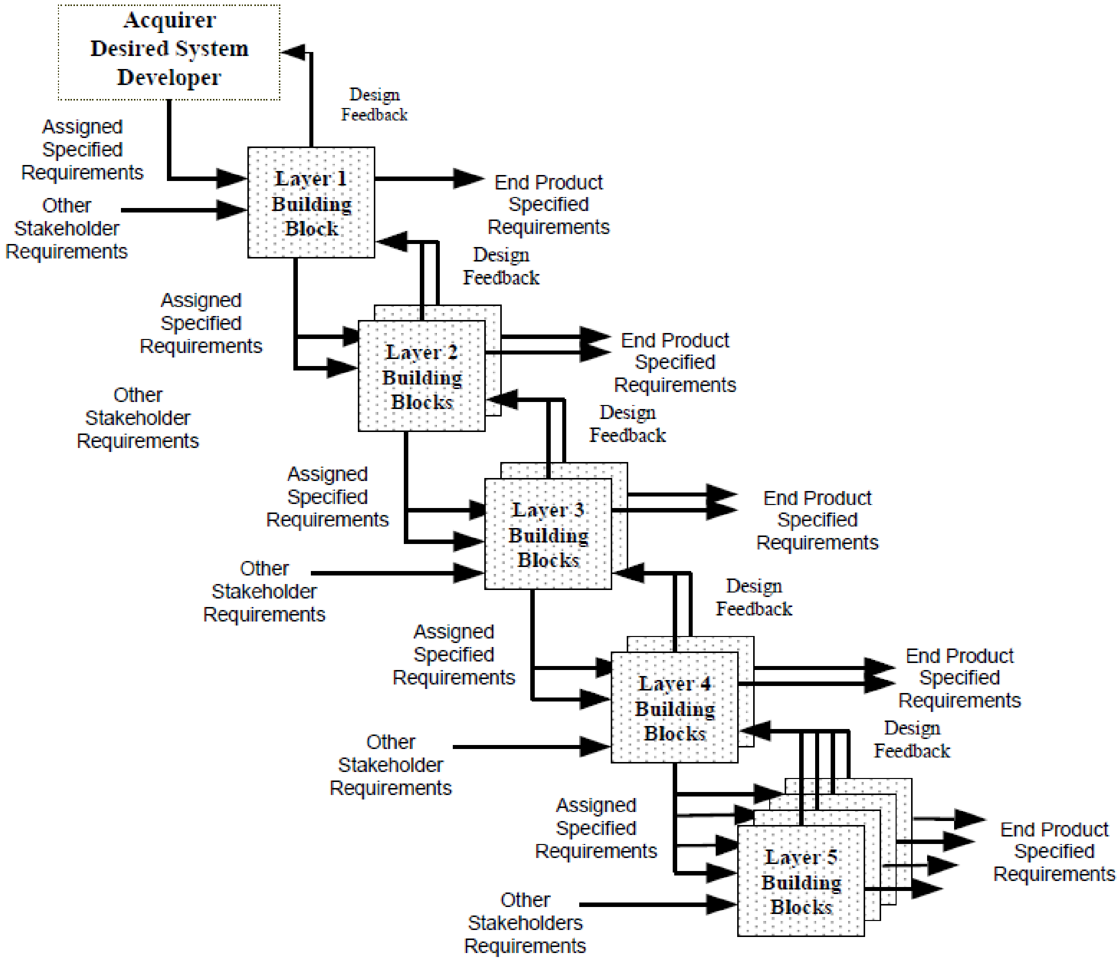

Figure 15. Top-down development. From [11]

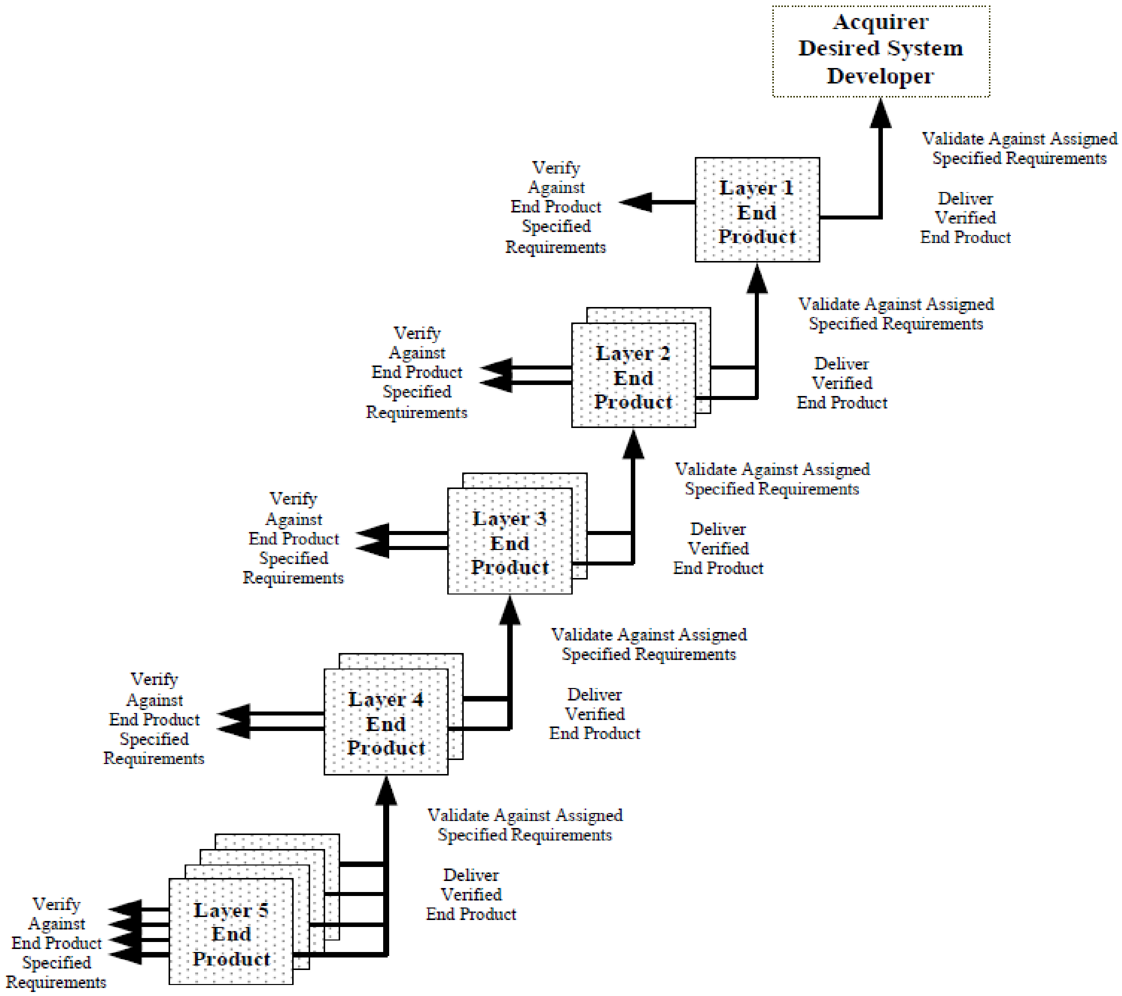

Figure 16. Bottom-up realization. From [11]

4. System Structure Summary

The system structure methodology provides a framework for engineering a system. The system is developed using a top-down layered process addressing user requirements as requirements are flowed down. Processes are applied at each layer via the enabling products to produce an end product that either meets specification requirements or set the requirements for its corresponding subsystems. Once end products are sufficiently defined by specifications the bottom-up product realization process is initiated. This process entails the validation process to ensure assigned requirements have been met prior to moving up to the next layer. This methodology ensures that variances and design anomalies are discovered and corrected at the lowest possible level to ease traceability and prevent possible interface problems with other end products during top layer verification. This framework is used for integration of evolutionary acquisition process and the modular open systems approach to tailor the framework to address the needs and requirements of the FCS program and contribute to Army Modernization Strategy overall. The next section of this chapter discusses the benefits of using evolutionary acquisition to achieve the objectives of this thesis.

C. EVOLUTIONARY ACQUISITION

One of the principal considerations identified in the acquisition strategy in Section A of this chapter is the acquisition approach. The acquisition strategy defines the acquisition approach a program will take to achieve full capability. A program may take an evolutionary approach or a single step approach to acquisition. The preferred DoD acquisition approach is evolutionary acquisition. According to DoD Directive 5000.1, evolutionary acquisition supports the Responsiveness policy that shall govern the Defense Acquisition System. DoD Directive 5000.1 describes Responsiveness as follows:

> *Advanced technology shall be integrated into producible systems and deployed in the shortest time practicable. Approved, time-phased capability needs matched with available technology and resources enable evolutionary acquisition strategies. Evolutionary acquisition strategies are the preferred approach to satisfying operational needs. Spiral development is the preferred process for executing such strategies [12].*

DoD Directive 5000.1 establishes that the preferred acquisition approach is evolutionary acquisition to address the Responsiveness policy. It further dictates that spiral development is the preferred process for executing that strategy.

The overall objective of evolutionary acquisition is to get capability out to the warfighter quickly. It provides the ability to leverage maturing technologies and implement them into user capabilities, thus minimizing technology obsolescence when fielding new systems. DoD Instruction 5000.2 states:

> *Evolutionary acquisition delivers capability in increments, recognizing up front the need for future capability improvements. The objective is to balance needs and available capability with resources, and to put capability into the hands of the user quickly. The success of the strategy depends on consistent and continuous definition of requirements, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a materiel concept (See Figure 17) [10].*

The two approaches to evolutionary acquisition are incremental development and spiral development. In incremental development, a desired capability is identified and an end-state requirement is known. That requirement is met over time by development of several increments, each dependent on the availability of mature technology. In a spiral development, the end-state requirements are not known at program initiation and are refined through demonstration and risk management. There is continuous user feedback and each increment provides the user the best possible capability. It is important to consider that besides being part of a larger system, each increment is developed and planned for as individual systems, as described in DODI 5000.2 and shown in Figure 17 below:

> *In an evolutionary acquisition program, the development of each increment shall begin with a Milestone B, and production resulting from that increment shall begin with a Milestone C. Each program or increment shall also have an Acquisition Program Baseline establishing program goals — thresholds and objectives — for the minimum number of cost, schedule, and performance parameters that describe the program over its life cycle [10].*

As described earlier, evolutionary acquisition enables the quick delivery of new capabilities to the warfighter to meet evolving requirements and threats while minimizing the risk of obsolescence. The challenges, however, lie in the successful insertion of each increment such that the system capabilities are fully utilized and integrated into legacy systems while allowing for future capability improvements. The next section describes the Modular Open Systems Approach (MOSA) to acquisition that enables a more seamless insertion of system capabilities as they are delivered to the end user.

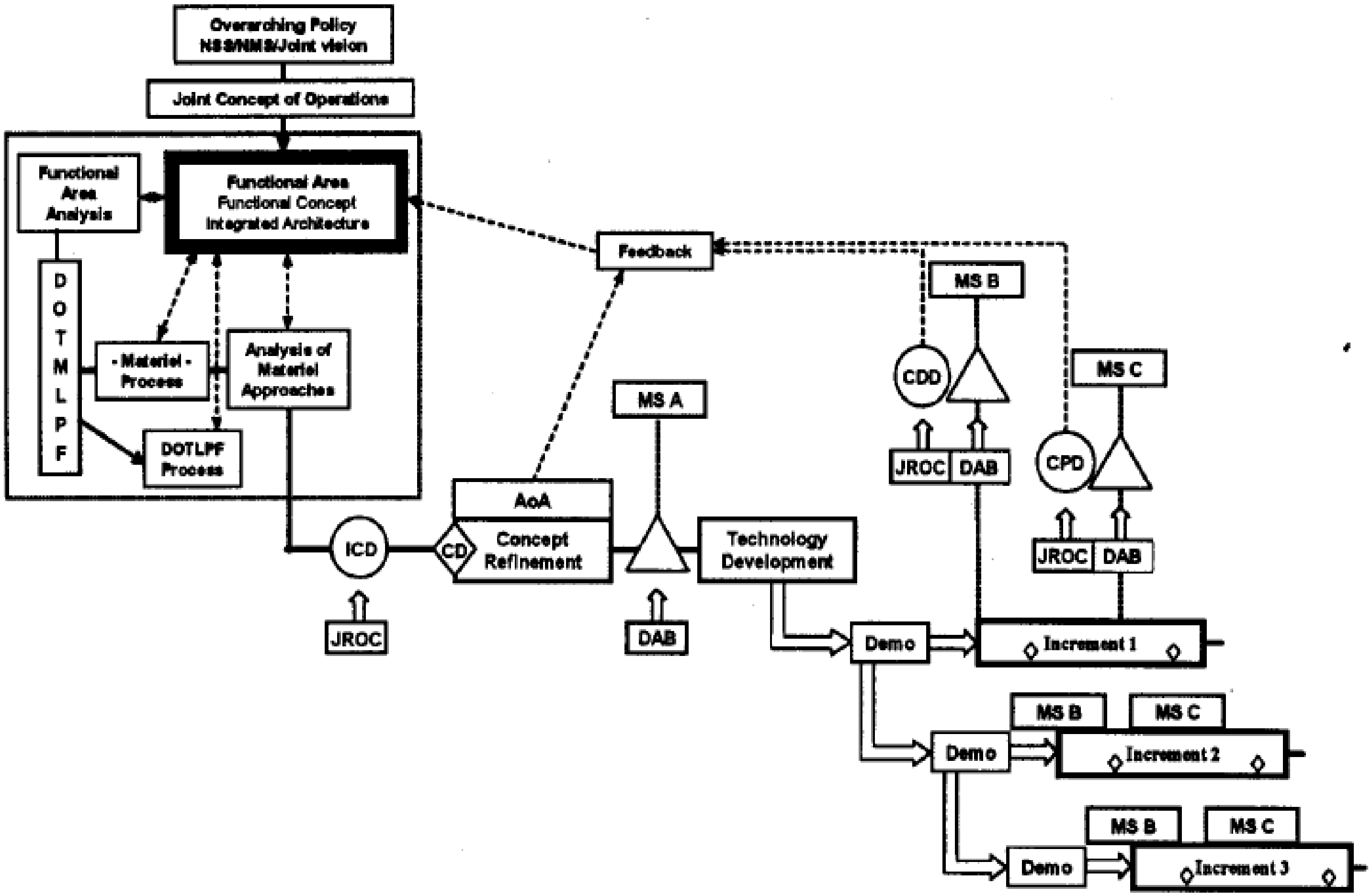

Figure 17. Requirements and Acquisition Process Depiction. From [10]

D. MODULAR OPEN SYSTEMS APPROACH (MOSA)

One of the other considerations incorporated in the development of the acquisition strategy is the Modular Open Systems Approach (MOSA). MOSA is both a business and technical strategy for developing a new system or modernizing an existing one. Application of MOSA to acquisition programs is mandated by DoD Directive 5000.1 which states:

> *Acquisition programs shall be managed through the application of a systems engineering approach that optimizes total system performance and minimizes total ownership costs. A modular open-systems approach shall be employed, where feasible [12].*

The application of MOSA enables a smoother transition of systems from the acquisition process to the warfighter. The objectives of MOSA are consistent with the characteristics that facilitate delivery of systems namely, designing for affordable change (i.e. modularity), employing evolutionary acquisition and spiral development, and integrating a strategy that ensures delivery of a system that is capable, upgradeable, affordable and supportable throughout its planned life cycle.

Modular design enables the efficient integration of new systems into legacy systems without the need for major modifications. It also allows for the ease of future changes and/or upgrades to the system. Evolutionary acquisition and spiral development, as described in the previous section, enables the rapid delivery of new capabilities to the warfighter to meet evolving requirements and threats while minimizing the risk of obsolescence. The application of sound systems engineering practices ensures delivery of a system that is capable, upgradeable, affordable and supportable throughout its planned life cycle. The framework to achieve that objective was discussed earlier in this chapter. MOSA facilitates the achievement of the following program objectives as listed in the Open Systems Joint Task Force (OSJTF) Guide 2004 [13]:

- Adapt to evolving requirements and threats
- Promote transition from science and technology into acquisition and deployment
- Facilitates systems integration
- Leverage commercial investment
- Reduce the development cycle time and total life-cycle cost
- Ensure that the system will be fully interoperable with all the systems which it must interface, without major modification of existing components
- Enhance commonality and reuse of components among systems
- Enhance access to cutting edge technologies and products from multiple suppliers
- Mitigate the risks associated with technology obsolescence
- Mitigate the risk of a single source of supply over the life of a system
- Enhance life-cycle supportability
- Increase competition

MOSA incorporates modular design, key interfaces and open standards for key interfaces to support achievement of the stated objectives. Figure 18 below illustrates the vision, principles, and benefits of implementing MOSA in an acquisition program.

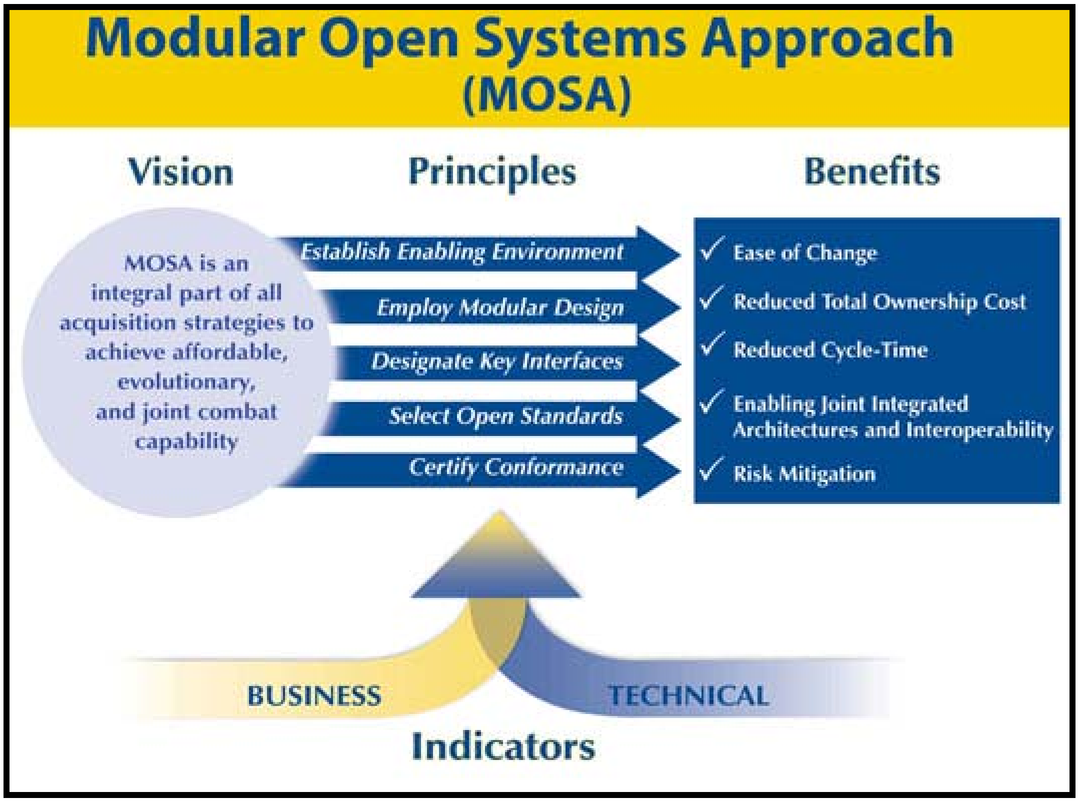

Figure 18. Modular Open Systems Approach (MOSA). From [13]

1. MOSA Implementation Plan

The MOSA implementation plan utilizes an Integrated Product and Process Development (IPPD) team approach. The IPPD team generally includes all of the stakeholders involved in the acquisition, deployment and employment of the system. Incorporating MOSA into a standardized systems engineering process early in the program and throughout the acquisition process increases the effectiveness of MOSA. Effective MOSA implementation during systems design results in the greatest benefit to the users of the resulting product. The MOSA implementation plan provides a framework for the application of MOSA using specific objectives, tasks, principles, and milestones. It describes how MOSA fits into a program's overall acquisition process and strategies for technology development, acquisition, test and evaluation, and product support. The implementation plan describes the steps a program will take to analyze, develop, and implement a system or system-of-systems architecture based on MOSA principles. It also describes how to monitor and asses MOSA program implementation progress. Figure 19 illustrates the MOSA framework and the principles used to achieve the objectives.

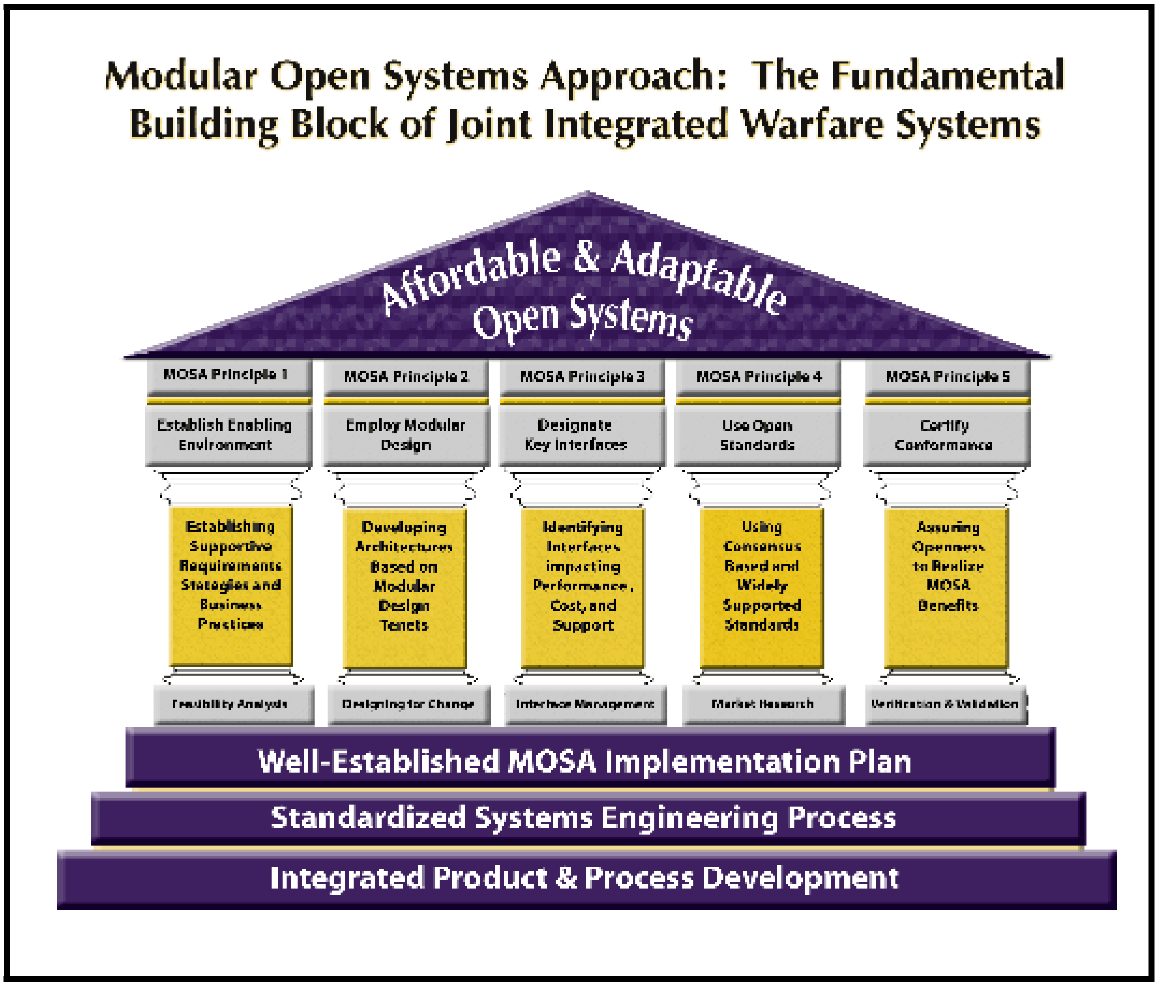

Figure 19. The MOSA Framework. From [13]

The MOSA implementation plan, addresses the following five major tasks as delineated from the OSJTF guide 2004 [13]:

a. ***Identify and analyze capabilities and strategies that could most effectively be pursued by open system design solutions.*** This task assesses the applicability of MOSA to a specific program such that the capabilities and strategies of that program are sufficiently addressed. The OSJTF Guide lists the many acquisition strategies, operational capabilities, and performance requirements that lend themselves to the use of open systems. Within the scope of this thesis, however, MOSA enables the employment of evolutionary acquisition and spiral development. It also enables the achievement of several of the MOSA objectives mentioned earlier. Those specific objectives will be discussed in the next chapter as the MOSA is applied specifically to the FCS program.

b. Assess the feasibility of open systems design solutions. This task utilizes the business case for assessing the feasibility of applying MOSA. A review of technology and standards identifies the risk areas that have substantial impact on development, operation, and sustainment of a system. It considers the changes in technology and threats to evaluate the total life-cycle costs of designing the system as an open rather than a closed system.

c. Establish performance measures to assess MOSA implementation progress. This task establishes the metrics used to determine MOSA implementation progress. This task is essential for the realization of the benefits of MOSA which directly translate to the system's smooth transition from acquisition to delivery to the warfighter**.**

d. Use MOSA principles to develop an open architecture. The five MOSA principles (Establish an Enabling Environment, Employ Modular Design, Designate Key Interfaces, Use Open Standards, and Certify Conformance) are the foundation of effective MOSA implementation (see Figure 19 and Appendix). They are fundamental to the design and implementation of open architectures. These principles are based on the experiences of programs that have implemented MOSA. The five principles are the minimum set of best business practices required for effective MOSA application and will be discussed further in the next section.

e. ***Identify and resolve MOSA implementation issues and report the unresolved issues to Milestone Decision Authority.*** The benefits of MOSA can only be realized if MOSA implementation can be accurately assessed. A procedure for assessing MOSA progress, identifying implementation issues and resolution of those issues is critical to maintaining focus in achieving a system that exhibit the desired open systems characteristics. The procedure should be based on a set of measures or attributes indicating that the characteristics associated with each MOSA principle will be present as the system is being developed and when the system is complete.

The application of MOSA and its principles enables a smoother transition of systems from the acquisition process to the warfighter. The objectives of MOSA are consistent with the characteristics that facilitate delivery of systems namely, designing for affordable change (i.e. modularity), employing evolutionary acquisition and spiral development, and integrating a strategy that ensures delivery of a system that is capable, upgradeable, affordable and supportable throughout its planned life cycle. MOSA, in conjunction with the employment of a robust systems engineering methodology, facilitates the ability to plan and implement throughout a systems life cycle, from initial design to product sustainment. The next chapter describes the implications of these considerations to FCS and to the overall Army Modernization strategy.

IV. INSERTION STRATEGY AND FCS IMPLICATIONS

A. INTRODUCTION

The Future Combat Systems (FCS) is envisioned as the core of the Army's strategy for full-spectrum modernization. It is designed to meet current and future equipping requirements in a strategic environment of persistent conflict. An environment of persistent conflict poses specific challenges for the Army. As described in the 2008 Army Modernization Strategy document:

> *An era of persistent conflict demands continuous modernization. In the past the Nation could anticipate a strategic pause at the end of a conflict that afforded an opportunity to rebuild military strength in advance of future conflict. Today's environment of persistent conflict offers no such luxury. Therefore, today's Army must build the capabilities it needs in the 21st century. This must be done while restoring the capacity to sustain operations over an extended period [5]*

The Army requires the capability to conduct "full-spectrum" operations from traditional warfare as well as complex, irregular warfare to civil support and disaster relief. It demands the capability to conduct these operations in myriad terrains to meet the evolving threats derived from global trends that shape the strategic environment. Specific trends of this evolving security environment include globalization, population growth, increasing resource demands, natural disasters, weapons of mass destruction proliferation, and failed and failing states.

This chapter describes the development of an insertion strategy to facilitate achievement of FCS envisioned objectives and its contributions to the overall Army Modernization strategy. While this insertion strategy is directed toward the Army and FCS, it is intended to be a framework that would be useful throughout DoD for any large complex system of system acquisition program. The insertion strategy is based on the formal combination of three of the acquisition strategy considerations discussed previously. Combining the three considerations leverages each consideration's positive characteristics to enable a tailored strategy that facilitates the insertion of technology into the current force while allowing for adjustments to accommodate future increments.

B. THE INSERTION STRATEGY: COMBINING THE THREE ACQUISITION CONSIDERATIONS

As previously mentioned, FCS is at the core of Army modernization. It is envisioned to address the urgent needs of the current fight while, at the same time, accelerate transformation to prepare the future force. According to the 2008 Army Modernization Strategy document, the fundamental issue in accomplishing the four elements of the Army Modernization Strategy is to methodically set the conditions to execute the planned strategy.

> *The Army must methodically set the conditions to execute the Spin-out plan while maintaining the flexibility to respond to urgent needs. FCS Spin-outs are based on requirements that are defined in accordance with the Joint Capabilities Integration and Development System. FCS Spin-outs are programmed in the Army's base budget request. The fielding plan adheres to Joint acquisition and force management, doctrine, requirements and metrics. Accordingly, technologies will be demonstrated and deemed mature before the Army commences Low Rate Initial Production of FCS Spin-out systems [5].*

The document further states that two essential efforts are required to set the conditions for the Spin-outs. First, the Army must address the capability gaps of the Current Force that must host Spin-out technologies. Secondly, the Army must leverage the full capacity of the Army Science and Technology community affording the Army the flexibility to address its needs [5].

The Army can efficiently and effectively address these issues by thoroughly incorporating the three considerations identified in the previous chapter to develop a tailored insertion strategy that facilitates achievement of their objectives. The Army has already recognized that evolutionary acquisition, specifically the spiral process, enables for the quick delivery of new capabilities to the warfighter to meet evolving requirements and threats while minimizing the risks of obsolescence. This strategy alone, however, does not provide the adequate robustness required for implementation of a complex system of systems such as FCS.

Employing MOSA to acquisition further enhances the benefits gained from employment of the evolutionary acquisition strategy. As described in the previous chapter, MOSA is an enabler to successfully implement an evolutionary acquisition strategy. The application of MOSA to FCS establishes a framework that contributes to achieving FCS objectives. MOSA addresses the actual insertion phase of the strategy by integrating a methodology that ensures delivery of a system that is capable, upgradable, affordable and supportable throughout its planned lifecycle. FCS application of modular design and open architecture is demonstrated by FCS BCT. The 14 FCS BCT systems are designed to be interchangeable to enable tailoring of the BCT's composition to meet operational requirements. The Multifunctional Utility/Logistics and Equipment (MULE) Vehicle, for example, shares a common chassis among its three variants: Transport, Countermine and Armed Robotic Vehicle – Assault-Light. Using a common chassis enables the modularity design of the system.

While the modular design and open architecture characteristics of FCS is a step in the right direction towards facilitating insertion of technology the researcher could not ascertain if MOSA principles were applied to the extent where MOSA benefits can be fully realized. For example, one of the MOSA principles is to "Establish an Enabling Environment" and to achieve this, the developers must "Identify and mitigate barriers or obstacles that hamper or undermine MOSA implementation." From the perspective of technology insertion, it was evident that not all potential barriers were identified and addressed earlier,

> *FCS engineers discovered problems with JTRS radios related to storage temperatures and shock and vibration on the FCS ground vehicles. Efforts to resolve this problem have stalled because not all the affected parties have been included in the joint engineering team dialogue. In another example, JTRS requirements are not aligned with current force vehicles. The FCS program has not*

received a unified set of requirements from the user representative for spin out 1 current-force vehicles [15].

The inability to foresee and plan for such eventualities has a cascading effect on the rest of the system of systems. This most often results in cost overruns and schedule delays.

For a program scope that entails complex systems of systems such as FCS, however, the application of a more robust systems engineering framework is necessary for total life cycle consideration. The Army intends for continuous modernization of its forces using this modernization strategy. The system structure concept integrates evolutionary acquisition and MOSA into an overarching framework that applies a “cradle-to-grave” perspective. Considerations originating from the very beginnings of requirements generation, concept development and system acquisition are integrated into the framework with the overall objective of a seamless, effective and efficient insertion of technology to the warfighter.

Integrating evolutionary acquisition, specifically the spiral process, and MOSA within the systems structure framework as the part of the enabling products capitalizes on the unique benefits from each process towards development of a complex system of systems while enabling the rapid fielding of new technology and seamless insertion into legacy equipment and to future upgrades. The framework proceeds to develop the system of systems within the scope of the objectives and goals of the FCS program while maintaining a path toward successful fielding of the Spin-outs and ultimately of FCS BCT. It enables a process that is flexible to accommodate changing requirements from the warfighter to counter evolving threats. Modularity and an open architecture design contribute to this framework’s flexibility. It is responsive to constantly changing technology and supports its rapid transition into capabilities ensuring that the warfighter is always equipped with state-of-the-art capabilities maintaining the Army’s dominance across the full spectrum of operations now and in the future. Evolutionary acquisition enables the quick delivery of maturing technologies and minimizes the risks of obsolescence while MOSA, an enabler of evolutionary acquisition, ensures the seamless insertion into legacy systems without the need for major modifications. Figure 20 is a top-level view of how the spiral process and MOSA can be integrated into a system engineering framework. It illustrates MOSA and the spiral process applied at every phase of the development process from requirements development to deployment. Specifically, MOSA and the spiral process are integrated into the system structure as part of a collection of enabling products.

C. SUMMARY

The Navy has made concerted efforts to implement open architecture in support of the development of systems that are affordable, operationally effective and suitable and can be a timely solution to satisfy user needs. The Army has recognized evolutionary acquisition as the fastest and surest way to get capabilities out to the warfighter quickly, as well as modernize the Army. Complex system of systems development, however, requires the integration of several acquisition considerations, tailored to enable the achievement of the goals for a specific program. Programs similar in scope to FCS require processes that are flexible and responsive in order to facilitate the effective and efficient insertion of newly acquired systems. Combining evolutionary acquisition and MOSA within the system structure framework, as presented in this thesis, results in a flexible and responsive strategy that promotes effective and efficient insertion of newly acquired technology. It enables the responsiveness necessary for rapid deployment of maturing technology enabling the warfighter to benefit from the capabilities sooner. It enables the flexibility and responsiveness to adjust to the changing requirements due to the changing threats that the warfighter face in current operations. It also enables the flexibility to accommodate future upgrades and future additions to the system of systems without costly modifications to fielded systems. The insertion strategy, therefore, can not simply be developed in the latter phases of system acquisition just prior to delivery. Evolutionary acquisition and MOSA principles, integrated via the system structure concept must be considered up front and reiterated throughout the entire systems engineering and development process (Figure 20).

Within the scope of this thesis, it is recommended that the Army promote a consistent and common view of systems engineering across the FCS program and eventually, given the ultimate goal of continuous modernization, across the Army as a whole. To that end, the Army should adopt similar system engineering practices and strategies currently employed by the Navy and tailor it accordingly to fit FCS program goals and overall Army modernization. The Naval Systems Engineering Guide was developed by the Navy to help ensure development of systems that are affordable, operationally effective and suitable, and can be a timely solution to satisfy user needs at an acceptable level of risk. The framework for this Guide is an industry standard, ANSI/EIA-632, *Processes for Engineering a System.* The standard was developed to replace the SE military standard, MIL-STD-499 as part of the 1994 DoD Acquisition Reform initiative prescribing the use of "performance-based" acquisition specifications and the substitution of the standards and practices used in the commercial marketplace for military specifications and standards [11]. Similarly, the organizations currently in place in the Army, specifically within Army Training and Doctrine Command (TRADOC), can be designated to oversee Army wide development of SE practices. Subordinate commands such as Army Capabilities Integration Center (ARCIC) and its Future Force Integration Division (FFID), and TRADOC Analysis Center (TRAC) can provide the common and unique SE requirements and implementation approach for FCS as well as other development and acquisition programs.

Additionally, the Navy has promulgated directives pursuant to the promotion of open architecture. The Assistant Secretary of the Navy, Research, Development and Acquisition, assigned PEO IWS overall responsibility and authority for directing the Navy's Open Architecture (OA) Enterprise. It directed the establishment of an OA Enterprise Team comprised of OA domain leads, ASN, OPNAV, and SYSCOM representatives, who will collectively oversee the development and implementation of the processes, business strategies, and technical solutions, which support cross Enterprise requirements in addition to domain specific needs [13]. The Enterprise Team defines the overarching OA acquisition strategy and guidance to be utilized in future OA applicable procurements tailored as necessary to incorporate domain specific requirements. The Army should form similar OA teams to develop the strategies and procedures and to ensure compliance to maintain a path to effective system insertion and operational fielding.

Naval policies and procedures were added to systems engineering industry standards, such as the Electronic Industries Alliance (EIA) 632, to develop a tailored approach to systems engineering and ensuring compliance with DoD acquisition policies. As the Army is also under the cognizance of DoD policies, the Army can similarly develop SE strategies by applying Army policies and procedures to the same industry standards. To implement the strategy, a lead organization should be designated to coordinate all efforts and maintain consistency throughout program execution. For each system within FCS, a domain lead should be appointed to lead all efforts within their cognizant system. The considerations discussed in this thesis should be incorporated into an insertion strategy to develop a single FCS wide approach to systems engineering, open architecture and evolutionary acquisition to seamlessly insert the 14 systems within FCS, its network, and most importantly the soldier, into the current force and eventually into the future force.

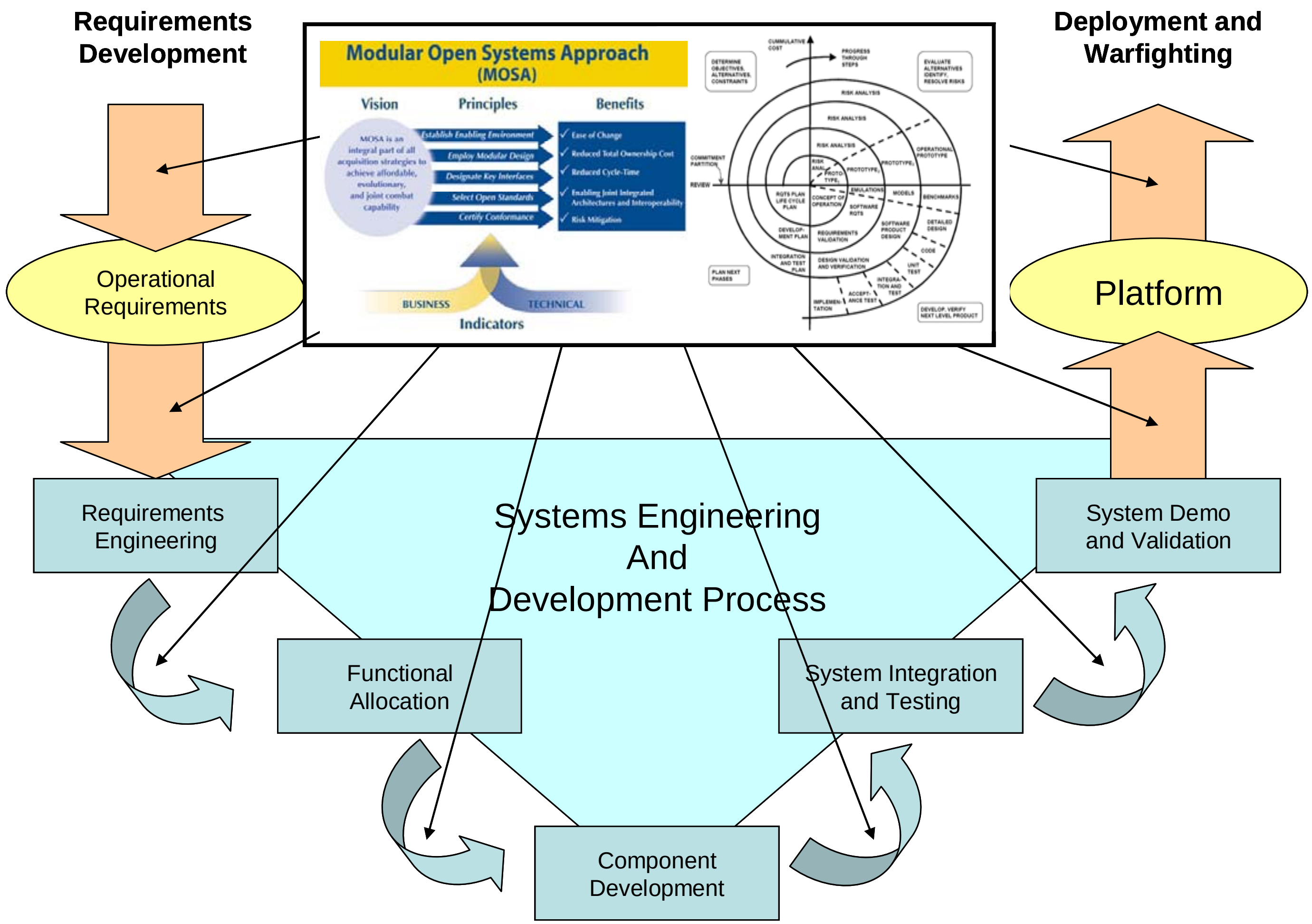

Figure 20. Systems Engineering Framework with MOSA and Spiral Acquisition Integrated. Portions of the graphic are from [7], [16] and [17]

V. CONCLUSIONS

A. SUMMARY AND CONCLUSIONS

The Army is committed to ensure that it continues to be equipped with capabilities that guarantee its stature as the preeminent land combat force in the world. To that end, the Army has adopted a strategy for a comprehensive upgrade of its Current Force via the Future Combat Systems program. In an era of persistent conflict, the Army must continue to meet current operational requirements and implement force modernization simultaneously. It cannot pause at the end of a conflict to rebuild military strength in advance of future conflict. A continuous modernization strategy must be employed to "reset" and rebuild Army forces simultaneously. Future Combat Systems is a key enabler to meeting that objective. This thesis examined the integration of evolutionary acquisition and MOSA into a systems engineering framework to ensure seamless insertion of newly acquired technology. Its main objective is to employ strategies that facilitate delivery of technology to the warfighter effectively and efficiently.

The Army has recognized that evolutionary acquisition enables the rapid fielding of FCS technologies as they mature. It has implemented the Spin-out plan to leverage FCS R&D efforts to insert new capabilities into the Current Force. Evolutionary acquisition minimizes the acquisition process time to enable a quick transition from science and technology to capabilities that the warfighter can use. It also minimizes the risks of technology obsolescence ensuring that warfighters are equipped with state-of-the-art capabilities, maintaining the advantage over evolving and ever changing threats in current and future operations. Evolutionary acquisition and the spiral process, however, do not sufficiently address the insertion of newly acquired technology and ensuring that the right capabilities are acquired to meet warfighter requirements. Evolutionary acquisition primarily addresses the acquisition phase of a system's life cycle. Complex system of systems development and continuous modernization programs, such as FCS, require a more robust approach that encompasses the system's entire life cycle from requirements development to disposal. The insertion strategy, therefore, must be an integral part of program and system design from concept to deployment.

Utilizing a Modular Open Systems Approach to acquisition ensures the seamless insertion of newly acquired systems into existing systems and facilitates insertion of future envisioned systems. MOSA manages the interfaces between systems thereby ensuring interoperability between all the systems within a complex system of systems. An open architecture design further promotes seamless insertion thus enabling the execution of an evolutionary acquisition strategy.

Similar to the acquisition strategy, the insertion strategy must be tailored according to the specific program. Acquisition strategy goals and objectives can be utilized to develop the insertion strategy concurrently. Insertion strategy must be considered at the beginning of a program to determine the feasibility of the processes to be employed. The integration of evolutionary acquisition and MOSA within a sound systems engineering framework results in an insertion strategy that is responsive and flexible with the greatest benefit to the end user of the resulting products.

B. AREAS FOR FURTHER RESEARCH AND STUDY

The immensity and complexity of FCS provides ample opportunity for systems studies to be conducted to examine and evaluate a variety of issues from requirements development, technology maturity, and testing and evaluation. Detailed research and study may be conducted in the requirements development process that facilitates delivery of technologies to the warfighter efficiently and effectively. Research into the development of strategy that ensures alignment and cohesion between JCIDS and the acquisition process and its implications to technology delivery may be further examined.

Additionally, studies may be conducted to examine technology maturity levels and the minimum requirements to ensure program success. Assessment of technology maturity levels is a critical aspect in successful execution of MOSA and evolutionary acquisition. Inaccurate assessments of technology maturity have often resulted in cost and schedule overruns despite disciplined employment of applicable strategies.

APPENDIX

A. MOSA PROGRAM ASSESSMENT AND REVIEW TOOL (PART)

OSJTF has developed a set of indicators, in the form of implementation questions to help assess the extent to which MOSA is implemented in an acquisition program, and also to identify actual or potential MOSA implementation issues. These questions are representative of the actual questions used in the MOSA Program Assessment and Review Tool (PART), which is an automated analytical tool that relies on objective, data evidence-based judgments to assess and evaluate MOSA implementation. The MOSA PART is an adaptation of the OMB Program Assessment Rating Tool (PART), which is a questionnaire designed to provide a consistent approach to rating programs across the Federal government. The responses to the questions, provided on the MOSA Implementation Questions tab of the PART, will be evaluated to determine the overall implementation level of MOSA, identify actual and potential implementation issues, and determine individual areas where improvements might be made. The evaluation results are shown in the Assessment Report tab of the PART. Program managers can use either MOSA PART or other tools to identify specific MOSA implementation issues that their Integrated Product Team must address and satisfactorily resolve. In case such issues cannot be resolved at the lower level, program managers must report them to the Milestone Decision Authority for final resolution [14]. Table 2 and Table 3 are the Business and Technical indicators from the MOSA PART automated analytical tool used to assess and evaluate MOSA implementation.

SECTION A: BUSINESS INDICATORS	
A1	To what extent is MOSA incorporated into the program's acquisition planning?
A2	To what extent did the program plan for its implementation of MOSA?
A3	To what extent is the program's MOSA implementation based on systems engineering principles and processes?
A4	To what extent are responsibilities assigned for implementing MOSA?
A5	To what extent is the program staff trained on, or have relevant experience in MOSA concepts and implementation?
A6	To what extent does the program's configuration management process encompass changes to key interfaces and corresponding standards?
A7	To what extent have program requirements been analyzed, and refined as needed, to ensure that design-specific solutions are not imposed?
A8	To what extent do the system level functional and performance specifications permit an open systems design?
A9	To what extent are modular, open system considerations included as part of alternative design analyses?
A10	To what extent are mechanisms established to migrate key interfaces that are proprietary or closed to key interfaces that are open?
A11	To what extent are MOSA principles reflected in the program's performance measures?

Table 2. Section A of MOSA PART. From [14]

SECTION B: TECHNICAL INDICATORS	
B1	To what extent is the system’s architecture based on related industry or other standard reference models and architectural frameworks?
B2	To what extent is an architectural description language used to define system modules and interfaces?
B3	To what extent does the system’s architecture exhibit modular design characteristics?
B4	To what extent is the system’s architecture capable of adapting to evolving requirements and leveraging new technologies?
B5	To what extent has the criteria for designating key interfaces been established?
B6	To what extent has the program designated key interfaces?
B7	To what extent has the program assessed the feasibility of using open standards for key interfaces?
B8	To what extent have standards selection criteria been established that give preference to open interface standards?
B9	To what extent are open standards selected for key interfaces?
B10	To what extent are validation and verification mechanisms established to assure that system components and selected commercial products conform to the selected interface standards?
B11	To what extent do system components and selected commercial products conform to standards selected for system interfaces?
B12	To what extent do system components and selected commercial products avoid utilization of vendor-unique extensions to interface standards?
B13	To what extent can system components be substituted with similar components from competitive sources?

Table 3. Section B of MOSA PART. From [14]

B. MOSA PRINCIPLES

The five major principles constitute the core of a Modular Open Systems Approach to acquisition. They are the indicators that are used to assess the progress and effectiveness of MOSA in a particular program. As illustrated in Figure 19 the realization of MOSA benefits is dependent to the adherence to the five major principles. The following sections discuss the five MOSA principles.

1. Establish an Enabling Environment

This principle involves the establishment of supportive requirements, business practices and strategies for technology development, acquisition, test and evaluation, and product support. Supportive practices include but are not limited to:

- Program requirements and system level functional and performance specifications that allow for open systems development and will not impose design specific solutions.
- Systems Engineering Plan and technology development, acquisition, test and evaluation, and product support strategies that are conducive to MOSA implementation.
- Identify and mitigate barriers or obstacles that hamper or undermine MOSA implementation.

2. Employ Modular Design

This principle involves the incorporation of sound Systems Engineering process to develop and employ a modular design. A functional decomposition of the system is conducted to identify the functional elements that should be modularized. The process of decomposing higher-level functions into lower-level functions, identifying interfaces and allocating performance functions is repeated until modular architectures are defined at increasing levels of detail. For legacy systems, a functional and capabilities analysis may be conducted to gather information on the existing design and perform modular partitioning and services mapping and interfaces to known functions and capabilities.

Existing requirements documents provide additional information on other systems/subsystems that must be interfaced.

3. Designate Key Interfaces

A key interface is defined as "an interface for which the preferred implementation uses an open standard to design the system for affordable change, ease of integration, interoperability, commonality, reuse or other essential considerations such as criticality of function" [14]. The interfaces identified in the previous section are evaluated to identify key interfaces using the definition above. The process is repeated from the top-level design components/modules and their submodules until all key interfaces are designated. The distinctions between key and non-key interfaces are illustrated in Figure 21 below.

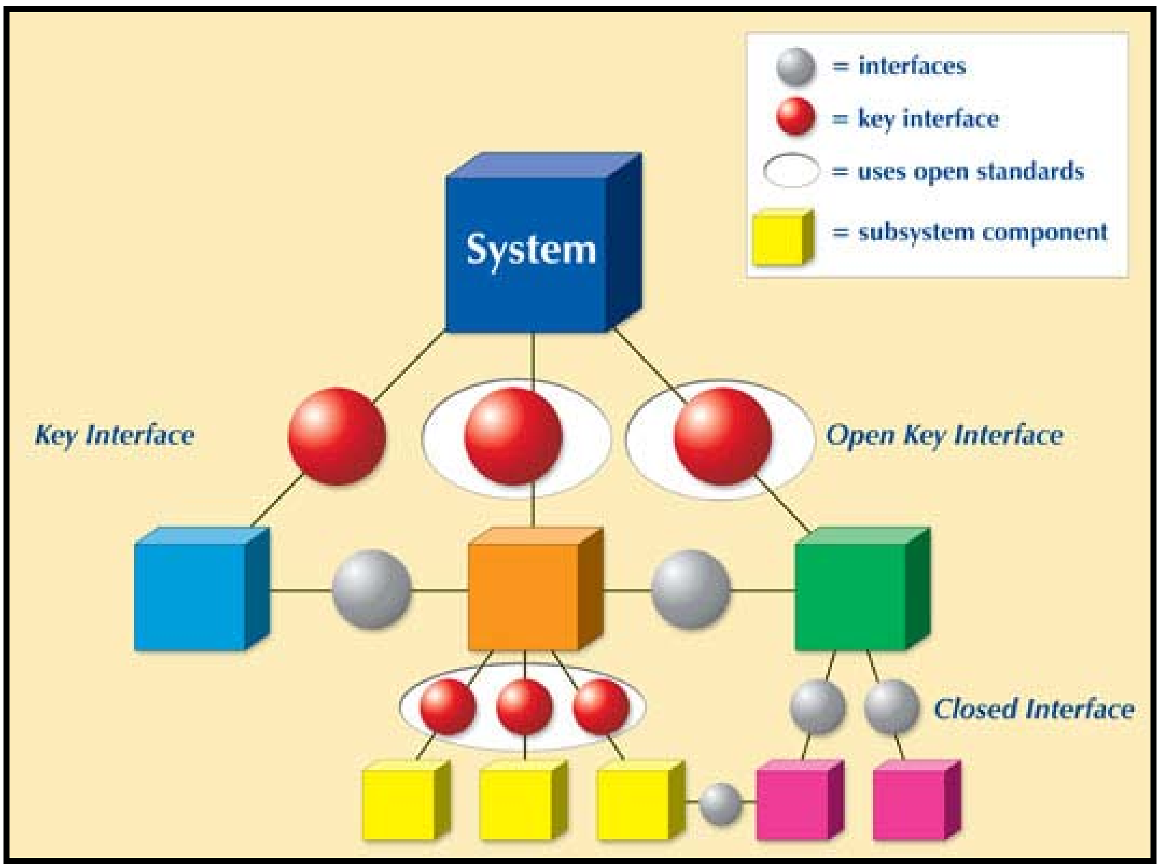

Figure 21. System Interfaces. From [14]

Additionally, a level of implementation to which the design aspires to maintain control over the key interfaces must be determined. An overall program life cycle and sustainment assessment defines the level of interface control because, if defined too low, efficient technology insertion may be limited, whereas, defining the level too high, may lead to the use of proprietary interfaces for major system components, resulting in limited supplier support. Figure 22 below illustrates the different levels of implementation.

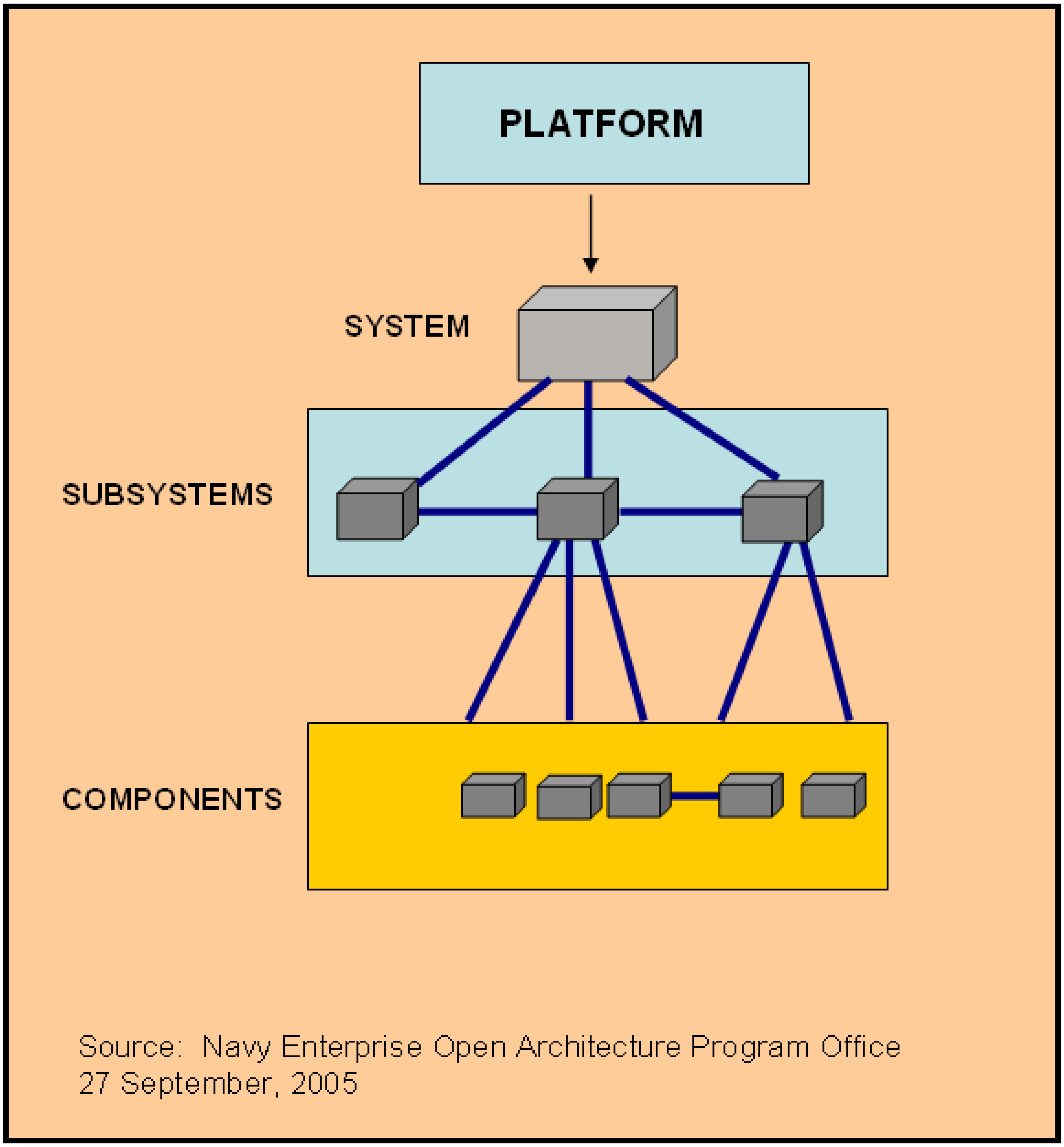

Figure 22. Open-systems Approach Application Levels. From [16]

4. Use Open Standards

This principle determines the feasibility of using an open interface standard for each of the key interfaces identified previously. Key interfaces are carefully examined to ensure that the use of an open standard is both feasible and appropriate, based on performance and business objectives. If the use of open interface standards is not feasible now, future opportunities within the system may become available to take advantage of the benefits of using open standards.

5. Certify Conformance

This principle dictates that validation and verification mechanisms must be established to ensure that the system and its component modules conform to the external and internal open interfaces. These external and internal interfaces continually change as systems evolve through spiral development and in response to requirements and technology changes. Conformity tests ensure that the interfaces have not significantly altered to the extent that new capabilities cannot be seamlessly inserted into legacy systems and, at the same time, diminish the system's capacity for interoperability with future increments.

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