Gateway To Space

ASEN 1400 / ASTR 2500

Class #11

Colorado Space Grant Consortium
Today:

- Announcements

- Next Time

- One Minute Report Questions

- Two Talks – HASP 2013 and Requirements + Foam Core cutting and Box Construction
Announcements:

- Hardware orders

- Grades posted

- Passwords now

- Arduino Updates – SD card done but compass is not

- Compass slides will be posted soon

- Can help one on one or do by yourself
Announcements:

Upcoming Deadlines

- HW#7 Heater due today
- PDR Presentations due 10/14 7 AM
- Design Document Rev A/B assigned and due 10/14
- HW #8 is due next class (Fun but challenging)
- Remaining hardware orders by this Friday
Next Time...

Systems Engineering

Colorado Space Grant Consortium
One Minute Reports:

- Workshops for structure and design?
- Page limit was too short for the proposal
- Put examples of good proposals on the website
- How much is the pressure sensor?
- Does it just measure pressure inside the box?
One Minute Reports:

- Wiring diagrams are messy…

- Comment about wiring for flight
Questions?

Colorado Space Grant Consortium
Our Mission

• To build a payload for solar observation onboard a high altitude balloon platform
• Cheaper and better than current alternatives
• Design
  • Base housing and camera housing that moves side to side and up and down
  • Uses light sensors to tell how far off from the sun the camera housing is pointing
  • Information is used to tell the motors how far to turn and which direction
Designing
Building
Our Payload!
Traveling
Integration in Texas
Thermal Vacuum Testing
More Travelling!
Flight in New Mexico
Flight
Results
Results
Results

• Tracked throughout flight
• Over 6000 total images taken
• 75 images definitely contained the sun
• Half of the images taken in the tracking window contained the sun
Our Plan

- Write the final science report
- Fix our payload
- Propose to fly again!

Questions?
Foam Core

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Foam Core:

- When cutting foam core, remember you are cutting through three layers

- Best to cut each layer individually

- Go slow, use metal edge ruler

- Be mindful of blade

- Foam Core Document
When cutting foam core, remember you are cutting through three layers. Best to cut each layer individually. Go slow, use metal edge ruler. Be mindful.

Foam Core:
Foam Core:
**Foam Core:**

- Draw centerlines between inner and outer lines

- All edge cuts are at 45 degree angles to the centerline

- Cut inside edges first and only through top paper and foam not bottom paper (hinge)

- Cut outside edges last but all the way through

- Go Slow and don’t cut the tables

- Please dispose of Xacto blades properly

- Don’t forget to account for insulation
Foam Core:

- Don’t forget about switches, LEDs, etc
Foam Core:

- Glue it together and strengthen corners

- Please don’t go overboard, weight is still an issue
Foam Core:

- After gluing, cover your seams with aluminum tape

- Do not glue top lid of box. Tape only for easy access after flight without destroying your box to open it
**Foam Core:**

- Balloon attachment tube hole should run through center of box on non-opening side

- Make hole diameter as close to tube diameter as possible

- Secure with paper clip

- Make sure paper clip does not interfere with inner diameter
Requirements

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Requirements:

- What is a Requirement?

- Requirements define the design space and thus the project. They DO NOT DEFINE the MISSION.
Why spend all the time on requirements?
- They let you know when you are done. (With implementation and finally verification)

What is the difference between Verification & Validation?
- Verification is did you build the thing right
  *You captured the performance*

- Validation is did you build the right thing
  *You captured the spirit*
Requirements:

Requirements make sure that the end product comes out as the customer desired it to (validation) with the performance to accomplish the job (verification)
<table>
<thead>
<tr>
<th>How the customer explained it</th>
<th>How the Project Leader understood it</th>
<th>How the Analyst designed it</th>
<th>How the Programmer wrote it</th>
<th>How the Business Consultant described it</th>
</tr>
</thead>
<tbody>
<tr>
<td>How the project was documented</td>
<td>What operations were installed</td>
<td>How the customer was billed</td>
<td>How it was supported</td>
<td>What the customer really needed</td>
</tr>
</tbody>
</table>
Requirements:

- Five aspects of a good requirement

1. CLEAR
2. NECESSARY
3. TRACEABLE
4. ATTAINABLE
5. HAVE A METHOD OF VERIFICATION
1. **Clear**

- Make sure you, your customer, AND your team understand the goals

- Every requirement should capture one idea, not multiple at a time

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No person shall spit in, or in any other way contaminate the pool, its floors, or dressing rooms.
2. Necessary

- A statement of need for a problem/challenge

- Without a single requirement, the design will not end up the same way

*If the requirement appears to be stand alone then is it truly necessary*
1. Clear
Make sure you, your customer, AND your team understand the goals.

Every requirement should capture one idea, not multiple at a time.

THE IDEAL MISSILE DESIGN FROM THE VIEWPOINT OF VARIOUS SPECIALISTS

- AERODYNAMICS
- PROPULSION
- STRUCTURES
- PRODUCTION
- GUIDANCE
- CONTROLS
- ANALYSIS
3. Traceable

A requirement should never appear to come from nowhere, you should be able to trace it all the way back up to the mission

- Exists in a hierarchy of breaking down the problem
- Lower level requirements answer this fundamental question “What do I have to do to do X or Y?”
**Requirements:**

- Requirements flow from your mission statement and mission objectives.

- They are always traceable back to the mission statement.

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**Anatomy of Requirements**

1. **Mission Statement (aka Mission Goal)**
   - A very general description of the problem being addressed by the system.

2. **Mission Objectives**
   - 3 to 5 general statements elaborating the Mission Statement.

3. **Objective Requirements**
   - Quantify each objective: when, what, where, for how long.

4. **System Requirements**
   - The system as a whole must perform to this set of specifications in order to meet the objective requirements, mission objectives, and mission statements.

5. **Subsystem Requirements**
   - Each subsystem must perform to these specifications in order to meet the criteria defined above. This part is done separately for each subsystem i.e. power, mechanical, computer, science, thermal.

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**Step 1:** General definition. Subjective description and a few numbers.

**Step 2:** Numbers and ranges. Focus in on defining the problem.

**Step 3:** Subsystems. Repeat step 2 for every subsystem, tracing from system requirements.

*Koehler & Pilinski 2007*
4. Attainable

- A design challenge should be physically possible and requirements help bound the problem

  - A requirement must be met (at some point)
  - Lack of resources, design methods, and human smarts must be taken into account
  - Don’t find yourself saying, “Well it was too hard”
5. Have a Method of Verification

- If you have a need then you must verify your end product meets that performance

*To truly answer the question, “Are you done and ready to fly?” you must have verified each of your requirements*
Requirements:

Examples

A black sports car shall reach 60 mph in 3 seconds

EPS may consume 70W at 5V and 12V

A space imager will be cooled to 0K to monitor Thermal IR
Requirements:

Examples

A **black** sports car shall reach 60 mph in 3 seconds
*Lacks Traceability & Necessity*

EPS **may** consume 70W at 5V and 12V
*Lacks Clarity (how long?)*

A space imager **will be** cooled to **0K** to monitor Thermal IR
*Lacks Attainability & Verifiable*
**Requirements:**

**Do Not Tell HOW**

- A requirement should bound the solution but not be the solution

*BobSat shall measure the rotation rate of the BalloonSat through the duration of your flight.*

*BobSat shall measure the rotation rate of the BalloonSat in three axes to a resolution of 0.1 degree/sec using a magnetometer and gyroscope from SparkFun for 15 minutes of the flight.*
**Requirements:**

**The Right Words:**

Standardized Wording

**SHALL:** Something that must be verified in the final design

**SHOULDN'T:** A stretch goal of the project (i.e. pie in the sky)

**WILL:** Statements that are facts or explanations

Star Wars/Yoda was right! “There is no try, only do or do not”
The Wrong Words:

Don’t use words that are vague like: Minimum, Maximum, Average, Better, Worse, Maximize, Minimize, Simultaneous, Rapid, Real-Time, Satisfactory, Adequate, Sufficient, Always, Sometimes, May, Most, Ideal(ly), Significant(ly)

Your requirements should be strong and self-supporting; these words aren’t.

Avoid being wordy in your requirements, generally that leads to capturing multiple goals at the same time, each requirement should convey one point.
Requirements:

The V
Even now as you write your requirements consider:
- How are you going to make sure you meet them in the end?
- What kind of testing are you going to need?
- How will you turn the testing data into something meaningful
- Converting voltages from a sensor into units (C, psi, G, etc)?
- Characterization of your experiment so that you know the data you gather on flight is correct?
- Fundamentally you are answering the question of will your BalloonSat survive without you for 4 hours
- Consider doing a full mission simulation to show (don’t/never guess) that you can meet your mission
Requirements:

And one reminder, test early, test often.

DANDE did 3 months of 56 hour DITL tests before they got it right.
Announcements:

- Good examples to look at from 2011
  - Team 05
  - Team 07

- Good examples to look at from 2010
  - Team 01
  - Team 02
  - Team 04
  - Team 05
  - Team 09
2.0 Requirements Flow-Down Chart

Mission Statement: Our BalloonSat *Aliguid In Spatio* will ascend to approximately 30 kilometers into the atmosphere to determine if bacterial microbes that inhabit the surface of the earth are able to withstand the harsh environment of near space, as well as to attempt to discover if there are bacterial microbes that inhabit the tropopause.

Objective 1 (Derives from Mission Statement): Our BalloonSat will measure the inside temperature, outside temperature, and humidity of the BalloonSat during the flight to assess the environment.

Objective 2 (Derives from Mission Statement): Our BalloonSat will also carry our bacterial samples into near space to test them if they can survive in that harsh environment.

Objective 3 (Derives from Mission Statement): Our BalloonSat will carry a sterile petri dish and expose it to the atmosphere at the altitude of the tropopause to see if any bacteria live in that environment.

Requirement 0.1 (Derives from O1) We will run the HOBO datalogger for the entirety of our flight to gather inside and outside temperature as well as humidity data from the start to finish of our flight.

Requirement 0.2 (Derives from O2) We will carry three different sets of bacteria to test if they can survive. We will expose one set of bacteria to all of the effects of near space: low temperature, low pressure, and radiation. We will then expose one set of bacteria to just the radiation by sealing it so it retains pressure and by heating it so it does not go to low
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Parent Req.</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>The radiation system shall measure UV radiation as altitude increases</td>
<td>Mission Statement</td>
<td>Verified through verification of requirements S1-S4</td>
</tr>
<tr>
<td>P2</td>
<td>The camera system shall record the flight from launch until landing through a series of pictures</td>
<td>Mission Statement</td>
<td>Verified through verification of requirements S5, S5.1</td>
</tr>
<tr>
<td>P3</td>
<td>The balloon sat shall follow the requirements presented in the balloon sat user guide</td>
<td>Mission Statement</td>
<td>Verified through verification of requirements S5, S6, S7, S8</td>
</tr>
<tr>
<td>P4</td>
<td>The HOBO system shall record internal and external temperature along with relative humidity</td>
<td>Mission Statement</td>
<td>Verified through verification of requirements S9</td>
</tr>
<tr>
<td>P5</td>
<td>The budget will be under $300 dollars.</td>
<td>Mission Statement</td>
<td>Budget</td>
</tr>
<tr>
<td>Level</td>
<td>Number</td>
<td>Derivation</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>M.S.</td>
<td>Payload must ascend to an altitude of approximately 30.5 kilometers with a balloon provided by the Edge of Space Sciences</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>M.S.</td>
<td>Payload must collect and store science data related to the mission objective</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>M.S.</td>
<td>The payload must carry an active heater system, keeping the internal temperature of the payload above -10°C</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>M.S.</td>
<td>The payload must be constructed from foam core</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>M.S.</td>
<td>The total mass of the payload must not exceed 850 grams and the budget of the project must not exceed three hundred dollars.</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>M.S.</td>
<td>The payload must allow for a HOBO H08-004-02 and the provided external temperature cable</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>M.S.</td>
<td>The payload must allow for a Canon A570IS Digital Camera with two AA lithium batteries</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>M.S.</td>
<td>The payload must have contact information written on the external of the payload, alongside an United States flag</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>M.S.</td>
<td>The team will be ready to launch on November 6, 2010, at Windsor, Colorado, at 6:50 AM.</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>M.S.</td>
<td>The team shall adhere to all safety procedures outlined in the proposal</td>
</tr>
</tbody>
</table>
2.0 Requirements Flow Down

The requirements flow down is designed to portray how the requirements relate to the objectives and the goal. The goal is derived from the mission statement. The level 0 requirements are the mission objectives. The mission objectives are derived exactly from the goal and mission requirements presented by Space Grant. Each objective has several requirements underneath it that explain how it will accomplish the objective. The requirements are considered level 1 requirements on the flow chart. In the chart, the name of the objective or requirement is in the left column, the middle column has the specific objective or requirement, and the far right column shows where that specific goal or requirement is referenced.

The goal of Team Lightning Rod was to send a balloon satellite equipped with two electromagnetic generators to an altitude of thirty kilometers to determine if the kinetic energy from vibrational and rotational motion can be harnessed as supplemental energy source for future spacecraft.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Mission Objectives Level 0</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>Fly a satellite to 30 km</td>
<td>Goal (G)</td>
</tr>
<tr>
<td>O2</td>
<td>Keep the internal temperature of the satellite above -10 degrees Celsius</td>
<td>Goal (G)</td>
</tr>
<tr>
<td>O3</td>
<td>Keep the overall weight of the satellite below 1200 g</td>
<td>Goal (G)</td>
</tr>
<tr>
<td>O4</td>
<td>Fly a Cannon Camera and the HOBO data logger on the satellite</td>
<td>Goal (G)</td>
</tr>
<tr>
<td>O5</td>
<td>Capture and store vibrational energy using the vibrating electromagnetic generator</td>
<td>Goal (G)</td>
</tr>
<tr>
<td>O6</td>
<td>Capture and store rotational energy using the rotating electromagnetic generator</td>
<td>Goal (G)</td>
</tr>
<tr>
<td>O7</td>
<td>Compare the results of the rotational generator and the vibrational generator to see which one is most effective</td>
<td>Goal (G)</td>
</tr>
<tr>
<td>Requirements</td>
<td>Objective 1 Requirements Level 1</td>
<td>Reference</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>O1.R1</td>
<td>Satellite <em>Zeus</em> shall be attached to a helium weather balloon that shall carry it up to 30 km.</td>
<td>O1</td>
</tr>
<tr>
<td>O1.R2</td>
<td>Satellite <em>Zeus</em> shall be attached to the balloon on a piece of rope that shall run directly through the center of the satellite.</td>
<td>O1</td>
</tr>
<tr>
<td>O1.R3</td>
<td>Satellite <em>Zeus</em> shall be kept stable on the rope by using washers and clips.</td>
<td>O1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Objective 2 Requirements Level 1</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>O2.R1</td>
<td>Satellite <em>Zeus</em> shall be kept above -10 degrees by using an electric heater that shall be created by Team Lightning Rod and shall be powered using 9V batteries.</td>
<td>O2</td>
</tr>
<tr>
<td>O2.R2</td>
<td>Satellite <em>Zeus</em> shall have ½ inch foam insulation to keep the Satellite above -10 degrees Celsius</td>
<td>O2</td>
</tr>
<tr>
<td>O2.R3</td>
<td>Satellite <em>Zeus</em> shall also have no holes to contain the heat in the satellite.</td>
<td>O2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Objective 3 Requirements Level 1</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>O3.R1</td>
<td>Satellite <em>Zeus</em> shall be less than 1200 grams by keeping a very meticulous budget that keeps track of the weight of every piece of equipment that shall be on the satellite.</td>
<td>O3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Objective 4 Requirements Level 1</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>O4.R1</td>
<td>Satellite <em>Zeus</em> shall fly the Cannon camera to capture photos of near space.</td>
<td>O4</td>
</tr>
<tr>
<td>O4.R2</td>
<td>The camera on Satellite <em>Zeus</em> shall be programmed ahead of time so that it shall work independently of all other electronics during the flight.</td>
<td>O4</td>
</tr>
<tr>
<td>O4.R3</td>
<td>The HOBO datalogger shall be a standalone item in the satellite that shall record the internal temperature, external temperature, and relative pressure as measured by the sensors.</td>
<td>O4</td>
</tr>
<tr>
<td>O4.R4</td>
<td>The HOBO datalogger information shall then be used to determine the satellites position at certain times during the ascent and descent of the satellite.</td>
<td>O4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Objective 5 Requirements Level 1</th>
<th>Reference</th>
</tr>
</thead>
</table>
**OBJECTIVE**

The mission of Team Solkraft is to test the effectiveness of different types of solar panels (monocrystalline and polycrystalline) under conditions on the ground and up to near-space conditions of approximately 30 km.

**MISSION REQUIREMENTS LEVEL 0**

<table>
<thead>
<tr>
<th>Requirement Number</th>
<th>Requirement</th>
<th>Where it comes from</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 0.1</td>
<td>The solar panels on the BalloonSat shall be exposed to near-space conditions</td>
<td>Mission Objective</td>
</tr>
<tr>
<td>M 0.2</td>
<td>Team Solkraft shall measure the internal and external temperature with varying altitude</td>
<td>Mission Objective</td>
</tr>
<tr>
<td>M 0.3</td>
<td>Team Solkraft shall measure the light intensity with varying altitude</td>
<td>Mission Objective</td>
</tr>
<tr>
<td>M 0.4</td>
<td>Team Solkraft shall test for variations in solar cell output under varying climate conditions</td>
<td>Mission Objective</td>
</tr>
<tr>
<td>M 0.5</td>
<td>Team Solkraft shall meet the requirements for the request for proposal</td>
<td>Mission Objective</td>
</tr>
<tr>
<td>M 0.6</td>
<td>Team Solkraft shall make sure no one is hurt during construction and testing</td>
<td></td>
</tr>
</tbody>
</table>

**MISSION REQUIREMENTS LEVEL 1**

<table>
<thead>
<tr>
<th>Requirement Number</th>
<th>Requirement</th>
<th>Where it comes from</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 1.1</td>
<td>The solar panels shall be attached to the angled sides of the BalloonSat</td>
<td>M 0.1 M 0.4</td>
</tr>
<tr>
<td>M 1.2</td>
<td>Team Solkraft shall be able to record the altitude of the BalloonSat using data from EOSS GPS</td>
<td>M 0.2, M 0.3</td>
</tr>
<tr>
<td>M 1.3</td>
<td>Team Solkraft shall be able to record and save data during the flight</td>
<td>M 0.2, M 0.3, M 0.4</td>
</tr>
<tr>
<td>M 1.4</td>
<td>Team Solkraft shall maintain a minimum internal temperature of</td>
<td>M 0.5</td>
</tr>
</tbody>
</table>
# Level 0 Requirements

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>Test energy generation capabilities of Earth's magnetic field</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.1</td>
<td>Measure magnetic field as function of altitude</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.2</td>
<td>Reach an altitude of 30km</td>
<td>Mission Statement</td>
</tr>
<tr>
<td>0.3</td>
<td>Keep internal temperature above -10°C</td>
<td>RFP</td>
</tr>
<tr>
<td>0.4</td>
<td>Keep total weight and money spent under 850g and $250 respectively</td>
<td>RFP</td>
</tr>
<tr>
<td>0.5</td>
<td>Take inflight pictures, correlate pictures to heading, and measure temperature (internal and external)</td>
<td>RFP</td>
</tr>
<tr>
<td>0.6</td>
<td>Safety &amp; Reliability</td>
<td>RFP</td>
</tr>
<tr>
<td>0.7</td>
<td>BalloonSat must be able to fly again</td>
<td>RFP</td>
</tr>
</tbody>
</table>

# Level 1 Requirements

## Requirement 0.0: Test energy generation capabilities of Earth's magnetic field

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>Induce emf (electromotive force) in solenoid</td>
<td>0.0</td>
</tr>
<tr>
<td>0.01</td>
<td>Measure current with ACS712 Low Current Sensor Breakout</td>
<td>0.0</td>
</tr>
<tr>
<td>0.02</td>
<td>Record and timestamp current readings with Arduino Uno</td>
<td>0.0</td>
</tr>
<tr>
<td>0.03</td>
<td>Measure resistance of solenoid-current sensor-Arduino Uno circuit</td>
<td>0.0</td>
</tr>
<tr>
<td>0.04</td>
<td>Calculate power generated in circuit</td>
<td>0.0</td>
</tr>
<tr>
<td>0.05</td>
<td>Recover and analyze data and compare with altitude and field strength readings</td>
<td>0.0</td>
</tr>
</tbody>
</table>

## Requirement 0.1: Measure magnetic field as function of altitude

<table>
<thead>
<tr>
<th>#</th>
<th>Requirement</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>Measure magnetic field strength with MicroMag 3-Axis Magnetometer</td>
<td>0.1</td>
</tr>
<tr>
<td>0.11</td>
<td>Record and timestamp field strength readings with Arduino Uno</td>
<td>0.1</td>
</tr>
</tbody>
</table>