Conducting Science with a CubeSat: The Colorado Student Space Weather Experiment

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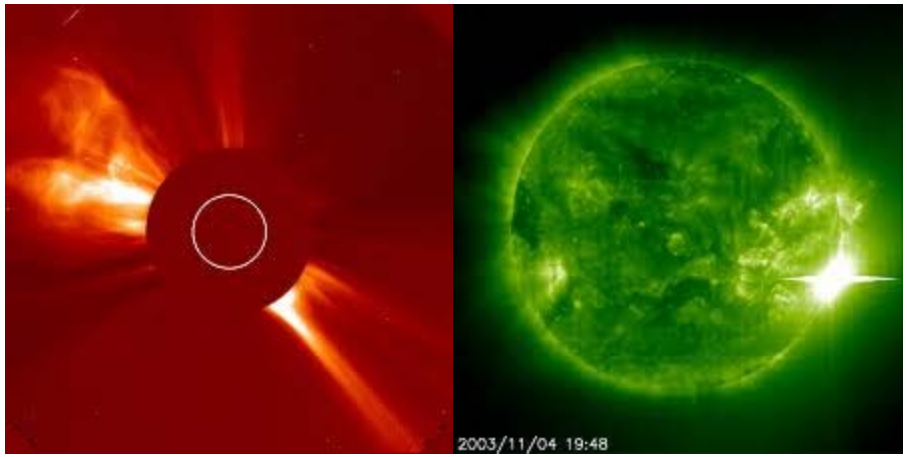
CSSWE Science

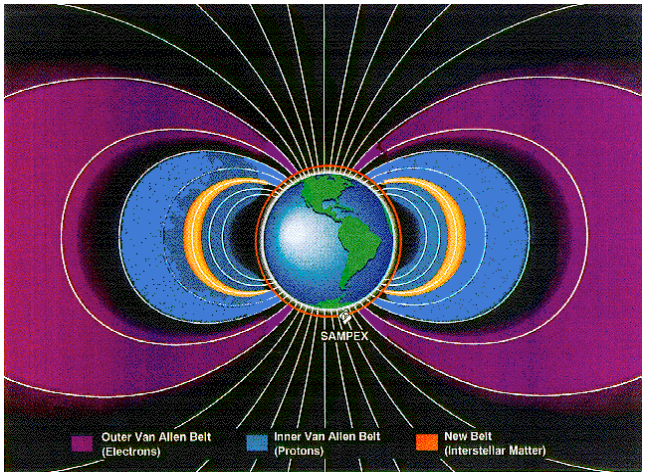
Science Objectives

To understand the relationships between solar energetic particles (SEPs), flares, and coronal mass ejections (CMEs), and to characterize the variations of the Earth's radiation belt electrons.



Science Questions:

1. How do the flare location, magnitude, and frequency relate to the timing, duration, and energy spectrum of SEPs reaching Earth?
2. How does the energy spectrum of radiation belt electrons evolve and how does this evolution relate to the acceleration mechanisms?



Relevance

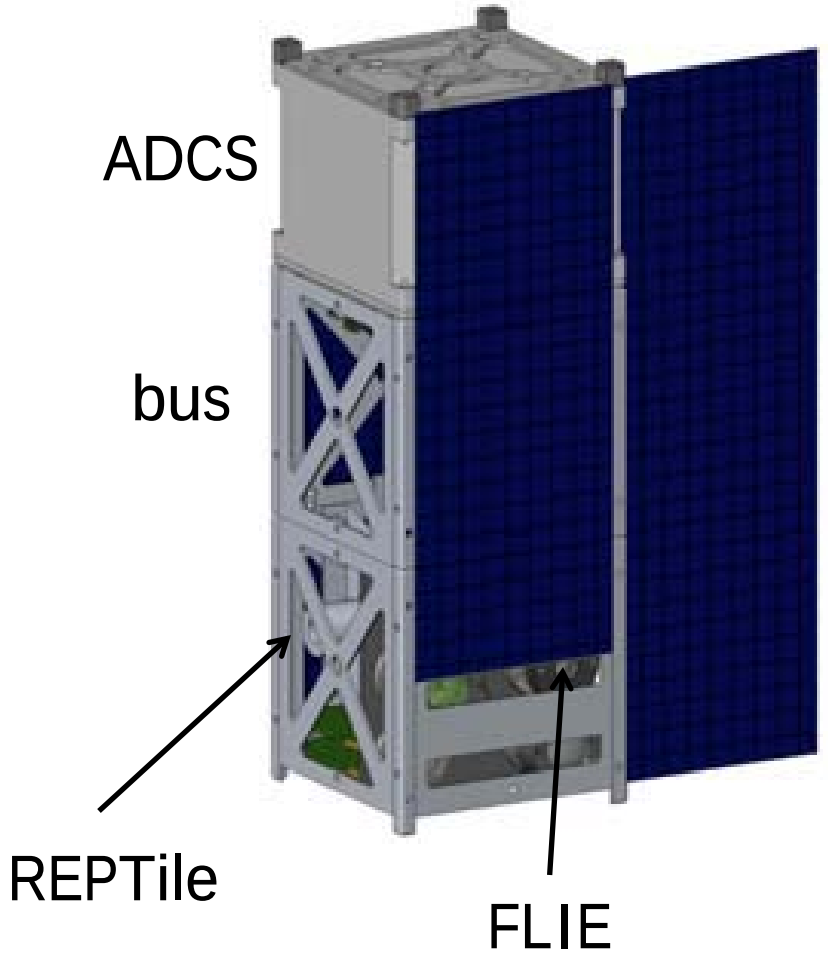
"Satellite Gone Wild Threatens Cable Programming"

"On 5 April, [Galaxy-15] experienced a major fault and its services were switched to a back-up spacecraft. Engineers have not yet established the cause, but damage from a solar storm is one possibility being investigated."

Galaxy-15
"zombie sat"

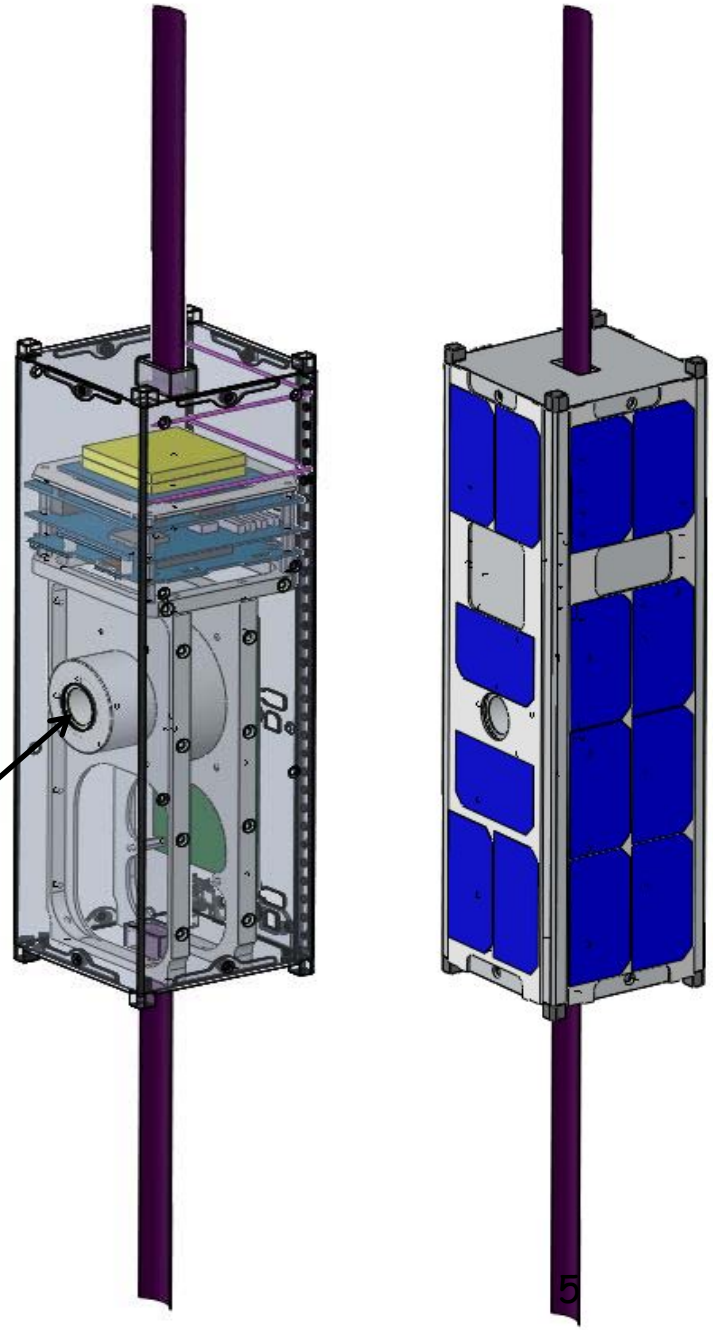
CSSWE Rev 1

- Two instruments
  - FLIE (sun pointing)
  - Reptile
- 3 axis control (2^o)
  - 1^0 knowledge
- Deployable panel
- Power issues
  - ADCS driven
- Mass issues
  - ADCS
  - REPTile shielding



CSSWE Rev 1

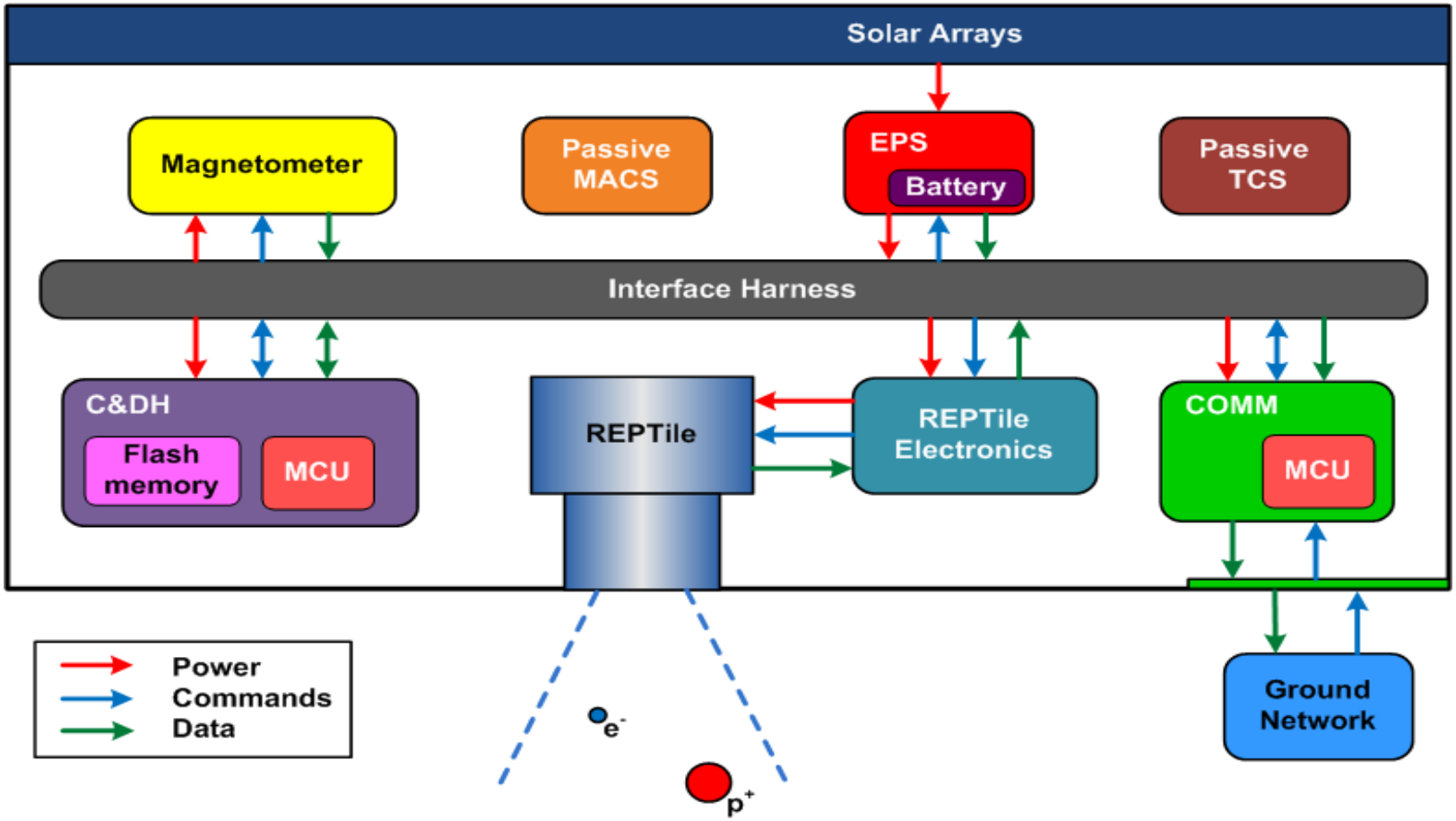
- One instruments
  - REPTile
- Passive magnetic attitude
  - 10º control
- Deployable antennas
- Body mounted solar panels
- No mass issues
  - Increased REPTile shielding
- Currently at PDR/CDR stage



System Philosophy

- Project Goals:
  - Make new science measurements
  - Educate students
- Approach
  - Keep it as simple as possible
  - Use commercially available systems where possible
  - Do one thing well and don't add bells and whistles

Simple Block Diagram



System Components

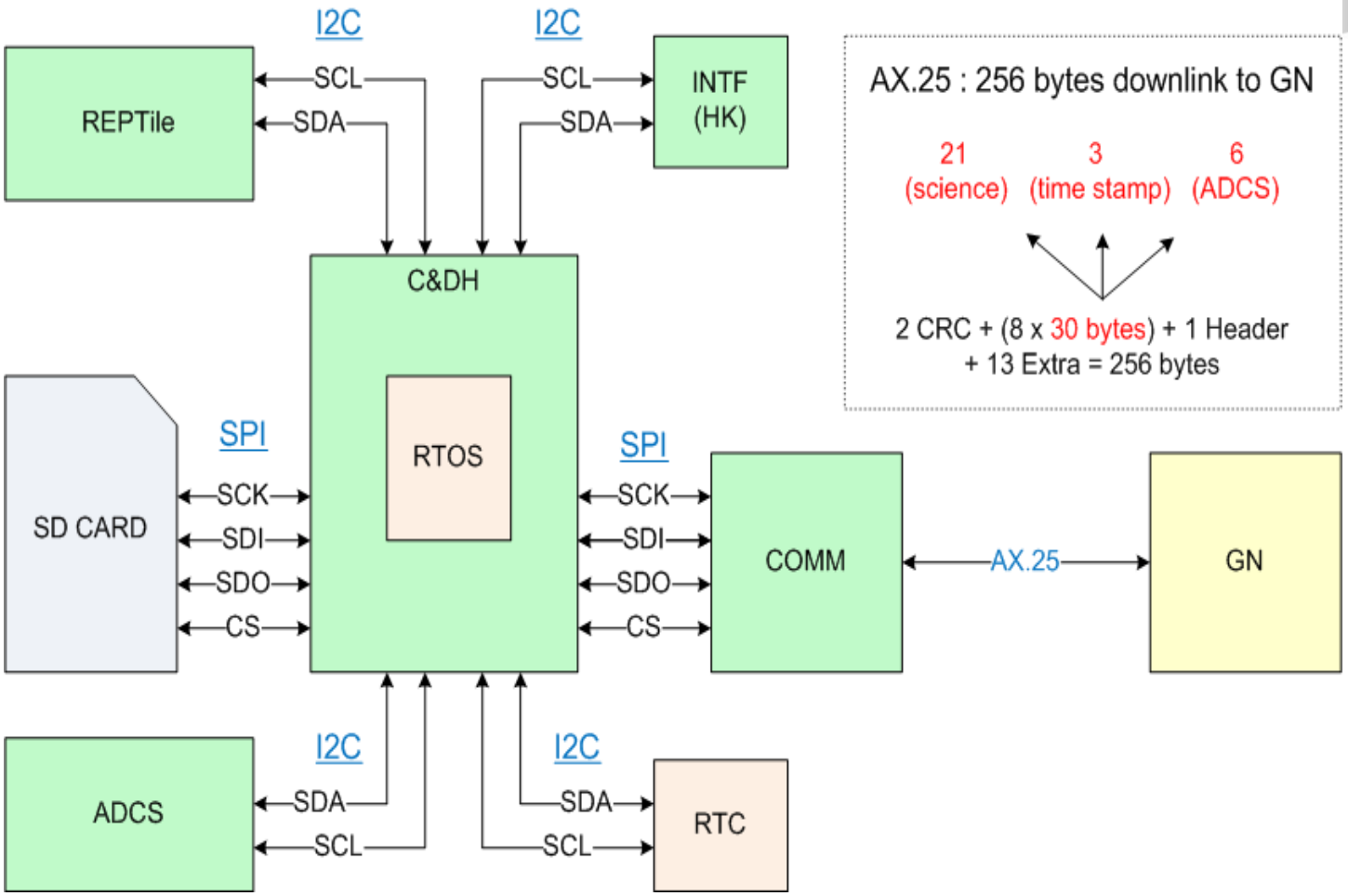
- C&DH
  - Pumpkin FM430 processor board
- Attitude system
  - Passive magnetic control
  - Magnetometer determination
- Passive thermal system
- EPS
  - Developing in house solution while considering commercial options(Clyde-Space, GomSpace, Tiger)
- Communications
  - Developing in house UHF (430MHz) half-duplex system using commercially available GMSK modem. Also considering commercial solutions (ISIS, AstroDev).

Current System Budgets

Subsystem	Mass (g)	Volume (cm^3)	Power (mW)	
			Insolated	Eclipse
Structure	**840.9**	310.8	0	0
EPS	380.3	116.1	3116	153
C&DH	88.3	32.5	340	340
REPTile	**1209.6**	184.5	920	920
COMM	109.3	25.5	713	758
ADCS	19.1	12.0	2	2
Interface	100.0	84.9	0	0
Total	**2747.5**	766.3	5091	2173
Available	4000	3400	6750	2934
Margin	**31.3%**	**77.5%**	**24.6%**	**25.9%**

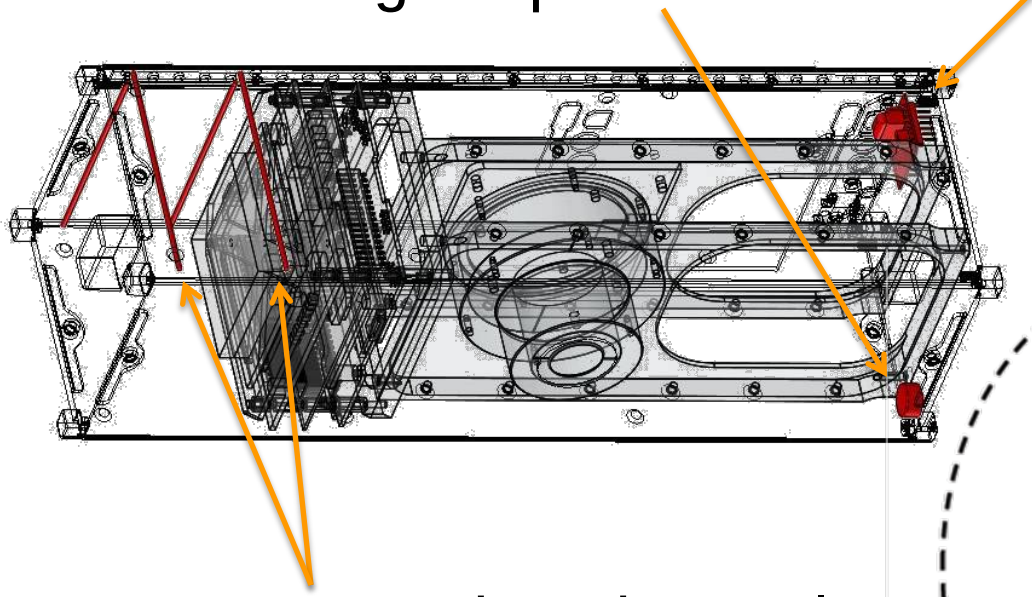
4.8W orbit avg power

C&DH


I2C
SCL
SDA
REPTile
I2C
SCL
SDA
INTF
(HK)
C&DH
RTOS
SPI
SCK
SDI
SDO
CS
SD CARD
SPI
SCK
SDI
SDO
CS
COMM
AX.25
GN
I2C
SDA
SCL
ADCS
I2C
SDA
SCL
RTC
AX.25 : 256 bytes downlink to GN
21
(science)
3
(time stamp)
6
(ADCS)
2 CRC + (8 x 30 bytes) + 1 Header
+ 13 Extra = 256 bytes

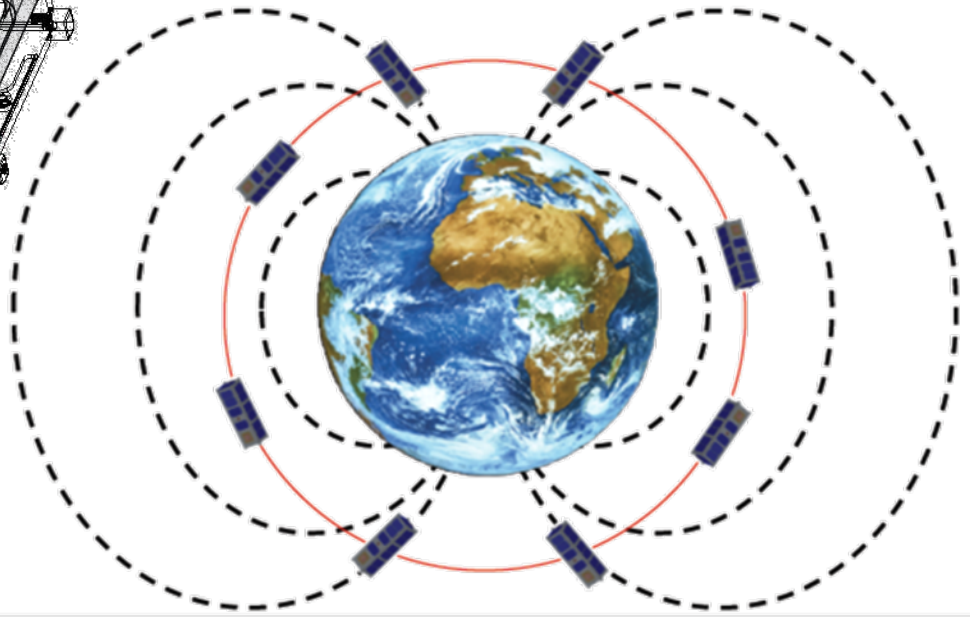
ADCS

- Bar magnet supplies restoring torque



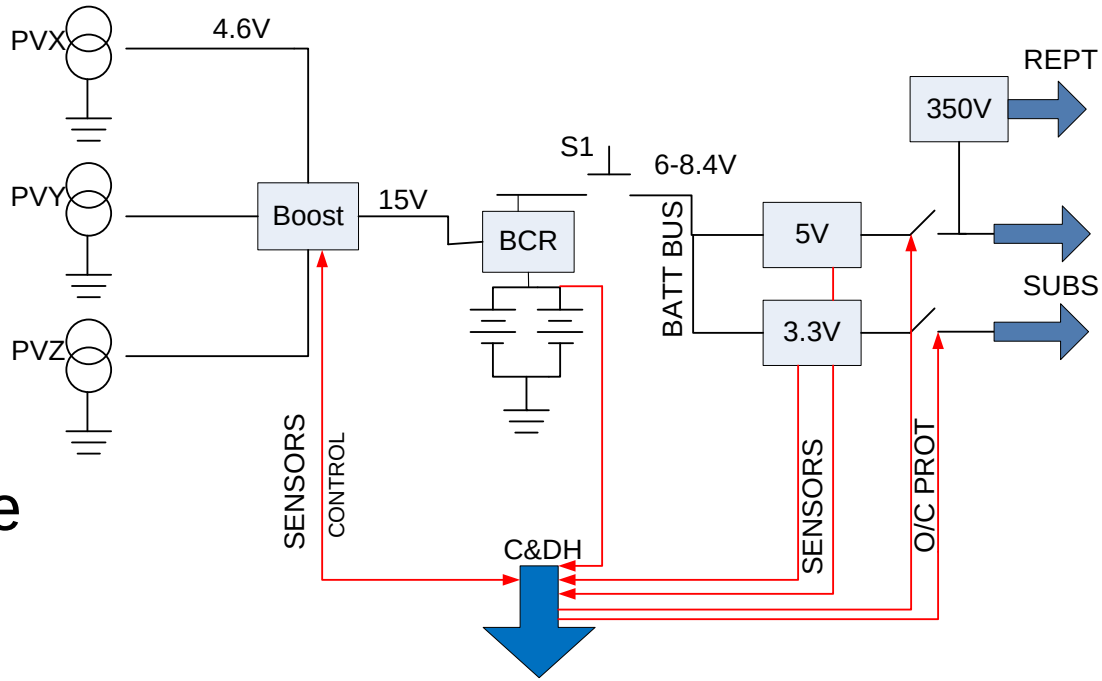
- Hysteresis rods supply dampening

- Magnetometer used to determine 2-axis spacecraft attitude relative to local magnetic field



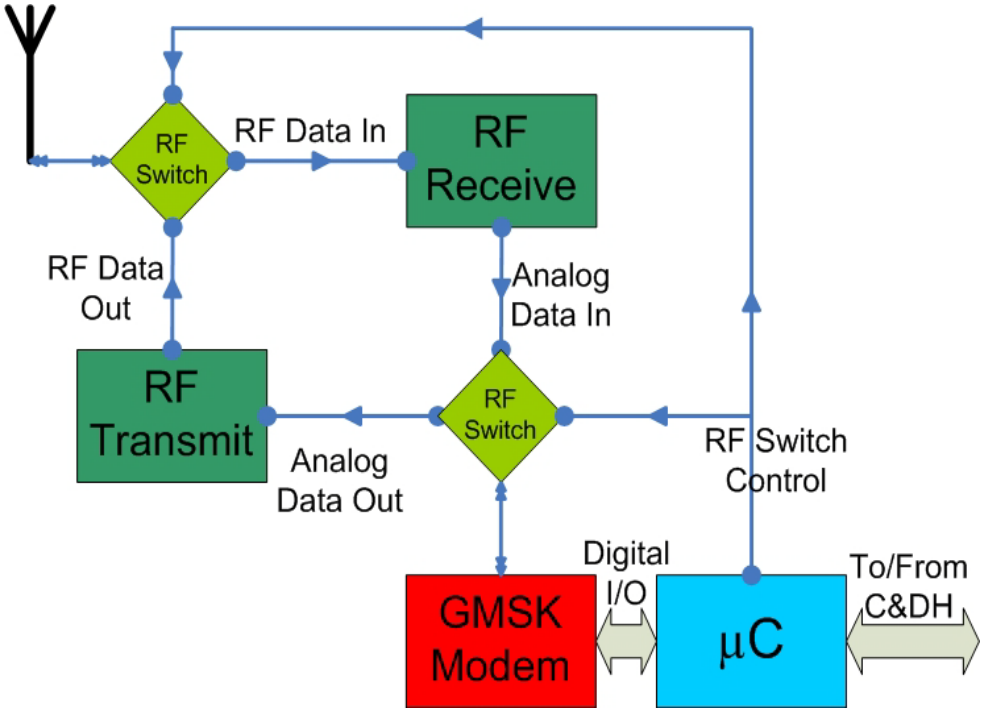
EPS

- Designed by students
- No peak power tracking
  - Removes controller
- Solar cell configuration trade
  - 6s to 8s
  - 2s3p to 2s4p
  - Removes need for boost
- PV Cells – Emcore Triple Junction GaAs/GaInP
- Battery – Li-Ion



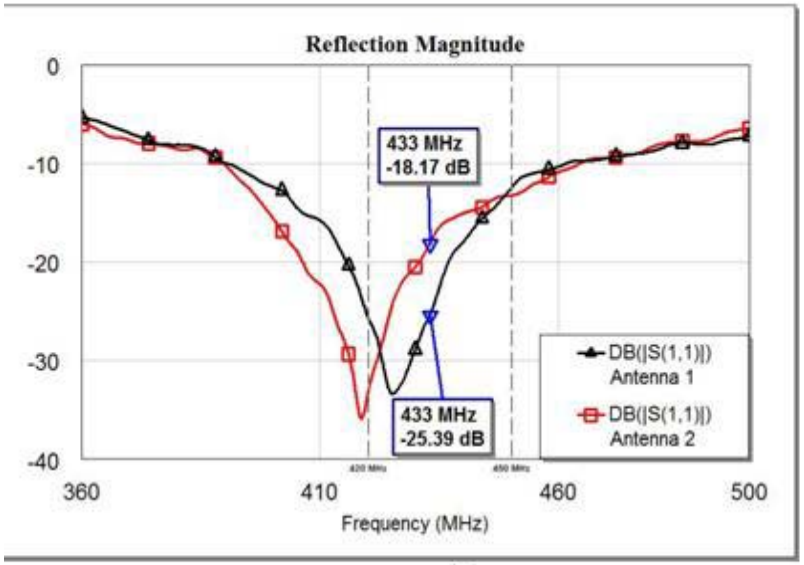
Communications

- Half-Duplex
- 433 MHz
- GMSK with AX.25

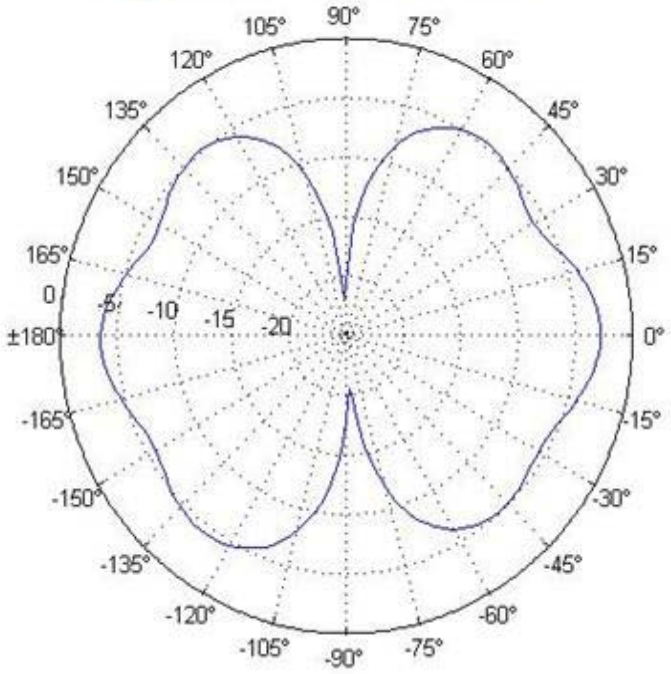


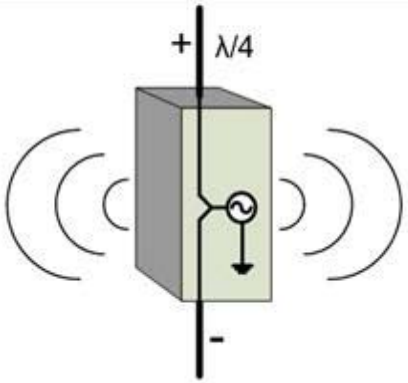
Symbol	Uplink	Downlink	Units
EIRP	39.51	-4.34	dBW
Propagation Losses	-152.49	-152.49	dB
Receive System Gain	-6.00	18.71	dB
Received Power	-118.98	-138.13	dBW
System Noise Power	-200.83	-200.64	dBW-Hz^{-1}
Carrier to Noise Ratio Density	81.85	62.52	dB-Hz
Minimum Pr/No	55.42	55.42	dB-Hz
Margin	26.43	7.09	dB

Antenna Configuration



Gain Plot at 432 MHz (dBi)

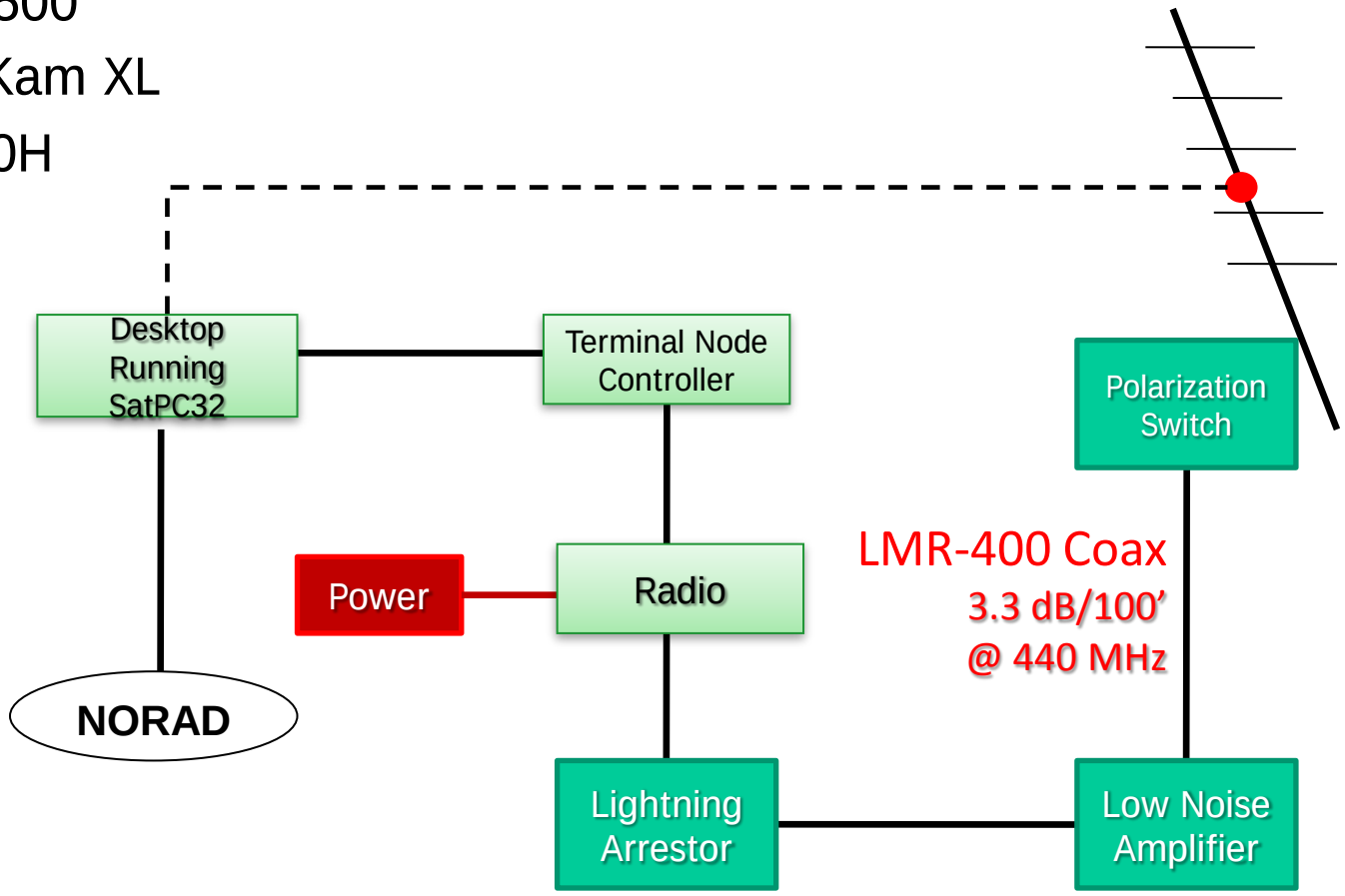




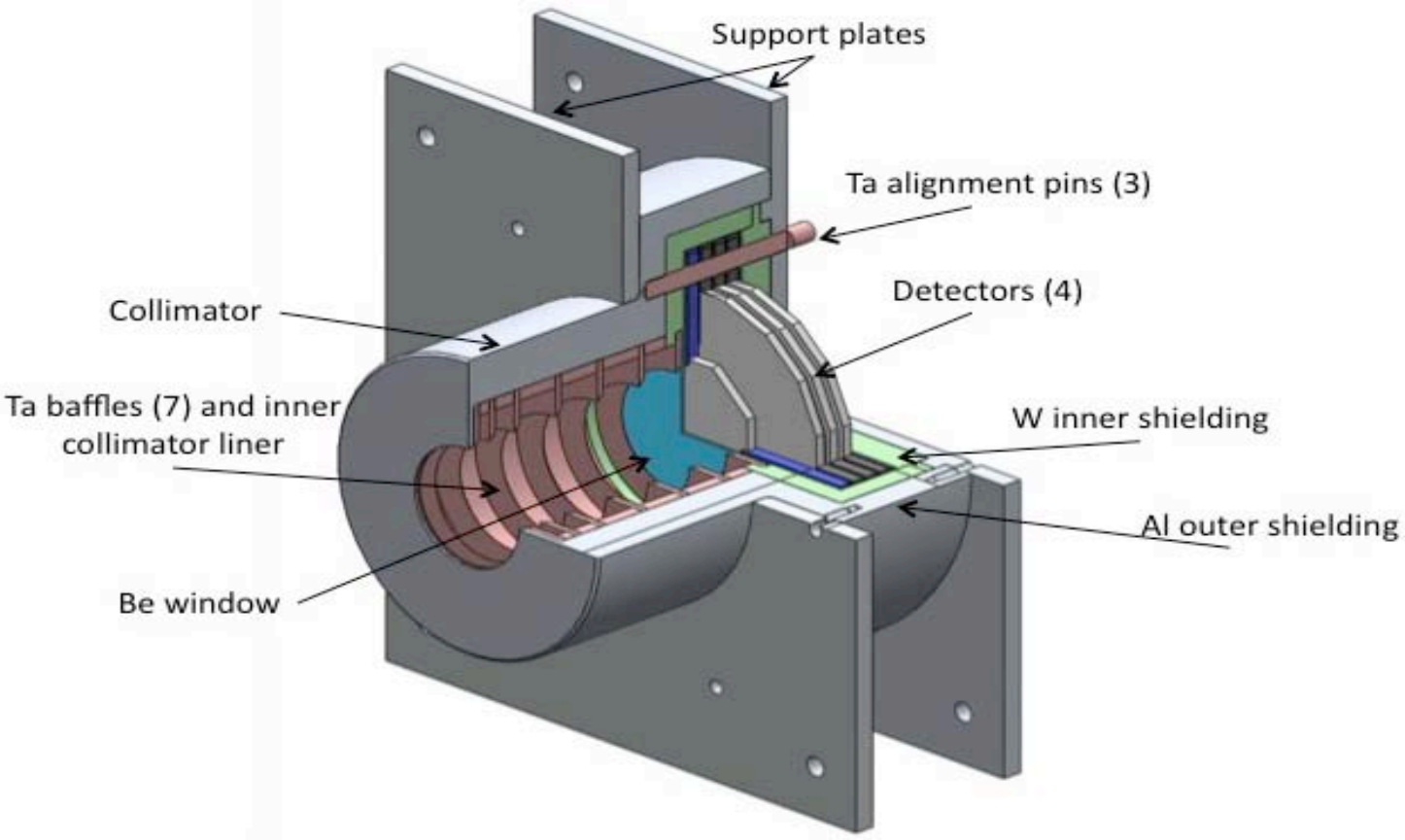
Antenna Elements
are 18.8cm Each

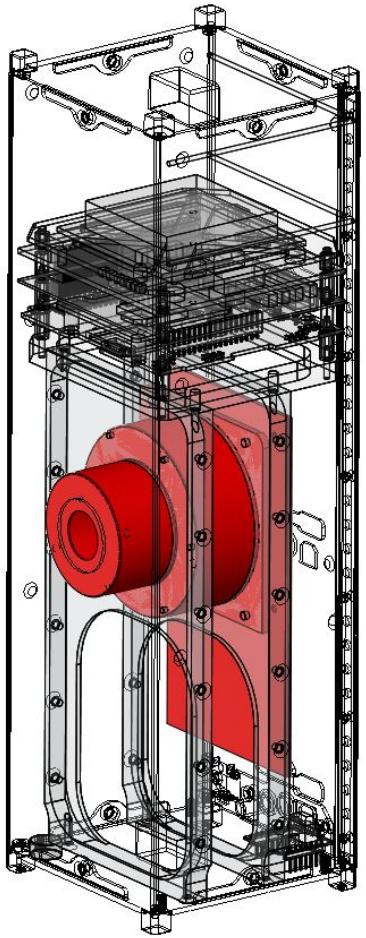
Ground Station

- Antenna M2 436CP42
- Rotor Yaesu G-5500
- TNC Kantronics Kam XL
- Radio ICOM 9100H

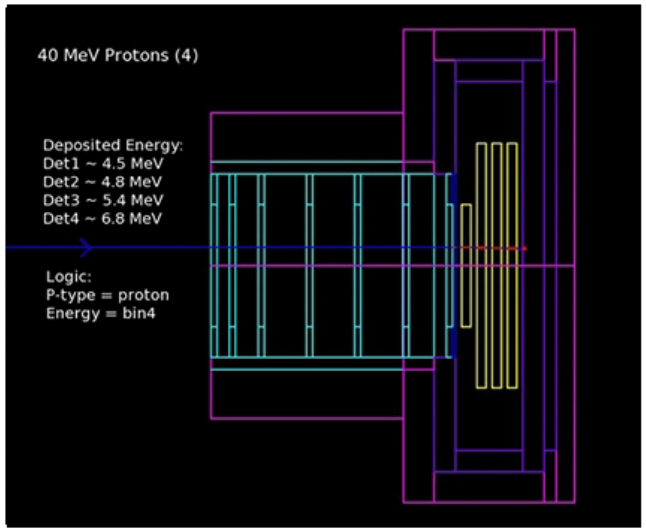


REPTile

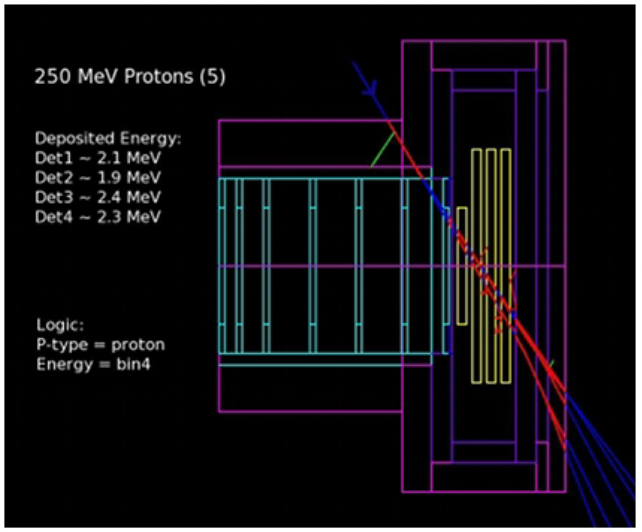

Support plates
Ta alignment pins (3)
Collimator
Detectors (4)
Ta baffles (7) and inner collimator liner
W inner shielding
Al outer shielding
Be window



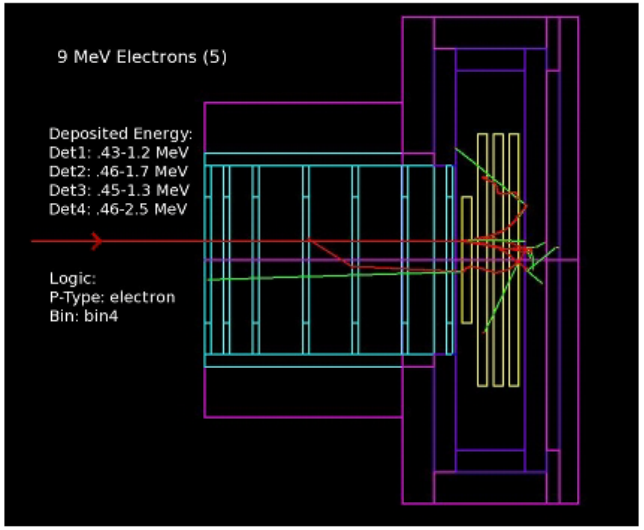
GEANT Simulations



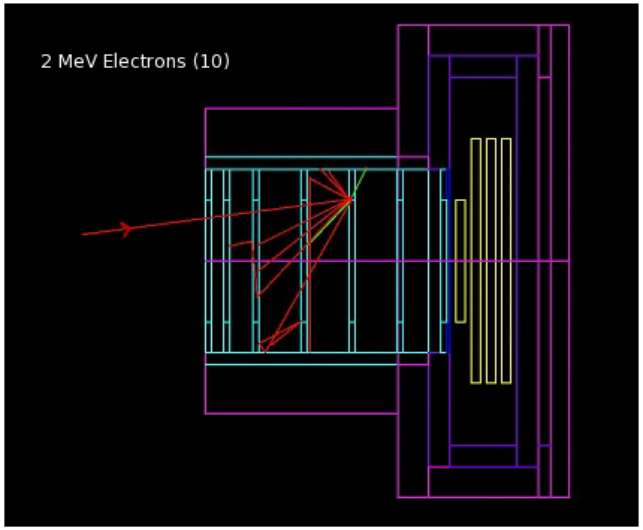
a) Signal protons



b) Shield penetrating protons

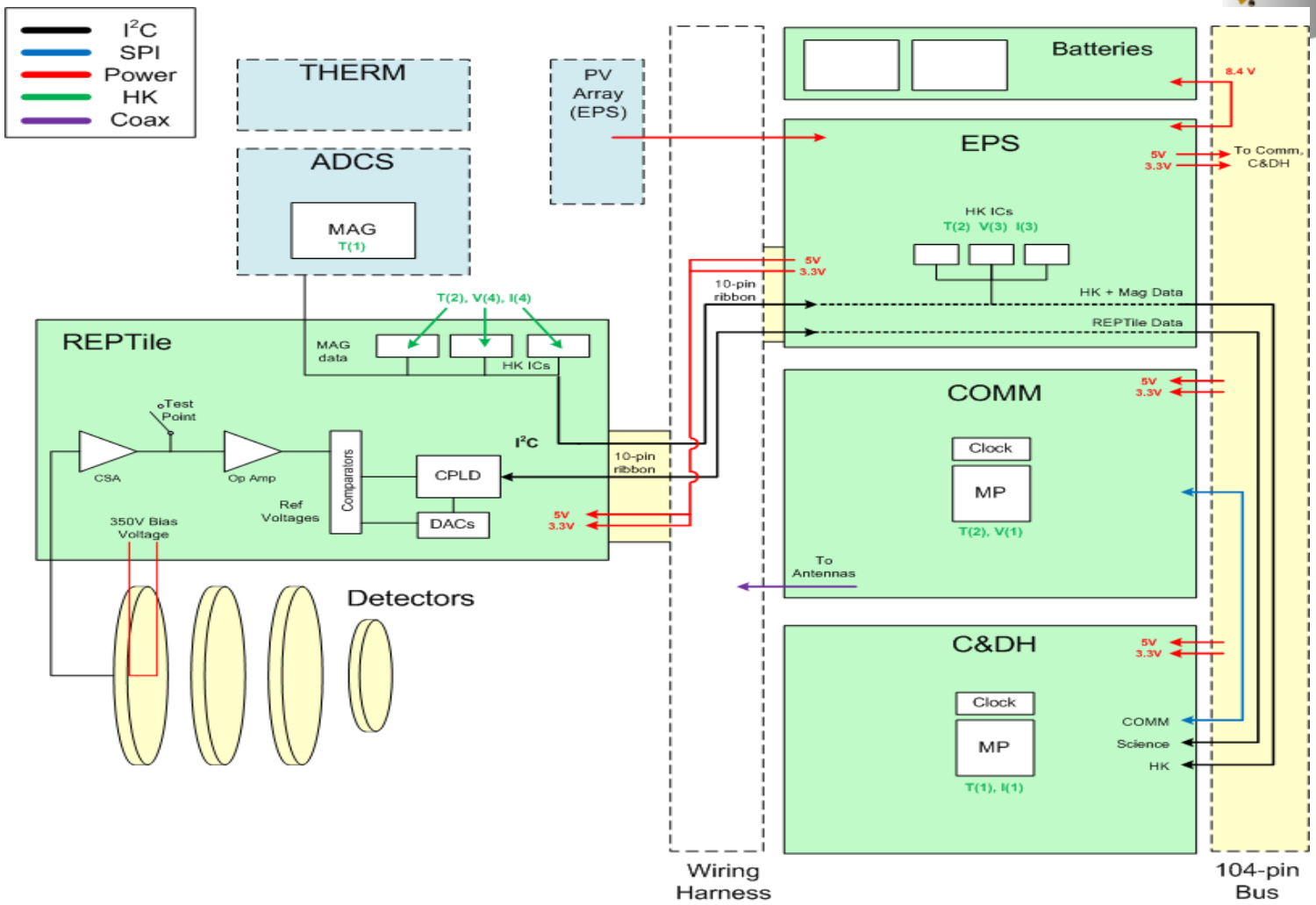


c) Signal electrons



d) Collimator demonstration

REPTile Interface



Education

- CubeSat project is offered as a graduate project course similar to senior design
  - One of four current projects
  - Students typically participate for 1-2 semester
  - Directed at the masters level
  - Reviews occur 2x each semester
  - Top students are hired over the summer
- Mentoring from LASP professionals
  - Students take the lead on the project
  - Professionals provide regular feedback

Summary

- CSSWE is working towards a late 2011 delivery
- Students are leads on all of the systems
- Finding students with RF/comms and EPS interest or expertise is a challenge
  - Newly developed commercially available products are being considered for these systems
- REPTile has gone through multiple design revisions and will be ready for testing in late 2010
- Students working on the project are engaged and excited