Systems of Systems and Interoperability

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Brief INCOSE Overview

The International Council on Systems Engineering (INCOSE) is a not-for-profit membership organization founded to develop and disseminate the transdisciplinary principles and practices that enable the realization of successful systems.

Vision
- A better world through a systems approach.

Mission
- To address complex societal and technical challenges by enabling, promoting, and advancing systems engineering and systems approaches.

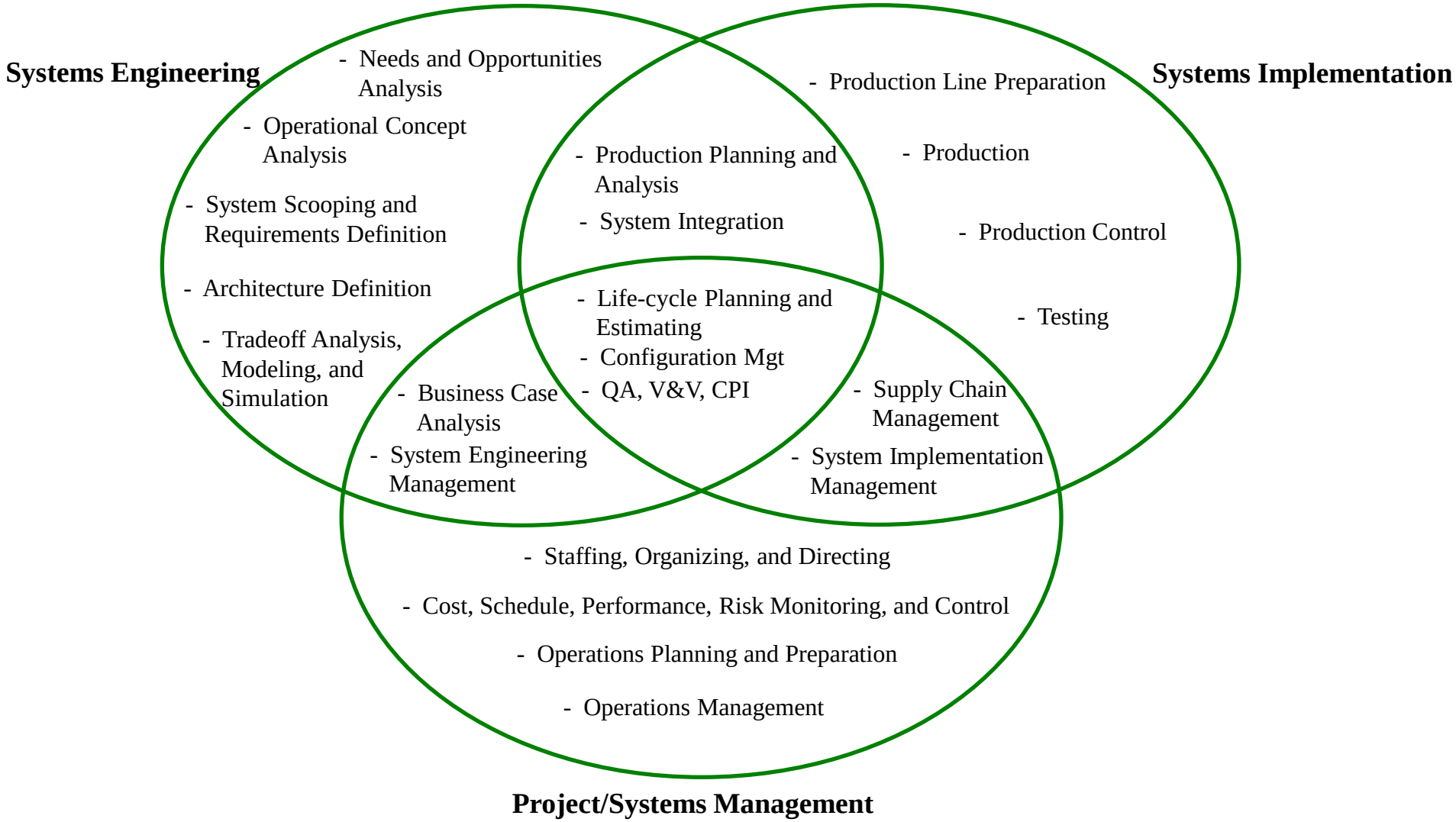
Goals
- To provide a focal point for dissemination of systems engineering knowledge.
- To promote international collaboration in systems engineering practice, education, and research.
- To assure the establishment of competitive, scale-able professional standards in the practice of systems engineering.
- To improve the professional status of all persons engaged in the practice of systems engineering.
- To encourage governmental and industrial support for research and educational programs that will improve the systems engineering process and its practice.

INCOSE has grown significantly since its formation in 1990 with a membership >19,000 that represents a broad spectrum – from student to senior practitioner, from technical engineer to program and corporate management, from science and engineering to business development.

INCOSE Website

INCOSE-What is Systems of Systems Engineering?

A system of systems (SoS) is a collection of systems, each capable of independent operation, that are interoperable to achieve additional desired overall system success. The following example shows an Enterprise SoS. [JCIDS]



INCOSE-Definition of Systems of Systems

- A “system of systems” (SoS) is a System of Interest (SOI) whose elements are managerially and/or operationally independent systems.
  - These interoperable and/or integrated collections of constituent systems usually produce results unachievable by the individual systems alone.
  - Because an SoS is itself a system, the systems engineer may choose whether to address it as either a system or as an SoS, depending on which perspective is better suited to a particular problem.
  - The following characteristics can be useful when deciding if a particular SOI can better be understood as an SoS (Maier, 1998):
    - Operational independence of constituent systems
    - Managerial independence of constituent systems
    - Geographical distribution
    - Emergent behavior
    - Evolutionary development processes
- System-of-systems applies to a system-of-interest whose system elements are themselves systems; typically these entail large scale inter-disciplinary problems with multiple, heterogeneous, distributed systems (INCOSE SEH V4.0 Appx C & V3.2.2 Appx D).

INCOSE-Systems Engineering Body of Knowledge Defines Interoperability

(1) *Degree to which two or more systems, products or components can exchange information and use the information that has been exchanged.* (ISO/IEC 2009)

(2) *The ability for two or more Object Request Brokers to cooperate to deliver requests to the proper object.* (ISO/IEC 2003)

(3) *The capability to communicate, execute programs, and transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.* (ISO/IEC 1993)

- **Source**

(1) ISO/IEC/IEEE. 2009. Systems and Software Engineering - System and Software Engineering Vocabulary (SEVocab). Geneva, Switzerland: International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC)/ Institute of Electrical and Electronics Engineers (IEEE). ISO/IEC/IEEE 24765:2009.

(2) ISO/IEC. 2003. *Information technology -- Open Distributed Processing -- Part 2: General Inter-ORB Protocol (GIOP)/Internet Inter-ORB Protocol (IIOP), 3.2.19*. Geneva, Switzerland: International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC), ISO/IEC 19500-2:2003.

(3) ISO/IEC. 1993. Information technology--Vocabulary--Part 1: Fundamental terms. Geneva, Switzerland: International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC), ISO/IEC 2382-1:1993.

INCOSE-Interoperability Is the Key to SoS Success

- Interoperability depends on the compatibility of elements of large and complex systems to work as a single entity.
  - This feature is increasingly important as the size and complexity of systems continue to grow.
    - Pushed by a trend toward ever faster electronic digital systems and
    - Pulled by the accelerating pace of digital technology development, commercial firms and national organizations span the world in increasing numbers.
  - As their spans increase, these commercial and national organizations want to ensure that their investment in legacy elements is protected and that new systems added over time will work seamlessly with the legacy systems to form a system of systems.

INCOSE-Standards Are the Key to Interoperability Success

- Standards have also grown in number and complexity over time, yet compliance with standards remains one of the keys to interoperability.
  - The standards that correspond to the layers of the ISO-OSI Reference Model for peer-to-peer communication systems have grown tremendously in recent years.
    - Currently, it is difficult to identify the number of standards that apply to the global communications network.
    - Interoperability increases in importance as the world becomes better connected due to:
      - Ever expanding communications networks.
      - Nations continue to perceive the need to communicate seamlessly across international business and military coalitions.

Suggested Levels of Interoperability

Level 1. Initial - Isolated interoperability in a manual environment among stand-alone systems. Usually requires manual extraction and integration of data from multiple systems (“sneaker-net”).

Level 2. Managed - Connected interoperability in a peer-to-peer type environment. Relies on electronic links with simple electronic data exchange. Consists of shared, simple data types, such as voice, text email, and graphics. Scarce fused information.

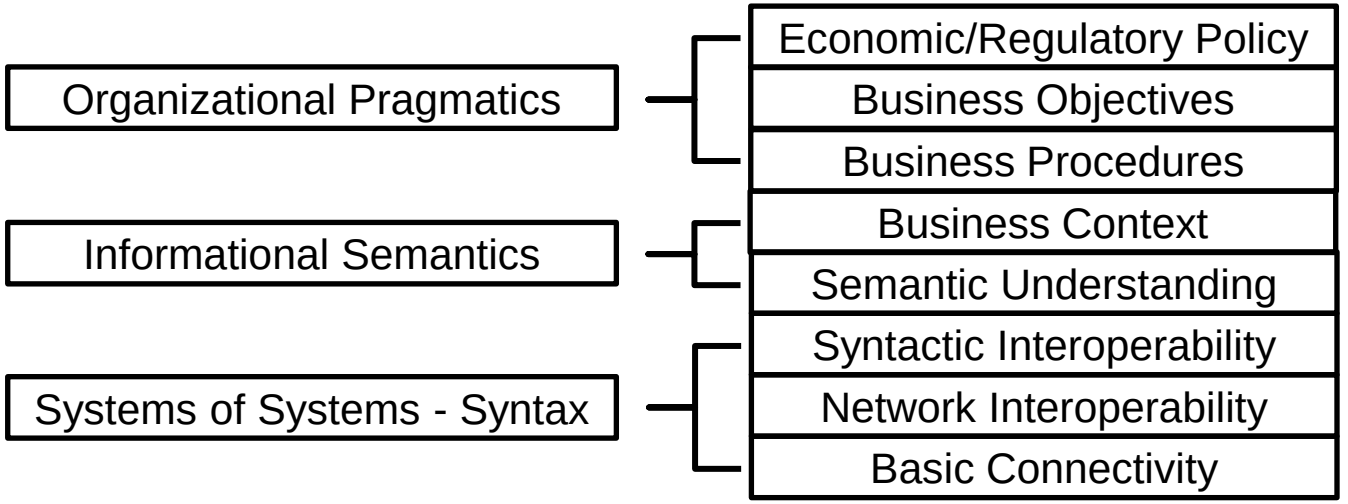
Level 3. Defined - Functional interoperability in a distributed environment. Systems reside on local area networks that allow data to be passed from system to system in increasingly complex media exchanges. Data contains fused information from simple formats.

Level 4. Planned - Domain based interoperability in an integrated environment. Systems are connected via wide area networks. Information is exchanged between independent applications using shared, domain-based data models. Enables common business rules and processes to execute mutually agreed services.

Level 5. Optimized - Enterprise-based interoperability in a universal environment. Systems are capable of using a common information space across multiple domains. Multiple users can access complex data simultaneously. Data and applications are fully distributed and shared. Data has a common interpretation and application.

Achieving Organizational Interoperability

Organizational stakeholders must work in unison at each level of system implementation to achieve an interoperable system of systems.



Derived from the GridWise® Architecture Council IMM

Conclusions and Improvement Areas

- A barrier to interoperability is the lack of coordinated ownership of the problem.
- Shortsighted decisions and lack of requirement decomposition promotes a single system’s view at the expense of other systems.
- Consistent and detailed structures for enforcing interoperability are required for program success (use standards).
- Standards-based interoperability eliminates the barriers associated with proprietary applications and ecosystems.
- The OIIE and ISO 18101 provide a neutral industrial digital ecosystem for which allows existing applications and systems to be included via adaptors.