

The MITRE Corporation

Evolving Systems Engineering

The U.S. federal government faces ever increasing complexity in its systems and enterprises. For example, the FAA's National Airspace System, the DoD's Global Information Grid, the IRS's tax systems, and DHS's Secure Border Initiative's SBInet all present immense complexity. To successfully bring value to the users of the systems in these enterprises requires the disciplined methods and "big picture" mindset of traditional systems engineering plus new methods and mindsets aimed at addressing the increased complexity.

► **Three key questions about new systems engineering landscape:**

1. What is so fundamentally different that we need to extend our systems engineering methods?
2. What do we mean by an enterprise?
3. What is enterprise systems engineering?

1 What is fundamentally different?

A mix of interdependency and unpredictability, intensified by rapid technology change, is driving the need for new systems engineering techniques. When large numbers of systems are networked together to achieve some collaborative advantage, interdependencies spring up among the systems. Moreover, when the networked systems are each individually reacting to both technology and mission changes, the environment for any given system becomes essentially unpredictable. The combination of massive interdependencies and unpredictability is fundamentally different. Systems engineering success is defined not for an individual known system, but for the network of constantly changing systems.

Since our customers' needs are driving the trend toward collaborative advantage and adaptivity, we must evolve our methods to their changing situation. The changing situation is characterized by several specific features:

- Our customers face extremely complex problems in which stakeholders often disagree on the nature of the problems as well as the solutions—problems and solutions are at the same time technical and social.
- Their missions are changing rapidly and unpredictably—thus systems must interoperate in ways their originators never envisioned.
- Even without a predefined direction, the systems will keep evolving and responding to changing needs and emerging opportunities—the network is inherently adaptive.
- People are integral parts of the network, and their purposeful behavior will change the nature of the network—individual systems must be robust to changes in their environment.

Thus the systems that we help engineer are facing additional, fundamentally different challenges. However, when a system is bounded with relatively static, well-understood requirements, the methods of traditional systems engineering (TSE) are still applicable and powerful. It is the increased complexity of problems and solutions that has caused us to extend the systems engineering discipline into a domain we call enterprise systems engineering (ESE).

2 What do we mean by an enterprise?

By “enterprise” we mean a network of interdependent people, processes, and supporting technology not fully under the control of any single entity. In business literature, an enterprise frequently refers to an organization, such as a firm or government agency; in the computer industry, it refers to any large organization that uses computers. Our definition emphasizes the interdependency of individual systems and even systems of systems. We include firms, government agencies, large information-enabled organizations, and any network of entities coming together to collectively accomplish explicit or implicit goals. This includes the integration of previously separate units. The enterprise displays new behaviors that emerge from the interaction of the parts.

3 What is enterprise systems Engineering?

ESE is the domain of systems engineering that concentrates on managing uncertainty and interdependence in an enterprise. It encompasses and balances technical and non-technical aspects of the problem and the solution. It fits within the broad, multidisciplinary approach of systems engineering, as shown graphically below. It is directed toward building effective and efficient networks of individual systems to meet the objectives of the whole enterprise.

In performing ESE, we engineer the enterprise and we engineer the systems that enable the enterprise. In particular, we help customers shape their enterprises, aligning technology to support goals. We support their business planning, policy-making, and investment strategies. We also determine how the individual systems in the enterprise perform and how they affect each other.

At MITRE, we consider ESE as a domain that focuses on complexity in the broader practice of systems engineering. It is not a replacement for TSE and often both TSE and ESE capabilities must be applied in combination to achieve success.

Basic Tenets in ESE Practice

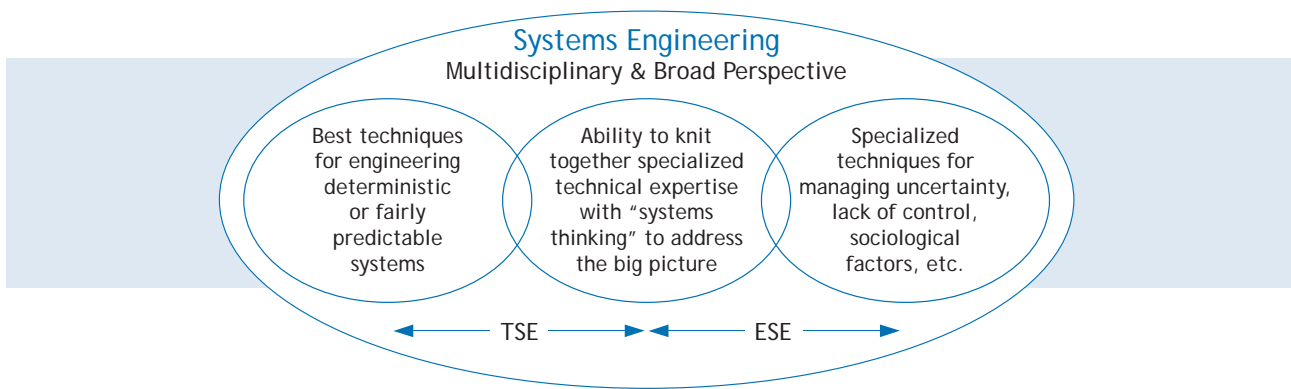
Systems thinking. Seeing wholes, interrelationships, and patterns of change.

Context awareness. Being mindful of the political, operational, economic, and technical influences and constraints.

Accepting uncertainty. Acknowledging that some problems cannot be solved by prescriptive or closed-form methods.

Complex systems evolution. Drawing from the fundamental principles in the sciences of evolution, ecology, and adaptation, e.g., considering variety, self-organization and selection.

Matching practice to the problem. Knowing when and under what circumstances to apply prescriptive methods and when to apply complex systems principles and associated practices.



TSE and ESE Domains of Systems Engineering