ESD.33 Systems Engineering
Lecture 1
Course Introduction

Instructors:

Dr. Qi Van Eikema Hommes

Mr. Pat Hale

Mr. David Erickson

Teaching Assistants:

Ellen Czaika

Ipshita Deepak

Agenda

- Welcome and Introduction of Teaching Staff
- Why are we here?
  - What are Systems?
  - What is Systems Engineering?
  - Why do we study Systems Engineering?
- Course Schedule and Logistics

Dr. Qi Van Eikema Hommes

- ESD Research Associate and Lecturer
- 8 years of work experiences in automotive companies (Ford and GM)
  - Senior Research Scientist at GM R&D
  - Powertrain Systems Engineer at Ford

MIT	Ph.D. and M.S. in Mechanical Engineering	University of Kentucky	B.S. in Mechanical Engineering

Dr. Pat Hale

- SDM Director, ESD Senior Lecturer
- Military experience:
  - 20 years in U.S. Navy: submarines
- Industry experience:
  - Draper Labs (Director, Systems Engineering)
  - Otis Elevator (first Director, Systems & Controls Engineering)
- Past INCOSE president

David P. Erickson

Academic Background

B.S. Mechanical Engineering
University of Minnesota

M.S. Mechanical Engineering
Engineer's Degree in Ocean Engineering
Massachusetts Institute of Technology

MBA
Cornell University

Ipshita N. Deepak (Teaching Assistant)

About me:

Product designer/ manager, systems engineer, mobile tech enthusiast, a mother, vocal artist and a second year SDM student

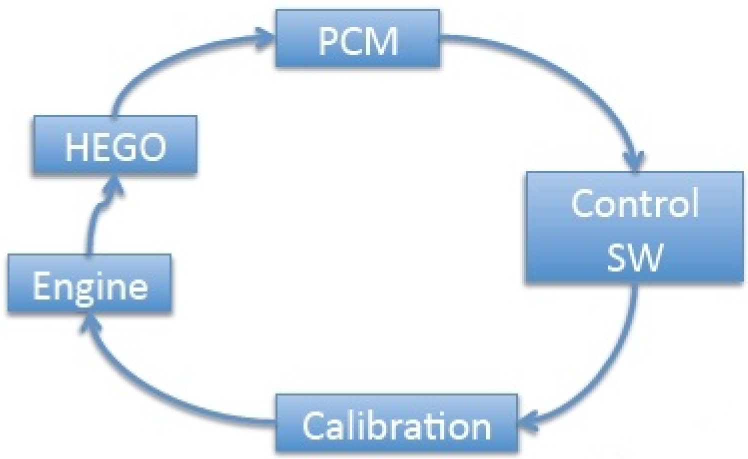
Ellen Czaika (Teaching Assistant)

About me:

- SDM08
- Former manager of systems engineering team
- Ethnographer
- Athlete (numerous sports: rowing, yoga, skiing/snowboarding, hiking, biking, sailing, surfing, etc.)

Why Are We in This Class?

My Story on Systems Engineering



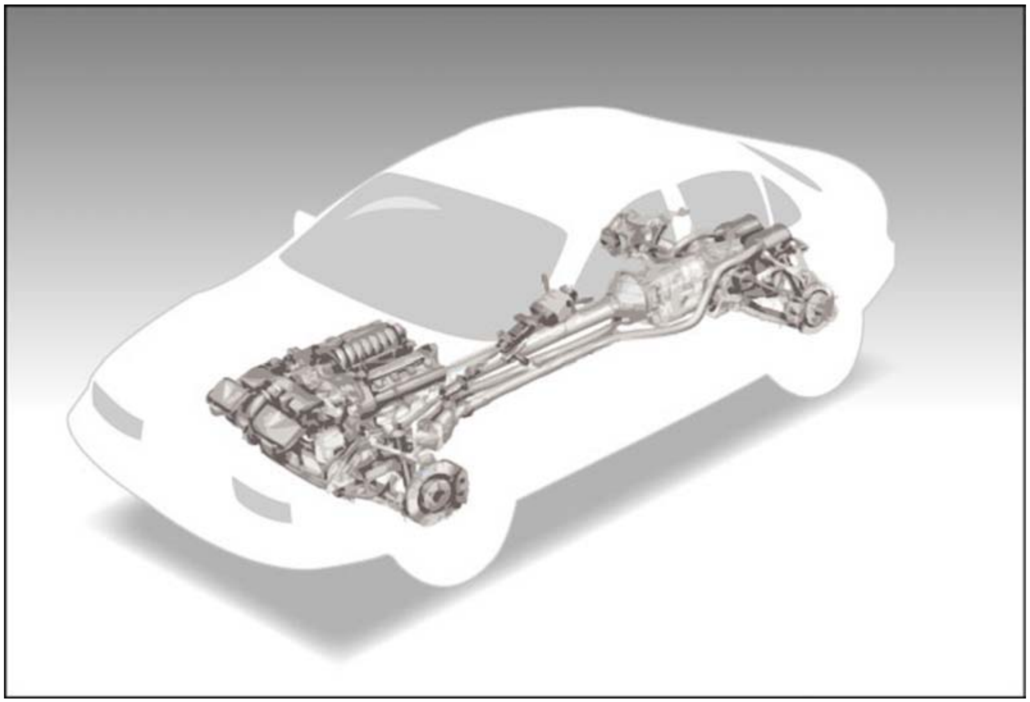


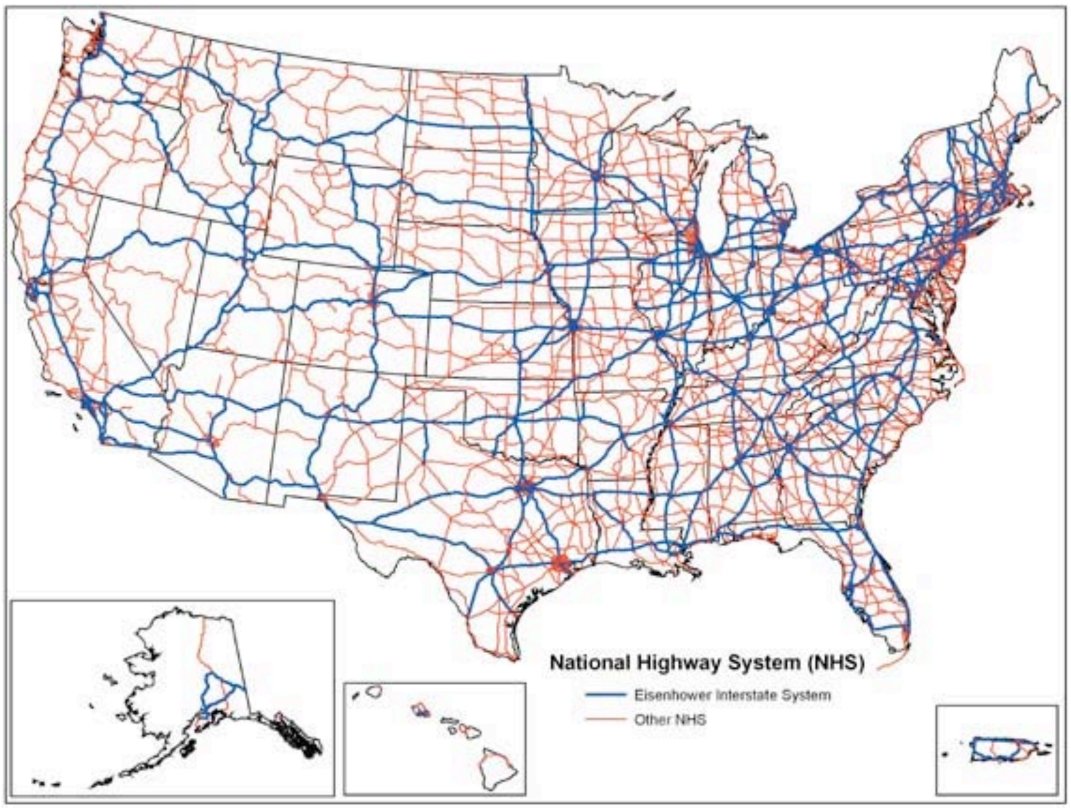
Image by MIT OpenCourseWare.

Is This a System and Why?

Power grid image removed due to copyright restrictions.
Image can be found at HowStuffWorks.com.

http://science.howstuffworks.com/power.htm/printable

Is This a System and Why?



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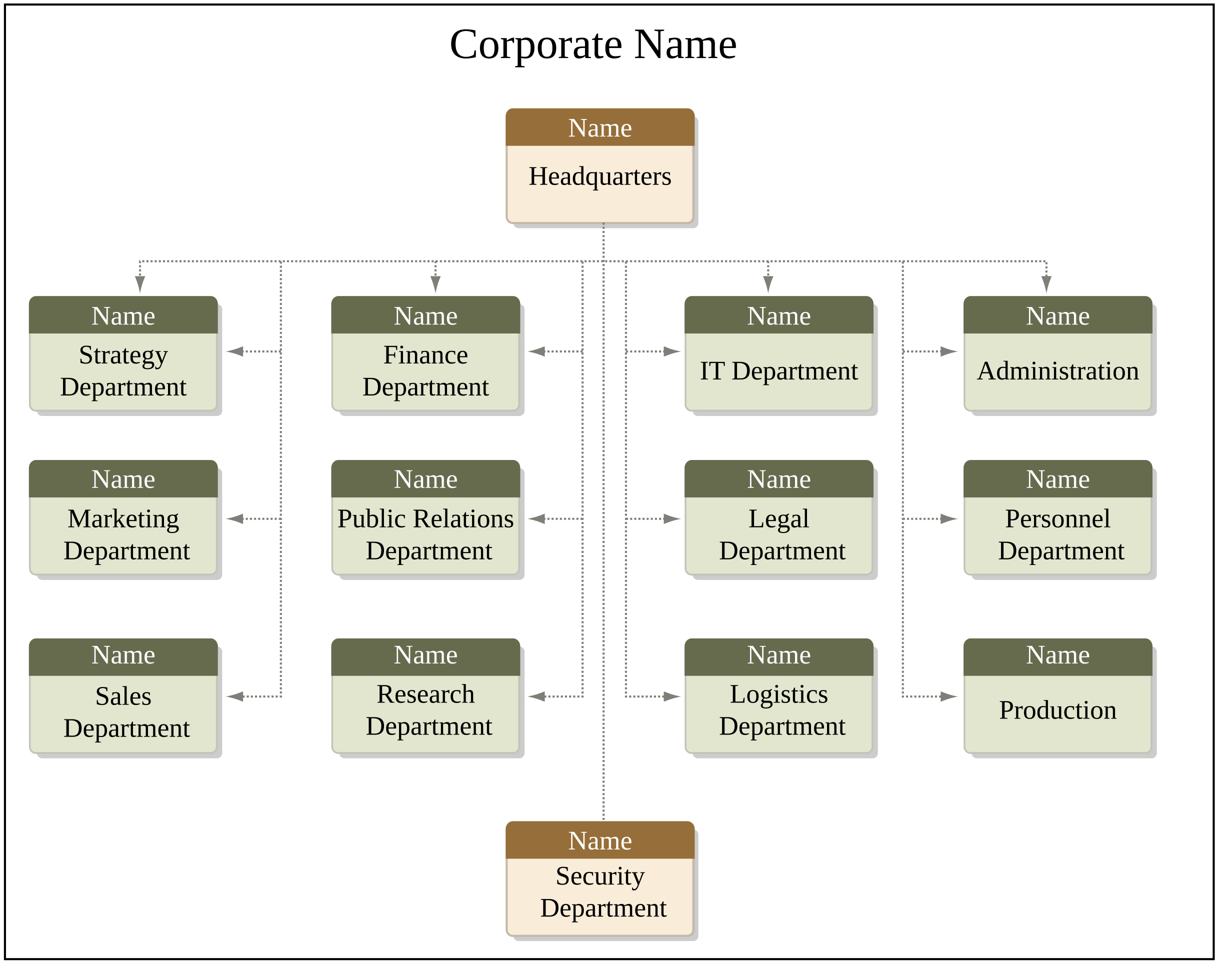

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Is This a System and Why?

http://ccl.northwestern.edu/netlogo/models/WolfSheepStrideInheritance (ANIMATION)
Works in Firefox browser

Wolves eats sheep.
Sheep eat grass.
Wolves and sheep reproduce.
They move in random directions.

Try when there are more wolves than sheep.

What Types of Systems Have You Worked on?

Why do you call them "systems?"

Definition of Systems

- A combination of <u>interacting elements</u> organized to achieve one more stated purposes.
- An integrated set of elements, subsystems, or assemblies that accomplish <u>a defined objective</u>. These elements include products (hardware, software, firmware), processes, people, information, techniques, facilities, services, and other support element.

Source: INCOSE SE Handbook, V3.2

Characteristics of Systems

- Interaction
- Hierarchical
- Emergent
- Dynamic
- Interdisciplinary

Digital Photography

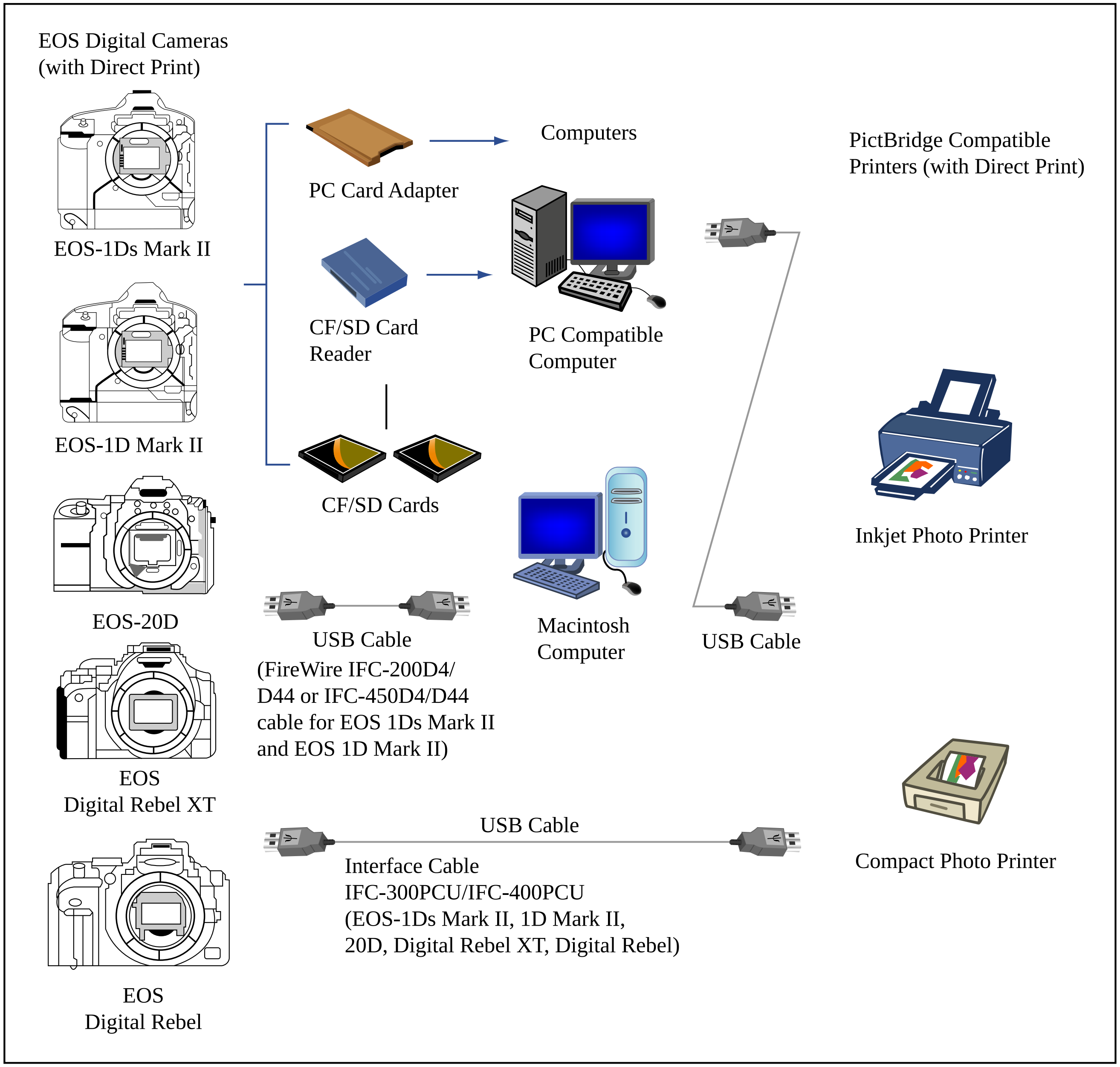


Image by MIT OpenCourseWare.

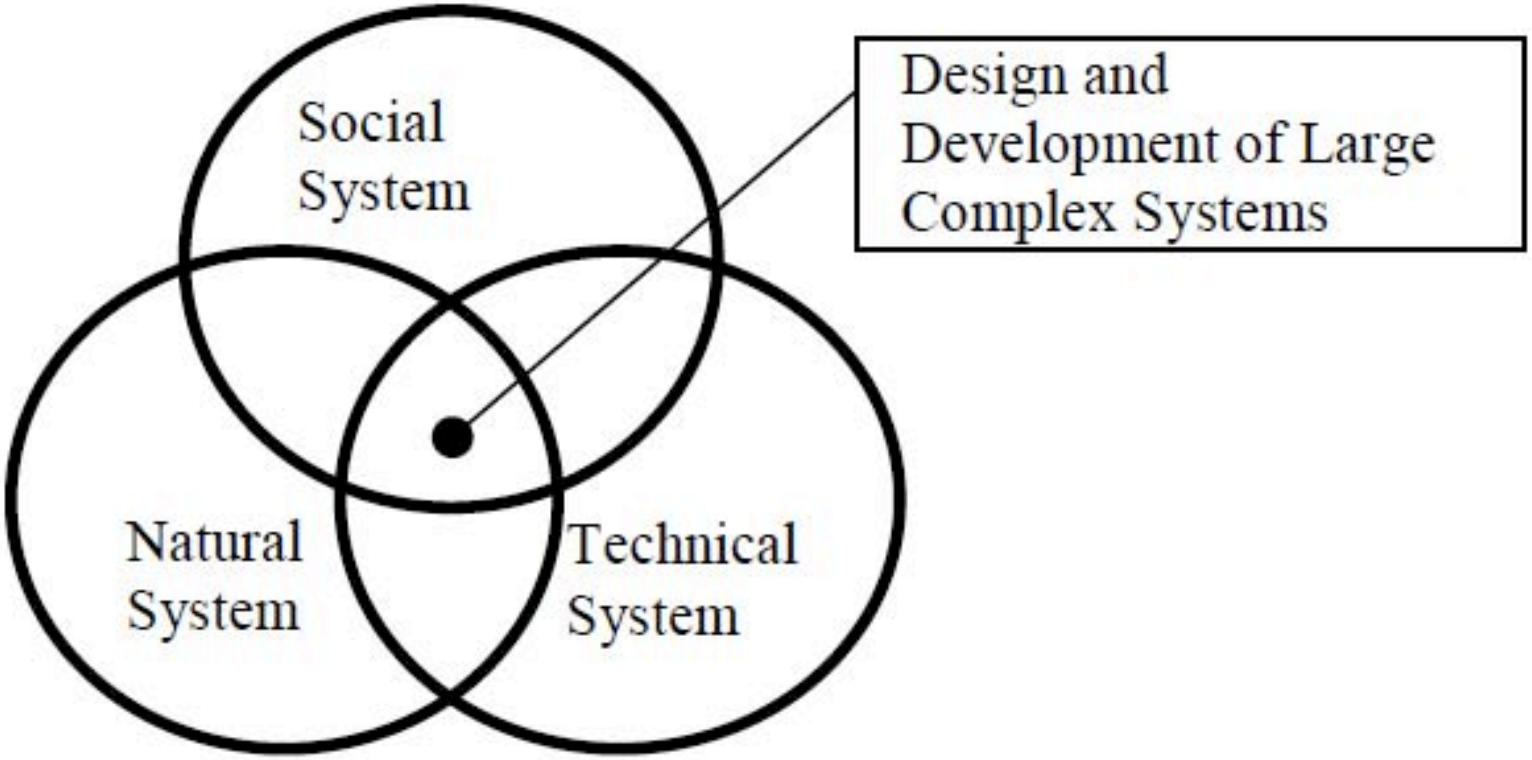
System of Systems

Large-scale inter-disciplinary problems involving multiple, heterogeneous, distributed systems.

- *System elements operate independently.*
- *System elements have different life cycles.*
- *The initial requirements are likely to be ambiguous.*
- *Complexity is a major issue.*
- *Management can overshadow engineering.*
- *Fuzzy boundaries cause confusion.*
- *SoS engineering is never finished.*

Source: INCOSE SE Handbook V3.2

This Class' Focus



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What is Systems Engineering?

- Systems engineering is a discipline that concentrates on the design and application of the whole (system) as distinct from the parts. It involves looking at a problem in its entirety, taking into account all the facets and all the variables and relating the social to the technical aspect.
- Systems engineering is an iterative process of top-down synthesis, development, and operation of a real-world system that satisfies, in a near optimal manner, the full range of requirements for the system.

INCOSE SE Handbook V3.2

What is 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, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal. SE considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

INCOSE SE Handbook V3.2

Application Domains of Systems Engineering

- Aerospace
- Urban Infrastructure
- Communications systems
- Data and information systems
- Healthcare systems
- Electric power systems
- Production/construction systems
- Waste disposal systems
- Transportation systems
- Financial systems
- Education systems
- …

Source: Blanchard, Fabrycky, Systems Engineering and Analysis, 5^{th} ed.

Waterfall Process Model

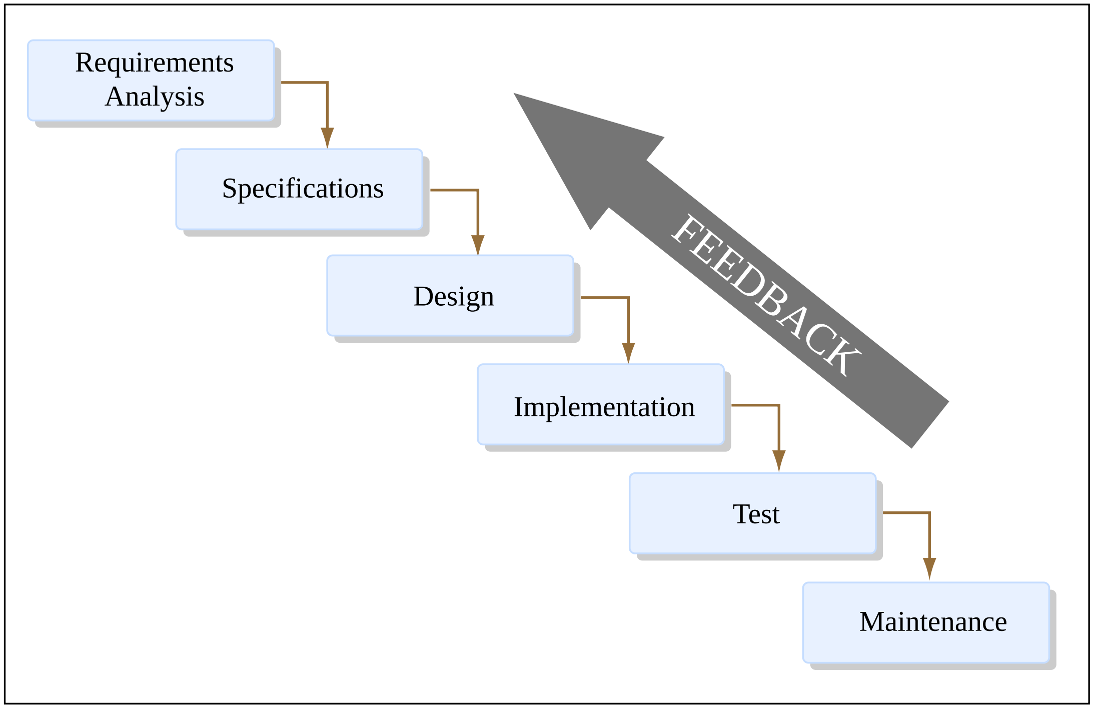


Image by MIT OpenCourseWare.

Introduced by Royce in 1970, initially for software development.

Source: Blanchard, Fabrycky, Systems Engineering and Analysis, 5th ed.

Spiral Process Model

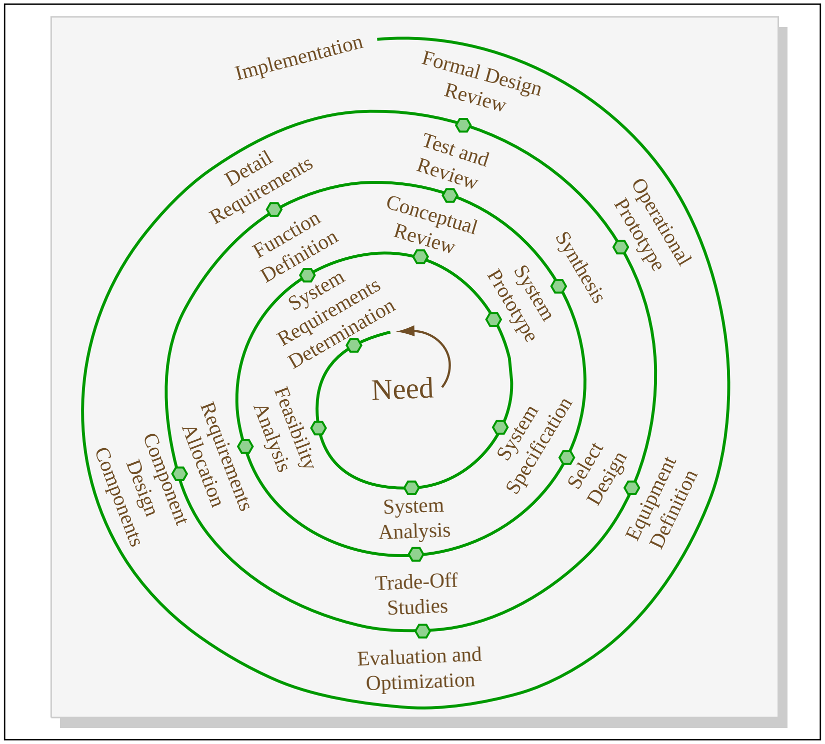
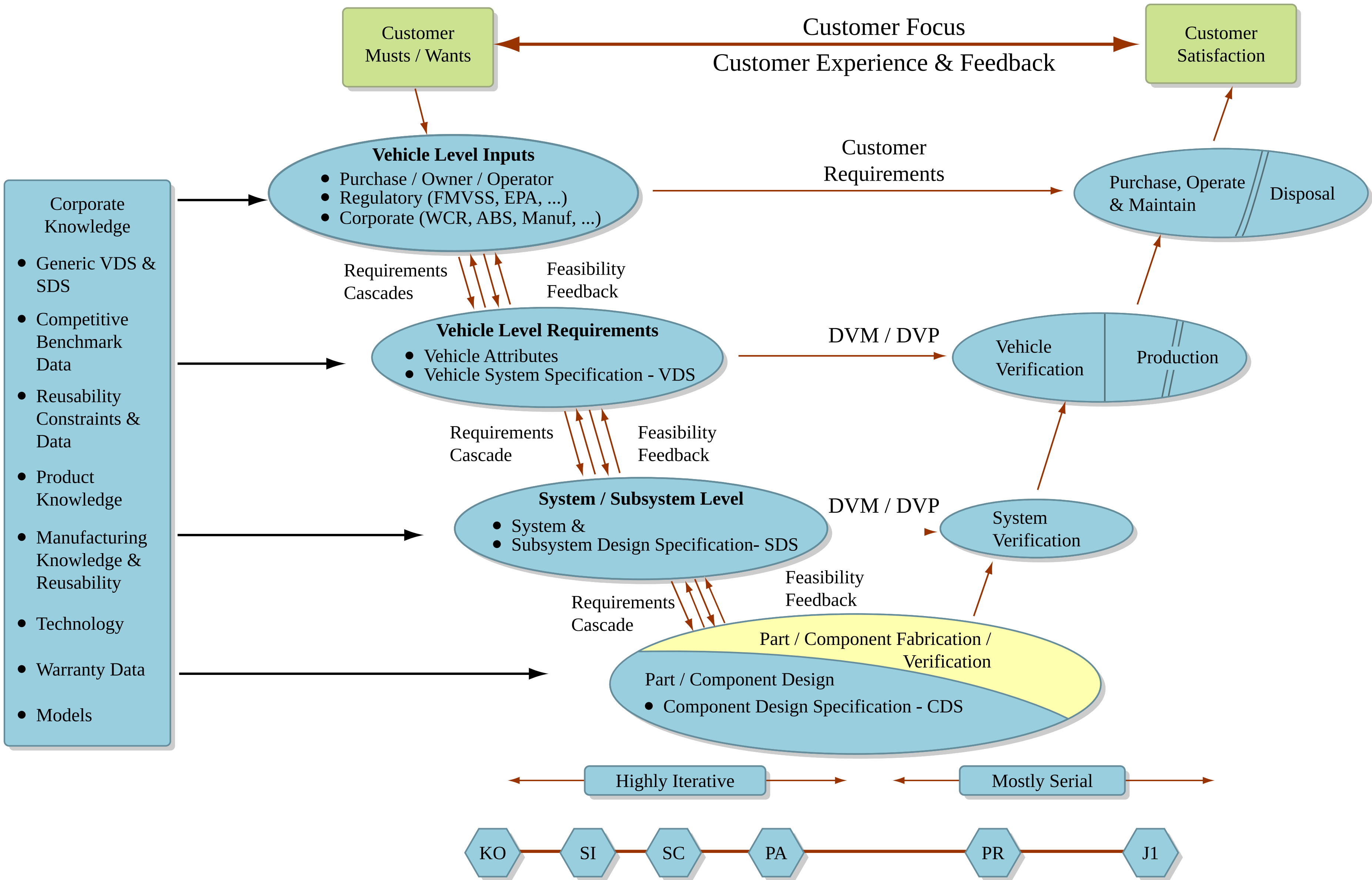


Image by MIT OpenCourseWare.

Source: Blanchard, Fabrycky, Systems Engineering and Analysis, 5th ed.

- Boehm, 1986.
- Adapted from Waterfall model
- Iterative
- Prototyping

System Engineering Implemented in FPDS



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INCOSE VEE Model

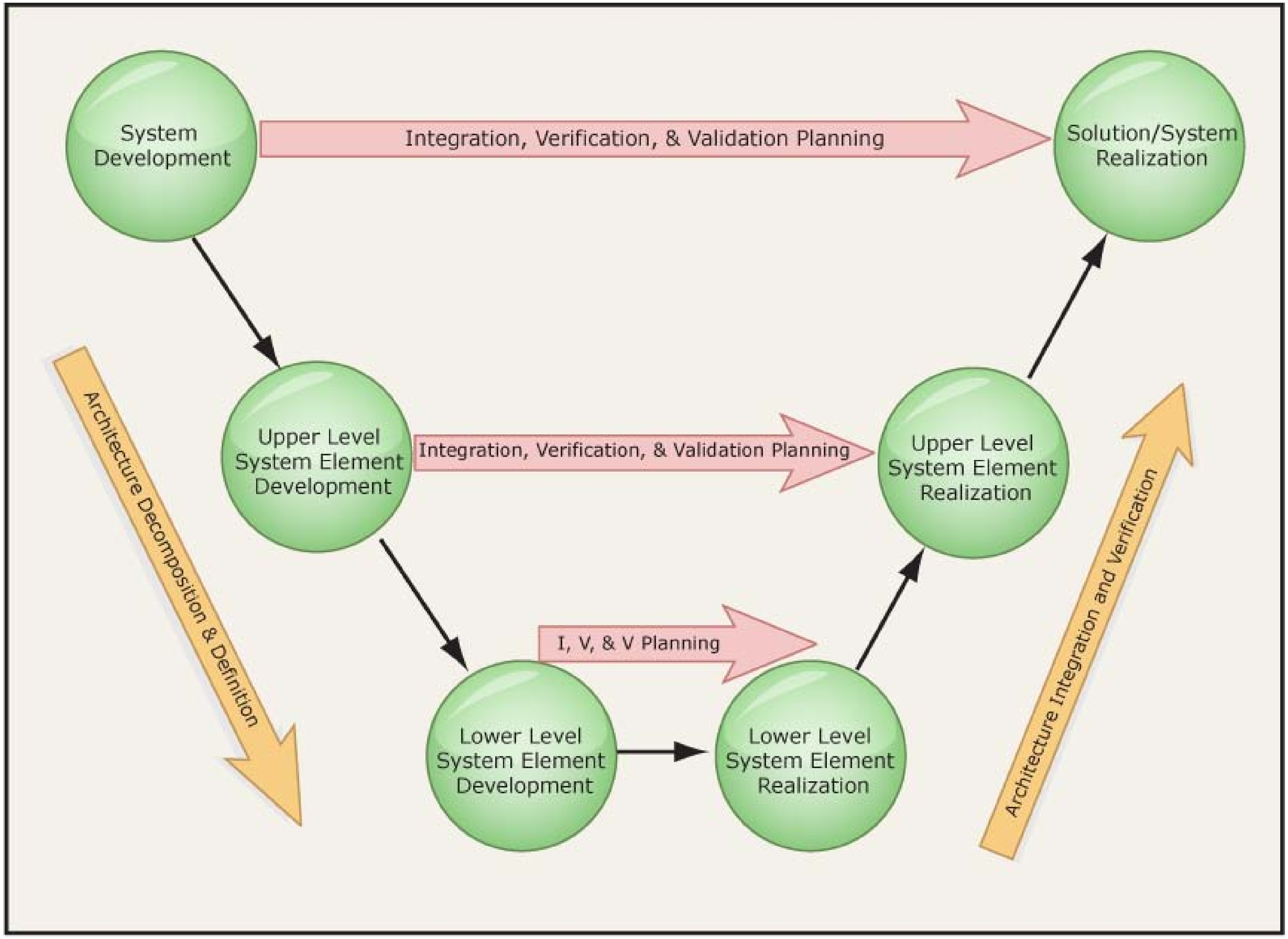


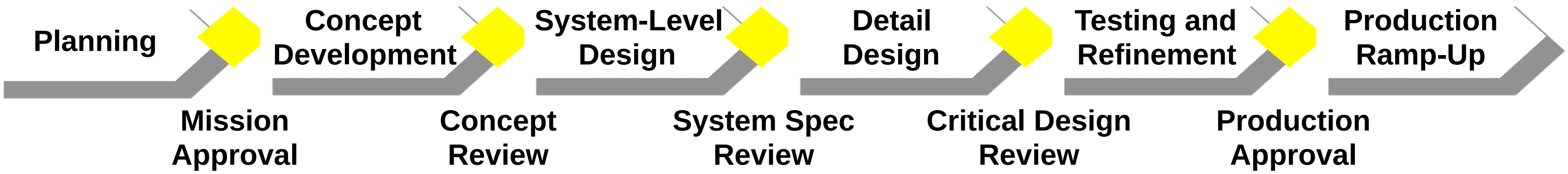
Image by MIT OpenCourseWare.

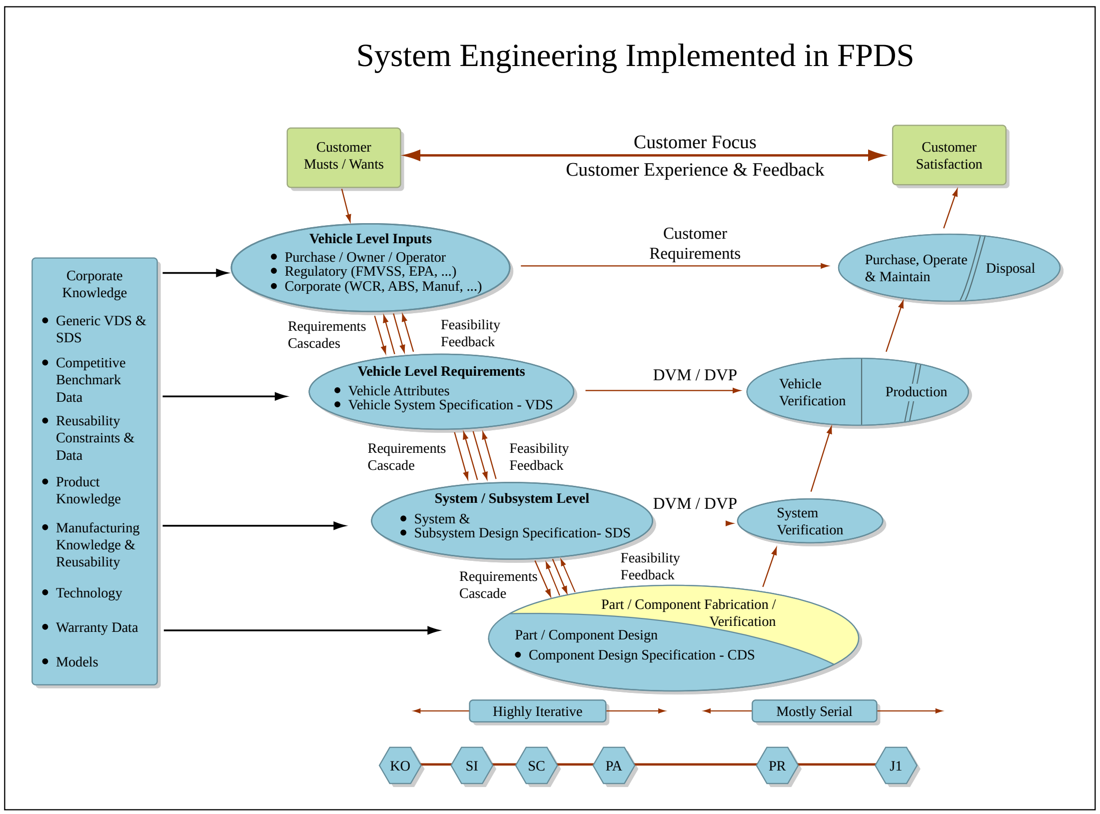
Is There a Winner?

- It is observed that preferences expressed by individuals and groups for one of the system models is subjective.
- Research is needed to see which model fits what situation better.
- Class Discussion:
  - What are common among these processes?
  - Is Systems Engineering the same from Product Development?

Systems Engineering vs. Product Development

Product Development Process (Ulrich and Eppinger)





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The Value of Systems Engineering

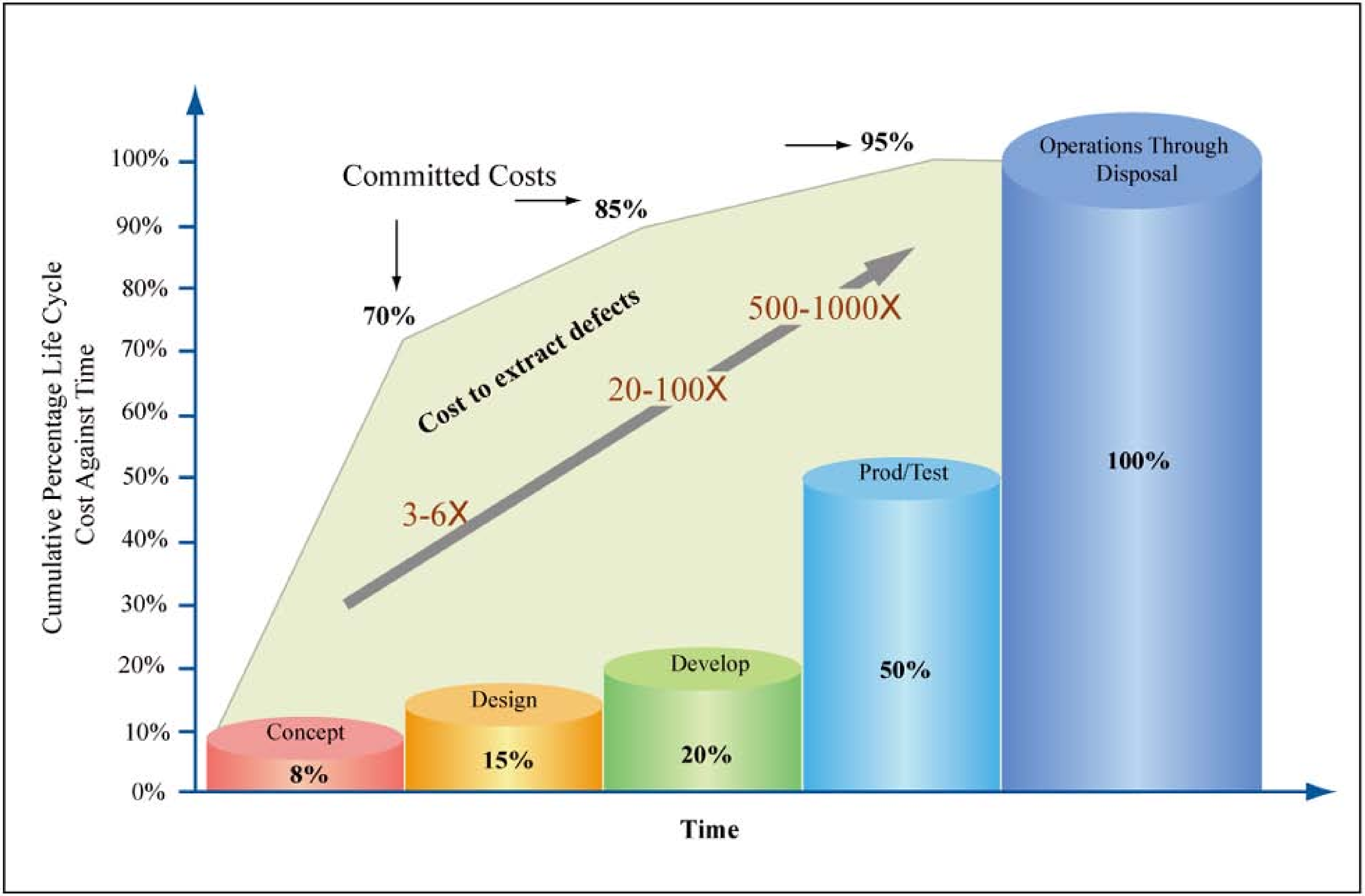

Image by MIT OpenCourseWare.

The Value of Systems Engineering

- Systems engineering efforts reduce cost and schedule overrun.
- Class discussion: Why? Think back about the characteristics of systems.
  - Interaction
  - Hierarchical
  - Emergence
  - Dynamic
  - Interdisciplinary

History of Systems Engineering

1940s

The Machine Age → The Systems Age →

The Machine Age

- **Reductionism**—Everything can be reduced, decomposed, or disassembled to simple indivisible parts.
- **Analytical** way of thinking
  - Take apart what is to be explained
  - Explain the smaller parts.
  - The whole is the sum of its parts.
- **Mechanism**
  - Cause and effect, deterministic thinking
  - Closed System Thinking—ignore the environment a phenomenon is in.
- **Mechanization**
  - Industrial revolution (18-19th century)
  - Machine substitute people for physical work
  - Dehumanization of work

Examples of Machine Age Thinking

- Ancient roots
  - Aristotle (*Physics—fire, earth, air, water, aether)*
  - Archimedes
- Biology
  - Study of cells and organs
- Physics
  - Study of atoms
- F. W. Taylor “Scientific Management”

Class Discussion Points

- Your examples?
- Strength and Weakness of Machine Age Thinking

The System Age

- Circa 1940s
- Supplementing the Machine Age thinking
- **Expansionism**
  - All objects and events, and all experience of them as parts of larger wholes.
  - Stochastic view of the systems.
- **Synthetic Thinking (Systems Thinking)**
  - Instead of focusing on explaining the whole but taking it apart, synthetic thinking focuses on explaining something in terms of its role in the larger system.
  - The whole is not equal to the sum of its parts—sometimes more, sometimes less.
- **Teleologically oriented**
  - Systems have purposes
  - More focuses on the human aspect of organization design and management.

Machine Age vs. Systems Age

Machine Age Thinking	Systems Age Thinking
Reductionism	Expansionism
Analytical thinking	Synthetic thinking
Mechanization	Teleologically Oriented

- These two eras show continuous human inquiry to understand the world.
- They are complementary, not contradictory.
- System Engineering is a more recent phenomenon.
- Understanding the history helps us to think critically.

INCOSE

- The International Council on Systems Engineering (INCOSE) is a not-for-profit membership organization founded to develop and disseminate the interdisciplinary principles and practices that enable the realization of successful systems.
- Mission: Share, promote and advance the best of systems engineering from across the globe for the benefit of humanity and the planet.
- Vision: The world's authority on Systems Engineering.
- http://www.incose.org/

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Course Learning Objectives

- This course intends to help you develop the capability of systems thinking by introducing classical and advanced systems engineering theory, methods, and tools. After taking this class, you should be able to:
  - Develop a systems engineering plan for a realistic project.
  - Judge the applicability of any proposed process, strategy, or methodology for systems engineering using the fundamental concepts from disciplines such as of probability, economics, and cognitive science.
  - Understand system engineers' role and responsibilities. Understand the role of organizations.
  - Apply systems engineering tools (e.g., requirements development and management, robust design, Design Structure Matrix) to realistic problems;
  - Recognize the value and limitations of modeling and simulation.
  - Formulate an effective plan for gathering and using data.
  - Know how to proactively design for and manage system lifecycle targets.

Course Layout

Lecture 4
Stakeholder Analysis and Requirements Definition

Lecture 2
Systems Engineering As Human Activity

Lecture 13
Design Verification and Validation, Lifecycle Management

Lecture 5 innovation in Systems Engineering

Lecture 6 Axiomatic Design and DM-DSM Method

Lecture 7 CPM and DFSS

Lecture 8
Trade Space Exploration Concept Selection

Lecture 10 : Experiments
Lecture 11 : Robust Design I
Lecture 12: Robust Design II

Course Materials

- Textbooks:
  - INCOSE Systems Engineering Handbook, V3.2.
  - "40 Principles"
  - QBQ
- Reference books:
  - **Strongly recommended**: Blanchard, B. S., and Fabrycky, W. J., *Systems Engineering and Analysis*, 5^{th} edition, Prentice Hall, 2010.

Course Policies

- Reading –please be prepared for class discussions
- Class sessions
  - 2 sessions/week, 2 hours/session
  - Session 3, 3 hours, project proposal
  - Sessions 19 and 20, 4 hours, final presentations.
- Attendance and class participation
  - Instructor will randomly pick student names for class discussion

Class Time Commitment

- Course is H 3-0-6
- This is a 9 units class in a normal semester (14 weeks).
- Summer is 10 weeks, which means this course requires 12.6 hours of work per week.
- 12.6 hours = 4 hours in class + 8.6 hours outside
- 8.6 hours include reading, homework assignments, and project work.

Grading

- Project (presentations and reports):
  - Individual Project proposal (presentation and 1-page) 10%
  - Mid-term (group presentation) 10%
  - Final (group presentation) 20%
- Homework Assignments 10% x 5
  - The first four are individual assignments 10% x 4
  - The fifth is a group presentation 10%
- Attendance and class participation 10%
  - Each class unattended without instructors' permission reduces 1% of the grade
  - Please let the instructor know if you are unable to attend the class.

Term Project

- The goal is to apply the systems engineering methods and tools to a topic that fits your interest / your industry.
- Acceptable topic examples:
  - Design of a new system (technical, organizational, enterprise level, etc.). The project must have enough detail so that it can demonstrate the use of the methods and tools taught in the class.
  - In-depth investigation of a successful or failed project
- Choose a project that you have access to information and data.

Term Project Deliverables

- Proposal (Session 3)
  - Individual students propose project topics
  - Voluntarily form teams of 3-5. Four-member teams are strongly encouraged.
  - Submit team formation report by Session 5.

- Mid-term presentation (Session 9)
- Final presentation (Sessions 19 and 20)

Homework Assignments

- What if you were called to help NHSTA investigate the Toyota sudden acceleration safety recall?
- Most of the homework assignments will be centered around the question: What could have been done to prevent the problem?
- Your study should not be focused only on Toyota, but automobiles in general.
- More about the case study in a few slides.

Homework Requirements

- Homework is individual-based. Collaboration is encouraged, but work must be turned in by individuals.
- Acknowledge all help received.
- Provide references to data and information sources.

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