Module 2:
Applied systems engineering
(an introduction)
Session 1 of 5

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

Version 6.2.1

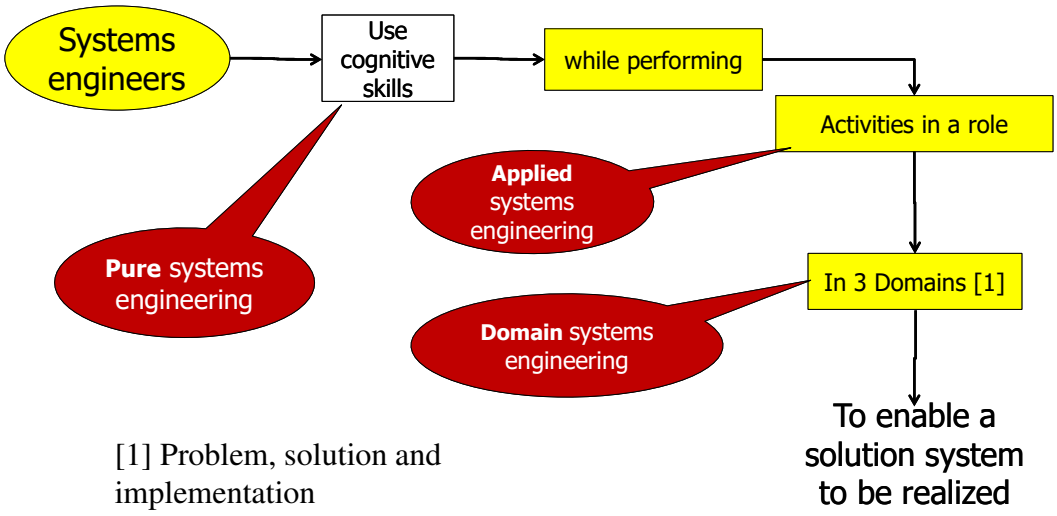
Pure and applied systems engineering

1. Pure systems engineering (SE)
   - Systems thinking and beyond
     - Cognitive skills, problem formulation/remedying, quantitative methods, decision-making (covered in COPS)
2. Applied systems engineering (scenarios)
   - Requirements, architectures, V&V, engineering management, engineering, *ilities, etc.
3. Domain systems engineering

Generic Similar to Mathematics (pure and applied SE)

Continuum adding domain SE

Pure, applied and domain systems engineering



[1] Problem, solution and implementation

Objectives

1. To introduce the context for systems engineering which provides an insight as to the reasons for the many definitions of, and viewpoints on systems engineering
2. To provide an example of viewing a situation from the HTPs.
3. To alert participants to the state of the discipline
4. To provide the participants with the background for the activities performed by systems engineers in various stages of system development
5. To provide a context for the different lifecycle models
6. To introduce some useful tools and frameworks for systems engineering

Contents

1. Systems engineering as perceived from the eight Holistic Thinking Perspectives (HTP); perceptions you will find nowhere else
2. The reasons for the various definitions of systems engineering
3. How systems engineering relates to problem-solving
4. Pure and applied systems engineering and the benefits of the separation
5. The iterative systems development process
6. The little-known reason why the waterfall, spiral and V model of systems engineering are different views of the same process
7. The two systems engineering paradigms and why using the wrong one dooms the project to failure
8. The benefits of using Model-Based Systems Engineering (MBSE) and why it's much ado about nothing new

Knowledge components-1

- Lecture
  - Sets the context and provides overview
- Readings
  - 0202 FUSE Chapter 20 Eight deadly defects in systems engineering and how to fix them
  - 0203 Kasser J.E., Hitchins D.K., Clarifying the Relationships between Systems Engineering, Project Management, Engineering and Problem Solving, APCOSEC, Yokohama, Japan, 2013
  - 0204 Kasser J.E., *SEMP, TEMP and SHMEMP! It's time to stop the Mishigas*, Researches and Development Directions in Systems Engineering, the Gordon Center, Technion, Haifa, Israel, 2010
  - ~~0205~~ reading deleted
  - 0206 FUSE Chapter 29 Yes systems engineering you are a discipline
  - 0207 FUSE Chapter 26 Seven systems engineering myths and the corresponding realities
  - Continued ...

Knowledge components-2

- Readings (cont.)
  - 0208 Systems Engineering Chapter 21 MBSE (Update of POSE Chapters 9.6 and 12.21)
  - 0209 Kasser, J.E., Lerner B., Two major misconceptions of systems thinking exposed, British Computer Club Webinar, April 2023 (https://youtu.be/fxZa-qpnAnU)
  - 2010 Kasser, J.E., Lerner B., A History of Systems Engineering its evolution and devolution, Southern Maryland Chapter of INCOSE, July 2024 (https://youtu.be/Gmnc-78TUuM)
- References – provide details summarized in lecture and COPS prerequisite course
  - Systems Engineering Chapter 2 Perceptions of Systems Engineering
  - Systems Engineering Chapter 6 The nine-systems model (update of POSE Chapter 16)
- Exercises

Topics

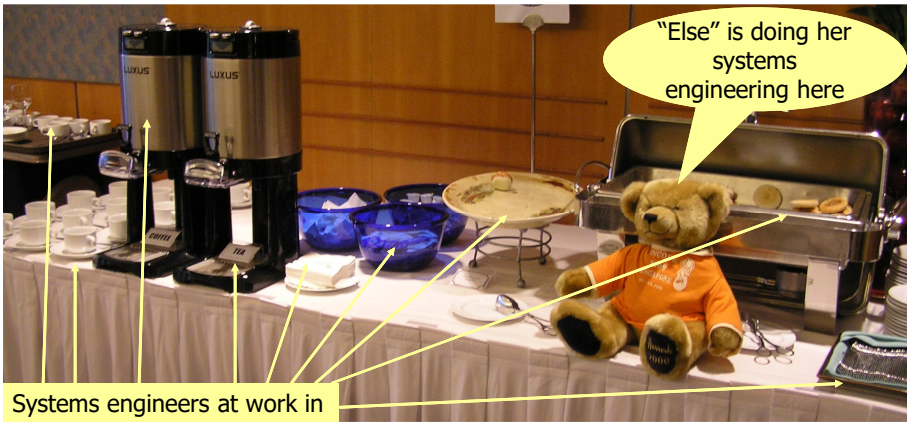
- **Framing the problem**
- **Systems engineering (SE) as perceived from the HTPs**
  1. ***Big Picture***
  2. ***Continuum***
  3. *Operational*
  4. *Functional*
  5. *Structural*
  6. *Generic*
  7. *Temporal*
  8. *Quantitative*
  9. *Scientific*

What is systems engineering?

- It depends!
- Many different definitions and descriptions of systems engineering
  - Text books have some commonality but bulk cover different topics
- Systems engineering successes and failures
- **Systems engineering cannot be differentiated from other disciplines**
- Myths and defects abound unquestioned
- **Need to understand the reasons to help successfully communicate with other systems engineers who have different ideas about systems engineering**
- **Need to evolve consensus on the nature of systems engineering?**

Bear with me: helicopter view

- "Else" sees the Big Picture through a mirror behind you



Parable of blind men and elephant*

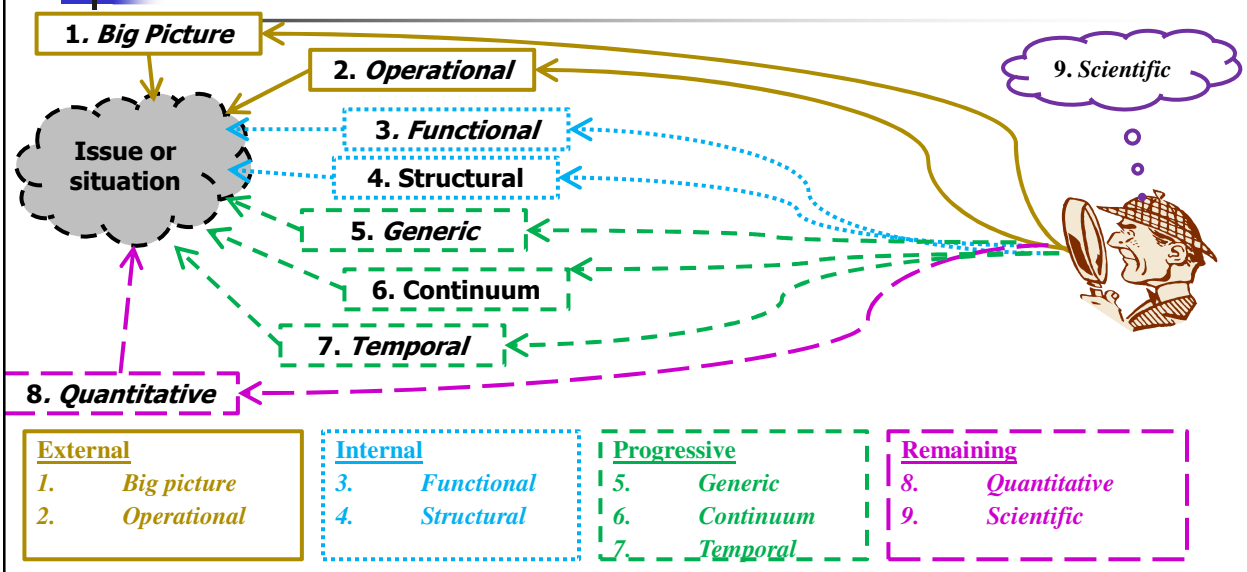
"… And so these men of Indostan
Disputed loud and long,
Each in his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the wrong!
MORAL.
So oft in theologic wars,
The disputants, I ween,
Rail on in utter ignorance
Of what each other mean,
And prate about an Elephant
Not one of them has seen!"

* Yen, D. H., The Blind Men and the Elephant, 2008, http://www.noogenesis.com/pineapple/blind_men_elephant.html, last accessed 26 October 2010

Framing the problem

1. Undesirable situation
   - No consensus on the nature of systems engineering
2. Assumptions
   - Different views are based on partial views of a whole (the elephant)
3. FCFDS
   - An understanding of the reasons for the undesirable situation
   - Myths being questioned
   - Consensus being formed on nature of systems engineering
4. Problem
   1. Perceive systems engineering from the HTPs
   2. Apply systems thinking and critical thinking to systems engineering
   3. Infer FCFDS
5. Solution
   1. To Be Determined (TBD) - Follow the problem-solving process to infer the FCFDS

Systems thinking : the Holistic Thinking Perspectives*

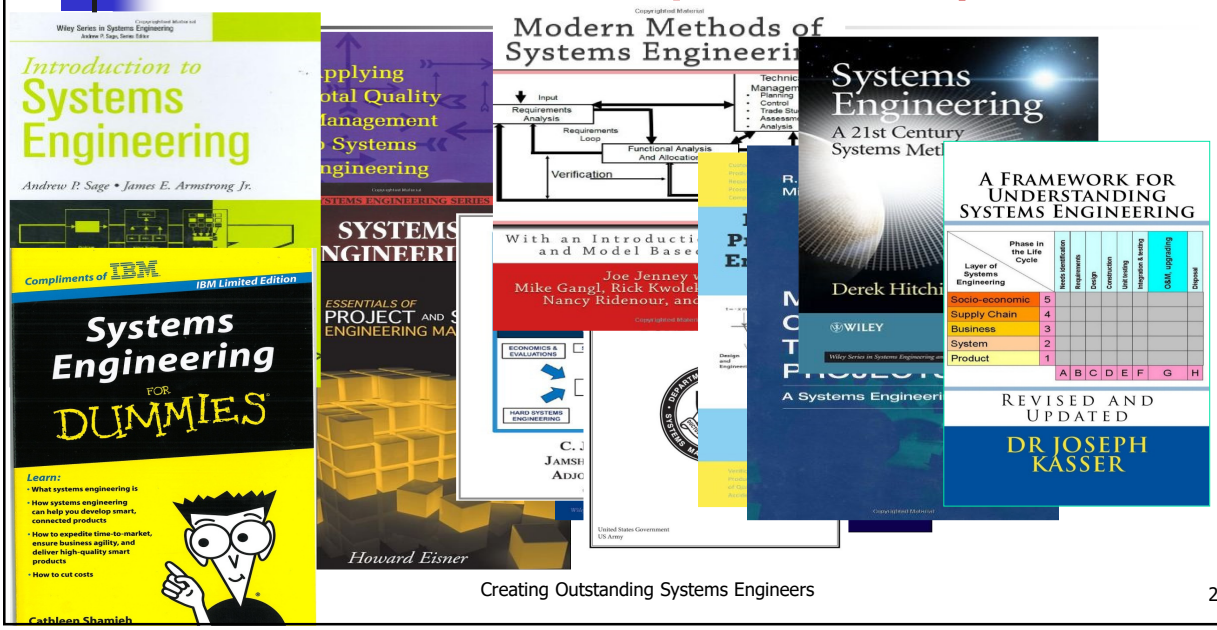


External	Internal	Progressive	Remaining
1. Big picture	3. Functional	5. Generic	8. Quantitative
2. Operational	4. Structural	6. Continuum	9. Scientific
		7. Temporal	

Big Picture perspective

- Context for systems engineering (SE) in domains
- Systems thinking
- Different views and opinions
- Systems engineering (SE) is performed in projects
- Process, product, problems
- Overlaps with other disciplines
- Focus on process

Text books (a selection)



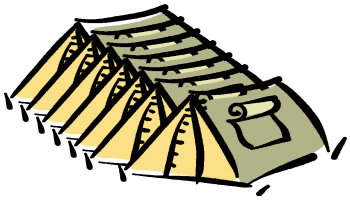
Continuum perspective: observe

1. Different camps of systems engineers
2. Dichotomies
   - Complexity
   - Systems and systems of systems
3. Differences between
   - Lifecycle models
   - Systems engineering and other disciplines
   - Roles and activities
     - SETR and SETA
   - Various processes
   - 'A' and 'B' paradigms

Nine camps in systems engineering (SETA/SETR)

1. Lifecycle*
2. Process*
3. Problem*
4. [Meta-]Discipline*
5. Domain*
6. Systems thinking and non-systems thinking*
7. Enabler*
8. Specific system
9. Model-based Systems Engineering**

Anyone can have a foot in more than one camp at the same time



* Kasser, J. E. and Hitchins, D. K., "Yes systems engineering, you are a discipline", *proceedings of the 22nd Annual International Symposium of the INCOSE*, Rome, Italy, 2012 .
** Kasser, J. E., Model-Based Systems Engineering: Back to the future?, proceedings of the APCOSEC, Yokohama, 2013.

Reasons systems engineering is confusing and sometimes contradictory (book coverage?)

Camp/ Pure/Applied	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Lifecycle (all or part)[1]	X	X	-	X	-	X	-	X	X
Process	-	X	-	X	-	X	-	X	X
Problem	-	-	X	-	-	-	X	-	X
[Meta-] Discipline	-	X	-	-	-	-	-	-	X
Domain	-	-	-	-	-	X	-	-	X
Systems thinking	X	-	X	-	X	-	X	-	X
Enabler	-	-	-	-	X	-	-	-	X
Pure systems engineering	X	-	X	-	X	-	X	-	X
Applied systems engineering	X	X	X	X	-	X	-	X	X

Note 1 The parts of the lifecycle may be different, so what is done is different

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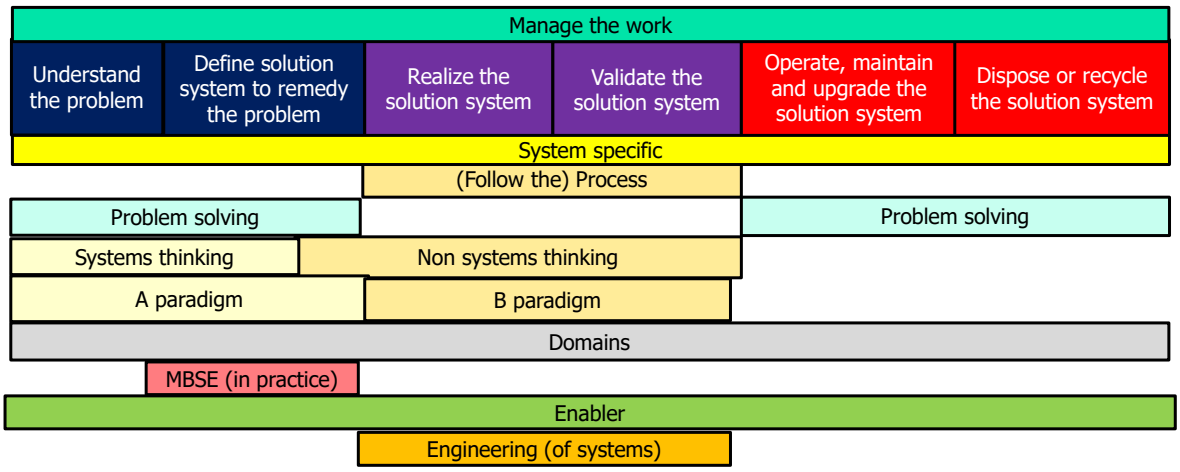
Camps in the system life cycle in a discipline (single perspectives)



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Types and styles of systems engineers

- Types
  - Characteristics
    - Five types (*Quantitative* perspective)
- Styles
  - The way they behave (*Operational* perspective)
    - Kemp D, Elphick J., The One-eyed Systems Engineer – Pirate or Prophet? An analysis of the effectiveness of different systems engineering leadership styles, INCOSE 2012
- Similar to management types and styles
  - *Generic* perspective

Creating Outstanding Systems Engineers

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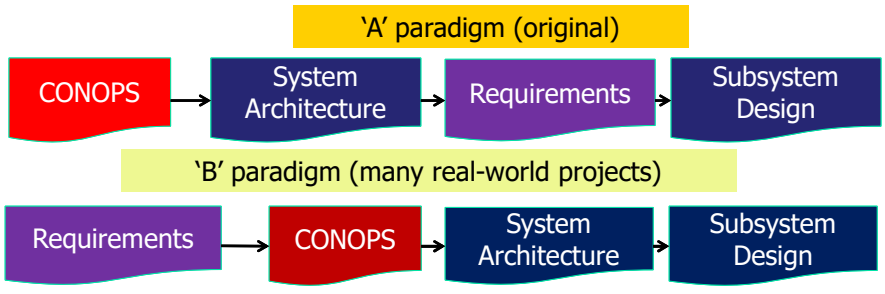
Two requirements (SE) paradigms*

- **The "A" Paradigm** [starts in HKM²F column A]
  - Create requirements from CONOPS; Successful projects are characterized by common vision of future desirable situation
  - Original systems engineering of the 60's
  - Create/architect a process to realize the solution
    - (Biemer and Sage, 2009, page 153), (Kasser and Palmer, 2005)
      - The SEMP
- **The "B" paradigm** [starts in HKM²F column B]
  - Requirements are one of the inputs to the 'systems engineering process'
  - Create CONOPS from requirements
    - (Denzler and Mackey, INCOSE 1994), (Guo, 2010)
  - Taught in most systems engineering courses
    - E.g. (Martin, 1997 page 95), (Eisner, 1997 page 9), (Wasson, 2006 page 60) and (DOD 5000.2-R, 2002, pages 83-84)
  - Follow the process

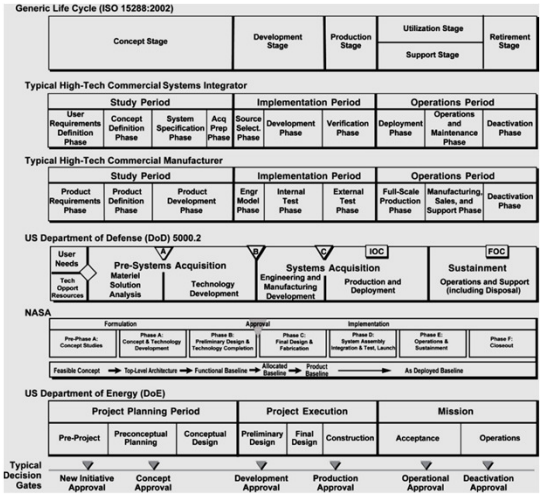
* FUSE Chapter 28

'A' and 'B' paradigms



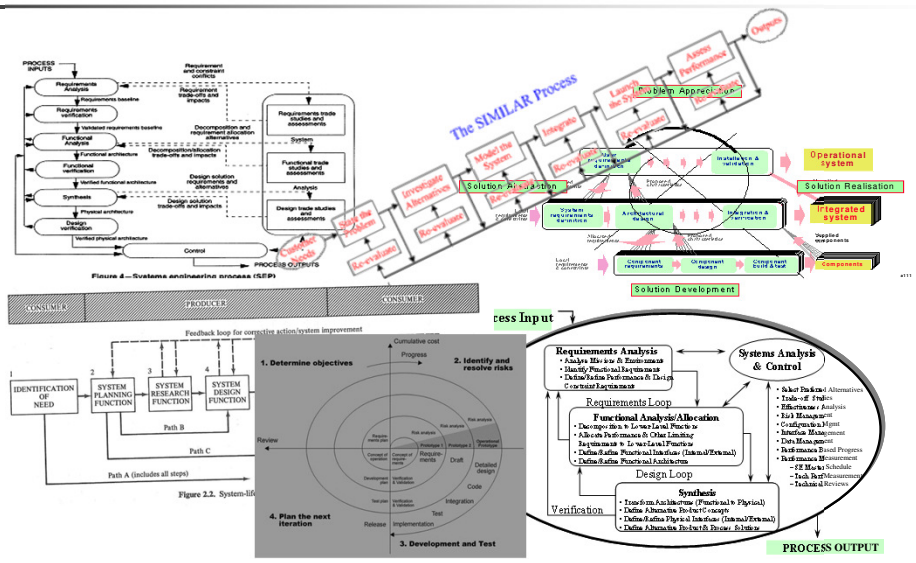
- Shown as a linear flow for educational purposes
  - E.g. an infeasible requirement may modify the CONOPS which would be shown as a confusing feedback loop
- Constraints (legal, etc.) also drive CONOPS and system architecture in both paradigms
- System architecture may change during subsystem design

Comparison of Lifecycle models*

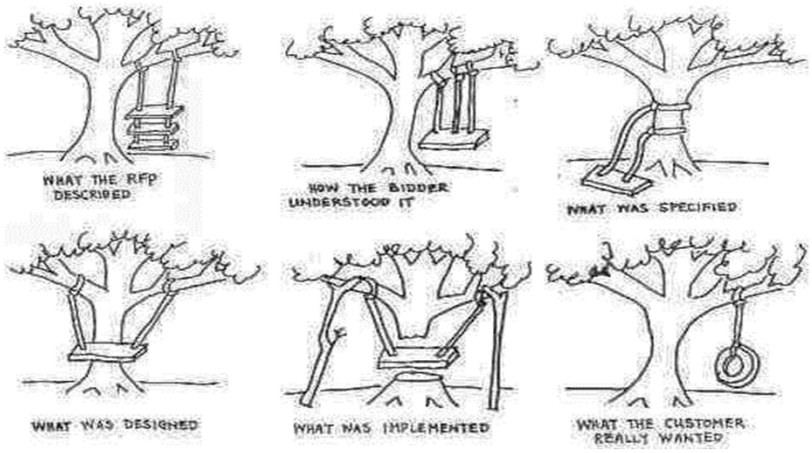


* INCOSE SE Handbook Version 3.21

Which process and why are they different?

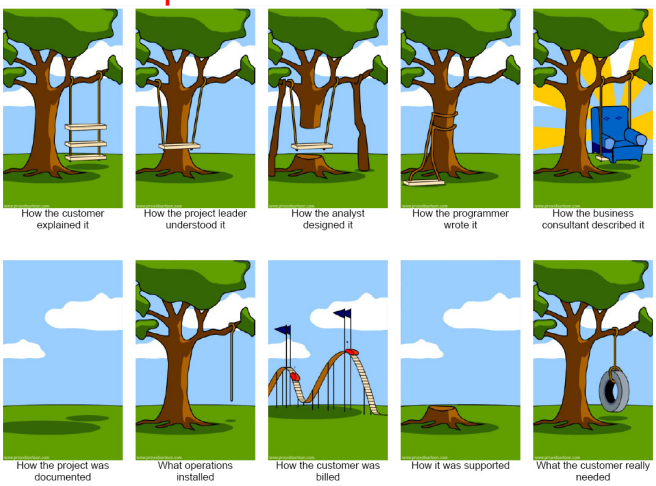


The systems engineering process (1970)

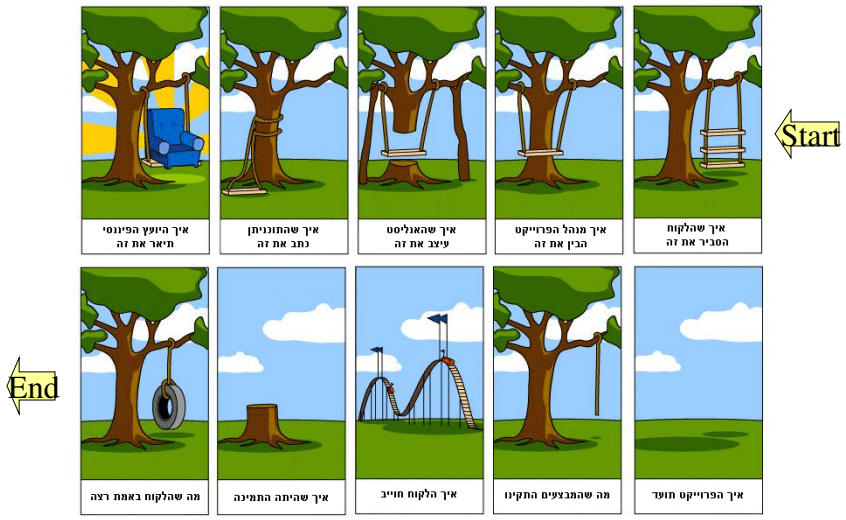


The systems engineering process (2010)

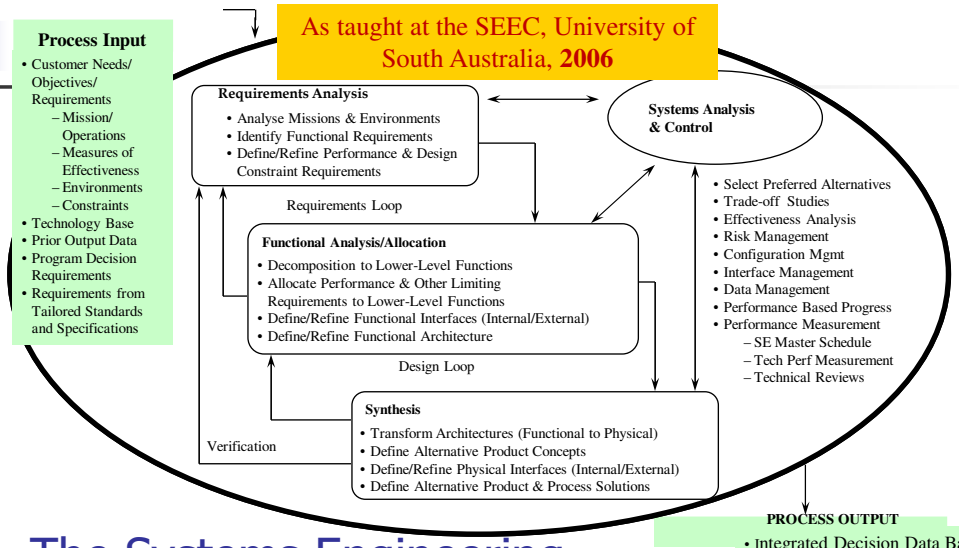
More complex



International process



As taught at the SEEC, University of South Australia, **2006**



The Systems Engineering Process (The "egg")

Creating Outstanding Systems Engineers

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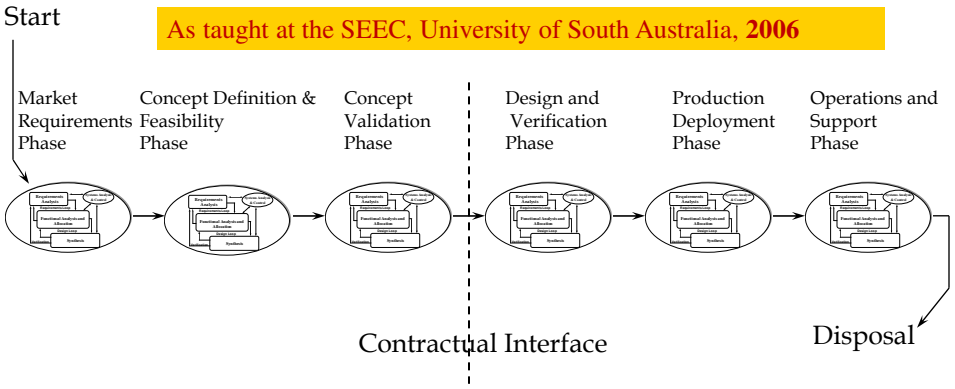
A Typical System Lifecycle



Each phase invokes the Systems Engineering Process, see egg

Tools paradox

1960's*

- Probability
- Single thread – system logic
- Queuing theory
- Game theory
- Linear programming
- Group dynamics
- Simulation
- Information theory

2005**

- Databases
- DOORS
- CORE
- Drawing tools
- PowerPoint
- Visio
- Word processors
- Spreadsheets
- Etc.

* Wilson, 1965; Alexander and Bailey, 1962; Chestnut, 1965
** Jenkins, Steve, A Future for Systems Engineering Tools, *PDE 2005*, The 7th NASA-ESA Workshop on Product Data Exchange (PDE) http://www.marc.gatech.edu/events/pde2005/presentations/0.2-jenkins.pdf

Roles: Jenkins (1969)*

1. He tries to distinguish the wood from the trees – what's it all about?
2. He stimulates discussion about objectives – obtains agreement about objectives.
3. He communicates the finally agreed objectives to all concerned so that their co-operation can be relied upon.
4. He always takes an overall view of the project and sees that techniques are used sensibly.
5. By his overall approach, he ties together the various specializations needed for model building.
6. He decides carefully when an activity stops.
7. He asks for more work to be done in areas which are sensitive to cost.
8. He challenges the assumptions on which the optimization is based.
9. He sees that the project is planned to a schedule, that priorities are decided, tasks allocated, and above all that the project is finished on time.
10. He takes great pains to explain carefully what the systems project has achieved, and presents a well-argued and well-documented case for implementation.
11. He ensures that the users of the operational system are properly briefed and well trained.
12. He makes a thorough retrospective analysis of systems performance.

*

Roles: Sheard (1996)*

* Sheard, S. A., 1996, *Twelve systems engineering roles*, proceedings of the 6th Annual International Symposium of the NCOSE.

1. Requirements Owner (RO)
2. System Designer (SD)
3. System Analyst (SA).
4. Validation and Verification (VV)
5. Logistics and Operations (LO)
6. Glue (G)
7. Customer Interface (CI)
8. Technical Manager (TM)
9. Information Manager (IM)
10. Process Engineer (PE)
11. Coordinator (CO)
12. "Classified Ads Systems Engineering" (CA)

Further updates in reading 0210

Systems Engineering Standards?

- Mil-STD-499
  - systems engineering management
- Mil-STD-499A
  - engineering management
- ANSI/EIA-632
  - processes for engineering a system
- IEEE 1220
  - the application and management of the systems engineering process

There aren't any Standards that apply to systems engineering

Each Standard is a partial view of an encompassing process

SE Categories	MIL-STD-499C	ANSI/ EIA 632	IEEE-1220	CMMI	ISO-15288
Conceptualizing problem and/ alternative solutions	No	No	No	No	No
Mission/purpose definition	No	No	✓	✓	✓
Requirements engineering	✓	✓	✓	✓	✓
System architecting	✓	✓	✓	✓	✓
System implementation	No	✓	No	✓	✓
Technical analysis	✓	✓	✓	✓	✓
Technical management/ leadership	✓	✓	✓	✓	✓
Verification & validation	✓	✓	✓	✓	✓

Based on Table 5 in Honour E.C., Valerdi R., "Advancing an Ontology for Systems Engineering to Allow Consistent Measurement", CSER 2006

Myth and reality of Systems Engineering Standards

- Myth*
  - There are Standards for systems engineering
- Reality*
  - There are no such Standards
  - Standards cover
    - **Process** for **engineering systems**
      - different parts of the process
    - Engineering **Management**
  - Moreover, Standards focus **on wrong aspect**
- "**The Systems Engineering Process is a generic problem-solving process**, which provides the mechanisms for identifying and evolving the product and process definitions of a system".
  - IEEE 1220-1998 Section 4.1

MIL-STD's freely available at http://www.everyspec.com

* J. E. Kasser, "Seven systems engineering myths and the corresponding realities," the Systems Engineering Test and Evaluation Conference, Adelaide, Australia, **2010**.

Exercise 2-11 (what)

1. **WHAT to do**
2. For each chapter in FUSE:
   1. Determine which HTP is the primary perspective (see next slide)
3. Prepare and present (<5 minutes)
   1. This slide and lesson version number
   2. Problem formulated per COPS problem-formulation template
   3. Compliance matrix
   4. Findings from exercise
   5. Lessons learned from session
      1. With source (lecture, reading, exercise, etc.)
4. Save as a PowerPoint file as Exercise2-11abcd.pptx
5. Post/email presentation as, when and where instructed

Exercise 2-11 (How)

- For each chapter in FUSE:
  - Skim introduction and summary
    - Think and make decision
  - If no decision
    - Skim figures
    - Think and make decision
  - If no decision
    - Read chapter
    - Think and make decision
  - If no decision
    - Skip and return if time permits
  - Document reason
  - If chapter looks interesting
    - Read *after completing the exercise*

Exercise 2-12 knowledge reading

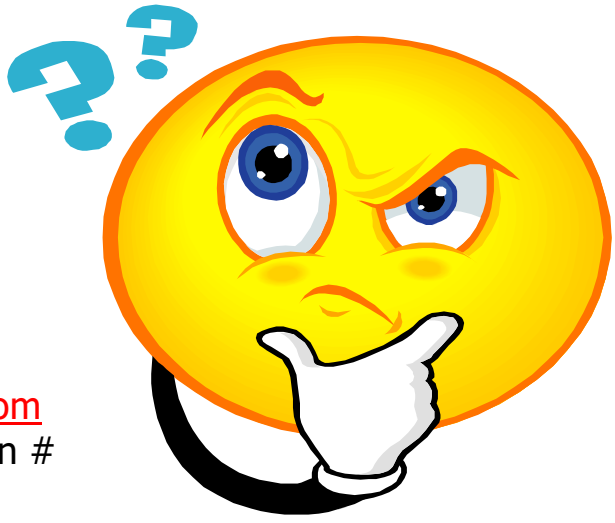
1. Prepare a brief on two main points in reading 0202 (< 5min)
2. Presentation to contain
   1. Formulated problem per COPS problem formulation template
   2. A summary of the content of the reading (<1 minute)
   3. The compliance matrix
   4. This slide, and lesson version number
   5. A list of the 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 Exercise1-12-abcd.pptx
4. Post/email presentation as, when and where instructed
5. Brief on one main point

Exercise 2-13 knowledge reading

1. Prepare a brief on two main points in reading 0203 (< 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 Exercise2-13-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



Email:
beyondsystemsthinking@yahoo.com
Subject: <class title> BWM Lesson #