Phoenix

Successes, Failures, and the Realities of Developing a CubeSat

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SEDS UMD Guest Talk
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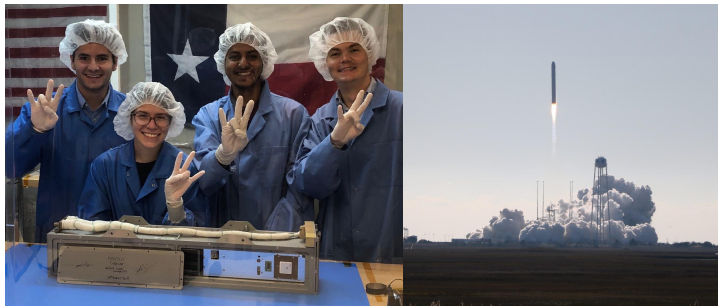
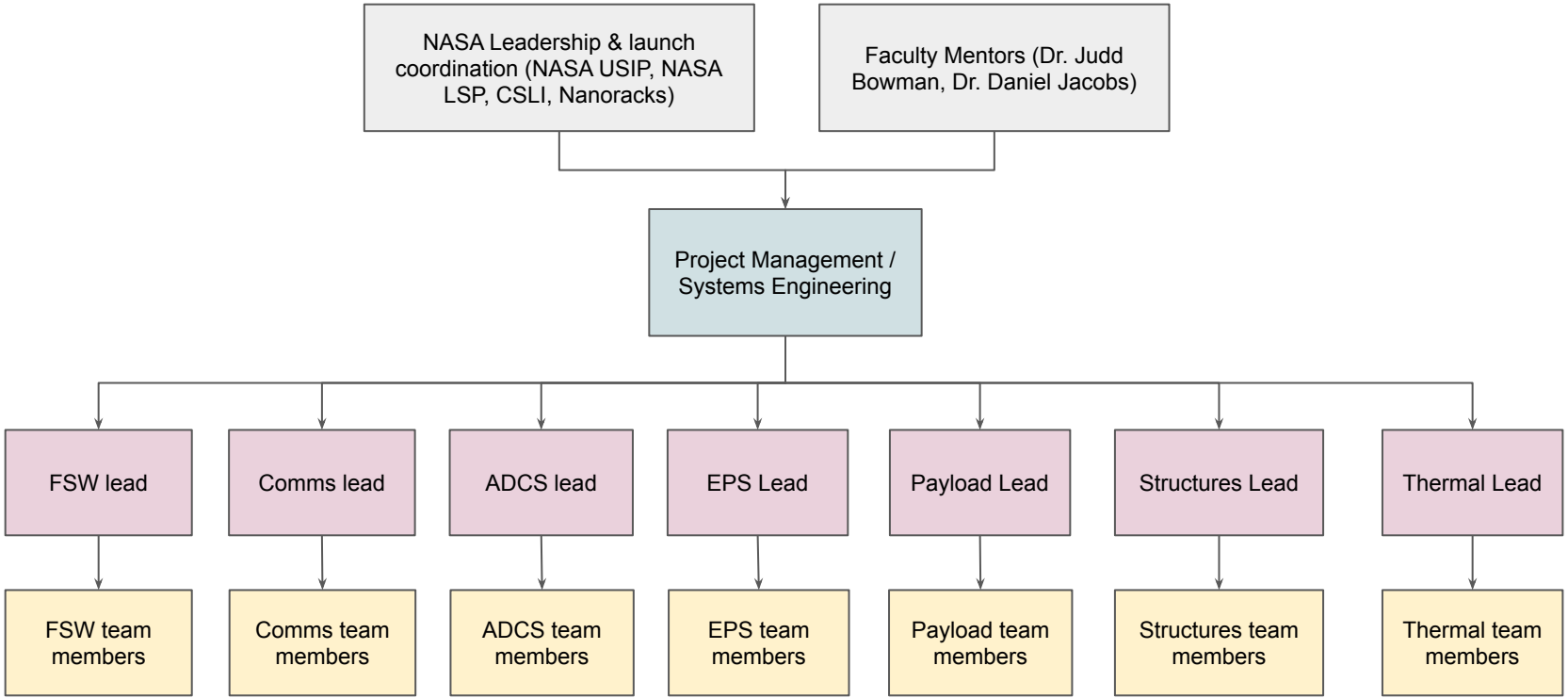
Project Overview

- Mission Objectives
  1. Successfully design, integrate, test, and launch a CubeSat into LEO capable of capturing and downlinking an infrared image of Phoenix, AZ
  2. Study the effects of urban heat islands through infrared remote sensing
- Funded $200,000 for development as an student flight research opportunity by NASA USIP and NASA Space Grant
  - USIP = Undergraduate Student Instrument Project
    - Funded opportunity for undergraduate students to obtain hands-on experience in pursuing projects relevant to NASA's missions
  - Additional funding & support provided by ASU's Low Frequence Cosmology (LoCo) Lab
- First student-led CubeSat mission developed at ASU
  - Involvement: ~80 students total, primarily undergraduate (98%)
  - First CubeSat in space from ASU
- Project Timeline
  - **Proposal submission:** Fall 2015
  - **Development:** April 2016 - August 2019
  - **Launch:** Nov. 2, 2019 aboard NG-12 (part of ELaNa-25)
  - **ISS Deployment**: Feb. 19, 2020



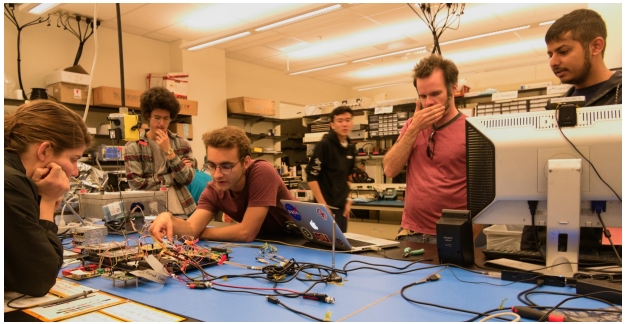
Phoenix team photo (top, credit: Craig Knoblauch), Spacecraft delivery to Nanoracks (bottom left, pic credit: Tristan Prejean), Launch of NG-12 (bottom right, credit: Vivek Chacko)

General Team Structure



Team Communication

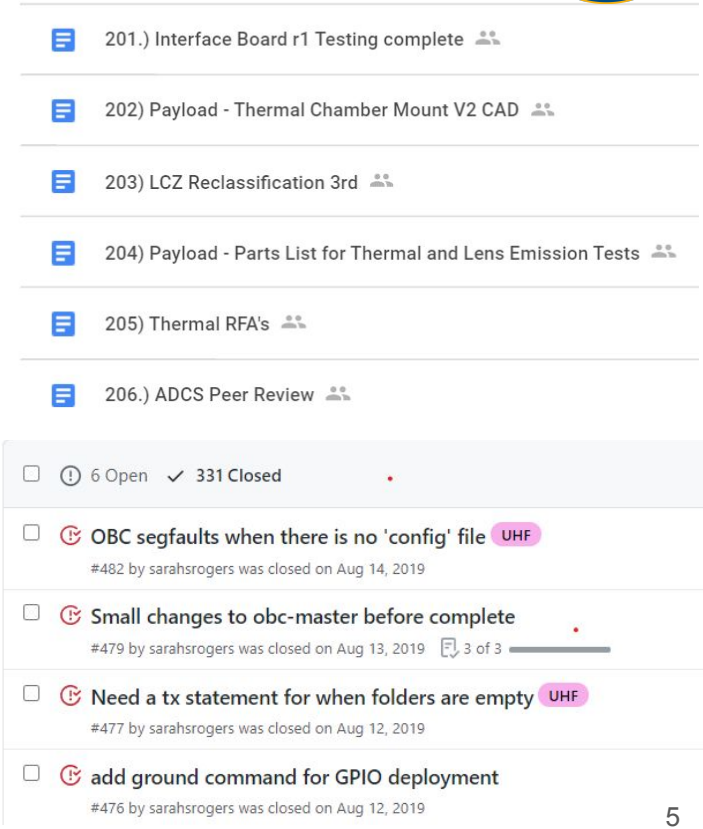
- Meetings
  - Weekly all-hands tagups (with mentors)
    - Discuss schedule, large items/issues, make sure everyone is on the same page and lined up for the next week
  - Separate weekly subsystem team meetings
    - Work out subsystem-level issues, schedule, etc. Invite other subsystems to these as necessary
  - Get more frequent as schedule/issues get more critical
- Always - best if everyone works together as often as possible - teams should not be isolated!
  - Learn the “vocab” of various disciplines
  - Minimize playing “telephone” as much as possible
  - Everyone on the team should aim to be a systems engineer and understand the system!
- A lot can be gained by talking to people with experience
  - Talk to people about best practices, test procedures, methodologies, etc.
  - Go to CubeSat conferences (SmallSat, CalPoly workshop, etc.)
  - Talk to people who have worked on similar hardware



Team meetings & working sessions (PC: Yegor Zenkov)

Organization - What Worked?

- Communication: Slack channel (General)
  - Involved faculty mentors and others from outside of ASU
- Documentation
  - Google drive FTW (everything in one place, good for transparency)
  - Task memos - detail task objective, how it was done, next steps, relevant people involved
    - Will eventually have a running list - reference tasks by referencing memos
  - Make use of Github issues and branches!
    - More on this - listen to The Art of Space Engineering (TASE) Episode 3



Organization - What Worked?

- Setting schedules
  - Start with your big deadlines (design reviews, demos, etc), then set smaller, more achievable milestones
  - Used Gantt to track larger milestones (design reviews, demos, releases, etc.) and general critical path
    - Don't make this too fine in detail - you don't have time to keep up with that
  - Used tracking spreadsheet instead of Gantt to track smaller milestones - everyone can play with this
- Keep track of how long issues/items are open -
  - don't let things sit for too long or you'll be scrambling to fix it when you need it (not fun)

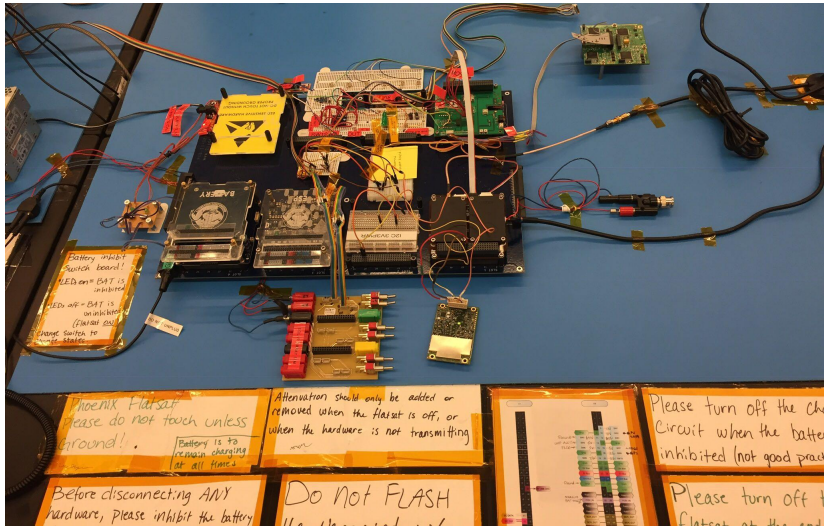
Communications

Task	Owner	Start Date	Initial Due Date	Actual End Date	Status	Notes	Memo
UHF Tape Measure Monopole Antenna Bend Test	Mecah	2017-05-16	2017-07-16		Complete		Memo #154
Beacon + ICOM + TNC Receive APRS (AX20) + GSE decode	Nick	2017-07-05	2017-07-21		Complete	Ground support equiptment - hooking it up to the antennas of the ground station and reviece packets to decode	
UHF Tape Measure Monopole Antenna Bend Radius Test	Nick & Jaime	2017-07-28	2017-07-31		Complete		Memo #9
Interface with the TNC (v1)	Nick	2017-07-25	2017-08-02		Complete		
Interface with the ICOM9100	Mecah	2017-07-25	2017-08-02		Complete		Memo #3
Demonstrate full signal path thorugh switches (2 meter APRS)	Nick	2017-07-31	2017-08-03		Complete		Memo #21
Finish UHF Antenna Trade Study	Sarah	2017-07-28	2017-08-08		Complete	Will buy endurosat model in september	
Control switches on ground station antenna	Nick	2017-08-14	2017-08-21		Complete		Memo #46
Interface with the TNC (v2)	Nick	2017-08-28	2017-09-04		Complete		Memo #45
Interface with ICOM-9100 radio & TNC over remote computer	Mecah	2017-09-01	2017-09-11		Complete		Memo #13

Lessons Learned on Defining a Mission

- Before writing any requirements - determine:
  - What is mission success and what's important to achieve it?
  - Also - what's most important to you for developing this mission?
  - **BE SPECIFIC** - do not make broad statements on your objectives
  - What are requirements for the system vs nice to haves?
- Get very familiar with how requirements are structured and how to write them
  - Your requirements (and objectives/scope) define all of the work you are going to do
  - Get a good handle on the different requirements levels and their traceability
  - Hold a good SRR with the right people
  - NASA SE handbook has a good appendix on this
- Analyze the objectives/requirements of NASA missions
  - these are very direct and there is a well-defined path from goal to lower-level requirements
  - Search for proposal documents of past missions - might find this there
- Phoenix started off with broad objectives, that didn't consider requirements vs nice to haves
  - For more detail see my interview on the CubeSatBOK podcast

Realities of CubeSat Development (Hardware)



Phoenix FlatSat (using FlatSat board from ClydeSpace) (PC: Sarah Rogers)

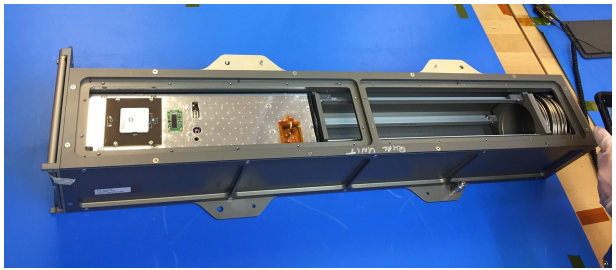
- Cubesat is essentially your software - make this robust, start as soon as possible
  - Also why it's important for teams to talk
  - For software dev - whoever developed an app for a subsystem met with that team and got to know the hardware and subsystem requirements very well
- Datasheets don't tell you everything
  - There will be a lot of working with vendors to figure out technicalities
  - Also good to meet people who've used similar hardware
- Have good lab practices
  - Things will break (we broke 5 components - sent back for repair), you reduce this by having good lab management & enforced procedures
- See TASE Episodes 3-6 for more stories

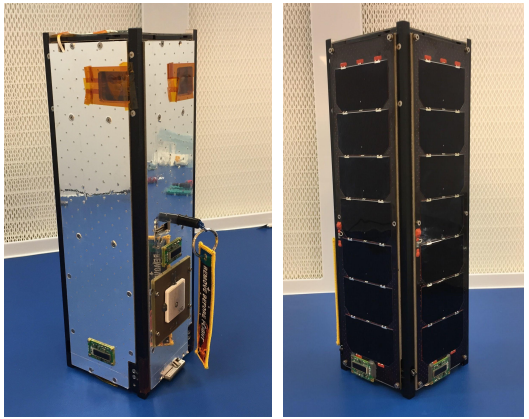
Realities of CubeSat Development (Time)

- Time commitment - varies depending on phase
  - Greater commitment required when you get to hardware - long hours in the lab to get things finished - split work or collaborate as much as you can (had multiple people on an app so others could take over)
- Turnover
  - Summer & winter break - very slow, plan around this
  - Turnover is high - stay up to date on documentation, helps with onboarding
  - Recruitment - we found it best to let anyone join, BUT they had to onboard themselves
    - See TASE podcast Episode 4 for discussion (and eventually Episode 12)
- Psychological stuff
  - Mistakes will be made along the way - that's just part of the learning process!
  - Learn from your mistakes and move on, don't dwell on the past and don't get stuck in your head
  - Always take time to slow down and reflect (on progress, self, etc.)
  - Get to know your team well and be cognizant of morale
  - Be honest/transparent about schedule, commitments, etc.

Final Thoughts

- Summary
  - Spend quality time sorting out your requirements and objectives
  - Start off with a good foundation for team structure, documentation, and communication
  - Half of the battle is just setting up a organizational structure and getting a handle on what you need to do - things get easier if you've got that
- Despite hierarchy - at the end of the day, making a CubeSat comes down to people working together to make it work (no hierarchy *vibe*)
  - Lean on your team and they'll lean back on you





Phoenix in Nanoracks Deployer (left), flight assembly (right)
(PC: Sarah Rogers)

Questions?

For more ways to learn about Phoenix, check out the following:

- Project website: http://phxcubesat.asu.edu/
  - Licensing documents, design reviews, proposal, other resources
- The Art of Space Engineering Podcast
  - Episodes on FSW dev & structures/integration/delivery
- **In development:** paper describing comprehensive history of developing Phoenix