

# Introduction to Systems Engineering

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## Objectives:

- Define systems engineering
- Understand some of the tasks of systems engineering
- Relate these topics to real systems



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## What is systems engineering?

Group 1: You already know.

OR

Group 2: You already know,  
but you don't know you know it.



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## Definitions

**Engineering:**

- Solving problems using scientific knowledge

**A System:**


- A set of interacting entities forming an integrated whole





**Quality:**

- The extent to which requirements are met
- A process for consistently producing products that meet customer expectations

**Systems Engineering:**

- It is what systems engineers do!



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The Systems Engineering Tasks		
Understand customer needs	Design the system	Produce documentation
State the problem	Perform sensitivity analyses	Lead teams
Discover requirements	Assess & manage risk	Define technical perform. measures
Validate requirements	Perform reliability analyses	Prescribe tests
Investigate alternatives	Integrate system components	Conduct design reviews
Define quantitative measures	Design & manage interfaces	Verify requirements
Model the system	Maintain configuration management	Perform total system test
Perform functional decomposition	Provide project management	Perform TQM

(Moody, et al.)

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## Successful Systems Development

Meets Needs

The Triad

On Time

On Budget

Wired  
SILICON VALLEY ORGANIZATION

California State University  
College of Engineering

California State University  
SPACE

LABOR & WORKFORCE  
DEVELOPMENT AGENCY

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## Understanding Customer Needs

*"If you don't know where you're going, it is unlikely you'll end up there."*

- Forrest Gump

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## State the Problem

- "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth."

JFK, May 1961

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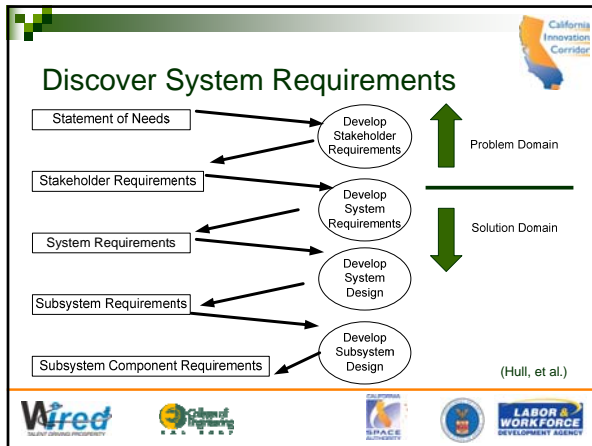
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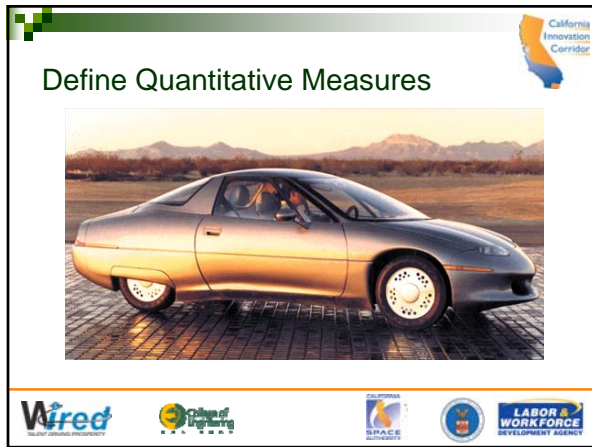
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- ### Validate Requirements
- Are the requirements consistent?
  - Will satisfying the requirements meet the customer needs?
  - Can a real-world solution be built that will satisfy the requirements?
- Is the RIGHT system being built?**
- 
- Logos for Wired, Calicut Engineering, SPACE, and LABOR & WORKFORCE are at the bottom.

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## Verify Requirements

- Are the requirements consistent?
- Does the current solution meet the requirements? If not,
  - Change requirements
  - Change current solution

**Is the system being built RIGHT?**



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## Prescribe Tests

- Every requirement must be
  - Verified
  - Validated
- Tests must be
  - Designed
  - Planned
  - Executed
  - Analyzed
  - Paid for....








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## Exploring Alternatives

- From requirements
  - Problem Domain vs. Solution Domain
- Alternatives
  - Cheaper
  - Faster to develop
  - Technically challenging
  - Degree of conformance to requirements
- Alternatives reduce project risk

Apollo Architecture Alternatives

- Nova DF
- Saturn DF
- EOR
- LOR

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## Perform Functional Decomposition

- Decomposing a functional relationship while ensuring that its original function is maintained.
  - To ensure all necessary functions will be performed
    - And no unnecessary functions will be!
  - To map functions to requirements
  - To map functions to physical subsystems

Icarus Architecture    Wright Flyer Architecture

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## Model the System

- A model is an abstraction of the real system
- Models are faster and cheaper than developing the real system
- Models are manipulated to generate simulation data
- Models are used to evaluate alternative solutions
  - They provide data for analysis
- For Example: Models for Aircraft Development

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## Create a System Design

- Design is solution realization
- Design is mostly decision-making
- Design is creative
- Design is....
  - the topic of my parallel session....

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## Conducting Design Reviews

- The SE process is controlled by “decision gates”
- These are used to move from one phase of development to the next
- Several well-accepted examples:
  - System Requirements Review
  - Preliminary Design Review
  - Critical Design Review
  - Test Readiness Review

NASA's Project Life Cycle Process Flow

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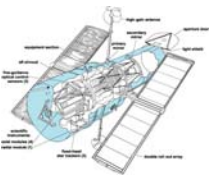
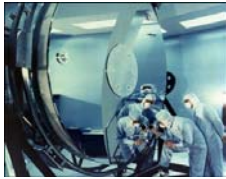
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## Performing a total system test

- End-to-end test: One of the final verification processes is to perform a test of the fully-integrated system.

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## Maintaining configuration management

- In systems development, changes are inevitable:
  - in requirements
  - in design
  - in implementation
- Configuration management ensures that changes are
  - identified, controlled, communicated and recorded

Apollo 13 clip

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## Documenting all activity

- Systems engineering needs to be an explicit process
  - System must be verified and validated
  - Requirements must be traceable
  - Current configuration of the system must be known
  - Past decisions must be traceable
  - ...and on and on and on....
- Therefore, all activities must be documented in a common repository
  - Platform and display independent
  - Accessible to anyone, anywhere


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## Who does systems engineering?

- Systems Engineers
- Design Engineers
- Project/Program Managers
- Any "speciality" engineers
  - Mechanical, Aero, Civil, Software, Materials, etc...
  - System Architects
  - Quality Engineers
- Cost accountants
- Marketing
- Purchasing
- etc., etc., etc.

It really doesn't matter who..  
...as long as it gets done!


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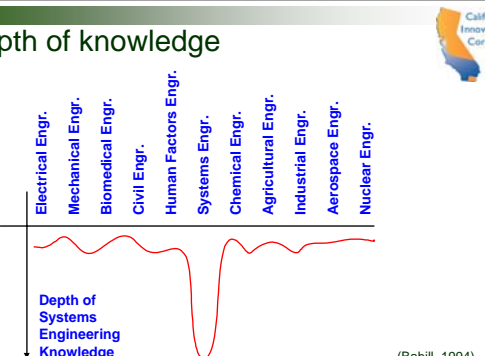
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## Depth of knowledge



(Bahill, 1994)


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## A Systems Engineering Definition






“Systems engineering is an interdisciplinary engineering management process that evolves and verifies an integrated, life-cycle balanced set of system solutions that satisfy customer needs”  
- U.S. Department of Defense (2001).

**In my view, it is simply:**

- IDEAL....
- RATIONAL.....
- “GOOD” ENGINEERING?

Possible Synonyms for Systems Engineering:  
Program Management, Research and Development (R&D), Product Development, Concurrent Engineering, Integrated Product Teams (IPT)

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## SE as a Profession

- Professional societies
  - International Council on System Engineering (INCOSE)
  - IEEE Computer Society (Software Systems Engineering)
- Journals
  - Journal of System Engineering
  - INSIGHT
  - Symposium Proceedings
- Educational Programs
  - Undergraduate and Graduate Degrees in SE (approx. 50)
  - Industrial and Systems Engineering (approx. 25)
  - Computer and Systems Engineering (approx. 40)
- Practitioners
  - Aerospace (NASA, Boeing, Lockheed-Martin, Military)
  - Software Engineering
  - Capital Projects (buildings, transportation, factories)
  - Growing in other areas (biomedical, consumer products)

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