

**A Framework and Methodology for Enhancing Operational Requirements
Development: United States Coast Guard Cutter Project Case Study**

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Submitted to the System Design and Management Program
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Engineering and Management

at the
Massachusetts Institute of Technology
May 2010

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ABSTRACT

Within any major United States Coast Guard cutter acquisition project, developing the operational requirements in the early phases of acquisition is difficult as the complexity of the system is not easily understood until the detailed design is completed. This can lead to requirements that are too broad or analysis efforts strategically focused on sections that are not at high risk to future design efforts or within sections that are decoupled from the major design parameters. This is often experienced when analysis studies are conducted independently and not evaluated from a total systems perspective.

In order to improve the requirements generation methodology within United States Coast Guard acquisition, this thesis introduces a process focused Operational Requirements Framework. This framework synthesizes program, sponsor, and technical authority requirements a generic framework that focuses on a high-level systems engineering viewpoint to ensure that all requirements processes and their interactions are understood simultaneously. Within this framework, stakeholder analysis, operations and missions, and the design effects of “ilities” and interfaces are added to enhance the requirements development process. These new processes provide a better understanding of how the operational requirements meet value for all stakeholders and how the interaction of these requirements over the life cycle affects the acquisition project.

This thesis also establishes a methodology, adapted from Responsive Systems Comparison (RSC), and practical application of this methodology in a current Coast Guard acquisition project. This 5-process method provides a diverse group of stakeholders key insight into the overall interaction of value, design variables, and contextual life cycle changes and their impact to the overall project. This can improve the coordination of the operational requirements generation and provide prioritization into analysis work necessary to establish a total systems approach towards requirements generation.

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ACKNOWLEDGEMENTS

I would like to first thank my wife, Christine, and two sons, Colman and Conrad, for making the ultimate sacrifice during the past year. Despite my frequent and long absences from home, they kept a positive outlook, provided encouragement for my continuing educational quest, and touched my heart with their love and devotion from a distance. You are my inspiration.

The true heart of my thesis efforts are attributed to the staff and colleagues at the Systems Engineering Advancement Research Initiative. Dr. Donna Rhodes provided leadership, guidance, and helped me transform my vision into reality. Dr. Adam Ross and Hugh McManus provided the key tools for my development of a revised RSC methodology. Thank you for your support and time to better understand value for complex system development.

Captain Bruce Baffer provided the mentorship not only showing me the value of the System Design and Management program at MIT, but also for guiding my studies during the past year. Thank you.

Many Coast Guard personnel helped me better understand the difficulties of establishing the requirements foundation for large cutter acquisition. While this list was long, there were several key personnel greatly influenced my work at MIT. I would like to personally thank Captain Brad Fabling, Commander Scott Buttrick, Commander Brendan Kelly, Lieutenant Commander Jay Main, Pete Boyd, Rubin Sheinberg, Chris Cleary, Barney Black, Jim Snyder, Bert Macesker and the many staff at the Coast Guard's Research and Development Center for their extended efforts in my studies.

I also appreciate the many students in the SDM Classes of '09 and '10 that provided great camaraderie and the forum to share diverse industry experience and enabled flexible group planning for my extensive thesis research. Mario Montoya helped synthesize many of my thoughts not only for our group projects but also for research at MIT. Thank you.

Finally, I owe great thanks to Pat Hale who provided the guidance and leadership for my understanding of the SDM Program and its value to my Coast Guard career and future aspirations beyond the Coast Guard.

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LIST OF ABBREVIATIONS

AA	Alternatives Analysis
AMIO	Migrant Interdiction
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CDP	Capability Development Plan
COI	Critical Operational Issues
CONOPS	Concept of Operations
DHS	Department of Homeland Security
DoD	Department of Defense
DoDAF	Department of Defense Architecture Framework
DR	Defense Readiness
DRUG	Drug Interdiction
FOC	Full Operating Capability
GPO	Government Printing Office
HSE	Human Systems Engineering
HSI	Human Systems Integration
ICGS	Integrated Coast Guard Systems
ILSP	Integrated Logistics Support Plan
IOC	Initial Operating Capability
IPT	Integrated Product Team
KPP	Key Performance Parameter
LAN	Local Area Network
LCCE	Life Cycle Cost Estimate
LMR	Living Marine Resource
MATE	Multi-Attribute Tradespace Exploration
MNS	Missions Needs Statement
MSAM	Major Systems Acquisition Manual
OLE	Other Law Enforcement
OPC	Offshore Patrol Cutter
ORD	Operational Requirements Document
PORD	Preliminary Operational Requirements Document
PWCS	Ports, Waterways, and Coast Security
RAM	Reliability, Availability, Maintainability
RSC	Responsive Systems Comparison
SAR	Search and Rescue
SELC	Systems Engineering Life Cycle
SER	Solution Engineering Review
SI	Systems Integrator
VUAV	Vertical Unmanned Aerial Vehicle

CHAPTER 1: Introduction

1.1 Context

“Our job is nothing less than to recapitalize the Guard.

Mission execution begins here.”

- Rear Admiral Ronald J. Rábago, Assistant Commandant for Acquisition (U.S. Coast Guard, 2009b)

This quote by the current head of the Coast Guard’s Acquisition Directorate is more important today than any other time in the history of the Coast Guard. With an aging fleet of aircraft, boats, and cutters (ships larger than 65 feet in length), along with Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) electronic systems that are obsolete, the Coast Guard is moving ahead on the largest recapitalization in its history valued at over 27 billion dollars (U.S. Coast Guard, 2009b). The importance of delivering the correct capabilities to Coast Guard’s operational programs is vital for future Coast Guard mission success.

In the mid-nineties, the Coast Guard understood the importance of this large recapitalization and decided that the best approach to fill the gaps in capability was to contract under a system of systems approach, the Deepwater program. This program, contracted in 2002, formalized the approach to integrate new aircraft, cutters, while modernizing legacy assets and providing new C4ISR systems to the Coast Guard. Figure 1-1 below details the information integration of Coast Guard assets within this framework:

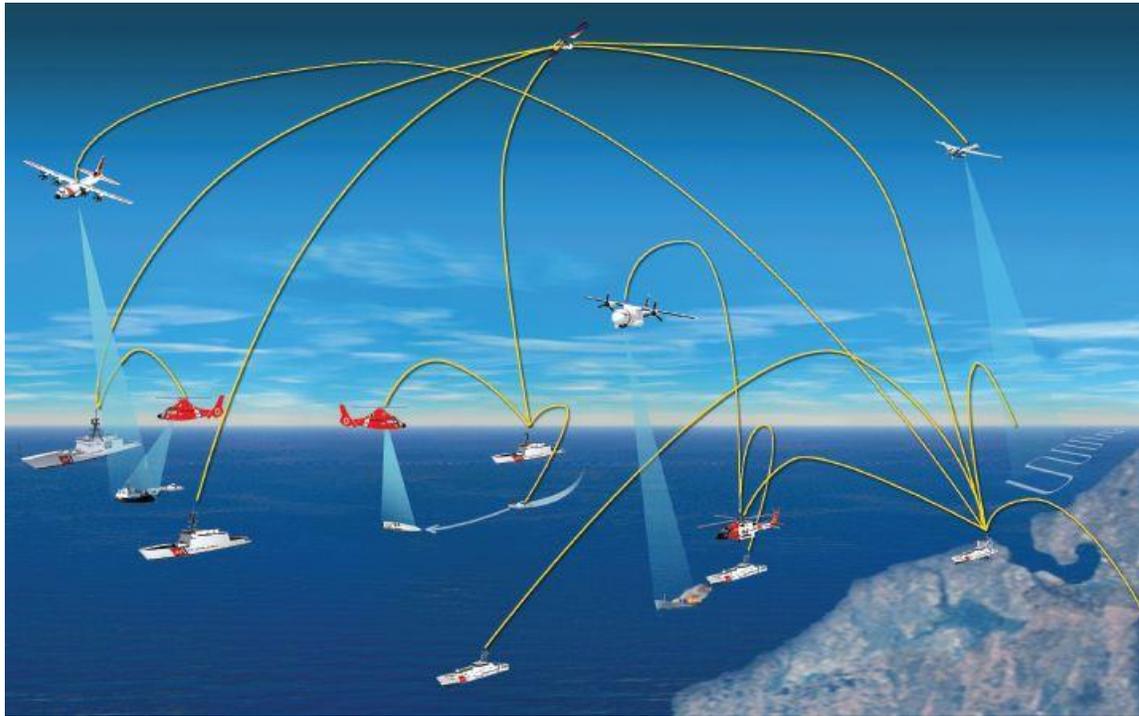


Figure 1-1: Coast Guard's Future Fleet Rendering (U.S. Coast Guard, 2009b)

The intent was to have a commercial contractor provide the lead systems integration role in designing and building the next generation of Coast Guard assets ready to perform the missions of the Coast Guard with increased operational effectiveness and reduced total ownership cost. This performance based contract would upgrade the capabilities of the current fleet, and enable new capabilities that would reduce the gap in mission analysis for the present and projected future operational needs.

In the years that followed the contract award, several of the large Deepwater projects experienced trouble in the design and construction phases of the plan. The 123-foot patrol boat conversion (legacy upgrade) experienced structural design problems leading to their removal from service in November 2006. The Vertical Unmanned Aerial Vehicle (VUAV) project was delayed indefinitely due to changing technological developments. The Fast Response Cutter (FRC) project suspended design work due to technology concerns and excessive design risk such as weight and horsepower concerns. Additionally, the Offshore Patrol Cutter (OPC) was delayed

5 years due to problems meeting costs and controlling requirements changes over time (U.S. GAO, 2007).

Following several years of difficulty managing the overall project with a contractor as the lead systems integrator, the Coast Guard made a decision in 2007 to take over as the systems integrator for all future projects, modify its acquisition directorate's organization to better handle the overall program management, and to merge these projects into the full requirements of the Coast Guard's Major Systems Acquisition Manual (MSAM). A decision was made that the multi-year contract with Integrated Coast Guard Systems (ICGS) would not be renewed in 2011.

1.2 Thesis Motivation

Following the decision to lead the Deepwater program efforts by the MSAM and integrate the projects into the Coast Guard's acquisition system, and following the recommendations of the Government Accountability Office, the Coast Guard (2007) published a management plan in July 2007 called the Blueprint for Acquisition Reform. The document defined the strategic plan to incorporate all acquisition programs under a single acquisition directorate, efficiently sustain operational activities, acquire single class systems, and ensure integration of all assets. As the systems integrator for all programs, the Coast Guard needed to align all functions of requirements generation, research and development, contracting, program management, and resources (budget and people) to best deliver affordable, capable, and timely assets (Figure 1-2).

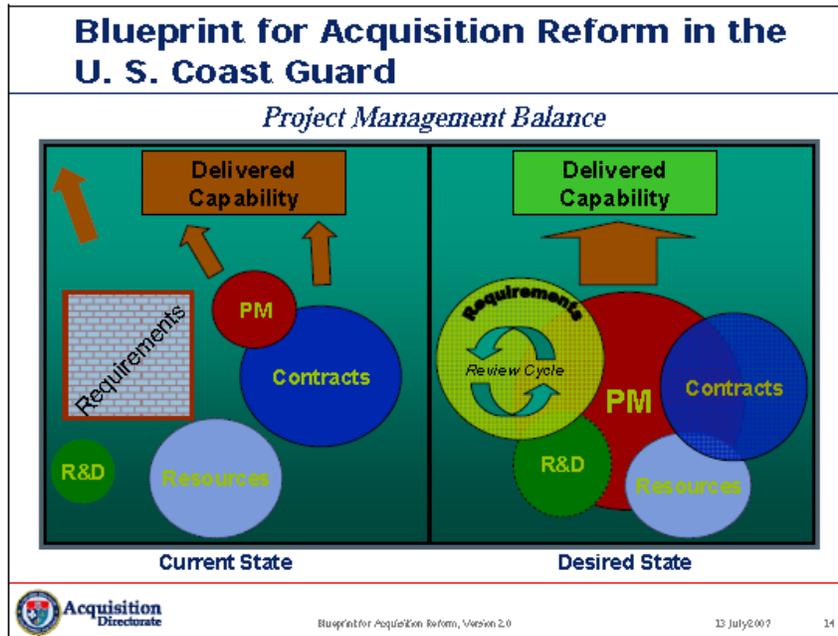


Figure 1-2: Program Management Balance (U.S. Coast Guard, 2007)

This new initiative to consolidate a more matrixed viewpoint of delivering capability combined with the initiative to consolidate staff elements within the Acquisition Directorate would enable the Coast Guard to effectively become the Systems Integrator (SI) for all major acquisitions. In response to this, the Acquisition Directorate (CG-9) (U.S. Coast Guard, 2009a) published the Systems Integrator Model that establishes this role as a collaborative initiative with the Sponsor (CG-7), Technical Authorities (CG-1, CG-4, CG-6), and the Planning, Resources, and Procurement (CG-8), and partner agencies ensuring engineering, technical, business, and financial challenges that are inherent in the complex acquisition environment (Figure 1-3). This requires information sharing, teamwork and well coordinated efforts to efficiently deliver new assets to the fleet.

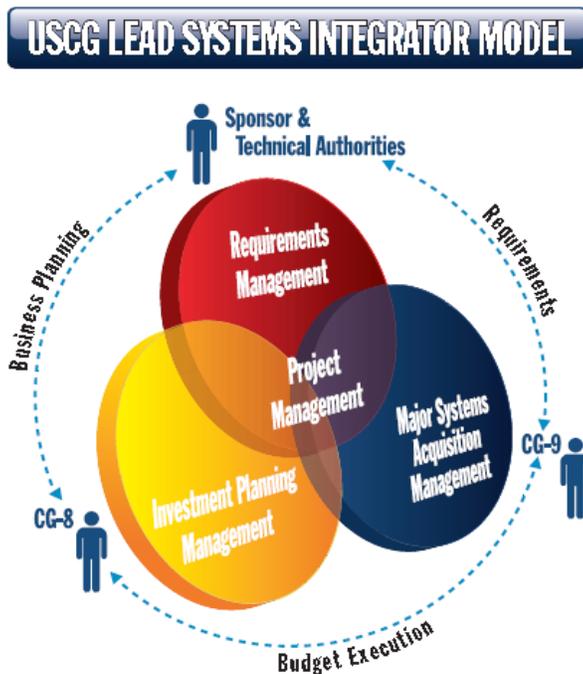


Figure 1-3: Lead Systems Integrator Model (U.S. Coast Guard, 2009a)

As the lead for requirements management, the Assistant Commandant for Capability (CG-7) drafted a Requirements Generation and Management Process Publication in March 2009. The objectives of the manual include providing uniform procedures for the development of asset requirements documents, establishing a collaborative environment for the requirements generation, and that the operational requirements are reviewed by CG-7 throughout the evolutionary requirements development (U.S. Coast Guard 2009d).

Simultaneously, the Department of Homeland Security (DHS) mandated the Coast Guard institute Acquisition Directive 102-01. This directive was developed to define common acquisition standards and practices across DHS components, creates a single point of accountability in the Acquisition Decision Authority and establishes a standard but tailorable life cycle framework for all acquisitions (U.S. DHS, 2008). One of its largest impacts to Coast Guard acquisition standards was the incorporation of a new Systems Engineering Life Cycle (SELC). This required a nine-stage process starting at Acquisition Decision Event 1 (formerly

named Milestone 1) with the incorporation of a solution engineering phase concurrent with the requirements generation.

To meet this need, the Coast Guard’s Acquisition Directorate modified the MSAM to include these new SELC requirements in the acquisition. These include the SELC artifacts, reviews, and stage approvals required to ensure a robust systems engineering approach to the acquisition process around each Acquisition Decision Event. These processes tailor the acquisition timeline starting from the Analyze/Select Phase to disposal of the assets (U.S. Coast Guard, 2009c) (Figure 1-4).

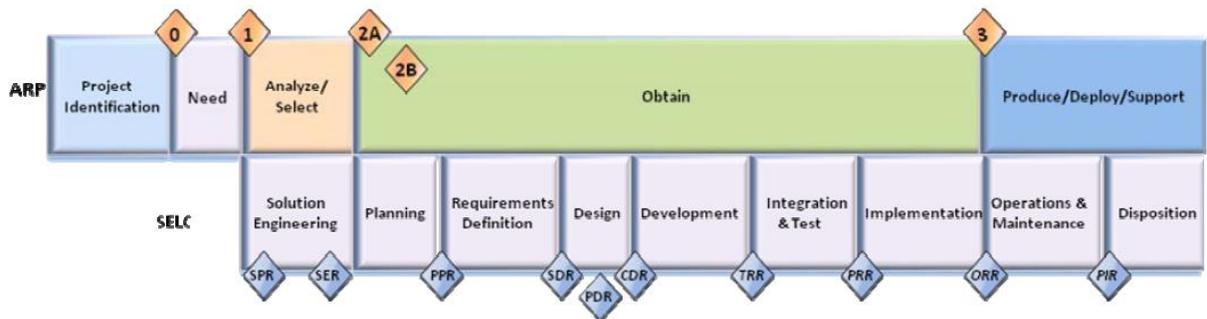


Figure 1-4: MSAM with SELC Process

1.3 Thesis Focus

With these new SELC, MSAM, and collaborative requirements, the complexity and importance of efficiency and effectively completing the requirements generation and associated planning requirements in the Analyze/Select Phase of the acquisition process (between Acquisition Decision Events 1 and 2) is more important than ever for a successful project. For a major cutter acquisition this is further complicated by the interaction of the asset needs with the rest of the cutter fleet and other asset integration (fleet mix) as well as understanding the specific details of lower level systems and their effects on the system as a whole.

In order to better develop the Preliminary Operational Requirements Document (PORD) and final Operational Requirements Document (ORD) during this phase, this thesis answers the following questions:

1. Can a high level framework be developed based on the research of other major systems approaches for the development of an Operational Requirements Document (ORD) that best captures and prioritizes all life cycle stakeholder requirements for major cutter acquisition?
2. Is there a tool or methodology that can assist the efficiency of this cutter ORD development from the beginning of the Analyze/Select Phase of acquisition from a high level systems engineering perspective?

CHAPTER 2: Operational Requirements Framework

2.1 Introduction

In major cutter acquisition programs, there is great importance developing a comprehensive set of requirements in order to maximize value for all stakeholders internal and external to the cutter project. Major Coast Guard acquisition projects are those defined by the Major Systems Acquisition Manual (MSAM) (U.S. Coast Guard, 2009c) where the project life cycle costs are estimated to exceed \$300M. Because of their inherent complexity and their high cost and value to Coast Guard operations and to the public at large, these projects follow specific processes and procedures. Often these procedures for each phase of acquisition can take several months to several years to complete. This can lead to a set of processes that answer specific questions, but it is often difficult to understand their contributions to other processes and the entirety of the project.

The development of the Operational Requirements Document (ORD) within the Analyze/Select Phase of acquisition serves as a foundation for the integration of all stakeholders' needs in terms of acceptable and desired levels. The difficulty in understanding these needs is often compounded in cutter acquisitions due to a large number of stakeholders and needs as well as the interrelationships of these needs based on the complexity of the cutters and support structure. This chapter will define the MSAM requirements, synthesize the relationships on the different processes and lay out a high level systems engineering framework for best understanding and developing an ORD that enables the project to acquire cutters that can best meet the operational requirements while minimizing costs to all stakeholders. Figure 2-1 shows the initial Operational Requirements Framework that will be expanded in the remaining sections.

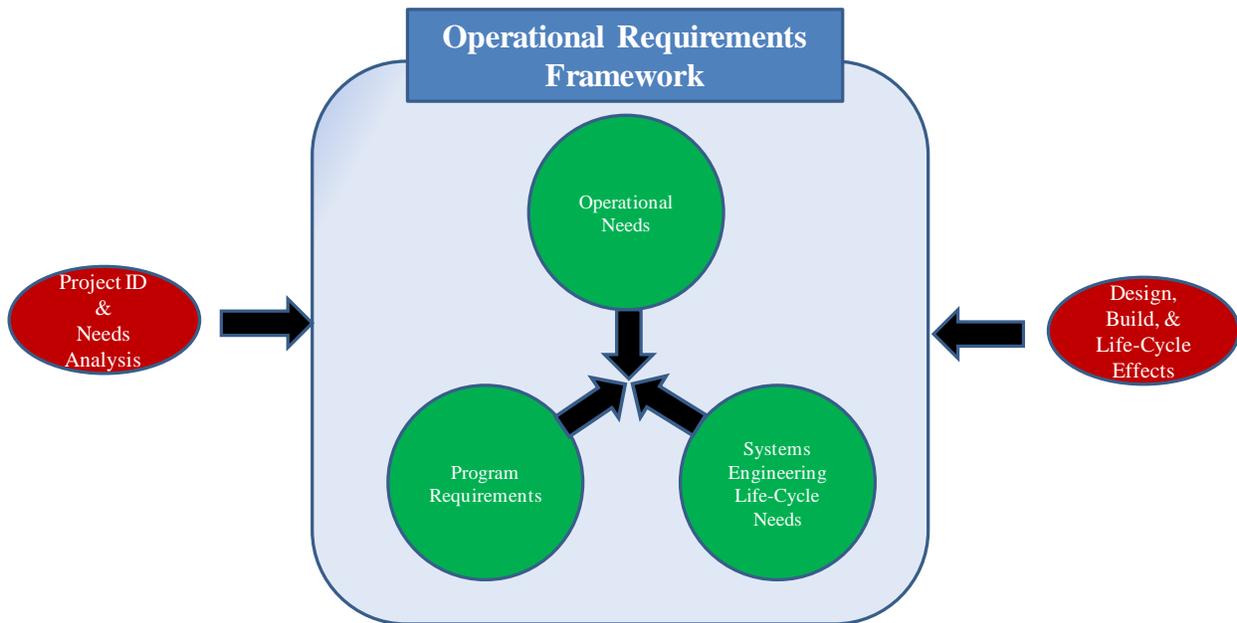


Figure 2-1: Operational Requirements Framework Basis

This framework outlines how the operational needs, program requirements, and systems engineering life cycle needs interact together to form the basis of the ORD. Early acquisition phase analysis and projected later phase design, build and life cycle effects will be introduced to ensure their influences are captured in the ORD development.

2.2 Inputs to the Operational Requirements Framework

2.2.1 Stakeholder Analysis (Stakeholders, Value Determination, and Prioritization)

One of the critical inputs to the framework vital for the holistic understanding of the overall cutter and its operation within the contextual needs is the identification of stakeholders and their influence and impact on the project. Brugh and Varvasovszky (2003) define stakeholder analysis as a way, “To evaluate and understand stakeholders from the perspective of an organization, or to determine their relevance to a project or policy.” For purposes of this document, stakeholder analysis includes understanding stakeholders that influence or are influenced by a cutter acquisition project, their value determination, and the prioritization of their

influence on the project. This understanding of the stakeholders, their changing needs and development of new stakeholders within a cutter's acquisition and operations sets up an important foundation for the entire Operational Requirements Framework.

2.2.1.1 Stakeholders

Stakeholders generally can be defined as:

“All people, organizations, and institutions that are a part of the system environment because the system provides some benefit to them and they have an interest in the system. This includes end users, operators, bill payers, owners, regulatory agencies, victims, sponsors, maintainers, architects, managers, customers, surrogate customers, testers, quality assurance, risk management, purchasing and the environment.” (Bahill and Dean, 2009)

Understanding these stakeholders and their contributions to and from a business gives relevancy and direction to implement direction to best achieve strategic management goals (Freeman, 1984). Within the Coast Guard cutter acquisition projects, these stakeholders include both internal and external stakeholders that impact or are impacted by the cutter development itself. These stakeholders can include the acquisition project office, Coast Guard technical authorities, Coast Guard policy holders, budget offices, sponsors, users, maintenance groups, operational commanders, facilities managers, other operational assets, shipbuilders, Congress, regulatory authorities, and other U.S. and international operational partners. These stakeholder groups are large with often conflicting goals for the cutter acquisition program. Without a thorough understanding of their goals, the Operational Requirements Framework is difficult to construct and evaluate for meeting these high level goals.

While the MSAM and the Requirements Generation Manual do not specifically include guidance on completing a stakeholder analysis for major acquisition projects, several other documents detail the importance of this to defining the requirements. NASA's Systems Engineering Handbook (2007) states that the identification of stakeholders and expectations is the foundation within the systems engineering development process. The list of process activities within this stakeholder expectation process is shown in Figure 2-2 below:

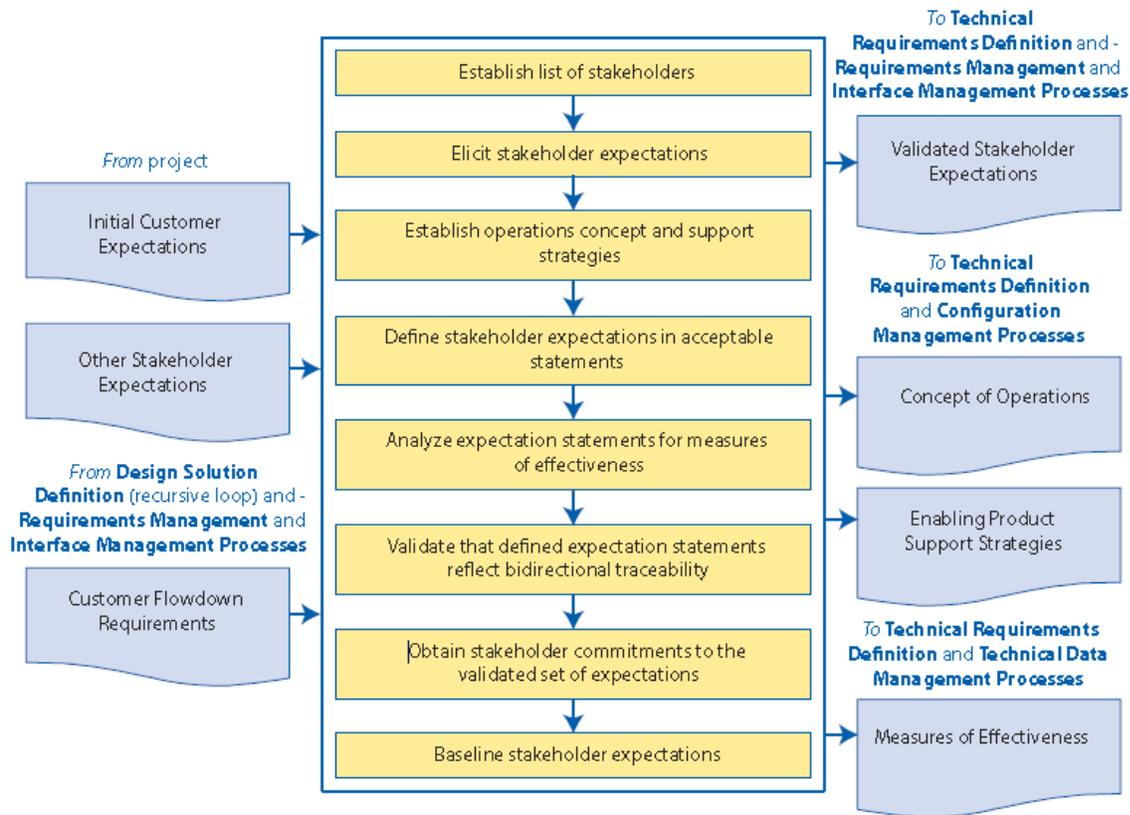


Figure 2-2: Example of Stakeholder Expectation Process (U.S. NASA, 2007)

This Stakeholder Expectation process becomes the starting point for all iterative design cycles from program initiation through the Produce/Deploy/Support Phase. Within NASA’s Systems Engineering Framework, the basis of establishing these expectations comes from the mission authority or strategic objectives that are driving the project to meeting a new directive or need within the organization. These translate to the objectives of the missions which are the basis for the requirements architecture. The objectives are understood by engaging all stakeholders on their needs, capabilities, external interfaces, assumptions, and constraints from their collective viewpoints (U.S. NASA, 2007).

Bahill and Dean (2009) also discuss the importance of understanding stakeholders as the input into the requirements development process. In their recursive requirements model, they state that identifying the stakeholders and understanding the motivations, interests, constraints, and

external pressures are essential for complex systems development. They further state the importance of understanding stakeholders throughout the life cycle of a product such as life cycle costs versus acquisition costs and the impact of this on different stakeholder's motivations.

Crawley (2008) details the importance to understanding stakeholders and beneficiaries as the first step in developing goals for any project in his Needs to Goals Framework. Within this framework, stakeholders are identified, their needs are evaluated, and their needs are interpreted as prioritized goals. Importantly, the identification of all stakeholders including those directly beneficial stakeholders (such as the shipboard operators for Coast Guard cutter programs) is the first step within this framework. Then by understanding their prioritization relative to the projects goal, the beginnings of the hierarchy of the requirements generation process can be realized.

Within each of these stakeholder analysis sections, understanding the entire list of stakeholders both within and external to the enterprise (U.S. Coast Guard), is important for identifying all personnel and organizations that influence or are influenced by any major cutter acquisition project. This should include not only stakeholders that have direct influence on the cutter program, but also those that will influence the program during construction and operational use. Secondly, the high level set of stakeholder expectations, constraints, and desires need to be understood. For the project office within a cutter acquisition this could be related to its budgetary, performance, and schedule requirements that were originally generated as the input into the Acquisition Decision Event 1 briefing (required entry point to enable a project to proceed in to the Analyze/Select Phase). For the project sponsor this could include providing new assets to fill new or existing high level operational requirements that are constrained by high level fleet analysis work considered prior to Acquisition Decision Event 1.

2.2.1.2 Value Determination

Following the high level determination of stakeholders and needs, the project needs to understand the value generated within the overall acquisition project for all stakeholders. Keeney (1992) defines value as principles used for evaluation. These values establish criteria for understanding decision making criteria or making judgments as to the effects of action or inaction. He further denotes the notion of value focused thinking; what you want and then understanding how to methodically obtain a system that meets those needs. This can enable more satisfied stakeholders compared to the review of alternatives by themselves as value focused thinking can lead to new concepts that may have not been realized upfront. When these values are explicitly written, they are considered objectives. These objectives become the fundamental cornerstones of the decision making process for any major cutter acquisition.

Within decisions involving multiple stakeholders, value-focused thinking can lead to a more productive interaction to determine a final solution to a problem or to address a need (Keeney, 1992). When the entire group of key stakeholders understands all the values simultaneously, there is a better understanding of each other's needs and tradeoffs are more easily understood by the entire group. This will lead to more thorough requirements development and decision making throughout the acquisition process.

According to Crawley (2008), value within an enterprise is delivered as an exchange of giving a benefit at cost to key stakeholders that are direct beneficiaries of the system under design. Value is only delivered when both benefit as shown in Figure 2-3 below:

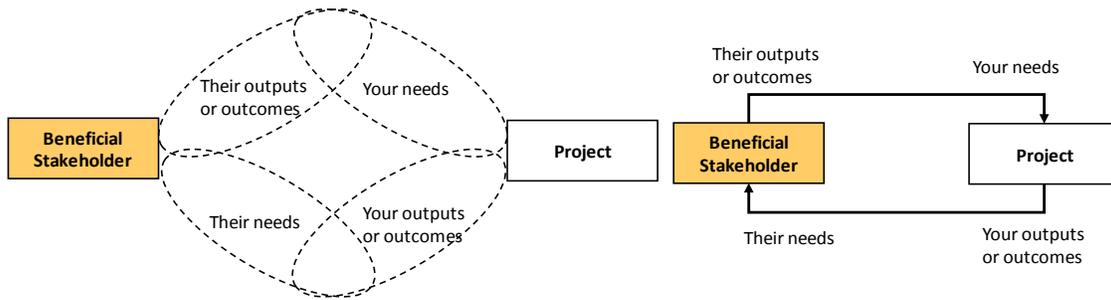


Figure 2-3: Value Delivery Exchange Model (Crawley, 2008)

This framework illustrates the importance of understanding this high level understanding of value amongst all stakeholders to understand how each of their needs and their contribution to the project creates value.

Murman et al. (2002) distinguish value creation as the combination of value identification, value proposition and value delivery phases. For the value identification phase, the stakeholders need to be identified and their activities need to be aligned to the overall value of the project. This is the thorough understand of their needs according to the overall project. Next, the value proposition is how to balance the competing needs of all the stakeholders within the project to maximize the overall value of the project itself. This involves tradeoffs of the stakeholders to best define and create a concept. This step is started in the requirements generation and iteratively through the entire design processes up to Acquisition Decision Event 3. The last phase, value delivery, is completed during construction of the system and operating the final product. These three value creation phases demonstrate the complete value proposition of the project and needs to be understood prior to starting the development of the requirements document in order to create a holistic value related vision within the development of the Operational Requirements Framework.

Understanding the importance of value focused thinking within the Analyze/Select Phase of cutter acquisition will enable a more complete set of requirements and a common understanding of the values and how they relate to one another. This will form the basis for further

understanding of the values (objectives) within a major cutter acquisition. Figure 2-4 below shows a generic value determination for a common stakeholder, shipboard users, and details both the input and output values needed. By understanding all stakeholders and their high level value determinations prior to drafting the ORD, many initial insights into the many and often conflicting values across all stakeholders will emerge.

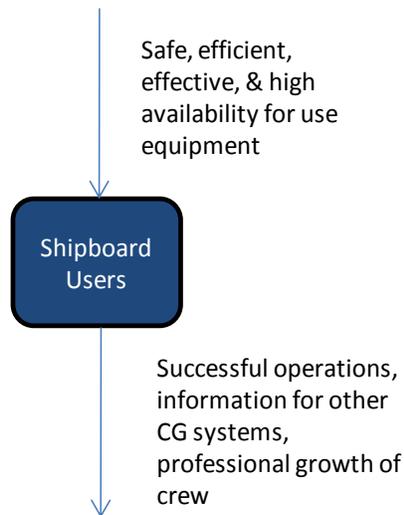


Figure 2-4: Example of high level Value Determination for Shipboard Users

2.2.1.3 Stakeholder Prioritization

The last step in the developing stakeholder inputs into the Requirements Document Framework is to establish a first level prioritization of stakeholders. This high level prioritization of stakeholders enables an understanding of how the stakeholder needs relate to the value delivery for the whole project and enables the first step in the initial assessment of operational requirements development. This grows the understanding of all stakeholders and their value to any project. It also ensures that stakeholders and their needs are reviewed for the entire life cycle of the project, not just the design and build stage of a major cutter acquisition.

Crawley (2008) recommends prioritizing beneficial stakeholders as a beginning for goals prioritization within subsequent requirements formulation while giving more insight on how the stakeholders affect or are affected by any major project. This informs how critical a stakeholder and their needs are to a project by understanding the influence of stakeholders on the project in its entirety.

Within stakeholder theory literature, identifying stakeholders and understanding their interests are important to the success of any business. This identification of critical stakeholders and evaluating their needs is part of a manager's or corporation's role (Post, Preston, and Sachs, 2002). The importance of proactively understanding stakeholders and their interests enable the possibility to establish mutually acceptable solutions to problems without the need to address their needs later under more pressure related circumstances. This leads to a more dynamic way to assist in the tradeoffs among competing stakeholders in maximizing value creation.

From a project management perspective, understanding stakeholders and their impact on a project's success is important. Bourne (2009) concludes that identifying and understanding stakeholders is important within each stage of a project. The prioritization of these stakeholders enables project managers to better meet and manage the expectations of all stakeholders. This can be done by analyzing the power of stakeholders, their influence and urgency or importance throughout a project's life cycle.

One such methodology to assist in the stakeholder prioritization within Coast Guard cutter acquisition is to understand the saliency of the stakeholders associated with the project. Mitchell, Agle, and Wood (1997) define saliency as, "The degree to which managers give priority to competing stakeholder claims." Their approach evaluates this saliency by understanding the attributes of power, legitimacy, and urgency of stakeholders. Power is the ability to influence other stakeholders or the project through the use of force or threat, through material or incentive means, or by symbolic influences. Legitimacy is based on the perception that a stakeholder's needs are appropriate within the project within norms based on

organizational, societal, or individual means. Urgency is the degree of immediate attention based on time sensitivity or criticality to the stakeholder.

Within their construct of saliency, the interaction of these attributes and the degree to which stakeholder possesses these attributes, establishes the degree of saliency. Grossi (2003) adapted the Mitchell, Agle and Wood’s saliency model and renamed the attribute of *urgency* as *criticality* with the framework (Figure 2-5).

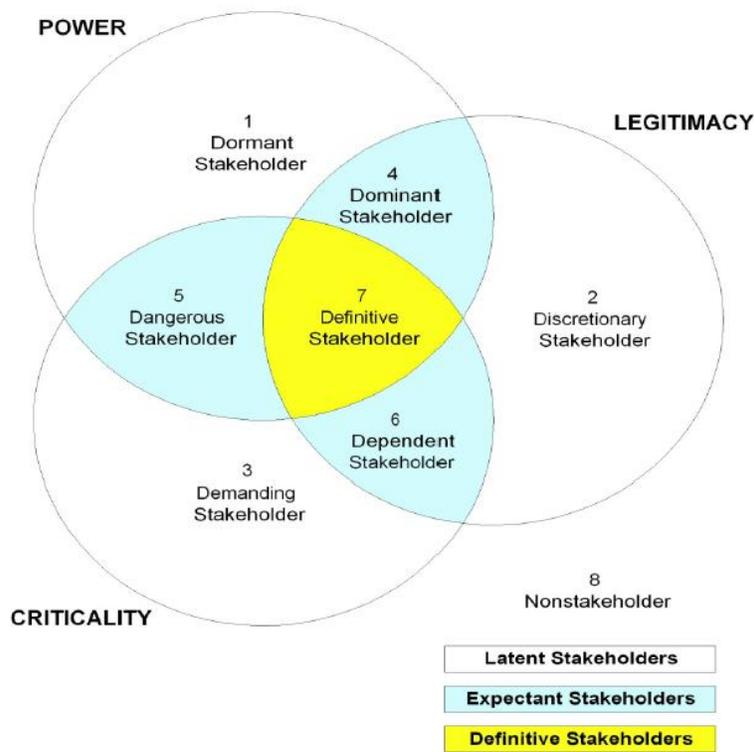


Figure 2-5: Saliency Framework (Grossi, 2003)

Within this framework the latent stakeholders exhibit only one attribute and hence their saliency is low. Expectant stakeholders are those who exhibit two attributes and have medium saliency. Definitive stakeholders are those who exhibit all three attributes and are the most influential within any project. These broad categories of stakeholders assist the understanding, influence,

and prioritization that a stakeholder possesses during the beginning of the development of thorough requirements or goals of a major system.

This saliency framework is important to understand in the dynamic realm as stakeholders may change categories throughout the life cycle of any acquisition. The project team should evaluate this and understand the implications of time frame within the prioritization of stakeholders.

Dormant or discretionary stakeholders such as maintainers may not have criticality or power at the early stages of acquisition, but once the ships are operational, they will likely have more impact on the project. This dynamic stakeholder prioritization gives insights into needs that may not have been considered within the beginning of a requirements development process.

2.2.1.4 Summary of Stakeholder Analysis

With a comprehensive understanding of stakeholders involved, the value they create and need for any new cutter acquisition, and an understanding of the stakeholders' prioritization, the project team will be better able to construct a more comprehensive list of operational requirements for a large cutter acquisition program. The ORD development process itself will also give new insights into this stakeholder analysis as an iterative approach. On this basis, Figure 2-1 can be updated to show these relationships to the Operational Requirements Framework as per Figure 2-6 below.

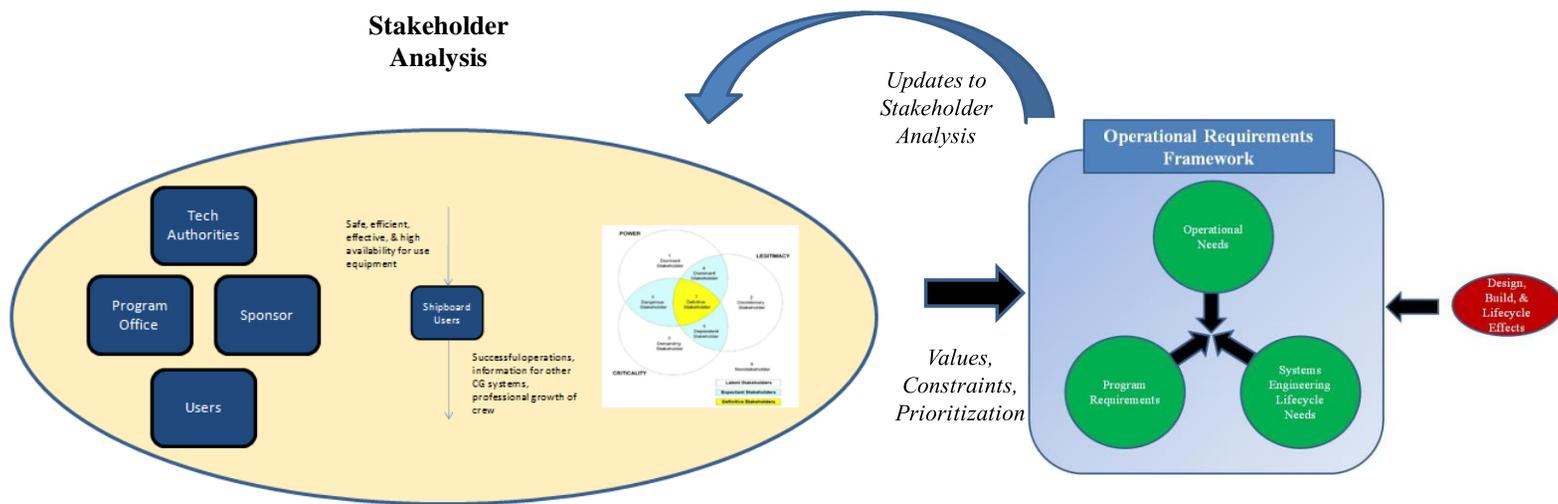


Figure 2-6: Stakeholders, Value Determination, and Saliency Inputs to Operational Requirements Framework

Within this input to the framework, the stakeholder analysis provides an understanding of all of the stakeholders, their values, constraints, and gives a realization of the saliency of each stakeholder within the acquisition project. This analysis provides a basis for starting the ORD development and also provides a foundation of where to plan for more detailed studies based on the value exchange or noted polarization of values between stakeholders. This will not only assist the drafting of the ORD, but will assist the project manager in developing the Capability Development Plan and the sponsor in developing the Analysis Plan. Both serve to focus the development of the ORD to key processes and analyses.

Within the stakeholder analysis, there is also a recursive element to what appears on the static model as shown in Figure 2-6. As the ORD develops there needs to be a continual review of the stakeholder analysis. This can be particularly important during the more in-depth analysis work that is completed such as a shipboard manning analysis, tradeoff analysis for certain attributes, or for further utility versus cost analysis done within the Operational Requirements Framework. This feedback may better quantify the values of each stakeholder or change their relative saliency. This stakeholder re-evaluation should be revisited often during the ORD development.

2.2.2 Operations and Missions Inputs

The Mission Need Statement (MNS) and the Concept of Operations (CONOPS) are the two key documents used as guidance in developing the ORD. These documents enable an understanding of why a new asset is needed and what functional relationship this asset has to the many other operational units throughout the Coast Guard. By thoroughly understanding the high level needs for a new project and the operational and support functions, the ORD development can better link specific operational requirements to high level functional needs in the Coast Guard.

2.2.2.1 Mission Need Statement

The MNS is a formal written document of the strategic need of a Coast Guard asset and required for any major acquisition. It formalizes the acquisition and links the capability gap documented

in the Mission Analysis Report (pre-Acquisition Decision Event 1) to a particular acquisition that will perform the functions necessary to fill this need (U.S. Coast Guard, 2009c). According to the DHS Acquisition Directive 102-01 (2008) the approval of the MNS, “Provides formal DHS executive-level acknowledgment of a justified and supported need for allocation of limited resources to resolve a mission deficiency with an effective solution. In the broader view of the acquisition life cycle, it represents the initiation of formal acquisition program management and the beginning of the investment process.”

The MNS also helps to establish the high level requirements of a new cutter acquisition as it establishes the missions and needs that the new program requires to fill and why the current operational fleet cannot meet all required tasking. This links how the new asset connects to the high level Coast Guard and DHS strategic objectives. By understanding these high level needs, the acquisition goals and objectives are submitted and are the baseline for the development of the entire acquisition plan.

Within the MNS development, the sponsor needs to assess the current cutter fleet, the anticipated changes within the fleet mix, and other potential future or emerging functions that an asset needs to meet the overall objectives of Coast Guard operations. Then by flowing those down to a specific asset or proposed asset, the MNS answers how a new acquisition program will fill these missions. The layout of the MNS includes two sections; (1) missions and capabilities and (2) program justification.

With a well written and approved MNS, the acquisition program can proceed to develop a greater understanding of the stakeholders, operations, and functional requirements of the proposed system.

2.2.2.2 *Concept of Operations*

The concept of operations according to the MSAM (U.S. Coast Guard, 2009c) is “A description of a proposed asset or system in terms of the user needs it will fulfill, its relationship to existing assets, systems or procedures and the way it will be used.” The importance of this document helps to describe how the system will tactically operate within a certain environment detailing the overall picture of the operation (Rainey, 2004). According to the DHS Directive 102-01 (2008), the CONOPS also provides a link between the MNS and the ORD by translating the missions needed into functional capabilities. By giving operational scenario-based context, it provides parameters for asset use, characteristics of alternative solutions and informs detailed design documents. This document is pivotal in the development of the ORD and establishes a baseline for stakeholders within a cutter acquisition program to understand how an asset will be used to complete its activities and missions.

Wasson (2006) describes a CONOPS as a set of objectives that show how a specific user intends on using a system operationally. These include how to deploy a system, configure, check, use, maintain, and how the system is retired after its useful life. These objectives can be understood by looking at the total system in operation through a Systems Operations Model or a workflow of operations for specific mission requirements. Dorfman and Thayer (1990) further describe the operational concept as a stakeholder’s view of how the system is designed, produced, operated, trained, maintained, and retired to achieve their goals.

Within the Coast Guard’s CONOPS development cycle, this document is required to include missions, stakeholders, constraints, assumptions, operational descriptions, operational and support mission scenarios leading to listing of functional capabilities. This ensures a complete understanding of functional needs of the system and how the system is intended to be operated within its contextual environment. The U.S. Department of Transportation (2007) further elaborates that a CONOPS shows a view of the system in actual use that each stakeholder can understand. A well written CONOPS will answer the following questions:

1. Who are the stakeholders involved with the system?
2. What are the elements and high-level capabilities of the system?
3. Where are the geographic and physical extents of the system?
4. When will the sequence of activities be performed?
5. Why is this system needed? (Problem or opportunity)
6. How will the system be developed, operated and maintained.

Graphically this is shown as Figure 2-7 below:

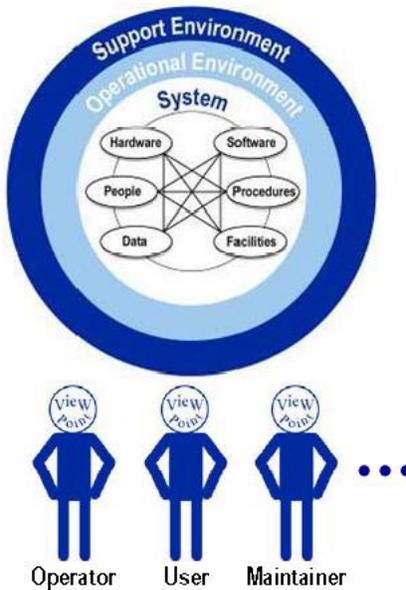


Figure 2-7: Concept of Operations (U.S. DOT, 2007)

Understanding the system operations from a stakeholder perspective in the operational and support environment is important to the development of the ORD ensuring to include a robust linkage to all stakeholders, their needs and priority within the framework. This stakeholder viewpoint ensures that the CONOPS addresses all aspects of the operational and support environments, critical to enhancing the functional requirements that will be used as a basis in developing the ORD. By using stakeholder analysis information, the development of the

CONOPS will be more complete in assessing how the stakeholders play a role in the operational scenarios and missions analyses that are generated.

The operational section of the CONOPS describes a key understanding of the use context of the system. This includes a thorough description of the policies, assumptions, constraints (many of which will be discovered with any concurrent stakeholder analysis), and operations of the system. It is important to directly understand and quantify specific external policies that constrain the system development. This could be policy towards environmental compliance, safety related equipment, etc. The assumptions could include how the system will perform the needed new set of missions needs from the MNS based on current operational guidance.

Within the operational context, the CONOPS needs to thoroughly describe the system’s intended operational area, understood environmental conditions, other units, and/or information technology systems. Then, based on written operational descriptions, the mission operations matrix can be developed which shows the prioritization of the major operational functions described to the specific mission that the systems has to perform. An example of this is included in Figure 2-8 below:

Functional Capability	Missions										
	SAR	CD	AMIO	LMR	OLE	PWCS	DR	MS	MEP	ICE	WWM
Boat Operations	P	P	P	P	P	S	P				
Helo Operations	P	P	S	P	S	P	P				

P: Primary Relationship
S: Secondary Relationship

Figure 2-8: Mission Matrix Example (U.S. Coast Guard, 2009c)

The support environment the analysis of the CONOPS includes the logistical support functions necessary to carry out the missions. The theoretical support context should be understood when describing the operational scenarios in the CONOPS as this gives insights on how support and

logistics interface with the operational setting. Ultimately, this support understanding will develop into support missions that detail how the system will be maintained. Within this framework, the support missions become “support modes” that assist and enable operational mission completion. According to the Coast Guard’s Requirements Generation and Management Process Publication (2009d), the CONOPS should specifically list the support functional prioritization as shown in Figure 2-9.

Functional Capability	Support MODES					
	Homeport	Underway	Inport	Import foreign	Dry Dock	
Administration		P	P	P		
Organic Maintenance	S	P	P	P		
Subsistence		P	S	P		
Medical		P	S	P		
Inorganic Maintenance	P		S	S	P	
MWR	S	P	P	P		

P: Primary Relationship
S: Secondary Relationship

Figure 2-9: Support Functional Capabilities Matrix (U.S. Coast Guard, 2009d)

2.2.2.3 Summary of MNS and CONOPS

The MNS and CONOPS provide both the important understanding of the overall Coast Guard goals for a cutter acquisition project and how the new asset would contribute to carrying out Coast Guard missions. These two documents enable this understanding while giving ORD and later design specification insights on how the cutter operates through all missions. This ultimately is the basis for ORD planners to understand the operations and support prioritization and the context (scenarios) behind these mission matrices. These functions can be flowed to more specific operational and support specifications through function analysis and through more detailed functional analysis with high prioritization, high risk, or low fidelity activity understanding.

By new system and subsystem concept generation during the functional analysis process of the ORD development, new functions may emerge or changes to existing functions may need to be changed. This will lead to future updates of the MNS and CONOPS to ensure that the requirement traceability and new needs become the basis for requirements traceability throughout the cutter's life cycle. Figure 2-10 shows a summary of the Operations and Missions Analysis inputs to the Operational Requirements Framework.

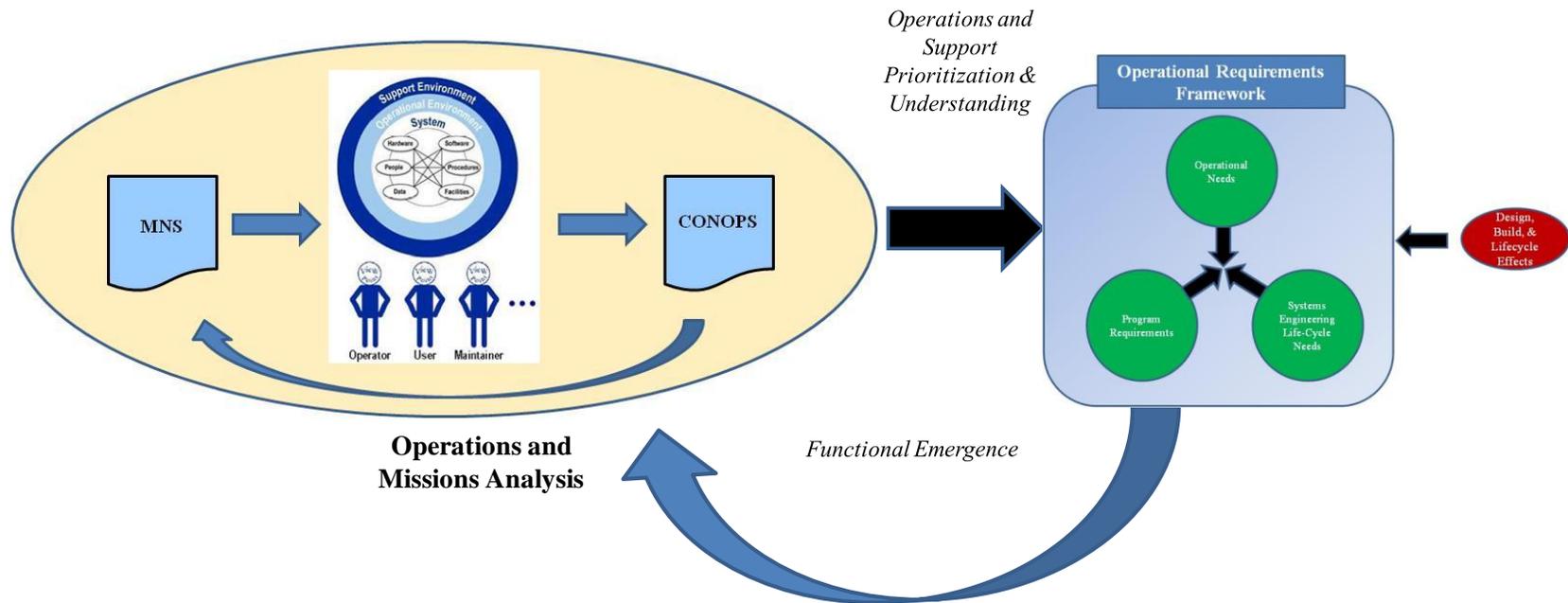


Figure 2-10: MNS and CONOPS Input to Operational Requirements Framework

2.2.3 Summary of Operational Requirements Framework Inputs

Understanding the stakeholder analysis, operations, and missions provides vital information for the development of the ORD and later design documents. This information provides insights on the organizations, personnel, and systems that are impacted by a new cutter project, each of their needs, how these influence decisions on requirements of the cutter, and how the new cutter will be operate during both sea-going and inport missions.

There also is an important correlation between the stakeholder analysis and operations and missions analysis sections. Both provide information needed to complete their respective sections of the ORD. Because of these synergistic relationships, both input sections should be completing in parallel and should have key members within the working groups that work on both sections. In this manner, they become dependent on one another and should be updated accordingly.

Based on this Figure 2-11 below summarizes the overall inputs into the framework.

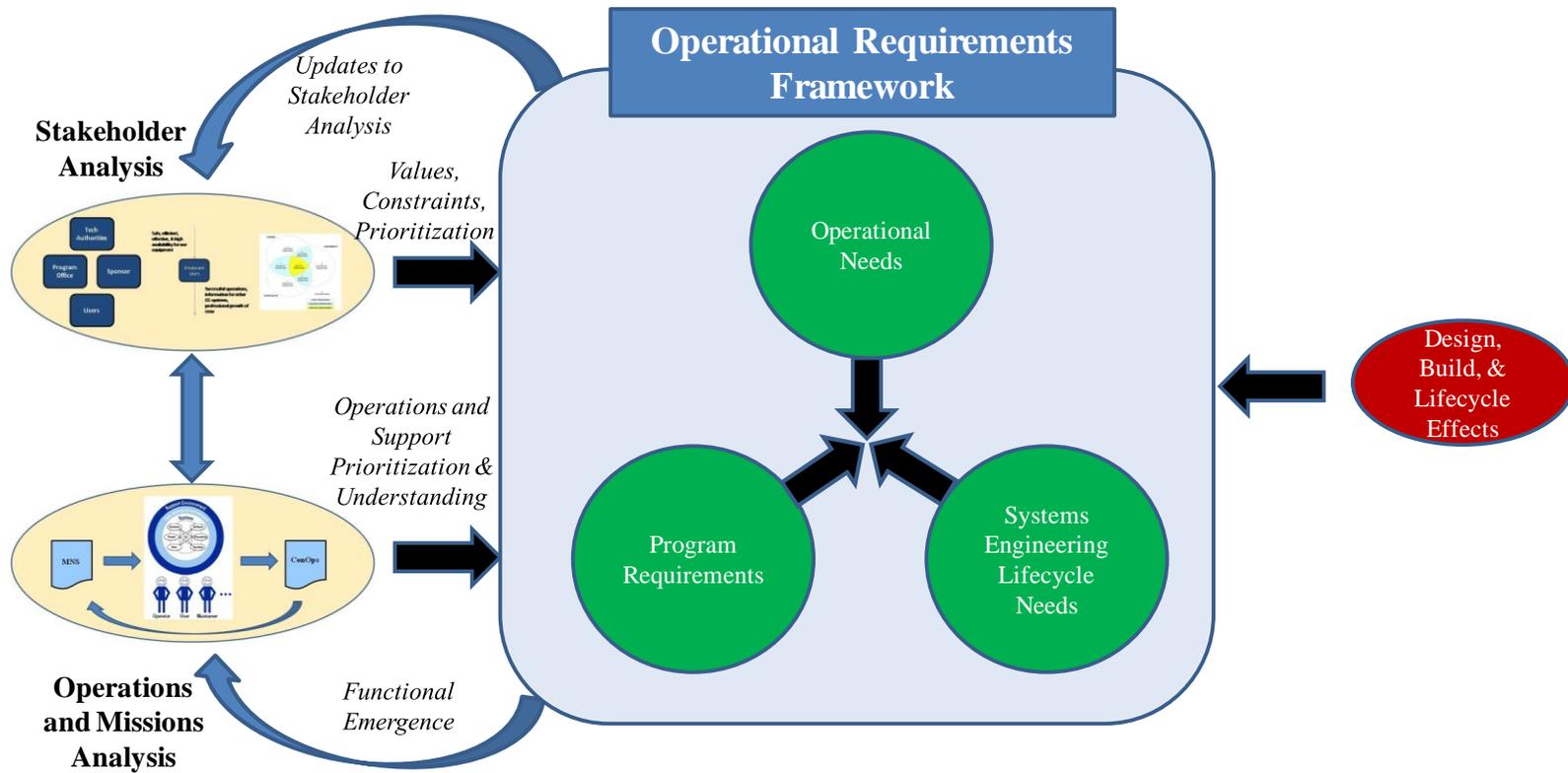


Figure 2-11: Input Summary to Operational Requirements Framework

2.3 Design Effects on the Operational Requirements Framework

Now that several important inputs to the Operational Requirements Framework are understood for developing holistic requirements, there are several “downstream” effects that influence the framework. These effects are typically characteristics that are more thoroughly examined after Acquisition Decision Event 2, but they need to be analyzed at least at a high level in the Select/Analyze Phase of acquisition. This gives insight on important design considerations that affect the content contained in the ORD. NASA’s Systems Engineering Handbook (2007) establishes the importance of many different sources of requirements and their impact to the CONOPS and the detailed design processes (Figure 2-12 below). The two downstream inputs that will be discussed are the “ilities” and interface requirements within any cutter acquisition project.

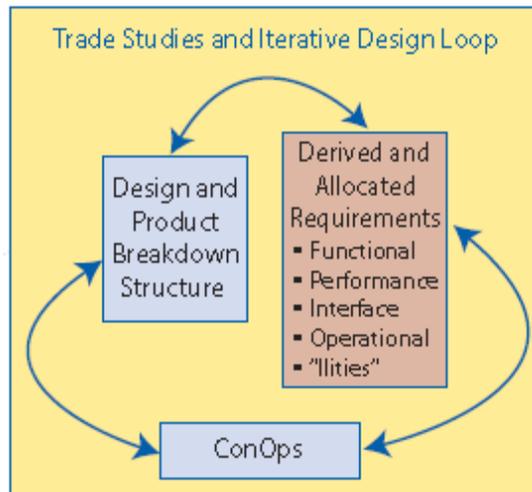


Figure 2-12: NASA's Trade Studies and Iterative Design Loop Processes (U.S. NASA, 2007)

2.3.1 “Ilities”

“Ilities” are quality attributes that describe the non-functional requirements used to evaluate the performance of a system (Wikipedia, 2010). These quality attributes are labeled as “ilities” as they often end in suffix, “ility”. These attributes are often implicit values that stakeholders desire, but are not always directed stated during requirements generation analysis, but rather become more apparent during later design, implementation, and operational stages of acquisition. Charette (1990) points out that these non-functional requirements can be more important than the functional requirements as they often establish the overall “success” of a project in the eyes of its users. Since ship design teams are required to account for the functional analysis and associated “ilities”, the ORD development should examine the high level requirements for these important system characteristics (U.S. Navy, NAVSEA, 2009). Table 2-2 below describes many common “ilities” in many systems.

“ILITIES”					
Accessibility	Accountability	Accuracy	Adaptability	Affordability	Availability
Changeability	Standards compliance	Compatibility	Configurability	Customizability	Degradability
Designability	Durability	Effectiveness	Efficiency	Evolvability	Extensibility
Fidelity	Flexibility	Habitability	Installability	Integrability	Interchangeability
Interoperability	Maintainability	Mobility	Modifiability	Modularity	Operability
Orthogonality	Portability	Precision	Predictability	Reliability	Repeatability
Reproducibility	Responsiveness	Reusability	Robustness	Safety	Scalability
Securability	Simplicity	Stability	Suitability	Supportability	Survivability
Sustainability	Tailorability	Testability	Traceability	Upgradability	Usability
Value Robustness	Versatility				

Table 2-1: Listing of “ilities” (adapted from- Wikipedia, 2010)

Often in complex systems these quality attributes are difficult to understand and manage as they both influence each other and are often difficult to quantifiably value. This perceived system value leads to the importance of these “ilities” and according to Williams (2000), should be

incorporated into the system architectural review. Within the Operational Requirements Framework, these qualities should be analyzed for applicability and coupled with the stakeholder analysis to best understand the overall stakeholder value understanding.

One of the difficulties in reviewing the many “ilities” is that they are not equivalent in how they relate to the system. Ross (2010) gives several characterizations of “ilities” to help group them into categories to better understand the “ilities” and their importance to value in a dynamic environment. He includes categories by structure, operation, time-based property or new ability. The structural “ilities” are those that do not depend on usage or the environment in which the system is operating. An example would be modularity or orthogonality. The operational “ilities” are those that are dependent on use or the environment and include survivability and interoperability. Several “ilities” can be either structural or operational such as changeability, flexibility, adaptability, and robustness. Time-based “ilities” are those that are time dependent and include sustainability, reliability, maintainability, and availability. New ability “ilities” are those changing in relation to how they are used such as installability and implementability.

An important group of “ilities” that directly relate to the understanding of a system’s dynamics or how the system acts due to change over time are “ilities” that relate to change. These provide insight into understanding a system’s change over time and can give an important understanding of value of a system through changing contexts or environments. Ross, Rhodes, and Hastings (2008) list “ilities” that describe change includes robustness, versatility, changeability, flexibility, adaptability, scalability, modifiability, and survivability. Using the definitions of Ross, Rhodes, and Hastings (2008) and those of Fricke and Schulz (2005), the below list defines several of these change related “ilities”:

1. **Robustness:** The ability of a system to maintain functional capability of specified system parameters through changing context or environment without the need to externally change the system. This also includes systems that are value robust. That is the ability of a system to meet or exceed changing stakeholder expectations that can both

require change or no change to the system. An example would be the ability of a cutter to be able to connect to a new satellite communication network without needing to change the installed C4ISR system.

2. **Versatility:** The ability of a system to satisfy diverse needs of stakeholders without changing form. An example of this would be the ability of a buoy tender to carry out an expanded set of law enforcement duties without requiring as-built changes to the cutter.
3. **Flexibility:** The ability of the system to be easily changed (form or function) by external means to meet changes in the context or environment. An example would be the ability to easily upgrade a small boat and small boat launching system to better meet changing mission requirements.
4. **Adaptability:** The ability of the system to be changed by internal means. An example would be a software system on a cutter that enables the user to change how the system output information is displayed and analyzed based on changing information.
5. **Scalability:** The ability of a system to change the level of system parameters by either increasing or decreasing single elements or combining multiple elements of the system together. For a cutter, this might include a diesel generator that can be physically upgraded with a larger unit (extra space, etc. included in the original design).
6. **Modifiability:** The ability of the system to change parameters and can be expressed in either form or function. An example would be the ability of cutter to add a new radar system.
7. **Survivability:** The ability of the system to minimize the results of a finite disturbance on the expected performance of the system. This can be done via passive (robust) or active (changeable) techniques. Passive survivability can be achieved with adding hardness,

stealth, redundancy, or diversity within a system. Active survivability can be achieved by regenerating (repairing), evolving, relocating, or retaliating (Richards, et al., 2007). A cutter meeting a specific level of shock hardness through adding shock mitigating structures, etc. to subsystems is an example of achieving passive survivability.

8. **Changeability:** The ability of a system to change its form or function given a level of reasonableness for resources such as time, money, materials or level of effort. This “ility” is dependent on other “ilities” to describe. Flexibility and adaptability describe where the change agent is taking place to change the system’s form relative to the system’s boundary. Scalability and modifiability are used to describe the effect of the form change on the system.

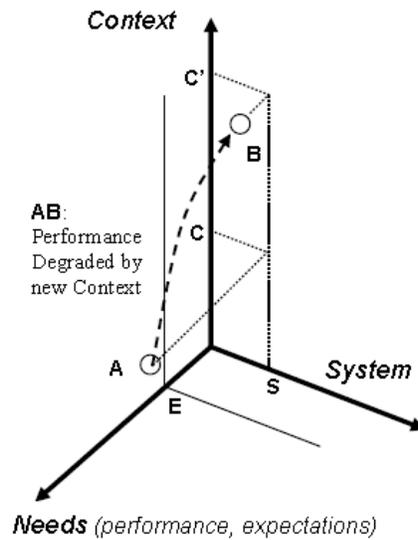


Figure 2-13: Three Dimensional "Iility Space" Depiction (McManus et al., 2007)

McManus et al. (2007) propose a depiction to help illustrate these “ilities”. This 3-D “ility space” is bounded by the system (physical form by design variables), stakeholder needs, and context or environment. In Figure 2-13, the example shows going from state A to B shows a loss of performance by a changing environment or context. Passive robustness can be shown by a

change in the vertical context axis without a change to the system value (change in form). Versatility can be shown as a change in needs without a change in the system or change in context. Flexibility can be described as a change in the system without changing needs or context. This depiction can assist in understanding ilities and how they affect the overall system and give insight on how to influence life cycle changes in the ORD development.

Because many “ilities” relate to and are dependent upon others, the relationships need to be well understood. Cutters typically are constructed for a service life exceeding 20 years. This creates a challenge to operators, planners, and maintainers because the operational, environmental, and budgetary environments can change drastically within this period. Within the ORD development, understanding ways to design cutters to be able to adapt or change to these external changes is important for the life cycle value of the cutter.

According to Fricke and Schulz (2005), changeability is an important life cycle consideration in systems that are highly connected with other systems, have high design and build costs, and require high operational and maintenance costs. This can be illustrated by Figure 2-14 below. As the degree of changeability increases in a project, there is a point where the total cost of the project is minimized. To maximize performance, cost, and ability to adapt, Coast Guard cutter acquisition projects must try to understand this early in the ORD development.

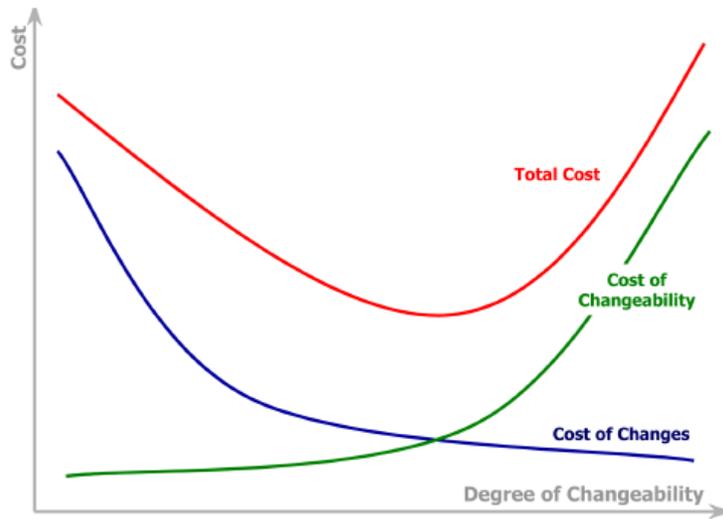


Figure 2-14: Degree of Changeability versus Cost (Fricke and Schulz, 2005)

As discussed earlier by the definition of changeability, there are many “ilities” that define the characterization of changeability. To ensure the understanding of the life cycle effects, all of these influences need to be understood within the ORD development.

Ross, Rhodes, and Hastings (2008) expand the definition above to detail this “ility” interaction. They characterize change in a system as described by three elements: (1) the change agent, (2) the mechanism of change, and (3) the effect of the change. Pictorially, this is shown in Figure 2-15 below.

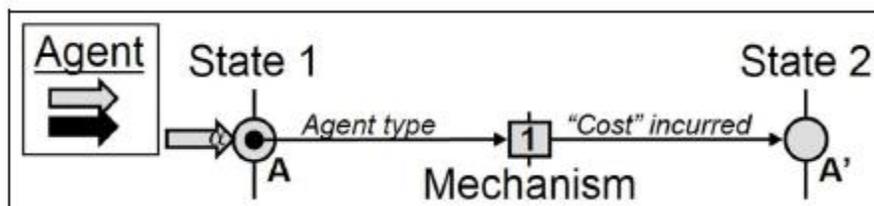


Figure 2-15: Depiction of System Change (Ross, Rhodes, and Hastings, 2008)

A system that starts at state 1 is forced to change to state 2 by an agent. These agents can be people influencing a system, the environment, etc. Because these agents can act within the system or external to the system, there is a distinction between these characterizations. If the change is external, this is considered a flexible type of change. Those acting internally are considered adaptable types of change. A change such as changing out a crane on a cutter is a flexible type of change, while a crane that can change the load capacity through a change in the wire rope and associated equipment are adaptable.

The change mechanism is the path that the system needs to take to “travel” between states 1 and 2. This is the “how” the system changes and requires what are the necessary conditions, resources in time or money, and the constraints of the system. This gives choices of what desired output state is acceptable, the cost or schedule impacts, and how this change is achieved.

The change effect is the difference in the two states of change in terms of the systems parameters which capture physical, operational or functional characteristics of the system. A system’s change effects can be described by “ilities” such as robustness, scalability, and modifiability. These change effects describe the descriptions of the changeability based on the desired change mechanism of the system. If a cutter needs to shift to missions that require a higher use of small boats in the future, the designer can make the cutter design robust or have specific a small boat aboard that will meet the expectations of stakeholders’ needs for different mission prioritization scenarios. The designer can make the system scalable so that either bigger small boats can be accommodated or including the ability to add more small boats in the design. The designer can also make the small boat and launching system modifiable in their ability to be changed to incorporate new style launching systems or new small boats.

The synthesis of the change agents, mechanism, and effects to go from state 1 to 2, gives an overall understanding of changeability within a system. Ross, Rhodes, and Hastings (2008) developed a framework for developing changeability requirements of the system. First is understand the resources (costs or costs related to time) available for a change. These costs can

be an understanding of the direct costs associated with a change or the “cost effects” of the change within the system. Second is whether the change agent should be internal (adaptable), external (flexible) to the system. Third is the change effect on the system. This includes the decision on whether to change the system by scalability, modifiability or robustness to a specific system parameter. An example of this would be the description of changeability of a computer LAN on a cutter through the statement, “The computer LAN system shall be flexibly scalable to increase the number of computer stations by 5 percent for less than 2 percent of the total system cost.”

This changeability can also be viewed in respect to modularity, integrability, and redundancy. Fricke and Schulz (2005) use these three “ilities” relating to flexibility, adaptability, and robustness. Modularity is the clustering of a system’s functions into a common system form with defined interfaces and can be used for flexible, adaptable or robust systems. Redundancy is the duplication of component or subsystem to enable system option for contingencies or safety reasons and can be used in flexible and robust systems. Integrability is a structural depiction of applying open or common interfaces within the system and applies to both flexibility and adaptability. Integrability should be considered in components and subsystems that require interoperability and compatibility for long term effectiveness. These three “ilities” are important considerations on managing how to incorporate changeability into the system.

Understanding the changeability of a system within a future context gives valuable insights to the ORD development and enables a better understanding of tradeoffs that may need to be further analyzed. While these tradeoffs are more specifically defined in final concept design and detailed design, understanding the high level understanding of changeability and related dynamic “ilities” at the beginning of ORD development enhances the overall time dependent influence into ship design.

2.3.2 “ilities” within Coast Guard Requirements

While the MSAM (U.S. Coast Guard, 2009c) does not specifically address “ilities” requirements as a separate analysis during ORD development, there are several sections of the ORD that are applicable. These primarily focus around how the asset will work within its intended environment, how the asset will be used by operators, and how the asset will be maintained. The majority of these attributes fall within the suitability section of the ORD and are summarized as:

- **Interoperability:** The scope of the system’s interaction with other systems including C4ISR interactions.
- **Operational Availability (includes reliability, maintainability, and designed supportability):** The probability of the system to be able to be able to perform mission requirements when called upon. Often associated to reliability, availability, and maintainability (RAM) or (RMA) of the system.
- **Supportability and Sustainability (Integrated Logistics Support, Ten Elements of Logistics):** The overall support model for the system including all logistical elements and how they will be incorporating into the life cycle of the system.
- **Survivability:** The conditions in which the system must survive in a hostile environment including natural or man-made changes.
- **Human Systems Integration (HSI) (safety, usability, maintainability, operability, suitability, simplicity, accessibility, habitability, and trainability):** The factors that identify the system should work with human interfaces in all operational and support modes of the system.

The Requirements Generation Manual (U.S. Coast Guard, 2009d) recommends that the following additional “ilities” be examined in addition to those listing above. As a set of “ilities”

these establish Critical Operational Issues (COI). These are key concerns of the system that must be examined in operational testing and are linked with the performance attributes in the MNS and CONOPS.

- **Mobility:** The capability of a system to move from location to location while still completing its mission requirements.
- **Deployability:** The capability of a system to be relocated to another area of operation.
- **Transportability:** The capability of a system to be moved to another location via towing, self-propulsion or via cargo transport.

Combining these two sets of “ilities” establishes guidelines for assessing operational capabilities or supporting capabilities that ultimately relate to overall performance of the system. Together they assess the desired operational and suitability characteristics of the cutter and provide insights into how the cutter will work with other Coast Guard, DOD, and the public as well as how time might affect the operating environment or stakeholders’ needs.

Reliability, Availability, and Maintainability or RAM is an important and required part of setting system effectiveness requirements within the ORD. Operational Availability is the supportability level of the hardware and software in terms of the predicted reliability, mean time between failures, and mean time to repair (U.S. Department of Navy, 2003). Within the ORD development, these supportability requirements and the operational analysis of the CONOPS need to be analyzed to obtain the beginnings of what types of maintenance and support models will be used at a reasonable in cost. Ideally there is an Operational Availability level beyond which there is little gain in performance while increasing the system’s cost.

Within the RAM analysis, the potential maintenance requirements and methodology should also be evaluated with respect to the CONOPS. This allows subsystems of the cutter to be

individually evaluated for Operational Availability levels needed to maintain required operations. This could include the start of subsystem analysis of attached boats, C4ISR systems, aviation related equipment, weapon systems, cranes, and other mission critical major components. Understanding each of their effectiveness needs during the ORD will significantly increase the understanding of significant sources of availability challenges during ORD development.

Each Coast Guard cutter project needs to review both the Coast Guard required and the dynamic “ilities” to evaluate the high level understanding of the system prior to the ORD development. In order to enhance the understanding, the following should be reviewed prior to ORD development:

1. What are the design factors within the project that affect interoperability, operational availability, supportability and sustainability, survivability, human system integration, mobility, deployability, and transportability?
2. What changes (stakeholder needs, context changes, etc) within the life cycle of the project that will affect these key factors?
3. Can changeability enhance life cycle performance of these factors?
4. What are the implications of incorporating changes through redundancy, modularity, or integrability?
5. What are the highest priority “ility” effects that need to be further analyzed within the ORD development processes?

With understanding the “ilities” and life cycle effects on the project, the ORD development process will have more insights on prioritizing analysis work to best define the operational requirements.

2.3.3 Interfaces

Crawley (2009) defines interfaces as the connecting points between systems, subsystems, modules, and parts that define the system in how it is physically connected and how it functions together in its operation. These interfaces are also locations within a system where complexity is determined by their form and function. By their identification and understanding, the system’s functions are better understood and can be managed throughout the development of a major system.

Maier (1998) relates the importance of interfaces in systems by the following heuristic:

“The greatest leverage in systems architecting is at the interfaces. The greatest dangers are also at the interfaces.”

This leads to the necessary effort to understand these interfaces to maximize the value in the system, but also to reduce the risk of the system not operating or behaving as intended if the interface description, design, and implementation are not well understood. This apparent complexity through the interfaces must be carefully managed.

In the cutter ORD development, the interfaces are integral in the composition and analysis of functionality. According to Bahill and Dean (2009), interfaces along with stakeholders’ needs, expectations, and constraints are necessary to establish the overall requirements of a system. As a key component to the overall ORD, they need to be explicitly understood and analyzed throughout the PORD and ORD development.

Within the beginnings of the Design Phase of acquisition following the ORD development, interfaces and their high level requirements need to be understood for a robust design cycle. The functional analysis needed to flow down functional requirements to specific subsystem specifications and component requirements require a thorough understanding of these interfaces to be completed (U.S. Department of Navy, 2003). Bahill and Botta (2008) also state that within design the interfaces between subsystems and the external environment must be designed. A few specific interface designs should be used throughout a system to minimize the total number of unique interfaces. Importantly, the interfaces should be analyzed to remain constant even when subsystems are upgraded or changed.

Interfaces affect the “ilities” and the future needs of stakeholders. Within the architectural guidelines of the Department of Defense Architectural Framework Version 1.2 (DoDAF) (2007), interoperability within different systems must ensure that external interfaces are specifically described and consistent with the steps used to develop internal relationships. This will ensure that displaying of information has a common format for use across all systems.

The importance of understanding existing and future interfaces is specifically important for completing requirements analysis (U.S. Defense Acquisition University, 2009). These future interfaces may lead to specific requirements for an interface constraint such as a standard data transfer type or the human interface as to the operation of a system on how this will be intended to operate within mission specific tasking. This will lead to the analysis of the changeability of the system and whether interfaces will be used throughout the life cycle of the system. These “stable” interfaces ultimately define a standard or the incorporation of several standards within a system and can be difficult to change within resource constraints (Crawley, 2009). For these “stable” interfaces, modularity and decoupling multiple components and their interactions may enable the changeability of the system. But, with modularity, the complexity in the system may be increased (Crawley, 2009).

Within cutter acquisition projects, external interfaces can include the conduit of information flowing to and from other Coast Guard units and the boating public at large, how users are intending to operate specific components, how the cutter is going to be towed, how the aircraft are landed, etc. Internally, this could include how component information is managed and exchanged by different systems, the internal power distribution systems, monitoring systems, and equipment mounting systems. These interfaces need to be reviewed for the ORD development particularly with respect to how these systems and the cutter react with the environment within the operational scenarios outlined in the CONOPS, or how users and maintainers will interact with the components. If, for example, there is a shift in maintenance philosophy for the entire fleet to have electronically monitored and centralized maintenance, this will need to be accounted for in the ORD.

In summary, the known and potential interfaces within a cutter development drive the complexity of the system, the interaction of the cutter with other Coast Guard, DOD, and public operators, but also impact interoperability, maintainability, operability, supportability, and changeability of the cutter. These interfaces need to be carefully determined and managed throughout the acquisition and deployment phases.

2.3.4 Summary of Design Effects

The development of the ORD requires an understanding of the “ilities”, interfaces, and how they change over the life cycle of any major project. These design effects importantly provide insight into the challenge of how internal and external interfaces and “ilities” influence the ORD and what further analysis needs to be completed in order to define specific interface requirements into the ORD. Figure 2-16 below shows the relationship of the Operational Requirements Document and the design effects.

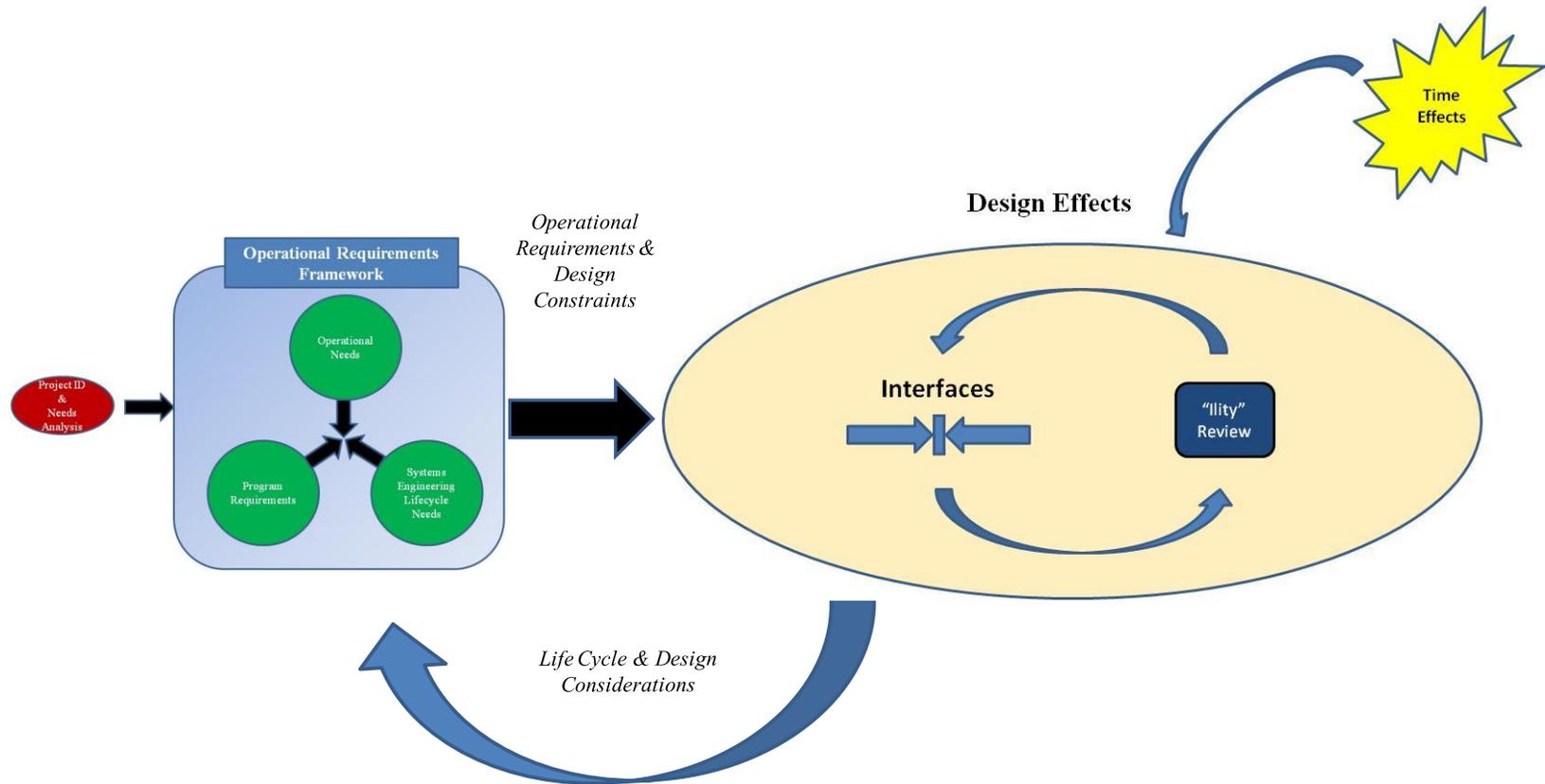


Figure 2-16: Design Effects on Operational Requirements Framework

The Operational Requirements Framework provides both the operational requirements and design constraints necessary for the later design team to most effectively complete the functional allocation to design specifications. The design effects in turn provide the Operational Requirements Framework life cycle and design considerations that influence specific operational requirements. These combined with the framework input provide the essential foundation for the development of a thorough and balanced ORD.

2.4 Operational Requirements Framework

With the thorough understanding of the inputs and design effects, a more complete Operational Requirements Framework can be constructed. This framework is intended to capture all Select/Analyze Phase systems engineering, sponsor, and program management requirements that integrate and form the high level systems engineering perspective within the project important to the ORD with the new processes described in sections 2.2 and 2.3. Within the MSAM, these requirements are independently described but are not integrated within a process framework. This framework will enhance the overall project process flow and enhancement of the Capability Development Plan (CDP) that describe specifics management of all Analyze/Select Phase activities.

Figure 2-17 details the Operational Requirements Framework. This framework is focused on the development PORD and ORD as two distinct process paths. This process depiction details the dynamic nature of requirements generation vice the traditional view of listing all requirements within the requirements generation. The remaining sections will overview PORD and ORD process paths synthesizing the MSAM and Requirements Generation Manual ORD development steps.

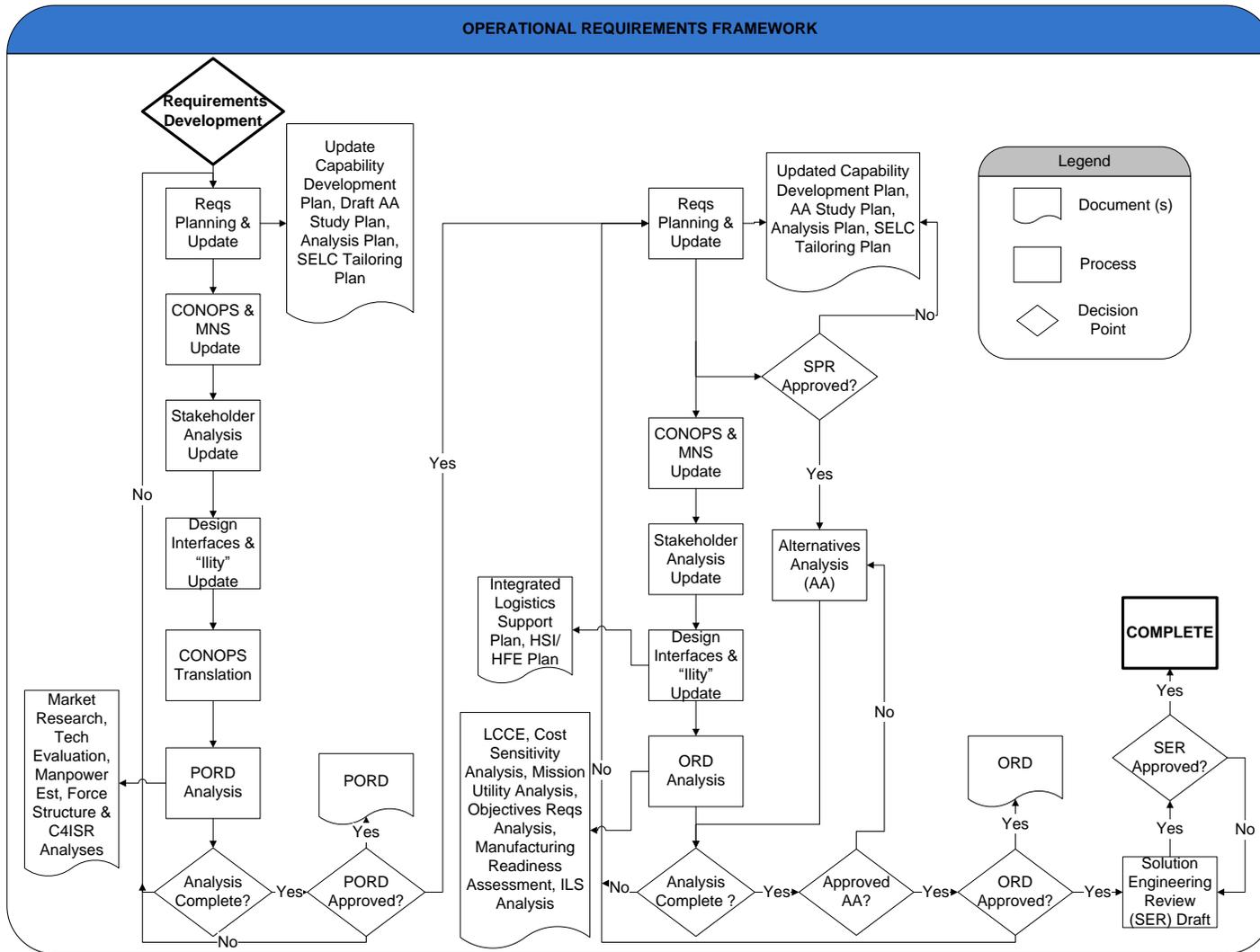


Figure 2-17: Operational Requirements Framework

2.4.1 PORD Processes

The PORD process section establishes the initial requirements parameters that are the foundation for early analysis and study work. These processes should be completed within a 6-month period and contain the high level requirements necessary for more in-depth analysis and modeling.

The first step is to establish the common acquisition IPT across all internal stakeholders responsible for the acquisition, requirements, and systems engineering processes. These members will review the pre-Acquisition Decision Event 1 documents of the project and formulate an outline of the entire Select/Analyze Phase processes, review the required documentation, and develop a high level management plan to synthesis this vast amount of information. Together, this outline will become the common foundation for the Draft Alternatives Analysis (AA) Plan, the Analysis Plan, the Systems Engineering Life Cycle Tailoring Plan, and updating the Capabilities Development Plan (CDP). The Capabilities Development Plan should contain and be the guiding document for this foundational plan.

Following the planning review, the next processes include CONOPS and MNS review and update, the Stakeholder Analysis, and the Design Effects. These processes contained in sections 2.2 and 2.3 develop the functional needs of the project identified earlier within the project to the potential design, build, operations, and maintenance effects. This synthesis and review early within the PORD development will provide prioritization guidance to the analysis step to follow. They also provide feedback and changes to the CONOPS and MNS documents as the requirements are determined and there is a need to clarify operational scenarios or mission prioritization.

With the inputs to the Operational Requirements Framework and the downstream design effects evaluated, the latest CONOPS translation is developed that details the draft Critical Operational Issues (COI) which are the technical parameters used to measure operational and suitability effectiveness for the project. These parameters should also include potential ranges and identify what specific COI's or range information may need further evaluation to become stable

requirements. This translation should also identify known conflicting COI's where dependencies and interactions need to be better studied for final determination and prioritization.

With the list of COI's, design effects, framework input information, the PORD analysis process initiates. This is the development of independent studies that help formulate the understanding of COI levels, cost to performance tradeoffs, and the understanding of capabilities that are technically feasible given the knowledge of the needs of the project to the inputs identified in early process steps. These analyses include Market Research, Technical Evaluations, Manpower Estimates, Force Structure, and C4ISR Analyses with specific requirements outlined in the U. S. Coast Guard's Requirements Generation and Management Process Manual (2009d). Their outline and connection to the overall PORD outline was identified in the Analysis Plan at the beginning of the PORD process section and are continually updated with changing information within the IPT.

The next step is to evaluate whether the information gathered is sufficient to meet the requirements of the MSAM for the PORD development to move towards PORD approval. If the information is not sufficient to become the foundation for the ORD development and continued more in-depth analysis work, the PORD processes should be repeated. The intent of the PORD is to provide the broad system characteristics to meet the capability gaps in the MNS and the operational context in the CONOPS (U.S. Coast Guard, 2009d). The final PORD should contain these performance statements and Key Performance Parameters (KPP) that best define these needs. The KPPs are critical issues that are required to meet the performance gap identified or those required by a higher authority, regulation, or policy. Minimizing KPPs within the PORD enables a larger tradespace exploration within the ORD development processes as the KPPs become fixed parameters vice more broadly defined parameters.

2.4.2 ORD Processes

Once the PORD is signed, the planning of the ORD takes place. The planning process focus is to ensure that all high risk areas in the ORD are identified with an analysis or other strategy to

reduce the risk. Also, this planning review highlights developing the tactical Alternatives Analysis (AA) Study Plan and preparing for the SELC Milestone, the Study Plan Review (SPR).

The Study Plan Review required by the MSAM (U.S. Coast Guard, 2009c) and the DHS Acquisition Directive 102-01 (2008) requires that a SPR occurs prior to the start of the AA. This ensures alignment within the stakeholders and higher authorities as to the scope of the available alternatives and ensures that other analysis work carried out in conjunction with the ORD is not redundant or using different analytical criteria.

Once the SPR is approved, the AA occurs simultaneously with the ORD development processes. Because of this simultaneous development both the AA and ORD, there must be an established method to pass information between the two analyses. This includes updating the AA for changing ranges of parameters and updating the ORD with analysis work on specific parameter's affordability, suitability, and feasibility for a given concept. Managing this coordination between the AA and the ORD is critical for the final ORD and subsequent design specifications.

The ORD specific processes following the planning phase of the ORD are similar with respect to the PORD development, but with more in depth analysis, particularly with respect to cost. The ORD inputs, Stakeholder Analysis, and CONOPS and MNS updating continue to occur throughout the continuous ORD development process.

Next, the design effects are analyzed. As these design effects develop into more specifics, they identify the information necessary to develop the Integrated Logistics Support Plan (ILSP) and the Human Systems Integration (HSI) Plan. These capture the logistical and user interfaces necessary for the project.

Once these are completed, the ORD analysis provides the detailed information on parameters, their impact on the developing preferred solution from the AA and understanding the dynamics of the parameters to cost, schedule, and performance. This analysis includes the Life Cycle Cost

Estimate (LCCE), Cost Sensitivity Analysis, Mission Utility Analysis, Objectives Requirements Analysis, Manufacturing Readiness Assessment, and the ILS Analysis.

These ORD processes are repeated until the IPT is confident that the ORD parameters capture the significant requirements for the dominant solution being simultaneously determined in the AA. Once both the AA and the ORD analysis work are completed, the ORD is submitted for review and approval.

The final step to ensure readiness for the project to complete the Operational Requirements Framework is to draft the ORD and project documents for the Solution Engineering Review (SER). This review captures all the documents and analyses within the Analyze/Select Phase to ensure that the project is coordinated within the technical, program, and sponsor's objectives to move towards Acquisition Decision Event 2 approval. Completing this review validates the ORD development and completes the Operational Requirements Framework.

2.4.3 Summary

The Operational Requirements Framework is a synthesis of processes that links early acquisition phase information with lifecycle and design effects to most effectively create the ORD. This can be shown as a continuous process from the start of the ORD development until the ORD and associated documents are completed by synthesizing the operational needs, project office requirements, and the systems engineering life cycle needs within a common framework. This enables the timely flow of information and coordination necessary to develop robust requirements for major acquisition projects.

CHAPTER 3: Applying Responsive Systems Comparison to Operational Requirements Development

3.1 Introduction

Within the Operational Requirements Framework developed in Chapter 2, there is a significant amount of analysis that must occur in order to develop a robust set of operational requirements for major cutter acquisition programs. Because this entire process involves many stakeholders in the development of these complex and long life cycle systems, there is a need to understand key tradeoff information in the beginning stages of ORD development. Moreover, these cutters have life cycles in excess of 20 years leading new missions, new operational requirements, and changes within the Coast Guard that will affect the effectiveness of the cutter during its time in commission.

The Responsive Systems Comparison (RSC) method was developed to assist in balancing how future shifts in context (changes in a system's budget, needs, interaction with other systems, and missions) interact with design choices for current constraints and expectations (Ross et al., 2009). This method combines Dynamic Multi-Attribute Tradespace Exploration (MATE) (Ross and Hastings, 2006) with Epoch-Era Analysis (Ross and Rhodes, 2008) to guide the formation and selection of concepts that perform best within a changing environment. This includes a 7-process method determining the value of a proposed system, how value can be delivered through different concepts, identifying changes in needs and context in specific time periods (epochs) and understanding how the concepts responds to these changes within a specific sequence of epochs (eras). A designer can then obtain insights into value within a system, understand concepts within this design space, assess which concepts can perform within a dynamic environment, understand tradeoffs, and develop an overall understanding of the systems within the development and deployment phases.

Within Coast Guard cutter acquisition projects, the development of the ORD is typically accomplished utilizing an Integrated Product Team (IPT). This team is generally comprised of a

diverse group of stakeholders within Coast Guard offices of Human Resources, Engineering and Logistics, C4ISR, Capability, and Acquisition within a written charter (U.S. Coast Guard, 2009d). These members typically have extensive experience within their own domains relating to cutter requirements, but often do not fully understand all aspects of the complex cutter design.

The following process is a modified version of the Ross et al. (2009) RSC method and the process description format described by Viscito (2009). While these methods use analytical modeling of utility to assess tradespace analysis of multiple concepts, this revised methodology focuses on understanding relationships among external influences, needs, and parameters of a system under consideration. Without a complete set of full ship design parametrics and because often ship based design parametrics are not independent of each other, this methodology can develop insights for the IPT in a general systems overview of the cutter to better guide detailed analysis within the Operational Requirements Framework. This could be used at the very beginning of the framework following the initial IPT training.

Derived from the work of Ross et al. (2009), this thesis proposes a tailored 5-process RSC methodology to capture systems needs, design considerations, and effects of change within the system. Each step includes required inputs, analysis activities, and outputs. This method could be used in a one to three day workshop following the ORD IPT establishment to assist in formulating key high level system details of the new cutter acquisition project. This high level systems viewpoint will enrich individual team members of the IPT with a more in-depth understanding of the project and challenges throughout the cutter's life cycle. The following sections describe how this method is used within a major cutter acquisition project.

3.2 Methodology

3.2.1 Process 1: Value-Driving Context Definition

Process 1 is the basis step to identify the understanding of value for the entire cutter project, what stakeholders are internal and external to the project, and how value is transferred within the

project. The summary of the inputs, activities and outputs are contained below with the inputs to this process as documents, analyses, or data that IPT members consider vital for the development of the ORD. The summary of the inputs, activities and outputs are shown below:

Inputs:

- 1.I.1 MAR
- 1.I.2 MNS
- 1.I.2 CONOPS
- 1.I.3 IPT Charter
- 1.I.4 Capabilities Development Plan
- 1.I.5 Fleet Mix Analysis (if available)
- 1.I.6 Need Phase Concept Analysis Study documents
- 1.I.7 Long Range Acquisition Planning Schedules
- 1.I.8 Other

Activities:

- 1.A.1 Define problem definition
- 1.A.2 Define project boundaries
- 1.A.3 Identify internal and external stakeholders
- 1.A.4 Indentify internal stakeholder value flow
- 1.A.5 Identify exogenous uncertainties
- 1.A.6 Define system value proposition

Outputs:

- 1.O.1 Problem statement
- 1.O.2 Project boundary definition
- 1.O.3 Project time constraints
- 1.O.4 Sketch of external, internal, and key internal stakeholders and value exchange within the enterprise
- 1.O.5 List of external uncertainties
- 1.O.6 List of mission statements for key internal stakeholders

Within Process 1, the inputs (1.I.1 to 1.I.8) include documents and analysis information obtained prior to Acquisition Decision Event 1. These documents provide the basis for the cutter project, constraints, and insights into the operational and support needs. To enable a more efficient workshop, a member of the IPT should have a thorough understanding of each document and be able to quickly describe key information of this document to the rest of the team. The workshop could be started with these individuals giving a five minute summary of each of these inputs.

Next the team will focus on defining the top level problem definition of the cutter project (1.A.1). This is usually summarized in the MNS within the Mission and Capability and Program Justification sections. This answers the first question is why the cutter project is needed and what specific high level functional this project will address (1.O.1).

The team then needs to review the scope of the project and identify the project boundary definition (internal versus external) (1.A.2). The internal project areas could be the cutter itself and its associated subsystems, but should not include other systems outside of the project that will become constraints on the cutter design. Examples include independent design considerations within the project (helicopters, standard small boats, etc.) (1.O.2). Also, the time constraints of the project should be discussed and listed including the expected time to operational capability and expected service life of the cutter (1.O.3).

The next step is to understand the stakeholders involved in the project (1.A.3). This is brainstorming and listing all groups that influence or are influenced by the project during the entire life cycle of the project. They also should be categorized as either internal or external to the enterprise itself. The enterprise is the entire “business” that encompasses the project to build, support, operate, and repair the proposed system. Internal stakeholders could include the IPT offices or a subset thereof. External stakeholders could include users, Congress, shipbuilders, contractors (design and support), etc. Key decision stakeholders should be identified as the internal stakeholders that have high saliency within the project (1.A.4). This group of internal stakeholders can quickly change the project direction and understanding what they value to each other and gives an understanding of important factors of the project. The stakeholders and value flows between key stakeholders can be sketched to depict the enterprise value exchange as per Figure 3-1 (1.O.4).

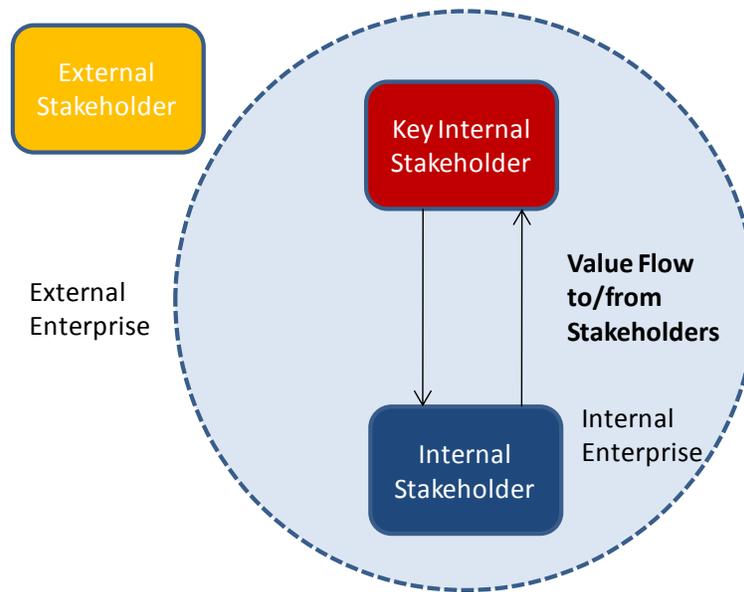


Figure 3-1: Stakeholder Enterprise and Value Relationships

The next activity is to solicit from the team all potential external uncertainties that might affect the value flow of the key internal stakeholders (1.A.5). Examples could include resource availability and fluctuations to the project, changes in the operational environment such as increasing or decreasing port security needs, changes in regulations, etc (1.O.5).

The last step in this process is to the overall value proposition of the project (1.A.6). This is done by drafting concise mission statements for each of the key internal stakeholders. Each mission statement should include constraints and what each stakeholder is trying to accomplish (1.O.6).

In summary, Process 1 derives the overall project mission, key stakeholders, and their value propositions. This is the overarching information as the foundation for understanding how the design should relate to the stakeholders' needs.

3.2.2 Process 2: Value-Driven Design Formulation

Process 2 defines the beginning understanding of design variable impact on value. This is completed by understanding objectives, how to articulate measuring these objectives, relating these measurements to specific design variables that cause their values to change and then assessing their influence on these objectives.

Inputs:

- 2.I.1 CONOPS
- 2.I.2 Key internal stakeholder mission statements
- 2.I.3 Need Phase concept analysis study documents

Activities:

- 2.A.1 Review the CONOPS
- 2.A.2 Mission statement decomposition to attributes
- 2.A.3 Design-value mapping
- 2.A.4 Refine design-value mapping impact

Outputs:

- 2.O.1 Operational and sustainability considerations
- 2.O.2 Mission statement decomposition
- 2.O.3 Design variables to attribute impact matrices
- 2.O.4 Revised design variables to attribute impact matrices
- 2.O.5 Design drivers

Within this process, the first step is to review the CONOPS (2.I.1) that was either signed or drafted within the Need Phase of acquisition (2.A.1). The CONOPS will give insights to the IPT as to required missions and mission functions necessary for those missions. The IPT should review and assess the Mission Operations and Support matrices. This will also give insights how the project will operate with other Coast Guard and external systems leading to knowledge of operational and sustainability considerations that should be listed including related constraints (2.O.1).

The next step is to decompose the mission statements found in Process 1 (2.I.2) for all key internal stakeholders (2.A.2). This is accomplished first by brainstorming objectives necessary

to meet the mission statements. These objectives should be high level objectives and not specific subsystem objectives. These are then translated into attributes or specific measures of meeting the objectives. The attributes include units of measure, the expected range of measurement from the least to most desirable, and rank by weighting the importance of each to the entire set. Because this analysis does not model attributes or utility, attributes can be qualitative in nature. The total weight of the attributes should total 10 and the total number of attributes should be maintained at less than 15 per stakeholder. These attributes become the performance characteristics of an asset that describe how to measure the functional capabilities (objectives) as described in the Requirements Generation Manual (2009). Table 3-1 below is a template for this mission statement decomposition (2.O.2).

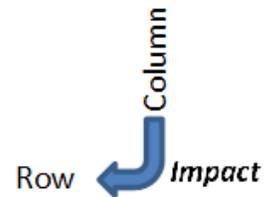
Key Internal Stakeholder:				
Mission Statement:				
Objectives:				
a.				
b.				
x.				
Attribute (Acronym)	Units	Range		"Weight"
		"worst"	"best"	(0-10)
Attribute 1				
Attribute n				

Table 3-1: Key Internal Stakeholder Attributes

With the attributes of the project understood for each stakeholder, the assessment of how they relate to a cutter design is initiated (2.A.3). This is the relationship of a design variable within this design's control to a stakeholder's value (attribute based). Examples of design variables for cutters are hull material type, length, speed, hull type, etc. This relationship mapping is completed by brainstorming design variables that impact the attributes of the stakeholders and reviewing the Need Phase design study documents (2.I.3). The impact of design variables on the total life cycle costs of the project should also be included. A matrix representation of this relationship is used to assess the design variables' impact on the attributes for each key internal stakeholder (2.O.3). Table 3-2 below is an example of this matrix.

DESIGN-VALUE MAPPING MATRIX

Key Internal Stakeholder:				
Attributes	Design Variables	Design Variable 1	Design Variable n	Total Impact
	Attribute 1		9	1
Attribute n		3	9	12
Total		12	10	
Lifecycle Cost		1	9	
Total w/Cost		13	19	



Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

Table 3-2: Design-Value Mapping Matrix

Once the matrices are completed, the design variable impact should be reviewed and revised (2.A.4). The design variables that do not have a high impact on any attributes should be removed. Also, design variables should be added for attributes that do not have any high impact correlations. These revised design-value mapping matrices (2.O.4) reveal several of the key design drivers of the project. These design drivers should be listed with their range of values as determined by the subject matter experts within the team (Table 3-3 below). The design drivers are important to understand during the ORD development and help to establish key inputs to design studies (2.O.5).

DESIGN DRIVERS

Name	Units	Range	
		Low	High
Design Driver 1			
Design Driver n			

Table 3-3: Design Drivers

3.2.3 Process 3: Epoch Characterization

Process 3 is the start of assessing future uncertainties, how these uncertainties can impact the design, and how the project might mitigate these uncertainties. Each snapshot for a specific time period (epoch) can experience dynamic changes significantly impacting design variable choices or value to stakeholders. Understanding these relationships early with a project can provide an understanding of how to better reduce these dynamic effects.

Inputs:

- 3.I.1 Project time constraints
- 3.I.2 List of external uncertainties affecting key stakeholder value
- 3.I.3 Key internal stakeholder attributes
- 3.I.4 Design drivers

Activities:

- 3.A.1 Develop external changes
- 3.A.2 Develop changes in attribute levels and new attributes
- 3.A.3 Develop epoch descriptor definitions
- 3.A.4 Assess epoch descriptor to design variable and attribute impact

Outputs:

- 3.O.1 Epoch descriptions
- 3.O.2 Epoch descriptor impact matrix
- 3.O.3 New design variables and attributes

Using the time constraints (3.I.1) and external uncertainties (3.I.2) affecting key stakeholder value in Process 1, a more complete set of future context changes affecting all stakeholders can be assessed (3.A.1). The following list can assist in the development of these uncertainties based on prevalent categories within a cutter's service life.

Technology: Known or estimated future changes in specific subsystem or other technology (e.g. changes in data transfer technologies, etc).

Policy: Changes in overall government policies or Coast Guard specific policies (e.g. changes in cutter manning, environmental considerations, etc.).

Budget: Changes in budget impacting the project including acquisition, operational, and repair/upgrade funding (e.g. decrease in estimated operational funding until acquisition completed).

Systems of Systems: Changes in other systems that interface with the project or a change to a specific interface (e.g. the future decommissioning of a class of cutter/boat or a change to data transfer methods to the cutter).

Missions: Changes to missions or priority of the mission sets compared to those identified in the CONOPS (e.g. buoy tenders conducting frequent maritime law enforcement missions).

Along with these external changes, there also might be new stakeholders involved with the project with new objectives and associated attributes. The existing key internal stakeholders might also have new needs in attributes or changing levels of existing attributes (3.I.3). These attribute changes should be explicitly discussed updating the original attribute list (3.A.2). Together the list of external changes form a list of potential epoch vectors (changes within the project). These epoch vectors can explicitly be described by an epoch descriptor or a specific externality that is causing this change (3.A.3). These epoch descriptors might also have constraints that are imposed or limit the epoch change. Table 3-4 below should be used to capture these epoch names, descriptors, and constraints (3.O.1).

EPOCH DESCRIPTIONS

Epoch Name	Epoch Descriptor Category	Epoch Descriptor	Units	Range
EN 1		ED 1		
EN n		ED n		

Table 3-4: Epoch Descriptions

Next, the epoch descriptors’ impact on the original set of attributes (3.I.3) and design drivers (3.I.4) are reviewed to understand how these changes affect the needs and design (3.A.4). From this the total impact effects can be obtained (3.O.2) and a new list of design variables with new variables added to understand the impact of the epoch vector. The new attributes (needs) are

also added (3.O.3). The relationship of the epoch descriptors to the design variables provides correlation on design variables and attributes that are sensitive to changes within the system. Also, this shows which epoch descriptors have the biggest impact on the overall sets of design variables and attributes. Table 3-5 details the epoch descriptor impact matrix.

EPOCH DESCRIPTOR IMPACT MATRIX

Design Variables	Epoch Descriptors		Total Impact
	ED 1	ED n	
DV 1			
DV n			
New DV x			
Total			
Attributes			
Attribute 1			
Attribute n			
New Attribute x			
Total			

Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

Table 3-5: Epoch Descriptor to Design Variable and Attribute Impact Matrix

3.2.4 Process 4: Era Analysis

Process 4 is the analysis of how the potential futures may affect the project and how changeability can be reviewed to mitigate the effects of change towards best meeting the objectives of all stakeholders. This gives knowledge of not only the current state of the project, but also the future state.

Inputs:

- 4.I.1 Project time constraints
- 4.I.2 Epoch descriptions
- 4.I.3 New design variables and attributes

Activities:

- 4.A.1 Develop specific epoch time periods
- 4.A.2 Assign epoch descriptor prioritization by time period
- 4.A.3 Define the system transition rules across epochs
- 4.A.4 Develop era strategies
- 4.A.5 Develop strategy evaluation criteria
- 4.A.6 Evaluate era strategies

Outputs:

- 4.O.1 Era time periods
- 4.O.2 Era descriptions
- 4.O.3 Era rules effects matrix
- 4.O.4 Era strategies
- 4.O.5 Strategy evaluation results

Using the project time constraints (4.I.1), the first step is to develop 2 to 4 specific time periods that correspond to natural breaks within the project's life cycle (4.A.1). Time periods could start at specific critical project milestones including the current time period, the Initial Operating Capability (IOC) milestone, the Full Operating Capability (FOC) milestone, or to the project's estimated mid-life overhaul projected date. These periods define the specific epoch time periods within the life cycle of the project and the overall era construct (4.O.1).

Based on experience and knowledge of the personnel, the team reviews the epoch description (4.I.2) and epoch descriptor impact matrices (4.I.3) and determine what specific time period each epoch descriptor would likely occur and assigns an epoch for each variable accordingly. By rank ordering each epoch descriptor list by time period from the most to the least likely to happen within each epoch (4.A.2), a specific era description is formed (4.O.2). Several different eras can be formed based on the prioritization of the epoch descriptors. Table 3-6 below shows an example of the era descriptions.

ERA DESCRIPTION

Era Name	Time Period	Period Description	Epoch Descriptor	Comments
Era Name 1	1		Current State	
	2		Epoch Descriptor 1	
	3		Epoch Descriptor 2	
Era Name n	1		Current State	
	2		Epoch Descriptor 1	
	3		Epoch Descriptor 2	

Table 3-6: Era Description

With the eras defined, the next step is to assess the transition rules of systems between the epochs in these eras (4.A.3). This is the initial step in the changeability assessment of the system. This is done by assigning system transition rules that enable the system to transform from one epoch to the next within the era beginning with the current state (Epoch 1). These rules specify how design changes across epoch boundaries within an era. Each transition can have several potential transition rules that could include having a passively robust design. This is a design able to meet changing attribute levels or expectations without changing the system. Also, each rule can show changeability by a change agent type (flexible or adaptable), the change effect (scalable, modifiable, or not required for a robust design) and the parameter (design variable) enabling the change to occur (more specifics about changeability are contained in Chapter 2). Table 3-7 below shows an example of transitioning from Epoch 1 to 2 with two different rules to meet the need to increase the number of small boat launching systems on a cutter (4.O.3).

ERA RULES EFFECTS MATRIX

Era Name: _____

Epoch Transition	Rule #	Name	Robustness	Changeability				Parameters Enabling Change	Comments
			Robust	Change Agent Type		Change Effect			
				Flexible	Adaptable	Scalable	Modifiable		
1 to 2	R1	E1-2R1	X					Small boat launching systems	2 in original design
1 to 2	R2	E1-2R2		X		X		Small boat launching systems	Space, weight, or power in original design for potential future use

Table 3-7: Era Rules Effects Matrix Example

Once all of the rules are explicitly assigned in an era, a list of epoch combinations and transition rules result in era concepts (4.A.4). For a specific era with three epochs (3 epoch transitions including from the current state) with 2 rules each, there are 8 era strategies. These era strategies should be specifically reviewed for feasibility (or revise the changeability rules to meet the specific era strategy) and then developed into an era strategy description listing (4.O.4). Table 3-8 shows an example of how to capture this information including a short title that gives insight into the strategy’s changeability.

SYSTEM ERA STRATEGIES

Era Strategy	Rule Sequence	Short Title
A	R1-R3-R5	
X	R1-R2-R4	

Table 3-8: System Era Strategies

Once the strategies are reviewed and understood, the next step is to develop strategy evaluation criteria (4.A.5). These criteria could include “ilities”, performance criteria, life cycle cost, or specific high priority attributes of the system and should be limited to less than 10 total criteria. They then can be used to compare or evaluate the different strategies for the most preferred era strategy (4.A.6). One suitable comparison is the Pugh method (Pugh, 1991). This is evaluating the strategies against a baseline (any selection from the era strategies) to show the relative

difference of the strategies to the baseline. The criteria can be weighted or equally counted in the evaluation. Table 3-9 below shows an example of the Pugh method.

STRATEGY EVALUATION
Baseline Strategy: _____

		Strategy			
		A	B	C	D
Evaluation Criteria	X1				
	X2				
	X3				
	X4				
	X5				
	XN				
	$\Sigma +$				
	$\Sigma -$				

Legend: + Better; 0 Same; - Worse

Table 3-9: Strategy Evaluation

If there are several strategies close in the evaluation, the highest scoring becomes the baseline and then the evaluation is completed again to show the dominant era strategy that best meets the changes in needs or external changes (4.O.5).

3.2.5 Process 5: Review

Process 5 is the opportunity to review and highlight the major outputs from the previous processes and to explicitly list team member individual learning points. This summary will provide the basis for how to apply this knowledge to future analysis work and to establish a basis for requirements generation.

Inputs:

- 5.I.1 Process 1-4 outputs

Activities:

- 5.A.1 Review value proposition and stakeholders
- 5.A.2 Review attributes and key design variables
- 5.A.3 Discuss changeability and impact to attributes and design variables
- 5.A.4 Develop list of important analysis studies
- 5.A.5 Discuss individual lessons learned

Outputs:

- 5.O.1 List of present and future important value exchanges
- 5.O.2 List of important stakeholders in acquisition and operational phases
- 5.O.3 Attribute and design variable groupings
- 5.O.4 Changeability impact to project
- 5.O.5 List of analysis studies
- 5.O.6 Lessons learned

With the information from steps 1 through 4 available (5.I.1), the team should review and highlight key learning points from each section. First review the overall project value proposition, the stakeholder listing, and how value is exchanged within this large group (5.A.1). The team should list the top three value propositions that are important to the requirements generation process in the present acquisition timeframe and also those that are significant once the cutter is operational (5.O.1). Next, the team should review the stakeholder listing and discuss the salient stakeholders during design and operation of the cutter. The team should also discuss the potential key tension points between these stakeholders (5.O.2).

Next, the team should review the updated attribute and design variable listings (5.A.2). Within this review, the team should list the attributes that may be critical to the requirements generation and are candidates for Key Performance Parameters (KPP) for the project and also list the attributes that are most affected by the design variables as they may need to be the starting point for new analysis work (5.O.3).

To provide insight into future influences on the project, the team should reflect upon the changeability analysis and discuss how this might influence the attributes and design variables (5.A.3). The team should list attributes and design variables that are most impacted by change and given the most probable era analysis, list what design considerations are important to address the future states (5.O.4).

The next step is to formulate a listing of prioritized analysis work that is likely to be critical to the generation of the requirements documentation (5.A.4) (5.O.5). This listing should focus on the sensitivity of attributes, design variables, and changes to the project. This might also include areas that the team had difficulty coming to consensus on during specific RSC processes.

With this overview of the modified RSC processes, each team member should now share their key insights into the project from these processes (5.A.5) (5.O.6). These should highlight not only the new insights, but also what areas of the project impact their own efforts and may be difficult to resolve.

3.3 Summary

This methodology provides a template for large projects to assemble key stakeholders to discuss and develop keen insights into any large and complex project. This can be applied and adapted to any phase of acquisition to provide a more synergistic understanding to the project. This systems' viewpoint enables a better understanding of the interactions of the entire project on individual requirements to ensure that in all analysis work, understanding the overall effect on the entire system should be continually evaluated.

CHAPTER 4: U.S. Coast Guard Cutter Project Case Application

4.1 Introduction

With the understanding of the tailored RSC methodology developed in Chapter 3, a practical application can be demonstrated. While this methodology could be used within a broad range of a product or services' development, this chapter will focus on the use of this method within a Coast Guard major cutter project. As one of the latest and largest acquisition projects within the Coast Guard, the Offshore Patrol Cutter (OPC) provides a project that is near completion of the Select/Analyze Phase of acquisition.

This chapter will provide a background of the OPC project and complete the adapted RSC methodology within the known information of the project and how this relates to the development of the operational requirements. The following sections detail the OPC background and apply this RSC 5-process methodology to create insights into the OPC project.

4.2 OPC Background

The OPC is a project formed to develop a new class of cutters to replace the capabilities of the United States Coast Guard's aging 210-foot Reliance and 270-foot Famous class fleets. These 27 cutters, originally built from the early 1960's to the early 1990's, reached or will reach their service life expectancies within the next 20 years. The OPC project was originally started within the 2002 Deepwater contract from ICGS, but was cancelled in 2006 and restarted as a separately procured project. The current project reached Acquisition Decision Event 1 completion in January 2008.

The OPC project budget is estimated at \$8B with an estimated 25 cutters to be constructed (GAO, 2009). The OPC missions include 7 main areas: Ports, Waterways, and Coastal Security (PWCS); Search and Rescue (SAR); Drug Interdiction (DRUG); Migrant Interdiction (AMIO); Living Marine Resources (LMR); Other Law Enforcement (OLE); and Defense Readiness (DR)

(Fabling, 2010). These missions are focused on the cutter operating offshore in the Atlantic Ocean, Caribbean Sea, and Pacific Ocean while providing for the maneuverability to operate near shore for combined operations with other Coast Guard units. The cutters need to operate autonomously with a range in excess of 8500 nautical miles and endurance minimum of 45 days for food and water while at sea.

The OPC project is the largest cutter acquisition project in the Coast Guard's history and provides an important platform to carry out the many missions of the service. This also includes being interoperable with other DoD components while using common C4ISR systems and subsystems to complete defense missions.

4.3 Adapted RSC for OPC

4.3.1 Process 1: Value-Driving Context Definition

For the OPC project, Process 1 is the basis step to identify the understanding of value for the entire cutter project, what stakeholders are internal and external to the project, and how value is transferred within the project. Many of the inputs are described with the OPC background section and provide a foundation for understanding the project. The summary of the inputs, activities and outputs related to the OPC are contained below:

Inputs:

- 1.I.1 MAR
- 1.I.2. MNS
- 1.I.2 CONOPS
- 1.I.3 ORD IPT Charter
- 1.I.4 Capabilities Development Plan
- 1.I.5 Fleet Mix Analysis (if available)
- 1.I.6 Need Phase Concept Analysis Study documents
- 1.I.7 Long Range Acquisition Planning Schedules

Activities:

- 1.A.1 Define problem definition
- 1.A.2 Define project boundaries
- 1.A.3 Identify internal and external stakeholders
- 1.A.4 Indentify internal stakeholder value flow
- 1.A.5 Identify exogenous uncertainties
- 1.A.6 Define system value proposition

Outputs:

- 1.O.1 Problem statement
- 1.O.2 Project boundary definition
- 1.O.3 Project time constraints
- 1.O.4 Sketch of external, internal, and key internal stakeholders and value exchange within enterprise
- 1.O.5 List of external uncertainties
- 1.O.6 List of mission statements for key internal stakeholders

The OPC is the primary offshore platform to carry out Coast Guard missions. With needs to cover a large part of the Pacific Ocean, Atlantic Ocean, and Caribbean Sea, the OPC needs to fulfill 7 mission areas (OLE, SAR, LMR, PWCS, AMIO, DRUG, and DR). As the capability replacement for the entire Medium-Endurance cutter fleet, the OPC bridges a critical gap in Coast Guard mission effectiveness. This gap is identified in the MNS and provides the basis for the following problem statement (U. S. Coast Guard, CG-09, 2008) (1.A.1) (1.O.1).

Problem Statement: To develop a system that will replace the capabilities of the current Medium-Endurance Cutter fleet and carry out defined mission requirements in a more efficient and effective manner.

The project boundary definition below details the specific internal and external to both the concept cutter system and to the project team including stakeholders primarily within Coast Guard Headquarters directorates (1.A.2) (1.O.2). This group is responsible for the direct interaction to facilitate developing the requirements, design specifics, and overseeing the construction and testing of the cutters.

Project Boundary Description: The boundary of the project is defined by internally including all contracted system components related to the cutter and the personnel responsible for acquiring the new assets. External to this project are systems that are used with the project, components that are defined as interoperable with the project, and organizations and people that influence or interact with the project including the operators.

The time constraints on the OPC project consist of the time needed to complete a robust design, concept selection, and construction. With the potentially large number of cutters needed (in excess of 20), there will likely be a large (10 plus year) continued construction period followed by a 30-year service life for each cutter. The following is a summary of this time constraint (1.A.3) (1.O.3).

Project Time Constraints: The project must reach Initial Operating Capability (IOC) by 2018 and be designed with an expected service life of 30 years.

The next step is to understand the stakeholders and their exchange of value (1.A. 3) (1.A.4). Within the project boundary, there are several stakeholders including those identified by the ORD Charter (U.S. Coast Guard, CG-751, 2009). These include the Technical Authorities (engineering, C4ISR, and human resources), Sponsor (CG-7, CG-5, and user representatives), Project (CG-9 and related R&D and support service offices), and those commands working in collaboration with these offices. Also, the Budget Office (CG-8) provides the important link from the Congressional Budget Office to the project regarding funding. The key or most salient stakeholders within the project are the Project Office, Sponsor's Office and the Technical Authorities. These three groups provide the leadership and direction of the project throughout its life cycle.

External to the project, there are many influential offices, other service organizations, and commercial vendors. They significantly impact the project with resources, ability to carry out the project, and provide for life cycle services.

Within the internal stakeholders value is exchanged throughout the duration of the project. At the highest levels these value exchanges are important as they guide the prioritization of each stakeholder. A graphical representation of the stakeholders and value exchange is shown in Figure 4-1 below (1.O.4).

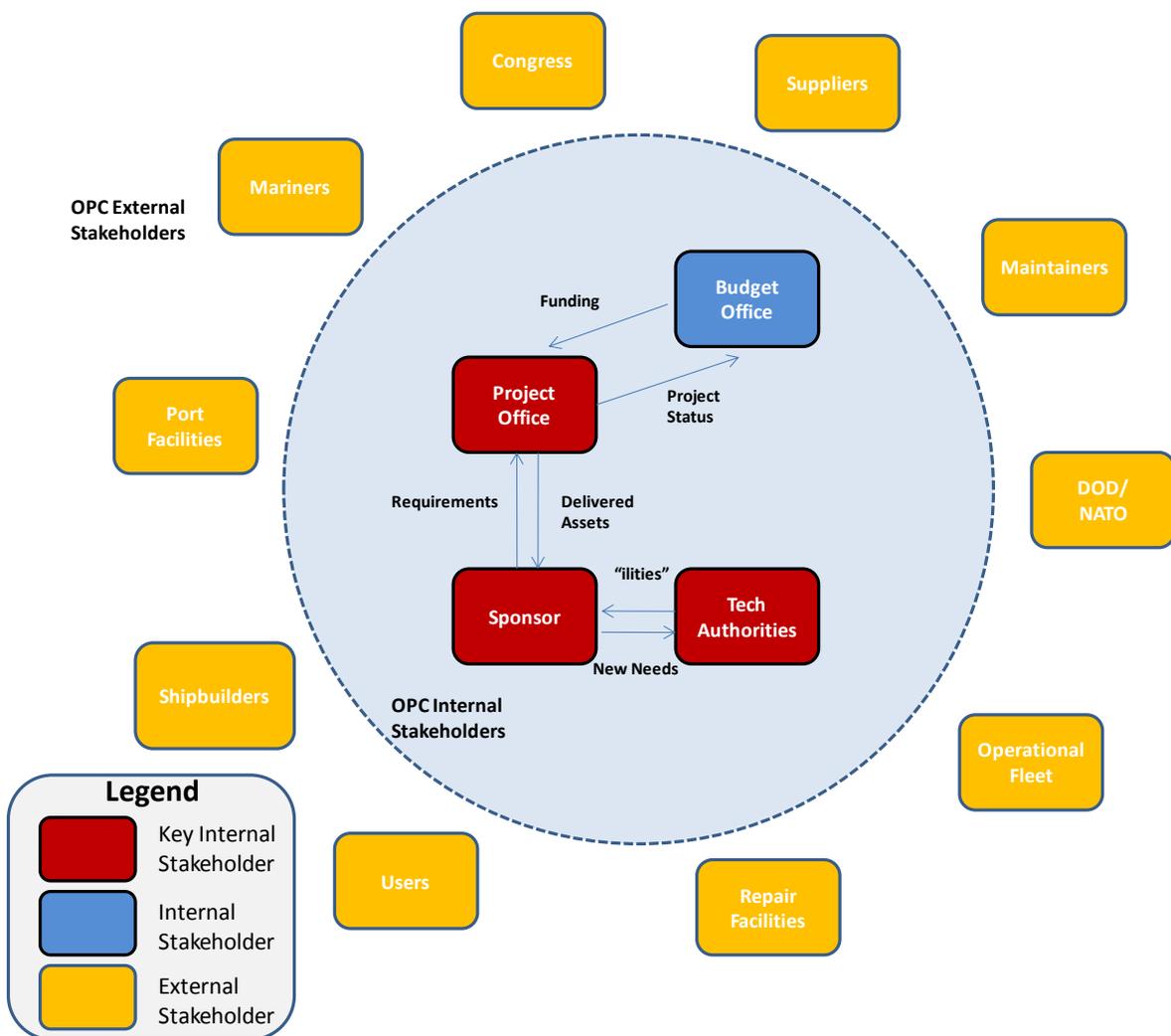


Figure 4-1: OPC Stakeholder Enterprise and Value Relationships

Within the current project, there are several external uncertainties that may affect the OPC project during the ORD development (1.A.5). Because the project is the largest cutter acquisition in the history of the Coast Guard, there is a significant scrutiny with Congress and the public as to the ensure that this project remains on budget and delivering assets that the Coast Guard can effectively use. The summary of these external uncertainties are captured below (1.O.5).

External uncertainties:

- Budget constraints for project based on reducing government budgets during economic downturn and large size of OPC project
- Final OPC homeport locations and impact to sustainability, operational and acquisition costs
- Changing mission prioritization

The last step of this process is to define the system value proposition for each of the three identified stakeholders, Project Office, Sponsor, and the Technical Authorities (1.A.6). Based on the inputs, the following list of mission statements depicts the high level needs of these stakeholders (1.O.6).

Mission Statements:

Project Office: Provide a new cutter fleet meeting operational requirements within a defined budget level and delivery to coincide with decommissioning of current WMEC fleet.

Sponsor: Develop operational requirements that meet the mission needs of the Coast Guard and Coast Guard user requirements.

Technical Authorities: Ensure new developed system meets legacy, external constraints, and design standards with technologies that maximize capability within established risk requirements.

4.3.2 Process 2: Value-Driven Design Formulation

Process 2 is critical to understand the needs of the stakeholders and how these needs relate to design variables.

Inputs:

- 2.I.1 CONOPS
- 2.I.2 Key internal stakeholder mission statements
- 2.I.3 Need Phase concept analysis study documents

Activities:

- 2.A.1 Review the CONOPS
- 2.A.2 Mission statement decomposition to attributes
- 2.A.3 Design-value mapping
- 2.A.4 Refine design-value mapping impact

Outputs:

- 2.O.1 Operational and sustainability considerations
- 2.O.2 Mission statement decomposition
- 2.O.3 Design variables to attribute impact matrices
- 2.O.4 Revised design variables to attribute impact matrices
- 2.O.5 Design drivers

First, the CONOPS is reviewed with particular attention to the Mission Functionality Matrix that defines the functional priorities by the 7 mission areas of the OPC (2.A.1) and the high level definitions of the functions. The CONOPS also provides details on the mission support functionalities needed for the OPC. Based on this information, the high level subsets of functional requirements are listed below (2.O.1).

Operational and Sustainability Considerations:

- Needs to be self-sustainable in operating environment for extended periods of time
- Must land legacy helicopters
- Must deploy with legacy small boats
- Must conform to Coast Guard’s 2-level maintenance system for supportability
- Must provide real time information into Coast Guard common operating system
- Must conform to current and anticipated future environmental regulations
- Must interoperate with Navy and NATO fleets for support and joint operations

Using this information and the key stakeholder mission statements can be decomposed into specific objectives and attributes (measure for the objectives) to best describe the overall attribute set for the project (2.A.2). For each stakeholder, these are kept to less than 10 to facilitate the ability to complete all five steps of this methodology. Tables 4-1 through 4-3 below detail the mission statement decomposition for each key stakeholder (2.O.2). Each attribute has a short title for use in the remaining processes.

Key Internal Stakeholder:		Sponsor		
Mission Statement:		Ensure requirements meet legacy, external constraints, design factors, and design risk.		
Objectives:		a. Provide capability of meeting 7 mission areas (LMR, DRUG, AMIO, DR, PWCS, SAR, OLE)		
Attribute (Acronym)	Units	Range		"Weight" (0-10)
		"worst"	"best"	
Air Capability (Air Cap)	hrs/day	2	12	2
Small Boat Capability (SB Cap)	# people-hrs/day	20	100	3
Sensor Capability (Sensor Cap)	low-medium-high	low	high	1
Human Operability (pers/mission need) (Hum Op)	low-medium-high	low	high	1
Speed to Avg Mission Station (Spd to Station)	kts	12	25	1
Communications Capability (Comms Cap)	low-medium-high	low	high	0.5
Mission Range (Range)	nm	5000	10000	1
Ship Endurance (End)	days	30	60	1.5

Table 4-1: Sponsor Mission Statement Decomposition

Key Internal Stakeholder:		Project Office		
Mission Statement:		Provide new cutter fleet meeting operational requirements within a defined budget level and delivery to coincide with decommissioning of current WMEC fleet.		
Objectives:		<ul style="list-style-type: none"> a. Provide sponsor 25 ships meeting defined capability levels. b. Provide fleet within \$8B acquisition budget c. Provide first operational cutter by 2018 and last cutter by 2030. d. Minimize lifecycle costs of cutter. 		
Attribute (Acronym)	Units	Range		"Weight" (0-10)
		"worst"	"best"	
Number of Ships Acquired (Ship #)	#	15	30	1
Capability of Each Ship to Requirements (Cap)	Qualitative Range	1	10	4
Acquisition Budget (Acq Budget)	\$B	12	6	2
Operational/Sustainability Costs (Op Costs)	\$B	40	30	2
Schedule Years to IOC (Time to IOC)	years	10	6	1

Table 4-2: Project Office Mission Statement Decomposition

Key Internal Stakeholder:		Technical Authorities		
Mission Statement:		Ensure requirements meet legacy, external constraints, design factors, and design risk.		
Objectives:		<ul style="list-style-type: none"> a. Provide sponsor 25 ships meeting defined capability levels. b. Provide fleet within \$8B acquisition budget c. Provide first operational cutter by 2018 and last cutter by 2030. d. Minimize lifecycle costs of cutter. 		
Attribute (Acronym)	Units	Range		"Weight" (0-10)
		"worst"	"best"	
Level of Legacy Compatibility (Legacy Comptbl)	low-medium-high	low	high	3
Conformance to Standards (Stds Conf)	low-medium-high	low	high	1
COTS Technology Capable (COTS Cap)	no-yes	no	yes	2
Design Confidence (Desgn Confid)	low-medium-high	low	high	4
Cost of Maintainability (labor & \$) (Maint)	low-medium-high	low	high	1

Table 4-3: Technical Authorities Mission Statement Decomposition

These attributes are mapped to design variables (2.A.3). Based on cutter design knowledge, the cutter design variables can be described for each of the key stakeholders. The design variables to attribute impact matrices are constructed to show how these design variables impact the attributes. Figure 4-4 below shows the relationship of these design variables to the sponsor's attributes (2.O.3).

DESIGN-VALUE MAPPING MATRIX

Key Internal Stakeholder: Sponsor

Attributes	Design Variables	Length (ft)	Power (hp)	Propulsion Type(Diesel, CODAG, CODAG, Turb)	Antennae Space (ft ³)	Crew Size (#)	Habitability/person (ft ³)	Boat Launch System (davit, single pt, ramp)	Beam (ft)	Draft (ft)	Hangar Capability (0, 1, 2 helos)	Weight (LT)	Total Impact
Air Cap		3	0	0	1	3	1	3	3	1	9	3	27
SB Cap		3	0	0	1	3	1	9	3	1	6	3	30
Sensor Cap		1	1	0	9	0	0	1	1	0	0	1	14
Hum Op		1	0	0	1	9	1	3	1	0	0	0	16
Spd to Station		9	9	9	0	0	3	1	3	3	0	3	40
Comms Cap		3	0	0	9	3	0	0	3	0	0	1	19
Range		9	9	9	1	1	3	3	3	1	3	9	51
End		3	1	3	0	9	9	1	3	1	3	3	36
Total		32	20	21	22	28	18	21	20	7	21	23	
Lifecycle Cost		3	3	9	1	9	3	3	1	1	1	3	
Total w/Cost		35	23	30	23	37	21	24	21	8	22	26	

Column

Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

Row  **Impact**

Table 4-4: Sponsor Original Design-Value Mapping Matrix

Within this original Sponsor Design-Value Mapping, several design variables (beam and draft circled on Table 4) do not have high impact on any attribute. By removing these two design variables (2.A.4), and noting that every attribute is highly impacted by a specific design variable, the final revised design-value mapping matrix for the sponsor is shown in Table 4-5 (2.O.5).

DESIGN-VALUE MAPPING MATRIX (REVISED)

Key Internal Stakeholder: Sponsor											
Attributes	Design Variables	Length (ft)	Power (hp)	Propulsion Type(Diesel, CODAG, CODAG, Turb)	Antennae Space (ft ³)	Crew Size (#)	Habitability/person (ft ³)	Boat Launch System (davit, single pt, ramp)	Hangar Capability (0, 1, 2 helos)	Weight (LT)	Total Impact
SB Cap	3	0	0	1	3	1	9	6	3	26	
Sensor Cap	1	1	0	9	0	0	1	0	1	13	
Hum Op	1	0	0	1	9	1	3	0	0	15	
Spd to Station	9	9	9	0	0	3	1	0	3	34	
Comms Cap	3	0	0	9	3	0	0	0	1	16	
Range	9	9	9	1	1	3	3	3	9	47	
End	3	1	3	0	9	9	1	3	3	32	
Total	32	20	21	22	28	18	21	21	23		
Lifecycle Cost	1	3	9	1	9	3	3	1	3		
Total w/Cost	33	23	30	23	37	21	24	22	26		

Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

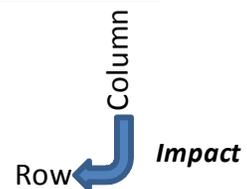


Table 4-5: Sponsor Revised Design-Value Mapping Matrix

This same process is completed for the Project Office (2.A.3). Reviewing the impact values, the four design variables of antennae space, habitability, beam, draft, and weight do not have high impact on any attributes as shown in Table 4-6 (2.O.3). Revising the design variable listing and ensuring each attribute has a highly influential design variable association, the new design-value mapping matrix is shown in Table 4-7 (2.O.4).

DESIGN-VALUE MAPPING MATRIX

Key Internal Stakeholder: Project Office													
Attributes	Design Variables	Length (ft)	Power (hp)	Propulsion Type(Diesel, CODAG, CODAG,Turb)	Antennae Space (ft ³)	Crew Size (#)	Habitability/person (ft ³)	Boat Launch System (davit, single pt, ramp)	Beam (ft)	Draft (ft)	Hangar Capability (0, 1, 2 helos)	Weight (LT)	Total Impact
Ship #		3	0	0	1	3	1	3	3	1	9	3	27
Cap		3	3	9	1	3	1	9	3	1	6	3	42
Acq Budget		1	3	9	3	0	0	1	1	0	1	1	20
Op Costs		1	3	3	1	9	1	3	1	0	1	3	26
Time to IOC		9	9	9	0	0	3	1	3	3	0	1	38
Total		17	18	30	6	15	6	17	11	5	17	11	
Lifecycle Cost		3	3	9	1	9	3	3	1	1	1	3	
Total w/Cost		20	21	39	7	24	9	20	12	6	18	14	

Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

Row ← Column ↓ *Impact*

Table 4-6: OPC Project Office Original Design-Value Mapping Matrix

DESIGN-VALUE MAPPING MATRIX (REVISED)

Key Internal Stakeholder: Project Office

Attributes	Design Variables						Total Impact	
		Length (ft)	Power (hp)	Propulsion Type(Diesel, CODOG, CODAG, Turb)	Crew Size (#)	Boat Launch System (davit, single pt, ramp)		Hangar Capability (0, 1, 2 helos)
Ship #		3	0	0	3	3	9	18
Cap		3	3	9	3	9	6	33
Acq Budget		1	3	9	0	1	1	15
Op Costs		1	3	3	9	3	1	20
Time to IOC		9	9	9	0	1	0	28
Total		17	18	30	15	17	17	
Lifecycle Cost		3	3	9	9	3	1	
Total w/Cost		20	21	39	24	20	18	

Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

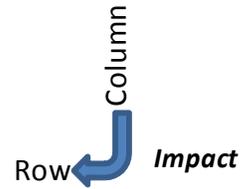


Table 4-7: OPC Project Office Revised Design-Value Mapping Matrix

The last key internal stakeholder, Technical Authorities', attributes can be assessed to the design variable influence. Habitability, beam, and draft do not have high impact on attributes (2.O.3) (Table 4-8) and can be removed from the design-value mapping (2.O.4) (Table 4-9).

DESIGN-VALUE MAPPING MATRIX

Key Internal Stakeholder: Technical Authorities													
Attributes	Design Variables	Length (ft)	Power (hp)	Propulsion Type(Diesel, CODAG, CODAG, Turb)	Antennae Space (ft ³)	Crew Size (#)	Habitability/person (ft ³)	Boat Launch System (davit, single pt, ramp)	Beam (ft)	Draft (ft)	Hangar Capability (0, 1, 2 helos)	Weight (LT)	Total Impact
		Legacy Compat	3	0	3	9	3	3	3	3	1	9	3
Stds Conf	3	0	3	1	3	1	9	3	1	6	3	33	
COTS Cap	1	1	0	3	0	0	9	1	0	0	1	16	
Desgn Conf	1	0	0	1	9	1	3	1	0	1	9	26	
Maint	9	9	9	1	1	3	1	3	3	1	3	43	
Total	17	10	15	15	16	8	25	11	5	17	19		
Lifecycle Cost	3	3	9	1	9	3	3	1	1	1	3		
Total w/Cost	20	13	24	16	25	11	28	12	6	18	22		

Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

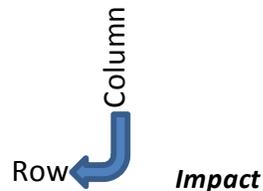


Table 4-8: OPC Technical Authorities Original Design-Value Mapping Matrix

DESIGN-VALUE MAPPING MATRIX (REVISED)

Key Internal Stakeholder: Technical Authorities

Attributes	Design Variables									
		Length (ft)	Power (hp)	Propulsion Type (Diesel, CODAG, CODAG, Turb)	Antennae Space (ft ³)	Crew Size (#)	Boat Launch System (davit, single pt, ramp)	Hangar Capability (0, 1, 2 helos)	Weight (LT)	Total Impact
Legacy Compat		3	0	3	9	3	3	9	3	33
Stds Conf		3	0	3	1	3	9	6	3	28
COTS Cap		1	1	0	3	0	9	0	1	15
Desgn Conf		1	0	0	1	9	3	1	9	24
Maint		9	9	9	1	1	1	1	3	34
Total		17	10	15	15	16	25	17	19	
Lifecycle Cost		3	3	9	1	9	3	1	3	
Total w/Cost		20	13	24	16	25	28	18	22	

Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

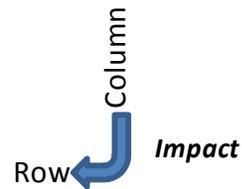


Table 4-9: OPC Technical Authorities Revised Design-Value Mapping Matrix

With this understanding of the final design variables to each of the key stakeholder’s attributes, the final list of design drivers is formed. These are the design variables that significantly affect all stakeholders plus those that are performance related design variables. Table 4-10 details the final design driver listing for the OPC project (2.O.5). The ranges are values that are values that best define the design variable bounds given the understanding of the attribute levels based on design experience.

DESIGN DRIVERS

Name	Units	Range	
		Low	High
Length	ft	290	400
Power	hp	10000	30000
Propulsion Type	Level	Diesel	Turbine
Antennae Space	ft ³	4000	9000
Crew Size	personnel	75	110
Habitability	ft ² /pers	20	40
Boat Launch System	Level	Davit	Ramp
Hangar Storage Capability	# Helicopters	0	2
Weight	LT	2800	4000

Table 4-10: OPC Overall Design Drivers

4.3.3 Process 3: Epoch Characterization

Process 3 is the start of assessing future uncertainties and how the design can impact how the project mitigates these uncertainties. Each snapshot for a specific time period of relatively fixed context and need (epoch) can experience dynamic changes significantly impacting design variable choices or value to stakeholders. Understanding these relationships early with a project can provide an understanding of how to better mitigate these dynamic effects.

Inputs:

- 3.I.1 Project time constraints
- 3.I.2 List of external uncertainties affecting key stakeholder value
- 3.I.3 Key internal stakeholder attributes
- 3.I.4 Design drivers

Activities:

- 3.A.1 Develop external changes
- 3.A.2 Develop changes in attribute levels and new attributes
- 3.A.3 Develop epoch descriptor definitions
- 3.A.4 Assess epoch descriptor to design variable and attribute impact

Outputs:

- 3.O.1 Epoch descriptions
- 3.O.2 Epoch descriptor impact matrix
- 3.O.3 New design variables and attributes

Using the time constraints (3.I.1) and external uncertainties (3.I.2) affecting key stakeholder value in Process 1, a more complete set of future context changes affecting all stakeholders are assessed for the OPC project (3.A.1). The following lists many of these uncertainties based on prevalent categories within the OPC's expected 30-year service life.

Technology: VUAV integration; major C4ISR system upgrade; and new and more capable (size, range, personnel carried) small boats.

Policy: Marine engine emission reductions; reduced copper content from shipboard systems (sea water systems); increased intelligence gathering into government-wide system.

Budget: Loss of acquisition budget prior to IOC; increase in operational funding for increased operational usage.

Systems of Systems: Deploying with National Security Cutters; new cutter-deployed helicopters.

Missions: Support of arctic region for fisheries; adding environmental cleanup response capability; more frequent international presence particularly for peace keeping missions.

Analyzing the list of external changes above leads to several key changes within the project (3.A.2). First there is a likely change in operating area. This is due to the potential to operate the OPC within the Arctic Region to support primary missions. This would add environmental operating constraints on equipment and will likely require stronger hull structure to reduce the risk of damage by floating ice. Also, because of potential environmental considerations on design, there may be a need to look at materials selection for systems and the main hull form that are not normally used in traditional cutter design. Understanding the driving factors in each listed change, an epoch descriptor can be defined to identify the level of change (3.A.3). Table 4-11 describes these epoch periods and their associated descriptors (3.O.1).

EPOCH DESCRIPTIONS

Epoch Name	Epoch Descriptor Category	Epoch Descriptor	Units	Range	Constraints
Add VUAV Requirement	Technology	Availability of VUAV Technology	Level	Small-Large	Requires hangar storage
C4ISR Upgrade		C4ISR Racks	Level	Small-Large	Original design space, weight, and power
Small Boat Upgrade		Small Boat Size	ft	24-35	C4ISR Info to/from cutter remain same
Reduced Engine Emmissions	Policy	Engine Emmissions Rating	Tier	2 to 4	Weight
Overboard Discharge Reduction		Discharge Copper Content	Level	Low-Medium-High	Maintain original system service life
Intelligence Gathering System (SCIF) Addition		SCIF Size	Level	Low-Medium-High	Location near operational spaces
Acquisition Budget Reduction	Budget	Project Baseline	%	-20	
Operations Surge	Systems of Systems	Operational Availability	Dimensionless	0.85-0.92	Major equipment remains same
Deploying with National Security Cutters		Range Increase	%	5 to 20	Same operational conditions
Upgrade Ship-Based Helicopters		Helicopter Weight Increase	%	5 to 50	Size less than HH-60
Artic Region Operations	Missions	Ice Region Use	Level	Low-Medium-High	Floating ice capability only
Environmental Response		Equipment Storage	ft ³	Small-Large	Storage only
International Operations		Water/Food Storage	% Increase	5 to 20	Same operational conditions

Table 4-11: OPC Epoch Descriptions

Next, the impact of these epoch descriptors are assessed to the attributes, design variables and new attributes and variables described above (3.A.4). Table 12 shows these epoch descriptor impacts (3.O.2) including the new attributes, material types and hull strength, and new design variables, ice capability and environmental impact (3.O.3).

EPOCH DESCRIPTOR IMPACT MATRIX

Design Variables	Epoch Descriptors													Total Impact
	VJAV	C4ISR Racks	Small Boat Size	Engine Emissions Rating	Discharge Copper Content	SCIF Size	Project Baseline	Operational Availability	Range Increase	Helicopter Weight Increase	Ice Region Use	Equipment Storage	Water/Food Storage	
Length	1	0	1	3	0	1	1	0	9	1	3	3	3	26
Power	3	0	3	0	1	1	3	3	9	3	9	3	3	41
Propulsion Type	1	0	1	9	0	0	9	9	9	3	9	1	3	54
Antennae Space	9	9	0	0	0	9	3	3	1	3	1	1	1	40
Crew Size	3	3	3	1	1	3	9	9	3	1	1	3	9	49
Habitability	1	1	1	3	1	3	3	3	3	1	3	3	9	35
Boat Launch System	3	0	9	1	1	0	3	3	3	3	1	1	1	29
Hangar Storage Cap	9	0	3	1	0	3	1	1	3	9	1	1	1	33
Weight	3	1	9	3	3	3	3	3	9	9	9	9	9	73
Material Types	1	0	1	3	9	1	9	3	3	1	1	1	1	34
Hull Strength	3	1	3	1	0	1	3	1	9	9	9	3	3	46
Total	37	15	34	25	16	25	47	38	61	43	47	29	43	
Attributes														
Air Cap	3	3	3	0	0	1	3	3	3	9	3	3	1	35
SB Cap	3	1	9	1	1	1	3	3	3	3	3	3	1	35
Sensor Cap	9	9	0	1	0	3	3	3	1	3	1	1	1	35
Hum Op	3	3	1	3	1	3	1	1	1	1	0	0	0	18
Spd to Station	1	1	1	3	1	1	9	3	9	3	3	3	3	41
Comms Cap	1	3	0	0	0	1	1	3	1	3	1	1	1	16
Range	1	0	1	1	1	3	3	1	9	3	9	9	9	50
End	1	0	1	1	1	1	3	3	9	3	3	9	9	44
Ice Capability	1	1	1	1	3	1	9	1	9	3	9	3	3	45
Environmental Impact	1	0	1	9	9	1	3	3	3	1	3	1	1	36
Total	24	21	18	20	17	16	38	24	48	32	35	33	29	

Impact Scale: 0-None; 1-Slight; 3-Moderate; 9-High

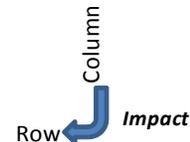


Table 4-12: OPC Epoch Descriptor Impact Matrix

Reviewing this matrix reveals several key findings. First, the epoch descriptors, project baseline, range increase, and ice region use have the largest impact on both design variable and attributes. This high impact leads to the recommendation that these potential external studies should be well examined before the final requirements or designs are finalized.

Second, the propulsion type and weight are design variables most impacted by all epoch descriptors. This would lead to the importance of ensuring that any design constraints on these two variables are reviewed for potential future uncertainty and review of how changeability could be incorporated into the design.

Last, the attributes of range and ice capability were most impacted by epoch descriptors. This means that these two potential performance parameters in the ORD should have significant analysis prior to determining their expected levels of performance.

4.3.4 Process 4: Era Analysis

Process 4 provides the OPC project with the understanding of changeability based on an anticipated era with distinct epoch descriptors.

Inputs:

- 4.I.1 Project time constraints
- 4.I.2 Epoch descriptions
- 4.I.3 New design variables and attributes

Activities:

- 4.A.1 Develop specific epoch time periods
- 4.A.2 Assign epoch descriptor prioritization by time period
- 4.A.3 Define the system transition rules across epochs
- 4.A.4 Develop era strategies
- 4.A.5 Develop strategy evaluation criteria
- 4.A.6 Evaluate era strategies

Outputs:

- 4.O.1 Era time periods
- 4.O.2 Era descriptions
- 4.O.3 Era rules effects matrix
- 4.O.4 Era strategies
- 4.O.5 Strategy evaluation

Using the project time constraints developed earlier, the OPC project can be broken into 4 specific time periods (epochs) (4.A.1). These correspond to natural milestones within the programs or changes in how the cutter will be built or used. The time period allocations are listed below (4.O.1):

Time Periods:

- Period 1: Static snapshot during ORD development (present)
- Period 2: Present to IOC, approximately 2018
- Period 3: IOC until mid-life of cutter, approximately 2033
- Period 4: Mid-life to end of service life, approximately 2048

Reviewing the epoch descriptions found in Process 3, each time period can be characterized by the most likely epoch descriptor to occur defining the most likely era to occur (4.A.2). This is determined by experience within past acquisition projects and knowledge of current future systems of systems studies. The most likely era for the OPC project is shown in Table 4-13 (4.O.2).

ERA DESCRIPTION

Era Name	Time Period	Period Description	Epoch Descriptor	Comments
OPC Most Likely	1	Present	Current State	Snapshot at Present
	2	2010-2018	Ice Region Use	Expand missions into Artic Region
	3	2018-1033	Availability of VUAV Technology	Add mature VUAV capability to cutter
	4	2033-2048	Small Boat Size	Change size of small boat

Table 4-13: OPC Most Likely Era Description

This era starts with the current state, then after the first OPC is operational, there is an addition of a VUAV to the cutter to support many of the missions. At the mid-life of the cutter, there will likely be a new small boat design that is likely going to be larger than today’s current Over-the-Horizon Boat.

Within this most likely OPC era, there are 5 rules that characterize the changeability or design robustness between the four epochs (4.A.3). These rules define the strategies to maintain system utility across these system epoch changes. To simplify the analysis, only a maximum of two transitions rules per epoch were reviewed. The details of the transition rules are described in Table 4-14 (4.O.3).

ERA RULES EFFECTS MATRIX

Era Name: OPC Most Likely

Epoch Transition	Rule #	Name	Robustness	Changeability				Parameters Enabling Change	Comments
			Robust	Change Agent Type		Change Effect			
				Flexible	Adaptable	Scalable	Modifiable		
1 to 2	R1	E1-2R1	X					Hull strength increased for ice class designation	Performance and cost likely to be impacted by added weight
1 to 2	R2	E1-2R2		X				Original hull design can be built with added hull strength in future without modifying other systems	Weight reserve in original design and understanding performance changes in strengthened cutter
2 to 3	R3	E2-3R1		X				VUAV Storage, Antennae Space, C4ISR Space	Space, weight, and power in original design for addition of VUAV
3 to 4	R4	E3-4R1	X					Size of small boat launching systems	Large system capable of varying size boats
3 to 4	R5	E3-4R1		X				Size of small boat launch systems	Space/weight/power in original design for upgrade of launch system at future date

Table 4-14: OPC Most Likely Era Rules Effects Matrix

Following the development of the rules effects matrix, 4 different system era strategies emerge as the combination of the different sequences of these rules (4.A.4). These are system era strategies to maintain value and are all feasible during the life cycle of the cutter. Table 4-15 describes each strategy (4.O.4).

SYSTEM ERA STRATEGIES		
Era Strategy	Rule Sequence	Short Title
A	R1-R3-R4	Strgthned Hull/VUAV Strg/Lg SB Launch
B	R1-R3-R5	Strgthned Hull/VUAV Strg/Mod Launch
C	R2-R3-R4	New Class/VUAV Strg/Lg SB Launch
D	R2-R3-R5	New Class/VUAV Strg/Mod Launch

Table 4-15: OPC System Era Strategies

Based on the system knowledge, four different strategy evaluation criteria emerge (4.A.5). These include: (1) life cycle cost, (2) implementability (cost, effort, and outcome of construction efforts), (3) performance, and (4) designability. Equally weighting these criteria is used to evaluate the four strategies. In this first round of evaluation, they are compared to strategy A and the results are shown in Table 4-16 (4.A.6). Strategies C and D are the most preferred by the criteria and because of the close results, strategy C was chosen to be the baseline in the 2nd round of evaluation.

STRATEGY EVALUATION

Baseline Strategy: A

		Strategy			
		A	B	C	D
Evaluation Criteria	Life Cycle Cost	N/A	+	+	+
	Implementability	N/A	-	-	-
	Performance	N/A	+	+	+
	Designability	N/A	0	+	+
	$\Sigma +$		2	3	3
	$\Sigma -$		1	1	1

Legend: + Better; 0 Same; - Worse

Table 4-16: OPC Era Strategy First Round Evaluation

During the second round of evaluation strategies C and D were equal in evaluation (Table 4-17). Based on the implicit knowledge that cost and performance are likely more important to all stakeholders, strategy D is the best choice for this era (4.O.5).

STRATEGY EVALUATION

Baseline Strategy: C

		Strategy			
		A	B	C	D
Evaluation Criteria	Life Cycle Cost	-	-	N/A	+
	Implementability	+	+	N/A	-
	Performance	-	-	N/A	+
	Designability	-	-	N/A	-
	$\Sigma +$	1	1		2
	$\Sigma -$	3	3		2

Legend: + Better; 0 Same; - Worse

Table 4-17: OPC Era Strategy Final Evaluation

Based on this strategy selection, the changeability assessment shows that for this era, a flexibly modifiable system is preferred over purely robust systems. While this may not always be true, this gives insight that a more comprehensive study of modifying systems through change is likely needed for a more comprehensive ORD.

4.3.5 Process 5: Review

Based on the analysis during processes 1 through 5, this review serves to summarize the findings.

Inputs:

- 5.I.1 Process 1-4 outputs

Activities:

- 5.A.1 Review value proposition and stakeholders
- 5.A.2 Review attributes and key design variables
- 5.A.3 Discuss changeability and impact to attributes and design variables
- 5.A.4 Develop list of important analysis studies
- 5.A.5 Discuss individual lessons learned

Outputs:

- 5.O.1 List of present and future important value exchanges
- 5.O.2 List of important stakeholders in acquisition and operational phases
- 5.O.3 Attribute and design variable groupings
- 5.O.4 Changeability impact to project
- 5.O.5 List of analysis studies
- 5.O.6 Lessons learned

Based on the analysis of the OPC project in processes 1 through 4, the following is a summarized list of the outputs (5.O.1 to 5.O.5)

List of High Priority Present and Future Value Exchanges

- Tradeoffs of requirements to project baseline
- Funding to meet long term planning
- User feedback to/from sponsor

Design Drivers (Includes Change Related Drivers)

- Length
- Propulsion Type
- Antennae Space
- Crew Size
- Habitability
- Boat Launch System
- Hangar Storage Capacity
- Weight
- Material Types

Attributes (Includes Attributes Related to Change)

- Air Capability
- Small Boat Capability
- Sensor Capability
- Human Operability
- Speed to Station
- Communications Capability
- Range
- Endurance
- Ice Capability
- Environmental Impact

Changeability Impact

- Small boat launching systems and VUAV modifiability (cost, technology, etc.)
- Hull strength impact to performance attributes (sensitivity analysis)
- Level of ice strengthening necessary for potential ice mission

List of Analysis Studies

- Range effects and sensitivity on design and performance parameters
- Propulsion type effects on design concepts
- Future helicopter deployment study

4.4 Summary

Within the OPC project, the adapted RSC methodology highlights the importance of maintaining funding at project baseline levels that a list of key attributes and design variables are available that provide a starting point for the development of the PORD and a foundation for initial analysis work within this PORD development. Because of the potential context changes within the OPC project, the method highlights the need to study small boats and their associated launch and recovery systems for modifications during the life of the cutter. Also, VUAV storage, weight, and power considerations should be reviewed often within the ORD development. Because of the significant impact to attribute and design variables, early analysis should focus on either adding a strengthened hull or to provide a flexibly modifiable design that allows for strength additions to later design iterations while minimizing the impact to the overall systems of the cutter.

CHAPTER 5: Summary, Conclusions, and Future Work

5.1 Summary

Within recent United States Coast Guard cutter acquisition projects, developing and understanding the operational requirements were difficult to manage. Within Chapter 1, the difficulties of understanding the many activities in developing the operational requirements motivated the development of a systems level framework for operational requirements generation.

Within Chapter 2 an Operational Requirements Framework, specific to United States Coast Guard major acquisition projects that assembles program, systems engineering, and sponsor related activities, was developed into a single processed based and iterative analysis. This framework incorporated important stakeholder, Concept of Operations, and Mission Need Statement review and updating into the process mapping. This enabled the understanding of potential design effects on the project throughout its life cycle, emphasizing the interfaces and “ilities” that best design the final system. With this process-based framework, the coordination and evaluation of the many factors contributing to the final set of operational requirements was better understood for all aspects of a potential project.

In order to improve the operational framework planning, Chapter 3 described an adapted Responsive Systems Comparison, a 5-step methodology that can be used to outline and direct the planning processes. This method determined the understanding of design in relation to stakeholder value through a high level study by experience personnel without extensive analytical analyses. It also identified key stakeholders and their needs into measurable attributes. By reviewing the impact of design variables on these attributes, a better understanding of design impact to needs is established. The potential changes external to the project are evaluated and mitigation through robust or flexible designs evaluated for the project. Ultimately, this method leads to the understanding of key design variables, attributes, and life cycle considerations that

are useful in prioritizing studies during the assembly of Preliminary Operational Requirements and final Operational Requirements Documents.

In order to test this methodology, an analysis of the Coast Guard's Offshore Patrol Cutter project was demonstrated in Chapter 4. The analysis detailed a list of key stakeholder attributes, key variables and methods to account for likely changes in context during the life of the project and identified the need to further study range, propulsion types, and future helicopter integration study during the development of the operational requirements. These insights into this project show the value of this methodology to give a team an overall systems view of the entire project.

5.2 Conclusions

The following conclusions answer the original question, "Can a high level framework be developed based on the research of other major systems approach for the development of an Operational Requirements Document (ORD) that best captures and prioritizes all life cycle stakeholder requirements for major cutter acquisition?"

1. The Operational Requirements Framework (Figure 2-17) synthesizes the operational, program, and life cycle engineering requirements from the MSAM into an interconnected set of processes that focus on PORD development and leading to the more comprehensive ORD. These processes ensure a logical progression of process steps into an iterative cycle of updating and expanding on past analysis information. This iterative approach maintains the proper balance of in-depth study with the impact to the overall system.
2. Key to this overall processed based framework is the importance of adding stakeholder, operations and missions, interface, and "ilities" analyses to the Operational Requirements Framework. These stakeholder and operations/mission analyses provide critical understanding of the stakeholder value exchange and prioritization of operations into the recursive requirements development. The interface and "ilities" provide the important

life cycle considerations necessary to better define the range of stakeholder value that define the design tradespace, and also an understanding of the key design variables that indentify how a potential system responds to external changes to the system throughout its life cycle. The life cycle effects coupled with design considerations can lead to updating the CONOPS operational scenarios or the prioritization of functional capabilities to mission accomplishment for an improved design in future phases of acquisition.

3. Changeability is an important consideration for ensuring that life cycle changes are properly anticipated not only in design, but also in the any Operational Requirements Framework. By the early identification of potential external changes and how they impact the design and value to the stakeholders, a more comprehensive set of Operational Requirements is formed. This provides more value to all stakeholders at a lower life cycle cost.
4. Introducing a process-centric Operational Requirements Framework enables in-depth analysis to occur while also ensuring that the overall system's effect of these studies is reviewed and updated into other analysis work.

The following conclusions answer the second thesis focus question, “Is there a tool or methodology that can assist the efficiency of this cutter ORD development from the beginning of the Analyze/Select Phase of acquisition from a high level systems engineering perspective?”

1. A 5-process Responsive Systems Comparison methodology can be used to identify key Operational Requirements document information through the use of experienced internal project stakeholders. This 5-process methodology can quickly identify planning prioritization within the Operational Requirements Framework by understanding design considerations and life cycle effects on the needs and constraints of a developing system.

2. The adapted RSC methodology is beneficial within a major cutter project at the beginning of the Select/Analyze Phase of acquisition as shown in the analysis of the OPC example. By decomposing the project missions through design considerations, the OPC analysis provides key information on the project's value determination, important attributes, design drivers, life cycle effects, and analysis prioritization. This early identification of attribute, design, and life cycle interaction, improves the efficiency of the entire ORD development by all stakeholders understanding the overall systems perspective of the project.
3. This methodology can be used to understand the development of cutter requirements and future design considerations for Coast Guard cutter acquisition. It also allows for cutter specific design, performance, and changeability considerations in developing requirements within a holistic systems approach without detailed analyses.
4. The adapted RSC methodology provides a diverse group of stakeholders the opportunity to understand value, design considerations, and changing contexts simultaneously. Even as implicit knowledge, this allows for a better synergy throughout any large project development.

5.3 Future Work

The following are recommended future studies that would build upon the methods and analyses conducted within this study.

1. The Operational Requirements Framework, while important for the development of the Operational Requirements Document, could be expanded to cover the Project Identification and Need Phases of acquisition. This could include the development of the PORD within the early project development to better identify feasibility and concept understanding particularly in the Concept of Operations and Fleet Mix analysis initiatives.

2. The Operational Requirements Framework could also be expanded into the Obtain Phase of acquisition. This would enable the process development of detailed design analysis into ORD changes while still assessing life cycle effects within a structured framework.
3. Because the adapted RSC methodology enables a high level interaction of systems and subsystems, it could be applied to the system of systems studies in the Need Phase of acquisition. This would enable a better understanding of the fleet mix of cutter acquisition within the Coast Guard and expanded DoD environments. This could also provide different concept evaluations including comparing non-material solutions to material solutions within the Coast Guard operational environment.
4. With the use of simplified cutter parametric modeling and through the use of operational utility models, the adapted RSC methodology could be expanded to include Multi-Attribute Tradespace Exploration (MATE) within a cutter project. This would give a higher fidelity to the impact analysis and provide potential more options to consider for analysis particularly in projects where budgets are constrained or likely to change based on the project's progression throughout the acquisition phases. The analysis could also provide a more analytical approach to understanding changeability within a cutter design.
5. The adapted RSC methodology could also be modified and expanded to other major projects such as aircraft, C4ISR systems, public infrastructure related projects, or other large projects with high complexity or many subsystems.
6. This methodology can be tested with an integrated product team during the development of the operational requirements. This may include Coast Guard projects such as the Heartland Waterways or Ice Breaker projects when they reach the Analyze/Select Phase of acquisition.

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