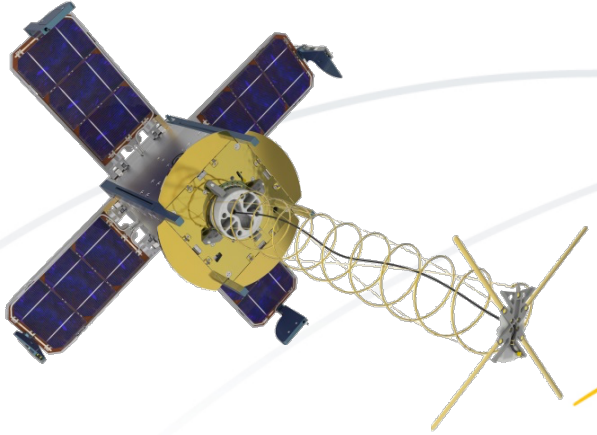

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ISR
Intelligence and Space Research
Los Alamos National Laboratory
From Space, In the Air, On the Ground

The Radiation and Reliability Program for the LANL-Designed 1.5U CubeSat System

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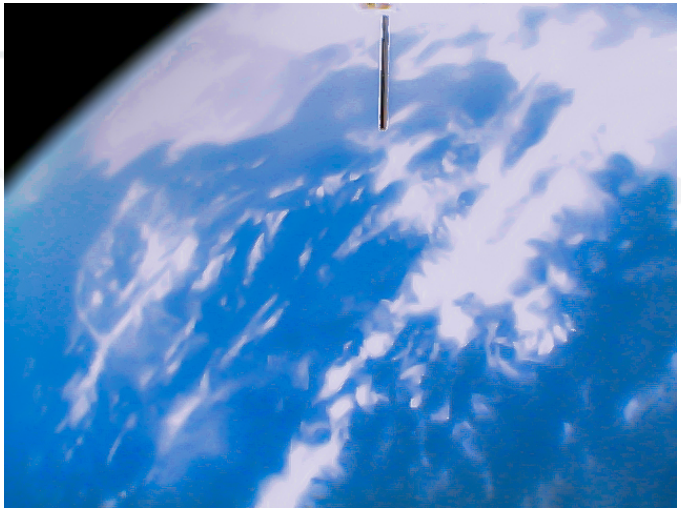
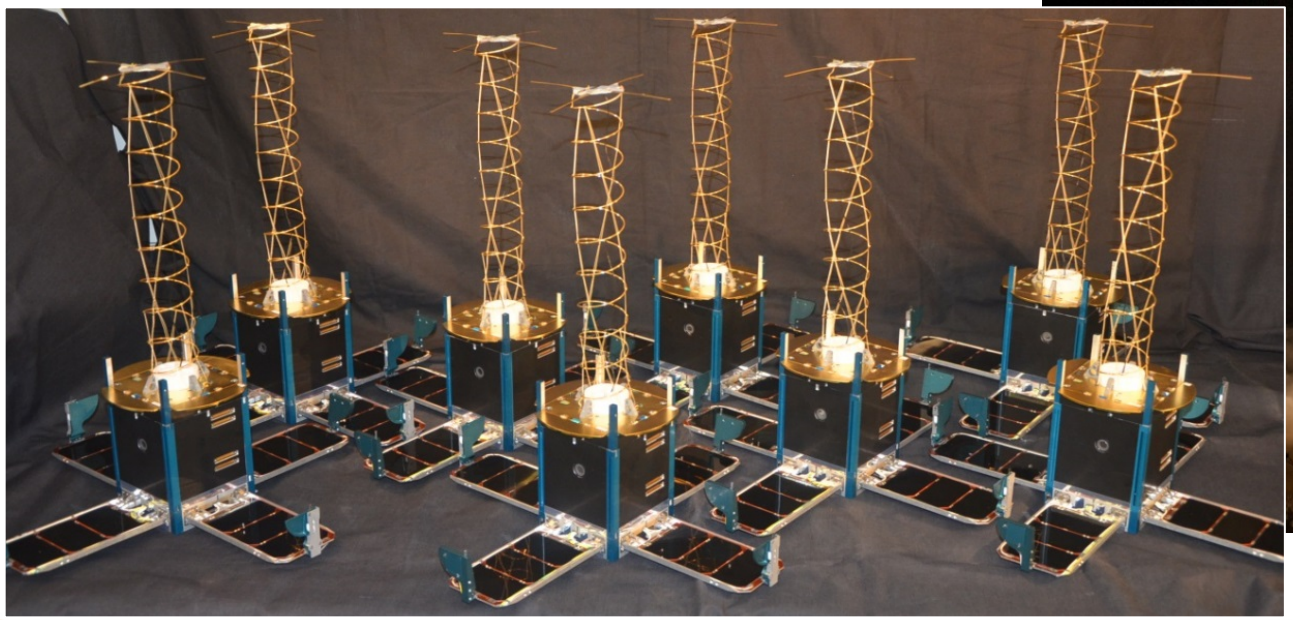
Overview

- Overview of the LANL 1.5U Block 1 CubeSat
- System Reliability Architecture
- Radiation Testing
- Environmental Testing

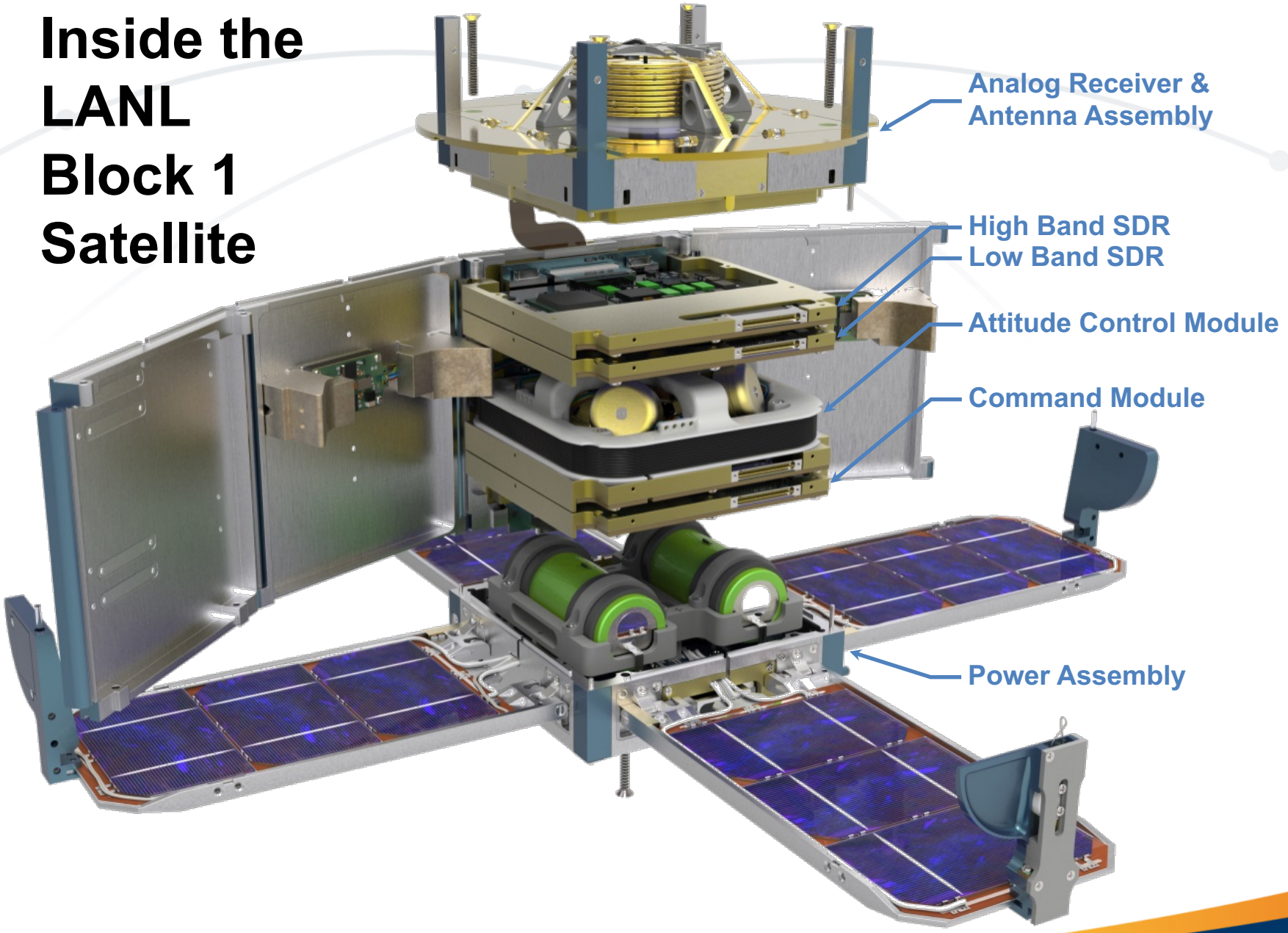
LANL Block 1

- 8 1.5U Satellites Launched
  - November 19, 2013
  - 500km altitude, 40.5° inclination
  - < 2 years from design to delivery
  - ~ 2 years on orbit





Inside the LANL Block 1 Satellite



Is there anything we can do to increase reliability in the radiation environment (RHA)?

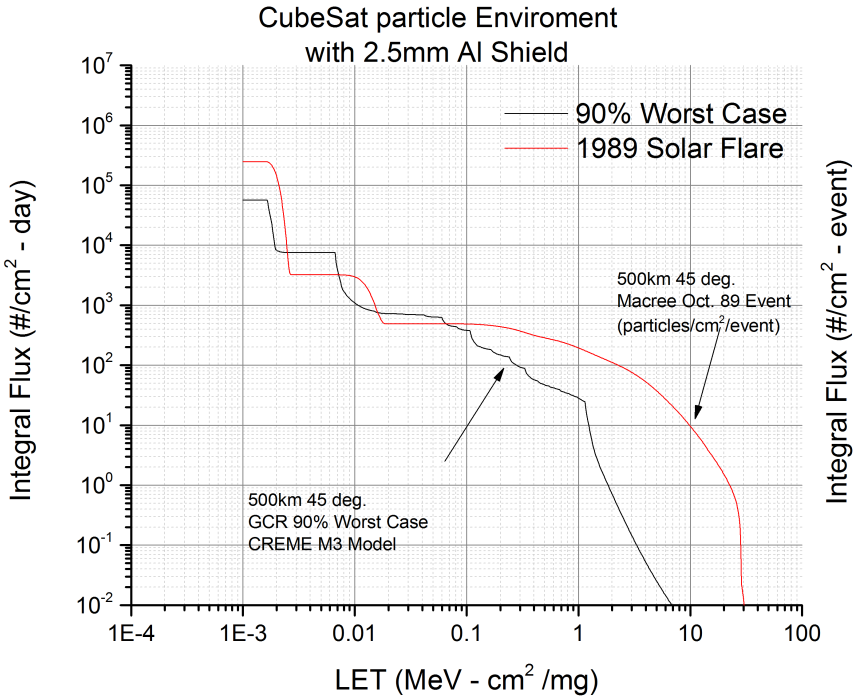
- Numerous CMOS COTS Parts
- Short Time Frame

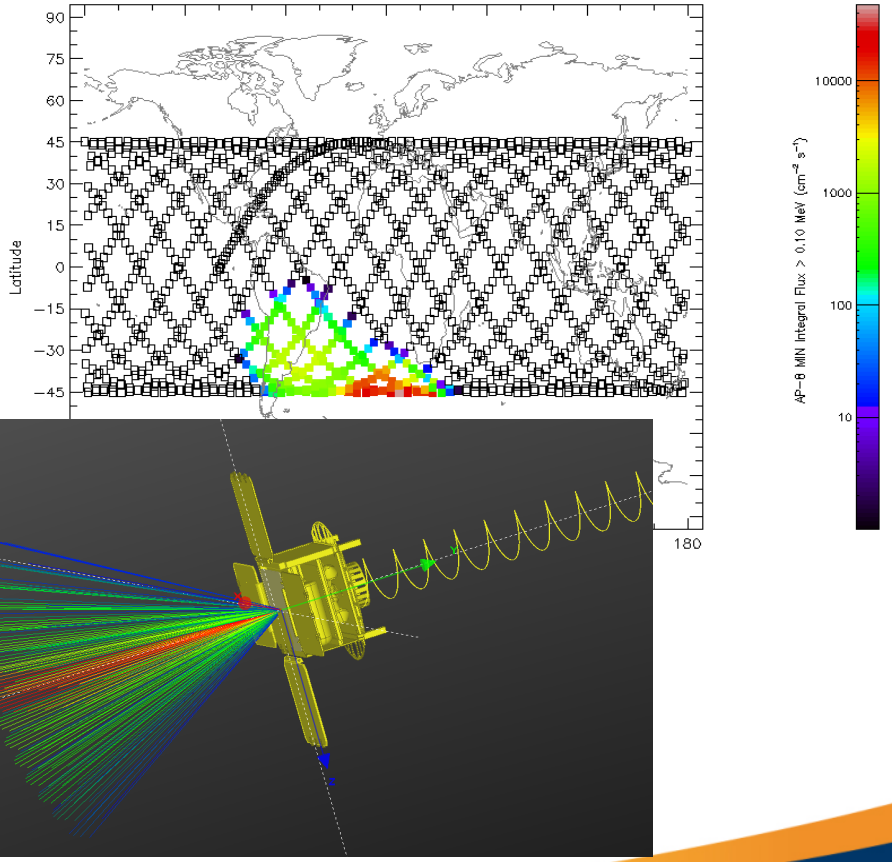
Plan

- Risk Assessment
- Reliable System Architecture
- Strategic Parts Testing
  - Prescreen Parts in neutron
  - Test Critical Parts in Heavy Ion

Radiation Environment and Testing

- Use Inexpensive available COTS electronics
- Simulate the radiation environment
  - Small TID risk (Some parts tested for TID anyway)
  - Some risk from particle environment
- Test to reduce risk





System Reliability Architecture

- MicroSemi ProASIC 3 FPGA (Good Radiation features) Monitors current draws / battery voltage / etc.
  - Boot pointers and watch dogs reside here.
  - Can power cycle sub-circuits
  - Command module can power cycle entire boards
- Common Digital Template
- Three Independent Code Loads (256 Kbytes) in Microprocessors – each board has 3 code banks
  - Bank 0 – loaded pre-launch, cannot be over-written by ground command
  - Bank A – loadable on-orbit, normal flight code
  - Bank B – loadable on-orbit, normal flight code
- “Short Dog” Watch Dog timer (~1.5 min)
  - Reboots code to each of 4 identical microprocessors
- “Long Dog” Watch Dog time (1-3 days)
  - Resets everything to launch state (Bank 0)
  - Dog must be “fed” with ground command.

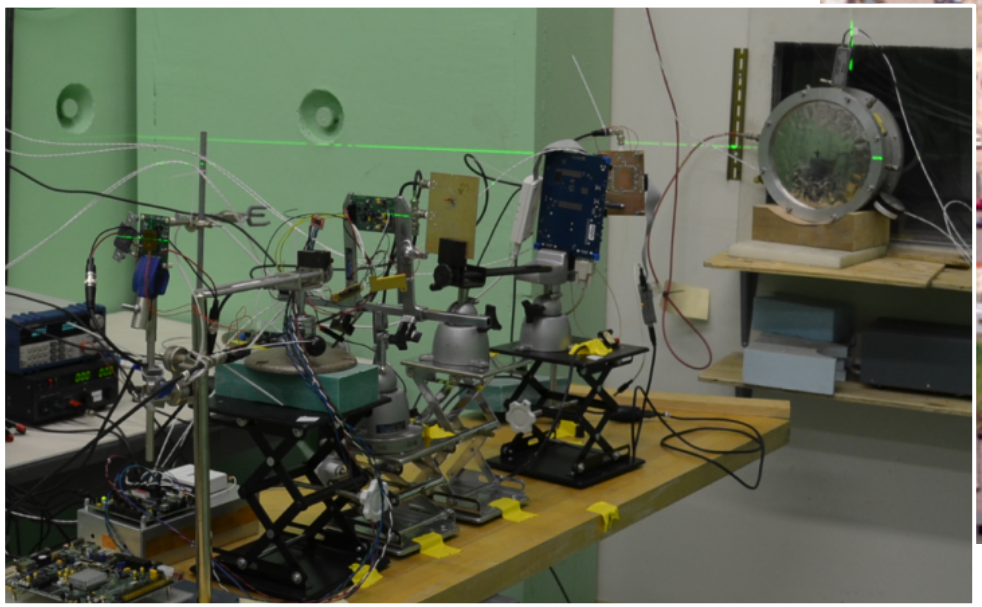
How do we Choose Parts?

- Can I turn it on and off?
- Critical parts screened for destructive radiation effects
- Ensure that parts that cannot be power cycled can not latch-up.
- Commonality across circuit boards

Preliminary SEE Testing

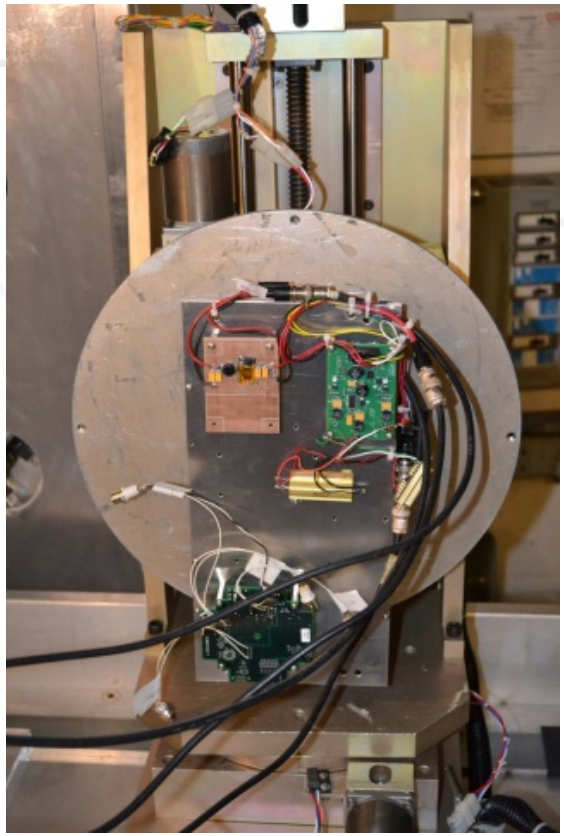
LANSCE
Los Alamos Neutron Science Center

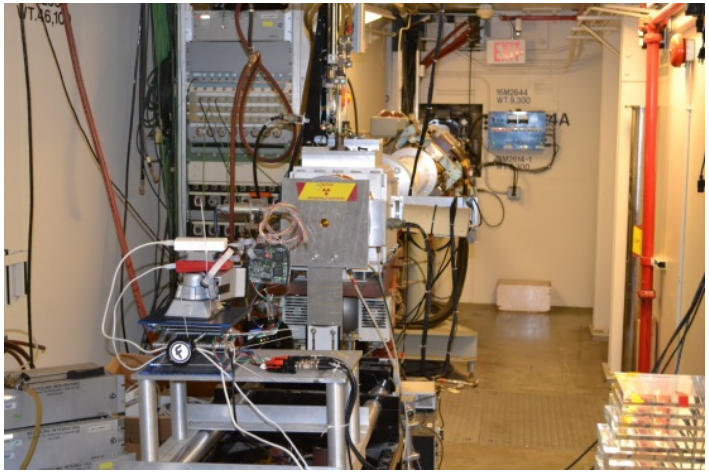
- 5 - >600 MeV neutron spectrum
- 1E6 n/cm^2/s (now 3E6 n/cm^2/s)
- De-lidding not required
- Covers a significant portion of our radiation environment



Heavy Ion and Proton Testing at LBNL

- 11 parts determined to system critical
  - Parts that could not be power cycled
  - Single points of failure
  - Tested in Heavy Ion
  - One part off-ramped after this test

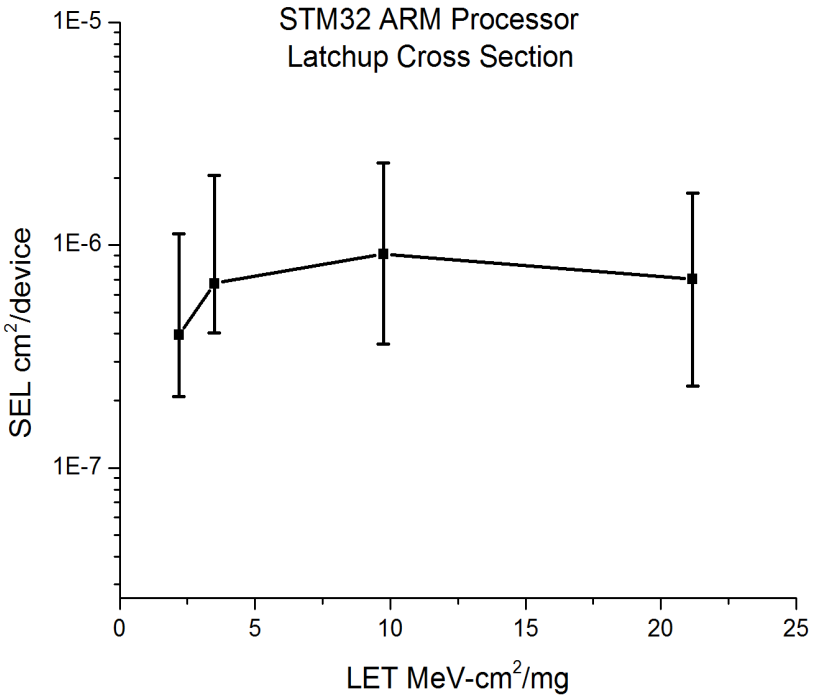




- Proton Testing performed to test scrubber

Approach Allows Access to More Parts

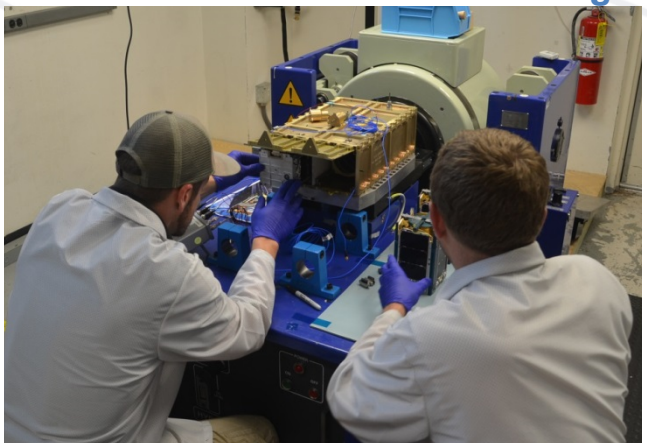
- Microprocessor Tested in Heavy Ion, n, p+
- Non-destructive Latchup observed with all ions tested as well as n and p+
- 188 day Constellation SEL rate
- Our approach to reliability enables us to use this part with confidence.



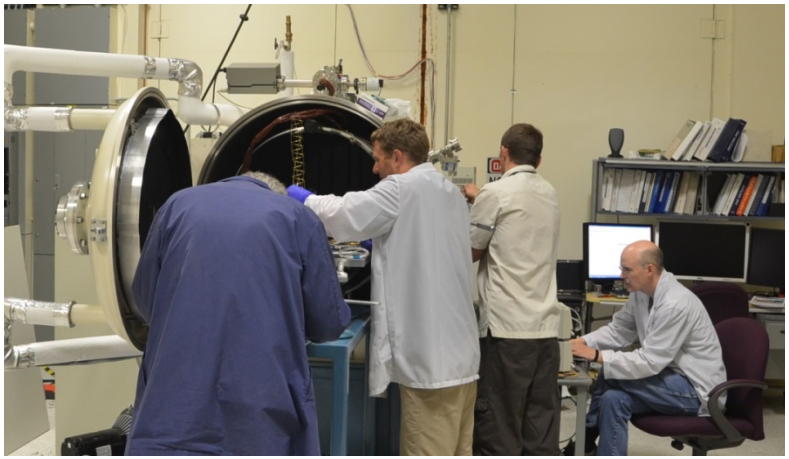
Environmental Testing

- Remember it is a satellite
- Qualified to GEVs
- Qualification and acceptance levels
  - Random Vibration
  - Thermal Cycling
  - TVAC Cycling
  - Workmanship vibe

3 Axis Random Vibration Testing



Thermal Vacuum Testing

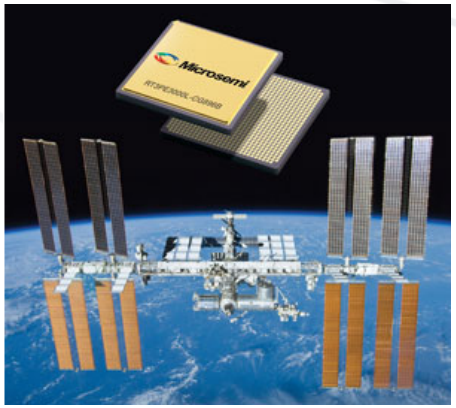


Summary

- Our Approach to Radiation Testing and Reliability Enables:
  - Ability to tailor risk to each mission
  - Access to more parts (COTS)
- The LANL-designed 1.5U CubeSat system was successful.
- Technology and approach tested on CubeSats but applicable to all satellites (10kg, 25kg, 100 kg, etc. as required for mission)
- Radiation Results published (NSREC Data Workshop 2013, Fairbanks et. al.)

Back up Slides

ProASIC 3 FPGA



- Flash based FPGA
- Configuration memory inherently hard against SEU
  - Flash memory is generally only susceptible to SEUs during write
- SRAM, IO, clock networks can be TMR'd through VHDL flags for synplicity
- Can be reprogrammed on orbit until TID=16krad(Si)
- LANL is funded to further study TID effects for use on other programs. Low dose rate testing to begin June 1.

Feature	Test Limit	Onset LET	Saturation Cross-Section
Configuration Flash Cells	96 MeV-cm²/mg Heavy Ions	No errors observed	No errors observed
D-Type Flip-Flops	96 MeV-cm²/mg Heavy Ions	6 MeV-cm²/mg	$2E^{-7}$ cm² per flip-flop
SRAM Memory	96 MeV-cm²/mg Heavy Ions	1 MeV-cm²/mg	$4E^{-8}$ cm² per memory bit
FlashROM Memory	96 MeV-cm²/mg Heavy Ions	No errors observed	No errors observed
D-Type Flip-Flops	63.5 MeV Protons		$5E^{-14}$ cm² per flip-flop
SRAM Memory	63.5 MeV Protons		$1E^{-13}$ cm² per memory bit

Contact

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