Use of Ada in a Student CubeSat Project

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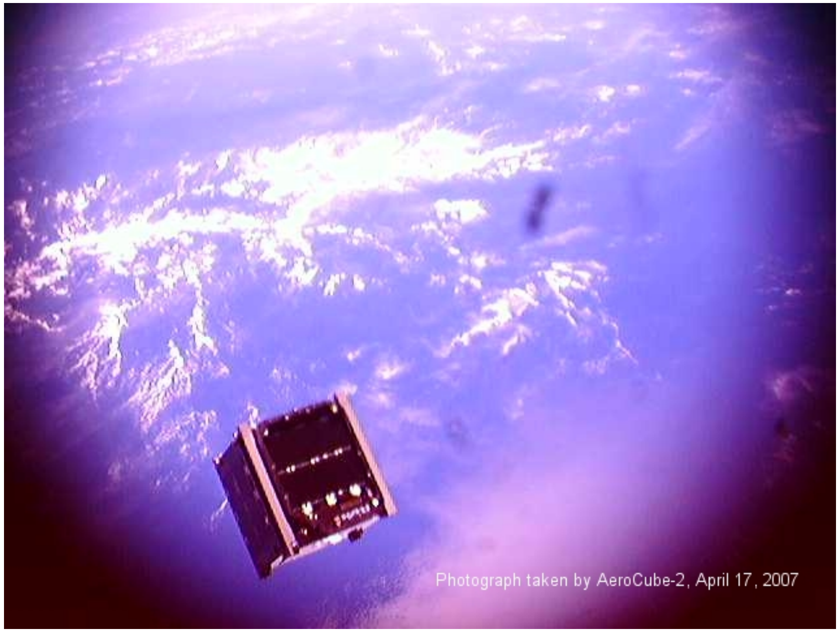
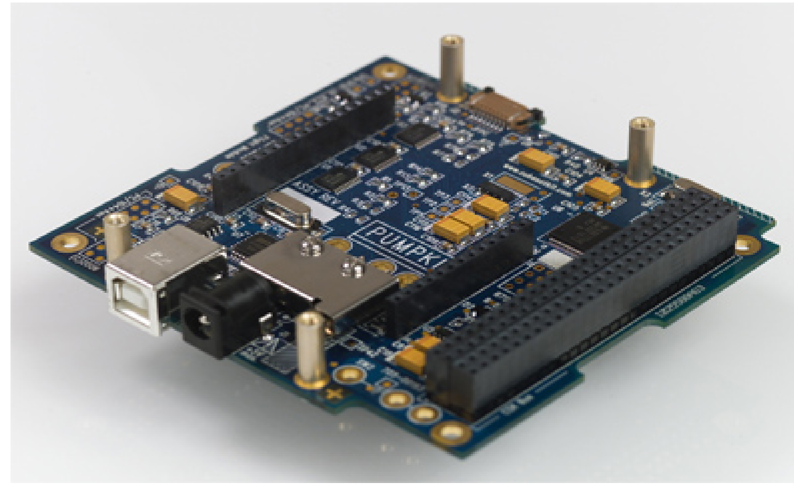


CubeSat Standard

- Developed by Cal Poly and Stanford University
- 10 cm x 10 cm x 10 cm, 1 kilogram mass
- Can be double or triple units (10x10x20 cm or 10x10x30 cm, 2 or 3 kg)
- Powered by photovoltaic cells and rechargeable (i.e. Li-Polymer) batteries
- 1.5 W to 2.5 W maximum power, average determined by orbit
- Usually launched piggy-back with commercial satellites
- Initially only used by universities, now commercial and military interest
- Construction costs $30,000 to $50,000 for single units
- Launch costs $30,000 to $50,000 for single units

CubeSat Hardware

CubeSat Kit™ Flight Module



CubeSat Kit™ Flight Module CPU

Cal Poly P-Pod

Clyde Space EPS with batteries

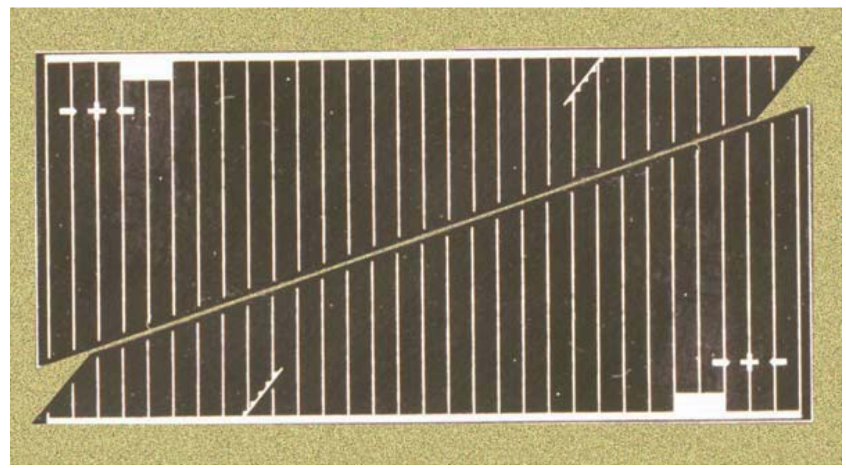
CubeSat Hardware

VERMONT TECH

Microhard MHX2400 2.4 GHz
Spread Spectrum Modem

GPS Creations GPS500 board

KySat with pc boards



2 Spectrolab 1.55 x 3.18 cm TASC solar cells

Arctic Sea Ice Buoys

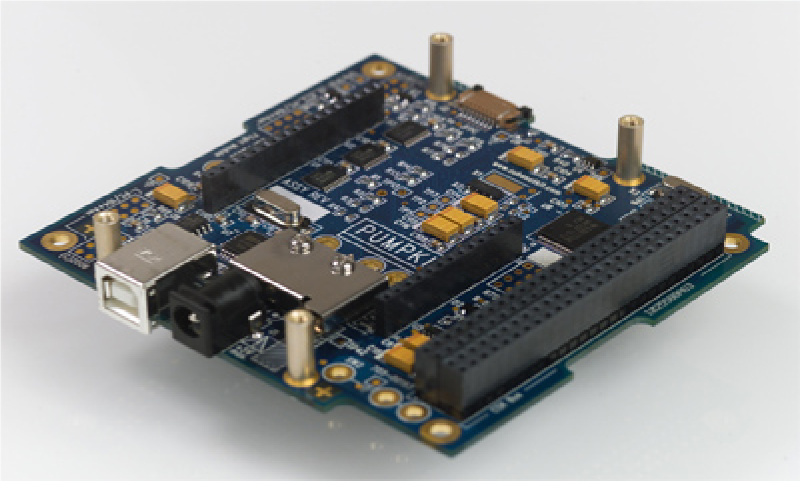
- Buoys will share hardware and software with our CubeSat satellite
- Measures: Wind speed, direction, temperature and GPS position
- Data uploaded to Iridium Satellites via Short Burst Data Modem Service
- Ultra low power Texas Instrument MSP430 CPU on Li-Polymer batteries and photovoltaic cells
- Working on the simpler software for the buoys will give us good experience before tackling the much more complicated CubeSat software

Arctic Sea Ice Buoy Hardware

NRG Wind Vane

NRG Anemometer

Iridium Short Burst Data Modem



Cubesatkit Flight Module CPU

Vermont Tech Student Involvement

- Aeronautical Engineering Technology Associates (2 year) students take 2 semesters of Spacecraft Systems and a Satellite Lab
- They develop the general specifications for a CubeSat
- Electro-Mechanical Engineering Technology Bachelors (4 year) students can take an Aerospace Track with the 2 semesters of Spacecraft Systems and a Satellite Lab, which becomes their Senior Project
- They implement the specific systems for the CubeSat
- Software Engineering Bachelors students would implement parts of the software systems for their Senior Project

Vermont Tech CubeSat Project

- Using a CubeSat Kit for the spacecraft structure and CPU board
- Comes with a development board and the Salvo Real Time Operating System
- Texas Instrument MSP430 CPU
- Spectrolab TASC 27% efficient triple junction photovoltaic cells
- Clyde Space Electrical Power System with Li-Polymer batteries
- 3 axis magnetometer and sun sensor for attitude determination
- 3 axis magnetic torque coils for attitude control
- Microhard 2.4 GHz spread spectrum modem for 2-way communication
- 440 MHz amateur frequency data beacon
- Ground communication station to be part of the worldwide GENSO network
- Camera and other instruments to be determined

MSP430 CPU Description

- Lowest power microcontrollers/microprocessors available
- Various peripherals can be had on the chip
- We are looking at an MSP430F2618
- 116 kb of flash, 8 kb RAM, 12 bit SAR A to D, 2x12 bit D to A, analog comparator, DMA, hardware multiplier, 2 USCI interfaces
- 2 µA low power, 500 µA full speed
- From low power to full speed in one microsecond
- No Ada compiler for the MSP430

Why Use Ada?

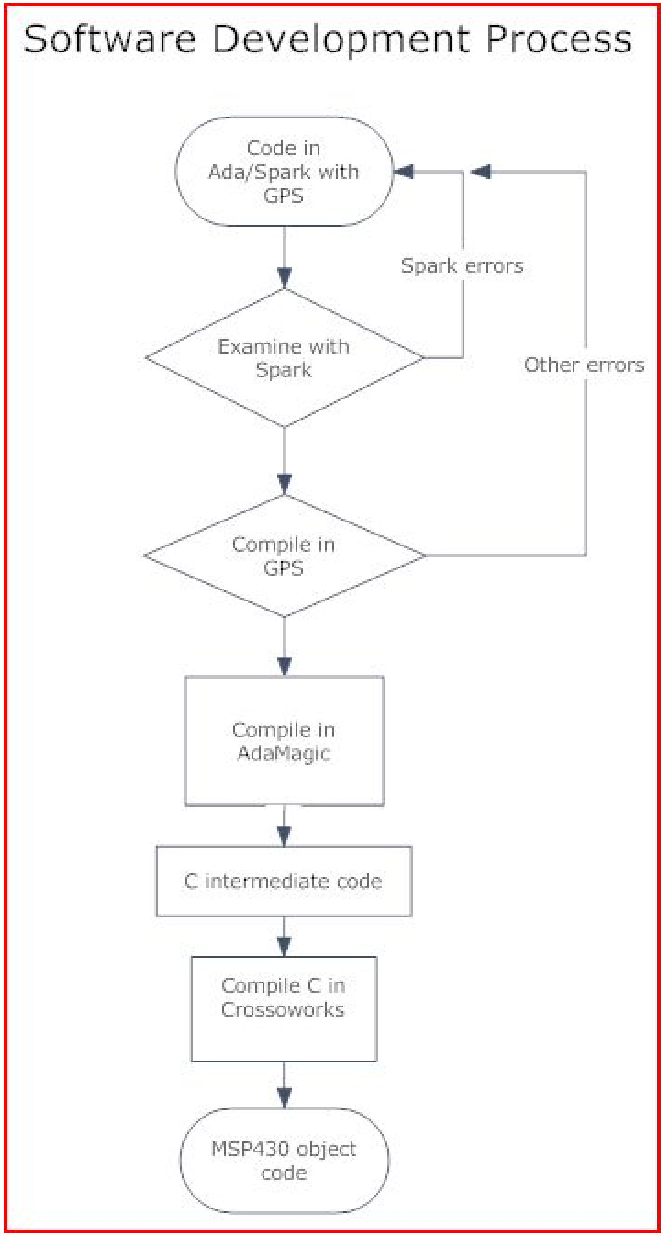
- Although not safety critical, the software is mission critical
- Satellite cost of $30,000-$50,000 and launch cost of $30,000-$50,000 and several years’ effort would be lost by a software failure
- Ada offers a greatly improved probability of error-free software when compared with C used in most CubeSat projects
- 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 in a real-world embedded system

Ada and SPARK

- SPARK allows for a further increase in the reliability of our software
- SPARK annotations allow for various conditions to be checked by static analysis
- Although small by SPARK standards, our Arctic Sea Ice Buoy and CubeSat have only one chance to get the software right
- There is a high cost for failure
- A rare opportunity for our students to work on a real-world, very high integrity system using the best tools available
- For the Arctic Sea Ice Buoy, we can use sequential Spark and eliminate the run-time system
- For the CubeSat, we can use the RavenSPARK subset of the Ada Ravenscar Tasking Profile for high integrity real-time programming

AdaMagic

- There is no Ada compiler for the Texas Instruments MSP430 series of processors we are using
- The availability of the AdaMagic compiler front end which produces ANSI C as the intermediate language allows us to do these projects in SPARK/Ada
- The C output from AdaMagic is then run through the Rowley Crossworks cross compiler to produce object code for the MSP430
- This was our plan when we considered Ada only, and also will work with SPARK/Ada
- This same procedure, for a different purpose, was discussed by Praxis at the Ada Europe 2004 conference in “High Integrity Ada in a UML and C World”



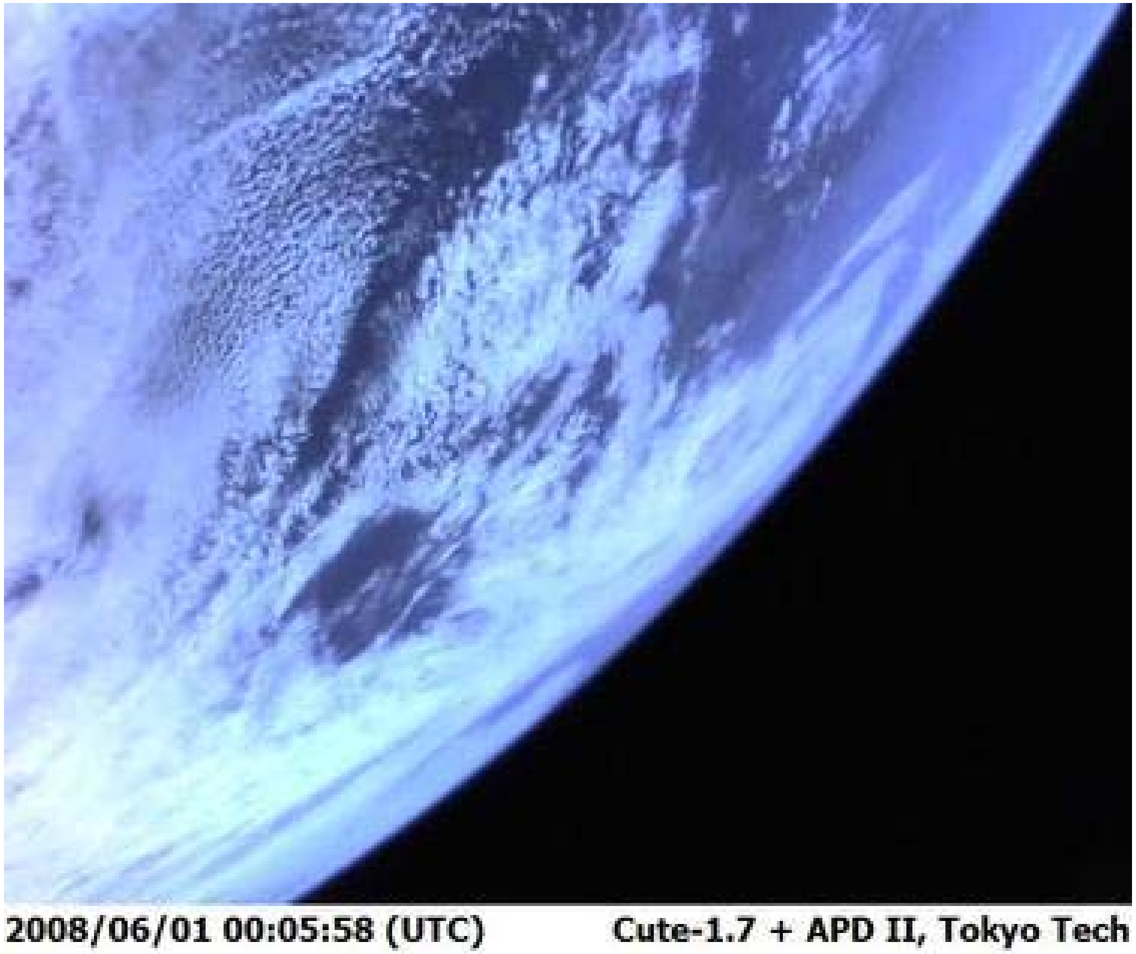
- Software written in SPARK/Ada
- Checked with the Praxis High Integrity Systems' Spark Toolset
- Compiled with Adacore's GNAT Pro
- Sofcheck's AdaMagic to produce C intermediate code
- Rowley's Crossworks C to object code forTexas Instruments' MSP430 CPU
- Pumpkin's Salvo RTOS

Recent CubeSat Activity

- ESA selected 9 CubeSats (plus two back-ups) for debut of Europe’s new Vega launch vehicle in late 2008 or early 2009.
- NSF announced funding for CubeSat-based science missions for space weather and atmospheric research.
- The National Reconnaissance Office (NRO)announces the Innovative Experiments Initiative to develop new technologies on CubeSats.
- April 28th on a PSLV-C9 rocket out of Sriharikota, India. 6 CubeSats on this launch were: AAUSAT-II, CanX-2, Cute-1.7+APD II, Compass One, Delfi-C3, and SEEDS.

PSLV-C9 Launch with 6 CubeSats

Cute-1.7 + APD II Photo from 620 km

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Acknowledgements

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

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