



# Systems Thinking for the Enterprise

## A Thought Piece

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This paper is about a way of managing the acquisition of capabilities for large-scale enterprises that is different from the traditional “specify and build approach” commonly employed by U.S. government agencies in acquiring individual systems or systems of systems.

To motivate the direction of my remarks, let me start with an example of how the Federal Reserve Board (the Fed) helps manage perhaps the most complex enterprise in the world today - the U.S. economy. How complex is it? As measured by the gross domestic product, the 2005 U.S. economy is estimated at \$12.4 Trillion, involves nearly 10,000 publicly traded companies and millions of consumers. All of these companies and consumers are operating in their own self-interests.

By U.S. law, the Fed is charged with maintaining a balance between growth and inflation in the U.S. economy. Remarkably, the Fed has basically four tools available to it to maintain this balance. 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. Of course, 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.

Think about that. 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 self interests and – at the same time – the interests of the Fed.

What a powerful model for engineering enterprise capabilities.

## Thesis



- **An enterprise is a complex social system**
- **Enterprise capabilities evolve**
  - through the emergence and convergence of technologies and
  - their integration into social, institutional and operational organizations and processes
- **The critical role of enterprise engineering is to shape, enhance and accelerate the evolution of enterprise capabilities**
- **Enterprise engineering processes complement traditional systems engineering**
  - Stimulates interactions among enterprise organizations and agents to create innovation that moves and accelerates enterprise evolution

An enterprise is a complex social system. The implication is that there are strong elements of unpredictability or unknowability of future events or conditions (at a detailed level) in the enterprise.

Enterprise capabilities come about through evolutionary processes. There are important technology and cultural dimensions to this evolution.

Like the Fed example, the critical role of enterprise engineering is to guide and manage processes that are largely evolutionary.

Enterprise Engineering processes complement more traditional systems engineering (SE) processes by incentivizing programs developing system capabilities to behave in ways that serve both program needs and enterprise needs.

## Enterprise



- **An entity comprised of interdependent resources that interact with each other and their environment to achieve goals [1]**
  - Resources include people, processes, organizations, technology, funding, etc.
  - Interactions include coordinating functions, sharing information, allocating funding. etc.
- **Examples**
  - **Chain hotel enterprise**
    - Independent properties operate as agents of the hotel enterprise in providing lodging and related services
    - Hotel provides business service infrastructure, “branding,” etc.
  - **Military command and control (C2) enterprise**
    - Organizations and individuals that develop, field and operate C2 systems
    - Includes acquisition community and operational organizations and individuals that employ the systems
      - Includes government organizations, non-profits, and commercial companies

The key notions in this definition are: (1) interdependence and interactions among the elements of the enterprise and (2) interactions between the enterprise and its environment.

Historically, many of us in the SE community have focused primarily on hierarchical relationships and we’ve tended to isolate the systems from the environment in which it is contained (often by assuming the environment is “fixed” or “static”).

The examples show how broad our definition of enterprise really is.

# Enterprise Engineering



## ■ What it is

- An emerging discipline for developing enterprise capabilities
- A multidisciplinary approach that takes a broad perspective in synthesizing technical and non-technical aspects of an enterprise capability
  - Encompasses and balances technical, political, economic, organizational, operational, social and cultural dimensions.
- Directed towards improving the effectiveness, productivity, and efficiency of enterprise-wide and cross-enterprise operations and outcomes.

## ■ How it works

- Based on the premise that an enterprise is a collection of self-serving organizations and individuals [2]
- Coordinates, harmonizes and integrates the efforts of organizations and individuals through processes informed or inspired by processes in natural evolution [3] and economic markets [4]
- Manages the evolution of enterprise capabilities through interventions that shape, enhance and accelerate the emergence and maturation of technologies and their integration into social, institutional and operational systems and processes [5]

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Enterprise Engineering is:

- An “emerging discipline.”
- About developing “enterprise capabilities” and these are different from “system” or “SoS” capabilities (about which more, later).
- A discipline whose implementation synthesizes both technical and non-technical dimensions.
- Directed towards achieving enterprise-level outcomes.

Enterprise Engineering works by:

- Understanding that an enterprise is a collection of self-serving entities.  
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 in its own self interest will – automatically and at the same time – innovate and operate in the interest of the enterprise. The enterprise engineering processes are focused more on recognizing and leveraging universal human predispositions and social forces rather than ignoring or changing them. Remember the Fed example.
- Coordinating through processes informed by natural evolution and economic markets. Remember the Fed example.
- Managing largely through interventions instead of controls. Remember the Fed example.

## Enterprise Capabilities



- **Involve contributions from multiple elements, agents or systems of the enterprise**
- **Frequently not knowable in advance of their appearance**
  - **Not yet known which technologies and standards will achieve market dominance**
    - **May still be emerging**
  - **May be no identifiable antecedent capability embedded in the cultural fabric of the enterprise**
    - **Need to develop, integrate capability into social, institutional, and operational concepts, systems and processes of the enterprise**
- **Examples: world-wide web, net centrality\***

\* Net-centricity is an information superiority-enabled concept of operations that generates increased combat power by networking sensors, decision-makers, and shooters to achieve shared awareness, increased speed of command, higher tempo of operations, greater lethality, increased survivability, and a degree of self-synchronization. In essence, (Net-centricity) translates information superiority into combat power by effectively linking knowledgeable entities in the battlespace. [6]

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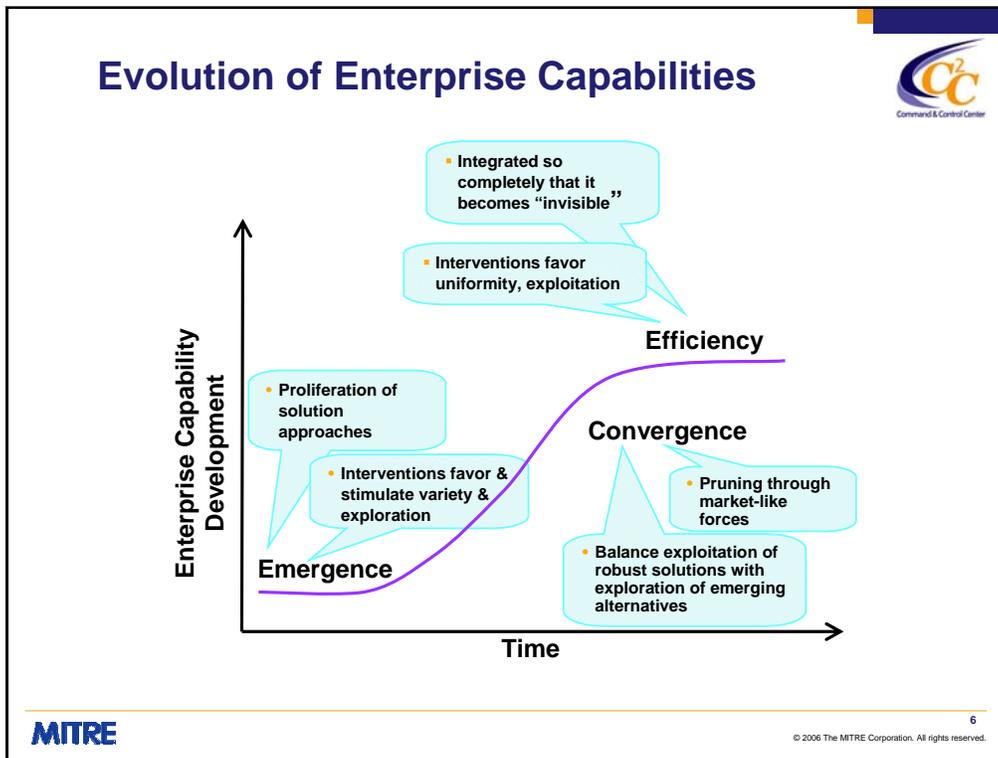
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Enterprise capabilities involve contributions from multiple entities.

They are generally not knowable in advance of their appearance: technologies may still be emerging and there may be no identifiable antecedent capability 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 in our 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.



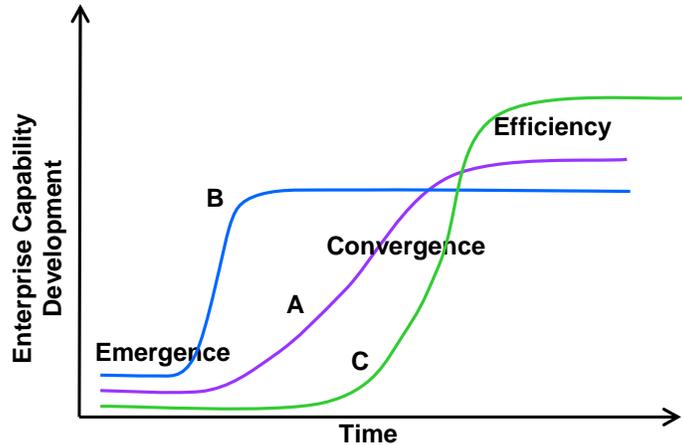
Enterprise capabilities evolve through emergence, convergence, and efficiency phases as suggested by the stylized s-curve in this figure. This is similar in its essentials to the technology adoption curve.

- 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.

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.

## Shaping, Enhancing and Accelerating Enterprise Capability Evolution



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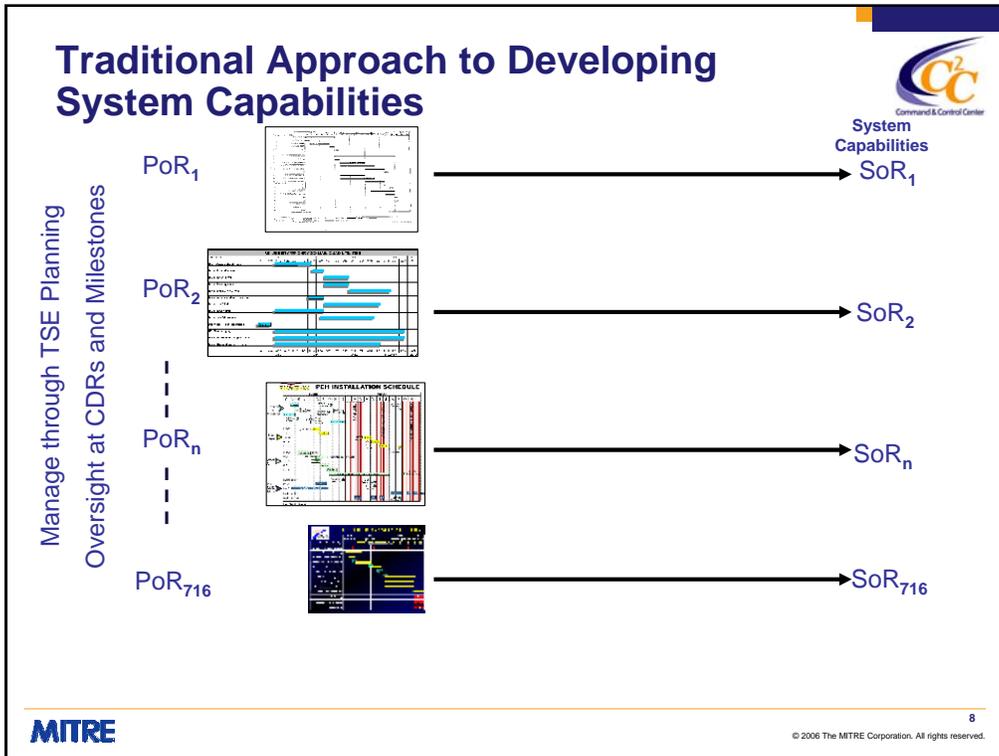
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This figure shows notionally how enterprise engineering intervention processes can affect the evolution of an enterprise capability.

For illustration purposes, let us assume curve A depicts how a capability would evolve in an enterprise without purposeful interventions.

In curve B, enterprise engineering processes shorten the exploration phase (perhaps by early down-selecting to a small number of acceptable enterprise-wide standards for a particular technology). This provides the benefit of converging more quickly to an efficiency phase but at the cost of a less optimal efficiency phase (perhaps because superior alternatives were never explored due to the foreshortened emergence phase). Conventional examples of this type of premature convergence include the competition between VHS and BetaMax systems of video recording and QWERTY and Dvorak keyboard arrangements.

Curve C depicts a situation in which exploration of an enterprise capability is extended, perhaps to consider additional emerging technology alternatives. This has the effect of deferring exploitation of a preferred approach beyond either of the other two curves, but in the end it results in the most successful efficiency phase.

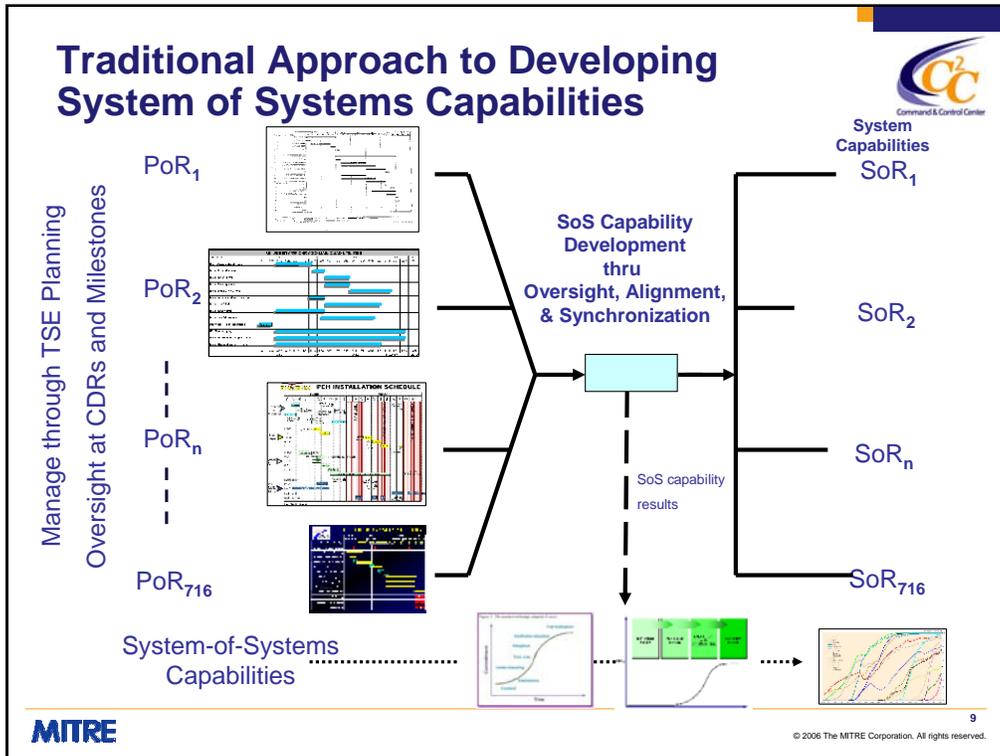


Within the Department of Defense (DoD), systems of record (SoRs) are developed by the acquisition community through funded programs of record (PoRs) using traditional system engineering (TSE) methods and processes.

The PoRs create a plan to develop a system capability and execute to the plan.

The TSE process works well when the system requirements are relatively well known, technologies are mature, and the capabilities to be developed are those of the systems, *per se*, and not of the enterprise.

There are many hundred PoRs in the DoD, a number of which are enormously complicated.



The traditional approach to developing multi-system capabilities is through an executive oversight agency that aligns and synchronizes the development of the individual SoRs to develop a capability that is greater than the sum of the individual SoRs.

This approach works well for systems-of-systems that are being developed together as a persistent, coherent, unified whole, particularly when:

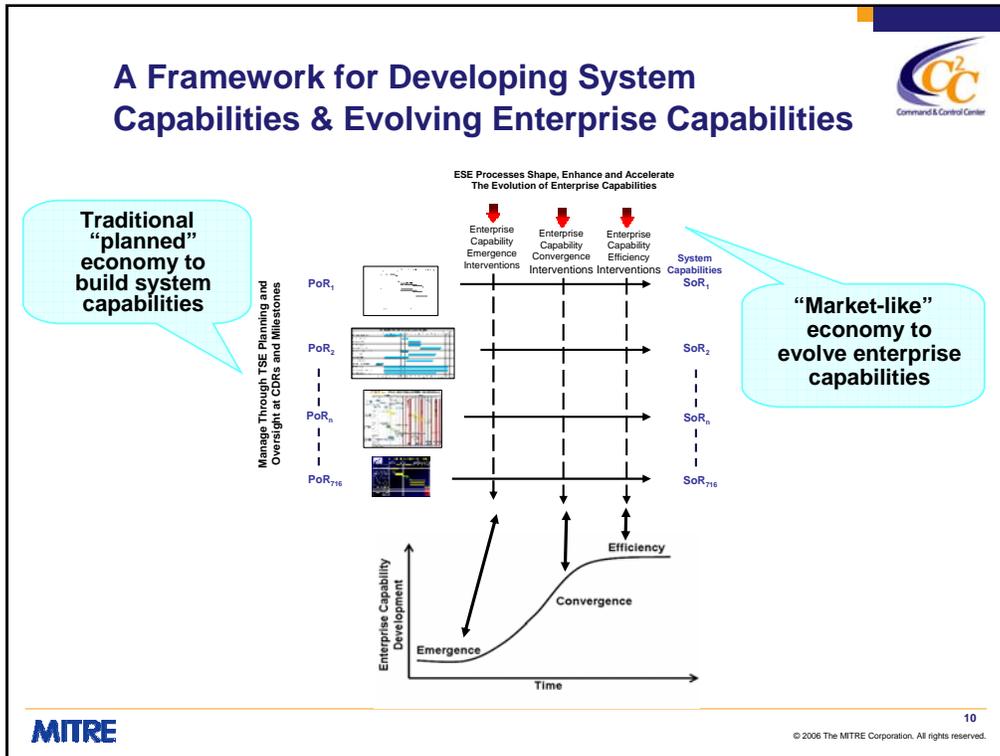
- The identity and reason-for-being of the individual elements of these SoSs are primarily tied to the overarching mission of the SoS and,
- The operational and technical requirements are relatively well known and the implementation technologies are mature.

Examples include the Atlas ICBM system, an air 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 self-serving 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.

## A Framework for Developing System Capabilities & Evolving Enterprise Capabilities



This chart shows an approach in which enterprise engineering processes shape the evolution of enterprise capabilities through emergence, convergence and efficiency phases via “market-like” mechanisms at the same time that individual system capabilities are being developed via the traditional system engineering approach of building to a plan.

The basic notion is to stimulate innovation by and interactions among PoRs to move the enterprise towards an enterprise capability at the same time the PoRs are developing their SoRs. Specific “interventions” depend on the phase or state the enterprise capability is in. Their purpose is as described in Chart 6.

This approach is similar in its essentials to the Fed intervening in the U.S. economy in which the collective response of organizations and individuals operating in their own self interests to those interventions serve their needs and the Fed’s at the same time.

Some examples of stimulating innovation within a government acquisition setting are:

- **DARPA Grand Challenge:** For a \$2M prize, the U.S. government got multiple millions of dollars of innovation in critically important autonomous robotic vehicle technology by sponsoring a “race.” This accelerated the application of that technology to military applications up the evolutionary curve.
- **Acquisition Program Reviews:** The government could consider changing acquisition program review criteria. One example might be that for a program to pass a milestone review, it must show adequate technical progress at the milestone plus demonstrate that it collaborated with another program that produced variety in an enterprise capability during the emergence phase. Another example might be to streamline program reviews for programs that can demonstrate the creation of variety in an enterprise capability during the emergence phase.
- **Metadata Market:** The government could consider establishing a metadata market incentive fund. Create a value exchange matrix for each program in which rows are “value taken from the enterprise” by a PoR and columns are “value provided to the enterprise” by a PoR. The idea would be to reward programs with richly populated matrices and give little or no reward to programs with sparsely populated matrices.

## Monitoring the Evolution of an Enterprise Capability



- An enterprise capability is a characteristic of the enterprise in its operation

- Implications

- Enterprise evolution/performance assessment should be strongly tied to the behavior of operational units employing systems in actual operations
    - Measures should focus on capturing changes in the ways operational units interact

- Evolution and utilization of enterprise capabilities have strong elements of social system structure and dynamics

- Implication: definition and assessment of enterprise measures should include sociologists as well as operational and technical experts

- Example criteria for shaping & monitoring evolution of net centric capability

Emergence	Convergence	Efficiency
Increase total no. of interface control documents among PoRs	Decrease ICDs; increase use of common standards among PoRs	Predominant use of single std among operational units
Increased volume of voice, email, chat & IM among operational units	Less episodic, more continuous interactions among opnl. units	Predominantly continuous interactions among opnl. units

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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 in actual operations.
- Formal verification of 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 (does it keep accurate time?) and not as the sum of its myriad mechanical and electrical parts.

Evolution is measured by change over time

- The implication is that criteria for shaping that change will depend on the phase the evolution is in (emergence, convergence, efficiency).

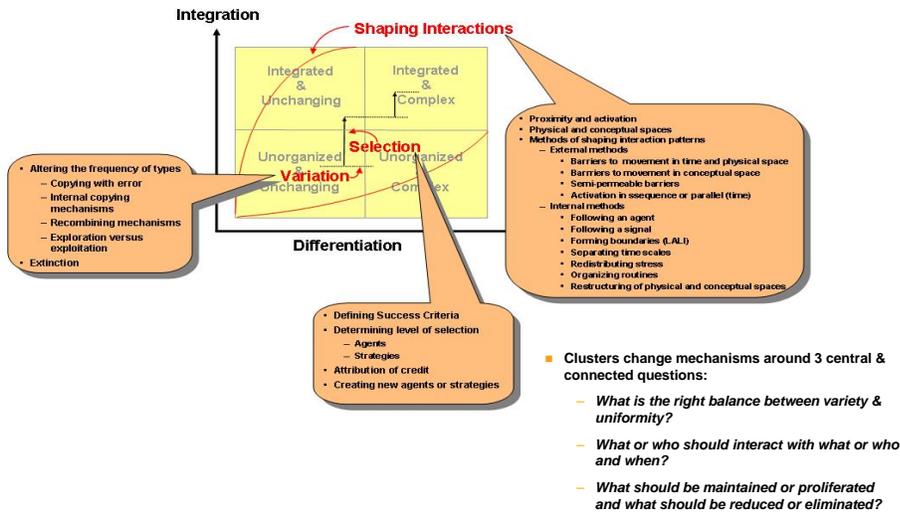
There are strong cultural elements of achieving an enterprise capability

- The implication is that the definition of enterprise measures should include technical, operational and social system experts.

The table suggests some example criteria for the evolution of a military net centric capability.

- They may appear counter-intuitive at first sight.
- But consider them in an emergence-convergence-efficiency phase framework.

# Techniques for Evolving Complex Systems [5]



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Change mechanisms in a complex system can be clustered around 3 central and connected questions:

- What is the right balance between variety and uniformity?
- What should be the interaction patterns among agents of the enterprise?
- What should be maintained or proliferated and what should be reduced or eliminated?

There is a detailed discussion of these questions in Reference 5.

## Take Aways



- **Enterprise capabilities are frequently not knowable in advance of their appearance**
  - Technology and cultural aspects
- **Enterprise capabilities evolve**
  - through the emergence and convergence of technologies and
  - their integration into social, institutional and operational organizations and processes
- **The critical role of enterprise engineering is to shape, enhance and accelerate the evolution of enterprise capabilities**
- **Enterprise engineering processes complement those of traditional systems engineering**
- **Enterprise evolution/performance assessment should be strongly tied to the behavior of units in live operations**
  - Involvement of sociologists as well as operational and technical experts

Enterprise capabilities are not knowable in advance of their appearance. They evolve over time. There are important technology and cultural aspects.

Enterprise engineering is largely about intervening in “technology and social system” evolutionary processes to shape and accelerate outcomes.

Enterprise engineering complements traditional systems engineering.

Assessments of enterprise capability performance and evolution should be strongly tied to the behavior of the enterprise in live operations.

## References



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