Space Symposium 2012

AMSAT *Fox* Satellite Program

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Background

- AO-51 was the most popular ham satellite
- Could be worked with simple equipment - HT and “arrow” antenna
- Widely used in scouting, educational and demonstration events
- Failed in November 2011
- Need replacement ASAP!

Background (cont)

- Good old days of free launches for AMSAT are gone
- Microsats once a low-cost path to orbit
- Commercial launch costs are > $1M
- AMSAT cannot afford to launch a microsat

AMSAT *Fox* Launch Strategy

- Take advantage of large and growing interest in CubeSats
- Develop family of CubeSats that have ham radio transponders and are capable of hosting science experiments
- Partner with universities to develop science and education missions
- Launch provided by primary mission via grants or NASA ELaNa program
- After primary mission completed, satellite provides amateur radio transponder

CubeSat Technical Challenges

- Very small size (4-inch cube)
  - 1/16 volume of AO-51
- Mass limit
  - 1.33 kg
- Limited space for solar cells - limited power
- Limited area for antennas

Fox Program Phases

- Phase 1 satellites
  - 1U CubeSats
  - FM analog transponder
  - Digital data up to 9600 bps
- Phase 2 satellites
  - 1U to 3U CubeSats
  - Software defined radio transponders
  - Linear and high-performance digital modes

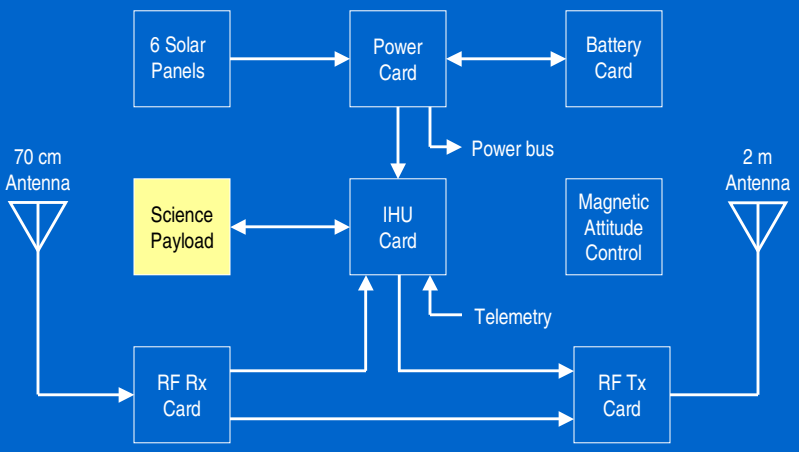
Fox-1 Satellite

- Proposal submitted to NASA for launch as an educational mission - Nov 2011
- Penn State student experiment with MEMs gyros
- Requested orbit - 650 km ("A Train")
- Requested launch - 2nd Half 2013
- Accepted into NASA ELaNa program - Feb 2012

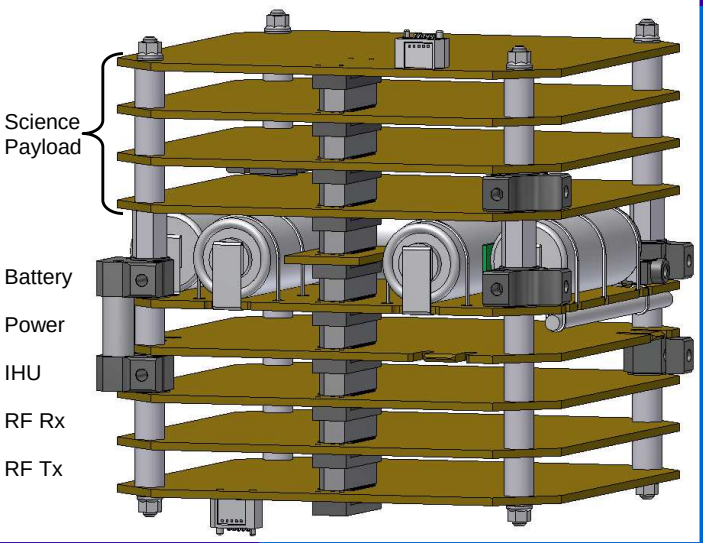
Fox-1 Satellite Overview

- Transponder Mode
  - FM analog repeater
  - Telemetry sent simultaneously with voice in sub-audio band as low-speed FSK
- Data Mode
  - FSK Digital data up to 9600 bps
  - Will be tested on-orbit for use in future missions

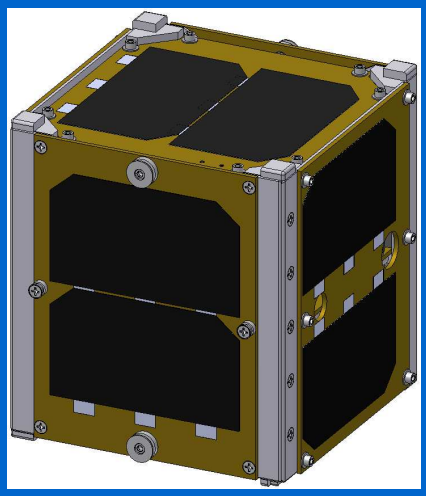
Fox-1 Avionics



Avionics PCB Stack

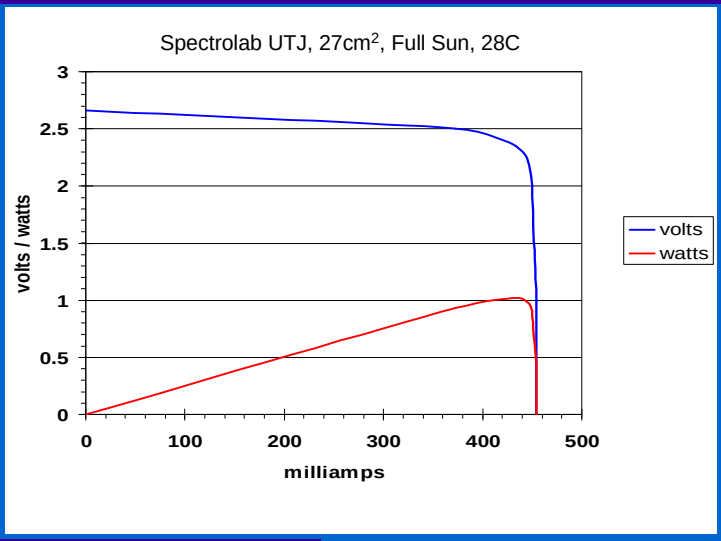


Solar Panels

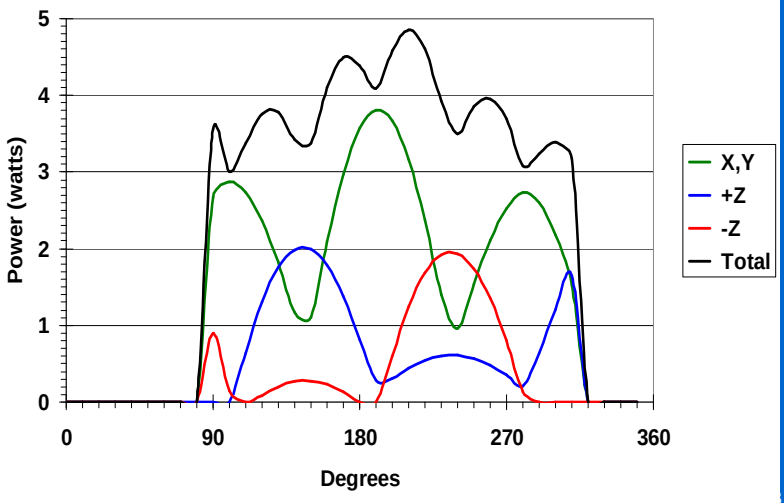


- 6 solar panels
- 2 cells per panel
- Spectrolab Ultra Triple Junction cells
- Space-rated
- 28% conversion efficiency

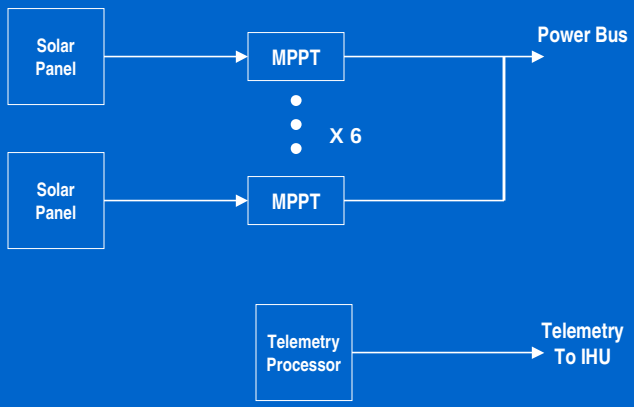
Solar Cell Characteristics



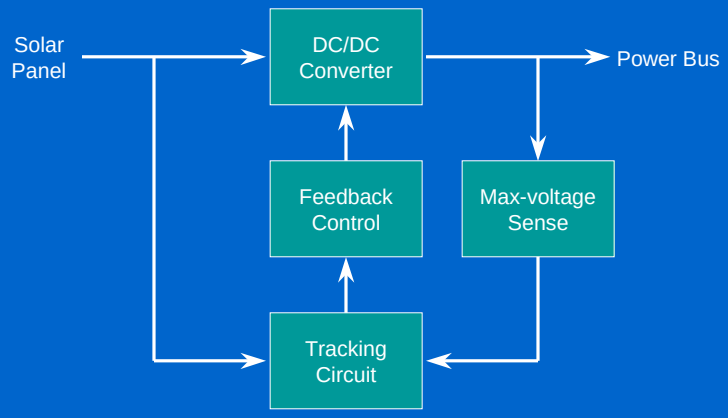
Generated Solar Power



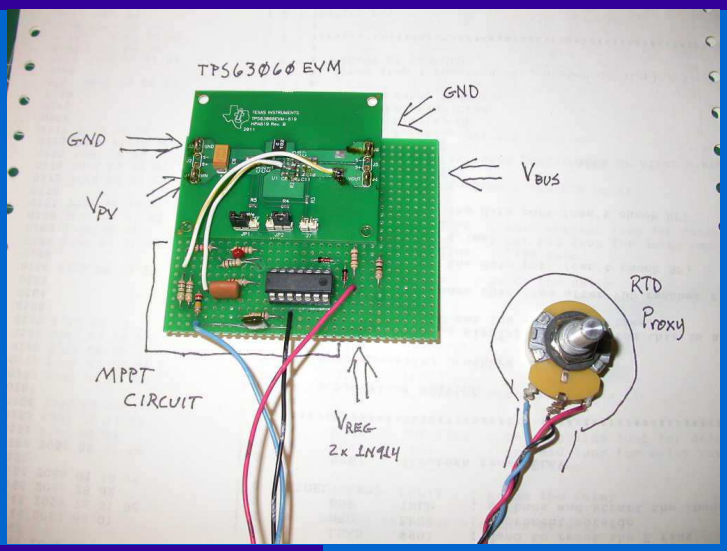
Power Card



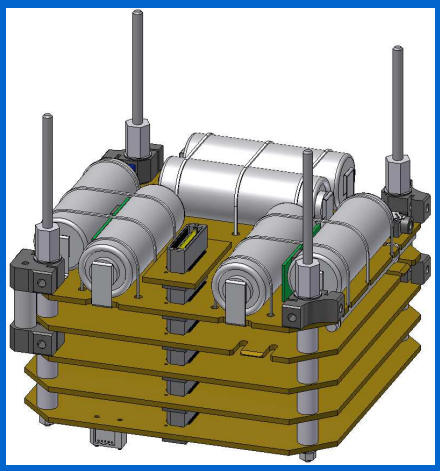
MPPT Operation



MPPT Test Circuit



Battery Card



- 6 Cadnica (NiCad) A cells
- 3.6 V nominal
- 12 watt-hours capacity
- 10% depth of discharge for long life
- Battery protection circuitry
- Active thermal control
- Telemetry processor

IHU Card

- Collects telemetry information
- Operates science experiment
- Sends telemetry as sub-audible low speed FSK in transponder mode
- High speed FSK in data mode
- Executes commands from ground control

IHU Card (cont)

- ST Microelectronics STM32L
- Ultra low power CPU
- 32-bit processor
- 33 MIPS
- 128K FLASH program memory
- 16K RAM
- 64K non-volatile FRAM
- Micro-SD card
- MEMs gyros

IHU Software

- Open source SW tools (GNU C compiler)
- LINUX or Windows development environment
- FreeRTOS operating system
- STM32 "Discovery" card for SW development
- FreeRTOS running on Discovery card
- Drivers for I^2C, SPI, serial ports running
- Modems for high and low speed data will be done in software

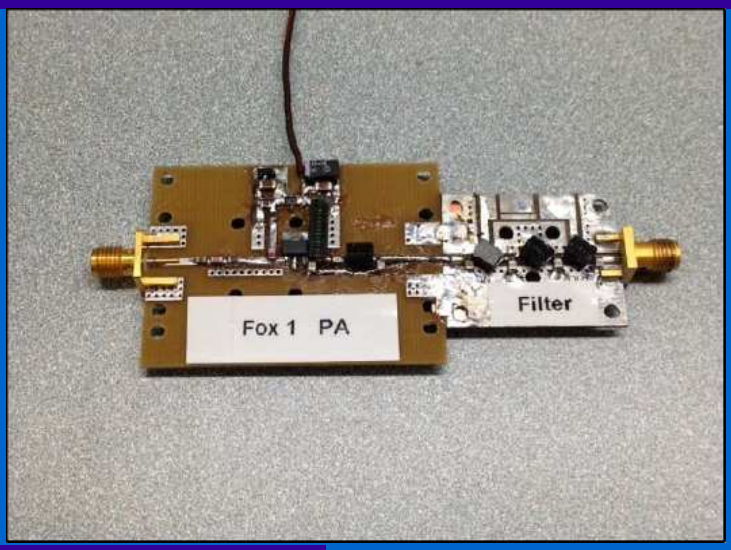
RF Rx Card

- 70cm FM receiver
- LNA with SAW filter
- Automatic frequency control
- Provides audio to IHU and RF Tx
- 67 Hz PL tone detector
- 2 minute timer to key RF Tx

RF Tx Card

- 2 meter FM transmitter
- Audio inputs from IHU and RF Rx
- Audio processing (deviation limiter, filters, mixer etc.)
- True FM exciter
- Power amp produces > 400 mW

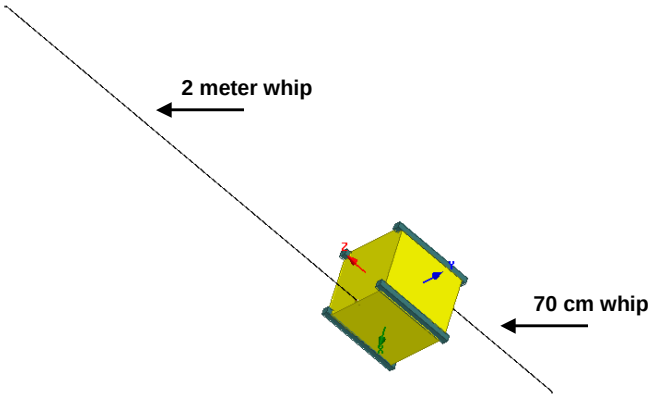
RF Power Amp



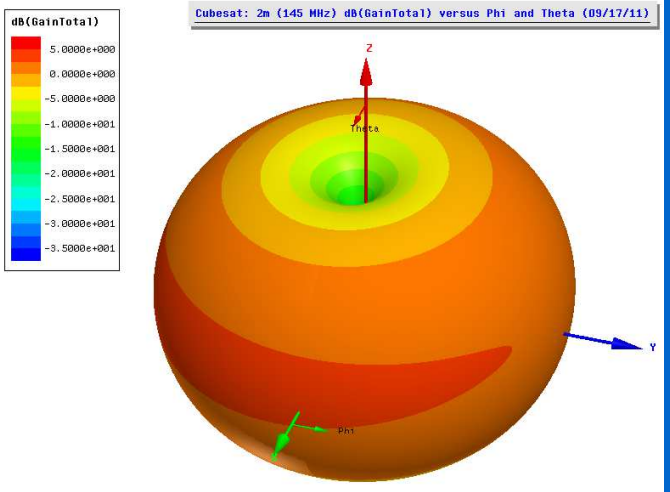
Attitude Control

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

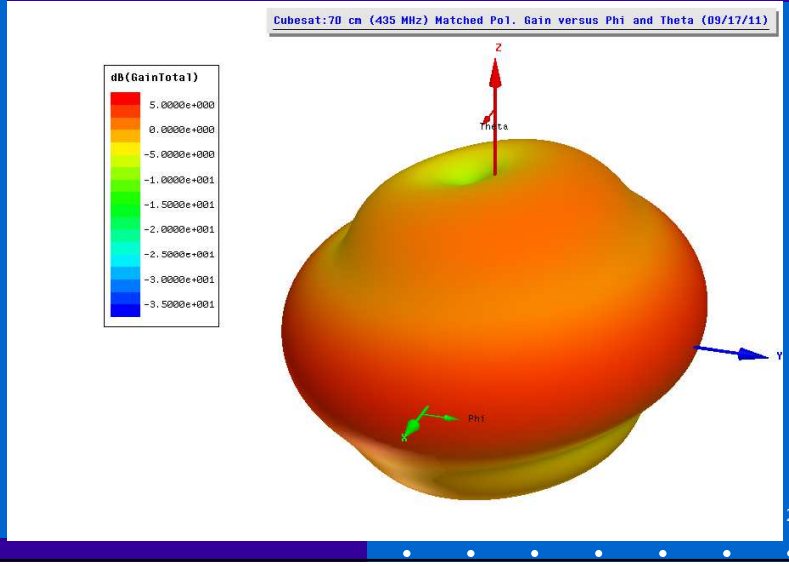
Antennas



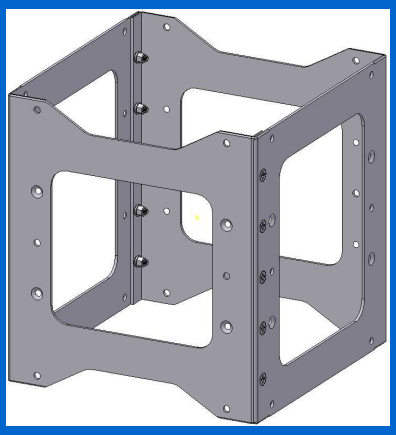
VHF Antenna Pattern

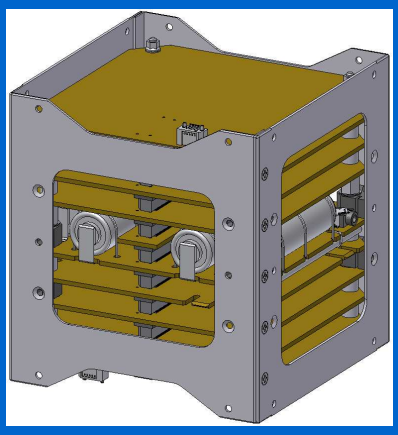


UHF Antenna Pattern

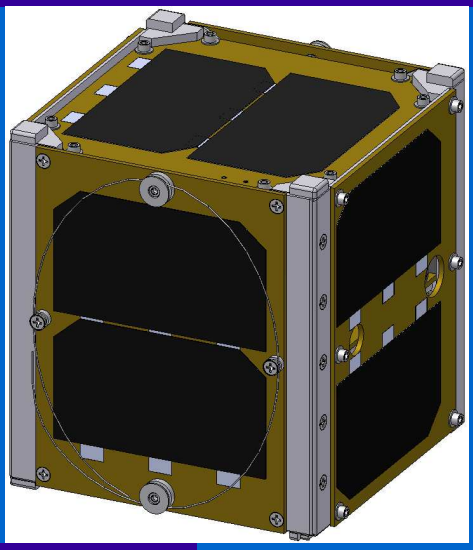


CubeSat Structure and PCB Stack





Assembled *Fox-1* Satellite



Satellite Projects based on *Fox-1*

- AubieSat-2 & 3
- RadFxSat

AubieSat-2 & 3

- Two CubeSats
- Proposal for National Science Foundation grant
- Auburn, University of Alabama & AMSAT
- 1-year science mission - atmospheric physics
- Ham transponder after science mission is complete

AubieSat-2 & 3 (cont)

- Alabama to provide science payload
- Auburn to provide 3U structure and gravity gradient boom
- AMSAT to provide avionics based on *Fox-1*
- Proposal submitted
- Response from NSF expected in November
- NSF grants are highly competitive!

RadFxSat

- Vanderbilt University and AMSAT
- 1U CubeSat
- Based on *Fox-1* (flight spare)
- Science payload provided by Vanderbilt
- NASA ELaNa proposal

RadFxSat - Science Mission

- Advance the state of the art in understanding the effects of space radiation on electronic components
- Demonstrate an on-orbit platform for radiation qualification of components for space flight
- Validate and improve computer models used to predict radiation tolerance of semiconductor manufacturing processes

RadFxSat - Secondary Mission

- Formal STEM education of university undergraduate and graduate students at Vanderbilt University
- Formal STEM education of high school teachers and students at Vanderbilt University
- Informal STEM education via amateur radio transponder operation

RadFxSat - Mission Profile

- Science mission runs simultaneously with amateur radio transponder
- Science data transmitted via low-speed downlink
- Requested launch 2H 2014
- Requested orbit - 650km (same as *Fox-1*)
- NASA ELaNa proposal due Nov 12
- Response expected Feb 2013

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

Any Questions?