Lunar Lander / Orbiter CubeSats

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NASA Consortium Development Grant

- Vermont Technical College: Carl Brandon (structure, thrusters, communication, navigation, electronics) and Peter Chapin (software)

- University of Vermont: Jun Yu (low energy transfer and radiation environment modeling) and Jeff Frolik (spacecraft coordination, landing)

NASA Consortium Development Grant

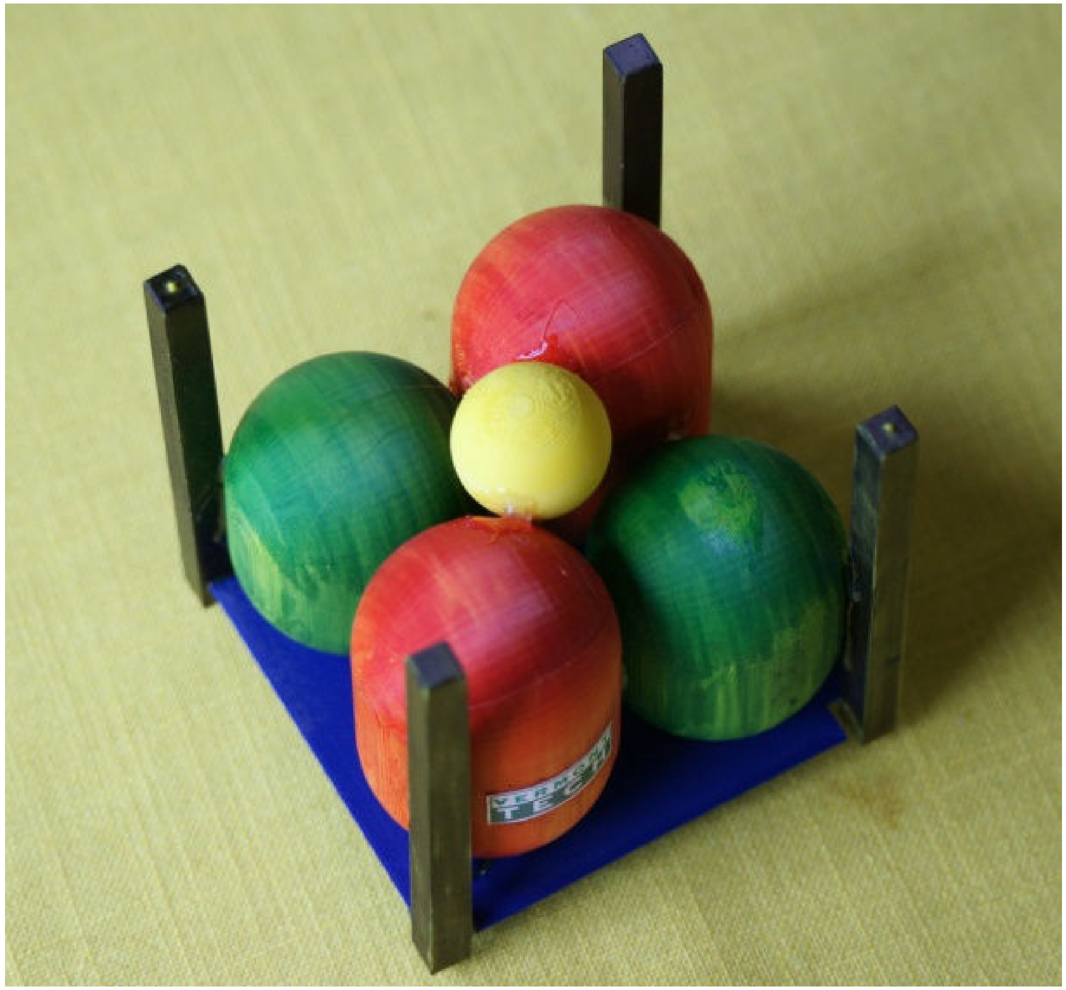
- Norwich University: Ron Lessard and Danner Friend (optical sensors and robotics)

- Undergraduate students and graduate students (UVM) from the above institutions and St. Michael's College

- Assistance from NASA Goddard Spaceflight Center and NASA Jet Propulsion Laboratory personnel

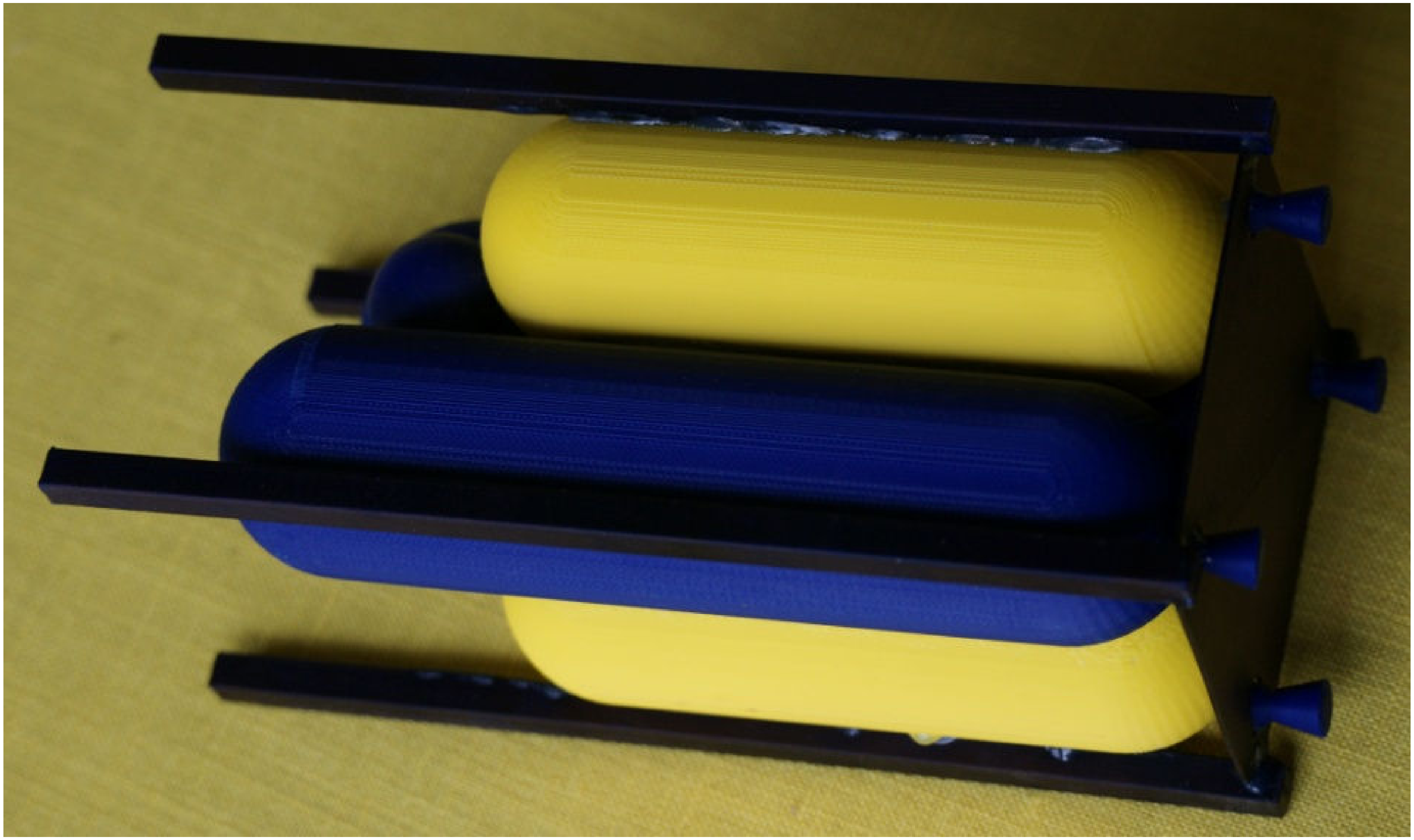
Three Spacecraft

VERMONT TECH



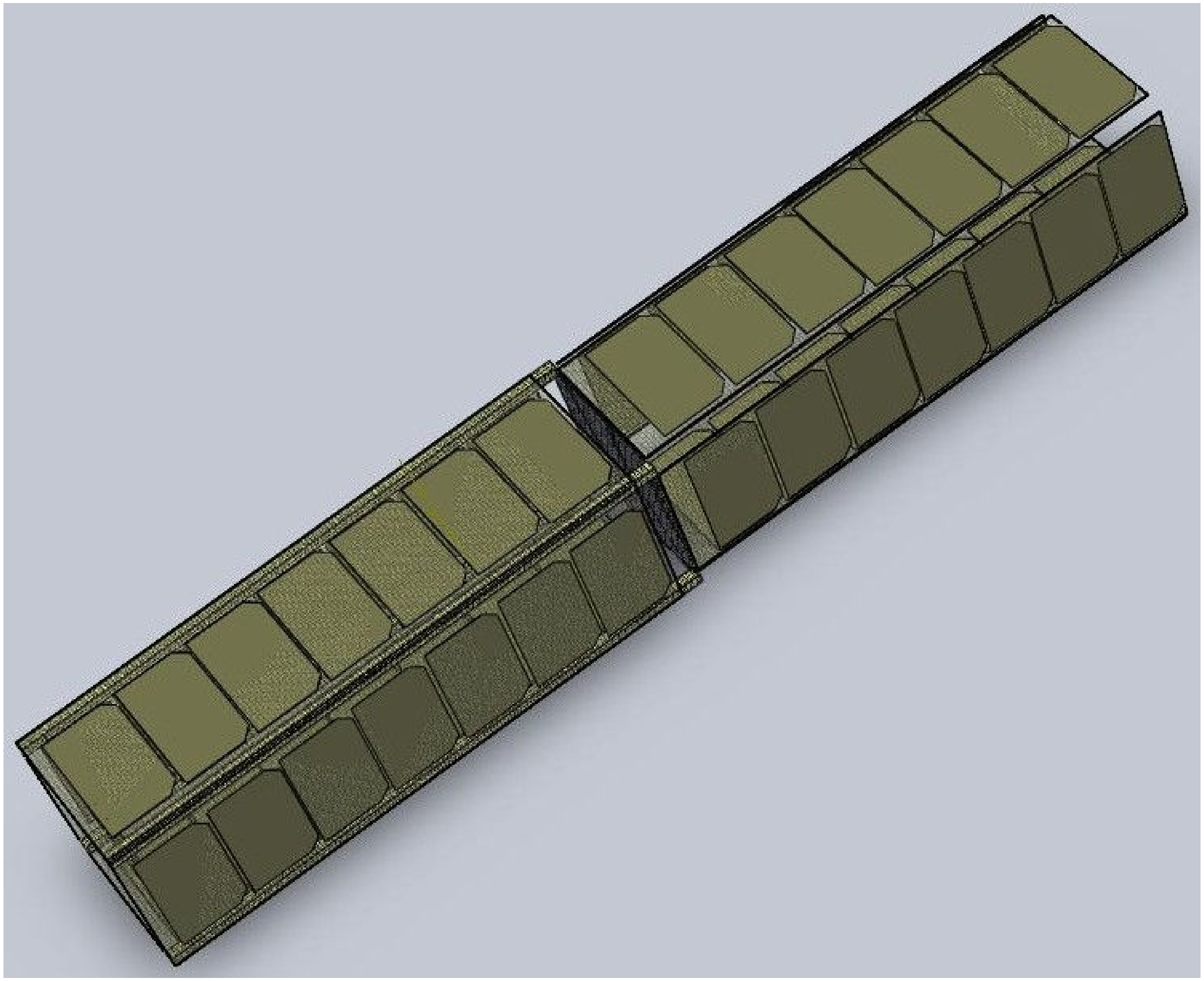
Single CubeSat Lunar Lander

Three Spacecraft



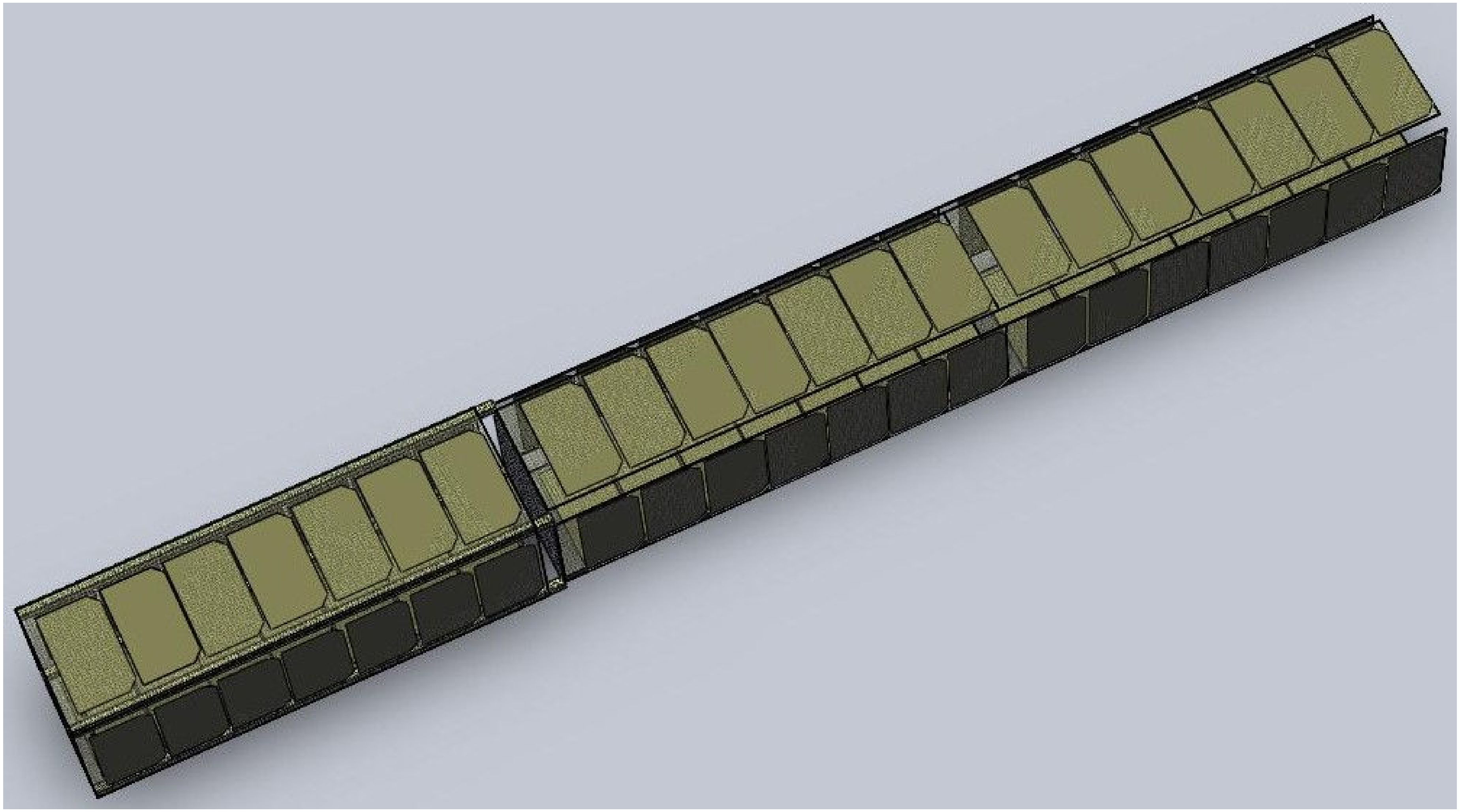
Double CubeSat Booster

Three Spacecraft



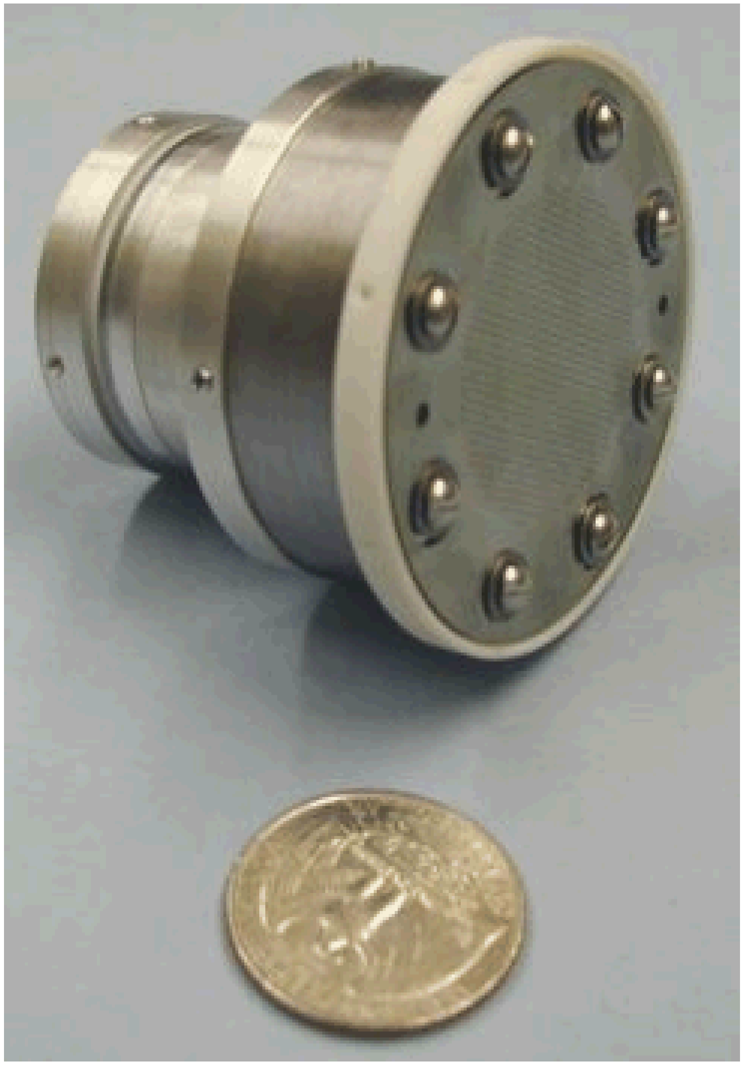
Triple CubeSat Ion Lunar Orbiter

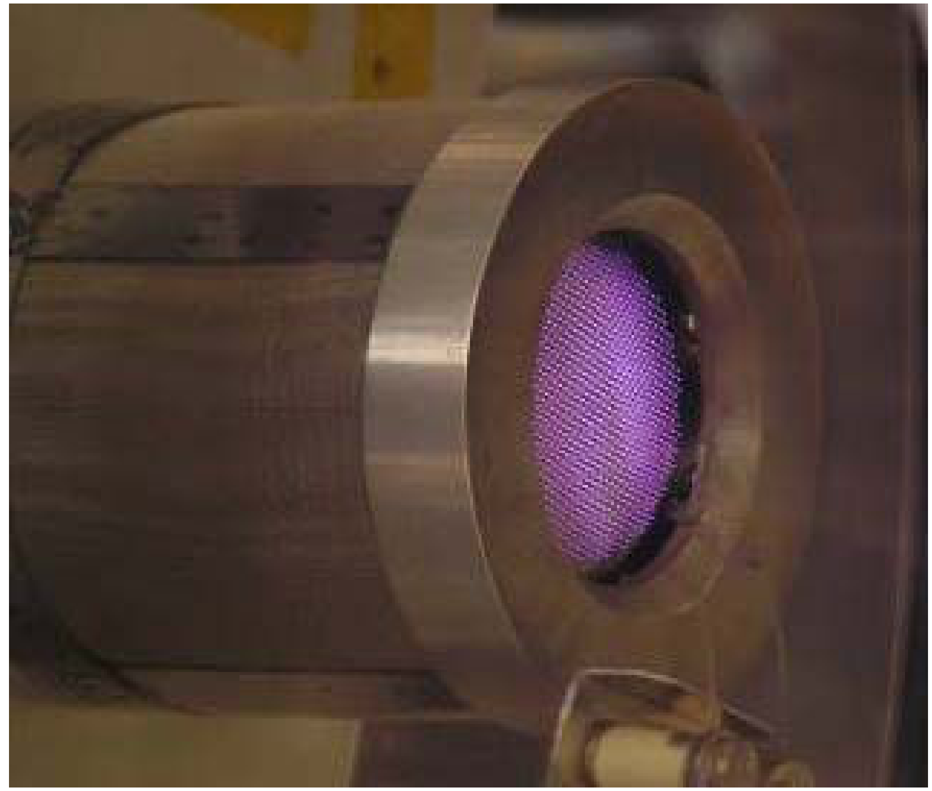
Three Spacecraft



Higher Power Triple CubeSat Ion Lunar Orbiter

Three Spacecraft





JPL Miniature Xenon Ion (MiXI) Thruster

Technology Prototyping

- Use of carbon fiber composite for CubeSat structures
- Development of a 1N mono-propellant thruster
- Designing a CubeSat sized thruster gimbal
- Developing a CubeSat sized 200-300 atmosphere xenon tank

Technology Prototyping

- Miniaturizing the xenon pressure regulator and gas flow control as used in the ESA SMART-1 spacecraft
- Converting the NASA Goddard GEONS navigation system to Ada/SPARK and developing the associated hardware
- Developing the associated electronics and sensors
- Developing optical means for lunar landing attitude control and lateral velocity control

Chemical Propulsion System

- Lander and Booster will each have four 1 N thrusters

- Monopropellant: Hydroxyl Ammonium Nitrate and Methanol (88%:12% by mass) mixed

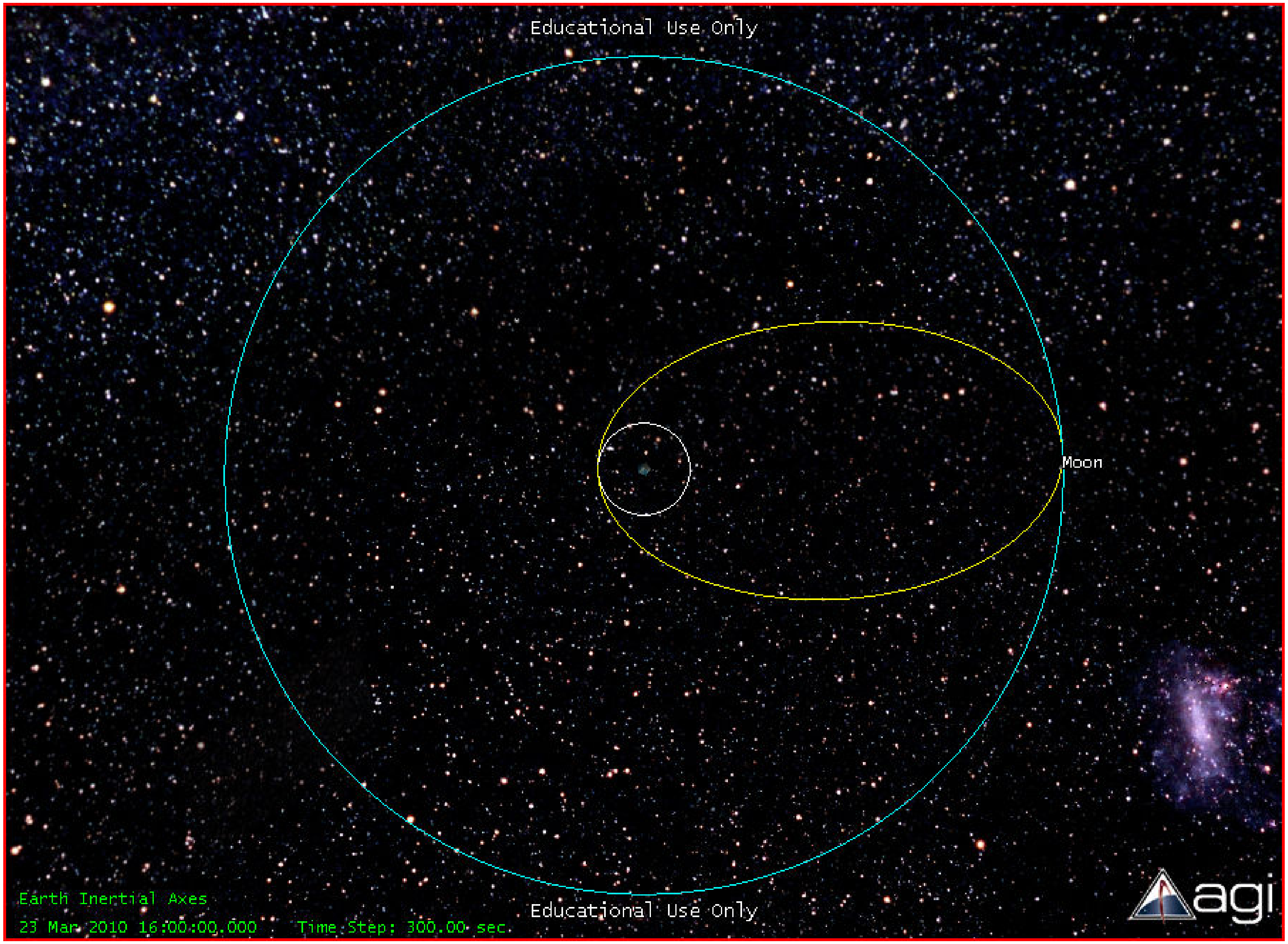
- Specific Impulse about 270 seconds

Ion Propulsion System

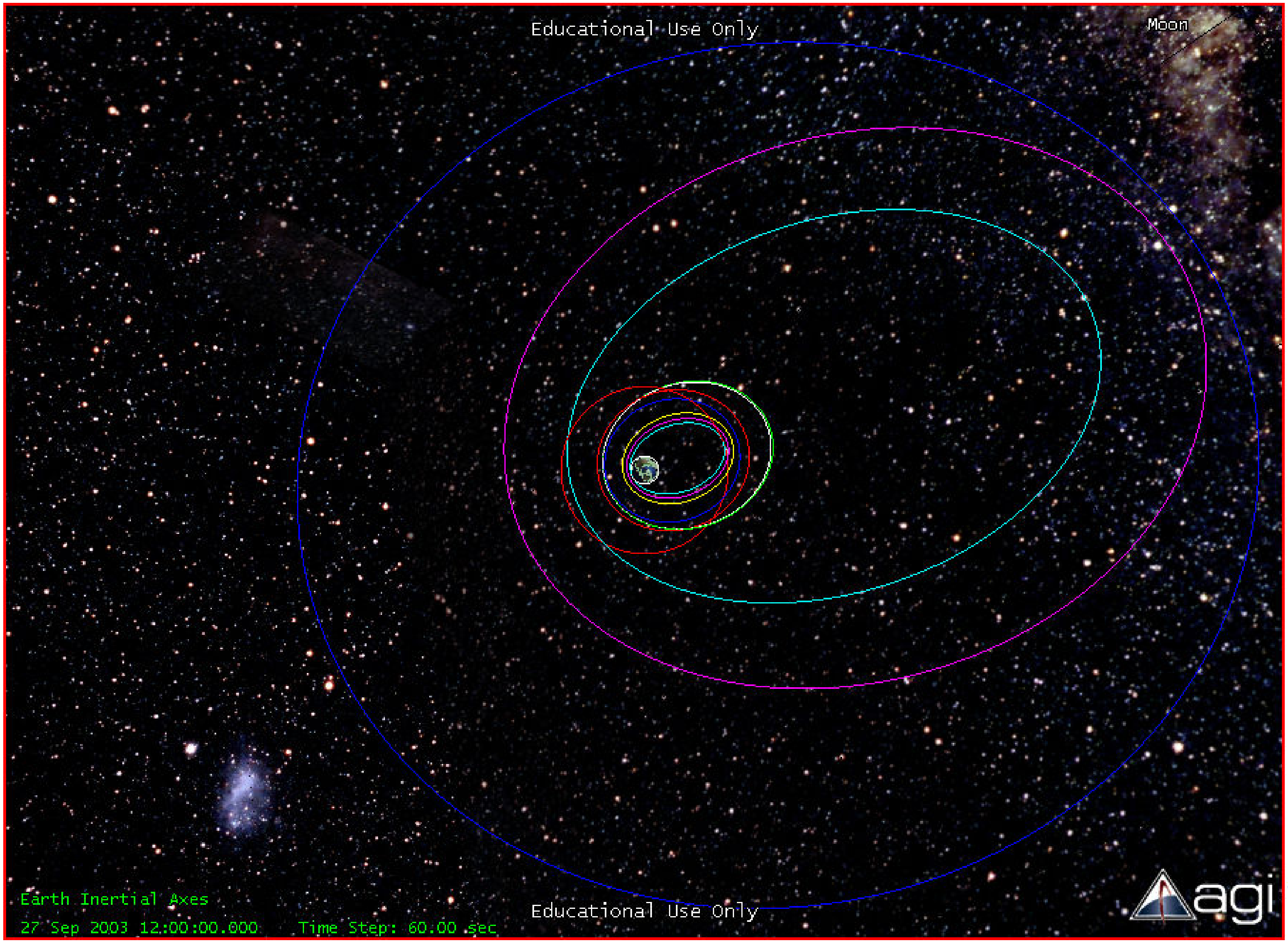
- Triple CubeSat orbiter will have one MiXI 1 mN thruster, Specific Impulse about 2,500 – 3,000 seconds

- Power for the xenon ion drive will come from photovoltaic cells on the spacecraft body and four fold out 30 cm x 10 cm panels

Bi-Propellant Orbits



Ion Drive Orbits ala SMART-1



Vermont Tech Student Involvement

- Electro-Mechanical Engineering Technology Bachelors students can take the Spacecraft Systems course and work in the CubeSat Lab, on the Lunar spacecraft which becomes their required Senior Project

- They implement the specific systems for the CubeSat.

Vermont Tech Student Involvement

- Software Engineering Bachelors students would implement parts of the software systems for their Senior Project and are currently developing a test framework for the navigation system.

- Other Electro-Mechanical students have worked on a steerable dish antenna for the GENSO ground station and a testing system for the Lunar lander landing gear

Vermont CubeSat Project

- Carbon fiber composite for structural components (including fold out photovoltaic panels)

- Using a CubeSat Kit CPU board

- Texas Instrument MSP430 CPU

Vermont CubeSat Project

- Spectrolab TASC 27% efficient triple junction photovoltaic cells

- Clyde Space Electrical Power System with Li-Polymer batteries

- 3 axis magnetometer (near earth) and sun, earth, moon sensor for attitude determination

- Differential thrusters (chemical), and gimbaled ion thruster for attitude control

Vermont CubeSat Project

- NASA Goddard GPS Enhanced Onboard Navigation System (GEONS) for navigation (rewritten in Ada/SPARK)

- Radios for 2-way communication to be determined

- Ground communication station to be part of the worldwide GENSO network

- Camera modules to be used for celestial navigation.

Why Use Ada and SPARK?

•Although not safety critical, the software is mission critical. We won't be able to patch it.

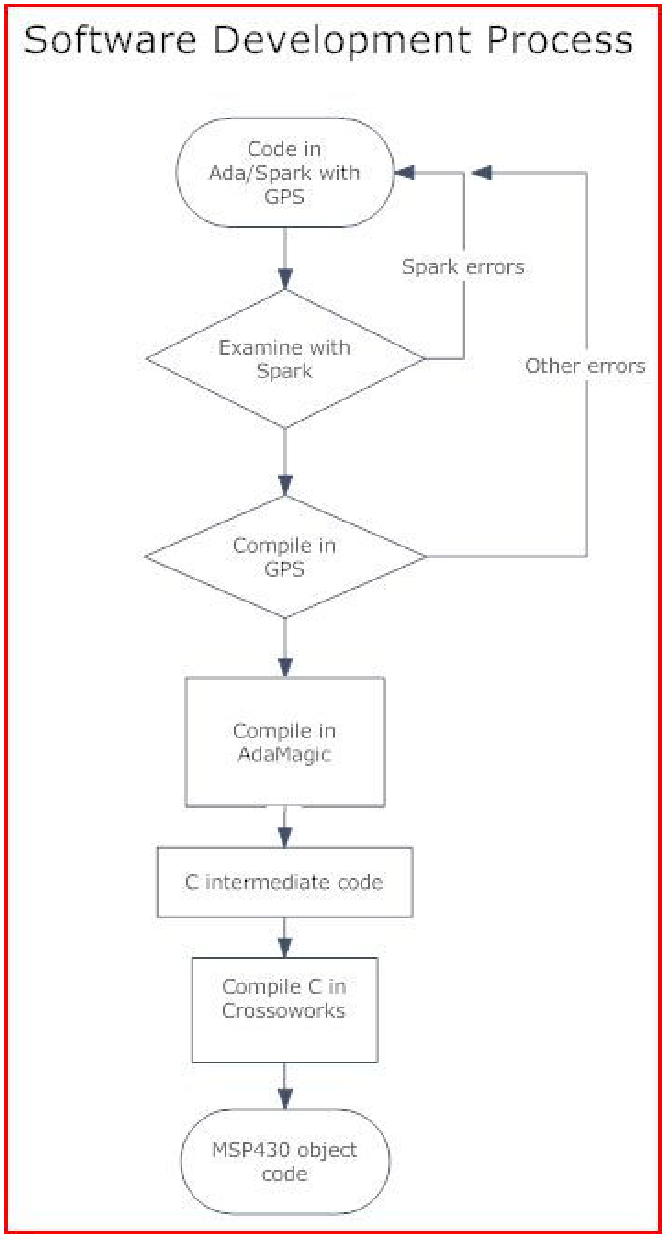
•Satellite cost of $100,000-$300,000 and launch cost of $200,000-$300,000 and several years' effort would be lost by a software failure

•Ada/SPARK offers a greatly improved probability of error-free software when compared with C used in most CubeSat projects

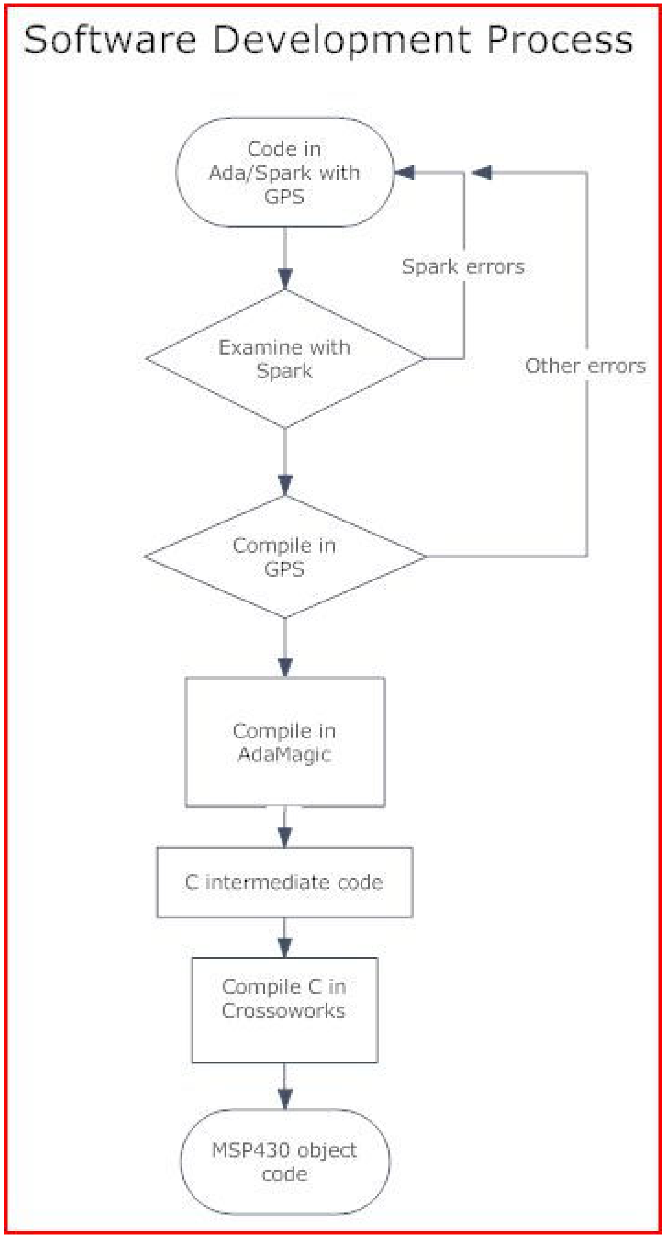
Why Use Ada and SPARK?

•The development and debugging time would be less; helpful with our smaller resource base

•Students get a chance to use the best software engineering features in Ada and SPARK in a real-world embedded system



- Software written in Ada/SPARK
- Checked with the Praxis High Integrity Systems' SPARK Toolset
- Compiled with Adacore's GNAT Pro



- Sofcheck's AdaMagic compiles to produce C intermediate code
- Rowley's Crossworks C to object code for Texas Instruments' MSP430 CPU
- Pumpkin's Salvo RTOS if needed

Acknowledgements

- NASA Vermont Space Grant Consortium
- NASA
- Vermont Technical College
- AdaCore, Inc.
- Praxis High Integrity Systems
- SofCheck
- Applied Graphics, Inc.

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