ENGINEERING THE ENTERPRISE

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Abstract - This paper suggests a way of engineering the capabilities of large-scale enterprises that is different from classical "specify and build" approaches commonly employed by government agencies in acquiring individual systems or systems of systems. The view presented is that enterprise engineering does not replace or add a layer to classical systems engineering but that it complements classical approaches by shaping the environment in which individual systems are developed to achieve enterprise goals.

INTRODUCTION

In the government sector, there is substantial interest in engineering information technology-based enterprise capabilities. Much of the growing body of knowledge in enterprise engineering has been informed by fields as diverse as: evolutionary biology, ecology, market economics, social design, and complexity. These disciplines are far removed from classical engineering and management on which traditional government system development and acquisition are based.

In addition, government statutes and policies for engineering and acquiring systems and classical approaches to systems engineering have coevolved in a way so that there is great sympathy and harmony between them.

Together, the unfamiliarity of the emerging enterprise engineering discipline and its application to engineering and acquiring government systems and the known accordance of classical techniques with current law lead many to believe that system engineering inspired by the new thinking cannot be employed and must wait for expansive changes in government policy and statutes. This has frustrated engineering and acquisition practitioners and policy makers alike.

This paper takes the point of view that good systems engineering and acquisition has always been informed by diverse disciplines, usually intuitively and informally, and that there is ample room for expanding and formalizing that practice and applying it to the engineering of government enterprise capabilities. What is needed is a change of mindset that enables engineering and acquisition practitioners to question prevailing, largely implicit assumptions under which most organizations operate. [1]

ENTERPRISE AND ENTERPRISE CAPABILITIES

An enterprise is an entity comprised of interdependent resources that interact with each other and their environment to achieve goals.[2] Resources include people, processes, organizations, technology, funding and the like. Interactions include coordinating functions, sharing information, allocating funding and the like. That this definition is quite broad can be seen by considering the following examples.

- A chain hotel in which independent hotel properties operate as agents of the hotel enterprise in providing lodging and related services while the company provides business service infrastructure (e.g., reservation system), branding and the like.
- A military command and control (C2) enterprise of organizations and individuals that develop, field and operate C2 systems, including the acquisition community and operational organizations [3] and individuals that employ the systems.

Historically, government acquisition and engineering communities have focused on hierarchical relationships and have tended to isolate the systems or capabilities from the environment in which they are contained, often by assuming the environment is "fixed" or static."

An enterprise capability involves contributions from multiple elements, agents or systems of the enterprise. It is generally not knowable in advance of its appearance: technologies may still be emerging and there may be no identifiable antecedent embedded in the enterprise culture. The personal computer (PC) emerged as a replacement for the combination of a typewriter and a hand-held calculator, both of which were firmly embedded in our social, institutional and operational concepts and work processes. The PC is not an enterprise capability by this definition. But the internet is an enterprise capability. Its technology has been emerging and – more importantly – there was no identifiable antecedent capability embedded in the cultural fabric of our society before its emergence.

EVOLUTION OF ENTERPRISE CAPABILITIES

Enterprise capabilities evolve through emergence, convergence, and efficiency phases as suggested by the stylized s-curve in Figure 1. This is similar in its essentials to the technology adoption curve. Emergence is characterized by a proliferation of potential solution approaches (technical, institutional and social). Many of these potential solutions will represent evolutionary dead-ends and be eliminated (convergence) through market-like forces. This will be followed by a final period (efficiency) in which the technology is integrated and operationalized to such a degree that it becomes invisible to the humans, institutions and social systems that use them.

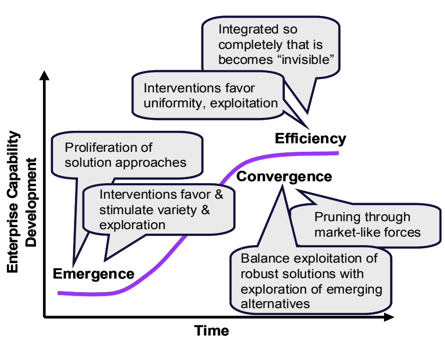

Figure 1. Evolution of Enterprise

Enterprise capabilities will evolve through emergence, convergence and efficiency phases whether or not an enterprise (or society) has intervention processes in place to actively manage them. Thus the critical role of enterprise engineering processes is to shape, enhance and accelerate the "natural" evolution of enterprise capabilities. In the emergence phase, interventions will favor and stimulate variety and exploration of technologies, standards, strategies and solution approaches and their integration and operationalization in and across enterprise organizations, systems and operations. In shaping convergence, the goal of interventions is to narrow the solution approaches and start to balance exploitation of more robust solutions with exploration of emerging alternatives. In the efficiency phase, interventions favor exploitation of that which is known to work through proliferation of a common solution approach across the enterprise.

ENGINEERING AND ACQUISITION: THE CLASSICAL APPROACH

Within most government agencies, systems are developed by the acquisition community through funded programs using classical system engineering methods and processes. The programs create a plan to develop a system capability and execute to the plan. The classical process works well when the system requirements are relatively well known, technologies are mature, and the capabilities to be developed are those of a system, *per se*, and not of the enterprise.

The classical approach to developing multi-system capabilities is through an executive oversight agency that aligns and synchronizes the development of the individual systems to develop a capability that is greater than the sum of the individual systems. This approach works well for systems-of-systems (SoSs) that are being developed together as a persistent, coherent, unified whole, particularly when: the identity and reason-for-being of the individual elements of these SoSs are primarily tied to the overarching mission of the SoS, the operational and technical requirements are relatively well known, and the implementation technologies are mature. Examples include the Atlas ICBM system, a missile defense system, or NASA's original Apollo Moon Landing capability.

But this process breaks down for enterprise capabilities. Enterprise capabilities evolve through largely unpredictable technical and cultural dimensions. Enterprise capabilities are implemented by the collective effort of organizations whose primary interests, motivations, and rewards come from successfully fielding system capabilities. The identities of the individual elements of the enterprise do not strongly derive from the resulting enterprise capability.

ENTERPRISE ENGINEERING

Enterprise engineering is an emerging discipline for developing enterprise capabilities. It is a multidisciplinary approach that takes a broad perspective in synthesizing technical and non-technical (political, economic, organizational, operational, social and cultural) aspects of an enterprise capability. Enterprise engineering is directed towards enabling and achieving enterprise-level and cross-enterprise operations outcomes.

Enterprise engineering is based on the premise that an enterprise is a collection of entities that want to succeed and will adapt to do so. The implication of this statement is that enterprise engineering processes are more about shaping the space in which organizations develop systems so that an organization innovating and operating to succeed in its local mission will – automatically and at the same time – innovate and operate in the interest of the enterprise. Enterprise engineering processes are focused more on shaping the environment, incentives and rules of success in which classical engineering takes place. Enterprise engineering coordinates, harmonizes and integrates the efforts of organizations and individuals through processes informed or inspired by natural evolution and economic markets. Enterprise engineering manages largely through interventions instead of controls.

ACHIEVING OUTCOMES THROUGH INTERVENTIONS

The way the Federal Reserve (the Fed) "manages" the U.S. economy suggests a way of shaping the evolution of government enterprise capabilities. The Fed has basically four tools to maintain a balance between growth and inflation in the $12.4 trillion U.S. economy which consists of 10,000 publicly traded companies and millions of consumers, all operating in their own interests. It can: sell or purchase government securities; change the reserve requirements for banks; change the discount rate at which banks borrow money from the Fed; and change the short-term Fed funds rate at which banks borrow money from each other. Separately and in combination, these mechanisms serve to increase or decrease the supply of money in the economy. Great economic analysis skill is needed in deciding how many securities to sell or buy and when, and whether and how much to change reserve requirements, discount and Fed funds rates, and when. But, generally, the economy responds in a way the Fed intended. The Fed harnesses the complexity of the myriad of interconnected organizations and individuals in the U.S. economy through a handful of interventions to achieve its purpose. Companies and consumers innovate to make and change decisions in response to the Fed's interventions in a way that serves their own interests and – at the same time – the interests of the Fed.

Think about managing the acquisition of government enterprise capabilities in a similar way. What are the big levers in government acquisition that could shape outcome spaces for individual programs in which they meet their own program goals while meeting the needs of the enterprise? A definitive answer to that is not yet known, but the levers likely surround managing the balance of technology exploration and exploitation to focus and accelerate the evolution of enterprise capabilities through its maturity curve (reference Figure 1).

What are the systems engineering problems, solutions, and disciplines that support decision makers to move levers in one direction or the other? System engineering at the enterprise level may be the counterpart to economic analysis at the Fed level (technical analysis and forecasting to support "moving the levers"). And this shapes and changes the environment for classical SE at the program level, which is about skillfully responding to the environment that surrounds the program (which is analogous to company financial experts who provide technical support to senior company management in making financial decisions in changing economic times).

GOVERNING AND MEASURING ENTERPRISE CAPABILITIES

Figure 2 suggests a framework for relating governance approach and measures of success to different situations in acquiring government capabilities. Much of the experience in engineering and acquiring government systems falls in the lower left-hand quadrant. Prescriptive, requirements compliance-based approaches work well in delivering systems built on a mature and homogeneous technology base using classical systems engineering processes. But their utility in a net-centric environment is less clear. Increasingly, the net-centric environment will be characterized by threads of functionality that are put together to serve an immediate operational need and then, just as quickly, are reassembled in another way for another purpose. The focus of success will shift to demonstrated value of services that enable functionality in operational environments. Enterprise demand for a service or offering will increasingly become its measure of value. Government programs and contractors that support them will increasingly ask and answer "what is it of unique value?" that we provide to the enterprise. Evolving enterprise capabilities is best served by the approach in the upper right-hand quadrant. While employed less frequently, the approaches represented by the two other quadrants have their uses: the lower right quadrant for concept explorations like the DARPA Autonomous Vehicle Grand Challenge and the upper left quadrant for meeting critical needs like enhanced armoring of existing military vehicles.

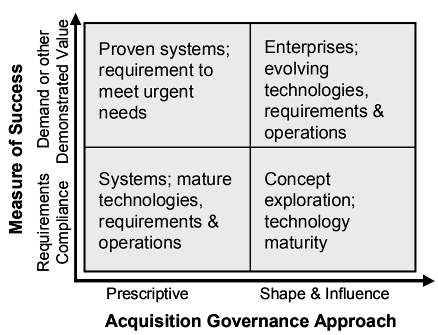

Figure 2. Relating Governance Approach and Success Measures to Different Acquisition Situations

There have been efforts in recent years to develop government enterprise IT acquisition policies and processes that are less prescriptive and attempt to provide more latitude for programs to collaborate and innovate (lower right quadrant of Figure 2). Many understand and appreciate the need for different governance approaches and success models and, indeed, even start in that direction. But there are deep structural issues in government enterprise IT acquisitions that continue to drive policy-makers, program offices, and contractors to the lower left-hand quadrant of Figure 2 regardless of their specific circumstances or intentions. The prevailing business models used in government programs (contract for the promise of a future capability) encourages programs and contractors to ask for more detailed guidance (to minimize cost, schedule and requirements risk) and discourages them from creating high demand services or offering because of the risk of driving the program out of its predefined requirements and expectations.

GUIDING AND MONITORING ENTERPRISE EVOLUTION

Exploration versus exploitation is an important trade between the creation of untested solutions that may be superior to solutions which currently exist and have so far proven best. This trade occurs across a wide range of situations in which the exploration of that which is new or emerging (variety) comes at some expense to realizing benefits of that which is already available (homogeneity). It is not always the case that variety is good and homogeneity is bad, or vice versa. [4] More variety is indicated during the emergence phase of an enterprise capability with a movement towards increasing homogeneity as the capability moves through convergence and efficiency phases of its evolution. The criteria for shaping that change will differ depending on the phase. Table 1 summarizes characteristics of each phase of enterprise capability evolution and ideas for shaping the exploration/exploitation balance.

Table 1. Guiding Enterprise Evolution

Enterprise Capability Phase Characteristics	Examples, Rules of Thumb & Anecdotes
Emergence	**Emergence**
• When there are no clear solutions or multiple, emerging solutions. • When extensive or long-term use can be made of a solution. • When there is low risk of catastrophe from exploration.	• Reward proliferation of potential solutions. Example: DARPA Grand challenge to accelerate evolution of critical autonomous robotic vehicle technology. • Operating systems and some applications (e.g., target tracking and identification) are among the longest lived elements of IT. • Modular enterprise architectures that provide market-like choices for different service layers.
Convergence	**Convergence**
• When there are multiple, adequate solutions with little performance differentiation. • When maintaining multiple solutions impairs enterprise performance or cost.	• Narrow the solution space by providing rewards or incentives to programs and contractors that achieve common solutions through collaboration. • Solutions are not prescribed from above.
Efficiency	**Efficiency**
• When there are a small number of mature solutions that dominate the market. • When the probability of technology change is low.	• Reward exploitation of existing solutions • Reward use of common solutions • Solution is not specified from above.

An enterprise capability is a characteristic of the enterprise in its operation. The implication is that enterprise performance should be strongly tied to the behavior of operational units employing enterprise systems and capabilities in actual operations. Measures intended to monitor the evolution of enterprise capabilities should focus on capturing changes in the way operational units interact. The evolution and utilization of enterprise capabilities have strong elements of social system structure and dynamics. The implication is that the definition of enterprise measures should include sociologists as well as operational and technical experts. Formal verification of the piece-parts of an enterprise capability will still need to be done as part of system sell-offs, but they should not be viewed as the primary indicators of an enterprise capability. Even as simple a system as a wrist watch is primarily evaluated holistically and not as the pair-wise interactions of its myriad mechanical and electrical parts.

Table 2 suggests some examples of measures for monitoring the evolution of military interoperability at the enterprise level.

Table 2. Monitoring Enterprise Evolution

Monitoring the Evolution (Interoperability Example)
Emergence
• Increased number of interface control documents (ICDs) among operational military systems. • Increased volume of voice, email, chat and instant messaging among operational organizations. • Communications emerging among previously non-interacting operational units.
Convergence
• Decreased number of ICDs • Increased use of common standards among systems. • Less episodic, more continuous interactions among military operational units.
Efficiency
• Predominant use of a single standard among systems • Predominantly continuous interactions among operational units.

THE ENTERPRISE MARKET: CHANGING THE RISK BALANCE WITH SOAS

The advantages normally cited for a service-oriented architecture [5] (SOA) approach to networked IT systems are: reduced complexity and cost of integration; enhanced reusability, better identification and management of dependencies among systems, and industry compatibility at the service level. Potentially more significant is the prospect that an SOA can move government acquisition away from paying for effort to make good on a promise (the contract) towards a market-like economy in which contractors develop product or service offerings that compete for market share. This has enormous implications for shifting the balance of risk in government enterprise acquisition from being essentially wholly owned by the government to being shared between the government, as consumer, and contractors as producers of services that are competing for market share. [6]

What follows is a simple example to illustrate the point. Consider a government community consisting of producers of a unique type of data (e.g., sensor data) and consumers who use the data to accomplish activities ranging from broad situation awareness, precise and immediate location finding, and detailed historical analysis. Taking a SOA approach to developing enterprise capabilities for the production and consumption of this sensor data suggests separating data, exploitation tools, and visualization tools in a relatively machine-independent way. Consider all potential government producers and users of the sensor information as the market for data services, exploitation tools, and visualization tools. Commonality for data flow and storage is critical across the entire market. The need for exploitation tools is driven by specific mission and activities, so its market is characterized by some common tools and some specialized ones. The market for visualization tools is probably many common and a few specialized ones. So, the one community behaves as three different markets: one for data, another for exploitation tools and a third for visualization tools. This suggests a government community of practice which governs the three levels of the SOA differently: a prescriptive, top-down governance approach for data; and a shaping/influencing governance approach for tools to encourage and enable contractors to innovate and differentiate their products and services and be rewarded with a larger market share.

SUMMARY

This paper has taken the point of view that good systems engineering and acquisition has always been informed by diverse disciplines, usually intuitively and informally, and that there is ample room for expanding and formalizing that practice and applying it to the engineering of government enterprise capabilities. This can be done without waiting for expansive changes in government policies and statutes. But it does require a change of mindset that enables engineering and acquisition practitioners to question prevailing, implicit assumptions under which most organizations operate.

REFERENCES

[1] Kemeny, Jennifer, Michael Goodman and Rick Karash. “The Acme story.” *The Fifth Discipline Fieldbook*, Peter M. Senge et.al. New York, NY: Currency Doubleday, 1994.

[2] This definition is similar in its essentials with that of *Enterprise* in the *Net Centric Implementation Framework*, v.1.0.0, 17 Dec 04, NESI.

[3] This example is intended to include government organizations, non-profits, and commercial companies.

[4] Axelrod, Robert and Michael D. Cohen. *Harnessing Complexity: Organizational Implications of a Scientific Frontier*. New York, NY: Basic Books 2000.

[5] A Service is a functional capability that is made available to consumers via an exposed network access point. From a consumer's point of view, services are perceived as black boxes on the network, in that their internal implementation is hidden from the consumer.

[6] Flyvbjerg, Bent, et. al., *Megaprojects and Risk: An Anatomy of Ambition*, Cambridge, UK: Cambridge University press, 2003.