ENES489P: SYSTEMS ENGINEERING PROJECTS

Introduction to Systems Engineering

Mumu Xu

Email: mumu@umd.edu

Institute for Systems Research | Aerospace Engineering

SYSTEMS ENGINEER: "BEST JOB IN AMERICA"

Money Magazine

Best Jobs in America by Donna Rosato with Beth Braverman and Alexis Jeffries. Oct. 9, 2009
Source: MoneyOnCNNMoney.com

"Money and PayScale.com, a leading online provider of employee-compensation data, surveyed 35,000 people online about what makes a great job, they rated intellectual challenge, a passion for the work, and flexibility just as highly as security.

1. **Systems Engineer**

Median salary (experienced): $ 87,100
Top pay: $130,000
Job growth (10-year forecast): 45%
Sector: Information Technology

What they do: They're the "big think" managers on large, complex projects, from major transportation networks to military defense programs. They figure out the technical specifications required and coordinate the efforts of lower-level engineers working on specific aspects of the project.

Why it's great: Demand is soaring for systems engineers, as what was once a niche job in the aerospace and defense industries becomes commonplace among a diverse and expanding universe of employers, from medical device makers to corporations like Xerox and BMW. Pay can easily hit six figures for top performers, and there's ample opportunity for advancement. But many systems engineers say they most enjoy the creative aspects of the job and seeing projects come to life. "The transit system I work on really makes a tangible difference to people," says Anne O'Neil, chief systems engineer for the New York City Transit Authority.

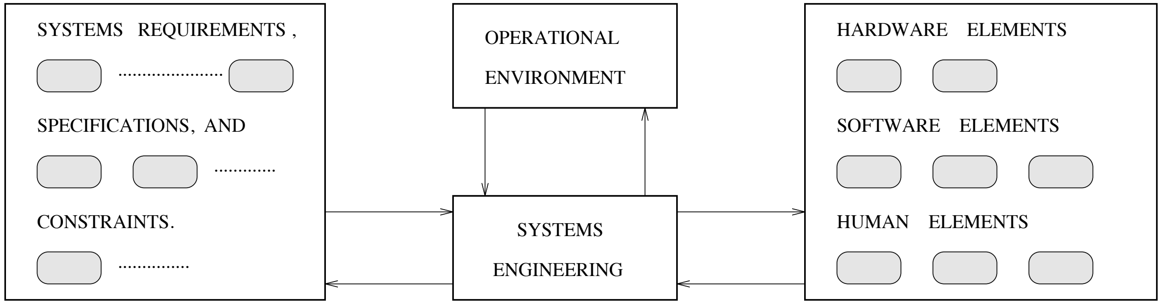
Drawbacks: Long hours are common; project deadlines can be fierce.

Pre-reqs: An undergrad engineering degree; some jobs might also require certification as a certified systems engineering professional (CSEP)."

http://finance.yahoo.com/career-work/article/107926/best-jobs-in-america.html

Our Definition

- Systems engineering is a discipline that lies at the crossroads of engineering and business concerns

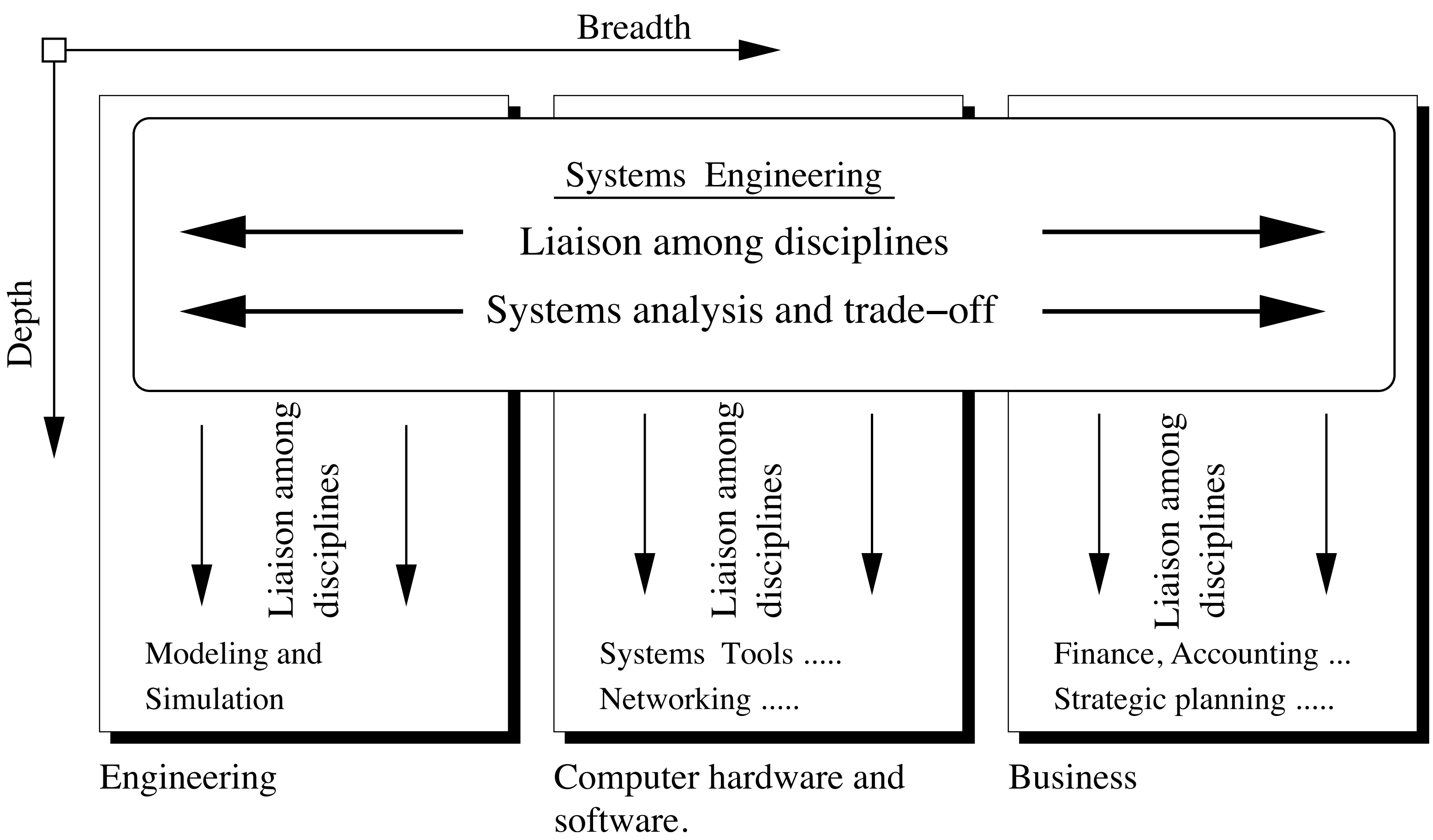


- Specific goals are to provide:
  - A balanced and disciplined approach to the total integration of the system building blocks with the surrounding environment
  - A methodology for systems development that focuses on objectives, measurements, and accomplishment
  - A systematic means to acquire information and identify areas for trade-offs in cost, performance, quality, etc.

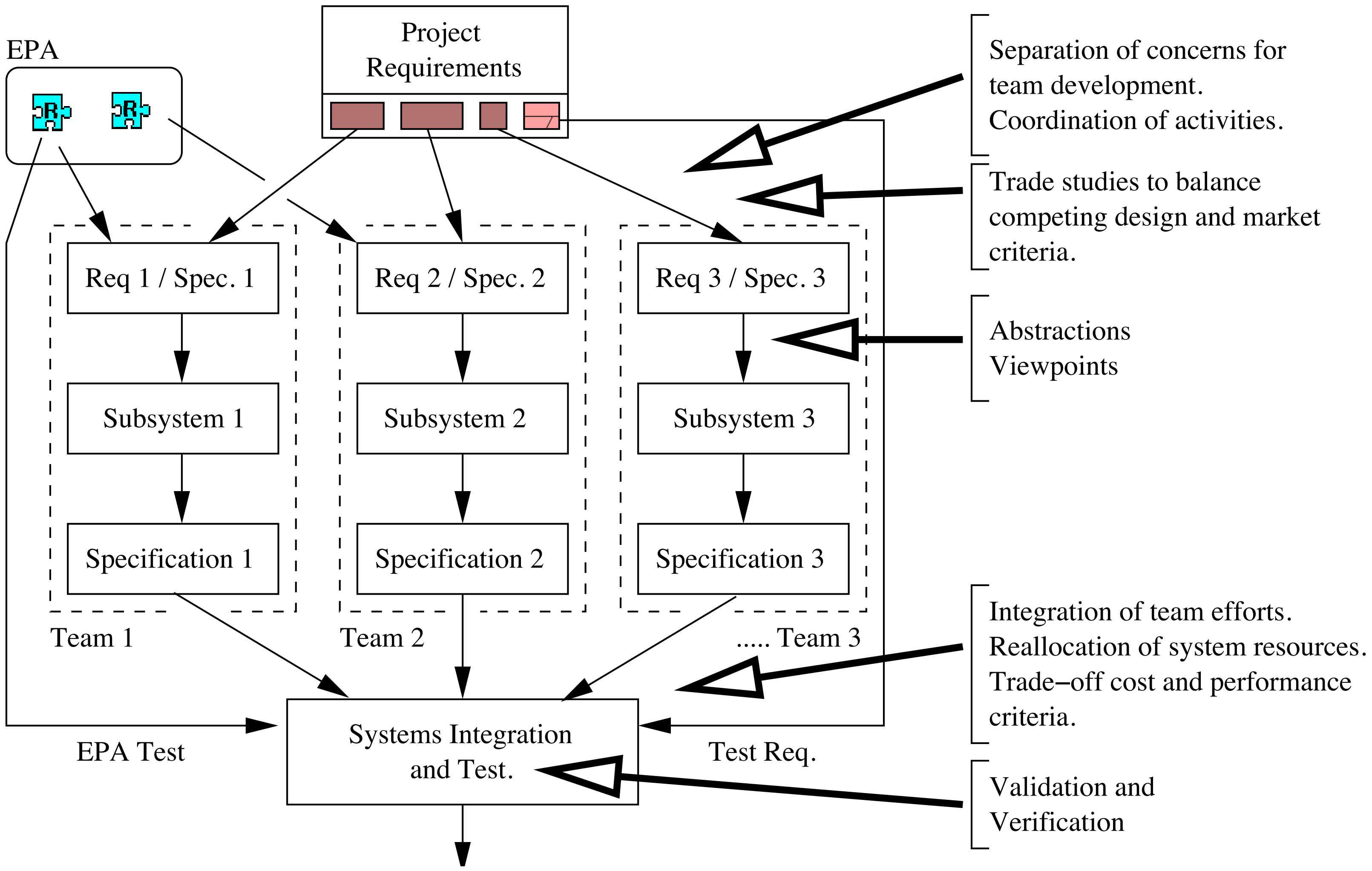
Practicing Systems Engineers

- Typical concerns on the design side:
  - What is the required functionality?
  - How well should the system perform?
  - What about the cost/economics
  - How will functionality be verified and validated?
- Typical concerns on the management side:
  - What processes need to be in place to manage the development
  - What kind of support for requirements management will be needed?

SE in Mainstream US Industry



SE at the Project Level



Motivation

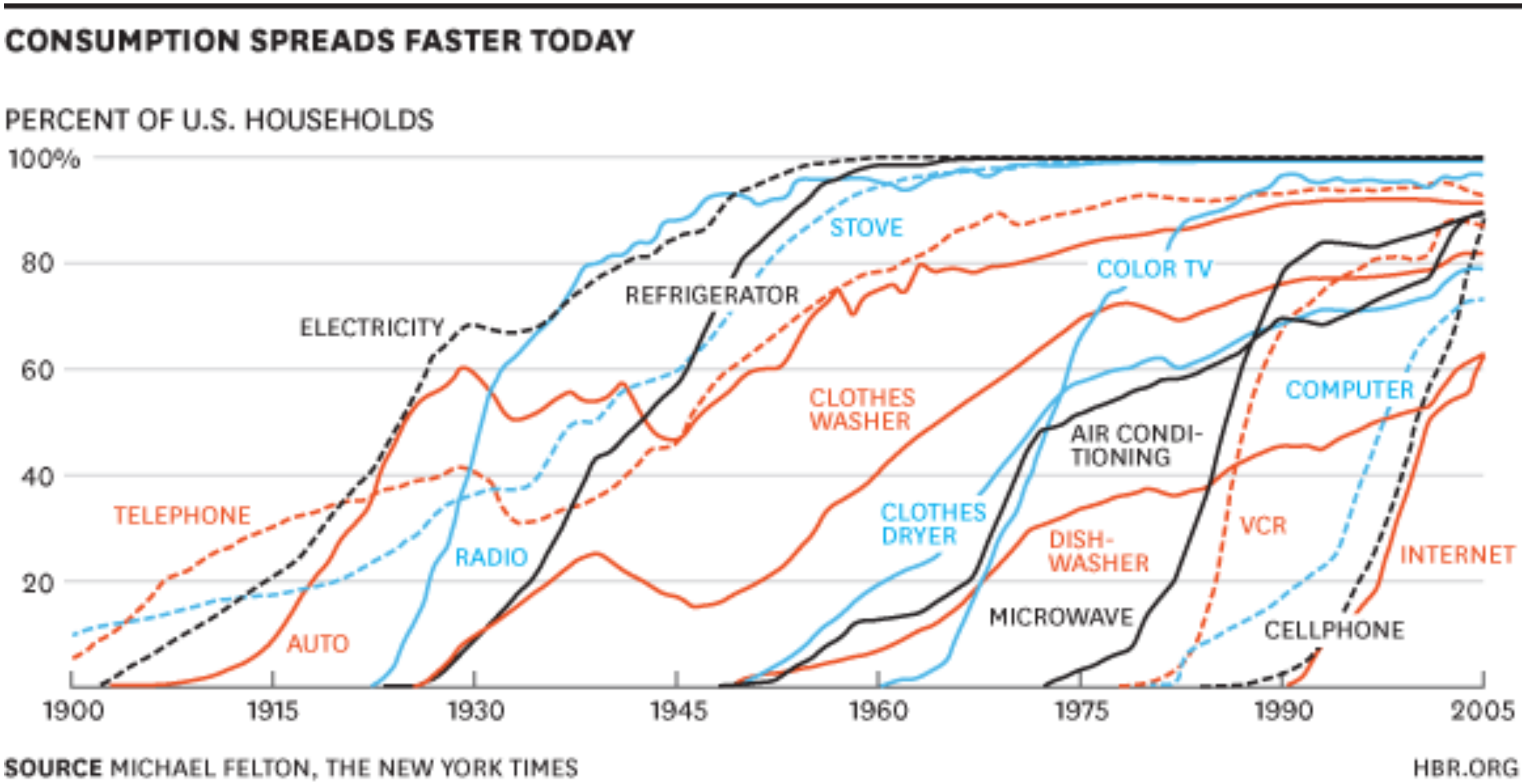
- We need a better approach to Systems Engineering

- Definition: System Integration
  - Process of deliberate assembly of parts of a system into functioning whole

- Complications kept in check through decomposition of separation of design concerns
  - Worked well when development was in-house
  - Modern systems are geographically distributed and much more complex

Increasing Demand for Limited Resources

Information-Centric Systems



Increasing Sensing Information

- Sensing in Aerospace Systems
  - F-16 (1974), 15 subsystems; $O(10^3)$ interfaces, 40% software
    - 2 million lines of code
  - F-35 (2006), 130 subsystems; $O(10^5)$ interfaces, 90% software
    - 8 million lines of code

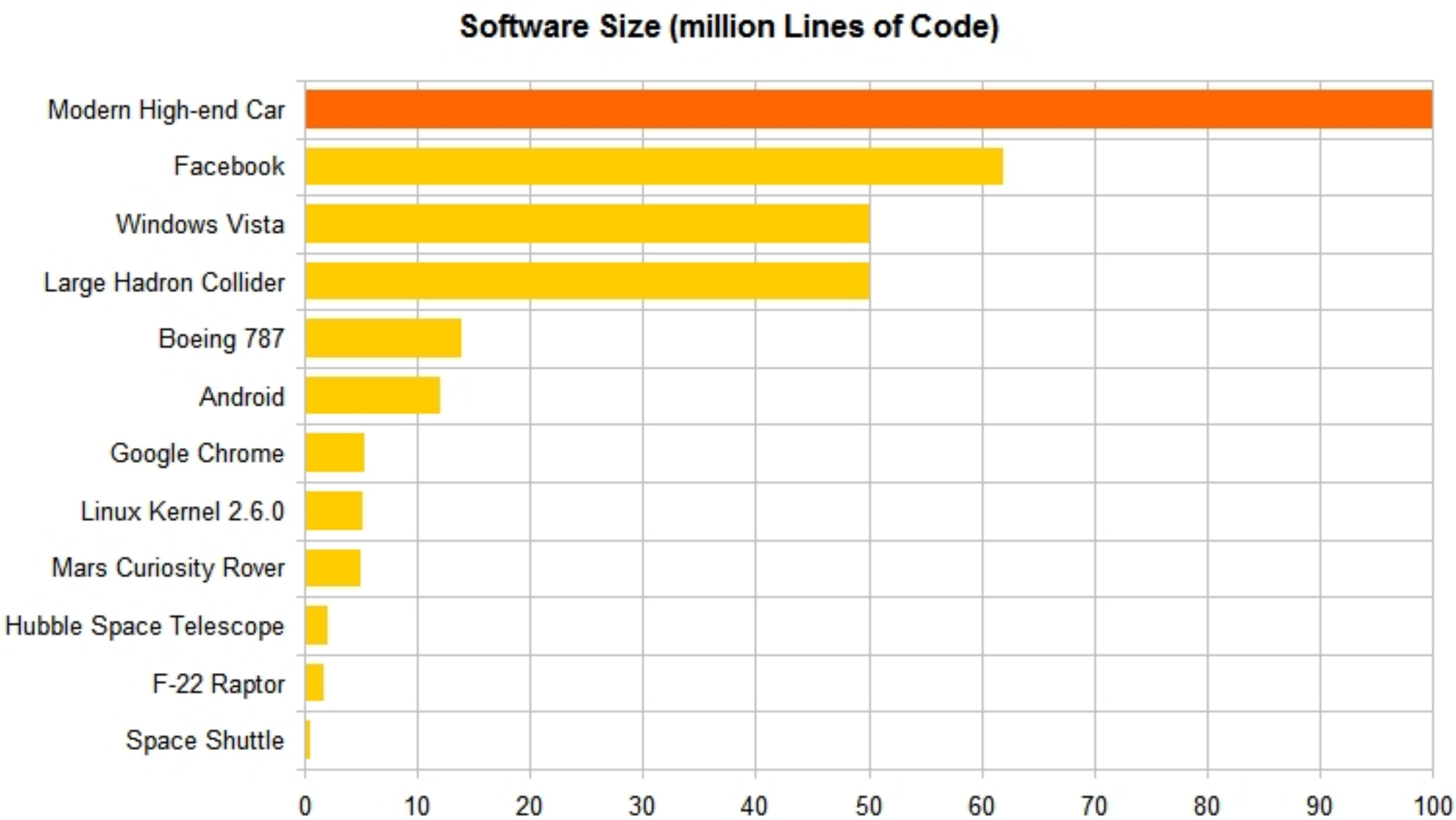
Example 1: Boeing 787

- Outsourced 70%: US, Asia, Europe, Australia
- 50 Tier 1 companies; Tier 2 and Tier 3 supply to Tier 1
- Final assembly ~3 Days
- Additional $12-18 billion due to delays
- Fuel Tanks
  - Jan 8, 2013 – 150L oil spill JAL in Boston
- Electronics
  - Dec 4, 2012 – United emergency landing
  - Dec 13, 2012 – Qatar grounded electric distribution problem
  - Dec 17, 2012 – Second United emergency landing
  - Jan 7, 2013 – Fire from Li-Ion battery JAL
  - Jan 8, 2013 – United faulty wiring to battery
- Engines
  - July 2012 – Fan shaft engine fails runway test
  - Jan 11, 2013 – Oil leak from engine
- Brakes
  - Jan 9, 2013 – All Nippon cancels flight, computer wrongly reports brake problem
- Cockpit
  - Jan 11, 2013 – Window cracks
  - Jan 15, 2013 – Smoke alert goes off

Example: Airbus A380

- Additional $6 billion additional costs
- Poor decisions and poor interactions led to one major poor decision
- Delay of 2 years due to complex wiring
- 530 km wire, 100K wires, 40K connectors, 1K functions
- First prototype Toulouse France, all wires too short
- Problem: Development 16 sites, 4 countries
    - Germany/Spain version 4 CAD
    - France/Britain upgraded version 5 (complete re-write)
- 1000 German engineers camped outside production facility
- Reason: co-CEOs were German and French. Airbus was a consortium of companies that merged in the 70s.

Lines of Code

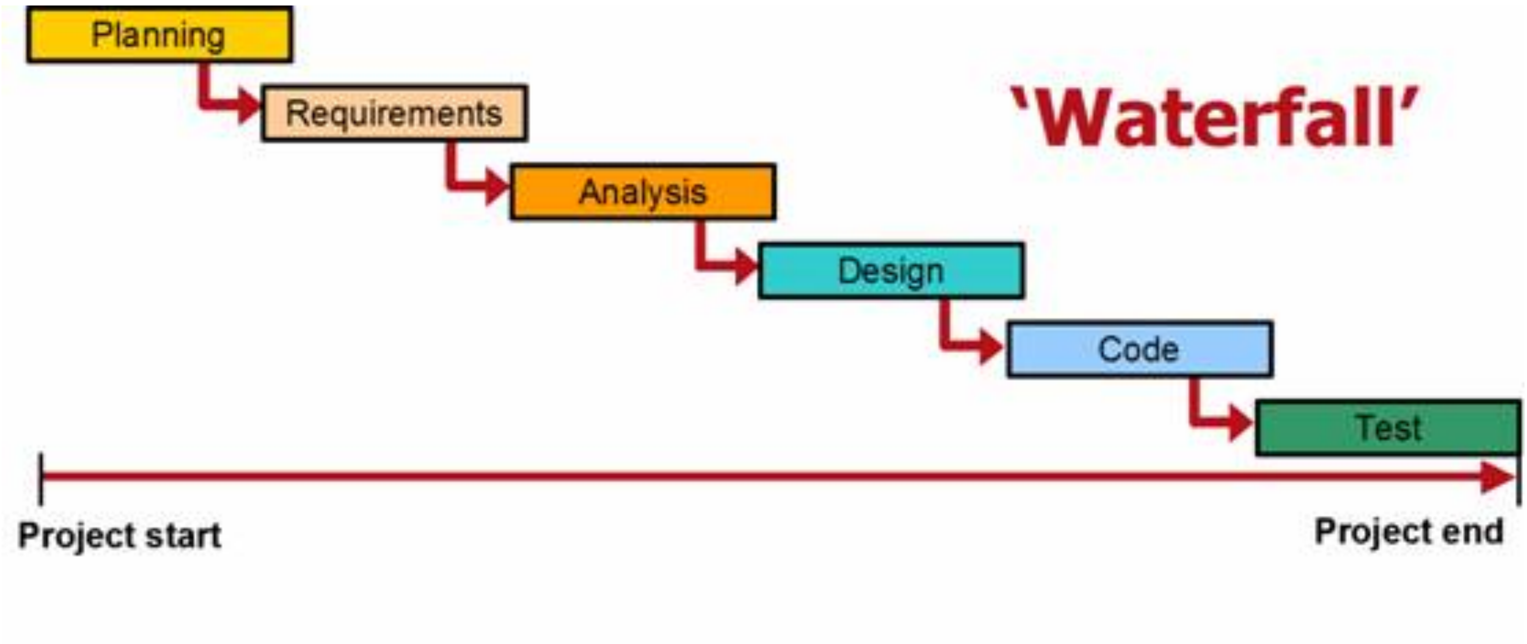


Error-Free Software

- Software and communication technologies need to deliver functionality that is correct and works with no errors
- Mars Climate Orbiter – 1999 probe lost ($125 million)
  - Two teams: imperial and metric
  - Problem: did not consider entire mission as a system; communication and training inconsistent; no complete end-to-end verification of software
- ACA Website
  - Overwhelmed with traffic on first day
  - 14 states (and DC) ran own site. 36 run by federal government
  - Problem: figuring out subsidies depends on IRS income
    - US Citizenship (Social security); Immigration status (DHS); No double-insurance (Veterans health administration, DOD, Office Personnel Management, Peace Corps, State Medicaid, Children's Health Ins. Program)
    - Once purchased, exchange provides information to insurance company
  - Traffic overload, large number of interactions with databases, tight deadline and limited budget

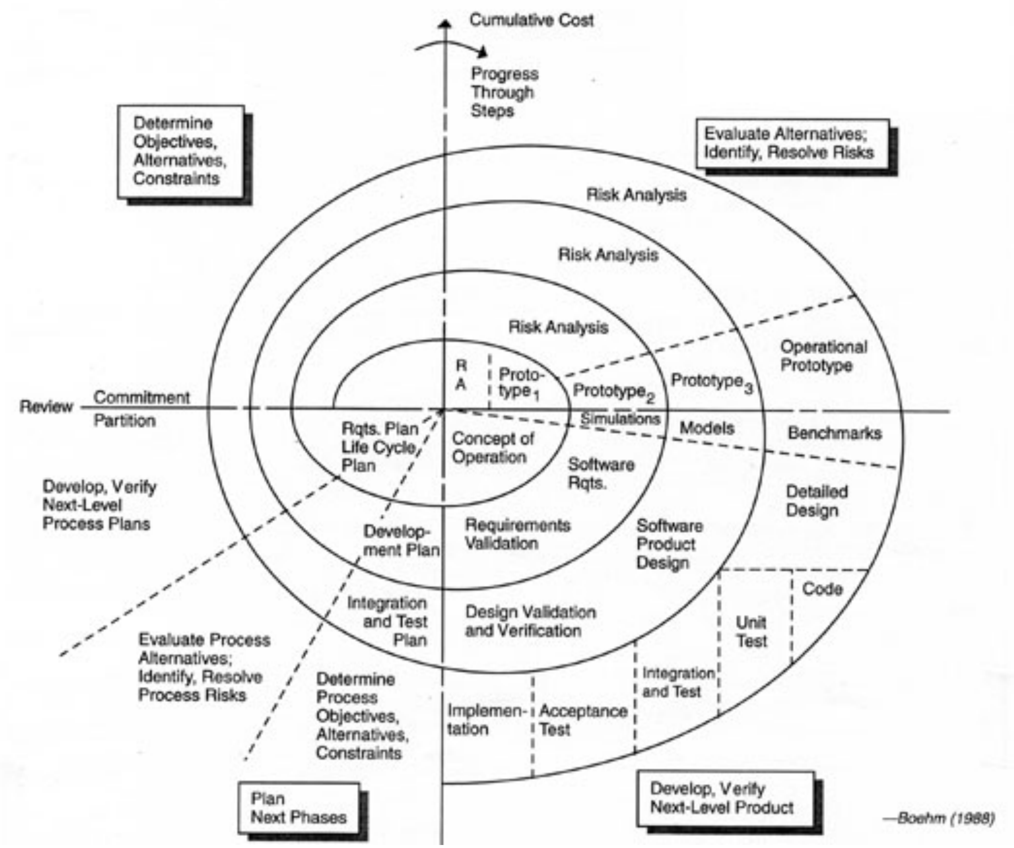
Models of Development: Waterfall

- Works well when solution method understood
- Limit: Changing requirements can cause cost overrun

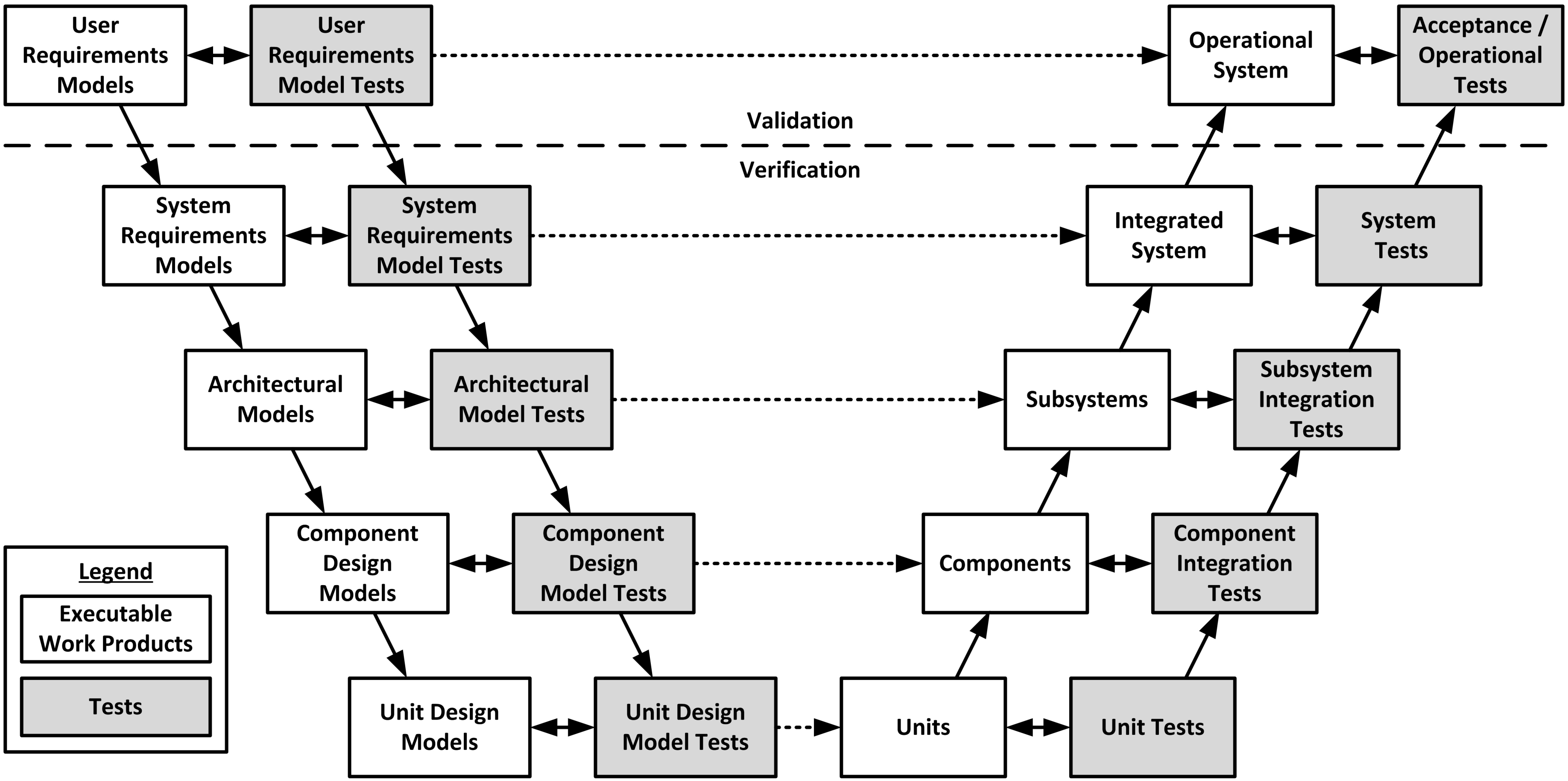


Models of Development: Spiral

- Assessment of management risk at regular stages
- Limit: Model can be easily corrupted and lead to sloppy work



Models of Development: V-Model

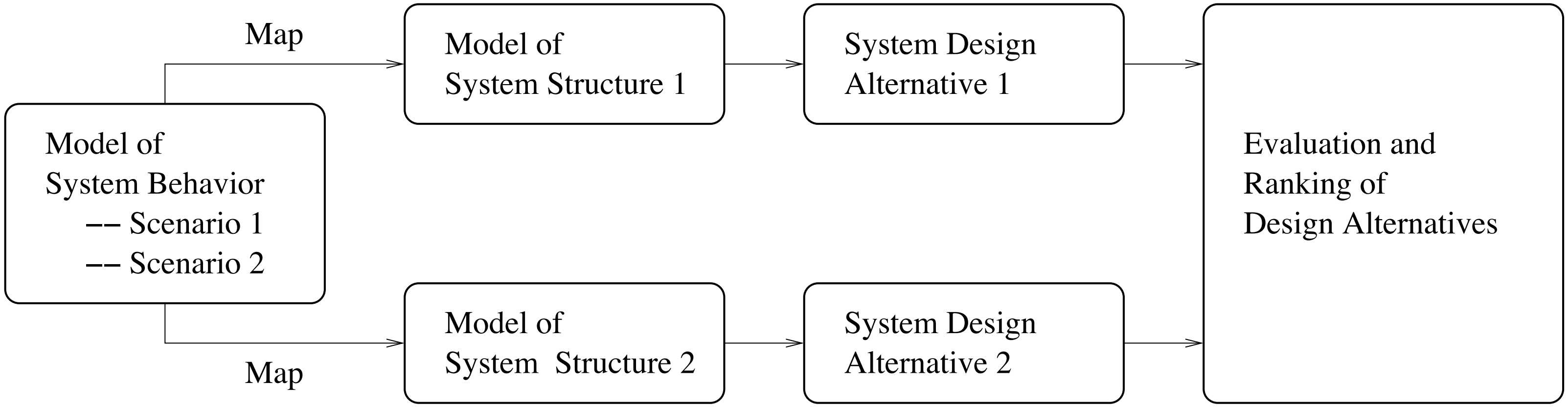


Model-Based Systems Engineering

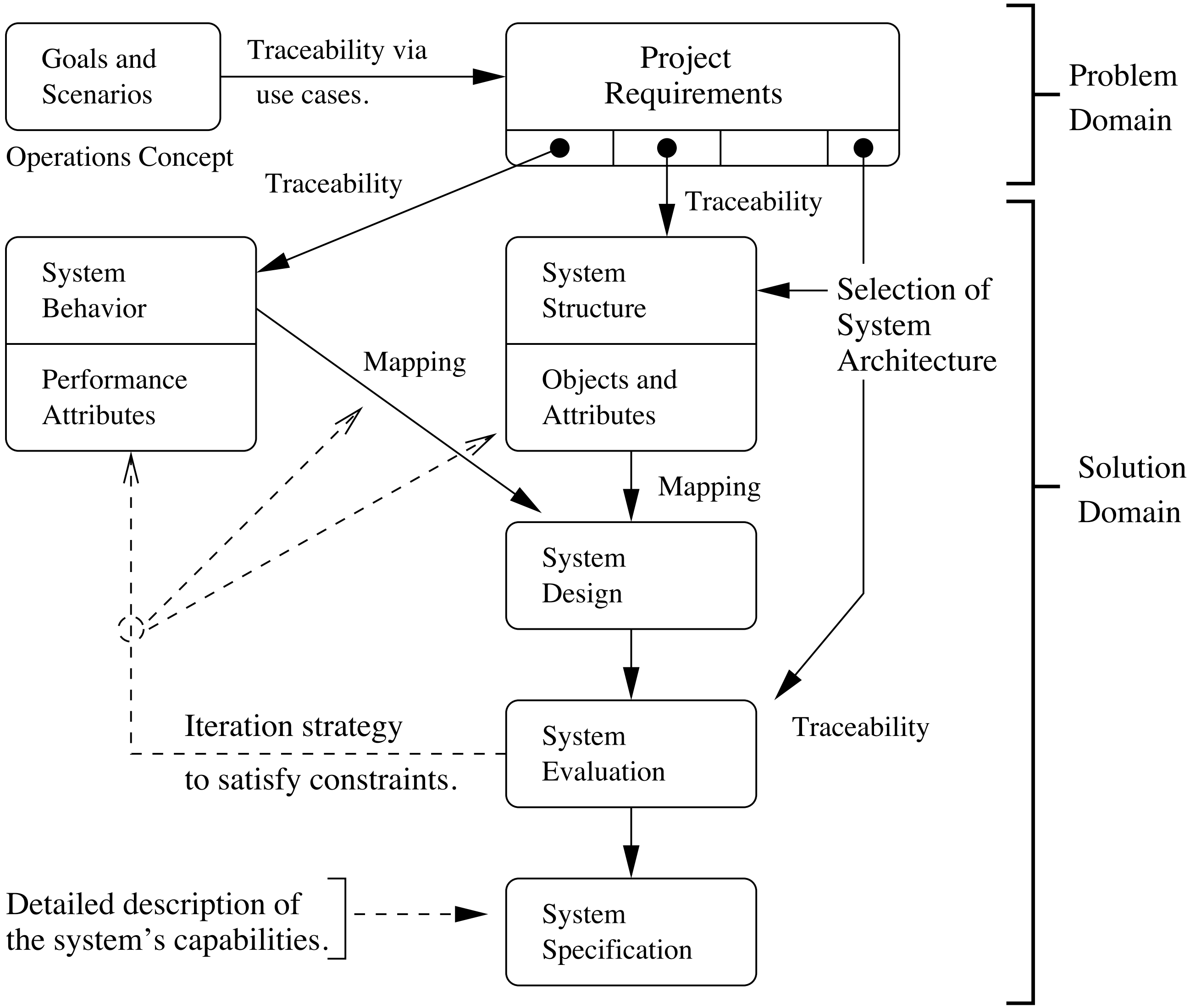
- MBSE: Focuses on development of models as opposed to documents
- Definition: formalized application of modeling to support systems requirements, design, analysis, V&V activities beginning in the conceptual design phase and continuing throughout development and life cycle phases – INCOSE
- Good solutions have:
  - Semi-Formal methods
  - Formal models
  - Abstraction
  - Decomposition
  - Composition

Strategies

- Function before Physical
  - Function that systems intend to provide
  - Candidate architecture for realizing that functionality



ENES489 Preview



Key Points

- Functional description dictates what the system must do
- A complete system description will also include statements on minimum levels of acceptable performance and maximum cost
- Further design requirements/constraints will be obtained from the structure and communication of objects in the models for system functionality

SysML Diagrams

- Graphical Modeling Language
- Supports specification, analysis, design, V&V of systems
- Not a methodology or a tool