AGILE PRACTICES IN A NANOSATELLITE DESIGN LABORATORY

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Thank you, and why I'm here

Foster conversation on software and system related to…

Aerospace

University/Industry/Government/etc

Complex systems

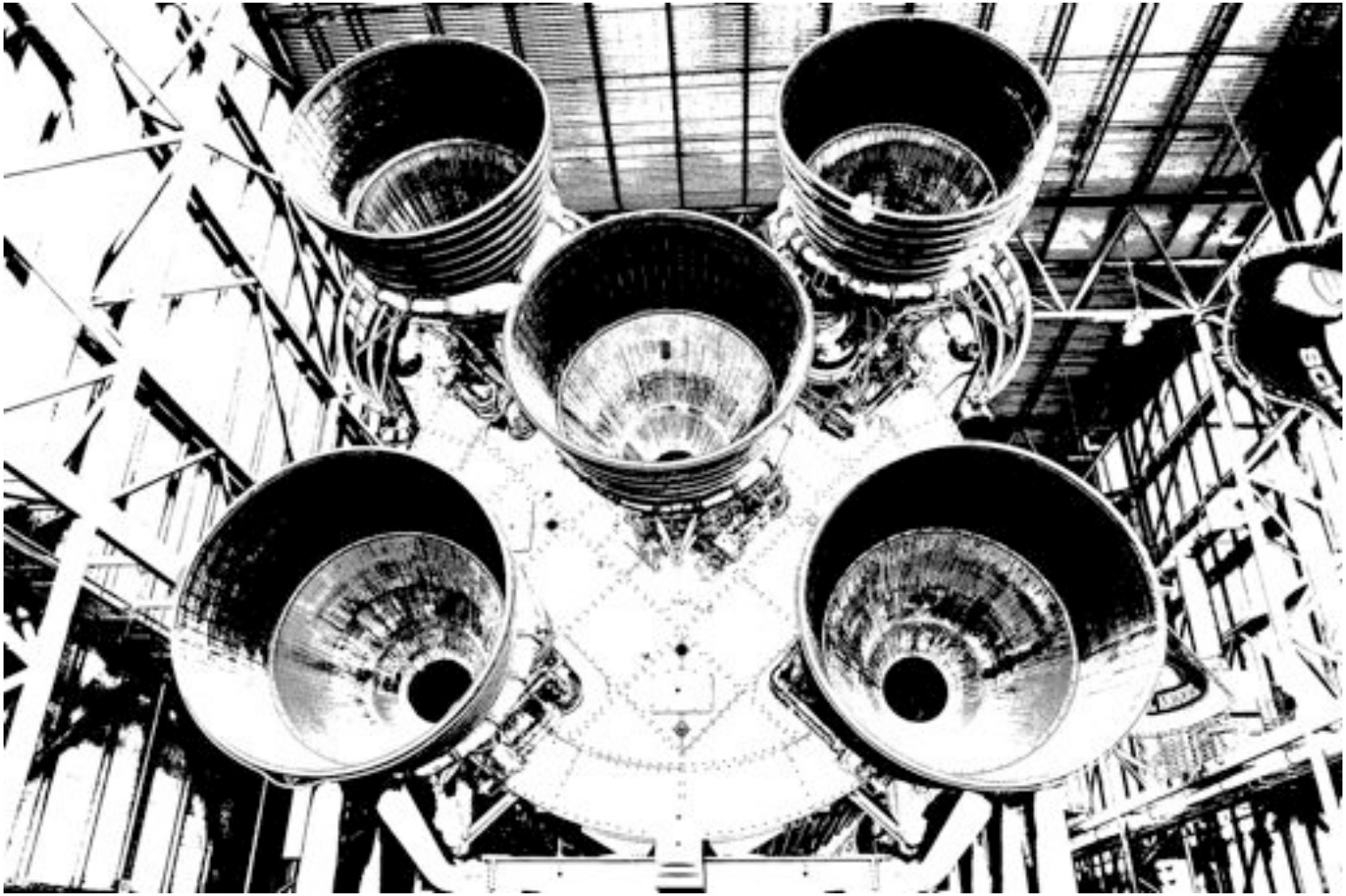
The Story

- Part 0 – Background
- Part I – Nanosatellites
- Part 2 – Agility

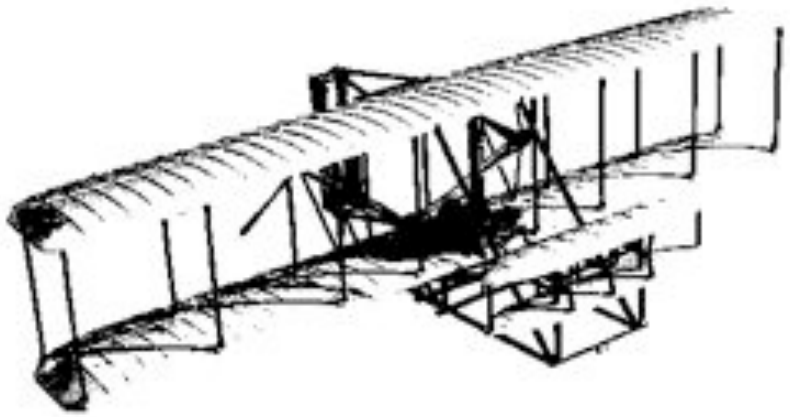
Personal Background/Confessions

- I am not a wizard…
  - But I can understand thinkgeek.com shirts.
- I wish everything was software defined.
- *I am a space nerd…*
  - And I have many things in orbit.
- I use vim.

Rorschach Test



Rorschach Test



Rorschach Test

Remember When?

Rorschach Test

Think Big…

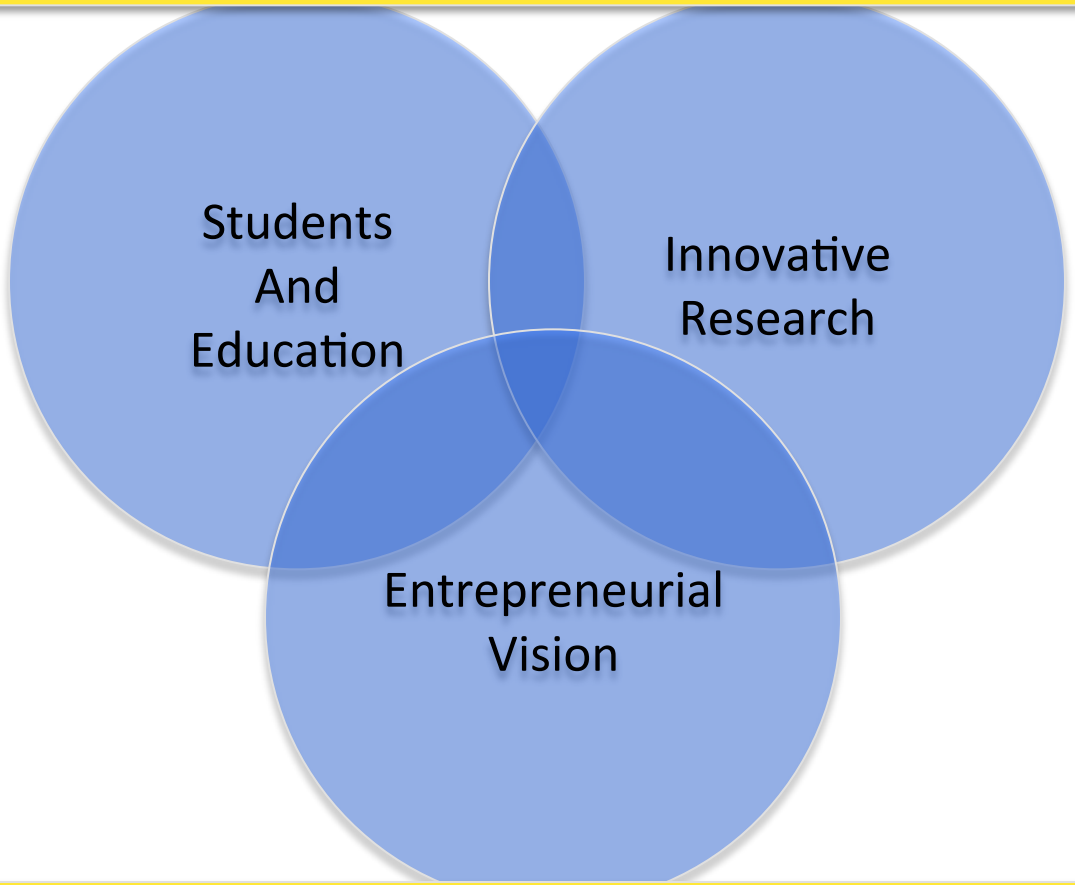
Can we cache the entire web?

Can we cache the entire Earth?

-- Julian Mann, CTO, Skybox

Michigan Exploration Labs (MXL)

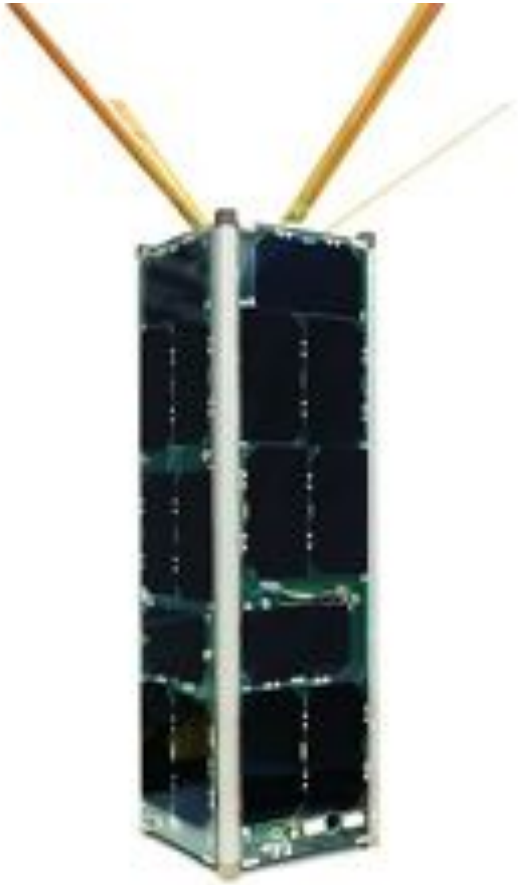
Enabling bold flight to extreme and remote environments.



…R&D, innovation in space…

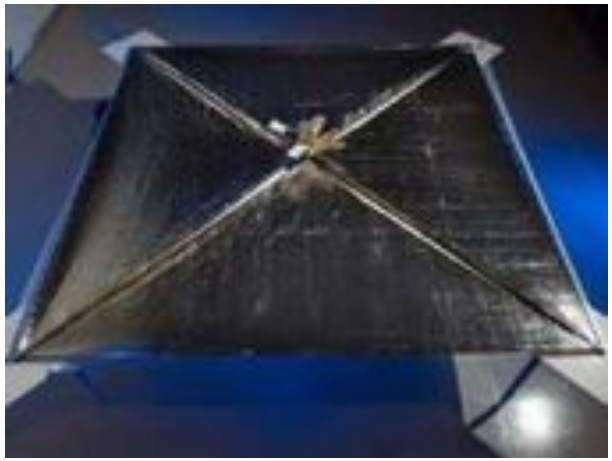
Part 1 – Nanosatellites

- **What's a nanosatellite?**
  - Small satellite with mass < 10 kg
- **Why?**
  - Easier access to space (cheaper and faster?)
  - Educational opportunities
  - Ability to perform novel missions
- **Potential Applications**
  - Distributed science missions
  - Technology demonstrations
  - Forerunner/precursor mission
- **HIGHLY constrained**
  - Size, Mass, Power, Cost, Delivery Time
  - Example: CubeSat form factor (1U=10cm^3, <1 kg)



RAX, the first NSF funded nanosatellite and built by MXL

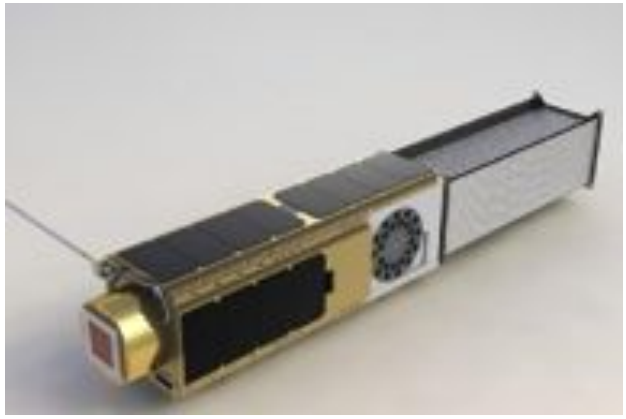
Examples



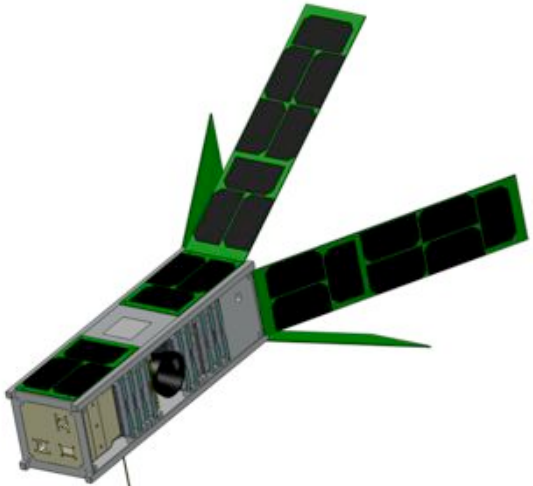
Nanosail-D @ NASA Marshall

SNAP-1 @ Surrey

Cinema @ UC-Berkeley



OOREOS @ NASA Ames



CADRE @ UMich

NSF Space Weather Cubesat Program

- Space-based measurements from small satellites have ***great potential*** to advance discovery and understanding of space weather.

- Equally important, such missions play a crucial role in ***training the next generation*** of experimental space scientists and aerospace engineers.

- Regular access to space, provided by small satellites, will ***maintain creativity and innovation*** in space science and aerospace engineering and keep a general widespread interest in space.

Moretto, T. and R. M. Robinson (2008),
Small Satellites for Space Weather Research,
Space Weather, 6, S05007, doi:10.1029/2008SW000392.

Initial Conditions – Sept. 2008

RAX is the first NSF-funded mission…

Cubesat form factor

Launch: STP –S26 December 2009

650 km, 72^{o} inclination

Delivery in less than 12 months

Deorbit within 25 years of mission end

Low mass…less than 3kg

The Team

Co-investigators:

Dr. Hasan Bahcivan

Prof. James Cutler

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

44 students and professionals working on RAX (no full time)

Motivation

RAX addresses *the fundamental nature of ionospheric plasma irregularities* in the Earth's thermosphere. These irregularities are the basis of a natural space-weather phenomenon that can compromise the operation of communication and navigation satellites—with potentially disastrous consequences for both commerce and safety.

Fredrick Church, Magnetic Storm of 1859

Motivation

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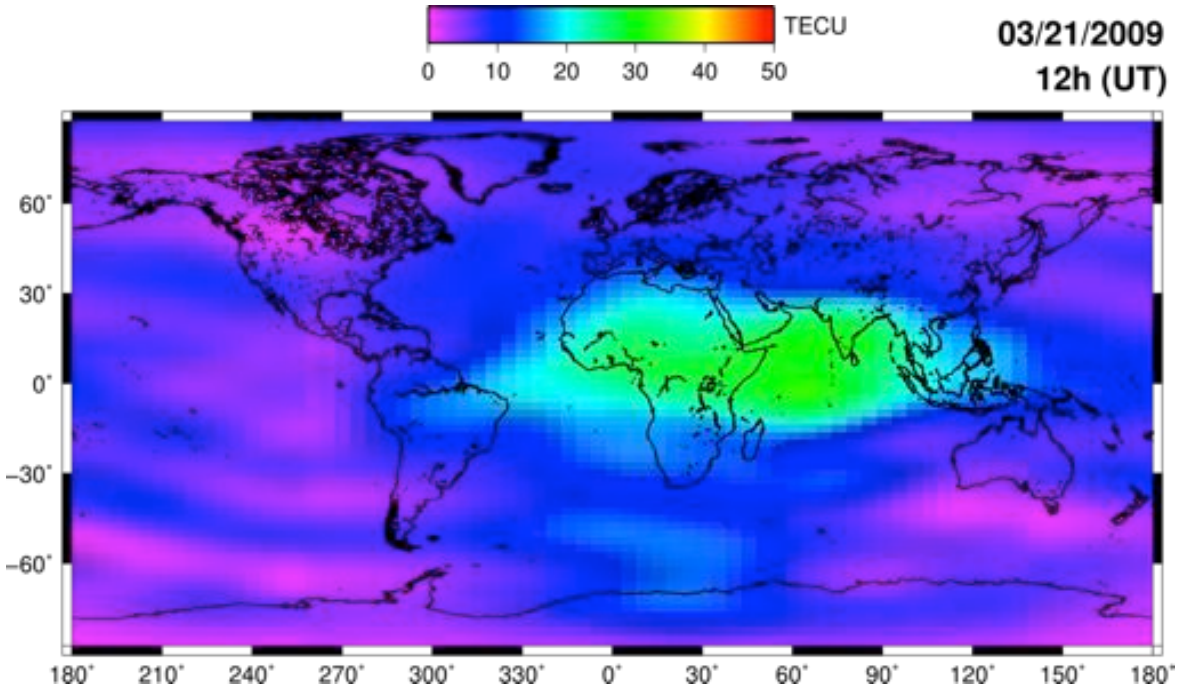


Concept of Operations

+

Transmitter

Incoherent Scatter Radar
(Arecibo, PFISR, ESR, Millstone)

Receiver

RAX Cubesat

Concept of Operations – 1

(to scale)

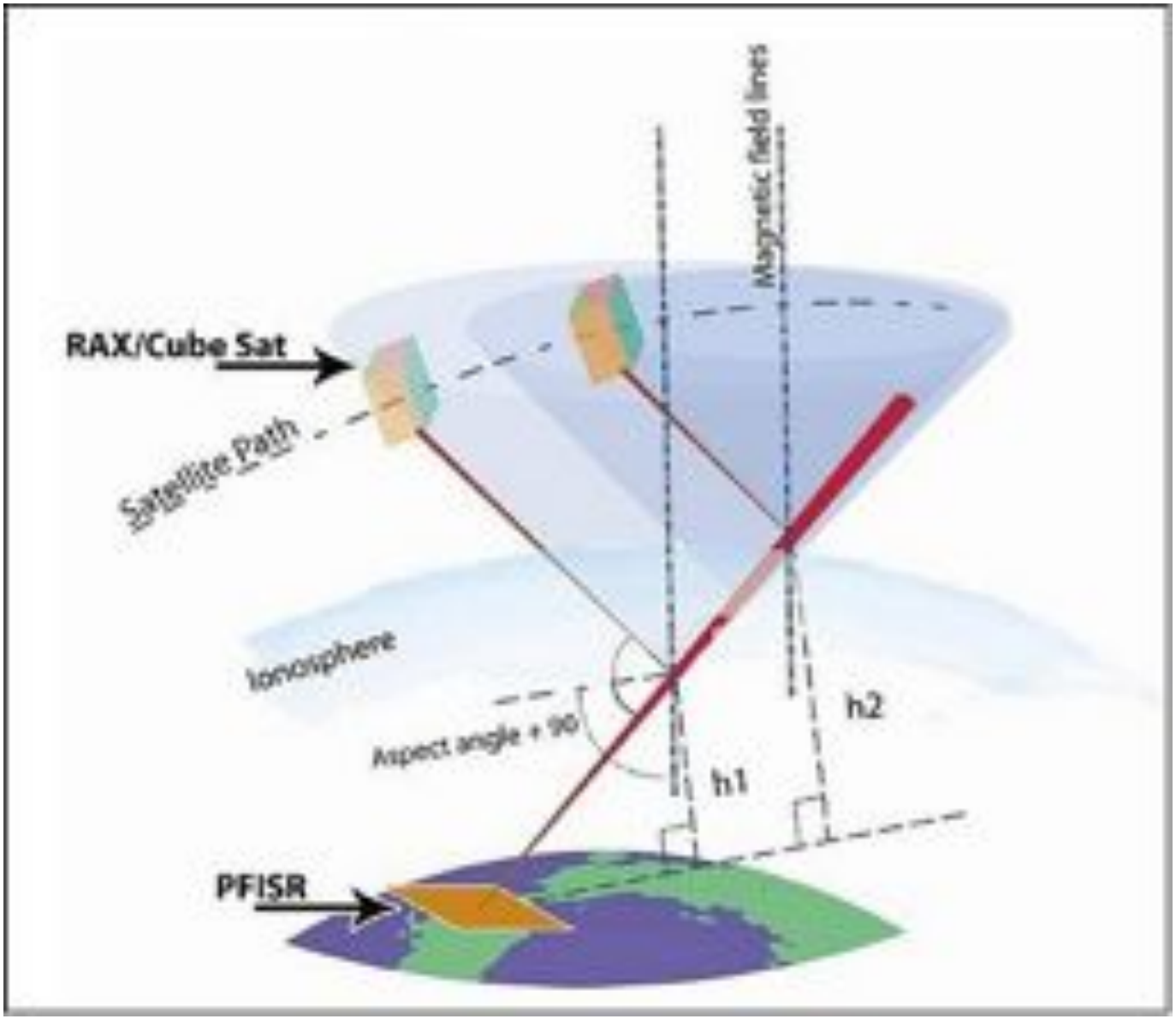
Transmitter

Incoherent Scatter Radar
(Arecibo, PFISR, ESR, Millstone)

Receiver

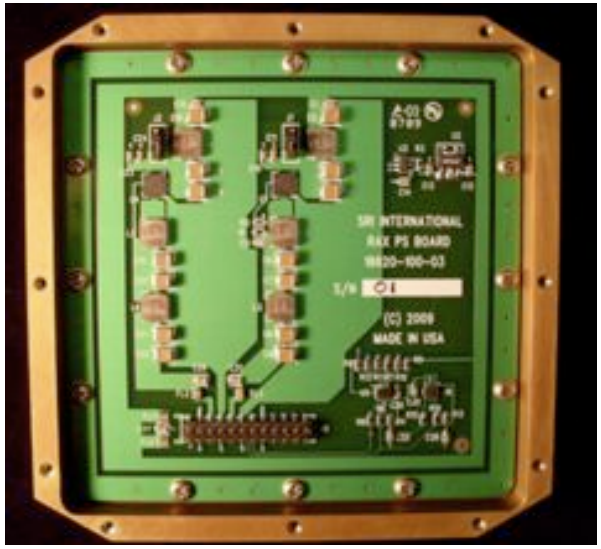
RAX Cubesat

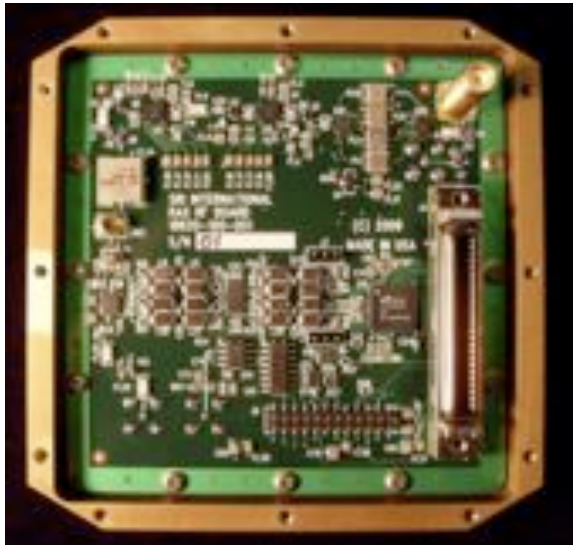
Concept of Operations



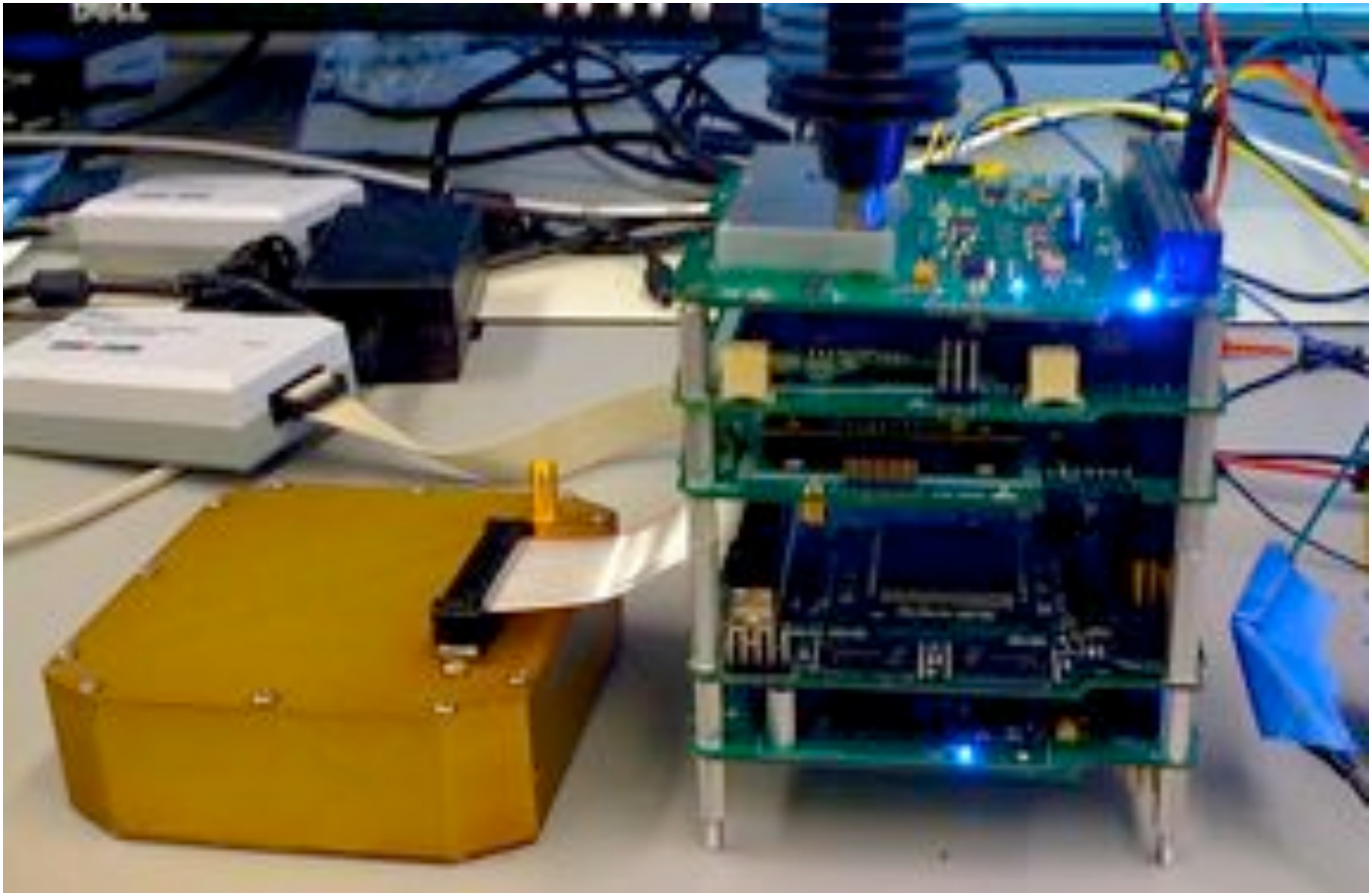
SRI Payload

Radar Receiver – RF Spectrum Analyzer

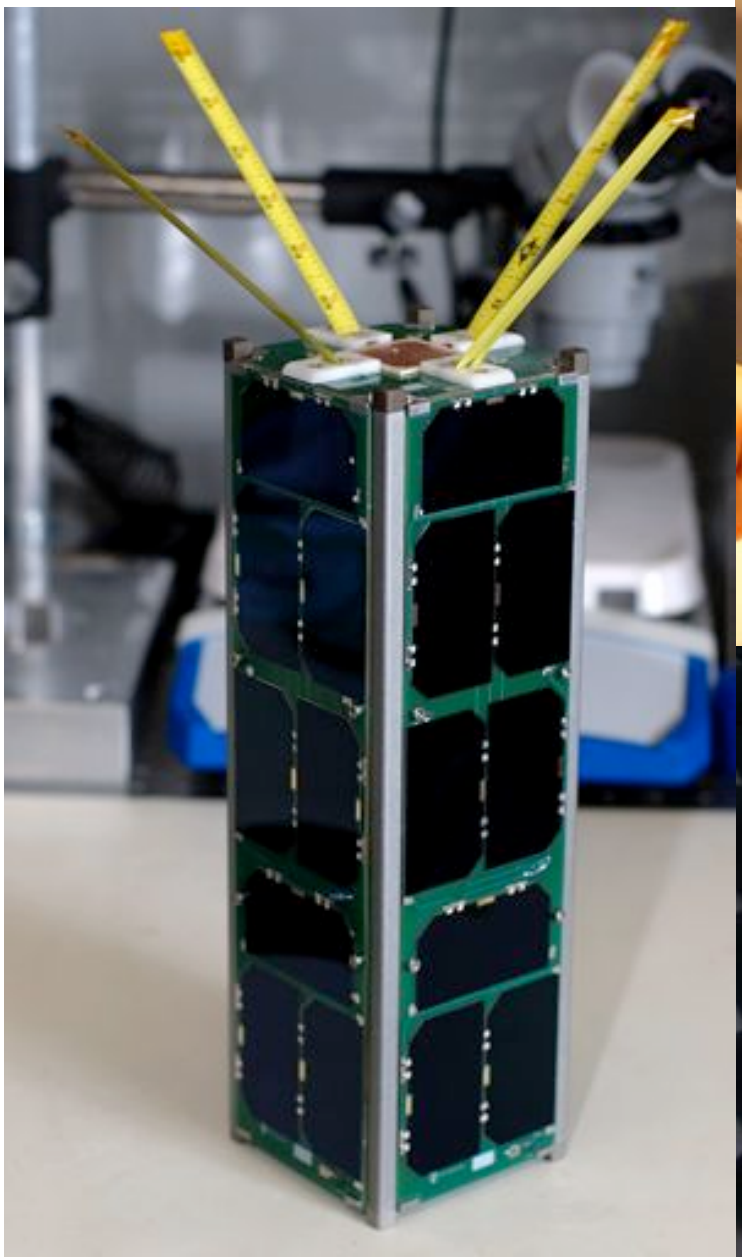


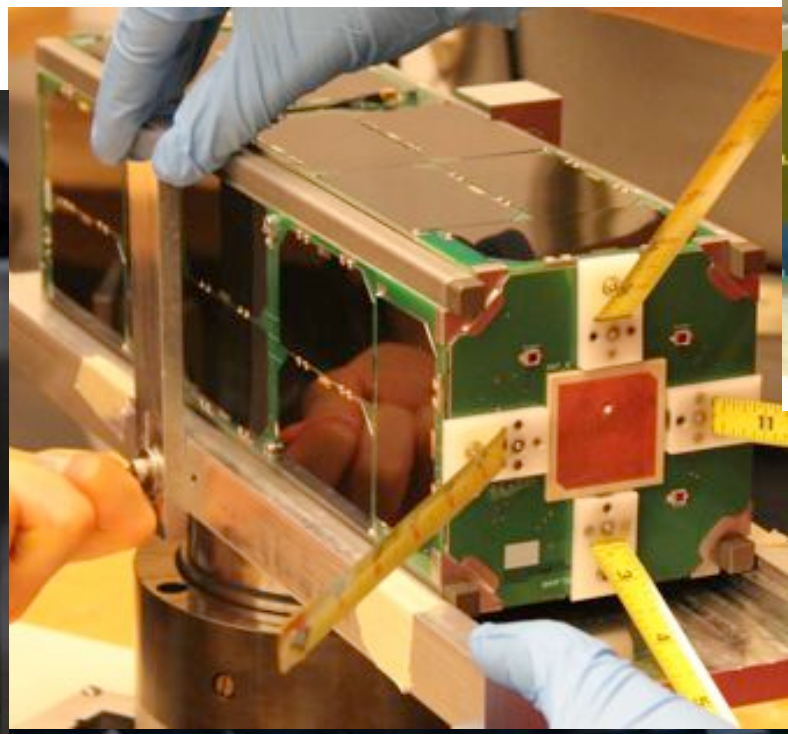


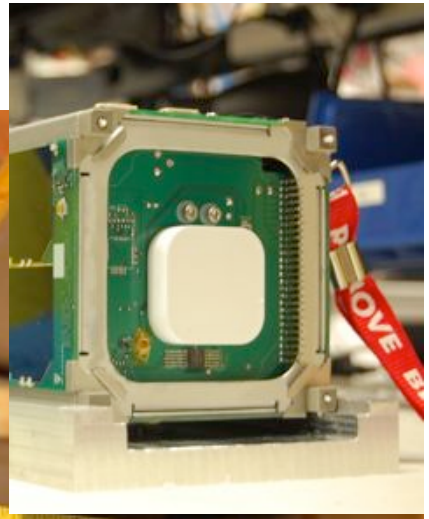
Radar Processing

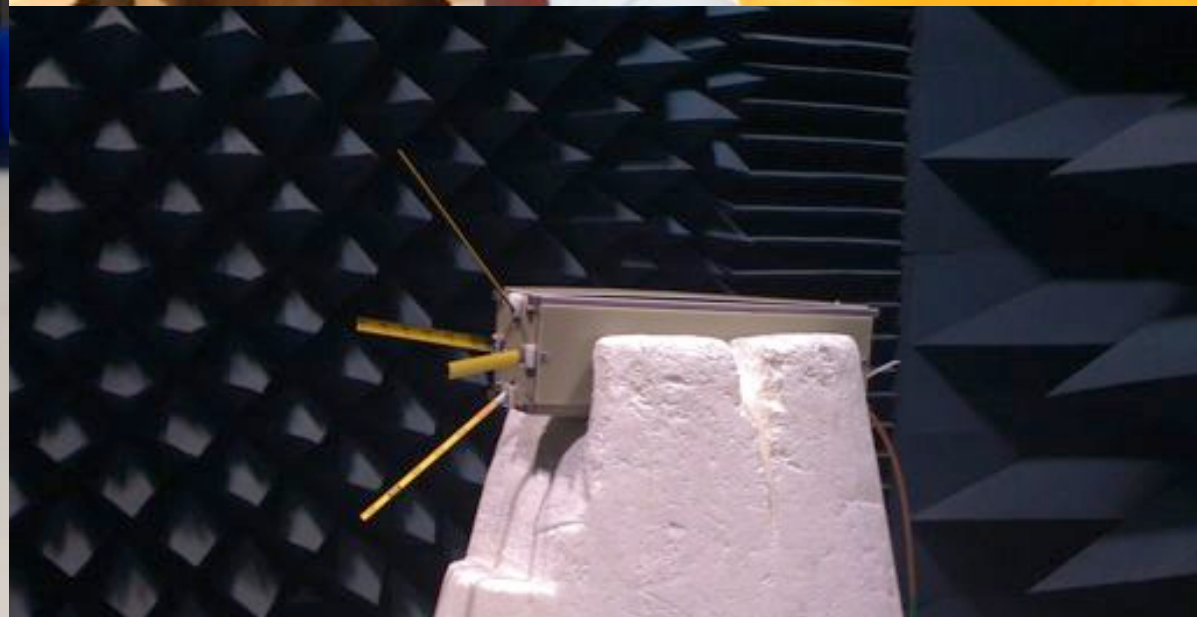


Antennas

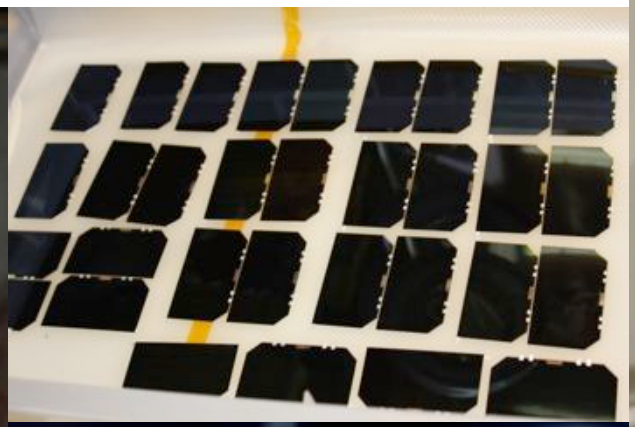


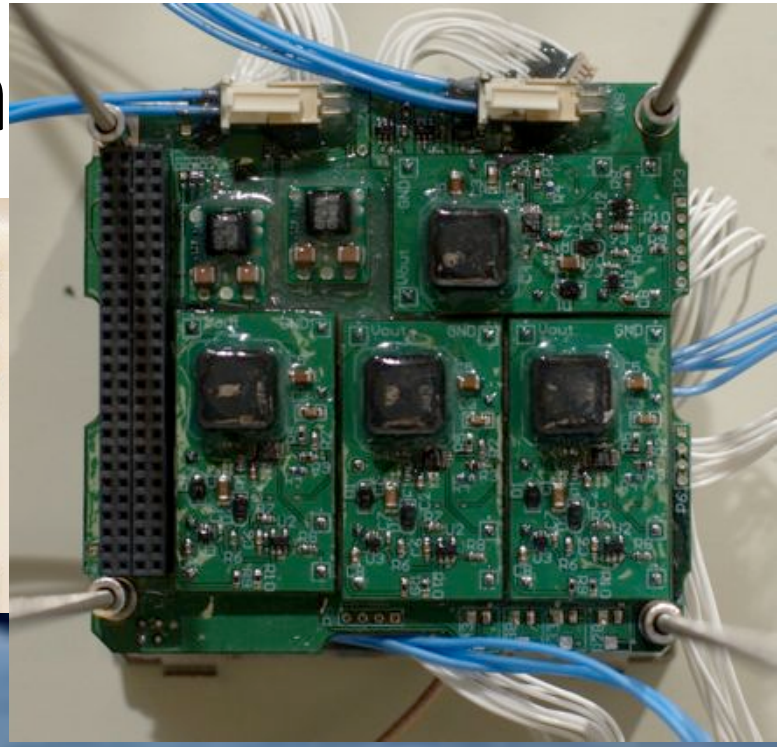


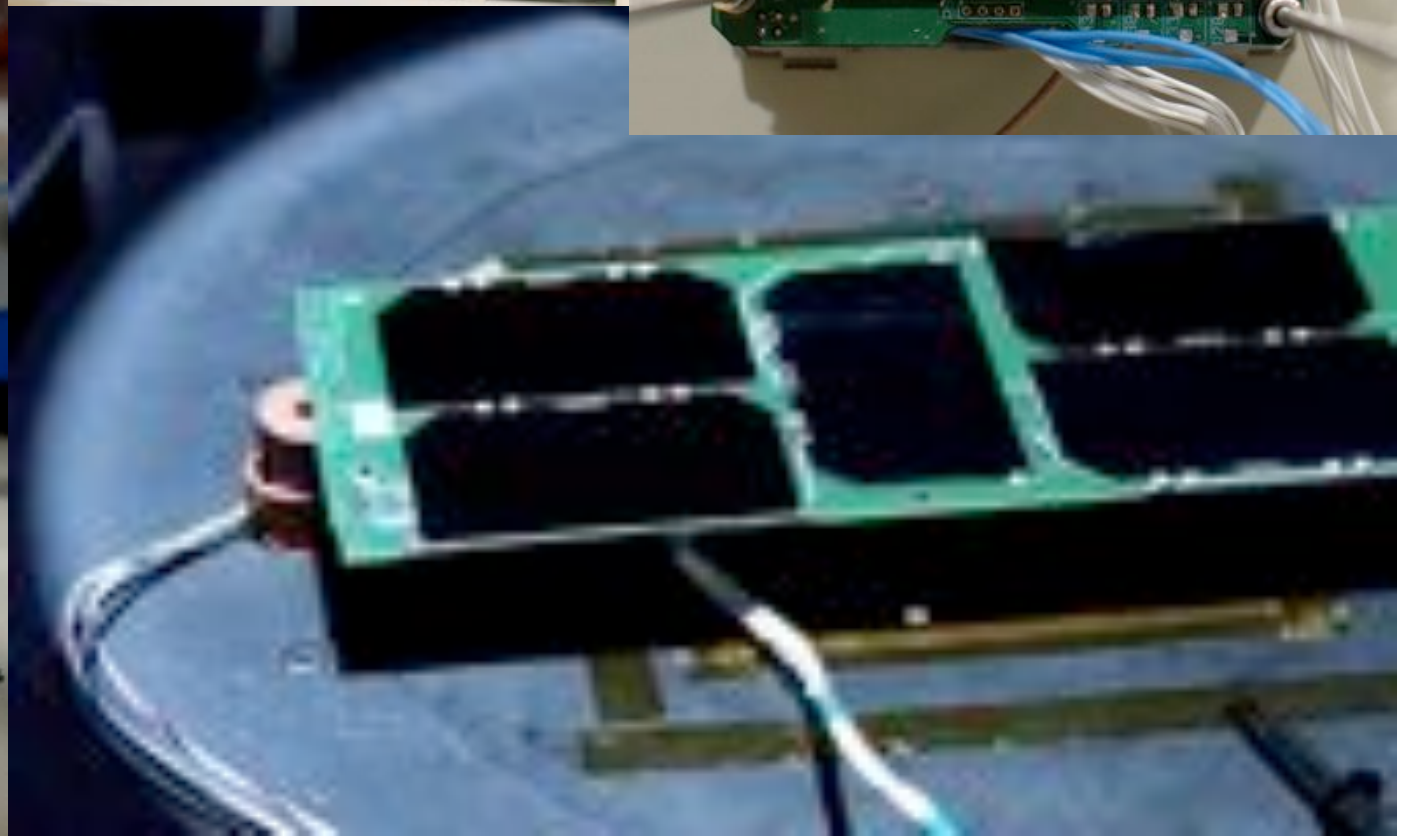




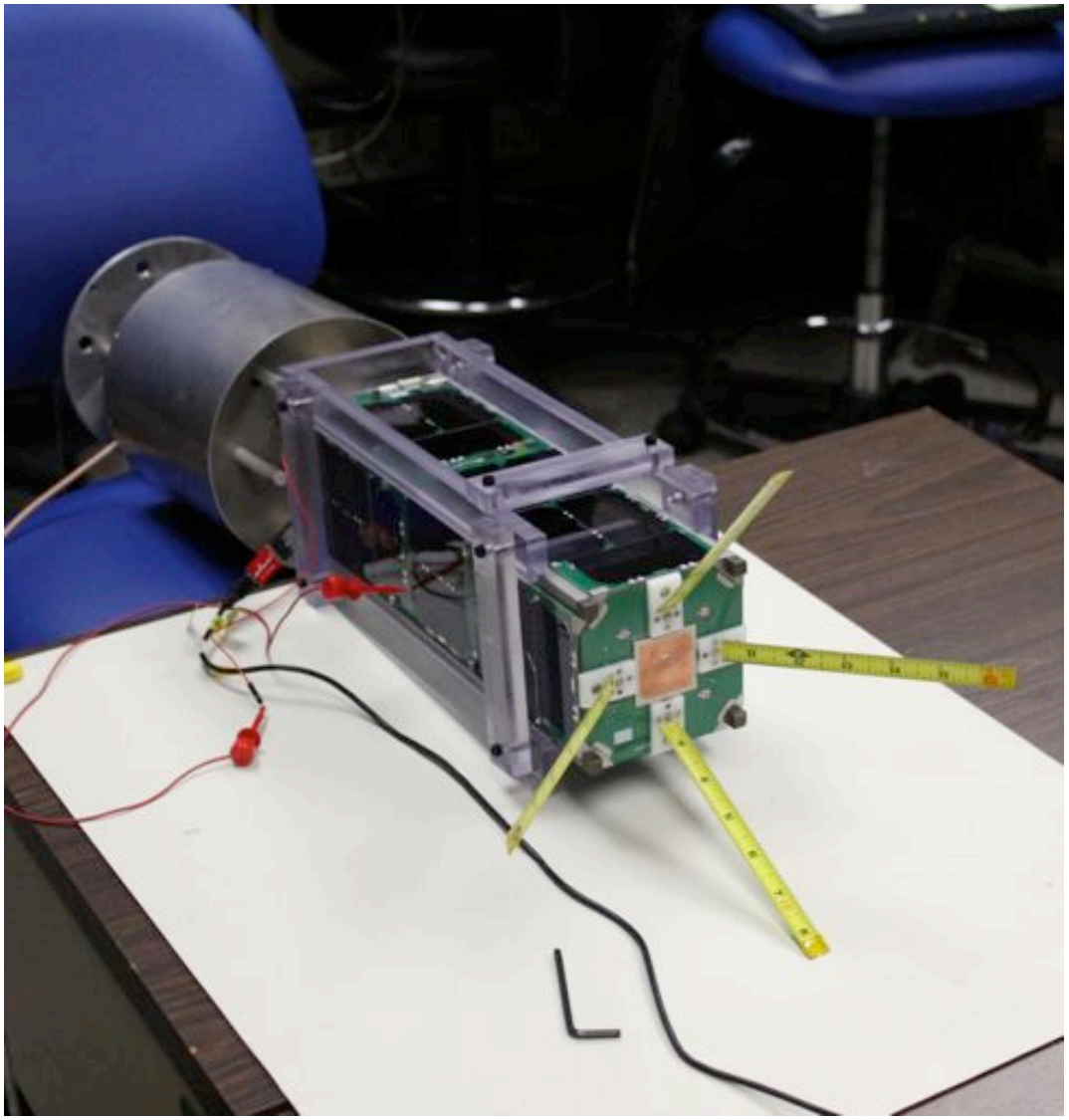
Electrical Power System

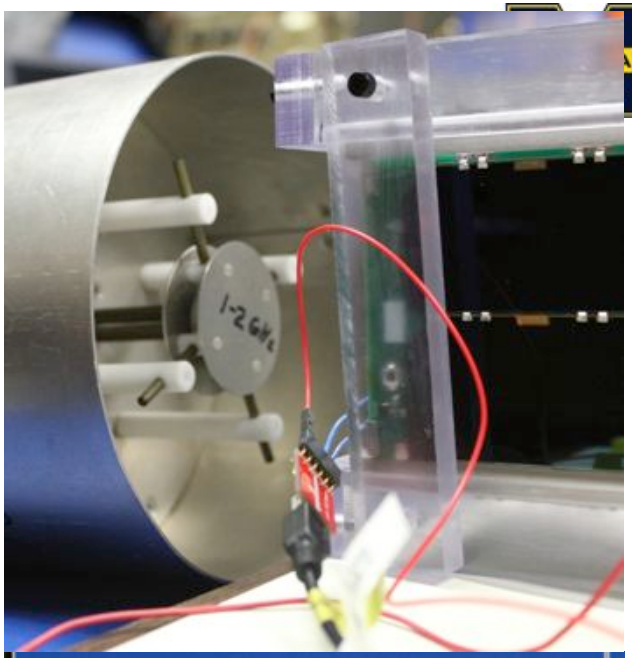




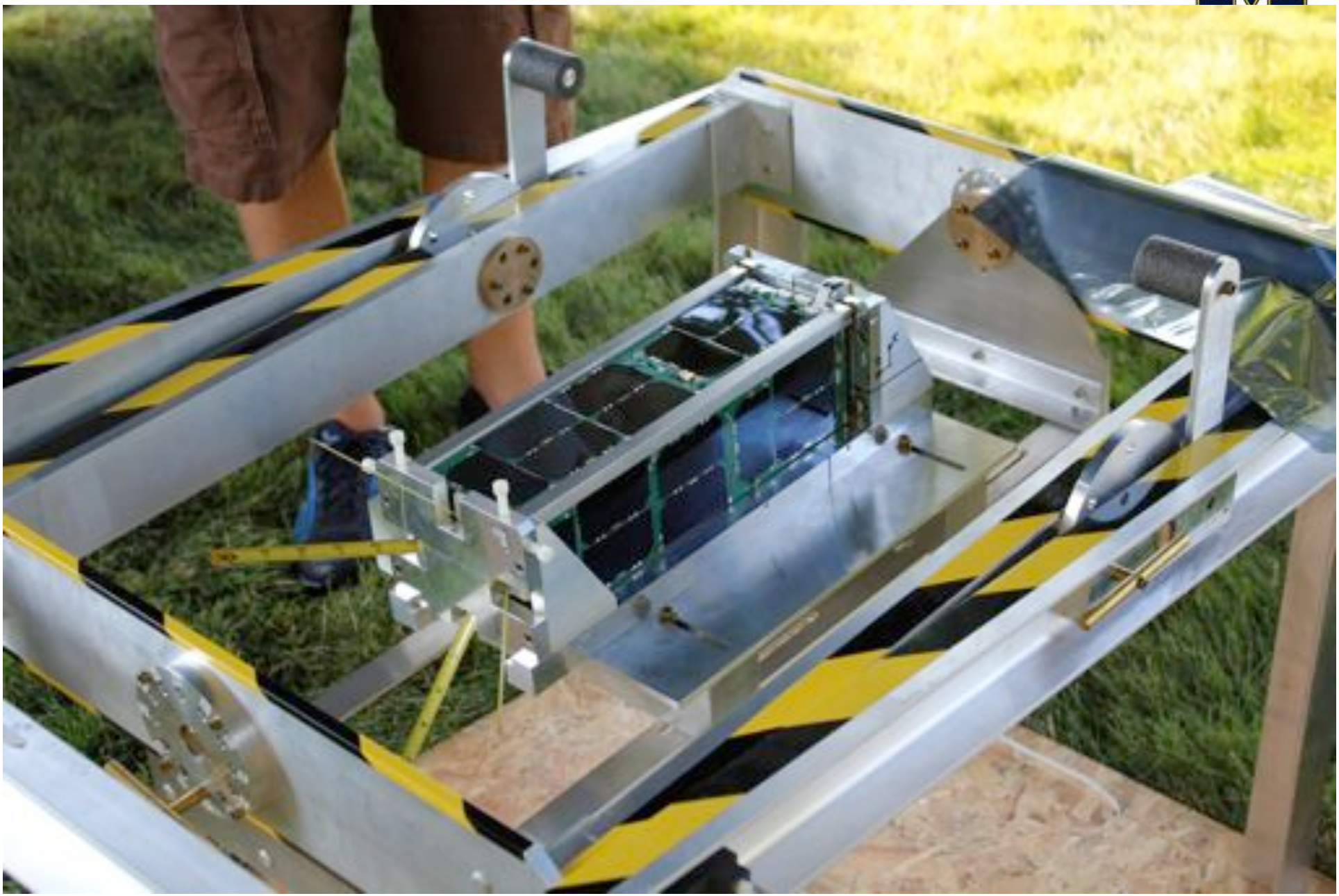


GPS Testing, 3rd of 3



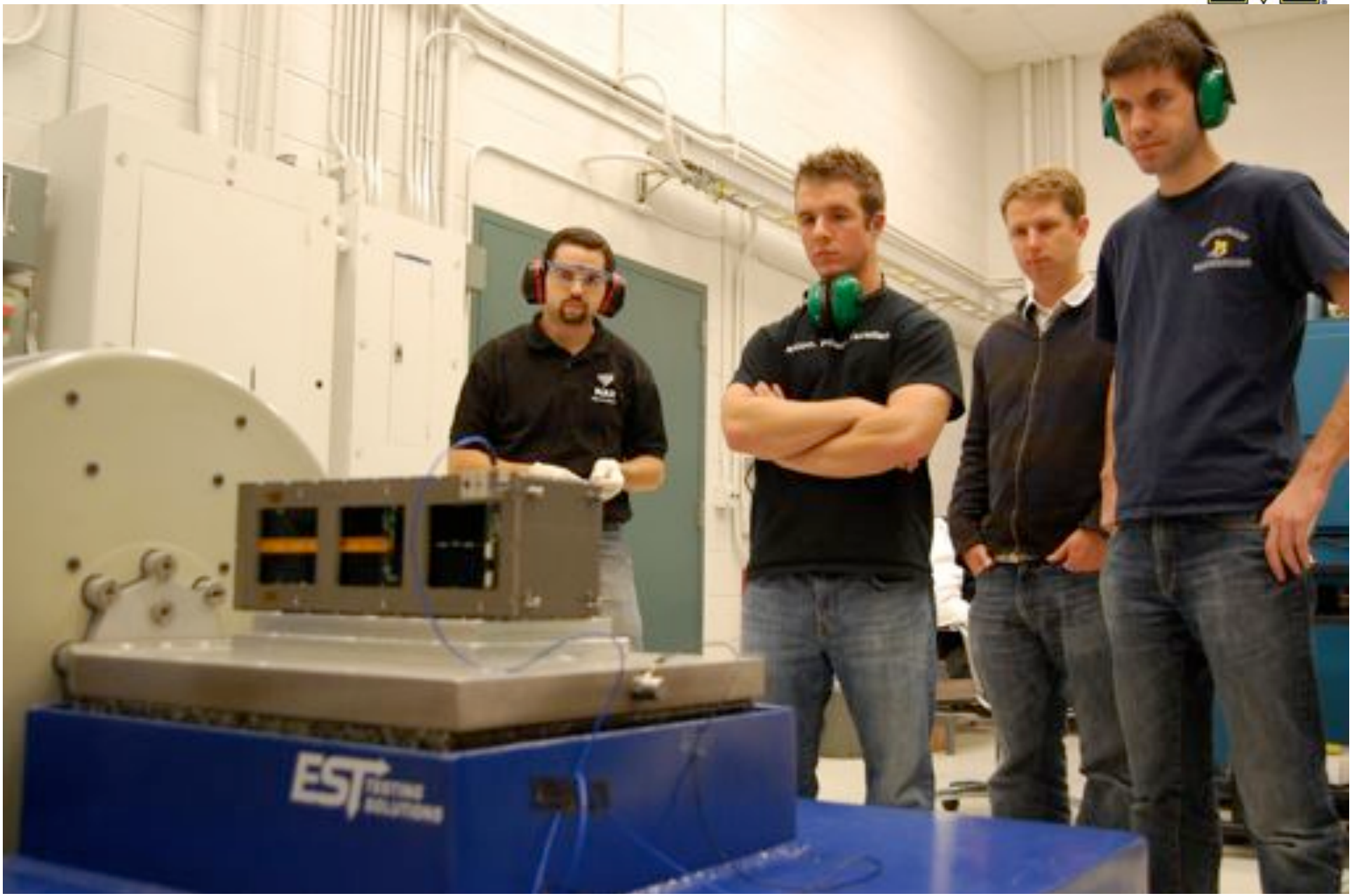


Magnetometer Testing

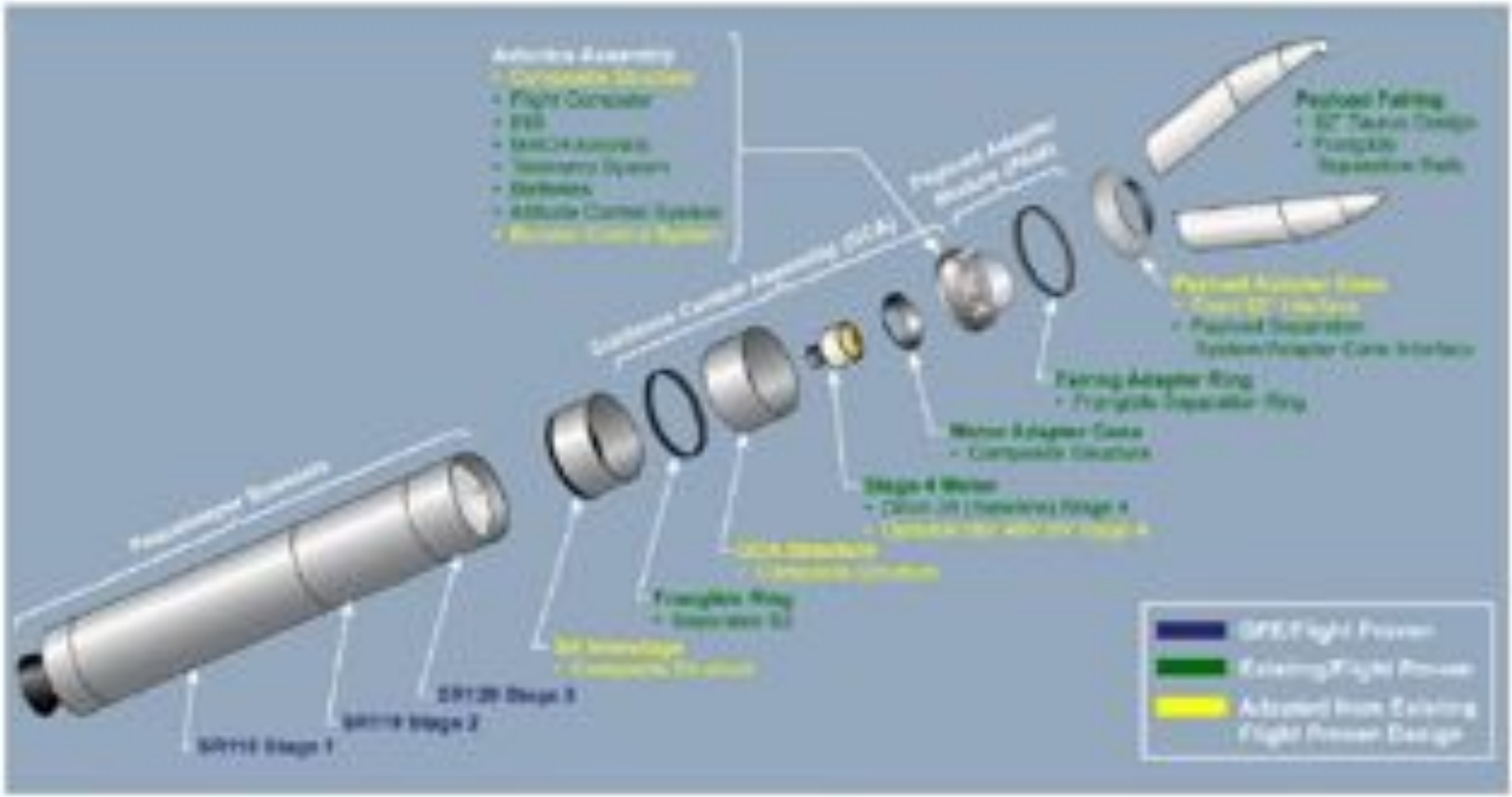


Magnetometer Testing

Shake Test, 1st of 3



Launch Vehicle Integration



Expanded view of the Minotaur IV launch vehicle

http://www.orbital.com/NewsInfo/Publications/Minotaur_IV_Fact.pdf#search=%22minotaur%20iv%22

KLC

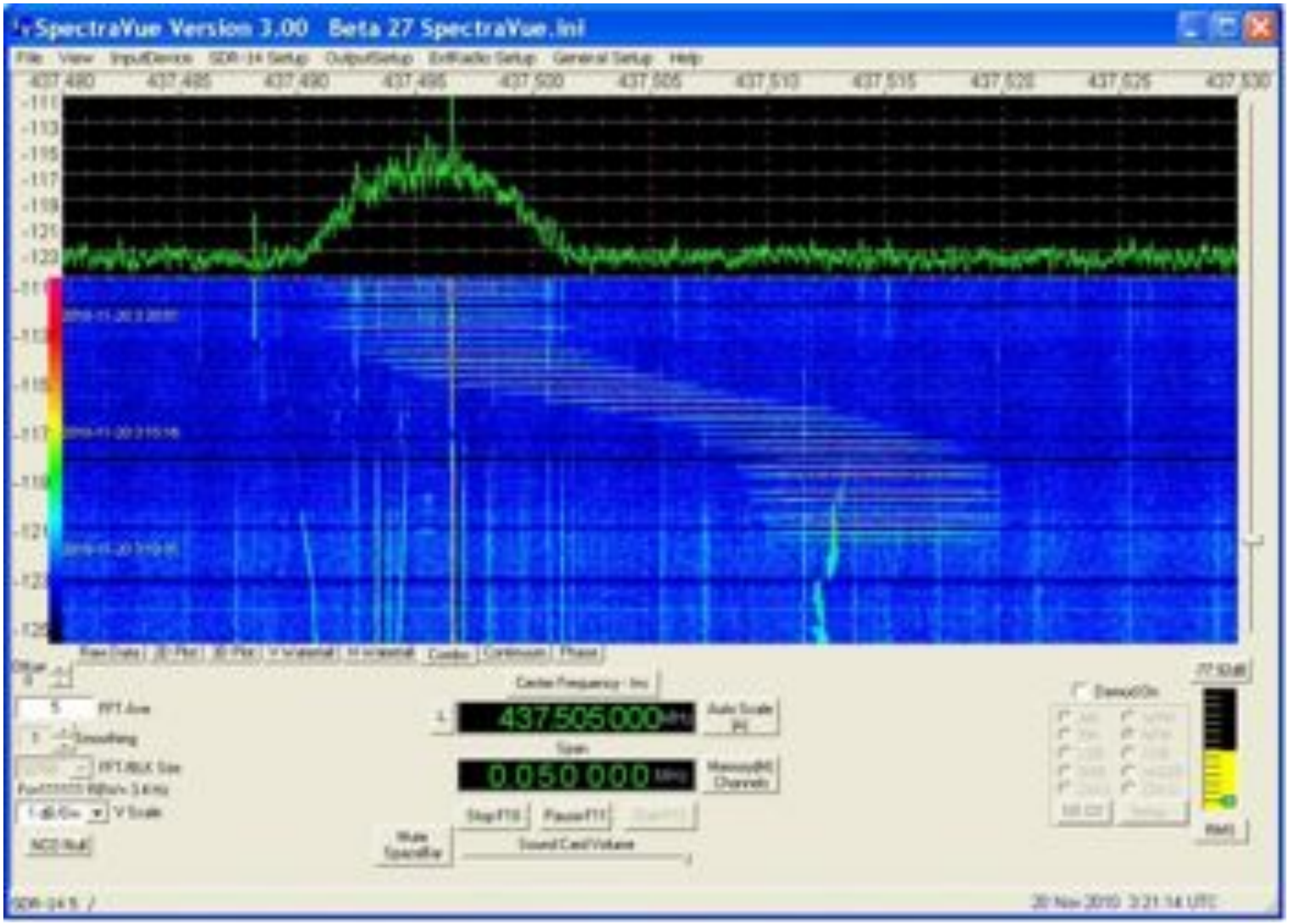
http://spaceflightnow.com/minotaur/stps26/101119tower/

KLC

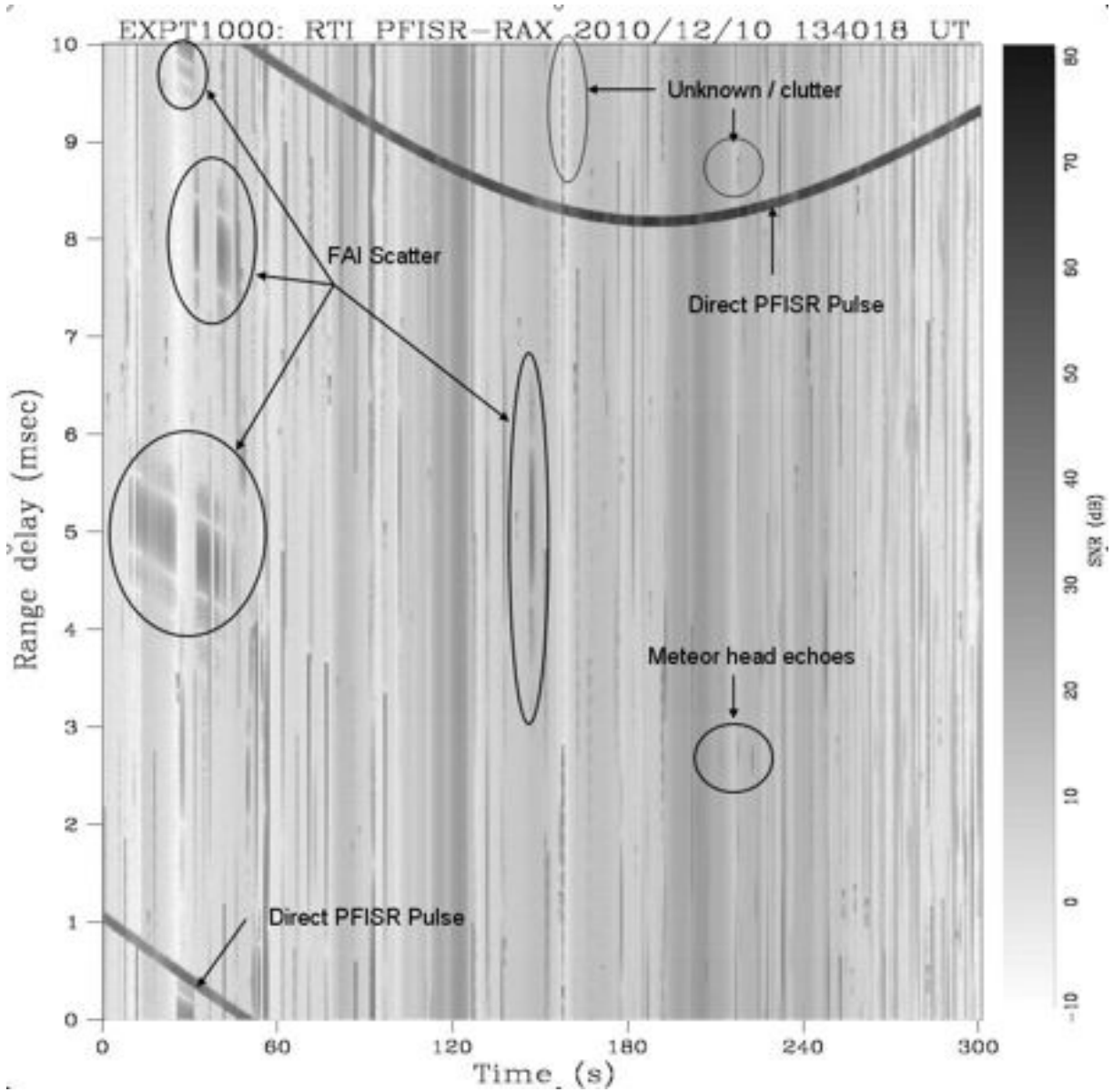
http://spaceflightnow.com/minotaur/stps26/101119tower/

Launch – Perfect

First Contact



First Data


EXPT1000: RTI PFISR-RAX 2010/12/10 134018 UT
Unknown / clutter
FAI Scatter
Direct PFISR Pulse
Meteor head echoes
Direct PFISR Pulse
Range delay (msec)
Time (s)
SNR (dB)
0
60
120
180
240
300
0
1
2
3
4
5
6
7
8
9
10
-10
0
10
20
30
40
50
60
70
80

Part 1 – Questions?

Part 2 – Agility

Disclaimer…

- I am not an expert of agile software development and related techniques.
- But we have a lot in common…

Customers

- NSF – National Science Foundation
- SRI Scientist
- STP – Space Test Program

Challenges

- Science versus engineering.
- MXL did not exist when RAX started.
- Launch was within 12 months.
- Hardware vs Software

MXL Did Not Exist

- Team difficult to recruit
  - Students had to be won over
  - SPRL was never won over
  - 5 months to get a team up and running and in training
- Start up funds to build lab space (bull pen)
- Agility…
  - Team was very fluid and dynamic at first. The program had to accept that.

Launch in 12 months

- First launch for NSF was purchased from STP.
- Extreme time pressure.
- New rocket…launch date likely to slip.
- Agility…
  - How do you maximize capability with a moving launch date?

Science vs Engineering

- AKA – constraints vs engineering
- Novel, innovative, aggressive science mission
- Agility…
  - Do we have a minimum bar or do we try to set the record given constraints?

Hardware vs Software

- How do we test our code independent of hardware?

- Heisenbugs vs Bohrbugs

Techniques

- Agile Team
- Scrum Meetings
- Pair Programming
- Distributed Leadership
- Iterative and incremental development
- Attention to detail

Enabler – Agile Team

- Small Core Team
  - Approximately 13 members (2 + 1 on software)
  - Interfaced to 20-30 other students.
- Core team intact during design and operations.
- Members had a key strength but system insight.
- Example
  - FGPA Payload interface -> Flight Software -> Ground Ops

Scrum Meetings

- Daily meetings: 9AM RAX Lab
  - What did you do?
  - What are you going to do?
  - Problems you encountered?
- Weekly Wiki Scrum
  - ENTIRE team filled out a wiki page, by Monday 9AM.
  - Entire team can review.
- Had to outlaw weekday drinking. ☺

Pair Programming

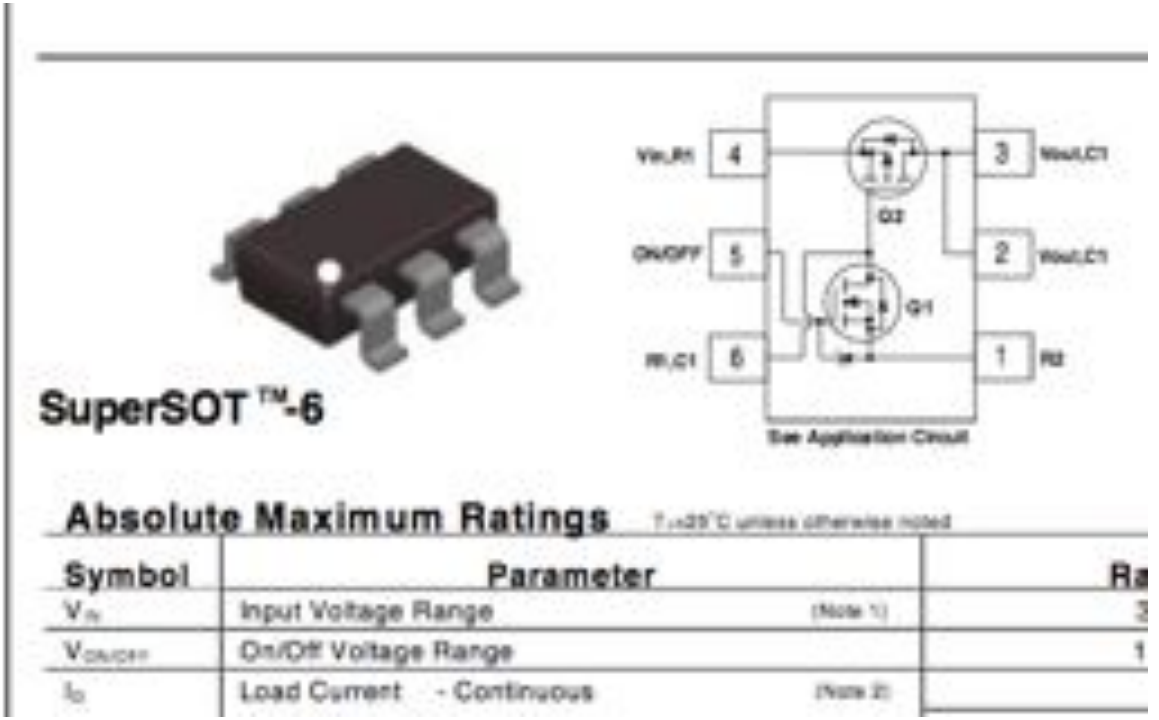
Distributed Leadership

- Co Investigators = science + engineering
- Three “Bus” Leaders
  - Project Manager, Post Doc, Co-I
  - Remove bottleneck
- Trusted team leads
  - Part of the core team
- Traditional Aerospace reviews and experts.

Iterative and Incremental Dev

Attention to detail

- Our coders had to read component spec sheets…
- Embedded and general computing mix



SuperSOT™-6

Absolute Maximum Ratings

Symbol	Parameter	
V_{IN}	Input Voltage Range	(Note 1)
$V_{ON/OFF}$	On/Off Voltage Range	
I_D	Load Current - Continuous	(Note 2)

Things we did wrong

- Coder health and proper pace

- Testing was important but we lacked experience.

Fear of the Weight of Experience

http://www.anoushehansari.com/slideshow/gallery/album1/large/DSC_0096Copy-2.jpg

Home Grounds (Boehm and Turner)

	Agile	Plan – Driven	RAX/MXL
Criticality	Low	High	High
Skill	Senior	Junior	< Junior
Requirements Change	Often	Rare	Often
Number of coders	Small	High	Small
Culture	Chaos	Order	Chaos and order

Agile Manifesto Review

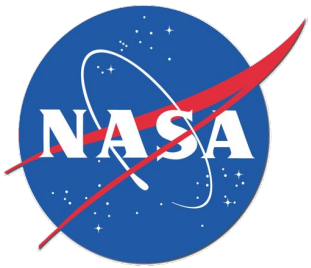
Manifesto	MXL Application
Individuals and interactions over processes and tools	Small team Simple ICDs Daily meetings Shared leadership
Working software over comprehensive documentation	Test as you fly Integrated testing ASAP Simple code
Customer collaboration over contract negotiation	Team = customers Joint code work with our customer
Responding to change over following a plan	The plan changed daily List of key tasks and capabilities Re plan as needed.

Conclusions and Opinion

- Our satellite team unexpected adopted many agile practices.
- The motivation for agile software applies to our small space systems as well.
- Poised for a fundamental paradigm shift in aerospace engineering.

"Ideas move faster than documents."

Acknowledgements



And many others…

Questions?