Spacecraft Design-Build-Fly Lab

16/18-873

Fall 2023 – Spring 2024

What Are We Doing Here?

We are going to:

- Design
- Build
- Test
- Fly (!!!)

a small satellite over the next 9 months.

Course Staff

Zac Manchester
Assistant Professor

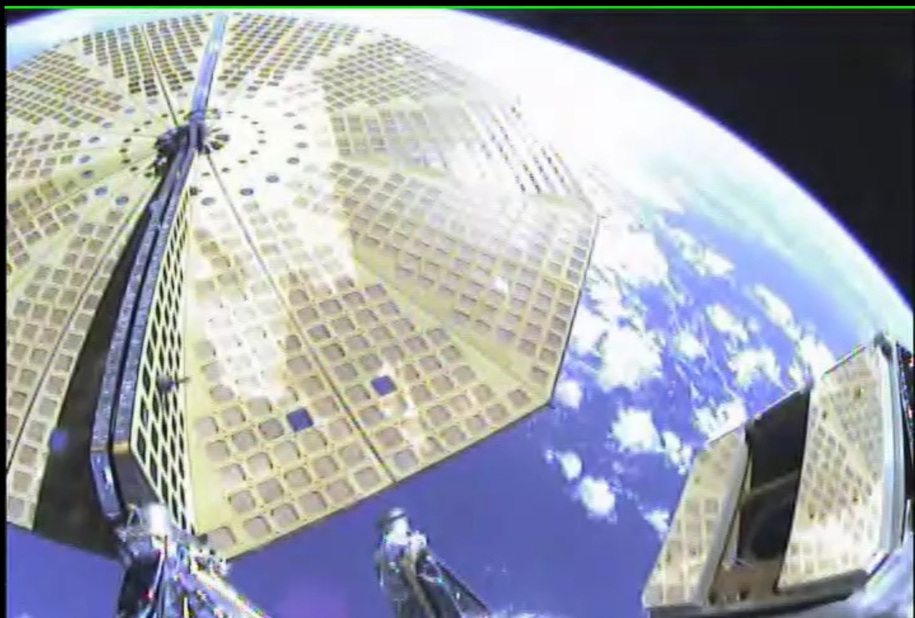
Brandon Lucia
Professor

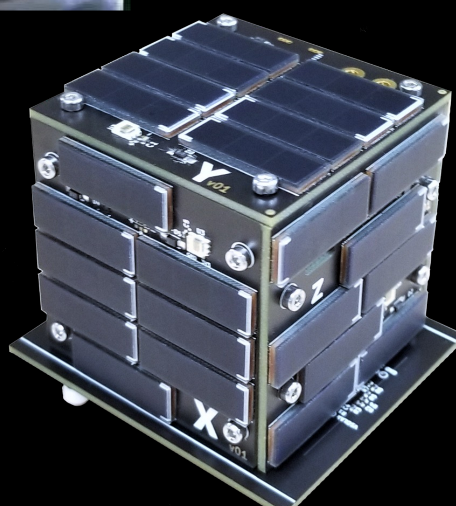
Neil Khera
Staff Scientist

Brad Denby
PhD Student

Paulo Fisch
PhD Student

Nanosatellites: getting to space on the cheap



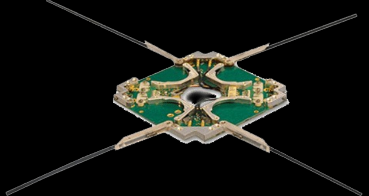


Background: Computational Nanosatellite Systems

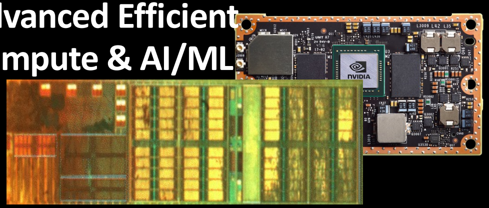
Getting to space on the cheap

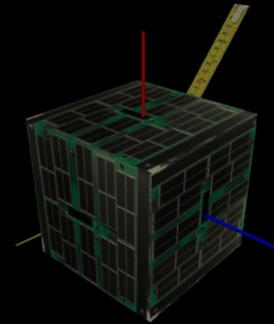
Earth imager &
hyperspectral sensor

LEO & Ground RF Comms



Advanced Efficient
Compute & AI/ML



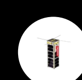


Motion planning, control, &
actuation

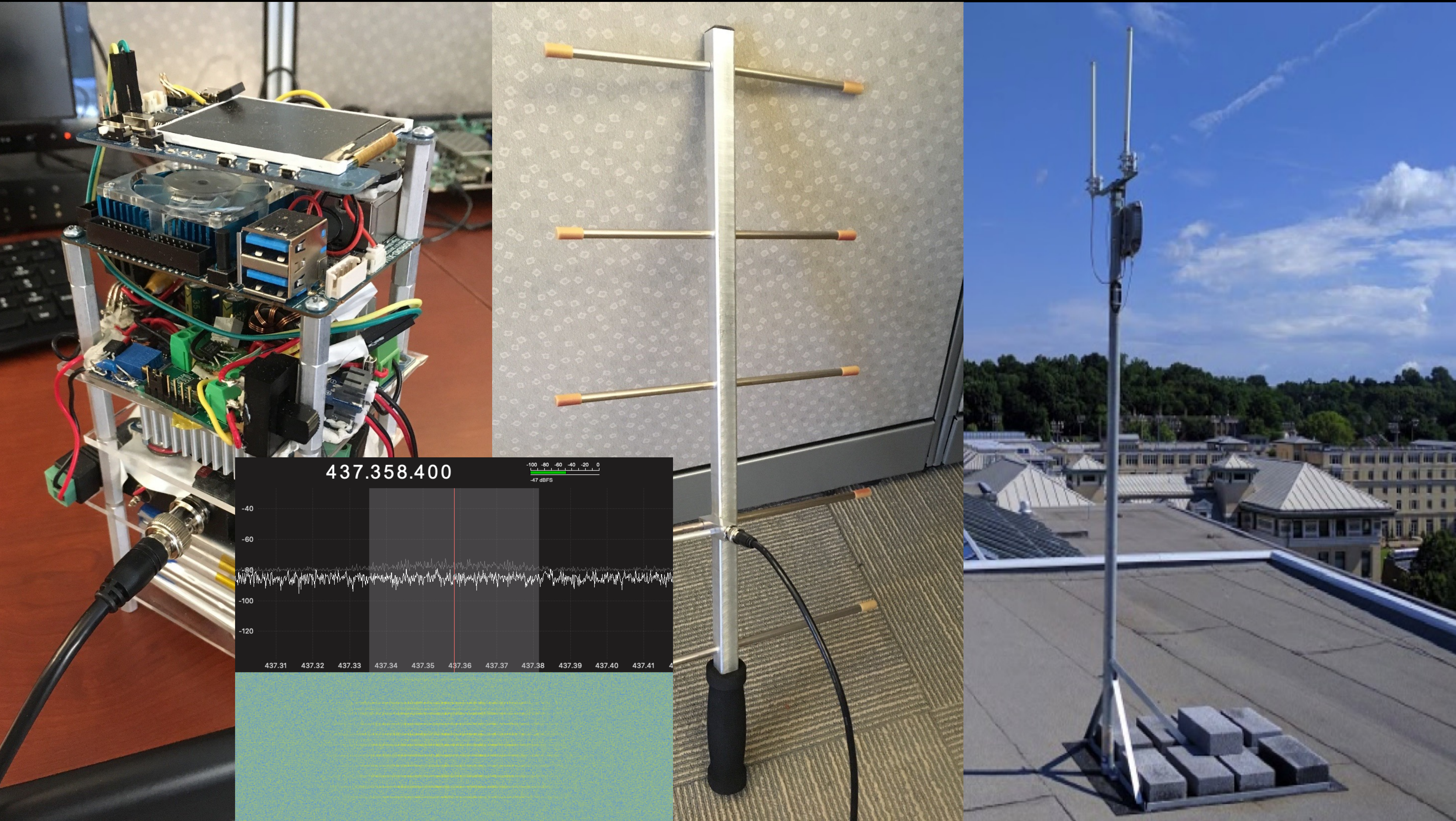
Monolithic
Height: 5.7 m
Mass: 2800 kg
Power: 3.1 kW
Cost: $650M

Cubesat
Height: 300 mm
Mass: 2-4 kg
Power: 5 W
Cost: $10k

Pocketqube
Height: 50 mm
Mass: 200g
Power: 100 mW
Cost: $2k



Background: Ground equipment for communication



Nanosatellites collect more imagery than they can downlink
On-board computing payloads look at every image

Imager &
hyperspectral sensor

Radio
transceiver

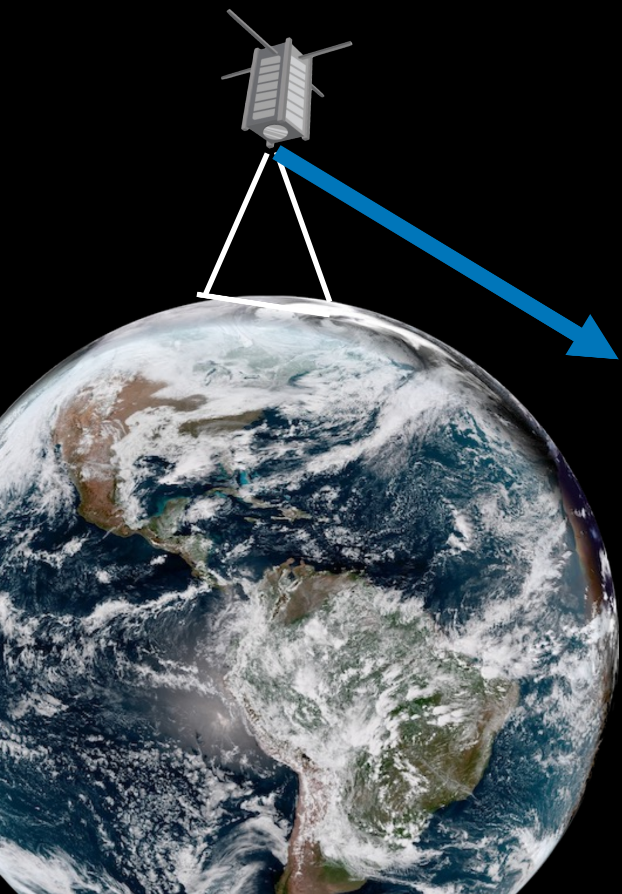
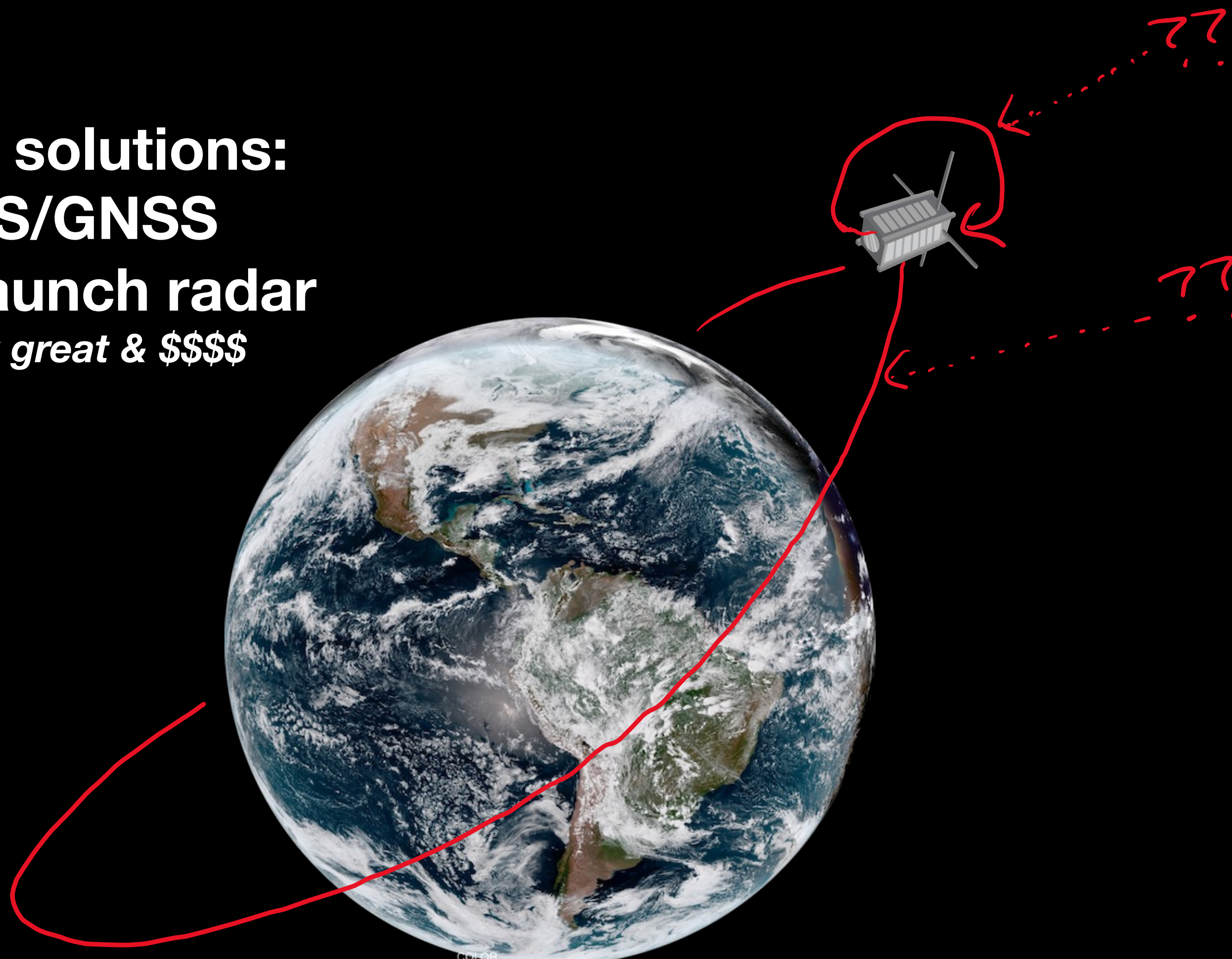


Image quality: 8K raw = 200MB
New frame every 1.7s, 90 min btw comm sessions

634GB per satellite
per orbital period!

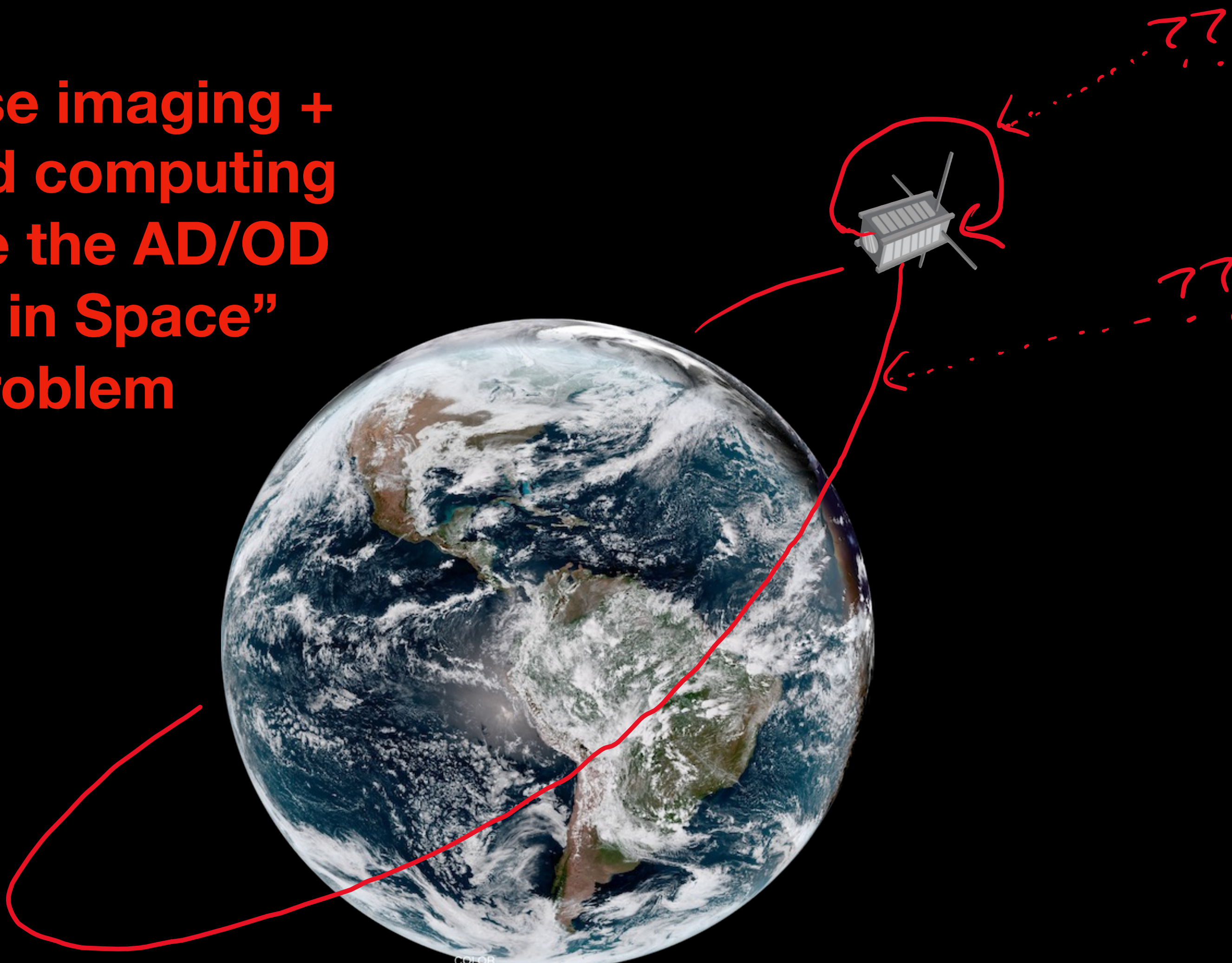
Attitude & Orbit Determination:
“where am I, and what am I looking at?”

Usual solutions:
GPS/GNSS
Post-launch radar
All not great & $$$$



Attitude & Orbit Determination:
“where am I, and what am I looking at?”

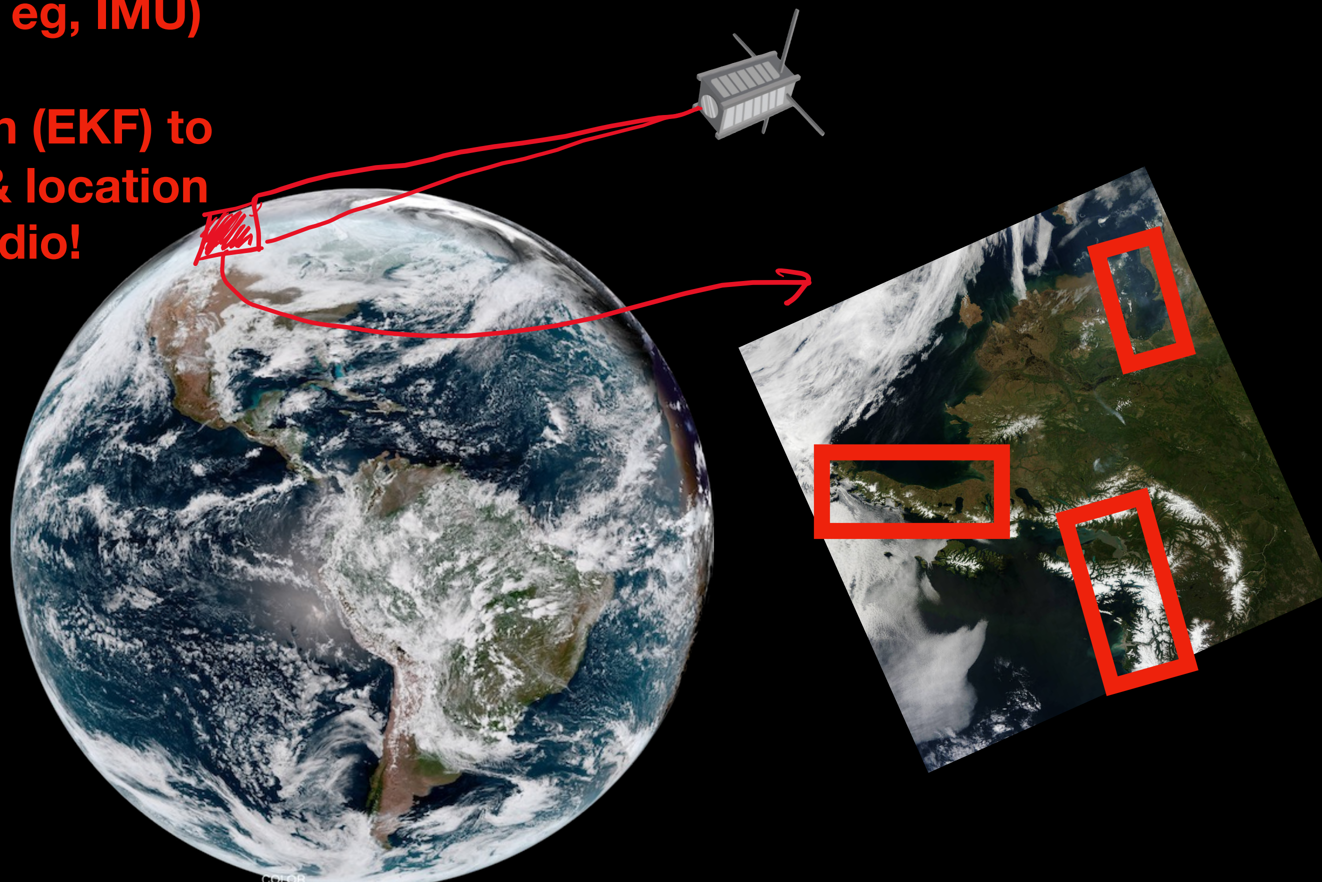
Idea: use imaging + onboard computing to solve the AD/OD “Lost in Space” problem



Attitude & Orbit Determination: “where am I, and what am I looking at?”

Train a visual ML model to run onboard & find *salient* landmarks (plus local sensors, eg, IMU)

Use state estimation (EKF) to zero in on attitude & location w/o GPS or radio!



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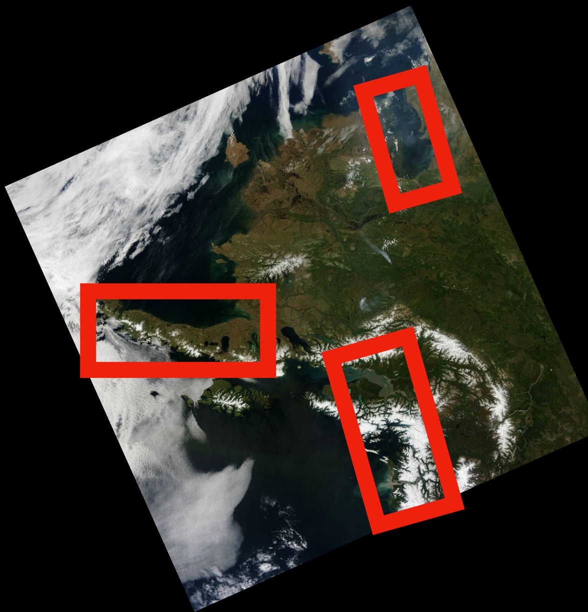

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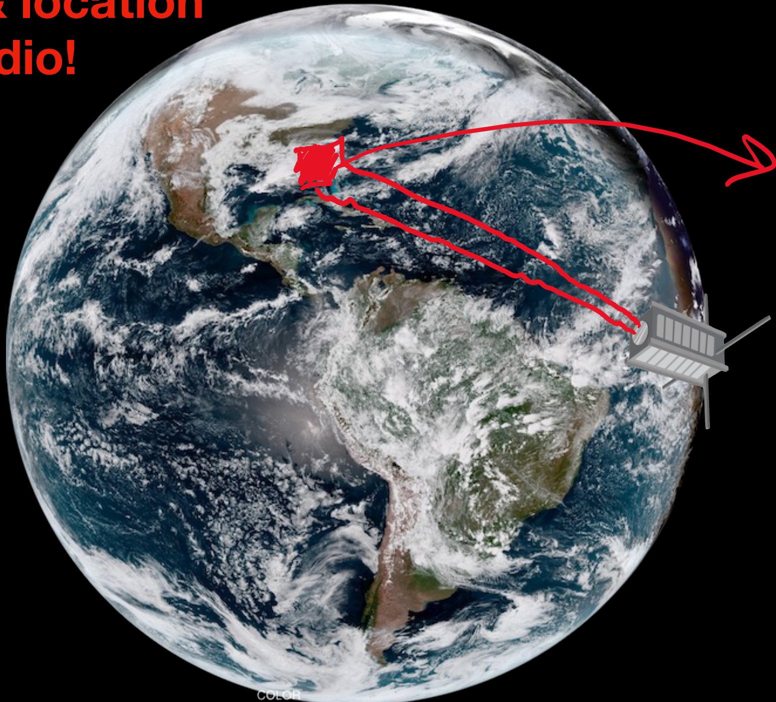

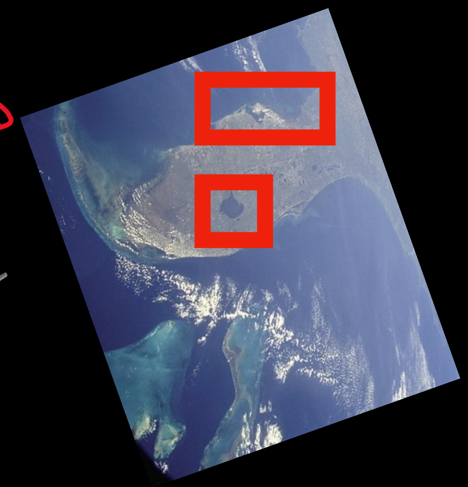

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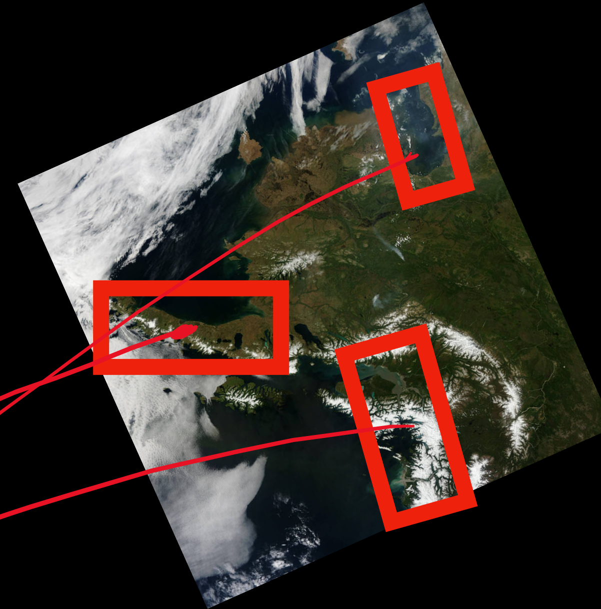

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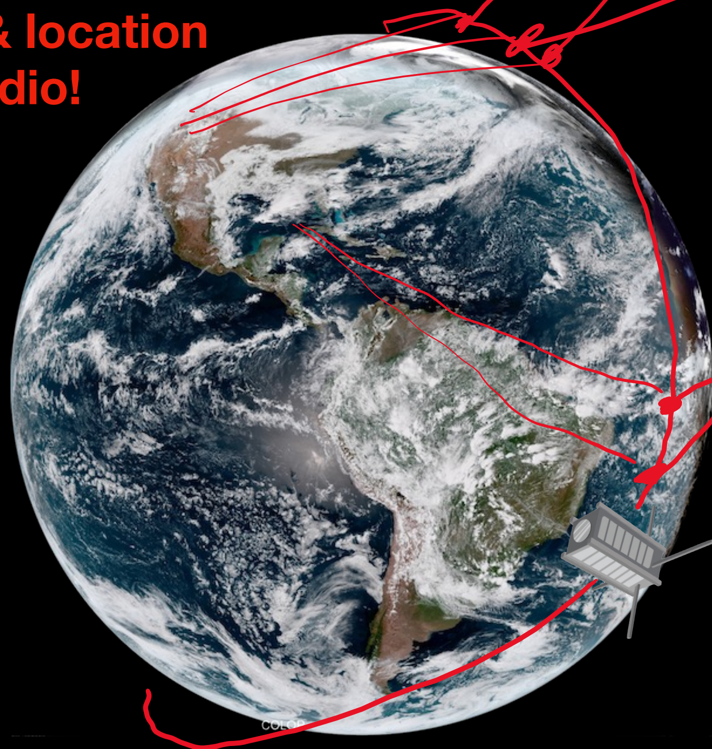
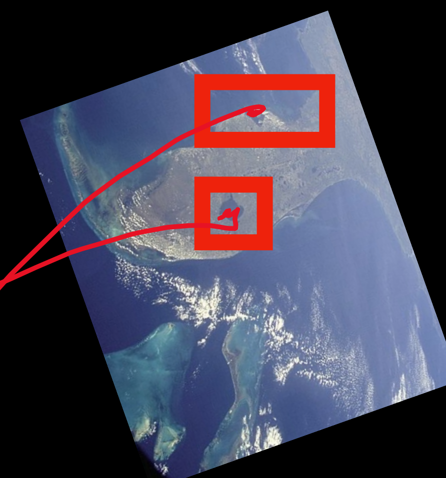




Mission

- Demonstrate “Lost in Space” visual orbit determination using low-cost camera system + on-board computing/ML.
- Camera + compute/ML + avionics + communication + power hardware & software systems
- State estimation ingests ML results & sensor outputs
- CONOPS & sim ultra-important for ML train/test
- LoRa flight HW + ground station for comms
- PDR/CDR in December
- Flight hardware ready in May
- Launch next year on SpaceX Transporter

Logistics

- This class will be **hands-on** and **fast-paced**.
- Students are expected to put in **12(+) hours per week**.
- There will not be regularly scheduled lectures. Instead, we will have a **weekly all-hands meeting** and **weekly sub-team meetings**.
- Use of Slack, GitHub, and project management/issue tracking tools is ***mandatory and it will help you***.
- Be a good teammate and an all-around good class citizen. ***The success of the mission depends on it!***

Teams: Mechanical

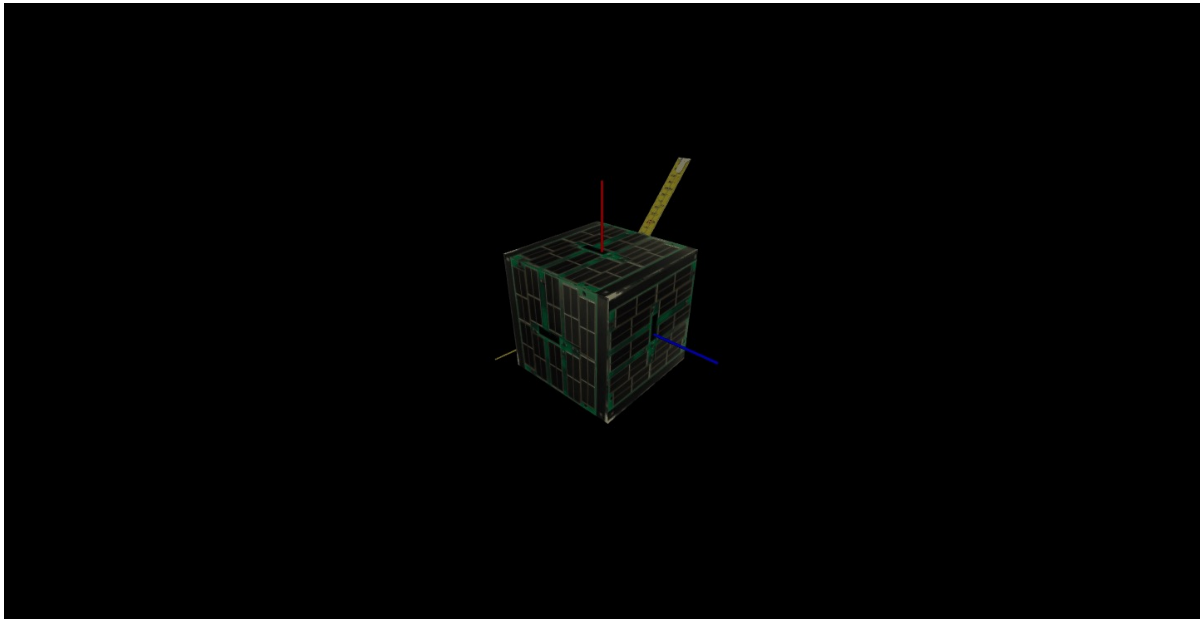
Responsibilities:

- Spacecraft Structure
- Deployment mechanisms
- Batteries
- Thermal
- Vibration
- Materials Selection
- Mass/Inertia Properties

Teams: Simulation + GNC

Responsibilities:

- Main flight software state machine
- Spacecraft simulation
- Attitude/orbit determination filter
- Controller implementation
- Hardware in the loop testing



Teams: Ops + Groundstation

Responsibilities:

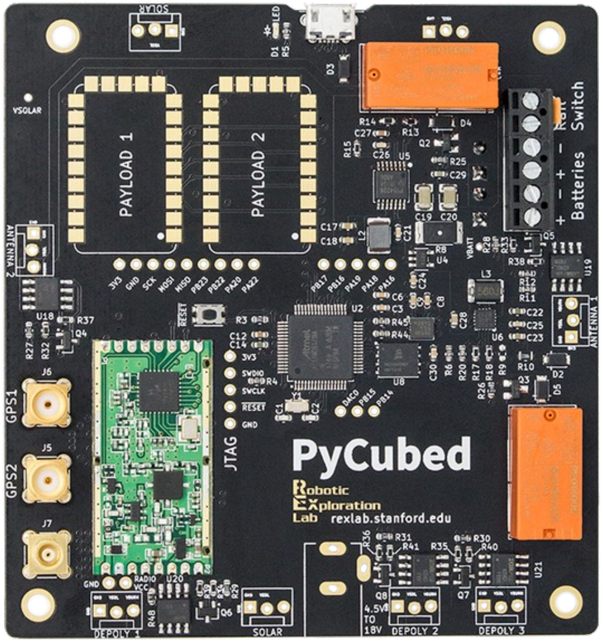
- Define coding scheme & proto
- Spec comm hardware & software
- RF link budgets
- Build ground station
- Local test with flight radio module
- Long-range field test
- Ground station deployment to remote site
- Ground operations planning & execution

HAMs, we need you!

Teams: Flight Software + Avionics

Responsibilities:

- PyCubed PCB layout + fabrication
- Torque coil drive electronics
- Camera
- Radio
- Low-level hardware-interface code
- Solar panels
- Antennas
- Power budgets



Teams: Payload + Vision

Responsibilities:

- Develop camera system hardware & software & integrate w/ flight software
- Build saliency-based landmark ID model
- Train ML model pipeline for onboard camera data from pixels to estimated landmark locations
- Integrate with GNC team to build AD/OD filter

Syllabus + Grading

Logistics for Today

1. Join the course Slack workspace (CMU-SpacecraftDesignLab-f23) and briefly introduce yourself in the #introductions channel.

2. Fill out team preference rank form

3. Make sure you are a member of the GitHub organization "cmu-spacecraft-design-build-fly-2023"

Join The Slack Org

https://tinyurl.com/ydjdrcu6

Team Preferences

https://tinyurl.com/yckk9ddp

GitHub Org

https://tinyurl.com/5n99mdvu

Course Survey (if you aren't enrolled)

https://forms.gle/EUMbGQwoNqgg2aAt7