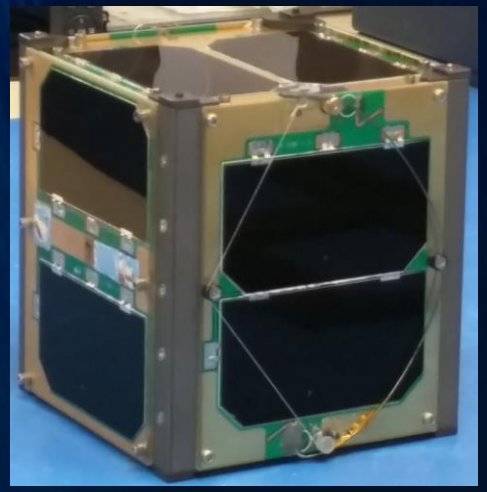
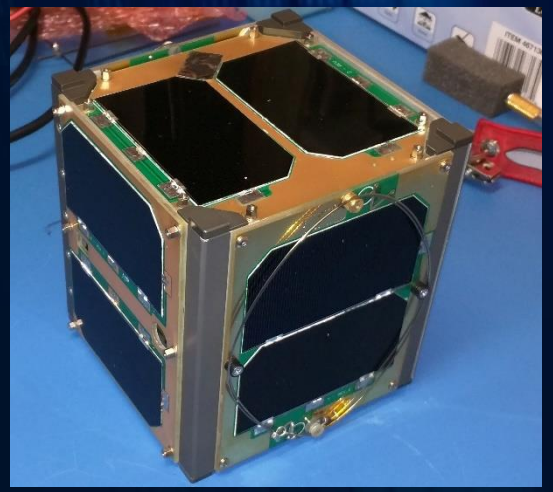
Engineering Update

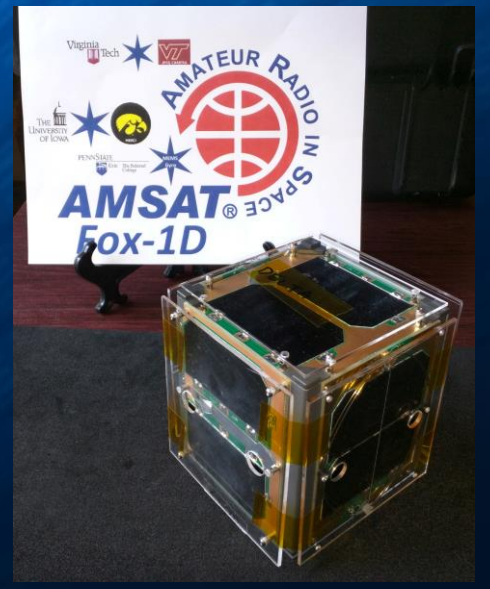
JERRY BUXTON, AMSAT-NA VP ENGINEERING

Engineering

FOX-1 SERIES ENGINEERING UPDATE







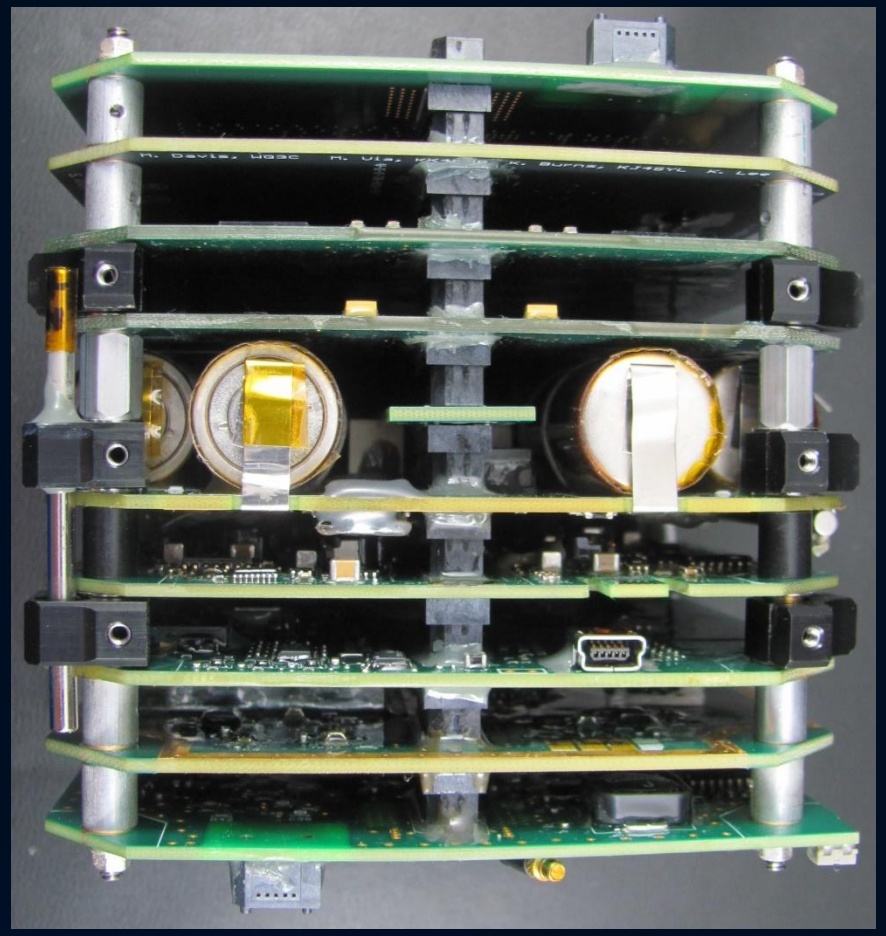
About the Fox-1 Program

Fox-1 Program

- Introduced in 2009
- AMSAT-NA's first CubeSat project
- Best opportunity to reach LEO
  - NASA CubeSat Launch Initiative (CSLI) = free launch
  - CubeSat standard design provides more launch opportunities
- Not just one, but a series
  - Common systems and bus
  - Host a variety of educational experiments

Fox-1 Program

- A marvel of miniaturization! (0603)
- Our own bus design, not commercial
  - ~8mm between PCBs
- Nine PCBs/Systems in a <10 cm. stack!
- Robust RF system, 800 mW output, AFC
- NiCd battery for longevity
- Powerful, low power STM32L151 MCU
- MPPT for maximum use of solar cells



Fox-1 Program

- A variety of university experiments
  - Vanderbilt ISDE radiation effects
  - Virginia Tech jpeg camera
  - University of Iowa radiation belt mapping
  - AMSAT L band downconverter
- Three CSLI ELaNa launches
- Two AMSAT purchased launches
- Five LEO satellites launched in a 30 month period!

Fox-1 Program

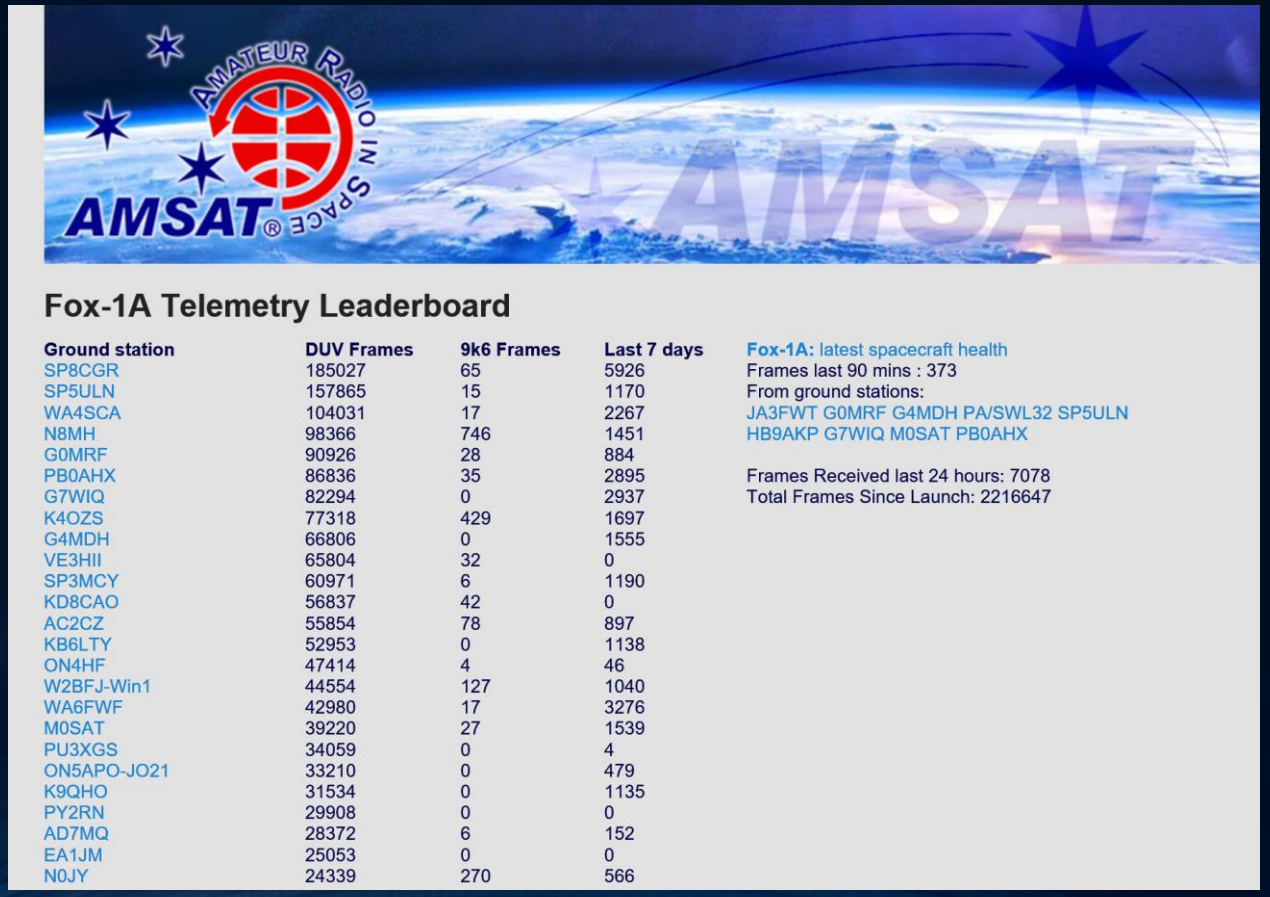
- Fox-1A – launched October 8, 2015
- RadFxSat/Fox-1B – scheduled to launch March 16, 2017
- Fox-1Cliff and Fox-1D – launching very soon as SpaceX resumes flight
- RadFxSat-2/Fox-1E – scheduled to launch December, 2017

Fox-1 Program

- Fox-1A / AO-85 proved that the concept works
- Lots of wonderful lessons learned (EXPERIENCE!)
- Five satellites = experience and improvement
  - Plus rapid aging, adrenaline rushes, sleeplessness, nail biting, nervous tics…
- LOTS of telemetry!
  - Study/verify/discover performance and expectations
  - Excellent science data for experiment partners

AO-85

- LOTS of telemetry received (as of October 21, 2016)



Fox-1A Telemetry Leaderboard

Ground station	DUV Frames	9k6 Frames	Last 7 days
SP8CGR	185027	65	5926
SP5ULN	157865	15	1170
WA4SCA	104031	17	2267
N8MH	98366	746	1451
G0MRF	90926	28	884
PB0AHX	86836	35	2895
G7WIQ	82294	0	2937
K4OZS	77318	429	1697
G4MDH	66806	0	1555
VE3HII	65804	32	0
SP3MCY	60971	6	1190
KD8CAO	56837	42	0
AC2CZ	55854	78	897
KB6LTY	52953	0	1138
ON4HF	47414	4	46
W2BFJ-Win1	44554	127	1040
WA6FWF	42980	17	3276
M0SAT	39220	27	1539
PU3XGS	34059	0	4
ON5APO-JO21	33210	0	479
K9QHO	31534	0	1135
PY2RN	29908	0	0
AD7MQ	28372	6	152
EA1JM	25053	0	0
N0JY	24339	270	566

Fox-1A: latest spacecraft health
Frames last 90 mins : 373
From ground stations:
JA3FWT G0MRF G4MDH PA/SWL32 SP5ULN
HB9AKP G7WIQ M0SAT PB0AHX

Frames Received last 24 hours: 7078
Total Frames Since Launch: 2216647

AO-85

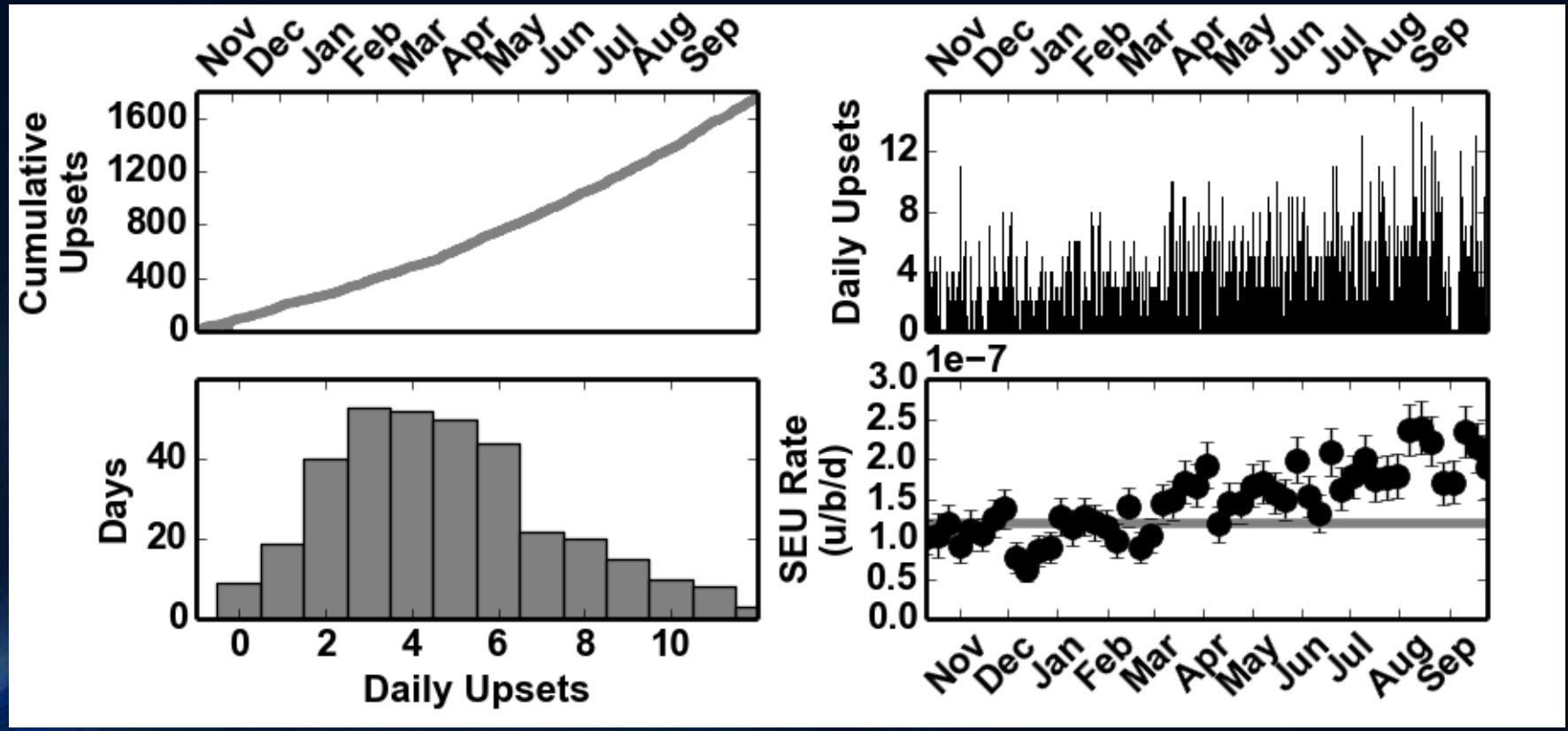
- Vanderbilt ISDE is very happy with the science

The Institute for Space and Defense Electronics at Vanderbilt University is home to faculty and full-time engineers dedicated to design, analysis, and testing of electronics for space and defense systems. The development of the Vulcan payload has presented unique opportunities to work with graduate and undergraduate students in developing flight boards. A larger outgrowth of the program has been the establishment of a student-led satellite club and amateur radio club, the latter motivating several students to receive their amateur licenses. Our partnership with AMSAT has been a great benefit to us. The leverage brought by the Fox team and the incomparably extensive set of ground stations of the world-wide amateur radio community have enabled us to collect a vast amount of data and claim mission success!

(excerpt from the Vanderbilt ISDE article in the Oct/Nov AMSAT Journal)

AO-85

- Vanderbilt ISDE science data

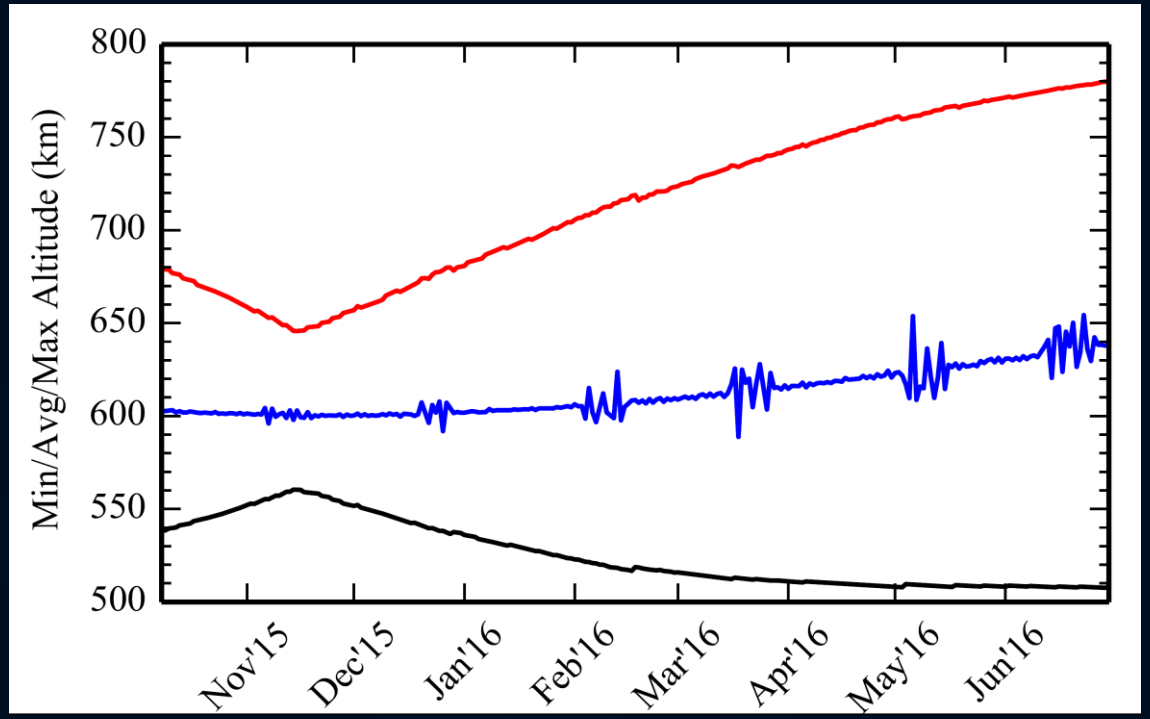


Our Partners Helping Us – The SAA and a Possible Connection to the Frequency of IHU Resets?

- 174 IHU Resets (as of October 21)

"We think we have figured out why the AO-85 memory error rate has been steadily increasing. The attached plot summarizes the altitude as we pass through the SAA and seeing a larger flux of protons. This could possibly also affect reset rates. This was done by following the satellite with pyephem and historical TLEs. It appears that the orbit has precessed. The apogee has moved relative to the SAA so we are crossing at higher altitudes, but I can't visualize how this happens in my head. Still trying to figure out where the noise in the average comes from, but its possibly due to assuming the SAA is within a square latlong box."

(Email from Vanderbilt)



Fox-1 Program

- Built relationships with NASA, launch providers, test facilities
- Learned about our abilities and limitations
- Opened the door to partnering with more educational institutions
  - More "free launches"
  - Provide communications systems for inclusion on their CubeSat designs
- New opportunities for educational outreach
  - Development of CubeSat IHU systems and functions

Fox-1 Program

- RadFxSat (fourth Fox-1 produced)
  - Demonstrates the maturity of the Fox-1 design
  - Demonstrates the work involved in producing one, even a mature design
- Building a satellite is not easy!
  - We want ours to reliably last years (the entire lifetime of the orbit)
  - "Low budget" means COTS, trade-offs, increased risk

RadFxSat-2

A.K.A FOX-1E

RadFxSat-2 Quiz!

RadFxSat-2 (Fox-1E) will have a linear transponder because

a) Drew kept bugging me for one
b) We were running out of parts for another FM repeater
c) The Fox Team was up to the challenge
d) We needed to grow on what we had learned

ALL OF THE ABOVE!

RadFxSat-2

- Partnership with Vanderbilt ISDE
  - All four experiment slots as RadFxSat
  - Testing FinFET technology
- ELaNa XX aboard maiden flight of Virgin Galactic Launcher One
- Our last set of NiCd "A" cells

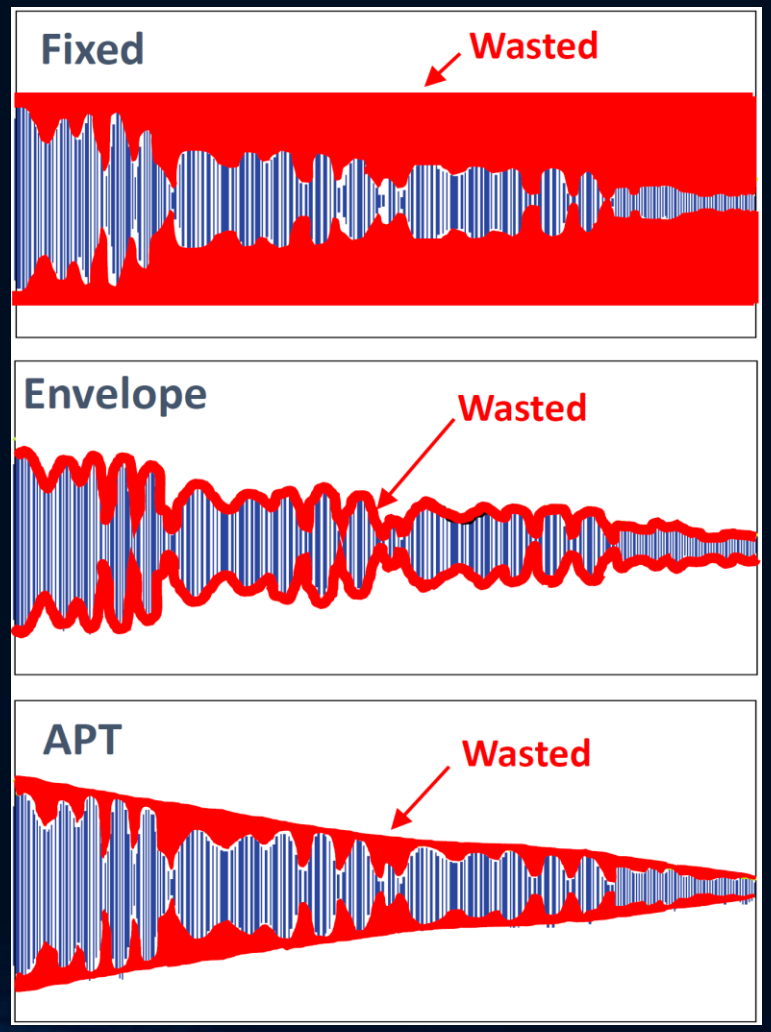
RadFxSat-2

- Fox-1E Linear Transponder (LT)
- Mode J (V/u) 30 kHz wide
- Separate 1200 baud BPSK telemetry channel
  - FoxTelem to decode
- Link budget targeting a handheld antenna e.g. “Arrow”
- Includes a new design for command receiver
- Innovative

RadFxSat-2

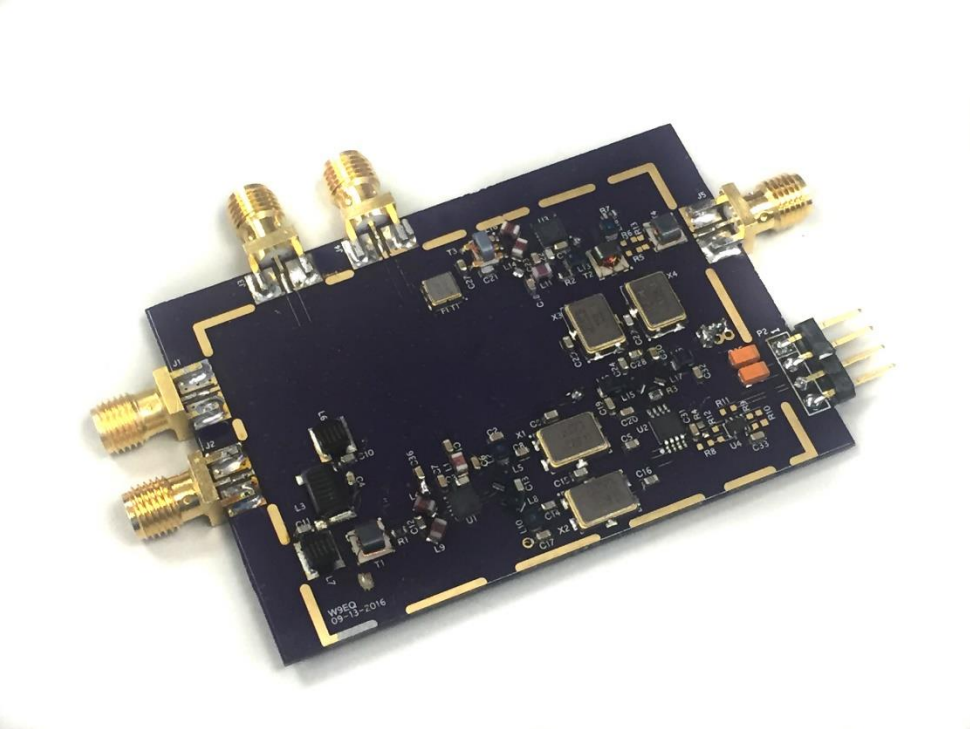
- Average Power Tracking (APT)

- Another way to improve the efficiency of a power amplifier when operated at a significant back off level is to use Average Power Tracking (APT). In this case, the value of the Vcc does not follow the instantaneous amplitude of the envelope, but it follows its average value. The complexity required in the modulator is a fraction of what is needed for ET, since now the Vcc envelope frequency is much lower. Although the efficiency achieved with this method is not as high as with ET, it is very convenient for small power amplifiers since the overhead current needed is much lower than with ET.



RadFxSat-2

- Prototype IF and mixers



Ready for Golf?

Engineering

ASCENT
(ADVANCED SATELLITE COMMUNICATIONS AND EXPLORATION OF NEW TECHNOLOGY)

ASCENT

PHASE 5 / CUBE QUEST CHALLENGE

Cube Quest Challenge

- Partnering with Ragnarok Industries, “Heimdallr” CubeSat
- We provide ranging, commands, data for the trip to the Moon
- We provide the downlink of the Challenge data while orbiting the Moon
- Once the CQC mission is complete (~1 month in lunar orbit) the satellite is handed over to us for use as a Phase 5 amateur radio satellite (lifetime TBD)
  - ~6 digital channels
  - Minimum 1 meter dish
  - AGT design

Cube Quest Challenge

- Rincon AstroSDR (same as P4B)
  - Original intent to create our own radio could not meet the timeline
- AMSAT designed Five and Dime patch antennas
- AMSAT designed power amplifier (similar to P4B) and low noise amplifier
- DVB-S2x implementation for the low SNR environment
- Omni antenna for deploy attitude and enroute pointing problems

Cube Quest Challenge

- GT-4 in late March 2017
  - Top 3 get EM-1, 4th and 5th are standby
- GT-4 will require test results and pictures of working hardware along with detailed descriptions of operation
- Launch: Late 2018
  - Competition ends 365 days after launch

Cube Quest Challenge

- Excellent development work in a 6U CubeSat format for
  - Ranging
  - Robust low SNR modulation
  - SSPA and LNA
  - Antennas
- …And we can take that with us

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SDR (SDX) DEVELOPMENT

SDR / SDX Development

- Continuation of the original plan for CQC
- FPGA (Field Programmable Gate Array) technology
  - A radio for any satellite
  - 20 MHz – 10 GHz
  - Just add "RF stuff" (LNA, PA, antennas, etc.)
  - You can make it be any kind of radio you like
    - digital, analog, FM, AM, SSB, C4FM, D-STAR…

SDR / SDX Development

- We are in the early stages
  - Just some knowledge/experience
  - “Texas Contingent” working on learning and designing multipurpose AMSAT SDR
  - AGT team also on a separate path to learning FPGA
- Fits well with our future plans
- FPGA knowledge can be applied to AstroSDR

SDR / SDX Development

- Excited and motivated teams
  - Difficult, but that's what makes it fun and worthwhile
- Puts the "ENT" in "ASCENT"!
- Very well documented for future AMSAT generations
  - Texas Contingent on a secure redmine server
  - AGT team open source on GitHub (pursued as terrestrial communications)
- Two separate paths increases diversity and reduces risk
  - If one team dissolves or fails, work still continues
- Will be shared in Symposium Proceedings and Presentations

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AMSAT GROUND TERMINAL (AGT)

AMSAT Ground Terminal

- Purposed as part of the Five and Dime paradigm
- Design a five and dime digital ground terminal:
  - Cost to purchase a COTS AGT < $1000
    - Possible kit sales for components
  - Plans freely available
  - Dish size ≤ 1 meter
  - Compatible with any digital five and dime satellite
- HOA friendly
  - DBS type dish with a GEO satellite

AMSAT Ground Terminal

- Worldwide team membership
  - Not covered by ITAR/EAR
    - It is a terrestrial amateur radio communication system, no satellite specific designs
  - Open source development
- Lots of activity
  - A variety of SDRs being explored and developed
  - Cheap and easy to find hardware
  - Antenna design
  - Michelle posts regular updates on YouTube

Q&A