

Vermont Tech SPARK/Ada Powered Spacecraft Update

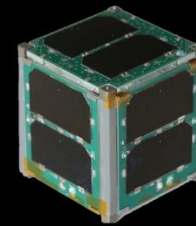
Copyright 2016 Carl Brandon

Dr. Carl Brandon & Dr. Peter Chapin
Vermont Technical College
Randolph Center, VT 05061 USA

carl.brandon@vtc.edu
+1-802-356-2822 (Voice)
<http://www.cubesatlab.org>

VERMONT TECH

CubeSat Lab



Vermont Lunar CubeSat

It worked until our reentry on November 21, 2015:

- We completed 11,071 orbits.
- We travelled about 293,000,000 miles (471,000,000 km), equivalent to over 3/4 the distance to Jupiter.
- 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° inclination orbit and remained in orbit until November 21, 2016. **It is the only one of the 12 ELaNa IV university CubeSats that operated until reentry, the last one quit 19 months earlier.**
- We communicated with it the day before reentry
- **Follow our project at cubesatlab.org**

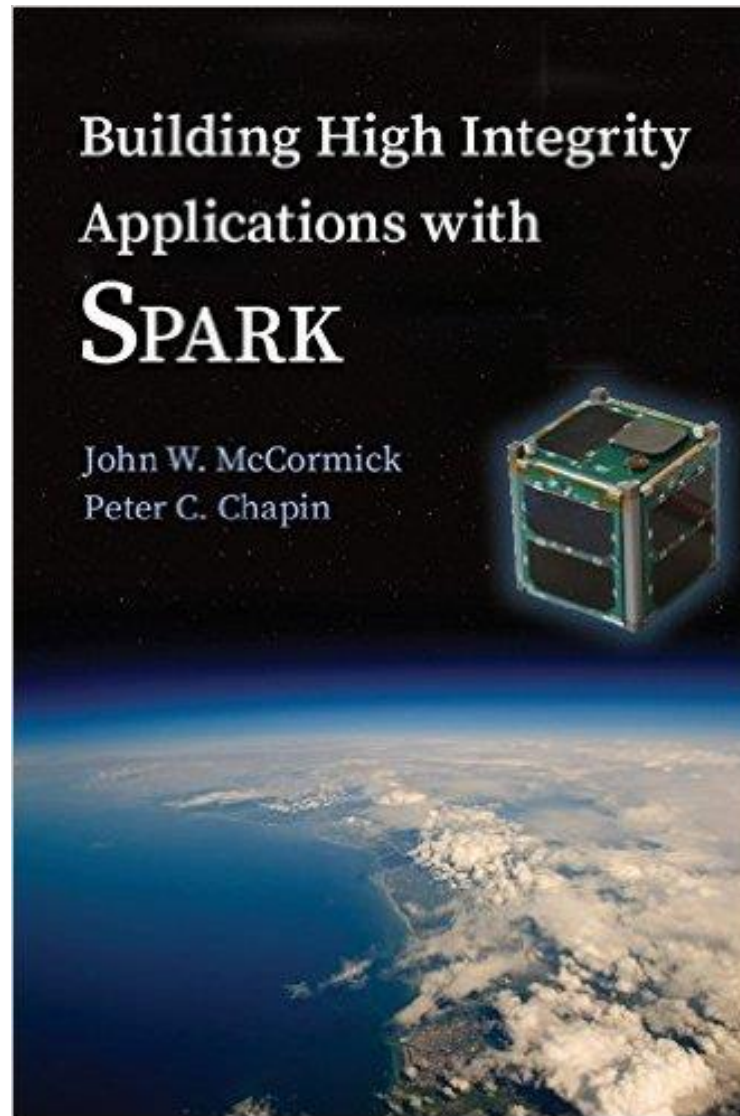
Vermont Lunar CubeSat SPARK 2005 software:

- 5991 lines of code
- 4095 lines of comments (2843 are SPARK annotations)
- a total of 10,086 lines (not including blank lines)
- The Examiner generated 4542 verification conditions
- all but 102 were proved automatically (98%)
- we attempted to prove the program free of runtime errors
- which allowed us to suppress all checks
- The C portion consisted of 2239 lines (including blank lines)
- Additional provers in SPARK 2014 would allow 100% proofs

Our new SPARK 2014 CubedOS CubeSat software:

- General purpose CubeSat software system
- Written in SPARK/Ada & proven free from runtime errors
- Currently in development for use in our Lunar IceCube flight software
- Can integrate existing Ada or C runtime libraries
- Uses a Low Level Abstraction Layer (LLAL)
- LLAL allows running on bare hardware, or OS such as Linux or VxWorks, easily modified for new hardware
- Provides inter module communication
- All modules are completely independent

A SPARK 2014 book is now available:



Vermont Lunar CubeSat

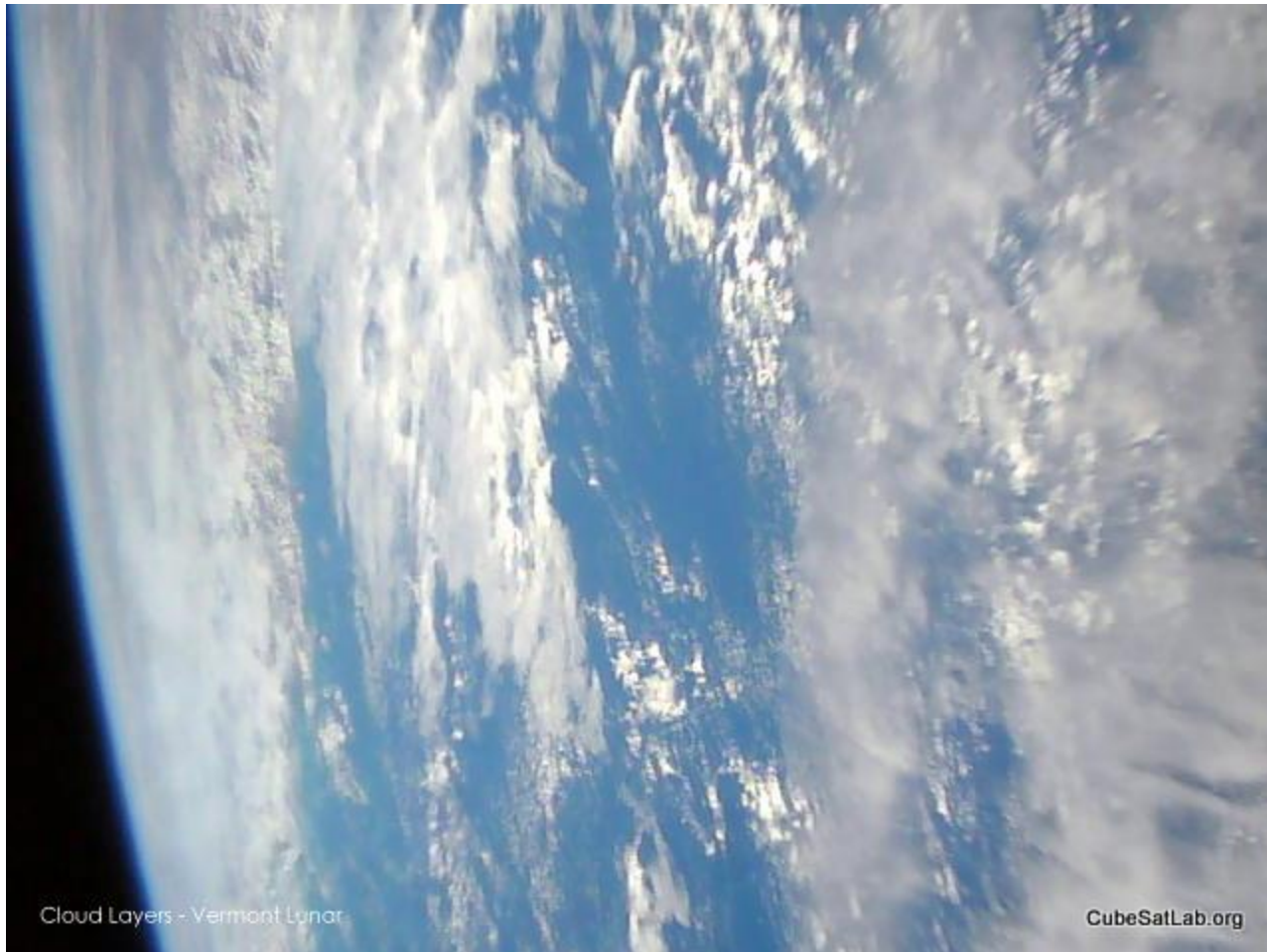


Ada Europe 2016

Our first picture of Earth

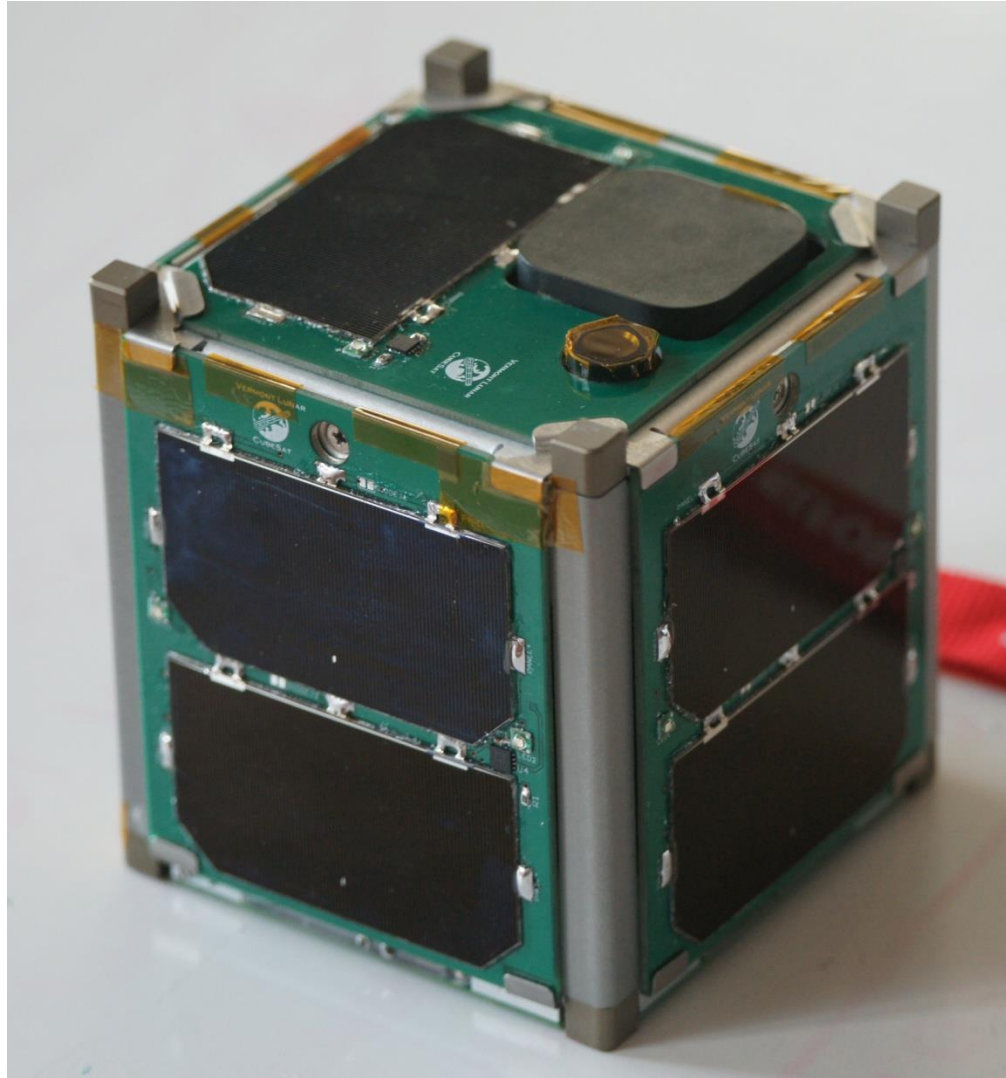
The North coast of Western Australia near Port Hedland

Vermont Lunar CubeSat



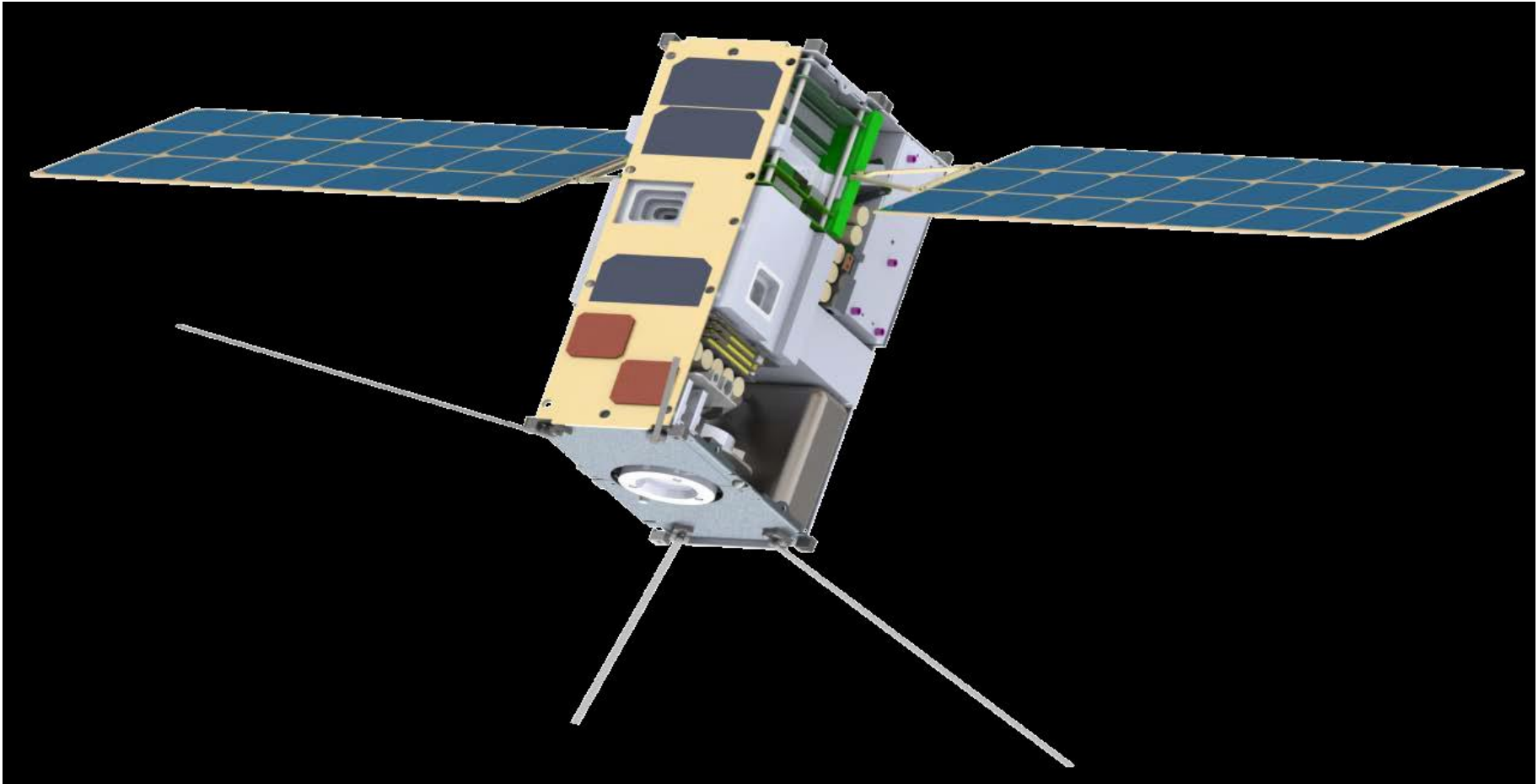
Clouds over the ocean, June 2015.

Vermont Lunar CubeSat VERMONT TECH



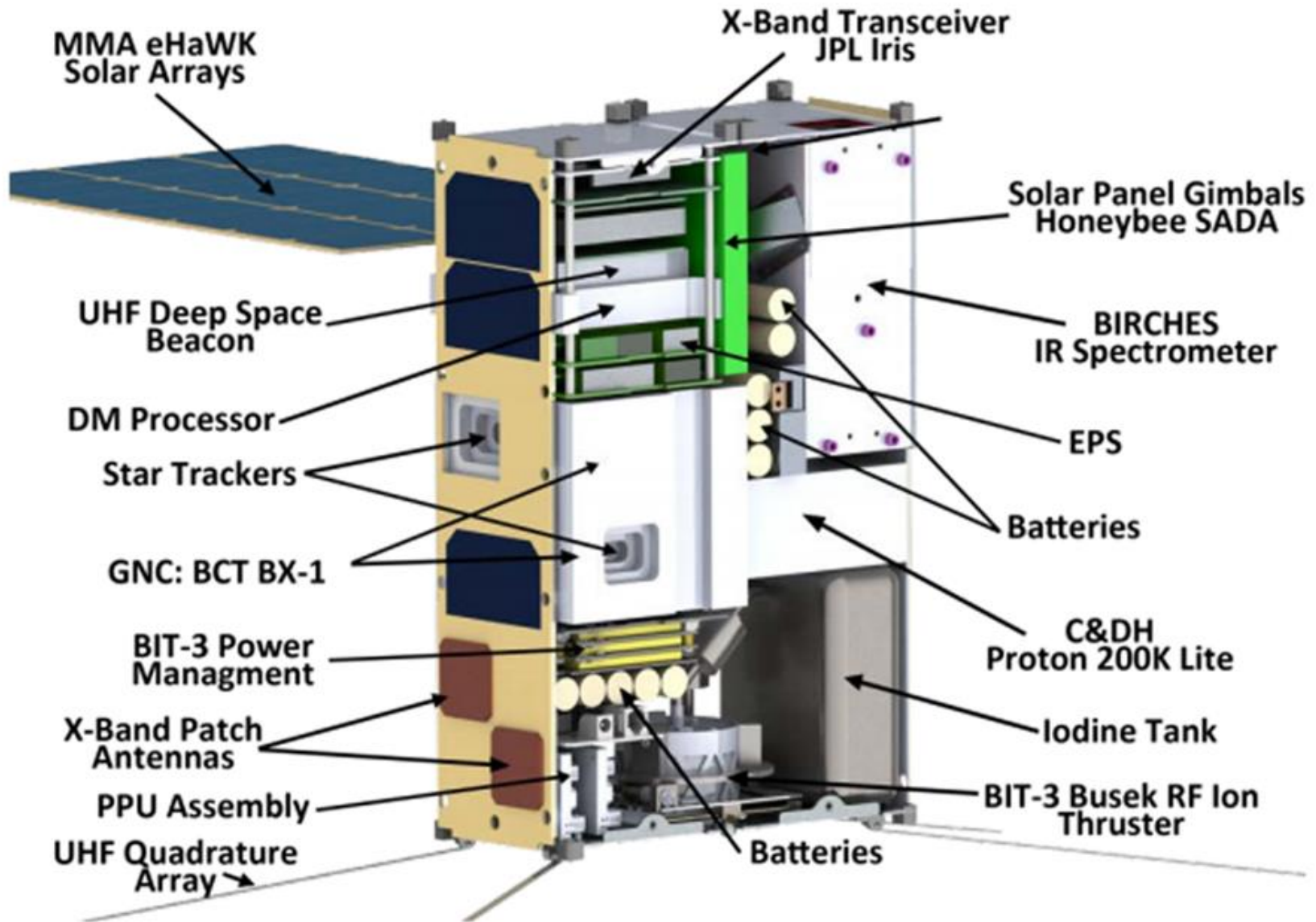
Vermont Lunar CubeSat (10 cm cube)

Lunar IceCube (10cm x 20cm x 30cm)

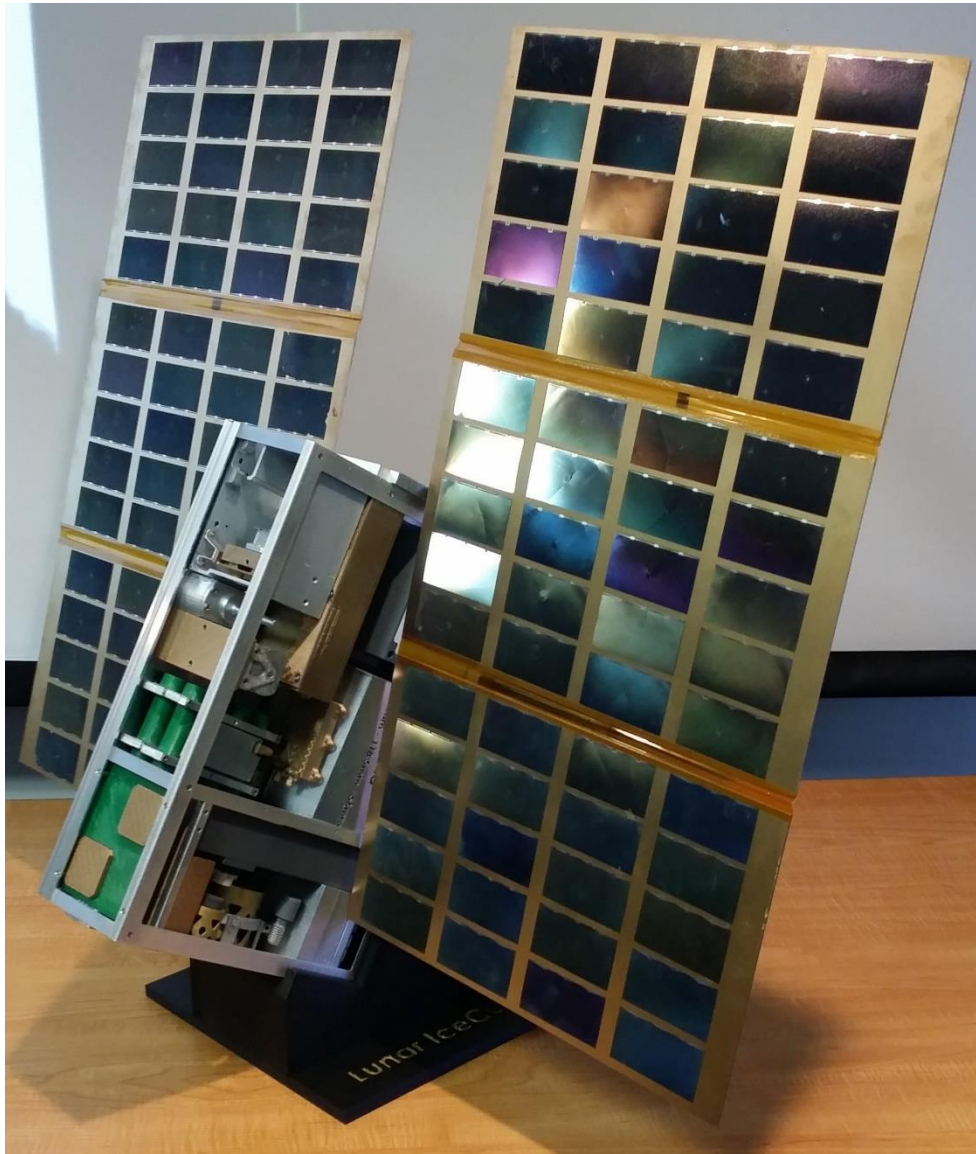


Lunar IceCube 6U CubeSat, Morehead State University, PI., Goddard (BIRCHES IR Spectrometer), JPL (Iris 2 data & nav radio) & Vermont Tech (Flight software). Busek ion drive with 1.5 kg Iodine propellant.

Lunar IceCube (10cm x 20cm x 30cm)



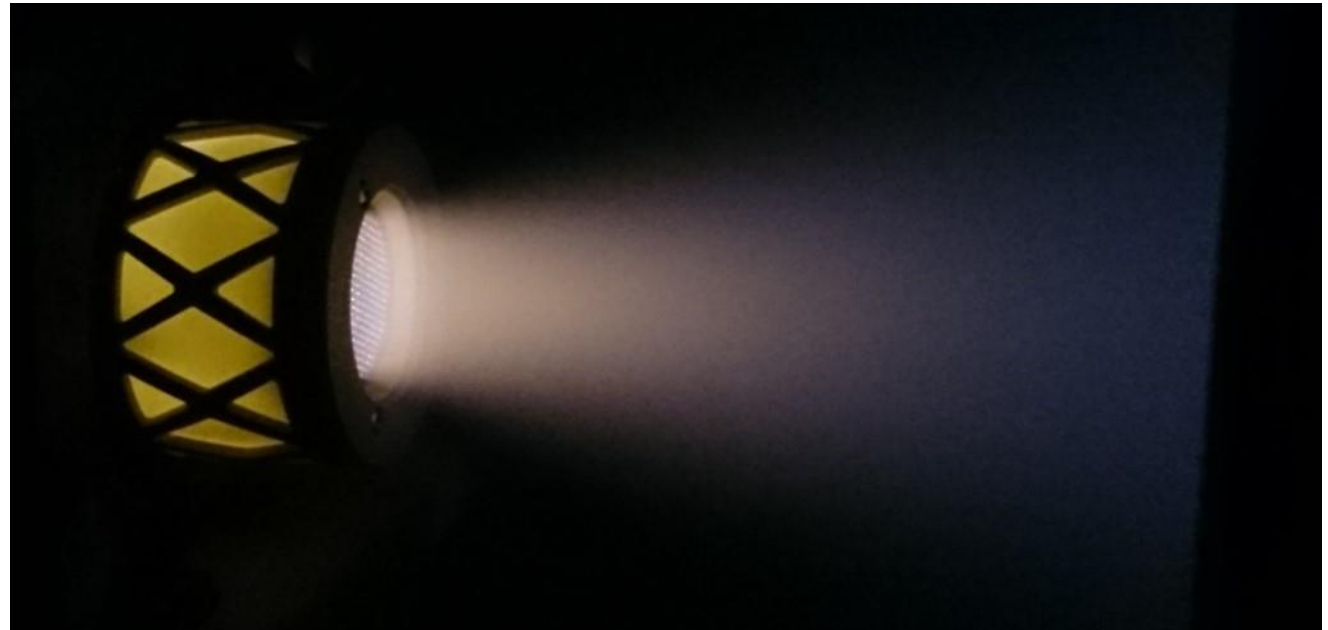
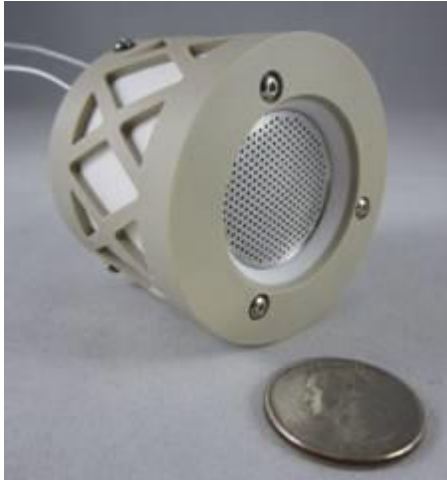
Lunar IceCube (10cm x 20cm x 30cm)



Lunar IceCube (10cm x 20cm x 30cm)



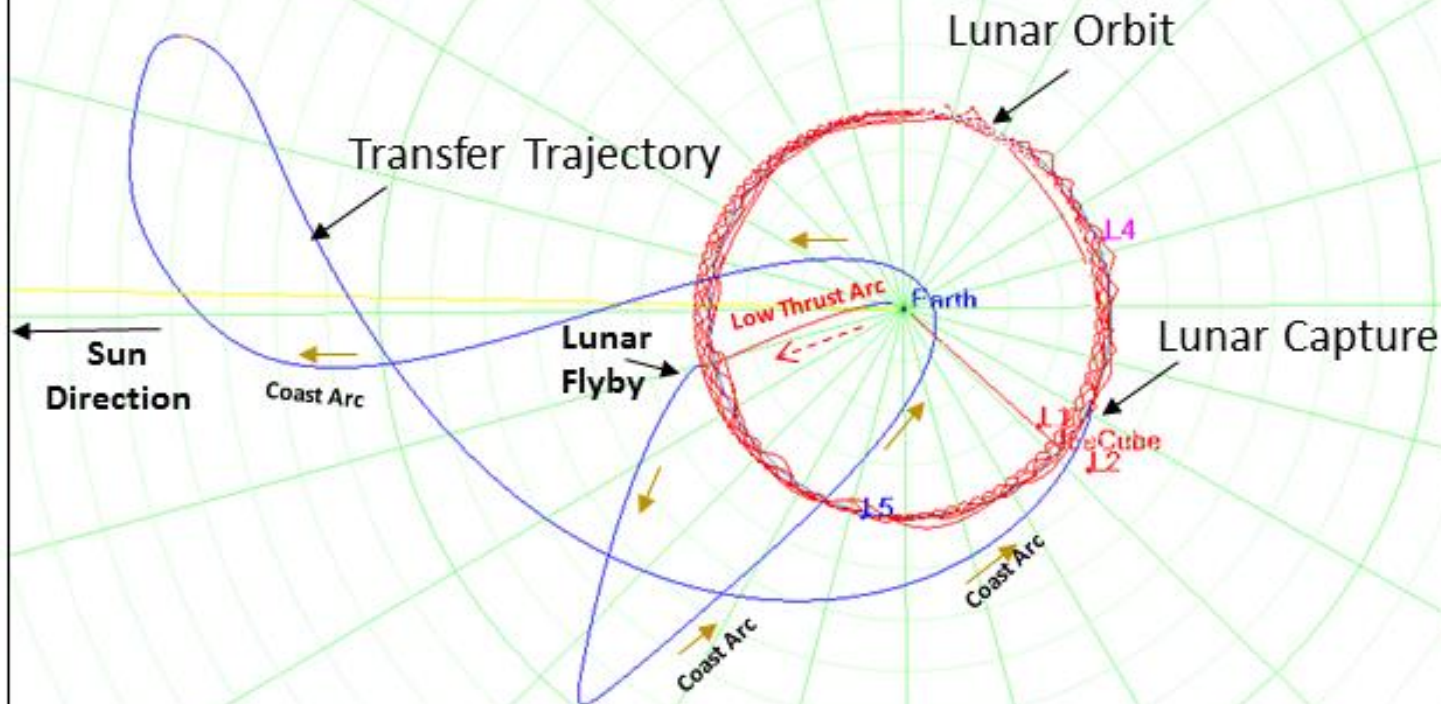
Busek Ion Thruster



BIT-3 Iodine Propellant

65W 1.4 mN, 3 cm beam width

Lunar IceCube Trajectory with Low Thrust Sun-Earth Rotating Frame



- Design based on proposal ICPS State
- Low thrust to 1st lunar flyby outbound
- ~180 day transfer back to moon
- Ballistic and low thrust capture into lunar science orbit

Sun SEM_L1 Axes
21 Sep 2018 13:19:32.093 Time Step: 600.00 sec

Lunar IceCube Launch Vehicle



NASA's Space Launch System 2018

Our Ground Station



Deep Space Network 70m Dish

Ada Europe 2016

Acknowledgements

- NASA Vermont Space Grant Consortium



- NASA



- Vermont Technical College

VERMONT TECH

- AdaCore, Inc. (GNAT Pro)



- Altran Praxis (SPARK)



- SofCheck (AdaMagic)



- Applied Graphics, Inc. (STK)



- LED Dynamics (PV boards)



- Microstrain (IMU)

