7.5.3 Unifying systems engineering: Seven principles for systems engineered solution systems

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Topics

- The problem
- The camps in systems engineering
- The principles
  - Based on sucessful systems of the 1960's and 70's
  - Updated for the 21st century
- Questions and comments

The problem

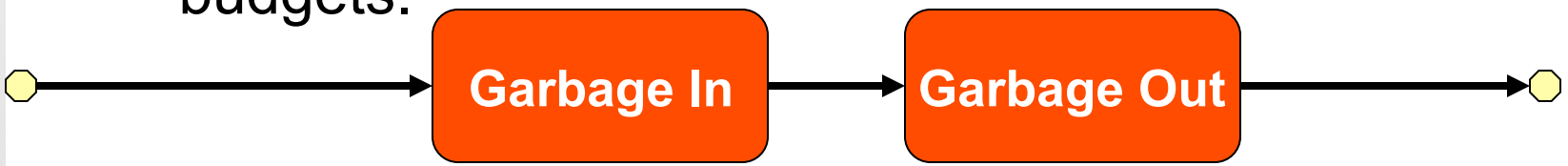
- Systems engineering is an emerging discipline
  - Several camps
- We need to move beyond this
- How?
  - Dissolve the problem
- Generic thinking
  - A discipline generally matures when an overriding **axiom** is presented and accepted by the majority of practitioners.
- We need an axiom
- This paper proposes an axiom

The systems engineering camps

- **The process camp**
  - Functional STP
- The discipline camp
  - Structural STP
- The problem camp
  - Operational STP
- The activity camp
  - Functional/operational STP with an objective definition

The process camp

- The successful implementation of proven, disciplined systems engineering processes results in a total system solution that is--
  - Robust to changing technical, production, and operating environments;
  - Adaptive to the needs of the user; and
  - Balanced among the multiple requirements, design considerations, design constraints, and program budgets.*



* United States Department of Defense 5000 Guidebook 4.1.1

The process camp

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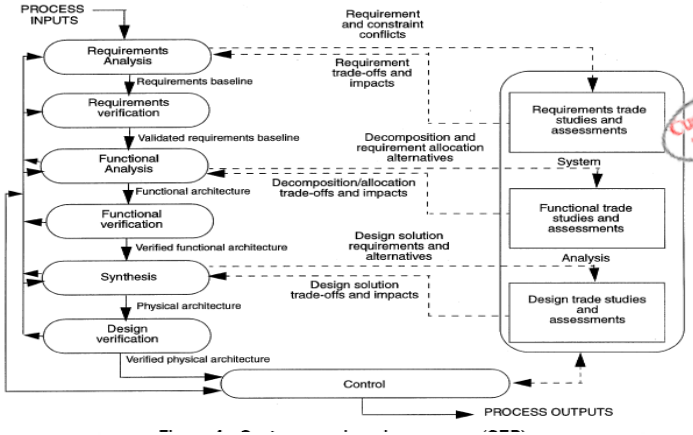
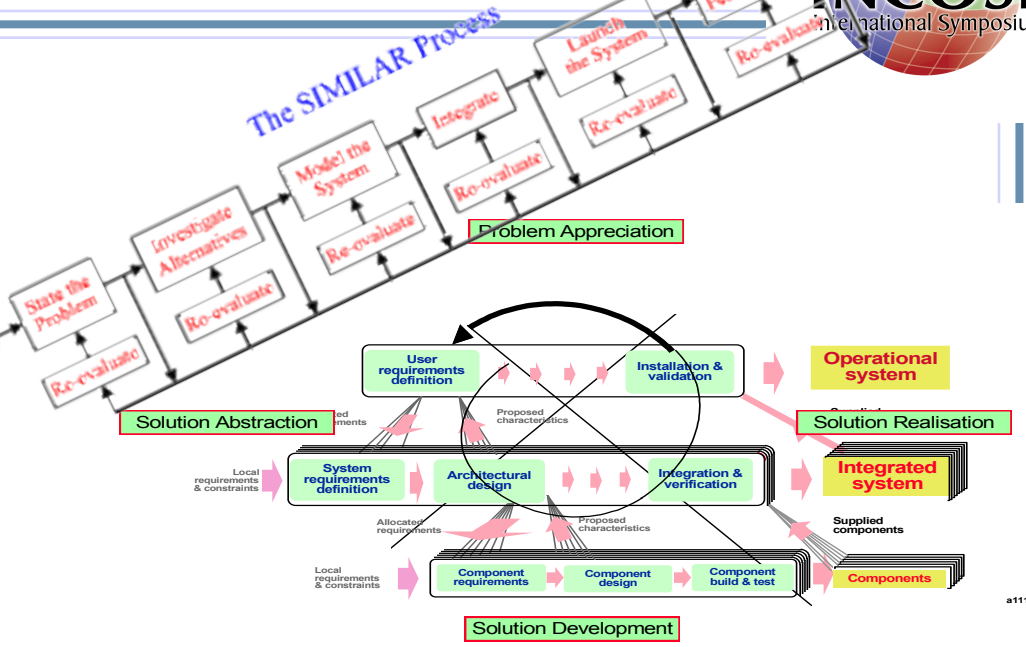
  - Robust to changing technical, production, and operating environments;
  - Adaptive to the needs of the user; and
  - Balanced among the multiple requirements, design considerations, design constraints, and program budgets.*
- A single process, standardizing the scope, purpose and a set of development actions, has been traditionally associated with systems engineering.**

* United States Department of Defense 5000 Guidebook 4.1.1

** Arnold, 2000 quoting (MIL-STD-499B, 1993) and (IEEE 1220, 1998)

Which process?





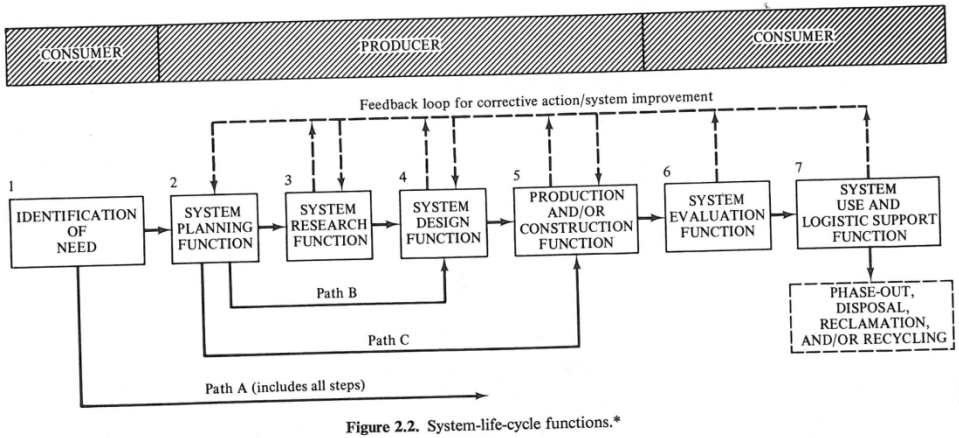
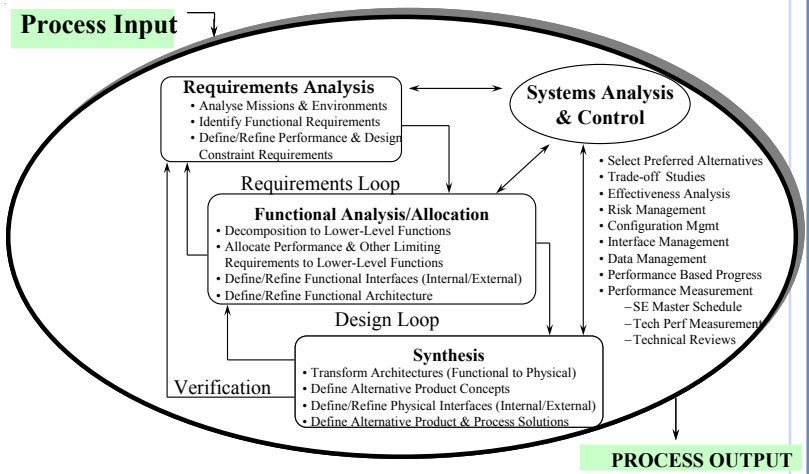


Figure 2.2. System-life-cycle functions.*



What systems engineering process?

- Each process seems to be different
  - Some overlap the problem solving process
    - Mar, Hitchins, etc.
  - Some cover the whole system lifecycle
    - Blanchard and Fabrycky, Bahill and Gissing, etc.
  - Some cover the ‘realization of the solution’ part of the system lifecycle
    - MIL-STD 499, EIA-632, IEEE 1220, etc.
- Which one is “the” process?

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The discipline camp

- **It is necessary for systems engineering to become an engineering discipline** if it is to fulfil its promises and thereby survive.
  - Wymore, 1994
- If systems engineering is to become a world class discipline it must … map all of its existing systems engineering activities …
  - Mar, 1994

The elements of a discipline

- "A discipline possesses
  - a specific area of study,
  - a literature, and
  - a working community of paid scholars and/or paid practitioners".
    - Kline 1995

Overlaps project management

- Systems engineering –
  - "*The management function which controls the total system development effort for the purpose of achieving an optimum balance of all system elements. It is a process which transforms an operational need into a description of system parameters and integrates those parameters to optimise the overall system effectiveness*"
    - (DSMC, Defense Systems Management College 1996).

Overlap*

- Project management, Business Process Reengineering (BPR), concurrent engineering, TQM and theoretical SE all seem to be attributes of the same function; namely *producing a product to (the correct) specifications by an organization within the constraints of resources, budget and schedule*.

* Kasser, J. E. and Massie, A., "*A Framework for a Systems Engineering Body of Knowledge", proceedings of 11th International Symposium of the INCOSE, INCOSE, Melbourne, Australia, 2001.*

Overlap between PM and SE

- Text books for class on project management in MST systems engineering program
- Literature abounds with reports of overlap

Areas of concern are too broad

- A designed physical system (Product)
  - (that also contains human components).
- A human activity system (Process)
  - (engineering organisation).
- Roles and activities
- Span many disciplines
- Require pluralistic approaches
- Fundamentally different types

Systems engineering is taking over the world
Systems engineering is a meta-discipline

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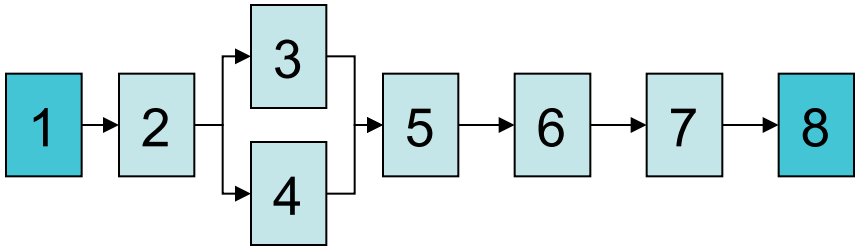
A systems engineering approach to problem solving*

1. Plan the work (Tasks 2-8)
2. Define the problem
3. Conceive solution options
4. Identify ideal solution evaluation criteria
5. Perform trade off to find the optimum solution
6. Select the preferred option
7. Formulate strategies and plans to implement the preferred option
8. Milestone review to obtain authorisation to proceed to implementation phase



* Tasks 2-7 from Hitchins, D. K., *Systems Engineering. A 21st Century Systems Methodology*, John Wiley & Sons Ltd., Chichester, England, 2007., Figure 6.2

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Activity Paradigm Criterion

- Projects contain streams of activities in series/ parallel
- If the activity ***deals with parts and their interactions as a whole***, then it is an activity within the set of activities known as **systems engineering**.
- If the activity ***deals with a part in isolation***, then the activity is not an activity within the set of activities known as systems engineering but is part of **'something else'**, e.g., engineering management, software engineering, etc.

What is systems engineering?

"… 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

Topics

- The problem
- The camps in systems engineering
- **The seven principles**
  - Based on sucessful systems of the 1960's and 70's
  - Updated for the 21st century
  - **Dissolving the problem**
    - **Addressing the solution system**

Principle 1

- There shall be a clear, singular objective or goal.
  - Identify the problem
  - Determine the feasible solution
  - Stakeholders agree on objective
    - Plurality leads to failure
  - Early stage systems engineering has to create that stakeholder consensus
    - Domain knowledge
    - Understand and address stakeholder concerns

Principle 2

- There shall be a concept of operations (CONOPS) from start to finish of the mission describing the normal and contingency mission functions as well as the normal and contingency support functions performed by the solution system that remedies the problem.
  - Scenarios or ‘use cases’
  - Normal and contingency
    - Mission and support functions
  - Clear vision of what solution system will do
  - “to-be” system
    - Business Process Reengineering
  - Facilitates complete and correct requirements

Principle 3

- The solution system shall be designed to perform the complete set of remedial mission and support functions for the operational life of the system.
  - Recognize that change will take place
  - Manage change
    - Project failures are due to failure to manage change not changes in requirements
  - Continuum of solutions
    - Technical
    - People
  - Lifecycle perspective is built-in
  - Effectiveness not cost-effectiveness

Principle 4

- The solution system design may be partitioned into complementary, interacting subsystems.
  - Function of system = function of (subsystems + emergent properties)
  - Optimized interfaces
    - Minimum coupling
    - Maximum cohesion
    - Homeostatic subsystems

Principle 5

- Each subsystem is a system in its own right, and shall have its own clear CONOPS, derived from, and compatible with, the CONOPS for the whole.
  - Principle of hierarchies
    - Big fleas have little fleas,
    - Upon their backs to bite 'em,
    - And little fleas have lesser fleas,
    - and so, ad infinitum.
    - And the great fleas, themselves, in turn
    - Have greater fleas to go on;
    - While these again have greater still,
    - And greater still, and so on.

Principle 6

- Each subsystem may be developed independently and in parallel with the other subsystems provided that fit, form, function and interfaces are maintained throughout
  - Systems engineers work in subsystems
    - Their system
  - Systems engineers work at the system level
    - Ensure fit, form, function and interfaces are maintained throughout

Principle 7

- Upon successful integration of the subsystems, the whole solution system shall be subject to appropriate tests and trials, real and simulated, that expose it to extremes of environment and hazards such as might be experienced during the mission.
  - Delivered systems are fit for purpose

Summary

- The problem
- The camps in systems engineering
- The principles

Questions or comments?