Gateway To Space

ASEN 1400

Class #12

Colorado Space Grant Consortium
Announcements:

- Announcements

- HW #8 Solution

- Guest Lecture – Systems Engineering
Announcements:

- First round of grades on website
- Passwords now
- HW #07 due next Tuesday, FEB 28
- HW #08 Due now
Day in Space:

Goats Live

One Minute Repots:

GoatsLive.com
Next Tuesday...

Spacecraft Structures
Next Thursday...

PDR

Presentations due at 7 AM
NOT on YouTube but in class

Colorado Space Grant Consortium
Questions?

Colorado Space Grant Consortium
Systems Engineering

Brandi Opland
Ball Aerospace

Gateway to Space
Fall 2006

Colorado Space Grant Consortium
Space
Wolverines
Project: ICARUS
Brandi Opland—
7 years at Ball Aerospace

Internship 2010
- Work on Space Based Space Surveillance (SBSS)
- Worked on Fault Protection Trees and Contingency Flowcharts
- SBSS launched in Sept. 2010 and I worked part time at Ball through my 5th year at CU.

SBSS-Bus and Payload
- Worked Mission Operations
- Data trending and data analysis tools
- Space Operations Data Analysis (SODA) trending tool

Aquila-Payload
- TVAC—Test data trending and analysis
- Functional Configuration Audit (FCA)—Verification Sell off

A Few Proposals
- System Architecture and System Requirements

Apex-Bus
- Requirements Manager (Allocation, requirements traceability, DOORS)
- Verification System Engineer (Verification Tracking, DOORS)
Introduction to Systems Engineering

February 23, 2016
What is Systems Engineering

• Is a systematic, interdisciplinary approach that transforms customer needs into a total system solution
• A framework of interrelated activities that spans Design, Management, and Realization of systems
• Balances customer needs with system capabilities
• Led and organized by Systems Engineers – But all functions play a role
• It is the technical “glue” which makes separate design disciplines and subsystems function together to provide an integrated system
Be a “Systems Thinker”

• The Design Engineer
  – The specialist's viewpoint
  – Views the system from the inside
  – Concerned with other system elements only as they affect their own design task
  – Not necessarily how their system may affect others

• Systems thinkers
  – Views the system from the outside.
  – Concerned with the effect of all system elements as they affect overall system design / performance / cost / schedule
  – Concerned no matter where the hole in the boat is
Systems Engineering must focus on the entire problem: optimize the whole, not the parts!
The Art & Science of Systems Engineering

• Art of Systems Engineering
  – Technical Leadership
  – Understanding how all the individual pieces go together to make the big picture

• Science of Systems Engineering
  – Systems Management
  – Managing all the details for every piece of the system and keeping them in synch

• Cost, Schedule, Performance, & Risk

To be Successful, we must balance both technical leadership and systems management into complete systems engineering
Systems Engineering “V” Model
Architecture

• System Architecture is the overall structure of the program, internal interfaces, and how it interacts with external interfaces
  – System Level – Constellation of Satellites, Ground stations, etc.
  – Spacecraft Level – Subsystems and interfaces that make up spacecraft
  – Subsystem – Components and technologies that make up subsystem

  – Architect’s role is to ensure customer requirements and needs are properly addressed in the system
    • Identifies utility and flexibility of the system
    • Optimizing architecture can make spacecraft trades easier
Spacecraft Architecture

(image credit: NASA/GSFC)
Concept of Operations

- Concept of Operations (CONOPS)
  - How the system will be used
  - Links technical requirements with user’s needs
    - Requirements do not fully represent customer’s wishes…
  - Operational scenarios, timelines, block diagrams, orbital maneuvering among the products
  - Example: Assignment Requirements do not specify how often payloads need to operate, could reduce overall power required

NO USER WOULD EVER DO THAT!
Con Ops Example – ALL-STAR

Ejection from P-POD
- EPS and CDH activated
- ACS despins to safe level

Launch
- Any vehicle with P-POD

Start Up
- Solar Panel deployed
- Structure deployed
- COM and Attitude acquisition
- Bus Checkout
- Payload Checkout

Mission Operations
- Inactive Payload
- Payload Operations
- COM Pass
- PROP Burn

S-band Link
- 1 Mbit/s

Ground Station

End of life
- 1 year life time

Ground Operations

ALL-STAR User
- Tasking and commanding
- Data processing
Requirements Management

- A requirement is a “single, verifiable shall statement”
- Requirements dictate the form, fit and function the system design shall meet
- Requirements address both characteristics as well as capabilities
  - Characteristics = what the system shall be
  - Capabilities = what the system shall do
- Higher level requirements are decomposed to lower level requirements

Level 0 (Mission)

Level 1 (System)

Level 2 (Subsystem)

Level 3 (Component)
Why are requirements important

Clearly communicating requirements is essential

- How the customer explained it
- How the project manager understood it
- How the engineers designed it
- How materials ordered it
- How it was built
- How the customer really wanted it
Design Integration

• Balance the needs of the customer with the capabilities of the spacecraft
• Balance the needs of the individual subsystems
  – Allocate mass, volume, power constraints
  – Relate it to their assignment
• Ensuring subsystems are talking with one another
  – Making sure they are compatible
• Identifying subsystem interfaces

*It's kind of like Herding Cats*
Risk Management

- Risk management is done throughout the entire program life cycle
- Risk is defined in two dimensions
  - Probability of occurrence
  - Consequence if the risk occurs
- Identify risks while there is still time to react
- Put in place mitigation strategy to minimize or eliminate risks
- Sources of risks include:
  - Poorly defined technical tasks or cost estimations
  - Poorly defined requirements and interfaces
  - Low technological maturity (technical risks)
  - Unrealistic project planning or inadequate resources
  - Inadequate workforce skill level

![Risk Matrix](RiskMatrix.png)
Hardware Integration

• Assembly of spacecraft hardware

Spitzer Space Telescope from design to integration
Verification and Validation

• Verification
  – “Did we build the system right”
• Validation
  – “Did we build the right system”
• System Testing
  – Functional tests
  – Vibe tests (drop tests)
  – Shock tests (swing tests)
  – Thermal Vacuum tests
  – Acoustic tests

ALL-STAR and team at vibe test at Lockheed Martin
Mission Operations

• Starts when spacecraft development is initiated and continues through final disposal of space asset

• Provide mission requirements support for development of operational systems
  – Used to plan and control launch vehicle and spacecraft operations

• Developing mission profiles, operational procedures and related operational documentation

• Balance and allocate operational requirements with operational performance

• Determine operations integration tasks
  – Defining capabilities and constraints associated with launch vehicles, spacecraft and mission control and ground systems
Summary

• Systems Engineering is an integrated composite of people, products, and processes
  – Forms a structured development process
  – Spans design, production, and operation of systems
• Balances the needs of the customer with the capabilities of the system
• Uses technical leadership and systems management
  – Integrates all disciplines and specialty groups into team
  – Manages cost, schedule, performance, and risk
• There is no perfect solution
  – Systems engineering produces the optimal solution for the entire spacecraft