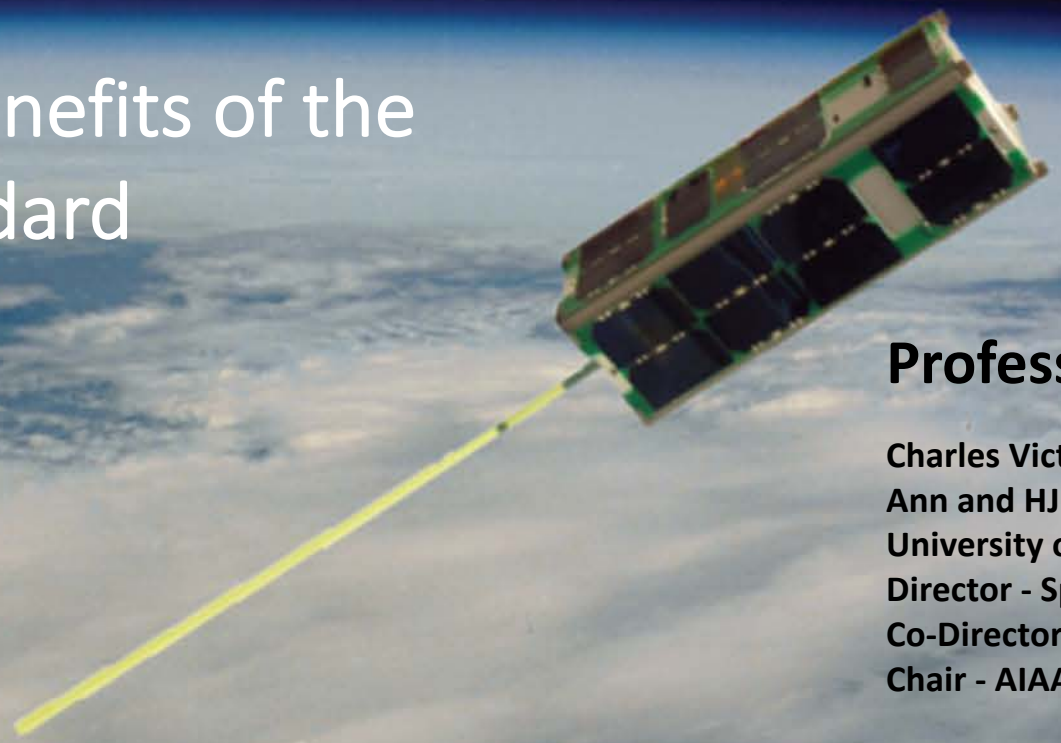
# So you want to build a CubeSat .... with students ---- Really?

## Educational benefits of the Small Sat Standard

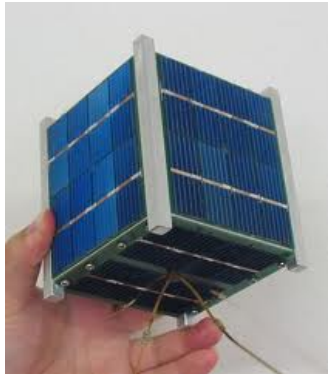



**Professor Scott Palo**

**Charles Victor Schelke Endowed Professor**
**Ann and HJ Smead Aerospace Engineering Sciences Department**
**University of Colorado Boulder**
**Director - Space Technology Integration Lab (STIg)**
**Co-Director – Active Remote Sensing Lab (ARSenL)**
**Chair - AIAA Small Satellite Technical Committee**

# The Vision circa 1999

PC104

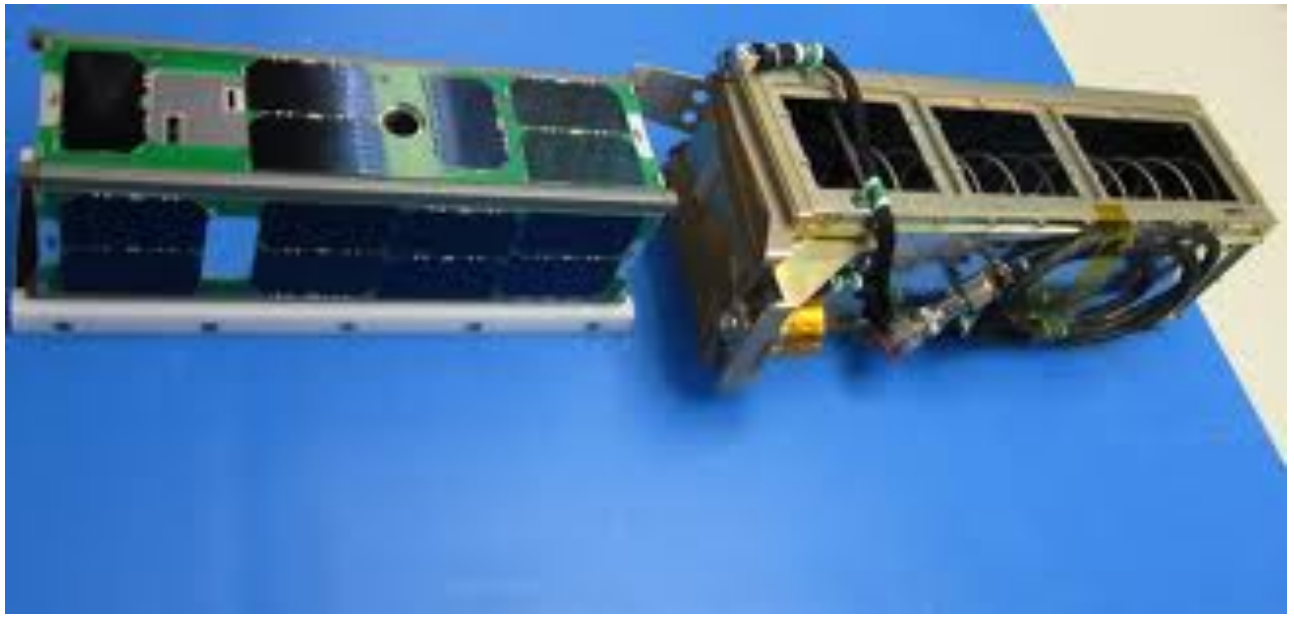


CubeSat
1kg/1L

Bob Twiggs

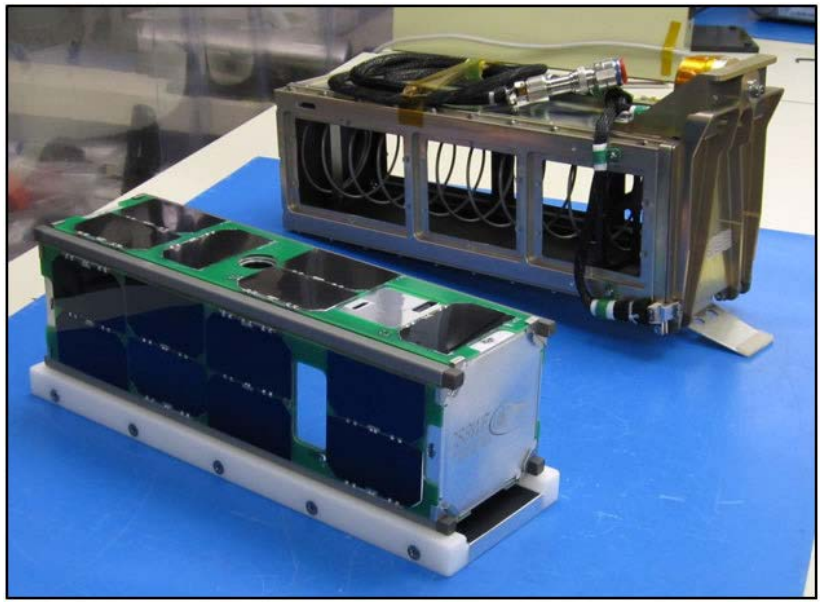
The Problem:
How to launch these satellites?

# The solution



The PPOD
A containerized dispenser

# For Reference




Density 1kg/L

# Thoughts on building a CubeSat in a university environment

the lessons I have learned

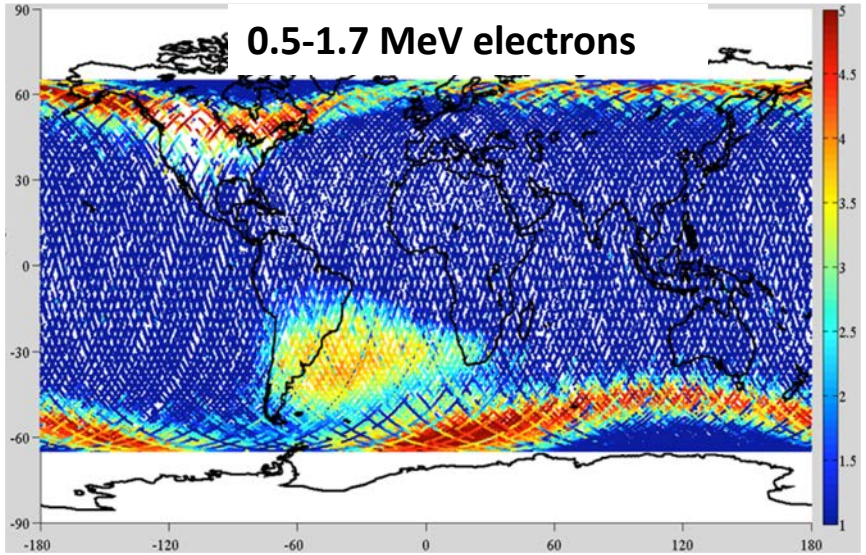
# Building a CubeSat – top 8 list ($2^3$)

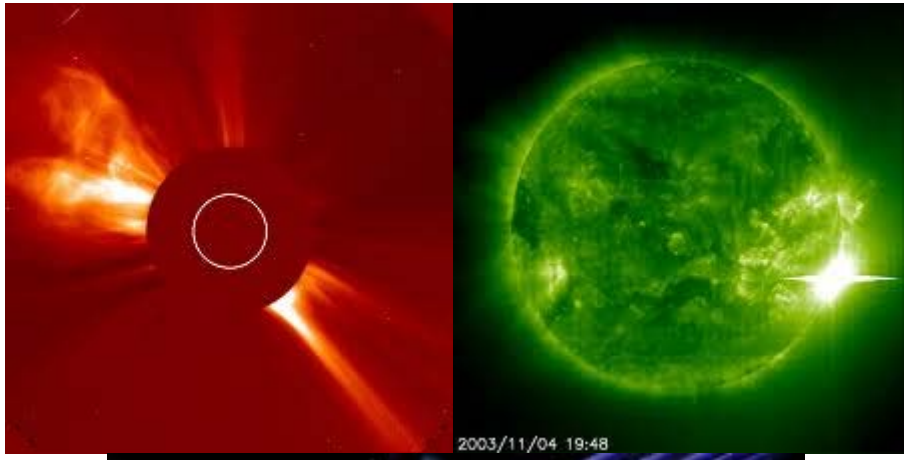
1. Have a purpose
   - You need direction
   - You need guidance on when to say NO
   - Avoid building Frankensat

# CSSWE Science – Living with a star

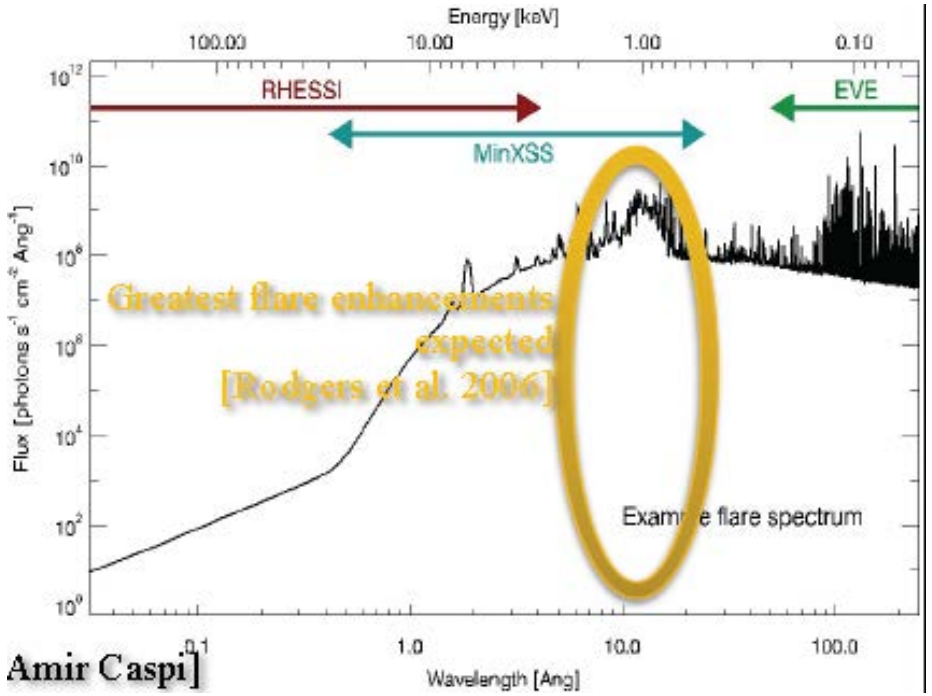
Science Objectives

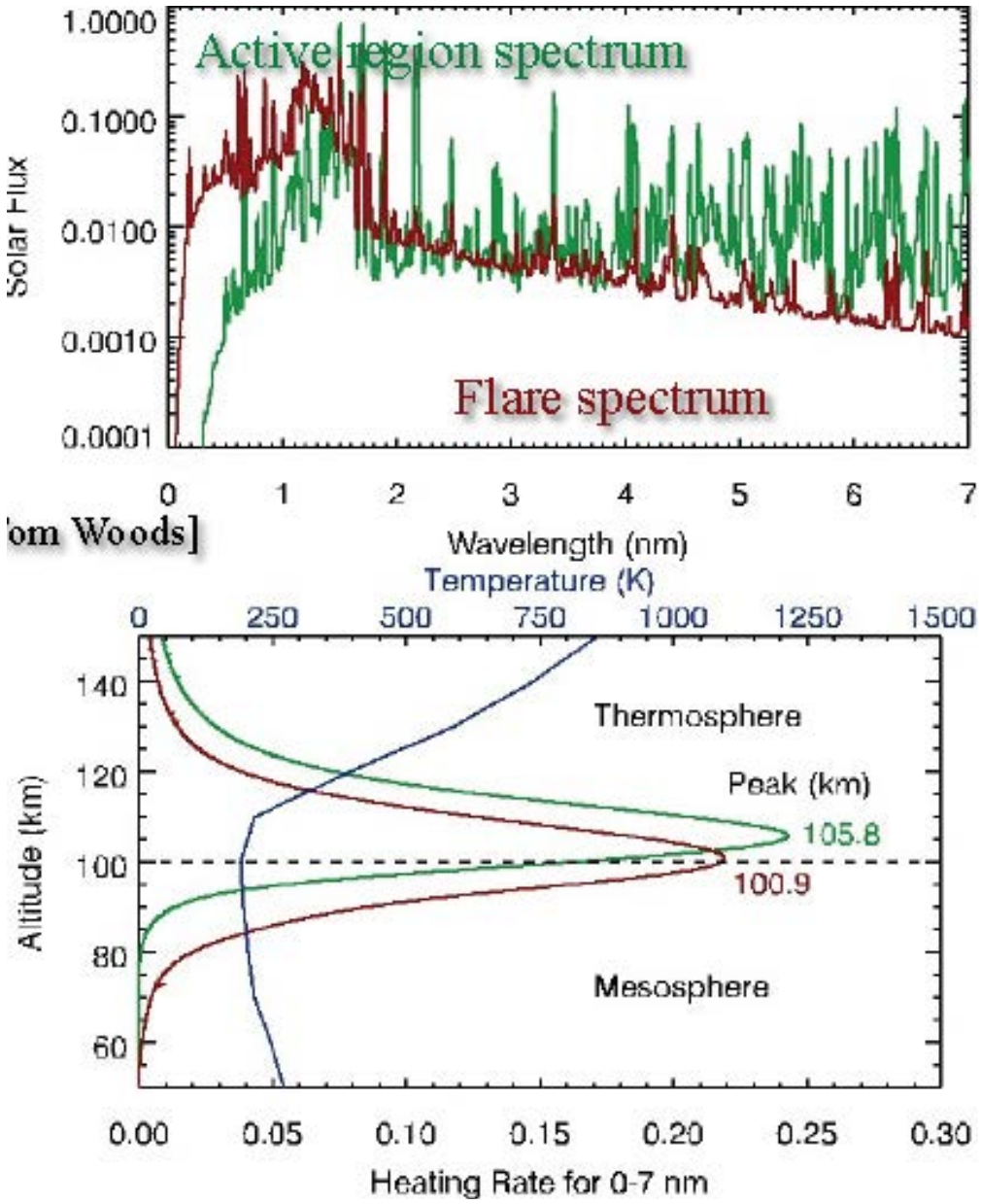
To understand the relationships between solar energetic particles (SEPs), flares, and coronal mass ejections (CMEs), and to characterize the variations of the Earth's radiation belt electrons.



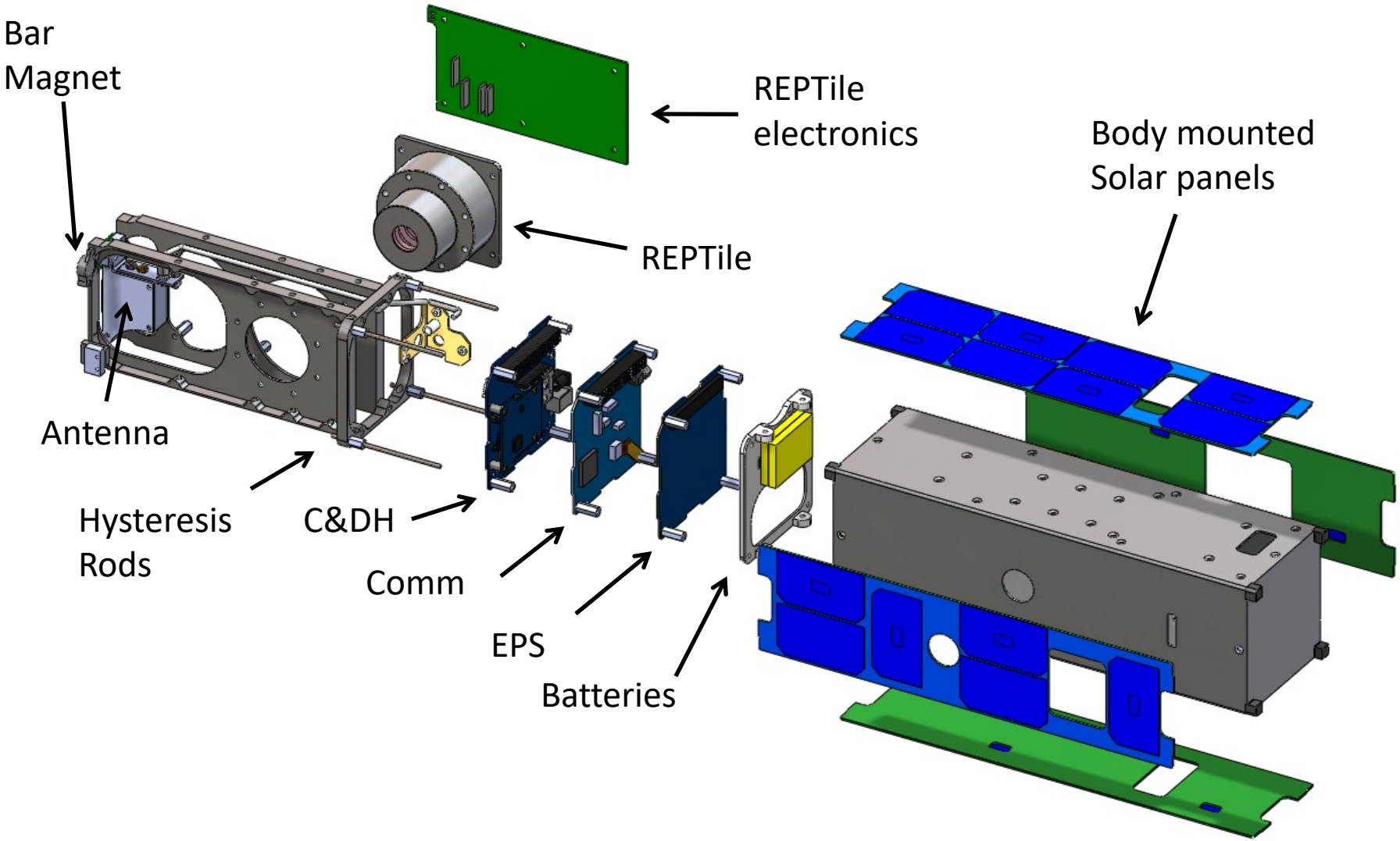

# MinXSS Science



# Building a CubeSat

1. Have a purpose
2. Define requirements and interfaces


Bar
Magnet
REPTile
electronics
Body mounted
Solar panels
REPTile
Antenna
Hysteresis
Rods
C&DH
Comm
EPS
Batteries

# Building a CubeSat

1. Have a purpose
2. Define requirements and interfaces
3. Develop a plan with milestones

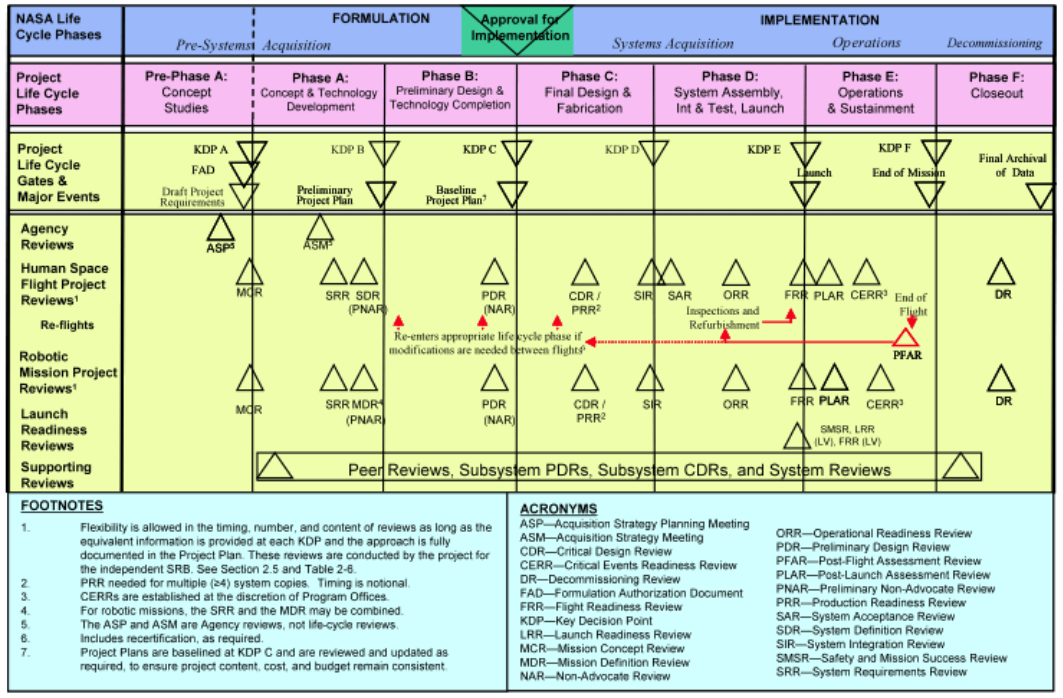
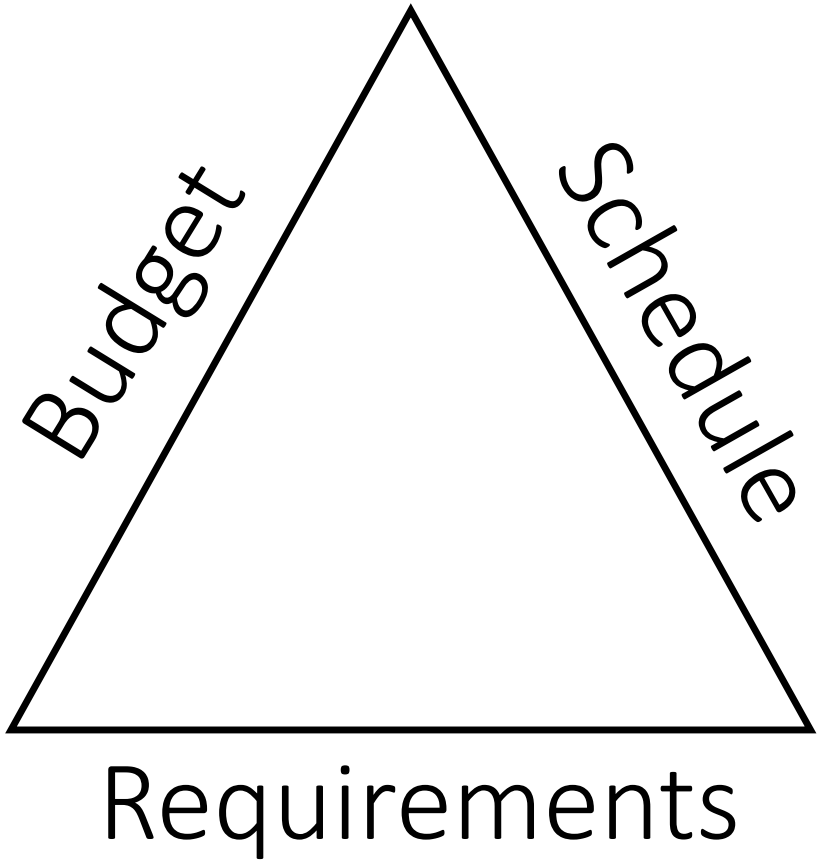


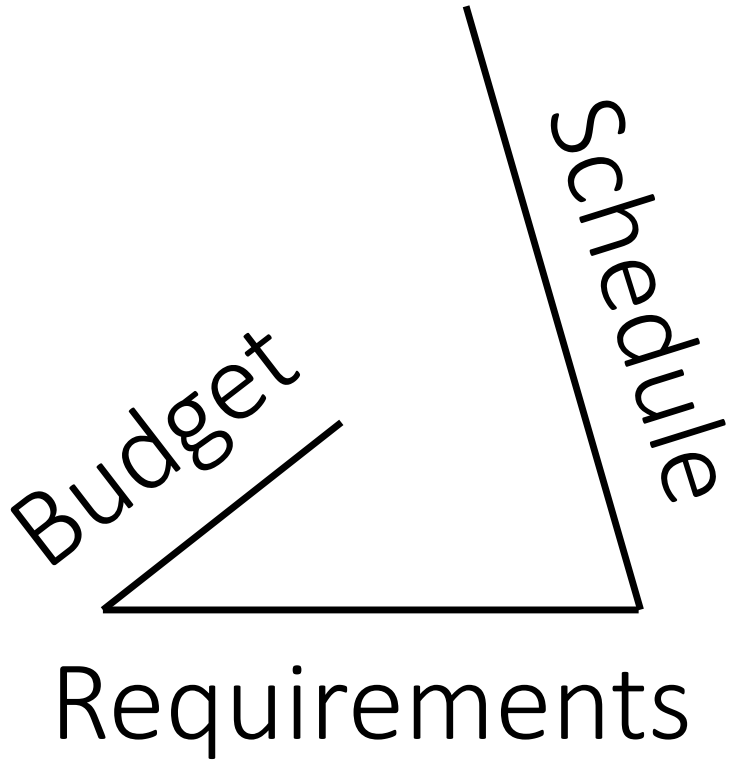
Figure 5-2 – The NASA Project Life Cycle


"IN PREPARING FOR BATTLE I HAVE ALWAYS FOUND THAT PLANS ARE USELESS, BUT PLANNING IS INDISPENSABLE."
DWIGHT D. EISENHOWER
Lifehack Quotes

# Understand The Iron Triangle



# Closing the iron triangle will be your biggest challenge

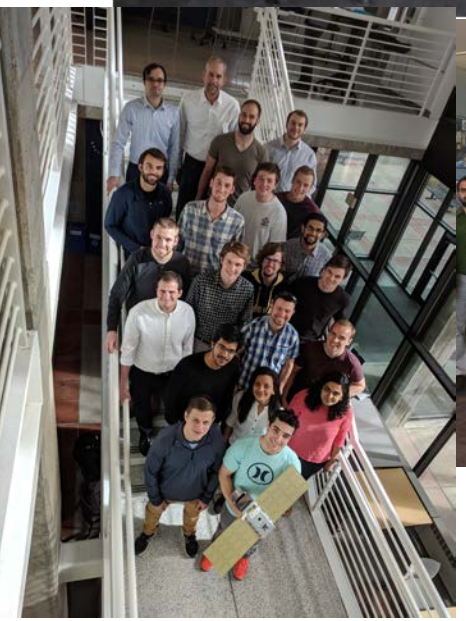


# Building a CubeSat

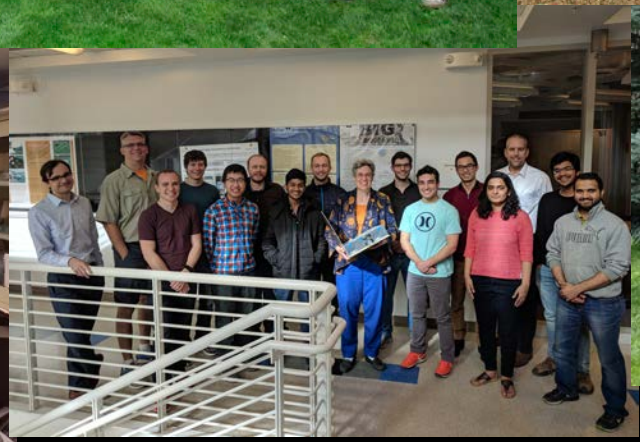
1. Have a purpose
2. Define requirements and interfaces
3. Develop a plan with milestones
4. Documentation, documentation, documentation

# Student Teams



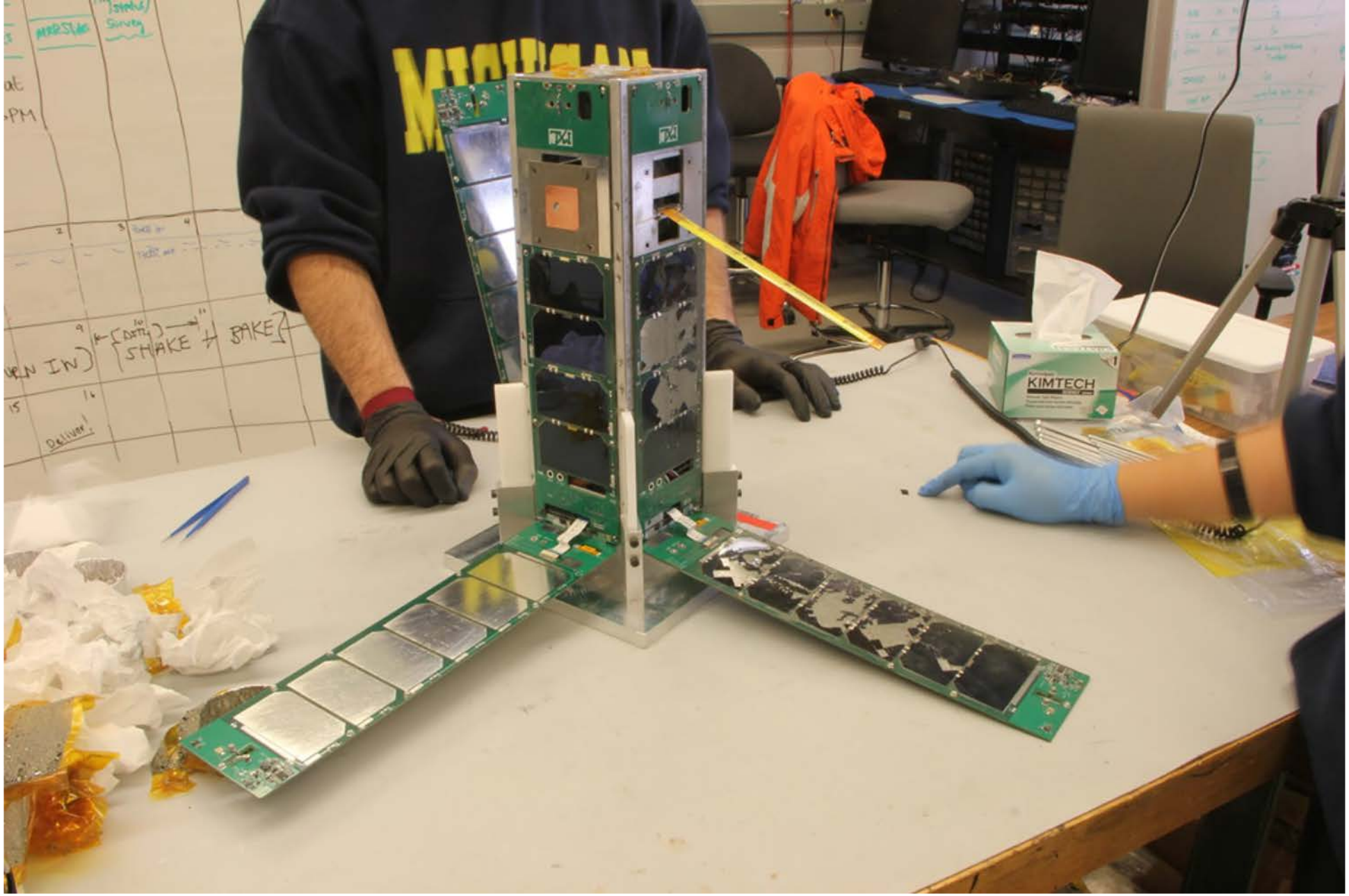





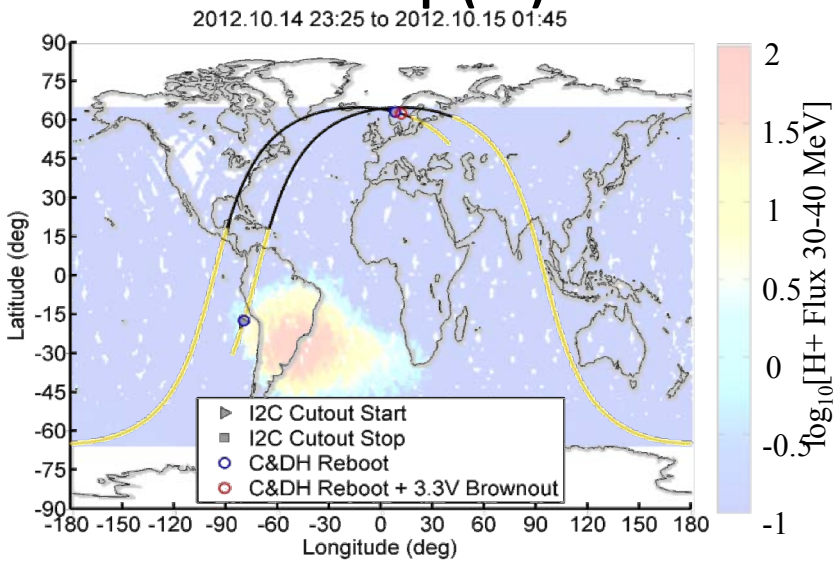



# Building a CubeSat

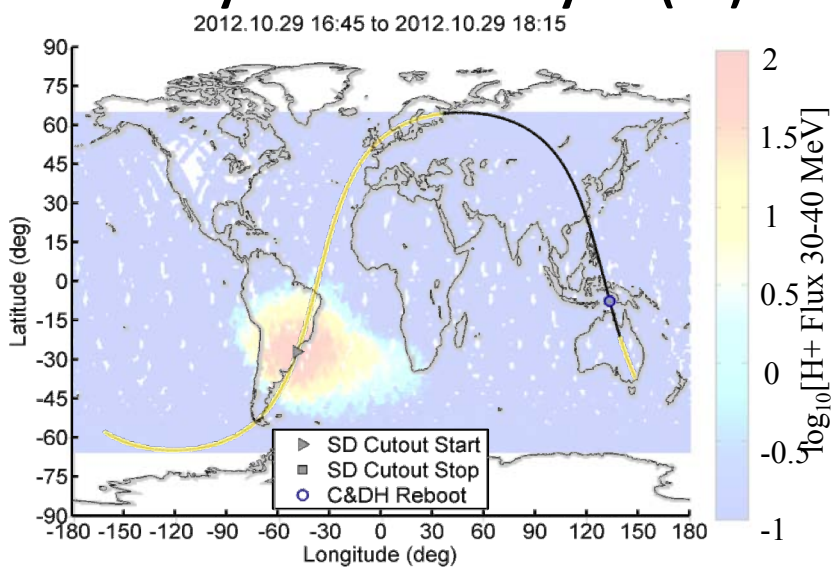
1. Have a purpose
2. Define requirements and interfaces
3. Develop a plan with milestones
4. Documentation, documentation, documentation
5. Problems will occur – expect them


KIMTECH

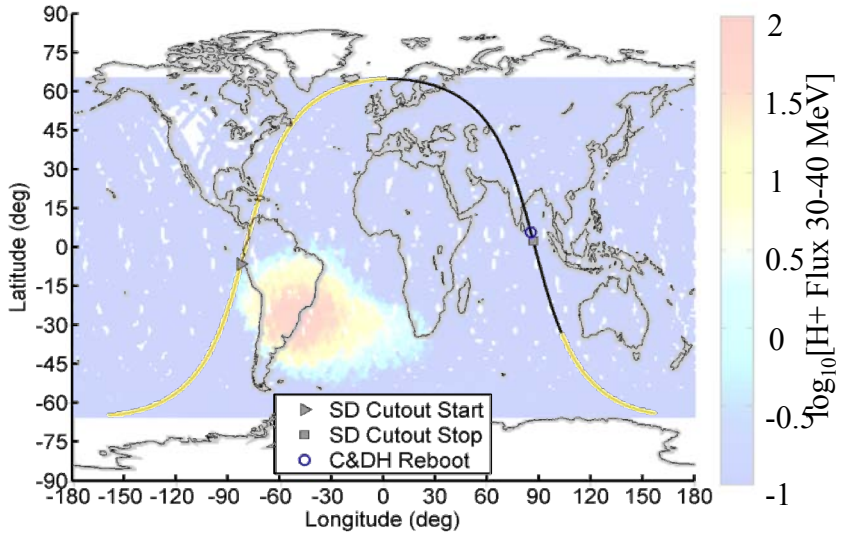
## Latch-up (E2)



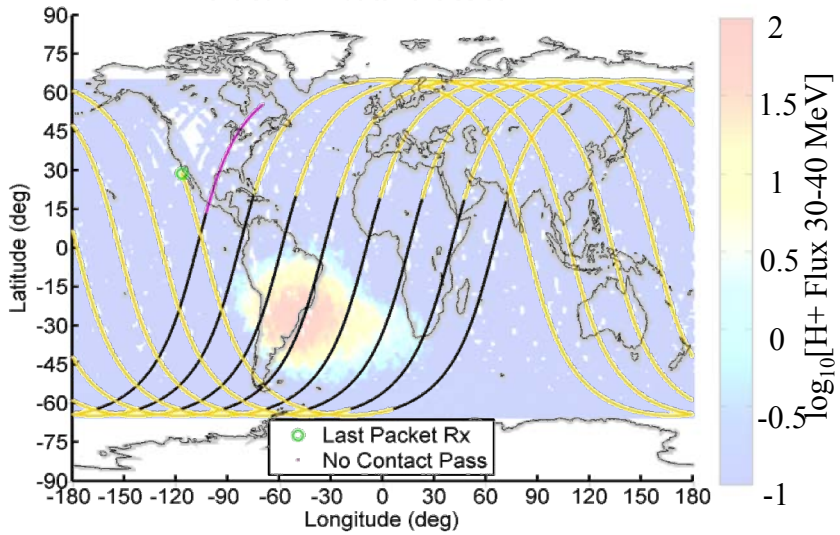

## Battery Drain Anomaly #1 (E3)




## Battery Drain Anomaly #2 (E5)

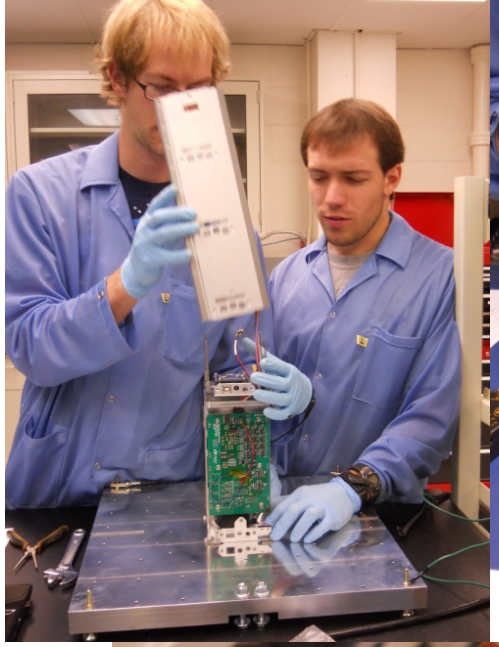


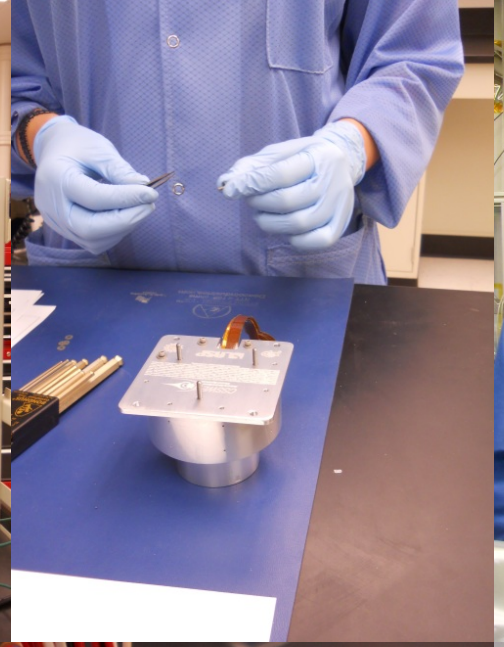

## Loss of Contact (E6)

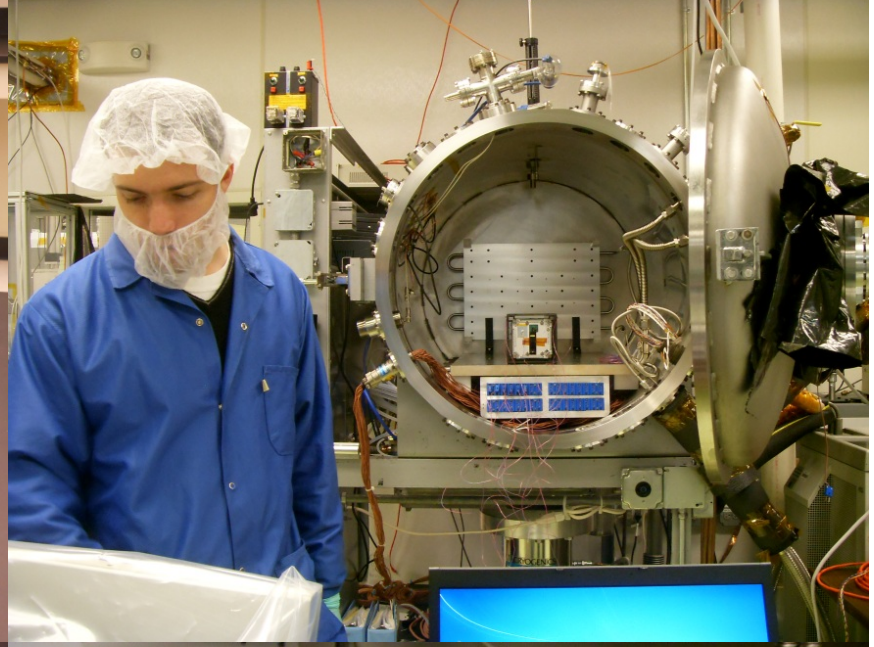


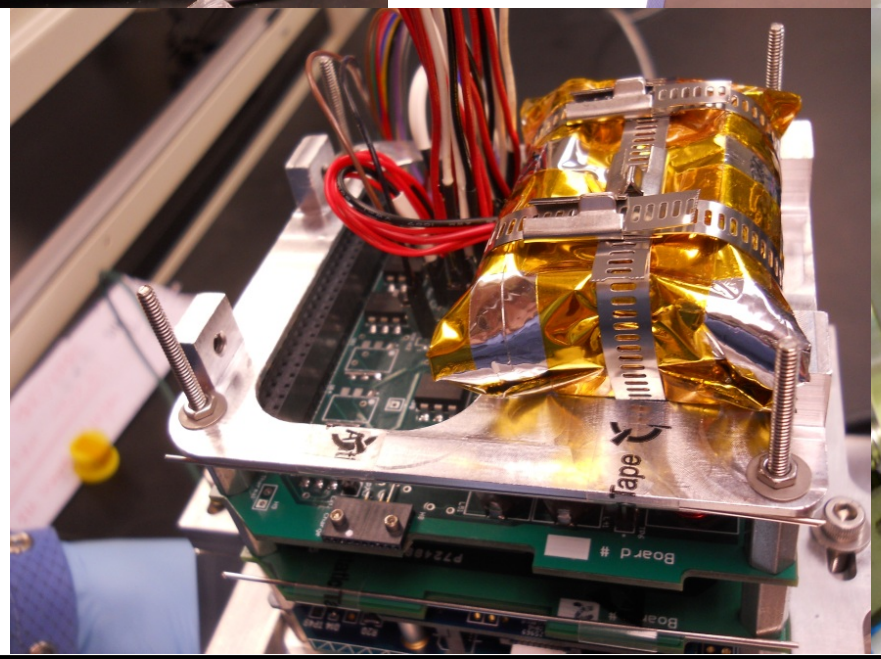
# Building a CubeSat

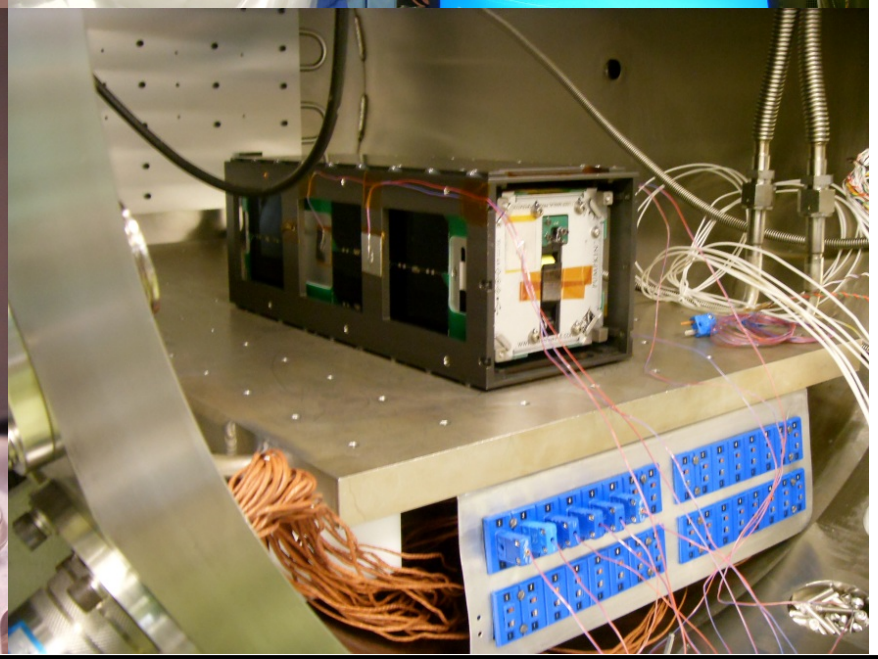
1. Have a purpose
2. Develop requirement and interface
3. Develop a plan with milestones
4. Documentation, documentation, documentation
5. Expect problems the will occur
6. Test, test, test … as you will fly

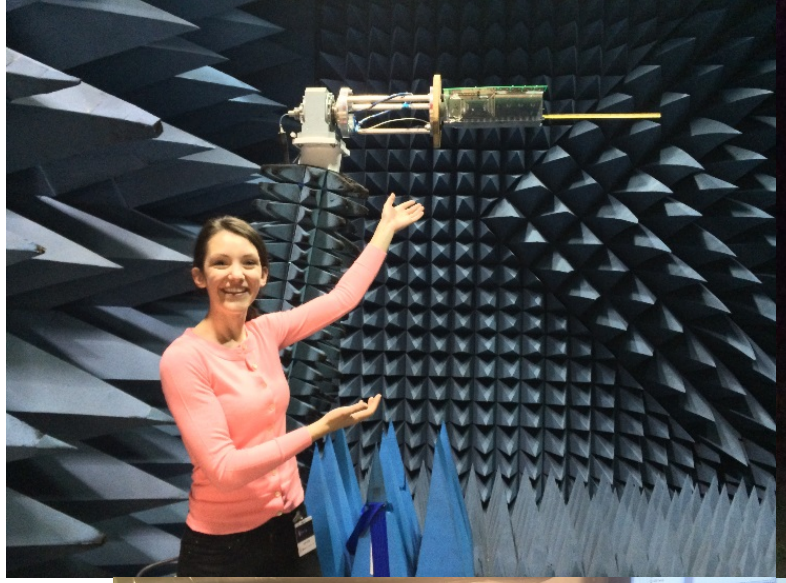


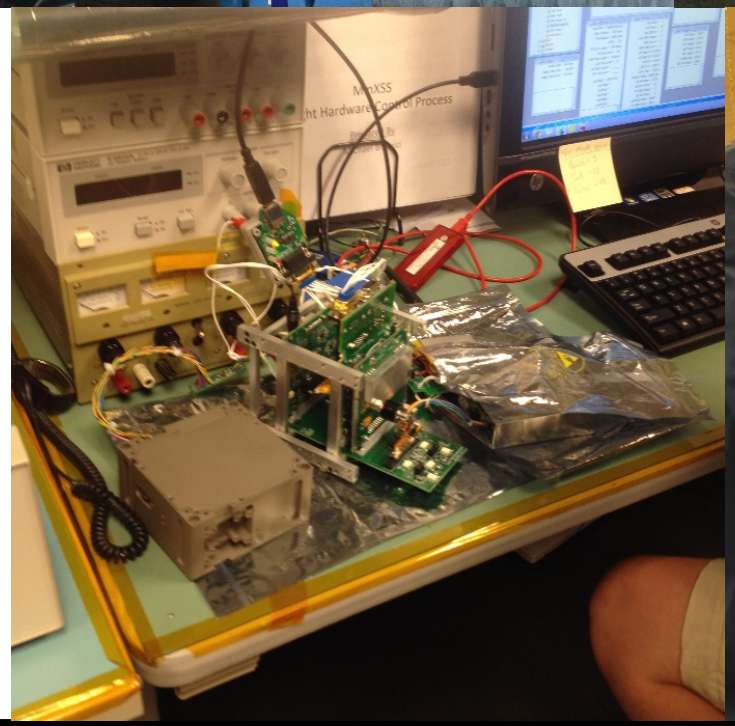








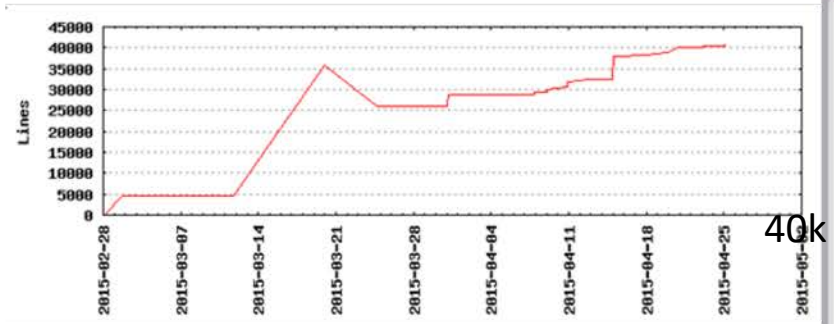




# Building a CubeSat

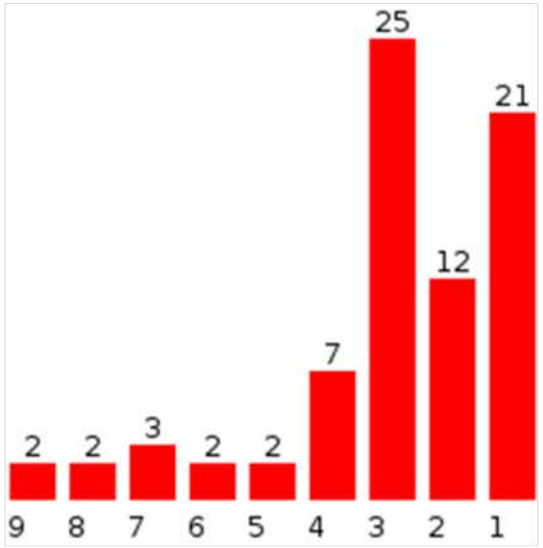
1. Have a purpose
2. Develop requirement and interface
3. Develop a plan with milestones
4. Documentation, documentation, documentation
5. Expect problems the will occur
6. Test as you fly
7. Hardware is done – the software goes on and on and on ….

# Lines of Code




40k

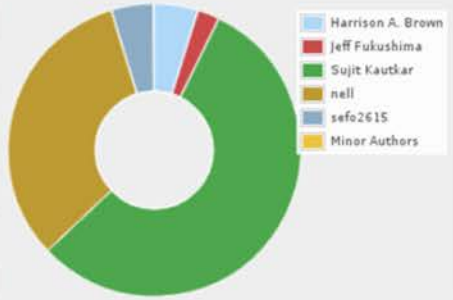
# Commits by week




The following historical commit information, by author, was found in the repository.

| Author | Commits | Insertions | Deletions | % of changes |
|---|---|---|---|---|
| Harrison A. Brown | 17 | 1747 | 114 | 4.84 |
| Jeff Fukushima | 4 | 689 | 247 | 2.43 |
| nell | 34 | 12073 | 353 | 32.29 |
| sefo2615 | 1 | 1552 | 254 | 4.69 |
| Sujit Kautkar | 3 | 21430 | 5 | 55.69 |

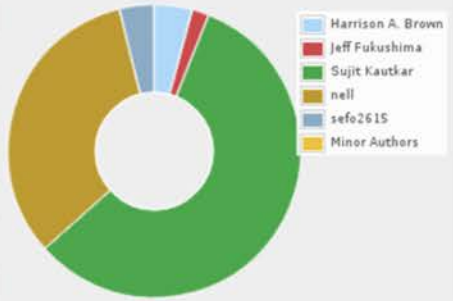
Show minor authors (2) ∨




Below are the number of rows from each author that have survived and are still intact in the current revision.

| Author | Rows | % in comments |
|---|---|---|
| Harrison A. Brown | 1565 | 38.15 |
| Jeff Fukushima | 694 | 26.66 |
| nell | 12198 | 51.75 |
| sefo2615 | 1421 | 22.03 |
| Sujit Kautkar | 21364 | 34.25 |

Show minor authors (2) ∨




The following history timeline has been gathered from the repository.

Show rows with minor work (2) ∨

| Author | 2015W09 | 2015W10 | 2015W11 | 2015W12 | 2015W14 | 2015W15 | 2015W16 | 2015W17 |
|---|---|---|---|---|---|---|---|---|
| Harrison A. Brown | | | | | | | | |
| Jeff Fukushima | | | | | | | | |
| Sujit Kautkar | | | | | | | | |
| nell | | | | | | | | |
| sefo2615 | | | | | | | | |
| **Modified Rows:** | 3629 | 74 | 96 | 21356 | 388 | 3499 | 6282 | 3163 |

# Building a CubeSat

1. Have a purpose
2. Develop requirement and interface
3. Develop a plan with milestones
4. Documentation, documentation, documentation
5. Expect problems the will occur
6. Test as you fly
7. Hardware is done – the software goes on….
8. Technology is the easy part

# Frequency Licensing

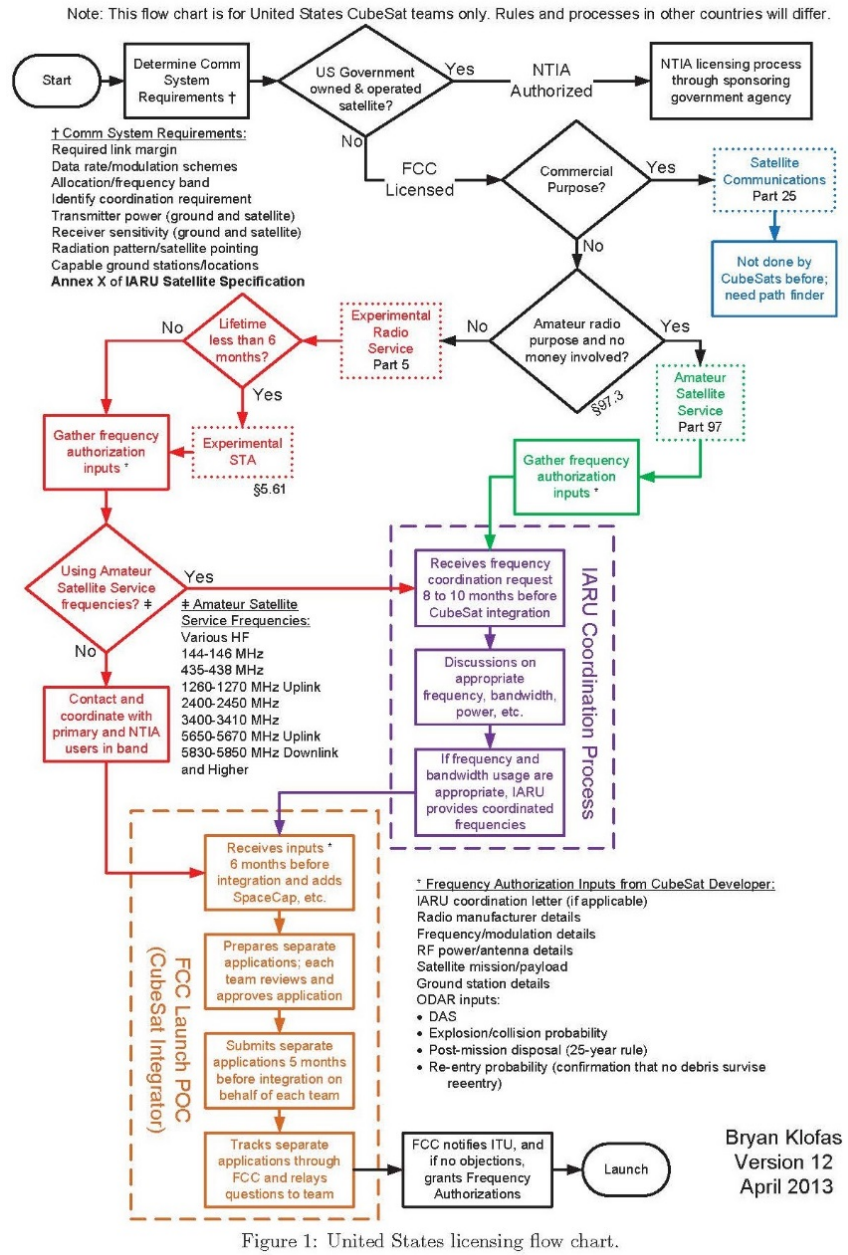


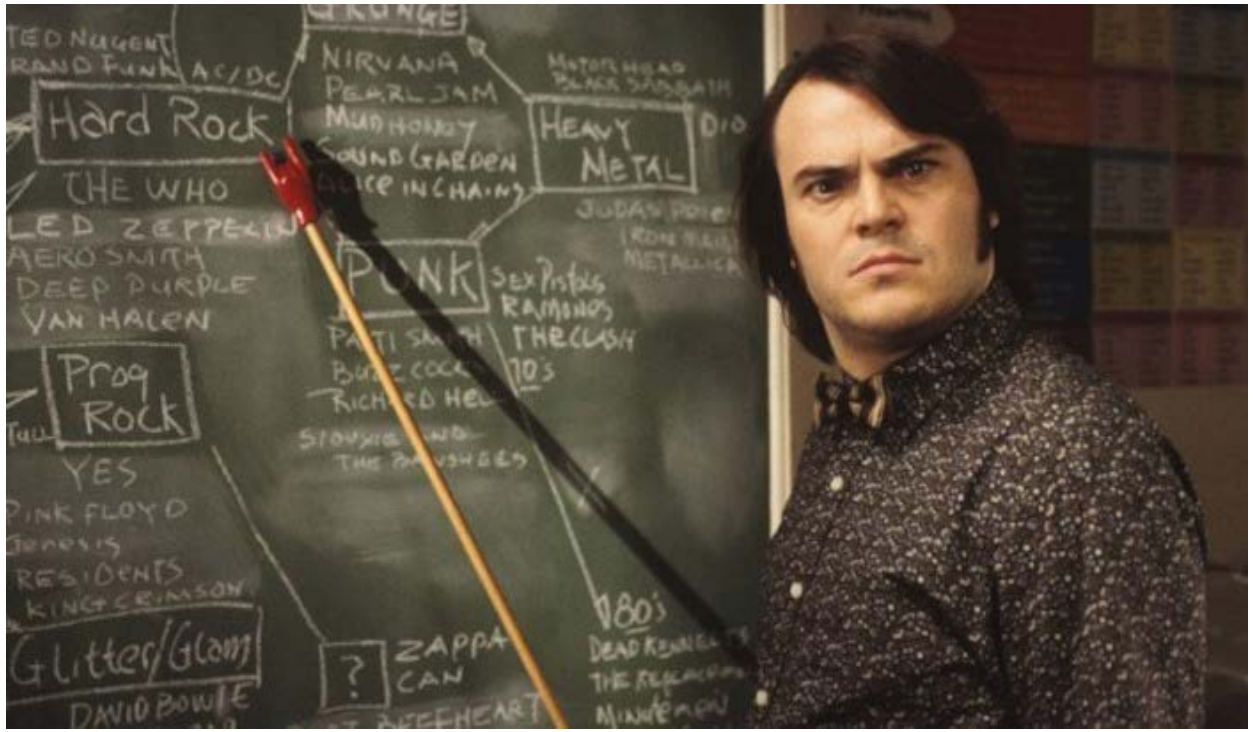
Figure 1: United States licensing flow chart.

Don’t underestimate the other tasks

# Lessons Learned

- It is wicked fun and it is wicked hard
- Make is simple … then simplify… repeat…
- The earliest decisions are the most critical
- Launches don’t wait for you – real deliverables
- Resources are scarce – you need to be creative
- Utilize your organizational strengths

# Educational Benefits




- Deadlines that are meaningful
- Hardware MUST work more than once…
- Software must be tested up, down and sideways.
- Interfaces and requirements must be clearly articulated and understood
- Students work in interdisciplinary teams to solve problems
- Students have real responsibility
- Professional interaction with sponsors
- Students learn about scheduling, lead times, procurement, licensing,… all the non-technical elements that will kill a project.