Lessons Learned on a Successful CubeSat Launch

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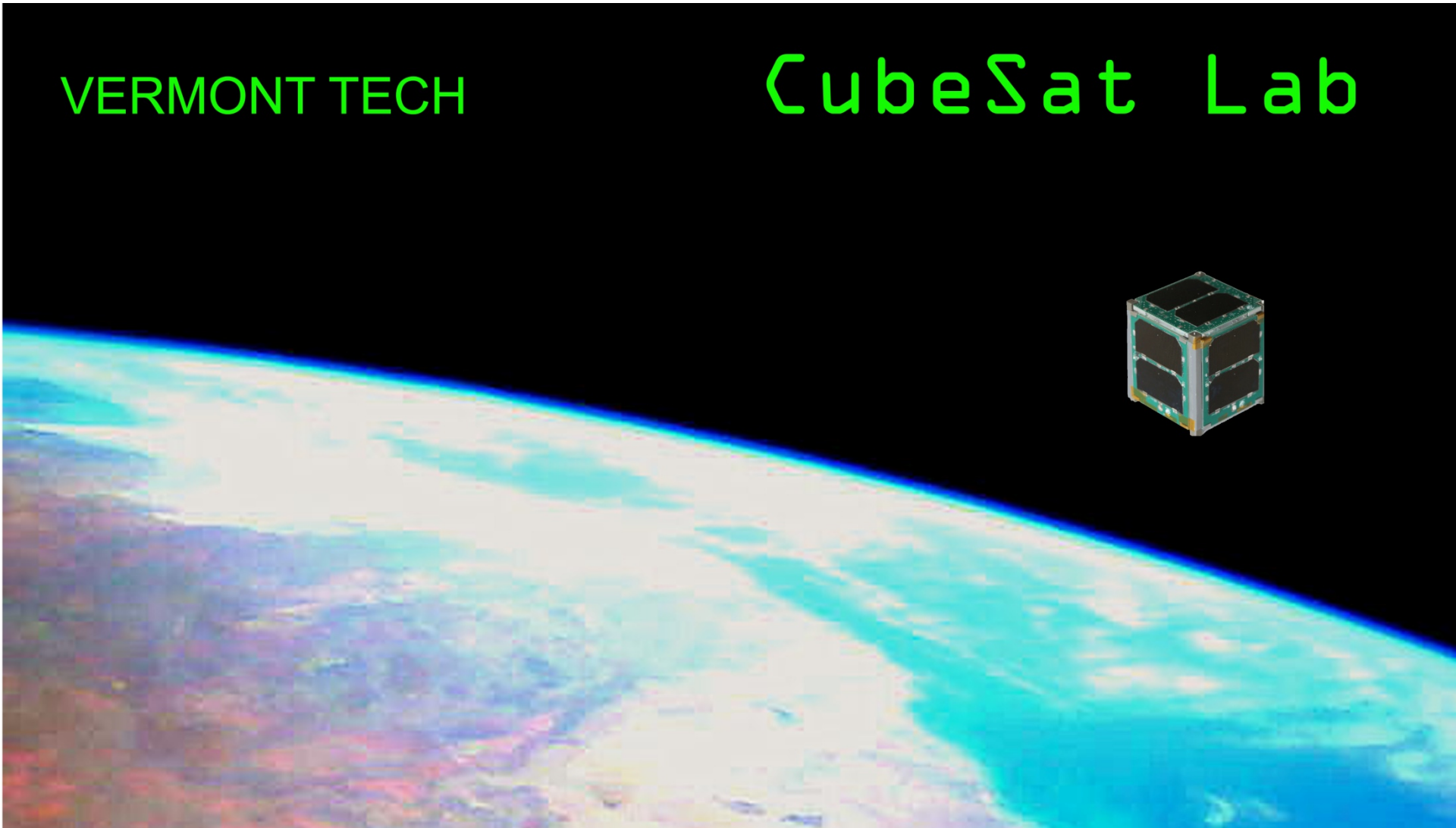


NASA ELaNa IV Launch

- NASA's 2010 CubeSat Launch Initiative (ELaNa)
- Our project was in the first group selected for launch
- Our single-unit CubeSat was launched as part of NASA's ELaNa IV on an Air Force ORS-3 Minotaur 1 flight November 19, 2013 to a 500 km altitude, 40.5^{o} inclination orbit and will remain in orbit about 3 years
- The Vermont Lunar CubeSat will test the Lunar navigation system in Low Earth Orbit
- Follow our project at www.cubesatlab.org

ELaNa IV Results

- 14 University / NASA CubeSats launched
- Only six were heard from at all
- One only lasted one week
- One only works in sunlight
- One took five weeks for first contact
- Ours, as many Vermonters do, took a 2 ½ month winter vacation

Lessons Learned from ELaNa IV

- Hardware reliability issues
- Software reliability issues
- Design issues
- Procedural issues
- Communication issues

Lessons Learned from ELaNa IV

Hardware reliability issues

- Electrical power system - batteries
- Mechanical structure - separation
- Bus communication – pull ups
- Radio issues – beam width
- Ground Station 6 months early
- Temperature range of components
- Vibration test – check list & E. M.
- Re-measure after final assembly

Lessons Learned from ELaNa IV

Software reliability issues

- Design reviews
- Language selection (SPARK/Ada)
- Static analysis tools (SPARK 2014)
- Repository
- ISIS antenna electrical model testing

Lessons Learned from ELaNa IV

Design issues

- Multiple busses
- Protuberances
- Power budgets
- Realistic testing – PV solar intensity
- Problems and solutions from previous missions
- Be able to test all systems via USB

Lessons Learned from ELaNa IV

Procedural issues

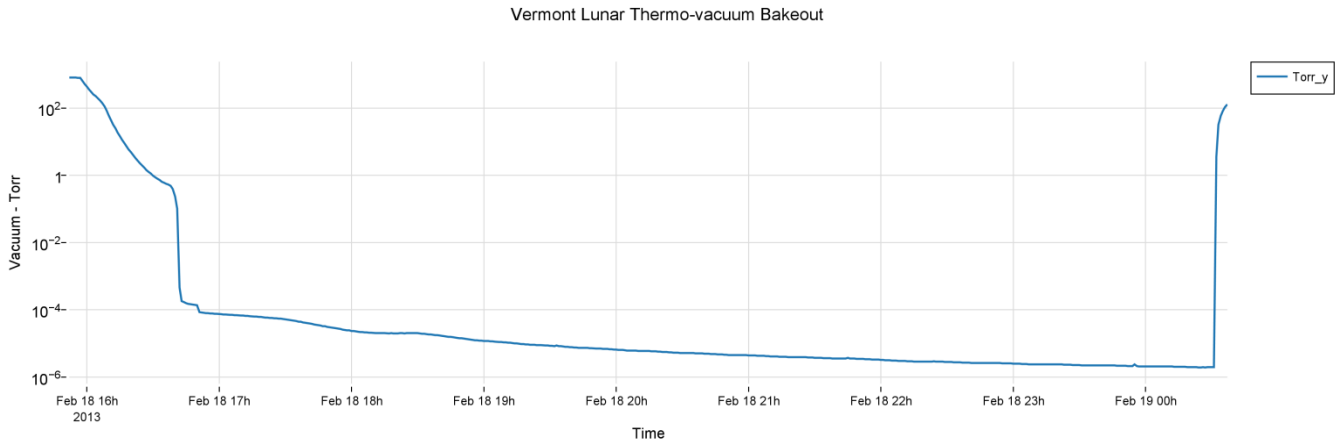
- Nobody has any space experience
- NOAA camera license
- IARU frequency coordination
- FCC/NTIA transmitter license
- FCC launch permission
- Airline transportation of CubeSats

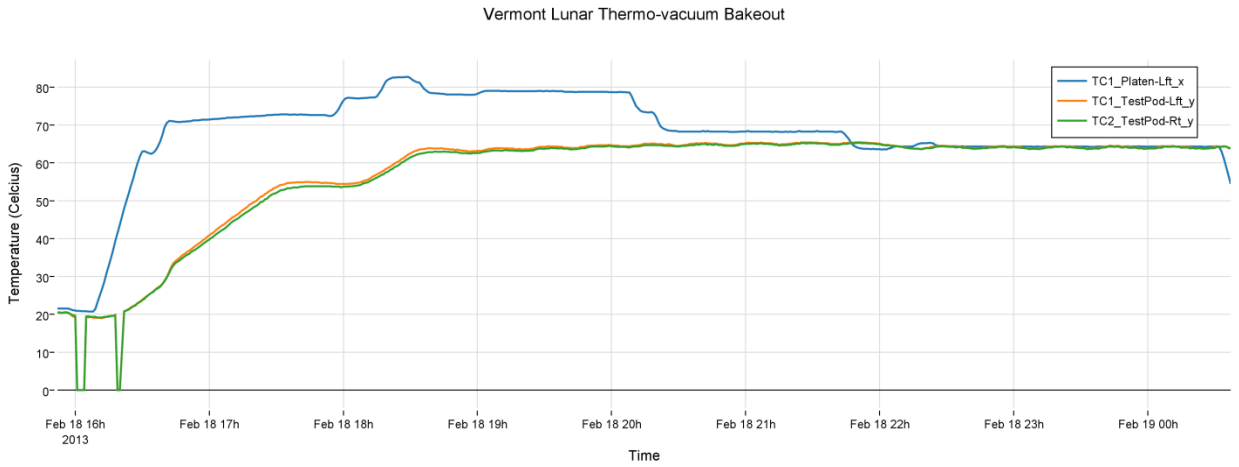
Lessons Learned from ELaNa IV

Communication issues

- Test plans
- MPP Schedules
- ODAR
- Verifications Users Guide
- AMSAT IARU link budget
- Ground activities (integration)
- CubeSat “Cookbook” needed
- Talk to hardware vendors

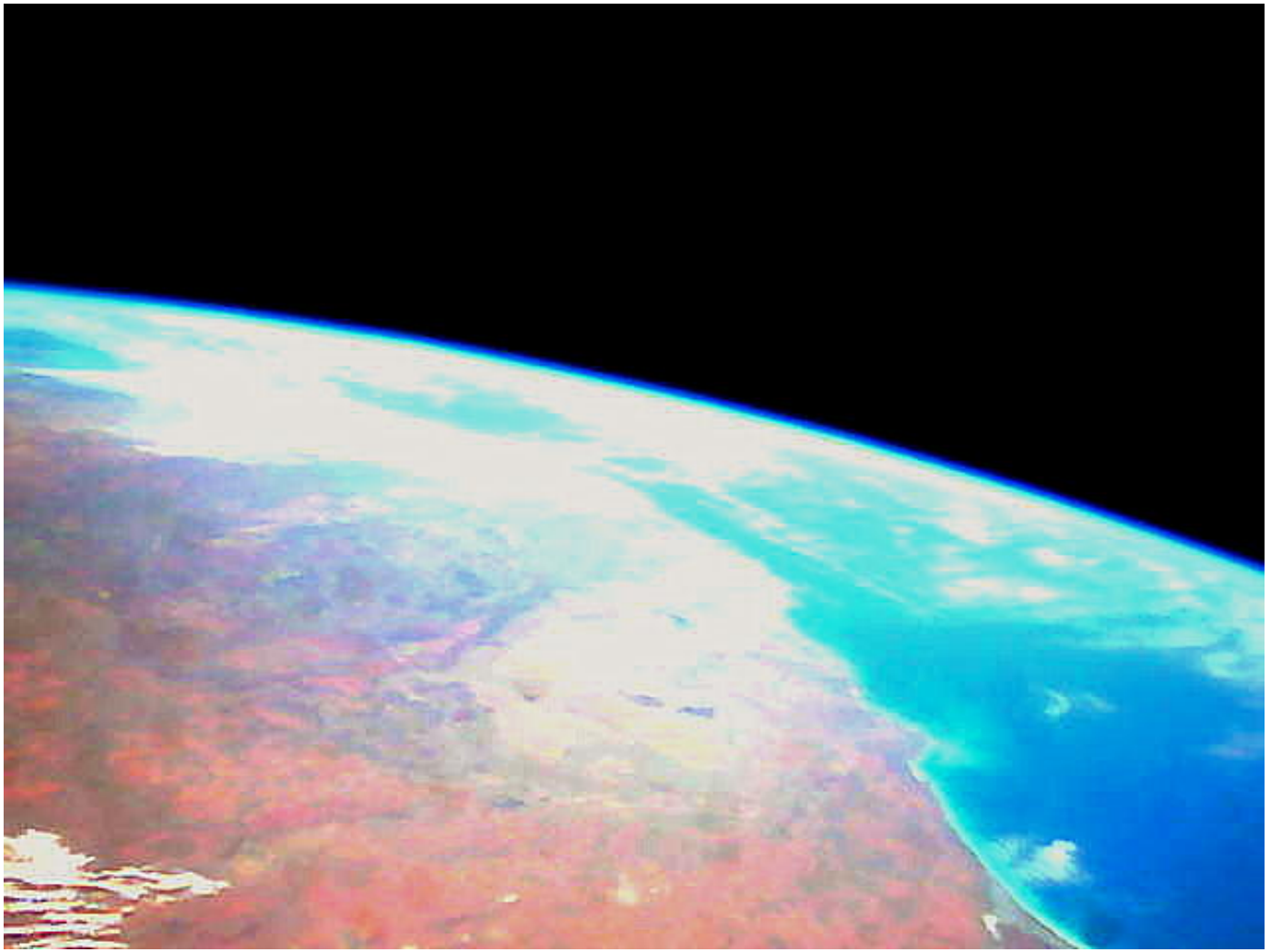
Lessons Learned from ELaNa IV





plot.ly

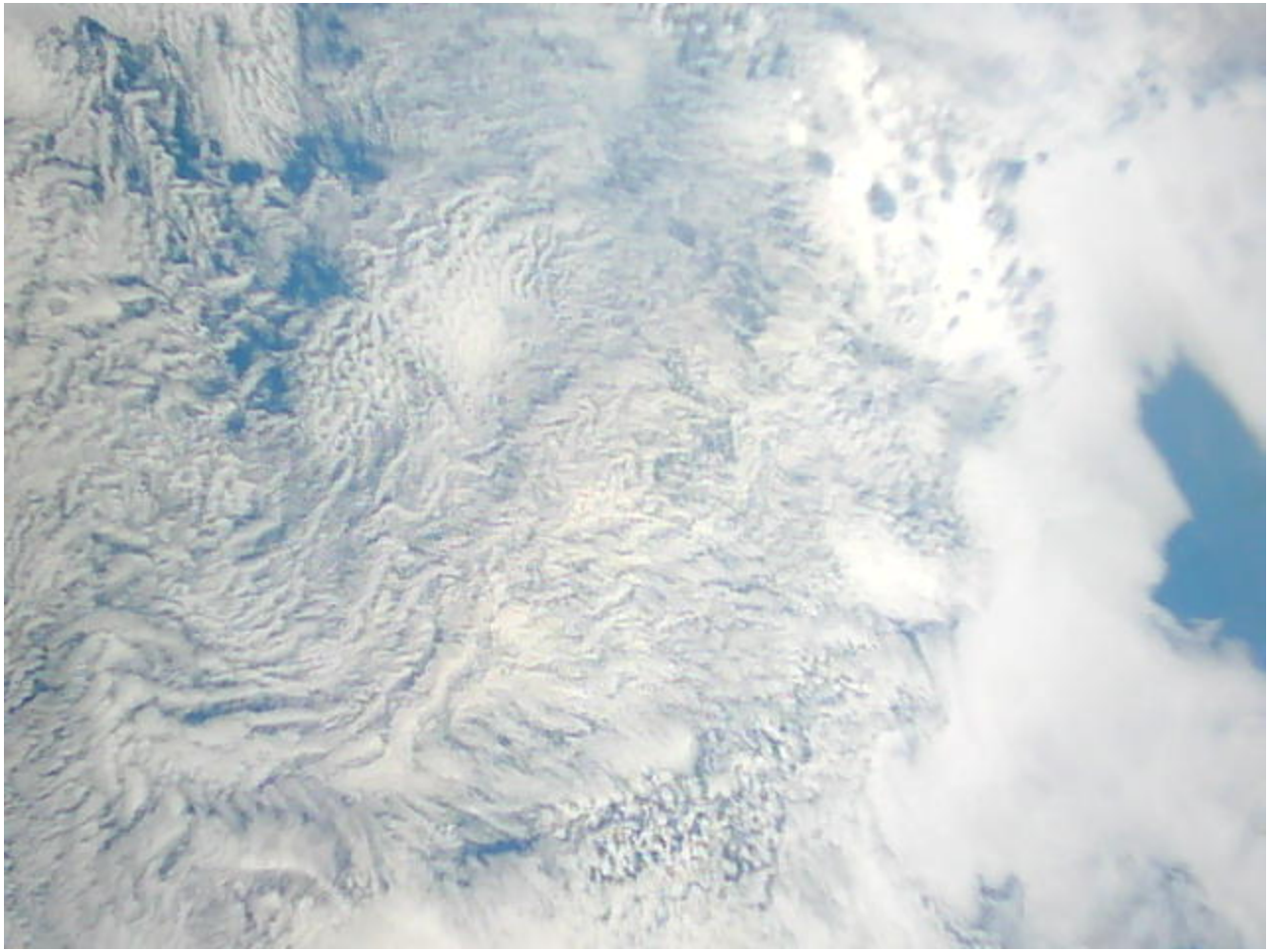
Lessons Learned from ELaNa IV



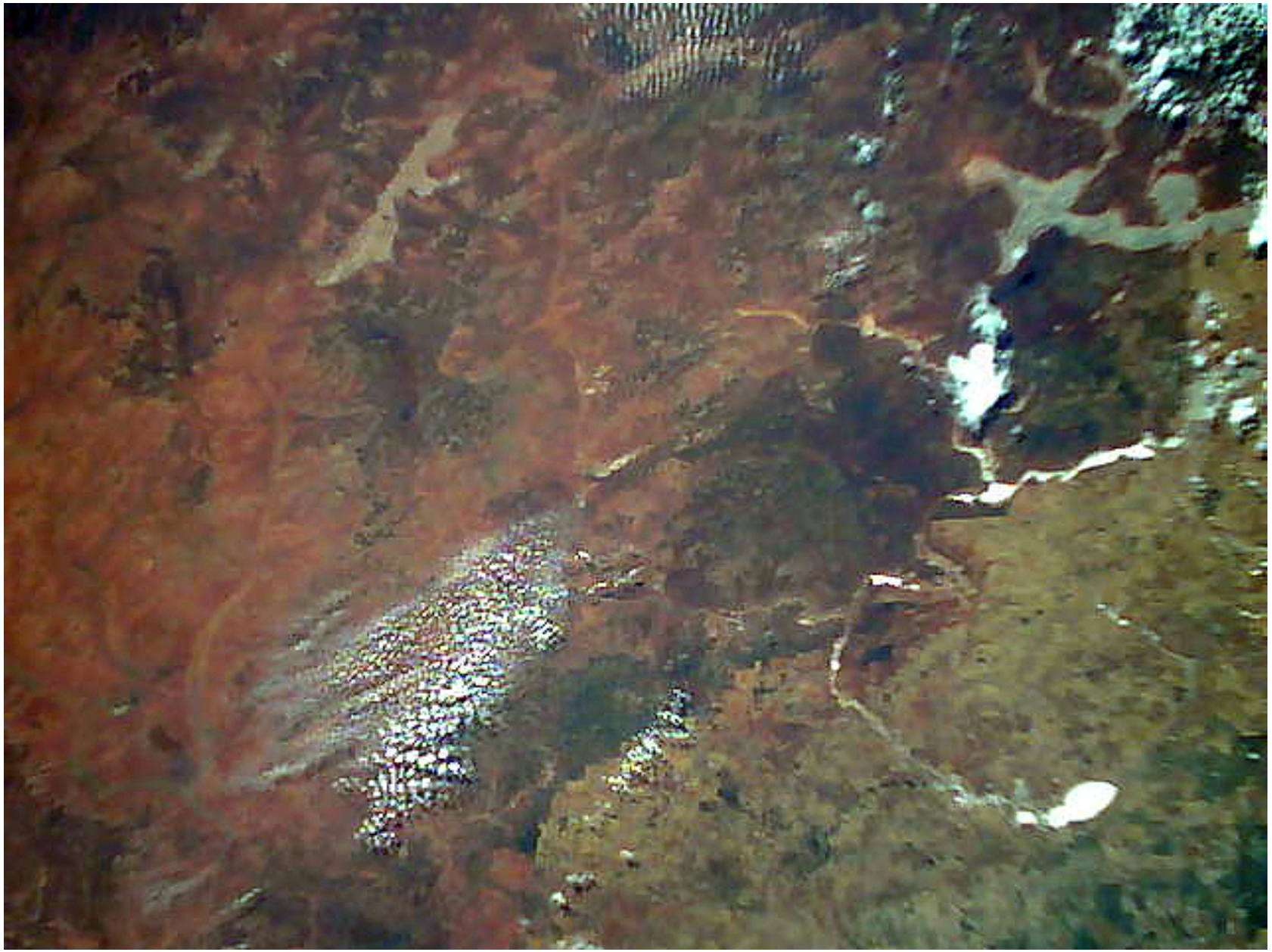
Our first picture of Earth

The North coast of Western Australia near Port Hedland

Lessons Learned from ELaNa IV



Clouds over the ocean.



Western Australia north of Perth

Lessons Learned from ELaNa IV

Clouds over the ocean.

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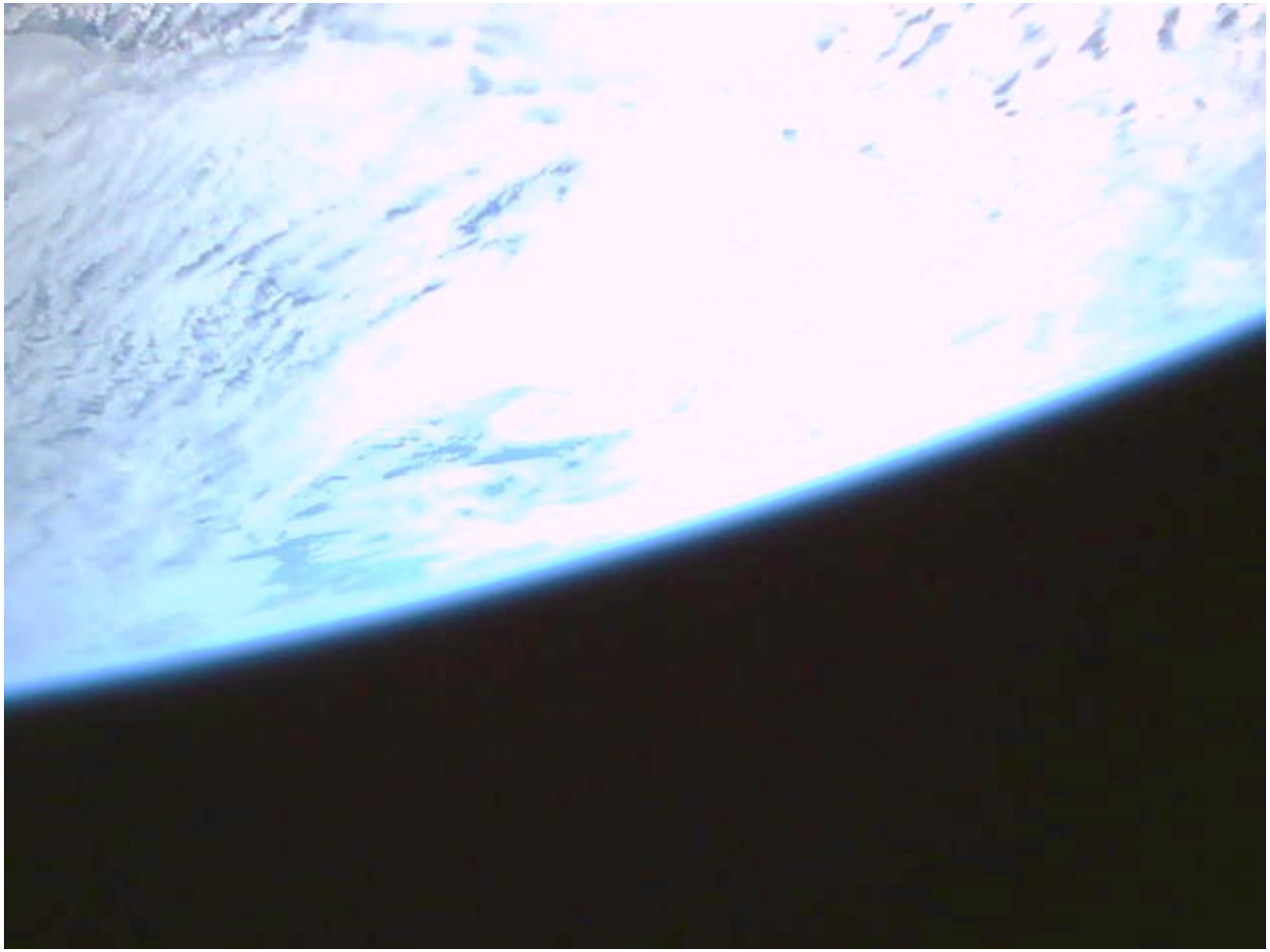
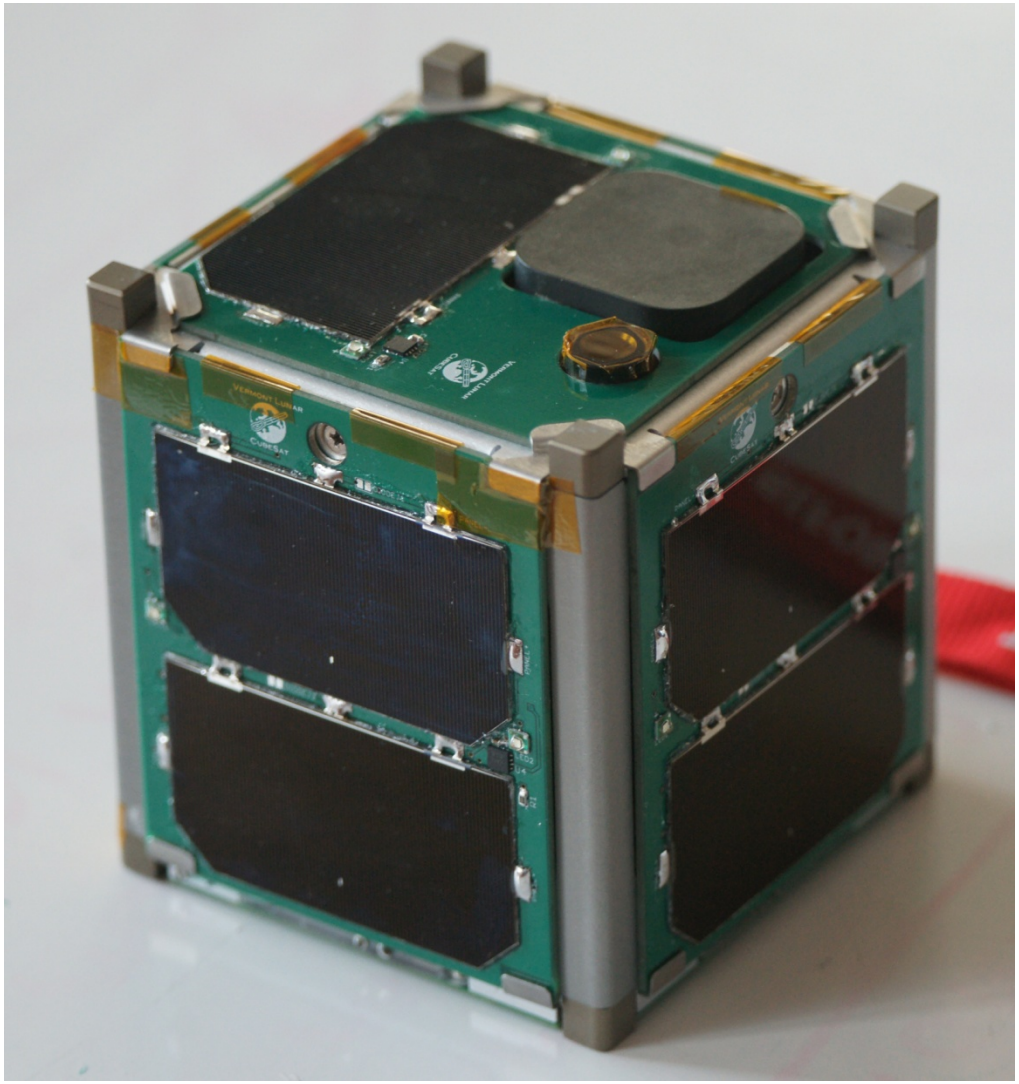


More clouds.

Our ELaNa IV CubeSat

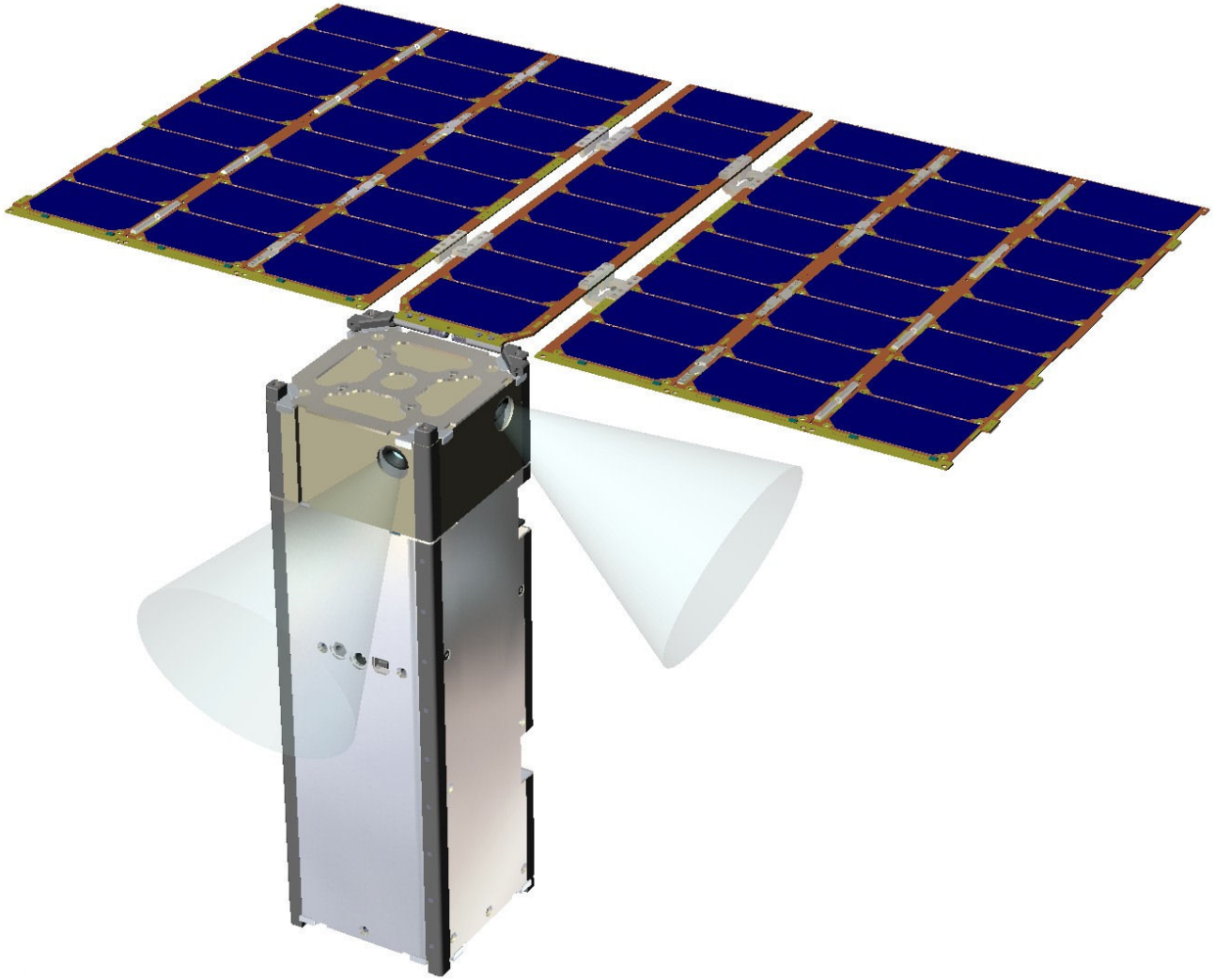
VERMONT TECH



Vermont Lunar CubeSat

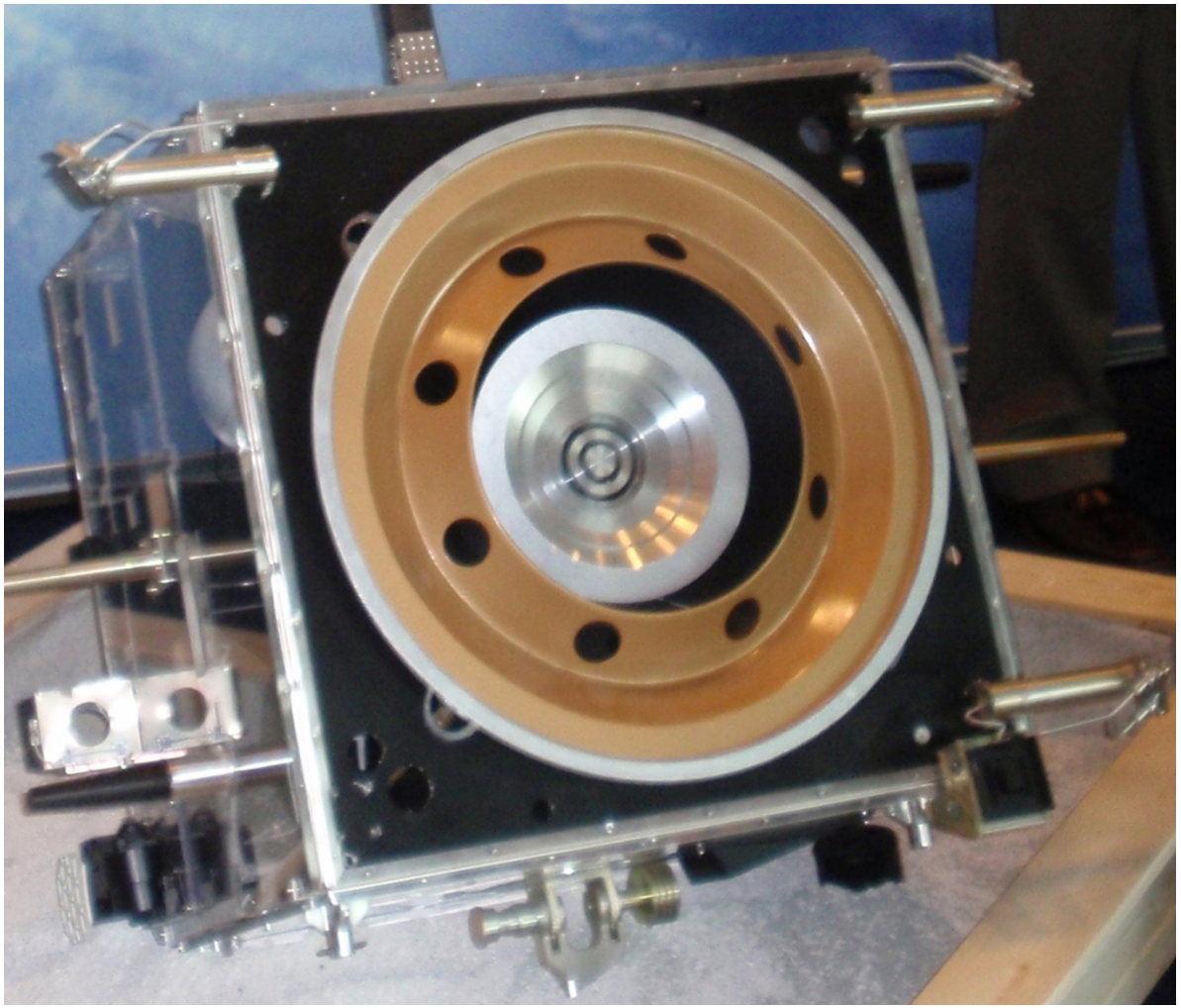
Brandon - CubeSat Developers Workshop - 2014

Follow on Ion Drive CubeSat



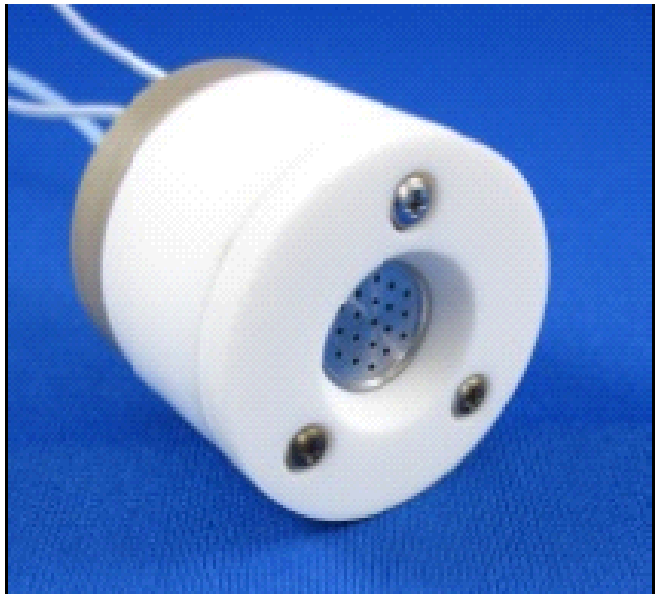
Triple CubeSat with CubeSat Kit 56 W fold out PV panel.
Ion drive with 0.5 kg – 0.75 kg Xenon or Iodine.

1 m Wide, 367kg ESA SMART-1



82 kg xenon @ 150 atmospheres, 1,200W

Busek Ion Thrusters



BRFIT-1

10 W 0.067 mN

BRFIT-3

80W 1.6 mN

Student Participation

- 2011 (Summer) – 3 students (3)
- 2012 (Fall) – two graduated, one started (2)
- 2013 (Summer & Fall) one started (3) then two left (1)

Software Development Comments

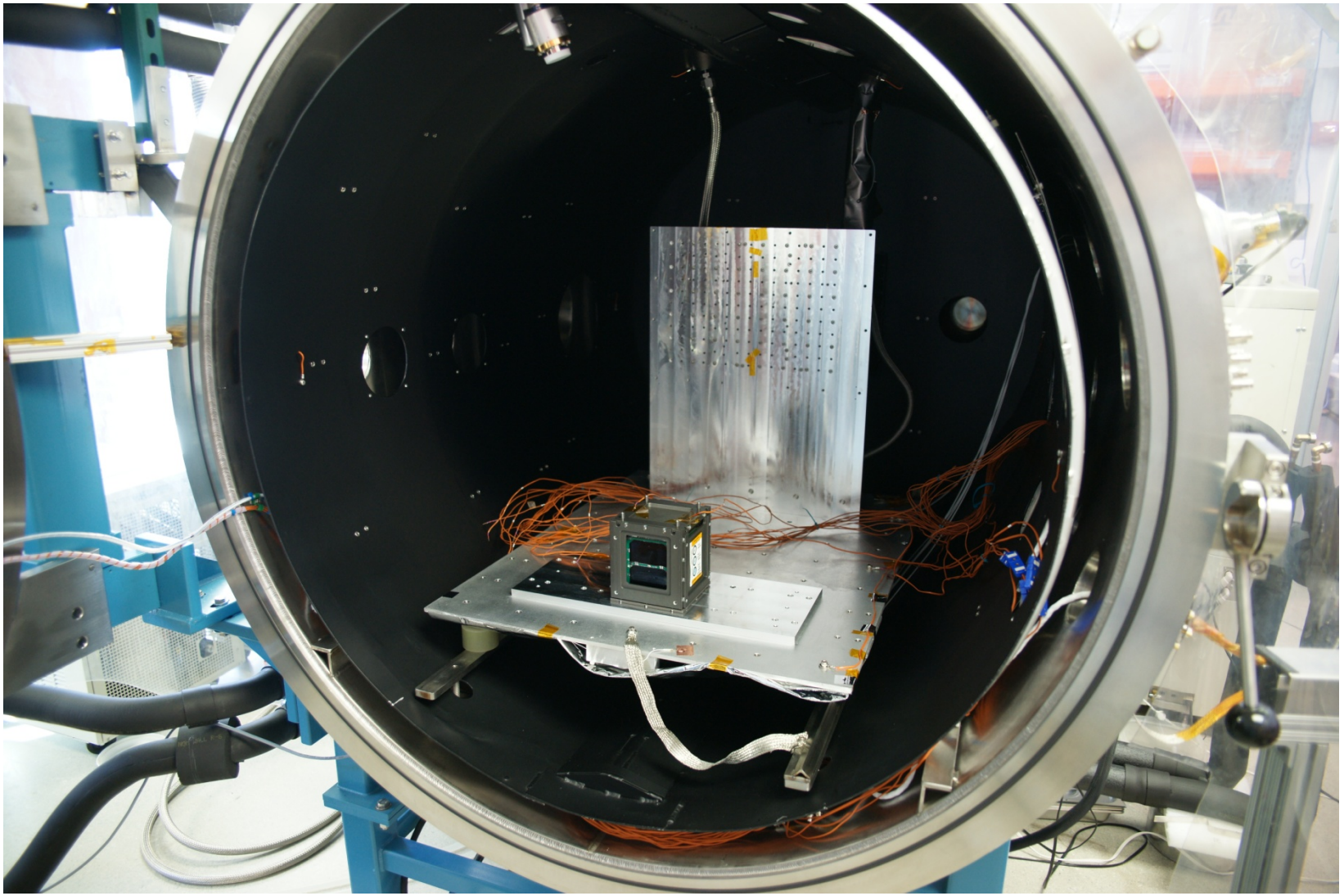
- No formal method used, it was “agile” like in practice
- Students worked on two campuses, some hardware was only available in Randolph (GPS, Radio)
- Human created configuration file describing the C compiler for AdaMagic could have errors
- AdaMagic, GNAT or Crossworks could have errors
- No runtime system used

Software Development Comments

- SPARK caught errors as we refactored the software as we developed greater understanding of the hardware
- SPARK helped the discipline of the software during turnover as some students graduated and were replaced
- Although we did not have a formal development process, without SPARK we probably would not have completed the project with the limited personnel resources and tight time constraint
- Although the CubeSat is limited to 1.3kg, the paperwork might be 130 kg ;)

X and Y axis Vibration Test

Vacuum Thermal Bakeout



ELaNa IV Launch Minotaur 1 – Wallops Island November 19, 2013, 8:15 PM

First two stages are Minuteman II first two stages, third and fourth stages are Pegasus second and third stages

Acknowledgements

- NASA Vermont Space Grant Consortium
- NASA
- Vermont Technical College
- AdaCore, Inc. (GNAT Pro)
- Altran Praxis (SPARK)
- SofCheck (AdaMagic)
- Applied Graphics, Inc. (STK)
- LED Dynamics (PV boards)
- Microstrain (IMU)

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