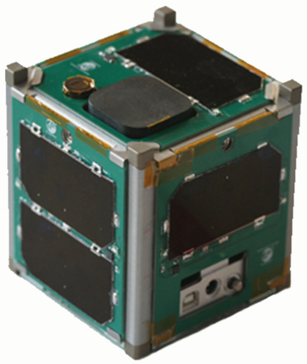
Vermont Technical College

CubeSat Laboratory

Vermont Lunar CubeSat



Project Overview

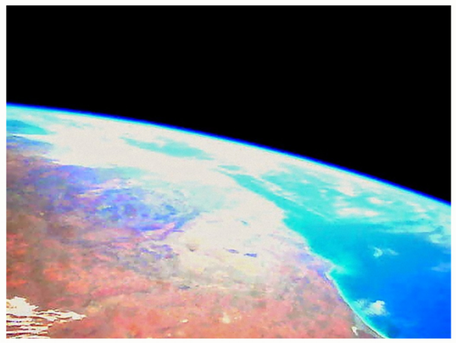
The CubeSat Laboratory at Vermont Technical College (VTC) is a collection of students, faculty, and staff building CubeSat technology spacecraft.

While CubeSats are being constructed by many groups around the world, both inside and outside of academia, what makes our work different is that we use the SPARK/Ada programming language for our software needs. As compared to the more commonly used C language, Ada makes it easier to write correct, robust software. SPARK adds the ability to create formal proofs (with the aid of tools) showing freedom from certain classes of runtime errors and other correctness properties. Our BasicLEO CubeSat, launched in November 2013 is the first CubeSat programmed with Ada and the first spacecraft of any kind programmed with SPARK.

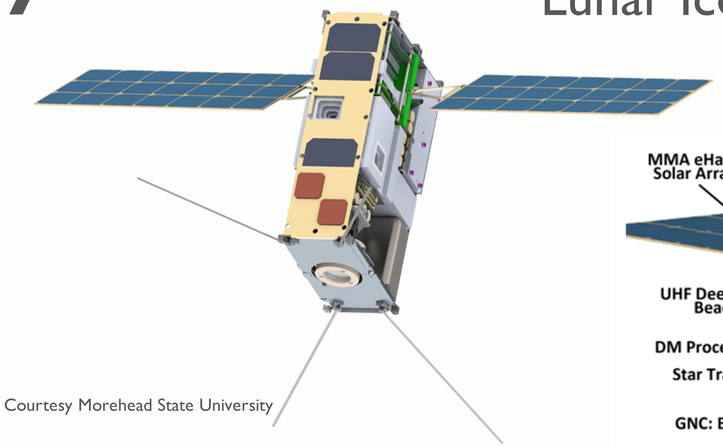
BasicLEO

The goal of the Basic Low Earth Orbit (BasicLEO) project is to explore the technologies required for building a viable CubeSat use SPARK/Ada for the flight control software. This project's predecessor was the Alaskan Ice Buoy Project that helped us learn about the CubeSat Kit hardware that is also being used in this project.

Our CubeSat was launched into low Earth orbit as part of NASA's ELaNa IV program on the Air Force ORS-3 mission. The launch vehicle was an Orbital Sciences Minotaur I rocket launched from Wallops Island, VA, on November 19, 2013. The mission, still ongoing, has been a success!



Lunar IceCube



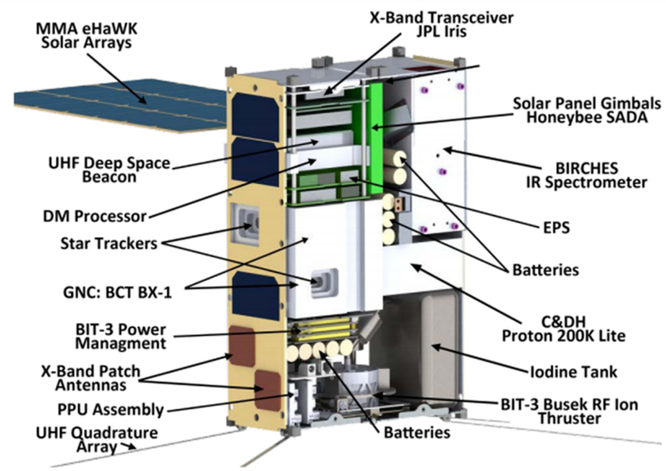
Courtesy Morehead State University

Mission Overview

We are working in collaboration with Morehead State University and NASA's Goddard Space Flight Center on a 6U CubeSat that will orbit the moon and study lunar volatiles. In particular the spacecraft will look for water in all its phases. Accordingly the mission is informally called "Lunar IceCube."

This mission involves a number of interesting technologies. For example: an iodine ion thruster being developed by Busek, an infrared spectrometer (the science instrument) being developed by Goddard, a radio being developed by JPL, and interaction with NASA's Deep Space Network.

Our role in this mission is the construction of the flight control software, using and extending the SPARK/Ada technologies we employed in our BasicLEO mission. Because of its mission critical nature, it is imperative that the flight control software be robust. We aim to demonstrate the effectiveness of SPARK at helping us achieve our reliability goals.



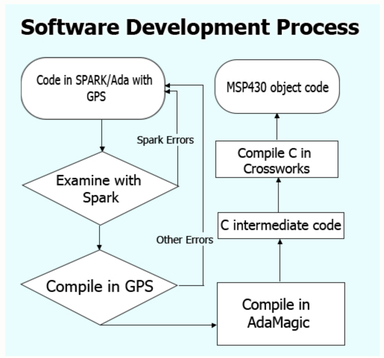
Courtesy Morehead State University

Software Components

For the IceCube mission we intend to use SPARK 2014. This is a change from our BasicLEO mission where we used SPARK 2005. Unlike the previous version of SPARK, the new SPARK 2014 language and tools offer a much richer and more powerful environment for software development.

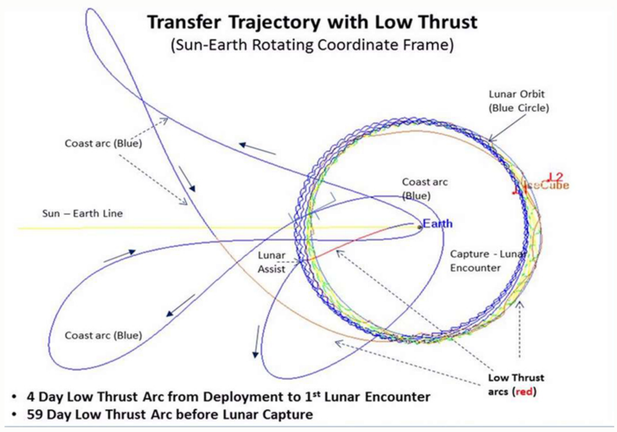
We also intend to use our CubeSat operating system CubedOS in the IceCube mission. Indeed, our intention is to use IceCube as both a proving ground and development platform for CubedOS. We anticipate that our experience working with CubedOS in IceCube will allow us to offer a much more refined and practical system to other groups when that time comes.

Because CubedOS makes heavy use of concurrency by way of Ada's Ravenscar profile tasking features, we will also be using IceCube as an environment for exploring SPARK 2014's upcoming support for tasking. We anticipate working closely with the SPARK development team during this process.



Cubed Os

CubedOS is an operating system intended for CubeSat flight control software. It has been used by Vermont Technical College in support of our IceCube work. However, the intent is for CubedOS to be general enough and modular enough for other groups to profitably employ the system. Since every mission uses different hardware and has different software needs, CubedOS is a really an application framework into which custom modules can be plugged to implement whatever mission functionality is required. CubedOS provides inter-module communication and other common services required by many missions. CubedOS thus serves both as a kind of operating system and as a library of useful tools.
CubedOS is written in SPARK with critical sections verified to be free of the possibility of runtime error. SPARK has also been used to provide some other correctness guarantees in certain cases. It is our intention that all CubedOS modules also be written in SPARK and proved free of runtime error (at least). However, CubedOS also allows modules, or parts of modules, to be written in full Ada or even C if appropriate. This allows CubedOS to take advantage of third party C libraries or to integrate with an existing C code base.



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Why Spark?

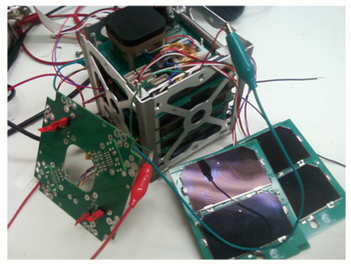
SPARK is a dialect of Ada that allows for the formal verification of programs. Using the SPARK tools it is possible to mathematically prove that one's software is free of many important classes of errors. Since CubeSat software is difficult or impossible to modify once it is deployed in space, increasing the robustness of that software is of great importance.

Software Metrics

The SPARK portion of the flight control program consists of 5991 lines of code and 4095 lines of comments (where 2843 comment lines are actually SPARK annotations), for a total of 10,086 lines. These numbers do not consider blank lines.

The C portion of the flight control program consists of 2239 lines (including blank lines). This does not include the header files or source files of the third party SD card library.

The final executable consumes 3874 bytes of RAM (not including stack space) and 45,428 bytes of ROM.



On The Web

Our Website:
http://www.cubesatlab.org/

Our Blog:
http://cubesatlab.blogspot.com/

Track The CubeSat:
http://www.n2yo.com/satellite/?s=39407

Vermont Lunar CubeSat Personnel

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Dr. Peter Chapin, Software Director

CubeSat

Dan Turner, Software Developer; William McGrath, Communications; Oliver Piluski, Fabrication

CubedOS & IceCube

Nicole Hurley, Niels Huisman

IceCube Personnel

Principle Investigators:

Benjamin Malphrus (Morehead State University), PI
Pamela Clark (JPL), Science PI
Mike Tsay (Busek Company), Co-PI

Poster Prepared by Chris Dunkle