SEPO COLLABORATIONS

Inside Knowledge for MITRE's Systems Engineering Community

Systems Engineering@MITRE

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Systems engineering has been at the core of our work since MITRE was formed in 1958. In this role, we are active in the early stages of planning for a government system as well as those activities associated with the development and upgrade of systems. Our role is reflected in the kind of systems engineering that we do. MITRE partners with government sponsors to apply systems engineering and life cycle support to their critical operational missions.

This issue of *Collaborations* contains some of MITRE's views of systems engineering and of what makes a good systems engineer. With emerging changes in technology and the growing requirement for global or enterprise systems of systems, there have been new challenges for systems engineering.

In *Collaborations'* next issue, we will discuss some of the innovative approaches we are exploring to meet those challenges.

MITRE Views of Systems Engineering

Every systems engineering organization probably has its own definition of systems engineering.

In 2000, MITRE's president, Marty Faga, said that the scope of systems engineering

> *involves all aspects of large-scale systems: technical, economic, as well as political, social, and environmental.*

In 2004, Jim Hill, MITRE director of systems engineering in the Air Force Center, said:

> *Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle …integrates all the disciplines and specialty groups into a team effort, forming a structured development process that proceeds from concept to production to operation.*

In a paper entitled *System Architecture and System-of-Systems*, John Jacobs, a former MITRE senior vice president, wrote:

> *The system-of-systems planner's effectiveness depends on his ability to control the development of the infrastructure elements, standards and guidelines, and to modify them as necessary so as to assure effective evolution. This is very difficult, because it involves political, sociological, economic, operational and other problems in the trade-off between the new elements and the sunk costs in the old elements.*
>
> *One of the serious problems in bounding the system-of-systems design problem is to define all of the elements over which the designer can exert control. It is important to limit the number of elements controlled within the scope of the resources available to control them.*

Although most systems engineers would agree with Jacobs' words, few would recognize that they were written in 1976.

Examples of MITRE systems engineering work across the Centers:

Coast Guard Enterprise Architecture Program

In 2002, the United States Coast Guard (USCG) called on MITRE to establish its Enterprise Architecture (EA) program. The program supports enterprise-level decisions and investments to achieve maritime domain awareness and enable more effective and integrated mission operations.

Working in partnership, the Coast Guard/MITRE team established the overall roadmap, principles, and governance approach for the EA program. Key EA results include the "As-Is" architecture for Coast Guard mission areas, concepts of operation and an architecture for all command centers, and a Technical Reference Model to guide technical solutions and standards. EA information is stored in a repository tool and plans have been prepared for integration with the Coast Guard's Web portal.

During architecture development, the team identified key gaps and needed capabilities. We also reviewed the Coast Guard's modernization program plans and resource proposals to determine whether they address these gaps and needs, and how well the plans are coordinated and integrated across programs.

Developing and applying the EA have required substantial coordination of architecture and planning activities across the Coast Guard, including two major modernization programs recently initiated—Deepwater and Rescue 21—and the EA efforts of the Department of Homeland Security.

CENTER FOR ENTERPRISE MODERNIZATION

For more information, contact Bruce Miller (brucem@mitre.org, 703-883-3736).

USMC Battlespace Management Air Defense System Engineering

MITRE's United States Marine Corps (USMC) air and missile defense team delivers high impact, objective technical analyses and solutions that significantly contribute to the operational effectiveness of the USMC Battlespace Management Air Defense Systems. The team provides the USMC with critical solutions across the spectrum of command and control challenges. These solutions range across concept development and requirements analysis for legacy and new sensors, solving challenging sensor registration, external cueing, correlation, and track filtering problems for legacy systems through innovative algorithm development; and providing key technical support to weapons systems in development.

Combining extensive investigation of test data with broad and deep knowledge of system capabilities, the team provided the Marines with a profile of end-to-end air defense performance. The other Services involved in Joint interoperability systems engineering are being encouraged to emulate this model.

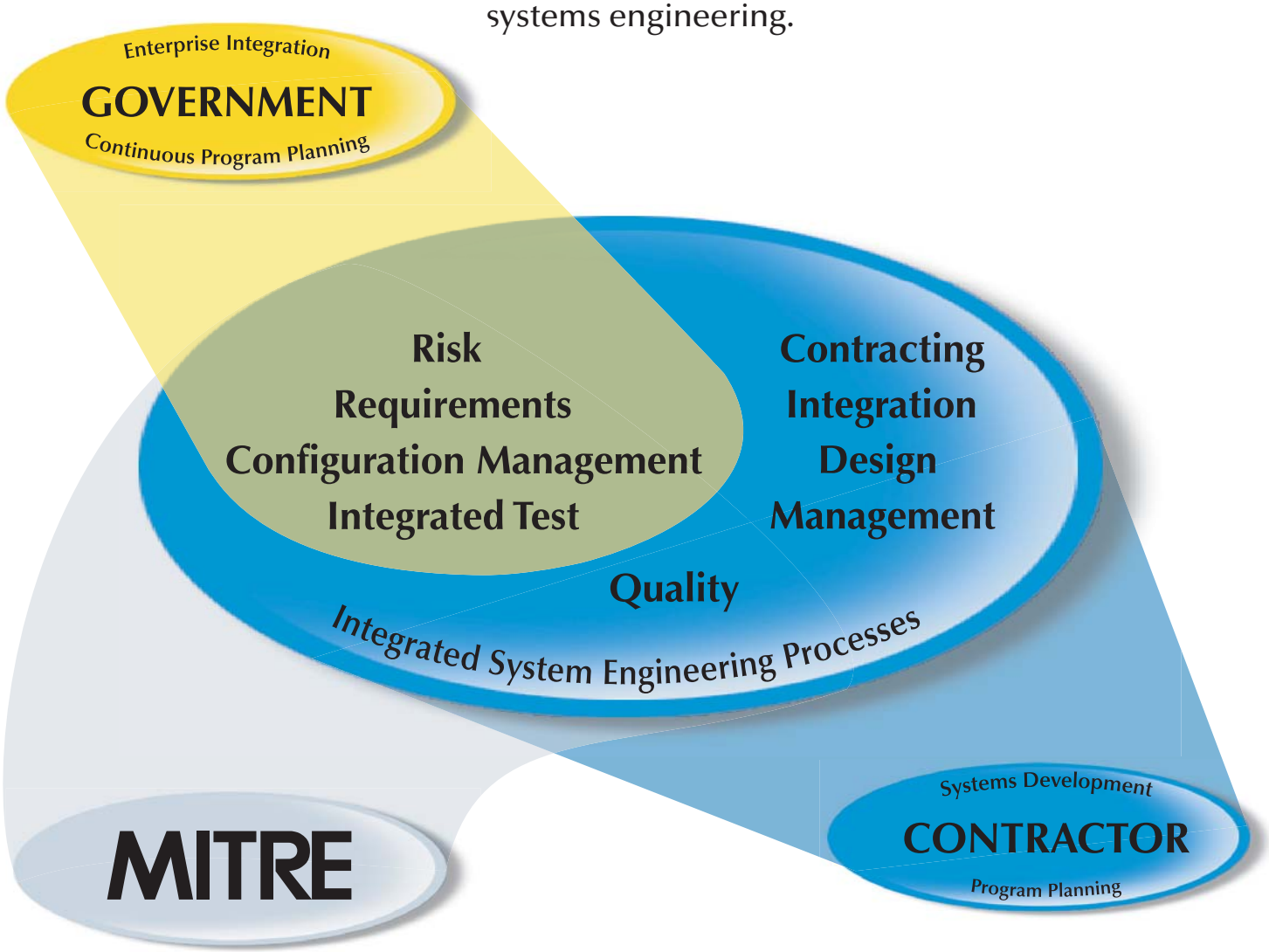
The Marines count on MITRE's systems engineering team to ensure proper design and employment of the system, and to identify problem areas and new ways to make the system better. The team provides the Marines with timely, thorough, and unbiased modeling, analysis, and technology assessments.

CIIS
Center for Integrated Intelligence Systems

For more information, contact Alexander Brofos (ambrofos@mitre.org, 781-271-7503).

Systems Engineering Is a Partnership

As this illustration shows, many basic systems engineering processes are done by both the government (as the buyer, user, and sustainer) and industry contractors (as the developers). This partnership and collaboration with all the other stakeholders are essential to systems engineering.



MITRE helps meld the Government and the Contractor processes into a stronger partnership.

A successful systems engineer:

Lives with the Past,

Deals with the Present,

and Knows the Future …

Predicting Future Requirements with Experimentation

Systems engineering begins and ends with the capabilities that are delivered to the operational user. Requirements for deploying enhanced capabilities often evolve from experiments that try out new operational concepts and new technologies. Since 1998, MITRE has participated in the Joint Expeditionary Force Experiment, better known as JEFX. Sponsored by the Chief of Staff of the Air Force (CSAF), JEFX is a series of highly-focused multi-dimensional experiments. JEFX participants include Air Force and other Service operators, coalition partners, industry representatives, technologists, and systems engineers who collaborate to develop and conduct experiments and evaluate results.

MITRE

Center for Air Force Command and Control Systems

JEFX is now conducted biannually, with the latest planned for this year. Each experiment has a specific focus. JEFX 2002 explored advanced processes to improve time-critical targeting, intelligence, surveillance, and reconnaissance management and Combined Aerospace Operations Center (CAOC) operations. JEFX 2004 will focus on Battle Management Command and Control with emphasis on air and space integration, Predictive Battlespace Awareness, and Effects-Based Operations. MITRE systems engineers have contributed to JEFX by designing and integrating new systems, testing procedures, providing training, and participating in the experiments. Many of the lessons from prior JEFX experiments have already been applied to support the warfighter in the field.

For more information, contact Carmen Corsetti (corsetti@mitre.org, 781-377-8417).

Transforming the Pentagon's Network Infrastructure

MITRE is providing systems research, analysis, planning, and engineering support to the Pentagon Renovation and Construction Program (PENREN/C) Information Technology (IT) efforts. Our support encompasses the life cycle of selected Command, Control, Communications, Computers, and Intelligence (C4I) systems, and we are instrumental in providing PENREN/C technical support in the areas of Department of Defense (DoD) engineering acquisition support, integrated systems engineering, architecture development, independent design assessments, system migrations and modernization, and the business process reengineering that is associated with changing technologies and DoD Transformation.

C3

Command, Control, Communication Center

MITRE representatives are working with an integrated products team to ensure the survivability of networks, data storage, and voice and messaging systems at the Pentagon and other U.S. military facilities. MITRE's job is making certain that the solutions the team devises fit with the rest of the IT infrastructure, much of which has been upgraded since 9/11.

Our involvement cuts across many areas. In addition to integration, cost analysis, and program control support, MITRE also has a major impact on the security of the system by helping to ensure that the appropriate elements for keeping the network secure are in place. We coordinate the activities of engineers, government representatives, and vendors to ensure that an IT system–parts of which will be relocated outside the Pentagon–functions seamlessly.

For more information, contact Keith Reck (kreck@mitre.org, 703-883-7450).

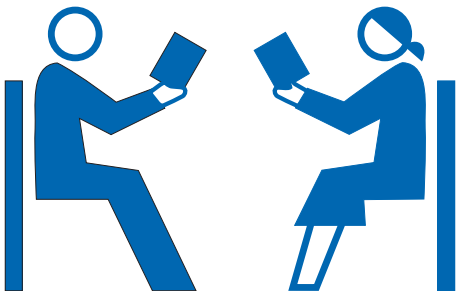
SEPO Library: A Resource That Makes Difference

The Systems Engineering Process Office (SEPO) Library is a central exchange for acquisition, systems, and software engineering process information. This information includes guidance documents developed by the SEPO staff and a host of MITRE contributors.

Also included is information from external sources (industry, government organizations, standards organizations, and professional societies) and links to external Web sites with information that can be used as reference material.

The taxonomy is separated into eight major areas:

- Acquisition Management
- Architectures
- Core Systems Engineering Processes
- Decision Support
- Systems Development
- Software Engineering
- Systems Engineering Support
- Systems Engineering



Our Web sites include an archive of SEPO's newsletter, *Collaborations*. Each issue offers insights into one important aspect of systems engineering. Previous issues include such topics as:

- Prototyping
- Configuration Management
- Decision Support
- Requirements
- Risk Management
- Working With the Customer

Some of the information on our internal Web site (Fast Jump: SEPO) is restricted to MITRE and government use. What we can share with the public is available on our public Web site at http://www.mitre.org/work/sepo/.

What's Next ...

For many of today's enterprise-wide or global systems, traditional systems engineering practices are not enough.

What if the requirements are uncertain and the cause-and-effect relationships among the interacting participants are too complex or not obvious enough to predict system behavior?

What if the system behavior itself changes over time as a result of interactions by participants? Add to these difficulties the large number of stakeholders whose interests must be recognized and whose constraints must be respected.

In the next issue of *Collaborations,* we will present some of the new directions in systems engineering we are exploring to meet these challenges.

The ideal systems engineer

- is technically strong
- embraces new and diverse technical topics
- learns new technologies and integrates them into programs
- understands the "big picture" but can drill down to the appropriate level of technical detail
- is operationally savvy in the system or systems domain
- understands the customer's mission and operation
- grasps the business viewpoint, always keeping cost, utility, and alternative methods in mind

Systems Engineering Lessons Learned

Some important lessons are apparent in MITRE's definitions of systems engineering, and we have learned others from our experiences in this type of work.

- Systems engineering is not limited to technical engineering. Economic, organizational, political, social, and environmental factors must also be recognized and considered.
- The systems engineer cannot control all these (often external) factors and constraints in devising engineering solutions.
- Successful systems engineering requires a team effort involving multiple disciplines and multiple stakeholders with different points of view, expertise, and requirements.
- Systems engineering begins early with a system concept and continues throughout the life of a system.
- Change is inevitable, whether because of changing requirements or changes in technology.
- All design decisions must allow for adaptation and change over time.
- Architecture is the place to start building flexibility for change.
- Spiral and evolutionary acquisition strategies are ways to insert change into a system.
- For most new systems and capabilities, the systems engineer must take legacy systems into account, weighing the tradeoffs between interfacing with the legacy systems (making evolutionary changes) or replacing legacy systems (making revolutionary changes).

Large-Scale or Small-Scale Systems – It's All the Same

Good systems engineering practices are critical at both the macro (system of systems) level and the micro (system) level. All systems require an understanding of the disciplines that make up the system.

As an example, David Roth, in *A Systems Engineering Discussion Regarding Software Radios*, explains what it takes to work on software radios.

An engineer must have expertise in communications theory, radio engineering, digital signal processing, hardware design, software design, mechanical engineering, and systems engineering. Also, he or she must provide the flexibility to cost effectively upgrade systems.

This is a publication of the MITRE Systems Engineering Process Office (SEPO).
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