Naval "Systems of Systems" Systems Engineering Guidebook
Volume II

Prepared by the Office of the ASN (RDA)
Chief Systems Engineer

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Naval SoS SE Guidebook, Volume II
Version 2.0

The Naval "Systems of Systems" Systems Engineering Guidebook (originally issued as the Naval Capabilities Evolution Process Guidebook) describes a comprehensive process for applying systems engineering principles to acquisition programs that may be characterized as systems of systems. The guidebook provides guidance on principles and recommended best practices to program managers and systems engineers in the design, development, deployment, and sustainment of such systems. It supports implementation of the guidance provided by the OUSD (AT&L) "Guide to System of Systems Engineering." In so doing, it combines the capability focus of JCIDS with the evolutionary acquisition strategy of the Defense Acquisition System to evolve to a networked, system of systems environment.

This Volume II of the Guidebook provides an initial set of best practices that can be applied to implement the recommended "systems of systems" systems engineering process. The intent is that this initial set will be significantly augmented by recommended best practices for capability-based acquisition and systems engineering from across the Naval acquisition community. In this regard, your best practices are solicited and are requested to be submitted to the ASN (RD&A) Office of the Chief Engineer.

Carl R. Siel, Jr., 12/12/06

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Foreword

The Naval "Systems of Systems" Systems Engineering Guidebook has been developed by the ASN (RDA) Office of the Chief System Engineer to support the Naval acquisition community in implementing capability-based acquisition and systems engineering for systems of systems in accordance with SECNAVINST 5000.2C. The Guidebook focus is on a systems engineering process that enables the realization of successful "systems of systems" that provide needed capabilities and functionality within a Net Centric Operating and Warfare environment.

The Guidebook is particularly intended to be utilized by System of Systems (SoS) systems engineering integrated product teams (SE IPTs). It provides recommended processes, methods and tools to aid program managers, their system engineering integrated product teams (SE IPTs), support teams, and contractors in delivering systems that satisfy the originating capability needs documents and that are integrated and interoperable.

The purpose of this Volume II of the Guidebook is to provide a compendium of recommended methods, techniques, and tools that enable the SE IPTs to execute the activities described by Volume I and deliver high quality products. Also, it will provide examples of the application of these to real world problems. It is intended to extend this initial set in the future to address additional areas such as safety, training, and logistics, and also to add best practices and use cases from the Naval acquisition community as they are identified and recommended. The current document is organized as follows:

- Section 1: Capability Specification and Metrics
- Section 2: Application of Quality Function Deployment
- Section 3: Developing the Capability Evolution Plan
- Section 4: Force Package Engineering Models
- Section 5: Developing the System Performance Document (SPD)

The Naval SoS SE Guidebook Volume II, Best Practices, is intended to be a living document and will be updated as needed in conjunction with the updates to Volume I. Recommendations for modifications or additions are welcome and will be included as appropriate. Please send comments and recommended changes to:

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1. Capability Specification and Metrics

This Section clarifies how military capabilities should be specified so that a force package can be analyzed, engineered and a portfolio of acquisition programs identified that will evolve to provide the desired military capability. The product of this effort will be a defined set of concepts, mission threads, and capabilities that can support capability-based planning, engineering, and acquisition.

The directives that apply to this Section are CJCSI 3170.01E, Joint Capabilities Integration and Development System, and DODI 5000.2, Operation of the Defense Acquisition System.

Defining specific capabilities and metrics should be one of the first tasks undertaken by an SE IPT in conducting the Naval Capability Evolution Process. The material presented herein is based on the DART (Defense Adaptive Red Team) Review of Joint Operating Concepts and Joint Functional Concepts[1]. This review described what a properly specified capability should address, including the capability attributes and the metrics required to assess the level of capability provided by a given system configuration.

The capability specification will be used to help each organization involved in a system acquisition grasp a consistent understanding of the capability requirements. This specification will include the military problem being addressed, the operational concept, the capabilities needed to implement the concept, and the attributes, metrics, measures, conditions and criteria used to measure the effectiveness of the system, SoS, or FoS provided.

Identifying and defining military capabilities requires an understanding of the Joint Operating Concepts (JOCs) or Joint Functional Concepts (JFCs) and the capabilities required to implement the concepts[1] as shown in Figure 1-1.

JP 1-02[2] defines the military capability and its four elements:

> **<u>Capability (Military)</u>:** The ability to achieve a specified wartime objective, i.e., win a war or battle or destroy a target set. It includes 4 major components:
> **(1) Force structure:** Numbers, size, and composition of the units that comprise defense forces, e.g., divisions, ships, air wings.
> **(2) Modernization:** Technical sophistication of forces, units, weapon systems, and equipment.
> **(3) Readiness:** The ability of forces, units, weapon systems, or equipment to deliver the outputs for which they were designed (includes the ability to deploy and employ without unacceptable delays).
> **(4) Sustainability:** The "staying power" of our forces, units, weapon systems, and equipment, often measured in numbers of days.

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[1] DART (Defense Adaptive Red Team) Review of Joint Operating Concepts and Joint Functional Concepts. Findings from Concept Review Workshop 30 September – 2 October 2003
[2] Joint Publication 1-02, Department of Defense Dictionary of Military and Associated Terms, 12 April 2001 (As Amended Through 7 October 2004)

Military Problem. Define the problem space, i.e., what is the military problem that the concept will address? In many cases, it will be useful to establish mission areas (for JOCs) or capability areas (for JFCs) that divide the overall problem space into distinct areas.[6]

Concept (the "How" or "Big Idea"). Develop the concept, i.e., the "big idea" for how the joint force will conduct the operation or function being addressed. In cases where mission/capability areas have been defined, develop an enabling concept that describes the "how" for accomplishing each of these areas.

Capabilities. Define the key capabilities needed to implement the concept, and if applicable enabling concepts. Capabilities should be expressed as "the ability to" execute a mission (for JOCs) or task (for JFCs).

Attributes. For each capability defined, state testable or measurable characteristics of the joint force that describe the capability.

Metrics. For each attribute, establish measures in the context of specified conditions (and eventually define specific criteria that can be validated empirically).

Figure 1-1: Relationship of Military Capabilities to JOCs or JFCs

Thus, a properly specified military capability integrates the evolution of military concepts, to the force structures, to the systems-of-systems, and must include the people, skills and support services necessary to sustain the operation. In other words – ***to achieve integrated, interoperable capabilities, we need to realign organizations and processes towards a system-of-systems capability.***

At the heart of this solution is the concept of using relevant systems-of-systems architectures based upon mission-oriented collections of:

- Concepts of Operations (CONOPS), processes, and organizational structures,
- Sensors, networks, systems and weapons,
- The people, skills and support services to sustain the systems-of-systems, which are treated as an integrated system.

The DOD Architecture Framework, Version 1.0 focuses on individual system architectures, vice systems-of-systems architectures, however Version 2.0 will include the Joint Capabilities Integration and Development System (JCIDS), the Planning, Programming & Budgeting System (PPBS), and Portfolio Management Overlays. An overlay is a specific set of architectural data that is designed to support the decision-making processes inherent in capability and systems-of-systems development.

1.1. System Definitions

Before proceeding, it is important to consider the various system definitions that are fundamental to the "Systems of Systems" system engineering process described in the following Sections.

System – The DAU Systems Engineering Fundamentals Guidebook[3] defines a system as "an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective." However, people from different disciplines have different views of what constitutes a system. An electrical engineer may view an integrated circuit chip or an integrated set of electrical units as a system. A software engineer may view an integrated set of computer programs as a system. A radar engineer may view a transmitter, receiver, antenna, power supply and signal processor as a "radar system." An integrated set of sensors, launching devices, weapons, networks, and processors may be termed a "weapons system."

The engineering of typical systems is a multidisciplinary team activity requiring the application of a mix of hardware, software, and human engineering methodologies. The standard systems engineering process[4] evolved over several decades within industry to address the engineering of complex systems consisting of a mix of hardware, software, and humans. The systems engineering process consists of requirements analysis, functional analysis/allocation, design synthesis and system analysis and control. It is applied iteratively across each phase of the system lifecycle.

System of Systems (SoS) - The OUSD (AT&L) "Guide to System of Systems Engineering[5]" provides the following definition for a SoS:

"a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities."

The term "system of systems" is used in this document to recognize the need to operate multiple platforms and systems in a collaborative manner to perform military missions. This leads to a need for a level of systems engineering that is necessary to assure that these system configurations are flexible, extensible, integrated and interoperable. The "system of systems" may also be generally characterized as "loosely coupled" due to its geographic distribution, a high degree of collaboration that is enabled by network communications, and decentralized management. The constituent platforms and systems are capable of operating fully independent of the integrated whole to achieve a useful purpose. They may join or leave the configuration randomly depending on the operational situation. When organized as a force package of interoperable systems they collaborate to achieve a desired emergent behavior. A Joint or Naval task force assembled to conduct a strike warfare mission is an example. It is composed of a number of independent platforms each possessing various sensors, weapons, and command, control, and communications assets that collaborate to achieve a highly coordinated mission against specific identified targets.

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[3] Systems Engineering Fundamentals Guidebook, Defense Acquisition University Press, January, 2001.
[4] Ibid.
[5] Guide to System of Systems (SoS) Engineering: Considerations for Systems Engineering in a SoS Environment (Draft), 25 September 06

Importantly, systems engineering methods, techniques and tools can be applied effectively to guide the architecting, implementation, and integration of "systems of systems." There are some unique considerations to be made including definition of an overarching architecture to which each component system adheres. Enabling computing and networking technologies are also required to achieve the integration and interoperability of the constituent platforms and systems such that necessary information may be exchanged and operated on effectively by each to accomplish the intended mission.

1.2. Defining the Military Problem

The statement of the military problem should describe the envisioned operating environment and the situation it poses specifically for that operating concept. Bounding the problem properly is essential to writing a good concept. Without a clear description of the problem to be solved, it is difficult to describe a meaningful solution (i.e., concept). The more narrowly a concept can be bounded, the easier it will generally be to develop a cohesive concept.[6]

1.3. Defining the Concept of Operations

Develop the concept, i.e., the "big idea" of how the joint force will conduct the operation or function being addressed. In cases where mission/capability areas have been defined, develop an enabling concept that describes the "how" for accomplishing each area. This "painting a picture" of operations or functional activities as envisioned is the essential element in providing actionable guidance for defining required capabilities and associated attributes and metrics.[7]

It should begin with identifying the Force Package that will be utilized to perform the mission. Then, the various threads should be identified that demonstrate the various combinations of sensors, engagement weapon system(s), and Battle Damage Assessment (BDA) sensors. For an Expeditionary Strike Group (ESG) performing the Land Attack mission, the sets of detection, engagement, and BDA assets (see Table 1-1) were utilized by the RDA CHENG Joint Fires SE IPT[8] as the basis for assessing the current capability to identify gaps and overlaps. From these combinations of assets, a number of mission threads should be developed to describe how the mission would be conducted.

Detection Assets	Engagement Assets	BDA Assets
CG AEGIS	AV-8 Strike	Satellite & Theatre Sensors
DDG/X Radar	F-18 Strike	Fixed Wing Aircraft
Fire Finder Radar	Helo Strike	Roto Wing Aircraft
Forward Observer (FO)	JSF Strike	Global Hawk & DDG/X Radar
Global Hawk	JSF Strike w/ Global Hawk	Global Hawk & JSF
Global Hawk & FO	DDG/X Gun Fires	Global Hawk & Theatre Sensors
Overhead Theatre Sensors	SSGN/TACTOM Strike	Marine Ground Units
Satellite & Theatre Sensors	Surface Assault	Forward Air Controller
	Amphibious Assault Team	Forward Observer

[6] DART, op. cit.
[7] Ibid.
[8] System Performance Document for Joint Fires in Support of Expeditionary Operations in the Littorals, Increment 1: Expeditionary Strike Group Sea-Based Fires (2007 – 2012), September 2005 Draft

Table 1-1: The ESG Assets for Detection, Engagement and Assessment

1.3.1. Force Package Structure

The Force Package concept addresses the units involved in executing a mission. The Navy typically deploys in two kinds of battle groups: Expeditionary Strike Groups (ESG) and Carrier Strike Groups (CSG). The ESG is made up of a defined set of platforms involving an Amphibious Assault Ship (LHA), Amphibious Transport Dock (LPD), Dock Landing Ship (LSD), Guided Missile Frigate (FFG), Surface Combatant (DDG), Guided Missile Cruiser (CG), Attack Submarine (SSN), and a Marine Expeditionary Unit (MEU). Table 1.2 shows the typical configuration for the first 3 ESG force packages that were fielded.

Standard	ESG 1	ESG 2	ESG 3
LHA	USS Peleliu (LHA 5)	USS Wasp (LHD 1)	USS Belleau Wood (LHA 3)
LSD	USS Germantown (LSD 42)	USS Whidbey Island (LSD 41)	USS Comstock (LSD 45)
LPD	USS Ogden (LPD 5)	USS Shreveport (LPD 12)	USS Denver (LPD 9)
DDG	USS Decatur (DDG 73)	USS McFaul (DDG 74)	USS Hopper (DDG 70)
CG	USS Port Royal (CG 73)	USS Yorktown (CG 48)	USS Mobile Bay (CG 53
SSN	USS Greenville (SSN 772)	USS Connecticut (SSN 22)	USS Charlotte (SSN 766)
	USS Jarrett (FFG 33)	USS Leyte Gulf (CG 55)	USS Preble (DDG 88)

Table 1-2: The First Three ESG Configurations

The ESG force package is relatively new, and its configuration was altered to determine what should be the best mix of platforms. Note that ESG 2 utilizes an LHD as the lead ship rather than an LHA, and each configuration added a different seventh platform: an FFG, a second CG, or a second DDG. The Joint Fires SE IPT decided to standardize the ESG configuration by eliminating the eighth platforms, and to utilize the LHA as the lead ship.

Given this combination of platforms, the Organizational Chain of Command should be associated with the Operational Nodes where these organizations will operate. For example, the Joint Force Maritime Component Commander (JFMCC) will be located in the Command Information Center (CIC) on the LHA.

1.3.2. Mission Threads

Mission Threads describe the typical ways in which the Force Package will conduct missions. Different combinations of sensors (intelligence, reconnaissance and surveillance); command, control, and communication systems; and weapon systems can be utilized to counter a threat or strike a target. A set of threads needs to be identified that is sufficient to demonstrate how all of the systems within the force package contribute to the overall capability of the Force Package.

The mission threads should outline organizationally how the mission sequence of events will be conducted. Each thread will involve a set of assets that will be used to conduct the mission. It will include sensors, reconnaissance vehicles, targets, mission plans, command, control, and communications equipment, weapon systems, and battle damage assessment assets.

1.4. Define the Capabilities Required

A capability statement should start with "the ability to" and include at least one action verb. Example of a capability: The ability to detect and defeat airborne threats to the Homeland. This definition, however, lacks the measurable attributes and conditions under which the capability can be effective assessed. Thus, the definition must be expanded to add the attributes, measures (of effectiveness), conditions, and criteria for measuring success, as depicted in Figure 1-2.

Capability requirements need to be elaborated by identifying the attributes and measures of effectiveness that describe how well the capability must be achieved. The attributes and measures of effectiveness represent the desired level of performance associated with the Force Package's ability to conduct the mission. The conditions which constrain how the force package can achieve the capability should be clearly stated which represent assumptions needed to properly measure compliance with the capability requirements. Criteria can then be specified which represent the minimally acceptable level of performance associated with a particular measure.

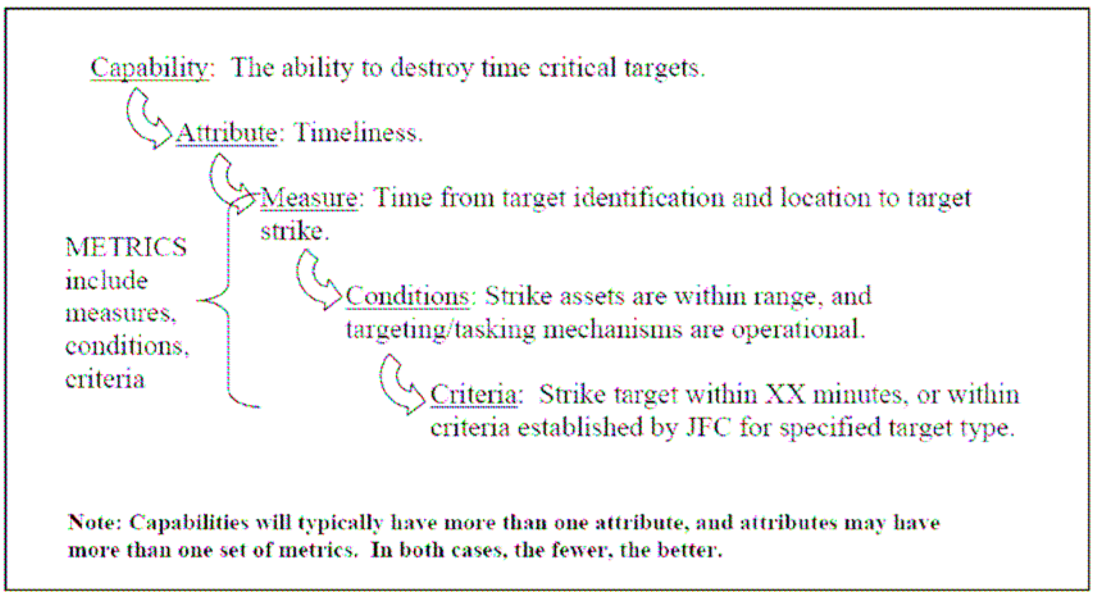

Figure 1-2: Capability Requirements

1.4.1. Identify the Metrics (Measures of Operational Effectiveness)

Metrics establish *standards* for the force package's attainment of the desired attribute in the context of the capability being considered. These standards should be defined in the context of a specific set of *conditions*. It should be noted that standards are composed of *measures* (established for each attribute in a concept, and adjusted over time), and *criteria* (which are likely to be identified and refined during experimentation, not in early drafts of the concept).

For example, the specification of Airlift Capability[9] is as follows:

[9] JP 1-02, op. cit.

The total capacity expressed in terms of number of passengers and/or weight/cubic displacement of cargo that can be carried at any one time to a given destination by available airlift.

The attribute associated with this airlift capability definition would be "capacity," while the measures would be number of passengers and weight/cubic displacement of cargo. The conditions would be "carried at one time to a given destination by available airlift." In order to properly assess a level of airlift capability desired, it would be necessary to specify the military problem and operational concept, quantify the measures, and specify the conditions and criteria.

1.4.2. Attributes

The attributes must be defined so that they can be measured. This means the attributes must be specified by establishing the units of measure. For the Airlift capability example, the attribute – capacity – would have to be specified so that measurements taken by any two organizations would result in a consistent result. In the definition provided above, the capacity attribute is expressed in terms of the measures – number of passengers, and/or weight/cubic displacement of cargo.

The measures must be clarified so that these measures can be understood. Number of passengers could mean a simple head count related to seating capacity, or it could be related to weight, given an average weight of a passenger, and its associated equipment/baggage. The measure for weight must be clarified to understand if the measures are in pounds or kilograms, and the measure for cubic displacement must identify the maximum size of the pallet storage area.

1.4.3. Measures

The measures represent the level of an attribute achieved by a given Force Package, under the established conditions and criteria. The measures of airlift capacity for the C-17 GLOBEMASTER III are 102 troops/paratroops or 170,900 pounds (77,519 kilograms) of cargo (18 pallet positions)[10]. Note that the cargo capacity measures are expressed in both pounds and kilograms, but not in volumetric measures (height, width, and depth) (see Table 1-3). Thus, these measures are insufficient to provide an understanding of the cubic displacement attribute of the C-17. The cubic displacement measures for the C-17 are shown below, but information concerning the size of the pallets is still missing.

Cargo Compartment:	Length:	88 feet (26.82 meters)
	Width:	18 feet (5.49 meters)
	Height:	12 feet 4 inches (3.76 meters)

Table 1-3: C-17 Cargo Compartment Specification

In addition, the Force Package used in this example is a single C-17. What is needed is to an understanding of the airlift capacity of a larger unit of aircraft, or the entire C-17 aircraft

[10] http://www.globemaster.de/c-17/

inventory of the air force, taking into consideration the relative availability of the aircraft, readiness, and sustainment considerations.

1.4.4. Conditions

The conditions represent the variables of the operational environment that may affect task performance. Without establishing the conditions under which a task is to be performed, it is impossible to establish appropriate criteria for its minimum acceptable performance. Based on the range the airlift is to be performed, there may be a related constraint associated with the availability of refueling aircraft to support the airlift operation. Therefore, the specification of the military problem and operational concepts must provide this information.

1.4.5. Criteria

The criteria define "the minimum acceptable level of performance associated with a particular measure." Today's fleet of C-17 aircraft may fall short of what is envisioned as being required in 2010. Thus, understanding the capability objectives and criteria enables the assessment of whether the given Force Package is sufficient to satisfy the desired capability or if a gap in capability will occur, and when it will be realized.

2. Application of Quality Function Deployment[11]

This Section will discuss the application of Quality Function Deployment (QFD) to gain an understanding of the Operational needs, and what systems improvements, changes, or new technologies can be employed to best benefit the war fighter. QFD utilizes matrices as a mechanism to assess product requirements, and when applied to Defense Systems, these matrices resemble many of the architecture views specified by DoDAF. However, since we are working with SoS/FoS, the QFD matrices will have to be customized to capture the operational, functional, and physical aspects of the Force Package. The QFD matrixes will become another set of products generated that support the generation of DoDAF products and will become part of the SoS/FoS architecture. Most of the system data in the QFD matrices can be derived from the architectural and design data that was used to develop the system.

What is Quality Function Deployment? Basically, QFD is a “quality system” used in commercial business practice to improve customer satisfaction with the quality of products and services. It concentrates on maximizing customer satisfaction (positive quality) by seeking out both spoken and unspoken needs, translating these into actions and designs, and communicating these throughout the organization end-to-end. Further, QFD allows customers to prioritize their requirements, enabling the company to benchmark itself against its competitors, and then direct its efforts to optimize those aspects of the product, process, and organization that will bring the greatest value for the customer.

QFD was developed to enable product developers to improve the way they specified the requirements for their products, demanding that each requirement be traceable back to a customer need. While it can be viewed that most of today’s products are in themselves systems-of-systems, the complexity of the DoN System-of-Systems will require that the QFD techniques be adjusted from merely identifying “product quality” characteristics to identifying “mission effectiveness” characteristics, and tracing these through concepts of operations and through the force structure and chain of command (organizationally) to the underlying processes, practices, systems, applications and people that contribute to mission effectiveness.

2.1. Application of QFD to Capability Evolution Planning

The Joint Capabilities Integration and Development System (JCIDS) is intended to focus on the establishment of Joint Capability needs through analysis done at the Joint Staff Level. Within the Department of Defense, this is the fuzzy front end of the system acquisition process. The goal of the Naval Capability Evolution Process is to understand the customer’s needs established by the Joint Staff as documented in the Initial Capabilities Document, and to derive a SoS/FoS solution which can be achieved in a timely and affordable manner. (Note: The Customers in this case are the warfighter, and they do not have requirements, they have needs. Since requirements must be achievable and affordable, needs must be analyzed and solutions derived which are achievable and affordable. Only then can the requirements for the solution be specified.)

[11] **Systems Engineering Handbook**, International Council on Systems Engineering, June, 2004.

Once an Initial Capabilities Document (ICD) is approved, the assigned service must decide how to satisfy the identified need through the acquisition of one or more systems, or improvements to fielded systems. This set of acquisition systems and improvements to fielded systems is referred to as the portfolio of acquisition systems, or acquisition portfolio, which will be invested in to provide the desired capability.

The initial stage of planning how a portfolio of systems will be acquired and evolved to provide the desired capability is to conduct an analysis of alternatives. *[Note that this portfolio of systems and the management of the portfolio is a different concept than a force package. An acquisition portfolio is a set of systems that will be invested in/acquired to contribute to a capability increment. A force package is a group of platforms and systems that may be very different, but can work together to achieve a mission.]* However, since we are performing the analysis at the missions/portfolio level, the complexities of the analysis demands that a range of alternatives be explored before selecting the most viable alternative for detailed analysis. This is where the application of QFD provides value, by providing the analysis team with an approach that focuses on understanding what the customer wants in the final solution, and mapping that to the key system performance parameters to guide the identification of alternative solutions.

Because Capabilities-Based Acquisition implies a System-of-Systems problem, there is a need to extend the use of QFD to capture the nature of how a Force Package conducts a mission, relating capability measures to the key system parameters that need to be provided in order for the mission to be effective. Thus, a series of QFD matrices will be utilized as shown in Figure 2-1.

The application of the QFD technique to assessment of Military Capabilities will involve understanding how a Force Package will execute its mission threads, and the effectiveness of the Force Package in achieving mission objectives. Measures of effectiveness goals should be identified and related to the various mission threads. Then, the mission threads are related to the Operational Activities conducted by the organizations in terms of how well the threads can be carried out by the organizations. The Activities are then related to the exchange of information, and also related to functions which describe how an activity is performed. The Functions are related to the systems, applications, and people used to conduct the activity. The systems, applications, and people are related to interfaces, communications links/protocols, and human-system integration (HSI) considerations. In addition, the systems, applications, and people are related to key performance parameters, and the interfaces, communications links/protocols, and HSI interfaces are related to Interoperability key performance parameters.

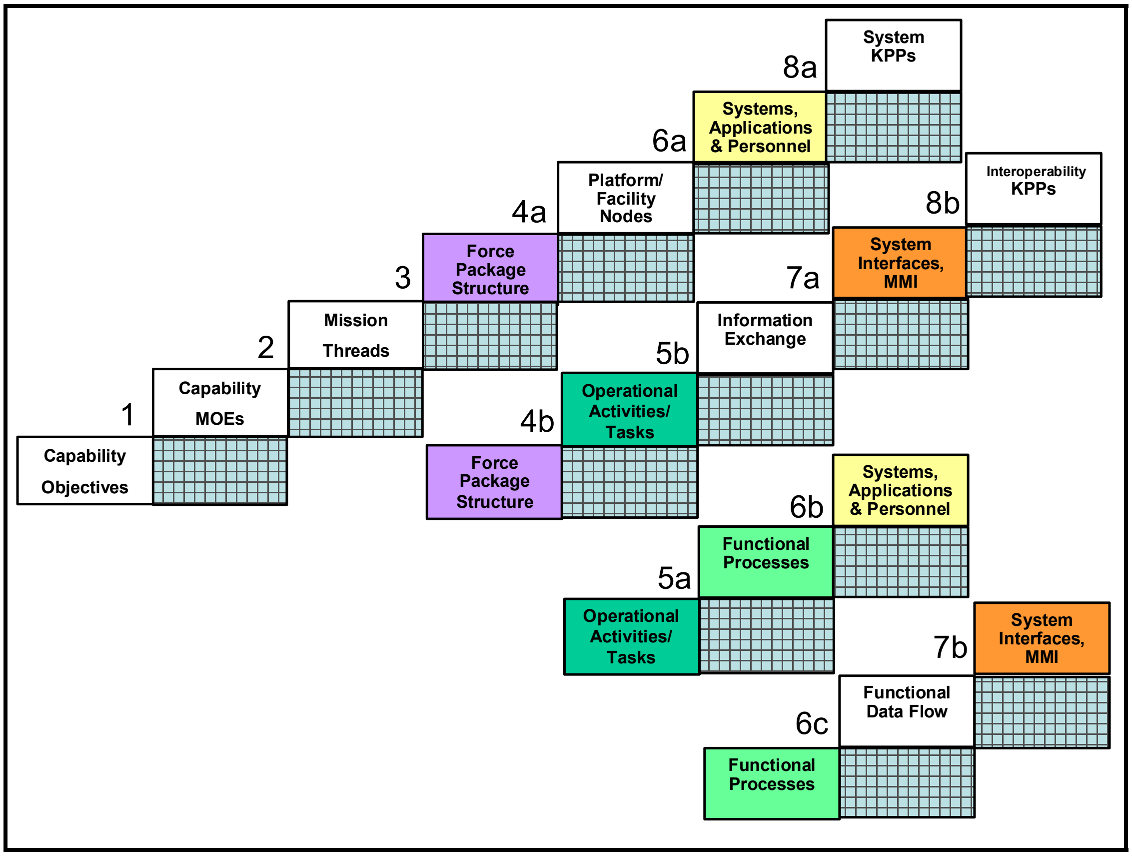

Figure 2-1: QFD Matrices for Capability-Based Planning

The Force Package must also be analyzed with regard to Readiness measures of effectiveness and Sustainment measures of effectiveness.

The focus of QFD is to understand from the operators' perspective what is important in order for the mission to be successfully carried out, and to relate the importance of the systems, applications, personnel skills, and interfaces among systems. Thus, the operators must be involved in completing the matrices and identifying what material, personnel, or organizational changes are necessary to execute the mission areas (for JOCs) or capability areas (for JFCs).

It may also be possible to reduce the number of matrices used by combining the headings on both axes. For example, the mapping of functions to systems could actually include the Operational Activities, and their decomposition to Functions on the left axis, and then align the force package physical layout along the top axis by identifying the platforms, then identifying the Operational Nodes that reside on the platforms, and then identifying the systems, applications, and personnel which operated within the Operational Node. Figure 2-2 provides an example of what such a matrix would resemble.

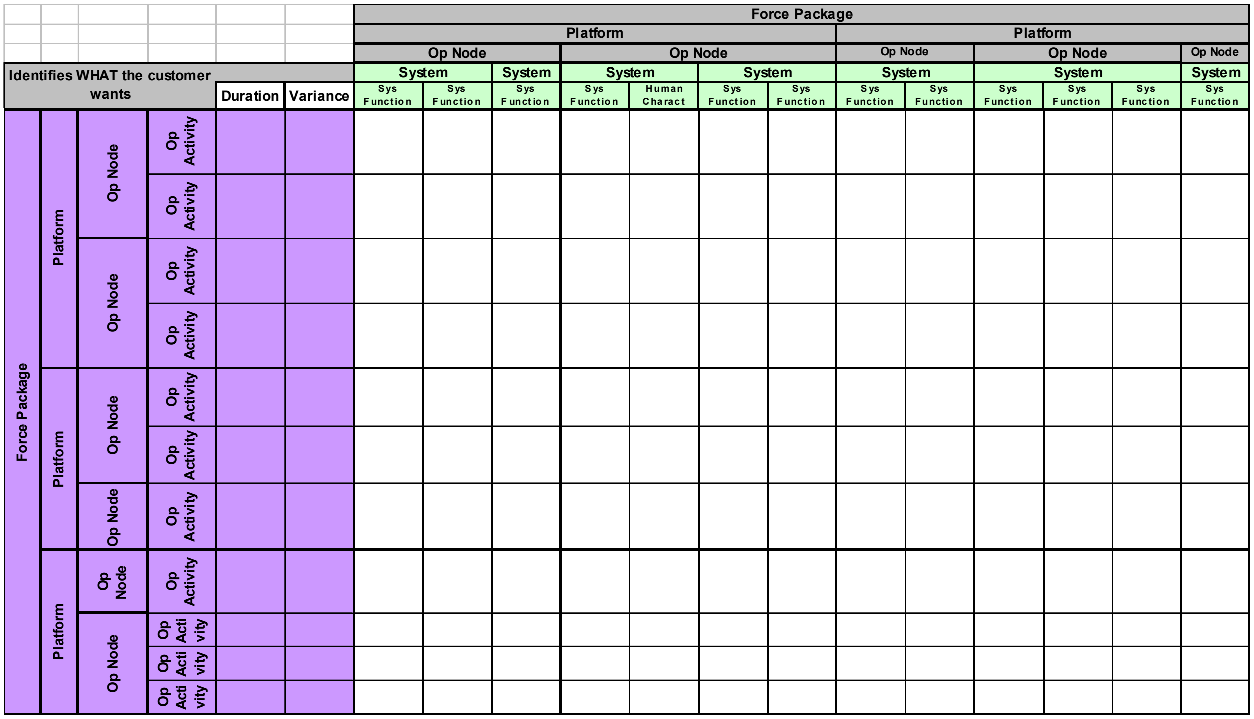

Figure 2-2: Force Package QFD Matrix Mapping Operational Activities to Functions

2.1.1. Capability Objectives related to Capability MOEs

Capability requirements should be specified in a manner that identifies an evolutionary growth path beginning with today's ability and extending out in time. Thus the capability objectives should be related to the Measure of Effectiveness (matrix 1 of Figure 2-1) for each increment in time. Figure 2-3 shows different ways of depicting this capability incremental realization.

FIGURE 2. **Evolutionary Increment Capabilities Comparison**

Requirement	Increment 1	Increment 2	Increment 3
Collect bio sample	Yes	Yes	Yes
IOC	1 year	5 years	12 years
Bio presence warning	No	Yes	Yes
# of bio agents	N/A	5 (10 obj)	25
time to warn	N/A	30 sec (tradable for # of agents)	15 sec
Remote warning	N/A	Objective	Yes
False Positive	N/A	10%	5%
False Negative	N/A	2%	1%
Volume	100 in^3 (50 obj)	200 in^3 (100 obj)	200 in^3
Weight (including power source)	not specified	15 lb.	10 lb.
Field programmable	N/A	Objective	Yes
MTBM	1 wk	3 days (1 wk obj)*	1 wk
Ruggedness	1% breakage	Same	Same
Silent operation	Yes	Yes	Yes
Collect chem agents & TIMS	Objective	Yes	Yes
Warn of chem agents & TIMS	No	Objective	Yes
Acquisition strategy	Commercial Item Evaluation	R & D Cost Plus	R & D Cost Plus
Runs	Begin Immediately	Concurrent with Increment 1	Follows Increment 2

**The reason that a lower MTBM is allowable from Increment 1 to Increment 2 is that the power sources are required to accomplish a greater number of required tasks.*

(Biological Agent Detector Example)

Capability Evolution Objectives:

- **Tied to Increments**
- **Each Capability Requirement Addressed**
  - **Traced Back to Need**
- **Rationale Captured**

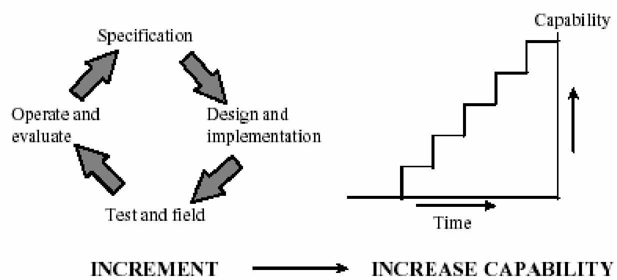

Figure 1. EA - An Incremental Approach

Figure 2-3: Capability Objective Increments

2.1.2. Capability Measures Related to Mission Threads

A series of mission threads must be identified and rated in terms of the capability measures of effectiveness (matrix 2 of Figure 2-1). Each Force Package is a combination of platforms and systems which will constrain the ways in which a mission can be carried out. The key ingredients involve sensors, mission planning systems, communication systems, weapon systems, and Battle Damage Assessment systems. Weaknesses in the effectiveness of a Force Package to perform the various mission threads should be identified and prioritized.

2.1.3. Mission Threads Relationships to Force Package Organizations

The organizations that comprise the force have a chain of command which dictates how missions are planned, executed, and assessed. For each mission thread, a different set of organizations may play a vital role in carrying out the mission (matrix 3 of Figure 2-1). Other organizations will play a support role, while still other organizations will have no role in that particular thread. For example, the ESG can perform strike missions by using Naval Gun Fire, Tomahawk missiles, aircraft, helicopters, or Marine Expeditionary Units. Each alternative will utilize a different set of organizations, while some organizations will be involved in each alternative, such as Intelligence.

2.1.4. Force Package Organizations related to Platform/Facility Nodes

The organizations that conduct the mission are located in operational nodes (rooms, tents, etc.) where they perform their tasks or operational activities (matrix 4a of Figure 2-1). Other organizations may be mobile units and housed in vehicles. For example, a Marine Expeditionary Unit (MEU) operates on-board the LHA, LPD, and LSD while at sea. The MEU staff performs its mission planning in the Landing Force Operating Center (LFOC - Operational Node). Then they are transported ashore aboard landing crafts. Once ashore they establish the LFOC ashore in a series of tent-based units.

What is important to understand is that the organizations utilize systems, equipment items, software applications, and personnel to perform their activities or tasks.

2.1.5. Force Package Organizations related to Operational Activities

Each organization performs operational activities with regards to their function (matrix 4b of Figure 2-1). For example, the intelligence organization will conduct intelligence preparation of the battle space to support the mission planning process. Understanding how this activity is conducted, what systems (sensors, imagery processing systems, etc.) are utilized, and how this activity could be improved is determined by relating the activity to information exchanges, functional processes, and system, applications, and personnel as described in the following Sections.

2.1.6. Operational Activities related to Functional Processes

Each of the activities that have been identified as needing improvement should be decomposed into the functional process or behavior by which the activity is conducted (matrix 5a of Figure 2-1). For example, the activity conducted by an Intelligence organization could involve receiving telemetry from an Unmanned Aerial Vehicle (UAV), storing the telemetry, processing the telemetry, displaying the data, and interpreting the data. Each is a step in the process of exploiting the intelligence data provided by a UAV. How systems, applications, and personnel process the telemetry data must be understood if the process is to be made more effective or timely.

Figure 2-4 depicts the functional processes for the two operational activities performed by a forward observer when generating a call for fire message. Note that the two operational activities are being performed by the Forward Observation Team, which represents both an organization and a node since it is also a location where the organization resides. In this example, each activity is described by a sequence of three functions, but in some situations there may be functions that are executed in parallel.

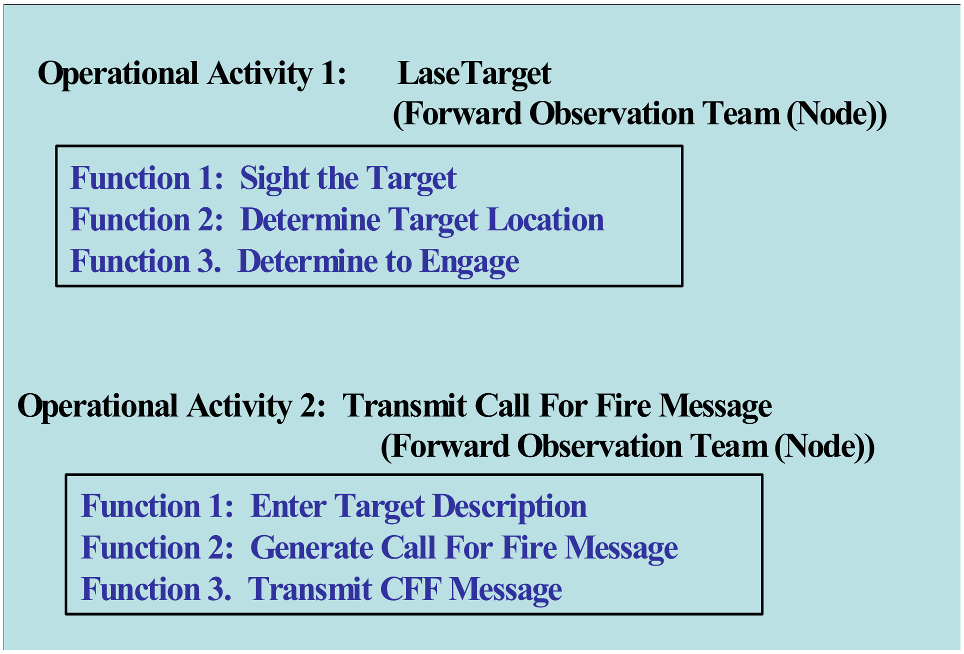

Figure 2-4: Relating Operational Activities to Functional Processes

2.1.7. Operational Activities related to Information Exchanges

Information that is exchanged among organizations is represented as inputs and outputs of operational activities (matrix 5b of Figure 2-1). For example, a UAV carrying a sensor will relay the data gathered via telemetry to a local ship, whose Intelligence organization processes the data, and exploits the results. The data transmitted between the UAV and the ship represents an information flow that is the output of an activity executed by the UAV – Gather Intelligence, and is input to the activity executed by the Intelligence organization – Process Video Intelligence. Relating information inputs and outputs to activities helps understand if better command, control, and communications system performance or bandwidth are needed.

Figure 2-5 depicts the Information Exchange for the Forward Observation Team generating a Call for Fire message. In this simplistic example, there is one information exchange – the Call For Fire message generated by the Forward Observation Team and received by the Supporting Arms Coordination Center (SACC) onboard the LHA.

Operational Activity 1: Lase Target
(Forward Observation Team (Node))

Function 1: Sight the Target
Function 2: Determine Target Location
Function 3. Determine to Engage

Operational Activity 2: Transmit Call For Fire Message
(Forward Observation Team (Node))

Function 1: Enter Target Description
Function 2: Generate Call For Fire Message
Function 3. Transmit CFF Message

Output: Call For Fire Message
(Information Exchange between
Forward Observation Team (Node) and the
Supporting Arms Coordination Center (Node))

Figure 2-5: Relating Operational Activities to Information Exchanges

2.1.8. Platform/Facility Nodes related to Systems, Applications, and Personnel

The nodes (rooms/locations) on each platform or within a facility may have systems installed and connected to a LAN, WAN, connected directly to communications equipment, or to other external networks or systems. In some cases, a work station may be configurable by selecting the applications to be loaded to support multiple functions. These nodes represent the work locations for the personnel within the organization (matrix 6a of Figure 2-1).

The systems, applications, and personnel that conduct the operational activities should be identified. This should include all communication systems used for local and external communications between nodes.

2.1.9. Functional Processes related to Systems, Applications, and Personnel

The functions identified in 2.1.6 above should be related to the systems, applications, and/or personnel that perform the function (matrix 6b of Figure 2-1). Functions are either automated (conducted by a system automatically), or may be performed by applications and personnel involved in conducting the activity. Some functions may be completely manual, but still need to be captured for context. How the combination of systems, applications, and personnel conduct the functional processes must be captured to understand what changes are necessary to improve overall mission effectiveness.

Using the example shown in Figure 2-5, a forward observation team identifies a target, and transmits a call for fire to the awaiting Supporting Arms Coordination Center (SACC) on the LHA platform. Establishing the relationship between the functions and the systems, application and personnel would result in the information presented in Figure 2-6.

Operational Activity 1: Lase Target
(Forward Observation Team (Node))

Function 1: Sight the Target	(Forward Observer (Person))
Function 2: Determine Target Location	(Laser Range Finder (System))
Function 3. Determine to Engage	(Forward Observer (Person))

Operational Activity 2: Transmit Call For Fire Message
(Forward Observation Team (Node))

Function 1: Enter Target Description	(Forward Observer (Person))
Function 2: Generate Call For Fire Message	(Laser Range Finder (System))
Function 3. Transmit CFF Message	(SINCGARS Radio (System))

Figure 2-6: Relating Functions to Systems, Applications, and Personnel

2.1.10. Functional Processes related to Data Transformation and Flow

The functional processes depend on data flow among the Functions which must be accounted for in the architecture (matrix 6c in Figure 2-1). The data represents inputs and outputs of functions, and result in the production of messages exchanged among operational activities.

For the example of the Forward Observation Team generating a Call for Fire Message, we have added the data flow to Figure 2-7. The Forward Observer must enter data into the Laser Range Finder so that the Call for Fire Message will include this important information. The Laser Range Finder then generates a digitally formatted message and transmits it to the radio for transmission over the air waves.

Operational Activity 1: Lase Target
(Forward Observation Team (Node))

Function 1: Sight the Target (Forward Observer (Person))
Function 2: Determine Target Location (Laser Range Finder (System))
Function 3. Determine to Engage (Forward Observer (Person))

Operational Activity 2: Transmit Call For Fire
(Forward Observation Team (Node))

Function 1: Enter Target Description (Forward Observer (Person))
Data Flow: Target Description
Function 2: Generate CFF Message (Laser Range Finder (System))
Data Flow: Digital Call For Fire Message
Function 3. Transmit CFF Message (SINCGARS Radio (System))

Output: Call For Fire Message
(Information Exchange between Forward Observation Team (Node) and the Supporting Arms Coordination Center (Node))

Figure 2-7: Data Transformation and Flow for Transmit CFF Functional Process

2.1.11. Information Exchange related to System Interfaces

The information exchanges (i.e., Messages) should be related to systems utilized in the mission thread to identify the key interoperability and integration requirements and issues (matrix 7a in Figure 2-1). Interoperability and integration problems will lead to the identification of needed system- to- system interfaces or other solutions such as greater bandwidth requirements. This represents operational data being exchanged by organizational nodes. However, the system used to generate, communicate or transmit these messages must be linked to the Information exchanges in order to ensure interoperability.

2.1.12. Data Flow related to System Interfaces

The data flow between system functions will require an interface if the functions are performed by two or more different systems or application. Data flowing within a single system represents an internal interface or data store, and is the purview of the single system program to ensure it is addressed by the system design. Relating data flows between two systems to interfaces (matrix 7b in Figure 2-1) help in the understanding of how and why the systems must interoperate.

2.1.13. System, Application, and Personnel Functions Related to Key Performance Parameters

The system, application and personnel functions should be related to Key performance parameters to identify what level of performance is required to improve missions effectiveness and timeliness (matrix 8a of Figure 2-1). Operators, support personnel, and developers should rate the system, application and personnel functions in terms of how well they are (or need to be) performed to satisfy these key performance parameters.

2.1.14. Relating Systems Interfaces to Interoperability KPP

The system interfaces should be related to the Interoperability KPP to establish the key interoperability challenges (matrix 8b of Figure 2-1). Previously, we mapped information exchanges, as well as the system data flows, to the System Interfaces. This matrix attempts to qualify how well each system interface must be implemented to satisfy mission objectives.

2.1.15. Capability Shortfalls

The QFD matrices should be analyzed to understand where capability shortfalls exist and how they can best be resolved. QFD matrices for capabilities are developed for a minimum two timeframes:

- **The Current, or As-Is Architecture** – The existing architecture represented by the platforms and systems currently being deployed to theater and those platforms and systems currently resourced in the Programs of Record (POR). The QFD Matrices for the current architecture should identify and specify the key performance parameters for systems and Interoperability, and rate where modernization improvements are most needed.

- **The Objective Architecture** – The conceptual requirements-driven target architecture representing the Capability Sponsor's objectives for the "final" capability that should extend beyond the Future Years Defense Program (FYDP). The Objective Architecture QFD matrices should rate and specify the key performance parameters for system improvements or new system acquisitions that, at incremental time frames, improve and satisfy Measures of effectiveness and capability objectives.

The Objective Architecture may involve several competing alternative solution sets of acquisition programs and/or enhancements to existing systems. Additionally, doctrine and tactics may change the way in which operational activities are performed, and these changes should be noted in the appropriate matrices and re-assessed as variations of the Vision Architecture.

A similar procedure is used to capture matrices that address the Force Package's Readiness and Sustainment models.

Shortfalls should be prioritized and solutions analyzed to identify where the best investments should be made to evolve the capability of the force package. The intent of this analysis in the Capability Evolution Planning process is to come away with the viable alternatives that will be pursued during the Analysis of Alternatives (AoA).

2.2. Application of QFD to JCIDS

The Naval Capability Evolution Process is initiated after the JCIDS analysis process is completed.[12] However, RDA CHENG has been involved in the DoDAF Version 2.0 effort, which has led to the development of a set of QFD matrices that supports JCIDS Analyses. These matrices have been submitted to the JCIDS Overlay committee for inclusion in the DoDAF Version 2.0 update.

The JCIDS policy requires the following analyses, as represented by Figure 2-8:

- **Functional Area Analysis (FAA)** identifies the operational tasks, conditions, and standards needed to achieve military objectives. It uses the national strategies, JOCs, JFCs, JICs, the Universal Joint Task List (UJTL), the anticipated range of broad capabilities that an adversary might employ, and other sources as input. Its output is the tasks to be reviewed in the follow-on functional needs analysis. The FAA includes capability-based analysis in identifying the operational tasks, conditions and standards.

- **Functional Needs Analysis (FNA)** assesses the ability of the current and programmed joint capabilities to accomplish the tasks that the FAA identified under the full range of operating conditions and to the designated standards. Using the tasks identified in the FAA as primary input, the FNA produces as output a list of capability gaps or shortcomings that require solutions and indicates the time frame in which those solutions are needed. It may also identify redundancies in capabilities that reflect inefficiencies. The FNA must include supportability as an inherent part of defining capability needs.

- **Functional Solution Analysis (FSA)** is an operationally based assessment of all potential DOTMLPF approaches to solving (or mitigating) one or more of the capability gaps (needs) identified in the FNA. On the basis of the capability needs, potential solutions are identified, including (in order of priority) integrated DOTMLPF changes that leverage existing materiel capabilities; product improvements to existing materiel or facilities; adoption of interagency or foreign materiel solutions; and finally, initiation of new materiel programs. Identified capability needs or redundancies (excess to the need) establish the basis for developing materiel approaches in ICDs and/or DOTMLPF Change Recommendations.

[12] Ibid

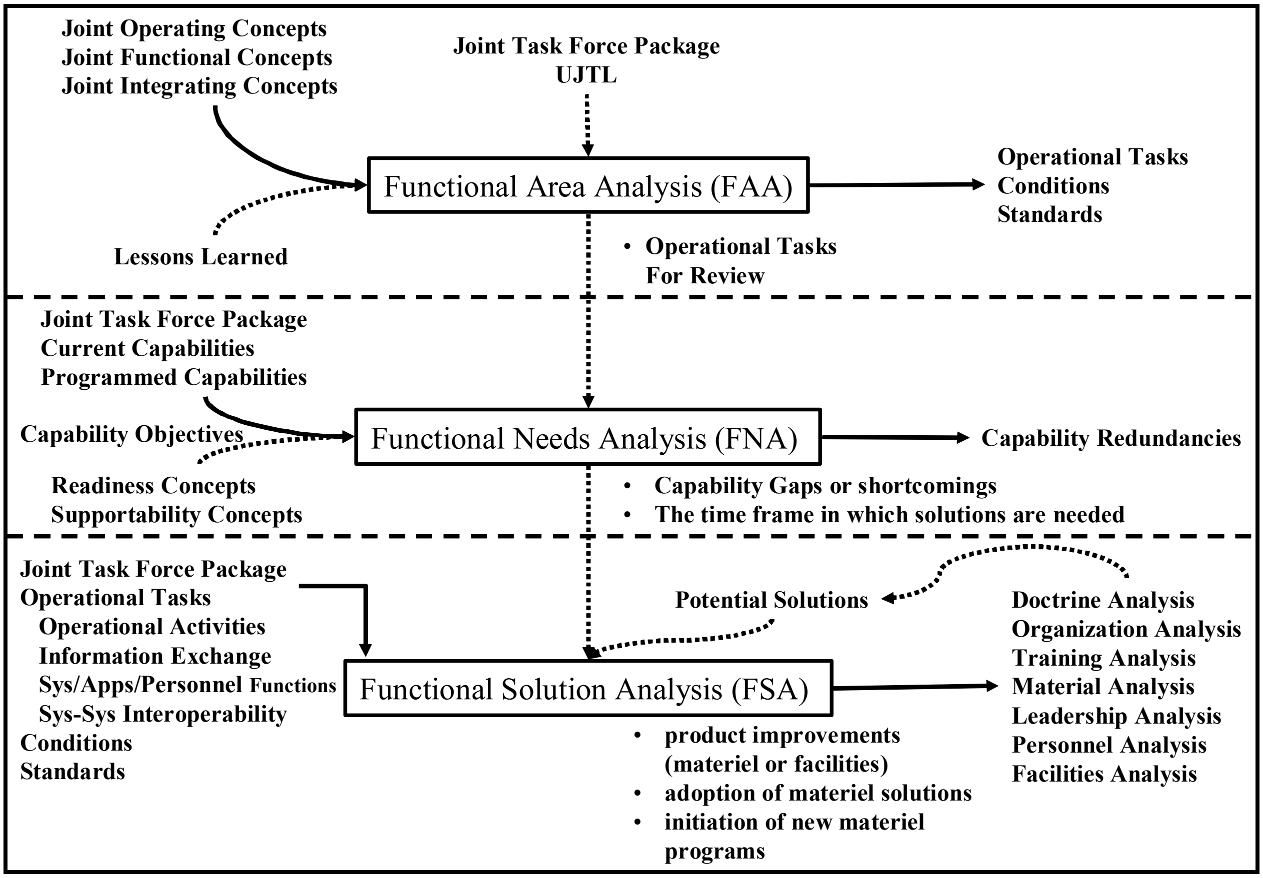

Figure 2-8: JCIDS Analysis Flow

2.2.1. Functional Area Analysis Matrix

The Functional Area Analysis matrix relates the Tasks, Conditions, and Standards to the missions identified in Joint Operating Concepts, Joint Functional Concepts, and Joint Integrating Concepts (Figure 2-9). The first step is to identify the tasks, conditions and standards that apply to the mission. Then the operational community input should be sought to rate:

- How critical is each task to accomplish the mission, and
- How well does the current, planned and future Force Package(s) DOTMLPF enable the task to be performed to standards

			Originating JFC, JOC, JIC Reference						Related JFC Ref.	Related JOC Ref.	Related JIC Ref.
			Mission			Mission					
			Current	Programmed	Future	Current	Programmed	Future			
Operational Task	Condition	Standard	▲ green	● green	◆ green						
		Standard	▲ green	● green	◆ yellow						
	Condition	Standard	▲ yellow	● green	◆ green						
		Standard	▲ red	● red	◆ red						
	Condition	Standard	▲ green	● green	◆ green						
		Standard	▲ green	● yellow	◆ red						
Operational Task	Condition	Standard	▲ yellow	● green	◆ green						
		Standard	▲ yellow	● green	◆ green						
	Condition	Standard	▲ red	● yellow	◆ yellow						
		Standard	▲ yellow	● yellow	◆ yellow						
	Condition	Standard	▲ yellow	● green	◆ green						
		Standard	▲ yellow	● green	◆ yellow						

Figure 2-9: Functional Area Analysis Matrix

The matrix captures the missions identified in the pertinent JOCs, JFCs and JICs, and provides the ability to identify related missions referenced in these documents. The Operational tasks, conditions, and standards are identified along the left columns. Then, the operators are asked to rate how well the task can be conducted by the identified force package using both currently fielded DOTMLPF elements and Programmed material items, and those anticipated in future timeframes.

This will result in the identification of the tasks that need to be further analyzed in the Functional Needs Analysis.

2.2.2. Functional Needs Analysis

The Functional Needs Analysis uses the tasks identified as a result of the Functional Area Analysis to identify the capability gaps or shortcomings that require solutions and indicates the time frame in which those solutions are needed. Thus, the additional item that must be addressed is the mapping of required capabilities necessary to perform the tasks to standard and achieve mission objectives. The Functional Needs Analysis addresses this by aligning the capability objectives columns for each mission, as depicted in Figure 2-10.

			Originating JFC, JOC, JIC Reference								
			Mission								
			Capability Objectives			Capability Objectives			Related JFC Ref.	Related JOC Ref.	Related JIC Ref.
			Current	Programmed	Future	Current	Programmed	Future			
Operational Task	Condition	Standard	▲ (green)	● (green)	◆ (green)						
		Standard	▲ (green)	● (green)	◆ (yellow)						
	Condition	Standard	▲ (yellow)	● (green)	◆ (green)						
		Standard	▲ (red)	● (red)	◆ (red)						
	Condition	Standard	▲ (green)	● (green)	◆ (green)						
		Standard	▲ (green)	● (yellow)	◆ (red)						
Operational Task	Condition	Standard	▲ (yellow)	● (green)	◆ (green)						
		Standard	▲ (yellow)	● (green)	◆ (green)						
	Condition	Standard	▲ (red)	● (yellow)	◆ (yellow)						
		Standard	▲ (yellow)	● (yellow)	◆ (yellow)						
	Condition	Standard	▲ (yellow)	● (green)	◆ (green)						
		Standard	▲ (yellow)	● (green)	◆ (yellow)						

Figure 2-10: Functional Needs Analysis Matrix

The matrix requires the user to identify or relate the capabilities required to perform each task. There is a presumed hierarchical relationship among these three elements: Mission, Task, and Capability. According to CJCSI 3170.01E, a mission is defined as the task, together with the purpose that clearly indicates the action to be taken and the reason therefore. So a mission must be composed of one or more tasks. The definition of a "capability" is the ability to achieve a desired effect under specified standards and conditions through combinations of means and ways to perform a set of tasks.

Thus, a mission in made up of one or more tasks, and the capability is the measure of effectiveness of the force assigned the mission. This implies that the Functional Needs Analysis is attempting to identify the capability shortfalls in the ways and means of a force to perform the mission or assigned tasks to specified standards. The force involves the organizations, command and control roles and responsibilities, and platforms, facilities, material items, and personnel it has at its disposal. So, the Functional Needs Analysis Matrix represents a relative assessment of the ability of a Joint Force, given its DOTMLPF elements, to achieve the mission. It relates the tasks that have to be performed to the capability objectives necessary to be achieved for each mission. This analysis leads to the identification of capability gaps or shortfalls that will feed the Functional Solutions Analysis.

2.2.3. Functional Solutions Analysis

The Functional Solutions Analysis (FSA) is intended to consider the range of DOTMLPF alternative for fulfilling the capability gap or shortfall. Thus, there are eight (8) matrices needed to support the FSA, one for each of the seven (7) DOTMLPF areas, and one to present a comparison of the alternatives considered, as depicted in Figure 2-11.

- **Doctrine Matrix**
- **Organization Matrices**
  - **Activity Performance Matrix**
  - **Organizational Interoperability Matrix**
- **Training Matrix**
- **Material Matrices**
  - **Functional Performance Matrix**
  - **System Interoperability Matrix**
- **Leadership Matrix**
- **Personnel Matrix**
- **Facilities Matrix**
- **Alternative Comparison Matrix**

Figure 2-11: Functional Solutions Analysis Matrices

It is necessary to understand that JCIDS policy directs that a material solution be sought only when it is determined that a DOTLPF alternative is not able to fill the capability gap or shortfall. Material solutions are typically more costly, and take more time to deliver to the operator, as depicted in Figure 2-12[13].

[13] Architecture Based Analysis To Support Capabilities Acquisition (Version 1.0), Mr. Charles Babers (used with permission)

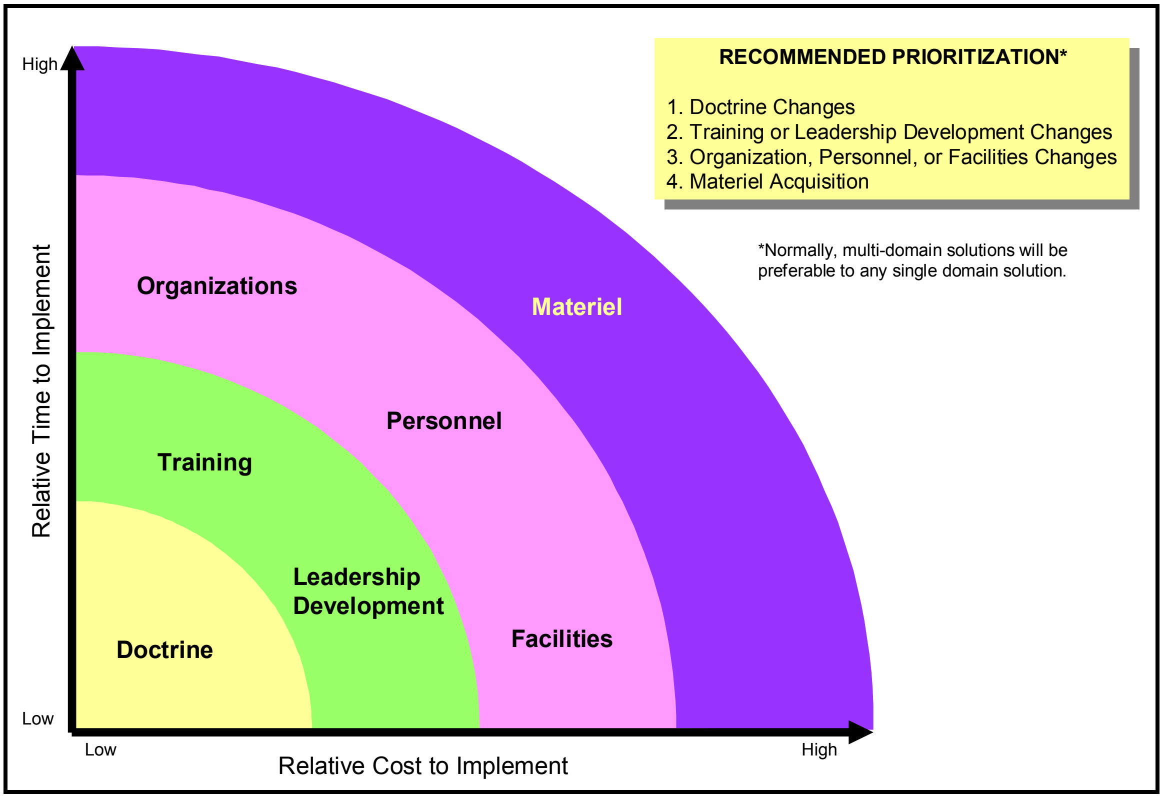

Figure 2-12: Relative Cost and Time Associated with Each DOTMLPF Domain

In addition to the ten (10) matrices identified in Figure 2-11, there will be one additional matrix to capture each of the alternatives assessed and its implications in terms of the DOTMLPF domains.

2.2.3.1. Doctrine Matrix

The Doctrine matrix provide a way for the various elements of doctrine both, current and proposed, to be assessed in terms of how well they support the achievement of the mission and tasks. This matrix maps the Doctrine from established doctrine publications to the tasks or sub-activities of the tasks. Figure 2-13 shows the Doctrine Analysis Matrix.

2.2.3.2. Organization Matrices

		Force Package				
		Doctrine Pub		Doctrine Publication		
	Process Sequence	Doctrine	Doctrine	Doctrine	Doctrine	Doctrine
Operational Task	Activity					
	Activity					
	Activity					
	Activity					
	Activity					
	Activity					
Operational Task	Activity					
	Activity					
	Activity					
	Activity					
	Activity					
	Activity					

Figure 2-13: (Proposed) Doctrine Analysis Matrix

2.2.3.2.1. Activity Performance Matrix

The Activity Performance Matrix (Figure 2-14) assess the organizations which make up the Joint Force and evaluates how well each task and its supporting sub-activities can be performed by the organizations. This assessment will allow the assessors to identify where organizational changes can be made to improve how the mission is carried out.

		Force Package						
		Org Element			Org Element			
	Process Sequence	SubOrg	SubOrg		SubOrg		SubOrg	
			SubOrg	SubOrg	SubOrg	SubOrg	SubOrg	SubOrg
Operational Task	Activity							
	Activity							
	Activity							
	Activity							
	Activity							
	Activity							
Operational Task	Activity							
	Activity							
	Activity							
	Activity							
	Activity							
	Activity							

Figure 2-14: (Proposed) Activity Performance Matrix (Organizational Domain)

2.2.3.2.2. The Organizational Interoperability Matrix

The Organizational Interoperability Matrix (Figure 2-15) maps how well the individual organizations can exchange information with other organizations that they need to interoperate with in support of the mission. In this matrix, the organizational elements of the joint force are listed across the columns and the tasks and sub-activities that must be performed. For each activity, the organization that generates an information exchange is identified, and the receiving organizations are identified.

			Force Package						
			Org Element			Org Element			
	Process Sequenc		SubOrg	SubOrg		SubOrg		SubOrg	
		Info		SubOrg	SubOrg	SubOrg	SubOrg	SubOrg	SubOrg
Operational Task	Activity	Info Exch	Output		Input	Input		Input	
	Activity	Info Exch		Output			Input		
	Activity								
	Activity	Info Exch			Output		Input		Input
	Activity								
	Activity	Info Exch							
Operational Task	Activity	Info Exch							
	Activity								
	Activity	Info Exch							
	Activity	Info Exch							
	Activity								
	Activity	Info Exch							

Figure 2-15: Organizational Interoperability Matrix

The color coding is a rating by the operational personnel (Customers) on how well the organizations can generate, transmit, receive or process the Information Exchange. This matrix will identify where organizational interoperability must be reviewed and improved.

2.2.3.3. The Training Matrix

The Training matrix identifies the joint tasks that must be performed to achieve the mission objectives along the left column. If the task can be broken down into lower-level tasks or activities, then these should be identified, and the standards against which the force is certified to is identified. Then the matrix identifies the critical elements of the Training Infrastructure, such as the training activities associated with the Operational Task, the course(s), facilities, training equipment, instructors, and operators skills which are the focus of the training activity, as shown in Figure 2-16.

	Process Sequence	Standard	Training Activity	Course	Facilities	Training Equipment	Instructors	Operator Skills
Operational Task	Activity							
	Activity							
	Activity							
	Activity							
	Activity							
	Activity							
Operational Task	Activity							
	Activity							
	Activity							
	Activity							
	Activity							
	Activity							

Figure 2-16: Training Matrix

2.2.3.4. The Material Matrices

2.2.3.4.1. The Functional Performance Matrix

The functional performance matrix (Figure 2-17) identifies the task that must be performed to accomplish the mission objectives, and breaks them down to the sub-activities, and functions that must be performed along the left-most columns. Along the top-most rows, the Force package is broken down to identify the Platforms and facilities that play a role in conducting the tasks. Within the platforms and facilities, the organizational locations (Operational/System nodes) are identified, and the systems, applications, and personnel which comprise the operational node are identified. The matrix permits the operational customers to rate how well the systems and applications perform the functions required to accomplish the task to standard.

			Force Package					
			Platform/Facility					
	Process Sequence	Functional Process Sequence	Operational Node			Operational Node		
			System	Application	Sysem	System	Application	System
Operational Task	Activity	Function						
		Function						
	Activity	Function						
		Function						
		Function						
	Activity	Function						
Operational Task	Activity	Function						
		Function						
	Activity	Function						
		Function						
	Activity	Function						
		Function						

Figure 2-17: Functional Performance Matrix

2.2.3.4.2. The System Interoperability Matrix

The System Interoperability Matrix identifies the Force Package in terms of the Platforms and Facilities, the Operational Nodes within the platforms and facilities, and the systems and applications at these locations along the left-most columns and across the top-most rows, as shown in Figure 2-18. This enables the system and applications that must be interoperable to be rated as to how well they can exchange information via established interfaces or networks.

				Force Package				
				Platform/Facility				
				Operational Node			Operational Node	
				System	System	Application	System	Application
Force Package	Platform/Facility	Operational Node	System		Interface ID			
			System				Interface ID	
			Application					Interface ID
		Operational Node	System	Interface ID				
			Application					

Figure 2-18: System Interoperability Matrix

2.2.3.5. The Leadership Matrix

The leadership matrix (Figure 2-19) identifies the tasks, sub-activities and leadership skill required to perform the mission along the left most columns. Along the top most rows, the force package is identified, and the leadership's positions are identified as defined by the command and control relationships among the organizational elements. This allows the assessment of the ability of the leadership within the Force Package to possess the necessary skills to accomplish the mission objectives.

			Force Package						
	Process Sequenc	Leadership Skills	Org Element			Org Element			
			Leader	Leader	Leader	Leader	Leader	Leader	Leader
Operational Task	Activity								
	Activity								
	Activity								
Operational Task	Activity								
	Activity								
	Activity								

Figure 2-19: Leadership Matrix

2.2.3.6. The Personnel Matrix

The personnel matrix (Figure 2-20) identifies the skills and quantity of personnel types required to support each task, sub-activity, and/or function along the left-most columns. Along the top-most rows the force package is broken down by Organizational Elements and the personnel categories that make up each Organizational Element are identified. This matrix can be used to assess the sufficiency of the number of personnel within each Organizational Element, and the proficiency of the personnel in terms of the skill set required to perform the tasks, sub-activities, and/or functions.

					Force Package						
	Process Sequence	Functional Sequence	Skills	Quantity of Trained Personnel	Org Element			Org Element			
					Personnel	Personnel	Personnel	Personnel	Personnel	Personnel	Personnel
Operational Task	Activity	Function									
		Function									
	Activity	Function									
		Function									
		Function									
	Activity	Function									
Operational Task	Activity	Function									
		Function									
	Activity	Function									
		Function									
		Function									
	Activity	Function									

Figure 2-20: Personnel Matrix

2.2.3.7. The Facility Matrix

The facility matrix identifies the operational tasks, sub-activities and functions which are performed to conduct the mission along the left-most columns. Along the top-most rows, the facilities that support the Force Package are identified, and the Operational Nodes located at each Facility, as well as the inventory of Systems, Applications, Personnel, and connectivity pathways (Interfaces or network connections), as shown in Figure 2-21. This matrix permits the operations customers to relate how the inventory of systems, applications, personnel, and connectivity pathways support the accomplishment of mission objectives. It can also rate the conditions of the facilities in terms of electrical, mechanical (heating, air conditioning, elevators, etc), security, survivability, etc., to identify where improvements may be required to maintain the facility in a state of readiness.

			Force Package					
			Facility					
	Process Sequence	Functional Process Sequence	Operational Node					
			System	Application	Person	Security	Mechanical	Connectivity
Operational Task	Activity	Function						
		Function						
	Activity	Function						
		Function						
		Function						
	Activity	Function						
Operational Task	Activity	Function						
		Function						
	Activity	Function						
		Function						
	Activity	Function						
		Function						

Figure 2-21: Facility Matrix

2.2.3.8. The Alternative Solutions Matrix

The alternative solutions matrix provides a summary of the different solutions considered within each of the DOTMLPF domain areas along the left-most columns. Along the top-most rows the evaluation criteria are listed, in terms capability objectives, lifecycle costs, timeliness, effectiveness, or other criteria, as shown in Figure 2-22. This matrix can then rate how the various alternatives or combinations of alternatives can best contribute to incrementally improving the capability and satisfy the capability objectives.

Solution Category	Solution Alternatives	Capability Objectives	Life-cycle Costs	Timeliness	Effectiveness	Other Crieria
DOCTRINE						
ORGANIZATIONAL						
TRAINING						
MATERIAL						
LEADERSHIP						
PERSONNEL						
FACILITY						

Figure 2-22: Alternative Solutions Matrix

2.3. Architecture Principles and Guidelines

The DoD Architecture Framework (DoDAF) provides the definition of "Architecture" as the structure of components, their relationships, and the principles and guidelines governing their design and evolution over time. While the DoDAF architecture views capture the components and their relationships well, by design the DoDAF does not provide architecture development guidelines. This Section of the document describes architectural principles and guidelines for

Force Package development and how the QFD matrices fit into the larger integrated architectures or are supported by them.

For example, if it is desired that the Expeditionary Strike Group (ESG) should evolve to a Force which delivers an expeditionary force ashore using primarily Air-lift vehicles, then the nature of the platforms involved in the ESG would have to be modified to include more air-lift carrying platforms. The architecture's data can be used to support acquisition plans to acquire the right quantity and mix of platforms and air-lift vehicles over an extended timeframe to satisfy the capability requirements.

2.3.1. Role of the Architecture

The purpose of the architecture is to provide the data needed by decision makers to conduct capability analyses, complete the QFD matrices, and support the development and evolution of the FoS/SoS in the context of an integrated force package of interoperable systems. The architecture does not stand apart from NCEP, rather it is an integral component that is developed and matures along with the rest of the process.

Architectures needed to support force development are not the same as the architecture a program office would build to specify the design of a system. Where program architecture would specify software and hardware blueprints, human machine interface details, and focus on the requirements for a single system, the architecture for an integrated force package would focus on defining each component system, the interfaces between systems and the business processes that together enable the "Systems of Systems" to achieve a desired capability. Thus, the focus on mission threads and QFD analysis found in this document.

2.3.2. Architecture Documentation Principles

An architecture's products must be tied to the rest of the SE process and, more specifically, to decision points within that process. This allows the architect to determine what products need to be produced, when to produce them, and what level of detail needs to be present. In order to tie architecture products to decision points in the NCEP or any other SE process the architect must understand what decisions need to be made. The process begins with these questions:

- What is the output of my SE process?
- What decisions need to be made to produce the output?
- What sort of information is needed to make those decisions?
- Which architecture products provide the information in a format that's understandable to the decision maker?
- When are the architecture products needed?
- How should my project be staffed to produce those products?
- Which software tools will help the architect build those products?

For example, if the output of the SE process is an electronic time card system, then decisions include: what are the expectation of its users, how many employees will use it concurrently, what technology options exist, and which technical option works best with the existing timekeeping business process. Concerning the time card software itself, the decision maker would probably like to know the advantages and disadvantages of different ways of entering time card data, ease of updating and maintenance, and how the software will interoperate with the business' existing software. Each of these decisions is made at a different point in the SE process, and many of the decisions are interdependent. It is the architect's job to recognize this and suggest the appropriate mix of architecture products that will provide the needed information – in essence, answer the question.

The following documentation method uses a series of spreadsheets that help the developers focus on what information the architecture needs to provide and how to organize the production of the products.

2.3.2.1. Step One

Step one focuses on identifying the architecture's customers and determining each customer's questions or decisions they need to make. In the "Customer-Question Matrix" (Table 2-1) the customers are listed along the top axis and a list of questions along the left axis. Next, the information needed to answer each customer's question is added to the matrix. Developing this matrix can be greatly improved by letting each customer see the responses of other customers. This typically results in fewer questions about redundancy, especially when the information needs between customers are similar.

	Business Owner / Managers	**Finance Department**	**IT Department**	**Users**
How will it be deployed?	Deployment milestones, overarching plan, IT integration plan	Deployment milestones, overarching plan	Deployment milestones, overarching plan, Interaction with development team	When the user must start using it
What data has to be saved?	Audit data requirements, Payroll data requirements, Timecard business rules	Payroll data requirements, Timecard business rules	Frequency of data backup and storage requirements	Need to track available vacation time
What is the testing plan?	Testing plan schedule, integration into overall development plan	Finance department test input	IT department test input and responsibilities	User testing plan

Table 2-1: Customer-Question Matrix

2.3.2.2. Step Two

In Step Two, the focus shifts from the customer's questions and decision points to which architecture products provide the information needed to answer the questions or support a decision. It is important to remember that even when several customers need similar information, the architecture product and the level of detail for that product might be different. For example, a business executive and a programmer would both need to understand the concept for the company's new time card system, but the level of detail needed by each would be much different.

For this matrix (Table 2-2), the information needed by each customer is listed on the left axis, and architecture products that could provide that information are listed along the top axis. Quite often, the information needed will span several architecture products. For instance, determining who can update a company's human resources database and under what conditions an update can occur may require activity diagrams, a logical data model, a business rules model, and other architecture products.

	System concept and program plan	Activity and Process Diagrams	Business Rules Description	Web-portal screen mockup	Regulation compliance traceability matrix	Data model
System concept information	White Paper			Graphics		
Federal and State timekeeping regulation compliance			Text Document		Spreadsheet	
Data needed for auditing, payroll, vacation tracking, and other requirements.		Activity Diagram	Data Flow Diagram	Graphics	Spreadsheet	Class Diagram
Timecard usage, review, and auditing business rules		Activity Diagram	State Chart		Spreadsheet	Class Diagram

Table 2-2: Product-Information Matrix

When possible, information needs as described by the customers should be consolidated so the matrix does not become unwieldy, but only when the information needed is at the same level of detail. Although two customers may need the same type of information to answer their question, the information they need may reflect a different level of detail. For example, if a business owner wants to understand database access permissions, then a business rules model might be the best architecture product to provide the information. However, the database developer would need a data model based on the business rules to build the database. Few business owners will look at or understand a data model, but it is the right product for the developer.

2.3.2.3. Step Three

The next step in the process matches each customer with the set of architecture products they need to answer questions and make decisions in a timely manner. This step gives the architecture developers the information they need to plan the architecture development process and integrate it into the overall SE process. The "customer-product matrix" (Table 2-3) supports this mapping, identifies when each product is needed, and highlights dependencies between products. In this matrix, the customers are again listed along the top axis, while the architecture products are listed on the left axis. Delivery dates, product formats, (e.g., activity diagram vice data flow diagram), metrics, and other information should be used to indicate the mapping between customers and products.

	Business Owner / Managers	Finance Department	IT Department	Users
System concept	DEC	DEC	DEC	
Activity and Process diagrams	JAN – High Level APR – Final	JAN – High Level MAR - Detailed	JAN – High Level MAR - Detailed	MAR - Detailed
Business rules description	JAN – Initial	MAR – Detailed	JAN – Initial MAR – Detailed APR - Final	
Regulation compliance traceability matrix	APR			
Data model		MAR - Business Rule Text	FEB - UML Class Diagram	

Table 2-3: Customer-Product Matrix

It is likely that a specific product, such as "the activity model," will be identified as being used by multiple customers. Keep in mind that each customer will probably use his activity model in a different manner, which should be captured in the "information" Section of the first matrix. This means that there will probably not be one activity model for the architecture. Rather, there will be several views of the activity model that are relevant to a specific customer's information needs, derived from the same pool of architectural data.

2.3.2.4. Step Four

Now that architecture products needed to support the SE process have been identified, the last step is to choose the software tools that the architects will use to produce products in a format useful for each customer's decision making process. Typically, an executive-level decision maker will not want to look at a product as displayed in a Computer-Aided Systems Engineering (CASE) tool, while a software developer will not get the information they need from a PowerPoint presentation. Therefore, the architecture should rely on a suite of tools to produce, store, and display the architecture's products. Each tool serves a defined purpose within the architecture, and together they support the creation and integration of the architecture.

Generally, there are four types of software tools used to support architecture development: CASE tools, databases, executable modeling tools, and web sites. Normally, one tool of each type is needed because each customer has different needs for viewing and using their architecture products. One word of caution: even though many vendors will try to sell a "one size fits all" software solution, very few tools support all aspects of your development process. Choose the tool that provides the information needed by that customer to support their decision making process. Don't expect a customer to modify their SE process or decision making criteria just because your software can't deliver the architecture in a form they can use.

2.3.2.5. Other uses for the Matrices

Understanding what products to produce is only half the challenge. The next challenge is determining how to staff the development project, including how many people to hire and what skills those people should have. The information contained in the matrices can help answer this question also. For example, data models are generally produced later in the SE lifecycle than system use cases are, meaning a project may not need to hire a data modeler at the very beginning of the project. Likewise, a completed set of matrices will normally show a need for several systems analysts toward the beginning of the lifecycle, one or two during the middle, and a large group at the end during the test and evaluation stage. So, by matching the expected delivery dates for each architecture product captured in the matrix, a good initial staff skill set and loading matrix can be produced. Staffing choices are not always intuitive, and the completed matrixes can significantly help the program manager justify his project funding requirements by having hard numbers to base his staffing plan upon.

3. Developing the Capability Evolution Plan

The Capability Evolution Plan is the primary product of the Capability Evolution Planning Process. It is the result of identifying Capability shortfalls and potential solutions using the QFD technique to the Force Package, and conducting an Analysis of Alternatives to understand the short-, mid-, and long-term impact on operational effectiveness offered by the various alternatives. Because we are dealing with a System of Systems problem, it may be determined that the evolution of a capability may involve more than one material and/or non-material change involving upgrades to fielded systems, changes to systems in the program of record, and new systems and technologies. The result is the identification of a plan for how this "portfolio" of acquisition programs will be funded, developed, tested, and fielded to enhance and evolve the desired capability to satisfy identified objectives.

The Capability Evolution Plan is therefore the guiding roadmap for a long-term investment strategy which may involve research into the application of emerging technologies, system upgrades, system decommissioning, the development and introduction of new systems, and changes in doctrine, tasks, and procedures for how Force organizations and personnel will conduct a mission.

Thus, the Capability Evolution Plan will itself be a living document that will change over time, even as the portfolio of acquisition programs moves through the Acquisition System. The Capability Evolution Plan should contain the following Sections to address the full lifecycle planning required to understand the complete level of investment, and time-line for evolving the capability to the desired objectives:

Capability Evolution Plan – Outline

- Mission Threads/Concept of Operations
- Capability Evolution Objectives
- Force Package Structure
- Readiness Concepts
- Sustainment Concepts
- System Service-life Profile
- Capability Evolution Description
- Technology Adoption Milestones
- Force Training and Transition Plan
- Capability Investment Strategy

Only by addressing all of these topics can the Naval Acquisition community and decision-makers fully appreciate what it will require in order to deliver and field the desired military capabilities. The Capability Evolution Plan attempts to relate the capability needs/requirements to the Force Structure plans, to technology and acquisition roadmaps, to personnel training strategies, and to the investment (total ownership costs) required. Thus, it will have to be maintained as the primary document governing how the Navy will invest in a particular capability.

The first iteration of the CEP will not be complete, but its lack of details in certain areas will highlight what areas need further investigation and analysis in order to establish a coherent, integrated roadmap. This integrated roadmap will facilitate capability management by understanding the risk associated with the Capability Evolution Plan, and how decisions at an individual program level will affect the realization of the full capability.

3.1. Mission Threads/Concept of Operations

The mission description and threads (identified in Section 1.3), which were used to identify the capability gaps/needs, need to be documented as the basis for establishing the capability evolution objectives.

3.2. Capability Evolution Objectives

This Section of the Capability Evolution Plan should capture the driving need for the enhanced capability from information captured in the Joint Capabilities Document (JCD) or Initial Capabilities Document (ICD) prepared by the Joint Staff. The purpose of the JCD and ICD are captured below[14].

The JCD is the result of a CBA *(capability-based assessment)* that identifies what is important to the joint warfighter and how to evaluate future systems in their ability to deliver those capabilities. A CBA uses relevant parameters and associated metrics to quantify the key characteristics (attributes) of systems and forces in order to determine how capable they are of performing those critical tasks needed to accomplish future military objectives. The JCD will in general cover a much broader scope of capabilities than that described in an ICD. The JCD may be the predecessor document for one or more ICDs and/or Joint DOTMLPF Change Recommendations (DCRs).

The ICD summarizes the results of DOTMLPF analysis and identifies any changes in U.S. or allied doctrine, operational concepts, organization, training and policy that were considered in satisfying the deficiency. The ICD will identify and summarize the DOTMLPF and policy changes (non-materiel approaches) that may address the deficiency in part or in whole as part of the list of approaches addressed in the Functional Solution Analysis (FSA). These DOTMLPF and policy changes may lead to the development of a Joint DCR.

The ICD documents the evaluation of balanced and synchronized materiel and non-materiel approaches that are proposed to provide the required capability. It further proposes a prioritized list of materiel and nonmaterial approaches based on analysis of the various possible approaches and their DOTMLPF or policy implications. Finally, the ICD describes how the approach(es) provides the desired joint capability and relates the desired capability to the key characteristics identified in the Family of Joint Future Concepts or CONOPS.

The Capability Evolution Objectives should present the key thoughts on how the capability needs to be evolved to satisfy the identified capability need, and the timeframe for incrementally evolving and delivering the associated portfolio of acquisition programs to the warfighter. It

[14] CJCSM 3170.01B, 11 May 2005, Operation of the Joint Capabilities Integration and Development System

should frame the problem, and capture the rationale for the material-type solution resulting from the JCIDS Joint Solution Analysis and the additional insight gained from the Analysis of Alternatives conducted by the Naval SE IPT during the Capability Evolution Planning Process.

3.3. Force Package Structure

The Force Package Structure represents the highest level of material planning and considers the number and types of platforms which will comprise the warfare units that will perform the missions. It should capture the force package structure currently being deployed, and describe the evolution of the force package over a long-term horizon. This should account for platforms that will retire and new platforms that are to be fielded for each time frame. Figure 3-1 shows a simplistic example of the force structure evolution objectives from 2004 to 2030 for a Marine Expeditionary Battalion.

Current Capability (Now)	Interim Capability (~2012)	Objective Capability(~2030)
• Landing Force • ~ 2.0 MEB' s with Advance Force • 50%mechanized/motorized • 50% air mobile • MEB Lift Finger Print • Pre-boated • 14,500 personnel • 325,000 ft² • 600,000 ft³ • 24-27 LCAC spots • 130 -148 CH-46 spots • Combat Loading Factor= 1.3 • Air Assault Radius ~ 40nm • Force Recycle Capability • Decontamination - no • Repair - limited • ~ 1 BLT/day • Air Combat Component • Partially Sea Based	•Landing Force • ~ 2.0 MEB' s with Advance Force •100%mechanized/motorized • 50% air mobile • MEB Lift Finger Print • Loose loaded • 16,500 personnel • 400,000 ft² • 700,000 ft³ • 28-32 LCAC spots • 170 -195 CH-46 spots • Combat Loading Factor= 1.7 • Air Assault Radius ~ 90nm • Force Recycle Capability • Decontamination - no • Repair -significant • ~ 1 BLT/day • Air Combat Component • Partially Sea Based	•Landing Force • ~ 5.0 MEB' s with Advance Force •100%mechanized/motorized • 50% air mobile • MEB Lift Finger Print • Loose Loaded • 18,500 personnel • 500,000 ft² • 900,000 ft³ • 40-50 LCAC spots • 500-600 CH-46 spots • Combat Loading Factor= 2.0 • Air Assault Radius ~ 150nm • Force Recycle Capability • Decontamination - yes • Repair -complete • ~ 1 BLT/day • Air Combat Component • Sea Based

Figure 3-1: Force Structure Evolutionary Objectives for a Marine Expeditionary Battalion

Each service performs Force Structure analysis in support of the Defense Planning Guidance in accordance with the inputs and constraints indicated in Figure 3-2. Given this direction, the services perform force structure analysis to determine how the service will comply with this planning guidance.

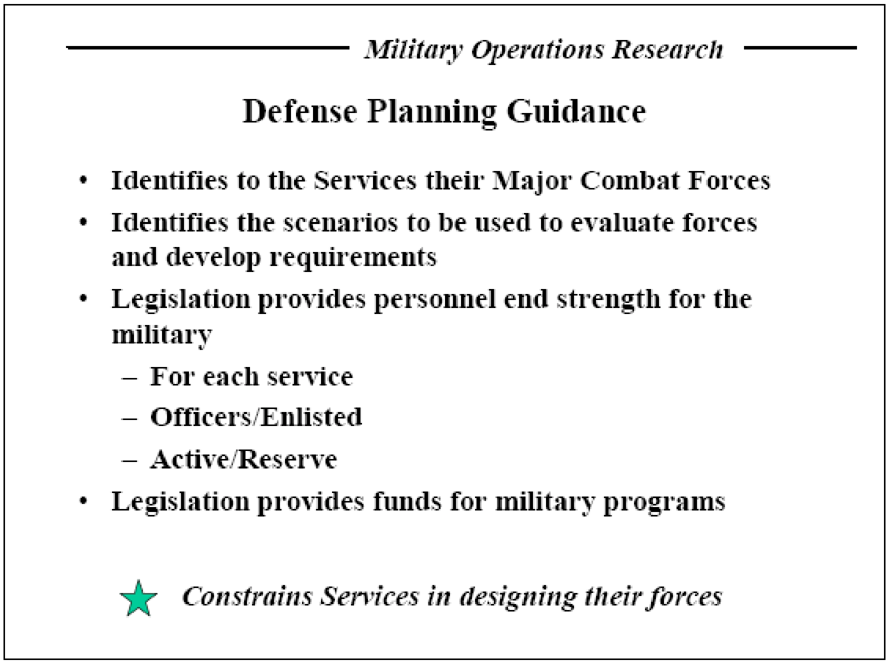

Figure 3-2: Defense Planning Guidance Affect on Force Structure

The Sea Power 21 Global Concept of Operations identifies the types and number of force packages which will constitute the Naval Force.

- Dispersed, fully-netted force integrated with joint forces
- Increase the number of independent strike groups from 19 to 37
    - 12 Carrier Strike Groups (CSG)
    - 12 Expeditionary Strike Groups (ESG)
    - 9 Strike/Missile Defense Surface Action Groups (SAG)
        - 3 surface combatants; at least 2 Aegis
        - Missile/air defense umbrella (Sea Shield)
        - TLAMs (Sea Strike)
    - 4 Guided Missile Submarines (SSGN/SOF)
        - Converted from Ohio-class SSBN
        - 154 TLAMs (Sea Strike)
        - 66 SEALs for special operations

Sea Power 21 calls for naval forces that are widely dispersed, fully netted, and seamlessly integrated with joint forces. It outlines a Global Concept of Operations centered on creating additional, innovative force packages to enhance deterrence and improve the ability to operate in more areas around the world. In the recent past, the Navy was only able to float 19 strike groups capable of independent action: 12 carrier battle groups and 7 surface action groups. A reorganization of units will provide 37 independent strike groups. The new force will have 12 carrier strike groups, 12 expeditionary strike groups, 9 strike and missile defense surface action groups, and 4 guided missile submarines that carry a SOF contingent.

The strike/missile defense surface action group, or SAG, will have 3 surface combatants, at least two of which will have the Aegis system for missile defense. Their ability to extend air and missile defense over friendly forces ashore make them key players in Sea Shield while their TLAMs allow Sea Strike operations. The four guided missile submarines will be conversions of Ohio-class Trident missile submarines, trading their SSBN designation for SSGN. They will have 154 TLAMs aboard and up to 66 SEALs and their associated equipment. Being virtually undetectable, the guided missile submarines will be ideal for covert operations and pack an awesome Sea Strike capability. As a point of reference, 218 TLAMs were fired during Operation Enduring Freedom and 288 during Desert Storm.

3.4. Readiness Concepts

Because Readiness is an element of the capability definition, each SE IPT will have to develop the Readiness Concepts which include the repositioned forces world wide, and how they will be maintained in a state of readiness. The SE IPT must establish a Readiness Concept for the Force Package for analysis purposes. The aging of key weapon systems remains a key challenge when assessing future military capabilities (Figure 3-3)[15]

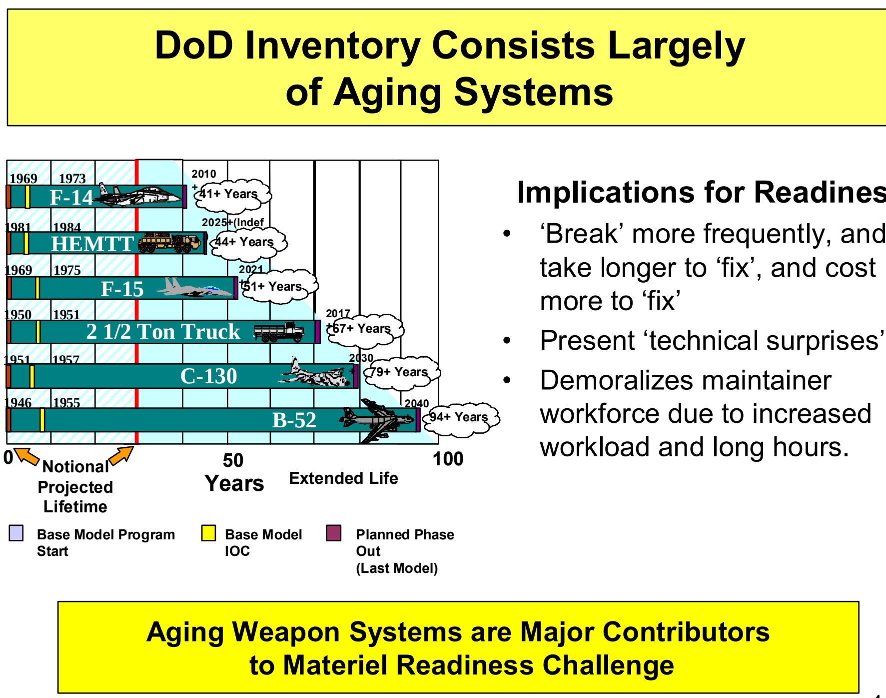

Figure 3-3: The Materiel Readiness Challenge

The readiness concept should address material readiness, Personnel Readiness, Training Readiness (see Figure 3-4), as well as Force Package Deployment timelines. Just like the Military capability of the Force Package, this will include establishing the level of readiness over the long term horizon. Things such as oversea base closings, platform rotations, rotational crewing infrastructure and accelerated deployment, and employment timelines need to be

[15] http://www.acq.osd.mil/log/mppr/materiel_readiness/mppr%20website%20charts.ppt

specified much like capabilities with the associated objectives, Statement of the Military Problem, Concepts of Operations, Readiness Capabilities, Attributes, and Metrics (measures, conditions, and criteria).

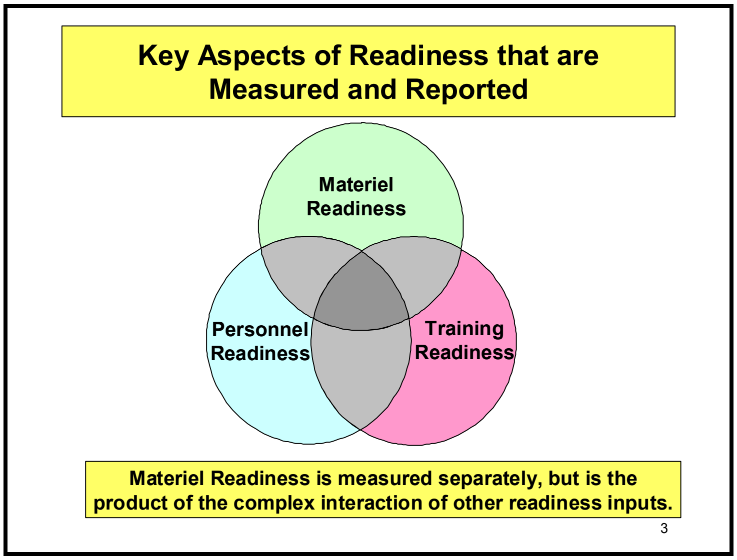

Figure 3-4: Relationship Among Readiness Elements

The CNO Sea Power 21 "Pillars" include Sea Basing to accelerate expeditionary deployment and employment timelines by pre-positioning vital equipment and supplies in-theater, preparing the United States to take swift and decisive action during crises. Strategic sealift will be central to this effort. It remains a primary mission of the U.S. Navy and will be critical during any large conflict fought ashore. Moreover, pre-positioned ships with at-sea-accessible cargo will be built and will await closure of troops by way of high-speed sealift and airlift. Joint operational flexibility will be greatly enhanced by employing pre-positioned shipping that does not have to enter port to offload. Figure 3-5 highlights the key tenets of Sea Basing.[11]

From this material it can been seen that the Readiness and Sustainment elements of a Force Package will represent the Sea Basing capabilities identified by Sea Power 21. The readiness element of a Force Package capability must outline the deployment concepts, timelines, and identify the skill-levels for operational personnel required for certification. As future systems are fielded to improve the readiness element of the capability of the Force Package, the associated training requirements, certification activities and milestones need to be identified.

Sea Basing is the core of "Sea Power 21." It is about placing at sea—to a greater extent than ever before—capabilities critical to joint and coalition operational success: offensive and defensive firepower, maneuver forces, command and control, and logistics. By doing so, it minimizes the need to build up forces and supplies ashore, reduces their vulnerability, and enhances operational mobility. It leverages advanced sensor and communications systems, precision ordnance, and weapons reach while propositioning joint capabilities where they are immediately employable and most decisive. It exploits the operational shift in warfare from mass to precision and information, employing the 70% of the earth's surface that is covered with water as a vast maneuver area in support of the joint force.[16]

SEA BASE Impact
Pre-positioned warfighting capabilities for immediate employment Enhanced joint support from a fully netted, dispersed naval force Strengthened international coalition building Increased joint force security and operational agility Minimized operational reliance on shore infrastructure
SEA BASE Capabilities
Enhanced afloat positioning of joint assets Offensive and defensive power projection Command and control Integrated joint logistics Accelerated deployment and employment timelines
Future SEA BASE Technologies
Enhanced sea-based joint command and control Heavy equipment transfer capabilities Intra-theater high-speed sealift Improved vertical delivery methods Integrated joint logistics Rotational crewing infrastructure International data-sharing networks
SEA BASE: Action Steps
Exploit the advantages of sea-based forces wherever possible Develop technologies to enhance on-station time and minimize maintenance requirements Experiment with innovative employment concepts and platforms Challenge every assumption that results in shore basing of Navy capabilities

Figure 3-5: Sea Basing Key Tenets

Department of Defense Instruction (DoDI) 4140.61, *Customer Wait Time and Time Definite Delivery*, "institutionalizes" Customer Wait Time (CWT) and Time Definite Delivery (TDD) as key logistics performance metrics by implementing policy, assigning responsibility, and prescribing procedures.[17]

DoDI 3110.5, *Materiel Condition Reporting for Mission Essential Systems and Equipment,* requires the services to establish quantitative condition status measurements (e.g., mission capable and not mission capable metrics) based on full funding, design characteristics of the systems, and planned peacetime usage.[18]

While some service metrics obviously are tailored for unique mission responsibilities (for example, the Navy's comparison of the mission capable rates of aircraft aboard a deployed carrier compared with the historical MC rates of aircraft aboard the four most recent carrier

[16] http://www.usni.org/Proceedings/Articles03/PROseabasing01.htm
[17] Materiel Readiness Metrics, Logistics Management Institute, LG`102T4, Aug 2003
[18] Ibid.

deployments), most metrics are reasonably consistent across the services. Those common metrics generally include: [19]

- Equipment readiness
- Supply and parts trends
- Depot status
- Customer wait time
- Manning (critical skills)
- Global Status of Resources
- Training System (GSORTS) trends
- Operations tempo (OPTEMPO)
- Personnel tempo (PERSTEMPO)
- Engine status
- Cannibalization rate
- Cost per operating hour
- Emerging issues.

AVAILABILITY RATES: This metric tracks the availability of key weapon systems. Weapon system capability/availability serves as the "report card" for the entire DoD logistics system. A mission-ready weapon system is the end product of sufficient amounts of maintenance, spares, personnel, test equipment, facilities, and other necessary input variables (Figure 3-6). There are two approaches to tracking availability: [20]

The *traditional approach* is based upon DoDI 3110.5. The mission capability format uses condition status codes (e.g., mission capable, not mission capable supply, and not mission capable maintenance) to identify the percentage of time that key weapon systems are available to perform their assigned missions.

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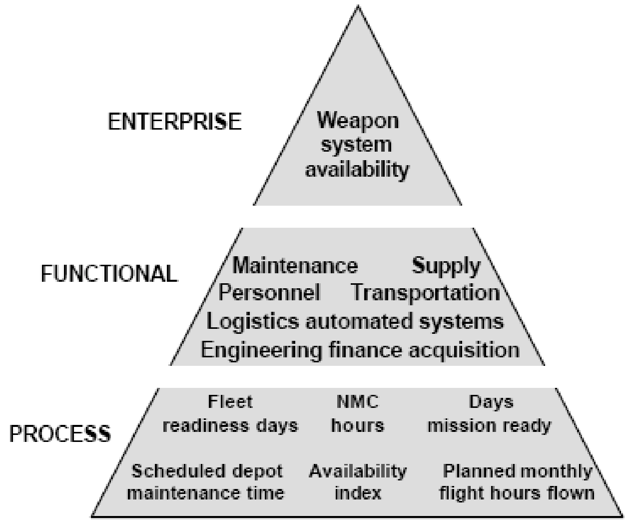
[19] Ibid.
[20] Ibid.



Source: Logistics Management Institute, *Inventory Stratification and Performance Reporting*, Albert J. Colaianni et al., CG103T1, October 2001, p. A-3.

Figure 3-6: Example of Supporting Functional Metrics

The *evolving approach* is based upon availability modeling. This metric uses the total number of weapon systems (by Mission Design Series (MDS)) that are available for operational requirements.

3.5. Sustainment Concepts

The SE IPT must establish Sustainment concepts that address how the Force Package will be sustained throughout the course of an operation. This will involve identifying the support vessels and platforms which will accompany the Force Package, and the inventory of material, spare parts, and technicians required to keep the Force Package in a sate of readiness to execute its daily assigned missions. The foundation for USD (AT&L)'s lifecycle framework can be portrayed across three dimensions as shown in Figure 3-7.

First, military requirements for rapid response, high mobility, and smaller footprint drive system requirements for high reliability, ease of maintainability, and transportability. These system requirements are translated into product and process design requirements through an integrated lifecycle systems engineering process. This process encompasses not only system design for reliability and maintainability, but also sustaining engineering of fielded systems to anticipate failures, assess and improve reliability, determine readiness and cost degraders, and ensure appropriate product upgrades. The process is facilitated by onboard prognostics and diagnostics, reliability centered maintenance procedures, and international standards for technical data. The systems engineering process also inherently includes the support engineering process, beginning in early concept development, and determines reliability/maintainability of the system, as well as the performance requirements for the post-fielding support process. The third dimension is the product support process, driven by desired outcomes, such as operational availability and mission reliability. This process is being transformed to focus on performance outcomes (versus DoD's historic focus on functional processes).

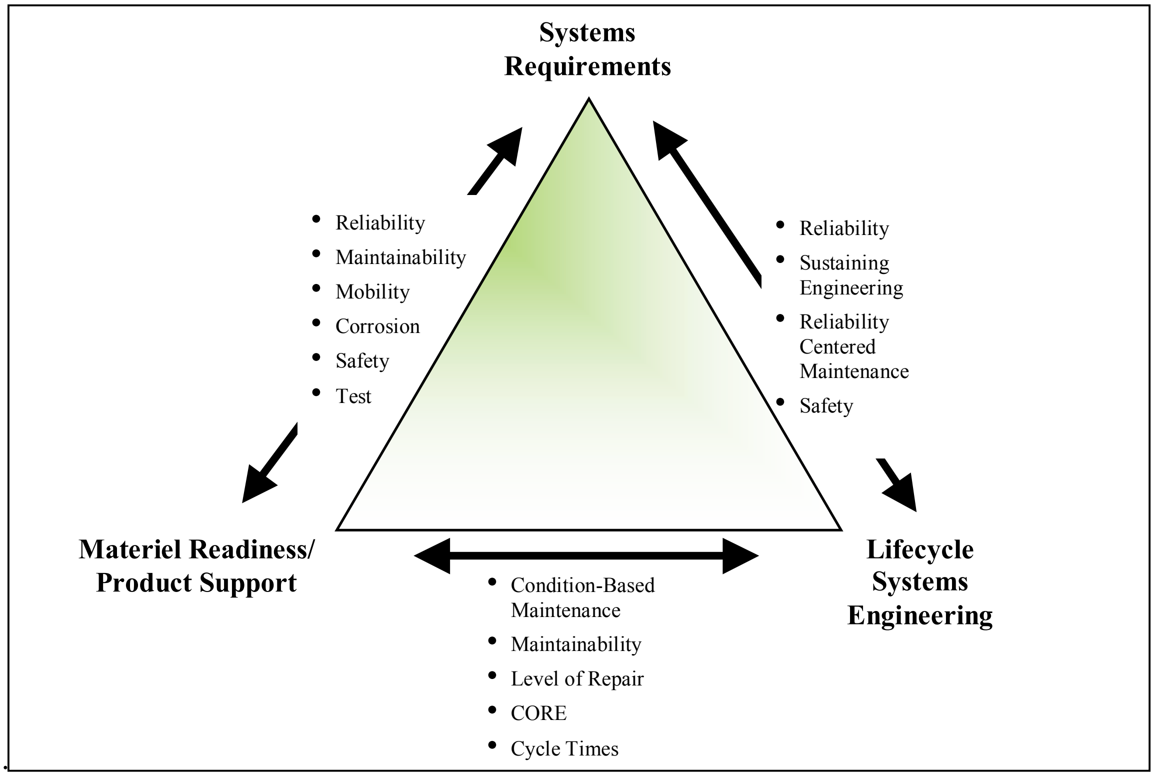


Figure 3-7: DoD Lifecycle Systems Engineering

Sustainment includes supply, maintenance, transportation, sustaining engineering, data management, configuration management, manpower, personnel, training, habitability, survivability, environment, safety (including explosives safety), occupational health, protection of critical program information, anti-tamper provisions, and information technology (IT), including National Security Systems (NSS), supportability and interoperability functions. Effective sustainment of weapon systems begins with the design and development of reliable and maintainable systems through the continuous application of a robust systems engineering methodology. This includes the following concepts[21] and is adapted herein to address the SoS/FoS challenges.

The SE IPT, in conjunction with users and material managers, shall conduct continuing reviews of sustainment strategies, utilizing comparisons of performance expectation as defined in performance agreements against actual performance measures. The SE IPT shall revise, correct, and improve sustainment strategies as necessary to meet performance requirements

Sustainment strategies shall evolve and be refined throughout the lifecycle, particularly during development of subsequent increments of an evolutionary strategy, modifications, upgrades, and re-procurement. The PM shall ensure that a flexible, performance-oriented strategy to sustain systems is developed and executed (Figure 3-8).

[21] Designing and Assessing Supportability in DOD Weapon Systems: A Guide to Increased Reliability and Reduced Logistics Footprint, October 24, 2003

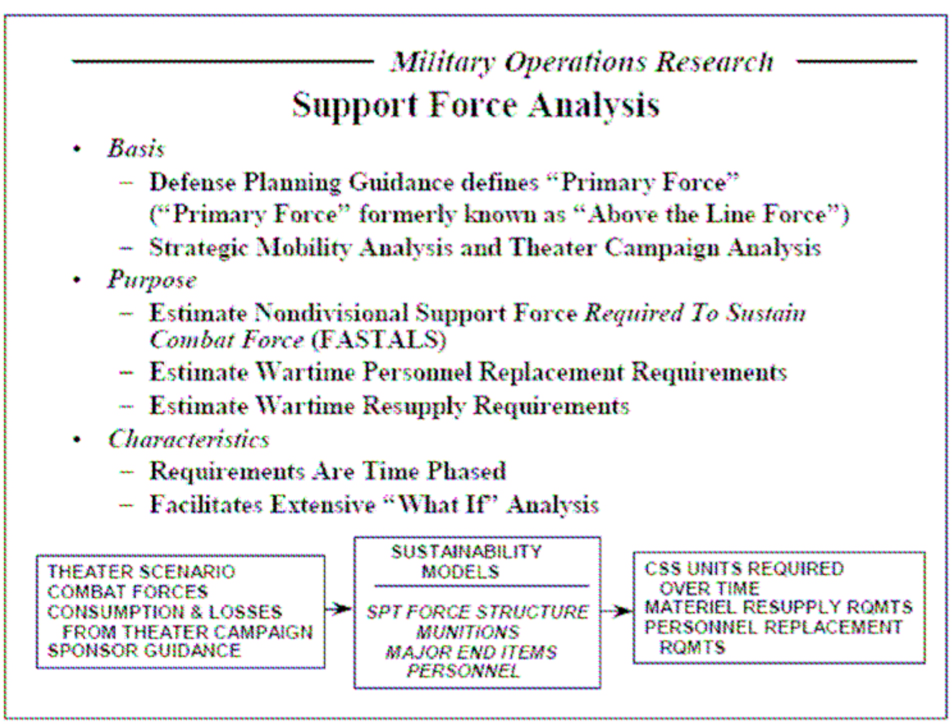


Figure 3-8: Sustainability Analysis

A significant number of systems and/or subsystems have life-limiting characteristics, e.g., metal fatigue (aircraft structures), corrosion, or mechanical wear. Such systems are normally designed and tested for a specified service life, but frequently operational requirements demand an extension of the service life beyond the originally planned date. As plans are laid for extending the service life of the system or subsystem, the program office should work with the Capability SE IPT to consider all aspects and impacts of the extension. All of the logistics elements must be analyzed for many of them, such as supply support, maintenance, training, and support equipment, are apt to be affected by the extension.[22]

[22] Acquisition Logistics Guide, December 1997, Third Addition

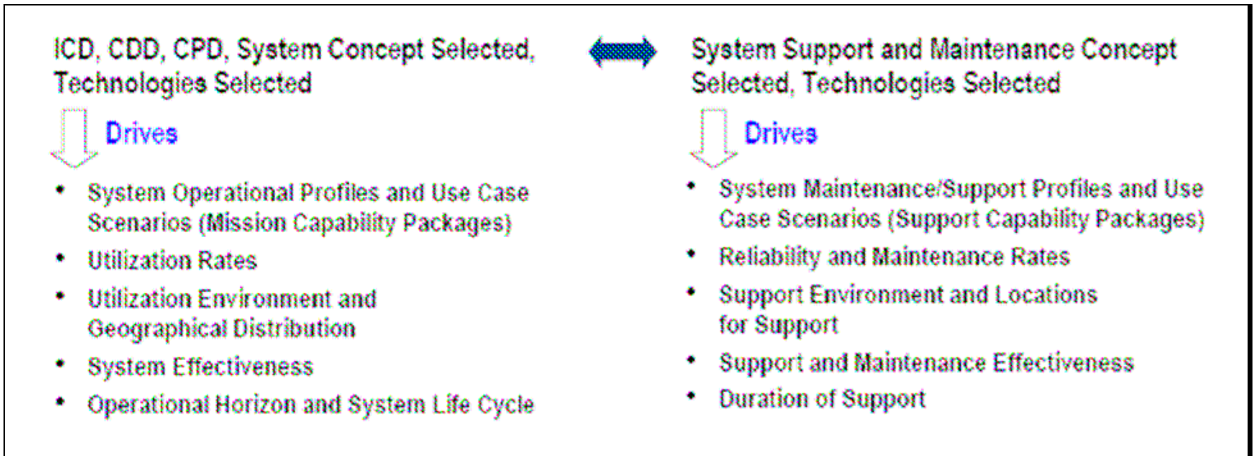


Figure 3-9: Relationship Among JCIDS Products and Sustainment Concepts[23]

The support strategy describes the supportability planning, analyses, and trade-offs used to determine the optimum support concept for a materiel system and identify the strategies for continuous affordability improvements throughout the product lifecycle (Figure 3-9). The support strategy evolves in detail, so that by Milestone C, it defines how the program will address the support and fielding requirements necessary to meet readiness and performance objectives, lower total ownership cost, reduce risks, and avoid harm to the environment and human health. The support strategy should address how the program manager and other responsible organizations will maintain oversight of the fielded system.[24]

The SE IPT must establish, maintain, and evolve for the Force Package a supply chain to maintain Readiness and Sustainment levels, and to supply materiel and logistics services to Naval units throughout the world. The supply chain consists of weapon system support contractors, retail supply activities, distribution depots, transportation networks including contracted carriers, Military Service and Defense Logistics Agency (DLA) integrated materiel managers (IMMs), weapon system program offices, commercial distributors and suppliers including manufacturers, commercial and organic maintenance facilities, and other logistics activities (e.g., engineering support activities (ESAs), testing facilities, cataloging services, reutilization and marketing offices).[25]

The SE IPT shall analyze the operational requirements of established Capabilities to assess that the Sea Basing Concepts, strategies, and investment plans provide supplies and services that support:[26]

- Rapid power projection;
- Improved readiness through performance-based logistics; and
- World-class standards for customer responsiveness.

The SE IPT shall analyze the Sea Basing and Material Supply Chain Management concepts to:

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[23] Designing and Assessing Supportability in DoD Weapon Systems: A Guide to Increased Reliability and Reduced Logistics Footprint, Oct 24, 2003
[24] Defense Acquisition Guidebook, Nov 2004
[25] DoD 4140.1-R, DoD Supply Chain Material Management Regulation, May 23, 2003
[26] Materiel Readiness Metrics, op. cit.

- Ensure the support of weapons systems through total lifecycle management, increased partnering, and adoption of modern information technologies.
- Establish end-to-end processes that are focused on maximizing customer service or warfighter support.
- Implement contemporary business systems and practices that enable the integration of people, information, and processes.

The SE IPT shall use the supply chain operational reference processes of Plan, Source, Maintain/Make, Deliver, and Return as a framework for developing, improving, and conducting materiel management activities to satisfy customer support requirements developed collaboratively with the support providers.

The SE IPT shall assess plans for the supply chain to ensure all elements are properly resourced to meet customer demand by developing and establishing support strategies that effectively and efficiently provide supply chain resources to meet supply chain requirements for future time periods. Materiel managers should collaborate with their customers or their representatives and maintenance and distribution/transportation managers to determine optimal support strategies that meet documented performance requirements.

The SE IPT shall assess provisioning plans and the acquisition of spares to support a Force Package deployment. Materiel managers shall work with program managers to ensure that item technical and logistics data relevant to end item supply support are documented and accessible to DoD and commercial materiel managers responsible for provisioning and follow-on support. The objective of provisioning data management is timely access to all data required to identify and acquire support items.

Where feasible, the SE IPT shall evaluate Readiness-Based Sparing (RBS) – an inventory requirements determination methodology that produces an inventory investment solution that meets Force Package performance requirements at minimum cost – to determine organic weapon system support provisioning requirements. When it is not feasible to use RBS models and processes, demand-based requirements determination methodologies may be used.

The SE IPT should evaluate item support goals established for all primary and secondary items to ensure that the supply system optimally uses available resources to meet weapon system and equipment performance objectives and personnel readiness objectives at the least cost. The objective in establishing item support goals is to provide logistics managers with quantitative targets that they may use to improve supply planning, asset allocation, and the contribution of limited inventories and limited procurement, repair, and distribution resources to better weapon system and personnel readiness capabilities.

The SE IPT shall evaluate forecasts for the demand expected to be placed on the supply system within a specified time period. The SE IPT may use models that consider only historical demand, models that combine future program data with historical demand or failure data and past and future program data to generate forecasts. To allow for continuing application of a model and the possibility of transition from one model to another, the DoD Components shall retain sufficient historical demand or failure data and, if applicable, program data.

The SE IPT shall evaluate the Force Package war materiel inventories consisting of peacetime operating stocks, training stocks, and war reserve materiel. The required war materiel inventories should be sufficient to sustain operations, as prescribed in Defense Planning Guidance and Joint Strategic Capabilities Plan scenarios, for committed forces.

3.6. System Service-Life Profile

The Service-Life Profile for the Force Package should designate when platforms will be decommissioned, and systems upgraded or replaced over the forecasted horizon. This profile is needed to enable decision-makers to understand how the investments in the portfolio will be incrementally fielded to achieve the capability objectives. By aligning the capability objectives with system increments, upgrades or replacement and investment profiles, it can be used to determine if additional investments are needed to achieve the capability objectives in the desired timeframe. Figure 3-10 depicts a conceptual System Service-Life Evolution Profile.

Platform/Node/System	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ESG (Force Package)												
LHA								LHA (R)				
TACC												
TBMCS	(V2.1)			V3.0								
JIC												
JFN Server	(V4.5)			V4.5			V5			V5.1		
IOS(v2)	(V2.0)					V3.0						
I3	(V3.4)	V3.5			V3.6			Replacement				
Flag Plot												
GCCS-M	(V1.5)		V1.6				V2.0			V2.1		
SACC										V2.1		
GCCS-M	(V1.5)		V1.6				V2.0					
IOW	(V2.5)				Replacement							
AFATDS	(V1.2)							V2.0				
LFOC												
IOW	(V2.5)				Replacement							
AFATDS	(V1.2)			V1.3			V1.5			V1.7		
IOS (V1)	(V1.0)					V1.1			V1.2			
DDG												
CIC												
GCCS-M	(V1.5)			V1.6			V2.0			V2.1		
NFCS	(V3.1)		V3.2			V3.3		V4.0			V4.1	
GWS 52" (Conventional)	(V2.3)					ERM						
ATWCS	(V2.6)		V3.0		V3.1				V3.2			

Figure 3-10: Example System Service-Life Evolution Profile

3.7. Capability Evolution Description (CED)

Similar to the DoDAF SV-8, a Capability Evolution Description (CED) provides a description of programs, platforms, and systems aligned to Mission Capabilities or Sub-capabilities[27] and their related Capability Increments[28] over time. As such, it exhibits an integration strategy for networks, sensors, weapons, and platforms. The CED supports achieving Mission Sub-capabilities by facilitating program alignment. Analysis included in a CED is based on: (1)

[27] A Mission Capability or Sub-capability can be either a direct warfighting capability or a function that crosses over several warfighting capabilities.
[28] A Capability Increment is a new or enhanced warfighting capability, achieved at least in part by a system-of-systems within the Mission Capability Package that enables a Mission Sub-capability to be achieved.

dependencies between capabilities and systems; (2) the relation between those systems and requirements; and (3) the relation between the requirements and acquisition programs.[29]

CEDs, which generally should be focused at the Mission Sub-capability level, provide decision makers a visual representation of the systems that are in the acquisition pipeline and how these systems will contribute to specific Mission Sub-capabilities. A CED may also illustrate holes or needs, such as where there are no funded systems that would complete a system-of-systems required to fulfill a Capability Increment.

The CED depicts the evaluation of desired Mission Sub-capabilities and is based on data collected from performance and interoperability assessments of the programs, platforms and systems. The data to be included in a CED is discussed in Section 3.7.1.

The recommended format for the CED was developed by RDA CHENG and OPNAV N70 and used for PR-05 and POM-06 assessments. The format is discussed in Section 3.7.2. An alternate approach is provided in Appendix B.

3.7.1. CED Assessments and Data Requirements

In order to develop a CED, the system-of-systems required to fulfill a Capability Increment are assessed as a function of existing performance and interoperability assessments that address the desired Mission Sub-capability, standard tactical situation (TACSIT), and time period. Typically, the CED must integrate the data from one or more such assessments, each with varying assumptions and timeframes, into a single, coherent evaluation. A utility of the CED is to show differences in study results.

The CED should capture the following information:

- Mission Sub-capabilities
- Capability Increments
- Tactical situation
- Time period
- Indications of whether or not a Mission Sub-capability is achieved
- Activities against which Capability Increments are assessed and how they may change upon the fielding of a given system or increment
- Contributing Systems and Platforms including schedules (e.g., IOCs and planned upgrades.)
- References for data sources

3.7.2. CED Format

A CED addresses a specific Mission Sub-capability and related Capability Increments. The CED should include a graphical description as well as a detailed written explanation. An example of the recommended format for the graphical portion of the CED is provided in Figure 3-11. (*Please note that the data in the example is fictional and was fabricated for illustrative purposes*

[29] Department of Defense Architecture Framework (DoDAF) Document.

*onl*y.) Maintaining a consistent format for CEDs provides decision makers a familiar visual tool that they can quickly understand and reference.

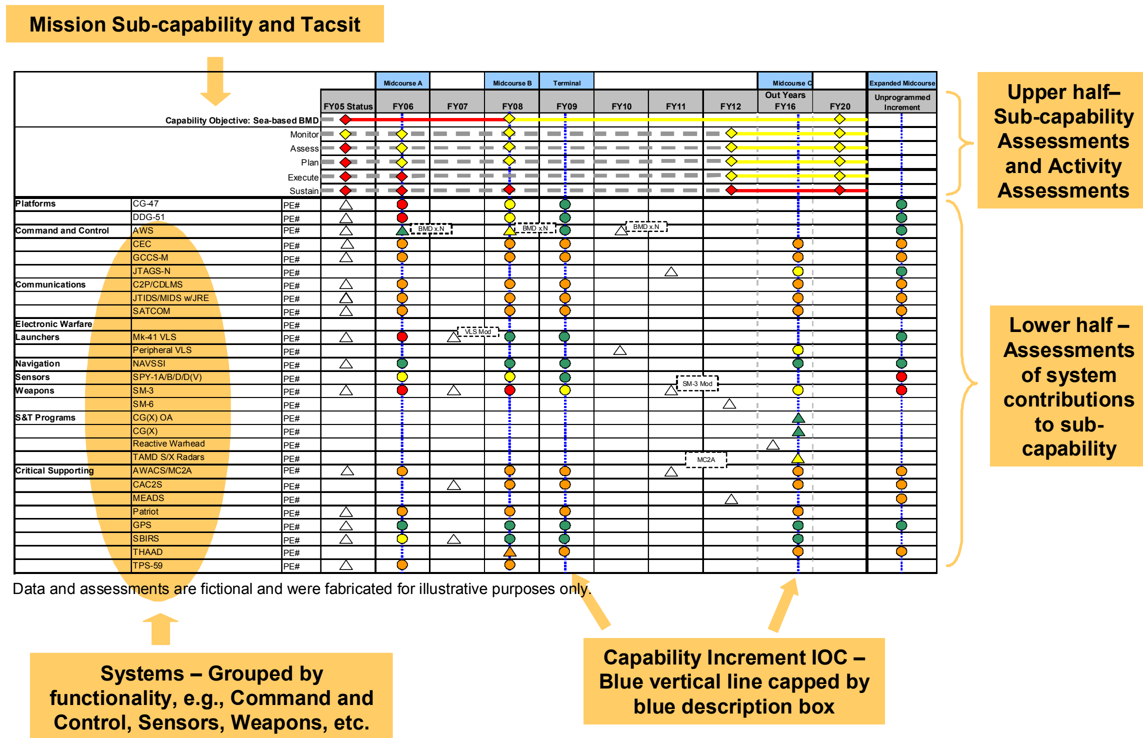

Figure 3-11: Representative CED Format

In the example, the top portion of the CED provides assessment information for the Mission Sub-capability, as well as Capability Increments (blue boxes). If necessary, capability assessment can be broken down to include the assessment of appropriate high level activities, such as Observe, Orient, Decide and Assess (OODA) or Monitor, Assess, Plan, Execute and Sustain (MAPES), and showing how they may change upon fielding of a given system or increment. A diamond indicates an assessment was done for that time period. The far right column is reserved as necessary for unprogrammed Capability Increments – those that rely on a system or multiple systems that are not currently funded but are necessary to complete the SoS for a given increment.

The bottom portion of the example CED provides the systems and platforms that contribute to the Mission Sub-capability and related Capability Increments (see Figure 3-11).

Triangles indicate the IOC[30] of a particular system (or platform) unless the triangle is in the current fiscal year column which then indicates the system is currently in existence. A system may have multiple triangles if there are funded upgrades planned for that system.

Capability Increments are indicated by a dashed blue line and a series of solid circles or triangles. Solid triangles indicate that a system's IOC date is coincident with the fielding of the

[30] IOC does not imply FOC. The CED may show when the first SoS is fielded, but does not address overall fielding plan.

Capability Increment and that the system is part of the SoS for that increment. Solid circles indicate that the given system was fielded prior to the date of the Capability Increment, and the given system is in the SoS that comprises the increment. The fill color of the triangle or circle reflects, in stoplight fashion, the system's (or platform's) contribution to its primary function.

Systems are divided into and assessed by their primary functions, e.g., Command & Control, Communication, Sensors, and Weapons. Platforms are assessed by their primary functionality with respect to the Mission Sub-capability, i.e., weapon or sensor, and their assessments should mirror the assessment of that weapon or sensor system. If the platform's primary function is both weapon and sensor, the platform assessment should reflect the system assessment with the least estimated capability.

The results of all assessments are depicted in stoplight fashion, where, generally, the stoplight colors are defined as

Green	Capability has been fully achieved
Yellow	Marginal capability
Red	No meaningful capability

The color orange has been used to indicate no assessment was available. The written portion of the CED must provide a detailed explanation of these measures and what they mean with respect to the specific assessment. The CED should include definitions of the stoplight colors used to depict the results of the Mission Sub-capability assessment. In addition, for each of the functional categories by which systems are assessed, i.e., weapon, sensor, etc., definitions of the stoplight colors used to depict the system assessment results must also be provided.

The CED graphic, then, provides a quick visual cue to the Mission-Sub-capability assessment and, if unsatisfactory, what systems are causing the shortcoming and why. For example, in the Figure, the CED shows a Capability Increment called "Terminal" planned for FY09 (Figure 3-11). Of the systems required to provide this capability, all that were assessed were assessed as green except for the interceptor. The interceptor is assessed as red and a quick look immediately reveals that the interceptor's IOC is not until FY12, clearly lagging all the other systems. (In addition to the graphic portion of the CED, text will be needed to document the details of the assessment.) Armed with the information provided in the CED, decision-makers can now determine how to proceed: e.g., Should funding for the interceptor be increased to push for an earlier IOC?; Can the schedules for other systems be slipped without impacting other Capability Increments?

3.8. Technology Adoption Milestones

This Section provides a description of suggested procedures for meeting the Technology Readiness Assessment (TRA) requirements of the Defense Acquisition System (DAS). A central theme of the acquisition process is that the technology employed in system development should be "mature" before system development begins. Normally, for technology to be considered mature, it must have been applied in a prototype article (a system, subsystem, or component), tested in a relevant or operational environment, and found to have performed adequately for the intended application. This implies a need for a way to measure maturity and for a process to ensure that only sufficiently mature technology is employed.

The Technology Readiness Assessment Deskbook[31] introduces Technology Readiness Levels (TRLs) as an accepted way to describe technology maturity and suggests activities that could be carried out by Program Managers (PMs), Component Science and Technology (S&T) Executives, Component Acquisition Executives (CAEs), and the DUSD(S&T).

Before an acquisition program can enter System Development and Demonstration (SDD) (at Milestone B) or Low Rate Initial Production (LRIP) (at Milestone C), technology maturity must be assessed. DoDI 5000.2, paragraph 3.7.2, establishes as acquisition policy that "…Unless some other factor is overriding in its impact, the maturity of the technology shall determine the path to be followed." Paragraph 3.7.2.2 states that "If [the] technology is not mature, the DoD Component shall use alternative technology that is mature and that can meet the user's needs."

DoDI 5000.2 includes a description of activities that occur before Milestone A. A collaborative effort produces an ICD that describes the requisite capabilities and time phased, operational goals. The analyses that lead to the ICD identify a preferred concept to be refined before a Milestone A decision. "The Milestone Decision Authority (MDA) designates the lead DoD Component(s) to refine the initial concept selected, approves the AoA plan, and establishes a date for a Milestone A review." Figure 3-12 graphically portrays the steps that the DUSD(S&T) normally anticipates in the assessment of technology readiness for an Acquisition Category (ACAT) I or IA milestone review. These steps are derived from information in the *Interim Guidebook*, as modified by DoDI 5000.2. However, the information in the guidebook is not mandatory, so the steps are merely suggested.

During Concept Refinement, an AoA is conducted to refine the selected concept. The AoA identifies needed technologies that are not yet mature. A plan for maturing these technologies is then described in a Technology Development Strategy (TDS) which is approved by the MDA at Milestone A. The following phase, TD, matures the technologies and reduces the risk. Starting during TD, the steps for a Milestone B TRA are as follows:

For the system, the PM or Project Leader conducts a risk assessment and develops an Acquisition Program Baseline (APB) and a Work Breakdown Structure (WBS). From the WBS, the risk assessment, and functional analysis, the PM identifies those technologies that are not already fully mature but that are critical to the accomplishment of goals for program cost and schedule and for system producibility, cost, and operational effectiveness. These will be listed as critical technologies. To support the TRA required before an upcoming Milestone B or Milestone C, the PM prepares a list of the critical technologies and a rationale for declaring these technologies to be critical. Substantiating information normally consists of descriptions of the status of components or subsystems, the testing that has been accomplished, and the results of this testing.

[31] Technology Readiness Assessment Deskbook, DUSD(S&T), September 2003

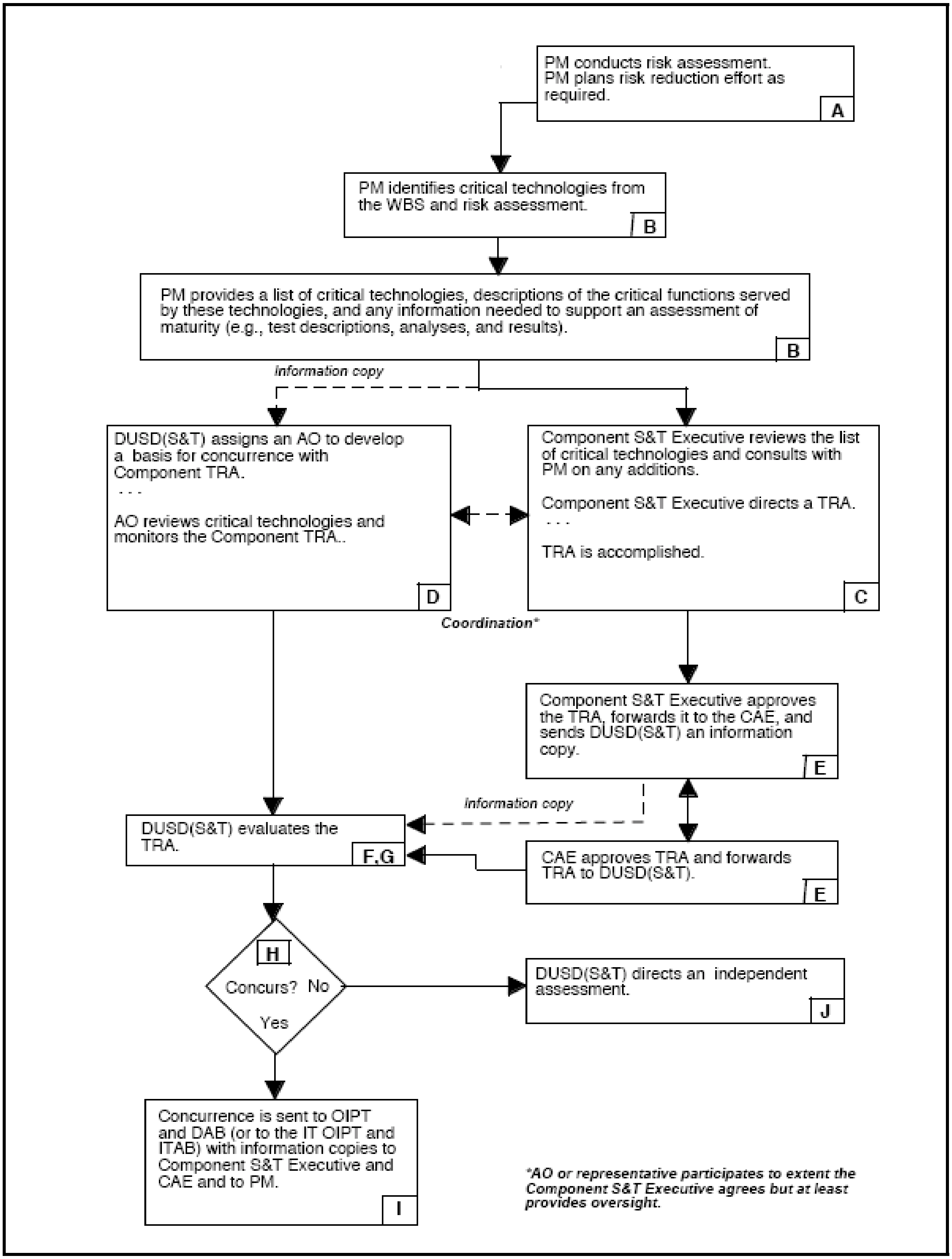

Figure 3-12: Process Flow for the Technology Readiness Assessment

Test environments and results are described in relation to the functional needs of the system concept. At least 16 weeks before a scheduled Milestone B or Milestone C (see Figure 3-12), the list of critical technologies and the supporting information are sent to the Component S&T Executive, with a request for a TRA. At the same time, an information copy is sent to the DUSD(S&T).

The Component S&T Executive coordinates with the PM on any additions to the list of critical technologies and on any additional information needed for the TRA. The Component S&T Executive directs and schedules the accomplishment of a TRA based on the PM's request and submission of the critical technologies information. The TRA is conducted in accordance with Component guidelines and procedures.

The DUSD(S&T) normally appoints a member of his/her staff to act as Action Officer (AO) to develop a basis for the DUSD(S&T) to concur with the Component TRA. This basis must be sufficient to fulfill the DUSD(S&T) oversight responsibilities, but it should not be a duplication of the Component TRA. The AO should review the critical technologies and the identification process, negotiate any perceived deficiencies, and provide oversight while the Component TRA is conducted. The AO should coordinate with the Component S&T Executive to determine to what extent the AO or technology specialists designated by the DUSD(S&T) could or should monitor or participate in the Component TRA. The Component S&T Executive is not required to agree to any such monitoring or participation beyond oversight.

When the Component TRA is completed, the Component S&T Executive approves it and forwards it to the CAE. At the same time, the Component S&T Executive sends an information copy to the DUSD(S&T). Subsequently, the CAE forwards the approved TRA to the DUSD(S&T).

The AO develops a basis for DUSD(S&T) concurrence. The approach can be tailored to the specific situation. The AO should minimize the impact on the PM and the Component S&T organization but still provide a sound basis for DUSD(S&T) concurrence. Monitoring or participating in the Component TRA will likely facilitate a quick concurrence. If the AO deems any critical technology to be insufficiently mature for the coming milestone, he/she tells the Component S&T Executive and the PM so that all involved have an opportunity to reach agreement on appropriate action. Upon receiving the report and official TRA from the CAE, the AO confirms that it is consistent with the information copy.

The AO prepares a memorandum of concurrence or non-concurrence for signature, presents the staff evaluation of the TRA to the DUSD(S&T), provides whatever backup information is needed, and acts on the DUSD(S&T)'s decision.

If the DUSD(S&T) does not concur, an independent assessment is required. The AO recommends a course of action and prepares a memorandum directing this action. The independent assessment should be a positive contribution to the acquisition program. For example, it could result in a revised, more realistic schedule, in the use of an alternative technology, or in a revised, evolutionary acquisition strategy. The independent assessment should be conducted as quickly as possible—whether this requires 1 day or several months. Typically, the Component funds the independent assessment.

Given this focus in DODI 5000.2 at the individual program level, the SE IPT must gather the various TRAs for the Portfolio of Acquisition Systems, and compile a prioritized list of technology risks, milestones, and investment strategies for the Portfolio of acquisition programs, that will mitigate and/or provide contingency approaches to dealing with technology maturity risks.

The Technologies associated with each program should be identified, and color-coded over the time frame to indicate how the technology maturity levels will progress so that the technology can be adopted by the program. How the technology adoption will contribute to the realization of the desired capability should be identified, and planned contingencies identified to demonstrate how technology risks are being managed for the portfolio of acquisition programs. Figure 3-13 shows a NASA example of the Technology Roadmap for the Origins Program.

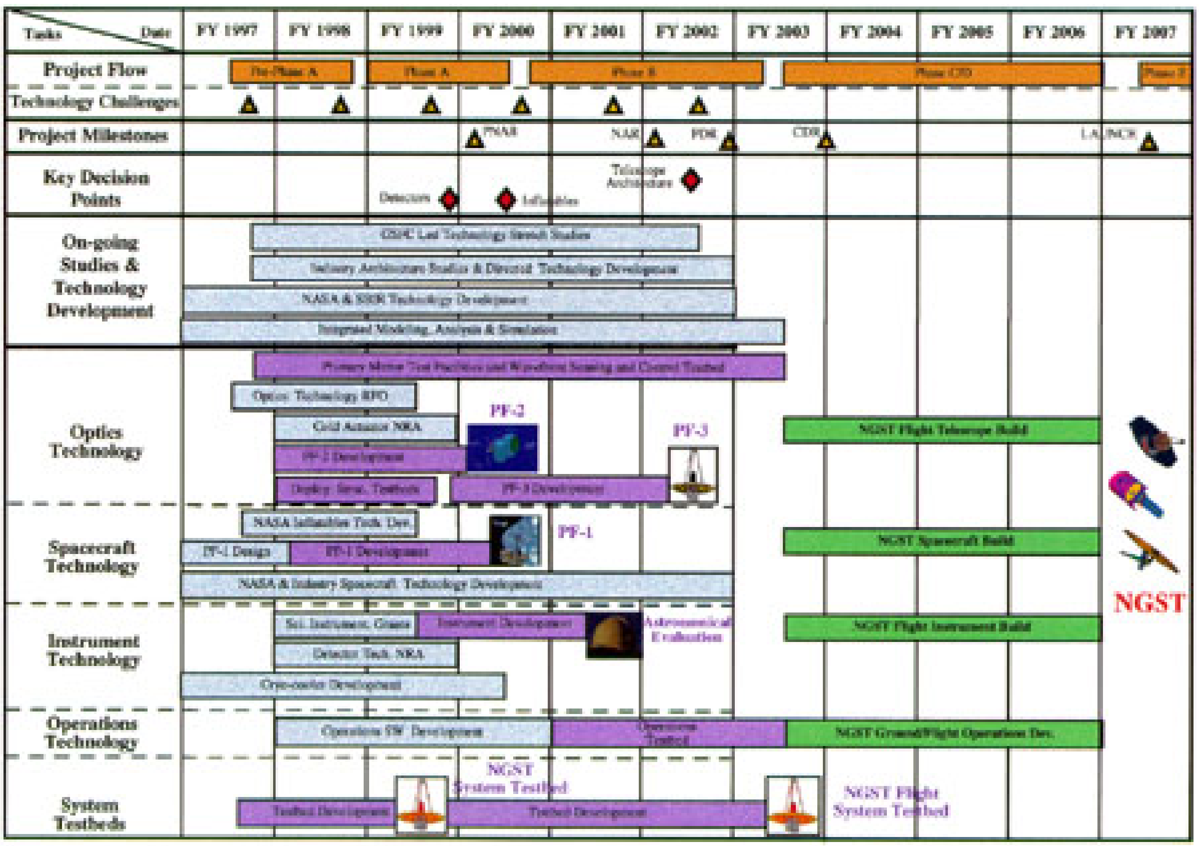

Figure 3-13: Origins Technology Roadmap[32]

3.9. Force Training and Transition Plan

The SE PT will compile the training concepts, strategies, and elements of logistic support that are required to certify that the Force Package Organizations are capable of executing Mission

[32] Origins Technology Roadmap, Version 1, NASA's Office of Space Science, 1997.

Essential Tasks, as newly acquired systems, equipment, applications, or enhancements are fielded. The force training and transition plan will identify the training requirements and timelines that integrates fielding milestones with the training programs and exercises that will ensure the Force Package maintains a state of readiness. This includes the certification actions required to ensure that the operators can properly execute the Mission Essential Task within established standards.

Training is the learning process by which personnel individually or collectively acquire or enhance predetermined job-relevant knowledge, skills, and abilities by developing their cognitive, physical, sensory, and team dynamic abilities. The "training/instructional system" integrates training concepts and strategies and elements of logistic support to satisfy personnel performance levels required to operate, maintain, and support the systems. It includes the "tools" used to provide learning experiences such as computer-based interactive courseware, simulators, and actual equipment (including embedded training capabilities on actual equipment), job performance aids, and Interactive Electronic Technical Manuals.

When developing the training/instructional system, the SE IPT should employ transformational training concepts, strategies, and tools such as computer based and interactive courseware, simulators, and embedded training consistent with the strategy, goals and objectives of the Training Transformation Strategic Plan (March 1, 2002) and the Training Transformation Implementation Plan.

The Department's vision for Training Transformation is to provide dynamic, capabilities-based training in support of national security requirements across the full spectrum of Service, joint, interagency, intergovernmental, and multinational operations. This new approach emphasizes the mission requirements of the combatant commanders (COCOM). The COCOM is the customer. The intent is to design systems and structure acquisition programs focused on the training needs of the COCOM. The desired outcome is to fully support COCOM requirements, missions, and capabilities, while preserving the ability of the DoD Components to train for their core competencies. The Under Secretary of Defense for Personnel and Readiness (USD(P&R)), as a member of the Defense Acquisition Board, assesses the ability of the acquisition program to support the Military Departments, COCOMs, and DoD Components.

"Training," in this context, includes training, education, and job-performance aiding. Joint training must be able to support a broad range of roles and responsibilities in military, multinational, interagency, and intergovernmental contexts, and the Department of Defense must provide such training to be truly flexible and operationally effective. Training readiness will be assessed and reported, not only in the traditional joint context, but also in view of this broader range of "joint" operations. Joint training and education will be recast as components of lifelong learning and made available to the Total Force—active, reserve, and DoD civilians. The Department will expand efforts to develop officers well versed in joint operational art. The interfaces between training systems and the acquisition process will be strengthened. The USD(P&R), as a member of the Defense Acquisition Board, assesses an acquisition program's ability to support the Combatant Commanders' and DoD Components' capabilities to provide HSI as an integral part of an acquisition program. The program manager should summarize major elements of the training plan in the Support Strategy. This should include logistics support planning for training, training equipment and training device acquisitions and installations.

A Special Note on Embedded Training. Both the sponsor and the program manager should give careful consideration and priority to the use of embedded training as defined in DoD Directive 1322.18: "Capabilities built into, strapped onto, or plugged into operational materiel systems to train, sustain, and enhance individual and crew skill proficiencies necessary to operate and maintain the equipment." The sponsor's decisions to use embedded training should be made very early in the capabilities determination process. Analysis should be conducted to compare the embedded training with more traditional training media (e.g., simulator based training, traditional classroom instruction, and/or maneuver training) for consideration of a system's Total Operating Cost. The analysis should compare the costs and the impact of embedded training (e.g., training operators and maintenance personnel on site compared to off station travel to a temporary duty location for training). It should also compare the learning time and level of effectiveness (e.g., higher "kill" rates and improved maintenance times) achieved by embedded training. When making decisions about whether to rely exclusively on embedded training, analysis must be conducted to determine the timely availability of new equipment to all categories of trainees (e.g., Reserve and Active Component units or individual members). For instance, a National Guard tank battalion that stores and maintains its tanks at a central maintenance/training facility may find it more cost effective to rely on mobile simulator assets to train combat tasks rather than transporting its troops to the training facility during drill weekends. A job aid for embedded training costing and effectiveness analyses is: "A Guide for Early Embedded Training Decisions," U.S. Army Research Institute for the Behavioral and Social Sciences Research Product 96-06.

3.9.1. Training Planning

This Section will prepare the Program Manager to understand training capabilities as an integral part of the Joint Capabilities Integration and Development System and, with assistance of the training community, translate those capabilities into system design features.

First, the Joint Capabilities Integration and Development System process should address joint training parameters for military (Active, Reserve, and Guard) and civilian personnel who will operate, maintain, and support the system. Training programs should employ a cost-effective solution, consisting of a blend of capabilities that use existing training programs and introduces new performance-based training innovations. This may include requirements for school and unit training, as well as new equipment training, or sustainment training. This also may include requirements for instructor and key personnel training and new equipment training teams. Training should be considered early in the capabilities development process beginning with the analyses that supports development of the Initial Capabilities Document and continues with development of the Capability Development Document.

The Capability Development Document should discuss the specific system training requirements:

- Allow for interactions between platforms or units (e.g., through advanced simulation and virtual exercises) and provide training realism to include threats (e.g., virtual and surrogate), a realistic electronic warfare environment, communications, and weapons.
- Embedded training capabilities that do not degrade system performance below threshold values nor degrade the maintainability or component life of the system.
- That Initial Operational Capability is attained and that training capabilities are embedded and met by Initial Operational Capability.
- An embedded performance measurement capability to support immediate feedback to the operators/maintainers and possibly to serve as a readiness measure for the unit commander.
- Training logistics necessary to support the training concept (e.g., requirements for new or upgrades to existing training facilities).

The training community should be specific in translating capabilities into system requirements. They should also set training resource constraints. Examples are:

- The training community should consider whether the system should be designed with a mode of operation that allows operators to train interactively on a continuous basis, even when deployed in remote locations.
- The training community should consider whether the system should be capable of exhibiting fault conditions for a specified set of failures to allow rehearsal of repair procedures for isolating faults or require that the system be capable of interconnecting with other (specific) embedded trainers in both static and employed conditions.
- The training community should consider whether embedded training capabilities allow enhancements to live maneuver such that a realistic spectrum of threats is encountered (e.g., synthetic radar warnings generated during flight).
- The training community should consider whether the integrated training system should be fully tested, validated, verified, and ready for training at the training base as criteria for declaring Initial Operational Capability.

From the earliest stages of development and as the system matures, the program manager should emphasize training requirements that enhance the user's capabilities, improve readiness, and reduce individual and collective training costs over the life of the system. This may include requirements for expert systems, intelligent tutors, embedded diagnostics, virtual environments, and embedded training capabilities. Examples of training that enhances user's capabilities follow:

- Interactive electronic technical manuals provide a training forum that can significantly reduce schoolhouse training and may require lower skill levels for maintenance personnel while actually improving their capability to maintain an operational system;
- Requirements for an embedded just-in-time mission rehearsal capability supported by the latest intelligence information and an integrated global training system/network that allows team training and participation in large scale mission rehearsal exercises can be used to improve readiness.

In all cases, the paramount goal of the training/instructional system should be to develop and sustain a ready, well-trained individual/unit, while giving strong consideration to options that can reduce lifecycle costs and provide positive contributions to the joint context of a system, where appropriate.

Training devices and simulators are systems that, in some cases, may qualify for their own set of HSI requirements. For instance, the training community may require the following attributes of a training simulator:

- Accommodate "the central 90 percent of the male and female population on critical body dimensions;"
- Not increase manpower requirements and should consider reductions in manpower requirements;
- Consider reduced skill sets to maintain because of embedded instrumentation;
- Be High Level Architecture compliant;
- Be Sharable Content Object Reference Model compliant;
- Be Test and Training Enabling Architecture compliant;
- Use reusable simulation objects.

3.10. Capability Investment Strategy

The SE IPT must establish a capability investment strategy that address the total lifecycle costs associated with each acquisition program in the portfolio, and summarize the total investment necessary to realize each capability increment. A Capability Investment Plan should document the direct and indirect costs associated with each of the lifecycle cost categories, identified in Section 3.10.1.[33]

The SE IPT should identify assumptions concerning full funding for each of the acquisition programs in the portfolio, as identified in Section 3.10.2.[34] Creating a fully funded portfolio will not be possible since the portfolio investment plan will typically extend beyond the FYDP.

The SE IPT should identify the manpower estimates for each of the acquisition programs in the portfolio, as identified in Section 3.10.3.[35] Manpower estimates should address manpower reductions that result from fielding automated systems that require fewer operational and support personnel to operate and maintain them.

3.10.1. Lifecycle Cost Category Definitions

The following paragraphs summarize the primary cost categories associated with each program lifecycle phase:

- **Research and Development** consists of development costs incurred from the beginning of the conceptual phase through the end of the System Development and Demonstration phase, and potentially into Low-Rate Initial Production. It typically includes costs of

[33] Defense Acquisition Guidebook
[34] Ibid.
[35] Ibid.

concept refinement trade studies and advanced technology development; system design and integration; development, fabrication, assembly, and test of hardware and software for prototypes and/or engineering development models; system test and evaluation; system engineering and program management; peculiar support (peculiar and common support equipment, peculiar training equipment/initial training, and technical publications/data) and initial spares and repair parts associated with prototypes and/or engineering development models.

- **Investment** consists of production and deployment costs incurred from the beginning of low rate initial production through completion of deployment. It typically includes costs associated with producing and deploying the primary hardware; system engineering and program management; peculiar support (peculiar and common support equipment, peculiar training equipment/initial training, and technical publications/data) and initial spares and repair parts associated with production assets; and military construction and operations and maintenance associated with system site activation.

- **Operating and Support** consists of sustainment costs incurred from the initial system deployment through the end of system operations. It includes all costs of operating, maintaining, and supporting a fielded system. Specifically, this consists of the costs (organic and contractor) of personnel, equipment, supplies, software, and services associated with operating, modifying, maintaining, supplying, training, and supporting a system in the DoD inventory. This includes costs directly and indirectly attributable to the system (i.e., costs that would not occur if the system did not exist), regardless of funding source or management control. Direct costs refer to the resources immediately associated with the system or its operating unit. Indirect costs refer to the resources that provide indirect support to the system's manpower or facilities. For example, the pay and allowances reflected in composite standard rates for a unit-level maintenance technician would be treated as a direct cost, but the (possibly allocated) cost of medical support for the same technician would be an indirect cost.

- **Disposal** consists of costs associated with demilitarization and disposal of a military system at the end of its useful life. These costs in some cases represent only a small fraction of a system's lifecycle cost and may not be considered when preparing lifecycle cost estimates. However, it is important to consider demilitarization and disposal early in the lifecycle of a system because these costs can be significant, depending on the characteristics of the system. Costs associated with demilitarization and disposal may include disassembly, materials processing, decontamination, hardware, collection/storage/disposal of hazardous materials and/or waste, safety precautions, and transportation of the system to and from the disposal site. Systems may be given credit in the cost estimate for resource recovery and recycling considerations.

The lifecycle cost categories correspond not only to phases of the acquisition process, but also to budget appropriations as well. Research and Development costs are funded from Research, Development, Test, and Evaluation (RDT&E) appropriations, and investment costs are funded from Procurement and Military Construction (MILCON) appropriations. Operating and support costs are funded from Military Personnel, Operations and Maintenance, and Procurement appropriations. However, some major automated information system programs may use defense working capital fund (DWCF) financing in place of appropriated funding (such as DWCF capital funds instead of procurement funds, or DWCF operating funds instead of operations and maintenance funds). The cost categories used in most acquisition documents (such as Selected Acquisition Reports and Acquisition Program Baselines) and in most budget documents (such as budget item justifications) are based on the appropriation terms. (Note that the term "program acquisition cost" as used in acquisition documents is the sum of RDT&E, Procurement, and possibly MILCON costs.)

3.10.2. Full Funding

It has been a long-standing DoD policy to seek full funding of acquisition programs, based on the most likely cost, in the budget year and out-year program years. Experience has shown that full funding is a necessary condition for program stability. DoD Directive 5000.1 affirms this full funding policy. Moreover, DoD Instruction 5000.2 requires full funding—defined as inclusion of the dollars and manpower needed for all current and future efforts to carry out the acquisition and support strategies—as part of the entrance criteria for the transition into system development and demonstration.

Full funding and program stability is especially important in joint and international acquisition programs. Underfunding or program instability on the part of one DoD Component can lead to unintended cost growth or instability for another DoD Component in a joint program, or even for another nation in an approved international cooperative program commitment. DoD Instruction 5000.2, Enclosure 9, imposes very strict approval requirements that must be met before DoD Components are permitted to terminate or make significant reduction to their share of approved international or joint programs. DoD Components contemplating termination of an international program should be aware of the termination provisions in the international agreement for that program. Current practice requires the nation terminating its participation in the program to pay substantial termination costs. Therefore, any DoD Component considering unilateral withdrawal from an international agreement must take into account the resultant costs that would be incurred.

Full funding is assessed by the Milestone Decision Authority (MDA) at each decision point. As part of this assessment, the MDA reviews the actual funding (in the most recent President's Budget submission or FYDP position) in comparison to the (time-phased) program office cost estimate. In addition, the MDA considers the funding recommendations made by the OSD Cost Analysis Improvement Group (for ACAT ID programs) or the DoD Component cost analysis team (for ACAT IC programs). If the MDA concludes that the current funding does not support the acquisition program, then the acquisition decision memorandum may direct a funding adjustment and/or program restructure in the next FYDP update.

3.10.3. Manpower Estimates

For Major Defense Acquisition Programs, 10 U.S.C. 2434 requires the Secretary of Defense to consider the estimate of the personnel required to operate, maintain, support, and provide system-related training, in advance of approval of the development, or production and deployment of the system. To satisfy this requirement, Table E3.T1, "Statutory Information Requirements," of DoD Instruction 5000.2, directs the development of a manpower estimate at Milestones B and C and at the Full-Rate Production decision review. Further guidance is provided in the USD(P&R) memorandum, "Interim Policy and Procedures for Strategic Manpower Planning and Development of Manpower estimates," dated December 10, 2003. Manpower estimates serve as the authoritative source for out-year projections of active-duty and reserve end-strength, civilian full-time equivalents, and contractor support work-years. As such, references to manpower in other program documentation should be consistent with the manpower estimate once it is finalized. In particular, the manpower estimates should be consistent with the manpower levels assumed in the final affordability assessment and the Cost Analysis Requirements Description.

Organizational responsibilities in preparing the manpower estimate vary by DoD Component. Normally, the manpower estimate is prepared by an analytic organization in the DoD Component manpower community, in consultation with the program manager. The manpower estimates are approved by the DoD Component manpower authority (for the military departments, normally the Assistant Secretary for Manpower and Reserve Affairs).

For ACAT ID programs, a preliminary manpower estimate should be made available at least three to six months in advance of the Defense Acquisition Board (DAB) milestone review in order to support the development of cost estimates and affordability assessments. The final manpower estimate should be submitted to the USD(P&R) in sufficient time to support the Overarching Integrated Product Team (OIPT) review in preparation of the DAB meeting. Normally this would be three weeks prior to the OIPT review meeting. The USD(P&R) staff will review the final manpower estimate and provide comments to the OIPT.

The exact content of the manpower estimate is tailored to fit the particular program under review. A sample format for the manpower estimate is displayed in the Table 3-1 below. In addition, the estimate should identify if there are any resource shortfalls (i.e., discrepancies between manpower requirements and authorizations) in any fiscal year addressed by the estimate. Where appropriate, the manpower estimate should compare manpower levels for the new system with those required for similar legacy systems, if any. The manpower estimate also should include a narrative that describes the methods, factors, and assumptions used to estimate the manpower.

MANPOWER ESTIMATE
(Program Title)
SERVICE[a]

	FYxx[b]	FYxx+1	FYxx+2	FYxx+3	FYxx+4	. [c]
OPERATE: [d]						
Military						
Officers						
Enlisted						
Civilian						
Contractor						
Sub-Total						
MAINTAIN: [d]						
Military						
Officers						
Enlisted						
Civilian						
Contractor						
Sub-Total						
SUPPORT: [d]						
Military						
Officers						
Enlisted						
Civilian						
Contractor						
Sub-Total						
TRAIN: [d]						
Military						
Officers						
Enlisted						
Civilian						
Contractor						
Sub-Total						
TOTAL:						

Notes:
[a] Provide separate estimates for Active and Reserve Components for each Service.
[b] Report manpower by fiscal year (FY) starting with initial fielding and continuing through retirement and disposal of the system (to include environmental cleanup).
[c] Until fielding is completed.
[d] Provide estimates for manpower requirements and authorizations. Provide deltas between requirements and authorizations for each fiscal year.

Table 3-1: Sample Format for Manpower Estimates

4. Force Package Engineering Models

This Section will describe an approach to developing executable models of a Force Package executing a mission that would support performance assessments of the Force Package Capabilities. The intent of the model is to provide a dynamic assessment framework that is highly compatible with the DOD Architecture Framework. The executable models are based on existing systems engineering practices abstracted to support Capability-based assessments, support SoS/FoS Interoperability and Integration engineering, and provide a basis for establishing the System Performance Document (SPD). The SPD documents the allocation of functional, performance, and interface requirements among the portfolio of acquisition systems.

Throughout this discussion, the generation of DoDAF products will be addressed. In addition, clarification of DoDAF strengths and limitations will be discussed and the resolutions/interpretations necessary to enable the executable models to be properly constructed will be provided.

The models will be discussed in a sequence which reflects the Capability Engineering Process, however the models can be constructed in any sequence. It is important that the integrated model will include three model levels:

- An Operational Model of the "business process" or how the Force Package Organizational Elements perform activities to achieve the mission.
- A Functional Model of how each activity is performed in terms of the functional flow, data flow, and control flow among Systems, Applications, and Personnel.
- A Physical Model of the platforms, facilities, the nodes (Centers, rooms, locations, etc.) within the platforms & facilities, the systems, application and personnel within each node, and the interfaces and networks among the systems.

The Capability Engineering Process and its outputs is compared to the standard systems engineering process[36] in Table 4-1.

Systems Engineering		Capability Engineering	
Analysis	**Outputs**	**Analysis**	**Outputs**
Requirements Analysis	System Requirements Baseline	Capability Analysis	Operational Model and Assessments
Functional Analysis and Allocation	Functional Architecture	Functional Analysis and Allocation	Functional Model of Decomposed Activities
Design Synthesis	Physical Architecture	Portfolio Synthesis	Physical Model
Systems Analysis	Trade-offs, Risk Reduction	Portfolio Alternative Analysis	Trade-offs, Risk Reduction

Table 4-1: Systems Engineering Versus Capability Engineering

There is a variety of systems engineering tools which may be used to support the Capability Engineering process and to develop associated data and models. Some of these focus on generating the DoDAF architecture views without an associated behavior model. The tool used to support this discussion is CORE, a Systems Engineering tool that supports the DoDAF and which generates a behavior model that can be executed via a discrete event simulator. Sufficient

[36] Systems Engineering Fundamentals Guidebook, Defense Acquisition University Press, January, 2001.

detail is provided to enable an experienced CORE user to implement a behavior model for a Force Package operational, functional, and physical architecture.

The CORE behavior model involves creating a functional-flow model with the addition of control constructs (ands, ors, conditional branching, loops, and iterates), and data flows as inputs or outputs of functions. Functions can consume or capture resources so resource utilization and limitations can affect process flow and queuing.

4.1. Capturing the Operational Model

The operational model is intended to capture the Organizational Elements that make up the Force Package, and the activities each organization performs within a mission thread. It is necessary to understand that a Force Package, such as an Expeditionary Strike Group (ESG) represents a multi-mission Force, and possesses assets that enable it to perform its missions in different ways. Thus, the mission threads identify the use of different assets (system, weapons, etc.) to achieve the mission objectives.

The RDA CHENG Joint Fires SE IPT used information from the Fires and Maneuver Mission Capability Package to devise a set of mission threads. A finite set of threads needs to be considered which address the use of a majority of assets. Figure 4-1 provides the assets used in each phase of the land attack mission threads.

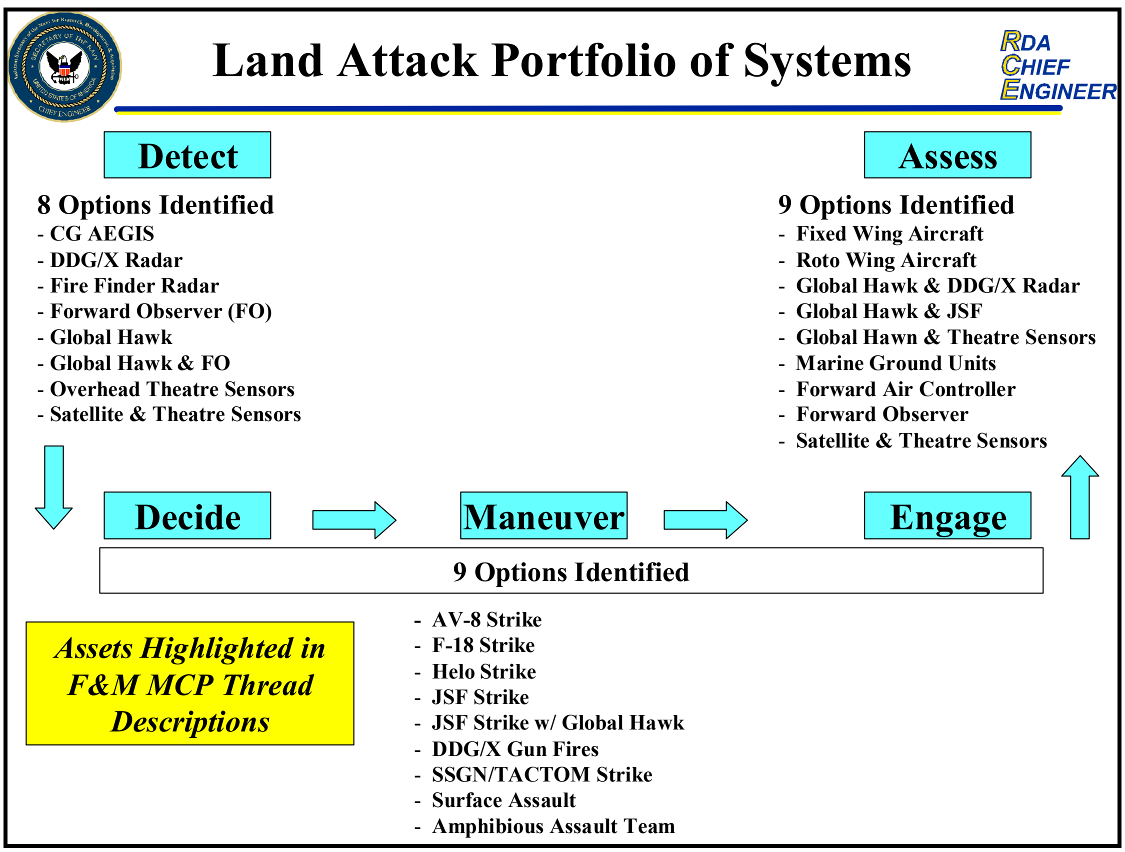

Figure 4-1: Assets Utilized in the Land Attack Mission Threads

4.1.1. The Organizational Parallel Structure

The Organizational structure for the Force Package needs to be identified and captured in the behavioral modeling tool. Figure 4-2 shows the ESG organization structure, and the platforms on which each organization was located. The organizational structure of the ESG was captured in CORE using the behavioral modeling framework, and is shown in Figure 4-3. Each parallel line in the structure represents the swim lane where the process executed by each organization is captured. This represents the ESG organizations being able to perform activities concurrently. An unnecessary branching was implemented to show the allocation of the organizational elements among the ESG platforms.

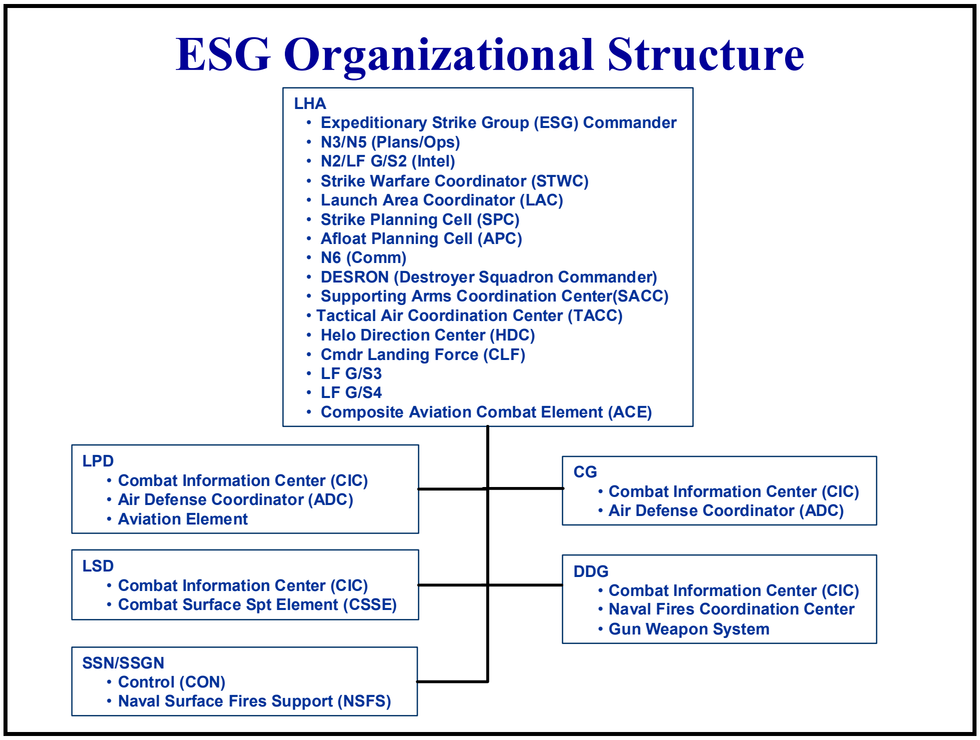

Figure 4-2: ESG Organizational Structure

An initial step in CORE is to create a top-level "System" element and give it an appropriate name. This System object will capture the Operational model and its behavior. Open the System Object in an Extended Functional Flow Block Diagram (EFFBD) and select the arrow in the center of the view. Insert a Parallel construct and create a parallel branch for each of the organizations. This represents a structure by which the operational process can be captured to understand how the organizations collaborate and exchange information to perform the mission thread (Figure 4-3).

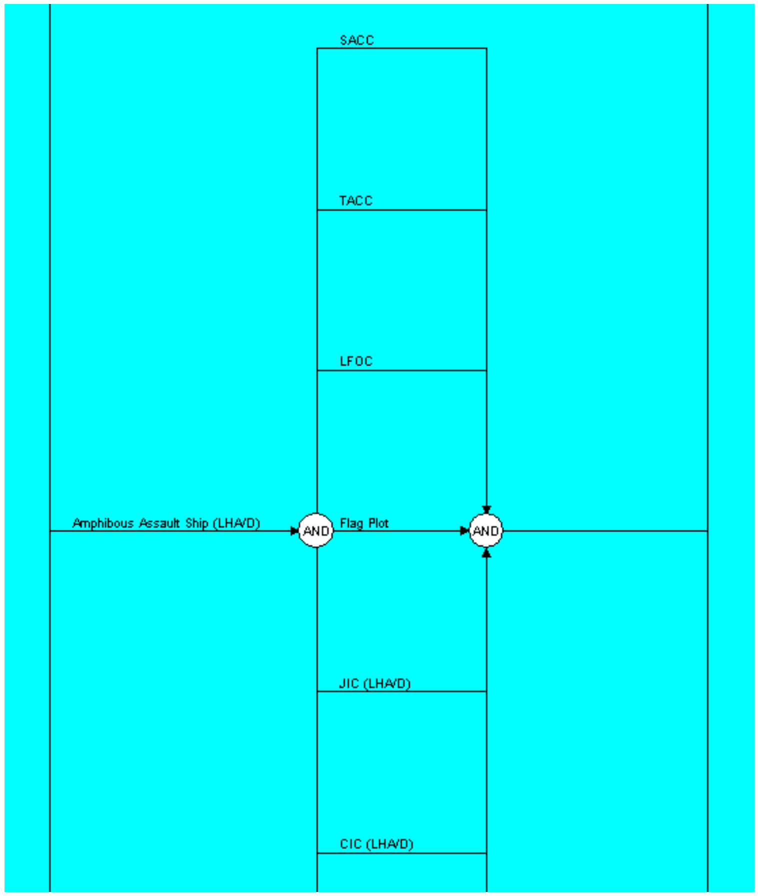

Figure 4-3: ESG Organization Structure Captured in CORE

Additionally, the Organizational structure should be captured as a hierarchical structure. In CORE the Organization class was used to capture the organizational elements as objects in the database, and the (TBD) relationship to establish a parent-child hierarchical relationship. This will be important later when the Activity modeling is completed, such that the activities can be assigned to the appropriate organizational element for traceability purposes. Figure 4-4 shows the Organizational hierarchical structure as captured in CORE.

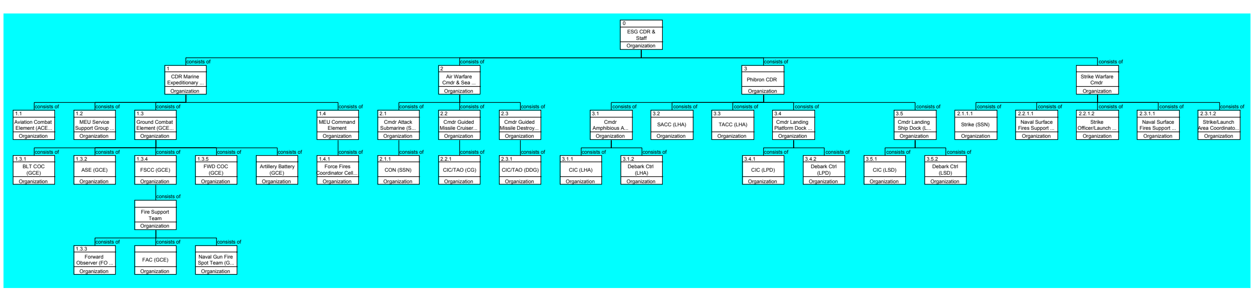

Figure 4-4: ESG Hierarchical Organization Structure Captured in CORE

4.1.2. The Sequence of Organizational Activity

Once the Organizational Structure is captured one should model the activities performed by each organization. The CORE Operational Activity class was used to capture the definition of each activity. The sequence of the activities needs to be addressed. Some activities can be performed in parallel, while others are sequential in nature. Figure 4-5 shows a segment of the land attack model where the activities are performed concurrently by two organizations, while each organization also is performing their sequence of Activities or business processes.

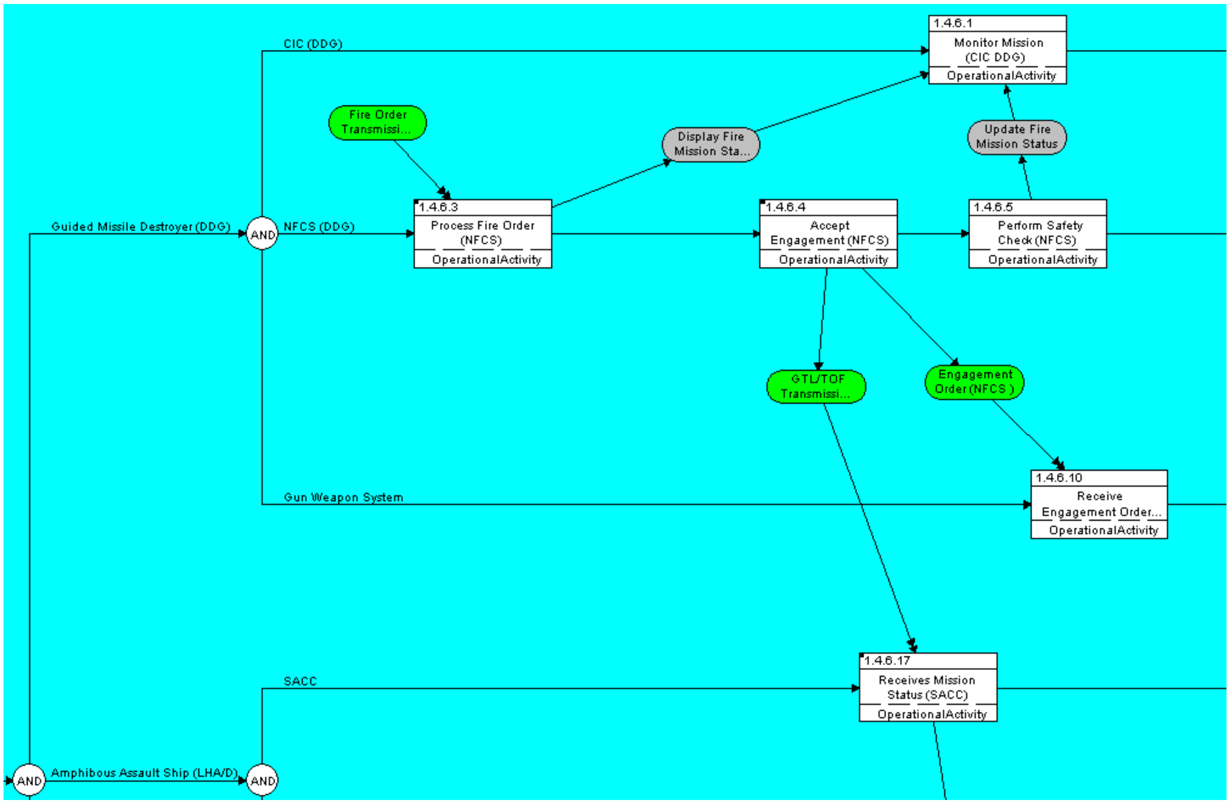

Figure 4-5: Concurrent Activities Represented in CORE

In addition, control logic can be used to establish conditional situations where several options may exist, and some condition causes the selection of which branch to execute. In CORE this can be done by using an OR construct or by using a multi-exit function. The selection of the branch can be based on random probabilities, or scripted within the multi-exit function to select the exit based on some condition. Figure 4-6 shows the use of a multi-exit function in CORE.

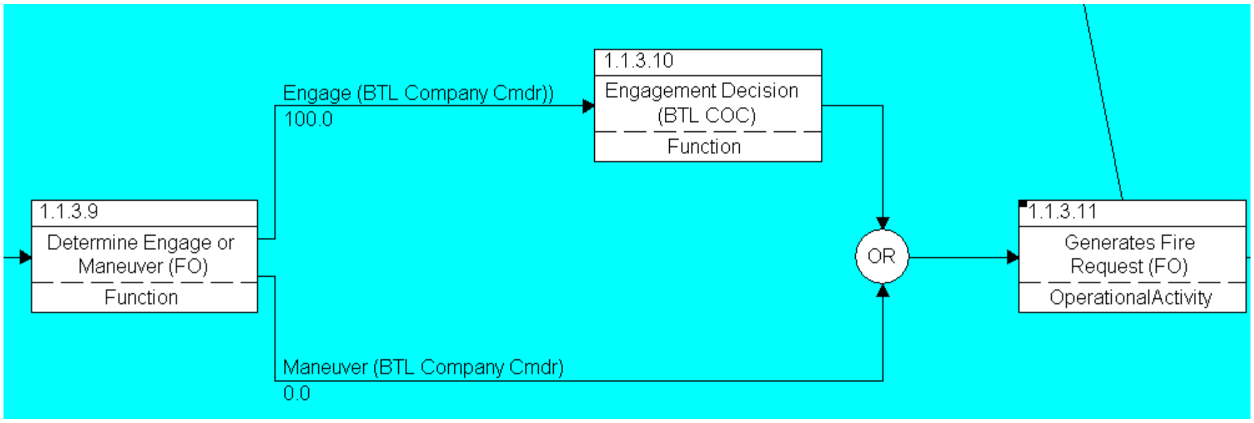

Figure 4-6: Use of a Multi-exit Function Control in CORE

4.1.3. Information Exchanges

The model needs to include the Information Exchanges between organizations. This represents the flow of data between the organizations, and can trigger activities. If the data flow is for informational purposes, then it is an input to an Activity, but will not constrain or trigger the activity. An Information Exchange which triggers an Activity must be present in order for the activity to be executed.

It is important to understand that Information Exchanges do not flow between organizations, but as inputs or outputs of activities. This enables the model of the Activities to represent the information exchanges as critical elements of the overall process.

For example, in the Land Attack model, a Forward Observer ashore, locates a target and transmits a Call For Fire (CFF) message to the Supporting Arms Coordination Center (SACC) where it is automatically received by the Advanced Field Artillery Tactical Data System (AFATDS) and is displayed for the operator. The issuance of the CFF message is a triggering of Information Exchanges, and it initiates the targeting process within the SACC. Figure 4-7 show this information exchange triggering the targeting process within the SACC.

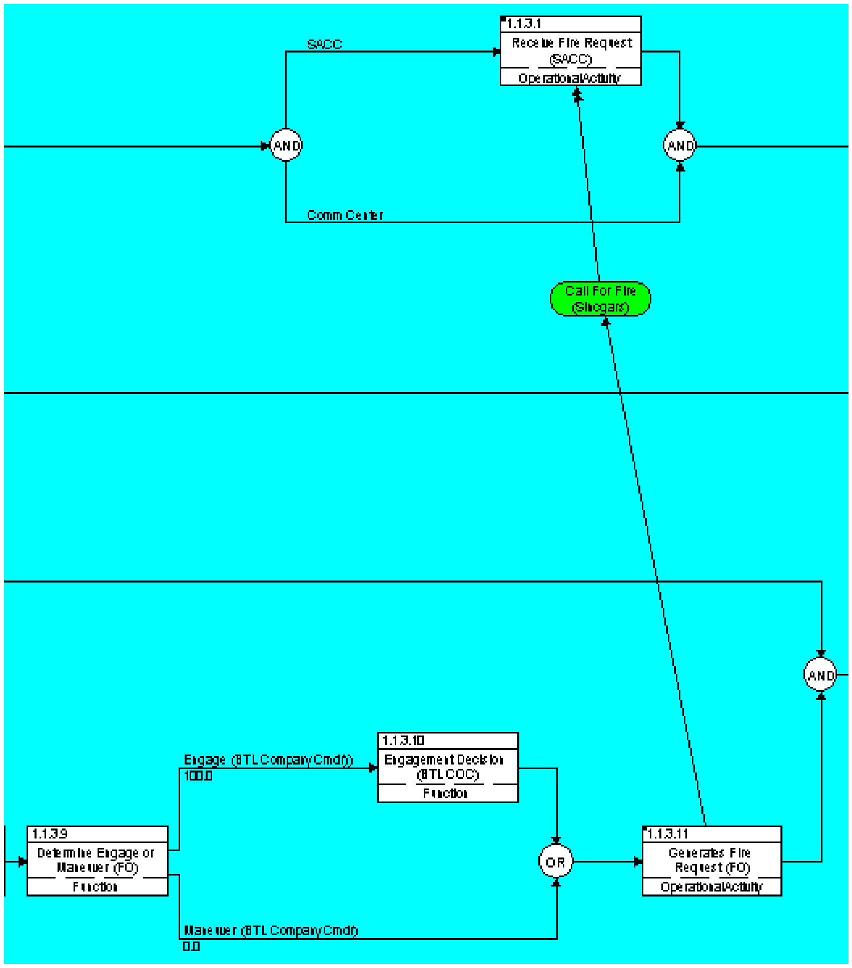

Figure 4-7: Call For Fire Triggering the Targeting Process in the SACC

4.1.4. Activity Timing and Resource Utilization

In order to make the process model represent the actual behavior of the Force Package, the time it takes to perform each activity must be included in the model. Within CORE, each Activity or Function has an attribute entitled Duration (see Figure 4-8). The duration attribute can be set as a constant value, or as one of 16 distinct probabilistic distributions. This timing data must be provided and verified by subject matter experts. In our example, the time it takes the Call For Fire message to be transmitted to the SACC is 2.1 seconds.

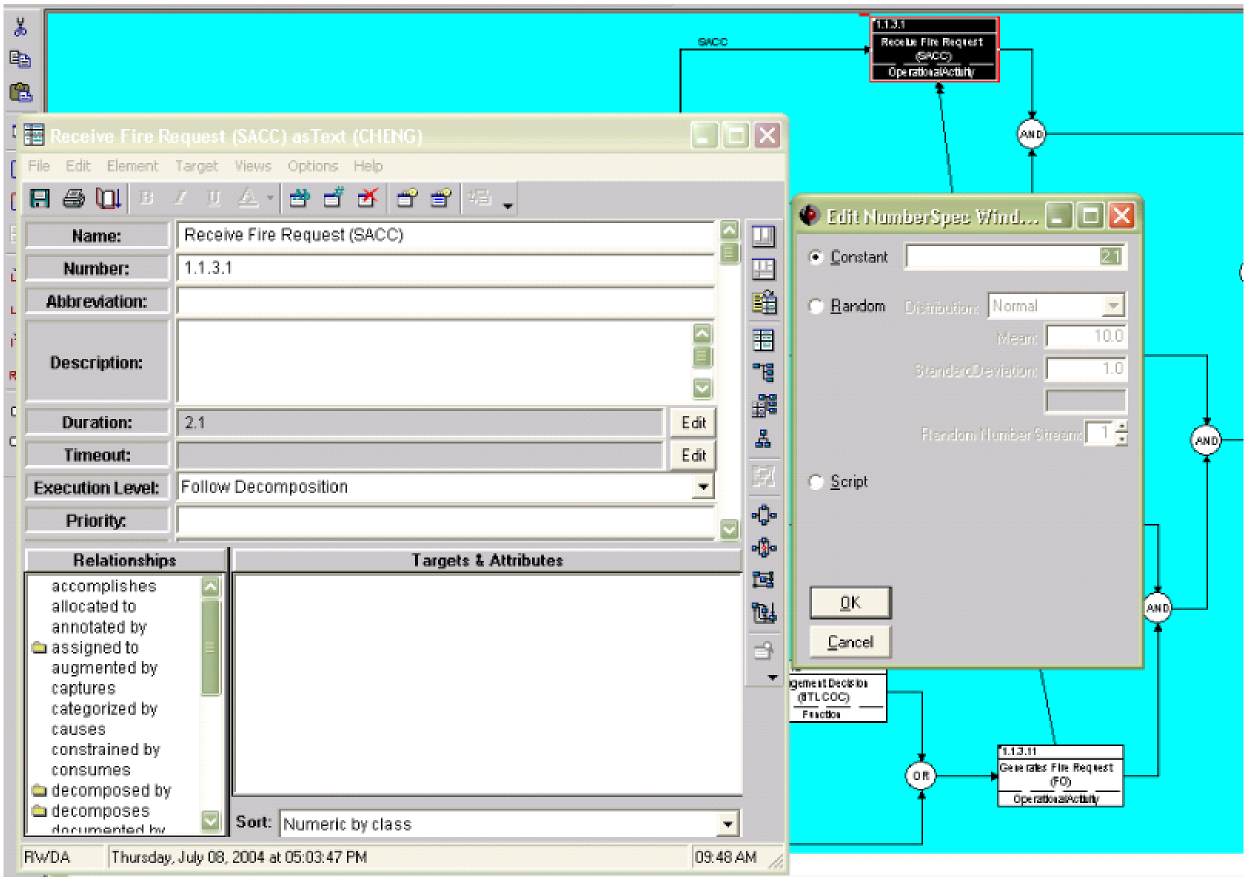

Figure 4-8: Duration Attribute Specification Window

In addition to timing, it may be important to address the use of resources to constrain the model. If a resource is needed to perform an Activity and it is not available, the activity will be delayed until the resource is available. A resource can be anything from fuel, bullets, workstations, or personnel.

There are two distinct types of resource used in CORE, the first being a reusable resource, such as a hammer. Only one person can use the hammer at a time. When one person is finished with the hammer, then the hammer becomes available to support another person's task. If both workers want to utilize the hammer at the same time, the first to acquire the hammer will be able to perform his/her task without any delay. However, the second worker must wait until the resource is available before he/she initiates his/her task. This resource is related to the activity by a "Captures" relationship, and the resource is released back into availability when the activity is completed.

The other type of resource is a consumable, where there is a limited inventory of the consumable, and when the inventory becomes empty, then the inventory must be refilled before the activities that consume the resource can be conducted. For example, the Gun Weapon System (GWS) consumes a resource called "shell" every time it fires. The resource is replenished by an activity "reload shell inventory" which in turn consumes a resource from the "52 shell inventory." Once the inventory is empty, the GWS can no longer be utilized to engage targets until the ship is resupplied. Figure 4-9 shows the resource usage in a Land Attack model where the resource being monitored was Rounds.

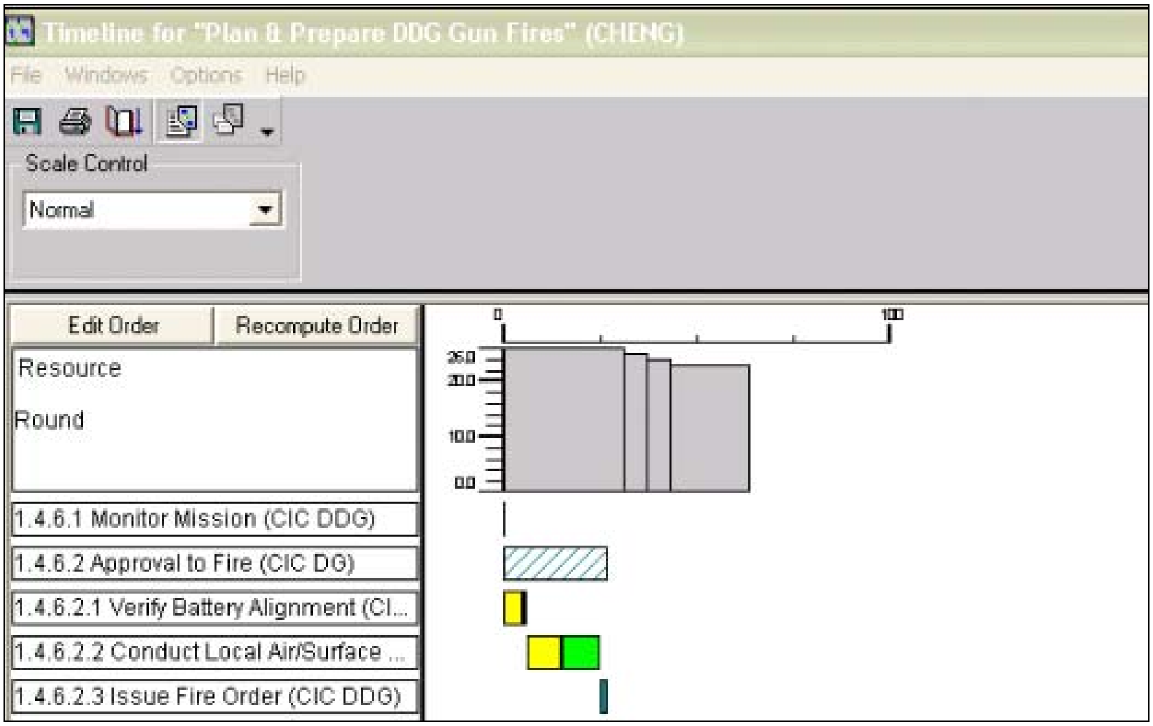

Figure 4-9: Resource "Rounds" Captured in the Simulation Timeline

4.2. Decomposing Activities to Functional Models

The Operational activities represent the tasks that are performed in support of conducting the end-to-end mission. They can be viewed as the organizational-level task that must be performed. Now we must capture the decomposition of each activity to understand how the Systems, Applications, and Personnel perform functions to execute the activity. (Note: While DoDAF does not address functions which are performed by personnel, it is necessary to understand the human's role in conducting the mission, so that the model can support DOTMLPF analysis.

To accomplish this decomposition in CORE, you simply open the desired operational activity as an EFFBD. This allows each Operational Activity to be defined in terms of a sub-level behavior model. Within this construct a parallel structure should be captured that provides a branch for each of the Systems, Applications, and Personnel that participate in accomplishing the Operational Activity. Figure 4-10 shows the functional decomposition and data flow among the SACC systems, applications, and personnel during the target assessment activity.

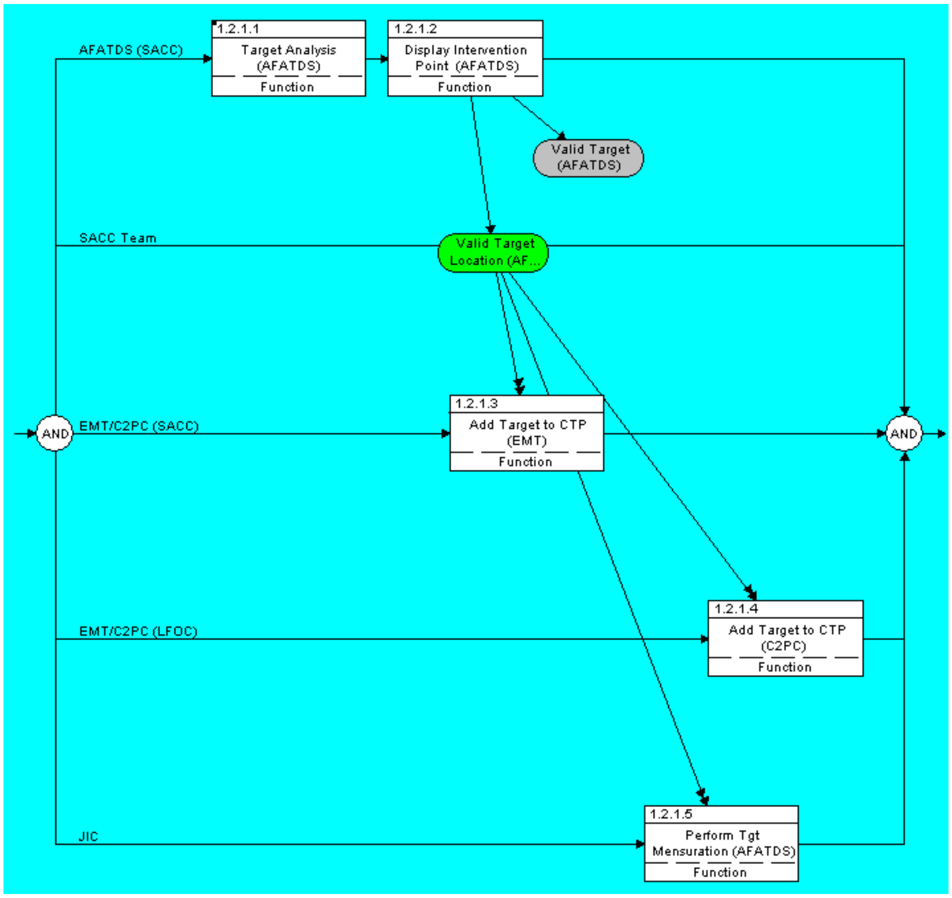

Figure 4-10: Decomposition of the Target Assessment Operational Activity

4.2.1. Capture the Functional Sequence

The parallel structure in the decomposition represents the fact that all of the elements in the model can be performing their function concurrently. However, there is normally a sequence of functional activities that dictates how the process is conducted. The sequence is controlled by the flow of triggering data among the functions on two or more branches on the parallel structure.

4.2.2. Capture the Functional Data Flow

If an input triggers the operational activity, then that input must be shown as an input to either a system, application, or personnel function which starts the process sequence. The remainder of the functional decomposition should address how that input is transformed into one or more outputs, representing the task completion. Thus, a lower level of data flow among systems, applications, and personnel needs to be captured. It differs from the Information Exchanges at the operational level in that much of those exchanges represent messages, video, telephony, or other means of communicating. The data flow in the functional decomposition represents specific data that is processed, displayed, analyzed, etc., by the systems, applications, and personnel.

4.2.3. Function Timing and Resource Utilization

Each of the functions has a duration attribute that specifies how long it takes to perform the function. Just as for the operational activities, this duration parameter can be set to a constant time, or to any one of 16 random distributions. As the simulator executes the model, it will walk the decomposition parallel structure, and determine how long each functional step takes. The sum of all of the steps determines the duration of the Operational Activity. Figure 4-11 shows the timeline associated with the DDG Gun Fire activity with the sequence and durations of the functional decomposition depicting the execution of the functional process that determines the activity duration. Functions can also require resources in order to be performed, as discussed in paragraph 4.1.4 Activity Timing and Resource Utilization.

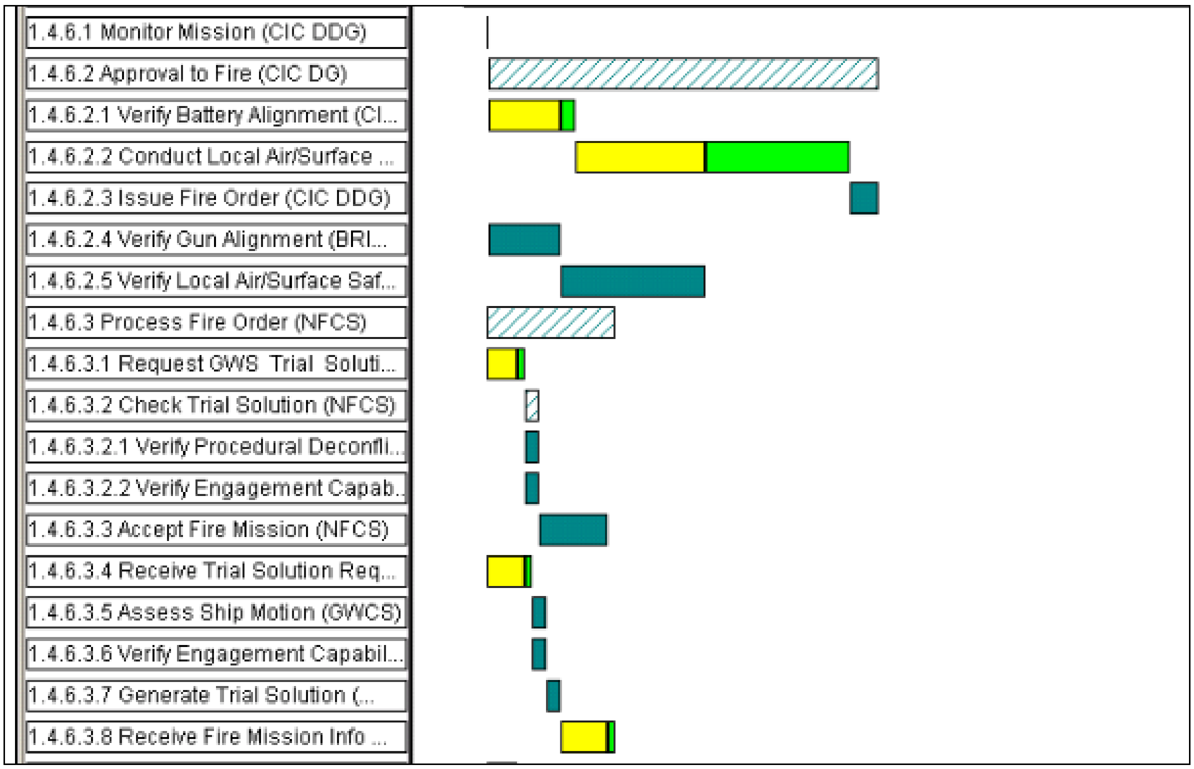

Figure 4-11: Timeline for the Target Assessment Operational Activity

4.3. Capturing the Physical Model

The physical model represents the architecture of the Force Package in terms of the platforms, facilities, nodes, systems, applications, personnel, interfaces, and networks. The term "node" is used to represent locations where an organization is deployed with its systems, applications, and personnel. The physical model will eventually capture the performance measures for current systems by adjusting the timing of the functions the systems perform in the functional model.

In addition, the interfaces and networks will be constrained by establishing the size of the data transfer pipe. When information/data flows occur in the operational or functional model, how long it takes for the message/data item to be sent and received is dependent on the size of the message/data item and the size of the interface/network.

Once constructed for the Current Architecture, the physical model represents one place where proposed changes to the force package architecture can be modified to assess how the proposed change affects mission performance.

4.3.1. Platform and Facility Layout

The top layer of the physical model represents the platforms and facilities that make up the Force Package. The facilities would represent ashore locations involved in providing command and control, communications, or intelligence, surveillance, and reconnaissance support. Platforms represent movable entities used to conduct the mission, such as ships, submarines, aircraft (Helo and fixed wing), satellites, transportation vehicles, or tanks.

At the top level, we can identify the interfaces and networks by which the various platforms and facilities communicate and exchange information. Within CORE, we use the Link class to establish a one-way communication path between the platforms (this is just a constraint levied by the simulation engine). At this level, the connection we will use is “connected thru” versus “connected to.” The “connected thru” relationship is used when the interface is “connecting to” a system/component contained within the platform. Rarely will there be a link that “connects to” a platform itself; links will typically be connected to a communications box (antenna, radio, etc.) which will then route the received message/data to an appropriate system.

4.3.2. Capturing the Nodes (Operational Locations)

Within each platform or facility, the nodes need to be captured and identified. The nodes represent the operating locations of the organizations identified in the Operational model. In some cases, the organizations will move from on-board a ship to a command center ashore. Thus, a node, such as the Landing Force Operations Center (LFOC), may be identified in more than one location.

4.3.3. Capturing the Systems, Operators, and Applications

Within the nodes, the systems, workstations, applications, and personnel need to be captured and identified. These elements represent the lowest level of the physical model that needs to be captured and these elements are allocated to the functions identified in the functional model. Figure 4-12 shows the decomposition of the LHA platform, identifying the nodes within the platform. The systems, workstations, applications, and personnel are embedded in the decomposition of each node as designated by the small black square in the upper left hand corner of the node box.

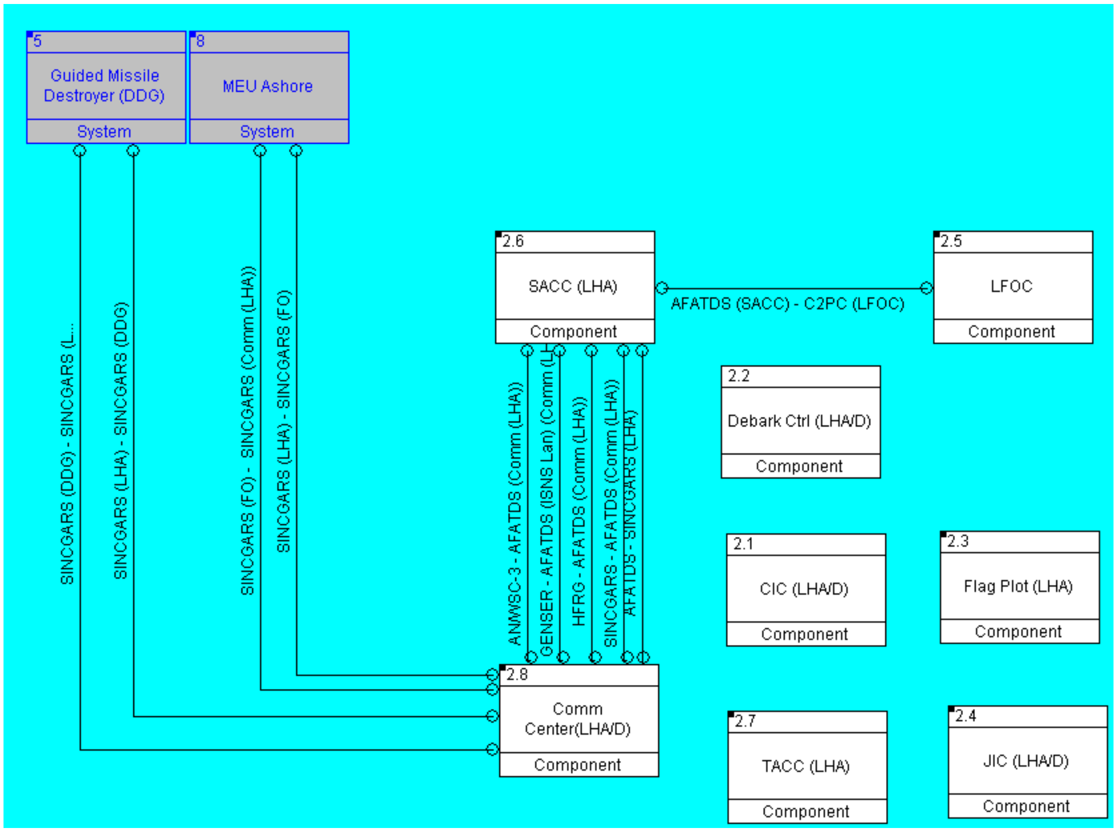

Figure 4-12: LHA Physical Decomposition

4.3.4. Identifying Interfaces and Networks

The interfaces and networks among systems, workstations, applications, and personnel need to be captured and identified. In some, platforms have internal interfaces and networks, as well as networks external to the ship. Internal systems typically must route data to communication systems (radios, broadcast systems) that transmit the data/messages via radio waves. Figure 4-13 shows an integrated systems view that identifies the platforms, nodes, systems, internal interfaces and networks, and external interfaces and networks.

CORE uses a mechanism called a link to represent a one-way transfer of data between two component elements. Thus, for a simple interface between two systems, one may need to establish two links that permit data to flow from system A to system B, and in reverse to flow data between system B to system A.

To represent a network in CORE, it is necessary to create a fictitious network component outside of the platforms and facilities. Create link pairs, as necessary, between every system that can connect over the network to establish the connectivity between platform communication systems and the network. This will enable systems on the platform to access the communication systems to access external networks.

Note, the functional model needs to be aligned with this additional network functionality so that the network component can distribute and receive broadcast messages. It may be necessary to utilize a true communication modeling tool if it is desired to assess the communication throughput/bandwidth issues. Core allows the indication of data flows across the interfaces/links and to do some limited assessment of the communications capabilities.

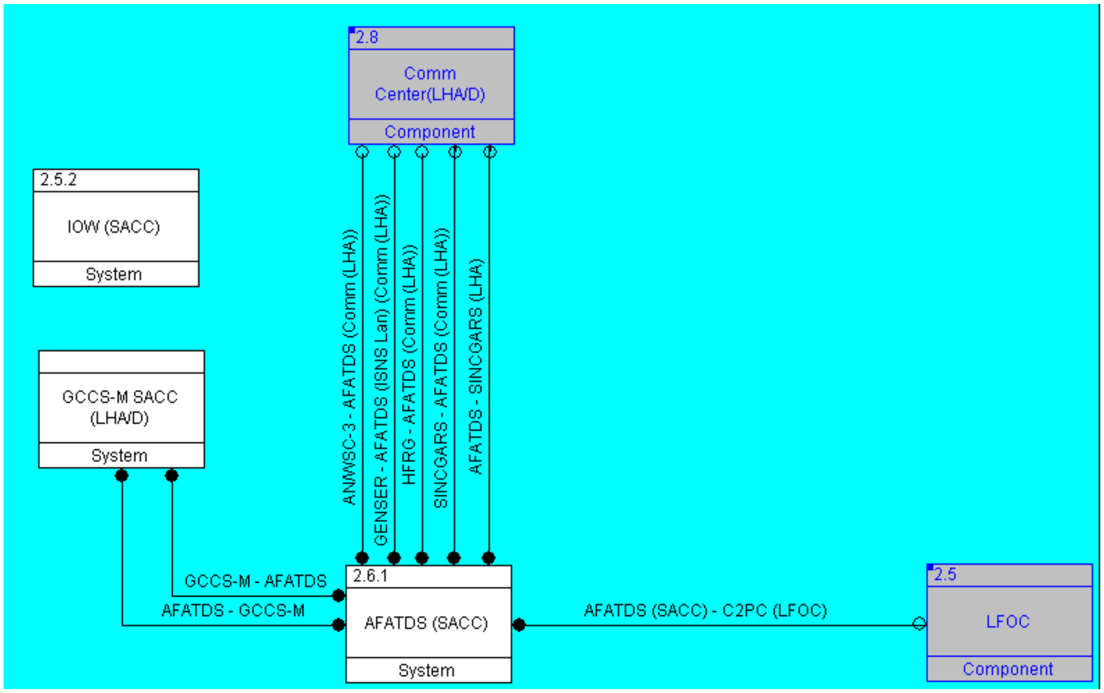

Figure 4-13: SACC Integrated System View

The link element has a "Size" parameter that can be set to constrain how much data can flow across the link (bandwidth). Figure 4-14 shows the link element, and a Size specification window.

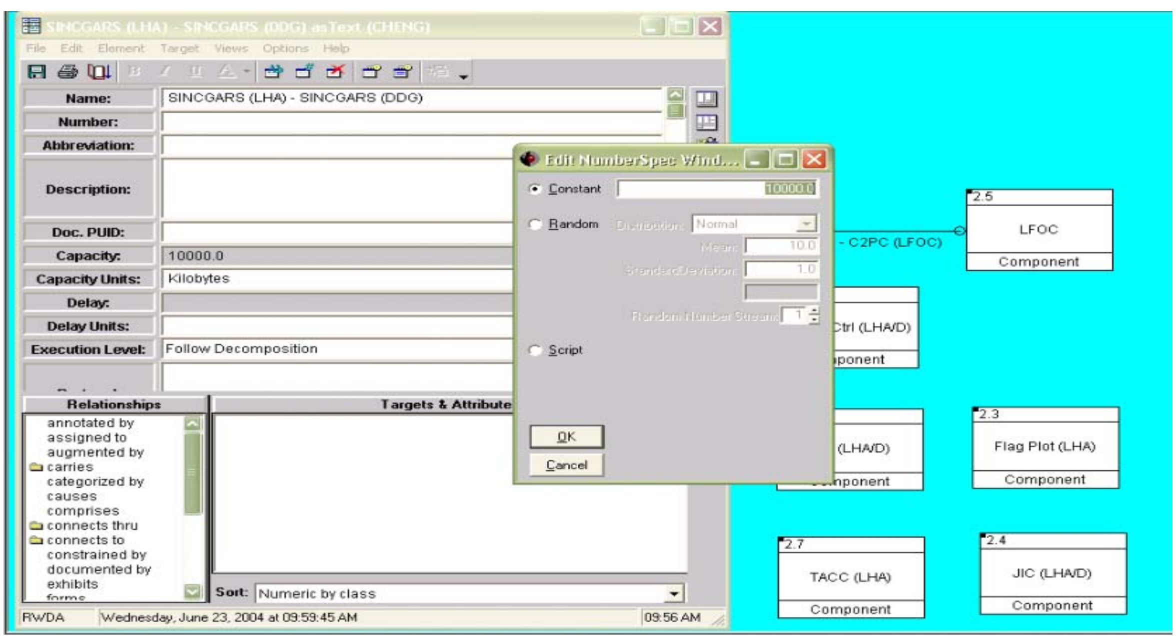

Figure 4-14: Link Element and Size Attribute Specification Window

4.3.5. Allocation of Functions to Systems, Applications, and Personnel

The functions captured in the functional layer of the model need to be allocated to the systems, applications, and personnel that perform the function. This linkage provides the basis for tracing which systems, applications, and personnel perform functions that accomplish the operational activities. This then provides a basis for conducting trade-off analyses to see where the model does not support its full set of requirements. It allows the model to integrate the operational layer, to the functional layer, to the physical layer. Thus any changes to the baseline model may have a positive or negative affect on the overall process timeline.

In CORE, to establish the linkage between functions and the systems, applications, and personnel, the functions must be selected and opened in the Text View. In the bottom left pane there is a set of allowable relationships, and the “allocated to” relationship can be selected to identify the specific system, applications, and personnel that perform the function. By right clicking the mouse in the right pane the list of the systems, applications, and personnel objects is presented and the appropriate object should be selected to establish the relationship link.

4.3.6. Allocation of Information Exchange and Data Flow to Interfaces

Information exchange and data flow must be allocated among the Interfaces by identifying which links are used to carry the data. Recognize that in the operational model the information exchange elements represent the messages that are transmitted among the organizations. In the functional model, an input Information Exchange message is an input to the initiating function. After that, the message is broken down into smaller data elements that are processed by systems, applications, or personnel. At the completion of the functional model, if there is an outgoing information exchange it is output from the final (or one of the last) function(s). This establishes how the information exchanges are prepared for individual data elements and distributed between organizations utilizing communications systems and networks, and the resulting receipt and responsive action to the message.

4.4. Execution of the Force Package Model

The model is modular, and you can execute the model at a universal level by selecting the top-most operational activity or any of the individual operational activities to understand how the model behaves. Given the timing identified in the operational activities and functions, the size of the information exchange or data elements, the size identified in the link elements, and the resource utilization identified for the operational activities and functions, the model will generate an informative timeline that shows the sequence of events, durations, resource contentions, functional bottlenecks, and communications delays.

In CORE, both operational activity and function elements can be opened in an Extended Functional Flow Block Diagram (EFFBD), which includes access to the Simulator Control Panel. Opening the Sim Panel provides access to the Timeline window and a Transcript window. The Transcript window will capture every step in the execution of the model and is useful in debugging the model to get it to behave properly.

The Simulator is a discrete event simulator that starts at the left-most input arrow, traverses the behavior diagram, and utilizes the object definitions to determine the model behavior. Figure 4-15 shows an example of the CORE Sim panel, Timeline, and Transcript windows.

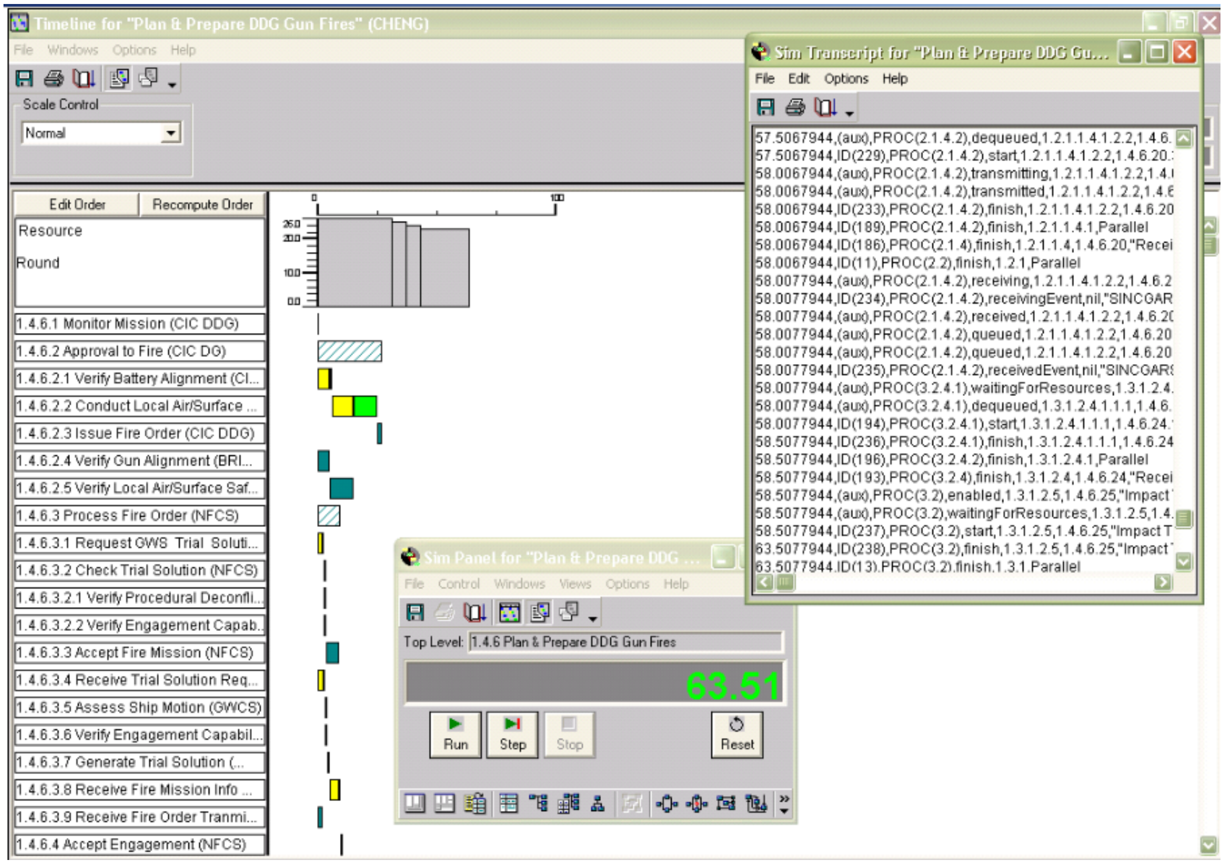

Figure 4-15: CORE Simulation Environment

4.5. CORE Schema Extensions to Support Force Package Modeling

The CORE database schema includes a schema for the DoDAF (previously known as the C4ISR Architecture Framework). This schema was developed in a way that separates the Systems Engineering schema from the Architecture schema, but does allow some relationships among key elements. In order to make the architecture executable, there is a need to make small modifications to the schema. The intent is to allow an OperationalActivity to be decomposed into functions, which is not permitted in the schema currently provided in CORE. The following table identifies the schema changes needed to support making the architectures executable:

Element	Relationship	Target Class
OperationalActivity	decomposedBy	Function
Function	inputs	OperationalInformation
Function	outputs	OperationalInformation

Table 4-2: Recommended CORE Schema Changes

The reason that the Function needs to input and output the OperationalInformation element is that an OperationalActivity may input or output an OperationalInformation element. Decomposition at the functional level requires that the OperationalInformation element be included in the decomposition as an input or output for consistency.

5. Developing the System Performance Document (SPD)

The SPD is developed by the SE IPT to document the results of Capability Engineering. The SPD identifies the architectural baselines (Current and Vision) for the SoS. It allocates functional and performance requirements across the portfolio of systems and provides measures of performance and measures of effectiveness for assessing the overall capability provided in response to the ICD. Additionally, it identifies the key interfaces among the portfolio of acquisition programs that must be controlled, and identifies the Qualification Requirements and relates them to the individual system Test and Evaluation Master Plans (TEMP) where the allocated requirements will be validated. As such, it is a key document for guiding the programs within the capability acquisition portfolio towards the necessary "horizontal alignment" to field the capability increments.

5.1. Rationale for the SPD

SECNAVINST 5000.2C identifies systems engineering IPTs, designated by ASN (RD&A) for FoS or SoS acquisitions, as responsible for deriving, allocating, describing, and documenting system performance among the ACAT programs and modifications that provide FoS or SoS mission capability. The SPD is identified as the document for capturing FoS or SoS performance. The SPD provides guidance to be utilized by the individual systems within a capability acquisition portfolio to develop their respective CDD, CPD, Information Support Plan (ISP), TEMP, and system specifications. The SPD for a FoS or SoS is jointly signed by the respective PEOs or program managers who lead the SE IPT. The SPD will be used by ASN (RD&A) as a means to maintain alignment of the programs during execution of the acquisition process (Portfolio Execution).

5.2. Structure of the SPD

The structure of the SPD includes scope (e.g., capability overview, document overview), applicable documents, requirements, qualification provisions, requirements traceability, and applicable appendices.

The requirements addressed should include:

- Required States and Modes
- Capability Requirements and Objectives
- KPPs
- Force Package Interoperability Requirements
- Force Package Functional Requirements
- Force Package Interface Requirements
- Computer Resource Requirements
- Human Systems Integration Requirements
- Environmental Requirements
- Safety Requirements
- Security and Privacy Requirements
- Training Related Requirements
- Logistics Related Requirements

- Force Package Qualification Requirements
- Other Requirements

Appendices should be provided to include:
- Force Package Objective Architecture
- Functional Interface Design Matrix
- Physical Interface Design Matrix
- Integration and Interoperability Test Matrix
- Integrated Portfolio Schedule

5.2.1. Required States and Modes

This Section identifies the operational states and modes for the FoS/SoS mission capability. In general, states should include tactical, test, and training. Tactical state descriptions should include the specific mission capability modes (e.g., conduct fires support). These may be further elaborated in terms of threads (e.g., Close Air Support Thread).

The test state description should identify the capability required to test and display the status of each system and communication pathways (Point-to-Point Interface or networks) comprising the FoS/SoS in order to assess the level of mission effectiveness and operational readiness of the FoS/SoS.

The training state description should identify the FoS/SoS capability to conduct realistic training missions at the Joint and Naval Task Force levels. The training state capability should be supported both in port and at sea. The intent is to enable our operational forces to train as they intend to fight, and to utilize the actual systems as the basis for training exercises.

5.2.2. Capability Requirements

This Section should first identify the originating requirements that establish the top-level capability objectives. These would include the capability requirements documented in the ICD, CDD, CPD, and related authoritative documents. Requirements statements from these documents for the desired capability should be identified and labeled with a unique identifier. The SE IPT should capture these requirements in an appropriate requirements management database. Commercially available requirements management tools should be leveraged to support the process of document decomposition to identify requirements and to establish a requirements management database. The Naval Collaborative Engineering Environment (https://ncee.navy.mil) provides a representative set of such tools and a supporting information management system to maintain traceability of the capability requirements.

The identified requirements should address FoS/SoS parameters such as responsiveness, range, accuracy, volume, lethality, etc. Logistics support and training requirements may also be identified. An example is the requirement for "responsiveness" for a Naval Fires Support thread within a Joint Fires expeditionary operation capability[37]:

Mission processing time: 2.5 minutes (threshold)/ 60 seconds (objective)
Total response time: 10 minutes (threshold)/ 5 minutes (objective)

These top-level capability requirements should then be allocated and elaborated for the various capability mission threads. The analytical process to accomplish this is typically supported by appropriate models and simulations that support verification of the requirements allocation. These also enable identification of performance measures associated with the requirements. The results may be captured in a table such as shown in Table 5-1 for the Naval Surface Fires Support responsiveness requirement in the 2012 timeframe[33].

NSFS FoS (2012)	Platform/ Frequency	Function	Event Number	Current Estimate Of Event Time (sec)	SPD Requirement for Event Time (sec)	Summation of Event Times (sec)
PFED/ TLDHS	Forward Observer	Find, Fix, Track	1		NA	0
SINCGARS	VHF	Comms link	2	.5	1 LOS 2 OTH	2
AFATDS	LHA/D	Mission C2, Target	3	30	30 (w/o external deconfliction)	32
SINCGARS	VHF	Comms link	4	.5	1	33
NFCS	DDG	Engage	5			
Digital Interface		Data link	6			
GWS	DDG	Engage	7		26	59
Aegis CIC	DDG	Local C2	8			
First round fired (ERM)	DDG	Weapon	9		1	60
Last round fired	6 rounds per mission	10 rounds/min	10	36	36	96
Flight Time	15-60 nm		12	210-420	264	
Last round arrives on target			13		----	300
Total Mission Time					300	300

Table 5-1: Naval Surface Fires Support (NSFS) Thread Requirements (2012)

5.2.3. Key Performance Parameters

CJCSM 3170.01B states the requirement for Key Performance Parameters (KPPs) to be identified and documented in the CDD and CPD. KPPs "capture the minimum set of operational

[37] System Performance Document for Joint Fires in Support of Expeditionary Operations in the Littorals, Increment 1: Expeditionary Strike Group Sea-Based Fires (2007 – 2012), September 2005 Draft

effectiveness and suitability attributes needed to achieve the overall desired capabilities" of the system, system of systems, or family of systems during the applicable development and deployment increment. They define threshold and objective levels of operational capability and may change during successive increments of development and deployment. KPPs are defined based on the full set of supporting analyses including: the AoA; the cost-schedule-performance tradeoffs analysis; the results of experimentation, testing, and evaluation; the lifecycle supportability and affordability analysis; lessons learned during the development and demonstration phase; and user feedback on fielded system increments.

CJCSM 3170.01B suggests the following questions, which should be answered in the affirmative before selecting a performance attribute as a KPP:

- Is it essential for defining the required capabilities?
- Does it contribute to significant improvement in warfighting capabilities?
- Is it achievable and affordable?
- Is it measurable and testable?
- Is the attribute supported by analysis?
- Is the sponsor willing to consider canceling or restructuring the program if the attribute is not met?

Typical KPPs define major elements of performance such as range, accuracy, and lethality. They are normally evaluated by rolling up a number of supporting attributes. For the SoS or FoS, the supporting attributes may be distributed across a number of systems. The evaluation and assessment process consequently demands automated capabilities to support the analyses and to manage the complexity of the relationships, since some attributes may impact more than one KPP. The NCEE provides tools and information management capabilities to support the analysis process.

KPPs defined for the SoS/FoS are then reflected and expanded in the respective CDDs and CPDs for each system in the acquisition portfolio. As an example, a candidate "range" KPP for Naval fires in support of an expeditionary force is defined and allocated as shown in Table 11 for the 2007 and 2012 time frames[38]:

Range: 100 nautical miles (threshold)/200 nautical miles (objective)

2007 Weapon	Shooter	Current Weapon Range (nm)	SPD Range Requirement (nm)
Conventional 5-inch Gun Munition	CG, DDG	13	NA
AV-8B + JDAM	AV-8B	xx (unrefueled)	110
Tactical Tomahawk	CG, DDG, SSN	900	110

[38] Ibid.

2012 Weapon	Shooter	Estimated Weapon Range (nm)	SPD Range Requirement (nm)
Extended Range Munition	DDG 81+	50	100
JSF + JDAM	JSF	xx (unrefueled)	200
Tactical Tomahawk	CG, DDG, SSN, SSGN	900	200

Table 5-2: Candidate Range KPP for Naval Fires Support.

5.2.3.1. Net-Ready KPP

A Net-Ready KPP is required for all Information Technology and National Security Systems that enter, process, store, or transmit DoD information except those that do not communicate with external systems. CJCSI 6212.01C, "Interoperability and Supportability of Information Technology and National Security Systems," provides extensive guidance on the definition of the Net-Ready KPP. The Net-Ready KPP is required to be documented in the CDD and CPD for each system in the capability acquisition portfolio.

5.2.4. Force Package Interoperability Requirements

The Force Package Interoperability Requirements describe the Operational nodes, systems and applications within these nodes, and the requirements for these to exchange information with other system and application elements within the Force Package Architecture. This information is generated for the objective architecture by utilizing the Section 3 process for defining the Force Package model. Information Support Plans (ISPs) for each of the systems in the acquisition portfolio should reflect the Force Package Interoperability Requirements.

The Force Package Interoperability requirements define the allocation of information flows between operational nodes and systems. Table 5-3 illustrates the operational information exchange for a close air support thread under a Naval fires mission capability.

From Node/System	From Activity	To Node/System	To Activity	Information Exchanged
CAS Aircraft	Update CAS Mission Commencement	Fire Control Team	Request Aircraft Status Update	9-Line Confirmation
CAS Aircraft	Update Aircraft Status	Fire Control Team	Clear CAS Mission	A/C Status Update
CAS Aircraft	Update CAS Mission Commencement	Fire Control Team	Request Aircraft Status Update	Depart Initial Point
CAS Aircraft	Contact FAC	Fire Control Team	Transmit Air Mission Information	On Station

CAS Aircraft	Engage Target (Air)	Supporting Arms Coordination Center	Monitor Engagement	Weapons Release
Supporting Arms Coordination Center	Distribute Engagement Decisions	CAS Aircraft	Engage Target (Air)	9-Line
Fire Control Team	Transmit Air Mission Information	CAS Aircraft	Update CAS Mission Commencement	9-Line
Fire Control Team	Request Aircraft Status Update	CAS Aircraft	Update Aircraft Status	A/C Status Update Request
Fire Control Team	Clear CAS Mission	CAS Aircraft	Engage Target (Air)	Clear Hot
Supporting Arms Coordination Center	Distribute Engagement Decision	CAS Aircraft	Contact FAC	FAC Contact Information

Table 5-3: Operational Information Exchange Example

Appropriate levels of analysis supported by modeling and simulation should be conducted to verify the operational architecture model and the associated interoperability requirements. An approach for verifying the logical behavior of the operational architecture is to implement an executable model. There are a number of commercially available systems engineering tools that support the development of executable architecture models. These include functional modeling tools such as CORE, the Rational Rose tool suite, and specialized tools based on Petri-net models. Other simulation tools may be used to assess the overall mission performance of the architecture or the performance of the supporting information exchange networks. The Naval Collaborative Engineering Environment (https://ncee.navy.mil) provides a representative set of systems engineering tools to support architecture modeling.

5.2.5. Force Package Functional Requirements

The Force Package Functional Requirements identify the functions and associated performance attributes required to execute the activities associated with the capability mission threads. The functions are to be allocated among the systems, applications in the capability acquisition portfolio and to the human operators.

Section 4.2 provides the process for defining the Force Package functional architecture. Note that the identification of the top-level force package functions should utilize the DoN Common System Function List (CSFL). The current version of the CSFL is maintained on the Naval Collaborative Engineering Environment website (https://ncee.navy.mil).

The functional architecture model should be verified by using the appropriate levels of analysis and modeling and simulation (M&S). The products can also be documented using DoDAF systems architecture views such as the SV-4 and SV-5. The resulting functional architecture baseline provides the basis for allocating functionality to the system, application, or personnel in the force package, as described by Section 4.3.5. Table 5-4 provides an illustration of the traceability of functions to the supported operational activities and to the supporting systems and their locations (nodes) for the "Engage Target" operational activity in support of Naval fires. Figure 5-1 provides an example SV-5 illustrating the traceability of operational activities to supporting functions for execution. Table 5-5 provides an example SV-6 documenting the functional interface design matrix.

Operational Activity	Supporting System Functions	Supporting System Nodes	Supporting Systems
Engage Target (Air)	Display CAS Mission Clearance	F-35B	JSF VMF System
		AV-8B	ATHS II
	Display CAS Mission Clearance (2)	AV-8B	ATHS II
Engage Target (Missile)	Modify Mission	TACTOM	TACTOM MCP
	Capture BDI Data	TACTOM	TACTOM MCP

Table 5-4: Force Package Functional Traceability

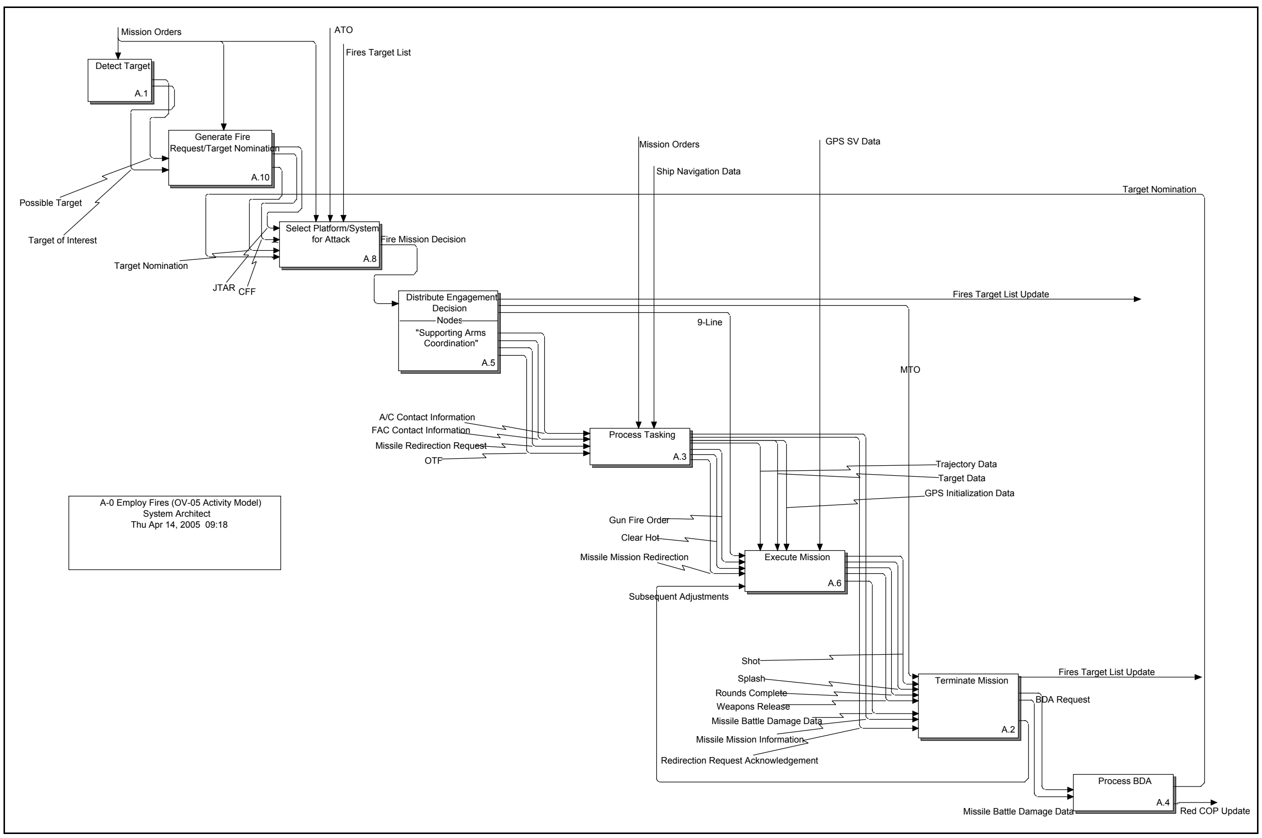

Figure 5-1: Example OV-5 Traceability of Operational Activities to Supporting Functions

Name	From System Function	From System Node	From System Entity	To System Function	To System Node	To System Entity
9-Line Brief	"Compose 9-Line"	FIST	Strikelink	"Process Mission Contents (2)"	AV-8B	"ATHS II"
AFU MFR	"Compose BDA Request"	SACC	AFATDS	"Display BDA Request Notification"	JIC	"DCGS-N 1.1"
ATI ATR	"Compose Target Nomination"	JIC	"DCGS-N 1.1"	"Process Target Information"	SACC	AFATDS
Aircraft Depart Initial Point	"Notify DPIP"	AV-8B	"ATHS II"	"Display DPIP"	FIST	Strikelink
Aircraft Depart Initial Point	"Notify DPIP"	F-35B	"JSF VMF System"	"Display DPIP"	FIST	Strikelink
Aircraft Final Attack Control	"Transmit CAS Mission Clearance"	FIST	Strikelink	"Display CAS Mission Clearance"	F-35B	"JSF VMF System"
Aircraft Final Attack Control	"Transmit CAS Mission Clearance"	FIST	Strikelink	"Display CAS Mission Clearance"	AV-8B	"ATHS II"
Aircraft On Station	"Notify On Station"	F-35B	"JSF VMF System"	"Display Aircraft Contact"	FIST	Strikelink

Table 5-5: Functional Interface Design Matrix (SV-6)

5.2.6. Force Package Interface and Network Requirements

The interface and network requirements necessary to execute the Force Package capability mission threads should be described in terms of the participating systems, the data transmitted along with accuracy and timeliness attributes, and the technical standards and specifications which apply. This information can be documented at the Force Package level in DoDAF architecture views such as the SV-6 and TV-1. Interface design specifications between the systems within the Force Package are guided by Interface Control Agreements and documented in Interface Control Documents.

5.2.7. Computer Resource Requirements

TBS

5.2.8. Human Systems Integration Requirements

Several existing instructions and guidance documents provide extensive guidelines and best practices for addressing the role of humans in systems, including the SoS. Particularly useful are:

- **NAVSEA INST. 3900.8A,** Human Systems Integration policy in Acquisition and Modernization
- **Virtual SYSCOM HSI Program Manager's Guide,** Vol. I and II

5.2.9. Environmental Requirements

TBS

5.2.10. Safety Requirements

Several existing instructions and guidance documents provide extensive guidelines and best practices with regard to systems safety, including the SoS. Particularly useful are:

- **OPNAVINST 5100.24,** Navy System Safety Program
- **MIL-STD-882D**, Standard Practice for System Safety
- **Software System Safety Guidebook,** December 1999

5.2.11. Security and Privacy Requirements

TBS

5.2.12. Training Related Requirements

TBS

5.2.13. Logistics Related Requirements

TBS

5.3. Tracing Requirements to System Specifications

The activities conducted by the SE IPT under Capability Evolution Planning and Capability Engineering establish a body of functional, performance, and interface requirements that ultimately flow down to each of the systems in the capability portfolio of acquisition systems. This flow is illustrated in Table 15, and is an iterative process with continuous feedback at each stage of capability evolution. The decisions made at each stage of capability evolution are captured and described by a number of key artifacts. These decisions and associated artifacts are captured in a “Capability Decision Database” to be accessible to and used by the capability acquisition portfolio programs as the basis for their respective CDDs, CPDs, ISPs, TEMPs, system specifications, etc. The traceability of the individual system’s capabilities to support the original ICD is thereby established, verifiable, and maintained for the life of the system. The

Naval Collaborative Engineering Environment (https://ncee.navy.mil) provides an information management capability to establish and maintain this traceability.

Source Documents	Capability Evolution Analysis	Capability Decision Database
JCIDS Analysis	Identify Capability Mission Requirements	AoA Preferred Alternative
ICD	Identify Capability Concept of Operations	Objective Portfolio Architecture
Joint, Naval Architectures	Define Capability Planned Portfolio Architecture	Capability Evolution Plan
	Perform Analysis & Trades	Capability System Performance Document
	Define Capability Objective Portfolio Architecture	Capability I&I Requirements
	Perform Functional Analysis and Allocation	Capability T&E Objectives
	Portfolio Synthesis	Portfolio Programs' SEP, CDD, CPD, ISP, TEMP
	Portfolio Analysis	

Table 5-6: Capability Requirements Flow

The complex interactions involved in the overall "Capability Evolution Analysis" process are indicated by the NCEP N-Square (N^2) chart illustrated by Figure 5-2. The key NCEP activities are listed along the diagonal of the chart. Inputs to each activity are indicated in the columns aligned with the activity. Activity outputs are indicated in the row associated with each activity. The source documents are listed across the top in the columns that they influence. The source data (e.g., force architectures) are listed across the bottom.

The iterative nature of the analysis process is highlighted by the number of times an output from a given activity feeds back to a previous activity. In the case of an evolutionary acquisition program, an AoA may be deemed necessary prior to each new increment of the system being developed. In this case, the program documentation produced for the preceding version of the system will serve as input to the AoA and the associated NCEP activities. The result is full traceability of the evolution of each system in the capability acquisition portfolio back to the originating ICD. Test and evaluation of the capability portfolio of systems is then supported by the Capability Decision Database that captures and maintains this traceability.

JCIDS Analysis; ICD Requirements	Force Structure; CONOPS	Force Structure; CONOPS		Capability Mission Requirements; KPPs				
Conduct AoA			Preferred Alternative; Objective Arch	Preferred Alternative; Objective Arch				Preferred Alternative; Objective Arch
	Planned Portfolio Architecture	Capability Alternatives; Arch Models						
Viable Alternatives; Objective Architectures		**Sensitivity Analysis**						
Capability Evolution Plan		Capability Evolution Plan	**Identify Capability Evolution**	Capability Evolution Plan				Capability Evolution Plan
	Objective Architecture Operational Model			**Portfolio Capability Analysis**	Objective Architecture Operational Model		Objective Architecture Operational Model	Objective Architecture Operational Model
	Functional Model				**Functional Analysis and Allocation**	Functional Model	Functional Model	Functional Model
	Physical Model			Physical Model		**Portfolio Synthesis**	Physical Model	Physical Model
System Performance Document				System Performance Document			**Portfolio Analysis**	System Performance Document
SEP; CDD; CPD; TEMP; ISP; System Specs	SEP; CDD; CPD; TEMP; ISP; System Specs	SEP; CDD; CPD; TEMP; ISP; System Specs	SEP; CDD; CPD; TEMP; ISP; System Specs	SEP; CDD; CPD; TEMP; ISP; System Specs				**Portfolio Programs Execution**
Joint, Naval Architectures	Joint, Naval Architectures		Joint, Naval Architectures			Joint, Naval Architectures		Joint; Naval Architectures

Figure 5-2: NCEP N^2 Chart

5.4. Tracing Qualification Requirements to Test Plans

Overall qualification provisions for the acquisition portfolio of systems provide test planning guidance to the individual systems within the acquisition portfolio. These FoS/SoS qualification provisions need to be established to support each phase of the capability development and deployment process. The individual system demonstration and test plans should align with the portfolio of systems qualification provisions in order to assess the contribution delivered in support of the capability identified by the ICD.

Joint Interoperability provisions should particularly be addressed by the portfolio of systems qualification requirements. CJCSI 6212.01C, Interoperability and Supportability of Information Technology and National Security Systems provides significant guidance with regard to the Joint interoperability testing and test certification process. Each system within the acquisition portfolio for the required capability must comply with this process. Traceability of each system's interoperability requirements to the portfolio of systems qualification provisions must be established early in the capabilities development process and continue throughout the system's lifecycle.

The point of departure for the acquisition portfolio of systems qualification provisions is the requirements management database. This database establishes the traceability of requirements from the originating capability documents to each of the systems within the portfolio of systems. Performance attributes are also identified with associated metrics. These establish the criteria for assessing the capabilities delivered by each system within the portfolio of systems and the contribution of each system to the overall required capability defined by the ICD.

Appropriate qualification methods should be identified to evaluate the requirement under assessment. Qualification methods include:

- **Demonstration**: The operation of the system, or a part of the system, which relies on observable functional operation not requiring the use of instrumentation, special test equipment, or subsequent analysis.

- **Test**: The operation of the system, or a part of the system, using instrumentation or other special test equipment to collect data for later analysis. Tests can be done at any level of system integration, from interim critical experiments to subsystem, system, and FoS/SoS level. Testing can also be done in combination with other techniques (e.g., Modeling and Simulation (M&S) and analysis). The testing level, degree of integration, general test concept, the use of and rationale for incorporating other techniques and the test location should be described for each test.

- **Analysis**: The processing of accumulated data obtained from other qualification methods. Examples include: analyzing the aggregate of sub-systems' tests to assure system-, SoS-, and FoS-level performance; data collection and analysis; reduction, interpolation, or extrapolation of test results; historical test data and analysis.

- **Inspection**: The visual examination of system components, documentation, etc.

- **Modeling and Simulation**: The use of M&S on part or all of the system to prove the system's functionality.

- **Special Qualification Methods**: Any special qualification method for the system, such as special tools, techniques, procedures, facilities, acceptance limits, use of standard samples, pre-production or periodic production samples, pilot models, or pilot lots. Specifics to location of test (i.e., ship or land-based) shall also be included. In some instances, tests may be run on sub-elements to prove the sub-elements are operational, however, the cost may be too prohibitive to force an integrated test.

Table 5-7 provides recommended qualification methods for the various SPD requirements. Table 5-8 provides an example portfolio requirements qualification matrix. Table 5-9 provides a sample system-to-system interface text matrix.

Section	Requirement	Qualification Method(s)
3.1	States and Modes	Demonstration
3.2	Capabilities	Test, M&S, Analysis
3.3	Information Exchange	Demonstration
3.4	Functions	Inspection, M&S, Analysis
3.5	Data Interfaces	Test
3.6	Computer Resources	Analysis
3.7	Human Systems Integration	Demonstration, Analysis
3.8	Environmental	Analysis
3.9	Safety	Analysis
3.10	Security	Analysis, Inspection
3.11	Training	Inspection
3.12	Logistics	Inspection
3.13	Test	Inspection
3.14	Other	TBD

Table 5-7: Recommended Qualification Methods

Capability Requirement No.	Section No.	Capability Description	Source/ Reference No.	Qualification Methodology and Level	Notes
R01	3.1	Tactical, test state, and training state	11	Demonstration	
R02	3.1.1	Tactical state	11	Demonstration	
R03	3.1.2	Test state	11	Demonstration	System operability test
R04	3.1.3	Training state	11	Demonstration	System operability test
R05	3.2.1	Responsiveness	1, 12, 13	Test, M&S, analysis	Data extraction and reduction for analysis
R06	3.2.2	Range	1	Test, M&S, analysis	Data extraction and reduction for analysis
R07	3.2.3	Accuracy	1	Test, M&S, analysis	Data extraction and reduction for analysis
R08	3.2.4	Volume	1	Test, M&S, analysis	Data extraction and reduction for analysis
R09	3.2.5	Lethality and effects	1	Test, M&S, analysis	Data extraction and reduction for analysis
R10	3.3	Functions	Derived	Inspection	Data extraction and reduction for analysis
R11	3.4	IERs	Derived	Test	Data extraction and reduction for analysis
R12	3.5	Data interfaces	Derived	Test	Data extraction and reduction for analysis

Table 5-8: Example Requirements Qualification Matrix

From System Entity	To System Entity	Data Exchanges	Applicable Missions	Integration Check[1]	Interface Test Level Completed[2]
ATHS II	Strikelink	Aircraft depart initial point	CAS		
		Aircraft on station			
		Aircraft position and target designation			
		Aircraft status			
		DPIP			
		OSR			
		Operator reply			
		Operator reply (2)			
DCGS-N 1.1	AFATDS	ATI ATR	TACTOM		
		BDA report			
ERGM	GWS	Projectile monitor	NSFS		
		Projectile monitor (2)			
JSF VMF System	Strikelink	Aircraft depart initial point	CAS		
		Aircraft on station			
		Aircraft position and target designation			
		Operator reply			
TACTOM	MDS/TTWCS	BDI	TACTOM		
		Health and safety			
AFATDS	DCGS-N 1.1	AFU MFR	TACTOM		

Table 5-9: Example System-to-System Interface Test Matrix

Appendix A: Project Plan for Implementing the ASN RDA CHENG System Engineering Integrated Product Team (SE IPT) Process Version 1.0

Prepared by: Director, Systems Engineering

A.1. References:

(a) SECNAVINST 5000.2C dtd 19 November, 2004
(b) RDA CHENG Charter dtd 11 July 2000
(c) DoD Directive 5000.1, "The Defense Acquisition System," dtd 12 May 2003
(d) DoD Instruction 5000.2, "Operation of the Defense Acquisition System," dtd 12 May 2003
(e) CJCSI 3170.01E, "Joint Capabilities Integration and Development System", dtd 11 May 2005
(f) CJCSM 3170.01B, "Operation of the Joint Capabilities Integration and Development System," dtd 11 May 2005
(g) CJCSI 3170.01B, "Requirements Generation System," dtd 15 April 2001
(h) NCEP Guidebook Version 1.1 dtd 23 May 2005
(i) DoD Architecture Framework Version 1.0 dtd 9 February 2004
(j) Defense Acquisition Guide, dtd 23 September 2004
(k) System Engineering Plan Preparation Guide, Version 1.0, November 15, 2005

A.2. Enclosures:

1. SE IPT Identification and Prioritization Process
2. SE IPT Organization and Start-up Process
3. SE IPT Transition Process

A.3. (1) Scope

The purpose of this memorandum is to develop the approach and processes that ASN (RD&A) Chief Systems Engineer (CHENG) will implement in providing senior leadership and focus to Program Executive Officers (PEOs), Systems Command (SYSCOMs), Direct Reporting Program Managers (DRPMs), and Program Managers (PMs) with respect to integration and interoperability of a Family-of-Systems (FoS) or a System-of-Systems (SoS). This document provides the processes that will be implemented to identify, prioritize, establish, and assist the System Engineering Integrated Product Teams (SE IPTs), chartered by ASN (RDA) CHENG, to conduct SoS and FoS systems engineering under current capability-based acquisition policies.

Presently, candidate FoS and SoS are emerging as potential material solutions for addressing the current identified capability shortfalls in an effort that will fully exploit naval warfare capabilities. To ensure that the constituent systems operate seamlessly in a net-centric warfare environment will require that we look across individual system boundaries and ensure that compatibility exists across the spectrum of legacy, programmed, and new systems. SE IPTs, with involved stakeholders, are the best way to recommend integration and interoperability solutions that will properly represent the stakeholders' equities.

A.4. (2) Background

Naval Forces are comprised of sea, air, space, and land platforms with a supporting C4ISR infrastructure that integrates them into a cohesive fighting force. Traditionally, both the requirements and the acquisition communities have had to organize around these types of sea, air, space, and land platforms because each of their unique operating environments, engineering challenges, design practices and supporting C4ISR technologies required specialized expertise. Thus, the organizations responsible for these platforms were typically aligned with the organizations that were responsible for installing the supporting technologies. This platform-centric approach, while useful, is not suited for the future network-centric system environment.

The new network-centric approach will demand that the various types of platforms and their supporting technologies, are resourced, acquired and operated by multiple communities through coordinated engineering efforts that will operate coherently with each other as a FoS/SoS. Capabilities delivered by a FoS/SoS will require a new management approach for making decisions about resourcing and acquiring platforms and their installed C4ISR supporting technologies.

Reference (a) directs ASN (RDA) to establish a Systems Engineering Integrated Process Team (SE IPT) for designated Navy and Marine Corps SoS or FoS. The intent of this provision is to provide a forum for the resolution of SoS and FoS systems engineering issues that cut across PEOs and SYSCOMs and for which no single PEO or SYSCOM has the sole authority to resolve. This does not preclude a PEO or PM from establishing a SE IPT for a SoS or FoS acquisition program within their purview. The RDA CHENG is also directed to assist SE IPTs for systems integration and interoperability compliance.

ASN (RDA) CHENG's charter, reference (b), identifies it as the senior technical authority within the acquisition structure for the overall architecture, integration, and interoperability of current and future Combat, Weapons, and Command, Control, Communications, Computer and Intelligence (C4I) systems used by the Department of the Navy. ASN (RDA) CHENG is responsible for the development of relationships and processes, within the acquisition structure, that will ensure that acquired component systems are engineered to interoperate with other systems as part of a larger force.

Beginning in 2003, the Department of Defense issued new policies, references (c) through (f), that altered the way the Services will acquire new systems or materiel items. These new directives replaced the former requirements generation process, reference (g), with the Joint Capabilities Integration and Development System, reference (e), as a means of addressing "Joint" capabilities and solutions rather than continuing to foster Service-unique solutions. Consequently, these directives mandate that the Services shall provide systems fully capable of operating in the "Joint" environment.

A.5. (3) Discussion

ASN (RDA) CHENG is responsible for establishing the policies, processes, and relationships among Naval Stakeholders for collaborative Naval capability evolution planning, capability

(SoS) engineering, and capability portfolio execution. This involves assessment of the current Naval operational capabilities inherent within the existing Naval Force, as well as, future capabilities expected to be gained from programmed and forecasted science, technology, and acquisition roadmaps.

ASN (RDA) CHENG developed the Naval Capabilities Evolution Process (NCEP) Guidebook, reference (h), to support the acquisition community in implementing capability-based acquisition and systems engineering in accordance with reference (a). The NCEP Guidebook will ensure an integrated and interoperable Naval force by guiding the systems engineering of the capabilities delivered by a FoS or SoS. SE IPTs are the preferred mechanism to work across individual system boundaries to achieve capability objectives in an incremental or evolutionary acquisition manner. SE IPTs are responsible for developing and maintaining FoS/SoS architectures in the form of operational system and technical architectures, standards, protocols, and processes in accordance with references (a) through (k).

A.6. (4) Action

Enclosures (1) through (3) describe ASN (RDA) CHENG's involvement with established FoS/SoS SE IPTs from initiation until the capability associated with the FoS/SoS is mature enough to no longer require the SE IPT to manage it, the responsibility for managing the capability is re-assigned, or the capability is no longer required. The first enclosure describes the prioritization process of eligible SE IPTs. Enclosure (2) provides the steps to organize and charter an SE IPT. Enclosure (3) provides a preliminary transition plan to disband an SE IPT when it is no longer required.

Nehal M. Shah
Director, Systems Engineering
ASN (RDA) CHENG

Enclosure 1 to Appendix A

SE IPT Identification and Prioritization Process

1.0 Overview.

This enclosure describes a preliminary methodology that ASN (RDA) CHENG will utilize to identify and prioritize potential SE IPTs for ASN RDA**.** Prioritization of potential SE IPTs by ASN RDA CHENG will be based on the following criteria:

1) The potential to efficiently provide "value-added" to OPNAV's Naval Capability Development Process (NCDP).
2) The Integration and Interoperability challenge associated with the desired SoS Capability.
3) The distribution of the SoS program offices among the PEOs, DRPMs, SYSCOMS, and laboratories.
4) The complexity of emerging joint concepts of operation which demand new Joint/Naval operational architectures that will evolve into new functional and physical architectures.

This methodology will continually be employed as a means of providing ASN (RDA) CHENG with recommendations on where new SE IPTs need to be established and to provide the rationale for SE IPT formation. Additionally, the analysis performed during the prioritization of SE IPTs will form the basis for the SE IPT charter, objectives, and Plan of Action and Milestones (POA&M).

2.0 Objectives.

The objectives are to:

- Monitor the identification of Naval and Joint capability gaps and shortfalls as described in paragraph 4.3 and determine if a SoS or FoS solution is required to fill the gap or shortfall.
- Respond to Integration and Interoperability deficiencies identified by OPNAV, CFFC, or experimentation.
- Select candidate SE IPTs for prioritization.
- Develop a methodology for SE IPT prioritization.
- Apply the methodology and prioritize SE IPTs including all stakeholders.
- Designate as "Special Interest" the prioritized SE IPTs.

3.0 Relationship to other efforts.

The SE IPT will include the appropriate PEOs, PMs, OPNAV, and related acquisition stakeholders to ensure that the SE IPT constituency involves warfighters, resource sponsors, and acquisition community representatives. In addition, on-going SE IPTs will be reviewed to capture best practices and lessons learned for institutionalization and incorporation in future SE IPTs.

3.1 OPNAV Coordination. Coordination of the SE IPT(s) and OPNAV's NCDP activities is needed to allow for the most efficient use of resources and to determine optimal solutions. OPNAV (N70) conducts Capabilities Assessment(s) for each POM cycle and ultimately becomes a key stakeholder in each SE IPT to ensure that the resource sponsors agree on how the proposed solution will be resourced. With a significant amount of data, tools, and personnel in common, the system engineering efforts of the SE IPT and the investment strategy of OPNAV can be coordinated to produce useful results to the Combatant Commanders.

3.2 Joint/Other Service/Coalition Support. Joint and other Service activities must be considered to ensure that Naval FoS and SoS integrate seamlessly with joint and potential coalition forces.

3.3 Naval Collaborative Engineering Environment (NCEE).
SE IPTs rely heavily on accurate and current data to support their activities and goals. Within ASN RDA CHENG, the NCEE will facilitate the collaborative engineering design and assessment efforts of the SE IPT.

4.0 Purpose.
The purpose of the SE IPT identification and prioritization process is to identify potential SE IPTs, to eliminate those determined not to be feasible, and then to develop a methodology for prioritizing the remaining SE IPTs for ASN (RD&A) consideration.

4.1 Organization. SE IPT prioritization process is being developed and managed by the Director, Systems Engineering. The process development will involve representatives from appropriate ASN RDA CHENG Directorates and necessary support personnel.

4.2 Work Breakdown Structure. Provide a logical sequence of tasks required to conduct this process in a recurring fashion in the following format:

Task Number	Task	Description	Start	Finish	Milestones/ Deliverables	Dates

In addition, the first three levels of the WBS should be drafted as the generic template for the process. Use the remainder of 4.3 and 4.4 to build the WBS - The WBS identifies the work to be performed, the schedule & milestones, and manpower, resources, travel and other costs to perform he work.

4.3 Identify and prioritize potential SE IPTs for RD&A CHENG participation.

4.3.1 Collect SE IPT Candidates. Consider the spectrum of Naval and Joint programs to include (at a minimum):

- ASN RD&A directed/special interest programs
- CNO Priorities

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- OSD/ Joint interest
- Naval FoS/SoS
- Mission Capability Portfolios (MCP/NCP)
- Legacy Systems
- ACAT Listing Candidates
- ONR FNC Candidates
- Advanced Concept Technical Demonstrations (ACTDs)

4.3.2 Conduct feasibility study to identify potential SE IPTs. After collecting potential SE IPTs, determine if there are any programs that will not benefit from an SE IPT. Develop criteria for not accepting programs.

4.3.3 Collect supporting data pertinent to SE IPT prioritization. Assemble data meaningful to the prioritization process by utilizing existing databases as feasible to populate the database(s).

4.3.4 Identify the areas to be addressed and products required. Determine the SE IPT goals that will be stated to concerned stakeholders. This will serve as the baseline and departure point for SE IPT discussions and socialization.

4.3.5 Consider "Value-Added" of SE IPT management. Consider the "pros and cons" of pursuing an SE IPT and whether it is worth the investment in time, money, talent, etc. Prepare ASN (RDA) CHENG decision brief for each potential SE IPT.

4.3.6 Identify SE IPT "Stakeholders." Determine commands, organizations, activities, laboratories, etc. that will have an impact on SE IPT proceedings and develop POCs.

4.3.7 Define the SE IPT Organization. Draft a preliminary organization for vetting with stakeholders; determine working group leadership, organization, etc.

4.3.8 Socialize SE IPT with Stakeholders. Determine the stakeholders' interest/support in pursuing an SE IPT, determine if there is universal support for this project, and determine if the project will benefit from an SE IPT process. Determine if the proposed areas to be addressed and required products are feasible and meet their needs.

4.3.9 Draft the SE IPT prioritization process. Define a prioritization process that considers the spectrum of Naval FoS/SoS portfolio of systems (e.g., Land Attack, TBMD, and Ship Self-Defense) systems engineering activities. The purpose of this process is to guide the SE IPT prioritization process towards portfolios where ASN RDA CHENG involvement can provide value added towards an integrated, net-centric warfare development of capabilities that is consistent with the Joint Chiefs and CNO objectives for an integrated force.

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4.3.10 Prioritize SE IPTs. Utilizing the framework established above, prioritize the potential SE IPTs for consideration.

4.3.11 Determine funding feasibility. Recognizing the funding constraints inherent in today's fiscal environment, review the SE IPT priority list with respect to the costs inherent in conducting an SE IPT, and determine where we will achieve the best return for our investment.

4.3.12 Provide Recommendation(s) to ASN (RDA) CHENG. Having fused the priority listing with available funding, develop and provide a recommended listing for consideration to ASN RDA CHENG.

4.3.13 Brief ASN RDA CHENG Leadership. Provide a brief on the purpose, scope, and reasoning on the prioritized list to ASN (RDA) CHENG leadership.

4.3.13 Coordinate with Naval and External Stakeholders. Coordinate the prioritized list with the Naval acquisition community and external stakeholders, including ASN RDA staff and DASNs, PEOs, SYSCOMS, OPNAV, MCCDC/HQMC, JFCOM, OSD AT&L.

4.3.15 Reconcile the prioritized list as necessary. Adjudicate disparities in opinion between Stakeholders.

4.3.16 Define the SE IPT Charter. Draft the Charter letter and outline the SE IPT leadership, goals, organization, Funding (if appropriate) and authority.

4.3.17 Provide the Recommended SE IPT list and "authorizing letter" to ASN (RD&A) for signature/release. ASN (RDA) CHENG provides ASN RD&A a prioritized list of SE IPTs (achievable within funding constraints) for designation as "special interest." In this package, forward, for ASN RD&A approval and signature, an authorization letter assigning ASN (RDA) CHENG as co-chair of the SE IPTs.

4.3.18 Stand-up the SE IPT upon ASN (RD&A) approval. Organize and hold the first meeting and outline the goals. Conduct follow-on training to SE IPT stakeholders/participants.

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4.4 Schedule & Milestones.

Task	Milestone Date
Complete SE IPT Candidate collection	XX XXX, '06
Complete quick feasibility study to determine	
likely SE IPT candidates	XX XXX, '06
Complete supporting data collection, pertinent to	
SE IPT prioritization	XX XXX, '06
Identify the Areas to be addressed and products required	XX XXX, '06
Complete development of "Value-Added" of SE IPT management	XX XXX, '06
Identify SE IPT "Stakeholders"	XX XXX, '06
Define the SE IPT Organization	XX XXX, '06
Socialize SE IPT with Stakeholders	XX XXX, '06
Draft the SE IPT prioritization process	XX XXX, '06
Prioritize the SE IPTs	XX XXX, '06
Determine funding feasibility	XX XXX, '06
Provide Recommendation(s) to ASN RDA CHENG	XX XXX, '06
Brief CHENG Leadership	XX XXX, '06
Coordinate the prioritized list with Naval and	
External Stakeholders	XX XXX, '06
Reconcile the prioritized list as necessary	XX XXX, '06
Define the SE IPT Charter	XX XXX, '06
Provide the Recommended SE IPT list and "authorizing letter" to ASN (RD&A) for signature/release	XX XXX, '06

4.5 Cost Summary.

- **Personnel Costs.**
  - Establish SE IPT process/methodology **TBD $K**
  - Conduct SE IPT prioritization activities **TBD $K**
- **Materiel Costs.**
  - SE IPT Support **TBD $K**
- **Other Costs.** **TBD $K**
- **Total Costs.** **TBD $K**

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4.5.5 Projected Cost Summary.

Task Number	Task	Cost Item			Projected Cost
		Person & Organization	Material	Other	

4.6 SE IPT Identification and Prioritization Products.

- List of SE IPT Candidate
- Initial feasibility study (s)
- SE IPT prioritization data
- List of areas to be addressed and products
- List of "Value-Added" of SE IPT
- SE IPT "Stakeholders"
- Draft SE IPT Organization
- Draft SE IPT prioritization process
- Prioritized list of potential SE IPTs
- Draft brief for CHENG Leadership
- Reconciled prioritized list of SE IPT candidates
- Draft SE IPT Charter(s) and ASN (RDA) authorization memo(s)

Enclosure 2 to Appendix A

SE IPT Organization and Start-up Process

Overview.

This enclosure will describe a preliminary methodology for ASN (RDA) CHENG to organize and start-up an SE IPT. This will be used as a Plan of Action and Milestones to further refine the SE IPT activities based on specific goals.

Objectives.

The objectives are to:

1. Establish a preliminary methodology for SE IPT start-up.
2. Provide guidance for selecting the optimal SE IPT participation and leadership.
3. Develop a methodology for SE IPT organization.
4. Establish SE IPT basic Level of Knowledge.
5. Develop needed SE IPT products.
6. Support the FoS/SoS as determined by the Resource Sponsor.

3.0 Purpose.

The process will provide a preliminary template in the form of a plan of action and milestones (POA&M) or steps that can be used to standup an SE IPT.

4.0 Organization.

SE IPT start-up will be managed by the Director, Systems Engineering. It may initially require a representative from each of the ASN (RDA) CHENG Directorates. The following is the initial list of representative assignments identified to contribute to the project:

- **SE IPT Chair** – An appointed position which will typically be the Senior PEO, DRPM, PM, or the largest funded Program manager, or the PEO, DRPM, PM with the most significant role in the SoS capability being acquired. The Chair is responsbile for establishing the SE IPT POA&M, for ensuring the SE IPT has proper stakeholder representation, and for socializing the SE IPT products, results, and recommendations throughout the stakeholder community.

- **SE IPT Co-Chair** – An assigned representative from ASN (RDA) CHENG initially, and reverting to a representative from an appropriate participating organization (e.g., CHENG of the lead SYSCOM). The Co-chair is the lead technical authority for leading the SE IPT in executing the Naval Capability Evoltion Process.

- **SE IPT Lead, Capability Evolution Planning** – An assigned position typically lfilled by the stakeholder most be involved in the JCIDS process as it relates to the capability being acquired and evolved. This individual is responsible for being a liaison with the AoA authority and will lead the SE IPT in the development, maintenance, and promulgation of the Capability Evolution Plan, as it evolves over time.

- **SE IPT Lead, Capability (SoS) Engineering** – An assigned position typically filled by the senior engineer from the PEO, DRPM or Program who has the most significant role in the SoS capability being acquired. The Capability (SoS) Engineer is responsible for developing the engineering models (operational, functional, and physical) that are needed to support trade sudies, Intergration and Interoperability analyses. The Capability (SoS) Engineer is responsible for establishing the functional and allocated SoS baselines, and for developing and promulgating the System Performance Document.

- **SE IPT Lead, Portfolio Manager** – An assigned position typically filled by the stakeholder most involved in the PPBES or Acquisition Roadmap development efforts. The Portfolio Manager is the SE IPT lead for developing the SoS Acquisition schedule, assess risks, and representing the SE IPT at program milestone reviews. The Portfolio Manager is the SE IPT for developing responses to ASN RDA CHANG or other acquisiton organizations to address impacts of the SoS capability as a result of proposed program cancellations, delays, funding reductions, or other acquisition related decisions.

- **SE IPT Operational Architect** – An appointed position typically filled by the stakeholder most involved in the conduct of Naval Operations. Responsible for the development of the SoS Operational Architecute by mapping the Joint Integrating Concepts to Naval Concepts of Operations, to missions and mission threads, and capturing how the Force Package organizational elements collaborate to conduct the missions. The Operational Architect is responsible for the maintenance of the Operational Architecture database, and the generation of the necessary DODAF Operational Views from this database.

- **SE IPT System Architect** – An appointed position typically filled by the lead PEO, DRPM, or Syscom. The System Architect is responsible for the development of the SoS System Architecute which encompases the functional and physical architectures and maintains the allocation of functions among the hardware, software and personnel. The System Architect is responsible for the maintenance of the System Architecture database, and the generation of the necessary DODAF System and Technical Views from this database.

- **SE IPT NetCentric Manager** – An appointed position typically filled by the lead SPAWAR representative to the SE IPT. Responsible for leading the development of the SoS Net-ready KPPs and the Integation and Interoperability assessments as it relates to the Naval C4ISR infrastructure. Ensures that the portfolio of acquisition programs are being properly developed to satisfy NetCentric certification requirments.

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- **SE IPT Life-cycle Cost Analysts –** An appointed position fulfilled by the lead PEO, DRPM, PM, or Syscom. The Life-cycle Cost Analysts is responsible for leading the cost analysis and trade-offs as it applies to Acquisiton, Personnel (manning), Production, Operations, and Support of the Portfolio of Acquisition Programs. Responsible for the development of the Portfolio Investment Roadmap Section of the Capability Evolution Plan, and maintaining alignment between this roadmap and the resources reflected in the POM and President's budget.

4.1 Work Breakdown Structure.

Provide a logical sequence of tasks or steps required to complete this effort in following format:

Task Number	Task	Description	Start	Finish	Milestones/ Deliverables	Dates

In addition, the first three levels of the WBS should be drafted as the generic template for the process. Use the remainder of 4.2 and 4.3 to build the WBS. The WBS identifies the workd to be performed, the schedule and milestones, and manpower, resources, travel and other costs to perform the work.

4.2 SE IPT Startup.

4.2.1 Stand up initial SE IPT meeting. Using the draft Charter and ASN (RD&A) authorization letter (products of the SE IPT Prioritization Process in Enclosure (1)), invite stakeholder representatives identified during SE IPT Prioritization Process to participate. The membership will vary between Capability Evolution Planning, Capability Engineering and Portfolio Execution processes. Participants will include program office (government and industry), SYSCOM personnel that support the portfolio programs, and the resource sponsors and fleet personnel representing the warfighter.

4.2.2 Refine areas to be addressed and products required. During SE IPT Prioritization Process, areas were drafted. Once ASN (RDA) CHENG has established a particular SE IPT, involved stakeholders may wish to refine the scope of the SE IPT and further define expected product outputs. As the SE IPT scope is refined, additional SE IPT members may be required from newly-identified stakeholders. At this point, the SE IPT Chair will be responsible for developing a draft Systems Engineering Plan that includes formal technical reviews and decision points.

4.2.3 Refine SE IPT organization. The draft Charter contained a preliminary SE IPT organization, which may require modification as a result of changes to SE IPT scope and Stakeholders. The SE IPT should be organized around key issues and risks identified in the SEP. Define working groups as necessary and identify leadership. During this process an SE IPT co-chair should be identified as the systems engineering representative of the major Stakeholder (i.e., the major program represented within the FoS/SoS).

4.2.4 SE IPT Roles. SE IPT members play two roles: first, they perform the work necessary to execute the plans and build the SE IPT products, and second, they represent their organizational interests within the SE IPT. Thus in the case of portfolio program members, they are expected to bring knowledge and expertise to perform engineering and analytical analyses, they are expected to make the SE IPT aware of decisions that may adversely affect their programs, and they are expected to keep their Program Managers aware of the effect of SE IPT actions on their program. In the case of members representing resource sponsors and the fleet, they must ensure that the SE IPT analyses are based on current operating doctrine and consistent with the NCDP guidance. In assigning roles, include the designation of a transition agent to assume SE IPT leadership when ASN (RDA) CHENG withdraws from SE IPT participation.

4.2.5 Obtain funding. Once a draft SEP is developed and the SE IPT organization is refined, stakeholders should provide funding for their participation in SE IPT operations in accordance with an agreed upon plan of SE IPT activities, products, schedule and resource requirements.

4.2.6 SE IPT Activities and Products. SE IPT activities will specifically focus on executing the NCEP Capability Evolution Planning, Capability Engineering, and Portfolio Execution processes. The conduct of these technical activities will necessitate extensive interaction and coordination across the organizations and programs responsible for acquiring, delivering and supporting the systems within the acquisition portfolio. The SE IPT serves as a forum for vetting and resolving the FoS/SoS cross-cutting issues within the portfolio.

Specific products to be generated by the SE IPT include:

- Portfolio System Engineering Plan
- Current, Planned, and Objective Portfolio Architectures
- Capability Evolution Plan
- System Performance Document
- Force Package Operational Model
- Portfolio Functional Model
- Portfolio Physical Model
- Portfolio Qualification Requirements
- Integration and Interoperability Test Matrix
- Portfolio Integrated Schedule
- Portfolio Assessments
- Portfolio Functional Model

4.2.7 SE IPT (Peer) level reviews of FoS/SoS Programs. The purpose of the SE IPT review is to vet technical issues and related impacts on the individual program costs and schedule. This allows Program Managers to challenge technical decisions made by the SE IPT and present recommend alternatives. SE IPT decisions may affect the allocation of functions, performance constraints (e.g., error budgets and time allocations) and the interface requirements between portfolio systems that may also affect cost and/or schedule. Program Managers, resource sponsors, and fleet stakeholders will participate in advising the SE IPT Chair.

4.3 Schedule & Milestones.

Task	Milestone Date
ASN RD&A Authorization Letter signed/released	*XX XXX, '06*
Conduct Initial SE IPT standup meeting	*XX XXX, '06*
Refine areas to be addressed and expect output products	XX XXX, '06
Refine SE IPT organization	XX XXX, '06
Draft Systems Engineering Plan	XX XXX, '06
Obtain funding	XX XXX, '06
Conduct SE IPT (Peer) reviews	As required
Draft Planned Portfolio Architecture	XX XXX, '06
Draft Objective Portfolio Architecture	XX XXX, '06
Draft Capability Evolution Plan	XX XXX, '06
Draft System Performance Document	XX XXX, '06
Develop Integrated Architecture Model	XX XXX, '06
Develop Portfolio Functional Design Model	XX XXX, '06
Develop Portfolio Physical Design Model	XX XXX, '06
Development Portfolio Qualification Requirements	XX XXX '06
Develop Integration and Interoperability Test Matrix	XX XXX, '06
Develop Portfolio Integrated Schedule.	XX XXX, '06
Conduct Portfolio Assessments	XX XXX, '06

4.4 Cost Summary.

- **Personnel Costs.**
  - Establish SE IPT process/methodology **TBD $K**
  - Conduct SE IPTs **TBD $K**
- **Materiel Costs.**
  - SE IPT Support **TBD $K**
- **Other Costs.** **TBD $K**
- **Total Costs.** **TBD $K**
- **Projected Cost Summary.**

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Task Number	Task	Cost Item			Projected Cost
		Person & Organization	Material	Other	

4.5 SE IPT Products.

- Portfolio System Engineering Plan (SEP)
- SE IPT (Peer) Review Decisions
- Risk Identification and Management
- Current, Planned, and Objective Portfolio Architectures
- Capability Evolution Plan
- System Performance Document
- Force Package Operational Model
- Portfolio Functional Design Model
- Portfolio Physical Design Model
- Portfolio Qualification Requirements
- Integration and Interoperability Test Matrix
- Portfolio Integrated Schedule
- Portfolio Assessments

Enclosure 3 to Appendix A

SE IPT Transition Process

1.0 Overview.

This enclosure describes a preliminary methodology for ASN (RDA) CHENG to transition its role as co-chair or to effect disestablishment of the SE IPT itself. The concept of operations for FoS/SoS SE IPTs is for ASN (RDA) CHENG to co-chair the establishment of the SE IPT during its early operations and to withdraw from this role once the SE IPT operations have been established. This Section will provide the guidelines for the orderly transition of the SE IPT co-chair. In the contrary instance wherein the stakeholder commitment to the SE IPT is not sufficient to sustain operations, either through a lack of stakeholder representation or funding, it would be necessary to draw down SE IPT activities and disestablish it, with the concurrence of ASN (RDA) CHENG.

ASN (RDA) CHENG will relinquish its role as the SE IPT co-chair when the following criteria are achieved:

1. The predetermined transition milestone date has arrived, or

2. The SE IPT has an approved Capability Evolution Plan, and
3. The SE IPT has an approved System Performance Document, and
4. The SPD Allocated Baseline has been properly resourced in the POM, or

5. The ASN RDA Chief Engineer determines that the participating stakeholders are not productively working towards the achievement of items 2-4 and further expenditure of resources in support of the SE IPT is futile.

2.0 Objectives.

The objectives of this project are to:

1. Provide a high-level description of SE IPT Systems and their related FoS/SoS.
2. Document historical, relevant information
3. List key players with contact information
4. Provide current/effective charters/Memorandum of Agreements/Memorandum of Understandings (MOA/MOU).

3.0 Purpose.

The process will provide a preliminary template in the form of a plan of action and milestones (POA&M) or steps that can be used to transition the co-chair of the SE IPT from ASN (RDA) CHENG to an appropriate organization (e.g., the lead SYSCOM).

4.0 Organization

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4.1 Project Organization. SE IPT transition will be managed by the Director, Systems Engineering. It may require a representative from each of the ASN (RDA) CHENG Directorates. The following is the initial list of representative assignments identified to contribute to the project:

SE IPT Co-Chair
SE IPT Coordinator

4.2 Work Breakdown Structure.
Provide a logical sequence of tasks or steps required to complete this effort in the following format:

Task Number	Task	Description	Start	Finish	Milestones/ Deliverables	Dates

In addition, the first three levels of the WBS should be drafted as the generic template for the process. Use the remainder of 4.3 and 4.4 to build the WBS. The WBS identifies the work to be performed, the schedule and milestones, manpower, resources, travel, and other costs to perform the work.

4.3 Transitioning the SE IPT.

4.3.1 Transitioning the SE IPT from ASN RDA CHENG Co-Chair Role

4.3.1.1 Background. A FoS/SoS SE IPT has been established and activities are well established. ASN (RDA) CHENG provides the SE IPT co-chair and the major Stakeholder provides a systems engineering chair. Continued SE IPT activities are desired, the required resources are established, and it has been decided that ASN RDA CHENG will transition from the co-chair to a participatory role.

4.3.1.2 Management Approach. SE IPT activities will continue uninterrupted. A change of management focus may be required by the change in SE IPT co-chair. However, the focus of the transition will be on organizational changes required to effect the transition. It is not anticipated that a change in the SE IPT co-chair will result in any changes to required SE IPT funding or membership.

4.3.1.5 Coordinate Transition Planning Meeting.

4.3.1.4 Coordinate transition with major Stakeholders. Identify the stakeholders and develop a formal agreement between them to continue operations with the new co-chair. This may be accomplished during normal SE IPT meetings.

4.3.1.5 Develop Transition Task List. Identify project activities to be completed before transition can begin. Determine transition timeline. Establish transition milestones.

4.3.1.6 Brief ASN RDA CHENG Leadership. Provide a brief on the transition plan to ASN RDA CHENG leadership.

4.3.1.7 Coordinate the transition plan with Naval and External Stakeholders. Coordinate the transition plan with the SE IPT Stakeholders, including ASN RDA CHENG staff and affected DASNs, PEOs, SYSCOMS, OPNAV, MCCDC/HQMC, JFCOM, OSD AT&L. This coordination may be conducted via the SE IPT membership to their respective Stakeholders.

4.3.1.8 Revise the SE IPT Charter. Revise the Charter if necessary and submit to ASN RD&A for approval/signature.

4.3.2 Transitioning the SE IPT to Cease Activities

4.3.2.1 Background. A FoS/SoS SE IPT has been established and activities are well underway. ASN RDA CHENG provides the SE IPT co-chair and the major Stakeholder provides a systems engineering chair. Continued SE IPT activities are no longer desired, either because funding has not been provided to continue SE IPT activities or because Stakeholder support has been withdrawn. It has been decided that the SE IPT should transition from active operations.

4.3.2.2 Management Approach. SE IPT activities will cease, with the timeline dependent on the reason for the termination decision and available funding/participation remaining. Focus of the transition will be on documenting SE IPT work to date and archiving of work products.

4.3.2.3 Coordinate Transition Planning Meeting.

4.3.2.4 Confirm Remaining/Available Funding. Verify available funding data, including restrictions on when funding must be expended or will be recouped.

4.3.2.5 Develop Transition Task List. Identify project activities to be completed before SE IPT activities are terminated. Determine the transition timeline. Establish the transition milestones.

4.3.2.6 Establish Roles & Responsibilities. Determine SE IPT roles and responsibilities required for termination as well as identify those personnel required to perform those functions. Assign transition support staff.

4.3.2.7 Additional Transition Tasks. Identify the IPT products to include as a minimum an AV-1. Describe system documentation and how information is stored and accessed. Describe the system documentation and how information is stored and accessed. Include details on where documentation is stored and how it is accessed to include: Architecture products, the Collaborative Environment, Modeling and Simulation products, Interoperability and Integration assessments, System Performance Documents, System Engineering Plans, Information Support Plans, JCIDS products, and all lessons learned

4.3.2.8 Brief ASN RDA CHENG Leadership. Provide a brief on the transition plan to ASN RDA CHENG leadership.

4.3.2.9 Coordinate the transition plan with Naval and External Stakeholders. Coordinate the transition plan with the SE IPT stakeholders, including ASN RDA CHENG staff and affected DASNs, PEOs, SYSCOMS, OPNAV, MCCDC/HQMC, JFCOM, and OSD AT&L. This coordination may be conducted through the SE IPT membership to their respective stakeholders.

4.3.2.10 Draft SE IPT disestablishment letter. Draft a letter disestablishing the SE IPT and submit to ASN (RDA) CHENG for approval/signature.

4.4 Schedule & Milestones.

Task	Milestone Date
Conduct SE IPT transition planning meeting	XX XXX, ‘XX
Coordinate transition with major Stakeholders (if required)	XX XXX, ‘XX
Confirm Required/Remaining Funding	XX XXX, ‘XX
Develop Transition Task List	XX XXX, ‘XX
Establish Roles & Responsibilities	XX XXX, ‘XX
Develop and obtain necessary training (if required)	XX XXX, ‘XX
Identify IPT products to be archived	XX XXX, ‘XX
Describe system documentation archive	XX XXX, ‘XX
Brief ASN RDA CHENG Leadership	XX XXX, ‘XX
Coordinate the transition plan with Naval and External Stakeholders	XX XXX, ‘XX
Determine funding feasibility	XX XXX, ‘XX
Provide Recommendation(s) to ASN RDA CHENG	XX XXX, ‘XX
Brief CHENG Leadership	XX XXX, ‘XX
Coordinate the prioritized list with Naval and External Stakeholders	XX XXX, ‘XX
Revise the SE IPT Charter (if required)	XX XXX, ‘XX
Draft SE IPT disestablishment letter (if required)	XX XXX, ‘XX

Enclosure 3 to Appendix A

4.5 Cost Summary.

- **Personnel Costs.**
  Establish SE IPT process/methodology **TBD $K**
  Conduct SE IPTs **TBD $K**
- **Materiel Costs.**
  SE IPT Support **TBD $K**
- **Other Costs.** **TBD $K**
- **Total Costs.** **TBD $K**
- **Projected Cost Summary.**

Task Number	Task	Cost Item			Projected Cost
		Person & Organization	Material	Other	

4.6 SE IPT Products.

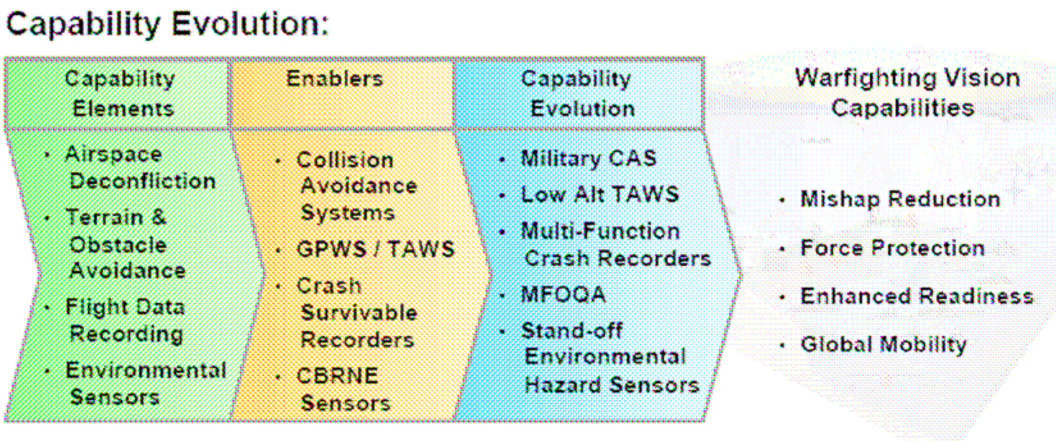
- SE IPT Transition Plan and Task List.
- Stakeholder agreements (if required)
- Funding revisions/plan
- SE IPT product archive plan
- SE IPT Charter revision (if required)
- SE IPT Disestablishment Letter (if required)

Appendix B: Core Avionics Master Plan (Appendix A-5, Flight Safety)

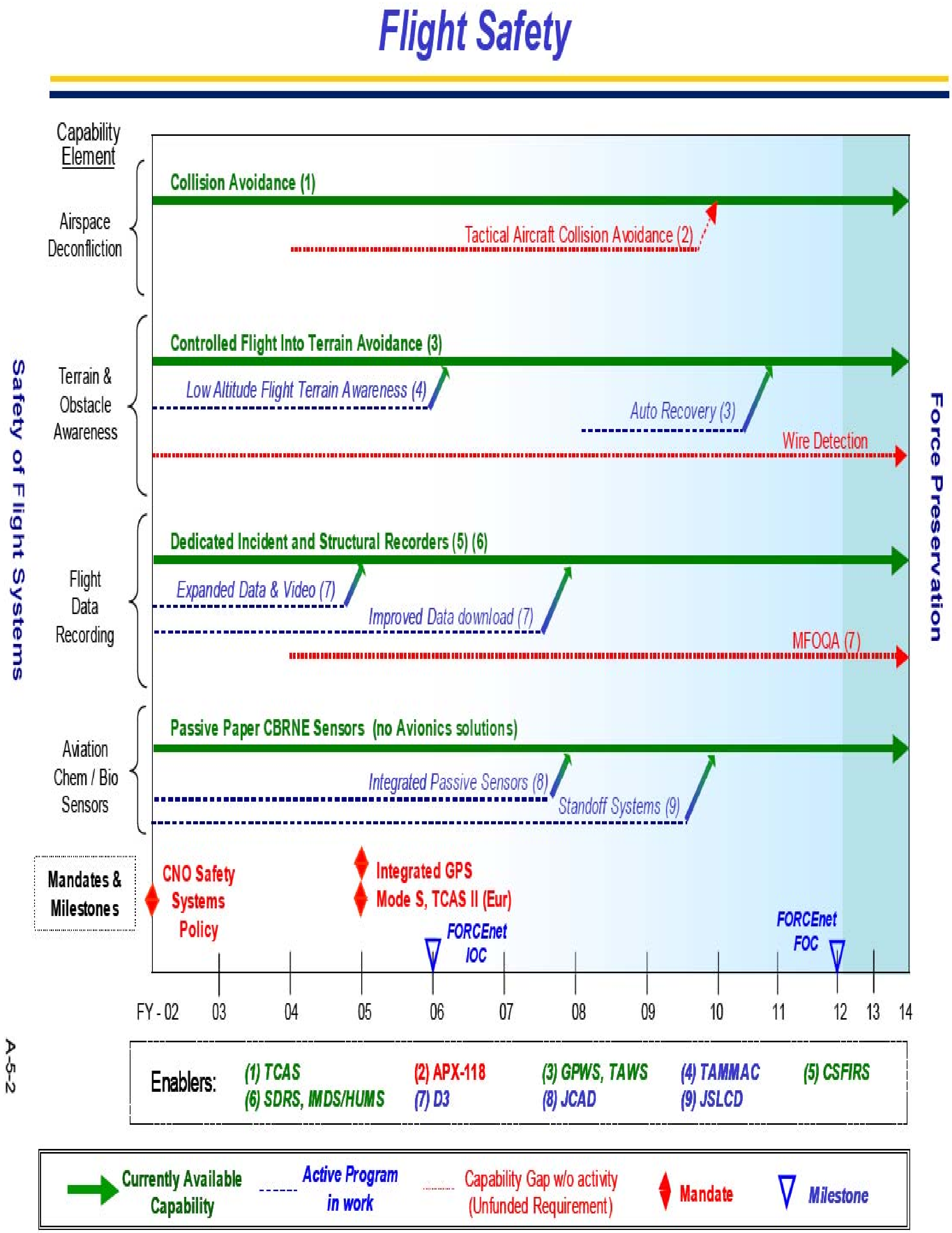
This appendix is provided as an alternate example of the construction of a Capability Evolution Description (see Section 3.6).

B.1. Flight Safety

Scope. Avionics that provide airspace deconfliction or collision avoidance, terrain awareness, flight incident operational parameter recording, aircraft maintenance diagnostics systems and aircrew protection from Chemical, Biological, Radiological, and Nuclear Environmental (CBRNE) threats.



Baseline to Vision Transition. Naval Aviation currently follows rigorous policy and aggressively implements safety systems considered necessary to minimize mishaps. There are mandated safety system requirements for new production, remanufactured and transport aircraft. Additional safety systems are considered for integration based upon aircraft operational performance, mission risk and available resources. While commercial safety systems offer potential solutions to some aircraft, these systems will not operate effectively in all tactical flight regimes. Research and development initiatives have been established to address these requirements. Furthermore, Naval Aviation is analyzing the benefits of operational concepts such as Military Flight Operations Quality Assurance (MFOQA), which supports pro-active management of flight performance information to prevent failures and mishaps. MFOQA would leverage data collected in existing safety equipment and perform additional analysis to identify unsafe trends or impending hazards. Flight safety systems need to be interoperable with Joint and Allied forces, civil and national authorities and regional civil aircraft. Flight safety equipment can enable platforms to meet Sovereign Airspace Communications, Navigation, Surveillance / Air Traffic Management (CNS/ATM) compliance requirements to support Global Mobility. Mishap reduction directly enhances aircraft availability and squadron Operational Readiness. This version of the CAMP has been expanded to cover environmental sensors as core avionics equipment. CBRNE sensors are used to protect the aircrew in hazardous environments and will be used to enhance Force Protection by warning other warfighters of battlespace dangers. The operational concept of Full-Dimensional Protection includes equipping weapons systems with capabilities that support safe operations in war and peacetime operations.


Flight Safety
Capability Element
Airspace Deconfliction
Collision Avoidance (1)
Tactical Aircraft Collision Avoidance (2)
Terrain & Obstacle Awareness
Controlled Flight Into Terrain Avoidance (3)
Low Altitude Flight Terrain Awareness (4)
Auto Recovery (3)
Wire Detection
Flight Data Recording
Dedicated Incident and Structural Recorders (5) (6)
Expanded Data & Video (7)
Improved Data download (7)
MFOQA (7)
Aviation Chem / Bio Sensors
Passive Paper CBRNE Sensors (no Avionics solutions)
Integrated Passive Sensors (8)
Standoff Systems (9)
Mandates & Milestones
CNO Safety Systems Policy
Integrated GPS
Mode S, TCAS II (Eur)
FORCEnet IOC
FORCEnet FOC
FY - 02
03
04
05
06
07
08
09
10
11
12
13
14
Safety of Flight Systems
Force Preservation
A-5-2
Enablers:
(1) TCAS
(2) APX-118
(3) GPWS, TAWS
(4) TAMMAC
(5) CSFIRS
(6) SDRS, IMDS/HUMS
(7) D3
(8) JCAD
(9) JSLCD
Currently Available Capability
Active Program in work
Capability Gap w/o activity (Unfunded Requirement)
Mandate
Milestone

B.2. Guidance, Mandates and Milestones

CNO Flight Safety Systems Policy. (Nov 1999) OPNAV Memorandum. Directs incorporation of specified flight safety systems into the following categories of Naval Aviation platforms:

- New Production and Remanufactured aircraft shall be delivered equipped with Crash Survivable Flight Incident Recorder (CSFIR), integrated GPS, Ground Proximity Warning System (GPWS), Collision Avoidance System (CAS) and Integrated Maintenance Diagnostic System (IMDS).
- Aircraft with a primary mission of passenger or troop transport shall be equipped with commercial standard CSFIR, integrated GPS, GPWS and CAS for comparable civilian aircraft.
- All other aircraft (legacy tactical, secondary mission transport, and trainers) shall be equipped with avionics safety systems as prioritized during budget development. Factors considered in allocating resources toward these systems include preservation of life, aircraft mission profile, safety record, enhancement of safety, difficulty of integration, integration and retrofit cost, force structure, expected service life remaining, and availability of resources.

GPS Integration. (Sep 2005) Public Law, Defense Authorization Act. "After Sep 30, 2005, funds may not be obligated to modify or procure any DoD aircraft, ship, armored vehicle, or indirect-fire weapon system that is not equipped with a GPS receiver." As of Mar 04, more than 95% of Naval aircraft had incorporated embedded GPS receivers.

Traffic Awareness and Collision Avoidance System (TCAS II). (Jan 2000) European Air Traffic Control mandate. All civil aircraft carrying more than 30 passengers are required to have TCAS II for access to European airspaces. TCAS II is equivalent to commercial Aircraft Collision Avoidance Systems (ACAS). Beginning January 2005, the mandate will apply to all civil aircraft carrying more than 19 passengers. NATO has agreed that military transport aircraft will work to incorporate this functionality for access to European airspaces by January 2005.

B.3. Capability Element Evolution

Airspace Deconfliction. Aircraft midair collision avoidance is a function of awareness of adjacent traffic and tracking relative movement. On-board navigation equipment and coordination with air traffic control agencies support safe separation in positive control environments.

Current Capability:

TCAS II is the current standard for civil aviation and has been adopted as a COTS solution for most military transport aircraft. TCAS II detects and tracks other aircraft in the vicinity by using the Mode S (Select) waveform to interrogate and reply to other similarly equipped aircraft to determine their position, heading, and altitude. If TCAS II software algorithms determine that collision is imminent, an aural and visual Resolution Advisory (RA) is provided to the pilot to take evasive action. During the RA, TCAS II coordinates vertical maneuvers between the affected aircraft.

Evolutionary Activity:

Tactical Aircraft Collision Avoidance. (2010) State of the art transponders have been designed to facilitate addition of capability to receive and transmit Mode S. If connected to the 1553 databus, the signal can be modified to include GPS position, which greatly enhances position information relative to the radar positioning function performed by standard Mode S. If the signal is constantly broadcast ("squittered"), the resulting information exchange format is called Automatic Data Surveillance - Broadcast (ADS-B), also known as Enhanced Surveillance (see Cooperative Surveillance and Combat ID Section for more details). While primarily designed for air traffic management, this functionality could also provide collision avoidance to combat aircraft whose flight maneuvers cannot be supported by civil systems (TCAS II and ACAS). No program of record has been established to develop and integrate this capability.

Terrain and Obstacle Avoidance. This capability element addresses equipment that provides awareness of proximity with the ground to prevent Controlled Flight Into Terrain (CFIT) mishaps.

Current Capability:

Naval Aviation has incorporated GPWS into some transport and tactical platforms to prevent CFIT mishaps. The system monitors aircraft state, on-board altitude calculation systems and radar altimeter readings. GPWS uses aural warnings to alert the aircrew to impending CFIT. The Terrain Awareness Warning System (TAWS) software algorithms provide predictive CFIT warning capability by comparing aircraft altitude, attitude, and airspeed developed from GPS and/or INS against onboard terrain database information. This capability is only available to those platforms that can host the database and have sufficient processing power to host the TAWS algorithm. The Tactical Aircraft Moving Map Capability (TAMMAC) can host TAWS and eliminate the need for a dedicated GPWS. Aircraft with suitable multifunction displays will be able to graphically indicate a potentially hazardous CFIT condition.

Evolutionary Capability:

Low Altitude Flight Terrain Awareness. (2006) The next spiral development of TAWS plans to deliver capability to support Nap of the Earth (NOE) flight, primarily for helicopters. Higher fidelity digital terrain database information and improved processing capability will be required to support lower altitude flight.

Auto Recovery. (2011) The U.S. Air Force F-16 incorporates the capability for the aircraft to self-recover from out-of-control flight when the pilot has been incapacitated and is not responding to imminent CFIT. The JSF has included this capability requirement in their capabilities document. TAWS is being evaluated as a potential system to contribute to auto-recovery.

Wire Detection. Wire strikes frequently result in Class A mishaps. Industry is making strides in wire detection through advancements in active and passive sensor technologies. Although this is an area of Joint interest, no Naval Aviation program has been established to develop and implement wire detection and avoidance capability.

Flight Data Recording. This capability element addresses equipment that records aircraft maintenance and operational mission performance parameters during flight.

Current Capabilities:

New production and remanufactured platforms are required to incorporate CSFIRS and IMDS capabilities. Digital data and voice recorders are the industry standard. The Naval Safety Center sets standards for critical performance parameters to be recorded, preferred length of time for cockpit voice recording, and proper format for rapid download and analysis capability. Structural Data Recording Sets (SDRS) provide the capability to accurately record and monitor critical component performance in order to maximize the airframe service life of selected fixed wing platforms. Maintenance Data Processing Station (MDPS) Ground Support Equipment (GSE) is used to periodically download SDRS data, which is sent to NAVAIR for analysis. Results are provided back to the Fleet in Structural Appraisal of Fatigue Effects (SAFE) reports. Other aircraft use Health and Usage Monitoring Systems (HUMS) to track component wear and provide warning of impending failures.

Evolutionary Activity:

Expanded Data and Video. (2005) Advancements in digital information recording and miniaturization technology are enabling consolidation of redundant platform structural and mission performance recording systems. The Digital Data Download (D3) CSFIR will meet legacy system requirements and provide full form, fit and functional interchangeability with current crash survivable modules. It is a state of the art, solid state, crash survivable recorder with expanded voice and data recording capabilities and provisions for growth to video recording. D3 will combine separate SDRS and CSFIRS data recording functions into one box. Weight and space savings will improve aircraft performance or make room for additional capability integration.

Improved Data Download. (2008) D3 is developing an improved data download format that will enhance data retrieval and processing. It is a low risk upgrade that leverages commercial data transport advancements. More detail on data transfer technology improvements is available in the Mission Avionics appendix.

MFOQA. MFOQA is a knowledge management process that downloads flight data after every flight and provides quantitative information regarding aircrew and aircraft performance to improve proficiency, procedures, and safety. MFOQA proactively uses aircraft data systems to reduce operational risk. The process serves to identify human error (a causal factor in 80% of aviation mishaps) on a near real-time basis and provides tools to measure the effectiveness of Operational Risk Management (ORM) intervention strategies. MFOQA builds on the success of proven commercial standards utilized by the civilian aviation industry. D3 will support MFOQA data collection and analysis. MFOQA analysis also supports fatigue life monitoring, aircraft maintenance and system troubleshooting, and Mishap Investigations. Although it is considered a primary candidate to meet mishap reduction goals, no formal program has yet been established to develop and implement MFOQA within Naval Aviation.

<u>Chemical, Biological, Radiological, Nuclear & Environmental Detection (CBRNE)</u>. CAMP 2004 has expanded to include this core set of sensors in recognition of the increase in these threats and gains made by survival equipment program managers.

Current Capabilities:

Current technology is limited to protective clothing and portable detection devices with standard first aid kit type antidotes for some types of chemical exposure. Current concepts of operations for managing chemical, biological, radiological, and nuclear effects require advance notification and pre-planning to outfit aircrews with chemical suits and masks. Current technology provides limited passive capability for chemical detection, and primarily consists of taping a paper detector to the windscreen. There are currently no avionics sensors for CBRNE.

Evolutionary Activity:

Integrated Passive Detection. (2006) Unmanned Aerial Vehicles (UAVs) assigned to Chemical Biological Defense (CBD) missions will carry Hyperspectral Imagery (HSI) equipment coupled with laser sensors, or other on-board Chemical Biological (CB) detectors. These platforms will provide point detection information on Chemical Biological Radiological (CBR) hazards and link that data through existing networks to appropriate command and control elements. These capabilities will be transportable to manned aircraft. Sensors will not only characterize the environment, but will also enable aircrews to take appropriate preventive measures to avoid the harmful effects of the hazardous agents.

Stand-Off CBRNE Detection. (2009) Stand-Off sensors are being integrated into Naval Aviation platforms that will be used for CBD missions, enabling equipment or aircrews to remotely characterize hazardous environments without risking exposure.

Appendix C: Definitions

Following each term definition, the originating source of the definition is identified in brackets, unless the term has been originated by this document.

C.1. Terms

Acquisition Portfolio. The subset of the Force Package associated with the military capability identified by the ICD that includes the platforms, facilities. systems, networks, and interfaces which will be acquired, modified, or enhanced.

Analysis of Alternatives. The evaluation of operational effectiveness, operational suitability, and estimated costs of alternative systems to meet a mission capability. (CSCSI 3170.01E)

Analysis of Materiel Approaches. The JCIDS analysis to determine the best materiel approach or combination of approaches to provide the desired capability or capabilities. Though the AMA is similar to an AoA, it occurs earlier in the analytical process. (CJCSI 3170.01E)

Architecture. The structure of components, their relationships and the principles and guidelines governing their design and evolution over time. (JCIDS)

Attribute. A testable or measurable characteristic that describes an aspect of a system or capability. (JCIDS)

Capability (Military). The ability to achieve a specified wartime objective, i.e., win a war or battle or destroy a target set. It includes 4 major components:

(1) force structure: Numbers, size, and composition of the units that comprise defense forces, e.g., divisions, ships, air wings.
(2) modernization: Technical sophistication of forces, units, weapon systems, and equipment.
(3) readiness: The ability of forces, units, weapon systems, or equipment to deliver the outputs for which they were designed (includes the ability to deploy and employ without unacceptable delays).
(4) sustainability: The "staying power" of our forces, units, weapon systems, and equipment, often measured in numbers of days. (JP1.02)

Capability Development Document. A document that captures the information necessary to develop a proposed program(s), normally using an evolutionary acquisition strategy. The CDD outlines an affordable increment of militarily useful, logistically supportable, and technically mature capability. (CJCSI 3170.01E)

Capability Needs. The needs that must be met to ensure a reasonable degree of mission success. (DODAF)

Capability Production Document. A document that addresses the production elements specific to a single increment of an acquisition program. (CJCSI 3170.01E)

Family of Systems. A set or arrangement of systems that provide similar capabilities through different approaches to achieve similar or complementary effects. (CJCSI 3170.01E)

Force Package. An assembly of platforms and facilities (ships, aircraft, submarines, land vehicles, and spacecraft) organized to accomplish specific missions.

Function. A task, action, or activity expressed as a verb-noun combination (e.g., Brake Function: stop vehicle) to achieve a defined outcome. (IEEE 1220)

Functional Architecture. An arrangement of functions and their subfunctions and interfaces (internal and external) which defines the execution sequencing, conditions for control or data-flow, and the performance requirements to satisfy the requirements baseline. (IEEE 1220)

Functional Requirement. A statement which identifies what a product or process must accomplish to produce required behavior and/or results. (IEEE 1220)

Functional Verification. The process of evaluating whether or not the functional architecture satisfies the validated requirements baseline. (IEEE 1220)

Human Systems Integration (HSI). A multi-disciplinary approach to systems engineering and logistics that emphasizes the roles, requirements, provisions, and accommodations of human capabilities and limitations in systems design and development. The aspects of system acquisition that concern humans include: human factors engineering (HFE); manpower, personnel and training (MPT); habitability and quality of life; personnel survivability; and safety and occupational health. (NAVSEA INST 3900.8A)

Initial Capability Document. Documents the need for a materiel approach to a specific capability gap derived from an initial analysis of materiel approaches executed by the operational user and, as required, an independent analysis of material alternatives. (CJCSI 3170.01E)

Information Exchange Requirement. A requirement for information that is exchanged between nodes. (DODAF)

A requirement for information to be passed between and among forces, organizations, or administrative structures concerning ongoing activities. Information exchange requirements identify who exchanges what information with whom, as well as why the information is necessary and how that information will be used. (RDA CHENG)

Interoperability. The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to make use the services, units, or forces and to use the services so exchanged to enable them to operate effectively together. (CJCSI 3170.1E)

Integrated Architecture. An architecture description that has integrated Operational, Systems, and Technical Standards Views with common points of reference linking the Operational Views and the Systems Views, and also linking the Systems Views and Technical Standards Views. An architecture description is defined to be an integrated architecture when products and their constituent architecture data elements are developed such that architecture data elements defined in one view are the same (i.e., same names, definitions, and values) as architecture data elements referenced in another view. (DODAF)

Integrated Data Base. A repository for storing all information pertinent to the systems engineering process to include all data, schema, models, tools, technical management decisions, process analysis information, requirement changes, process and product metrics, and trade-offs. (IEEE 1220)

Joint Capabilities Integrated Development System. Policy and procedures that support the Chairman of the Joint Chiefs of Staff and the Joint Requirements Oversight Council in identifying, assessing, and prioritizing joint military capability needs. (CJCSI 3170.01E)

Key Performance Parameters. Those minimum attributes or characteristics considered most essential for an effective military capability. KPPs are validated by the JROC for JROC interest documents, by the Functional Capabilities Board for Joint Impact documents, and by the DoD Component for Joint Integration or Independent documents. CDD and CPD KPPs are included verbatim in the Acquisition program Baseline. (CJCSI 3170.01E)

Knowledge, skills, and Abilities (KSA) – The human aptitudes (i.e., cognitive, physical, and sensory capabilities) and experience levels that are available in the intended user population and/or are needed to properly (efficiently and effectively) perform job tasks. (NAVSEA INST 3900.8A)

Major Command (MAJCOM) or Major Organizational Element. Denotes major military operational command organizations and other major functional organizations within a DoD Component. (DODINST 7730.64)

Measure of Effectiveness. A qualitative or quantitative measure of a system's performance or a characteristic that indicates the degree to which it performs the task or meets a requirement under specified conditions. MOEs should be established to measure the system's capabilities to produce or accomplish the desired result. (CJCSI 3170.01E)

The metrics by which a customer will measure satisfaction with products produced by the technical effort. (IEEE 1220)

Measure of Performance. A performance measure that provides design requirements which are necessary to satisfy an MOE. There are generally several measures of performance for each measure of effectiveness. (IEEE 1220)

Mode. An operating condition of a function or sub-function or physical element of the system. (IEEE 1220)

Net-Ready Key Performance Parameter. Assesses information needs, information timeliness, information assurance, and net-ready attributes for the technical exchange of information and the end-to-end operational effectiveness of that exchange. (CJCSI 3170.01E)

Node. A representation of an element of architecture that produces, consumes, or processes data. (DODAF)

Objective Architecture. The operational, functional, and physical architecture that incorporates the material solution concept intended to achieve an identified capability.

Operational Activity. A representation of the actions performed in conducting the business of an enterprise. The model is usually hierarchically decomposed into its actions, and usually portrays the flow of information (and sometimes physical objects) between the actions. The activity model portrays operational actions not hardware/software system functions. (DODAF)

Operational Architecture. A representation of the Operational Force, how it is organized, and how it performs its integrated processes/activities to achieve mission objectives. (DODAF)

Operational Model. An executable representation of the operational architecture.

Operational Node. A node that performs a role or mission. (DODAF)

Organizational Element. Functional organization within a military component. (DODINST 7730.64)

Performance Requirement. The measurable criteria that identifies a quality attribute of a function, or how well a functional requirement must be accomplished. (IEEE 1220)

Physical Architecture. An arrangement of physical elements that provides the design solution for a consumer product or life-cycle process intended to satisfy the requirements of the functional architecture and the requirements baseline. (IEEE 1220)

Physical Element. A product, subsystem, assembly, component, subcomponent, subassembly, or part of the physical architecture defined by its designs, interfaces (internal and external), and requirements (functional, performance, constraints, and physical characteristics). (IEEE 1220)

Planned Portfolio of Systems. The set of in service and approved/funded platforms and systems in the Fiscal Year Development Plan (FYDP) intended to satisfy an identified military capability.

Portfolio of Systems. The set of platforms and systems necessary to satisfy an identified military capability.

Quality Function Deployment (QFD) Technique. QFD is a technique for deploying the "Voice of the Customer." It provides a fast way to translate customer requirements into specifications and systematically flow-down the requirements to lower levels of design, parts, manufacturing, and production. (INCOSE Handbook, Appendix A)

State. A condition which characterizes the behavior of a function/sub-function or element at a point in time. (IEEE 1220)

System. Any organized assembly of resources and procedures united and regulated by interaction or interdependence to accomplish a set of specific functions. (DODAF)

System Element. A product, subsystem, assembly, component, subcomponent, subassembly, or part of the system breakdown structure which includes the specifications, configuration baseline, budget, schedule, and work tasks. (IEEE 1220)

Systems Engineering. An interdisciplinary collaborative approach to derive, evolve, and verify a life-cycle balanced system solution which satisfies customer expectations and meets public acceptability. (IEEE 1220)

System of Systems. A set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. (OUSD AT&L)

C.2. Acronyms

ACTD	Advanced Concept Technology Demonstration
AoA	Analysis of Alternatives
ASN(RDA)	Assistant Secretary of the Navy, Research Development & Acquisition
CCB	Change Control Board
CDD	Capability Development Document
CEP	Capability Evolution Plan
CFFC	Commander Fleet Forces Command
CHENG	Chief Systems Engineer (ASN(RDA CHENG))
CJCSI	Chairman, Joint Chief of Staff Instruction
CPD	Capability Production Document
C^4I	Command, Control, Communications, Computers & Intelligence
DAB	Defense Acquisition Board
DAG	Defense Acquisition Guidebook
DAS	Defense Acquisition System
DASN	Deputy Assistant Secretary of the Navy
DAU	Defense Acquisition University
DODAF	DoD Architecture Framework
DODI	Department of Defense Instruction
DoD	Department of Defense
DoN	Department of the Navy
DOORS	Distributed Object Oriented Requirements System
DOTMLPF	Doctrine, Organization, Training, Material, Leadership and education, Personnel, and Facilities
DSE	Decision Support Environment

EFDS	Expeditionary Force Development System
ESG	1) Executive Steering Group (of the SE IPT) 2) Expeditionary Strike Group
FIOP	Family of Interoperable Pictures
FNC	Future Naval Capabilities
FoS	Family of Systems
GIG	Global Information Grid
HSI	Human Systems Integration
ICD	Initial Capability Document
IDM	Interface Design Matrix
IEE	Integrated Engineering Environment
IEEE	Institute of Electrical and Electronics Engineers
INCOSE	International Council on Systems Engineering
IPR	In-Process Review
IPT	Integrated Product Team
ISP	Information Support Plan
ITM	Interface Test Matrix
I&I	Integration and Interoperability
JCIDS	Joint Capability Integration and Development System
$JBMC^2$	Joint Battle Management Command and Control
JFCOM	Joint Forces Command
KPP	Key Performance Parameter
LSE	Lead Systems Engineer
LSET	Lead Systems Engineering Team
MCP	Mission Capability Package
MNS	Mission Needs Statement
MOE	Measure of Effectiveness
MOP	Measure of Performance
NCDS	Naval Capability Development System
NCEE	Naval Collaborative Engineering Environment
NCEP	Naval Capability Evolution Process
NETWARCOM	Net-Centric Warfare Command
NFDS	Naval Force Development System
NMETL	Naval Mission Essential Task List
NTA	Naval Tasks
ONR	Office of Naval Research
OPNAV	Staff of the Chief of Naval Operations
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
PDR	Preliminary Design Review
PEO	Program Executive Office
PEO IWS	Program Executive Office, Integrated Warfare Systems
PM	Program Manager
PPBE	Planning, Programming Budgeting & Execution
PPBES	Planning, Programming Budgeting & Execution System
QFD	Quality Function Deployment

RDT&E	Research, Development, Test, & Evaluation
SE IPT	Systems Engineering Integrated Product Team
SECNAVINST	Secretary of the Navy Instruction
SET	System Engineering Team
SoS	System of Systems
SPD	System Performance Document
SRR	System Requirements Review
TACSITS	Tactical Situations
TEMP	Test & Evaluation Master Plan
T&E	Test and Evaluation
TRR	Test Readiness Review
V&V	Verification and Validation
WG	Working Group

Appendix D: Referenced Documents

D.1. Military Directives & Instructions

CJCSI 3170.1E, Joint Capabilities Integration and Development System, 11 May 2005

CJCS Manual 3170.01B, Operation of the Joint Capabilities Integration and Development System, 11 May 2005

DoD Directive 5000.1, May, 2003

DODI 5000.2, Operation of the Defense Acquisition System, May, 2003

DODI 7730.64, 11 December 04

Marine Corps Order 3900.15A, 26 November 02

NAVSEA INST. 3900.8A, Human Systems Integration policy in Acquisition and Modernization

OPNAVINST 3050.23, 5 November 01

OPNAVINST 5100.24, Navy System Safety Program

SECNAVINST 5000.2C, Implementation and Operation of the Defense Acquisition System and the Joint Capabilities Integration and Development System, January, 2005

D.2. Military Standards & Guidebooks

Department of Defense Acquisition Guidebook, 15 October 04

Department of Defense Architecture Framework, 9 February 04

Department of the Navy Acquisition and Capabilities Guidebook, 17 February 05

MIL-STD-882D, Standard Practice for System Safety

Naval Systems Engineering Guidebook, July, 2004

Software System Safety Guidebook, December 1999

Systems Engineering Fundamentals Guidebook, Defense Acquisition University Press, January, 2001.

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OUSD (AT&L) Guide to System of Systems (SoS) Engineering: Considerations for Systems Engineering in a SoS Environment (Draft), 25 September 06

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Naval Fires in Support of Expeditionary Maneuver Warfare Concept of Employment, March 2005, OPNAV

System Performance Document for Joint Fires in Support of Expeditionary Operations in the Littorals, Increment 1: Expeditionary Strike Group Sea-Based Fires (2007 – 2012), September 2005 Draft

Yurchak, John. Battle Force Capability (BFC)/Mission Capability Package (BF/MCP) Implementation Plan, Attachment A, 2002

Core Avionics Master Plan, NAVAIR