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Application and Validation of Concept Maturity Assessment Framework

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THESIS

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Abstract

Far too often decision makers select concepts based on insufficient data, resulting in projects that are over-budget, over-schedule, and not what the customer wants. Research efforts have proposed a stage-gated concept maturity framework as a tool to assess and increase the maturity of concepts. This research uses multiple validation techniques to demonstrate the value this framework can provide. Interviews with acquisition professionals capture qualitative and quantitative data on the utility of the elements of the framework and the acquisition process. This research also applies the framework to a current acquisition program to determine if it can be broadly applied for different types of developments. Lastly, this research looks to current acquisition policy and guidance to see if there is support for the maturity elements of the framework.

The results of this study led the research team to accept the framework as a useful guide and approach to assessing a concept's maturity. The majority of responses were favorable towards the activities recommended in the framework. The researchers were able to apply the framework in real-time to a concept in early development to the benefit of the sponsoring organization. The results of this study have also led to the formation of themes, best-practices, and lessons-learned concerning early concept development. The results affirm that when developing a concept people make the difference, more resources up-front are needed to fully understand a concept, and developers should avoid constraining the trade-space by pre-supposing a solution.

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JJ Homan

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I. Introduction

General Issue

It has been demonstrated often that when time and effort is invested early on in a system's development that the return on investment is significant (Government Accountability Office, 2008). Recently there have been many ongoing efforts to help quantify this early systems engineering process. These efforts have the goal to create a disciplined and repeatable process. Such a process will help guide future efforts towards constructive activities that will add value during the development.

Problem Statement

According to (Hughes, 2010) a mature concept is one that contains the right amount of information at the right development stage. Even if a concept is in its infancy it may be very mature if the concept's capabilities and limitations are fully understood. Conversely concepts that have existed for a very long time may be immature if the capabilities and limitations are not well understood or documented.

Determining if a concept is mature early on in system development can be difficult to assess. Developers can use systems engineering tools to help to uncover the "unknown unknowns" that can plague a systems development. These problems are often caused by unclear, undefined, or unattainable goals during systems development. The concept maturity model developed by Hughes attempts to quantify the risks and

unknowns associated with each proposed concept. The more thoroughly the concept is understood and documented, the more informed a decision can be made. This more informed decision will help mitigate the risks inherent to development of the system.

Research Objectives/Questions/Hypotheses

Previous research has proposed a "Concept Maturity Assessment Framework" method in which decision makers can determine the maturity of concepts as they progress through the acquisition process. The framework as developed by Hughes (2010) with collaboration from Barker (2010) will be referred to as the Hughes' Framework throughout this study. This thesis proposal will take the Hughes' Framework and first demonstrate its application. Secondly this thesis proposal will attempt to determine the utility and added-value of the framework to the decision maker. In other words, this thesis seeks to quantify and qualify the added-value of applying the framework assessment, and give a recommendation for or against future use during the acquisition process. The questions to be addressed are:

1. Is the framework a valid guide, that can be used to assess concept maturity?
2. Can the framework be applied in real-time during concept development?
3. What is the added-value to the decision maker in applying the framework?
4. Does the framework help reduce or mitigate the risk associated with concept maturity for the decision maker?
5. Should the framework be recommended for use during the acquisition process?

Methodology

To answer the research questions above, a structured three-level approach will be used to show how the framework can be applied and then assess the value-added to the decision maker. The methodology for this research will be focused on reasoning derived from interviews with relevant personnel, a real-time application of the framework, and a comparison to more commonly accepted sources.

The primary method of this validation effort uses a structured interview approach that seeks to understand the perceptions of relevant personnel related to the framework. The researchers will gather the opinions and recommendations of relevant experts, users, and practitioners with current or recent experience related to early systems development. The results from these interviews will form the foundation to help form an unbiased evaluation on the usefulness of the framework.

Demonstrating the framework's application will be focused on applying the framework to a weapon system that will destroy hard-to-defeat targets. This weapon system is currently in the concept development phase. Two separate defense contractors are competing for the opportunity to develop this weapon system. The authors will use the framework to assess the maturity of the separate concepts from each contractor and provide individual assessments to the responsible sponsoring military organization. This assessment will serve to demonstrate how the framework can be applied to assess concept maturity. The researchers will also help develop some of the information products as recommended by the assessment.

This assessment will not solely focus on the work of the competing contractors. The framework will be used to assess the work done by the government in defining the

need. Did the government adequately define the needs, objectives, tasks and/or measures the concepts will be judged against? Were the expectations clearly defined? These are just two of the questions this assessment will attempt to address.

The final step will be a review of accepted sources that help confirm or negate the conclusions drawn while using of the framework. This approach is not meant to stand-alone as a method for validation, but serves to support the findings, if applicable, derived from the structured interviews. The research team will evaluate approved policy and regulations as they relate to the framework as well as guidance and best-practices from practitioners to complete this assessment.

Assumptions/Limitations

The Hughes' Framework has been defined in a previous thesis with three staged gates to assess concept maturity based on its current phase in the system / product development process. These gates can be aligned to commercial and Department of Defense (DoD) acquisition processes. As the concept being considered for development progresses through the phases of the acquisition process, its maturity should also progress and be judged. This thesis assumes that the framework is ready and complete for application and no further changes will be made prior to validation. The authors of this thesis have no pre-conceived opinion as to the usefulness of the framework.

Even though the framework developed by Hughes can be applied to both commercial and DOD developments the research in this thesis will focus on the DOD relationships. The following section describes briefly the stage-gated process of the framework.

Gate 1: Opportunity Identification takes the approved Initial Capabilities Document (ICD) and assesses the proposed concepts on their ability to fill the capability gap. If analysis determines that a new material solution is necessary the concept maturity assessment requires the consideration of various aspects of the program such as architecture products found in the Department of Defense Architecture Framework (DoDAF), a CONOPS, AV-1, OV-5a/b, OV6-a, OV-4, OV-2, CV-2, CV-4, CV-6, and so on. These architecture documents help characterize all aspects of the proposed concept and how it will interact with everything else. These documents, if thorough and complete, will reduce the risk of "unknown unknowns" and provide a maturity assessment.

Gate 2: Concept Screening identifies and narrows down the possible solution concepts that should be pursued further through this phase. This gate is aligned with the Material Development Decision (MDD) in the DoD acquisition process. The information required at this gate is the updated architectural documents from the previous gate as well as architectural documents that technically define the concept. As the concept has been refined, its functionality, interactions, and cost/schedule projections must all be updated so that any changes that have been made are thoroughly understood and their impact is fully assessed. Having the most up to date information is vital at this step so that only the best concepts are allowed to proceed.

Gate 3: Concept Selection identifies and narrows yet again the concept(s) that should be pursued further through an analysis of alternatives. This gate is aligned with Milestone A (MSA) in the DoD acquisition process. The information required at this gate is an additional update to the previous architecture documents. Similar to Gate 2,

as the concept has been refined, its functionality, interactions, and cost/schedule projections must all be updated so that any changes that have been made are thoroughly understood and their impact is fully assessed.

Implications

If the Hughes' Framework proves to be a valid process and provides value to the acquisition process by better defining and characterizing the risks associated with the maturity / immaturity of proposed concepts then future efforts should be undertaken to integrate this framework into the DoD acquisition process. Some potential vehicles to help integrate this framework would be the Early Systems Engineering and Concept Characterization and Technical Description (CCTD) guides, which have already laid the foundation to increase the level of systems engineering efforts early on in the acquisition process. Integrating the required documentation for the stage gated concept maturity model into the Early Systems Engineering and CCTD guides could help prevent unexpected surprises from arising by thoroughly documenting and understanding key considerations of a concepts maturity.

This chapter has identified the problem which the research will address. The objectives of the research have been laid out and the questions this research seeks to answer have been proposed. The implications of this research if successful have been discussed along with the limitations and assumptions. Chapter two goes into the background information that went into the formulation of the framework developed by Hughes as well as a quick explanation of the existing DoD acquisition process and how the framework relates to it. Chapter three discusses in detail the methodology and research approach used to validate the Hughes' Framework. Chapter four starts with

the analysis of the structured interviews that were conducted and then discusses the practical application of the framework that the research team performed and ends with analysis of current policy. Chapter five will discuss the conclusions drawn from the analysis, answer the research questions, and present themes and lessons-learned. Chapter six includes recommendations the research team has concerning the Hughes' Framework and proposes further research.

II. Background

Chapter Overview

This chapter discusses several important components associated with validating the Hughes' Framework. Discussed first is the DoD development process with its decision gates and how concept maturity is a factor in early milestone decisions. The Hughes' Framework will then be explained in detail. This detailed understanding of the different maturity elements called out in the Hughes' Framework will be the basis of the validation research. The different maturity elements of the framework will be subjected to validation techniques to determine their utility.

Understanding DoD

DoD Acquisition often finds itself in the precarious position of having to satisfy conflicting stakeholders' needs. The user communities are starving for new and improved systems and technologies, and they want them yesterday. The DoD attempts to meet the user needs by developing weapon systems faster. At the same time, congressional oversight expects the DoD to build systems on a strict budget, with heavy requirements for documentation and reporting which often leads to a direct conflict with the users demand for increased performance and faster schedules. As a result of these pressures, the DoD often enters into contracts with defense contractors before requirements for the needed systems have been properly assessed and analyzed. The contractors, in an attempt to maintain the schedule while staying within a tight, closely monitored budget, often omit essential early planning steps, the very steps that would likely help them to succeed in the "long-term" (Government Accountability Office, 2008). Further, stakeholders decide to change or add requirements to meet

more current needs, which only cause additional delays and incurs additional costs, the very two things they were trying to avoid in the first place. These redesigns must navigate through entire supply chains, affecting many or most of the development team members (Government Accountability Office, 2008).

As previously mentioned, the process to initiate a weapons system within the DoD usually begins with the identification of an operational need found in a mission area. The DoD attempts to identify mature technologies within the Federal Government and commercial industry that would potentially satisfy the operational need (PMBOK Guide, 2008). A Capability-Based Assessment (CBA) is also done in parallel to determine if the need can be satisfied by a non-materiel solution. If it is determined that a materiel solution is required, an Initial Capabilities Document (ICD) is then produced, which depicts the operational deficiency, as well as an opportunity to provide a new capability (PMBOK Guide, 2008). In an effort to produce the ICD, needed capabilities are analyzed and potential nascent concepts are birthed. These early concepts are considered the seed corns of future systems and are expected to address capability shortfalls or to exploit new capabilities provided by new technologies (SAF/AQ, 2009). The definition of a concept is widely debated but shall be defined in this work as "a solution that meets the needs of the customers and users and identifies the resources required to develop the solution" (Hughes, 2010).

Early Decision Points

It is important to understand the considerations and discriminators for each progressive investment decision in the concept development process. This validation effort focuses on the three decision gates discussed in the Hughes' Framework as well

as the information maturity elements used to prepare for those decision gates (Hughes, 2010). The first gate, Opportunity Identification, occurs when the Joint Requirements Oversight Council (JROC) approves and validates an ICD (Chairman of the Joint Chiefs of Staff, 2009). The ICD contains requirements originating from user needs. The analysis conducted by the user to develop an ICD should identify the shortfall in military capability and determine that a new materiel product is required to meet the need. The JROC must determine if this development opportunity is important enough for the allocation of resources.

If the JROC determines that the ICD is complete and that it identifies a valid need, the next gate of the Hughes' Framework, Concept Screening, corresponds to a similar gate in the DoD 5000 Framework, Materiel Development Decision (MDD). The primary purpose of the MDD is to act as the official entry gate to the materiel development process. It also acts as a filter to prevent the concepts that are unfeasible for development or that do not meet the need identified in the ICD from progressing any further in the development process. A concept that meets the criteria and contains adequate information will undergo deeper analysis in the Materiel Solution Analysis phase.

The third screening gate of the Hughes' Framework, Concept Selection, occurs at Milestone A (MS-A). At this investment decision, a concept is selected based upon a set of criteria. The criteria should include user needs, risk associated with development, cost to manufacture, operate and sustain the solution, and the benefits the development brings to the DoD. A concept that demonstrates that it meets the

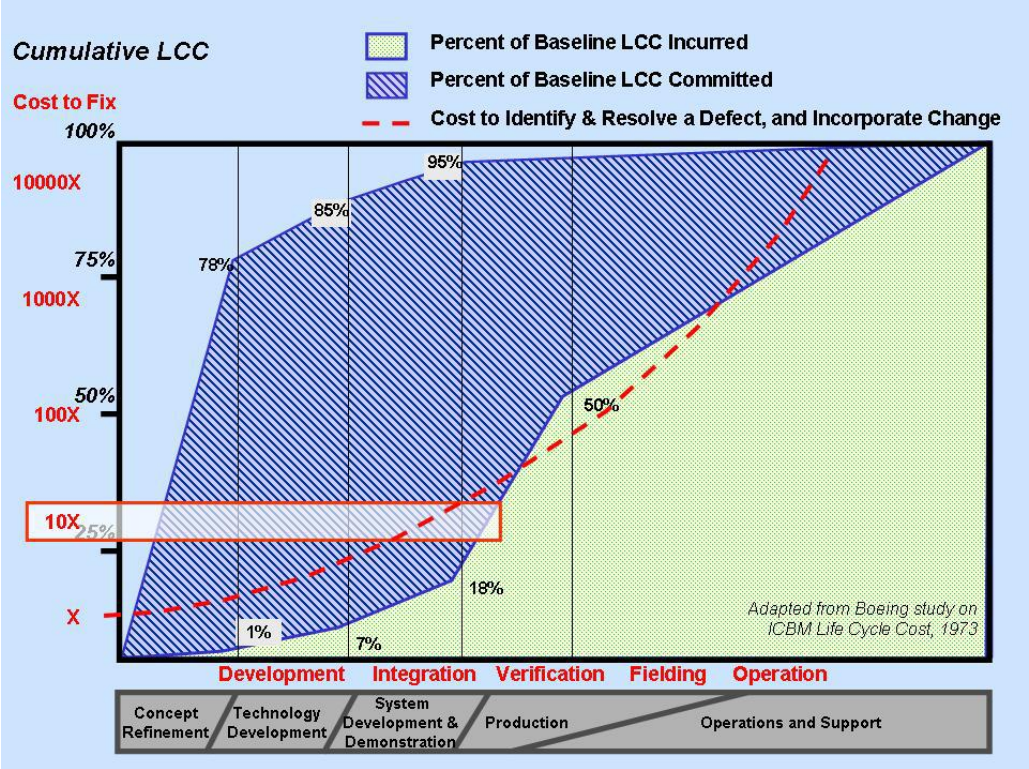
criteria and is selected will, assumedly, have resources allocated to conduct preliminary design (Department of Defense, 2008).

Departing From the Process

In 2008, the National Research Council (NRC) published a Secretariat of the Air Force Acquisition Science, Technology and Engineering (SAF/AQR)-commissioned study entitled "Pre-Milestone A and Early-Phase Systems Engineering: A Retrospective Review and Benefits for Future Air Force Systems Acquisition." Key recommendations of this report found that in many cases during pre-MS-A activities, "required documents were completed pro-forma and filed away, never to be seen again, or for which required steps were skipped completely" (NRC, 2008). The problem of departing from the structured development process due to external forces or instability surrounding the process is not new. This structured development process is great once the need and gaps are fully understood, but the "fuzzy front-end" of development, e.g. truly understanding in an unbiased manner what the needs and gaps are, requires more rigorous definition. Departures from the process are often driven by unanticipated problems such as changing customer requirements or roadblocks in the approval process (Repenning, Goncalves, & Black, 2001). A common departure from the process is called "firefighting," which is a term given to situations where developer's resources are used to fix unforeseen problems later in the development cycle. The many cost and schedule risks associated with firefighting are well documented (Repenning, Goncalves, & Black, 2001). Since early phase tasks are often skipped in order to save resources in the short-term, they routinely receive less attention than they should (Repenning, Goncalves, & Black, 2001). Developers want

to initiate their programs as early as possible, even if that means bypassing early systems engineering rigor. The GAO reported that the DoD frequently enters into development contracts with its contractors before disciplined system engineering processes have been completed. This practice introduces significant cost and schedule risk to a development program (Government Accountability Office, 2008).

It can be assumed that if the concept selection process continues to function without sufficient rigor, immature concepts will continue to be selected. These types of pre-MS-A decisions have a disproportionately large impact on the lifecycle of the program. In fact, nearly three-quarters of total system life cycle costs are influenced by decisions made before the end of the concept refinement phase at MS-A. On the other hand, about three-quarters of life cycle funds are not actually spent until after a production decision is made at Milestone C (MS-C) (NRC, 2008), (see Figure 1.), further strengthening the argument that DoD needs to place more emphasis on making good early decisions.



(Loren & Bullard, 2008)

Figure 1 – Impact of Early Decision Making

Improving Early Decision Making

In an effort to improve good early decision making, the DoD needs a process to assess the maturity of concepts as they are screened through early development. This process should establish a baseline by which all concepts are equitably judged and reviewed. In regards to this issue, the GAO recommends:

> Taking into account the differences between commercial product development and weapons acquisitions, we have recommended that DOD adopt a knowledge-based, incremental approach to developing and producing weapon systems. This type of an approach requires program officials to demonstrate that critical technologies are mature, product designs are stable, and production processes are in control at key junctures in the acquisition process. (Government Accountability Office, 2007)

Defining Concept Maturity

According to Hughes, a mature concept is one that contains the right amount of information at the right development stage (Hughes, 2010). In a stage gated process, the right information is determined by the level of investment associated with developing the concept for the next stage. This information helps the decision maker determine if advancing the concept is a good investment. The pieces of information needed by the decision maker at these investment decision points can be described as maturity elements. Thus, the collection of maturity elements at the appropriate development stage can help the decision maker to make a more informed decision. A SAF/AQR Guidance Memo dated 19 Dec 2008, "Early Systems Engineering Planning Documentation and Concept Characterization and Technical Description (CCTD) Implementation" contains the following language:

> Better assessments of concepts for the use of disciplined and robust technical planning will ultimately reduce the risk of a poorly planned concept being selected in an AoA, and represent an appropriate approach to structure programs for success and acquisition excellence. (NRC, 2008)

In concept development, there are several important factors in determining if the concept definition provides adequate information. The decision maker is faced with the task of asking enough questions to fully comprehend the maturity of individual concepts. The decision maker uses the available information to analyze operational and development risks. Is it possible for a concept to be considered mature if the concept includes a high technology development risk, as long as the risk is well-understood? If the answer is yes, this would imply that concept maturity is more dependent on the level of understanding rather than the technological and economical

feasibility. Assuming this is true, if the concept possesses high technology development risk, the concept can continue to mature if it also possesses a supporting risk management plan.

The Hughes' Framework

The framework developed by Hughes is designed to act as a benchmark and common language for those evaluating and developing material concepts. The framework is designed around three major decision gates in the front end of the DoD acquisition process. The information recommended at each gate is intended to characterize the needs of the intended users, in the form of a solution to meet those needs, or the resources required to develop the solution. The decision makers must determine if the concept before them is worthy of further development and can only make that determination if they are presented with the right type and amount of information.

The information that is developed and gathered prior to each decision gate is captured through a structured documentation process. Though there are many different ways to capture the data, Hughes uses the Department of Defense Architecture Framework (DoDAF) views as a way to present much of the information. Table 1, below, gives a description of the DoDAF 2.0 views that can be used to capture the information needed at the decision gates.

Table 1 – DoDAF Views

Description	View	Description	View
Legend: All View – AV Operational View – OV Systems View – SV Services View – SvcV Capability View – CV Standards View - StdV			
Describes a Project's Visions, Goals, Objectives, Plans, Activities, Events, Conditions, Measures, Effects (Outcomes), and produced objects.	AV-1	A mapping of system functions (activities) back to operational activities (activities)	SV-5a
The high-level graphical/ textual description of the operational concept.	OV-1	A mapping of systems back to capabilities or operational activities.	SV-5b
A description of the resource flows exchanged between operational activities.	OV-2	The emerging technologies, software/hardware products, and skills that are expected to be available in a given set of timeframes and that will affect future system development.	SV-9
The organizational context, role or other relationships among organizations	OV-4	The identification of services, service items, and their interconnections	SvcV-1
The capabilities and activities (operational activities) organized in a hierarchal structure.	OV-5a	A description of resource flows between services	SvcV-2
The context of capabilities and activities (operational activities) and their relation-ships among activities, inputs, and outputs	OV-5b	The relationships among and between systems and services in a given architecture	SvcV-3a
One of three models used to describe operational activity. It identifies business rules that constrain operations	OV-6a	The functions performed by services and the service data flows among service functions	SvcV-4
The identification of systems, system items, and their interconnections	SV-1	A mapping of services back to operational activities	SvcV-5
A description of resource flows between systems	SV-2	A hierarchy of capabilities which specifies all the capabilities that are referenced throughout the architectural descriptions	CV-2
The relationships among systems in a given Architectural Description. It can be designed to show relationships of interest, (e.g., system-type interfaces, planned vs. existing interfaces).	SV-3	The dependencies between planned capabilities and the definition of logical groupings of capabilities	CV-4

Description	View	Description	View
The functions (activities) performed by systems and the system data flows among system functions (activities).	SV-4	A mapping between the capabilities required and the operational activities that those capabilities support	CV-6
		The listing of standards that apply to solution elements	StdV-1

(Table Adopted from Hughes, 2010)

The process of developing a concept is ordered and iterative. Information is developed and gathered prior to each decision gate. However, this phase of product development is often very "fuzzy" so, there is an iterative aspect to the concept development process. With each new phase comes a greater amount of required detail, which could bring new revelations. This information is the foundation and a guide for the development activities following the gate. This ordered activity continues through the phases preceding the three gates with the activities of each subsequent phase building upon what had been accomplished, see Table 2. Additionally, circumstances may change during the course of development that may alter or negate the work accomplished in previous phases. An evaluation should be conducted to determine the impacts of any changes due to new revelations or changing circumstances.

Table 2 - Architecture Views by Gate

	All View	Operational Views						Systems Views						
Gate	1	1	2	4	5a	5b	6a	1	2	3	4	5a	5b	9
1	IA	IA	IA	IA	IA	IA	IA	IA	IA	IA	IA	IA	IA	
2	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
3	U	U	U	U	U	U	U	U	U	U	U	U	U	U

	Capabilities Views			Services Views					Standards View	
Gate	2	4	6	1	2	3a	4a	5	1	
1	IA	IA	IA	IA	IA	IA	IA	IA		IA – Initial/ as-is
2	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT – Initial/ to-be
3	U	U	U	U	U	U	U	U	U	U – Update

(Hughes, 2010)

Concept Evaluation and Selection within a Stage-Gated Process

The general purpose of every decision gate in the front end is to prevent any concept from continuing to a subsequent development phase before it is ready. At the end of a development phase, the development team needs to demonstrate to the decision maker that the concept is developed enough to proceed to the next phase and that further development of the concept will benefit the organization and the intended user. The elements used to assess and mature a concept should define the level of robust early planning required at a given decision point. A simple way to understand the appropriate time for any particular element is to relate the purpose of the element to the specific objective of the decision following a development stage. A descriptive, stage-gated process based upon processes used by the Department of Defense (DoD) is

presented here (Figure 2). The framework begins with the concept development phase.

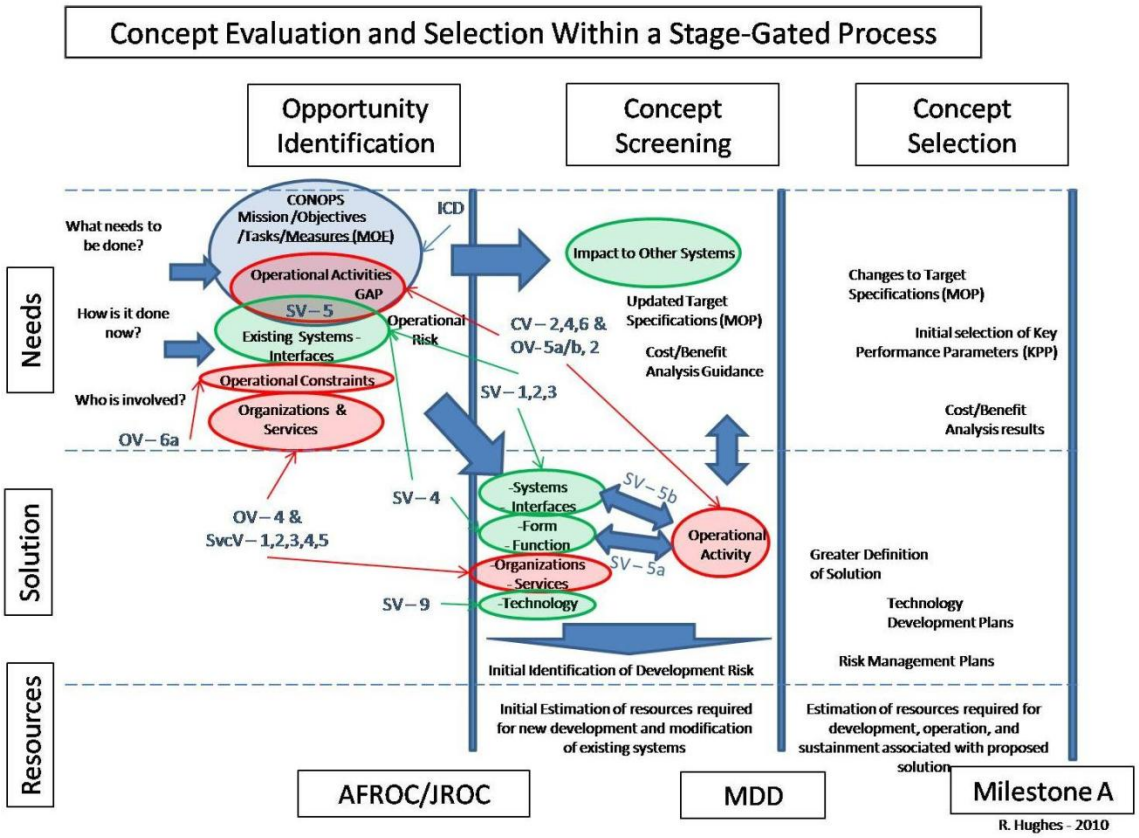


Figure 2 – Concept Maturity Framework

The first gate, Opportunity Identification, corresponds to when the Joint Requirements Oversight Council (JROC) approves and validates an Initial Capabilities Document (ICD) (Chairman of the Joint Chiefs of Staff, 2009), which contains mission requirements. The analysis conducted to develop an ICD should identify the shortfall in military capability, identify the user needs, and determine that a new development product is required to meet the need. The JROC must determine if this

development opportunity that was identified from a market environmental analysis is adequately important for the allocation of resources.

If the JROC determines that the ICD is complete and that it identifies a valid need, the next gate, Concept Screening, corresponds to the Materiel Development Decision (MDD). The primary purpose of the MDD is to act as the official entry gate to the materiel development process. It also acts as a filter to prevent the concepts that are infeasible for development, or do not meet the need identified in the ICD, from progressing any further in the development process. Any concept that the decision makers deem sufficient will undergo further maturity with deeper analysis in the Materiel Solution Analysis phase.

The third screening gate, Concept Selection, corresponds to Milestone A. At this investment decision, a concept is selected based upon a set of criteria. The criteria should include user needs, risk associated with development, cost to develop, operate and sustain the solution, and the benefits the development brings to the organization. A concept that demonstrates that it meets the criteria and is selected will, assumedly, have resources allocated to conduct preliminary design. Later gates with detailed design and fabrication/production readiness will be necessary, but substantial policy and guidance for these later gates exist for the DoD (Department of Defense, 2008). The information collected for these early decision gates will greatly affect and support the activities of the following development phases.

These decision gates define the concept maturity milestones that are used to prevent any concept from progressing to a phase of development before it is ready. A concept can pass through a decision gate if the products for the current phase of work

are complete and if the decision authority determines that there is benefit to further development. The worthiness of a concept for additional development is dependent upon contextual issues like resource constraints and political climate, in addition to a concept's maturity. A development team has no control over the contextual issues but it can ensure the proper definition and analysis associated with a decision gate has been completed. In an effort to mature a concept to the point of selection, the practitioner should develop and accrue a robust set of maturity elements that, when combined, will provide sufficient information to the final decision maker and will provide the foundation upon which the remainder of the project will be built.

Information Maturity Elements for Gate 1.

The ICD currently has no requirements for architecture products beyond a Concept of Operations (CONOPS) and an associated Concept Graphic (OV-1). However, there are several architecture maturity elements that can be useful in supporting the JROC's decision at this gate, and they can be developed from the documentation and information currently required in the generation of the Initial Capabilities Document. The Joint Ops Concepts and CONOPS (defined in AFPD 10-28 or IEEE Std 1362-1998) can be used to determine what the users need to do and how they expect to do it. A well-defined CONOPS identifies the mission area, timeframe, assumptions with regards to projected capabilities, desired effects and both the necessary and supporting capabilities that are needed. This information, as well as other information contained within a CONOPS, can be used to develop an overview of the system architecture products that will characterize the information associated with the desired capability (AV-1). The CONOPS should also include sequenced actions

for the operational and support scenarios envisioned by the user. Using tools such as Use Case modeling or traditional functional decomposition, this information can be captured in operational activity models (e.g., OV-5a/b in the DoDAF (DoDAF 2.0, 2009)), which show what must be done and gives the context of how it might be done. Any known rules or constraints that may restrict operations should be captured (e.g., OV-6a in DoDAF) to give a better understanding of the user environment. In addition, the identification of any organizations involved in the activities (OV-4) and resources that flow between activities (OV-2) will help characterize the situation for the design teams in future phases. Finally, the capabilities associated with the mission (CV-2) and how those capabilities support or interact with other operational activities (CV-6) and with each other (CV-4) should be captured.

Any existing systems and/or services (e.g. U.S. Air Force) involved with the desired capability described in the ICD should be identified (SV-1, SvcV1) and their interactions should be characterized. If further definition of the interaction and various systems and services associated with the concept is warranted, resource flows and existing/planned interfaces can be identified (SV-2,3, SvcV-2,3). In order to determine gaps between needed capability as defined by the operational activity models, e.g., OV-5, and current system capability, system and services functionality descriptions can be developed for current systems (SV-4, SvcV-4) and mapped to required operational activities using traceability matrices (SV-5, SvcV-5). During this early needs identification phase, these systems and services architecture elements would be restricted to existing systems/services for the time frame of interest, and would contain

only the detail necessary to identify the projected operational gaps and determine the reason for the gaps.

It should be noted that many of these architecture products are or may be required at later gates associated with the DoD acquisition process, but early collection of the information and definition of these products during the needs identification phase will help in the long-term effort. The initial development of these architecture elements before the first decision gate serves three purposes. First, the methodical development of the elements can be used to document existing capability, clarify any gaps in the capability, and characterize the operational risk associated with the gap. Second, the insight gained from these elements can aid in assessing the form of solution to meet the capability gap. Lastly, the elements serve as the foundation for future development phases. Each proposed solution will be designed and evaluated based upon requirements developed from the ICD (Hughes, 2010).

A very important component of the ICD that is not currently being adequately addressed is that of effectiveness measures (Sadauskas, 2008). As part of the needs identification process, needed capabilities should be identified in terms of tasks, attributes and measures. The measures at this level are best described as mission level Measures of Effectiveness (MOE). While the JCIDS policy has always required the inclusion of MOE's in the ICD, recent reports have suggested that ICD's are not adequately addressing how the operational needs are to be quantified for subsequent evaluation of alternatives (Sadauskas, 2008). The MOE's serve a similar purpose as the initial target specifications found in the product development literature, which is to guide the development and selection of potential solutions. Identification of MOE's is

critical to the concept maturation process, and is included herein as one of the maturity elements.

One final maturity element that is already required by CJCSI 3170.01G (2009) and should be developed in this early phase is an operational risk assessment. This risk assessment describes the risk of not filling the operational need. In DoD terms, this could be higher projected loss rates, greater numbers of personnel and systems allocated to missions, projected lengthening of the campaign duration, and/or increased vulnerability due to insufficient deterrent capabilities. In later stages, these operational risks will be weighed against the cost and technical risk associated with pursuing a materiel solution.

Information Maturity Elements for Gate 2.

After an organization decides to pursue a development opportunity, they should identify as many potential solutions as possible (CJCSM 3170.01D, 2009). These ideas should be developed, combined and discarded as they pass through a series of screens so that only a few of the best ideas remain for consideration (Wheelwright & Clark, 1992). The DoD calls this screen a Materiel Development Decision and uses it as a final check of the JROC recommendation to allow the further development of a materiel solution (Department of Defense DoD, 2008). The decision maker at MDD is called the Milestone Decision Authority (MDA). The MDA reviews the approved ICD and any proposed concepts to ensure that the material solution decision has a solid foundation, is based on justified information, and can be developed within time and resource constraints. If the concepts are deemed adequately mature, they proceed to the next phase of development where they are

further explored. In order to ensure that the approved concepts are adequately mature, and in an effort to encourage more rigor at this early gate, the MDA can draw upon important pieces of information defined herein as key concept maturity elements.

The information needed by the MDA at Concept Screening is largely associated with development of new or modified systems included in the proposed concepts (Figure 2). These concepts involve legacy systems and any anticipated changes in operations and/or materiel to existing systems should be identified. A critical piece of information for the decision maker at this stage is the scope of the required changes to implement the concept, since later decision gates will be increasingly associated with development of the individual component systems of the concept (CJCSM 3170.01D, 2009). If the full scope of the concept is not fully understood prior to a system development decision, either the full operational capability will not be realized, or significant cost impacts will be forthcoming to address needed modifications to other systems.

At this stage of concept development the actual proposed solutions are explained in terms of the required functionality (SV-4, SvcV-4), and the relationship between the need and solution is defined for the associated systems (SV-5, SvcV-5). These architecture elements may have been initially defined for existing systems during the needs identification process associated with Gate 1, but they will need to be updated and augmented for the envisioned modifications and/or developmental systems associated with a proposed concept. The interfaces and relationships between systems and services should also be updated (SV-1-3, SvcV-1-3). The technologies

critical to the solution need to be identified (SV-9) and any known standards applicable to the concept (StdV-1) should be captured (Hughes, 2010).

The level of detail required for any architecture element at this point should be driven by the decision at hand and the decision maker (Hughes, 2010). At the concept screening gate, scope and problem definition dominate the decision objectives, and the architecture definition to support this decision will likely require no more than subsystem identification for the component systems of the concept. Indeed, novel solutions considered at the concept screening gate will not likely support definition below this level. Even existing solutions where detailed information is available will not require all this detail be included in the architecture products at this early stage. The goals of this phase are to conduct the analyses to show the proposed solution will meet the identified needs and to identify and characterize the risks associated with the solution.

Concepts that are allowed to proceed through the screening gate will need to undergo further definition and will eventually have to compete against each other. The competition is in the form of a cost/benefit analysis and the criteria against which the concepts are measured should be identified prior to the Concept Screening gate. Quantitative target specifications (Measures of Performance) that describe system characteristics should be developed prior to the gate for use in the analysis. The DoD conducts an Analysis of Alternatives (AoA) during the concept refinement phase that acts as the cost/benefit analysis. The AoA study plan sets the parameters for the critical technologies and cost drivers, and decision objectives for the AoA. Sufficient risk identification associated with the technologies, interfaces, or changes to existing

systems should be completed to ensure that the AoA further addresses all pertinent issues (Hughes, 2010).

According to the AoA Handbook (Office of Aerospace Studies, 2008) the AoA study plan should describe how the following questions will be answered in the subsequent Materiel Solutions Analysis phase:

- What alternatives provide validated capabilities?
- Are the alternatives operationally effective and suitable?
- Can the alternatives be supported?
- What are the risks (technical, operational, programmatic) for each alternative?
- What are the life-cycle costs for each alternative?
- How do the alternatives compare to one another?

Due to the uncertainty associated with any new development, risks will still be present in a program or project regardless of the level of risk management. However, if an ample amount of rigor is applied, the more expensive risks can be identified and their impacts minimized. Further the assertion can be made that if risks are identified and sound risk mitigation plans are developed, a much more realistic idea of the resources required to complete development will be produced, thereby resulting in a more realistic cost estimate. It is during the risk identification phase when the important relationships between systems engineering and system architecture are defined. Risk management is the process used to manage the uncertainty associated with new development as described by Hillson (2004); therefore, risk management is a critical element of concept maturity.

Information Maturity Elements for Gate 3.

The purpose of the concept selection gate is to evaluate proposed concepts with respect to the customer's needs and to the resources required to develop the concept

(Ulrich & Eppinger, 2004). Again, this is similar to the DoD process as this decision point corresponds with Milestone A in the Defense Acquisition Framework. Following a successful Milestone A, entry into a technology development phase is approved for one or more prime contractors. The purpose of this phase is to reduce technology risk and to determine the appropriate set of technologies to be integrated into the full system (Department of Defense, 2008). The program formulation elements associated with the Milestone A are defined in DoD 5000 series and the Defense Acquisition Guidebook (Department of Defense), but additional concept maturity elements will be discussed here.

In both industry and the DoD, an investment decision must be made based upon the information and analysis contained in the materiel concept. Much of this information is efficiently and effectively conveyed and managed via architecture products. Although most architecture products are not required by DoD policy until the later Milestone B decision to enter a detailed design phase, the NRC study highlighted several important benefits to earlier development of systems architecture:

> 1. Architecture can mitigate internal and external system complexity risk by partitioning the system into separately definable and procurable parts.
>
> 2. Architecture can reduce lifecycle costs through the process of breaking down large systems into more easily managed components whereby potential cost and schedule risks can be identified.
>
> 3. The construction of a rigorous systems architecture developed early in the program will aid in reducing interface complexity control problems later in the program when they are much more costly to fix (NRC, 2008).

Some architecture elements created in earlier phases will need to be updated and others will require dramatic additions in the phase preceding the concept selection decision (Figure 2). The specifications (MOP's) to which the solution will be

measured may require updating. An initial identification of characteristics or attributes that are essential for the development of the capability should be conducted. Mitigation and management plans will need to be created for previously identified risks. A system level plan to develop new technologies or to integrate modified technologies should also be detailed for concept selection. The DoD calls it a Systems Engineering Plan (SEP) and uses it to describe the process of technology maturation (ODUSD(A&T)SSE/ED, 2008). The SEP provides traceability back to the users' needs via elements such as a CONOPs, risk identification and architecture definition eventually focusing attention towards a preferred system concept. The final version of the overall concept should be sufficient to characterize how the solution will meet the identified need, to characterize the amount of risk involved with developing the solution, and to give a reasonable idea of the full cost associated with the proposed solution. This work describes how the right combination of architecture views along with the other aforementioned maturity elements, can mature a concept relative to the early decision points in the development process.

The following chapter will discuss a proposed methodology for validation of the concept maturity framwork and its Concept Evaluation and Selection within a Stage-Gated Process. The process focuses on proving a time-phased element driven framework and its ability to correctly diagnose a healthy level of concept maturity at the needed time and phase. This validation effort will be based on the maturity elements discussed in this chapter and as presented in Hughes' Framework.

III. Methodology

A. Research Approach

The approach and methodology used by the researchers is focused on addressing the research questions and the main hypothesis that the Hughes' Framework adds value to understanding a concept's maturity in early development. Along with the validation effort, the research team was looking for areas to improve upon the framework if deemed appropriate. The purpose of this research is both summative and formative in nature. The first part of this methodology is summative in that the researchers were summing up conclusions about the framework in order to recommend and comment on its value (Patton, 2002; Krathwohl, 1998). The second part is formative, aimed at improving the framework if indicated by the data analysis and results (Patton, 2002; Krathwohl, 1998). In an effort to increase the strength of both the evidence and generated findings, the researchers chose the principle of triangulation as a method to improve the study's rigor and believability.

1. Triangulation.

Triangulation strengthens a study by combining different methods, data types, theories, and perspectives during the research effort (Patton, 2002; Denzin, 1978). This triangulation approach prompted a framework validation effort that would include (1) interviews with knowledgeable individuals experienced in early concept development, (2) an attempt to apply the framework to a real-world concept in development, and (3) an analysis of approved policy and guidance on items related to the maturity elements of the framework. This methodology will help increase the

confidence that any findings or conclusions made are supported by various angles and reduce the potential bias or errors from a single approach (Patton, 2002).

2. Internal & External Validity.

As a way to check the believability, level of significance, and ability to generalize the finding of this research, the concepts of internal and external validity are leveraged (Krathwohl, 1998). Internal validity is the power of a study to support a cause linking to an effect (Krathwohl, 1998). Interviews will be the mechanism used to test internal validity. The cause will be the interviewee's responses regarding the framework linking to the effect of a conclusion that supports or negates usage of the framework. The researchers will apply the five judgments as prescribed by Krathwohl (1998) to test for internal validity. Please see Table 3 below. If the interview method results in a favorable recommendation for the framework and the method is determined to be internally valid, then the researchers will test for external validity.

External validity is the power of a study's findings to be generalized to other areas outside of the controlled study (Krathwohl, 1998). In terms of this research, a test for strong external validity will show how the framework not only adds value to the subjects interviewed, but would add value to other organizations as well. Although, the interviews focused on subjects with backgrounds primarily in Air Force product development, the researchers will demonstrate the external validity of this study's findings as they apply to the greater DoD and even commercial product development organizations. Both the application and confirmatory sources approach of this methodology will be used to help test for the degree to which the framework

can be generalized. Similar to internal validity, Krathwohl (1998) prescribes five separate judgments that the research team will use to test for the external validity of this study's findings, see Table 3 below.

Table 3 – Five Judgments for Internal & External Validity

Internal Validity	External Validity
1. Explanation credibility	1. Explanation generality
2. Translation fidelity	2. Translation generality
3. Demonstrated result	3. "Demonstrated generality"
4. Rival explanations eliminated	4. Restrictive explanations eliminated
5. Credible result	5. Replicable result

(Krathwohl, 1998)

B. Triangulation Approach: Interview and Associated Methodology

1. Objectives & Reasoning.

The Hughes' Framework is a recent effort to assess concept maturity during early development. As part of this validation effort, the research team determined that individuals actively or recently involved in related early development would best be suited to assess the framework's value. These identified individuals are/were most engaged in the triumphs and pitfalls of the work involved with early development and capturing their perceptions of what is important to concept maturity is essential. Although the Hughes' Framework is born out of scholarly research, there is no proxy or substitute to compare it directly to in order to assess its value or correctness. For this reason, the research team avoided using a comparison to accepted frameworks or related guidance on concept maturity as the primary method of validation. The

interview methodology, therefore, will serve as the main cause for recommending acceptance or refusal of the framework. Likewise, the research team has the objective to ensure the methodology and findings of the interview approach are both internally and externally valid.

2. Design.

The research team framed the interview to gather both quantitative and qualitative data as a method for analysis and validation. The quantitative data would show the ratio of respondents voting favorably for or against the maturity elements within the framework while the qualitative data would allow for further analysis and uncover the rationale and context behind the interviewee's responses (Patton, 2002). The quantitative data would also help facilitate direct comparisons and contrasts between respondents (Patton, 2002). Krathwohl (1998) offers that quantitative methods alone are inadequate when, "detailed, in-depth information is sought . . . [and] you believe the perceptions of the participants differ from those of outside observers" (Krathwohl, 1998, p.243). This level of detail and perception of the interviewees is critical to fully understand what is important during early development.

a. Subjects.

Given the need for both quantitative and qualitative data concerning the framework, the research team next determined the appropriate subjects to interview. The researchers approached choosing subjects from several angles, but it was concluded that purposeful homogenous sampling would be the best option. Purposeful sampling has the benefits of focusing one's research effort on information-rich cases (Patton, 2002; Krathwohl, 1998), while homogenous sampling helps reduce

variation and the noise often associated with random sampling (Patton, 2002). The research team wanted to restrict the opinions on the framework's value and usefulness to individuals actively/recently involved in early development and avoid individuals that are not specialized in this field. This purposeful sampling may appear too biased by selecting such a homogenous subject base, but Patton claims, "what would be 'bias' in statistical sampling, and therefore a weakness, becomes intended focus in qualitative sampling, and therefore a strength" (Patton, 2002, p.230).

In an effort to identify the individuals desired for sampling, the research team created the concept of a practitioner. A practitioner would be the ideal candidate to interview. For the purposes of this research a practitioner can be defined as an individual who actively or recently prepares, constructs, designs, or manages the information and activities involved in early concept development. These individuals are the most experienced and knowledgeable people that understand how early development is done currently or in the recent past, and can recognize what information decision-makers need or desire to assess a concept's maturity. The insights of decision-makers would also be beneficial, but the research team recognized the extremely small sample of high-level decision-makers available in the DoD and the difficulty accessing them.

b. Sample Size.

The sample size was not a major concern during this study as mentioned previously regarding the subject base; the research team wanted the right people to focus the research on instead of the quantity. For this reason and other constraints such as the restrictive time to finish the study, limited travel resources, and willingness

of participants, the sample size would be lower than other social science research. However, Patton (2002) offers that unlike statistical sampling, research that is highly qualitative, ". . . [has] more to do with the information richness of the cases [subjects] selected and the observational/analytical capabilities of the researcher than with the sample size" (p.245). Accordingly, the research team was willing to limit the sample size to focus on information-rich candidates. Nevertheless, in an effort to limit the bias of any single organization within the Air Force, the research team sought to broaden the subject base and avoid interviewing a largely disproportionate number of individuals from the same organization. The research team recognizes the small sample size as a relevant target for criticism and a limitation of the research. Regardless, in keeping with Patton, the data and results from a small sample base can yield substantial findings with the appropriate care and rigor. These concerns will be at the forefront of this study's data analysis.

c. Structured Interview.

The interview was framed to gather the perceptions and viewpoints of the value of the maturity elements within the framework as well as any relevant discussion on related topics such as early development and acquisitions. The intent was to gather both quantitative data for consistency in results between respondents and qualitative data to promote a deeper understanding. With these goals in mind, the researchers determined a structured interview approach as recommended by Krathwohl (1998) would be best. This approach would include asking the interviewee common questions regarding the framework while allowing them time for follow-on discussion. A dilemma arose in that the research team did not want to artificially skew the

responses by pre-supposing a notion that the Hughes' Framework is useful by only asking questions about the framework itself. The framework as depicted in Figure 2 (Page-19), requires a level of explanation and background to fully understand its usage or value. Simply showing the framework to respondents and asking for their thoughts would require some explanation. Furthermore, as this study's authors are not the authors of the Hughes' Framework, a risk would lie in the ability of the team to articulate properly how the framework operates. This weakness could possibly result in an interviewee's misunderstanding of the Hughes' framework. Therefore, the focus was placed on whether or not a respondent perceived value in the content within the framework rather than merely its design and appearance. Finding a method to properly gain the best possible unbiased information from each respondent with a mixture of both qualitative and quantitative data became the priority and was addressed through studying and applying the methodology linked to both preference measurement and conjoint analysis.

d. Preference Measurement & Conjoint Analysis.

Preference measurement as discussed by Netzer et al. (2008) is the concept related to assessing a subject's likes, dislikes, and general degree of perceived value. A closely related concept, conjoint analysis, is a method commonly applied in market research when marketers want to determine what features of a product a customer wants or would purchase (Dahan & Hauser, 2001a). Netzer et al. (2008) comments that in the past, preference measurement was nearly synonymous with conjoint analysis in determining what features consumers preferred in a product. In their recent studies, Netzer et al. and Michalek, Feinberg, and Papalambros (2005) claim that

advances in preference measurement methods have evolved to include more than just marketing for companies. As mentioned by Netzer et al. the utility and breadth of methods for both preference measurement and conjoint analysis has expanded significantly. The methods and benefits are now far-reaching as further research has extended into policy-making, health care, engineering and academic research (Netzer et. al, 2008; Micahelek et. al, 2005)

The research team used principles of preference measurement and conjoint analysis to develop the interview approach used to discover the preferences of the respondents concerning their perceived value of the maturity elements within the framework. In a study regarding the utility of conjoint analysis towards customers selecting preferences for vehicle features in a web-based format, Dahan and Hauser (2001b) use cards with different representations of vehicles and ask the test subjects to select the cards they would most likely purchase by rank ordering them. In an effort to not only gain insight into what maturity elements the respondents for this validation effort of the framework value, the research team also desired to understand any potential value ranking or ordering of the elements. Consequently, the team chose to extend the method used in the Dahan and Hauser (2001b) study.

e. Card Selection Exercises.

The research team chose to use the idea of the respondents selecting cards that represented maturity elements in the Hughes' Framework during different exercises within the interview. These exercises were meant to harness the concepts inherent to conjoint analysis, and give an avenue for discussion and interaction with the respondents. As mentioned previously, the research team wanted to focus the

interview on the content of the framework rather than over its appearance or style and avoid relying on the ability of the researchers to properly explain the framework and possibly biasing the subjects. While discussing conjoint analysis in his article, Marder (1999) claims that any conjoint analysis study has a major assumption, that the overall, ". . . value of a product is the aggregation of the values of its characteristics" (p.2-3). Marder's findings support the approach that validating the value of the framework (the product) will be determined by aggregating the value of the individual maturity elements (its characteristics).

After determining that breaking up the framework into its maturity elements would be a logical approach towards validation, the research team reviewed different types of conjoint analysis methods discussed within a study by Hauser and Rao (2003) in order to find the best technique to conduct the interviews. The authors offer that more and more methods and techniques are evolving with time as well the notion of hybrid methods, which combine and tweak some traditional methods. Hauser and Rao further claim that no method is better than another as they all have strengths and weaknesses, and that tailoring the method to fit the research is what is important. In another conjoint analysis application study, Dahan, Hauser, Simester, and Toubia (2002) claim that empirical evidence exists that hybrid combinations of conjoint analysis methods, "often yield more accurate or more efficient predictions than either of the parent methods" (p.20). Dahan and Hauser (2001b) also claim that hybrid methods work well with research that is intended to measure the intensity of a preference.

The conjoint analysis methods selected for this framework validation effort are a hybrid mix of a full profile evaluation and the self-explicated method. In the full profile evaluation method, the features describe the product and the respondent is usually asked to rank order or give a preference rating for all the product variations based on their features (Hauser & Rao, 2003). Using the vehicle example, this method could have respondent's preference rank different configurations of a vehicle such as a mid-sized sedan with four-wheel drive, six-cylinder engine, and leather interior to a two-wheel drive, six-cylinder with cloth interior. In contrast, the self-explicated method asks respondents more about the features themselves than the products they describe in an effort to understand the relative value behind the features (Hauser & Rao, 2003). Using the vehicle example this method could have respondents describe what they like most about certain features such as why they prefer leather to a cloth interior or why they like leather in general. In relation to this validation effort a hybrid of these methods became the basis for the dual cards exercise approach to the interviews. Rather than features of a product to purchase as used in the Dahan and Hauser (2001b) study with vehicle preferences, the research team placed the information regarding maturity elements within the framework on the cards.

The interview asks each respondent for some background information to obtain context for the types and experiences of the individuals surveyed. Some of the specifics to this background information are masked to protect the anonymity of the respondents. After the background information, the researchers followed with the first of two exercises. During and after each exercise, the researchers asked related follow-on questions. Due to the short duration allotted for the interviews, the research team

chose to limit the number and scope of all follow-on questions and attempted to refocus any discussion that was overly detailed. Furthermore, the researchers did not want any respondent focusing too much attention on any one area at the risk of losing all detail in others. Although much more data and information could have been gathered in these interviews, during their conjoint analysis study, Dahan and Hauser (2001b) claim, ". . . due to respondent wear out, accuracy degrades as the number of questions increases (p.340). For these reasons, the researchers chose a streamlined and focused approach to constructing and applying the interview and exercises. Please reference Appendix A, for the structure and questions asked during the interviews.

The first exercise, the "As-Is" process, focused on the principles behind the self-explicated method and sought to understand how each respondent perceives to what extent the maturity elements are being accomplished now or recently during the early stages of development (i.e. post- need identification and pre- MS-A). In response to Drazen's (2004) opinions on subjective data, each respondent was asked to not think about what the correct answer is, should be or what other people answered, and that the focus of the study for all questions is completely based on their perceptions. In order to keep the context of the data as consistent as possible, each respondent was asked to focus their perceptions based on a time range from five years prior to the present. Since the self-explicated method focuses on the features as mentioned by Hauser and Rao (2003), the researchers chose to ask each respondent to describe how well, how bad, how often, how difficult, or any related comments concerning the information presented on the cards. This approach would lead to an

open, yet focused discussion to gather qualitative data on the perceptions of the maturity elements as they are accomplished now or recently.

The second exercise, the "To-Be" process, focused on using the full profile evaluation method, discussed in 2003 by Hauser and Rao, to ask each respondent to pick the maturity elements they deemed as adding value during early development. The respondents were asked to select any cards they perceived as adding value during early development and provide qualitative comments and any rationale. The respondents were told that the second exercise is independent of the first exercise and that they should only select cards they perceive as adding value regardless of if it is presently being accomplished. The respondents were also asked to describe an ordering or grouping for the cards they think are most efficient and effective at adding value as information to a decision maker. To limit any bias, the research team reminded each respondent that the researchers neither had any pre-conceived opinion as to the value of the cards nor that an ordering or grouping is necessary. Similar to the first exercise, the researchers asked focused follow-on questions such as what are the three most important activities for this new set of cards and if there is anything the respondent feels is missing or any additional information they would include. Finally, the interview concluded with time for each respondent to provide any additional comments concerning the cards, early product development, acquisitions in general, and/or any related comments.

f. Mapping to Maturity Elements.

Before the interviews and data collection could begin, the researchers needed a systematic process to break apart the Hughes' Framework into its maturity elements

that could then be presented to the respondents for discussion. An issue arose with simply presenting each maturity element directly from the framework due to the brevity of descriptions as well as the high number of elements. The Hughes' Framework as discussed previously leverages the use of the DoDAF architecture products to describe many of the maturity elements. The researchers did not want to bias the respondents by asking them to assess the value or current use of the DoDAF products directly. Furthermore, the descriptions for some of DoDAF products are lengthy and complex which could cause unnecessary confusion and discussion on the purpose behind each maturity element. For these reasons, the researchers chose to mask the use of any DoDAF products within the exercise cards and attempted to simplify the maturity elements as much as possible.

Besides the desire to simplify the information presented on the cards to avoid confusion, the researches attempted to reduce the overall number of maturity element cards as recommended by the Dahan and Hauser (2001b) study. Their study focused on the customers selecting their preferred vehicles represented by cards with information on them using a web interface, and they determined that customers had a difficult time rating vehicles as the number of cards increased (Dahan & Hauser, 2001b). By consolidating similar and related maturity elements within the framework, the researchers were able to reduce the number of cards used from 24 to 14, while still maintaining the original intent and necessary information. Two additional cards, which represent information required after the scope of the Hughes' Framework, were added by the research team to gain insight into the reasoning for their exclusion. The

mapping of the maturity elements to these 16 cards used in the exercise and the rationale for the two additional cards is explained below.

The method for the mapping was to group similar maturity elements from the framework under a more general and easily understood description. Further, the grouping often involved similar maturity elements for different stages described in the framework. Since the purpose of the interview was again to focus on the content within the framework, the researchers determined that generalizing the phases would not skew the data. These cards were labeled for identification purposes from "A" to "P". During the explanation of the interview process, the respondent was instructed to ignore the labels and that it has no significance other than for recording purposes. Finally, two cards, "J" and "O", represent common activities and products performed during development and acquisitions, but were not included in the framework. The researchers chose to add these cards to hopefully gain some insight into the reasoning for their exclusion from the Hughes' framework and allow for further discussion from the audience. The actual cards used during the interviews are depicted in Appendix B. The following section details and describes the mapping process for each card and Table 4, below summarizes the mapping.

A. *Rough order magnitude initial cost and schedule estimates.* This is not a DoDAF architectural document specifically called out in the framework but a combination of many elements in the framework that are the results of the analysis that is performed. In the concept screening phase this card represents the "Cost/Benefit Analysis Guidance" and "Initial Estimation of resources required for new development and modification of existing

systems" maturity elements. The card also represents the "Cost/Benefit Analysis Results" and "Estimations of resources required for development, operation and sustainment associated with the proposed solution" during the concept selection phase.

B. *Description of interfaces between system elements and the resources that flow between them, as well as the operational activities they support.* This card represents OV-2, SV-2 and SV-3 DoDAF architecture products. In the framework this would be the "Systems Interfaces" and "Operational Activity" maturity elements found in the concept screening phase.

C. *List of assumptions, constraints and enabling capabilities that are required for the system to operate effectively.* This card combines sections of a CONOPS and an OV-6a DoDAF architectural product. The CONOPS helps describe the assumptions, constraints, and enabling capabilities; while an OV-6a helps supplement with additional business rules and constraints the system must operate under. In the framework this would be the "Operational Constraints" maturity element in the opportunity identification phase.

D. *Organizational relationships, their roles and responsibilities, and how the flow of resources is expected to occur.* This card represents an OV-4 DoDAF architectural product. In the framework this would be the "Organizations & Services" maturity element in the opportunity identification phase.

E. *A decomposition of all operational activities or tasks, and the inputs/outputs between them.* This card represents OV-5a and OV-5b DoDAF architectural products. In the framework this would be the "Operational Activity" maturity element in the concept screening phase.

F. *Identification of the system as a whole, the elements that make up the system and their interconnections internally and external to the system.* This card represents an SV-1 DoDAF architectural product. In the framework this would be the "Existing Systems-Interfaces" maturity element in the opportunity identification phase as well as the "Impact to other systems" and "Systems interface" maturity elements in the concept screening phase.

G. *A description of the functions performed by systems and the interactions/resources flows required to perform that function.* This card represents an SV-4 DoDAF architectural product. In the framework this would be the "Form & Function" maturity element in the concept screening phase.

H. *A mapping of desired system capabilities to operational activities that must be performed and the system functions that support them.* This card represents the SV-5 and CV-6 DoDAF architectural products. In the framework this would be the overlapping of the "Operational Activities Gap" and the "Existing Systems Interfaces" maturity elements in the opportunity identification phase as well as the interactions between the

"Systems Interfaces, Operational Activity and Form & Function" maturity elements in the concept screening phase.

I. *A listing of maturing technologies that the development of the system may be dependent upon.* This card represents a SV-9 DoDAF architectural product. In the framework this would be the "Technology" maturity element in the concept screening phase and the "Technology Development Plans" in the concept selection phase.

J. *A listing of all industry, national and international standards that apply to the system (solution.)* This card represents a StdV-1 DoDAF architectural product. This is not called out in the framework but since it is a DoDAF product the interviewee's reaction on whether it should impact the decision maker's choice could provide some valuable information for the research.

K. *A listing of capabilities needed to solve the problem decomposed down to lower level enabling capabilities and the dependencies between them.* This card represents the CV-2 and CV-4 DoDAF architectural products. In the framework this would be represented by the "Operational Activity Gap" maturity element in the opportunity identification phase and the "Operational Activity" maturity element in the concept screening phase.

L. *A matrix matching required system capabilities to the operational activities that must be performed to achieve them.* This card represents the SvcV-1 through SvcV-5 DoDAF architectural products. In the framework this is represented by the "Organizations & Services" maturity elements in the opportunity identification and concept screening phases.

M. *A risk assessment matrix of the risky elements of system development and integration as well as a mitigation strategy.* This is not a DoDAF architectural document specifically called out in the framework but a combination of many elements in the framework that are the results of the analysis that is performed. In the opportunity identification phase this represents the "Operational Risk" maturity element. In the concept screening this represents the "Initial identification of development risk" maturity element. In the concept selection phase this represents the "Risk Management Plans" maturity element.

N. *Quantifiable measures of effectiveness (MOE) for the system and derived measures of performance (MOP.)* This card represents some of the information that is contained in an AV-1 DoDAF architectural product. This represents and combines parts of the "CONOPS Mission / Objectives / Tasks / Measures (MOE)" maturity element in the opportunity identification phase, the "Updated Target Specifications (MOP)" maturity element in the concept screening phase and the "Changes to Target Specifications (MOP)" and "Initial selection of Key Performance Parameters (KPP)" maturity elements in the concept selection phase.

O. *Initial test plan for how to evaluate the system against its MOPs and MOEs.* This card does not represent any maturity element in the framework nor is it specifically called out as a DoDAF architecture product. This card was added in the interview to gather reactions on

whether or not a test plan should be a factor for a decision maker early on when choosing between concepts.

P. *Concept of operations (CONOPS) describing the problem, the desired effects, assumptions, critical capabilities, enabling capabilities, sequenced actions and the end state.* This card represents more than just an OV-1 DoDAF architectural product. In the framework this represents the "CONOPS Mission / Objectives / Tasks / Measures (MOE)" maturity element in the opportunity identification phase.

Table 4 – Mapping of Exercise Cards Summary

Exercise Card	**Phase**	**Maturity Element from Hughes' Framework**	**Related Architecture / Acquisitions Products**
A	Concept Screening	Cost/Benefit Analysis Guidance; Initial Estimation of resources required for new development and modification of existing systems	
	Concept Selection	Cost/Benefit Analysis Results; Estimations of resources required for development, operation and sustainment associated with the proposed solution	
B	Concept Screening	Systems Interfaces; Operational Activity	OV-2, SV-2, SV-3
C	Opportunity Identification	Operational Constraints	CONOPS, OV-6a
D	Opportunity Identification	Organizations & Services	OV-4
E	Concept Screening	Operational Activity	OV-5a, OV-5b
F	Opportunity Identification	Existing Systems Interfaces	SV-1
	Concept Screening	Systems Interface	

Exercise Card	Phase	Maturity Element from Hughes' Framework	Related Architecture / Acquisitions Products
G	Concept Screening	Form & Function	SV-4
H	Opportunity Identification	Operational Activities Gap; Existing Systems Interfaces	SV-5, CV-6
	Concept Screening	Systems Interfaces; Operational Activity; Form & Function	
I	Concept Screening	Technology	SV-9
	Concept Selection	Technology Development Plans	
J	*not in Hughes' Framework		StdV-1
K	Opportunity Identification	Operational Activity Gap	CV-2, CV-4
	Concept Screening	Operational Activity	
L	Opportunity Identification	Organizations & Services	SvcV-1, SvcV-5
	Concept Screening	Organizations & Services	
M	Opportunity Identification	Operational Risk	
	Concept Screening	Initial Identification of Development Risk	
	Concept Selection	Risk Management Plans	
N	Opportunity Identification	CONOPS Mission / Objectives / Tasks / Measures (MOE)	AV-1, CONOPS
	Concept Screening	Updated Target Specifications (MOP)	
	Concept Selection	Changes to Target Specifications (MOP); Initial Selection of Key Performance Parameters (KPP)	
O	*not in Hughes' Framework	Test & Evaluation Master Plan (TEMP)	
P	Opportunity Identification	CONOPS Mission / Objectives / Tasks / Measures (MOE)	CONOPS, OV-1

3. Data Collection.

The research team identified the desired interview candidates using the concept of purposeful homogenous sampling as discussed previously. After discussion with various faculty members at the Air Force Institute of Technology and the Air Force Center for Systems Engineering, the research team compiled a list of potential candidates that are actively involved in Air Force related acquisitions. These candidates shared qualities and attributes of having experience, expertise, and knowledge within their respective fields. The candidate list included individuals from organizations throughout the Air Force at various levels of command and influence and representing different geographic regions of the US. The list also contained individuals with varying career status in the Air Force including active duty military and government civilians.

Due to time and resource constraints the delivery of the interview itself was conducted differently for participants not local to the research team. If the participant was in the local region, the interview was typically conducted at the participant's place of work in a private setting. If the participant was not local, then the interview was conducted using a telephone conference, also in a private setting. The questions and structure were exactly the same for both local and non-local interviews, and the only deviation was that the cards used during the two exercises were sent electronically to the participant who then printed a copy to reference. The local interviews were given the cards during the interview, which were separated. The only limitation the research team identified by this change was that the non-local participants might not be able to easily manipulate and organize the cards. This organization of the cards would be

useful when answering the question regarding if the participant felt there was any ordering or grouping of the activities. However, the content and cards themselves, separated or not, were consistent to all participants and the research team determined that interviewing the appropriate people was worth this minor deviation.

During the interview, the research team again explained the purpose of the interview and the general structure. The research team told each participant that the interview was scheduled to last approximately 30 minutes with up to an hour for follow-on discussion. The research team also reminded participants that any and all comments would be anonymous and could not be attributed to them. The research team did this to avoid any participant skewing their responses or withholding any negative information for fear of reprisal. Furthermore, the research team required data based on the respondents perceptions and thoughts, not the "approved" or "school-book" answers.

Both researchers participated in each interview regardless of the local or non-local format. The team used the approach of tandem interviewing as recommended by Krathwohl (1998). This approach allows two researchers to ask questions of the participants during the interview. Krathwohl claims that the benefits of tandem interviewing include allowing one researcher to record responses while another asks questions and allows for further clarification if another researcher's question requires it. This approach served this data collection well and allowed for a more seamless session with each participant. To record each participant's responses both researchers hand copied the bulk of the answers and associated dialogue. Conversation that was unrelated to the discussion and purpose of the interview was not recorded. At the

conclusion of the interview the research team compared data for consistency and to correct any deviations.

4. Data Reduction.

After all the interviews and data collection phase was finished, the research team began a process to reduce the information from the respondents into a more understandable and useful form. All the relevant hand-written notes were transcribed using a word-processing tool. The researchers again compared notes and ensured that any conflicting data was resolved. At this point, the research team reduced the remaining data using both a quantitative and also a qualitative approach. Regardless of the approach used, the originating source (interviewee) of the data was never eliminated.

The quantitative data included organizing the number of times a particular exercise card was selected during one of the two interview exercises. For the first exercise, the "As-Is" process, the researchers recorded the number of times each card was selected as well each time it was left out. The same approach was used for the second exercise, the "To-Be" process. The research team also recorded the number of times a card was indicated for one of the follow-on questions (i.e. most important, most time/resource consuming, etc.)

The researchers next evaluated and reduced the qualitative comments given by the respondents during the interviews. Due to the open-discussion format of the interviews many respondents gave comments concerning a particular exercise card at different points throughout the interviews. For this reason, the research team chose to group all comments concerning a particular exercise card, rather than separate

comments by exercises as in the quantitative reduction discussed previously. The research team also grouped all responses given regarding maturity elements that were missing or should be added. Finally, for all noteworthy comments not specific to any of the exercise cards or follow-on questions, the research team grouped these as general comments.

5. Data Analysis.

After organizing and grouping the comments and exercise card data, the research team began to study and analyze the complex and quantitative and qualitative information. The research team took a two-way approach to the data analysis. The first approach as recommended by Patton (2002) is deductive and seeks to analyze the data through the lens of an existing model, tool, or framework. This type of analysis looks at how a specific hypothesis is supported for or against by the available data and commonly involves taking the responses given to see how they compare or contrast to the concept in question (Patton). In reference to this study, the hypothesis used is that the Hughes' Framework adds value to early development. Patton offers that deductive analysis is primarily served by quantitative data, but qualitative data can also be used. The research team focused the bulk of the validation effort on deductive analysis of the interview data.

In contrast to deductive analysis, inductive analysis seeks to evaluate the available data without any lens, hypothesis, or pre-conceived opinions (Patton, 2002). This type of analysis is normally qualitative driven and attempts to look at the data for what it is saying alone and not in comparison to other known ideas. Taylor and Bogdan (1984) mention that often a research study heavy with qualitative data will

start deductive and then shift towards inductive. This claim supports the research goals of this study. Besides the validation effort of the framework, the researchers also wanted to understand the larger context of early development, acquisitions, the people involved, and any related findings the interview results could offer. Inductive analysis is a strong methodology for this type of approach as Patton adds, "the researcher strives to look at the data afresh for undiscovered patterns and emergent understandings" (p.454).

In support of the inductive analysis, the research team used the analysis techniques described by Patton (2002) to methodically and logically make sense of the vast amount of differing comments given by the respondents. Patton discusses the idea of developing codes and categories to understand qualitative data. He uses the concept of convergence to describe a technique of looking at qualitative data for what things fit together and any recurring regularities (Patton, 2002). These regularities lend to patterns that can be coded into categories for further analysis (Patton, 2002). During this coding process, Denzin (1978) recommends the concept of investigator triangulation as a method to strengthen the findings from a common qualitative data source. The research team adopted this approach and chose to have both members examine the comments and come up with a separate list of recurring regularities, categories, noteworthy observations and potential themes. After this initial examination the team compared and contrasted lists as recommended by Denzin.

6. Reporting.

As part of this validation effort, the research team desired to present the results of this study based on the researchers' opinions while including enough data so that

the reader can make their own conclusion on the usefulness of the framework. As part of the data reduction effort the research team grouped all exercise related comments and presents these for discussion. The research team leverages the use of histograms heavily to show the quantitative data related to the exercise cards. These histograms are useful, for example, for demonstrating the number of times a maturity element was selected in the "As-Is" or "To-Be" processes or which cards were rated more important than others. Also when appropriate the research team was able to make factual conclusions presented as ratios and percentages based on the data. Finally, the research team presents any derived themes, patterns, lessons-learned, and best-practices regarding this study in summary format for the reader. The results, conclusions, and recommendations from this study are presented in the subsequent chapters.

C. Application Methodology

As part of the summative evaluation research approach used in the validation effort of the Hughes' Framework, the research team examined if the framework could be applied to a real-world concept in development. This approach would highlight not only the value of the framework, but also the ease of use in applying it. The results of this application would be used to support the external validity or generalizations of the findings discovered during the interviews to other areas (Krathwohl, 1998). The following sections discuss the background and methodology of the framework real-world application effort.

1. Maturity Assessment & Background.

In the summer of 2010, the research team was asked to provide an assessment of the maturity of a concept in the early stages of development (i.e. post- need identification) for a weapon designed to destroy hard-to-defeat targets. The sponsoring military organization desired an outside and unbiased assessment of each development contractor's solution from an academic point of view. The research team chose to use the Hughes' framework as a guide to evaluate each contractor's proposal. This assessment did not aim to assess the goodness or effectiveness of a contractor's approach, but would be used to provide feedback on whether the Government (the sponsoring organization) has enough information to determine the weapon concept's maturity and preparation for further development.

For this assessment the research team gathered data on the currently available information by both the Government and each contractor. The research team attended developmental contractor program reviews, researched background material, system requirements, and other program related documents to gain an understanding of the overall concept and each contractor's specific solution. The researchers provided an assessment report to the sponsoring organization on information determined as sufficient, missing, or areas for improvement by applying the Hughes' Framework. Due to the official or proprietary status in this assessment, no details regarding the sponsoring organization or the weapon concept are provided in this study. However, as mentioned previously, the researchers were seeking primarily to demonstrate that the Hughes' Framework could be applied and the level of ease/difficulty, rather than the added-value of applying it. This initial assessment effort highlights how the

framework can be used as a guide to evaluating a concept's maturity and help identify potential gaps.

2. Architecture Effort.

After delivery of the concept maturity assessment, the sponsoring organization indicated a desire for the researchers to create the maturity elements described as missing or requiring improvement. Although, the researchers had limited knowledge of the program, they were able to create all the recommended maturity elements and architecture products in a usable draft form. These deliverables were completed at varying levels of details based on the available information. During this effort, the researchers noticed that regardless of the detail included in a maturity element, applying the framework at least highlighted areas that required more information. The research team used a PC-based application tool, System Architect, to create and design the architecture products and diagrams used in this effort. Table 5, lists the maturity elements and architecture products as described in the Hughes' Framework that were developed by the research team.

Table 5 – Architecture and Maturity Elements for Application

Product	Code	Use
Overview and Summary Information	AV-1	Sets the purpose, scope, methodology, products, and expected analyses to be performed for the entire architecture effort
Concept of Operations	CONOPs	Outlines the operation concept required by this system
Integrated Dictionary	AV-2	Definition of terms
High-Level Operational Concept Graphic	OV-1	High level graphical and textual description of operational concept
Operational Node Connectivity Description	OV-2	Connectivity and information flow between nodes

Product	Code	Use
Organizational Relationships Chart	OV-4	Shows organizational context, role or other relationships among organizations and units
Node Tree	OV-5a	Activities, relationships among activities, inputs and outputs
Activity Model	OV-5b	Activities, relationships among activities, inputs and outputs
Operational Rules Model	OV-6a	Describes business rules that constrain operations
Systems Interface Description	SV-1	Identifies systems, system items, and their interconnections

Due to the official and proprietary status of these products, the actual diagrams and models are not included in this study. When finished, the researchers briefed and delivered these products and the results of this effort to the sponsoring organization.

3. Feedback.

The research team requested feedback on the utility and value of both the assessment and maturity elements delivered to the sponsoring organization. The organization responded that the assessment was very useful at understanding the maturity of each contractor's conceptual solution and any gaps in information that may have been overlooked. The organization also commented that the maturity elements and architecture products delivered helped them understand the weapon concept further and was of value to them. Finally, the sponsoring organization requested that further architecture related work and collaboration between future students and faculty continue as the development program progresses. In summary, this application effort demonstrates that the Hughes' Framework can be applied to a real-time concept in early development and that in this specific situation the results were favorable and

perceived as adding value to the overall development effort by the sponsoring organization.

D. Confirmatory Sources Methodology

Related to the application approach discussed previously, the research team chose to use the concept of confirmatory sources to support the findings from the interviews and demonstrate the findings external validity. Patton (2002) discusses the concept of confirmatory significance in his research guidebook, offering that a finding supported by another work has confirmatory significance. This concept led the research team to look for approved works to include approved government and military policy, regulations, guidance; as well as any related literature or other scholarly sources to identify other works that confirm the value or recommend using of maturity elements within the framework in early development. Although this approach could be confused with the literature review that impacted creation of the Hughes' Framework, the researchers were searching for a very narrow group of works with the criteria that they relate to using maturity elements in early development (i.e. before MS-A).

Development of the framework by Hughes has much focus on the notion that a stage-gated approach is useful. Since the research team for this study chose to focus on if the contents of the framework add value rather than the stage-gated concept, the search for confirmatory sources will only involve looking for sources that recommend using maturity elements in the framework. If the findings of the interview results lead towards a conclusion that the framework does in fact add value to assessing concept maturity during early development, then the researchers will use any potential

confirmatory sources to generalize the findings past the small study sample. Regardless of the outcome of the interview data leading to favorable or non-favorable recommendation on the framework, these confirmatory sources should help the researchers show how the findings are externally valid.

E. Formative Evaluation

As discussed previously, the primary purpose behind this research study is the summative evaluation effort associated with validation of the Hughes' Framework. However, the research team also took an improvement approach to the framework as discussed by Patton (2002) regarding a formative evaluation. A formative evaluation aims to form or shape the thing being studied with the specific purpose of improvement (Patton, 2002). Regardless of if acceptance of the Hughes' framework as a tool for assessing concept maturity during early development is validated or not, the researchers will explore areas to improve or build on the framework. The research and results gained from the interviews, application, and confirmatory sources methods will all be platforms to recommend improvements to the framework as well as the opinions of the researchers.

F. Methodology Summary

The overall methodology used in this research is a summative evaluation, focused on the validation effort of the Hughes' Framework. The researchers also looked to provide a formative evaluation to recommend any improvements to the framework if deemed appropriate. The concept of triangulation as a method to strengthen the findings and rigor of this study are leveraged significantly throughout the validation effort. The validation effort is separated into three sections (1)

interviews with relevant personnel, (2) an application of the framework as tool to a DoD concept in real-time, (3) and an evaluation of accepted policies, best-practices, and guidance as they compare to the framework. During this effort, the research team looked to find the interview portion of this study internally valid, and then use the application and confirmatory sources portions to expound on the findings external validity.

The interviews, as the primary vehicle for validation, are focused on personnel within the DoD who have experience in early development and can best provide insight into the frameworks potential value. The researchers broke down the framework into its maturity elements and while applying preference measurement and conjoint analysis concepts asked the interviewees for comments related to the value and issues for each element. The application effort, led the researchers to apply the framework as a tool to assess a concept in development's maturity and then successfully create the missing maturity elements in a draft form or highlight needed information. Finally, the confirmatory sources methodology involves the researchers evaluating accepted guidance on early development and comparing them to the framework to look for similarities and disconnects.

IV. Analysis and results

The triangulation method strengthens this analysis by combining different research techniques independently. The first research technique used to validate the Hughes' Framework were structured interviews with knowledgeable individuals experienced in early concept development. The second research technique is an attempt to apply the framework to a real-world concept that is currently in the early stages of development. The last research technique is an analysis of approved policy and guidance that relates to the maturity elements of the framework.

Structured Interviews

The interview was framed to gather the perceptions and viewpoints of the value of the maturity elements within the framework as well as any relevant discussion on related topics such as early development and acquisitions. The tables in this chapter are an aggregation of the comments made by the respondents about cards that were presented to them as well as any other thoughts the respondents had in general about the acquisition process. These cards represented maturity elements within the framework as well as some other elements to help gauge any other maturity elements that may be missing.

Tables near the end of the structured interview section are compilations or the respondents' answers to the questions of "what maturity elements are used currently, what maturity elements would be important to you if you were making the decision, what would be your top three choices, and a notional order you think they should occur."

Exercise Card "A" Results.

The comments about this card were wide ranging, see Table 6 below. Some thought the acquisition community did a good job at this, while others felt the exact opposite. It was a common feeling of the interviewees that the acquisition community does not accurately capture the cost impact that concept solutions may have on external systems. Also many interviewees thought that this is an area that needs more attention and resources since cost overruns and schedule delays are far too prevalent. Some comments on how to improve this area included increasing the breadth of experience of the cost analysts involved with early cost estimates and more resources for training.

Table 6 – Qualitative Comments for Exercise Card "A"

Rough order of magnitude initial cost and schedule estimates.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element A
X	X		1. One of the most time intensive tasks. Data trickles into the costing teams and is heavily dependent on external sources. Doing costing for new alternatives can take a lot of time.
X			2. This is done sometimes because OSD demands it. More emphasis should be placed on this.
X	X	X	3. Spot on.
X	X		4. This happens near the end.
X	X		
X	X		6. This is refined during the AoA and is done well.
X	X		7. This is very optimistic in its projections for cost and schedule (CAIG & OSD) are funding to an 80% confidence level. Cost estimates are hard to do, but basing it on a previous related system might not be the best approach.
X	X		8. This is not done accurately and fails to capture the possible impact on other systems. Lots of from the hip, big guesses, only recently bringing real cost analysts to help estimate this we are bad at looking how the cost applies across many stakeholders and systems.
X	X	X	9. We can do better when the costs impact other systems, the hidden costs to the system.
X			10. We try to do this but it needs improvement. The people that do this work are licking the breadth of experience needed especially since this is hard to do early on. Lots of focus on the cost of the concept, need to look at how it affects other systems and the lifecycle (maintenance, logistics, ALC, operational) cost.
X	X	X	11. Threats to hold to MSA budget projections and threaten a Nunn McCurdy breach are common enough that more emphasis should be placed on cost then the technical accuracy. It's really hard to estimate early on but we often put more emphasis on cost and schedule than the technical piece.

When asked "What is important?" when presented with all of the cards it was tied for third with nine out of then ten interviewees that responded selecting this card. When limited to only their top three choices it was tied for fourth with only three out of the ten interviewees that responded choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was eleventh out of sixteen. After analyzing the comments and responses to the questions asked the

research team can conclude that the maturity elements in the framework represented by this card does add value to the decision making process.

Exercise Card "B" Results.

Overall the comments about the activities represented in this card were favorable, see Table 7 below. The overall feeling is that although these activities can be improved, they are being accomplished better than in the past. One noteworthy comment is that more emphasis should be placed on the timing and sequence of the interfaces, rather than only a description of what the interfaces are.

Table 7 – Qualitative Comments for Exercise Card "B"

Description of interfaces between system elements and the resources that flow between them as well as the operational activities they support.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element B
	X		
X			
X			
X			4. Once an OV-4 is done we can map out the interfaces.
X	X	X	
X	X		6. This is done better than we ever have because we are mostly involved with system of systems and computer based developments.
X	X		7. This is currently just a high level description, not as detailed as it can be.
X	X		8. When "Architectures" came into being they lent themselves very well to describing interfaces, but still needs to be done better. More emphasis should be placed on timing and sequence, not just what the interfaces are. It's not just wires to wires, its integration between systems that's very complex.
X	X		9. System of systems can be a challenge especially with net ready KPPs.
X			10. A lot of the requirements are done better because they are connected to the operators.
	X		11. Traditionally not done prior to MSA and is dependent upon the contractors that are proposing the solution.

When asked "What is important?" when presented with all of the cards it was tied for seventh with seven out of then ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for ninth with only one out of the ten interviewees that responded selecting this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was sixth out of sixteen.

After listening to the interviewees' description of the current acquisition process they nearly all said that this card was part of it. Most respondents included this card in their preferred "should be" process. Although few respondents included the associated activities in their top-three most essential, the majority indicated these activities add value to decision makers.

Exercise Card "C" Results.

The comments about exercise card "C" were wide ranging, see Table 8. Some respondents thought we did a good job at this while others felt the exact opposite. In general more effort and consideration should be put into understanding the assumptions and constraints that will constrain the solution by bringing in the users earlier and continue getting feedback during the process. Some respondents mentioned that too often a preferred solution has already been decided upon and this is used as a tool to artificially steer the selection process to that preferred solution. Other noteworthy comments included that information technology constraints are not understood or considered as much as they should be.

Table 8 – Qualitative Comments for Exercise Card "C"

List of assumptions, constraints and enabling capabilities that are required for the system to operate effectively.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element C
X	X		1. More emphasis should be placed on this.
X	X	X	
	X		
X	X	X	4. This is done fairly well (Identification of the scope of the problem)
X	X	X	
X	X		6. This is not done well because often the solution is already defined.
	X		7. Helps you understand the system. Not enough technical detail this early on to develop these architecture products.
X	X		8. Systems of systems do not understand interfaces and architectures are not dynamic. We need more user involvement and more feedback during the process.
X	X		9. Is tied to the tasks, conditions and standards you get from the operations guys during the CBA. Requirements elicitation may miss some assumptions & constraints. Future political impacts and leadership are hard to think about early on, but can greatly affect a program.
X			10. We are not considering Information Technology up front as much as it needs to be.
X	X	X	11. For the study plan they come up with the Ground Rules and Assumptions (GRA), this is done adequately.

When asked "What is important?" when presented with all of the cards it was tied for first with all ten interviewees that responded picking this card. When limited to only their top three choices it was tied for second with only four out of the ten interviewees that responded choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was second out of sixteen.

This card ranked high in the current process and what the respondent thought the process should be. This card also ranked very high in the order in which it should

happen. Based on the comments and responses, the research team concludes that there is value in the information elements this card represents.

Exercise Card "D" Results.

The majority of interviewees said that understanding the organizational relationships and flow of resources is currently accomplished poorly during early development, see Table 9. They see what is done now as just a list of stakeholders but it needs to be more than that. A standardized process to stakeholder analysis during early development was suggested by a couple individuals as a way to improve this activity. Interestingly, even though many said this was important and should be done early, when asked to order the cards by when they believed this activity should occur the majority placed this card towards the end of the process.

Table 9 – Qualitative Comments for Exercise Card "D"

Organizational relationships, their roles and responsibilities, and how the flows of resources are expected to occur.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element D
X	X		
X			
X			4. From a C4ISR perspective interface issues are better handled by contractors.
X	X		
X	X		6. Is "Goobered up." This is better when it addresses cross functional relationships, but it could use more up-front resources. It's hard to get money for programs that don't exist yet early on.
	X		7. This helps gather the environmental context. Not enough technical detail this early on to develop these architecture products.
X	X		8. We don't have the full level of detail on this. Stakeholder analysis is not done well, but it is very specialized. Time should be taken upfront in a disciplined process to perform this analysis. We don't have a disciplined process to do this in the Air Force; it's an important but difficult task.
X	X		9. Missing external areas but are getting better. We are starting to include the sustainment stakeholders.
X			10. This has improved mainly because we have tried to standardize the process; however standardizing can add complexity, time and cost to the process.
X	X		11. Still being figured out how to formalize this process. Shouldn't just be a list of stakeholders, we need to get all the stakeholders involved.

When asked "What is important?" when presented with all of the cards it was tied for seventh with seven out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for last with no one choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was thirteenth out of sixteen.

This card was said to be important by nearly all interviewees so it can be reasoned that it adds value. However, the timing at which the respondents indicated that they wanted this activity accomplished was later than what the Hughes' Framework recommends. This delay may be due to the different policy guidance regarding this subject. The resources and initial identification of the organizations responsible for developing the solution are what most DoD policy focuses on. The respondents were focused mainly on the organizations that would be involved in supporting the solution and their general feeling was that supporting organizations would not be identified until the system is defined. These reasons may explain the later sequencing for this card by the interviewees.

Exercise Card "E" Results.

The general feeling about card "E" is that is it done adequately for the most part but it can be performed better, see Table 10. Respondents mentioned that consistency can be a problem with the decomposition leading to missing considerations such as safety and security. Also, they claimed that this activity focuses too narrowly on the functional aspects of the solution, instead of supporting or external tasks. Furthermore, respondents worried that a prescribed solution may influence this decomposition if a rigorous approach is not adhered to.

Table 10 – Qualitative Comments for Exercise Card "E"

A decomposition of all operational activities or tasks, and the inputs/outputs between them.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element E
	X		
X	X	X	
X			4. We try to do this but it is not consistent.
X	X		
X	X	X	6. This is done the worst but it is very important. This is part of the CBA. Operational Viewpoints capture this data. We do it, but could do a much better job.
	X		7. Architecture products assist with this. The system is not defined as well as it could be.
X			8. Typically people handle requirements in this way but it prescribes the solution. Other areas typically not involved that should be are safety and security. A successful (but not done in the DoD) method is to hire requirements analysts. A lot of miscommunication on what "decomposition" really means. We put the solution into the decomposition too early and we only do it from a function view. We need to go farther than just the functions for the system.
X	X		9. The systems engineering approach takes this into account.
X			10. Starting to be fleshed out, at the early stages we are starting to decompose the concept and operational activities, can improve though.
X	X		11. This comes out of the CBA and gives a good idea of the mission areas. This can be done better but the increases will not impact the decision.

When asked "What is important?" when presented with all of the cards it was tied for seventh with seven out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for seventh with only two out of ten choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was fifth out of sixteen.

The information captured in this card was regarded highly based on the value that it could provide to decision makers if it is done properly. This is a product of the CBA process and is a great way to define the system if the decomposition is performed to fulfill the requirements of the need versus decomposing to a prescribed solution.

Exercise Card "F" Results.

There is a difference of opinion on how satisfactorily the activities associated with card "F" are performed currently, see Table 11. This difference may be due to the interviewees' interpretation of the card and that they may have only commented on one aspect of the information contained within. The research team attempted to clarify the meaning of the card to the interviewees but a couple respondents kept to their initial responses. Architecture products were mentioned as a way to capture and define the information in this card but some worried that only a portion of what needs to be documented is being addressed early in the process. A few of the interviewees noted that a majority of the information is just not available early on to capture these aspects of a concept. This lack of available information is a likely reason for the respondents' comments concerning the inadequate completion of card "F's" activities.

Table 11 – Qualitative Comments for Exercise Card "F"

Identification of the system as a whole, the elements that make up the system and their interconnections internally and external to the systems.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element F
X	X		1. This is done at a low level of quality and a lot of people just think this is just an OV-1.
X			
			3. Done fairly well.
X	X		4. The desired system.
X	X		
X	X		6. The Work Breakdown Structures are done well
X	X	X	7. Helps us understand the high level concept. We are getting better at developing architecture products, maybe some OV-1s are done early on now but most are put off until MSB. It would help to have a plan to flesh out.
X			8. This is done well once the contractors have responsibility, but it is not done well or at all before then.
X			9. This is core to acquisition planning. Interfaces for major efforts are done well but funding to do this work is an issue.
X			10. Close to (B) done a little better since it is close to the concept.
X	X		11. The CCTD is supposed to address this; maybe it is too specific for being so early. This is done during the analysis of alternatives and can be done better.

When asked "What is important?" when presented with all of the cards it was tied for seventh with seven out of the ten interviewees that responded selecting this card. When limited to only their top three choices it was tied for ninth with only one out of the ten interviewees that responded choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it tied for eighth out of sixteen.

The value in this card is the description of the system. The information elements that this card represents are the concept solution and all of its

interconnections. This information provides context to the decision maker on how the system operates and impacts other systems.

Exercise Card "G" Results.

Overall the interviewees claimed that the information captured in card "G" is created adequately, but it could be improved and accomplished earlier if funding and better management is available, see Table 12. One comment of note is that acquisition professionals spend a significant time on "what we want to do," and this element is done well, but the "who do you want to do it" is lacking. Some respondents mentioned that a possible reason for this inadequacy is that personnel analysts are no longer around.

Table 12 – Qualitative Comments for Exercise Card "G"

A description of the functions performed by systems and the interactions/resource flows required to perform that function.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element G
	X		
X			
X			4. This is done decently. Early on it is solutions based versus capabilities based.
X	X		
X	X		6. Use to be important now mixed in with the capability based assessment.
X			8. This is not done upfront and needs funding and better management.
X	X		9. We do a good job with architecture and mission simulation. Problem is architecture guys think good systems engineering will figure it out. Doing these documents after the fact is what usually happens.
X			10. Can put a lot of time into creating but the "What you want to do" is done well but the "Who you want to do it" is lacking. Personnel analysts are no longer around so who are you going to get to do it?
	X		

When asked "What is important?" when presented with all of the cards it was tied for thirteenth with five out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for last with no respondents selecting this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was twelfth out of sixteen.

Changes in policy may have diminished the importance of this maturity element but five out of ten respondents said it was important just not a top priority for

them if they were making the decision. The researchers conclude that the activities associated with card "G" can add value to decision makers.

Exercise Card "H" Results.

The observations regarding card "H" are depicted in Table 13 with many respondents commenting on its difficulty. The comment that this is hard to accomplish early on prior to MSA was mentioned multiple times. This factor may be due to the reasons mentioned previously that the level of detailed information is just not available during the early parts of development. Respondents offered that these activities should be developed with the users early to help address cost effectiveness, otherwise a presupposed solution may surface that is neither useful nor meet the user's needs.

Table 13 – Qualitative Comments for Exercise Card "H"

A mapping of desired system capabilities to the operational activities that must be performed and the system functions that support them.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element H
X	X	X	1. One of the more time intensive tasks. Prevents developing something that is not useful, or a solution that does not actually do what the user needs (no presupposed solution.)
X			
X			4. Is still growing pre-MSA.
X	X		
X	X		6. This is done in the decomposition.
X	X		
X			8. One of the deliverables is a traceability document. We do a decent job of this mapping.
X	X		9. Requirements traceability is not done rigorously early on, but we are improving.
X			10. It is hard to do, and it is trying to be done.
X	X		11. The user has to do this early on since cost effectiveness is a big issue (required Vs nice to have). It is hard to do this Pre-MSA.

When asked "What is important?" when presented with all of the cards it was tied for tenth with six out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for ninth with only one respondent choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was tenth out of sixteen.

This card ranked relatively low for importance and how early it should be done. It was also commented that these activities can require a significant amount of time and effort to produce. The maturity elements represented in this card may

provide some value to the decision maker but the time and resources needed to produce it may not be worth it. In a constrained time and budget environment at least in these early stages of development resources could be allocated to other areas that may have a more meaningful impact on the decision maker's choice. More research in the area of research allocation may be useful to determine the appropriate level of effort.

Exercise Card "I" Results.

A common response to card "I" was that developers are often too optimistic with technology projections on when they are ready to be incorporated into system developments. This lofty optimism can cause delays and expensive cost overruns while waiting for the technology to mature, see Table 14. Technology roadmaps, TRLs, TDSs were brought up as ways to ensure that technologies are ready. However, if the technologies are not mature at specific development point, respondents said we need a better idea of what "off-ramps" are available. Better cooperation with industry and incorporating manufacturing readiness levels early can help us understand what is feasible.

Table 14 – Qualitative Comments for Exercise Card "I"

A listing of maturing technologies that the development of the system may be dependent upon.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element I
	X		
X			
	X	X	
X			4. Is still growing pre-MSA.
X	X		
X	X	X	6. This is done well with Technology Readiness Levels and Technology Readiness Assessments, but they are overly optimistic with their maturation plans. We need better off-ramps and to be realistic with technologies that are not mature.
X	X	X	7. This is important if it is a technologically intensive system. This is usually obvious but contains a lot of optimism.
X	X		8. Technology transition needs better cooperation with industry, immature technologies and the people working them can be a problem. Maturing technologies should be tied with developments.
X	X		9. There is a need for technology roadmaps, however, there are cultural difference between what the labs determine is mature and what the acquisition needs. What technologies that are needed in the future should be tied into development planning. Acceptance of what a TRL really is can be debated.
X			10. Needs to be done more. We heavily rely on Technology readiness levels, but we can use manufacturing readiness levels in our maturity assessments. We should try and get the MRL people up front to understand what's feasible.
X	X		11. Technology development strategy and critical technology identification is done well currently when Lab representatives have input.

When asked "What is important?" when presented with all of the cards it was tied for fourth with eight out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for third with only three out of the ten interviewees that responded picking this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was seventh out of sixteen.

Although there was some debate on the accuracy of the technology assessments, there was no debate that developers need to understand the level of technological dependencies each concept may have. Knowing the risks that immature technologies may introduce to a solution can make a huge impact on the decision maker's choice. The researchers assess that the added value of the maturity elements represented by this card is high.

Exercise Card "J" Results.

Card "J" was not a part of the Hughes' Framework but was added in the interview to get opinions on its value early on in the development process and to understand reasons for its exclusion from the framework. The general consensus was that a listing of the standards is beneficial, but it is typically assumed that any system in development will be in compliance with accepted standards, see Table 15. The time and effort that would be used to understand these standards early in development would likely not be justified.

Table 15 – Qualitative Comments for Exercise Card "J"

A listing of all industry, national and international standards that apply to the system.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element J
	X		
X			
X			4. The desired system.
X	X		
			6. We do a decent job. However, when MIL-SPEC went away but ISO standards did not pick up everything.
X			7. There is not a lot of emphasis at MSA, only touched briefly and put off until MSB.
X			8. NESIE, we are more and more aware of the standards and paying more attention, but could do better.
X	X		9. Air worthiness and air certification. This is pretty straightforward to use but lots of challenges to get agreement on standards.
X			10. We can do this better, yes we probably should do it better, but who is going to pay for it?
X			11. Obvious ones are identified post AoA in the systems viewpoints, but they are not a discriminator when choosing between concepts.

When asked "What is important?" when presented with all of the cards it was last with only three out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for last with no interviewees indicating this card was most important. When the interviewees were asked to order the cards by when they believed the activities should occur it was sixteenth out of sixteen. These results support the authors' of the framework intention for only including maturity elements that add more value compared to their expected cost and are most appropriate during early development.

Exercise Card "K" Results.

The general responses for card "K" were that the described activities are currently accomplished to a certain degree, but they should be done better and earlier, see Table 16. Some respondents proposed that a way to improve these activities was with a more uniform process to capture and understand all of the capabilities. Respondents further commented that although combining capabilities to solve a problem can enhance the process; if new capabilities are discovered after development has begun, then integration can become a problem.

Table 16 – Qualitative Comments for Exercise Card "K"

A listing of capabilities needed to solve the problem decomposed down to lower level enabling capabilities and the dependencies between them.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element K
X	X	X	
X	X	X	
X			
X			4. What do we need to fix? Government does a pretty good job, but this needs better documentation.
X	X		
X			6. This is done well. We establish this early and often.
			7. Not enough technical detail this early on to develop these architecture products.
X	X	X	8. This is done okay, but is not done early enough.
X	X		9. From a requirements side we can do a better job but we need a more uniform process to capture and to understand all the capabilities.
X			10. We are doing this well, and trying to do it better. But do we look at the combination of capabilities to solve the problem?
X	X		11. This is done but problems come in later when new capabilities are proposed, then integration problems come up.

When asked “What is important?” when presented with all of the cards it was tied for tenth with six out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for third with only three interviewees selecting this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was third out of sixteen.

After analyzing the comments and responses to the questions asked the research team can conclude that the maturity elements in the framework represented by this card can add value to the decision making process. This ranked highly for importance to the interviewees and they indicated that it should be started fairly early during the acquisition process.

Exercise Card “L” Results.

A popular response to card “L” was that developers do not currently do a good job at the activities mentioned in this card, see Table 17. Some respondents said the matrix matching described in the card would be a good communication tool for relating requirements to capabilities. However, they also said creating the matrix and documenting the information may be difficult due to lack of details early on. The use of architecture products to capture these relationships was mentioned, but with complex systems these products can get overly complicated quickly and the product becomes the focus instead of the information it contains.

Table 17 – Qualitative Comments for Exercise Card "L"

A matrix matching required system capabilities to the operational activities that must be performed to achieve them.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element L
	X		
X			
X	X		3. Not a very good job.
X	X		4. This is the concept.
X	X		
X	X	X	6. This is done, but not done well. We need to trace our requirements.
			7. Not enough technical detail this early on to develop these architecture products.
X	X	X	8. This is a very good way to communicate. We don't do it much currently, but it's extremely valuable.
X	X		9. This needs to be done but it is not documented well currently other than the top level requirements.
X			10. This may get complex very fast. We make a list decently, the matrix idea might be hard to really make understandable. Danger is you can become more obsessed with the matrix than its purpose.
	X		11. Post AoA is where the requirements traceability happens.

When asked "What is important?" when presented with all of the cards it was tied for fourth with eight out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for seventh with only two out of the ten interviewees that responded choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was fourth out of sixteen.

Even though this card did not rank very high in importance with the interviewees, their comments indicated that this type of information can be very

valuable. The respondents described the activities associated with card "L" as being a valuable tool for decision makers; however, they also indicated that these activities can be a very time and resource intensive maturity element to produce. Regardless, the researchers have determined that a proper requirements traceability matrix does provide value to the decision maker when choosing between concepts.

Exercise Card "M" Results.

The responses indicated that developers perform satisfactorily at the activities associated with card "M", risk management, especially once the system has been defined, see Table 18. Respondents mentioned that often where developers get into trouble is when too much focus is placed on external risks to the system. More focus on the internal risks of a program are needed since when risks are identified the focus is external versus internal. Additionally, respondents specifically indicated that assessing cost risks are currently an area that is lacking.

Table 18 – Qualitative Comments for Exercise Card "M"

A risk assessment matrix of the risky elements of system development and integration as well as mitigation strategies.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element M
X	X		
X	X		3. Very good.
X	X	X	4. The desired system.
X	X		
X	X		6. This is done well; we establish this early and often.
X	X	X	7. What is the development risk? This gives perspective. Risks identified are focused on external factors instead of the internal risks (there needs to be more introspection.) We don't look at what we can't do, but what others can't do.
X	X	X	8. We are heavy on risk and we do a good job at it, however, we do not do cost risk very well.
X			9. We have a good handle on it but only after the system has been defined.
X			10. Good idea to use and we need to start it earlier.
X	X		11. We do risk, but the AoA doesn't address mitigation strategies and the quality of the risk assessments vary in their usefulness (very dependent on the team doing the assessment).

When asked "What is important?" when presented with all of the cards it was tied for fourth with eight out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for third with only three out of the ten interviewees that responded selecting this card. When the interviewees were asked to order the cards by when they believed the activities should occur it tied for eighth out of sixteen. The activities described in this card have a relatively high importance to the respondents and does provide value for decision makers.

Exercise Card "N" Results.

The comments related to card "N" centered on its importance though it is often delayed till later in development, see Table 19. The respondents mentioned that not a lot of work is put into this upfront and is usually not addressed until MS-B. Several respondents commented that these activities should be started earlier and should at a minimum contain an initial measure of "goodness" that the user desires. The interviewees mentioned that there has to be some MOEs created early on so as to effectively screen out concepts that will not meet the user's need.

Table 19 – Qualitative Comments for Exercise Card "N"

Quantifiable measures of effectiveness (MOE) for the system and derived measures of performance (MOP).			
Current	Important	Top three	Comments by interviewee # X on Maturity Element N
X	X		1. One of the most time intensive tasks. Decision makers need to know what the measures are. This is done well with qualitative data but can be subjective.
X			
	X		3. Fairly good
X			4. This happens near the end.
X	X		
X	X		6. The quality is hit and miss.
X	X		7. What is your measure of goodness? Not a lot is done upfront, not until MSB. You need to have some idea of the MOE early on.
X			8. This needs to be done but should be done earlier and we need to hold the users responsible for doing the tradeoffs.
X			9. Usually this comes into play during the analysis of alternatives but it can still be used earlier in the trade studies.
X			10. We have a hard time getting to the MOPs from the MOEs and there is no test plan early on. Test representatives are at the development planning groups but they often think it is a waste of time so early on in the process.
X		X	11. Is done and takes a lot of work to draft MOEs and MOSs but it is critical. The quality is variable and done early in the AoA process.

When asked "What is most important?" when presented with all of the cards it was tied for thirteenth with five out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for ninth with only one out of the ten interviewees that responded choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was fourteenth out of sixteen. The order provided by the respondents is inconsistent with their comments and could possibly be due to what they currently see happening in acquisitions versus what they believe should be happening. Further research with a stronger focus on studying the recommended order could provide additional insight and reduce inconsistencies with respondents' comments.

Some respondents discussed how this early in the acquisition process decision makers should have some measure of "goodness" that they can judge the proposed concepts against. Even if the MOEs are not defined early on decision makers can still make comparisons between concepts and their performance. Respondents also mentioned that at this early stage (i.e. pre-MS-A) the value of top level MOEs can be established, but the MOPs can be addressed later in the acquisition process.

Exercise Card "O" Results.

Card "O" was not a part of the Hughes' Framework but was added in the interview to get opinions on its value early on in the development process and insight into its exclusion from the framework. Overall the responses indicate that a test plan is typically not started this early in development, see Table 20. While considerations should be made that the MOEs and MOPs should be able to be tested, initial test plans are premature since the concept solution has not even been chosen yet. Initial

involvement of testers may be useful to ensure that the measures can be tested but beyond that it is questionable.

Table 20 – Qualitative Comments for Exercise Card "O"

Initial test plan for how to evaluate the system against its MOPs and EOEs.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element O
X	X		
			2. More emphasis should be placed on this.
X	X		
X			4. This happens near the end.
X	X		
X	X		6. This is not done early and is the lowest priority.
X			7. Not a lot is done upfront, not until MSB. Definitely don't need a lot of details in measures this early on; testing is just getting off the ground at MSA.
X			8. Involve the testers earlier, we are improving at this.
		X	9. This is not needed early on.
X			10. We have a hard time getting to the MOPs from the MOEs and there is no test plan early on. Test representatives are at the development planning groups but they often think it is a waste of time so early on in the process.
X			11. Test people have started an early involvement effort, but their time is limited.

When asked "What is important?" when presented with all of the cards it was fifteenth with four out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was tied for ninth with only one out of the ten interviewees that responded choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was fifteenth out of sixteen. Although a test plan is required later during development, the majority of

respondents indicated that starting it too early would be premature and not necessary. Similar to card "J," these results support the maturity elements included in the framework.

Exercise Card "P" Results.

The tasks and activities associated with card "P" was chosen as one of the most important elements that should be considered when assessing a concepts maturity, see Table 21. Nearly all respondents said that they must understand the problem first before any other activities are performed. However, respondents indicated that the quality of effort currently accomplished with the activities related to this card varies greatly. The main reason given for this variation is the experience of the people charged with developing these products. High personnel turnover and team breadth of expertise problems were identified as possible causes. More user involvement in these activities and clearer guidance are possible solutions that were recommended.

Table 21 – Qualitative Comments for Exercise Card "P"

Concept of operations (CONOPS) describing the problem, the desired effects, assumptions, critical capabilities, enabling capabilities, sequenced actions and the end state.			
Current	Important	Top three	Comments by interviewee # X on Maturity Element P
X	X	X	1. One of the more time intensive tasks. How you will use the system (know what the critical capabilities are and how they are implemented).
X	X	X	
X	X	X	
X	X	X	4. Describes the problem (ensures everyone is on the same page) this is not done with consistent quality (we are more solution than capability driven).
X	X	X	5. We need to understand the problem and the desired end state.
X	X		6. Because of personnel turnover it is not done as well as it has been done in the past.
	X	X	7. This describes the problem.
X	X	X	8. The acquisition community is not as involved with the development of CONOPS as they should be. Currently we are stove-piped into solving the one capability gap. We rarely back up the capabilities needed in a CONOPS. Capability Based Planning is addressing this but it is currently not done well. Development Planning does this well but the Program Managers are not involved.
X	X	X	9. Getting the CONOPS and its context are critical. It is very hard working with the MAJCOMs on requirements because they don't have the people committed to changing strategies, and they are too focused on today's "Fires."
X			10. Is done better than most and the users need to be involved early to help.
X	X		11. Usually there is an employment concept working group for replacement programs. The user typically wants to do what they do now just do it cheaper, better and faster. For new problems the CBA process is used along with the ICD to capture requirements.

When asked "What is important?" when presented with all of the cards it was first with ten out of the ten interviewees that responded choosing this card. When limited to only their top three choices it was first with eight out of the ten interviewees that responded choosing this card. When the interviewees were asked to order the cards by when they believed the activities should occur it was first out of sixteen. After

analyzing the comments and responses to the questions asked, the research team can conclude that the maturity elements in the framework represented by this card does add value to the decision making process.

Additional Comments.

Table 22, below, lists qualitative comments given by each respondent not directly related to any of the cards, but the researchers recorded them for the additional context they yield surrounding this study. A common pattern observed from the interviewees' comments was that all of the maturity elements in the Hughes' Framework can provide some utility to decision makers if they are done properly.

Table 22 – Additional Qualitative Comments

Other comments by interviewee # X
1. All of the maturity elements provide some value if they are done correctly.
2. Usually you see problems in the earliest parts of the process. High turnover of leadership is a problem and responsibilities are assigned as additional duties so it is not a primary concern. Defining the problem can take months if given bad guidance. Decision makers don't care about the details; they just want to know that the details have been worked out. Far too often too much effort is put into one maturity element at the expense of others and they spend too much time on areas they already know about.
3. The most time consuming part of programs was milestone/program reviews. Every review usually wanted its own format which adds more time. All maturity elements provide some value but to different degrees.
4. Educate the people doing the work "more training in early systems engineering." If systems engineering is done correctly the program reviews should be a lot easier to prepare for. Everything needs to be documented better. Patience is important; leaders need to understand it's going to take awhile.
8. Decision makers want to know the detailed analysis has been done, but does not need to know the details. It is a new idea prior to MDD to be thinking about all of these maturity elements.
9. All the elements can be useful, but we will need more money and time early on to do all these things well. Right now there isn't enough money budgeted.
10. I'd like to do all of these, but they all cost money; need more investment up front to accomplish.

Another common statement made was “we”, the DoD acquisition community, need to educate our acquisition workforce better, not just individuals, but how to work as an acquisition team towards a common goal. Furthermore, if the DoD wants better systems that perform, cost and are delivered when promised; then they need to provide the resources up front to do the systems engineering work necessary to make sure we are defining the right problem, pursuing the right solutions, and developing the right capabilities the users need.

Comments on Missing or Desired Information.

Table 23, below, captures the comments the interviewees had about what they believed was missing or should be added to the framework to help decision makers make better choices. Some of the comments came from a misinterpretation of what the cards represented with respect to the data that was supposed to be captured by the activities listed on the cards. A Concept of Employment is addressed in the Opportunity Identification phase of the framework represented with card “P”. An identification of stakeholders occurs in this phase also and is represented by card “D”. “What do we need” needs more definition is covered in this phase also with cards “P” and “C”. The other comments in Table 23 helped highlight general themes and areas of concern used in the following conclusions and recommendations chapters.

Table 23 – Qualitative Comments for Missing Elements

Comments on what is missing by interviewee # X
1. Add "Concept of employment" to the features of the CONOPS
2. Identification of stakeholders
3. Team development
5. "What do we need" needs more definition.
7. What is the resource commitment to the problem? What is the acquisition strategy? Supportability is ignored early on. Configuration management plans (who owns the data?)
8. Identification of specialty skill sets needed to solve the problem.
10. We use to have an analytic group of people that forecast what we will need in the future, where did they go?

Quantitative Results to the Exercise Cards

The following three histograms (Figures 3, 4, and 5) capture the interviewees' responses to the questions of what cards are done currently, what are important to adding value, and their top three most important activities, respectively.

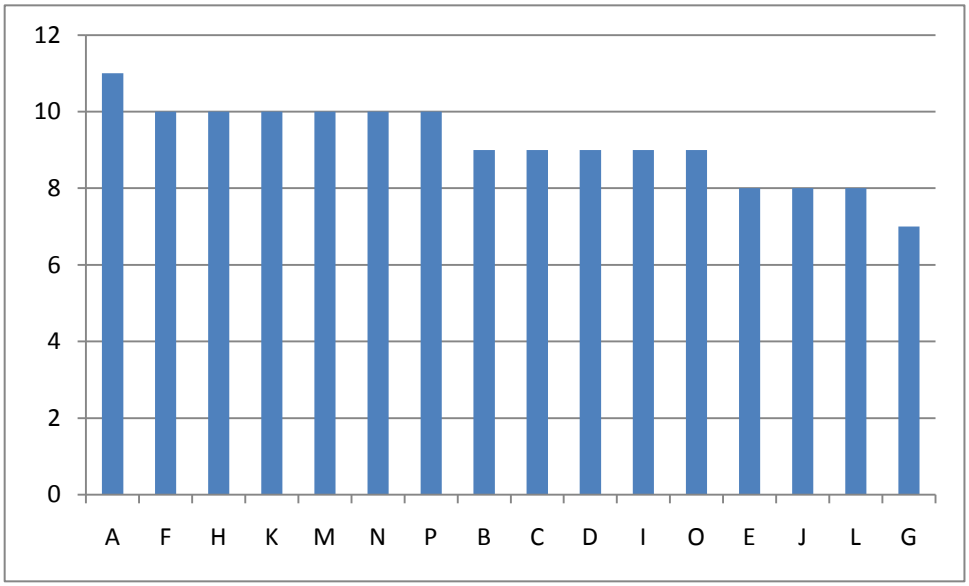


Figure 3 – What is done currently?

This histogram shows the aggregation of responses when asked if the activities and data that the cards represent presently occur during early development, see Figure 3. For the most part the respondents said the majority of the activities are performed to one extent or another. This histogram does not intend to capture the level of quality or difficulties in accomplishing the activities associated with each card, please refer to the previous sections on each card for further discussion.

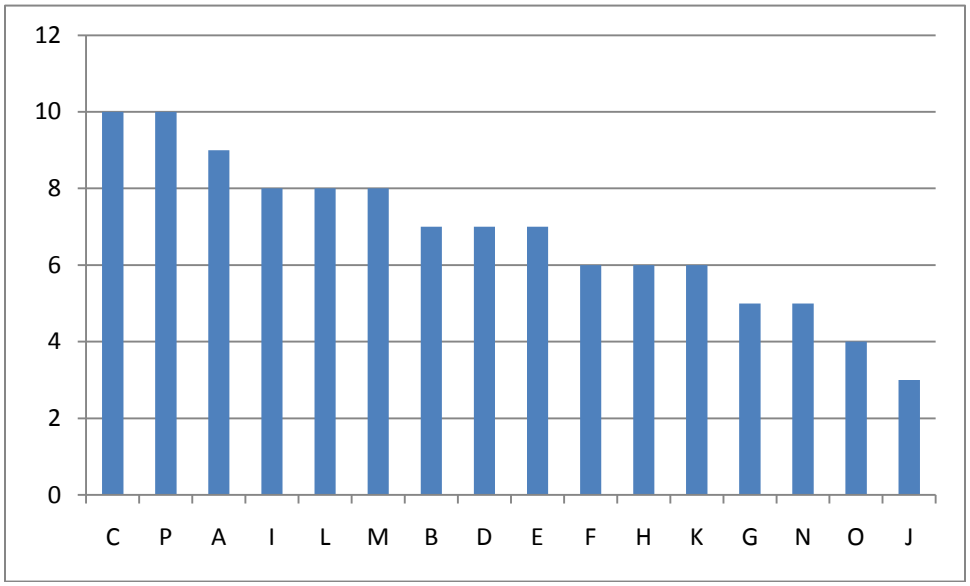


Figure 4 – What is important?

Figure 4 shows the total responses concerning the important activities that should be performed during early development. These activities ultimately support and inform the choices of the decision maker. One interesting observation is that of all of the maturity elements proposed by Hughes, the two that were added by the research team to see if there were any elements that may be missing from the framework, "O" and "J", ranked the lowest in their importance. Again, this figure supports that the

framework includes maturity elements that are recommended for use during early development and excludes activities that can be addressed later.

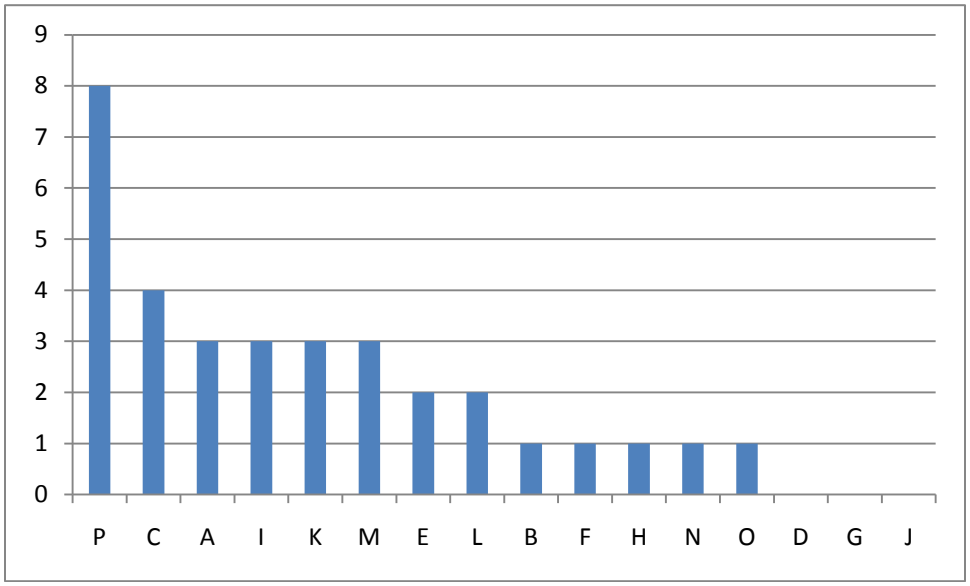


Figure 5 – Top three choices

Figure 5 shows the totals when respondents were limited to selecting only their top three most important activities. According to the respondents these activities are the most important sources of information that decision makers need. This histogram indicates a large preference towards card "P" compared to the others with a fair desire for cards "C" through "M". This histogram is only meant to supplement Figure 4, "What is Important", by offering insight into where respondents think maturity elements should be prioritized.

Responses to Ordering of the Maturity Elements

Another question asked of the interviewees was what order if any would they assign to when the information contained in the cards should be performed in order to

make a well-informed decision on a concept's maturity. The interviewees had a wide range of ordering with some activities occurring in parallel. There was as many as eight groups or steps in the process for some respondents and as few as three for others with activities occurring in parallel. For comparison the research chose to normalize the order for each interviewee. The range given by the interviewees was linearly normalized from zero to one. Activities that were identified as occurring first were valued at zero and the activities that occurred last were valued at one. All intermediate steps were normalized linearly between zero and one. Figure 6 shows the results of this ordered process from first to last.

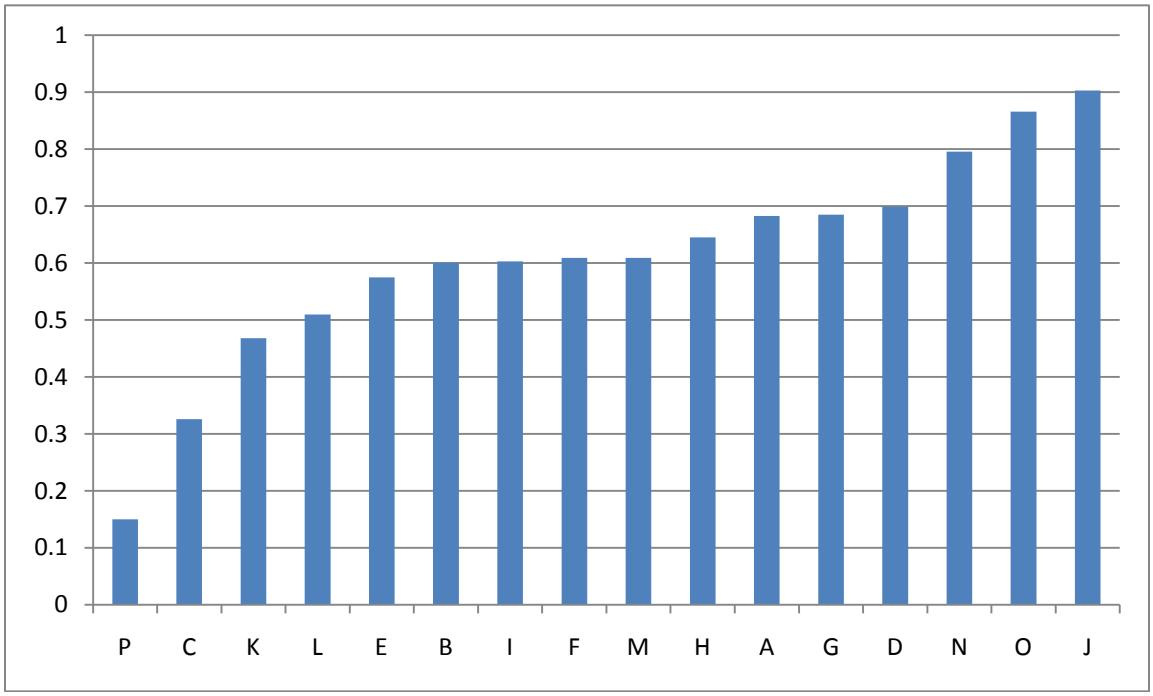


Figure 6 – Sequence of activities (respondents)

This generalized order does match up fairly well with the ordered placement of the maturity elements of the Hughes' Framework with a few exceptions that were

discussed earlier concerning the results of each card. Cards "O" and "J", the ones added by the research to see if there was any missing maturity elements for the framework, were again found at the end. One possible flaw in this chart could be the respondents applying a relationship between importance and order they should occur, however, the research team believes that for the majority of the respondents the order they assigned was the order they believed it should occur not just a ranking of importance.

For comparison, the research team also attempted to create a normalized order of the respective maturity elements contained within the Hughes' Framework, see Figure 7 below. Instead of from zero to one, the research team used a scale of one to three, where each interval represents one of the three gates in the Hughes' Framework. Additionally, some of the maturity elements are referenced in multiple stages. For example, card "K" is indicated in stages one and two and is given a normalized value of 1.5. This process was completed for each card. In comparison to the Figure 6, above, Figure 7 lines up with respect to the interviewees comments.

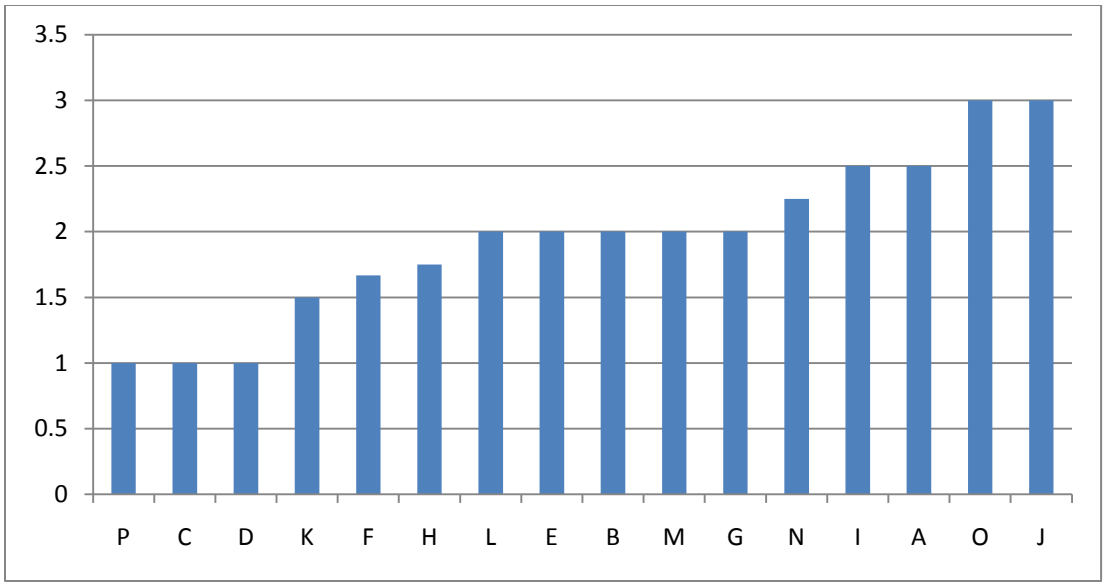


Figure 7 – Sequence of activities (Framework)

The research team recognizes that the ordering results from both the perspective of the respondents and the framework are somewhat awkward and are a likely area for criticism. The research team is in no way attempting to show that the general correlation between the two ordering histograms is a reason to accept the frameworks order. Instead, the researchers chose to include these results for discussion and to propose further research regarding this subject. As mentioned previously the intent of this study and the interviews was to focus on the content of the framework over the stage-gate approach. In conclusion, the research team proposes pursuing research focused on whether or not the stage-gate approach to the framework is supported by practitioners and related data.

Analysis and Results from Application of the Framework

The majority of the analysis and results for the application are contained within the methodology chapter due to the proprietary nature of the development program discussed and the need to speak in generalities concerning the effort. The research team reiterates that from an academic perspective applying the framework was not overly complex and did not require a deep background of the concept used. Instead developing the products involved organizing the available information rather than finding or creating additional data. In summary the application of the framework was successful and the sponsoring organization was pleased with the results.

Analysis and Results of Confirmatory Sources

We can look to current Department of Defense and Air Force policy and guidance for support in validating the Hughes' Framework. The Joint Capabilities Integration and Development System (JCIDS) (CJCSM 3170.01D, 2009) covers the majority of the acquisition process and has many aspects that overlap with the Hughes' Framework. The Early Systems Engineering (SE) Guidebook specifically addresses the timeframe of the Hughes' Framework from the initial needs identification to Milestone A (SAF/AQ, 2009). The Concept Characterization and Technology Description (CCTD) Guide (SAF/AQ, 2010) also addresses the timeframe up to the Milestone A decision point, but it begins when it has been decided that the solution to the need will be a materiel solution. The Hughes' Framework preceded the official releases of the CCTD Guide and the Early SE Guidebook. However, the Early SE Guide was available in draft form during the development of the framework.

Maturity elements of the framework are present in current policy and guidance to one extent or another. We can look at each phase of the framework and compare the maturity elements contained in each phase with what policy and guidance documentation says should be occurring. This comparison will lend credibility to the maturity elements since there is DoD and Air Force policy that support their use. The Concept Maturity Framework can be validated as a useful aid to the decision process if the maturity elements of the framework are supported by current policy.

In the Opportunity Identification phase of the framework the questions of "what needs to be done, how is it done now, and who is involved?" are answered with the maturity elements in that phase. The question of what needs to be done is answered with the CONOPS and Operational Activity Gap maturity elements in the Hughes' Framework. In the JCIDS process these maturity elements are addressed in the Capabilities Based Assessment (CBA); the CBA is the analytic basis of the JCIDS process. It identifies capability needs and gaps and recommends non-materiel or materiel approaches to address gaps (CJCSM 3170.01D, 2009). The Early SE Guidebook references these maturity elements as part of the CBA activities performed in the JCIDS process (SAF/AQ, 2009). The primary purpose of a CCTD is to provide information to decision makers. The CCTD Guide section one captures the first step of any engineering problem: defining the problem. Typically the information will come out of the CBA during the JCIDS process (SAF/AQ, 2010). The maturity elements that help characterize the question of what needs to be done are shown to be supported by current policy. The Early SE Guidebook urges developers to characterize the need and capability gap through a CBA during the JCIDS process and,

then that information should be captured in a CCTD to provide decision makers the information needed to make their choices.

How it is done now and what are the operational risks? These questions are addressed in the framework with the "Existing Systems Interfaces and Operational Risk" maturity elements. The JCIDS process addresses this question in Enclosure A. CBA Process 2.d states that the CBA sponsor must perform the operational assessment of the current and programmed force to provide the required capabilities, identifying capability gaps and potential force redundancies for each scenario. Finally, the CBA assesses the potential operational risk associated with each gap (CJCSM 3170.01D, 2009). The CCTD Guide addresses these questions in sections 3.3 and 7.1 where they discuss interfaces and operational risk. Section 3.3 describes all major external and internal interfaces necessary for a successful concept solution. It identifies those that will be available to support the fielded solution, as well as those that may require additional technology development and/or AF infrastructure development. Section 7.1 of the CCDT Guide documents the risks of the materiel concept satisfying the capability gap in the operational environment. Furthermore, risk is addressed with respect to completeness of the definition of the capability need statement and associated measures (MOEs, MOPs, KPPs, etc.) (SAF/AQ, 2010). The Early SE Guidebook addresses these questions in sections 1.5.2 System of Systems (SoS) Architectures, 3.4.1 Architecture Characterization, and 4.1 Risk. Section 1.5.2 discusses the need for SoS architectures to encompass the internal and external relationships, functions, and dependencies of all the constituent systems. Section 3.4.1 asserts that once all the concept nodes and their interfaces have been analyzed,

investigation of the system's potential to address stated needs/shortfalls can now begin. Simulating the concept system may uncover secondary missions for the new system, expose potential vulnerabilities to enemy countermeasures, and provide insight into satisfying original war-fighter shortfalls. Section 4.1 states that risk management is at the heart of technical and SE planning. During this phase a critical first step towards affordable, manageable, and executable Technology Development efforts begin. Risks should be assessed and managed as described in the DoD Risk Management Guide and the AF Risk Management Guide (AFPAM 63-128) (SAF/AQ, 2009).

Who is involved? This question is addressed with the "Operational Constraints" and "Organizations & Services" maturity elements. The maturity element addressing the operational constraints is not specifically called out in the Early SE Guidebook or JCIDS; however, the CBA process includes trade-space analysis and understanding constraints as some of the activities that should be performed. The CCTD Guide does address operational constraints in section 3.4 where it states that an understanding of user needs, constraints, and limitations in the operating environment assists with developing MOEs that can be used to assess military utility of a concept, including operational performance (e.g., reliability, maintainability, availability, supportability, sustainability, deployability, etc.) (SAF/AQ, 2010). The Organizations & Services maturity element refers to the identification of any organizations involved with a possible solution concept and the resources/services that will be expected to flow between them for success. The CCTD Guide and JCIDS manual address in depth the organizations responsible for

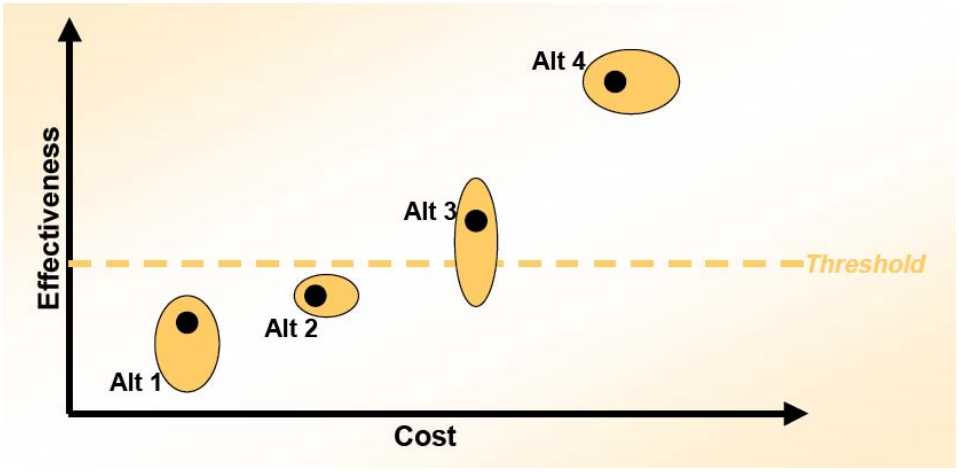
developing the solution but do not go into great detail about the organizational relationships within the concept solution other then pointing out the architectural products such as OV-4s and OV-2s. The Early SE Guidebook discusses this maturity element in section 1.5.1 titled "SE for SoS". It states that development or evolution of SoS capability is seldom driven solely by a single organization, but generally involves multiple Program Executive Officers (PEO), Program Managers (PM), and operational and support communities. While each individual stakeholder group's objectives and organizational contexts shape its expectations with respect to the SoS, any one group may well have limited knowledge of the constraints and development plans for the other systems. Planners may not recognize every SoS stakeholder, or may not realize that a particular organization or group needs to be included in deliberations (SAF/AQ, 2009).

As concept solutions pass through the first gate of opportunity identification the previous work is not abandoned. The maturity elements are updated as the concept becomes more refined and the solution becomes clearer. These maturity elements are the foundation for which the solution will be built from.

The Concept Screening phase prior to the second decision gate coincides with the Material Development Decision (MDD). In the previous phase of the framework, accurately defining the need was the major activity. In the Concept Screening phase characterizing the solution for a specific concept is the focus. The Hughes' Framework uses DoDAF architectural viewpoints to assist in the characterization. The maturity elements identified by Hughes that support this solution characterization are Systems Interfaces, Form & Function, Operational Activity, Organizational Services,

and Technology. The information contained within these maturity elements help develop the initial identification of risk and the initial estimation of the resources required for new development and/or modification of existing systems. The JCIDS manual Enclosure A, paragraph 1.f, states that the CBA should use the existing DOD Enterprise Architecture and related solution architectures as means of assessing the capability gaps and proposed approaches to mitigate them but it does not require them to be completed until Milestone B. The JCIDS manual discusses cost throughout the process but addresses the maturity elements in the Hughes' Framework in Appendix B to Enclosure B, paragraph 4.c.3, when it discusses the ownership cost as a Key System Attribute (KSA). Identification of development risks is not specifically addressed in JCIDS (CJCSM 3170.01D, 2009). The Early SE Guidebook specifically addressed the use of architecture products to develop and describe systems. Section 3.6.2 states that while the full set of DoDAF products is generally unnecessary for purposes of early SE, many "views" are highly relevant when maturing concepts for the purpose of an AoA. A number of these products identified in prior steps are actually used throughout the process as benchmarks to communicate concept maturity and performance as the concept(s) gain technical fidelity and receive approval to progress to further development stages. Initial identification of development risk is not discussed in the Early SE Guidebook, however, risk management and risk mitigation strategies are discussed in section 4.1. The Early SE Guidebook does not go into detail but in section 3.1 states that each concept developed will have been technically researched, analyzed, and evaluated against a validated set of mission-based requirements, and costed for the entire life cycle (SAF/AQ, 2009).

As concepts pass through the MDD, which corresponds with gate two of the Hughes' Framework, it has been decided that the concept solution will at least in part be a materiel solution. The last phase of the Hughes' Framework is the Concept Selection phase and ends at Milestone A, which corresponds with the third gate in the Hughes' Framework. The first maturity element in this phase is the "Cost / Benefit Analysis results." When a need is identified, and the operational risk of not satisfying that need is identified, there should be a level of importance associated with satisfying the need. The "Cost / Benefit Analysis results" is another aid that helps pare down the solution set to find the best fit at the right price. As stated in the Office of Aerospace Studies Analyst's Handbook, "Cost is never a measure of effectiveness" but what can be measured is the cost to concept effectiveness comparison (Office of Aerospace Studies, 2000). Figure 8, below, shows four alternatives and the cost estimates and effectiveness estimates for each alternative. The uncertainties of these estimates are represented by the error ellipses.



(AF Analyst's Handbook, OAS, 2000)

Figure 8 – Is the increase in effectiveness worth the increase in cost?

The JCIDS manual does not specifically reference a cost benefit analysis but it does address the issue in Enclosure B when talking about performance attributes and key performance parameters. It states that the threshold value for an attribute is the minimum acceptable value considered achievable within the available cost, schedule, and technology at low-to-moderate risk. Performance below the threshold value neither is operationally effective, suitable nor provides improvement over current capabilities. The objective value for an attribute is the desired operational goal achievable but at higher risk in cost, schedule, and technology. Performance above the objective does not justify additional expense (CJCSM 3170.01D, 2009). Both the CCTD Guide and Early SE Guidebook discuss cost estimates as described earlier in this section but they do not reference the cost benefit analysis results other than indicating this activity occurs during the Analysis of Alternatives (AoA).

The "Technology Development Plans" maturity element in the Hughes' Framework is represented in one form or another in current policy and guidance. In the Early SE Guidebook this maturity element is referred to as a Technology Development Strategy (TDS). In section four it states that the TDS is the foundation for the Acquisition Strategy and eventually the Life Cycle Management Plan (LCMP); it contains significant detail on program execution during the Technology Development (TD) phase, but also documents early planning for post Milestone B efforts. Therefore, it must include all activities necessary to successfully complete the TD phase (SAF/AQ, 2009). In the CCTD Guide this maturity element is referred to in section 6.2 as the Technology Maturation Approach. It states that the technology maturation approach will play a large role for decision makers in determining where

the concept enters the acquisition cycle, as it describes much of the technical work that remains to mature the concept. In some cases the path forward may be to defer embarking on a new system for several years in favor of investing in additional technology efforts (SAF/AQ, 2010). The JCIDS manual refers to a TDS as well but only goes into as much detail as saying that the TDS is dependent on the ICD and that the Capability Development Document (CDD) uses the TDS as an input (CJCSM 3170.01D, 2009). This may not be surprising since TDS is a product center activity while the ICD is a user generated document.

The "Risk Management Plans" and "Estimation of resources required for development, operations, and sustainment associated with the proposed solution" maturity elements are continuations of the work started in the Concept Screening phase. These maturity elements are updated and refined in the Concept Selection phase as the candidate solutions are narrowed down and a greater definition of the solution is developed. These maturity elements are supported by policy and guidance stated earlier in this section. Though the identification of risks was not specifically identified in some of the policy, risk management plans were identified as necessary elements needed for system development.

Overall there is an abundance of support for the maturity elements found in the Hughes' Framework for concept evaluation and selection. The Hughes' Framework was developed from current Department of Defense and Air Force policy and guidance. Since Hughes developed this framework nearly all of this policy has been revised updated or approved so it is a good measure that the DoD and Air Force leadership believe that these elements are needed. This Concept Maturity Framework

provides the roadmap for obtaining the right information at the right time so that decision makers have the necessary information to evaluate concept solutions and make an informed selection.

V. Conclusions

While seeking to answer the questions described in the research objectives, the research team discovered much more along the way. During this journey, the research team gained insight by talking with practitioners of the DoD acquisition process, reviewing policy and guidance, and by gaining real-world experience in applying the Hughes' Framework. These insights lead to patterns and themes that can be used to gain a better understanding of the current state of the acquisition process. Along with answering the research questions, the team will share some themes and lessons-learned that were revealed. These themes will not just be about specific aspects of the concept maturity framework but include themes that encompass a larger perspective.

Validating the Hughes' Framework

Previous research proposed a "Concept Maturity Assessment Framework" method in which decision makers can determine the maturity of concepts as they progress through the acquisition process. This study uses the framework to demonstrate its application while determining the utility and added-value of the framework to the decision maker. As part of the framework validation effort this study sought to quantify and qualify the added-value of applying the framework assessment, and give a recommendation for or against future use during the acquisition process. The research team returned to the research questions posed earlier in this thesis to offer recommendations concerning the framework's validation.

1. Is the framework a valid guide that can be used to assess concept maturity?

Through the confirmatory analysis of the framework, the application of the framework to a specific program in development, and the interviews conducted with

practitioners throughout the acquisition community, the research team can infer that the Hughes' Framework is a valid guide that can be used to assess concept maturity.

2. *Can the framework be applied in real-time during concept development?*

This framework is designed to line up logically with the early decision gates in the acquisition process. Some of the maturity elements called out in the framework are already needed at these decision points so extra effort was not necessary. Other maturity elements related the concept capabilities, functions, form, etc. were provided by the contracting company proposing the solution. This framework can be applied in real-time during concept development.

3. *What is the added-value to the decision maker in applying the framework?*

The added value to the decision maker is a reduction of uncertainty. The decision maker may not care or want to know about all of the detailed analysis that went into the maturity elements in the framework, but if he or she is certain that they have been considered and the risks are properly identified then they have sufficient information to make a well-informed decision.

4. *Does the framework help reduce or mitigate the risk associated with concept maturity for the decision maker?*

The answer is yes for the same reasons mentioned in the answer to question three. The framework helps reduce uncertainty. Uncertainty contributes to risk. Reducing the uncertainty reduces the unknown risks.

5. *Should the framework be recommended for use during the acquisition process?*

Based on the results of the research, the framework should be recommended for use during the acquisition process. The framework does not add any additional

requirements to the process. The majority of the information called out in the framework is required at some point in the acquisition process. What the framework does is help the user systematically order their thinking about the elements of the system earlier in the process and suggests a series of actions to take. This effort can help identify potential problems earlier before they require extensive amounts of resources to fix. Furthermore, by using the information maturity elements in the framework, risky development concepts can be exposed and then handled.

The research team finds that the Hughes' Framework is a valid tool that can be used by acquisition professionals as a guide for assessing the maturity of concepts. This framework uses maturity elements to capture information about concepts in real-time as the concepts are matured. These maturity elements provide valuable information that can be used to help avoid or mitigate the development of risky concepts.

Evaluating Internal & External Validity

As discussed in the methodology of this study, the research team would test for the internal validity of the findings from the interviews. The research team as a result of the interview responses accepted the primary hypothesis that applying the framework adds value to assessing concept maturity. The research team offers an opinion on the strength, internal validity, of this conclusion using the five judgments as discussed by Krathwohl (1998), see Appendix C. Then using Krathwohl's five judgments for external validity, the research team assesses the degree to which this finding can be generalized past the controlled interview study, see Appendix D. After applying the five judgments for both sets, the research team claims that the interview

approach of this study is internally valid. More importantly, the research team concludes that the findings of this validation effort of the framework can be generalized to all development organizations within the Air Force and have fair expectation of being of value to many other related organizations within the DoD as well as non-government organizations. This external validity of the framework promotes further use for both practitioners involved in early development and decision makers assessing a concept's maturity level.

Themes and Lessons-Learned

As mentioned previously, during this validation effort several important themes and lessons-learned were discovered. The following section sheds light on the context behind the Hughes' Framework and offers some best-practices and heuristics related to early development.

People Make the Difference.

A common refrain from respondents was "if done correctly;" it did not matter what part of the framework was being discussed. This leads to a discussion about the people doing the work. Does the Air Force and the DoD have the right people doing the early development work? "We" defined as the acquisition community can have all the tools in the world available to guide us through the acquisition process, but if we do not have the necessary training and experience to use these tools effectively then we are hindering the process. Nearly all respondents said "we need to do this better" for at least one area in the acquisition process, and some respondents specifically cited lack of experienced and motivated personnel doing the work as the problem. This lack of experience was not concentrated in one specific area of acquisitions. From the

earliest days where the need is identified, to the latter stages where solution-specific cost estimates are generated, experience and motivation of the teams and individuals performing the work is critical.

Resources! Resources! Resources!.

Another common statement from respondents was "if there is time and if there is money we could . . . " Systems Engineering (SE) has proven its worth over the last few decades, and the overall savings that are generated with engineering work to get the design right the first time has been demonstrated frequently. Honour (2004) explores the value of SE and through an analysis of six real-world statistical studies, he concludes applying SE activities correctly can have significant added value to development efforts. Despite this, it is still difficult to get the necessary resources allocated for early SE work to make sure all of the information that decision makers need gets to them. This information should be thorough and accurate but due to the time and resource constraints that are placed on programs this may not always be the case. This kind of change has to come from the top down, but the acquisition community needs to be able to show what the user will be gaining by investing more time and money up front.

Are we using the resources we have in the most effective way? Another common theme was that we spent too much time on certain activities as compared to others (i.e. activities A, B and C at the expense of X, Y and Z). One thing the researchers did in this study was attempt to assess the time and effort spent on the various maturity elements used when making decisions in comparison to added value of those maturity elements to the decision maker. Several respondents indicated that

the effort required to at least begin many of the maturity elements during early development was minimal and was worth the cost. However, they also indicated there needs to be balance and that spending extensive resources on detailed analysis too early on may be wasteful. Honour (2004) echoes this study's respondents, he offers that just doing SE activities for their own sake during development without proper planning and quality in execution can be ineffective. Instead, he recommends that great gains can be achieved through correctly applying quality SE efforts (Honour, 2004). Finally, Honour's (2004) research reaffirms this study's finding that effective use of resources during early development is critical, and he says that programs should strive to spend 15-20% of development resources on Systems Engineering.

I Have a Great Idea!.

Another theme identified from the interviews was the idea that we, the acquisition community, often prescribe a system-specific solution very early on. There was an impression given from some of the respondents that we choose a system-specific solution as a crutch to ensure resources are allocated and the development program continues. A solution that is too conceptual and does not have a specific system tied to it is often vulnerable to losing interest and potentially funding from decision makers. However, this approach puts too much resource emphasis on describing how the system will look and function without fully understanding the range of options available for fulfilling the needs of the user. Prescribing a system-specific solution towards the start of a development effort constrains the trade-space to use different solutions.

We Make Paper!.

"We do this but it is not documented well" is another common theme from the interview respondents. What does documenting something well mean? From the responses the researchers received, far too often the engineers or people doing the work thought all the documentation needed was the final report or briefing so that they could progress through one review gate and get ready for the next. Within the DoD and even the commercial world there needs to be a push towards using a consistent tracking of changes to the concept as it develops that is shareable between organizations. Model-Based Systems Engineering (MBSE) is a useful method to help track and share information during development and should be leveraged more by development organizations. Good documentation is not just a final report or a briefing; it is a story of how the system, concept or program has evolved from its earliest iteration to its current form.

What level of detail is appropriate? It is not useful to just document the captured data from a maturity element if the right level of detail and analysis does not go with it. The framework and many respondents during the interviews proposed that the architecture products such as those from the DoDAF are a useful way to capture this information, but the level of detail prescribed in DoDAF can be far more than what is necessary this early in the acquisition process. A balanced approach should be taken to ensure that sufficient detail is made available for an informed decision. Also this information needs to be stored and built upon since it will be needed in the latter stages of the acquisition process. At times decision makers just want to know that the analysis was done and not the details of the analysis. However, this is not to preclude

us from doing the analysis early and to the appropriate level of detail for it will pay dividends later in development.

The Glass is Half Full.

A theme brought up several times was that we are overly optimistic about what can be done during development, which leads to problems later. Budget and schedule estimates are getting better, but the risks that affect cost and schedule should be characterized more. Several respondents mentioned that a lot of time and effort is spent characterizing known risks. The unexpected risks are the ones that can cause havoc because existing mitigations strategies may not be adequate enough to resolve them. Better documentation and analysis early on would help balance this optimism and uncover problems that may be hidden.

VI. Recommendations

Improvements to the Hughes' Framework

Based on the themes, lessons-learned, and validation effort in general, the research team offers some suggestions for improvement as part of the formative evaluation of this study. The framework overall adds value, but there are some areas where further clarifications or additional detail would help:

- More emphasis on needs analysis is required. The problem definition and inputs can make some big assumptions when attempting to describe the need. In context of the DoD, The framework is designed to take an accepted capability gap from the JCIDS process and help mature a concept to fulfill this gap. This effort is described in the framework through activities such as CONOPS development and understanding the mission and objectives. Through this study this related maturity element was lauded as the most important and often overlooked activity during early development. The framework is iterative, but the research team concludes that a needs analysis and a problem definition are the launching point for all other maturity elements in the framework. In its current form the framework does not depict a notion of priority or emphasis in the maturity elements. Although avoiding assigning priority may have been the intent of the original authors, the research team believes the framework should at least capture the emphasis required on needs analysis.
- Cards "J" and "O" were added to gauge the value they may provide in assessing concept maturity. The research has shown that this information

represented by the cards did not add any significant value early in the development process. Although, the activities related to these cards have value and are required later on in development, the research team does not recommend adding maturity elements "J" and "O" to the framework.

- An explanation of the level of detail required for each maturity element, based on best-practices and heuristics gathered from practitioners. The guidance in the DoDAF manual is not sufficient to describe how to generate the maturity elements in the Hughes' Framework. The architecture view by gate (Table 2, previously) needs more than just saying "updated". A description of the possible additional information that should be added could be useful. This can help focus resources on areas that are most important to assessing the maturity of concepts, and prevent further instances spending too much effort one activity at the expense of another.

Recommendations for Further Research

- *Propose research to recommend a prioritization, resource allocation, and ordering of maturity elements*

As discussed previously, there is lack of prioritization concerning the maturity elements in the Hughes' Framework. The framework breaks up the maturity elements by gates but does not tell the practitioner where they should assign the greatest effort or resources. This study lays the foundation for what respondents perceived as more important. Further research could explore this prioritization based on different types of organizations.

Furthermore, the research team attempted to understand if the respondents perceived an ordering of activities based on schedule and inputs/outputs. However, the results were marginal and further research more focused on this ordering could help practitioners understand what activities should come before others or if accomplishing them in parallel is preferred. Also, this research should focus on the inputs and outputs of the activities in the framework and how they affect other activities. Finally, understanding the organizations or people that receive and deliver the necessary information during early development could help improve the framework's utility.

- *Propose research to understand differences and similarities of the framework's utility to the commercial sector*

This study was focused on validating framework's added value to the DoD. The authors of the framework intended it to be of value to commercial development sector as well. The implications from this study have shown that there should be value in applying the framework to developers in the commercial world, but additional research would support this claim. A similar interview approach could be applied to individuals involved in early development employed in the commercial world. The interview could be tailored to better understand the possible differences and similarities of using the framework between DoD and commercial early developments. This research could also lead into the creation of a concept maturity framework tailored specifically for the commercial world

- *Propose research to develop an explanation of the level of detail required for each maturity element, based on best-practices and heuristics gathered from practitioners*

The guidance in the DoDAF manual is not sufficient to describe how to generate the maturity elements in the Hughes' Framework or to what level of detail they should be prepared. There needs to be some type of "Framework Handbook" similar to the CCTD Guide and Early SE Guidebook that includes explanations for applying the framework. A description of the possible additional information that should be added could be useful. Additionally, further research could explore a method to integrate the framework into these DoD approved guides. Research into this area may help practitioners accomplish the activities in the framework to the appropriate level of detail for decision makers assessing the maturity of concepts.

Appendix A: Interview Structure & Questions

1. Explain the purpose of the interview
    a. To understand how a practitioner perceives a concept progresses through the acquisition process currently or recently and if there is a way to improve this process
    b. Focus on concept maturity not system design (i.e. after a need is identified and pre-MSA)
    c. Focus on how the practitioner perceives activities as adding value in information to the decision maker

2. Gather contextual and scope information
    a. Position and Organization
    b. Current Responsibilities
    c. Prior projects/program and experience

3. Explain Exercise #1 (As-Is Process)
    a. Ask interviewee to choose cards they think are currently accomplished at some form or level during the early stages of development (i.e. after a need is identified and pre-MSA)
    b. No "correct" answer, based on interviewee's perception
    c. All, some, or none of the cards can be used
    d. Ask interviewee if they do not understand the meaning of any cards and explain briefly
    e. As they pick cards ask the interviewee to comment on how well or bad each card is accomplished, how often, how difficult, or any other relevant information

4. Begin Exercise #1
    a. Record all responses including the letter designator of each card and related comments
    b. Record all responses unrelated to the cards separately

5. Explain Exercise #2 (To-Be Process)
    a. Ask interviewee to arrange the cards in the order (if there is an order, can group cards) they think is most efficient and effective at adding value as information to a decision maker determining if a concept is mature, well developed, or if the concept needs further work.
    b. Remind interviewee to only include cards they perceive as adding value and that coming up with an order is optional and only necessary if the interviewee believes an order is desirable (order refers to the schedule of activities, not a ranking of priority)
    c. Again related to early development (i.e. after a need is identified and pre-MSA)
    d. No "correct" answer, based on interviewee's perception
    e. All, some, or none of the cards can be used

6. Begin Exercise #2
    a. Record all responses including the letter designator of each card and related comments
    b. Record the order or grouping of cards (if applicable)
    c. Record all responses unrelated to the cards separately

7. Follow-on Questions for Exercise #2
    a. Ask interviewee to select the top 3 most important activities to adding value to a decision maker being able to assess the maturity of the concept and why? The three activities that they would want their people to spend the most time developing and refining
    b. Ask interviewee if there is anything not in the cards that stands out that they would want to include during early development (i.e. after a need is identified and pre-MSA)

8. Wrap-Up and Conclude Interview (ask for any final comments)

Appendix B: Interview Exercise Cards

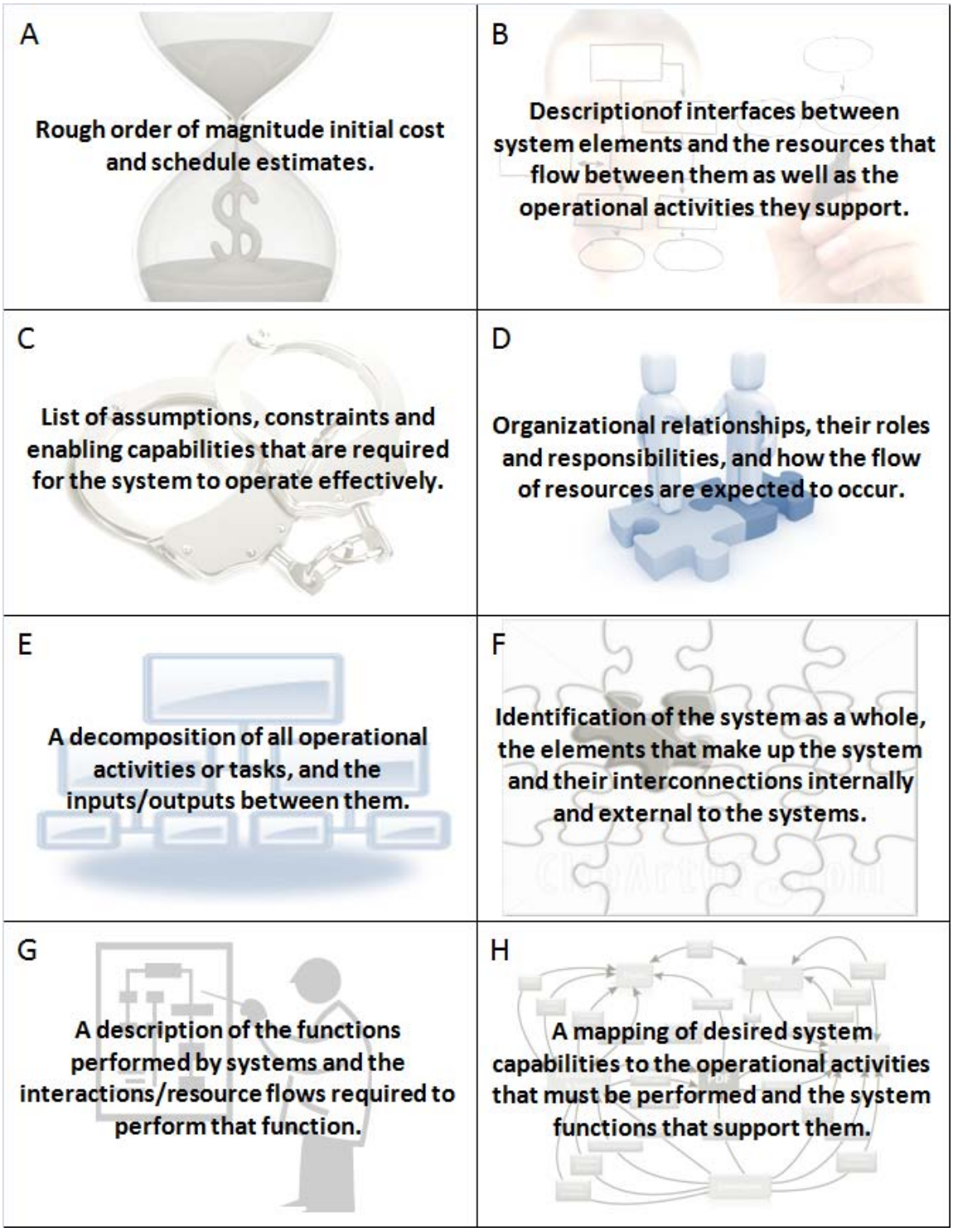


Figure 8. Interview Cards A-H

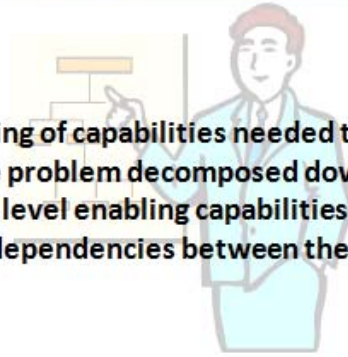
I

A listing of maturing technologies that the development of the system may be dependent upon.

J

A listing of all industry, national and international standards that apply to the system.

K



A listing of capabilities needed to solve the problem decomposed down to lower level enabling capabilities and the dependencies between them.

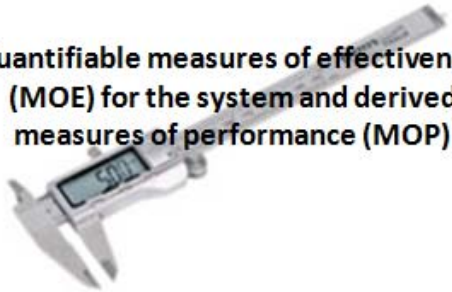
L

A matrix matching required system capabilities to the operational activities that must be performed to achieve them.

M

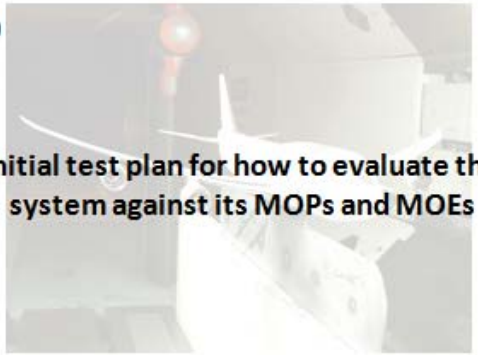
A risk assessment matrix of the risky elements of system development and integration as well as a mitigation strategies.

N



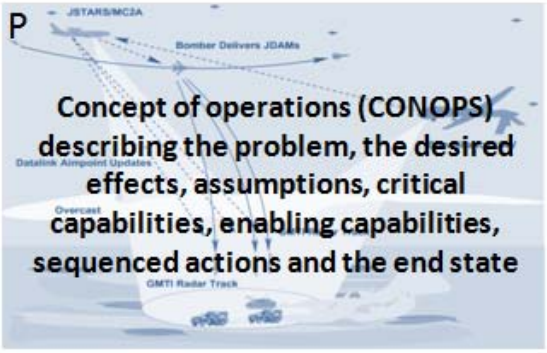
Quantifiable measures of effectiveness (MOE) for the system and derived measures of performance (MOP)

O



Initial test plan for how to evaluate the system against its MOPs and MOEs

P



Concept of operations (CONOPS) describing the problem, the desired effects, assumptions, critical capabilities, enabling capabilities, sequenced actions and the end state

Figure 9. Interview Cards I-P

Appendix C: Five Judgments for Internal Validity

Explanation Credibility

The first judgment for internal validity is explanation credibility. Krathwohl (1998) claims this judgment is, "the plausibility of a proposed relationship's explanation or rationale, built as it is on previous research and thought" (p.140). Krathwohl explains that this judgment deals with the credibility of the question, hypothesis, or prediction that the study is centered on. He says that this first judgment is critical as the rest of the study depends on it. The research team's hypothesis that the framework adds value is a reasonable causal relationship. The cause, applying the framework early on during development, can lead to the effect, being able to assess the maturity of a concept. The hypothesis makes no claim to the framework ensuring the concept is "good" or will guarantee a successful product. The hypothesis only claims that the framework can help assess if a decision maker has enough information to properly understand a given concept. Based on the Krathwohl's reasoning the research team claims to have a credible explanation or hypothesis.

Translation Fidelity

The next judgment is translation fidelity, "the faithfulness of the design choices to the meaning of the . . . hypothesis . . . as defined by the study's explanation or rationale" (Krathwohl, 1998, p.144). This judgment relates to the believability of the study's design used to defend the hypothesis (Krathwohl, 1998). Krathwohl offers that evaluating the "six-links" of a study's design can help determine translation fidelity.

Subjects, the Who Link.

The first link is the subjects or the *who* of the study. Krathwohl (1998) says that the subjects should be examples of individuals to whom the hypothesis would apply. In this study, the subjects are the practitioners who are or have been directly involved in work related to early development, which relates directly to this study's hypothesis.

Situation, the Where Link.

The second link is the situation or the *where* of the study (Krathwohl, 1998). Rather than a physical location for the study, the researchers discuss the situation as the subject's present and past experience with activities or programs related to early development. The researchers' asked the subjects to reflect on these experiences and knowledge to base their responses on.

Treatment, the Why Link.

Next, is the treatment link, which reflects the *why* of the study (Krathwohl, 1998). Krathwohl mentions that this link relates to the cause in the hypothesis, which again is applying the framework. The "To-Be" exercise corresponds to this treatment or cause in the sense that each respondent was choosing maturity elements in the framework as adding value.

Observations and Measure, the What Link.

The fourth link is observations and measures or the *what* of the study that Krathwohl (1998) claims relates to the effect in the hypothesis. The effect in this study is adding value to assess concept maturity. The measures and observations then

are the actual cards each respondent selected in the "To-Be" exercise as they map to the maturity elements in the framework.

Basis for Sensing Attributes or Changes, the How Link.

Krathwohl's (1998) fifth link is the basis for sensing attributes or changes or the *how* of the study. This link deals with how the study is conducted and the idea of determining if a cause implies the effect (Krathwohl, 1998). The research team offers that the card exercise methodology lets each respondent select the maturity elements they desired, which were then used to judge the frameworks overall value. This method is focused on the content within the framework as opposed to simply asking each respondent if they would recommend the framework. The respondents have direct experience with the maturity elements and not the framework. Therefore, it is appropriate to ask them questions related to the elements rather than the framework, which is how the research team chose to structure the interview study.

Procedure, the When Link.

The final link for assessing a design's translation fidelity is the procedure or *when* of the study. Krathwohl (1998) describes this link as the rules that the study was conducted under as they demonstrate a standardized and consistent process. All individuals interviewed during the framework study were asked the same questions and engaged in the same order of exercises and so on. The only deviation was the face-to-face as opposed to telephone contact method. The research team does not see this deviation as a degrading the procedures of the interviews. In summary the research team affirms that the study passes the second judgment, translation fidelity, based on the six design links approach.

Demonstrated Result

The third judgment as discussed by Krathwohl (1998) is a demonstrated result. Krathwohl proposes that, "a Demonstrated result appears when the evidence is authentic, there was precedence (or concurrence) of cause, and an effect occurred as was expected in terms of the relationship described by the hypothesis . . ." (p.147). From this proposal he gathers that a demonstrated result has strong evidence if four attributes can be shown.

Authenticity of Evidence.

The first attribute is the authenticity of evidence and ensures that the data and evidence gathered during the study is believable, unaltered, and from the stated source (Krathwohl, 1998). The researchers recorded the responses of each respondent and compared notes to ensure responses were accurate. The interviews were conducted by the research team rather than outsourced to an outside party ensuring that the responses came directly from the stated individuals.

Precedence of Cause.

The second attribute is a precedence of cause and Krathwohl (1998) offers that this attribute is nearly impossible to prove, but can be reasonably accepted. This attribute demands that the cause always precedes the effect. In terms of the study's hypothesis, the research team finds this attribute somewhat arbitrary since violating the attribute would require that the effect, the framework adds value, is an absolute. Since value is a matter of opinion that can only be accepted and never proven, the research team ignored this attribute.

Presence of Effect.

The next attribute is the presence of effect, which Krathwohl (1998) describes as being able to show that the desired effect actually occurred during the study or experiment. For this study, the effect, the framework adds value, is demonstrated through the conjoint analysis concept of aggregation as discussed in Marder (1999). Essentially, if the interview responses during the "To-Be" exercise supported accepting the maturity elements of the framework as adding value, then one could accept the framework as adding value.

Congruence of Explanation and Evidence.

The final attribute leading towards a demonstrated result is congruence of explanation and evidence (Krathwohl, 1998). This last attribute focuses on if the cause and effect are reasonable and if the evidence presented logically supports the findings of the study (Krathwohl, 1998). Krathwohl discusses that if the conceptual leap one must jump to reasonably accept the explanation given is small then the evidence for this attribute is strong. For this study, one could reasonably accept that performing activities and creating products of information concerning a particular concept would help one estimate how ready or "mature" he/she believes this concept to be. To summarize, the research team finds that the four attributes of the demonstrated result judgment should be accepted.

Rival Explanations Eliminated

Rival explanations eliminated is the fourth judgment for internal validity and Krathwohl (1998) claims, "for the projected explanation or rationale to be accepted, all reasonable rival or alternative explanations of the data must be eliminate" (p.148).

Krathwohl's definition for this judgment appears unlikely to eliminate every possible alternative explanation for the data. However, he offers that this judgment is meant to help the researcher increase the strength of their results, rather than force the researcher to explore every explanation in the realm of possibility, which would be a task that could take an eternity. Instead, the research team looked for weaknesses in the structure and inferences made of the interviews and discusses how these possible weaknesses do not degrade the core conclusions of this study.

The first area of concern is the mapping of the maturity elements from the framework to the exercise cards. This mapping is fundamental to any conclusions made on the value of the framework. If this mapping is in error then there would be no connection to the interview responses and the framework. The research team, however, as discussed in the methodology explains the details of the mapping to ensure all content within the framework was represented. Another weakness is that hypothesis for this study is that the framework adds value to decision makers assessing concept maturity. Though some individuals interviewed had experience in a decision-making role, one could argue that the study was conducted solely from a practitioner's point of view. One could further argue that these practitioners cannot accurately comment on what is of value to a decision maker in early development. The research team proposes that these practitioners are the ideal candidates for this study as they have first-hand knowledge with what information their bosses (decision makers) want to have available and more importantly how to get, create, or organize it. In closing, not every alternative explanation for the findings of this study could be eliminated, but

the research team does not recognize any rival explanations or weaknesses that destroy the validity of this study.

Credible Result

The final judgment discussed by Krathwohl (1998) is a credible result, and is, "a judgment that sums up the four earlier judgments and asks whether in terms of external prior evidence we can believe the result" (p.148). The research team evaluated the study using the previous judgments and determined that each passed with fair to strong evidence. The framework was developed only recently and this study is the first effort to assess its value based on an interview approach. Therefore, there is no prior evidence or a similar study available to support or negate the findings. Regardless, the research team is confident that the findings of the interview study are internally valid.

Appendix D: Five Judgments for External Validity

Explanation Generality

The first judgment for external validity according to Krathwohl (1998) is explanation generality and, "is a judgment of the plausibility of the generality that is claimed, implied, or inferred for the relationship" (p.177). Krathwohl discusses that this judgment is the most important to being able to generalize any findings from a study as the hypothesis must be logical and reasonable to apply to areas outside of the controlled study. This study's hypothesis is broad enough to encompass all areas related to early development. During the interviews the focus of the research was on practitioners with experience in early development mainly involved in Air Force organizations. However, the hypothesis and intent of the research would not preclude external organizations such as other military branches of service (i.e. Army and Navy), DoD development agencies, and even commercial industry. Using Krathwohl's rationale, the research team finds this study to satisfy explanation generality.

Translation Generality

The second judgment is translation generality and, "is a judgment of the extent to which the generality claimed, implied, or inferred in the study is represented in the operational choices of its design" (Krathwohl, 1998, p.180). Krathwohl offers that this judgment similar to translation fidelity for internal validity focuses on how the structure or design of the study is appropriate to generalize. Also, similar to translation fidelity he cites that six facets to the design can help explore a study's translation generality.

Subjects and Situations.

Krathwohl (1998) combines these facets for external validity and claims that strong external validity the subjects and situation used during the study should not be narrow and restrictive. The subjects, the practitioners involved in early development, were primarily from Air Force; but they were from a variety of organizations and prior experiences. Many of these individuals worked with or had worked with other military branches and DoD agencies and understood how the joint development operates in the DoD. In terms of the situation facet, many of the respondents had direct experience with joint early development projects and programs to base their responses promoting the external validity of this study's findings.

Treatment.

Whereas standardization and a consistent experimental approach promotes strong internal validity, too much can restrict the generality of the study (Krathwohl, 1998). The treatment in this study was the respondents selecting the maturity elements in the framework as adding value. However, the respondents were not restricted to select any or all of the cards if they did not feel they were of value. Furthermore, respondents were allowed to create maturity elements not on the cards allowing them to offer what they perceived as adding value regardless if the maturity element was on cards.

Observations and Measures.

This facet deals with how representative the chosen measures and instruments used during the study are of all possible measures and instruments for similar studies (Krathwohl, 1998). The cards used during the exercises were the measurement tools

used to gather the quantitative data and focus the qualitative discussion. These cards do not capture all possible maturity elements that a respondent could value during early development, but for the purposes of validating the framework the focus used is appropriate. The research team did include a few extraneous cards to the framework to increase the possible responses respondents could give.

Basis for Sensing Attributes or Changes Link and Procedure Link.

Again, Krathwohl (1998) combines these two design links for this facet of translation of fidelity. According to Krathwohl, these design links should be representative of similar studies and that unusual or overly restrictive methods to sense changes or conduct the procedures degrade external validity. Asking the respondents to comment on the cards regardless of the individual and then recording their comments is common to any market research related to conjoint analysis. Furthermore, the questions asked and procedures of the study could be conducted anywhere and any researcher with a basic knowledge of early development in the DoD could administer the interviews.

Time.

The final facet for translation fidelity is time, which though different from a design link for internal validity, Krathwohl (1998) claims is a very important factor to infer generality. Time is important as any generalizations regarding findings within a study, decay with the data and information used during the study. Many of the respondents had experience ranging from a couple years to over 30 years in DoD and industry acquisitions and development with varying experience in the early stages. However, to focus the responses based on the current or recent perceptions and to

reduce the likelihood that these responses are irrelevant or outdated, the research team asked each respondent to focus their responses on current experiences and up to five years prior. Additionally, the primary findings on what generic information is of value to a decision maker should be relevant regardless of the timeframe used.

"Demonstrated Generality"

Next, is "demonstrated generality", which "is a judgment of the extent to which the relationship appeared in all instances of the study in which it would be expected to do so and did not where it shouldn't" (Krathwohl, 1998, p.180). Krathwohl purposefully places quotations around this judgment to emphasize, "the logical impossibility of demonstrating generality in all the instances where it is intended to apply" (p.180). However, the research team offers that both the application of the framework and the confirmatory sources discussed previously in the methodology and analysis and results chapters help demonstrate the generality of the findings from the interviews.

The application shows how even from an academic point of view most of the maturity elements can be at least started very early on in concept development. The researchers were able to construct many of the maturity elements for the sponsoring organization, who indicated that these deliverables were helpful to understanding the concept. Additionally, the sponsoring organization was not an Air Force organization, but rather a separate DoD agency, which demonstrates that the framework can be applied to organizations external to the interview study.

Although the discussion on the confirmatory sources of the framework are neither mean to infer that the framework adds value nor that it should be

recommended for use, they do help support the findings of this study's generality. The confirmatory sources demonstrate that specific maturity elements within the framework are accepted by DoD policy. More importantly, Air Force guidance that is founded on inputs from practitioners, experts in the field, and best-practices (i.e. the CCTD and Early SE guides) also supports use of elements within the framework. In summary, the research team is confident that the demonstrated generality of this study's findings are favorable to reasonably pass this third judgment.

Restrictive Explanations Eliminated

Krathwohl's fourth judgment for external validity is restrictive explanations eliminated. Krathwohl (1998) describes this judgment as, "restrictive explanations (conditions) that were part of the study but would not be part of the target of generalization must have been eliminated for the inferential leap to the target to be confidently made" (p.181). He explains further that if the target the researcher is trying to generalize the findings towards is not actually represented in the study; then the researcher must discuss why reasons that would otherwise restrict using the target in the study should be disregarded.

In terms of this validation effort, the research team is seeking to generalize the findings of the interviews past the individuals interviewed and towards the target of the greater Air Force and related DoD organizations. As discussed in the previous judgments, the researchers do not see any reasons that would restrict the interview results for additional individuals in similar organizations. Each interview was conducted privately and allowed for the individual to respond based solely on their opinion without outside bias and were not restricted in forming any of their responses.

The same interview approach could be used for further studies with a different sample group. The researchers have no preconception that the results will be the same as in this study, but only offer that nothing should restrict the same result from occurring.

Replicable Result

The final judgment for external validity as discussed by Krathwohl (1998) is a replicable result, which "is a summary judgment of the forgoing judgments and of the extent to which the results of this study could be replicated in the target to which it is being generalized" (p.181). This judgment is similar to its counterpart for internal validity, a credible result, and essentially synthesizes the other judgments for a conclusion on the strength of external validity (Krathwohl, 1998). Krathwohl states that this judgment is at the heart of external validity and asks would similar results reproduce in the target of generalization. The research team believes that if the same type of study were conducted with a different sample that similar results regarding the framework's value would be reached. The research team is confident that the discussion on the previous four judgments can lead one to accept this study's generality to the Air Force and other DoD military branches and agencies with fair to strong confidence.

Bibliography

Barker, D. A. (2010). *Validation of a Concept Maturity Evaluation Framework.* Air Force Institute of Technology, Systems and Engineering Management. Wright Patterson Air Force Base: Air Force Institute of Technology.

Chairman of the Joint Chiefs of Staff, CJCS. (2009, March 01). CJCSI 3170.01G. *Joint Capabilities Integration and Development System.*

Dahahn, E., Hauser, J.R., Simester, D. & Toubia, O. (2002). "Application and Test of Web-Based Adaptive Polyhedral Conjoint Analysis." Cambridge MA: MIT Center for eBusiness.

Dahan, E. & Hauser, J.R. (2001). "Product Development – Managing a Dispersed Process." Cambridge MA: MIT Center for Innovation in Product Development.

Dahan, E. & Hauser, J.R. (2001). "The Virtual Customer." *Journal of Product Innovation Management*, 19, 5, 332-354.

Denzin, N.K. (1978). *The Research Act: A Theoretical Introduction to Sociological Methods.* New York: McGraw-Hill.

Department of Defense, DoD. (2008, December 08). DoD Instruction 5000.02.

DoD Deputy Chief Information Officer. (n.d.). *DoDAF Architecture Framework 2.0*. Retrieved 02 01, 2010, from http://cio-nii.defense.gov/sites/dodaf20/index.html

Drazen, P. (2004). "A Bayesian Truth Serum for Subjective Data," *Science*, 306, 462-466.

Government Accountability Office. (2007). An Integrated Portfolio Management Approach to Weapon System Investments Could Improve DOD's Acquisition Outcomes. GAO-07-388.

Government Accountability Office. (2008). *Increased Focus on Requirements and Oversight Needed to Improve DoDs Acquisition Environment and Weapon System Quality.* GAO-08-294.

Hauser, J.R. & Rao, V.R. (2003). "Conjoint Analysis, Related Modeling, and Applications," in Wind, J., Krieger, A., & Green, P.E. (Eds.), *Marketing Research and Modeling: Progress and Prospects, A Tribute to Paul E. Green* (pp. 141-168). Boston: Kluwer.

Hillson, D. (2004). *Effective Opportunity Management for Projects.* New York: Marcel Dekker, Inc.

Honour, E.C. (2004). "Understanding the Value of Systems Engineering." *Proceedings of the INCOSE International Symposium*, Toulouse, France.

Hughes, R. C. (2010). *The Development of a Concept Maturity Assessment Framework.* Wright-Patterson AFB: Air Force Institute of Technology.

Krathwohl, D.R. (1998). *Methods of Educational & Social Science Research*. (2nd ed.). New York: Addison-Wesley Longman.

Marder, E. (1999). "The assumptions of choice modeling: Conjoint analysis and SUMM," *Canadian Journal of Marketing Research*, 18, 1-12.

Michalek, J.J., Feinberg, F.M. & Papalambros, P.Y. (2005). "Linking marketing and engineering product design decisions via analytical target cascading," *Journal of Product Innovation Management*, 22, 46-62.

Netzer, O., Toubia, O., Bradlow, E.T., Dahan, E., Evgeniou, T., Feinberg, F.M., . . . Rao, V.R (2008), "Beyond Conjoint Analysis: Advances in Preference Measurements," *Marketing Letters*, 3, 337-354.

NRC, N. R. (2008). *Pre-Milestone A and Early-Phase Systems Engineering: A Retrospective Review and Benefits for Future Air Force Acquisition.* National Academies Press.

ODUSD(A&T)SSE/ED. (2008). *Systems Engineering Plan Preparation Guide, Version 2.01*. Washington, DC: ODUSD(A&T)SSE/ED: Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering, Enterprise Development.

Office of Aerospace Studies. (2008). *Analysis of Alternatives (AoA) Handbook.* Kirtland AFB, NM: Air Force Materiel Command (AFMC) OAS/A9.

Patton, M.R. (2002). *Qualitative Research & Evaluation Methods*. (3rd ed.). London: Sage Publications.

PMBOK Guide, D. E. (June 2003). *US Department of Defense Extension to: A Guide to the Project Management Body of Knowledge.* Fort Belvoir: Defense Acquisition University Press.

Repenning, N. P., Gonçalves, P., & Black, L. J. (2001). Past the Tipping Point: The Persistence of Firefighting in Product Development. *California Management Review , 43* (4), 44-63.

Sadauskas, L. (2008). Implications of Capability-based Planning on Requirements Engineering. *NDIA SE Conference.*

SAF/AQ. (2009). *Early Systems Engineering Guidebook.*

SAF/AQ. (2010). *Concept Characterization and Technical Description (CCTD) Guide.*

Taylor, S.J. & Bogdan, R. (1984). *Introduction to Qualitative Research Methods: The Search for Meaning*. New York: John Wiley.

Ulrich, K., & Eppinger, S. (2004). *Product Design and Development.* Boston: McGraw-Hill.

Wheelwright, S. C., & Clark, K. B. (1992). *Revolutionizing Product Development.* New York: The Free Press.

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14. ABSTRACT

Far too often decision makers select concepts based on insufficient data, resulting in projects that are over-budget, over-schedule, and not what the customer wants. Research efforts have proposed a stage-gated concept maturity framework as a tool to assess and increase the maturity of concepts. This research uses multiple validation techniques to demonstrate the value this framework can provide. Interviews with acquisition professionals capture qualitative and quantitative data on the utility of the elements of the framework and the acquisition process. This research also applies the framework to a current acquisition program to determine if it can be broadly applied for different types of developments. Lastly, this research looks to current acquisition policy and guidance to see if there is support for the maturity elements of the framework.

The results of this study led the research team to accept the framework as a useful guide and approach to assessing a concept's maturity. The majority of responses were favorable towards the activities recommended in the framework. The researchers were able to apply the framework in real-time to a concept in early development to the benefit of the sponsoring organization. The results of this study have also led to the formation of themes, best-practices, and lessons-learned concerning early concept development. The results affirm that when developing a concept people make the difference, more resources up-front are needed to fully understand a concept, and developers should avoid constraining the trade-space by pre-supposing a solution.

15. SUBJECT TERMS

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