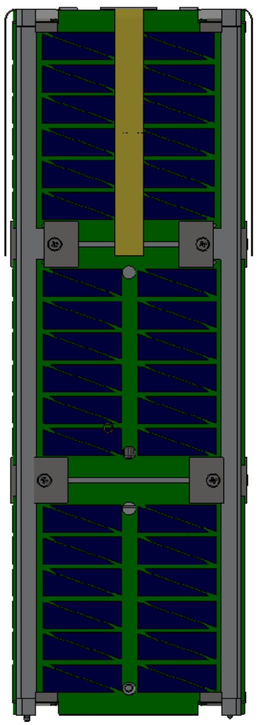
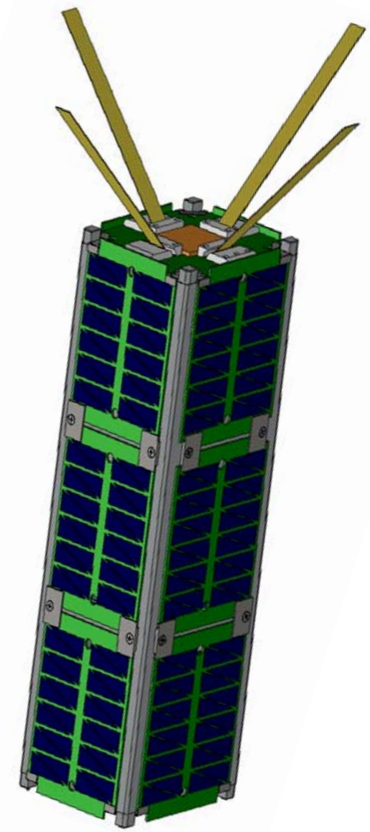
RAX: The Radio Aurora eXplorer



RAX
Radio Aurora Explorer



Matt Bennett
University of Michigan

CubeSat Workshop
Cal Poly, San Luis Obispo
April 22nd, 2009

Background

- Sponsored by National Science Foundation
- University of Michigan and SRI International Collaboration
- Co-investigators:
    1. Prof. James Cutler, University of Michigan
    2. Dr. Hasan Bahcivan, SRI International

Responsibilities Breakdown

SRI International

- Develop science objectives, requirements, and test plan
- Design, build, test radar receiver (primary payload)
- Manage science operations
- Analyze and report on science data

MICHIGAN

- Design, build, test, and deliver spacecraft
- Develop ground station and data transfer network
- Conduct mission operations
- Analyze and report on science data

RAX Team Breakdown

Team Breakdown:

29 students on core Michigan team
+8 students in Michigan project courses
+2 engineers from Space Physics Research Lab
+3 SRI engineers
+1 faculty member
+1 scientist

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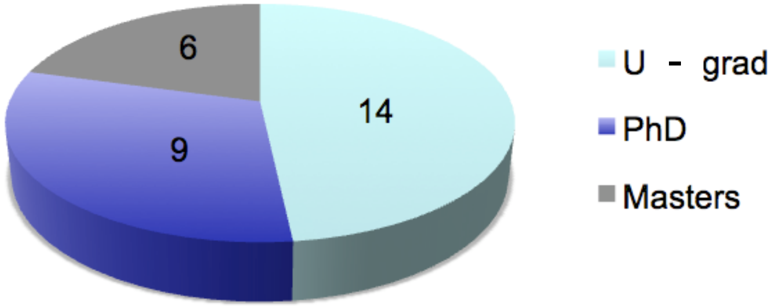
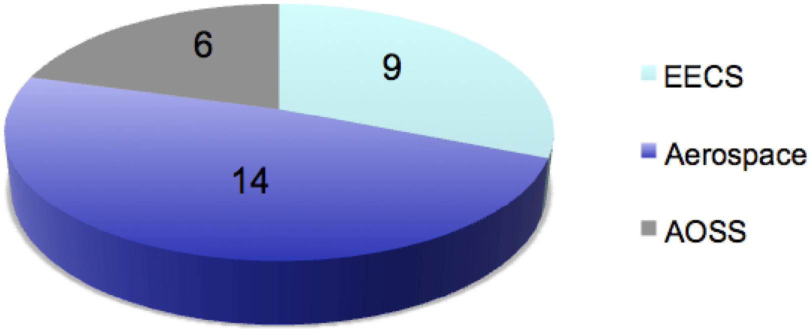
44 students and professionals working on RAX

Student Distribution by Class



Student Distribution by Department



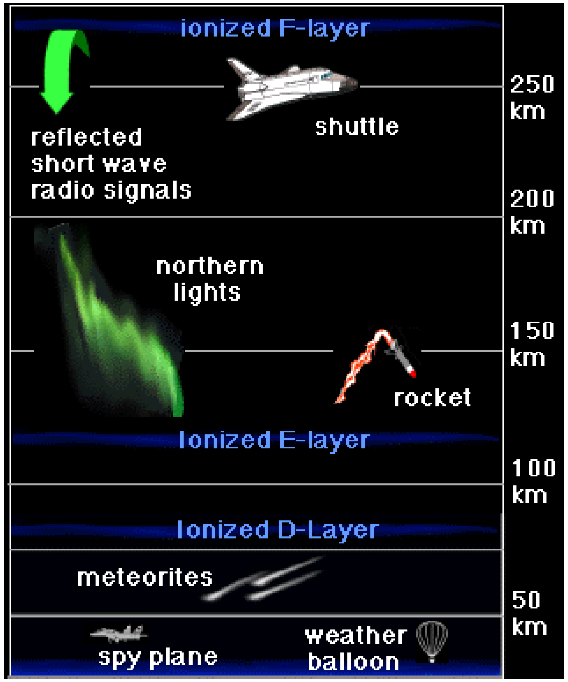
Mission Science

RAX Mission Objective:

Study formations and distribution of magnetic field-aligned plasma irregularities (FAI) located in the lower ionosphere

What are FAI?

- Dense plasma structures forming between E and F layers of the ionosphere
- Sizes range from sub-meter to kilometer scales

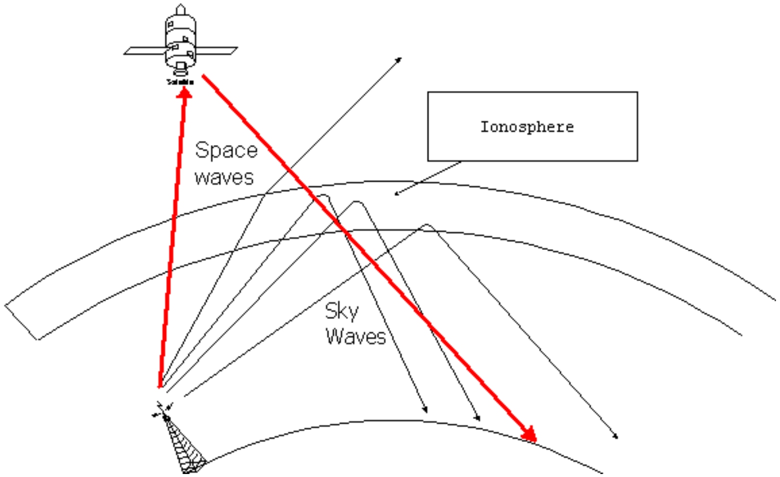


Courtesy UCAR: www.windows.ucar.edu/tour/link%3D/earth/Atmosphere/ion_regions.html

Mission Science

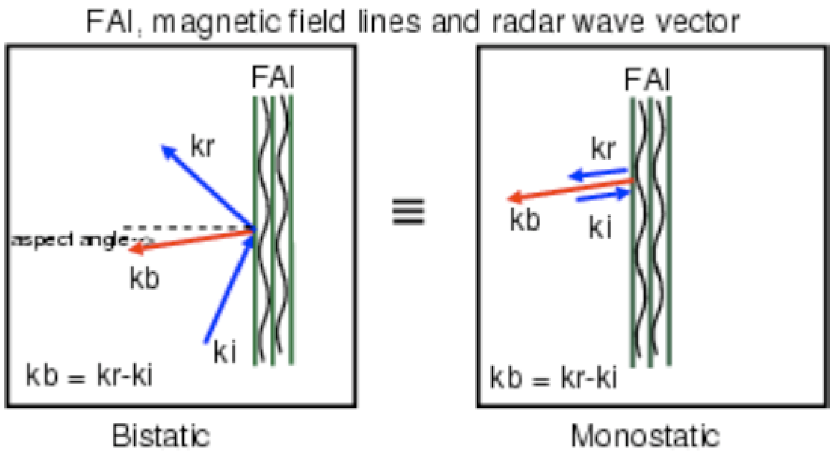
Why Study FAI?

1. FAI are known to disrupt tracking and communications with spacecraft
2. Formation is not yet predictable, and there are no methods of mitigation
3. Understanding physics of formation will lead to forecasting models



Why Study FAI from orbit?

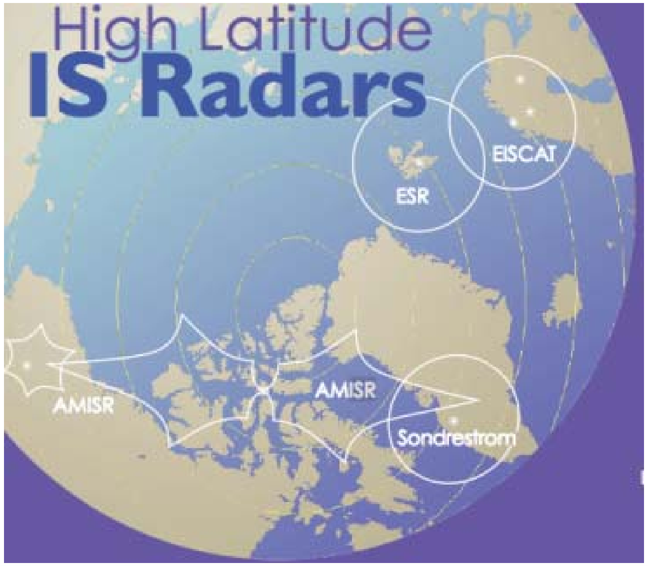
1. Ground radars beams do not always meet perpendicularity condition
2. Bi-static configuration required



Poker Flats Advanced Modular Incoherent Scatter Radar (PFISR)

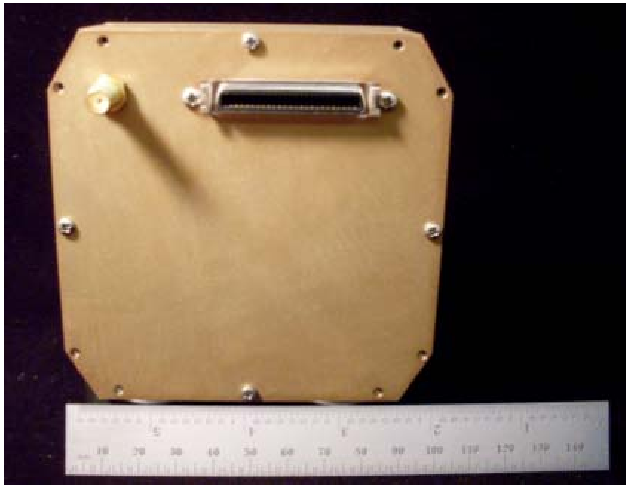
Other UHF ISRs

ISR	Freq. MHz	Power MW	BW	Inv. Lat.
PFISR	449.0	2.0	1.0	78
RISR*	443.0	2.0	1.0	81
ESR	500.0	1.0	0.6	75
Millstone	440.0	2.5	0.6	53
Arecibo	430.0	2.5	0.2	34

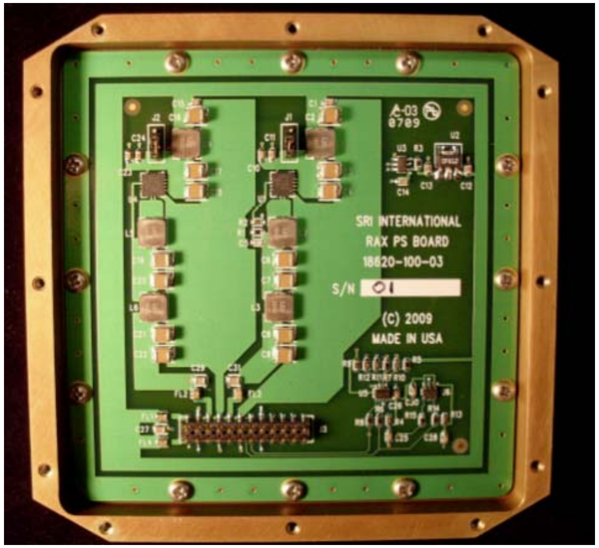


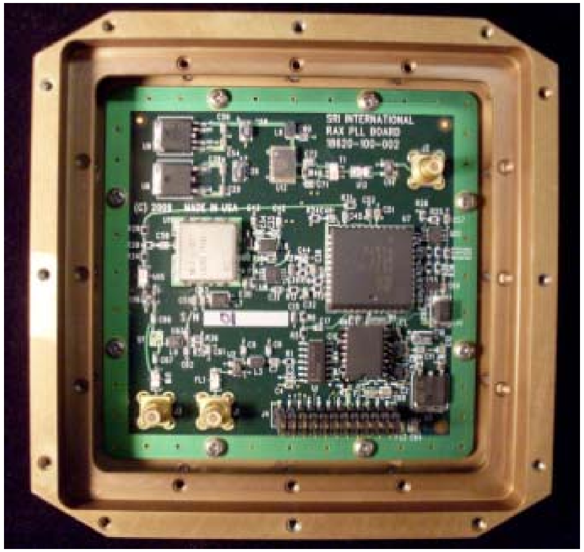
RAX Payload: UHF Radar Receiver

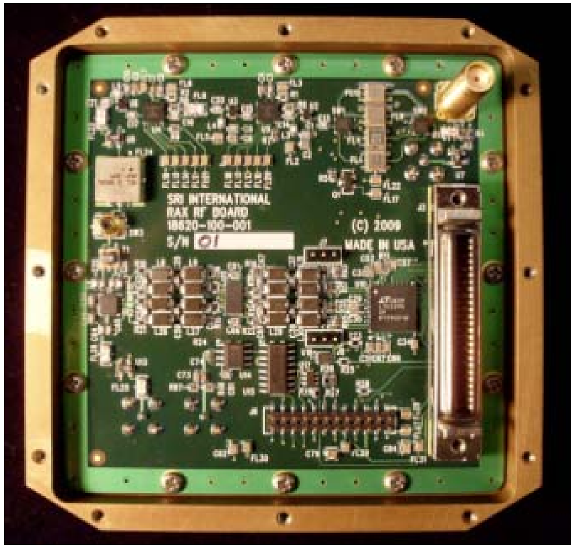
- 430 –500 MHz (4-Bands)
- Front-end band-pass pre-selector
- 14-bit digitizer
- Packaging
  - Material: 6061 Aluminum
  - Weight: 289 gm
- Power: 2.5 watts @ 7.5V



RAX Payload: UHF Radar Receiver



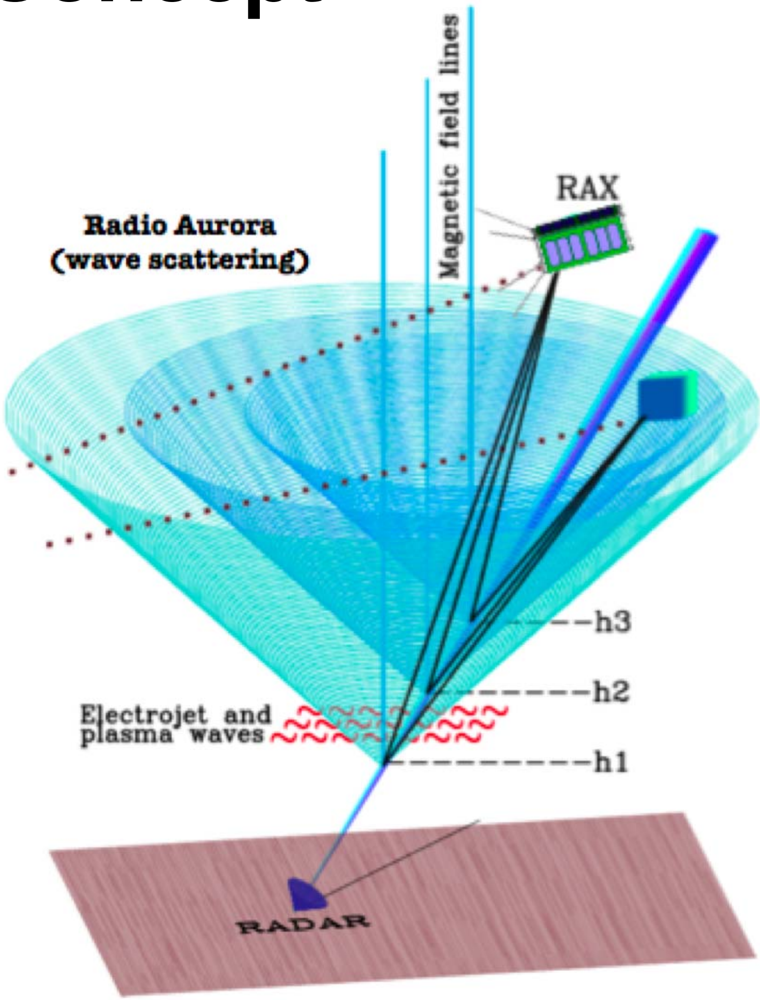




Experiment Concept

Receiver Measurements:
1. Scatter wave amplitude
2. Scatter wave phase
3. Convective electric field, E_c

Measurements Objectives:
1. FAI intensity (size)
2. FAI alignment with B-field



VIDEO

RAX System Overview

Dimensions: Standard 3U CubeSat

Mass: < 3 kg

Attitude Determination:

- Magnetometers (internal and external)
- Inertial measurement unit
- Sun sensors

Attitude Control: Passive magnetic

Position and Time: GPS receiver

Power system: Triple-junction solar panels
Li-ion batteries

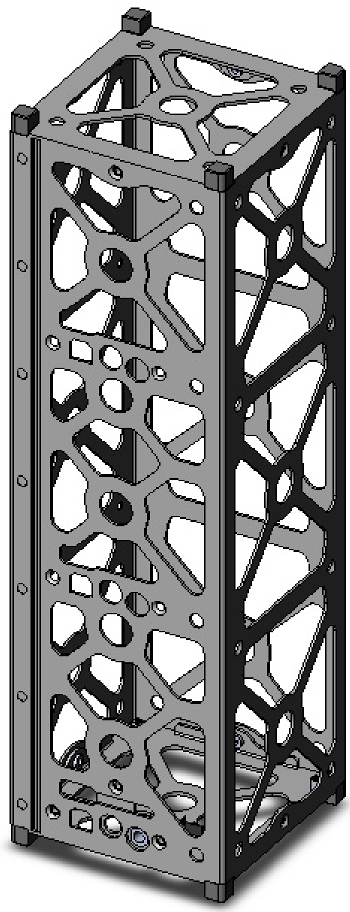
Processing power: Up to 520 MHz for payload

Communications:

- 38.4 kbps UHF transceiver
- 115.2 kbps, 2.4 GHz transceiver

Antennas: UHF Turnstile and 2.4 GHz patch

Subsystem Highlights: Structure



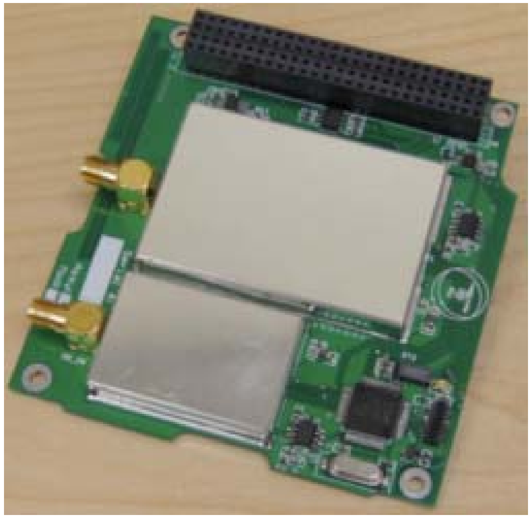
3U Skeleton
CAD Model RevD

Subsystem Highlights: Processors

Flight Computer:
CubeSat Kit FM430 FCPU

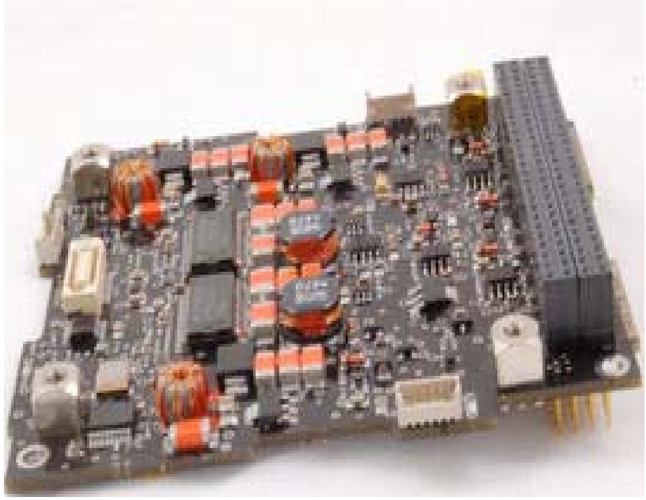
Instrument Data Processor:
Toradex PXA 270

Subsystem Highlights: Comm and Power



UHF TT&C Radio:
Astronautical Development Helium 100 transceiver

Primary Downlink:
Microhard MHX-2420 S-band transceiver



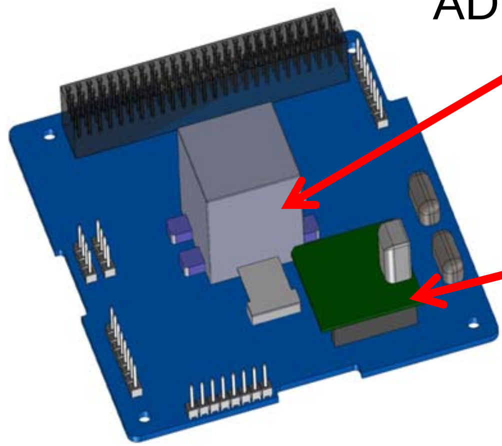
Electrical Power System:
Clyde Space 3U EPS

Subsystem Highlights: Position & Attitude

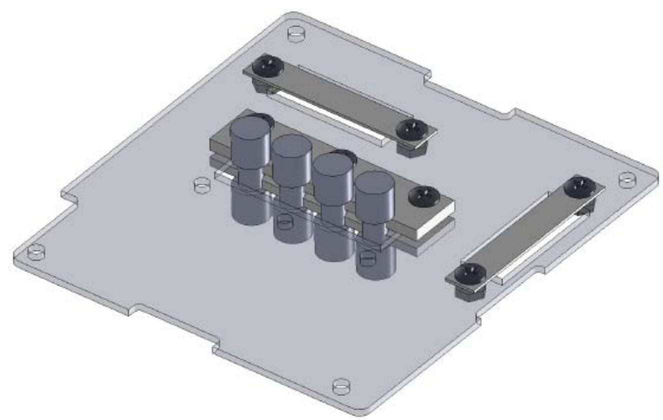
GPS Receiver
Novatel OEMV-1

ADIS 16405
IMU

PNI MicroMag3
Magnetometer



Attitude Determination Board

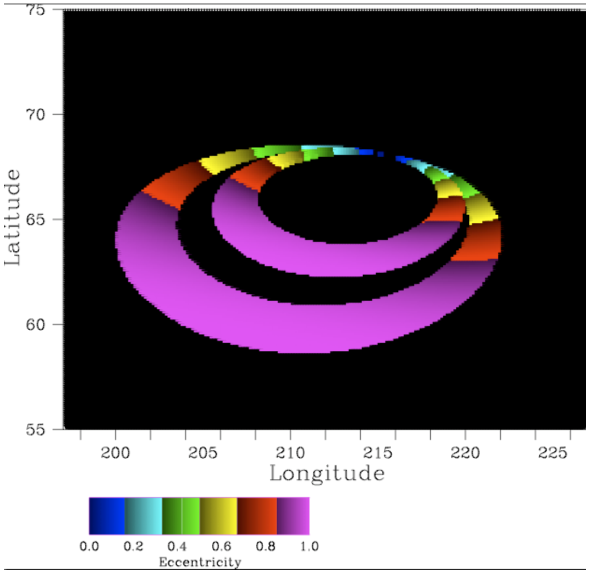


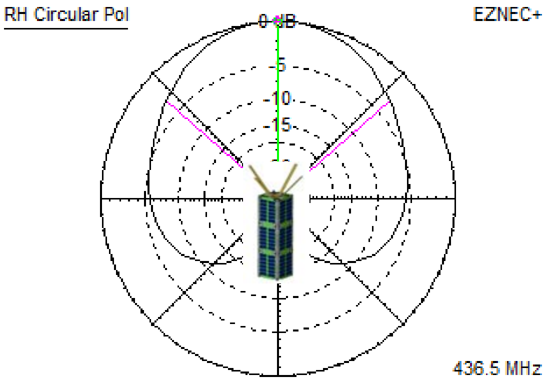
Attitude Control Board

Subsystem Highlights: UHF Antenna

Design Requirements

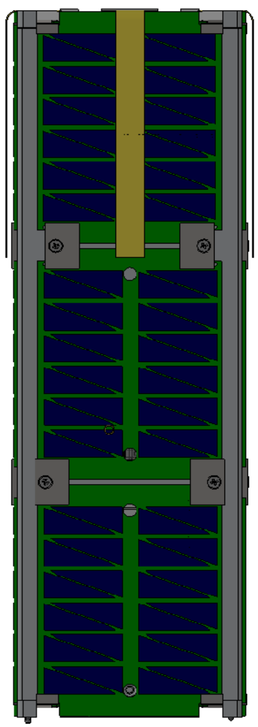
- Wide bandwidth (430 – 500 MHz)
- Circular Polarization
- Deployable
- Wide beamwidth (minimum 140 deg)



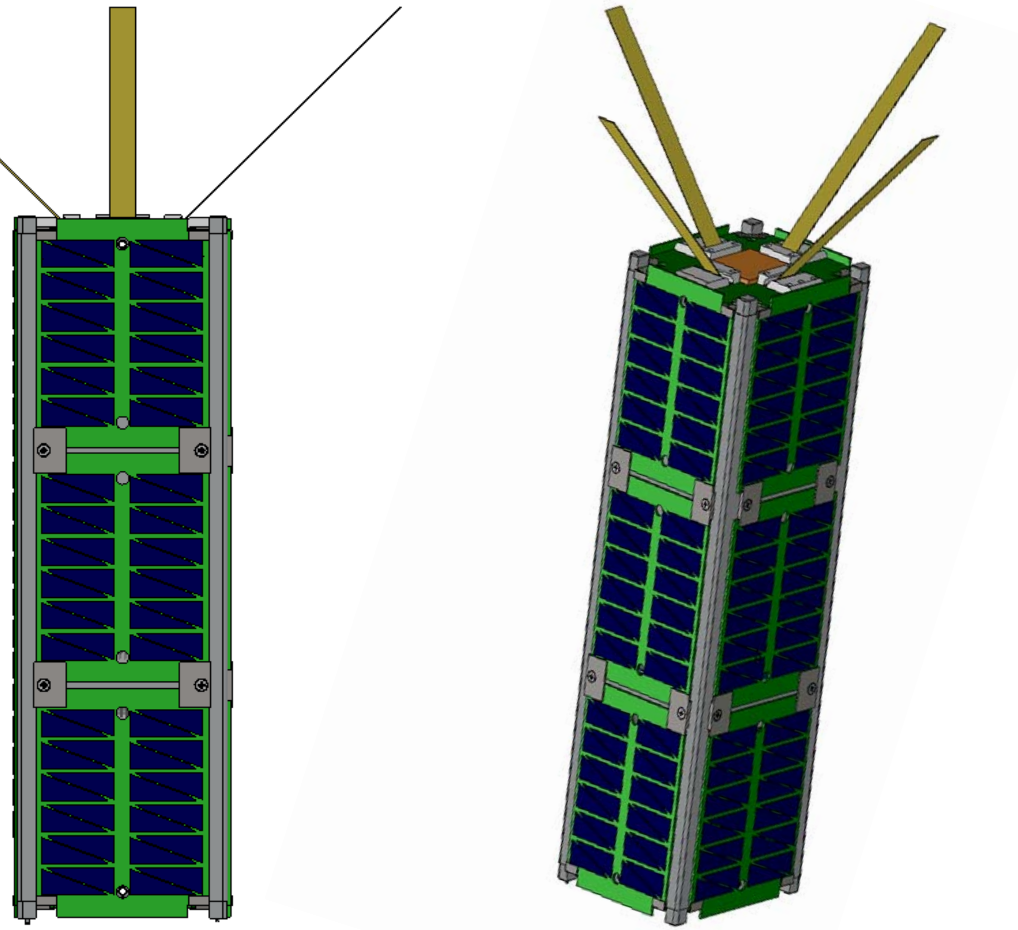


Elevation Plot		Cursor Elev	90.0 deg.
Azimuth Angle	0.0 deg.	Gain	1.47 dBic
Outer Ring	1.47 dBic		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	1.47 dBic		
Slice Max Gain	1.47 dBic @ Elev Angle = 90.0 deg.		
Front/Back	93.96 dB		
Beamwidth	97.2 deg.; -3dB @ 41.4, 138.6 deg.		
Sidelobe Gain	< -100 dBic		
Front/Sidelobe	> 100 dB		

Deployment Configurations

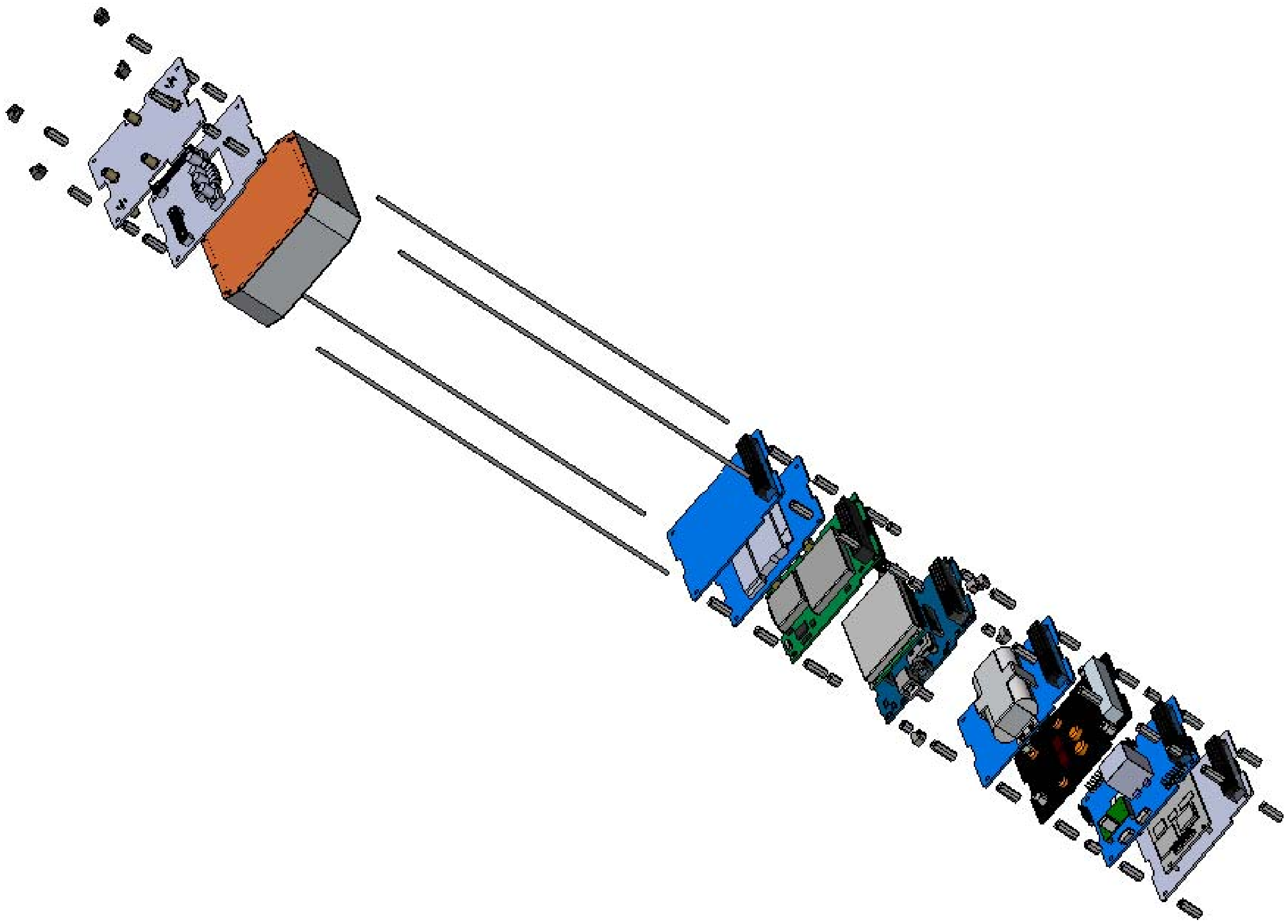


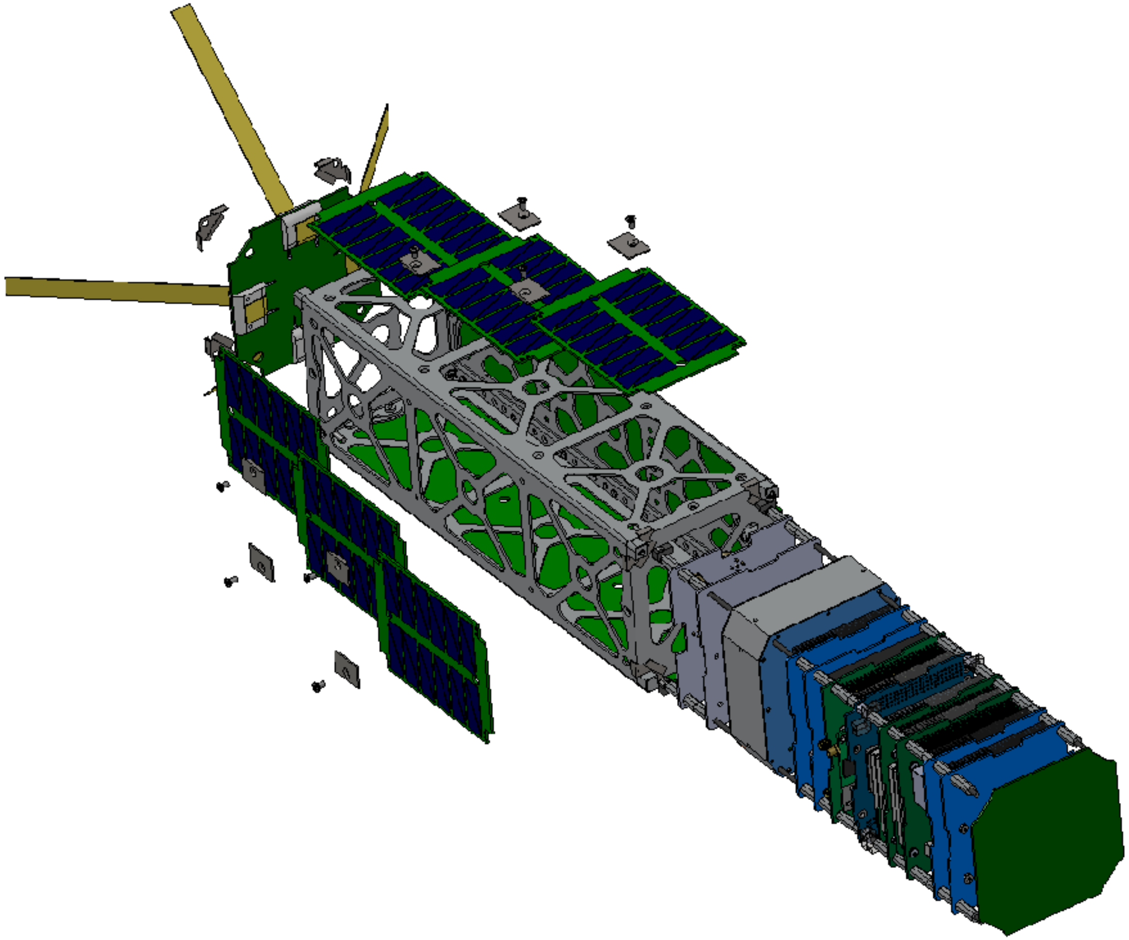
Antenna Stowed

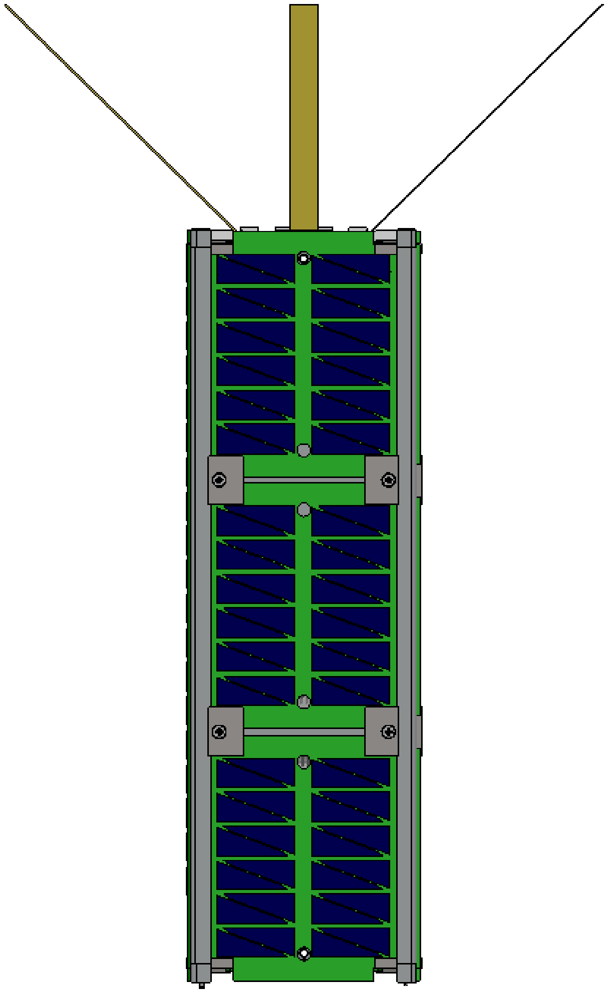


Antenna Deployed

The Stack

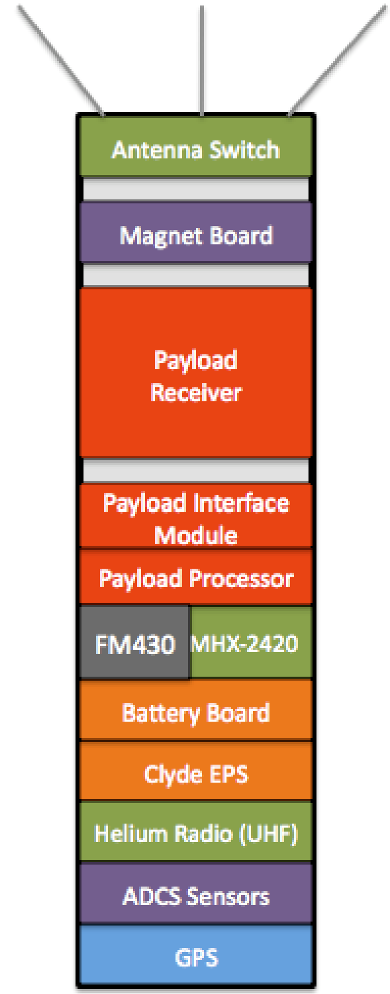




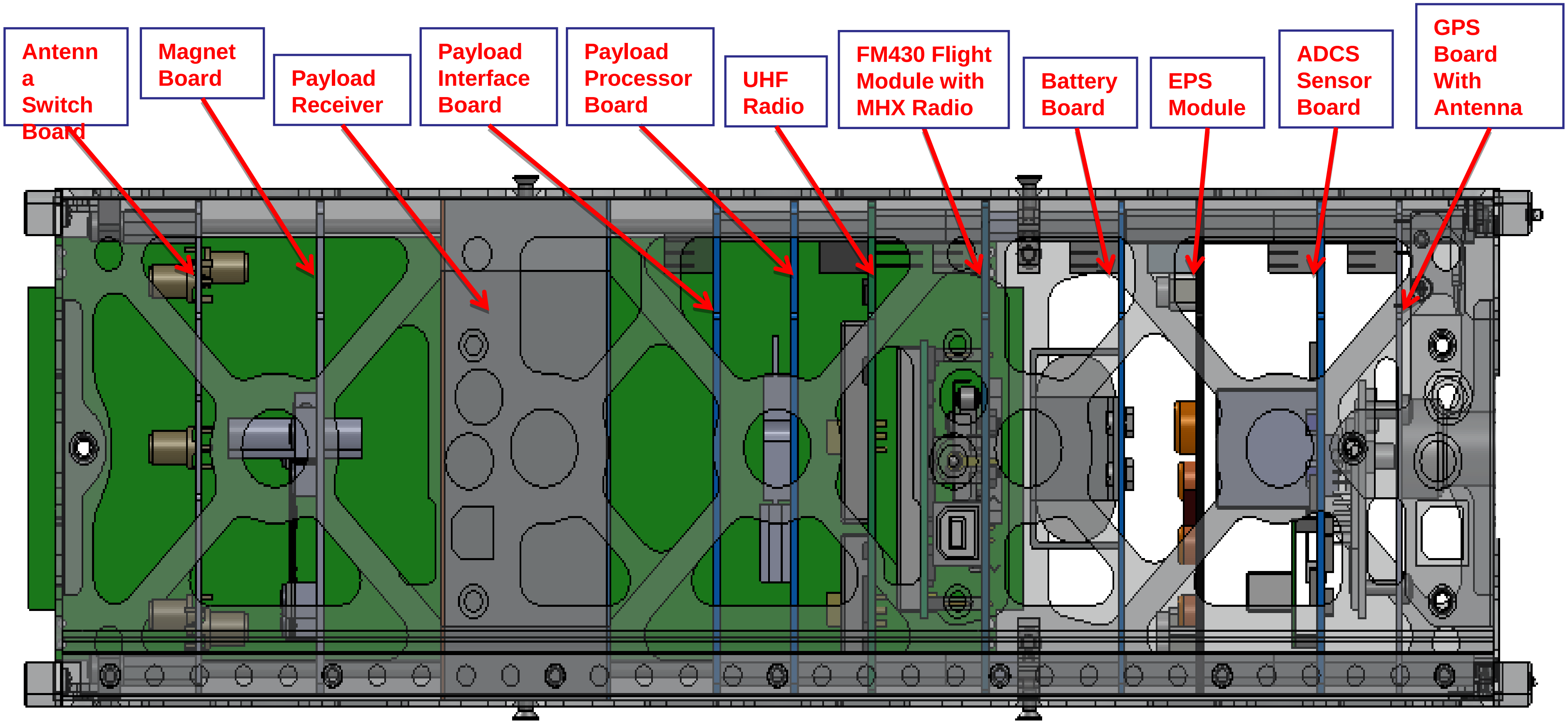


RAX System Overview

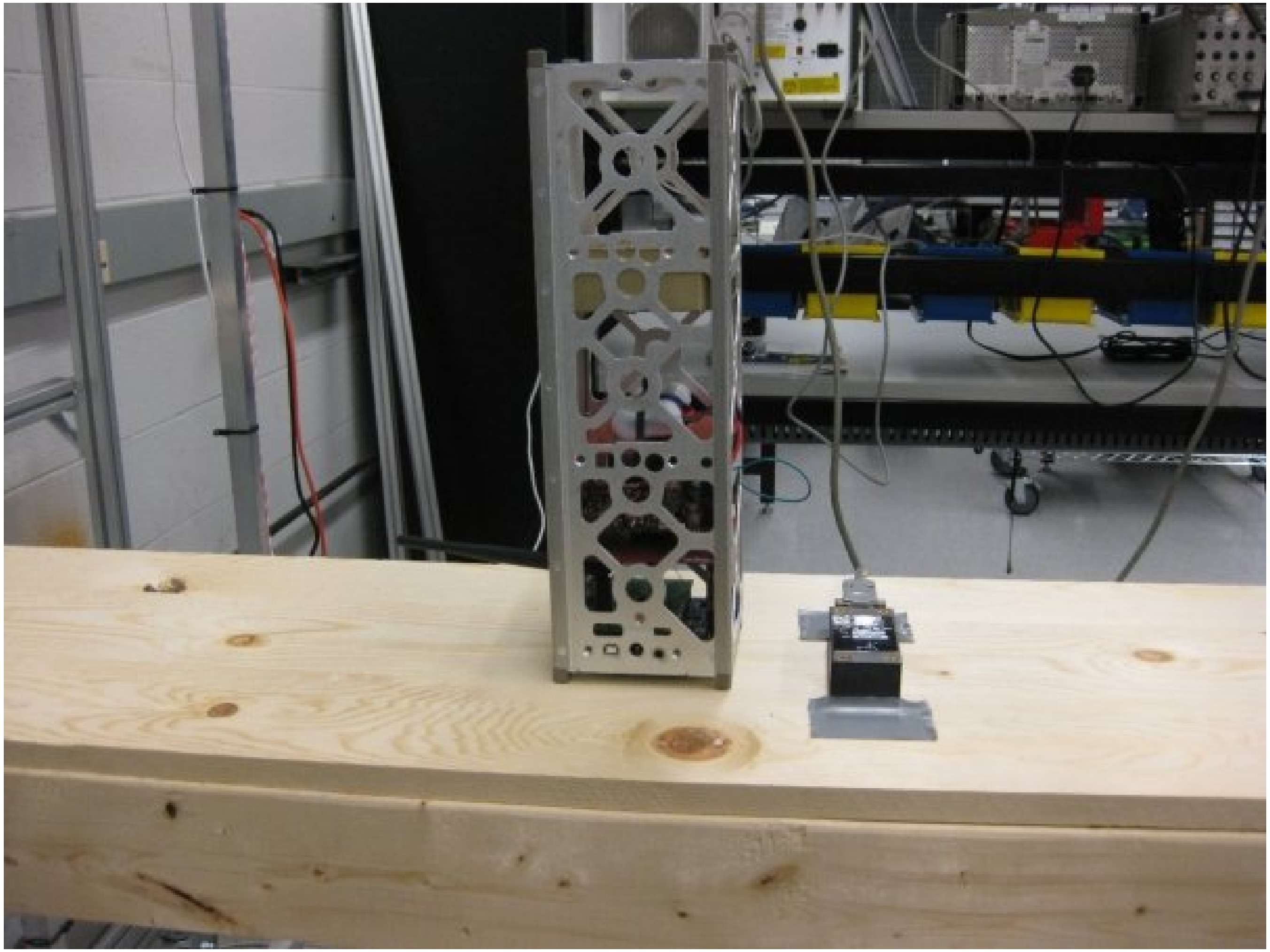
Color	Subsystem	Subsystem Purpose
RED	Payload	Performs radar data collection and processing
ORANGE	Electrical Power System (EPS)	Generates power and stores energy for eclipse operations
GREEN	Communications	Interfaces ground and spacecraft systems for data transfer
PURPLE	Attitude Determination and Control	Measures spacecraft attitude and stabilizes post-deployment spin
BLUE	Position and Time	Acquires position and universal time reference for synchronization of measurements with radar pulses
GREY	Command and Data Handling	Commands spacecraft subsystems and reports status



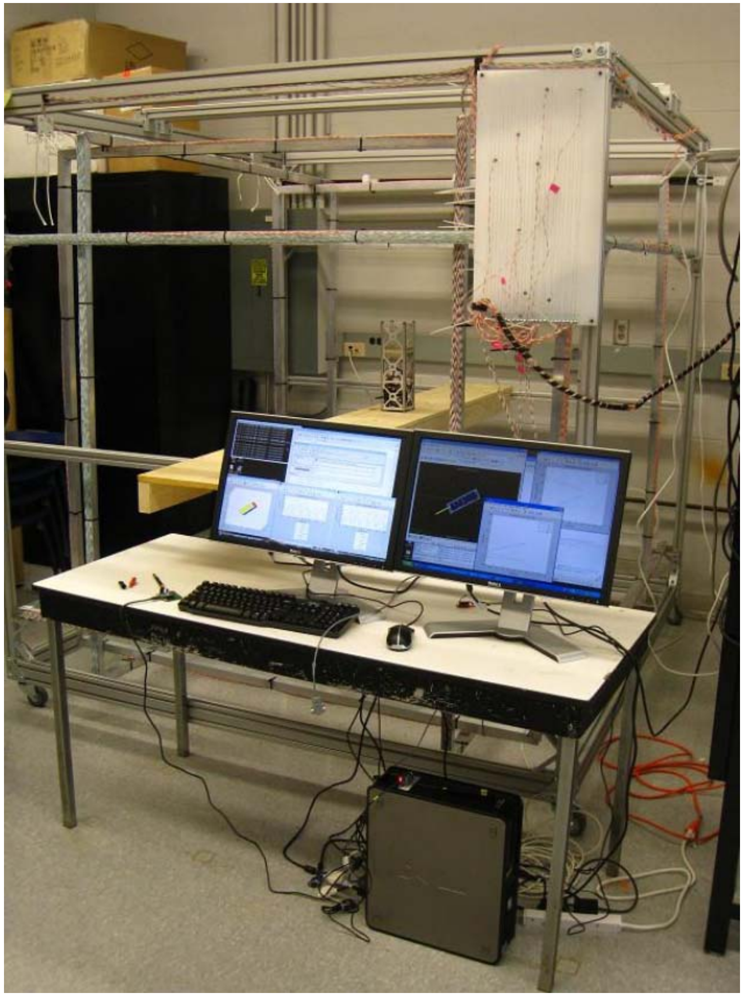
Board Layout



Integrated Testing

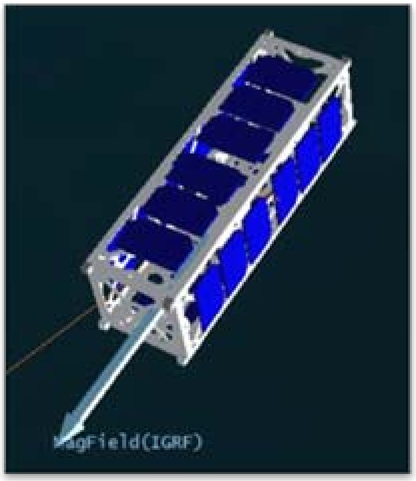


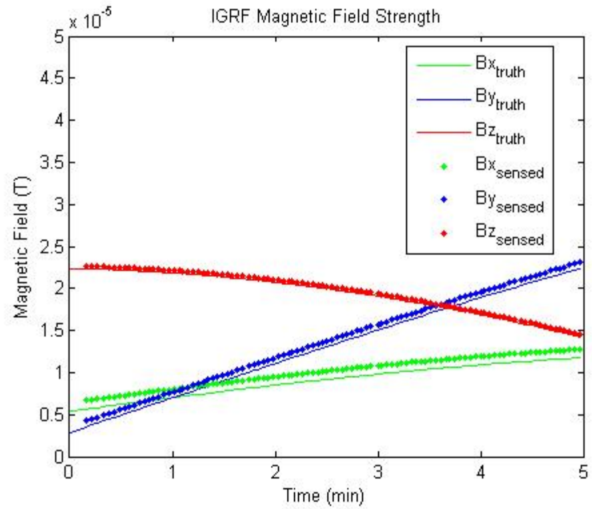
Helmholtz Cage

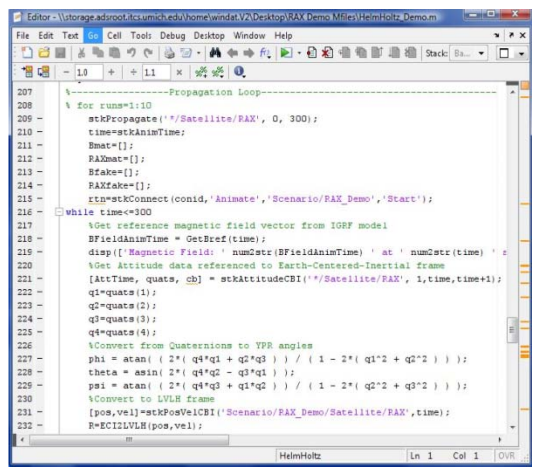


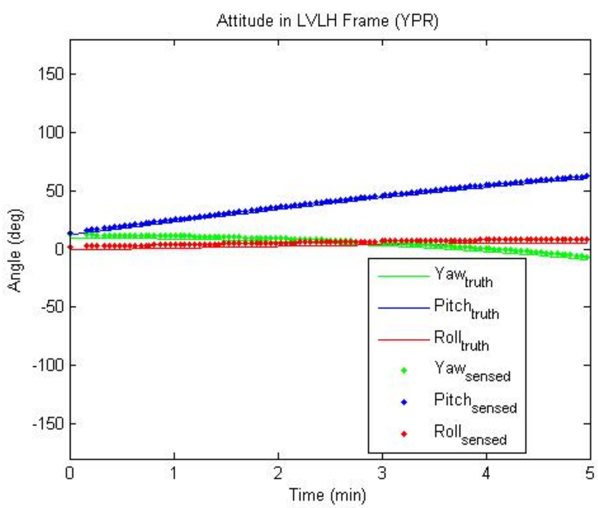
- Operation:
  - Matlab driven power supplies
  - 60,000 feet of copper wire
  - Loops generate magnetic field
- Capability:
  - Calibration and characterization of magnetometers
  - Analogue-Orbit simulator with IGRF referenced magnetic fields
  - Verification of magnetic attitude determination
- Submitted technical paper to the American Aeronautical Society

Magnetic Determination Testing

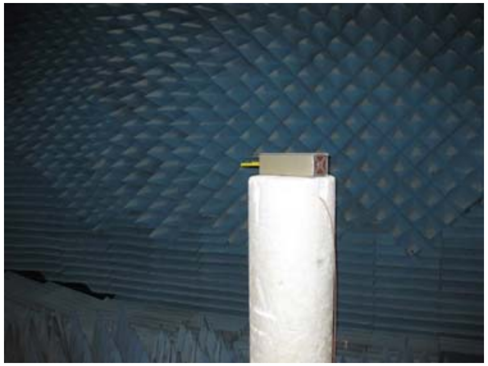








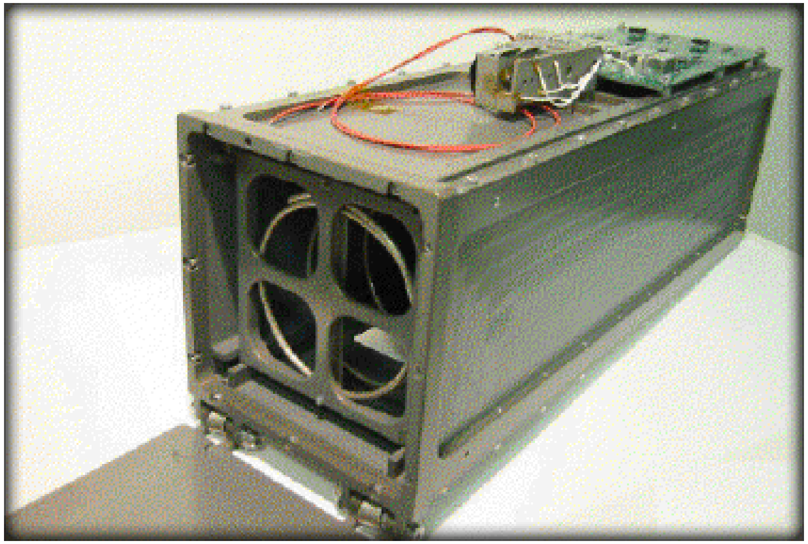
Michigan Facilities: Anechoic Chamber



Michigan Facilities: Plasma Dynamics and Electric Propulsion Lab

Launch

Launch Date: February 2010
Launch Vehicle: Minotaur IV
Launch Location: Kodiak Launch Complex (AK)
Orbit: 650 km circular, 72º inclination



Questions?