INCOSE Certification for Systems Engineers
&
Systems Engineering: Fundamental Maxims

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Sysnovation, LLC
13741 Johnson Memorial Drive
Shakopee, MN 55379 USA
www.sysnovation.com

David D. Walden, ESEP
Voice: +1-952-807-1388
Email: Dave@sysnovation.com

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Current Author Contact Information:
David D. Walden, ESEP
Sysnovation, LLC
13741 Johnson Memorial Drive
Shakopee, MN 55379 USA
Voice: +1-952-807-1388
Email: Dave@sysnovation.com
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Topics

- Systems Engineering Certification
- Systems Engineering Maxims
- Wrap Up and Conclusions

Formal Definitions of a System

- International Council on Systems Engineering (INCOSE):
  - An **integrated set** of **elements** that accomplish a **defined objective**. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support elements.
- ISO/IEC Standard 15288:2008
  - A **combination** of **interacting elements** organized to achieve one or more **stated purposes**
- Government Electronics & Information Technology Association (GEIA) Standard ANSI/EIA-632-1999
  - An **aggregation** of **end products** and **enabling products** to achieve a **given purpose**.
- Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE 1220-2005:
  - A **set or arrangement** of **elements** [people, products (hardware and software), and **processes** (facilities, equipment, material, and procedures)] that are **related**, and whose behavior **satisfies operational needs** and provides for the **life cycle sustainment** of the products.

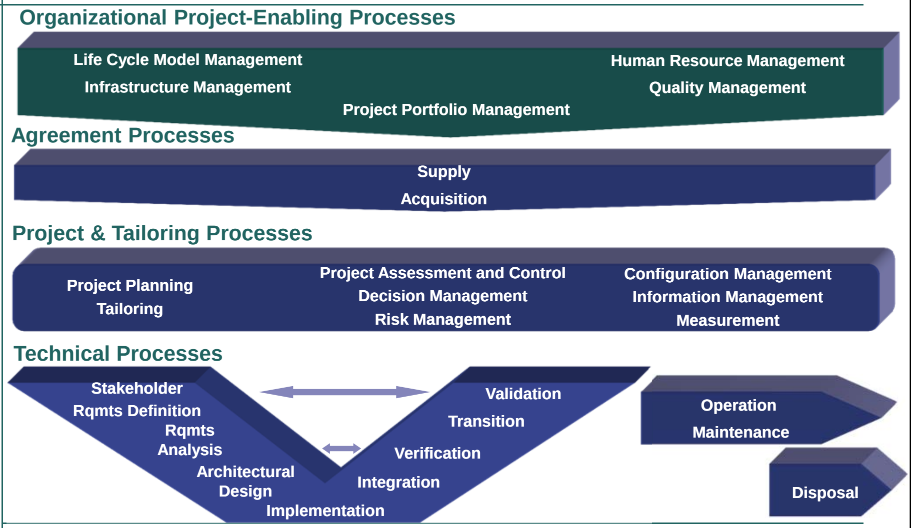
Sources as indicated

Formal Definitions of Systems Engineering

- International Council on Systems Engineering (INCOSE):
  - Systems engineering is an **interdisciplinary approach and means** to enable the **realization** of successful systems.
- Software Engineering Institute (SEI) Capability Maturity Model Integration (CMMI):
  - The **interdisciplinary approach** governing the total **technical** and **managerial** effort required to **transform** a set of customer needs, expectations, and constraints into a product solution and **support** that solution throughout the product's **life cycle**.
- Kossiakoff & Sweet:
  - The function of systems engineering is **guide the engineering** of complex systems.
- Blanchard & Fabrycky:
  - Basically, systems engineering is **good engineering** with special areas of emphasis (**top-down approach**, **life-cycle orientation**, **definition of system requirements**, and an **interdisciplinary or team approach**).

SYSNOVATION *SE Maxims* Sources as indicated 5

Another way to define Systems Engineering is by its underlying processes.



SYSNOVATION *SE Maxims* 6 Adapted from ISO/IEC 15288:2008

Maxim

- n. 1 : a general truth, fundamental principle, or rule of conduct 2 : a saying of proverbial nature

SYSNOVATION SE Maxims Source: Webster's Collegiate Dictionary 7

Fundamental Systems Engineering Maxims

1. Systems engineering **focuses on the whole**
2. Every system has a **life cycle**
3. Systems have **boundaries, interfaces, and hierarchies**
4. System **form** follows **function** follows **purpose**
5. A balanced system solution requires **trade-offs**
6. All systems have **risks** that must be managed
7. Following a **Systems Engineering process** increases your probability of success

These seven fundamental maxims permeate all aspects of the disciple of Systems Engineering.

SYSNOVATION SE Maxims 8

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Systems Engineering Focuses on the System as a Whole

- Systems Engineering has its roots in Cybernetics and General Systems Theory
- Fundamental concepts leveraged include:
  - Holistic view
  - Understanding relationships
  - Emergent properties

A goal of Systems Engineering is to maximize positive emergent properties while minimizing negative emergent properties.

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Every system has a life cycle

- Many life cycle models exist:
  - Firms used to be concerned only with development and production, in that order
  - Then came "cradle to grave" life cycles
  - Now we have "lust to dust" life cycles

Systems Engineering leverages the concept of life cycles to ensure all aspects of the system, from concept through disposal, are considered.

Example Life Cycle Stages

Stage	Purpose
Concept	Capture the stakeholders' requirements Define alternative concepts
Development	Refine system requirements Architect the system solution Build the system Verify and validate system
Production	Produce systems Inspect and test
Utilization	Operate system to satisfy users' needs
Support	Provide sustained system capability
Retirement	Store, archive, or dispose of the system

Adapted from ISO/IEC 15288:2002

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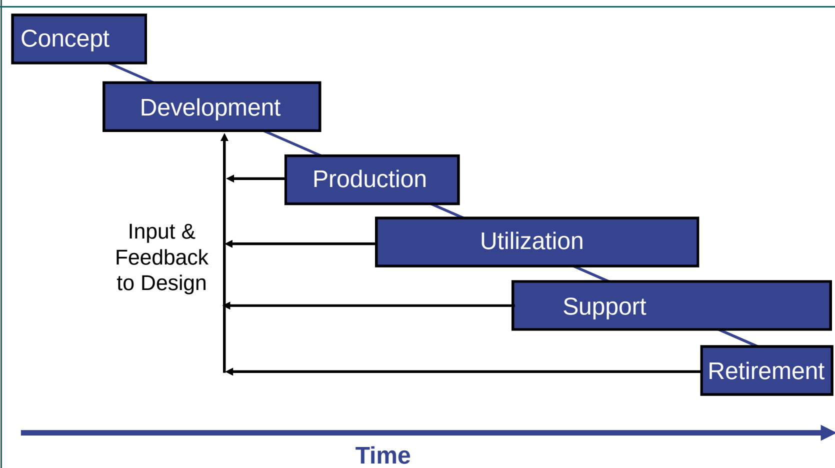
Life Cycle Thinking Creates Better Systems



"Think about the end before the beginning."

Adapted from ISO/IEC 15288:2002
Quote form ΩA, the Systems Engineering Honor Society

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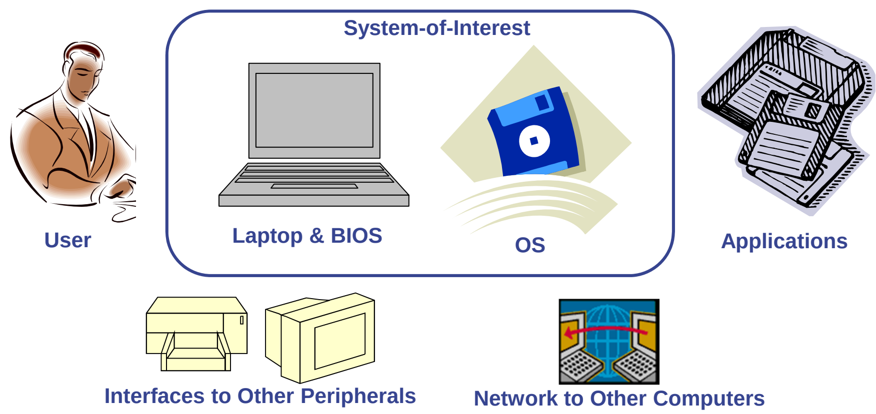
Systems Have Boundaries

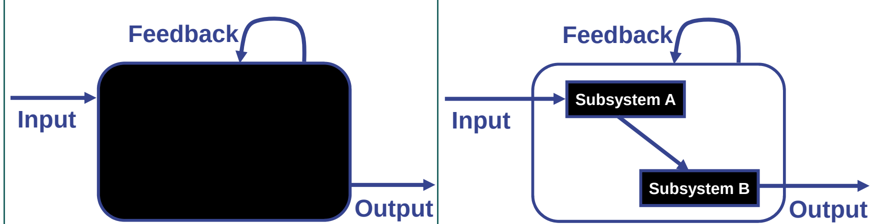


System boundary definition is one of the key tasks of Systems Engineering -- what is in/not in of the system-of-interest.

SE Maxims 16

Systems Have Interfaces

- External Interfaces
  - Go across the system boundary
  - Treat the system as a “Black Box”
- Internal Interfaces
  - Within the system boundary
  - Treat the system as a “White Box”



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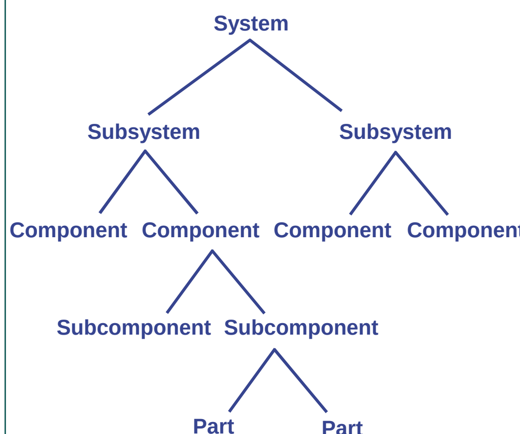
Systems Have Hierarchies

- Systems can be organized in a hierarchical manner
- A system hierarchy is a tree structure used to describe the system as consisting of its elements
- A system is designed from
  - system
  - to subsystems
  - to components
  - to subcomponents
  - to parts
- A system is integrated in the reverse order



SYSNOVATION *SE Maxims* Adapted from Kossiakoff & Sweet, 2003 18

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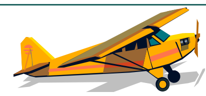
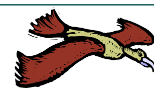
Form Follows Function Follows Purpose (Not Vice Versa)

- Purpose
  - Why the system is being realized
  - Defined by a Concept of Operations (CONOPS) and a set of Stakeholder Requirements
- Function
  - What the system must do
  - Defined by a Logical (or Functional) Architecture and a set of System Requirements
- Form
  - How the system does it
  - Defined by a Physical Architecture and a set of Component Requirements

Function vs. Form





Function	Airplane Physical Component	Bird Physical Component
Take off & land	Wheels, skis, or pontoons	Legs
Sense position & velocity	Navigation, air data, radar	Eyes
Navigate	Computer	Brain
Produce horizontal thrust	Engine	Wings
Produce vertical lift	Wings	Wings

Adapted from University of Minnesota CCE On-Line SE Principles Course

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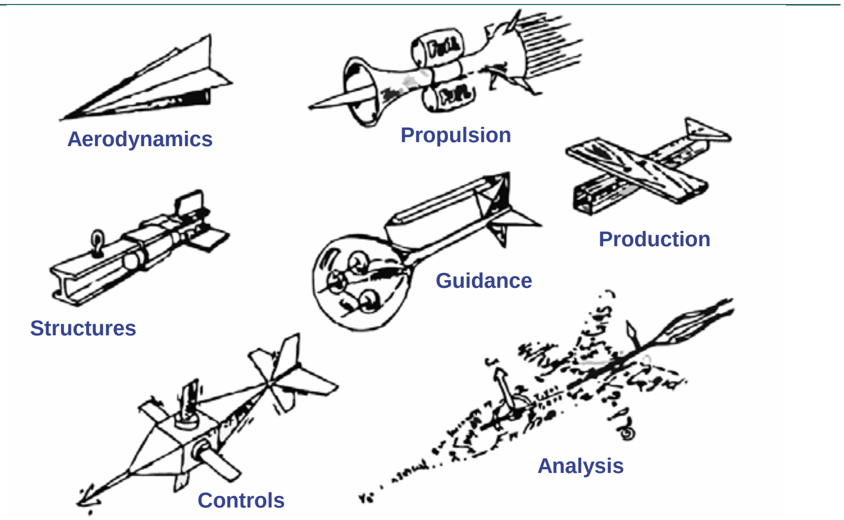
Systems Engineering has to Trade-off all of the Competing Interests and Perspectives so the best Balanced Solution can be Realized



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Systems Engineering is About Making Tough Decisions (and Sticking to Them)

- It is typically the Systems Engineers upon whom the difficult decisions fall
  - A system can only be optimized by addressing it as a whole
  - If any component of the system is optimized, then the overall system will not be optimized
- Systems Engineers use trade-off analyses to help with the decision making process

Good rule of thumb – if all the specialists aren't at least a little bit annoyed, it is likely the Systems Engineers did not do their job.

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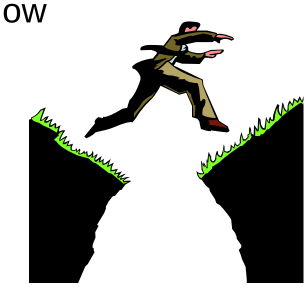
All Systems have Risks that Must be Managed

Unless you have...

- Technical goals that are very low
- An infinite schedule
- Unlimited budgets
- No enemies

… then you have risks!



All projects of significance have risk. Systems Engineering recognizes this and provides the methods and tools to manage risk.

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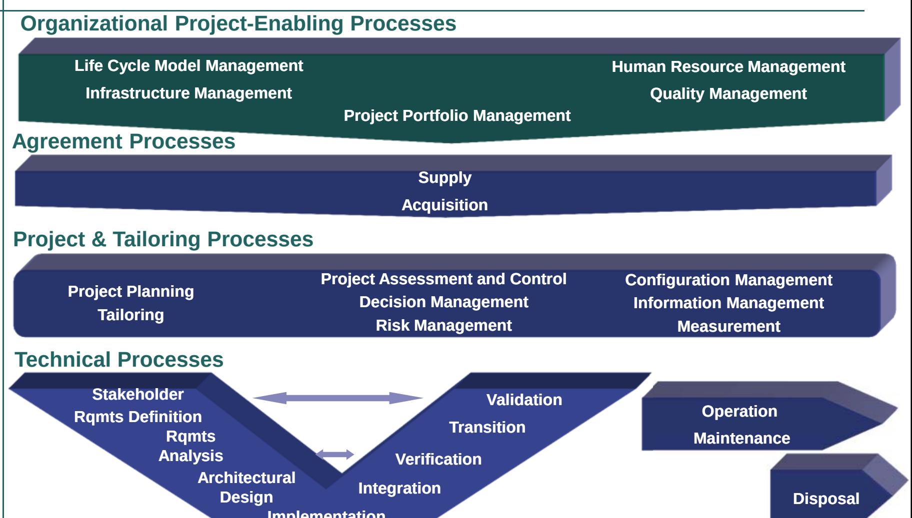
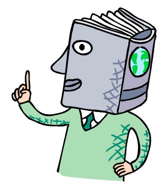
Here is one way to define the Systems Engineering Process



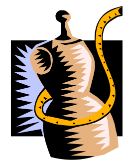
Adapted from ISO/IEC 15288:2008

Following a Systems Engineering Process Increases Your Probability of Success

- A standard process
  - Captures organizational knowledge
  - Allows for continual improvement
  - Helps avoid repeating mistakes
  - Lets you leverage industry best practices, such as external standards



- However, your standard processes must be tailored to the unique aspects of each project and system



"Not every process will apply universally."
"Reliance on process over progress will not deliver a system."
INCOSE Systems Engineering Handbook

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Why is Systems Engineering Important?

- The new business reality – ever increasing…
  - System complexity & scope
  - Rate of change & delivery/time-to-market pressures
  - Use of multi-organizational & geographically distributed teams
  - Business performance expectations
- Systems Engineering's response:
  - Systems viewpoint focusing on the whole
  - Focus on providing a balanced systems solution
  - Focus on managing risks
  - Leadership in a distributed & integrated development environment
  - Discipline to deal with complexity

Systems Engineering is, and will continue to be, a critical discriminator in the development of modern systems.

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Systemic Innovation for Business Results

COMMENTS? QUESTIONS?