BeaverCube: Coastal Imaging with VIS/LWIR CubeSats

Paula do Vale Pereira, Madeline Garcia, Madeleine Schroeder, Humberto Caldelas, Charles Lindsay, Alex Choi, Kaila Pfrang, Amelia Gagnon, Alex Meredith, Patrick McKeen, Jim Clark, Thomas J. Murphy, Sheila Baber, Sabrina Khan, Alex Miller, Gustavo Velez, Matthew Campbell, Jacob Coray, Jim Koldada, Tina Tran, Sam Austin, Alison Louthain, Tesla Wells, Mohammad Kabir, Ethan Sit, Christian Haughwout, Kerri Cahoy

Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge MA 02139

Agenda:

- Mission Overview
- Concept of Operations
- Subsystems
- Path Forward
- Acknowledgements

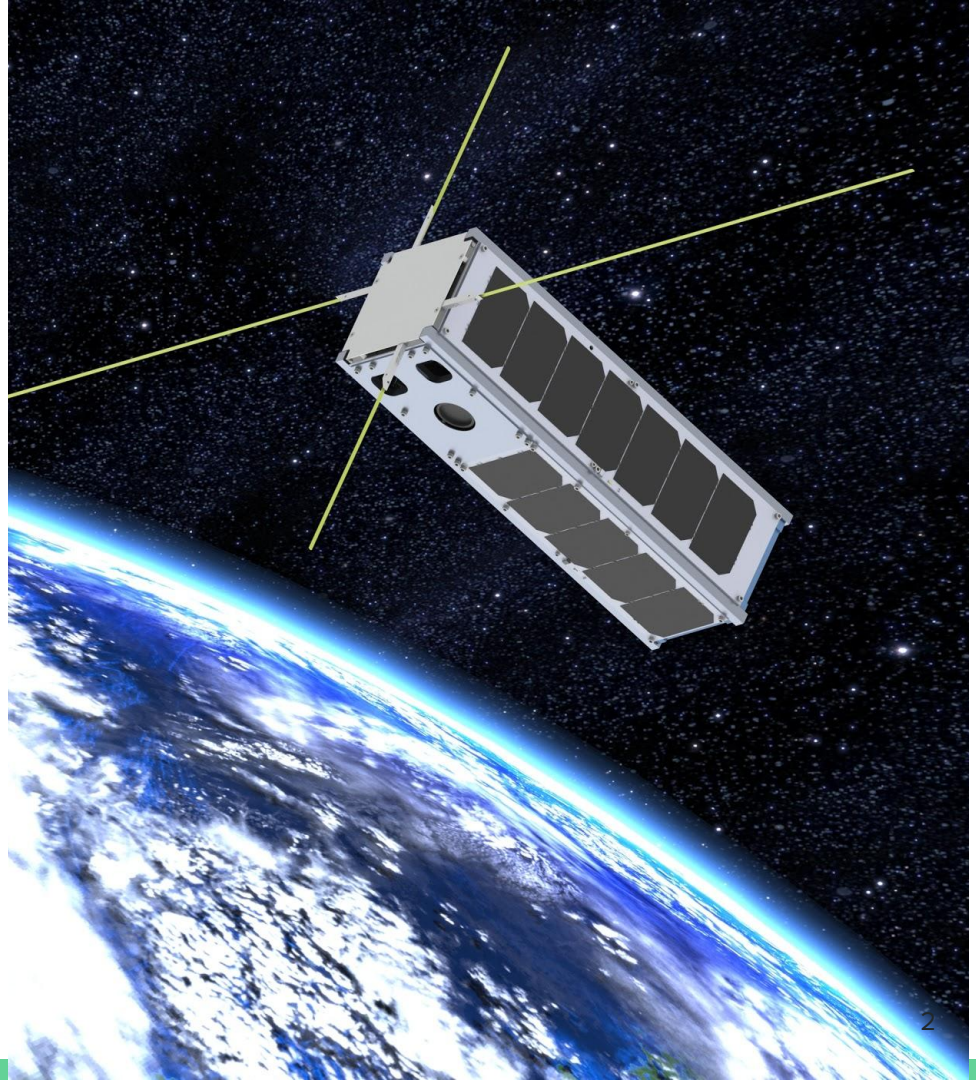


Image credit: P. do Vale Pereira (MIT)

Mission Overview

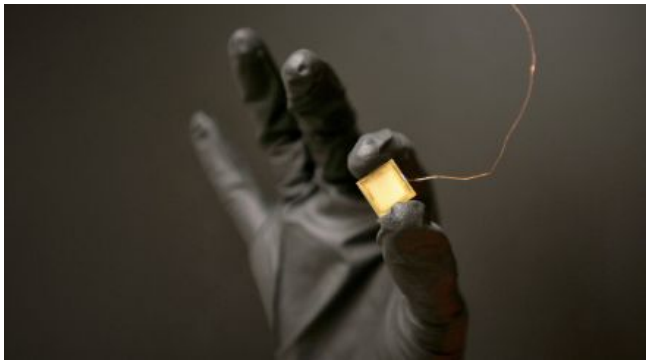
Mission Objectives

- Cloud top and ocean infrared data yield important insights
  - Scientific study of **Earth's climate and weather**
  - Large satellite platforms are expensive and offer limited observation frequency and locations

- This mission seeks to
  - Prove use of **CubeSat platform** to gather measurements using relatively low-cost cameras
  - Demonstrate operation of Accion's Tiled Ionic Liquid Electrospray (TILE) **propulsion technology** for orbital maneuvering
  - Serve as an **educational exercise** for students

- Future missions:
  - **Constellations** to expand measurement frequency/coverage

Visual+IR data post hurricane Florence [1]



Accion TILE Electrospray Thruster[2]

Image [1]: Paul Fucile (Sept 19, 2018)
Image [2]: Accion Systems

Main Mission Objectives

BeaverCube shall:

- Successfully capture a minimum of **20 infrared and 10 visual images** of the Earth;
- Measure **ocean color as well as sea surface and cloud top temperature**;
- Downlink scientific data (space-to-Earth) and uplink (Earth-to-space) commands to the **MIT UHF ground station**
- Operate for at least **90 days**;
- Perform **orbital altitude** changes.

Conops: Launch and Initialization

BeaverCube:

Altitude: ~405 km
Inclination: 51.6 degrees

Image credit: A. Frey and T. Wells (MIT)

ConOps: Operations

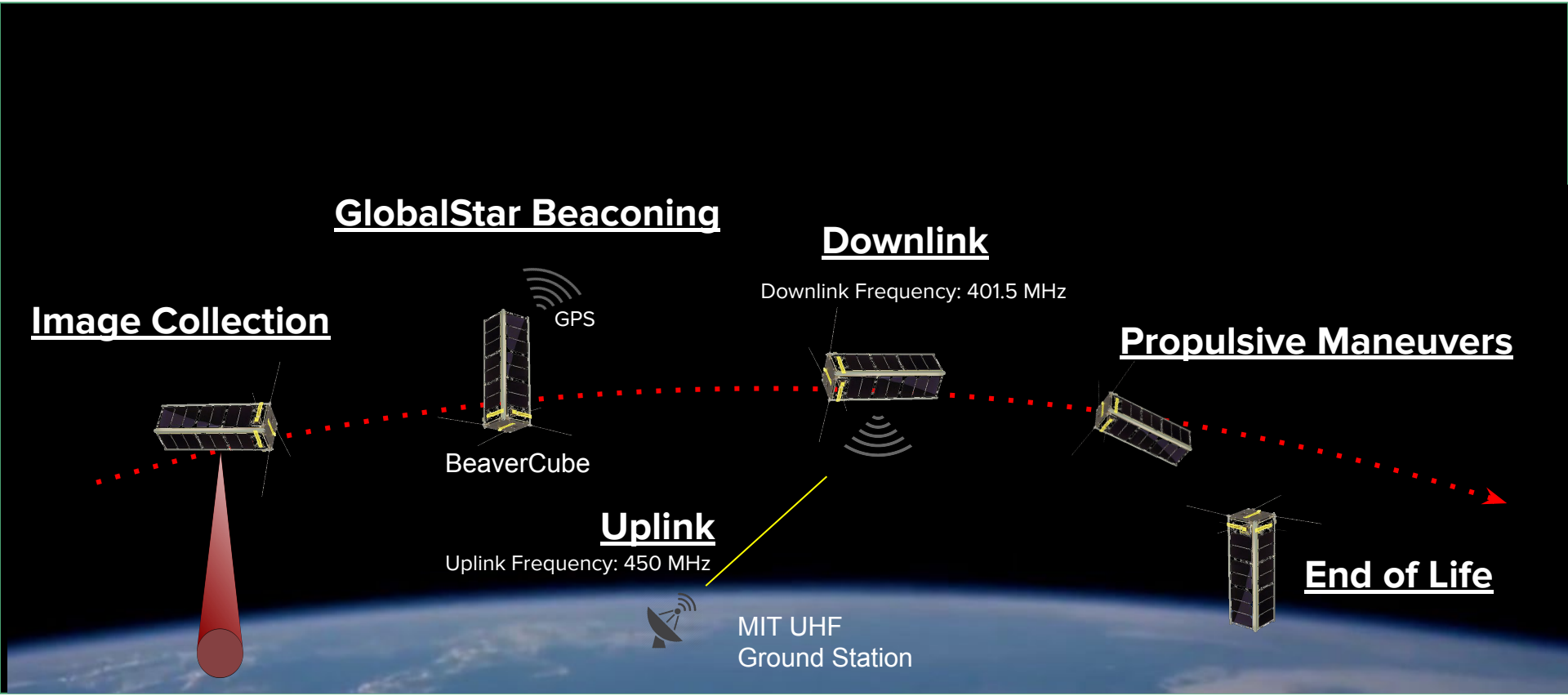


Image credit: A. Frey and T. Wells (MIT)

High Level CAD

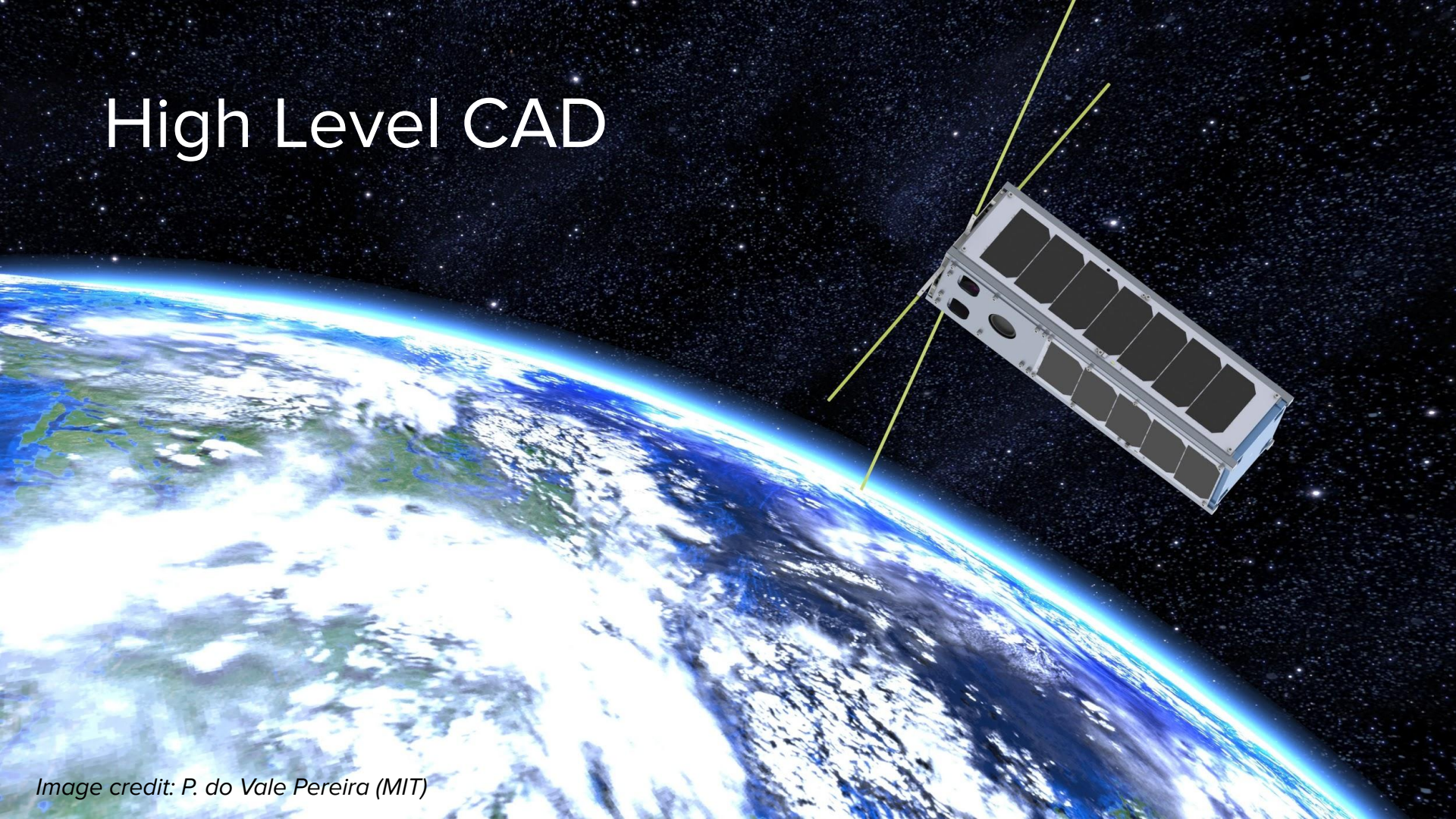


Image credit: P. do Vale Pereira (MIT)

BeaverCube CAD

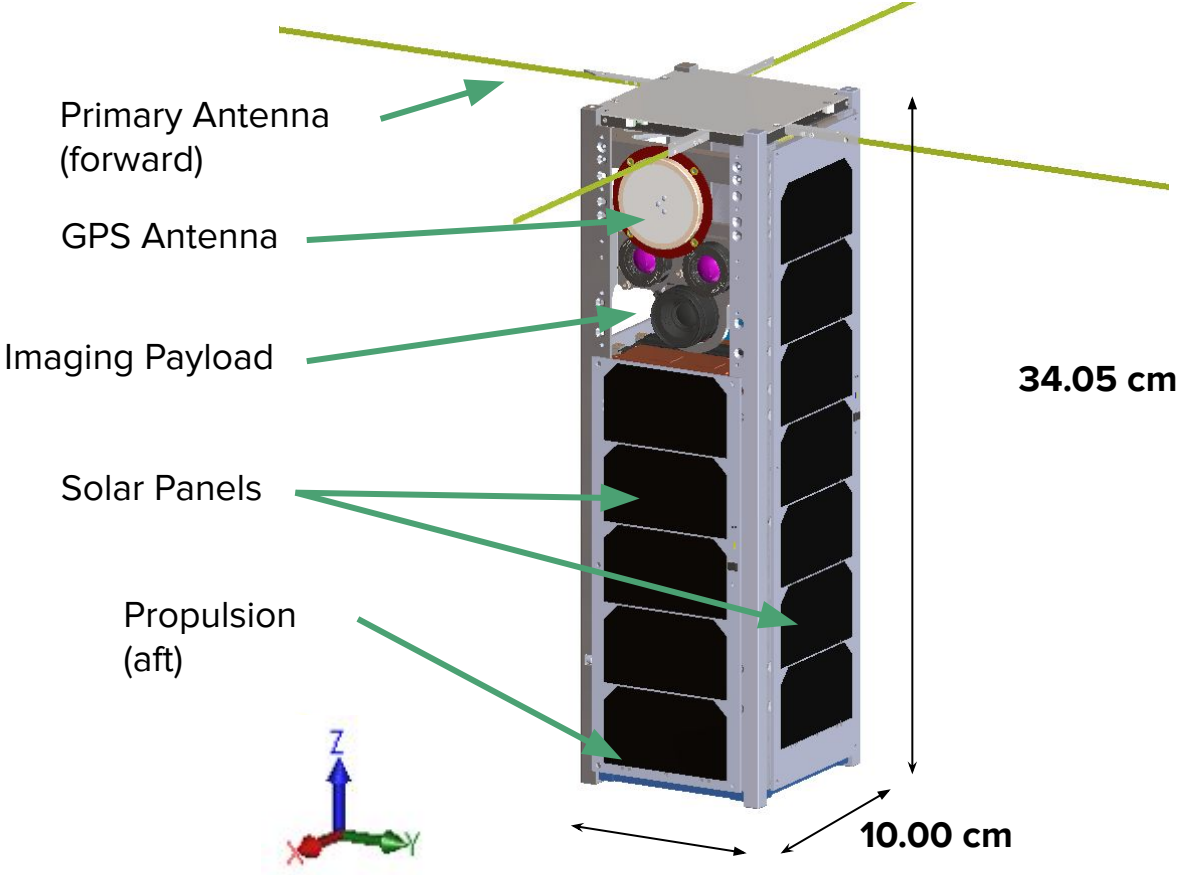


Image credit: M. Campbell and T. Tran (MIT)

Structures - CAD

- 2 mm thick solar panels
- 2.5 mm tall bolt heads
- 19 mm allowable protrusion

Center of Mass [mm] (With respect to the geometric center)	
X	-0.17
Y	+0.63
Z	-14.94

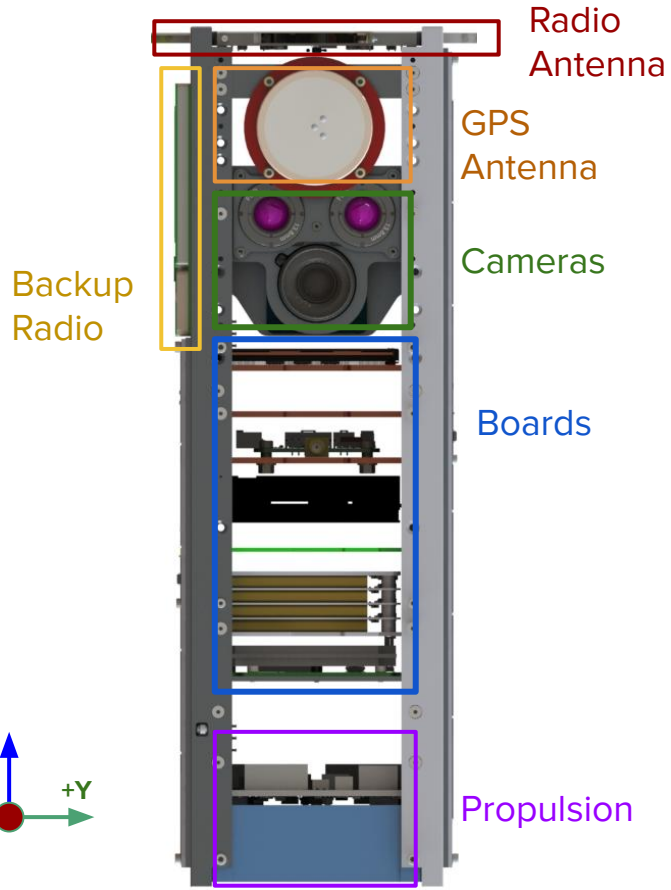


Image credit: M. Campbell, J. Coray and T. Tran (MIT)

Command & Data Handling

Hardware - C&DH BFC Render

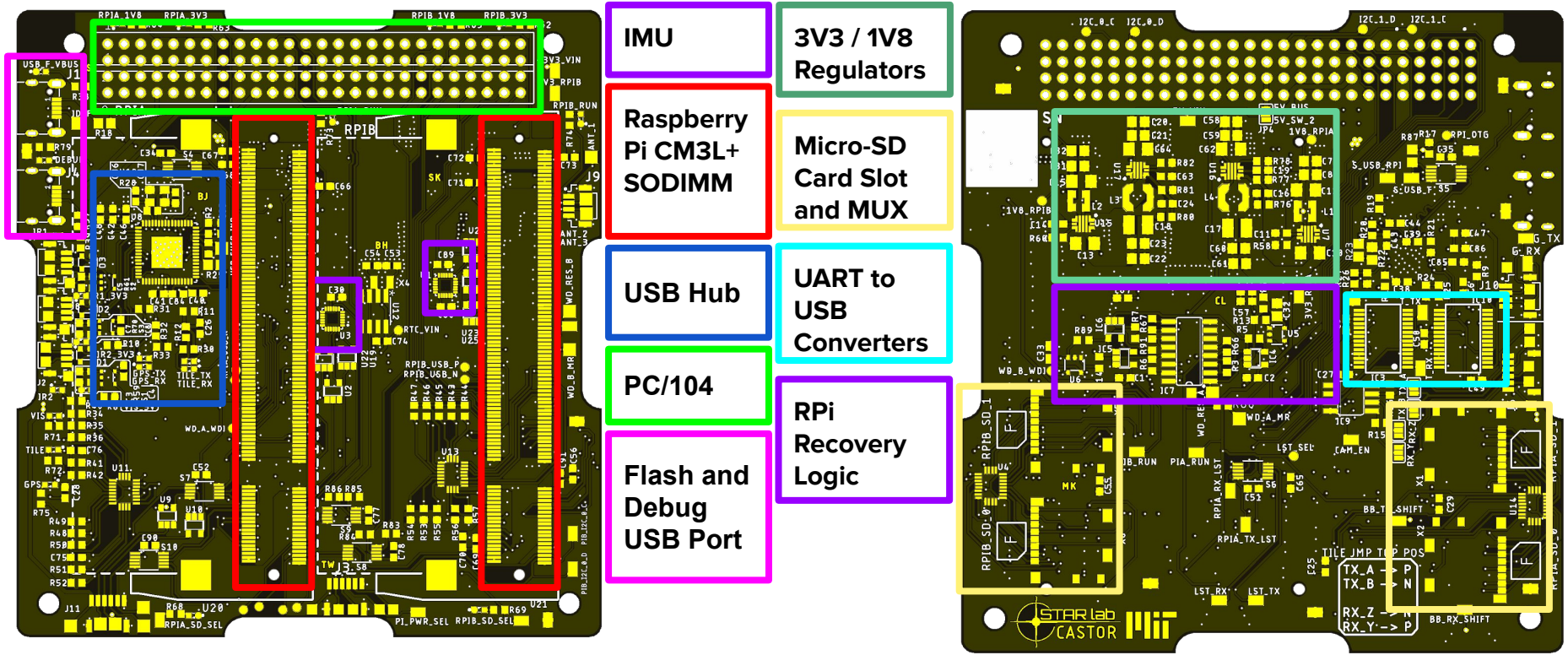


Image credit: C. Lindsay, E. Sit, B. John (MIT)

Approach - Payload

Payload- Science Motivation

- Deliver high resolution imagery in an area of importance for **ocean warming** and **commercial fisheries.**
  - **Cape Hatteras**
  - **New England**

- The targeted sites are co-located with important research infrastructure, particularly the **Ocean Observatories Initiative Pioneer Array**

- The region is also subject to damaging storms from both tropical and extra-tropical systems

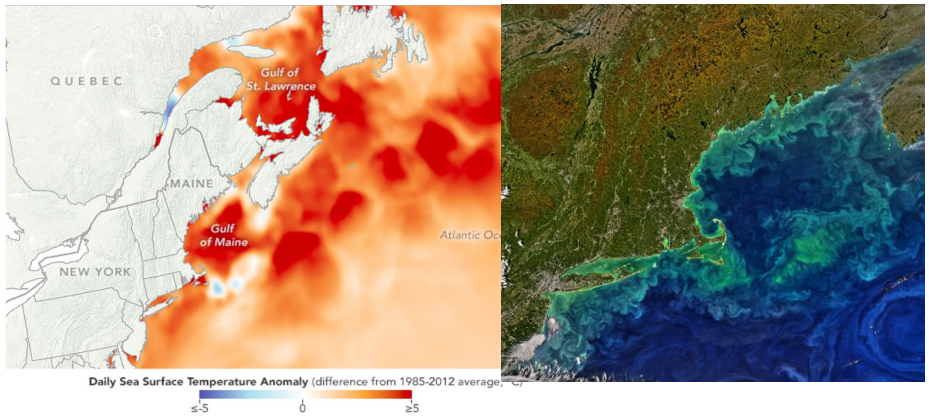
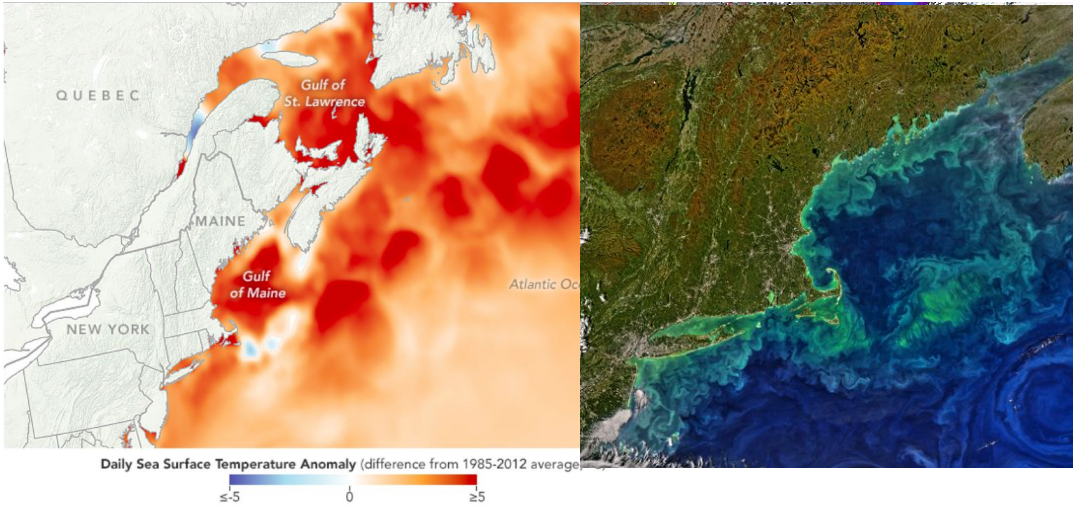


Image and Content Credit: S. Baber, A. Miller (MIT) and JHU APL

- The above image, generated using MetOp, (EUMETSAT series), GOES, Meteosat, and Suomi NPP, shows the temperature anomaly in degrees celsius between 1985 to 2012.

Payload: Science Motivation

Sea Surface Temperature (SST) is an indicator for temperature anomalies in the ocean and can be used to forecast storms and climate change trends.



Ocean Color is used to measure phytoplankton concentration in a region and can indicate the biological productivity of the region. It can also be used to track Colored Dissolved Organic Matter (CDOM), and can be used to track surface current patterns.

Image and Content Credit: A. Miller, S. Baber (MIT) and JHU APL

BeaverCube payload is equipped with two **thermal IR cameras** and a **visual camera** to detect high spatial and temporal resolution images to measure both SST and ocean color.

FLIR and Matrix-Vision.com

The data from **BeaverCube** will help **WHOI** develop higher resolution models of regional ocean processes. These models could help with **weather forecasts** and help predict migration patterns of marine life and help the **local fishing industry.**

Payload- Overview

Goal: Measure ocean color and sea surface temperature

Hardware:

- 2 IR Cameras
  - 11.5-12.5 um (M16 band)
  - 7.5-13.5um (Entire IR band)
- 1 Visual camera
  - 400-700 nm (Visual Spectrum)

Parameters Measured:

- **Sea Surface Temperature (SST) -** an indicator for temperature anomalies, weather patterns, and climate change
- **Ocean Color -** indicates the biological productivity of the region

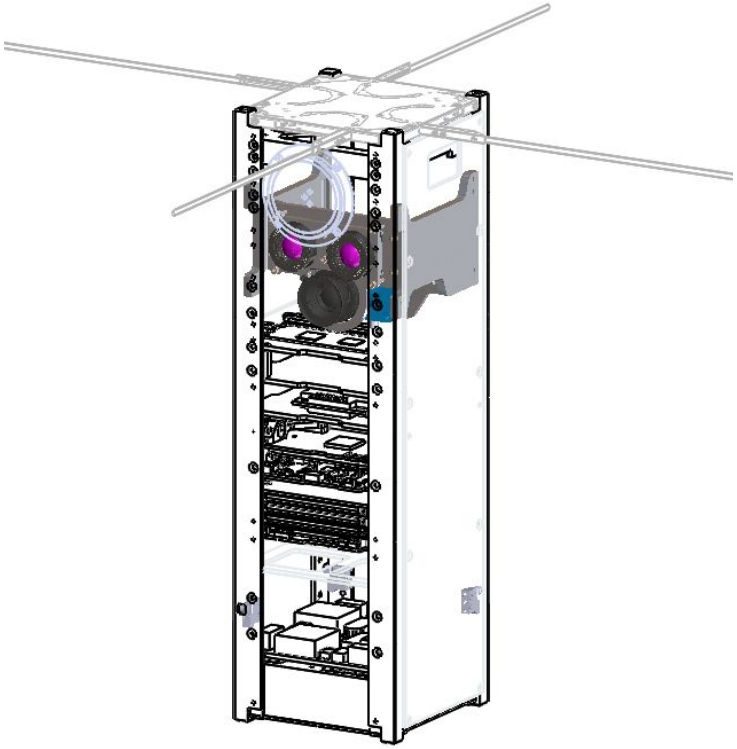


Image and Content Credit: S. Austin, M. Garcia, T. Tran, M. Campbell, J. Coray (MIT)

Payload- Phases Overview

Ground Station Pass (MIT):

Uplink target information

Downlink science and calibration images

Imaging:

Cameras take calibration and science images

Involves timed camera power on and power off

Post-Processing:

Calculate the gain factor from calibration buoy images

Apply to science images

Payload: Vicarious Calibration for IR and VIS Cameras

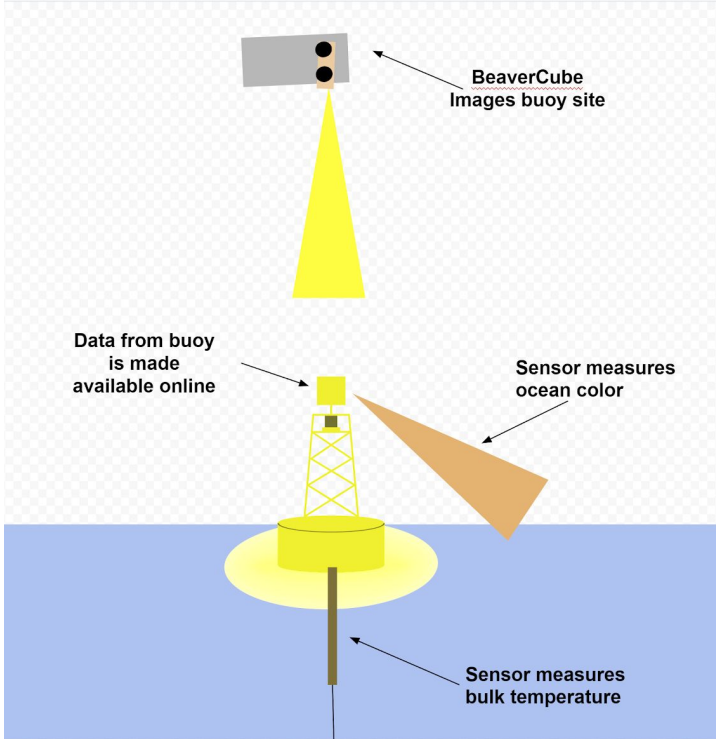


Image and Content Credit: Alex Miller and S. Baber (MIT)

Predict when BeaverCube will directly overpass a buoy.

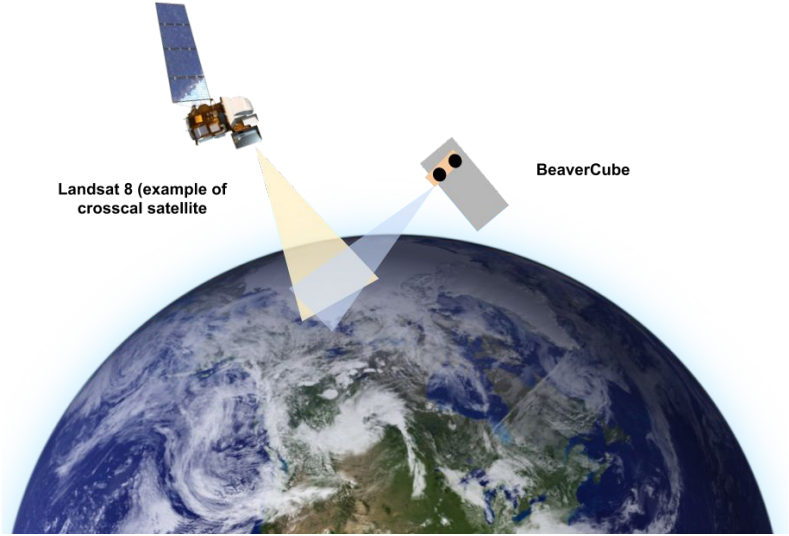
Capture calibration image.

Relate bulk water temperature to water skin temperature measured by BeaverCube at the buoy site. (IR only)

Identify the pixel area corresponding to buoy with IMU data and flight path simulation

Calculate gain value for the image

Payload- IR/VIS Cross Calibration with satellites



Predict coincident events

Correct data for atmosphere, viewing angle, clouds

Calculate brightness temperature for both BeaverCube and crosscal target

Designate cross cal satellite as “ground truth”

Image and Content Credit: S. Baber and A. Miller (MIT)

Calibration Target Modeling: Satellites

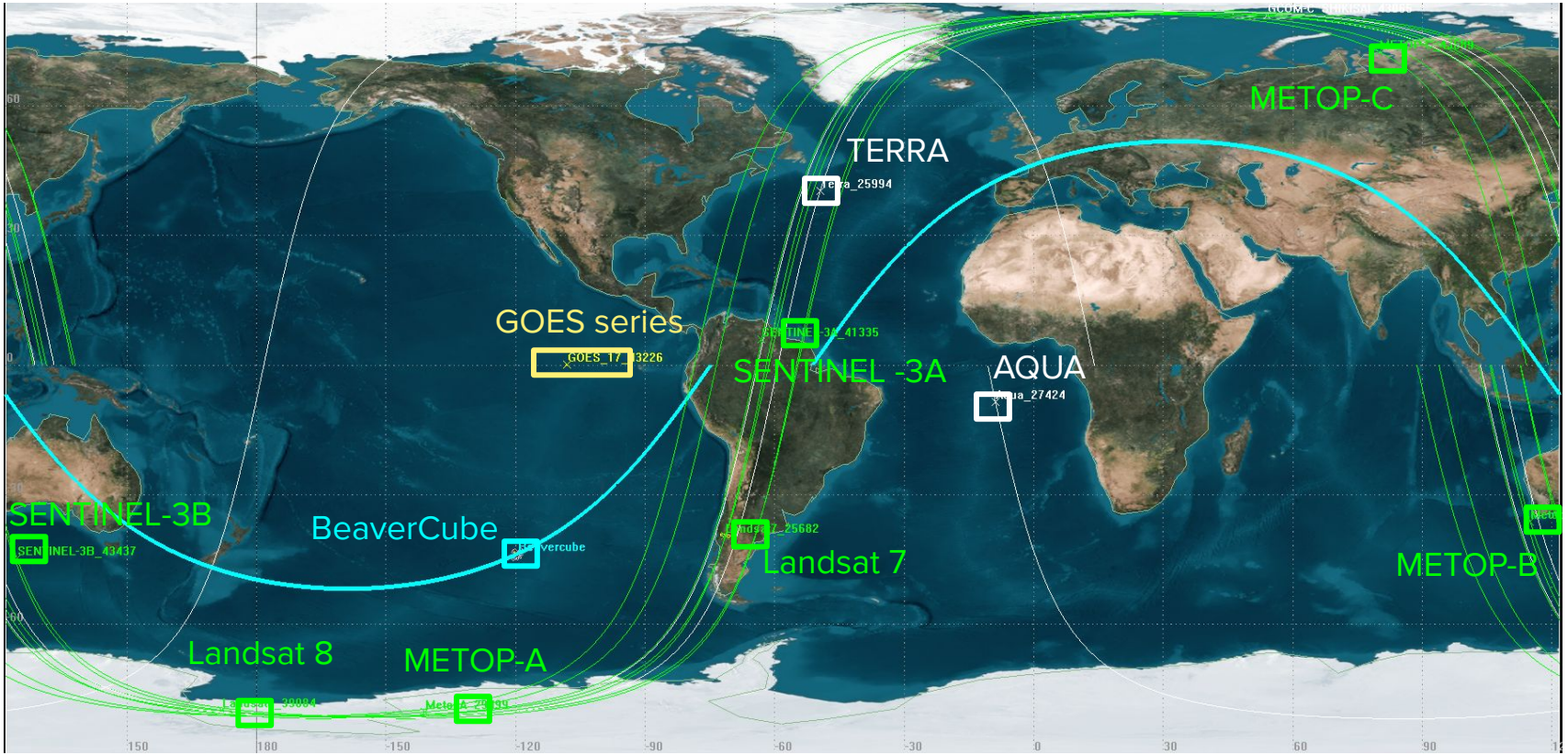


Image Credit: S. Baber and A. Miller (MIT)

Payload- Balloon Launch with Thermal and NoIR Cameras

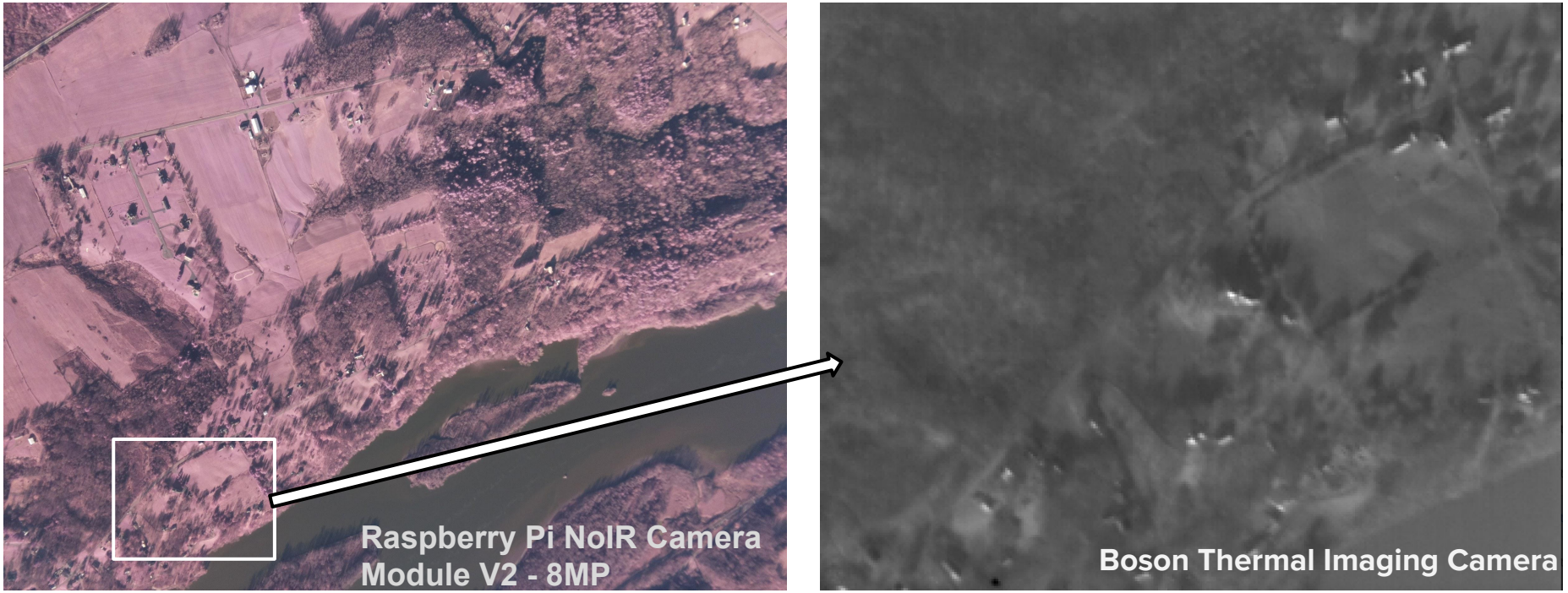


Image Credit: S. Baber, M. Garcia, K. Clark (MIT)

Payload- Balloon Launch with Thermal and Visible Imaging Cameras

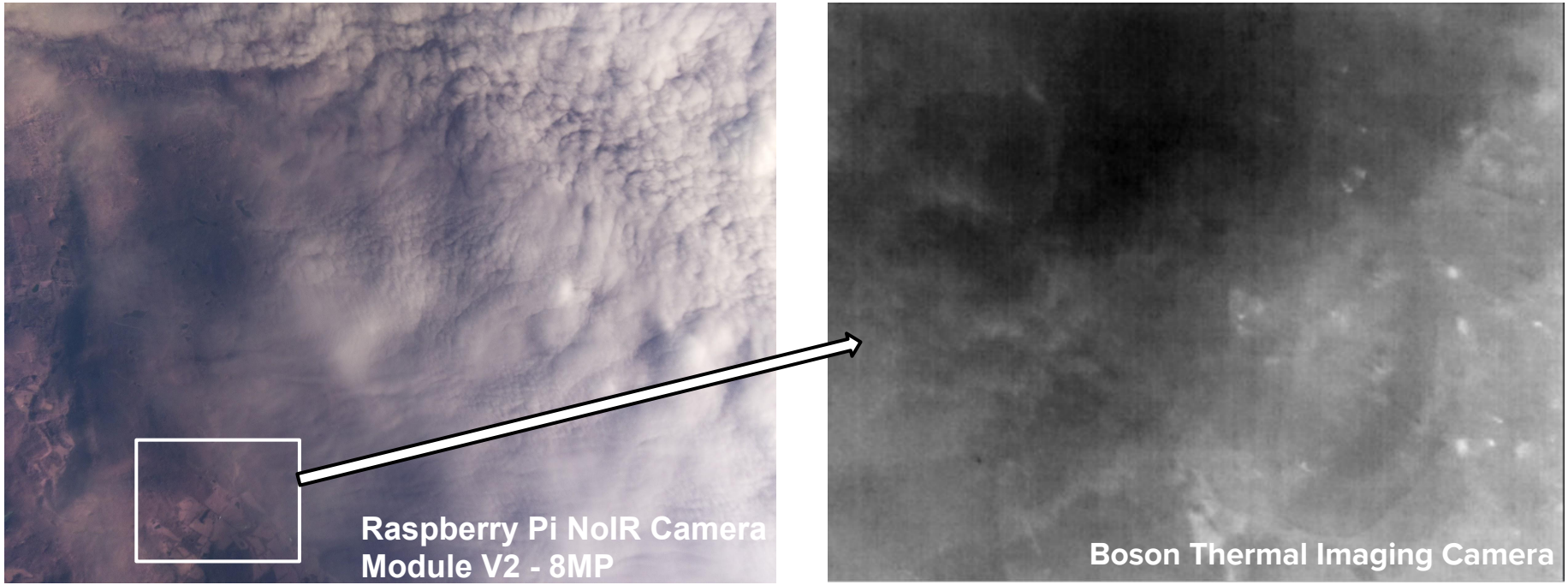
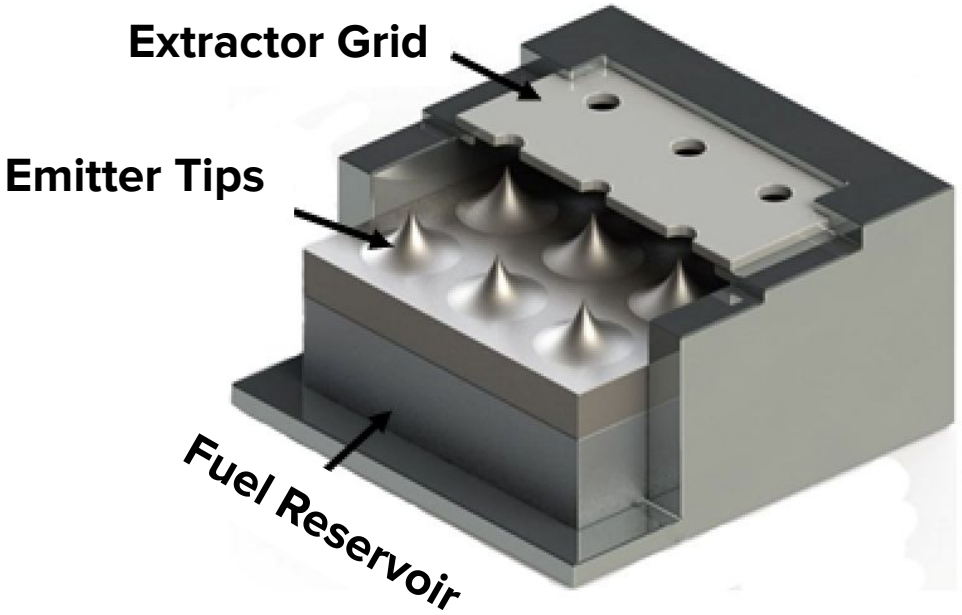


Image Credit: S. Baber

Approach - Propulsion

Propulsion: Design to Meet Requirements, Electrospray

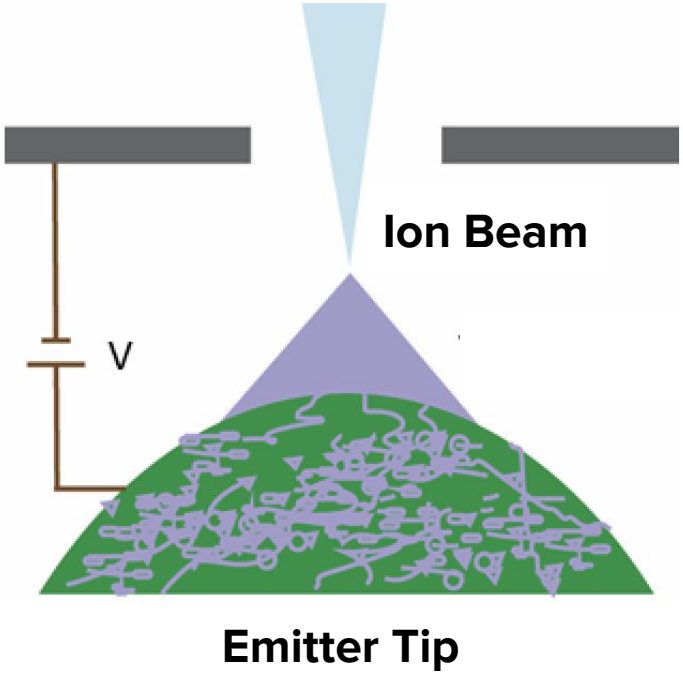
- Ionic liquid propellant in fuel reservoir
- Emitter chip with many emitter tips
- Voltage applied between emitter chip and extractor grid (1 - 2kV)



Adapted from http://www.mollahasan.com/

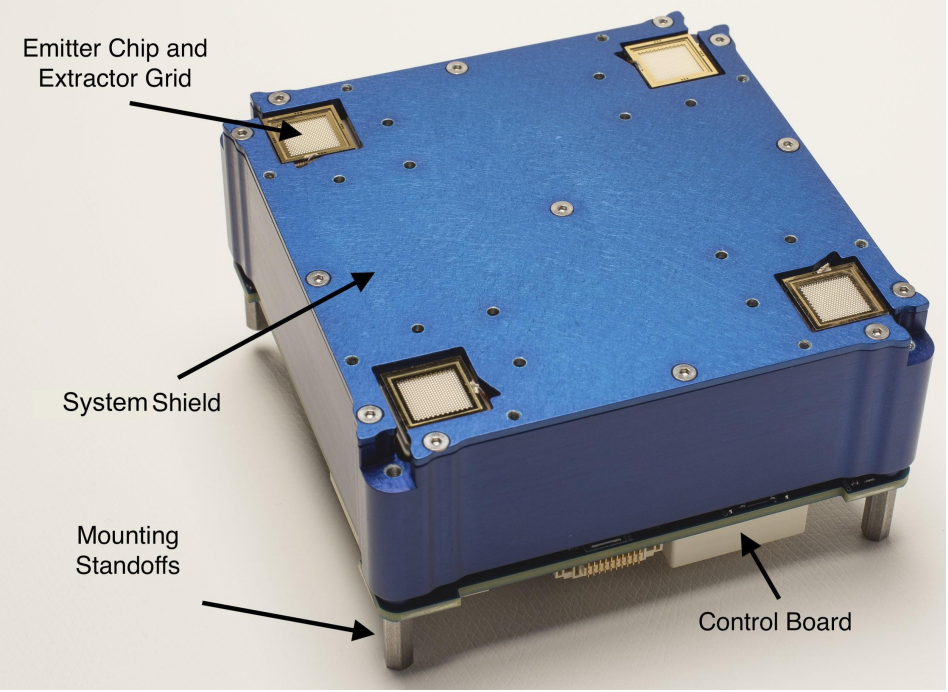
Propulsion: Design to Meet Requirements, Electrospray

- Electric force overcomes surface tension
- Ions evaporated from tips
- Ions accelerated in electric field between tip and extractor producing thrust



Adapted from http://www.mollahasan.com/

Propulsion: Design to Meet Requirements, Accion



System Design
• Propellant: Ionic Liquid • Size: 0.5U • Mass: 0.5 kg • Number of Thrusters: 4
System Capabilities
• Thrust: 50 μN per .5U unit • I_{SP}: 1800s • Acceleration: 12.5 μm/s^2 • Torque: 5E-7 Nm

Image Credit: Accion Systems and M. Schroeder (MIT)

Propulsion: Translational Maneuvers

- Demonstrate electrospray capability through orbit raising maneuvers
- For safety:
  - Propagate until at safe and approved altitude below ISS
  - Wait until primary imaging science mission downlinks images successfully
  - Maneuvering will be approved by NASA and CSpOC before initiation
  - Can be attempted multiple times until detectable maneuver is made

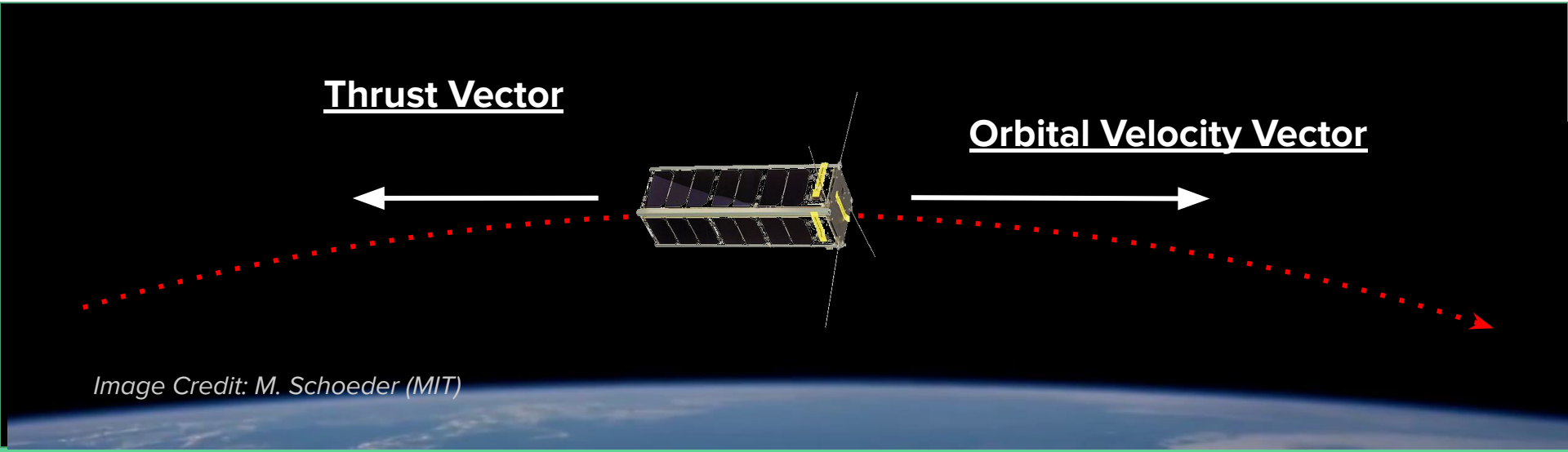


Image Credit: M. Schoeder (MIT)

Propulsion: Translational Maneuvers

- Maneuvers will be detected using GPS measurements
- GPS altitude readings from before and after maneuvers will be downlinked with propulsion system telemetry data after each firing

Parameter	
Thrust	50 μN
Burn Time	3.5 hours
Acceleration	12.5 μm/s^s
Altitude Change	280.6 m

Status & Next Steps

BeaverCube Status

Week of June 29th, 2020

Hardware:

- All Engineering Model COTS components have been ordered, waiting on delivery of NSL BlackBox
- Thermal, CnDH, GPS, and OpenLST Rev1 boards have been received and tested
- Payload structure Rev1 complete
- Rev1 rails ordered, preliminary fit checks completed
- Propulsion system ready for integration

Software:

- Payload, comms drivers complete;
- Writing power scripts

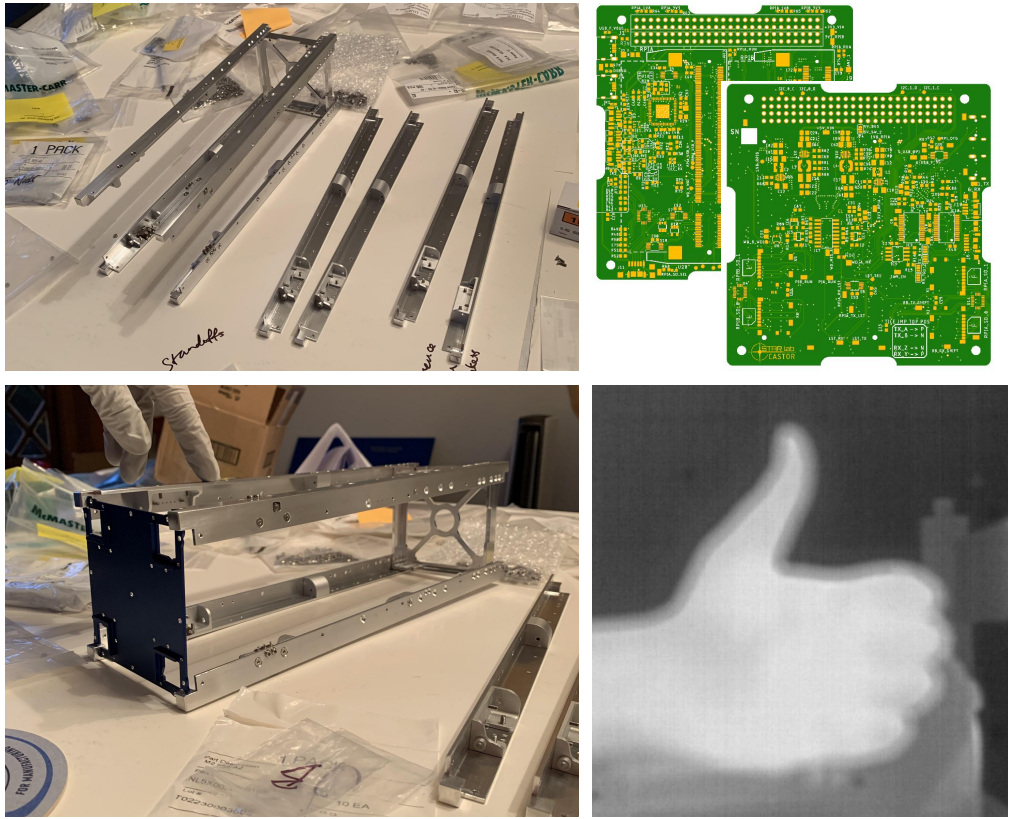


Image Credit: T. Tran, M. Garcia, C. Lindsay, E. Sit, A. Choi

Systems: Schedule Milestones

- **May 2020:**
  - Fit check of main components
  - TRR
  - Mass Mockup Vibration Test
- **August 2020:**
  - Space Vehicle Integration
  - Thermal Vacuum Test
  - Vibration Test Report Completion
- **September 2020:**
  - Handover to Launch Service Provider
- **Late 2020:**
  - Launch

Thank you for listening!

For questions, contact:

beavercube-staff@mit.edu

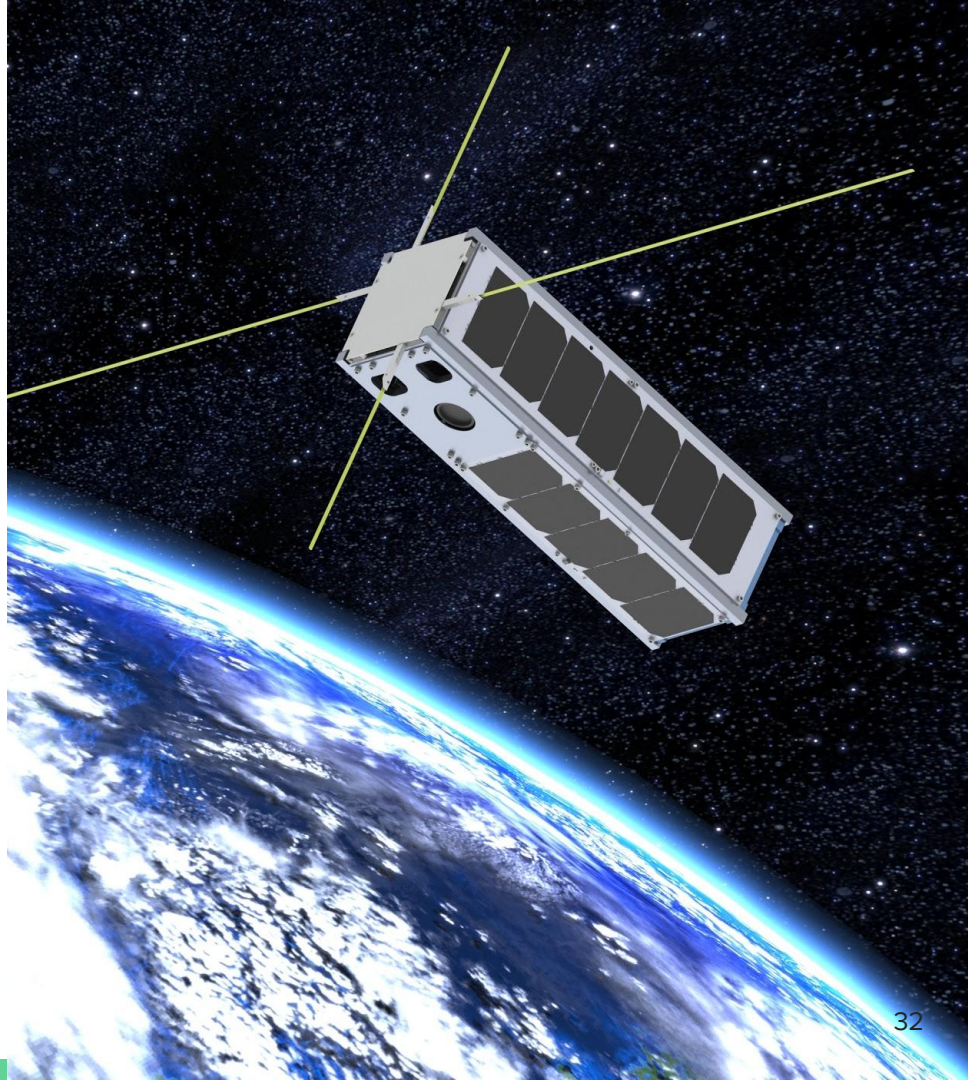


Image credit: P. do Vale Pereira (MIT)