One Minute Paper:

- Lecture was way to fast at the end (numerous)
- ADCS and C&DH…I would like a better understanding of what each is
- Do we seriously not get to build (S/C)?
- How are we going to launch our satellites?
- What GPS system do we use on the BalloonSat?
- What exactly is attitude?
- Do we get experience with all of these systems on our BalloonSat?
- What are the different types of orbits and what each one does?
One Minute Paper:

- How do the control systems work?
- How much $ do we have to build and what materials we use?
- Can’t wait to start building!
- At what point will we know enough to start building?
- How much of this info will be on the final?
- How long does it take to get a functional satellite?
- Are we going to have to know how to program to build a BalloonSat and the camera functions?
- Will there be other payloads besides cameras on our BalloonSats?
- When will make teams and who is funding our sats?
Announcements:

- HW 01 DUE Today
- HW 02 Assigned Today and DUE
- Last day to ADD class
- Movie Night This Thursday at 6:00 PM in DLC
- General Questions?
Origins:

- Started at Space Grant June 2000

- Was a student at Space Grant 1990-1995

- Programs have advanced

- Hard for freshman students to get plugged in

- Sink or Swim

- Graduation
Origins:

How it all started…

- Space Grant Meeting in San Diego Fall 2000

- Bob Twiggs introduced CubeSats

- Great concept but…
  - 80 to 100 new students a year
  - $35K to $50K
  - Complexity

- Seed was planted
What if students could get close to space?

- Met Edge of Space Sciences (EOSS) in Fall 1996
- 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 three items, BalloonSat was born
CUBESAT

- This class does not have the money to send to orbit

- Space Grant is interested

- We can build prototypes

- These prototypes may some day be converted to flight status

- Future is 52 CUBESATs going to Mars

- Here is where start...
BalloonSat
Missions to the Edge of Space
BalloonSat:

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

- A BalloonSat can reach 30 km (100,000 feet) for $300

- Students faced with many engineering challenges

- No microgravity

- BalloonSat can be recovered
Ballooning

- Why Ballooning?
  - Near Space Environment

- What Defines Space?
  - Vacuum
  - Radiation
  - Micro-acceleration

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Pressure</th>
<th>Horizon</th>
<th>Sky Color*</th>
<th>Cosmic Rays**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>1013 mb</td>
<td>3 miles</td>
<td>Blue</td>
<td>4 counts/min 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 Primaries and Secondaries</td>
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<tr>
<td>300 miles</td>
<td>0 mb</td>
<td>1500 miles</td>
<td>Black</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 (~$80)
  - Balloon (~$150)

- You mostly control launch
**BalloonSats**

- Easy to attach to balloon
- Easy to track and Recovery
- Fun for all
- You will build this semester
BalloonSat Uses:

- Space Hardware Demonstrations
- Atmospheric Studies
- Technology Prototypes
- Life Sciences Studies
- Remote Sensing
- Student Training
- BalloonSat is geared to college level freshmen of all majors but high school students have done it too.

- Taught every semester as part of a class titled *Gateway to Space*.

- Students are placed in teams of six and given an RFP and write proposal.
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
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 Hardware:

- Canon ELPH LT Camera
- 555 Timing Circuit
- Datalogger & Temp Probe
- Batteries
- Digital cameras
- Photodiodes
- Solar Cells
- Geiger tubes
- Hand Warmers and Desiccant
- Insulation
BalloonSat Construction:

Aluminum Construction

Foam Core Construction
BalloonSat Construction:

- Velcro
- Silicon Adhesive and Hot Glue
- Aluminum Tape
- Insulation
- Venting
- Condensation
BalloonSat Testing:

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

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

- 1200 gram latex balloon
- Gaseous Helium (~2 K bottles)
- Balloon filling system
- Flight string
- Radio Transceiver
- GPS
- Control Systems
- Parachute
- FAA notification
Launch Review:
BalloonSats

- Typical launch
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
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

![Graph showing temperature changes at 30 km with labeled events: Launch, Tropopause, Coldest, Burst (30 km), Landing.](image)
Burst:

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

Series of burst images
Burst:
Burst:
BalloonSat Testing:

- Drop Test
- Cooler Test
- Stair Test
- Whip Test
- Subsystem Tests
- Functional Tests
- Mission Sim Tests
BalloonSat Testing: Kick, Drop, Cool, and Whip
Recovery:

- Begins after launch
- Can track real-time
- Recovery complete same day
History and Results:
History and Results:

- 40 launches
- 4,000 students
- 96% 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:
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
In Colorado, we work with a company called EOSS or Edge of Space Sciences (www.eoss.org)

- EOSS is non-profit organization

- Total Launch cost $1,500

- You can launch your own

- This workshop will show you how

- You will launch your BalloonSat Saturday!
Closing Items:

- One Minute Report & Attendance Sheet

- Who is here for the first time?

- Pictures

- Space Grant Overview