Importance of Systems Engineering in Early Acquisition

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Background

The US Department of Defense is facing severe problems in delivering new systems with proposed performance within cost and schedule projections. There are a number of initiatives to identify the sources of these problems and solution options. One area which has been given particular attention is the role of systems engineering in the early stages of an acquisition. A recent study by the National Academies on pre-milestone A systems engineering (AF Studies Board) provides findings concerning the role of early Systems Engineering (SE), findings which reflect the general understanding of the importance of good technical work early in an acquisition program. This study reviewed experience with implementation of early systems engineering in major Air Force programs and assessed the impact of failing to address technical issues early in the life of an acquisition program. Not surprisingly, the study found that the lack of early SE can be shown to have direct impact on the future performance of the programs. Programs that are not built upon strong Government Program Office technical knowledge are not likely to succeed. At the same time the Defense Department has been reviewing the current acquisition process. Changes to defense acquisition regulations have been proposed which put much more emphasis on the initial stages of an acquisition. Systems engineering guidance to support the new policy provides an opportunity to provide added emphasis on early systems engineering.

Systems Engineering Guidance for Defense Acquisition

Defense acquisition policy is defined in a DoD Instruction (5000.02) which describes the mandatory regulations for the acquisition of DoD systems. The process is divided into phases as shown in figure 1, with explicit engineered products, reviews and criteria for passing major milestones which signal the release of funds and development authorities. To support the implementation of these regulations, the Defense Acquisition Guide (DAG) is an online resource which provides guidance for the implementation of acquisition programs from various perspectives. Also as shown in figure 1, there are 11 chapters in the DAG. Each chapter provides guidance from a different perspective. One of these perspectives is "systems engineering" which is presented in Chapter 4 of the DAG.

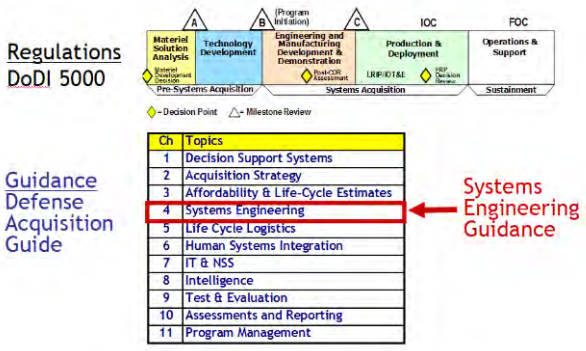

Figure 1: Defense Acquisition Policy and Guidance

The base DAG document is over 500 pages long, and guidance in each chapter addresses each phase of the acquisition process. This guidance provides advice to the acquisition program

manager and staff including the systems engineering team. This means that any added guidance to programs on systems engineering effectively 'competes' with guidance in other areas for program office attention and resources. So in investigating ways to better emphasize early systems engineering as a means for improving acquisition program success, we were faced with several questions: first from an SE perspective, what are the important engineering activities and products during the two early acquisition phases to be implrmrnted by the early program office? How do these SE activities relate to the other activities recommended for programs at the same times? What are the impacts of the SE activities on acquisition decisions?

Business Process Model of Acquisition Guidance

In order to address these questions we needed a structured approach to help understand how SE fits into larger acquisition context, and to do this we used Business Process Modeling (BPM). The use of BPM methodologies and standards allowed us to rapidly articulate processes in the acquisition workflow, depict the relationships among concurrent stakeholder activities, and convey information exchanges among those activities in the context of the enterprise (acquisition) process.

Specifically, this business process model has been developed for the 5000 process, SE guidance based on draft updates to DAG Chapter 4, and the relationships between SE guidance, DoD 5000 regulations, and the key guidance elements in other DAG chapters. The result was the Acquisition Guidance Model (AGM).

The AGM was modeled using Business Process Modeling Notation (BPMN), a graphical notation standard used to implement BPM constructs. The BPMN standard is currently maintained by the Object Management Group (OMG). Implementation of BPMN elements was achieved through the use of the commercial off-the-shelf (COTS) BPM development environment iGrafx Process 2007.

The AGM provides a mechanism to examine how systems engineering fits into of the range of actions within an acquisition program, how systems engineering leverages the results of other acquisition activities and which systems engineering products support acquisition decisions. In essence, the model provides the basis for a systems engineering analysis of acquisition guidance to identify the most important systems engineering actions in terms of potential impact on acquisition success. It is a visual representation of the plan for increasing critical technical knowledge and reducing risks to progress success

Figure 2 shows a schematic of the AGM layout which represents the guidance in each of the DAG chapters as independent, concurrent guidance lanes. These lanes correlate to the BPMN swimlane element, which is a visual enterprise level organization depicting the different functional activities in the process. For the initial version of the model the SE lane Chapter 4) has been represented in more detail and the elements in the SE lane were reviewed in terms of their relationship to the other guidance lanes and to the 5000 policy regulations.

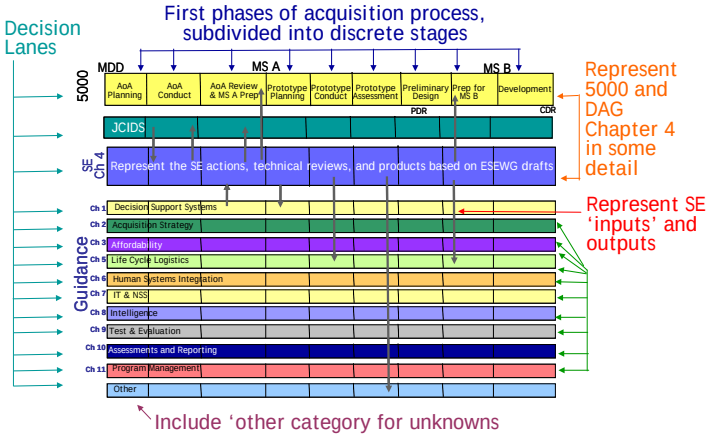

Figure 3: Layout of the model

An iterative approach was used in the model development, progressing from an initial skeletal implementation through a series of development review and update cycles with subject matter experts in each of the lanes. A snapshot of an early version of the AGM, best viewed in a 4ft by 10ft foot poster, is shown in a greatly reduced scale in Figure 4 below.

Figure 4: Snapshot of the model

Acquisition Guidance Model: Uses and Results

As the model was developed it has been used in several ways. In each case the model helped to abstract and display essential elements of the policy and guidance in a way that allowed the users to gain a system level perspective of the acquisition /guidance process, to identify timing, resources and information issues which would have been very difficult to discern without the perspective provided by the model, and to assess options from a broader system level perspective (versus the perspective of individual guidance lanes.) *In effect, the model provided the vehicle to apply systems thinking to the development and evaluation of acquisition guidance*.

The following sections describe several specific applications of the model.

- **Assessing the impact of DoD 5000 change Preliminary Design Review (PDR) and a report to the MDA before Milestone B (moves Milestone B to the right)**

This analysis made it clear the importance of key engineered products and technical reviews to the larger process and highlighted this to the broader community (see figure 5).

The acquisition PM needs to coordinate: industry, PO, and stakeholders to arrive at a balanced program that delivers required capability which industry can build within establish cost and schedule objectives. User capability needs must be balance against technology maturity and affordability objectives. These competing requirements cuts across a number of responsibility owners including SE as depicted in Figure 3. BPM captures those activities and needs lines for all responsibility owners. The model revealed the critical role SE has in maturing technology and the use of prototypes to further understand solution implementation implications. BPM clearly lays out why and how the Govt PO SE team remains engaged in establishing the program's system requirements, technical baseline and review points leading to a MS B decision. The model SE activities, when completed, ensure that the acquisition PM has the resident technical knowledge to proceed forward to developing and producing what the user requires.

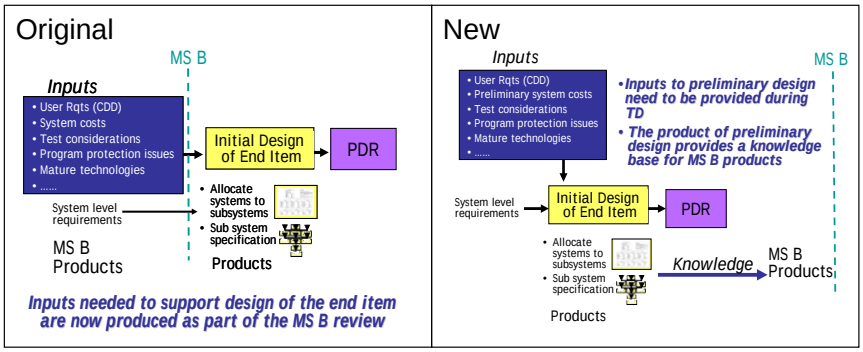

Figure 5: Assessing the Impact of Moving Program Commitment Decision to Follow Preliminary Design Review

- **Identification of critical SE activities and products and their impact on key program plans and decisions**

The BPM shows the essential role engineering analysis effort plays in formulating a range of material solutions and informing the follow on engineering work to mature those solutions. It clearly identifies the information paths between the user capability needs, Analysis of Alternatives (AoA) study, the Government Program Office (PO) SE task and its resultant technical review and product. Now an acquisition PM has a one or more system concepts that can deliver the capability required by the user, its technology components level of maturity, and the development path ahead. The technical knowledge gained by the Government PO from the engineering analysis activity increases the quality and thoroughness of the technical planning required for the technical demonstration phase. The SE staff can provide the technical inputs required by the formal documentation (e.g. TDS, SEP, TES) making business case for proceeding forward or not.

The BPM functions as a planning tool in laying out the key activities and their interdependencies and a resource template for determining schedule and funding requirements. It provides the acquisition PM a perspecitve across all aspects (lanes) of a program on the "who, what, how and when" of a Government program. The BPM provides a key service by depicting the work activities that generates the needed products, including documentation. PMs can now avoid a common trap of focusing on major reviews and their documentation vice on the SE activities required to generate the technical knowledge and related products to feed those early reviews.

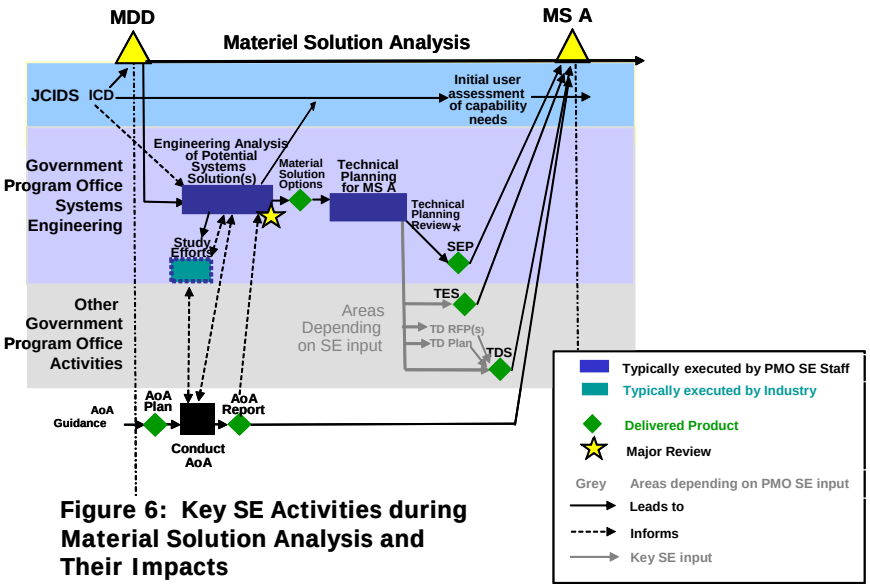

Figure 6: Key SE Activities during Material Solution Analysis and Their Impacts

- **Context for reviewing issues such as methods to ensure realistic user requirements**

An important consideration in establishing acquisition programs which can predictable meet performance requirements within budget and schedule commitments is the appropriate selection of achievable requirements for system performance or other quality attributes. Changes recommended to DoD 5000 are typically discussed in term of the added emphasis on early technical work which provides evidence that user requirements can be met. However, it is important to realize that the technical results may identify limits to technology or key cost and risk factors associated with user requirements, and if implemented with this in mind it provides the platform for a reassessment of user capabilities in terms of achievable capabilities for an increment of development.

- **Application of the acquisition guidance to specific programs**

The model provides a framework for identifying the key technical anchor points in the early acquisition stages as points where the program manager can assess available evidence to guide program decisions with the users as partners. As technical trades are made at these points, the users are key players in understanding the preferred trades which may include relaxation of requirements. They may also be points at which technical limits, risks or costs may make a recommended solution no longer viable to meet core user needs and hence require a rethinking of acquisition alternatives. These points are not only at the program Milestones, but they are also at key technical review points, which need to be viewed as anchor points for the acquisition process as well as technical reviews in the systems engineering lane. There are possibilities for future use of the AGM as a training tool and an acquisition tailoring tool for program managers.

Summary

This paper provides a description of the use of a 'systems' approach to assessing role of systems engineering in early acquisition. This systems approach is based on a business process model of acquisition regulations and guidance with a focus on recommended systems engineering activities, products and reviews and their relationship to the broader acquisition policy and guidance. The model has provided a tool to bring together different members of the acquisition policy and guidance community to work together to examine their respective roles in furthering acquisition success. It has provided the venue for identifying issues and information needs

arising from proposed changes in acquisition policy and options for addressing those issues. It has also provided the systems engineering community an opportunity to look at the way systems engineering is understood by others in acquisition and to factor this into how the community present the role and guidance for systems engineering as well as which systems engineering activities and products are emphasized in future guidance. The model continues to serve as a tool for identifying and evaluating guidance as well as other aspects of the acquisition process (e.g. documentation requirements).

Several important lessons were learned from the modeling process. First, outside of the SE community there is very limited understanding of systems engineering and its role in acquisition. The modeling process has helped change the way systems engineering is presenting what it offers to the acquisition process. Second, the systems engineering community is generally focused on the execution of their technical role and less aware of the larger context in which their products are used. The collaborative process of model development and review has opened the dialog and provided the venue for addressing key relationships between SE and other aspects of acquisition (e.g. AoA, costing). Finally, past presentation of SE guidance has been focused on SE practitioners versus the larger acquisition audience. It focused on defining technical reviews versus technical activities and products. SE guidance emphasized how systems engineering addresses technical issues ('V' diagrams) versus how systems engineering activities and products help to address program issues. Developing the model has helped identify different ways to articulate how systems engineering is executed and how it fits into the larger acquisition context which is an invaluable example of systems engineering benefit in executing an acquisition.

From the perspective of systems engineering, possibly the most important result of the model development and analysis is the way that this model has provided a mechanism to communicate the role and the importance of systems engineering and its products to the broader acquisition community. The model has provided a top level view of how systems engineering creates the foundational technical 'engine' for early acquisition. Most systems engineers take this for granted. Unfortunately, this is not a generally held view by others. By defining explicit engineering activities and products along with their relationships to other acquisition support activities and decisions, the model makes SE role tangible in terms that other communities can readily understand and appreciate.