

Radiation Reliability for CubeSat Experiments

Rebekah Austin

NASA AAQ Workshop – September 26th, 2016

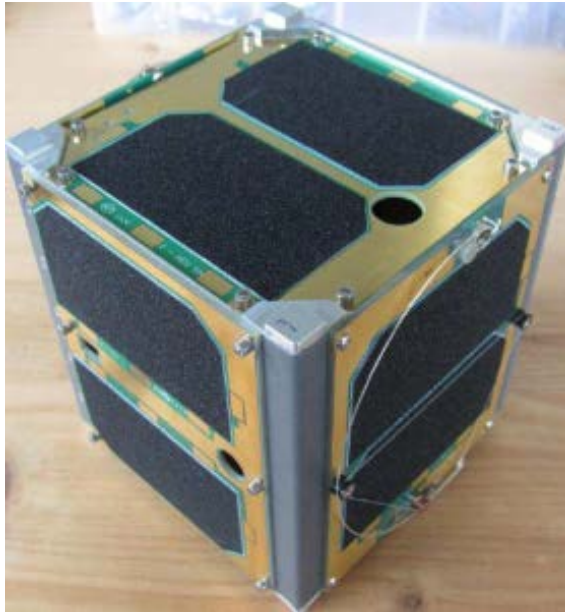
Background: RadFxSat Concept



Vanderbilt Engineering

- CubeSat partner provides spacecraft bus

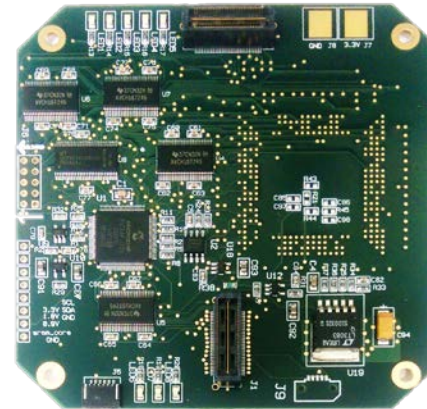
Example Spacecraft: Fox-1A



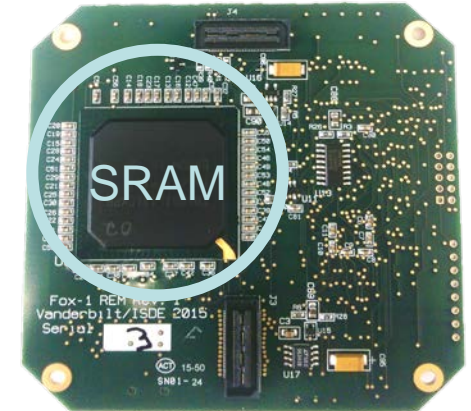
Courtesy of AMSAT

- Vanderbilt provides science payload

Example Payload: 28nm SRAM SEU Experiment



+Z Side



-Z Side

Background: Radiation Effects



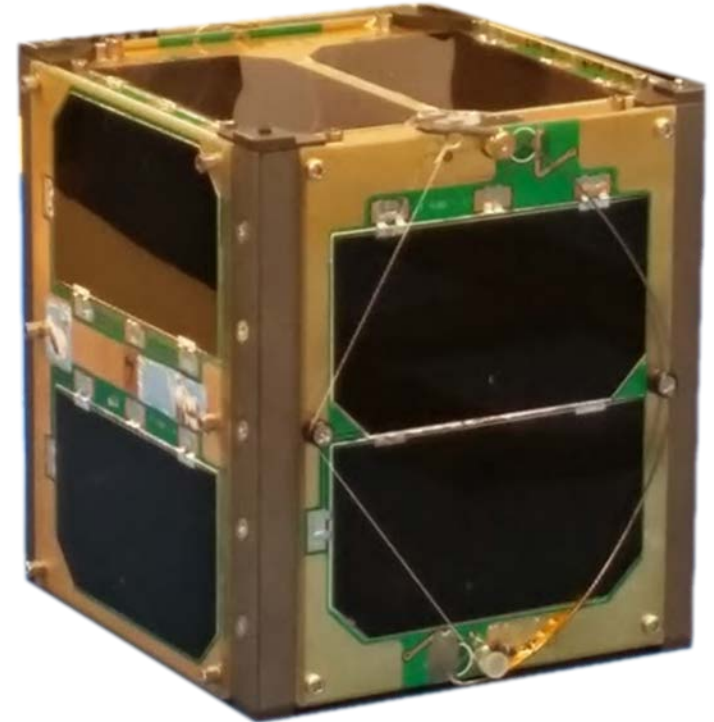
Radiation Effect	Physical Mechanism	Effect on CubeSat System
Total Ionizing Dose (TID)	Charge deposited in insulation oxides over time	<ol style="list-style-type: none">1) Increased power consumption2) Early system failure
Single Event Latch-up (SEL)	Self-sustaining high-current condition	<ol style="list-style-type: none">1) Premature system failure2) Drain battery
Single Event Upset (SEU)	Particle strike deposits charge to change the state of a memory cell	
Single Event Functional Interrupt (SEFI)	SEU in program and control registers of an IC	<ol style="list-style-type: none">1) Unknown behavior2) System crash

Background: Radiation Effects



Radiation Effect	Physical Mechanism	Effect on CubeSat System
Total Ionizing Dose (TID)	Charge deposited in insulation oxides over time	1) Increased power consumption 2) Early system failure
Single Event Latch-up (SEL)	Self-sustaining high-current condition	1) Premature system failure 2) Drain battery
Single Event Upset (SEU)	Particle strike deposits charge to change the state of a memory cell	
Single Event Functional Interrupt (SEFI)	SEU in program and control registers of an IC	1) Unknown behavior 2) System crash

- **Traditional Radiation Hardness Assurance (RHA)**
 - System reliability based on parts reliability
- **Commercial off-the-shelf (COTS) RHA**
 - System reliability based on system mitigation of part faults and failures
- **Shielding does not stop high-energy protons or galactic cosmic rays**
- **Two part RHA approach**
 - 1) Screening of COTS for Total Ionizing Dose (TID)
 - 2) System level mitigation of Single Event Effects (SEEs)

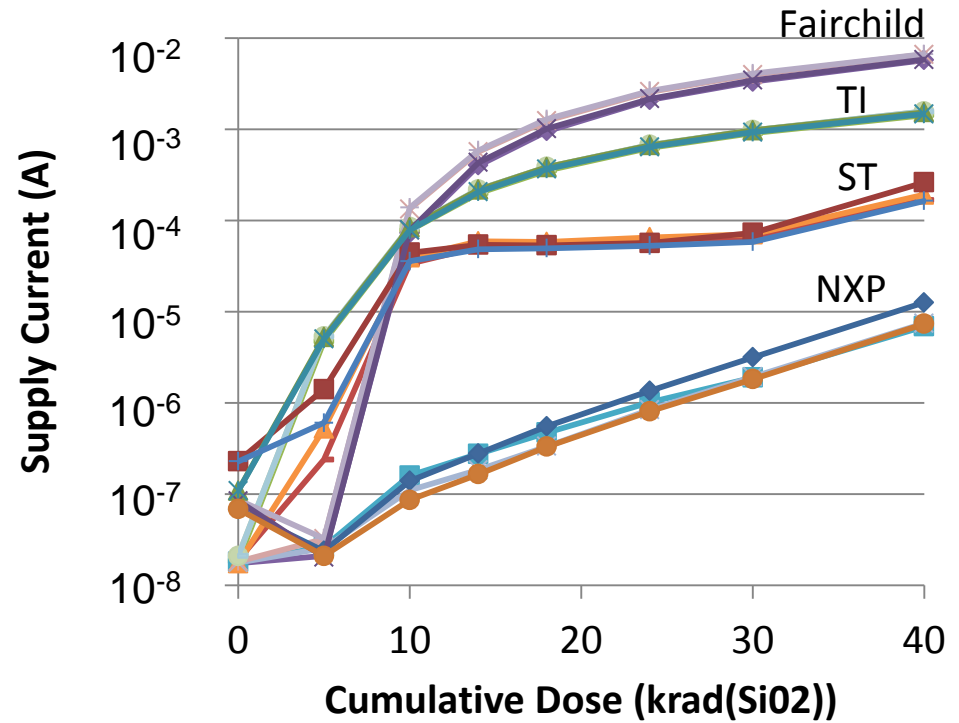


TID Screening



- Determine parts needed for mission
- Search part databases for existing testing
 - <http://www.nsrec.com/redw>
 - <http://radhome.gsfc.nasa.gov/radhome/raddatabase/raddatabase.html>
 - <http://radcentral.jpl.nasa.gov/>
- Perform TID characterization of candidate parts

D Flip-Flop Quiescent Supply Current

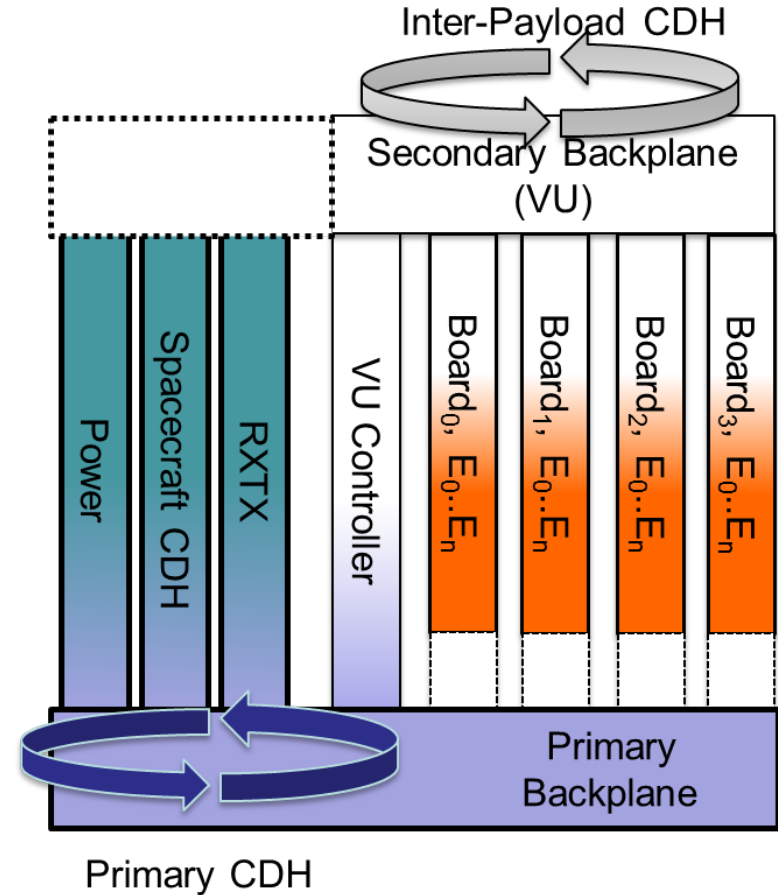


System-Level RHA: Radiation Effects and Reliability Testbed Architecture



Vanderbilt Engineering

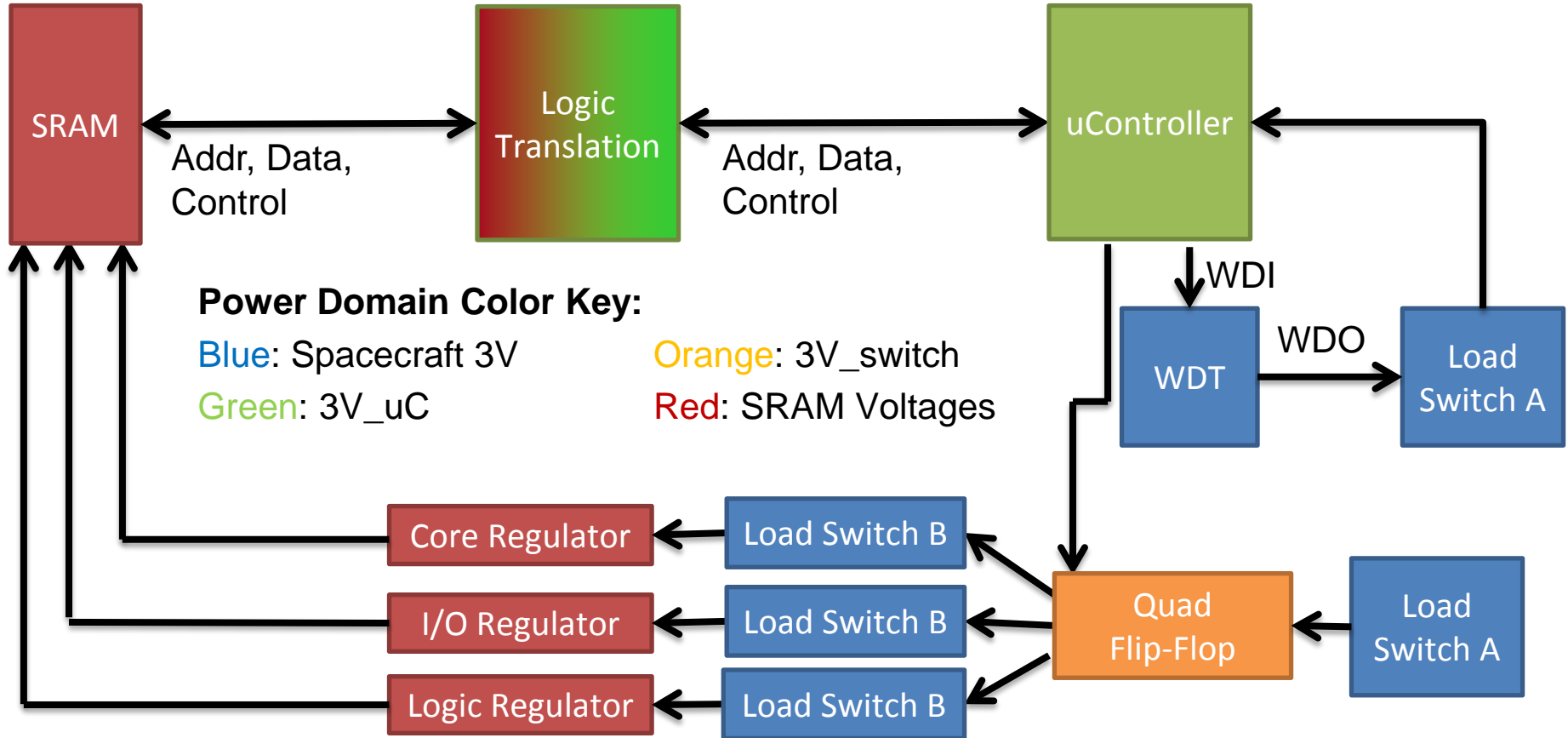
- **VU Controller**
 - Manages payloads
 - Isolates experiment board from spacecraft
- **Survivability Approach**
 - Use “high-rel” COTS when possible
 - System level radiation effects solutions
 - Proton tested at Indiana University, worked as planned



System-level RHA: Block Diagram of 28nm SRAM SEU Experiment



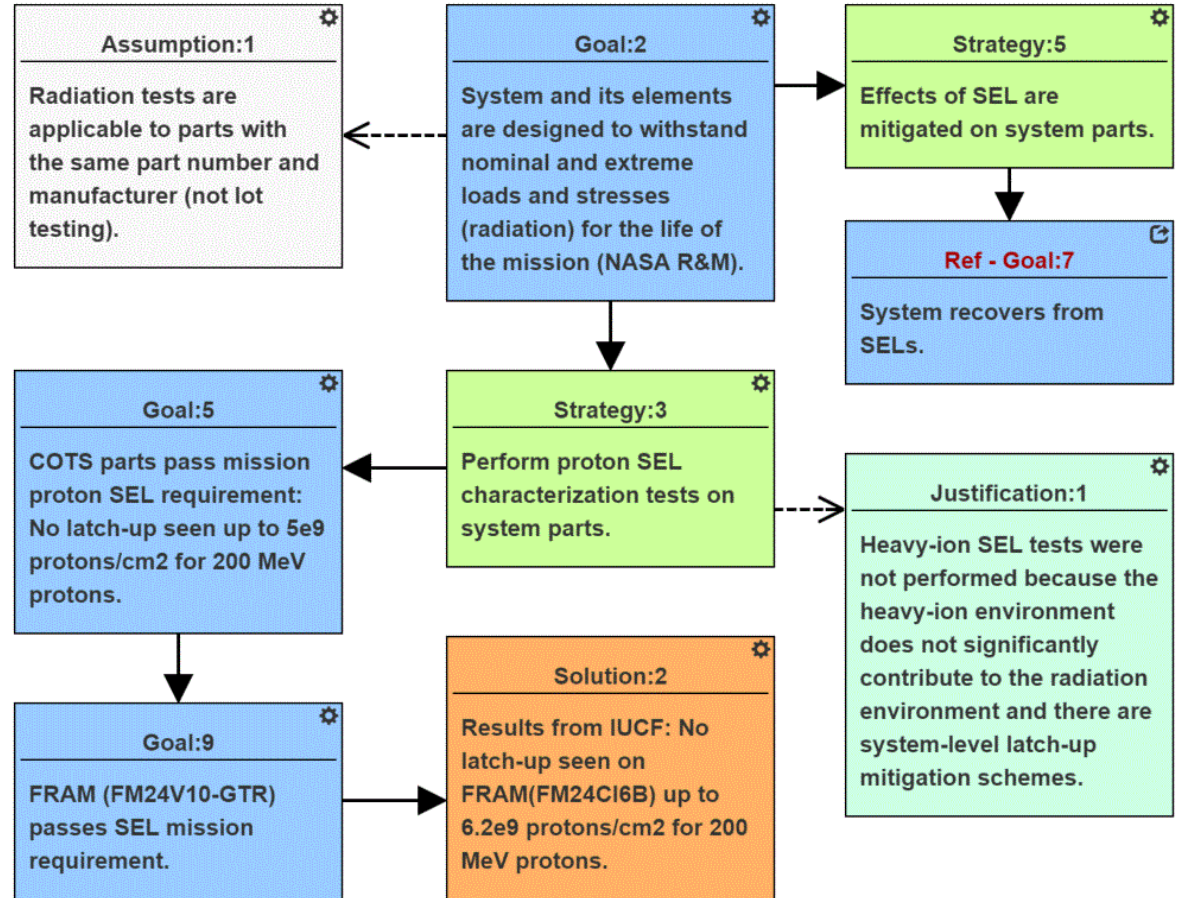
Vanderbilt Engineering



Radiation-Reliability Assurance Case



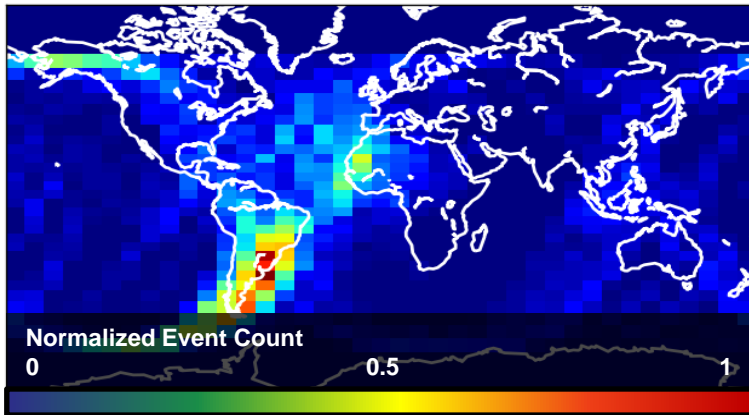
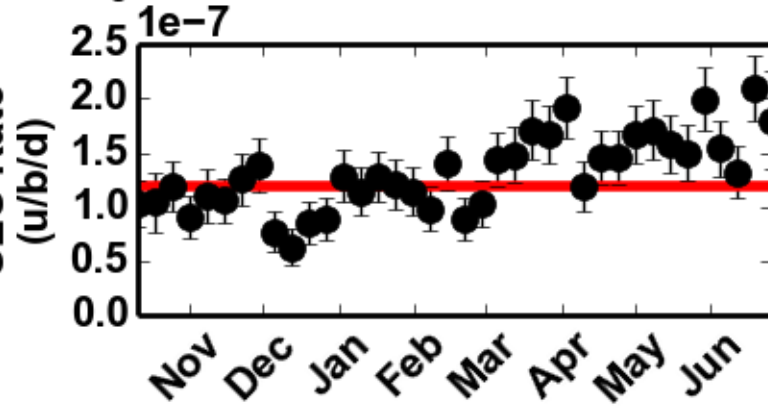
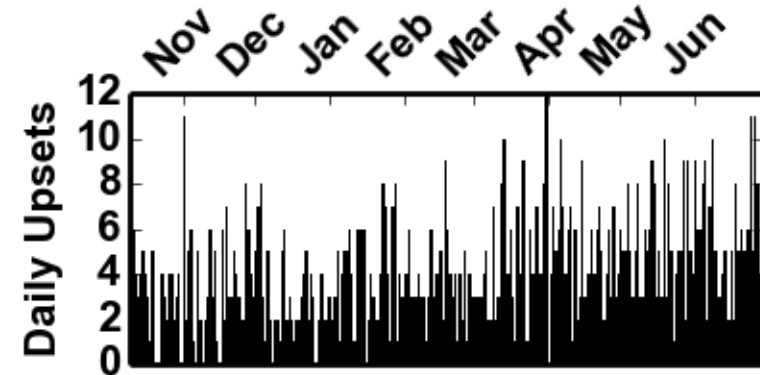
- Present testing and validation activities related to radiation reliability in a graphical format
 - Uses Goal Structuring Notation
 - Designed to complement and interact with Model-Based System Engineering programs



AO-85 Results



- Launched October 8th, 2015 as part of ELaNa-XII
- 800-500 km, 65° inclination orbit
- Carries 65nm SRAM SEU experiment



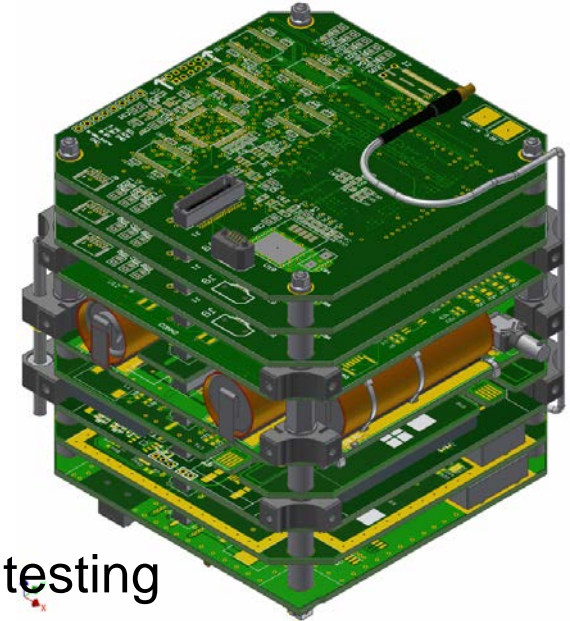
Geolocation of SEUs

Future Launches



Vanderbilt Engineering

- **Vulcan 2 – By the end of 2016**
 - Manifest: AMSAT Fox-1C/ELaNa-13
 - Purpose: 65nm SRAM SEU experiment
 - Status: Waiting for launch
- **Phoenix – End of Q2 2017**
 - Manifest: AMSAT Fox-1B/ELaNa-14 (JPSS-1)
 - Purpose: 28nm SRAM SEU experiment
 - Status: Integrated and going through pre-flight testing
- **TBD – End of Q4 2017**
 - Manifest: AMSAT Fox-1E/ELaNa-20
 - Purpose: 16nm FinFET SRAM SEU experiment
 - Status: Designing engineering unit



Fox-1B Cad Model
(Courtesy of AMSAT)

Summary



Vanderbilt Engineering

- **RadFxSat payloads deliver information on the reliability of commercial electronics**
- **Payloads use radiation-aware design techniques to design reliable experiments**
- **Three payloads have been delivered with 1 successful satellite launch and 3 more launches awarded in the next 2 years**
- **Incorporating radiation-reliability activities into Model-Based System Engineering**