A FRAMEWORK FOR ACHIEVING LIFECYCLE VALUE IN AEROSPACE PRODUCT DEVELOPMENT

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Abstract

Creation of lifecycle value - a balance of performance with cost and other attributes - represents a challenge for the development of aerospace products in the twenty-first century. This paper examines the concept of lifecycle value that stems from existing approaches of value management and analysis, lifecycle costing, and systems engineering. To ascertain common characteristics of lifecycle value creation, case studies were done for four aircraft programs: F/A-18E/F, JAS 39 Gripen, F-16C/D, and B-777. A lifecycle value creation framework is introduced, comprised of three phases: value identification, value proposition, value delivery. Based upon observed practices in the four case studies, six value creation attributes were identified. Capability maturity models for the six attributes and three value creation phases are presented. The resulting framework represents a starting point for programs seeking to create lifecycle value for aerospace products.

1 Motivation

The overarching objective of aerospace engineering is to conceive, develop and deploy high performance products to meet end user needs. Changes in geopolitical and global economic factors in the 1990s challenged the aerospace field to produce products "better, faster, cheaper". A holistic framework encompassing both performance and affordabilty considerations is provided by a focus on value. In the aerospace context, with long product cycle and life times, an appealing framework to consider is Best Lifecycle Value (BLV).

Best lifecycle value is a concept rooted in three existing approaches to system development and program management: value management and analysis, lifecycle costing, and systems engineering [1]. It has evolved to support a more holistic perspective than provided by any of the three separate approaches. BLV aggregates essential characteristics of these existing methods to provide an approach to system development based on common objectives. It is also closely aligned with a main premise behind lean enterprises: "Becoming lean is a process of eliminating waste with the goal of creating value [2]." At an enterprise level, creating value for all stakeholders requires considering the entire lifecycle.

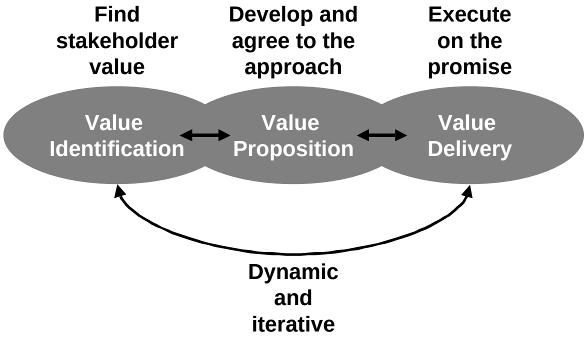
This paper determines factors enabling consideration and achievement of lifecycle value by examining four in-depth case studies. These case studies were part of a collaborative research project between the Lean Aerospace Initiative (LAI) in the US and the Lean Aircraft Research Program (LARP) in Sweden. Each group is a consortium of government, industry, and academia, and in the case of LAI, organized labor [3]. An early version of this work was developed collaboratively and was presented as Reference [4].

The scope of the research focuses on aerospace programs to characterize lifecycle value for complex systems. Specifically, the F/A-18E/F Super Hornet, the JAS 39 Gripen, the F-16C/D Falcon, and the B-777 programs were studied. Although different systems may define lifecycle value differently, there are common elements to the process of achieving lifecycle value that have been identified. The following characterization of best lifecycle value has been suggested by this research.

> *Balanced stakeholder expectation for effective system performance (quality, cost, and timing) and the associated risks to deliver best value throughout the life of the system.*

2 Value Creation Framework

Based on existing models and case studies a theoretical framework for lifecycle value creation has been developed [1], [2]. The structure for this framework consists of three somewhat sequential and iterative processes: value identification, value proposition, and value delivery. An illustration of this framework is shown below.



Lifecycle Value Creation Framework [2]

These three processes interact with each other and with the dynamic world in which they exist. Comparison of this model with existing models of value management, lifecycle phases, and system architecture, supported the evolution of the theoretical lifecycle value creation framework and resulted in a more refined understanding of value creation [1]. Each existing approach makes a unique contribution to the concept of lifecycle value. Individually these approaches have limitations. By creating a new focus on lifecycle value, the various perspectives can be combined, overcoming their individual limitations. Specifically, the definition of value is not limited to utility divided by cost, lifecycle considerations are not limited to operations and support costs determined by component reliabilities, a holistic perspective of system development is not limited to the system, but also to the enterprise involved in the development.

2.1 Assumptions

There are several underlying assumptions associated with the value creation framework. First it is assumed that value is a multi-dimensional system attribute, having at least a minimum set of dimensions related to technical capability, cost, and timing. It is further assumed that all stakeholders, regardless of individual differences, can agree to focus on value as a system attribute based on its importance. Perhaps the most important assumption of this framework is that the stakeholders will have the appropriate level of insight and influence into each process of identification, proposition, and delivery. This relies on clear communication and information flow between all involved.

2.2 Value Identification

Value Identification consists of determining the set of stakeholders, their needs and expectations, and their contributions for a system. The needs and expectations should be articulated in the form of system goals. A stakeholder is considered to be "any group or individual who can affect or is affected by the achievements of the organization's objective [5]." This is a broad group of interested parties such as, customers, end-users, acquirers, producers, integrators, developers, suppliers, financial supporters, political entities and/or communities. "Each stakeholder contributes unique information regarding corporate strategies and partnerships, market analysis, financial expectations, consumer or operator needs, certification and regulatory restrictions, and the timing of system development and availability based on their perspective [1]." The challenge here is balancing the perspectives of the stakeholders.

2.3 Value Proposition

The contributions and expectations identified must be translated into a system concept, architecture and program structure agreed to by all the stakeholders. The negotiation to balance the various contributions and expectations of the stakeholders is based on the common objective of achieving lifecycle value. While it is not suggested that stakeholders disregard their individual differences, support for a single value proposition is an essential link between value identification and delivery. The overall goal is to find a proposition that delivers maximum value to each stakeholder group, or a "win-win" outcome. It is important to communication the agreed up value proposition to the entire group of stakeholders.

2.4 Value Delivery

Developing, producing, operating and sustaining a system as well as managing the program that executes this work fall within value delivery. Moving to value delivery, the group of stakeholders increases to manage the transition from system architecture and program structure to system development and program execution. Although it may seem intuitively straightforward to deliver value for a given value proposition, in practice it is quite complicated. Fortunately, there are many strategies, practices, tools, and methods that help with this challenge, as revealed in the case studies. Within a given value proposition, there are multiple ways to develop and improve system lifecycle value.

2.5 Interactions

There are several interactions in this framework. They can be characterized into two primary types, those within the framework, for example between the three processes, and those between the framework and the external environment. There are a couple of points to consider regarding these interactions.

Due to the interactions in the framework between the three processes, value delivery is not likely to be successful without proper value identification and proposition. There may need to be iterations between the value proposition and value identification phases. Furthermore, the entire value creation may not become apparent until the value delivery process when the realized product becomes apparent. This can have important consequences. For example, follow through on value identification and proposition via successful value delivery can establish stakeholder reputation and credibility for future work.

Interactions with the external environment also have implications to consider. As an example, an external interaction may cause the need to reevaluate the value identification if the set of stakeholders or their values have significantly changed. This propagates throughout the framework causing adjustments in both value proposition and value delivery.

3 Case Studies

To meet the objective of identifying enabling factors in product development for achieving lifecycle value, four aircraft cases were selected for this work. They are a representative sample of various development strategies for complex systems. The F/A-18E/F Super Hornet is an upgrade from an existing system developed for the US Navy. The JAS Gripen is a “clean sheet” design, that is, a new system developed for the Swedish government. The F-16C/D Falcon represents a continual evolution with changes and improvements integrated into production blocks, developed primarily for the US Air Force. The B-777, developed by the Boeing Company, is an example of a product family based roughly on a platform architecture with one primary design and multiple derivatives.

3.1 Research Methodology

A case study methodology was selected based on the exploratory nature of this research [6]. One consideration for choosing cases was based on lifecycle phase of the program. Only programs in the production or operation phase of their lifecycle were considered. Primary consideration was given to development work done recently. This was due to practical constraints of collecting information, and for the purpose of studying product development strategies and practices that are modern.

After the cases were selected, a structured hybrid survey/interview tool was developed collaboratively by LAI and LARP. Case studies are typically highly dependent on the individual researcher. Based on the collaborative nature of this research, it was important to have a structured process to collect data in order to ensure that the information gathered was comparable between programs. The interview tool used contained questions in both multiple-choice and free response formats. LAI and LARP jointly pre-tested the tool at Saab Aircraft and Raytheon Aircraft and subsequently refined it.

Interviewees were selected to span a variety of backgrounds and perspectives for each case study. Each interviewee had the opportunity to respond to the survey portion of the tool before the structured interview.

The data collected from each case was primarily qualitative, in the form of practices and strategies. The data from over 150 interviews from the four cases were aggregated, leading to the results identified. The qualitative results were clustered into several groups from which six main themes, or value attributes, emerged supporting the lifecycle value creation framework. As it became apparent that the preferred coding scheme for the data aligned with the framework, the data collected were regrouped and synthesized into a set of best practices presented in a Capability Maturity Model (CMM) format. These two-dimensional matrices capture the information in a context independent format that is support by both the quantitative and qualitative data collected.

3.2 F/A-18E/F Super Hornet

There are four one-seat/two-seat sets of models in the F/A-18 family: the original A/B versions, the C/D, the C/D night strike, and the E/F Super Hornets. The A/B models were developed in the mid-1970s. The C/D models, which were primarily a systems upgrade, came ten years later, followed five years after that by the C/D night strike versions. The most recent versions are the E/F Super Hornet models.

A full-scale development program for the E/F models began in 1992. The US Navy understood the need to initiate a development program to modernize their fleet. But, in the aftermath of the A-12 program cancellation, both the Navy and the US government were concerned with the credibility of the development strategies and program management techniques that were standard practice in the industry at that time. The future of naval aviation relied on revolutionary changes taking place with the Super Hornet program.

With the exception of 90 percent commonality in avionics and limited similarity to the C/D airframes, the E/F versions are significantly different than previous Hornets. The E/F planes are 25 percent larger, having a 40 percent increase in un-refueled range, 25 percent increase in payload, three times greater bring-back ordnance, and five times greater survivability.

The F/A-18E/F program is organized into integrated, multi-functional product teams. Leadership focused the development efforts on keeping the program within a “box” of technical and programmatic requirements.

The Super Hornet successfully completed Operational Evaluation testing (OPEVAL) with the rating of “operationally effective and suitable”, the highest rating achievable. The program was never re-baselined and program goals set at the time of the contract award were met. The F/A-18E/F program received the Collier Trophy in 1999.

3.3 JAS 39 Gripen

JAS is the Swedish acronym for Fighter, Attack, Reconnaissance. Unlike other single/dual seat aircraft, the JAS 39A and B were not developed concurrently. The single-seat version was developed first, in the 1980s followed by the two-seat model in the late-1980s to early 1990s.

The Gripen was designed to replace the Viggen aircraft. In light of expenditures for the operation of the Viggen, it became evident that the next generation of aircraft needed to be smaller, more flexible, and significantly divergent from the rapidly increasing trend of the tactical aircraft lifecycle cost curve. The Gripen program was developed under a fixed price contract structure, including product development work and the production of the first 30 aircraft.

Several factors were important in the development of the Gripen. Although, it leveraged existing tacit knowledge retained from the Viggen program, there is no commonality between the Gripen and any other existing aircraft. New technologies incorporated in the design were often developed concurrent to the system development. This caused high technological uncertainty, emphasizing the need to minimize overall program risk. One approach to address this challenge was a unique, risk sharing arrangement between Swedish industry partners in the IG-JAS group.

The JAS 39 Gripen is the first 4th generation, fully digital computerized system, with true multi-role capability to be delivered. Considerable emphasis has been placed on reducing time required for routine maintenance resulting in rapid turn-around times and low operating costs. The program was able to reach targeted Life Cycle Cost (LCC) goals of 40 percent reduction over the LCC of the Viggen.

3.4 F-16C/D Falcon

Although there are only two single/dual seat sets of F-16 models, there have been around fifteen improvement efforts incorporated in various production groups of aircraft known as block upgrades. A new block has been introduced every few years or so starting with F-16A/B Block 05 in 1979. The new designation of F-16C/D came with the Block 25 upgrade in 1984. Although the F-16C/D model designation has remained the same throughout the most recent block changes (Block 40/42, 50/52, 60), the upgrades have been as significant as the Block 25 upgrade when the model names were changed.

A major thrust behind the F-16 concept was limited acquisition funds for new systems. Limiting the technical requirements to an acceptable level, preventing many “bells and whistles” from entering the design was a driving influence in the F-16 development.

The F-16 has survived significant changes in the global environment by being flexible enough to adapt the performance capability of the system to changing needs. The program has accommodated numerous customers, from all corners of the world, with a variety of needs and interests. The politics, the culture, and the specific interests of each customer have played a role in developing over 100 tailored versions of the F-16 system.

Since the original A/B models, upgrades have continued to increase functionality of the system.

These upgrades have been facilitated by the original system architecture, specifically in the avionics and flight systems structure. The F-16 has been able to maintain the benefits of being a small fighter while improving the total system performance over the slow course of evolutionary upgrade efforts.

The F-16 program has been recognized with many awards, including the Collier Trophy in 1975. Over 4 000 aircraft have been delivered to 19 countries with 48 follow-on procurements (repeat customers) by 14 countries and over 300 new orders in the last two years. In addition the F-16 program has achieved over 100 months of on-time deliveries.

3.5 B-777

The B-777 is the world's largest twinjet aircraft. Initial delivery of the original 777-200, or the "A market" aircraft, took place in 1995. Since then, a family of aircraft is being developed to support weight (passenger count and/or cargo) and range increases. This includes two derivatives already in service, the –200ER and the –300, and two derivatives in development, the –300ER and the –200LR. The range of the 777 family is approximately 5,000 to 8,800 nautical miles, carrying approximately 300 to 550 passengers, depending on model and configuration.

Three different companies launched a program to target a different area of the gap between the B-767 and the B-747 markets: the MD-11, the A330/A340, and the B-777. Filling a tight, niche market required a change in philosophy and approach from previous development programs.

Using digital design tools, 777s are built entirely from three-dimensional solid modeling technology. An integrated, cross-functional team structure has been used throughout the entire program. In addition, the 777 program follows a "working together" philosophy, leading to collaboration with many airline customers during development.

Creating a family of aircraft involves several goals in addition to increasing weight and range capabilities. These other goals include reducing the non-recurring development and recurring production costs and reducing nominal development time, while at the least maintaining the reliability, maintainability, and service ready levels of existing aircraft.

The 777 program had an unprecedented achievement by receiving type and production certification from both the US Federal Aviation Administration (FAA) and the European Joint Aviation Authorities (JAA) on the same day. The 777 is also the first airplane to earn FAA approval to fly extended-range twin-engine operations (ETOPS) at entry into service. The Collier Trophy in 1995 is among the many awards the 777 program has received.

4 Value Attributes

The following discussion of the value attributes is based on data that emerged from the clustering of the practices collected from all the case studies. The practices apply to one or more of the identification, proposition, or delivery processes in the value creation model. A detailed listing of all the observed practices may be found in Reference [1].

4.1 Holistic Perspective

A holistic perspective consists of both consideration of the entire system and consideration of the total system lifecycle. It is essential to balance long-term "–ilitiy" demands such as upgradability, maintainability, reliability, and reparability with more short-term concerns, such as cost and schedule pressures. To create value, it is important to consider the entire system and its lifecycle in order to integrate the stakeholder perspectives in an effective manner.

4.2 Organizational Factors

Multi-disciplinary teams in the early phases of value creation can be beneficial to facilitate the collaboration between the many functions that span a system's lifecycle. "The objective of collaboration is to create a richer, more comprehensive appreciation of the problem among the stakeholders than any one of them could construct alone [7]." In addition to cross-functional teams, enterprise culture is an important organizational factor. An enterprise culture based on a shared vision can create a robust environment for system development. Not sharing or committing to a common vision is likely to result in failure to meet program objectives.

4.3 Requirements and Metrics

Substantial long-term savings can be achieved by identifying and integrating a product's lifecycle costs into early requirements development. It is important to consider lifecycle requirements early, but it is equally as important to structure requirements to incorporate flexibility. "If the enterprise does not properly define and manage the evolving requirements set, the ultimate end product will not provide stakeholders with the expected solution [8]." In a complex system, defining, incorporating, allocating, and measuring technical and programmatic requirements is an integral part of the value creation for the system. Responsibility and accountability for the performance of the system and the program are often tied to the communication of requirements and the respective metrics.

4.4 Tools and Methods

Many tools and methods enable product development processes. Rapid development in information technology has also contributed to program performance. "The internet and other recent technology advances have enabled business-to-business integration: linking your business tightly with those of your value network partners to provide a quantum leap in competitiveness [9]." The tool set of systems engineering provides an approach to help a team pursue stakeholder expectations [8]. A particularly important method of systems engineering is risk management. Systematic risk management can facilitate evaluation and maintenance of the technical, cost, and schedule performance of the program.

4.5 Enterprise Relationships

Establishing cooperative relationships around common objectives is a key factor in creating value. What become the "traditional" ways of interacting in an enterprise are established by early encounters between stakeholders. "The efficacy of these relationships [face-to-face, within-group, and intergroup] invariably rests on the quality and richness of interpersonal communication and information processing activities: how individuals and groups share data, agree on agendas and goals, and iron out conflicts as they go about their work [10]." Significant changes in organizational size and structure throughout the lifecycle of the program can add pressure to relationships in the enterprise. "Organizationally, the firm is embedded in a web of cooperative relations with such stakeholders as supplier, creditors, customers, employees, and various community organizations. Unless these relationships are protected, the performance of the firm cannot be assured, let alone enhanced [11]."

4.6 Leadership and Management

"Leadership and management have different focuses but function interdependently to produce outcomes that sustain integrity, vision, values, and wholeness, while meeting the goals for which the organization was established [9]." The authority relationship of management between managers and subordinates is for the purpose of coordinating activities to develop, produce, and sell particular goods and/or services [9]. Leadership on the other hand reduces the feelings of anonymity, powerlessness, and lack of relationship to the whole that many people feel as part of a large impersonal organization [9]. The combination of leadership and management often represent the external view of a program. This external view typically accounts for the perception of how effectively value has been created. Identifying and standardizing management processes can facilitate the authority role of management while incorporating various personal styles of leadership.

5 Synthesis and Discussion

Evaluation of the case study data based on the lifecycle value model has led to codification of the observed practices and strategies into Capability Maturity Models (CMMs) for the three value creation processes based on the six value attributes. These CMMs are included at the end of the paper. As a product of this work, they are a synthesized presentation of the practices and strategies captured from the four cases studied. The CMMs remain to be tested, but provide a framework for organizations to assess their capability for product development to achieve lifecycle value. Many detailed practices observed from the case studies that support the CMMs are given in Reference [1]. The combination of the lifecycle value framework and the practices from the case studies suggests an approach that encompasses appropriate and successful strategies for product development, system design, and program management.

6 Conclusions

This paper characterizes lifecycle value by identifying the basis of the concept in value management, lifecycle costing and analysis, and systems engineering. A theoretical lifecycle value creation framework provides further development and characterization of the concept. Current industry best practices for achieving lifecycle value as observed in the four case studies are codified as capability maturity models related to the theoretical framework. The value creation framework and capability maturity models are offered as a starting point for programs seeking to achieve lifecycle value for aerospace products.

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Appendix – Value Creation CMMs

Capability Maturity Models (CMMs) are one useful way to describe process environments. They provide a structured way to relate qualitative process information with a quantitative measurement. CMMs often consist of five levels in a two-dimensional format, one dimension representing the cumulative levels of capability and the other representing the process characteristics. CMMs are useful for self-assessment purposes, by bringing together "relevant data in a way that will encourage the drawing of conclusions [6]." This is particularly helpful to strategically plan process improvement.

It is important to emphasize that thorough testing to validate the CMMs presented here has not been done. They were developed for illustrative purposes, with the intention that additional work would be required to make them suitable as an effective self-assessment tool. Nonetheless, it is interesting to understand a methodology by which they could be tested and subsequently used.

The process for using a CMM for self-assessment can be described generically. It involves three steps that are outlined here.

1. Preparation
    - Assemble assessment team and material.
    - Determine timing of assessment – how long will the assessment last.
    - Ensure all assessors understand the process and relevant context.
    - Define the "ground rules" for assessment.
    - Define the boundaries of assessment.
2. Assessment (This can be done collectively by the team or individually and then discussed as a group.)
    - Analyze each practice determining level of maturity. Note evidence to support the determination.
    - Determine the desired maturity level (for a specific time horizon).
3. Analysis and action planning
    - Based on gaps between current and desired levels of maturity, identify and prioritize implementation plans to eliminate or reduce the gaps.
    - Allocate resources to support the implementation plans.
    - Agree upon timing for the next assessment.

	Level 1	Level 2	Level 3	Level 4	Level 5
Holistic Perspective	***Focus:*** *What is the desired system capability? How is it defined?*				
	Desired system capability is unknown and not all stakeholder contributions are identified.	Desired system capability is identified in terms of form only; some stakeholder contributions are identified	Desired system capability is identified mostly in terms of form with some consideration of function. Core enterprise stakeholder contributions are clearly communicated.	Desired system capability is identified mostly in terms of function with specification of form. All enterprise stakeholder contributions are clearly communicated.	Desired system capability is identified in terms of function only. All enterprise stakeholder contributions are clearly communicated.
Organizational Factors	***Focus:*** *Who are the system stakeholders? What role do they each play in a discussion focused on system value?*				
	Few stakeholders are represented, and system value is not considered as the focal point for any discussion or decisions.	Some enterprise stakeholders are represented. Value is considered as part of the discussion regarding a system.	Representatives of core enterprise stakeholders contribute to value focused decisions.	Representatives for all enterprise stakeholders contribute to the value discussion.	Representatives for all enterprise stakeholders contribute to the value discussion. They have the authority to make value decisions for their organization.
Requirements and Metrics	***Focus:*** *Are stakeholder expectations clearly communicated?*				
	Stakeholders do not share their expectations.	Stakeholder expectations are expressed inconsistently.	Core enterprise stakeholder expectations are clearly communicated.	All enterprise stakeholder expectations are communicated, but level of consistency may vary between stakeholders.	All enterprise stakeholder expectations are clearly communicated.
Tools and Methods	***Focus:*** *Are state of the art and emerging technologies properly assessed? (This can help determine appropriate tools and methods to be used during value proposition and delivery.)*				
	Current state of the art and future technologies are unknown.	State of the art technologies are considered using a structured process.	State of the art technologies are properly judged using a structured process.	State of the art technologies are properly judged and some consideration is given emerging technologies using a structured process.	State of the art and emerging technology are properly judged and planned for accordingly using a structured process.
Effective Relationships	***Focus:*** *Is stakeholder leadership aligned on a common system value definition? Do stakeholders share their perspective through open communication?*				
	Stakeholder leadership is focused on individual organization priorities with little communication to facilitate common understanding of the system value.	Identification of various organizational cultures and backgrounds is communicated through unique system perspectives for each stakeholder leader.	There is acknowledgement and sensitivity to organizational cultural differences of various stakeholder leaders, resulting from open communication.	There is understanding of organizational cultural differences of various stakeholder leaders, facilitating communication focusing on common system priorities.	There is full leadership alignment throughout the enterprise based on open two-way communication, establishing program and system credibility.
Leadership and Management	***Focus:*** *Can the system value be stated in terms of a small number of goals and objectives for the system and program?*				
	Goals and objectives for the system and program vary for each stakeholder. In general they are unclear or may be unknown.	Goals and objectives of the system and program are identified from communication between a few stakeholders. Other stakeholders may or may not be aware of these goals and objectives.	Goals and objectives for the system and program are identified by a few stakeholders and then communicated to the rest of the enterprise.	Goals and objectives for the system and program are identified with agreement from most stakeholders and then communicated to the other stakeholders.	A small number of common goals and objectives for the system and program are identified and have been bought into by all stakeholders. They define what will be done, how it will be done, and what the success criteria are.

Capability Model for Lifecycle Value Identification [1]

	Level 1	Level 2	Level 3	Level 4	Level 5
Holistic Perspective	***Focus:*** *How can flexibility be incorporated? How can the system architecture accommodate lifecycle requirements?*				
	System architecture decisions are made with little consideration of required flexibility for lifecycle issues.	Flexibility in system architecture decisions is considered as a way to incorporate lifecycle issues.	Flexibility for lifecycle issues is incorporated inconsistently in the system architecture.	Flexibility for lifecycle issues is incorporated in the system architecture.	Flexibility in the system architecture is incorporated through a strategy for "graceful upgradability".
Organizational Factors	***Focus:*** *What visibility do stakeholders have to various system decisions? What participation do stakeholders have in system value trade-offs?*				
	System and program decisions are made by one or a few of the enterprise stakeholders with little or no consideration of lifecycle issues.	System and program decisions are made by some of the enterprise stakeholders with little or no consideration of lifecycle issues.	System and program decisions are made collectively by all enterprise stakeholders with some consideration of lifecycle issues.	System and program decisions are made collectively by all enterprise stakeholders with some consideration of lifecycle value.	System and program decisions are made collectively by all enterprise stakeholders focused on lifecycle value for the system.
Requirements and Metrics	***Focus:*** *Are both technical and programmatic requirements defined to reflect stakeholder expectations and contributions regarding the system? Do these requirements have established target values and measurable metrics?*				
	Requirements and metrics are understood but may or may not be concretely established, including little or no consideration of lifecycle issues.	Requirements and metrics are established and may or may not include lifecycle considerations.	Requirements and metrics are well established with target values. They include lifecycle considerations and are communicated throughout the enterprise.	Requirements and metrics are well established with target values. They include lifecycle considerations and are articulated and communicated unambiguously.	Requirements and metrics are well established with target values. They include lifecycle considerations and are articulated and communicated unambiguously, resulting from close interaction amongst enterprise stakeholders focused on lifecycle value.
Tools and Methods	***Focus:*** *Is a structured holistic approach used to decide and understand the implications of system trade-offs?*				
	System and program trade-offs are made with little or no consideration of lifecycle issues.	System and program trade-offs are made considering some lifecycle issues.	System and program trade-offs are made considering most lifecycle value attributes. The need to follow a structured method is identified.	System and program trade-offs are made considering all lifecycle value attributes. A systems engineering approach is established.	System and program trade-offs are made considering all lifecycle value attributes with equal credibility. A fully integrated systems engineering approach is implemented.
Effective Relationships	***Focus:*** *Is there a focus on the core competencies of each stakeholder to optimize system development in the enterprise?*				
	Development effort is concentrated in one organization with little interaction between members of the enterprise.	There is a strong sense of ownership for organizational responsibilities, with oversight required to manage any external development efforts.	Core competencies are identified as well as the need to share development responsibility and risk throughout the extended enterprise.	There is a focus on core competencies with support for development spread throughout the entire enterprise.	There is strategic risk sharing through a focus on core competencies with resources and responsibility allocated appropriately throughout the enterprise to manage development efforts.
Leadership and Management	***Focus:*** *Are program management practices consistent with value based goals and objectives? Is there a homogeneous management perspective portrayed throughout the enterprise?*				
	Management focus is on individual stakeholder priorities. There is no visibility for any stakeholder decisions that are made.	Management acknowledges the potential of identifying common system value priorities. There is visibility to decisions made, but they are based on individual stakeholder value systems.	Management agrees on the need for common system value priorities. Structured process(es) with visibility are used for decision making relating to system value priorities.	Management supports common system value priorities based on well-defined, structured process(es) for decision making, with visibility to all stakeholders.	A homogeneous management perspective exists regarding system value priorities stemming from a shared process for decision making, with visibility to all stakeholders.

Capability Model for Lifecycle Value Proposition [1]

	Level 1	Level 2	Level 3	Level 4	Level 5
Holistic Perspective	***Focus:** What visibility exists for the system, its interfaces, and its lifecycle?*				
	There is awareness of several levels of the system with little or no consideration of its lifecycle.	There is awareness of entire system with little or no consideration of its lifecycle.	There is good awareness of the entire system with some lifecycle considerations.	There is good awareness of the entire system and its entire lifecycle.	There is exceptional awareness of entire system and full implementation of lifecycle issues.
Organizational Factors	***Focus:** Are effective product based teams aligned with a relevant system decomposition?*				
	There are functionally specialized working groups, with little cross-functional interaction.	There are informal cross-functional working relationships.	There is a formal cross-functional structure in effective product Integrated Product Teams (IPTs).	Effective product IPTs are aligned with product decomposition and empowered by management support.	Effective product IPTs are aligned with product decomposition and empowered by management support. Balance between functional and product responsibilities is created through shared business processes.
Requirements and Metrics	***Focus:** Are metrics tracked and shared throughout the enterprise? Is metric tracking used for proactive program management?*				
	Progress based on metrics is not known. No structured plan exists to incorporate changes in requirements.	Progress based on metrics is used for reporting purposes in some parts of the enterprise. Changes in requirements are incorporated without regard for system level implications.	Progress based on metrics is shared regularly (perhaps monthly or quarterly) in various parts of the enterprise for program management. Changes in requirements are incorporated with some consideration of system level issues.	Progress based on metrics is shared regularly throughout the enterprise for program management. Changes in requirements are incorporated considering implications throughout the entire system.	Progress based on metrics is shared weekly throughout the enterprise for proactive program management. A common strategy to incorporate changes in requirements is utilized throughout the enterprise to consider the entire system.
Tools and Methods	***Focus:** Are tools used common and fully integrated through standard processes?*				
	Tools may or may not be used on an individual basis. Processes may or may not have been considered.	Multiple tools serve the same functions. Processes may or may not be established.	There are common tools for each function. Processes are established but inconsistent throughout the enterprise.	Common tools are fully integrated between functions. Processes are standardized to yield predictable results.	A single interface is used to access multiple services provided by common fully integrated tools. Common standardized processes are shared throughout the enterprise.
Effective Relationships	***Focus:** Does open communication create an enterprise culture based on a consistent standard of working relationships?*				
	Inconsistent working relationships exist in some areas of the organization.	Consistent working relationships exist at some levels of the organization.	Consistent working relationships and communication exist at all levels of the organization and through some of the enterprise.	Consistent working relationships and communication exist throughout the extended enterprise.	Consistent working relationships and communication exist throughout the extended enterprise optimized for each stakeholder by differentiated levels of visibility.
Leadership and Management	***Focus:** Do individuals throughout the enterprise take on leadership roles? Are there clear roles and responsibilities for distributed leadership?*				
	Individual leadership characteristics are exhibited inconsistently.	Good individual leadership is exhibited.	There is good individual leadership with clear roles and responsibilities.	There is good individual leadership with clear roles and responsibilities with a management support mentality to create buy-in to program responsibilities.	There is good individual leadership with clear roles and responsibilities with a management support mentality to create buy-in to program responsibilities following identified “best” management strategies that can be adhered to.

Capability Model for Lifecycle Value Delivery [1]