Today:

- Announcements

- One Minute Report Questions

- Next Time

- Recap on Spacecraft Overview

- BalloonSat Overview & RFPs
Announcements:

- HW#1 DUE

- HW#3 Q’s 1 – 3 Assigned

- Soldering class will be in here Tuesday, September 12, 2017 during normal class time

- Pictures and 1st time?
Announcements:

- Spatial Visualization test due Today at 1 PM

- May have moved to

- 46 out of 65 completed as of 8 AM
Announcements:

- Workshops start next Tuesday and Thursday for those that did not pass

- Look for email from Jacob Segil

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<td>Review + TEST</td>
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<td>Week 8</td>
<td>10/30</td>
<td>Review + TEST</td>
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*makeup sessions on Sundays 5-7pm in ITLL 150*
Announcements:

- Class email list

- Check that email is on the list

- Make any corrections

- If email is missing, write it on the list
Announcements:

- Last class

- Thanks for the feedback on format

- Rushed but will recap at the end of today’s lecture

- Slides are posted
One Minute Report Questions:

https://youtu.be/vmYPGsD2IrU

GoatsLive.com
Next Time...

Team Forming and Team Activity

HW #2 DUE
HW #3 Questions 3 – 10 & Proposal Assigned
Other Questions?

BalloonSats/RFP or Spacecraft Recap

Colorado Space Grant Consortium
Request For Proposals

Colorado Space Grant Consortium
What is an RFP?

- There is a lot of money out there

- There are a lot of ideas

- **Request For Proposal** bring them together

- Most satellites were at one time an RFP

- Most of you will write or help write a proposal in your job

- Now is your time to practice
Gateway to Space Theater
Gateway to Space Theater
BalloonSat Missions to the Edge of Space

Request For Proposal
#RFP 1400S17

Spring 2017 Announcement

Proposal Due No Later Than:

DATE: February 13, 2017
TIME: 8:00 AM
E. Proposal Instructions:
Proposals must be typed, 12 point, Times font, 1 inch margins, page number and team name in footer, single spaced, and project name in header. Proposal must be no less than 7 pages and not exceed 10 pages, including cover sheet and budget. Proposal must include drawings of idea (include dimensions), organization chart with those responsible for each task, functional block diagram, schedule of design, build, and test dates, itemized budget with total, mission statement detailing what you expect to discover. Examples of these items are included in the back of this announcement.

Proposal must be written in Microsoft Word (.docx) and shall not exceed 25 MB. Please send proposal via email to your instructor by 8:00 AM on September 21, 2015. All pictures, budgets and schedules must be included in the single, electronic file. Proposals turned in after deadline will be penalized by 15% to 99% depending on the lateness. There shall be zero unknowns in your proposal (i.e. To Be Determined or Will Figure Out Later). This is not your final design and it can and will change but your mission, at its core, should not unless directed by the instructor. Your weight and cost estimates should be as detailed as possible. Cover the HOW and WHY of your mission in great detail. Most students lose all their points here. Avoid weasel words. Do a VERY professional job on the formatting as well. Proposals shall be written in the third person.
RFP Tells How to Write a Proposal

- RFP give you format for proposal

- Three sections

I. Overview and Mission Statement: (WHY and WHAT?)
- State your mission concept concisely (Mission Statement)
- Explain **WHY** you want to do what your team is proposing
- Propose **WHAT** you plan to discover
- **This section shall be at least one page of your proposal**
- The **WHAT** and/or **WHY** should be referenced with at least three sources
  (i.e. do research on the **WHAT** and **WHY** of your mission and cite those research references).
II. Technical Overview: (HOW?)
- Explain completely **HOW** you will achieve your **WHAT** and **WHY** above with proposed design (Small changes expected as your design becomes more refined)
- Illustrate your design (Drawings with dimensions with design components shall be labeled)
- Discuss the hardware you will need and where you plan to acquire it
- Discuss **HOW** your team will turn your design into an actual satellite (“we will order hardware XYZ and then test with hardware ABC and then we will integrate it into the structure and then we will test the XYZ and then we will use these results to make further changes.”)
- Discuss **HOW** your team will test your design to ensure it meets all your science and mission objectives. This means have a detailed test plan.
- Discuss **HOW** you will keep people from getting hurt
- Include the special features of your design and **HOW** they will enhance and/or help you achieve your mission
- Include a preliminary summary of **HOW** you will do data retrieval during testing and after launch and recovery
- Include a Functional Block Diagram showing **HOW** all your systems of your design work together (HINT - Chris really likes these diagrams)
- Include a plan on **HOW** your team intends to track, meet, and verify all the requirements (coming up in Section G) of this RFP.
- All these requirements shall also be discussed in your proposal.
III. Management and Cost Overview: (WHO, WHEN, and COST)

- Create a detailed schedule of WHEN these events will occur. You may discover others to include while creating this schedule.
  (Design complete, acquire all hardware, prototyping design complete, testing final design complete, cold test complete, design reviews, other activities described on class syllabus (demos, mission sims, inspections, weigh-in), team meetings, etc)

- Include an organizational chart of WHO is on your team and their title

- Provide a plan of WHO is going to do what on the team with specific tasks listed (i.e. manage budget, software modification, camera programmer, etc.)

- You should include a brief description of WHO each team member.

- Document phone numbers, school, addresses, special skills, etc.

- Create a detailed and itemized budget for project COSTs with total including where hardware will be ordered.

- Include a plan on HOW your team will keep its budget & WHO will manage it.
To Recap RFP:

- Final weight shall not exceed **800 grams**

- Shall image the Earth or the Balloon during flight, record internal and external temperature, humidity and pressure levels, and g forces in x, y, and z directions

- Must have one additional experiment and one additional sensor (minimum)

- Must follow all the guidelines while writing proposal

- **Why and How** – this is your plan and foundation for project

- Using screen shots…
So...

- Take the ideas you came up with individually during the HW#2

- Start with these in your team and expand them during HW #3

- But...Keep It Simple Stupid (KISS Principle)

- Start now!

- You are writing a proposal not a request for proposal

- Proposals Due September 24th (18 days)
- Launch is November 11th, (67 days)
Presentation:

Presentation Templates

- On Class Website

- Final presentation should cover same items in final report

- CoDRs are before Proposals (Elevator Pitch)

- Quick Look Presentation (Post Launch)

- Final Presentations before Final Report
Final Written Report:

**Design Document Template**

- You will write your team’s final report throughout the semester with our Design Document revisions

- 1st Draft of DD Rev D is due at Expo

- Final draft is due after final presentations to allow incorporation of action items from Expo, presentations
Team Video (Optional):

- Must be 3 minutes or less
- Must be turned in at Expo
- Must be “presentable” to the public
- Extra, extra, extra credit if it goes viral (more than 100,000 hits)
Drawings:
Functional Block Diagrams
CONOPS

Colorado Space Grant Consortium
**Flight:**
- At take off accelerometer will detect ascent rates
- As altitude increases, sensors will detect changes in temperature, pressure, and humidity.
- After burst, accelerometer will detect the descent rates
- As altitude decreases, sensors will keep detecting changes in pressure, humidity and temperature

**Post Flight:**
- Prepare Satellite for another launch and follow this procedure

**Data and Analysis:**
- Bacteria will be taken to Mr. Kralj’s lab for incubation and analysis

**Pre-Launch:**
- 12 hours prior to launch, culture and sustain bacteria
- Assembly of structure and subsystems

**Launch:**
- Seal structure with glue and aluminum tape
- All switches on
- Camera turned on

**Recovery:**
- At most extreme altitudes the bacteria will be exposed to high level radiation, which the Geiger Counter will detect
Concept of Operations

Flight

Heater turns on and begins to warm the interior
Arduino One SD stores the collected data
Arduino Two powers on and stores data for Magnetometer
Arduino One Two and three switch light turns on
Flip Camera and Heater Switch to on
Flip Arduino Uno switches to on
Seal Structure with Aluminum Tape

Arduino Two SD stores collected data
Arduino 2 powers and measures radiation, heading, and external temp

Arduino Three SD stores collected data
Arduino 3 powers on measures internal temp, pressure, humidity, and acceleration
Camera begins taking pictures every fifteen seconds

After 500 photos takes video until SD full

Ground

Post

Track and retrieve via GPS
Power off all switches
Open data on laptops
Analyze and Draw Conclusions
Check functionality and ability to fly again

Landing

After 500 photos takes video until SD full

After 500 photos takes video until SD full

After 500 photos takes video until SD full

After 500 photos takes video until SD full
**Concept of Operation**

- **Mesosphere**
  - Take pictures on specific intervals of time
  - Collect data on altitude, beta, gamma, UV and IR radiation, temperature (internal/external), pressure, acceleration, and humidity
  - Save data on a micro SD card
- **Stratosphere**
  - Balloon burst at ~30 km
  - Parachute deployment
- **Troposphere**
  - Arrive at launch site
  - Prepare balloon
  - Turn on payload with switches
  - LED’s indicate they are functioning
  - Seal payload lid with aluminum tape
  - Lift off!!

- Payload design
- Testing
- Final assembly

- Payload recovery with GPS
- Expected LED’s off
- Expected batteries to be dead
- Data collection terminated
# Concept of Operations Diagram

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prelaunch</strong></td>
<td>Assembly of structure and subsystems. Ensure structure is sealed. Turn switches on. Turn camera on.</td>
</tr>
<tr>
<td><strong>Launch</strong></td>
<td>Measure changes in temperature, pressure, and humidity as altitude increases. Solar panel and wind turbine collect energy and voltages for each will be logged.</td>
</tr>
<tr>
<td><strong>Ascent</strong></td>
<td>Balloon ruptures. Accelerometer measures g-forces during burst.</td>
</tr>
<tr>
<td><strong>Burst</strong></td>
<td>Measure changes in temperature, pressure, and humidity as altitude decreases. Accelerometer measures descent rate.</td>
</tr>
<tr>
<td><strong>Descent</strong></td>
<td>GPS leads gateway to space class to recovery site. Turn switches off. Turn camera off.</td>
</tr>
<tr>
<td><strong>Recovery</strong></td>
<td>SD shields and Arduinos are connected to computers to collect data.</td>
</tr>
<tr>
<td><strong>Data Analysis</strong></td>
<td></td>
</tr>
</tbody>
</table>
So...

- Get started now (Due in 18 days)
- Teams next class (Due in 16 days)
- Be opened minded about your team and how ideas fit into the team’s ideas
Questions?

Colorado Space Grant Consortium
BalloonSat Overview

Class #3

Colorado Space Grant Consortium
Origins:

- Started at Space Grant June 2000
- Was a student at Space Grant 1990-1995
- Programs had advanced
- Hard for freshman students to get plugged in
- Sink or Swim
Origins:

What if students could get close to space?

- Met Edge of Space Sciences (EOSS) in Fall 1996
Origins:

- Promise of recovery and 100,000 feet
- Price was right
- Many launches every year
- Some of the same engineering challenges
Origins:

With the combination of these items, BalloonSat was born
The StratoShuttle-1 student balloon, an educational project by the Quest for Stars group, captured NASA's shuttle Atlantis soaring into orbit as seen from 89,000 feet on July 8, 2011. Tweeted @questforstars: "Atlantis, GO at Throttle up!"

CREDIT: Quest for Stars
View full size image
BalloonSat:

- BalloonSat is an excellent, low cost platform for “Walk” level student missions to the Edge of Space

- A BalloonSat weighing up to 9 kg can reach 30 km (100,000 feet)

- Students faced with many engineering challenges
  - Mach 1, -80 C, near vacuum, impact and burst

- No microgravity but BalloonSat can be recovered
**Ballooning**

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Pressure</th>
<th>Horizon</th>
<th>Sky Color*</th>
<th>Cosmic Rays**</th>
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<tbody>
<tr>
<td>Ground</td>
<td>1013 mb</td>
<td>3 miles</td>
<td>Blue</td>
<td>4 counts/min</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>All secondaries</td>
</tr>
<tr>
<td>85,000 feet</td>
<td>20 mb</td>
<td>350 miles</td>
<td>Black</td>
<td>700 counts/ Min</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Primaries and Secondaries</td>
</tr>
<tr>
<td>300 miles</td>
<td>0 mb</td>
<td>1500 miles</td>
<td>Black</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>All Primaries</td>
</tr>
</tbody>
</table>

* Chapter Fourteen discusses the topic of sky color  ** Chapter Eight discusses the topic of cosmic rays
Ballooning

- Ballooning is inexpensive
  - Helium (~$800) - Now Hydrogen (~$30)
  - Balloon (~$300)

- You mostly control launch
Ballooning

*When your balloon and payload ascend into the sky...*

Every student knows, *their* experiment is going where **no one**
- except astronauts - has ever gone before
BalloonSat Construction:

Aluminum Construction

Foam Core Construction
BalloonSat Construction:

- Velcro
- Silicon Adhesive and Hot Glue
- Aluminum Tape
- Insulation
- Venting
- Condensation
BalloonSats

- Easy to attach to balloon
- Easy to track and Recovery
- Fun for all
- You will build one this semester
What you will get:

- Batteries (some)
- Black Foam Insulation \( \frac{1}{4} \) and \( \frac{1}{2} \) inch
- 3 half sheets
- Velcro & hot glue
- Aluminum tape
- Xacto knives
- Flight tube USA flag
- Coolers
- Multimeter & Wire
- Gateway Store
What you will get:

- Must fill out inventory sheet when you use the store
What you will get:
What you will get:
What your team supplies:

- Batteries (some)
- Mission
- Design
- Time & Effort - Build, Test, Document, Fly, Recovery, & Analyze
- Hardware order forms (HW #6)

Batteries

Dry Ice
Past Student Experiments:

- Atmospheric radiation levels
- Solar cell efficiency
- Atmospheric soundings
- Video imaging
- High altitude effects on roaches
- Digital sound recording of upper atmosphere
- Temperature studies

Use Past Team Reports
Launch:

- Sites typically in eastern Colorado
- Liftoff is 7:00 AM
- 90 minutes up, 45 minutes down
Launch: Supported by EOSS

- 3000 gram latex balloon
- Gaseous Hydrogen (~2 K bottles)
- Balloon filling system
- Flight string
- Radio Transceiver
- GPS
- Control Systems
- Parachute
- FAA notification
Launch Review:
BalloonSats - Typical launch
Introductions:
Introductions:
Burst:

- Altitude variable
- One of the most violent moments of the flight
- Mach I

Series of burst images
BalloonSats

- Interesting burst
Balloon Satellites

ATOMIC BOMBS

PROJECT MAYHEM
Launch Review:
Recovery:

HAZELTON — Joe Nelson of Hazelton made an interesting discovery in one of his fields recently while he was harvesting.

A silver box approximately 5 1/2 inches square with wires and bolts sticking out of it was laying among the vines in the field. It was near dark and difficult to see any details.

“My first thought was that it was a bomb,” Nelson said.

The next morning after having a closer look, Nelson could see a hole cut in one side of the box with a camera in it. There is also what appears to be an antenna on one side and a switch on another. A long bolt appears to be running through the contraption, sticking out 3 inches on each side.

The box looks to be made of foam board held together by foil and duct tape. Several stickers of badgers and American flags decorate the box.

In another nearby field, he found a similar contraption. This one was white with stickers saying USA1 and a second box was connected to it by a cable.

Nelson said that the boxes may have been part of a school science experiment and someone may want to retrieve the cameras from the boxes.

For more information, call Trena at 677-4042, extension 600.
Recovery:

- Begins after launch
- Can track real-time
- Recovery complete same day
BalloonSat Testing:

- Drop Test
- Cooler Test
- Subsystem Tests
- Functional Tests
- Mission Sim Tests
- Whip Test

DO NOT FOCUS ON STRUCTURAL TESTING ONLY
BalloonSat Testing:

Kick, Drop, Cool, Whip, and Fore!
Quick Lesson on the Atmosphere
Environments at 30 km:

• How high do commercial jets fly?  ~10 km

• How high is the ozone layer?  ~20 to 50 km

• What are the layers of the atmosphere?
The 4 Layers of the Atmosphere:

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
Environments at 30 km:

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
Environments at 30 km:

Capt. Joe W. Kittinger jumps from a balloon at 102,800 feet.

Forgot to mention, he exceeded the speed of sound with his body.
Environments at 30 km:

Temperature varies in all directions as you climb through the different layers of the atmosphere.

Why?

Solar Radiation (UV, IR)
- Ozone Absorbs
- Surface Heats
- Convection
Environments at 30 km:

- Temperature can dip to -80°C
- Biggest killer of past missions
- Easy, repeatable science
Back to BalloonSats...
History and Results:
History and Results:

- Over 150 launches
- 22,550 students
- 98% recovery rate
- 90% recovered with some data
- 50% recovered with all expected data
- Papers have been written and presented
- More than 50% of students have continued with more research projects
History and Results:
History and Results:
Launch Review:
The Organizers

Introductions:
Introductions:
Introductions:
Introductions:
BalloonSats:

- BalloonSats are excellent way to do hands-on research
- Motivates you to go further
- See importance of your education
- Prepared to contribute to more complex projects
- Have the confidence to take the next step
Questions?
The Process: (Chris’s Process)

1. Mission – Thus the Mission Requirements (#10)

2. Orbit Selection

3. Launch Vehicle

4. Everything else
   - Structures, Interfaces, and Mechanisms
   - Power & Thermal
   - C&DH/Software
   - Communications
   - ADCS
   - MOPS
   - Other
Structures (#13)

- Project Management
- Systems Engineering
  - Comm
  - Structures
  - Thermal
  - ADCS
  - C&DH
  - Power
    - Ground Ops
    - Education
    - Prop
    - Science
    - Software
    - MOPS
Structures:

- Your launch vehicle helps direct your structure design
- Volume, CG, and weight constraints
- Launch loads and shock issues associated with LV
- Interface constraints
- Vibration constraints
Structures:

- The whole purpose of the structure is to support the payload
- Then the other systems

- Composites
  - Honeycomb
- Aluminum
  - Plate
  - Isogrid
- Titanium
- Stainless Steel
Communication:

- Transmitter (TX)
- Receiver (RX)
- Antennas (TX, RX, and Ground)
- Sometimes modems and TNC
- TX are big power hogs but usually not on all the time

- Signal to noise ratio

- Cell phone technology
- IP technology
- Satellite to satellite
Communication/Ground Ops:
MOPS/Ground Ops

- Project Management
- Systems Engineering
  - Comm
  - Structures
  - Thermal
  - ADCS
  - C&DH
  - Power
  - Ground Ops
  - Education
  - Prop
  - Science
  - Software
  - MOPS
Mission Operations (MOPS)/Ground Ops:

- “Houston, we have a problem”

- MOPS is the command center of the satellite
Mission Operations (MOPS)/Ground Ops:

- All human interaction occurs through this team
- Much coordination is required to properly operate satellite
- Failure modes determined FMEA
- Data storage and analysis
- All communication is done through MOPS
- Usually staffed 24/7
Mission Operations (MOPS)/Ground Ops:

- Some teams will have ground ops this semester if you...
  - Have a communication system

- Have a sensor(s) that need ground data to compare to flight data

- Have a mission that requires ground data
Mission Operations (MOPS)/Ground Ops:
ADCS (Maybe #21)

Project Management

Systems Engineering

Comm
Structures
Thermal
ADCS
C&DH
Power

Ground Ops
Education
Prop
Science
Software
MOPS
ADCS:

- Attitude Determination and Control System

D = Determination

C = Control

- Think of driving a car…
on a mountain pass at night without headlights and no tires - D vs. C?
ADCS:

D = Determination

- Determination Systems
  - Star Trackers, Magnetometer, Sun Sensors
  Horizon/Limb Sensors
ADCS:

- C = Control Systems
  - Torque Rods, Momentum/Reaction Wheels, Control Motion Gyros, Thrusters, gyros, booms
  - A lot of software and control laws
Propulsion (#18)

- Project Management
- Systems Engineering
  - Comm
  - Structures
  - Thermal
  - ADCS
  - C&DH
  - Power
  - Ground Ops
  - Education
  - Prop
  - Science
  - Software
  - MOPS
Propulsion:

Functions of Spacecraft Propulsion:
- Attitude Control
- Station Keeping or stay in orbit (Atmospheric drag)
- Delta V burns (orbit maneuvers)

- Different types
  - Mono-propellant
  - Bi-propellant
  - Cold Gas
  - Ion
Power:

- Miniature power plant
- Most spacecraft use less power than a 300 W light bulb
- Very complicated system
- There is high likelihood of power being the reason a satellite fails
- Batteries
Power:

- Solar cells
- Charging circuits
- Distribution system
- Control system
- Conversion system
Thermal:

- Can make or break a system literally

- Three types of thermal control: Active, Passive, Do Nothing

  - Active
    - Heaters, heat pipes, thermostats, cryogenics

  - Passive
    - Radiators, insulation, surface finishes, conductive materials

  - Do Nothing

- Usually a combination of first two
Thermal:

- Thermal Modeling
C&DH (#6, 8, 9, x2)

- Project Management
- Systems Engineering
  - Comm
  - Structures
  - Thermal
  - ADCS
  - C&DH
  - Power
    - Ground Ops
    - Education
    - Prop
    - Science
    - Software
    - MOPS
C&DH:

- Command and Data Handling (Computer)

- Basically a home computer but much smaller and less of a power hog

- The brain of a satellite

- Is pretty dumb without software

- Very difficult system, many unknowns and bugs
Software (#6, 8, 9, x2)
Software:

- Programmers are worth weight in gold
- Days of Voyager spacecraft are over
- Today, satellites are very complex and so is the software

```c
#include "inc.h"  // Include Library Files
#define MEMSIZE 0x200000L

void sample(void)
{
    /* Use this function to perform the following tasks:
        1) Sample each of the payload's sensors
        2) Sample the Geiger counter
        3) Write these values to memory
        4) Clear the Geiger counter */

    write(adcGetChar(ACCEL_X_LOW));  // Convert analog value for x low accel and
    write(adcGetChar(ACCEL_Y_LOW));  // Convert analog value for y low accel and
    write(adcGetChar(ACCEL_Z_LOW));  // Convert analog value for z low accel and
    write16(adcGet16(ACCEL_X_HIGH)); // Convert analog value for x high accel and
    write16(adcGet16(ACCEL_Y_HIGH)); // Convert analog value for y high accel and
    write16(adcGet16(ACCEL_Z_HIGH)); // Convert analog value for z high accel and
    write16(adcGet16(TEMP));        // Convert analog value for temp and write to storage
    write16(adcGet16(PRESSURE));    // Convert analog value for pressure and write
```
Other

- Project Management
  - Systems Engineering
    - Comm
    - Structures
    - Thermal
    - ADCS
    - C&DH
    - Power
    - Ground Ops
    - Education
    - Prop
    - Science
    - Software
    - MOPS
Other:

- Management (Team)
- Systems Engineering (#112)
- Budgets (Team)
- Contracts
- Planners (Team)
- Technicians, Manufacturers, Test Engineers (Team)
- Mechanisms
Mechanisms

Project Management

Systems Engineering

Comm
Structures
Thermal
ADCS
C&DH
Power

Ground Ops
Education
Prop
Science
Software
MOPS
Mechanisms:

- In addition to structure you have mechanisms

- People are afraid of mechanisms

- Two types, deployment and payload support

- They usually are single point failures

- Hard to test on ground as they are used in space
  - Mast example (Special Programs, Balloon)
  - KC-135 Boom Video
Say I Wanted You...

To take pictures from space with this...

- How would you do it?
Anatomy of a Satellite:
Anatomy of a Satellite:
Anatomy of a Satellite:
Anatomy of a Satellite:
Anatomy of a Satellite:
Anatomy of a Satellite:
Anatomy of a Satellite:
Anatomy of a Satellite: