Systems Simulation
ECE 597/697 S

Introduction to Systems Engineering

Prof. Michael Zink
Overview

- System
- Systems Engineering
  - Attributes
  - Process
  - Case studies
  - System life cycle
  - Software development
  - Components
- History
A system is a set of functional elements organized to satisfy user needs. These functional elements include hardware, software, people, facilities, data, and services.

- Raytheon

Any organized assembly of resources and procedures united and regulated by interaction or interdependence to accomplish a set of specific functions.

- DoD
Classification of a System

- **Service-oriented Systems:**
  - Airport: all components (planes, runways, pilots, ticket counters, etc.) provide a transport service.

- **Product-oriented Systems:**
  - Factory that builds electronic appliances

- **Process-oriented Systems:**
  - Oil refinery
Example: DCAS System

Average Number of Tornadoes per Year

Cyril Rush Springs Chickas Lawto

OK OneNet (wired)
Example: DCAS System

Distributed Collaborative Adaptive Sensing:

- **Hardware** ➔ Radars
- **Software** ➔ Meteorological Command and Control
- **People** ➔ End-users (Emergency managers, NWS)
- **Facilities** ➔ Towers
- **Data** ➔ Continental US climate
- **Services** ➔ Network access
Systems Engineering

“The definition, design, development and maintenance of functional, reliable, and trustworthy systems within cost and time constraints”

- Sage, “Introduction to Systems Engineering”

“An innovative and methodical application of scientific knowledge and technology to produce a device, system or process, which is intended to satisfy human need(s)”

- Voland, “Engineering by Design”

“Systems engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.”

- International Council of Systems Engineering (INCOSE)
Systems Engineering Process

- Develop final solution after successful prototype
- Deliver to client
- Feedback for next generation

- Select “best” solution
- Trade studies
- Modeling, simulation

- Define needs
- Verify needs with customer
- Functional and physical architecture

- Functions the system needs to perform
- Independent of implementation
- Decomposition, refinement and analysis

- Identify possible technical approaches
- Define system concepts
- “How will my system meet its requirements?”
Systems Engineering Process – Waterfall Model

- Requirements
- Analysis
- Synthesis
- Evaluation
- Implementation
Systems Engineering Process in CASA - Spiral
Case Study: First Flight

- System life cycle
- Followed spiral process
- Build four prototypes in a row
- Gained experiences and improved design:
  - Had to learn to become pilots
  - Built first wind tunnel
  - Designed and built engine
  - Designed and built propeller
  - Controls
- Made use of available knowledge:
  - Lilienthal’s wing design
  - Chanute’s glider design
- Flew 852 feet in 59 seconds on Dec. 17th 1903
Case Study: CASA’s first Test Bed

- Build a new system in a short time span
- Test components without real data
  - MC&C was designed and implemented without real data
  - Emulator was used to model radar data in a realistic manner
- Make use of existing knowledge and components
  - Modification of detection algorithms for S-band data
- Early end-user involvement
  - Feedback
  - Education
- Built prototype and went to production after testing and operation
  - Initial performance results
  - Allowed small changes
  - Maintenance experience
First Spiral Iteration

System development

• Systems Requirements Document (thru v3.1)
  – Description
  – Goals
  – Review Process
  – Background (climatology)
  – Requirements
    • Architecture
    • Sensing
    • Distributing
    • Detection
    • End User
    • Etc.

• Timelines
  IP1A_schedule_v2.fts
  IP1A_schedule_v20.fts

09/2006: DCAS system capability Verification begins

System Operation

IOP Plans:
07CSET_ops_plan.doc
08CSET_ops_plan.doc
09CSET_ops_plan.doc
07CSET_scientific_overview.doc
08CSET_scientific_overview.doc
09CSET_scientific_overview.doc
09 Translational Plan
09 Sustainment Plan
Merged Data: 2006
Second Spiral Iteration

System development

• Systems Requirements Document (thru v3.1)
  • Description
  • Goals
  • Review Process
  • Background (climatology)
  • Requirements
    • Architecture
    • Sensing
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    • Etc.

• Timelines
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  .
  .
  IP1A_schedule_v20.fts

03/2007:
The theme is to demonstrate and evaluate the fundamental concepts of DCAS and NETRAD, with a primary focus on observing severe weather events such as tornadoes and severe thunderstorms.

System Operation

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07CSET_scientific_overview.doc
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09CSET_scientific_overview.doc
09 Translational Plan
09 Sustainment Plan
Merged Data 2007
Third Spiral Iteration

System Operation

IOP Plans:
- 07CSET_ops_plan.doc
- 08CSET_ops_plan.doc
- 09CSET_ops_plan.doc
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- 08CSET_scientific_overview.doc
- 09 Translational Plan
- 09 Sustainment Plan

03/2009:
Prevent “Cutting of edges”
Merged Data 2009
System Life Cycle

- The course of developmental changes through which a system passes from its conception to the termination of its use and subsequent salvage.

- Maintenance (e.g., for jet engines)
- Support (teaching, small modifications)
- Dispose (e.g., nuclear power plant, oil rig)
- Example: Windows Life-Cycle Policy
The Department of Defense Instruction (DoDI) 5000.2 establishes a simplified and flexible process for managing all acquisition programs. This process, referred to as the Defense Acquisition Management Framework, is a continuum of activities that represents or describes defense acquisition programs. The framework is represented below.
Software Development Life Cycle

- Conceptualization
- Requirements and cost/benefits analysis
- Detailed specification of the software requirements

- Software design
- Programming
- Testing
- User and technical training
- Maintenance

Methodologies or models that can be used to guide the software development lifecycle:
- waterfall model (which was the original SDLC method)
- rapid application development (RAD)
- joint application development (JAD)
- the prototyping model
- the fountain model
- the spiral model
Systems Engineering Components

- Requirements Development
- Functional Analysis/Requirements Allocation
- System Architecture and System Design
- Integration, Verification and Validation
- System Analysis, Modeling and Simulation
- Technical Planning and Management
- Trade Studies
- Specialty Engineering
- Risk Management
Systems Engineering Roles

1. Requirements Owner
2. System Designer
3. System Analyst
4. Validation and Verification
5. Logistics and Operation
6. Glue Role
7. Customer Interface
8. Technical Manager
9. Information Manager
10. Process Engineer
11. Coordinator Role
12. “Classified Ads Systems Engineering”

1S. Sheard, *Twelve Systems Engineering Roles*
Systems Engineering Roles cont’d

- **Requirements owner**
  - Translate customer needs into requirements
  - Understanding functional architecture correct
  - Subsystem specifications

- **System Designer**
  - Creates high-level system architecture and design
  - Describes needs for subsystems
  - Architecture, high-level design, and verification

- **System Analyst**
  - Confirms that designed system will meet requirements
  - Modeling
  - Simulation
Systems Engineering Roles cont’d

- **Validation and Verification**
  - Plans and implements system verification
  - Writes system test plans and procedures
  - Respond to anomalies

- **Logistics and Operations**
  - Might initially operate system for customer
  - Bring maintenance, operations, logistics, and disposal concerns to the requirements
  - Create users’ manual

- **Glue Role**
  - Proactive trouble shooter
  - Very good understanding of internal interfaces
  - Tries to prevent interference between subsystems
Systems Engineering Roles cont’d

- **Customer Interface**
  - Present role of the customer internally
  - Interface to customer
  - Does not include full marketing process

- **Technical Manager**
  - Controlling cost
  - Scheduling resources
  - Maintaining support groups (e.g., computer support)

- **Information Manager**
  - Data management
  - Process asset management
Systems Engineering Roles cont’d

- **Process Engineer**
  - Capture systems engineering metrics
  - Reengineer
  - Mostly for internal purposes

- **Coordinator**
  - Coordinate groups
  - Team leadership
  - Ability to lead groups to develop own leadership skills

- **“Classified Ads Systems Engineering”**
  - Many more requirements for system engineer
  - Highly depends on a specific project
Verification vs. Validation

Both terms often get confused

In systems engineering:
• Validation: Is the system valid for the client/user?
  • “You built the right product”
• Verification: Is the system designed according to its specification?
  • “You built the product right”

Example:
• Supersonic Jets Inc. builds a commercial plane that flies Mach 2 with a max. range of 500 miles.
History

“Life was simple before World War II. After that, we had systems”

- Rear Admiral Grace Hopper, United States Navy Reserve

- Dates back to Bell Telephone Labs in the early 1940
- Major applications during World War II (e.g., aircraft carrier)
- First course in 1950 by Mr. Gilman (director of systems engineering at Bell) at MIT
- Adopted by industry and military
- Now taught in many colleges
- High focus in companies
Gantt Charts

- Bar chart that illustrates project schedule.
- Illustrates start and finish dates of elements of a project.
- Elements represent work breakdown structure of a project.
- Dependencies between elements can be shown.
- Show current schedule status.
- Named after Henry Gantt in the 1910’s.
Gantt Chart: CASA example
Summary

- Overview of systems
- Overview of Systems Engineering
- Case studies
- History