Module 2:
Applied systems engineering
(an introduction)
Session 4 of 5

Before discussing 'what' to do, this module helps the student understand the current state of the discipline

Version 6.2.3

Topics

- Framing the problem
- **Systems engineering (SE) as perceived from the HTPs**
  1. *Big picture*
  2. *Continuum*
  3. *Operational*
  4. *Functional*
  5. *Structural*
  6. ***Generic***
  7. ***Temporal***
  8. ***Quantitative***
  9. *Scientific*

Generic perspective

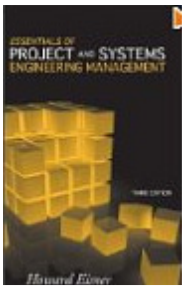
- What is systems engineering similar to?
  - Mathematics
  - Project management
  - Other disciplines
- Early stages of disciplines
  - Myths and defects
- Frameworks in other disciplines

Systems engineering is similar to Math

- Mathematics
  - A set of mathematical tools for remedying mathematical problems
    - Used in all disciplines
    - **Structured as pure and applied mathematics**
- Systems engineering – the activity (SETA)
  - A set of problem-solving tools for remedying complex problems
    - Deal with parts and their interactions as a whole
    - Used in all disciplines
    - **Structured as pure and applied systems engineering?**
    - **What about domain systems engineering?**

Overlap between Project Management and SE

- Costing and scheduling: Text books for class on project management in systems engineering program
- Literature abounds with reports of overlap



Project management

- Same knowledge and skills as systems engineering
  - Roe, 1995
    - SE technical breadth
    - PM management expertise
- Activities overlap systems engineering
  - E.G. Sheard 1996, Eisner 1997
- Manages cost and schedule without managing technical content.
  - Mooz and Forsberg, 2007

Wasteful and expensive

- Defense Acquisition University's two faces of systems engineering*
  - Technical domain - processes
  - **S**ystems **E**ngineering **M**anagement
    - Overlap with **P**roject **M**anagement
- Performed in a fragmented environment (practice)
  - Fragmented by discipline
- Different disciplines perform overlapping work
  - Legislated to do so in USA
    - e.g. engineering specialties
- Produce overlapping documents that are not independent
  - Shelfware

* *Systems Engineering Fundamentals.* Defense Acquisition University Press, 2001

Early stages of a discipline

- Systems engineering is in its early stages
- A discipline in these stages is characterized by
  - Debates based on subjective opinions ✓
  - Participants talking past each other ✓
  - A lack of listening ✓
  - Contradictory and confusing information ✓
  - **A number of defects and myths** ✓

Eight deadly defects*

1. Selection of independent alternative solutions
2. The V Model
3. Lack of a standard process for planning a project
4. The Waterfall model
5. Unanswered and unasked questions
6. Lack of a metric for the goodness of Requirements
7. Focus on technological solutions not solving customer's problems
8. The need to focus on people as well as process

* **FUSE Chapter 20,** Kasser, J. E., "Eight deadly defects in systems engineering and how to fix them", *proceedings of the 17th International Symposium of the INCOSE*, San Diego, CA, 2007.

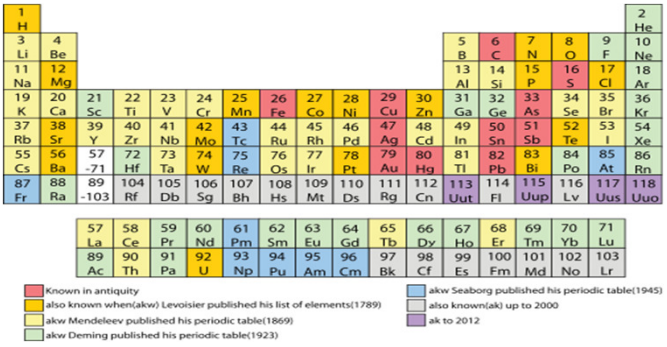
Seven systems engineering myths

- "It ain't what you don't know that gets you into trouble. It's ***what you know for sure*** that just ain't so."
  Attrib. Mark Twain 1835-1910
- Myth 1: There are Standards for systems engineering.
- Myth 2: The "V" model of the systems engineering process
- Myth 3: Follow the systems engineering process and all will be well
- Myth 4: Complexity needs new tools and techniques
- Myth 5: Systems of systems are a different class of problem and need new tools and techniques
- Myth 6: Changing requirements are a cause of project failure so get all the requirements up front.
- Myth 7: The single systems engineering process.

* **FUSE Chapter 26** Kasser, J. E., "Seven systems engineering myths and the corresponding realities", *proceedings of the Systems Engineering Test and Evaluation Conference (SETE 2010)*, Adelaide, Australia, 2010.

Framework (chemistry)

Sorted elements based on properties and left gaps in the Table



Pictures from Wikipedia Commons, March 2014

Frameworks (electrical engineering)

Ohm's law
1827
Maxwell's equations
1873

Pictures from Wikipedia commons

Temporal perspective

- History and origin
- Evolution

History and origin

"*Driven by cold war pressures to develop new military systems rapidly, **operations research**, **systems engineering**, and **project management** resulted from a growing recognition by scientists, engineers and managers that **technological systems had grown too complex for traditional methods of management and development**" **

** Johnson, S. B., *Three Approaches to Big Technology: Operations Research, Systems Engineering, and Project Management*, Technology and Culture (1997), 891-919.

In general - situation in 50's and 60's

- In the concept study design (needs identification) state
  - Single system context
  - Type IV/Vs identify real problem
  - Type III's and IV's design *both* solution system and implementation process
  - Operations research was a tool used by systems engineers
    - Note: Systems engineering was a tool used in operations research
- In the preliminary design state
  - Type II's implement solution system using implementation process
  - Most Type III+'s move on to next project
- In the rest of system life cycle
  - Type II's implement solution system using implementation process
  - Type III+ are available sometimes to help with problems that arise

Late 1960's and its legacy

- Type III, IV and V's are laid off
- Type II's are left
- Type II's write Military Standards to document what they are doing
  - Focus changes from 'problem focus' (III, IV and V) to 'document and follow the process' (II)
- Type II systems engineering is taught to the next generation and becomes "systems engineering"
  - Potential Type III, IV and V learn Type II systems engineering
  - Elimination of MIL-STD's did not change the paradigm
- Type IV/V improvements to the Type II process paradigm reaches point of diminishing returns

MBSE*

- **Model-based systems engineering (MBSE)** is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases
  - INCOSE-TP-2004-004-02, Version 2.03, September 2007

- **Operations research**, or simply **O.R.**, is the use of mathematical models, statistics and algorithms to aid in decision-making. It is most often used to analyze complex real-world systems, typically with the goal of improving or optimizing performance.
  - Wikipedia, accessed 12 January 2009

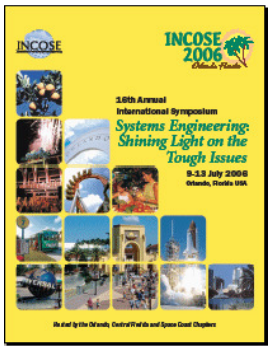
MBSE is an 'instance' (in HKM²F Layer 2) of 'class' OR – in object language

Type V's breaking the Type II mold?

* Kasser J.E., "*The Forthcoming Seldon Crisis in Systems Engineering*", Researches and Development Directions in Systems Engineering, the Gordon Center, Technion, Haifa, Israel, 2009,

Evolution is continuing

- The 16th International Symposium of the INCOSE
  - 8 - 14 July 2006
  - Orlando, Florida, USA
    - Risk Management
    - Software and Information Systems Engineering
    - Others



Evolution is continuing

- The 16th International Symposium of the INCOSE
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- The 2nd International Symposium on Management, Engineering and Informatics: MEI'06
  - 16 - 19 July 2006
  - Orlando, Florida, USA
    - Risk Management
    - Software and Information Systems Engineering
    - Others

Future?

- Model-based Systems Engineering (MBSE)
  - Reinventing Operations Research
  - A return to the 'A' paradigm using 20th century tools
  - Reading 0208
- Object Oriented Systems Engineering (OOSE)
  - Systems engineering without requirements
  - Reading 0209
- Other (if any)
  - To be determined and experienced

Why OR might replace SE

- Systems engineering is advancing up from HKM²F Layer 2 to tackle problems in Layer 3
  - Using Type II process paradigm which does not work in Layer 3
- OR has been successfully solving these problems for years
- "*Operations research is concerned with the heart of this control problem – how to make sure that the whole system works with maximum effectiveness and least cost*" (Johnson, 1954) p xi*)
- Many modern systems engineers would apply this goal to systems engineering.

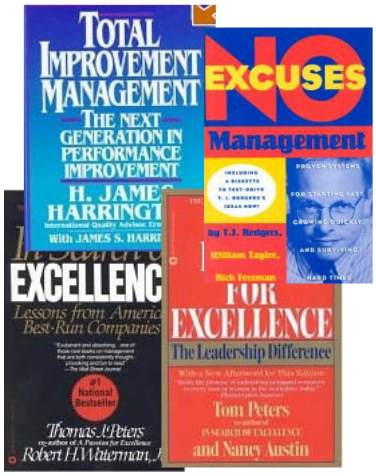
* Johnson, E. A. (1954). The Executive, the Organisation and Operations Research. Operations Research for Management, Volume 1. J. F. McCloskey and F. N. Trefethen. Baltimore, The Johns Hopkins Press.

Quantitative perspective

- Five types of systems engineers
- Costs expended over project lifecycle

The focus is on **people** not process

- Literature
  - Is full of advice as to how to make projects succeed
  - Has little if anything to say about the proliferating process standards
- Garbage-in-garbage-out



Five types of systems engineers*

- **Type V [Innovator, engineer-leader]**
  - Problem formulator and problem solver
  - Directs and performs systems engineering
- **Type IV [Problem formulator]**
  - Has the ability to examine the situation and define the problem
  - [Cannot conceptualise a solution]
- **Type III [Problem solver]**
  - Has the expertise to conceptualize the solution system and plan the implementation of the solution
- **Type II [Apprentice, doer]**
  - Has the ability to follow a process to implement a physical solution system
- **Type I [Problem causer]**
  - Has to be told "how" to so something

* Kasser, Hitchins and Huynh, 2009

Mapping abilities to Types

Ability to find similarities among objects which seem to be different (Generic perspective)	High	Problem solvers **(Type III)**	Innovators **(Type V)**
	Low	Imitators, Doers **(Type II)**	Problem formulators **(Type IV)**
		Low	High
"Ability to find" generally comes mainly from application of Generic and Continuum HTPs		**Ability to find** differences among objects which seem to be similar (Continuum perspective)	

* Original table in Gordon G. et al. "A Contingency Model for the Design of Problem Solving Research Program", Milbank Memorial Fund Quarterly, p 184-220, 1974 cited by Gharajedaghi, System Thinking: Managing chaos and Complexity, Butterworth-Heinemann, 1999

Committed costs vs. Lifecycle

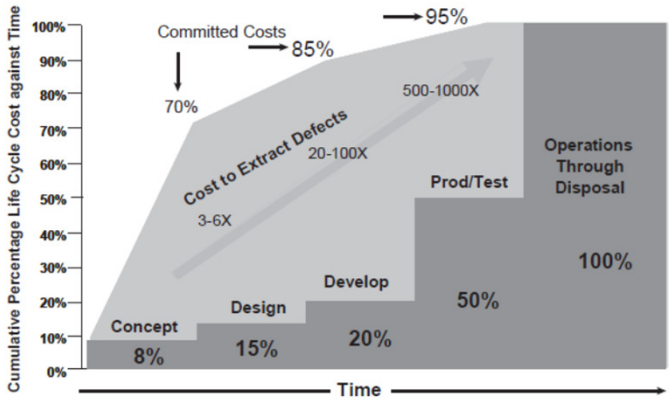


Figure 2-3 Committed Life Cycle Cost against Time [10]

DAU, 1993 quoted in INCOSE Systems Engineering Handbook 3.1 (2nd Printing) modified

Exercise 2-41 knowledge reading

1. Prepare a brief on two main points in reading 0208 (< 5min)
2. Presentation to contain
    1. Formulated problem per COPS problem formulation template
    2. A summary of the content of the reading (<1 minute)
    3. The compliance matrix
    4. This slide and lesson version number
    5. A list of the main points
    6. The two briefings
    7. Reflections and comments on reading (<2 minute)
    8. Comparisons of content with other readings and external knowledge
    9. Why you think the reading was assigned to the module
    10. Lessons learned from module and source of learning e.g. readings, exercise, experience, etc. (<2 minutes)
3. Save as a PowerPoint file as Exercise2-41-abcd.pptx
4. Post/email presentation as, when and where instructed
5. Brief on one main point

Exercise 2-42 knowledge reading

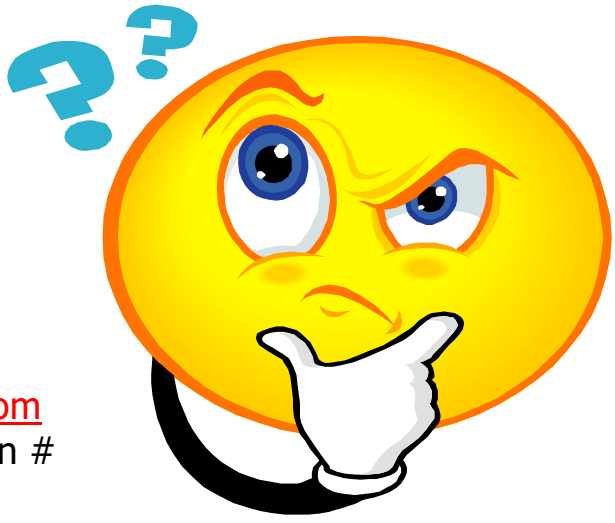
1. Prepare a brief on two main points in reading 0209 (< 5min)
2. Presentation to contain
    1. Formulated problem per COPS problem formulation template
    2. A summary of the content of the reading (<1 minute)
    3. The compliance matrix
    4. This slide and lesson version number
    5. A list of the main points
    6. The two briefings
    7. Reflections and comments on reading (<2 minute)
    8. Comparisons of content with other readings and external knowledge
    9. Why you think the reading was assigned to the module
    10. Lessons learned from module and source of learning e.g. readings, exercise, experience, etc. (<2 minutes)
3. Save as a PowerPoint file as Exercise2-42-abcd.pptx
4. Post/email presentation as, when and where instructed
5. Brief on one main point

Exercise 2-43 knowledge reading

1. Prepare a brief on two main points in reading 0210 (< 5min)
2. Presentation to contain
    1. Formulated problem per COPS problem formulation template
    2. A summary of the content of the reading (<1 minute)
    3. The compliance matrix
    4. This slide and lesson version number
    5. A list of the main points
    6. The two briefings
    7. Reflections and comments on reading (<2 minute)
    8. Comparisons of content with other readings and external knowledge
    9. Why you think the reading was assigned to the module
    10. Lessons learned from module and source of learning e.g. readings, exercise, experience, etc. (<2 minutes)
3. Save as a PowerPoint file as Exercise2-43-abcd.pptx
4. Post/email presentation as, when and where instructed
5. Brief on one main point

Any questions ?

1. Best
2. Worst
3. Missing



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