

AMSAT Space Symposium 2013

*Fox* Satellite Program Overview



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# Launch Cost Issue

- P3E to GTO..... \$10M
- ARISSat..... \$1M
- MicroSat to LEO..... \$500K
- 3U CubeSat to LEO.. \$300K
- 1U CubeSat to LEO.. \$100K



# Launch Strategy



- Take advantage of large and growing interest in CubeSats
- Develop family of CubeSats with ham radio transponders that are also attractive for hosting science experiments
- Partner with universities to develop joint science and education missions
- Get a free launch via the NASA ELaNa program

# Program Phases



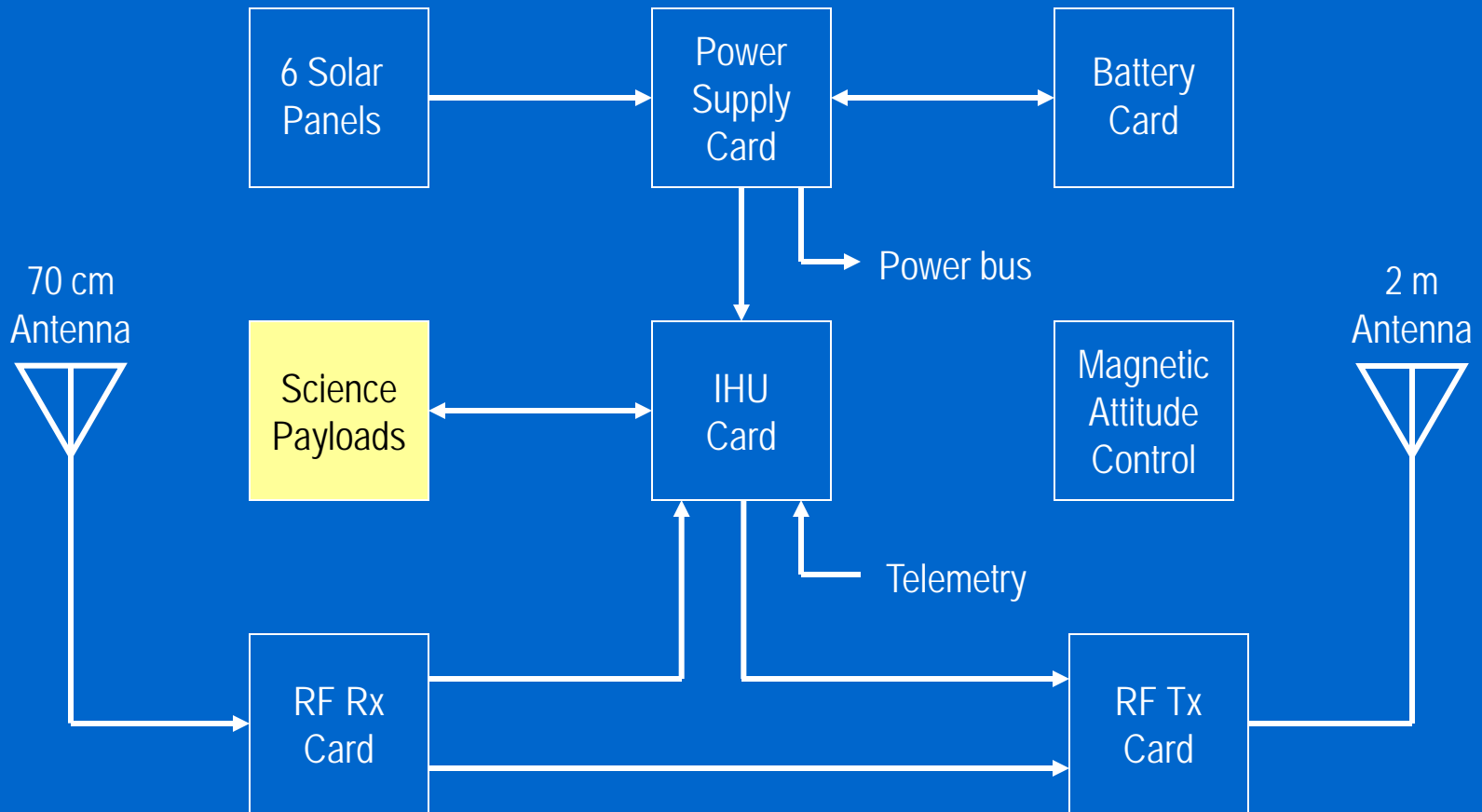
- Phase 1 (*Fox-1 type satellites*)
  - 1U CubeSat
  - FM voice repeater
  - FSK Digital data up to 9600 bps
- Phase 2 (*Fox-2 type Satellites*)
  - 3U structure
  - Software defined radio transponder
  - Linear, FM and high-performance digital modes

# *Fox-1* Launch Status

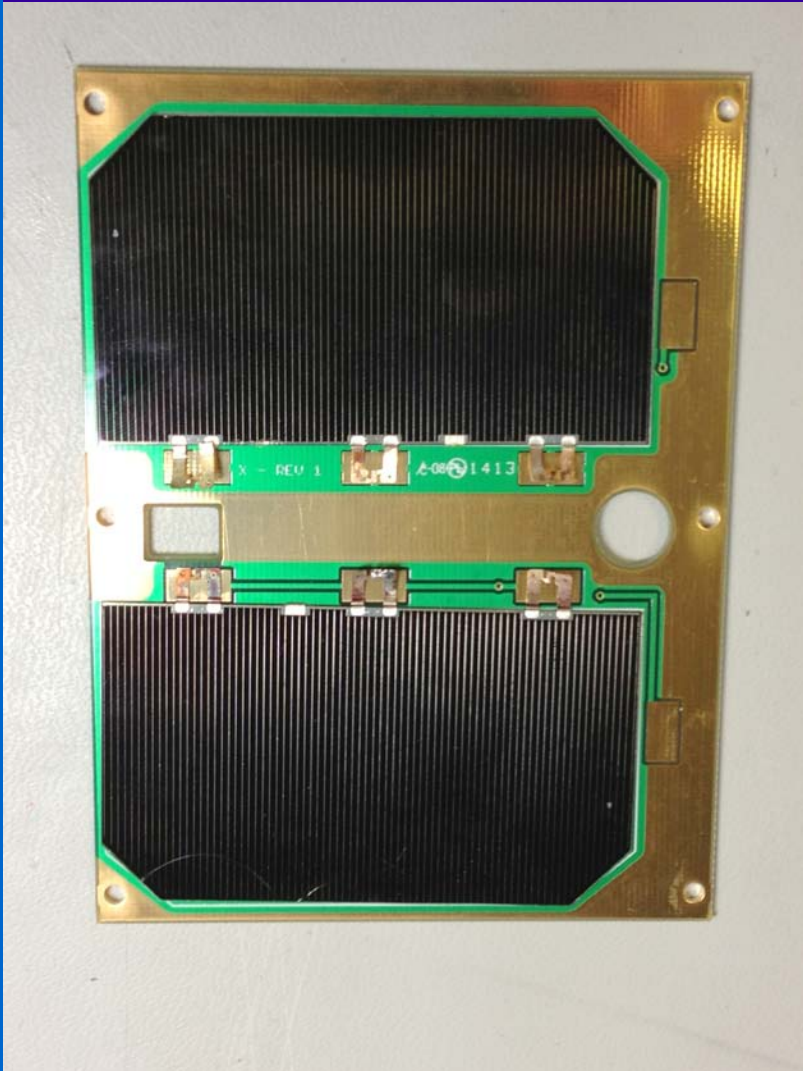


- Nov 2011 - Proposal submitted to NASA for *Fox-1*
- Feb 2012 - Accepted into NASA ELaNa program
- **Scheduled for launch December 2014**
  - ELaNa XII on NROL-55
  - Atlas V launch vehicle
  - Vandenberg AFB launch site
- Orbit is 470 km x 780 km @ 64 degrees
- Orbit lifetime is about 11 years

# Fox-1 Satellite Overview

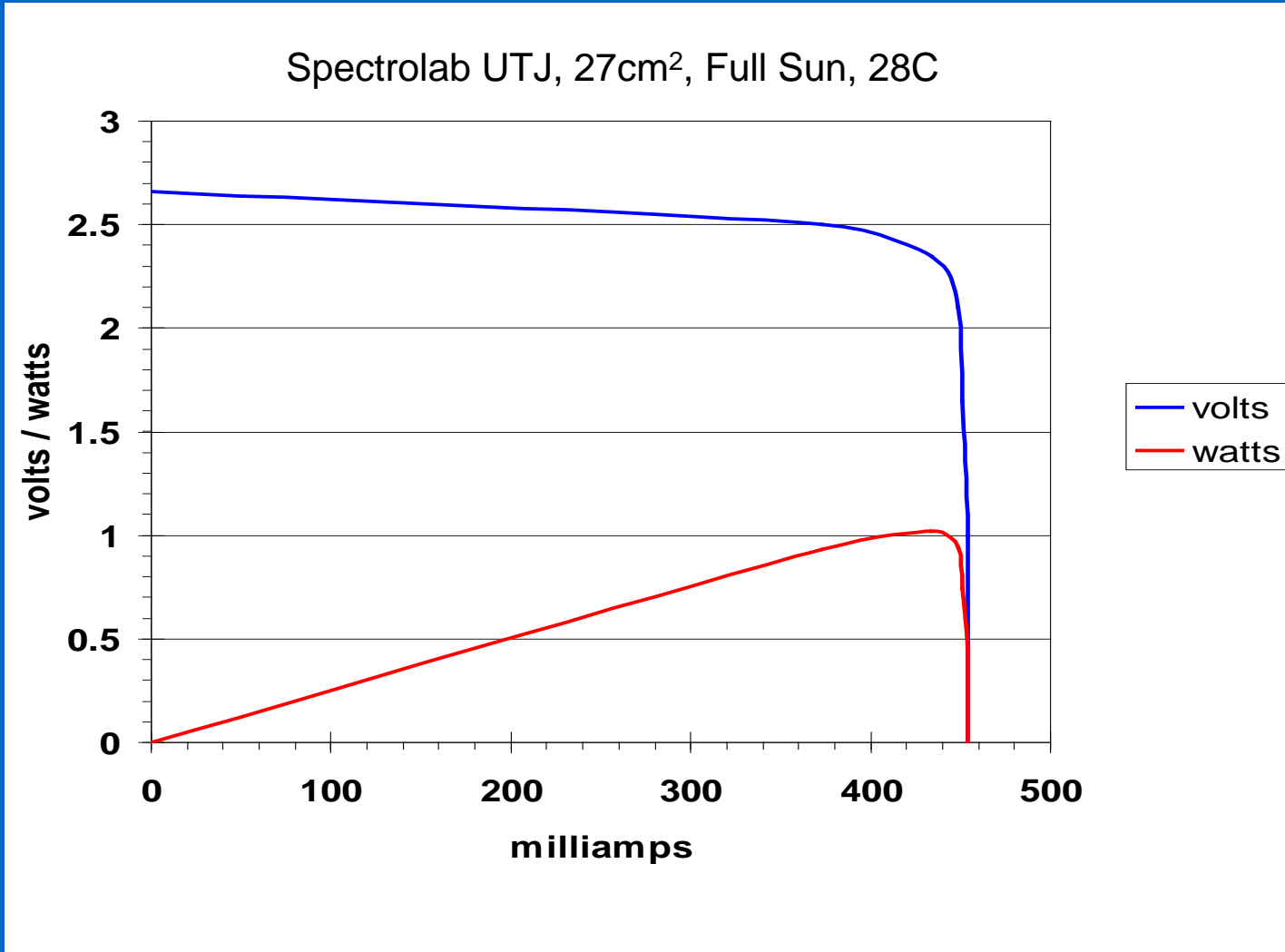


# Solar Panels



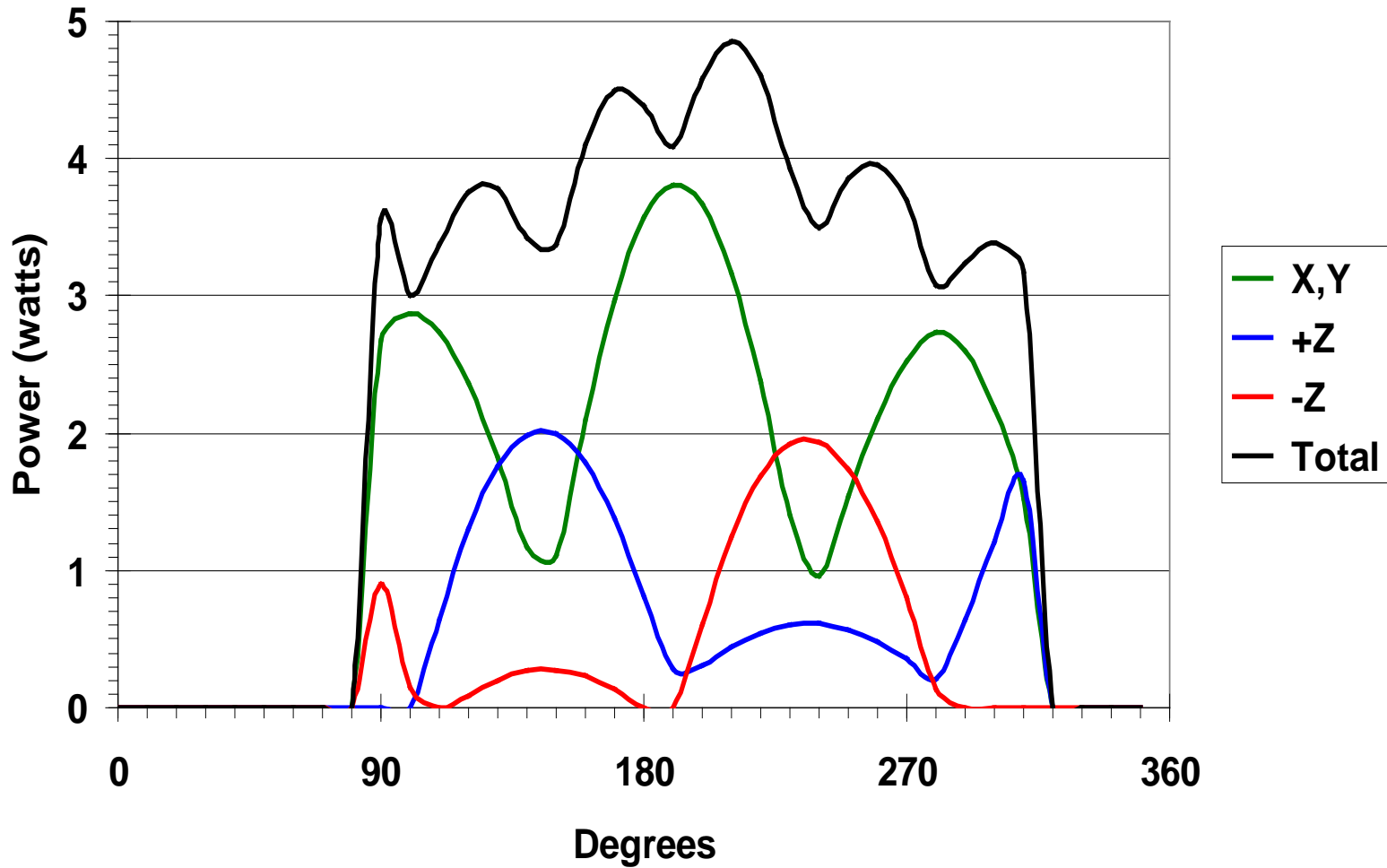
- 6 solar panels
- 2 cells per panel
- Spectrolab Ultra Triple Junction cells
- Rad-hard
- Space-rated
- 28% conversion efficiency

# Solar Cell Characteristics

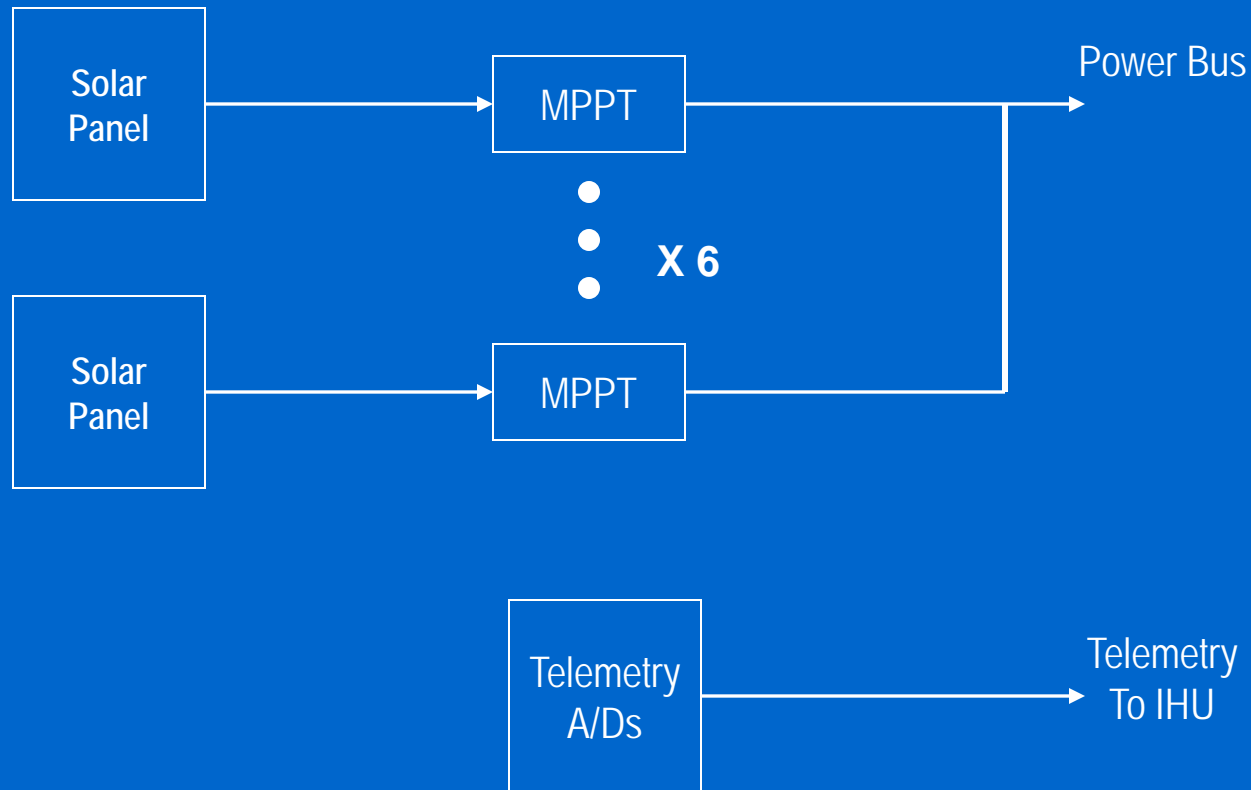




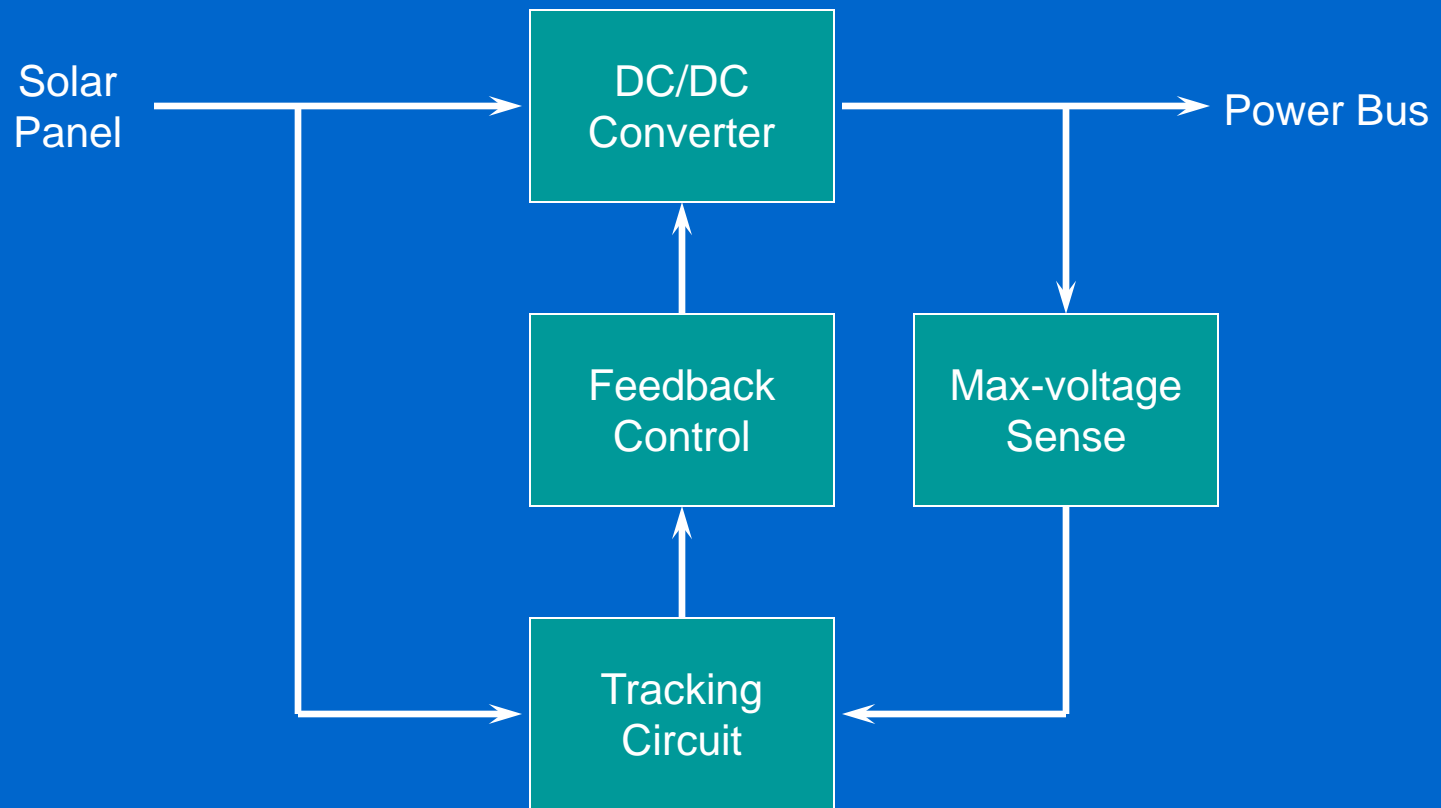
# Generated Solar Power



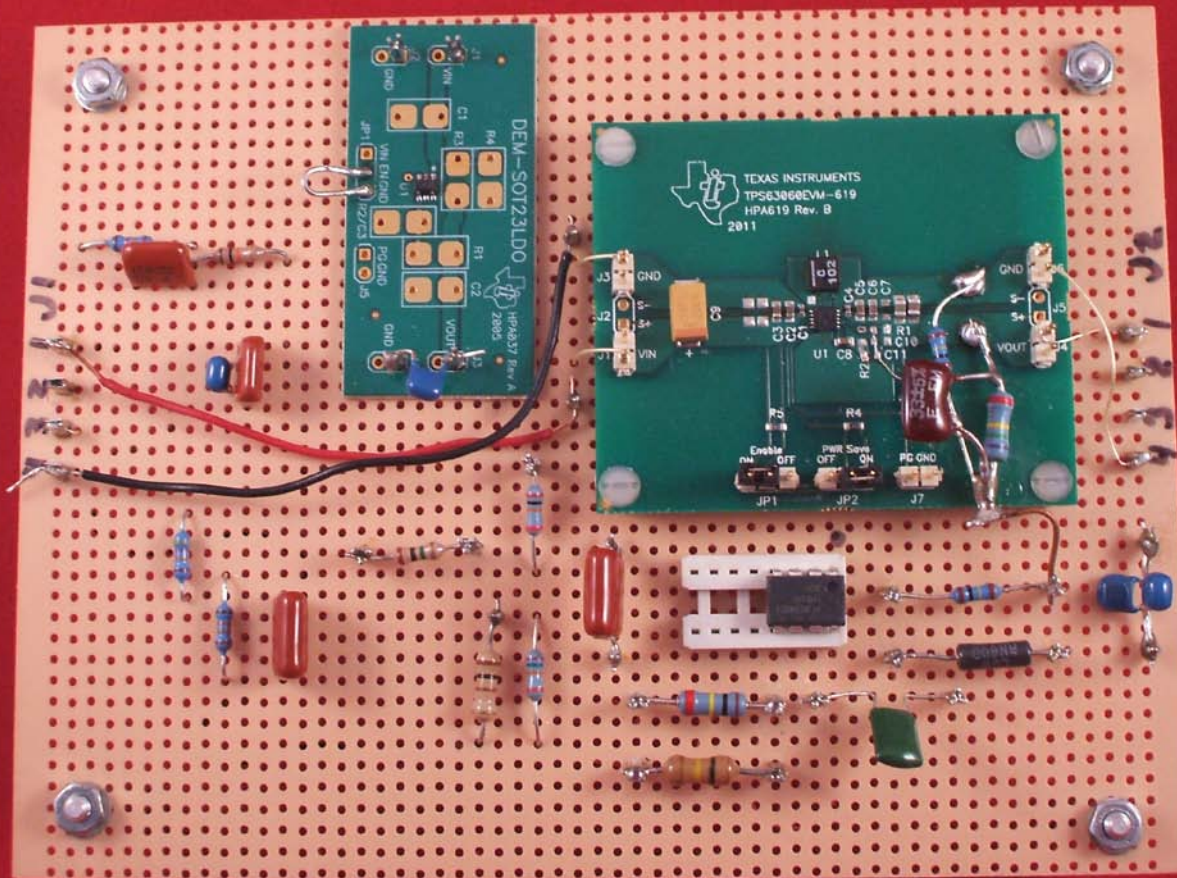
# Power Supply Card



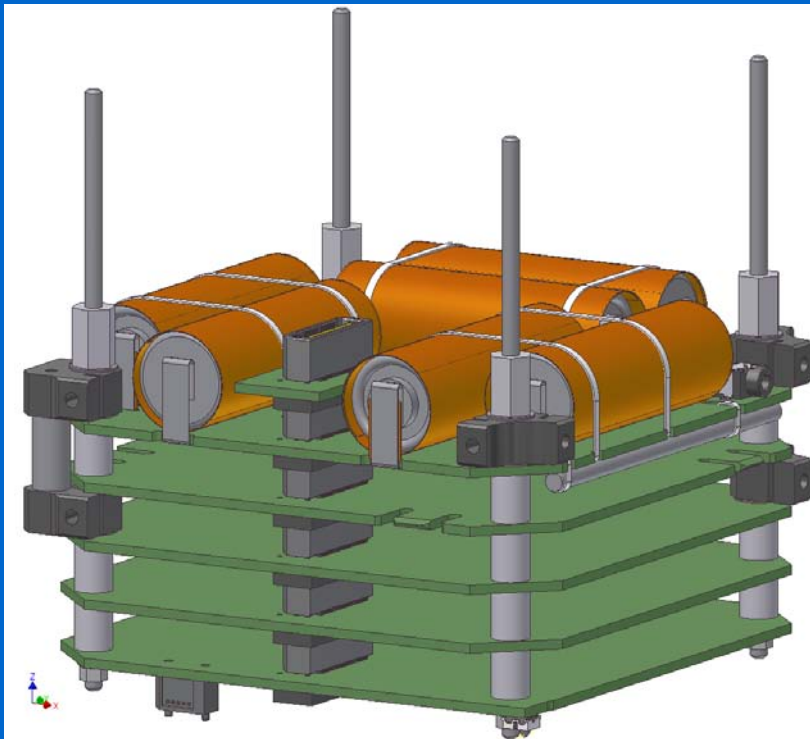
# MPPT Operation



# MPPT Prototype



# Battery Card



- 6 NiCad A cells
- 3.6 V nominal
- 3.4 Amp-hours
- 12 watt-hours capacity
- Active thermal control

# Battery Card



# Internal Housekeeping Unit



- Collects telemetry information
- Operates science experiment
- Generates telemetry downlink as sub-audible FSK mixed with voice signal in transponder mode
- Generates high speed FSK in data mode
- Executes commands from ground control

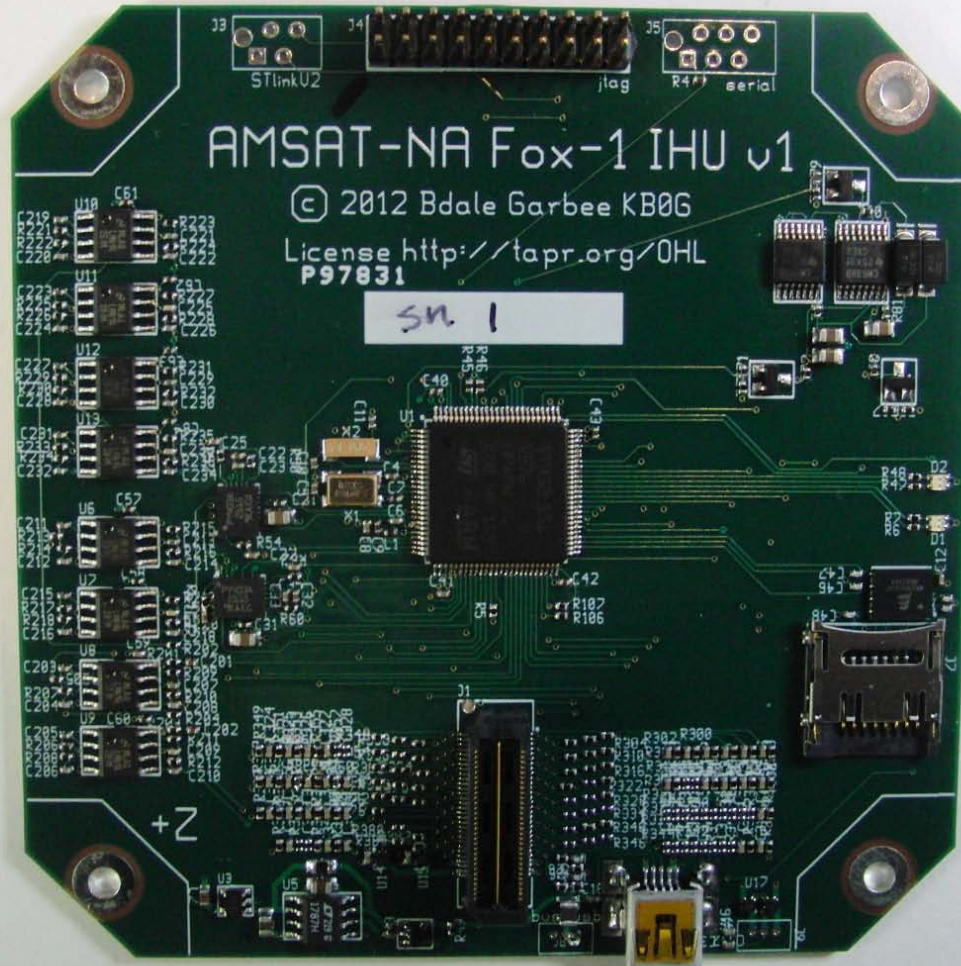
# IHU Card Processor



- *Ultra Low Power* ST Microelectronics STM32L
- 32-bit processor
- 33 MIPS
- 384K FLASH
- 48K RAM
- 128K Magnetorestrictive non-volatile RAM



# IHU Card Prototype



# Flight Software



- Open source SW tools (GNU C compiler)
- LINUX & Windows development environments
- FreeRTOS operating system
- STM32L "Discovery" card for SW development

# Flight Software on IHU



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Module	Status
SW Tools	running
Operating sys	running
Startup	design
SPI driver	running
I <sup>2</sup> C driver	running
USB driver	running
GPIO driver	running
DAC driver	running
ADC driver	running
Debug port	running
Serial driver	running
NV memory	running

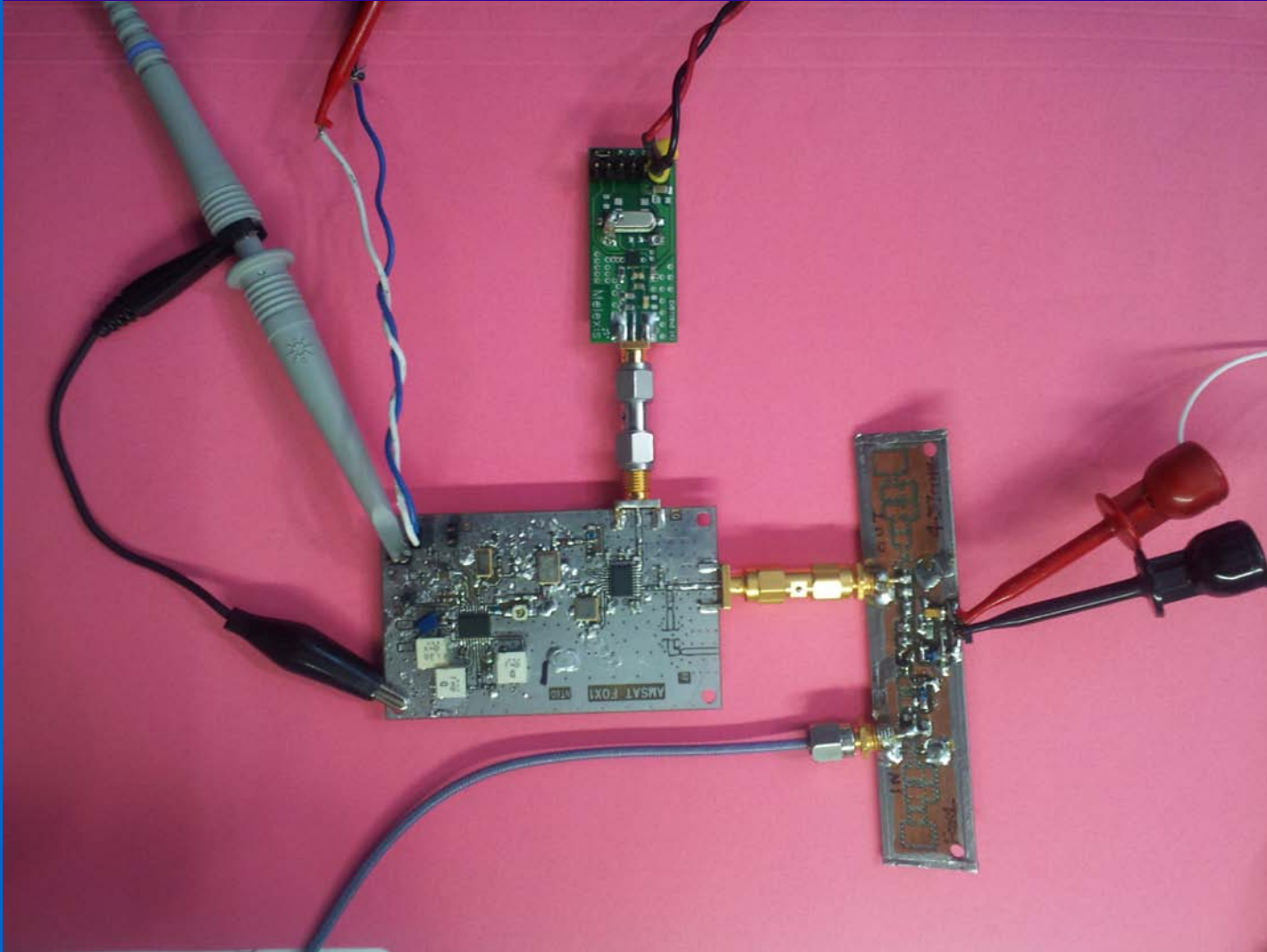
Module	Status
SW Arch	V1
MEMS exp	running
Rad Exp	running
Telemetry	design
Downlink	design
Uplink	design
Antenna	design
Health mon	running
Umbilical	running
Camera	design

# RF Receiver Card



- Operates on 70cm
- FM receiver
- LNA with SAW filter for high sensitivity and interference rejection
- Automatic frequency control

# Receiver Test Prototype

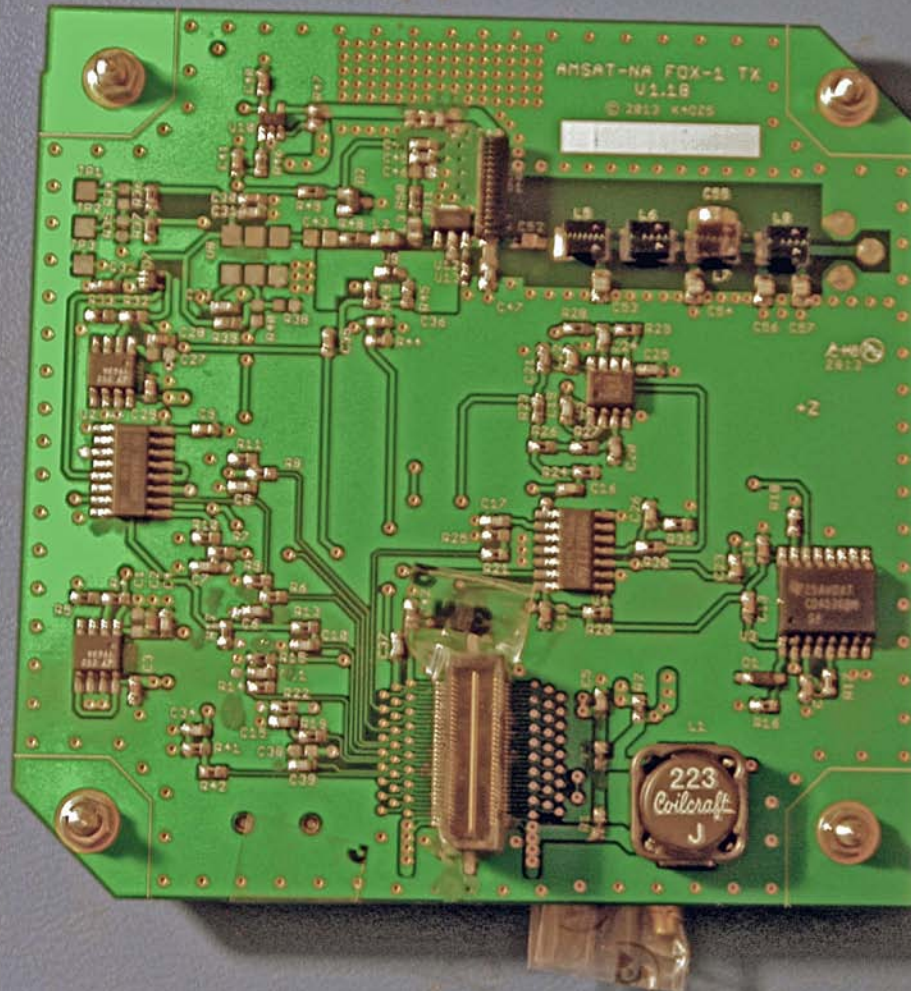


# RF Transmitter Card



- Operates on 2 meters
- FM exciter
- Power amp produces 400 mW minimum
- 800 mW max on fully charged battery

# RF Transmitter Card Prototype



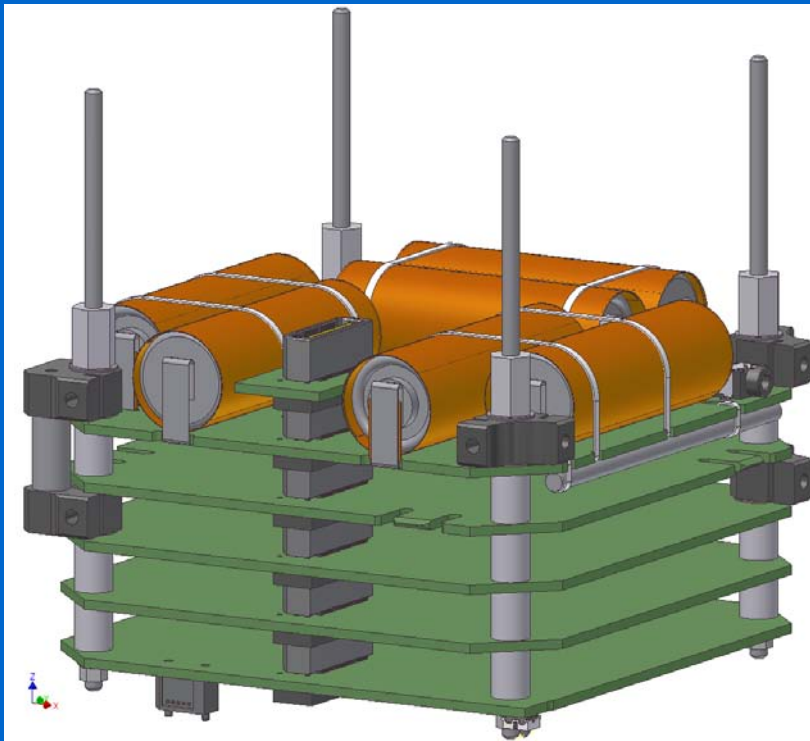
# Live Transmitter Demo



- Tune Radio to 145.980 MHz
- RF Tx Card
- IHU Card



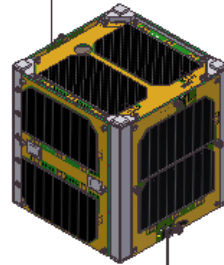
# Attitude Control System



- Passive magnetic system
- Aligns satellite z-axis with earth's magnetic field
- Bar magnet on structure
- Hysteresis rods on battery card for motion damping

# Antennas

70 cm whip



2 meter whip

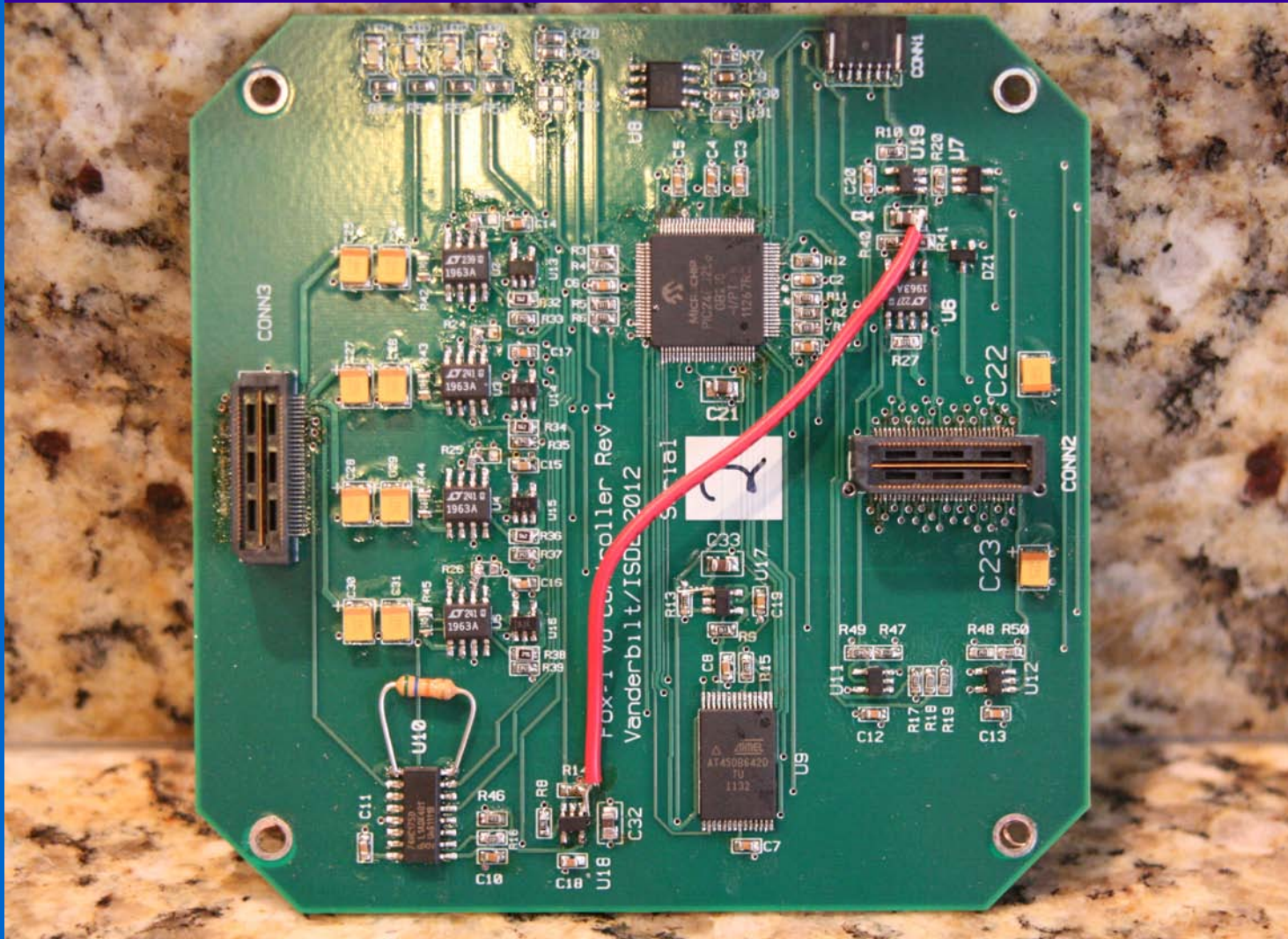


# Experiments on *Fox-1*

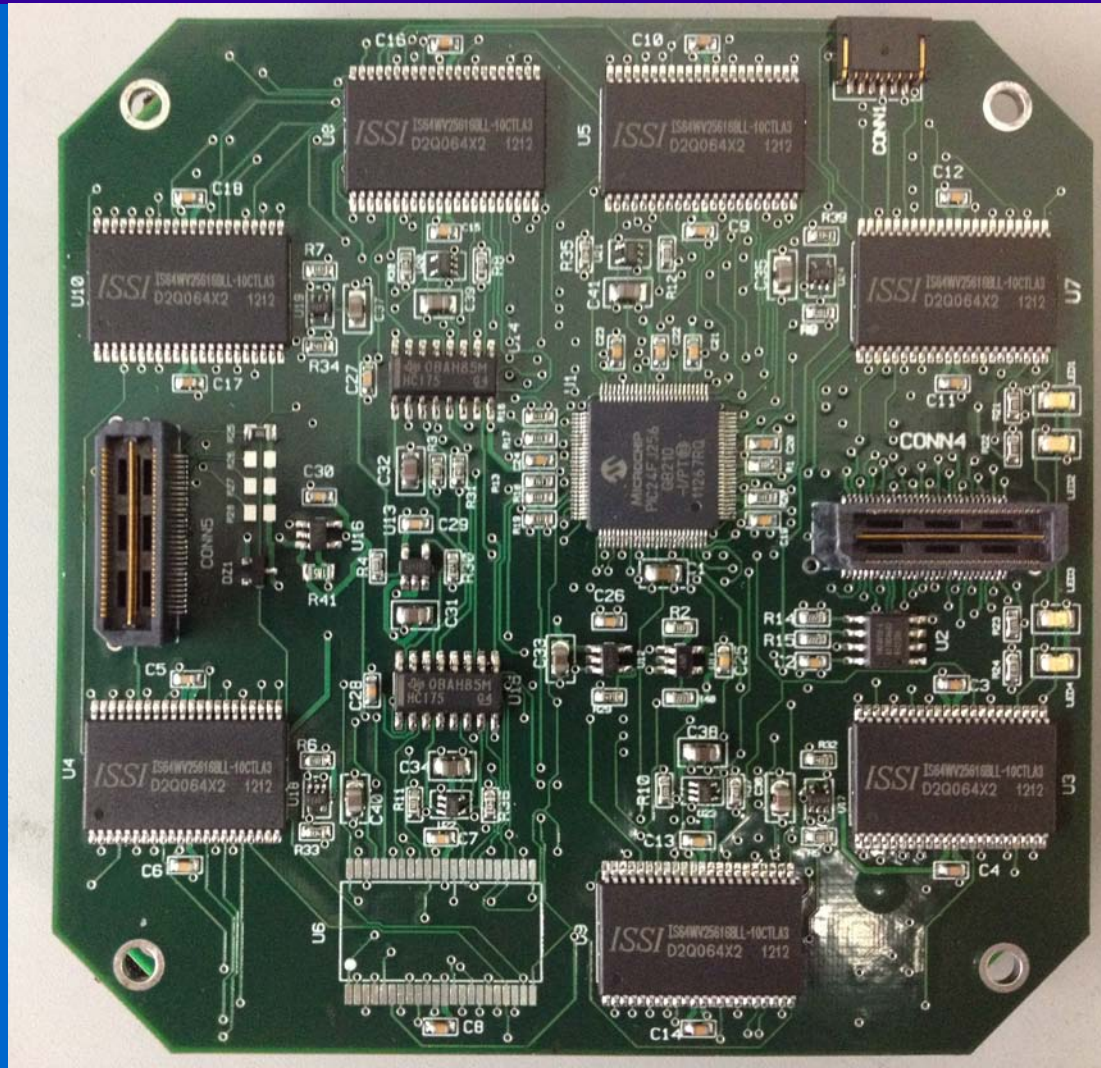


- MEMs gyros on IHU from Penn State
- Radiation Effects experiment from Vanderbilt University
- JPEG Camera from Virginia Tech

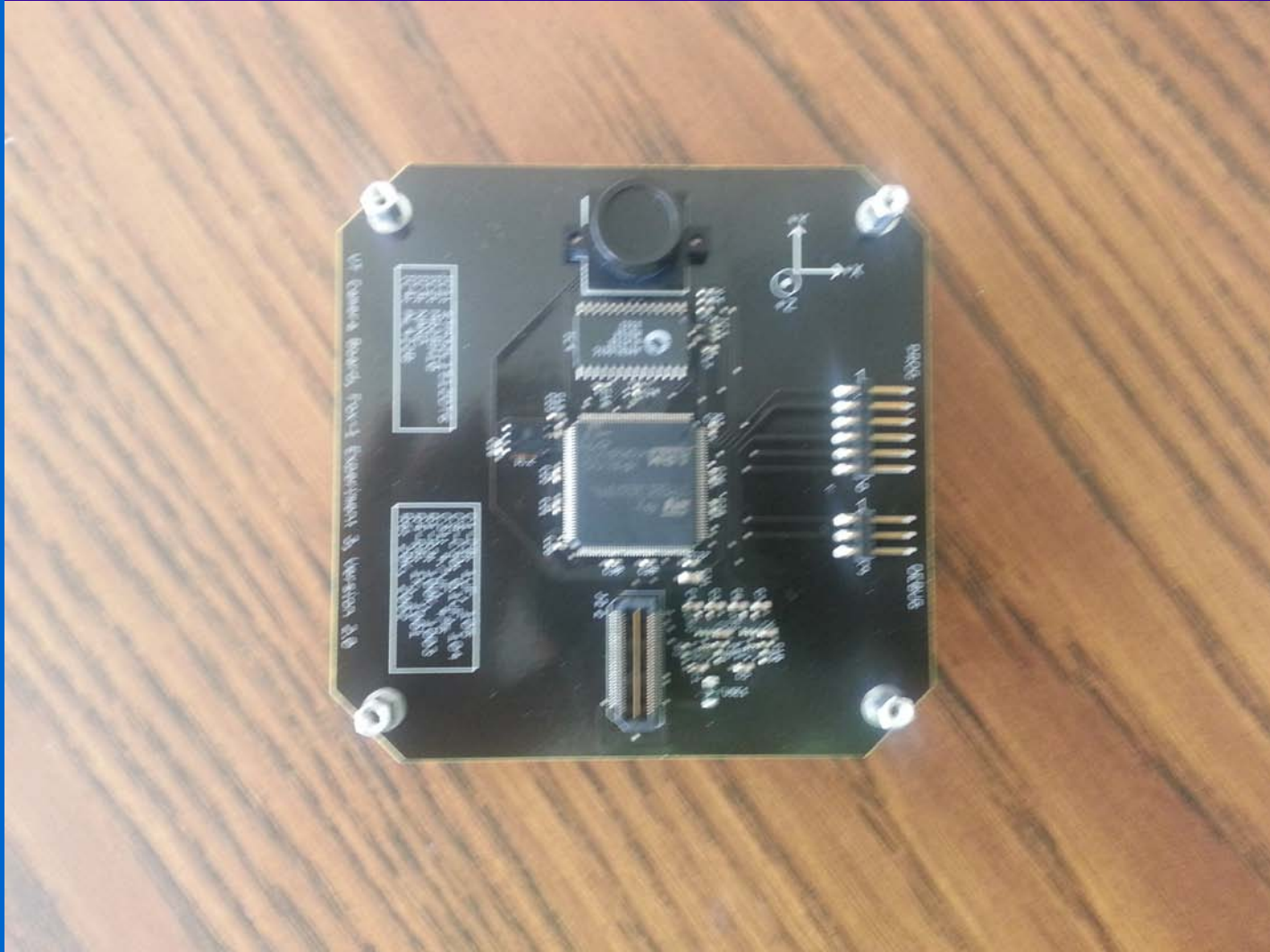
# Vanderbilt University Controller



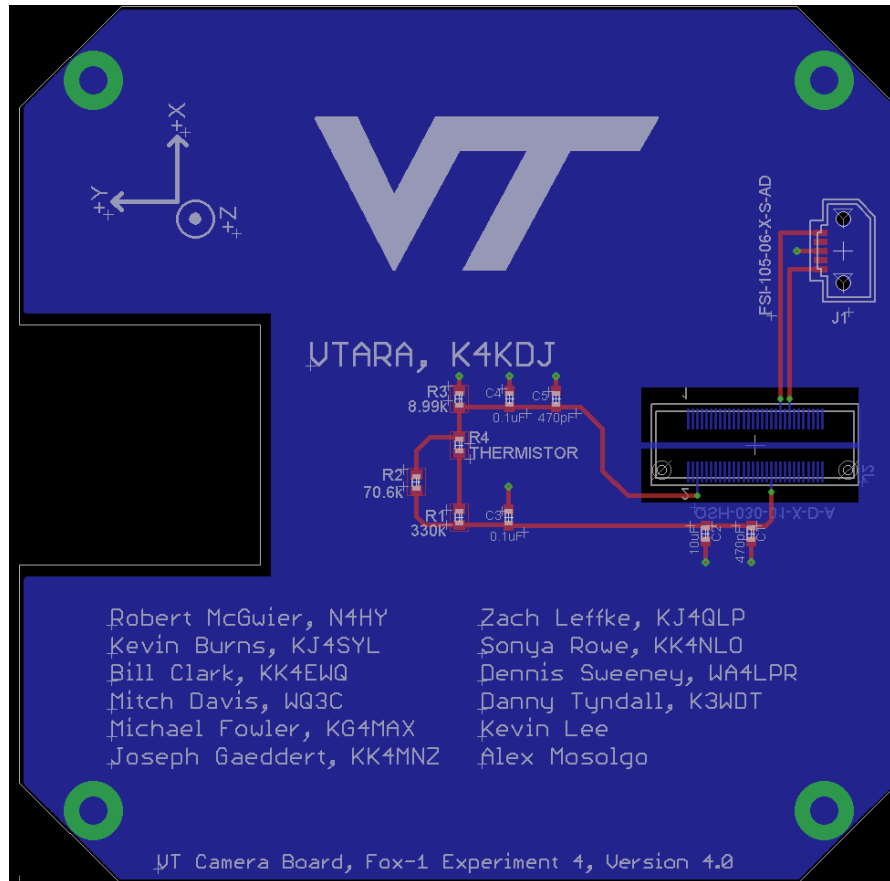
# Low Energy Proton Experiment



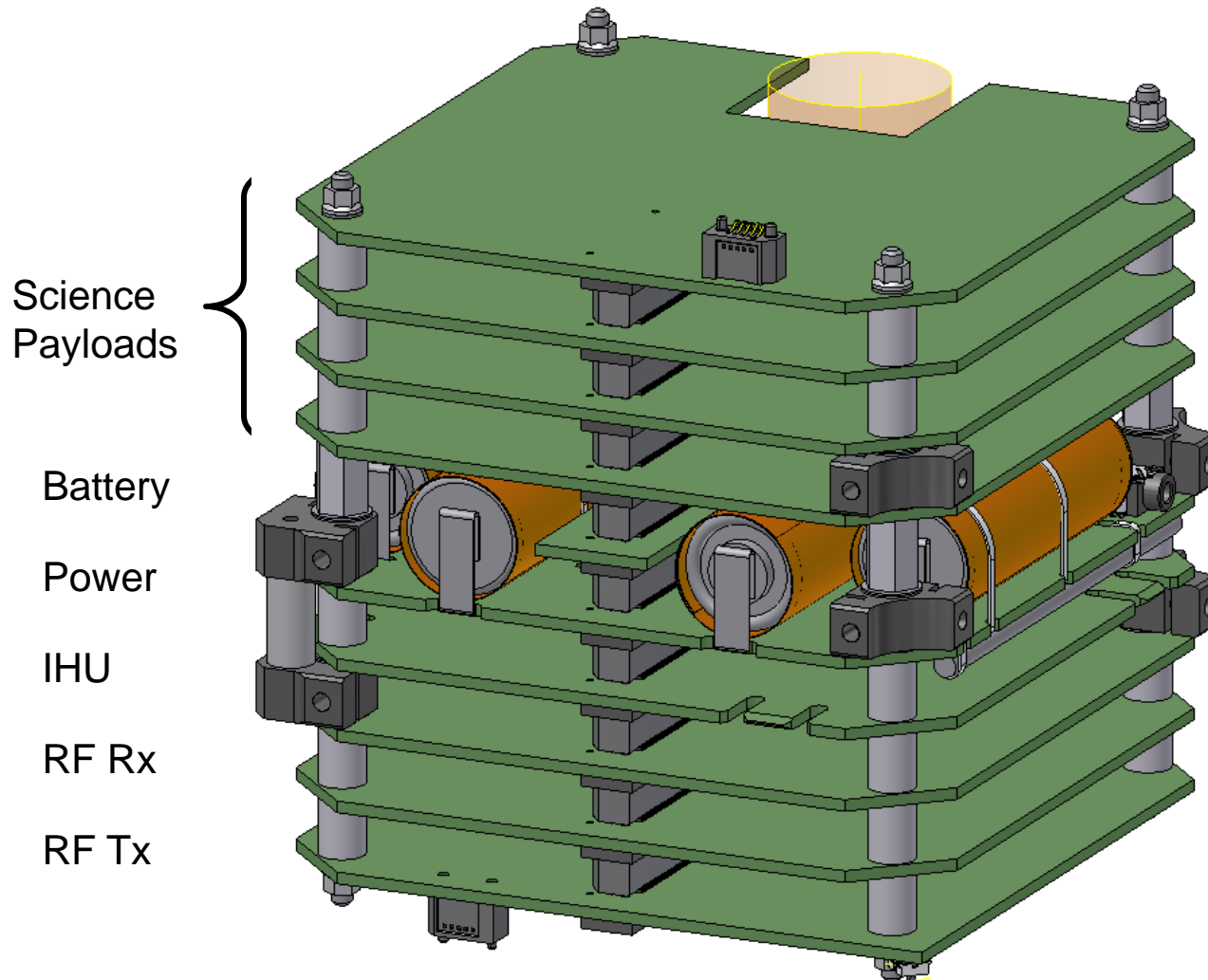
# Camera Card



# Experiment 4 Card PCB Design

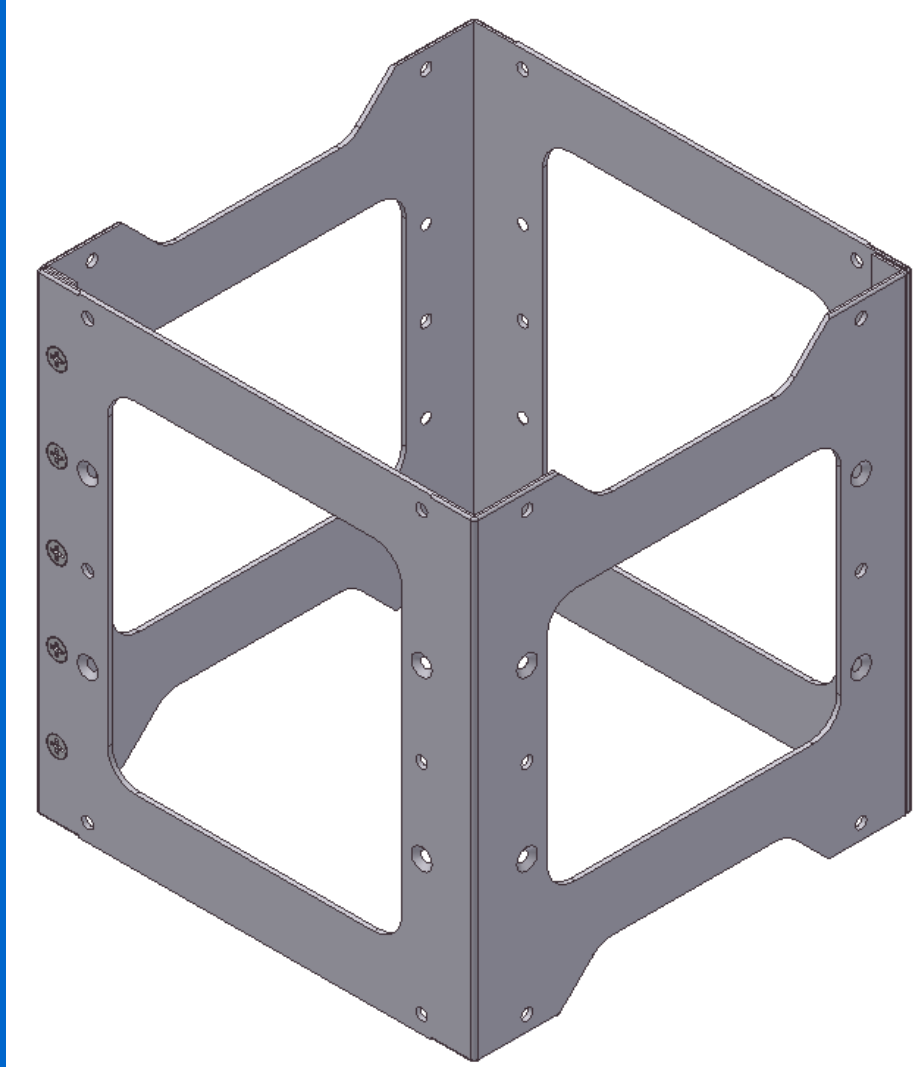


# Avionics PCB Stack

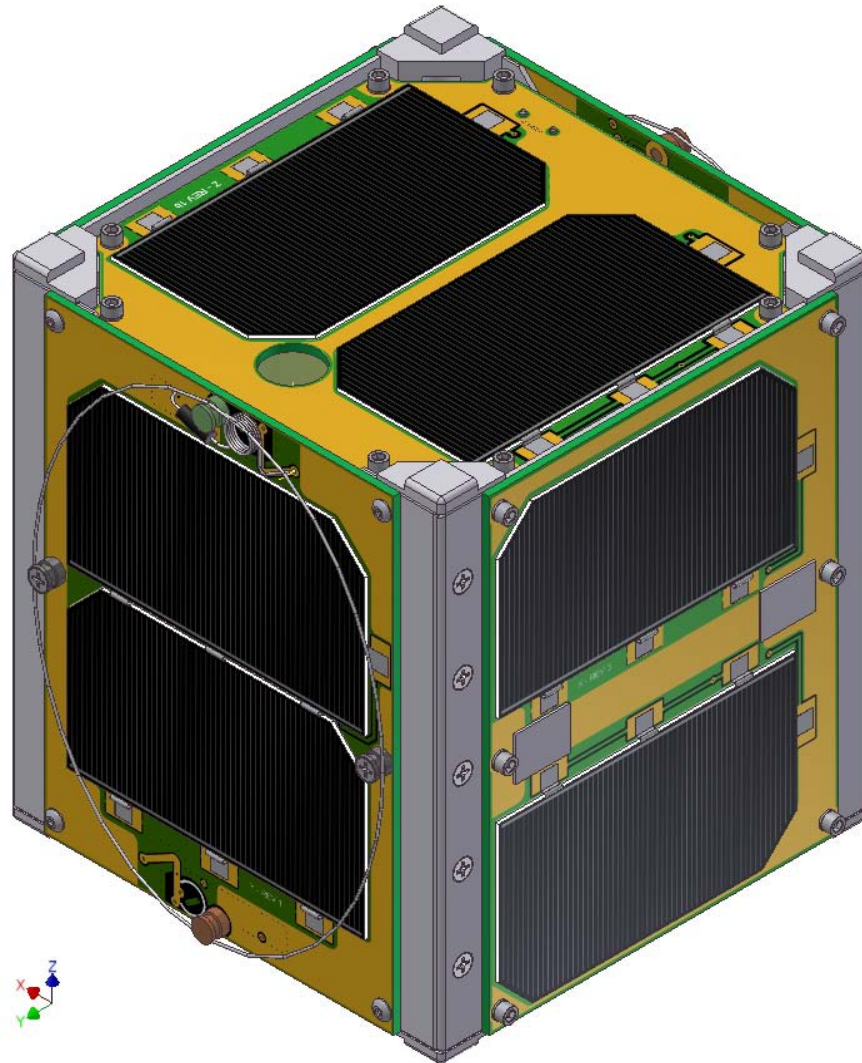




# *Fox-1* Structure



# Assembled *Fox-1* Satellite



# *Fox-1* Operational Modes



- Transponder Mode
  - FM analog repeater
  - Telemetry/experiment data sent as sub-audible, low-speed FSK simultaneously with voice
- Camera Mode
  - High-speed FSK downlink
  - Color JPEG photos (VGA resolution)
  - 1 photo per minute
  - Telemetry and experiment data multiplexed with image data

# RadFxSat



- *Fox-1* satellite bus
- Space radiation-effects experiments provided by Vanderbilt University
- Experiments run simultaneously with amateur radio transponder
- Proposal accepted into NASA ELaNa program March 2013
- No launch date yet

# AMSAT Classifieds



**\*\*\* HELP WANTED \*\*\***

**AMSAT is always hiring!**

- **Design engineering:** mechanical, electrical, PCB design systems, software, project management, thermal design
- **Satellite construction:** PCB construction, parts procurement, component fabrication, assembly
- **Satellite testing:** environmental testing, functional testing, requirements and regulatory compliance testing

Contact Tony Monteiro [aa2tx@amsat.org](mailto:aa2tx@amsat.org)



# Questions?



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