Systems, Systems Engineering, and INCOSE:

A Five Minute 50,000 Foot Overview

A "Primer" Prepared for the Attendees of the INCOSE Biomedical and Healthcare MBSE Challenge Team Workshop Breakout Sessions at the 2015 INCOSE International Workshop (IW)

Torrance, CA

January 24-25, 2015

Contents

- What is a system?
- What is systems thinking?
- What engineering?
- What is systems engineering?
- What is INCOSE?

What is a System?

- A system is a group of interacting, interrelated, or interdependent elements forming a complex whole. For example …..
  - An organism as a whole, especially with regard to its vital processes or functions
  - A group of physiologically or anatomically related organs or parts
  - A group of interacting mechanical, or electrical components
  - A network of structures and channels, as for communication, travel, or distribution
  - A network of related computer, software, hardware, and data transmission devices
  - An organization of people (individuals, groups), physical assets, goals, objectives, and operating standards (policies, procedures, rules) interacting to accomplish a common mission, purpose, or aim
- A system may be (a) naturally occurring, (b) formed (evolved) over time in a more or less haphazard or unplanned manner, (c) intentionally designed (engineered), or (d) created through a combination of any two, or all three, of the above.
- In general, physical systems can be described (i.e., modeled) in terms of their specific structure, behavior, and interconnectivity.

What is a System?

- System Related Concepts
  - System-of-Interest : This is "*the* system" of concern to those who have a stake or interest in it. Ideally, it is uniquely named, unambiguously described, and to the extent possible, universally and accurately understood in the same way by all of the parties (individuals, groups, organizations) involved.
  - System Life Cycle Stages: Conceptualization, Specification, Design (and Redesign), Construction/Integration/Test, Use, Retirement/Deconstruction/Disposal.
  - Other Important System Concepts/Terms: System boundaries, system context, open system, closed system, system-of-systems, subsystems, components, internal interfaces, external interfaces, inputs, outputs, emergent properties, outcomes, effects, unintended consequences, purpose, function, system performance , etc.
- Common Misconceptions/Assumptions
  - Everyone understands (sees, visualizes, interprets) the system in the same way when and if it has been fully and accurately described (documented, modeled, etc.) and subsequently "made available" and "communicated" to all.
  - Whenever I say or write the name of "the system" that I have in my mind, the person (or persons) on the receiving end of my "communication" instantly calls up from their memory banks a mental model of the system that exactly matches my mental model of the "the system," so there is no need to verify common understanding.
  - Variation in mental models associated with the naming, terminology, symbols, and images used in the description, development, analysis, operation, use, and improvement of a system is not important and requires little attention or effort.
- Clarification
  - Communication regarding "the system" is extremely important, and very challenging!

What is Systems Thinking?

- Systems thinking is the *process* of *understanding* how things, regarded as systems and components of systems, influence one another within a whole.
  - Systems thinking has its roots in the *General Systems Theory* as advanced by Ludwig von Bertalanffy in the 1940s.
  - In *Systems Science* it is argued that systems thinking is the only way to *fully understand* why a problem or element occurs or persists, and what all of the potential causes and effects of a problem or element behavior are.
- Thus systems thinking provides a very powerful approach to problem analysis that gives analysts the ability to view problems within the context of an overall system, and thereby better identify and prevent unintended negative consequences of proposed solutions (changes). Well-designed system models can enhance systems thinking, and are therefore an essential aid in the analysis of very complex systems.

What is Engineering?

- Engineering
  - "The application of science for the betterment of humankind."
  - The Scientific Method:
    - Ask a Question, Conduct Research, Construct a Hypothesis, Test the Hypothesis with an Experiment, Analyze Results, Draw a Conclusion
  - The Engineering Method:
    - Define the Problem, Conduct Research, Specify Requirements, Generate and Evaluate Solutions Options, Design and Develop the Solution, Verify that the Designed Solution Meets Requirements, Validate that the Solution Solves the Problem
- Common Misconceptions/Assumptions
  - Engineering and science are essentially or nearly the same thing
  - Engineering is a freeform "trial-and-error" invention process
  - Engineering is based primarily on the application of the Scientific Method.
- Clarification:
  - Engineering involves the use of both heuristics (rules of thumb) and science to meet needs and solve problems, using the Engineering Method.
  - E.g., an important engineering heuristic is: "Use the scientific method only when necessary." (i.e., don't study something you don't need to).
  - A Famous Quotation: "Scientists investigate that which already is; Engineers create that which has never been." *Albert Einstein*.

What is Systems Engineering?

- "Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focusses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal. Systems Engineering (SE) considers both the business and technical needs of all customers with the goal of providing a quality product that meets the user needs." – INCOSE
- Common Misconception/Assumption
  - Systems Engineering (SE) is a narrow branch of engineering associated with computers, software, and information technology (IT).
- Clarification
  - SE is a very broad , overarching, and generally applicable engineering discipline. For example, SE includes activities, knowledge, and skills associated with supply chain management and acquisition, project and risk management, consumer research, human resources management, and information and infrastructure management.
  - Many types of systems are developed using SE. These include biomedical systems, space vehicle systems, weapon systems, transportation systems, and so on.
  - SE involves the coordination of work performed by engineers from all other engineering disciplines (electrical, mechanical, biomedical, computer, software, etc.) as required to complete the engineering work on the project/program.

What is INCOSE?

- The International Council on Systems Engineering (INCOSE) is a not-for-profit membership organization founded to develop and disseminate the interdisciplinary principles and practices that enable the realization of successful systems.
- INCOSE was founded 25 years ago (1990), and has nearly 10,000 members worldwide.
- INCOSE's mission is to share, promote, and advance the best of systems engineering from across the globe for the benefit of humanity and the planet.
- See the "INCOSE Systems Engineering Handbook: A Guide for Systems Life Cycle Processes and Activities" for more information about Systems Engineering, and visit www.incose.org for more information about INCOSE.