A Systems Engineering Overview

One Engineer's Perspective from the Front Lines…

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INCOSE Definition of Systems Engineering

- Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining
  - customer needs and
  - required functionality early in the development cycle,
  - documenting requirements,
  - then proceeding with design synthesis and
  - system validation while considering the complete problem.

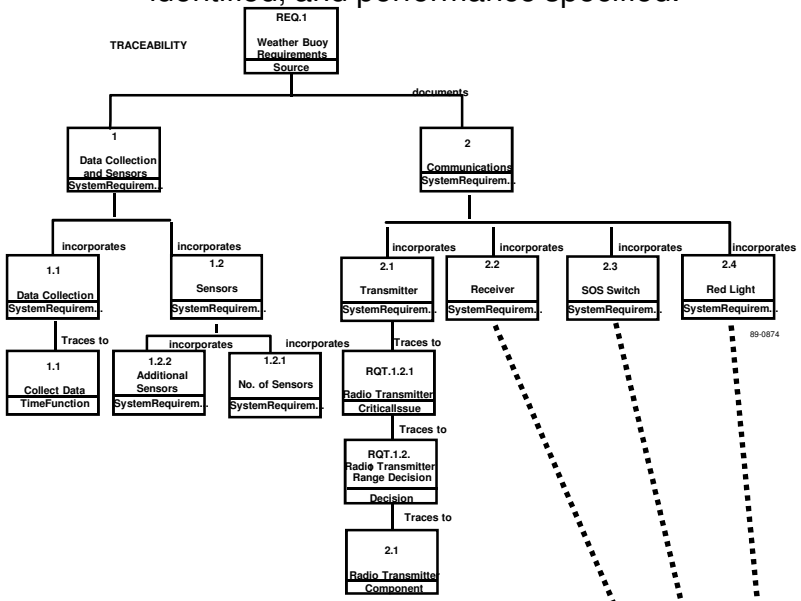
  Systems Engineering considers both the business and the technical needs of all customers with the goal of providing quality product that meets the user needs.

  - INCOSE Handbook v.3, page 1.5
    (Format and underlining added)

SE Methodology

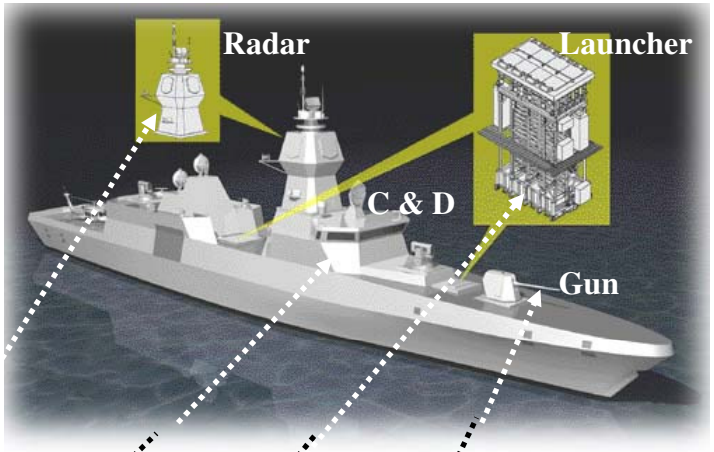
Requirements Analysis

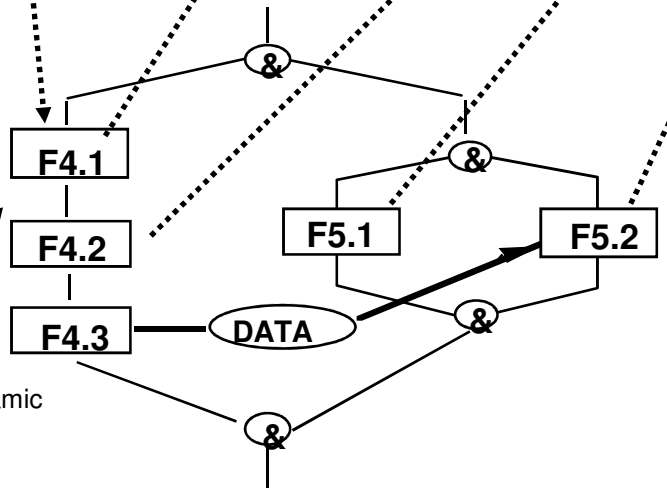
User Requirements are parsed, issues identified, and performance specified.



Synthesis

Functions and Performance are allocated to the components





Functional Analysis

- System Functions are defined:
  - ➔ data and control flows
  - ➔ executable graphical notation.
- System Requirements are verified using static & dynamic analysis

D. Cocks

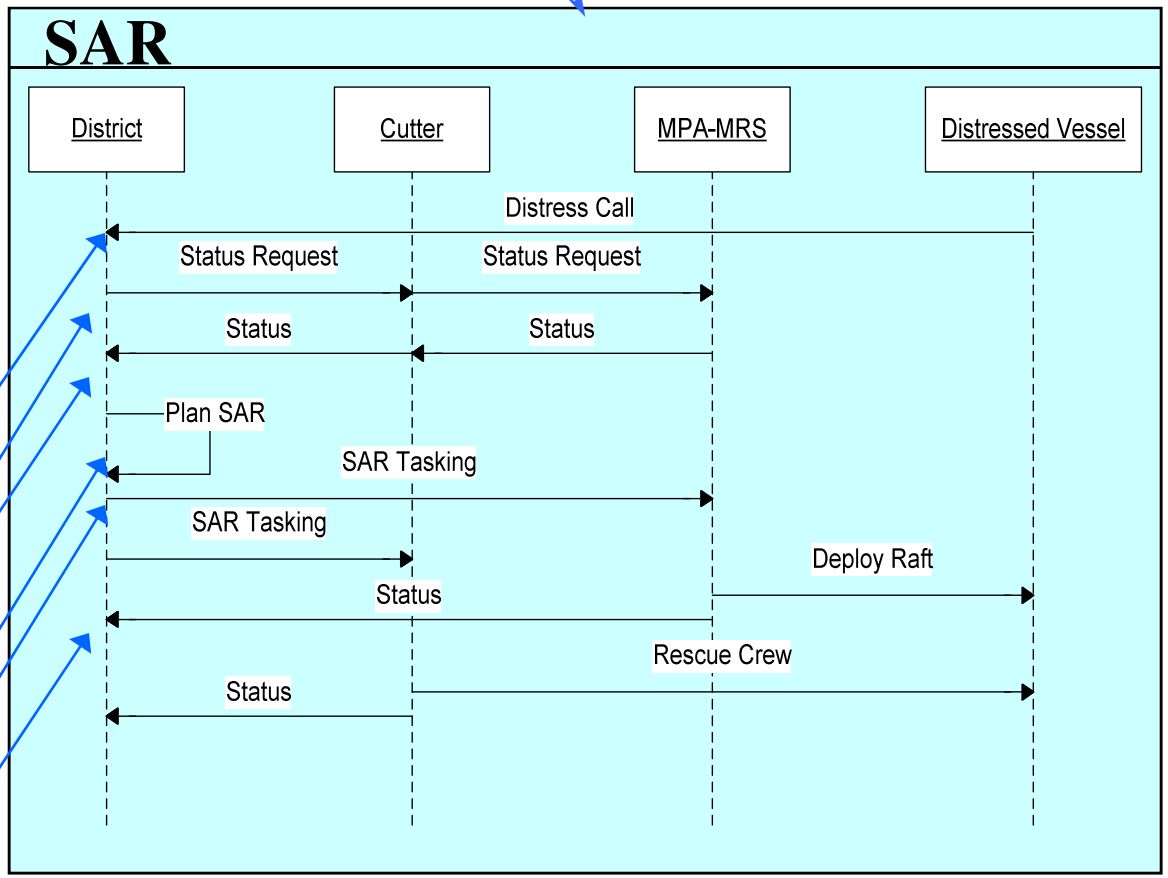
Using System Models to Identify and Analyze Requirements

Modeled as:

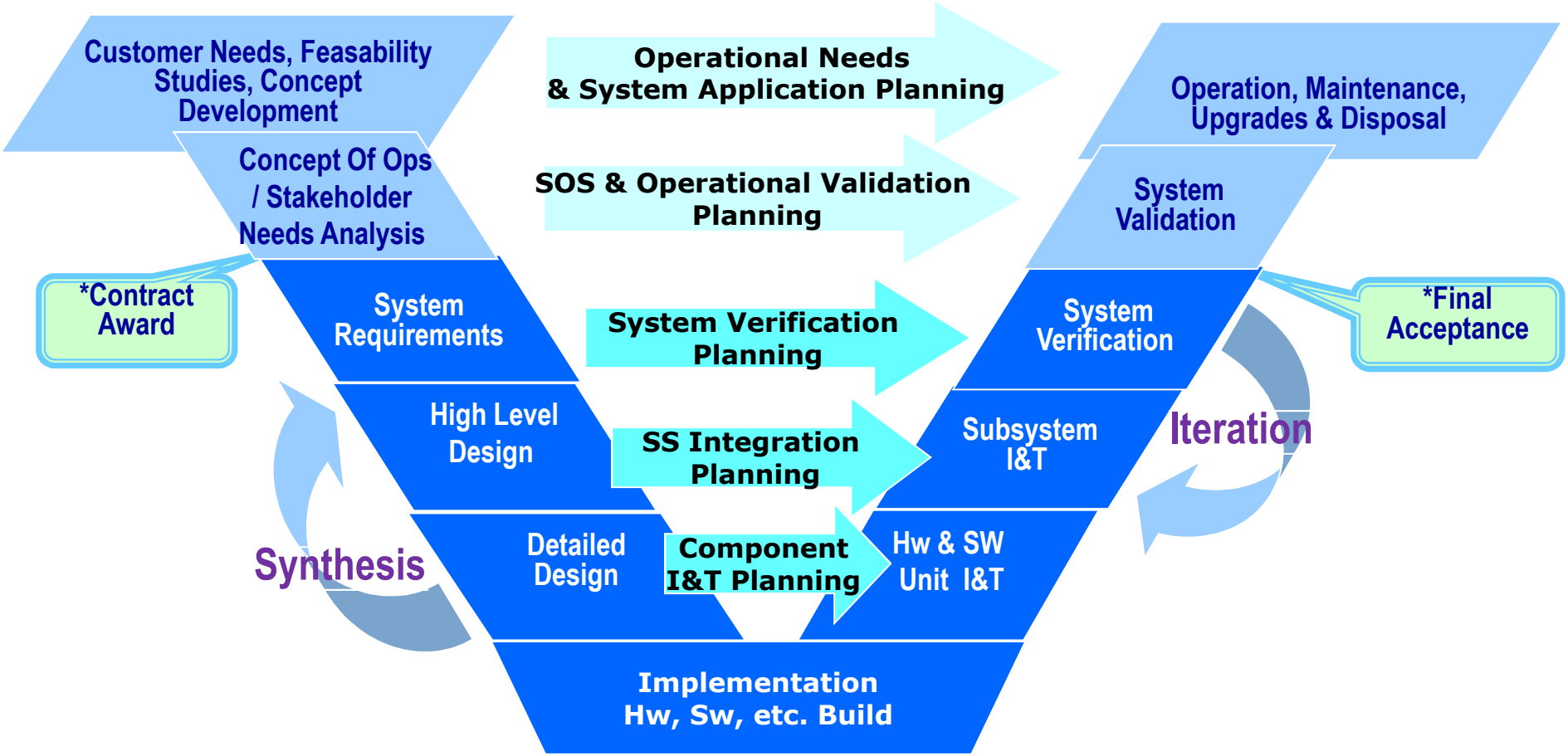
Mission Scenario:
District receives a distress call from a capsized vessel and dispatches an aircraft to drop a life raft and a cutter to recover the crew.

District C2 shall be able to:

1. **Monitor distress frequencies**
2. **Detect and record distress calls**
3. **Request asset status**
4. **Receive asset status reports**
5. **Assess mission availability**
6. **Plan SAR response**
7. **Disseminate tasking**
8. **Monitor mission execution**

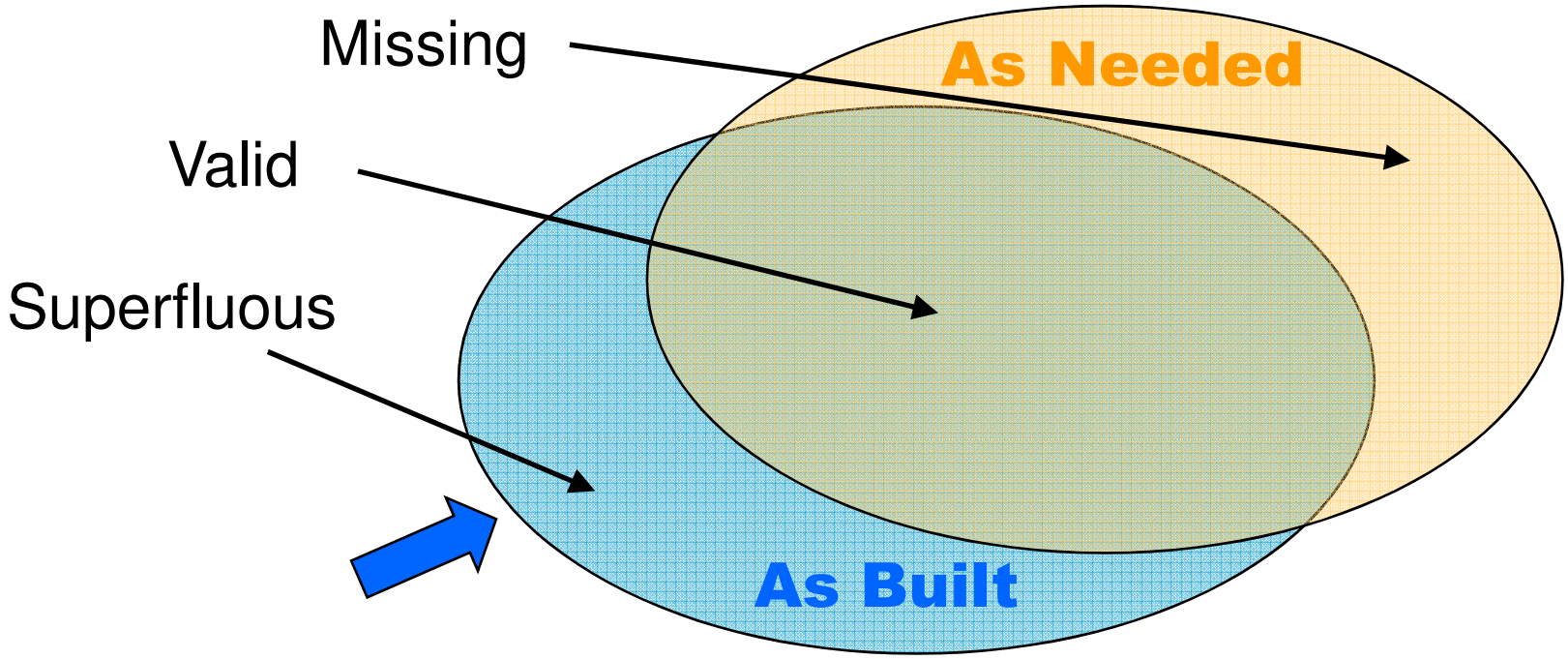


The "V" Diagram
System Life Cycle Stages/Phases



*Typical Single System Development Project-
Contract Award through Delivery & Final Acceptance

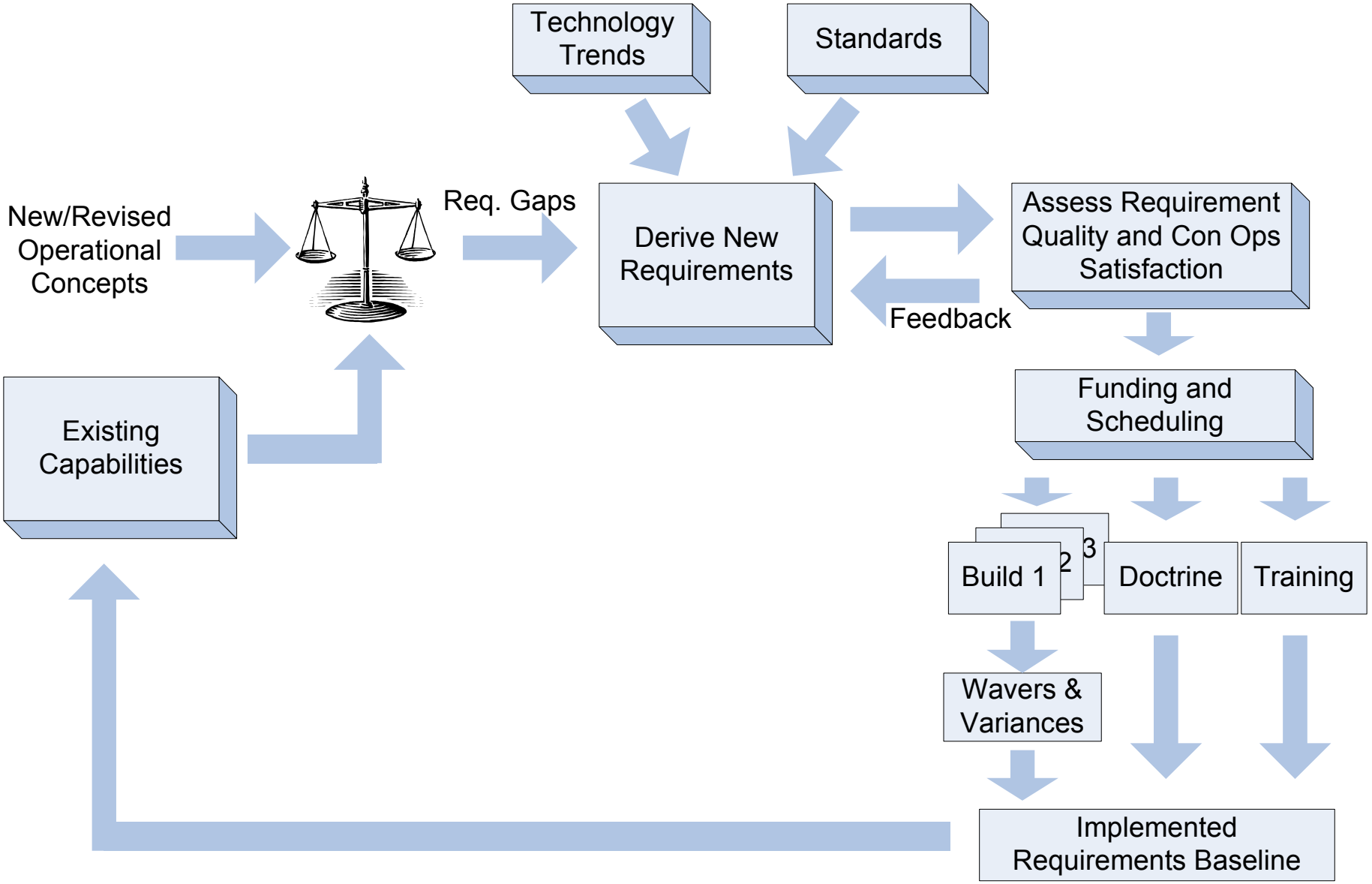
Requirements Discovery



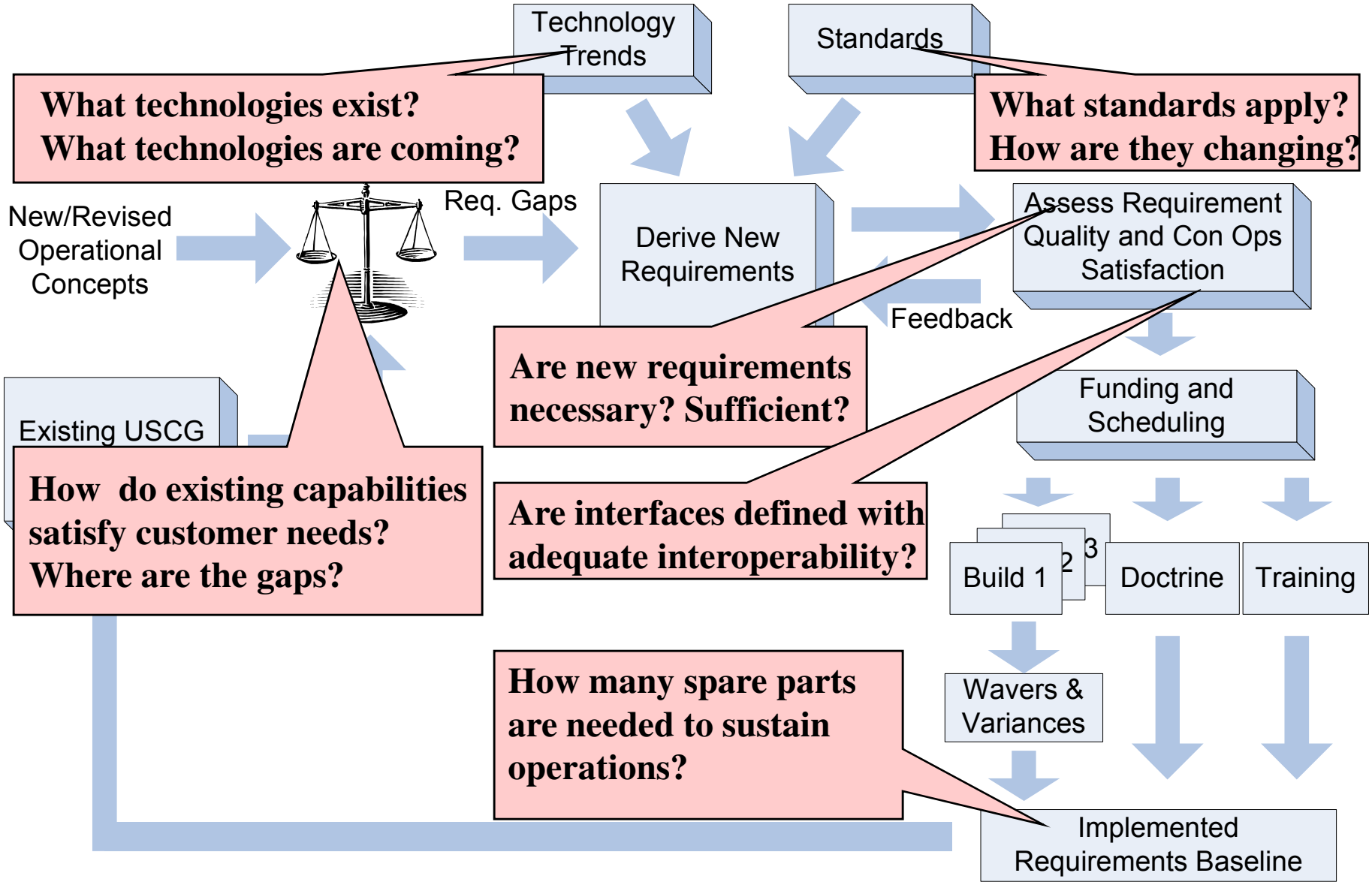
- By what analytical means can we get "As Built = As Needed"
  - Identify and capture every requirement that is needed
  - Identify and eliminate everything that is not

Adapted from "Designing the Construction Process", INCOSE Symposium, June, 2008.

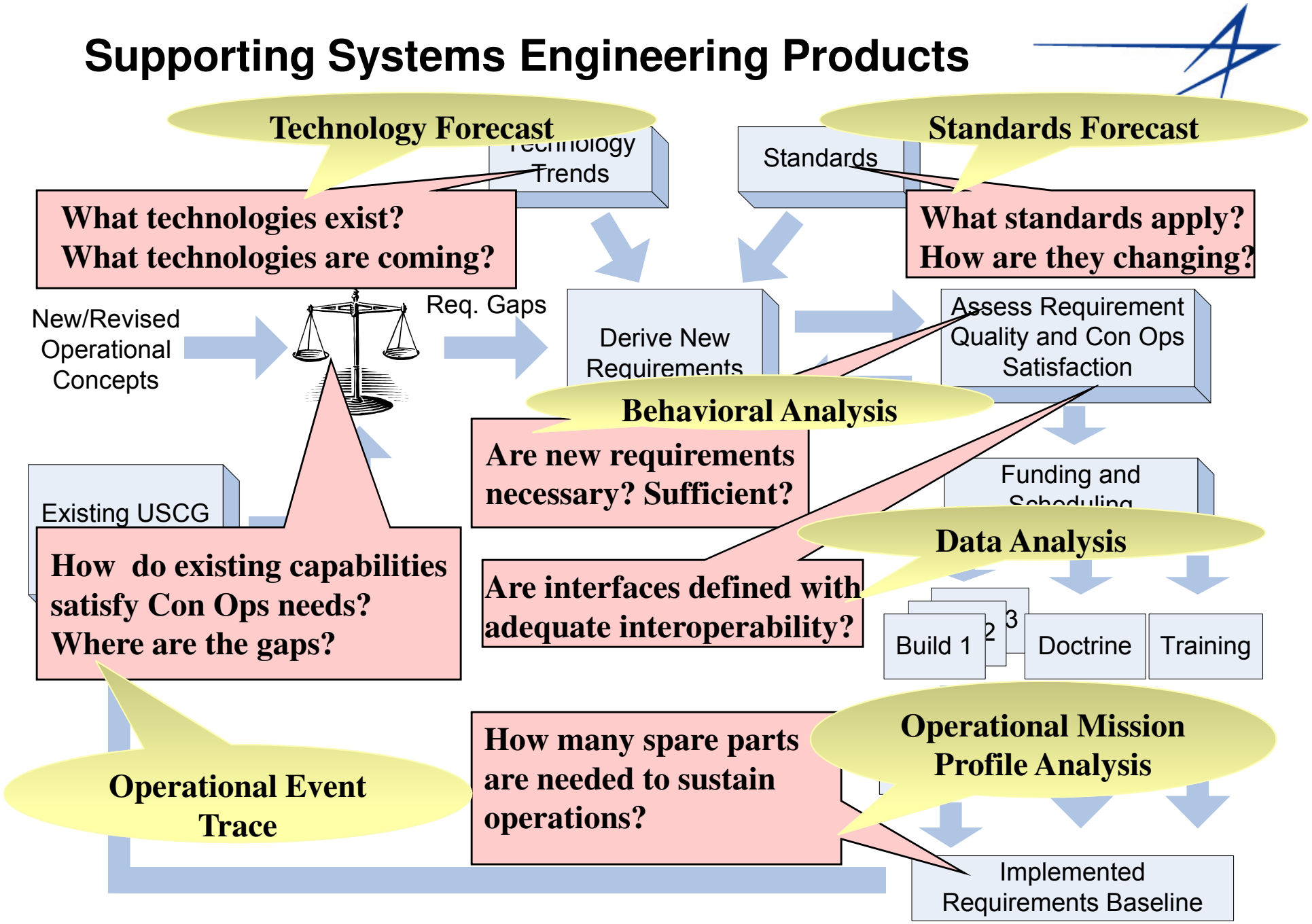
Notional Process Flow for System Development & Modification



Questions & Issues



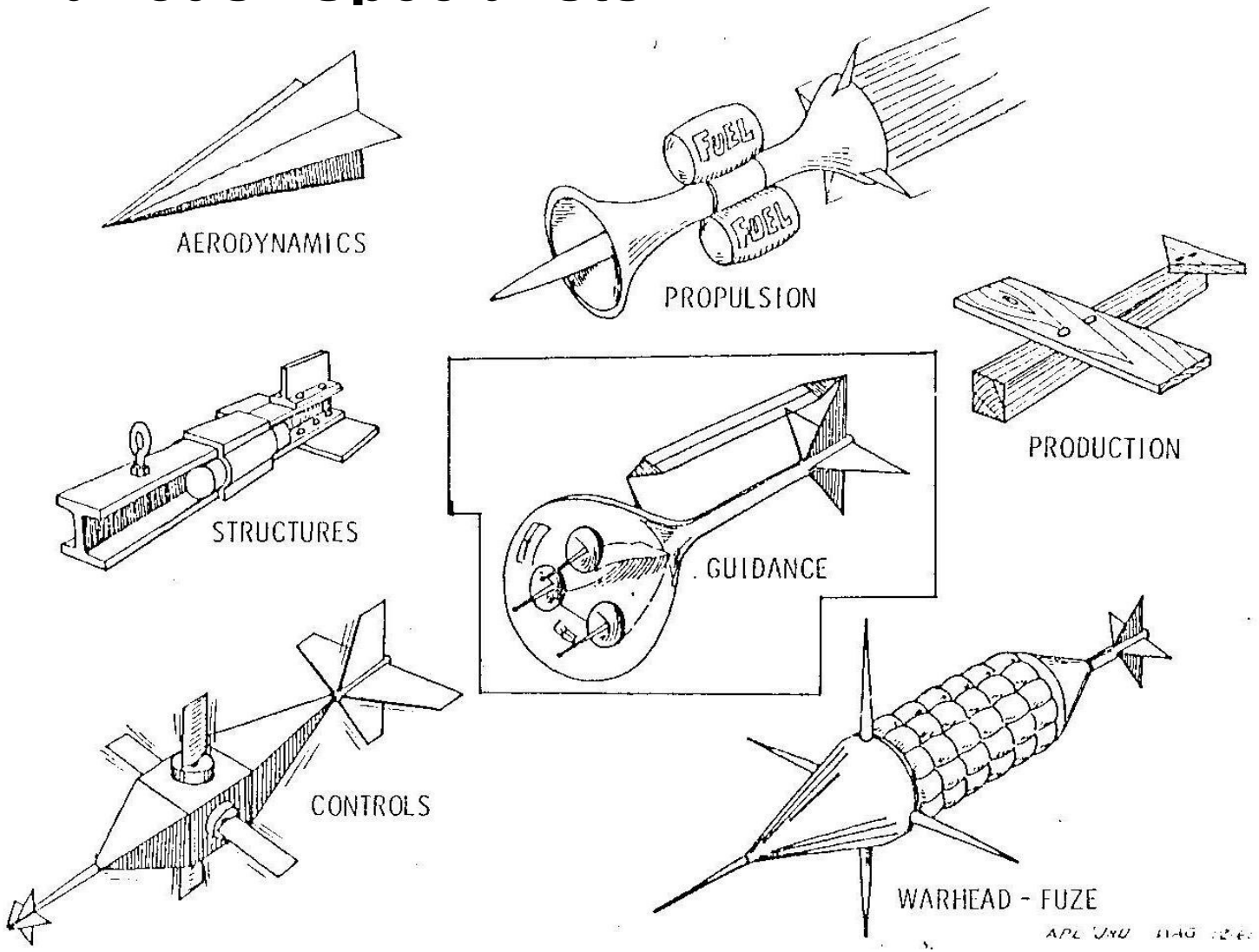
Supporting Systems Engineering Products



Skills and Methods that Support our Systems Engineering (SE) Process

- Risk Management – balancing risk against opportunity
- Requirements Development – creating clear, concise, unambiguous, verifiable statements of feasible capabilities that are required
- Requirements Analysis – determining that the stated set of requirements are necessary and sufficient to meet mission objectives. This includes identifying gaps and overlaps, in functionality, performance, and structure in a life cycle context.
- System Modeling (Functional, object-oriented, SysML) to flesh out and communicate baseline concepts of functionality and structure
- Performance Modeling & Simulation – applying, adapting, or creating models and simulations to characterize attributes of interest and then conducting the required analysis
- Trade Studies – the logical planning, execution, and defense (rationale) of engineering analysis
- Soft Skills – technical writing, public speaking, and interpersonal skills are necessary in order to get good ideas captured and communicated

Missile Design from the perspective of various "Specialists" *



Systems Engineers Must Balance Various Engineering Specialties

•Appears to be credited to someone (initials are not legible) at the Advanced Physics Laboratory of Johns Hopkins University, circa 1960

Systems Engineers Lead the Development Team

Provide baseline parameters and mission characterizations

Operationa Effectiveness Analysis

Needs to demonstrate system requirements satisfy operational missions

Needs to keep model parameters in synch with system design values.

Provide mapping of requirements to mission threads.

Provide baseline parameters and mission characterizations

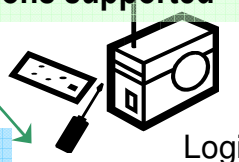
Human Factors Analysis

Needs to verify design complies with Human factors constraints.

Needs to define C4ISR interface to host Platform

Provide requirements derived from operational thread characterizations

Map component requirements to missions supported

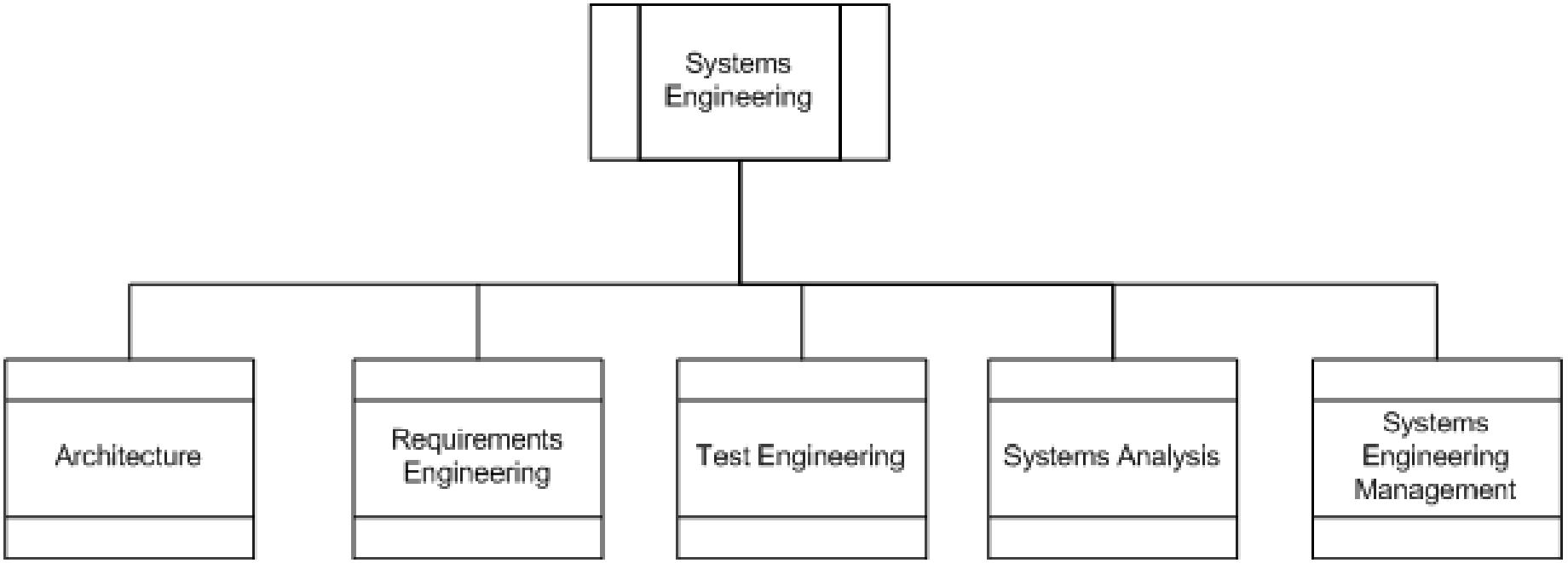


Logistics

Needs to justify which components have onboard spares.

Systems engineers need to think of themselves as the “Information Desk” where others come for answers

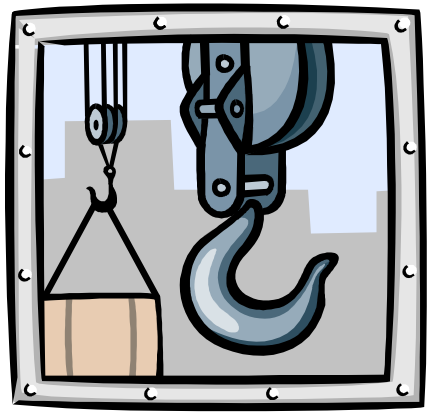
Five Roles of a Systems Engineer



- Systems engineers may be stronger (specialized) in one area but generally must be capable of working in any of these
- These five areas comprise just one possible characterization
  - One popular INCOSE paper defines systems engineering as 13 different roles

Teach Concepts by Simplifying the Problem….

- When teaching physics, we speak of "frictionless pulleys"
- When teaching Systems Engineering (SE), we say to assume that:
  - The customer provides a stable (though not necessarily complete) set of user requirements
  - The SE identifies a baseline set of functions to satisfy those user requirements
  - The SE chooses a physical baseline based upon trade studies of candidate architectures
  - The SE presents the baseline concept and resulting schedule and cost to the customer
- At some point the student discovers:
  - All real pulleys have friction
  - Real SE problems generally deviate from what we were taught to assume
- Pulleys and SE both work in the real world, but neither is "frictionless"

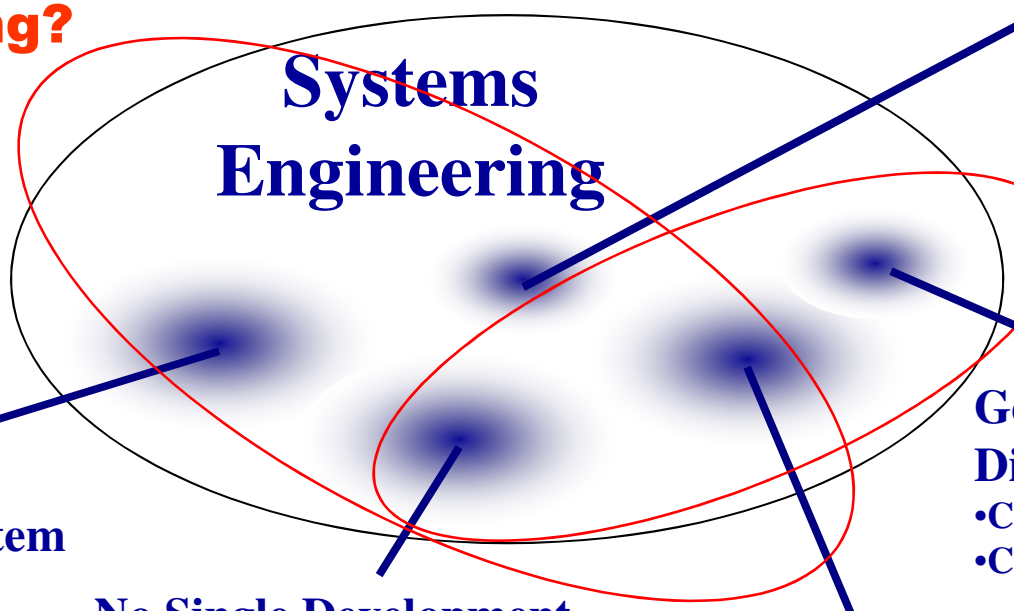


Various SE Project Characteristics

Are these really different disciplines, or is the SE discipline simply stretching to take on more complex problems?

Enterprise Systems Engineering?

Rapid Technology Advancement
- Life cycle mgmt.
- Interface mgmt.
- User acceptance



System of Systems Engineering?

Different projects Require different SE skills

Time-Variant System Composition
- Reliance on standards
- Flexible architectures

No Single Development Organization
- Schedule risks
- Budget risks
- Shared technology mgmt.

Emergent Behavior
- Technical risk mgmt.
- Validation/Certification

Geographically Distributed
- Coordination of actions
- Communications limitations

Summary

- Systems engineering is still maturing as a discipline
  - Each program seems to discover new manifestations of "friction" that bring new challenges to the effort
- Systems engineers rely on consistent execution of the same basic process in order to manage large, diverse teams on large, complex programs
  - Each domain may be different, but the process remains fairly consistent
- If the SE work is wrong, then all the other engineering effort on the program can, at best, successfully build the wrong solution
- Lack of soft skills can significantly limit the exchange and recognition of good technical work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