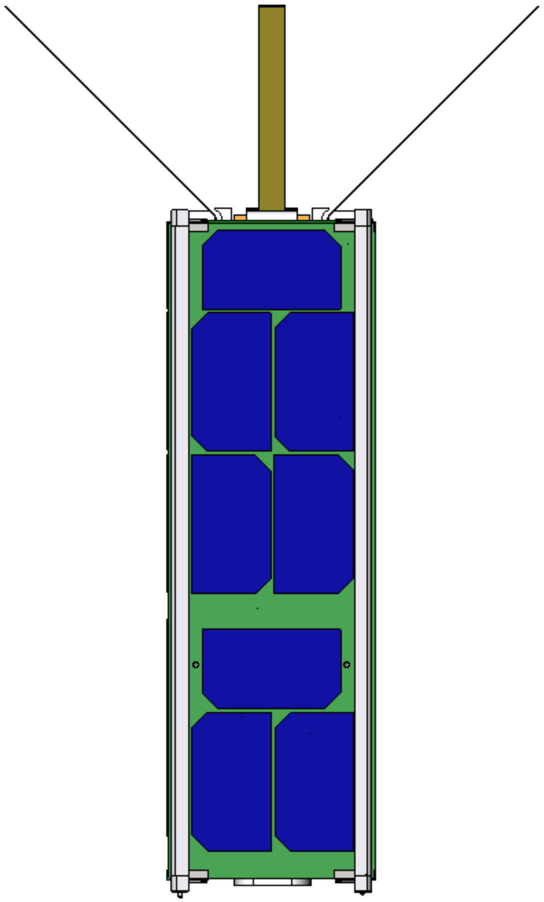
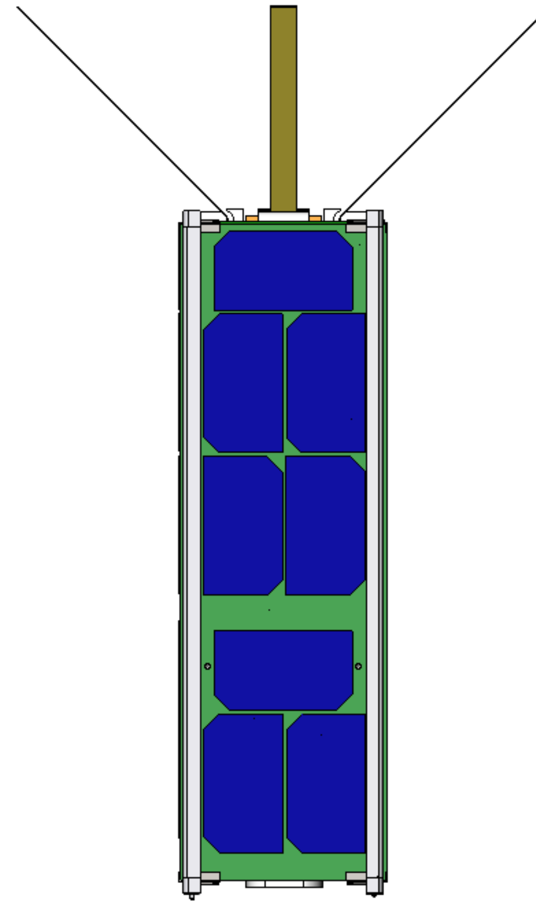
In-Lab Testing for Attitude Determination and Control



RAX

Radio Aurora Explorer

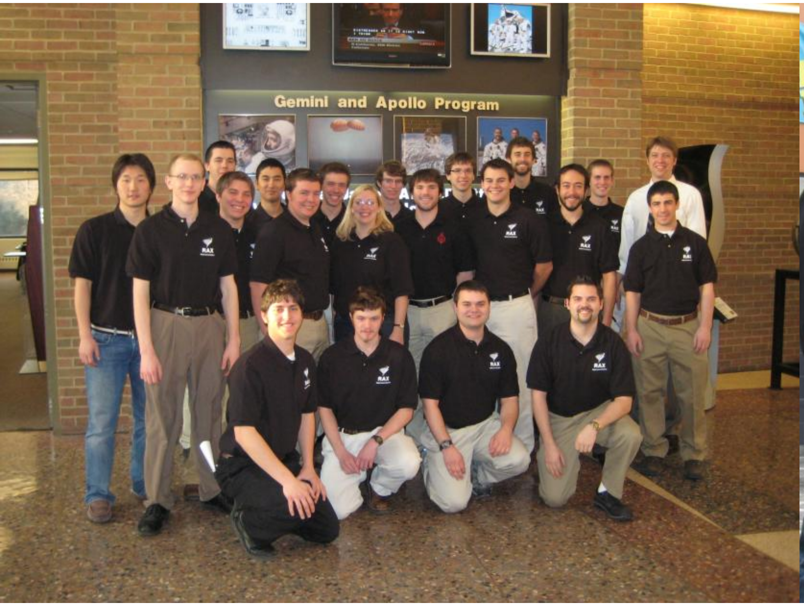


Kiril Dontchev
University of Michigan

CubeSat Workshop
Utah State University, Logan, UT
Aug 9th 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



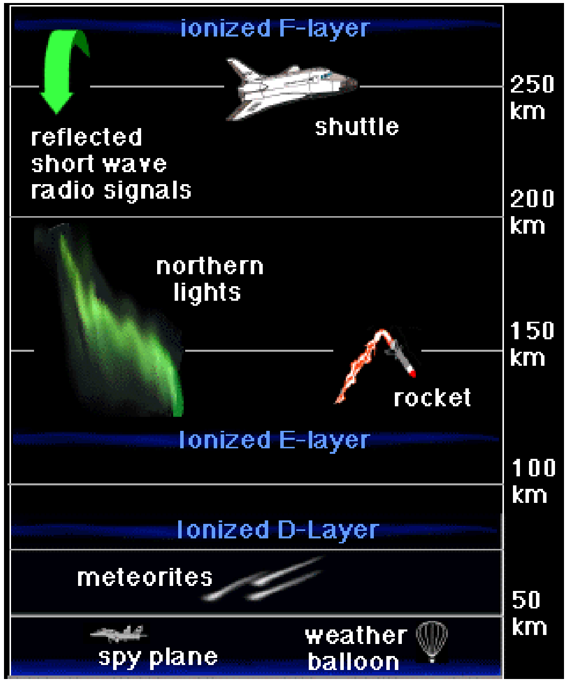
Mission Science

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

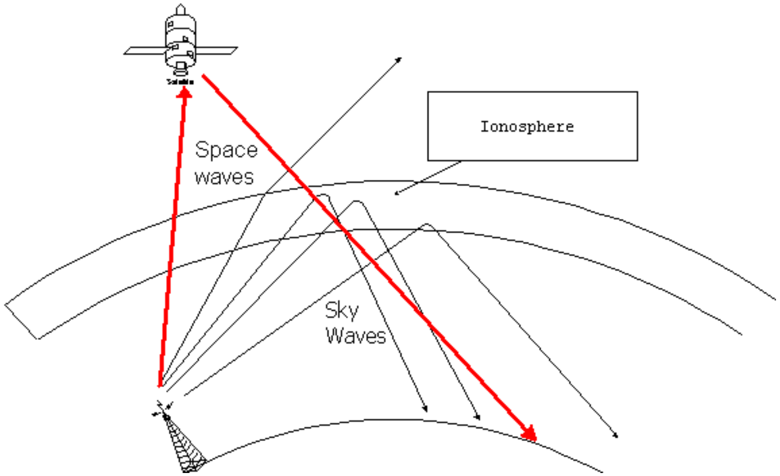


Courtesy UCAR: www.windows.ucar.edu/tour/link%3D/earth/Atmosphere/ion_regions.html

Mission Science

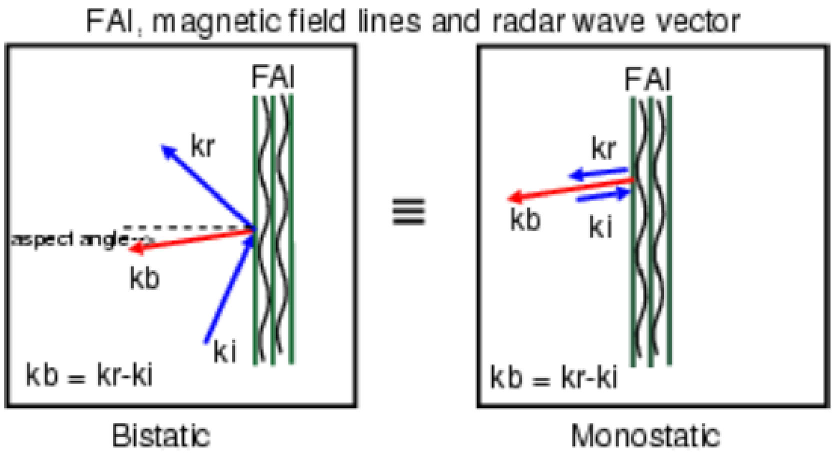
Why Study FAI?

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



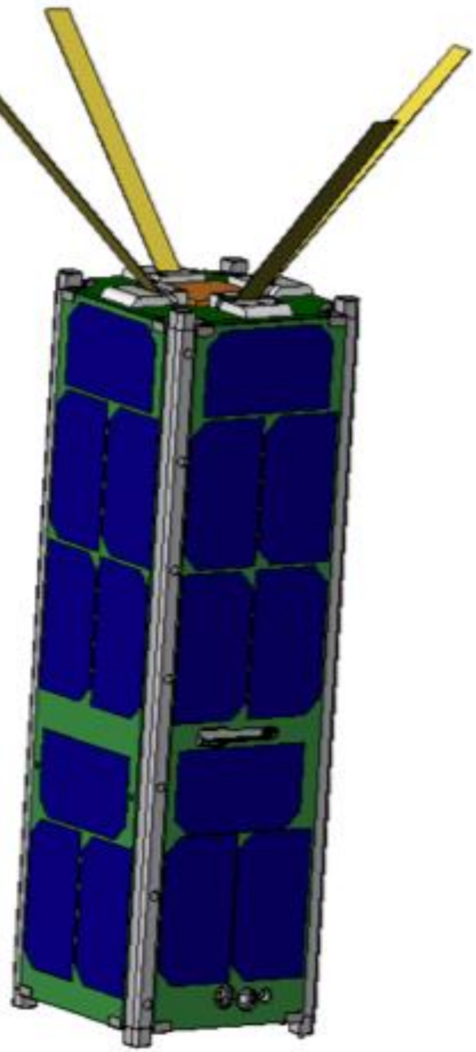
Why Study FAI from orbit?

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



Poker Flats Advanced Modular Incoherent Scatter Radar (PFISR)

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

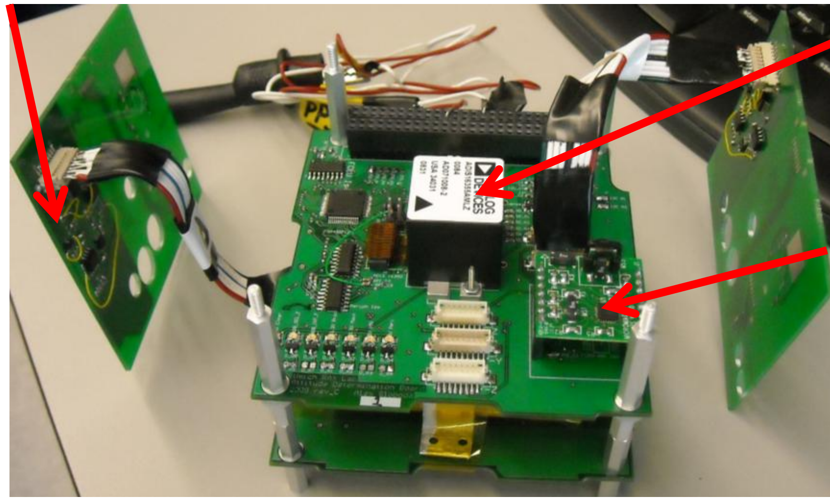
Subsystem Highlights: Position & Attitude

GPS Receiver
Novatel OEMV-1

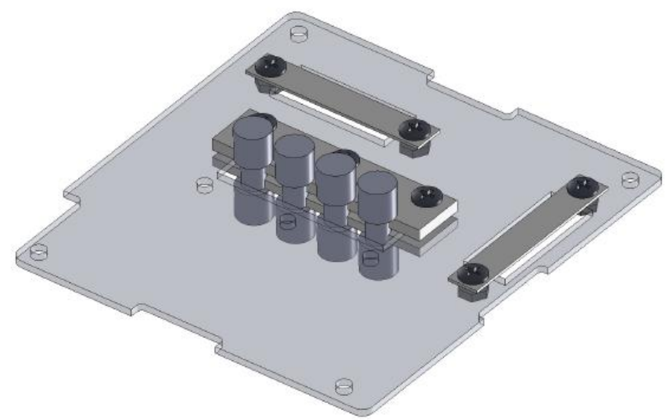
Sun Sensors

ADIS 16405 IMU

PNI MicroMag3 Magnetometer



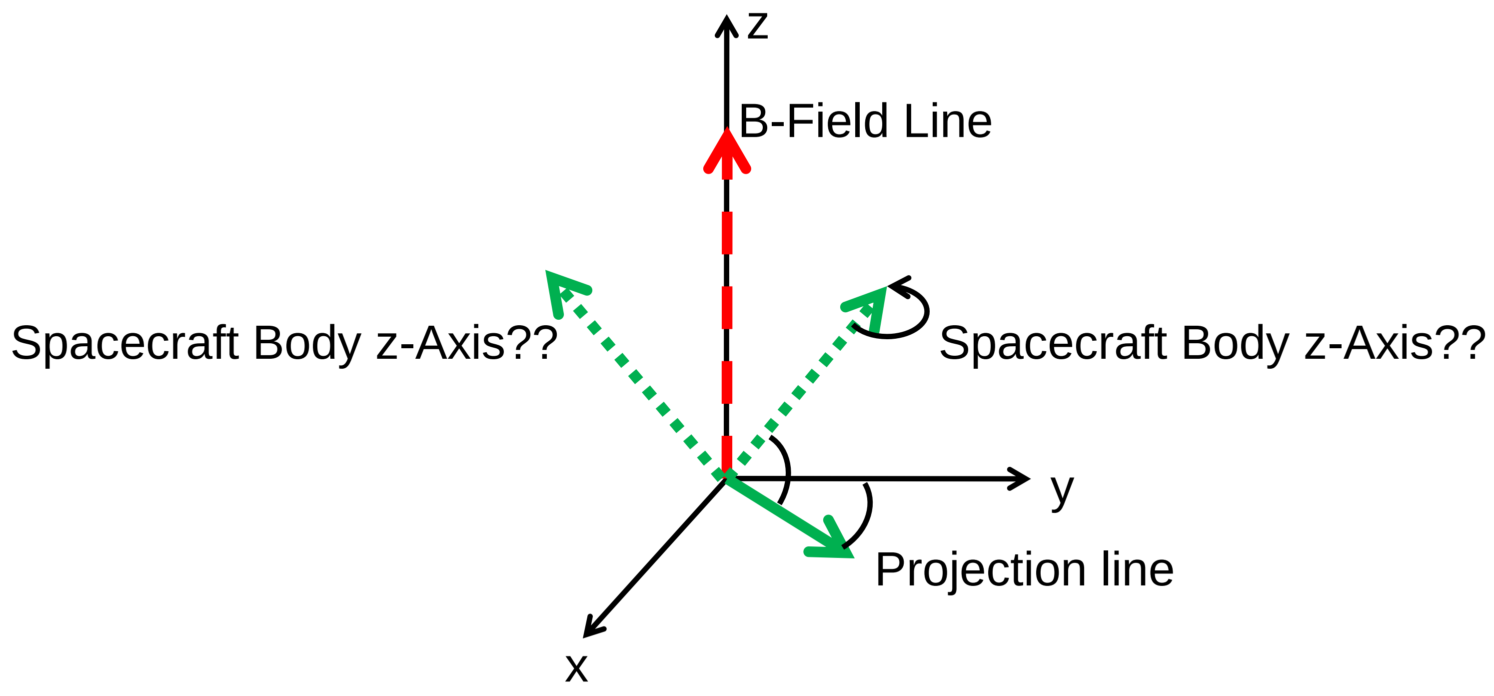
Attitude Determination Board



Attitude Control Board

Magnetic Attitude Determination

- A single 3-axis measurement sample will only provide 2-axis determination



- The yaw of the spacecraft is unobservable

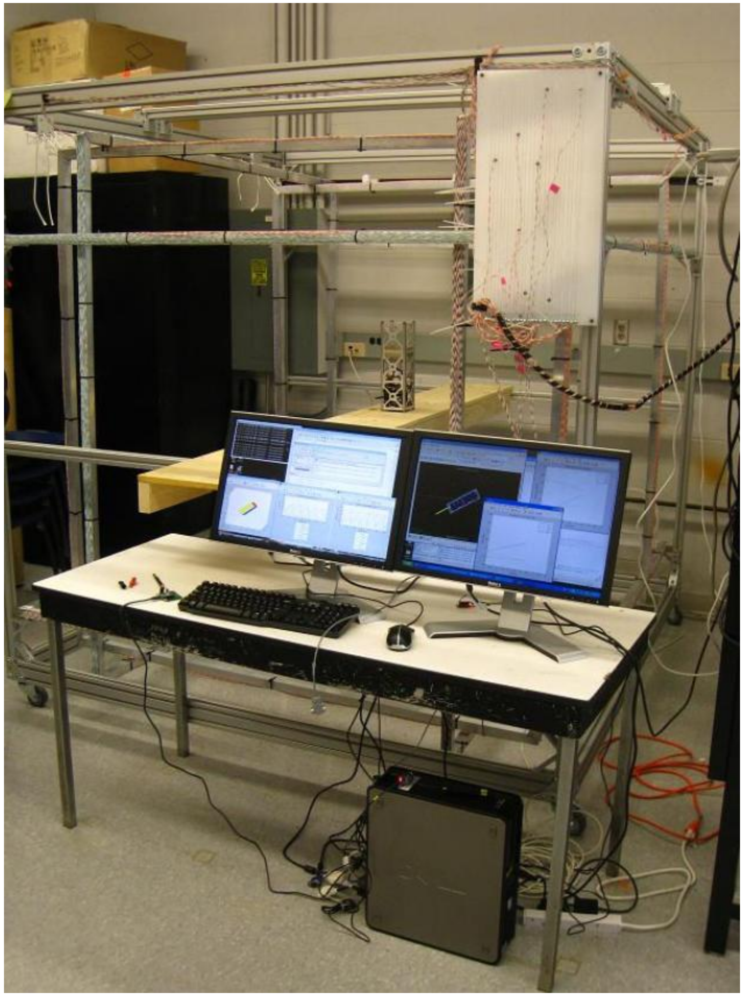
Magnetic Attitude Estimation

- Kalman Filtering with multiple measurements

M. Psiaki, F. Martel, P. Pal, "Three-axis attitude determination via Kalman filtering of magnetometer data," Journal of Guidance, Control and Dynamics, vol 13, no 3 1990

- Requires multiple **changing** samples for accurate determination or **additional** (different) onboard sensors

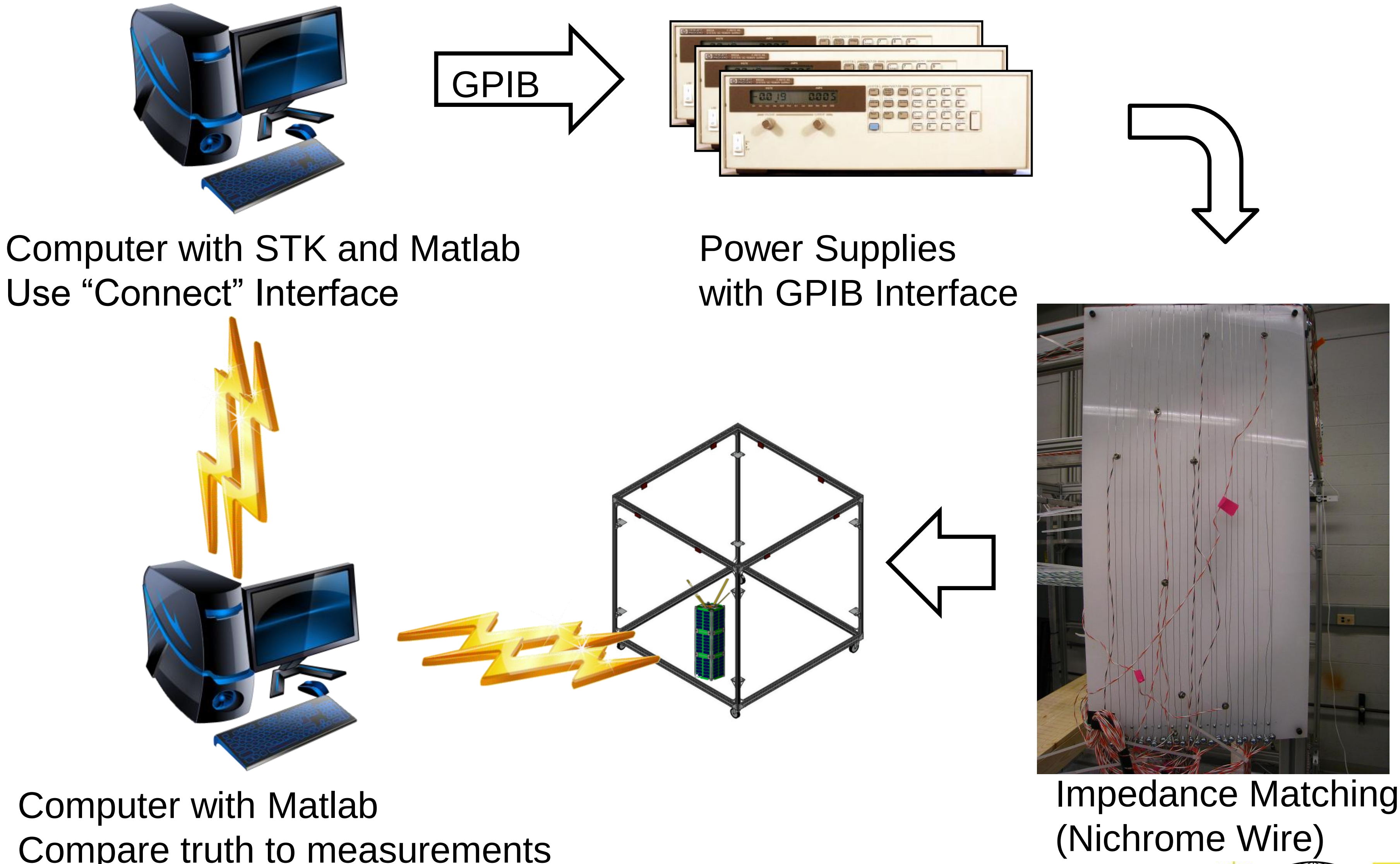
Helmholtz Cage



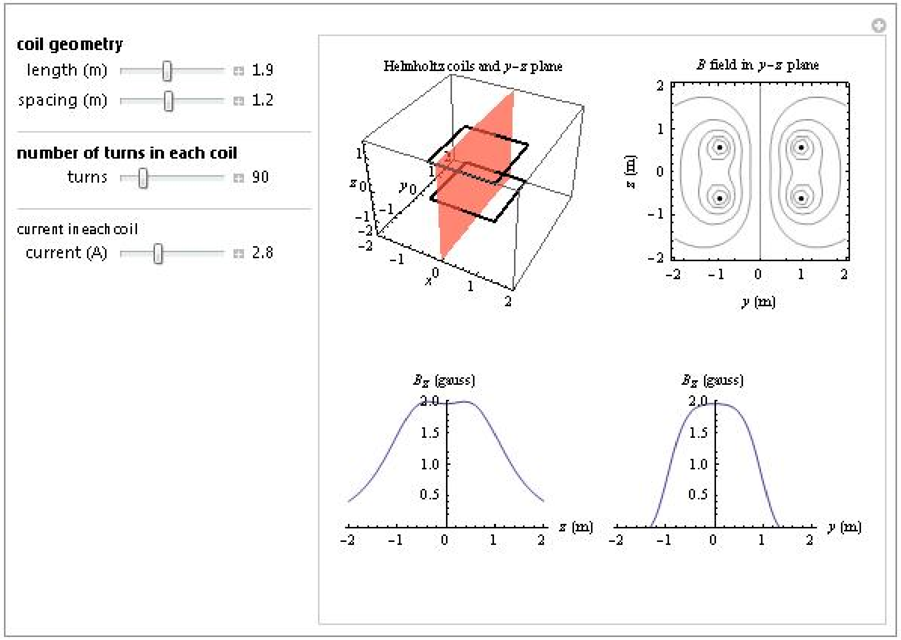
- Operation:
  - Matlab driven power supplies
  - 60,000 feet of copper wire
  - Loops generate magnetic field
- Capability:
  - Calibration and characterization of magnetometers
  - Analogue-Orbit simulator with IGRF referenced magnetic fields
  - Verification of magnetic attitude determination

"Dynamically Driven Helmholtz Cage for Experimental Magnetic Attitude Determination", AAS 2009

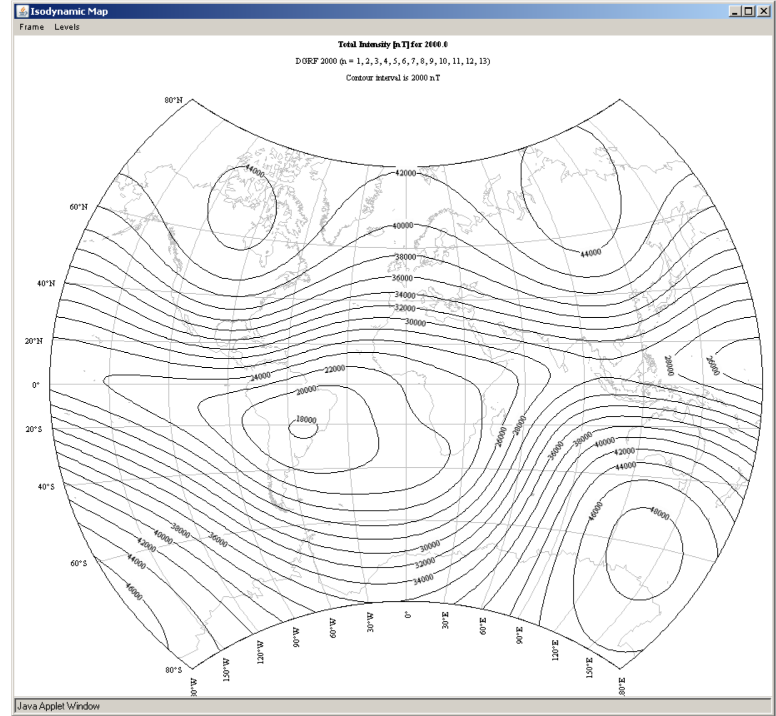
Helmholtz Schematic



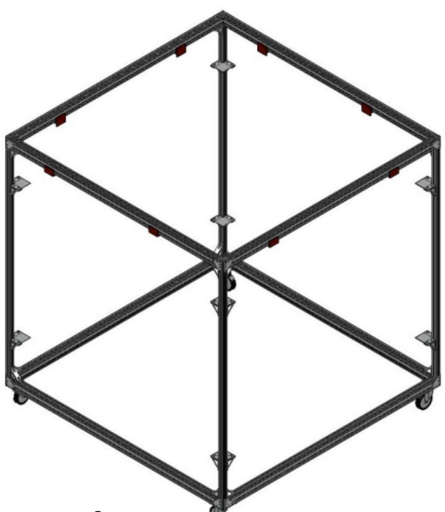
Helmholtz Design



http://demonstrations.wolfram.com/SquareHelmholtzCoils/



International Geomagnetic Reference Field Database

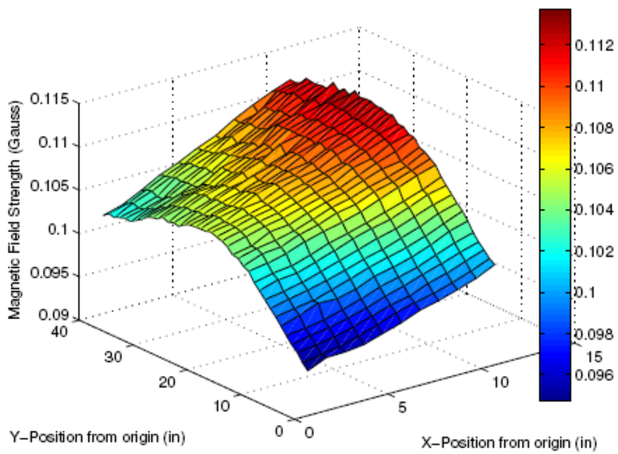


"DELFI-C3: Delft University of Technology's Nanosatellite," Delfi University

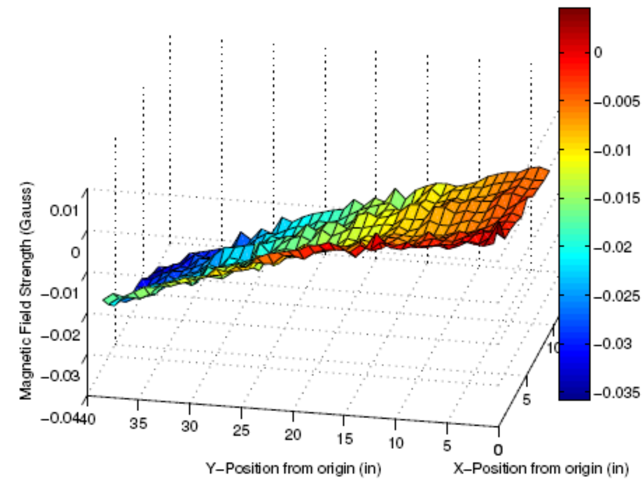
Radio Aurora Explorer

K. Dontchev

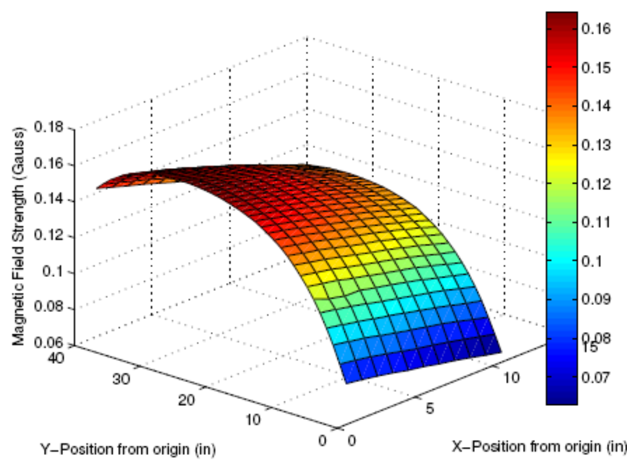
Helmholtz Accuracy



(a) B_x Magnitude



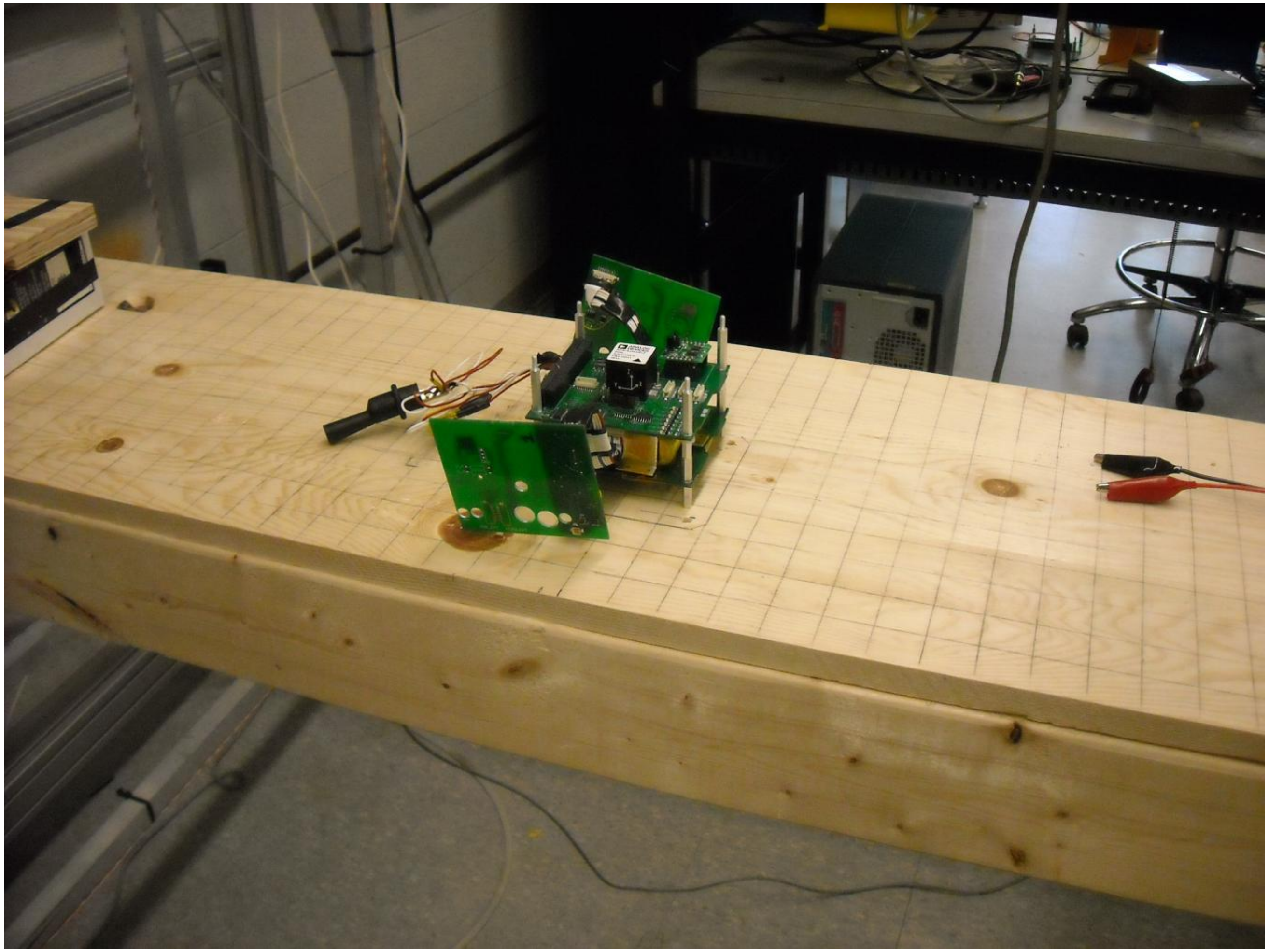
(b) B_y Magnitude



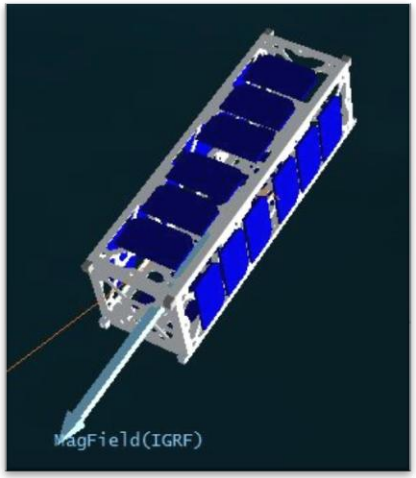
(c) B_z Magnitude

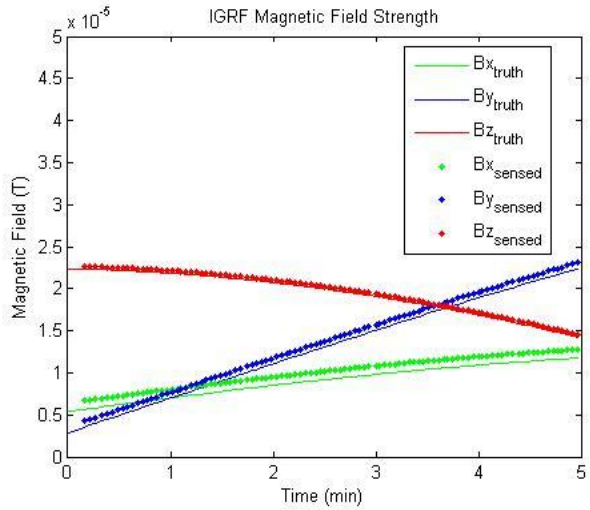
“Calibrating a triaxial accelerometer-magnetometer-using robotic actuation for sensor reorientation during data collection,” IEEE Control Systems Magazine

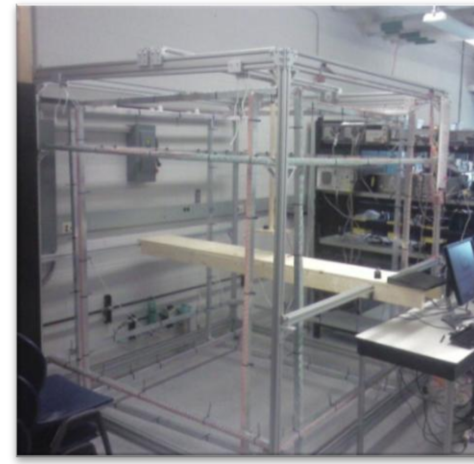
Integrated Testing

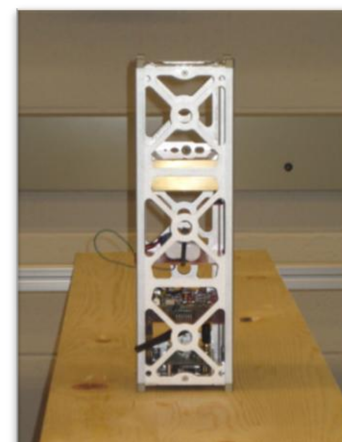


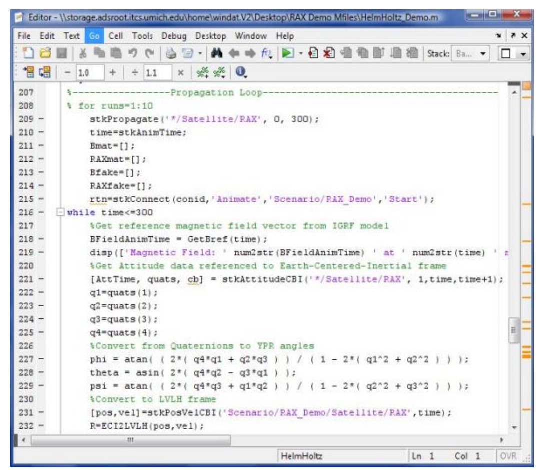
Magnetic Determination Testing

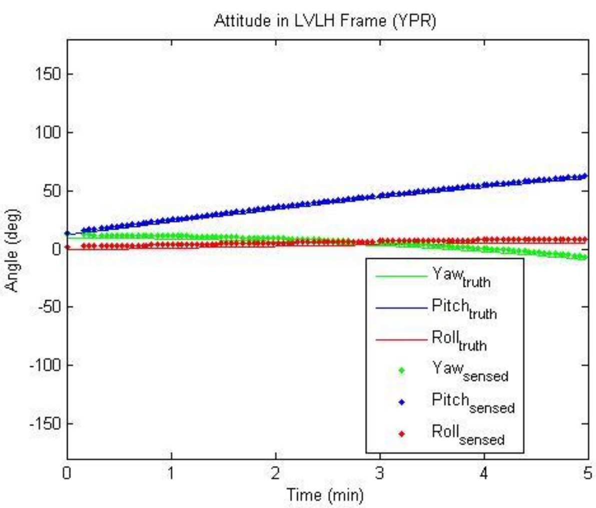












Air Bearing

- Acrylic sphere on non-magnetic air bearing
- Allows for full attitude determination and control testing
- Can be utilized **inside** the Helmholtz cage

Conclusions

- Magnetic determination must be done with multiple samples or multiple sensors

- In-house testing is difficult, but a dynamically driven cage is very useful

- Matlab and STK control add significant flexibility

Future Work

- Full integrated testing
- Total attitude estimation error measurement
- Sun sensors and solar cells
- Integrated GPS Simulator

Objective: A total position and attitude determination test facility within the RAX lab environment

Questions?

Contact us for more information!

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