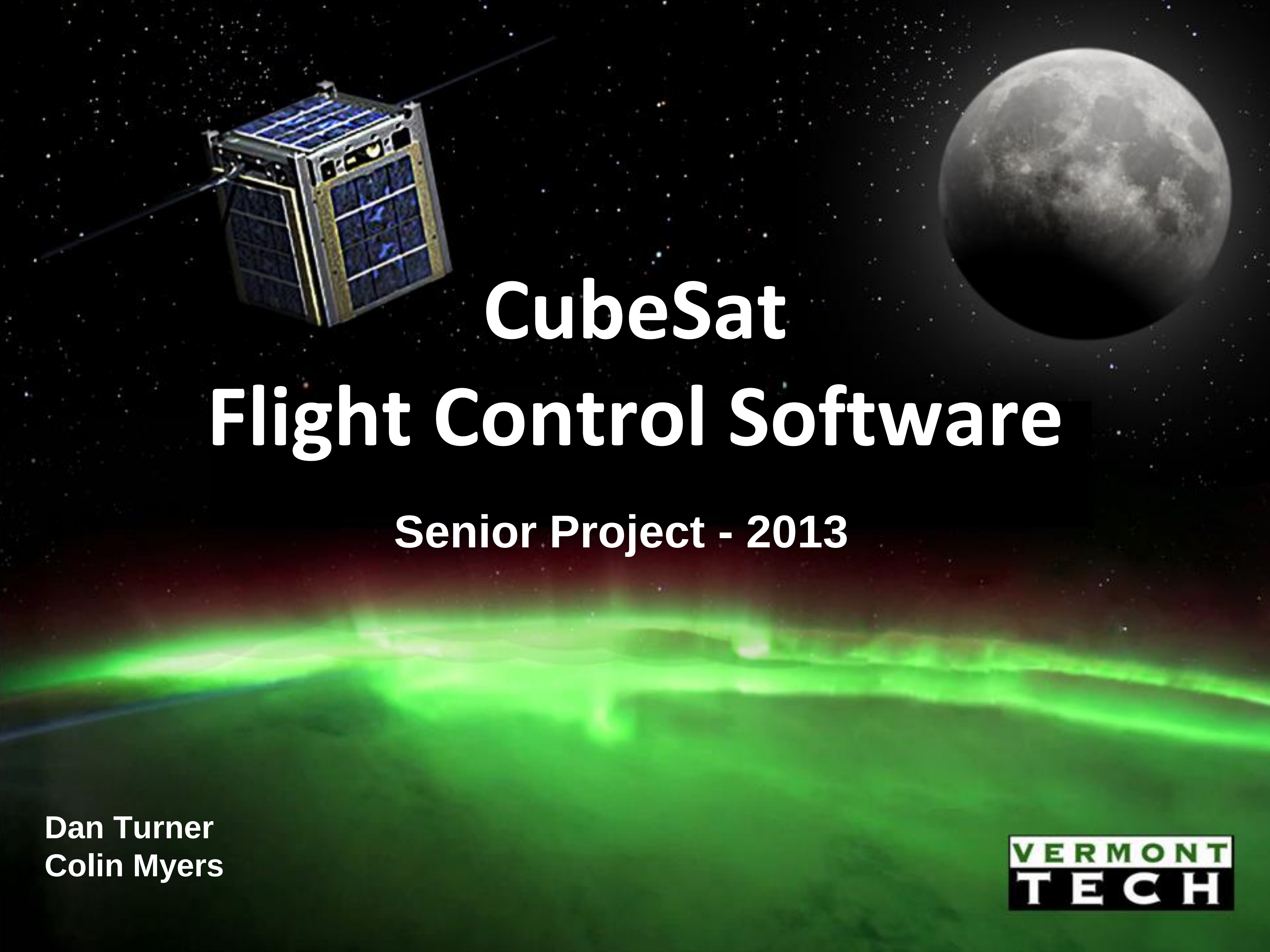


CubeSat Flight Control Software

Senior Project - 2013

Dan Turner
Colin Myers

VERMONT TECH

Project Description

- Flight Control Software for Vermont Techs CubeSat

- Scheduled to launch in September of 2013

- **Purpose:** Test onboard subsystems & a SPARK implementation of GEONS

- **Future Goal:** Send a CubeSat to the moon to either orbit or land on it.

- The completed CubeSat design will be used to replicate additional CubeSats for future missions.

Student Involvement

2011 (Summer) – Jeremy Audet & Matt Ward started the flight control software

2012 (Summer) – Dan Turner picked up where Matt and Jeremy left off with the flight control software

2012 (Fall) – Michael Collins and Colin Myers started working on the flight control software

2013 (Spring) – India Beauregard helped develop the IMU board

Other Acknowledgements

Carl Brandon- Principal Investigator

Peter Chapin- Software Director

Carl Wolf - Helped with designing the IMU board

Oliver Piluski (LED Dynamics) **-** Helped with the development and printing of the IMU board

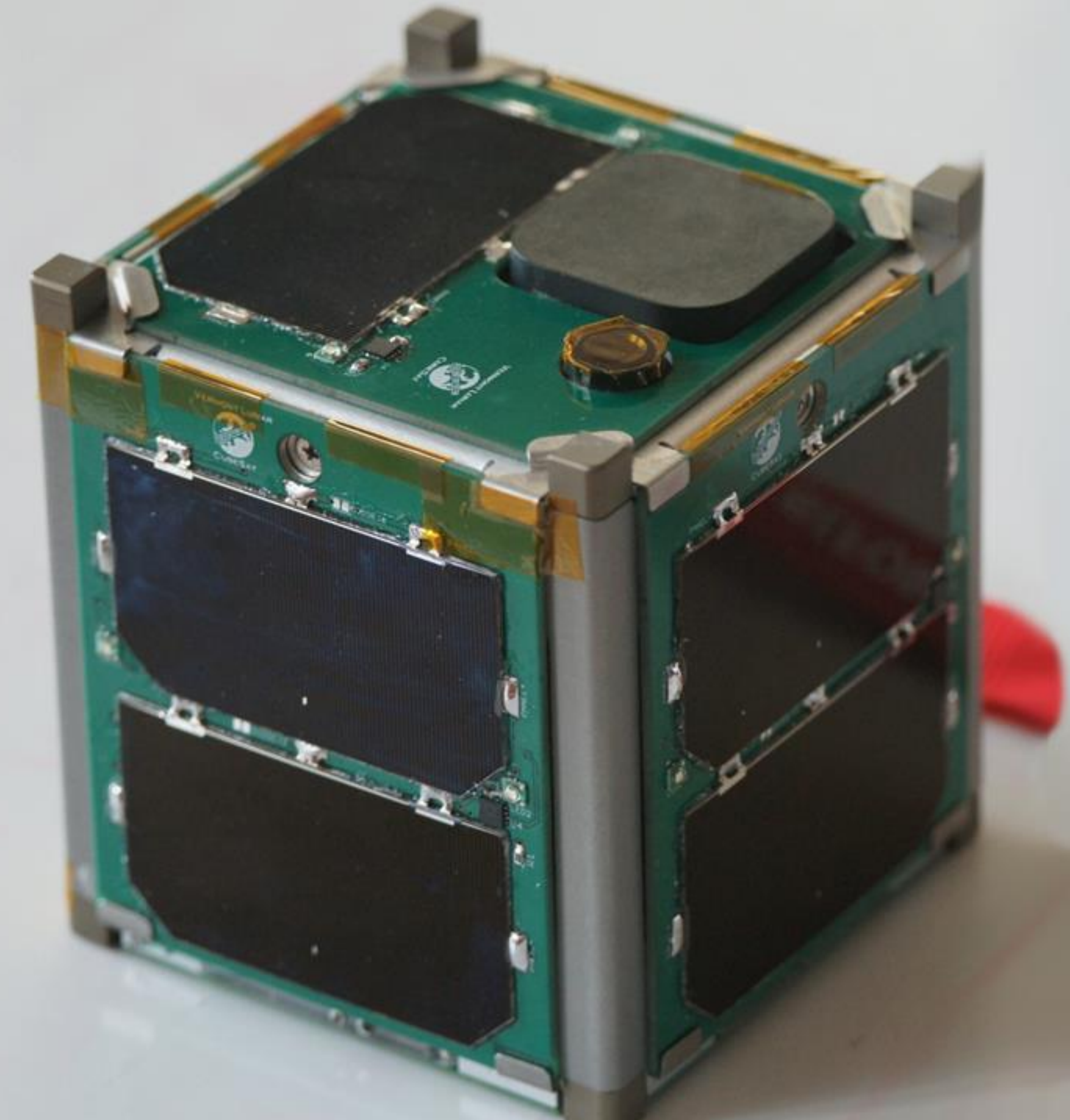
Barry Trutor (Microstrain) - Helped with IMU integration

Rob Devarney - Is currently assisting with the Ground Control

What is a CubeSat?

"CubeSats are a class of research spacecraft called nanosatellites. The cube-shaped satellites are approximately four inches long, have a volume of about one quart and weigh about 3 pounds."

--NASA


CubeSat

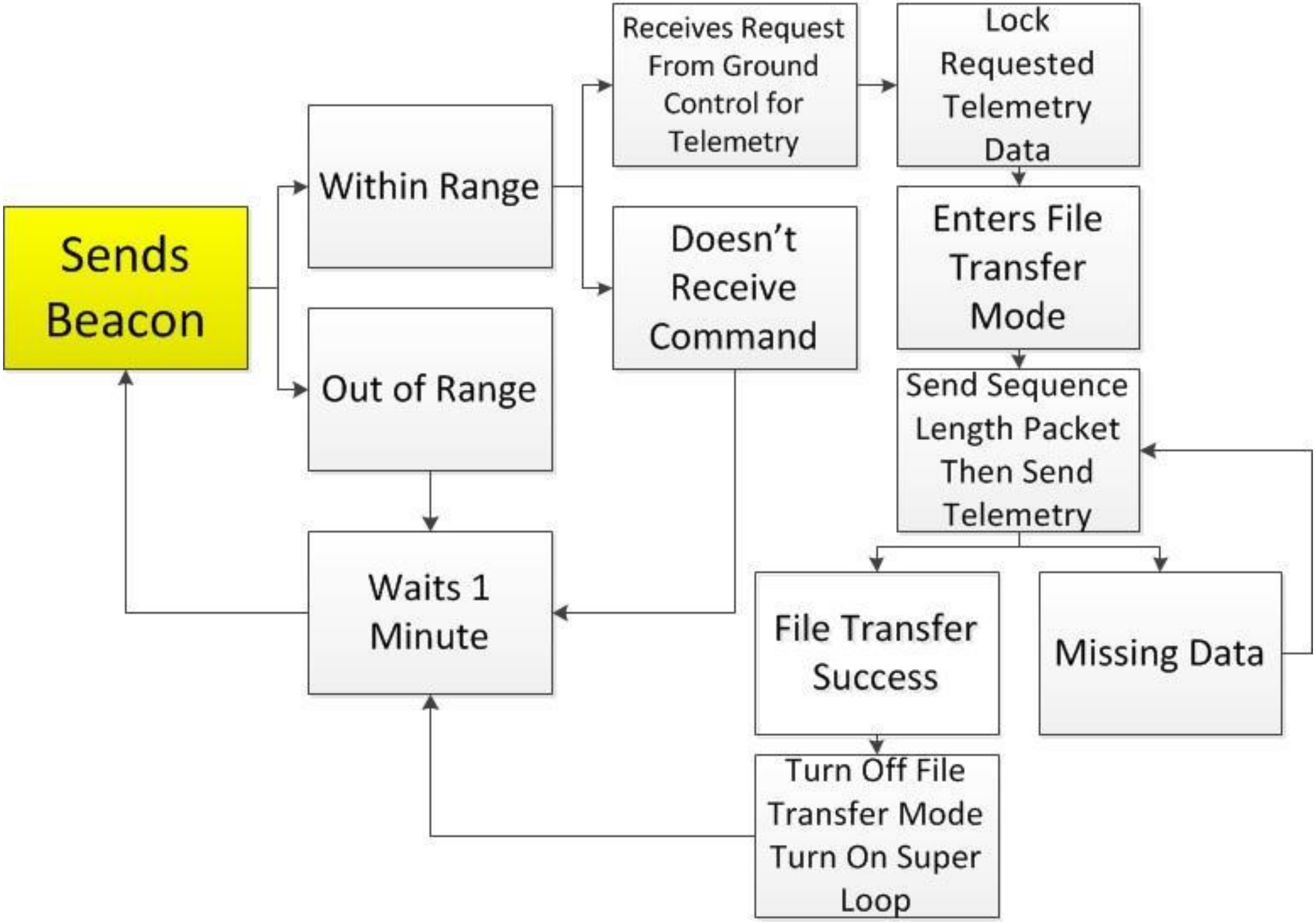
Hardware Requirements

Hardware consist of:

- Camera
- Inertial Measurement Unit (IMU)
- GPS
- Power Supply
- Radio
- MSP430 processor
- SD Card
- Antenna

Software Requirements

- The **Antenna** must be deployed no sooner than 45 minutes after the CubeSat is ejected from the rocket
- The **Radio** must send a beacon every minute if there is no communication with the Ground Control
- The **File System** must store telemetry data, error logs, and images on a SD card
- The **Camera**, **GPS** and **IMU** must save telemetry data to the file system
- The **Power Supply** must report battery status when requested
- All Flight Control Software must be written in **SPARK/Ada**



Sends Beacon

Within Range

Out of Range

Receives Request From Ground Control for Telemetry

Doesn’t Receive Command

Waits 1 Minute

Lock Requested Telemetry Data

Enters File Transfer Mode

Send Sequence Length Packet Then Send Telemetry

File Transfer Success

Missing Data

Turn Off File Transfer Mode Turn On Super Loop

What is SPARK/Ada?

“SPARK is a formally-defined computer programming language based on Ada, intended to secure and support the development of high integrity software used in applications where predictable and highly reliable operation is essential”

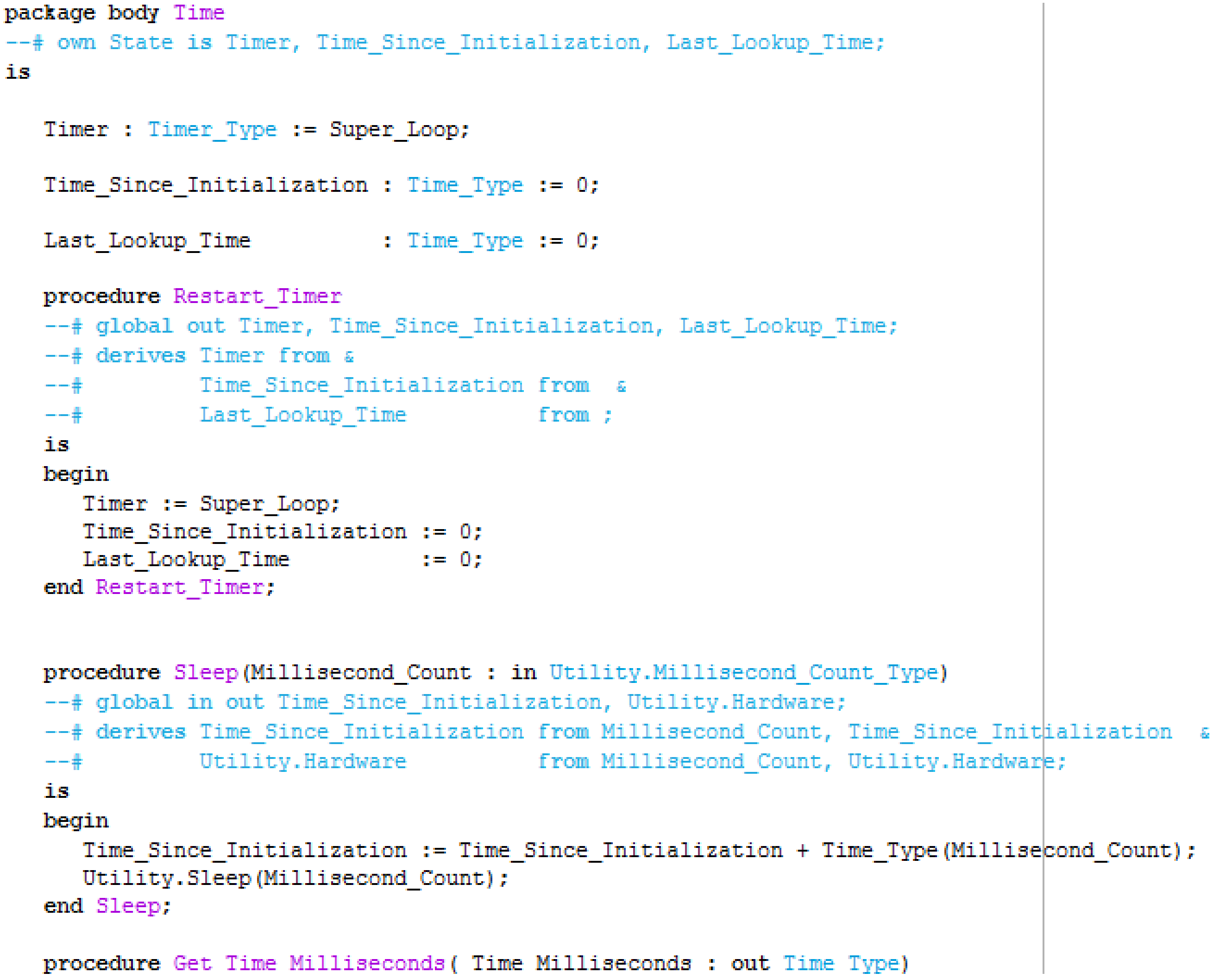
-- Wikipedia (SPARK programming language)

Why Use SPARK?

- If the software fails, we will lose the satellite

- Ada offers a greatly improved probability of error-free software when compared with C. Most other CubeSat projects use the C Programming Language.

- SPARK uses static analysis to prove our code free of run-time errors.



```
package body Time
--# own State is Timer, Time_Since_Initialization, Last_Lookup_Time;
is

   Timer : Timer_Type := Super_Loop;

   Time_Since_Initialization : Time_Type := 0;

   Last_Lookup_Time          : Time_Type := 0;

   procedure Restart_Timer
   --# global out Timer, Time_Since_Initialization, Last_Lookup_Time;
   --# derives Timer from &
   --#         Time_Since_Initialization from  &
   --#         Last_Lookup_Time          from ;
   is
   begin
      Timer := Super_Loop;
      Time_Since_Initialization := 0;
      Last_Lookup_Time          := 0;
   end Restart_Timer;


   procedure Sleep(Millisecond_Count : in Utility.Millisecond_Count_Type)
   --# global in out Time_Since_Initialization, Utility.Hardware;
   --# derives Time_Since_Initialization from Millisecond_Count, Time_Since_Initialization  &
   --#         Utility.Hardware          from Millisecond_Count, Utility.Hardware;
   is
   begin
      Time_Since_Initialization := Time_Since_Initialization + Time_Type(Millisecond_Count);
      Utility.Sleep(Millisecond_Count);
   end Sleep;

   procedure Get Time Milliseconds( Time Milliseconds : out Time Type)
```

Software Development Process

- There is no Ada compiler for our Texas Instruments MSP430 series processor

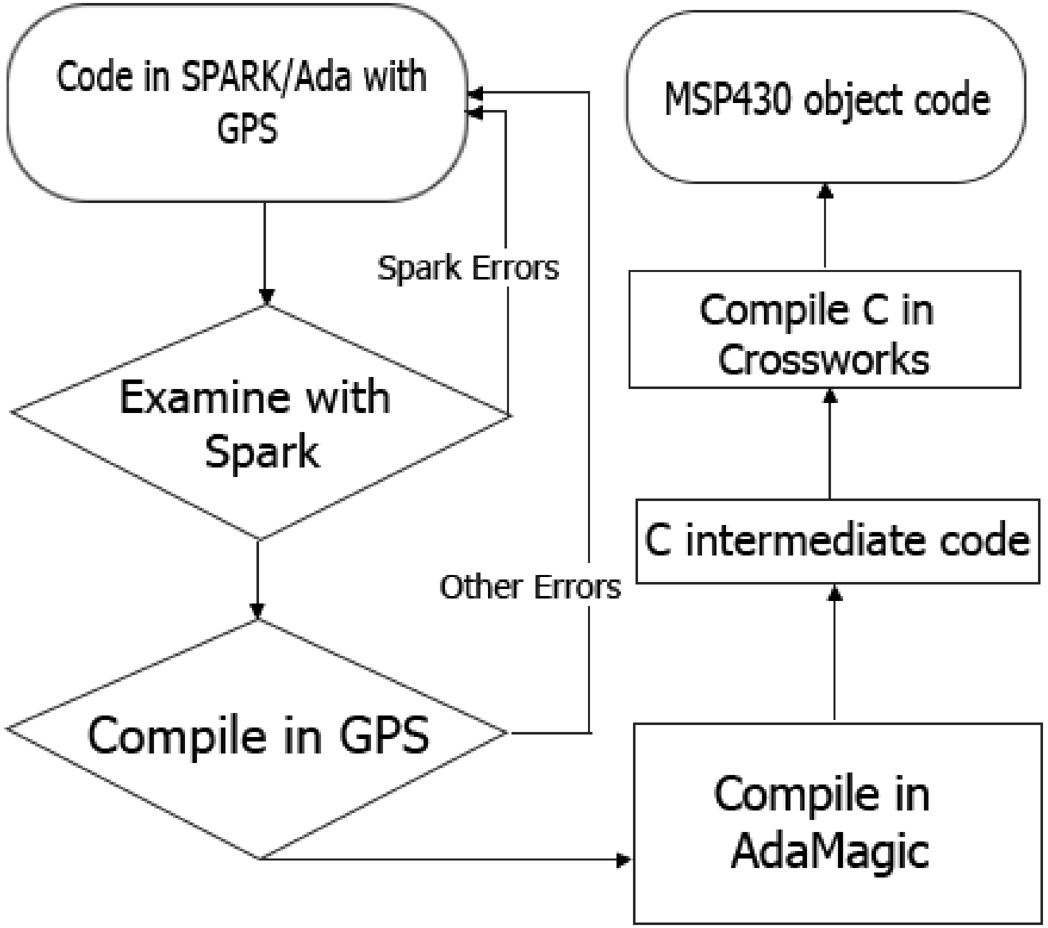
- In order to resolve this dilemma we must convert our Ada code to ANSI C with AdaMagic.

VERMONT TECH

Software Development Process

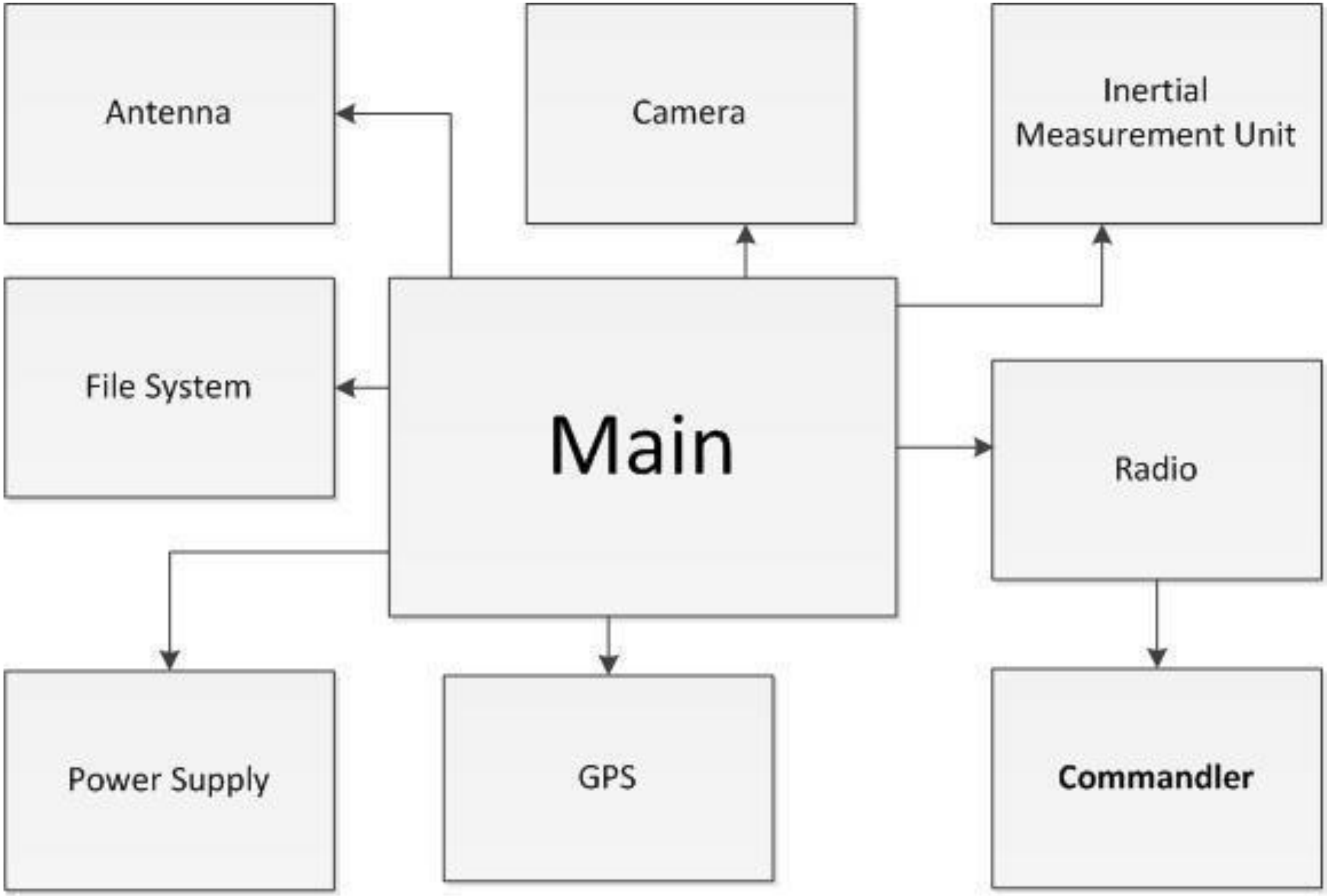
- Software is written in SPARK/Ada using AdaCore's GNAT Programming Studio (GPS)
- Checked with the Praxis High Integrity Systems' SPARK Toolset
- Compiled and checked with AdaCore's GNAT Pro compiler
- Sofcheck's AdaMagic compiler front end is used to produce ANSI C as the intermediate code
- Rowley's Crossworks C cross compiler for Texas Instruments' MSP430 CPU produces the object code

Software Development Process

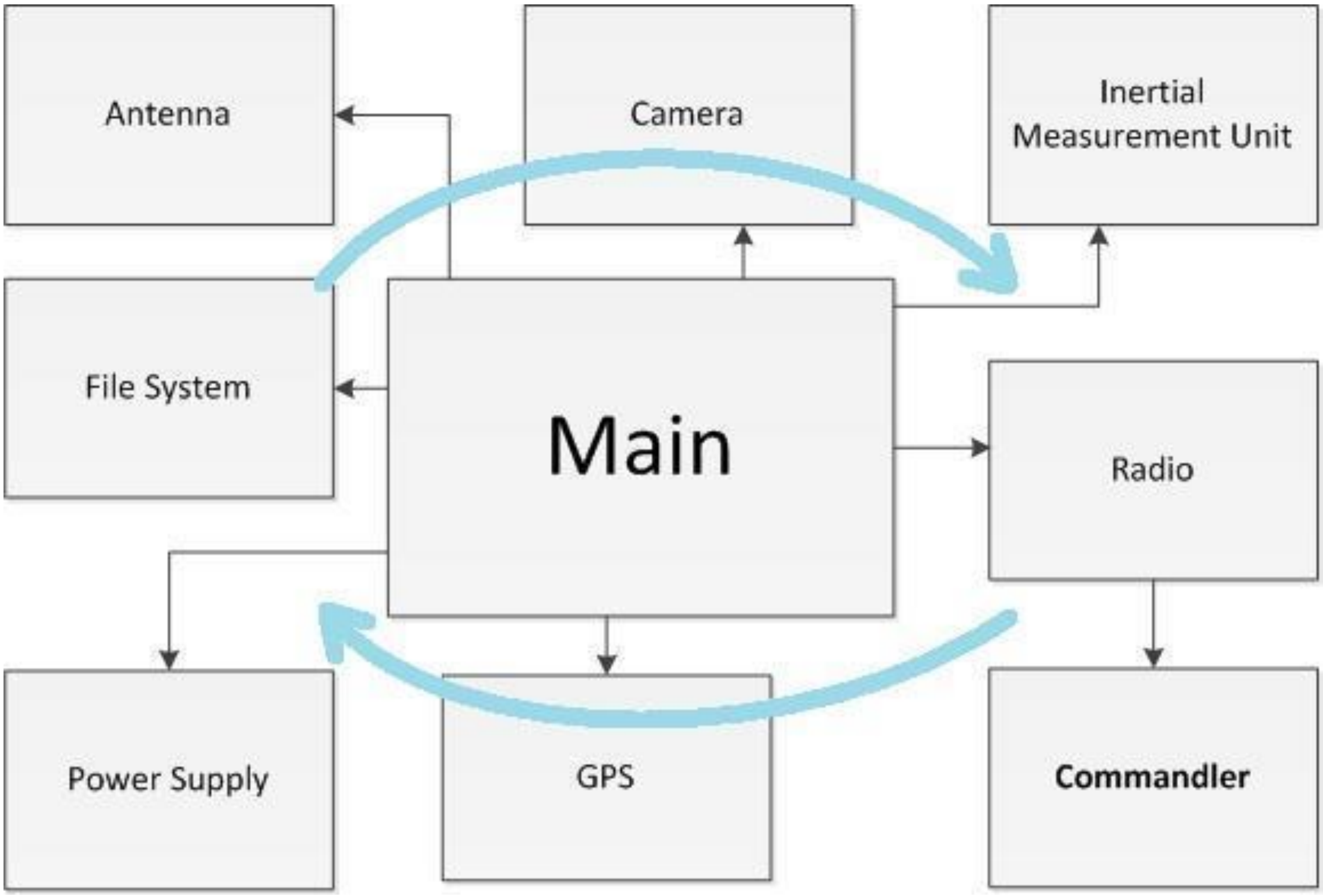


System Design

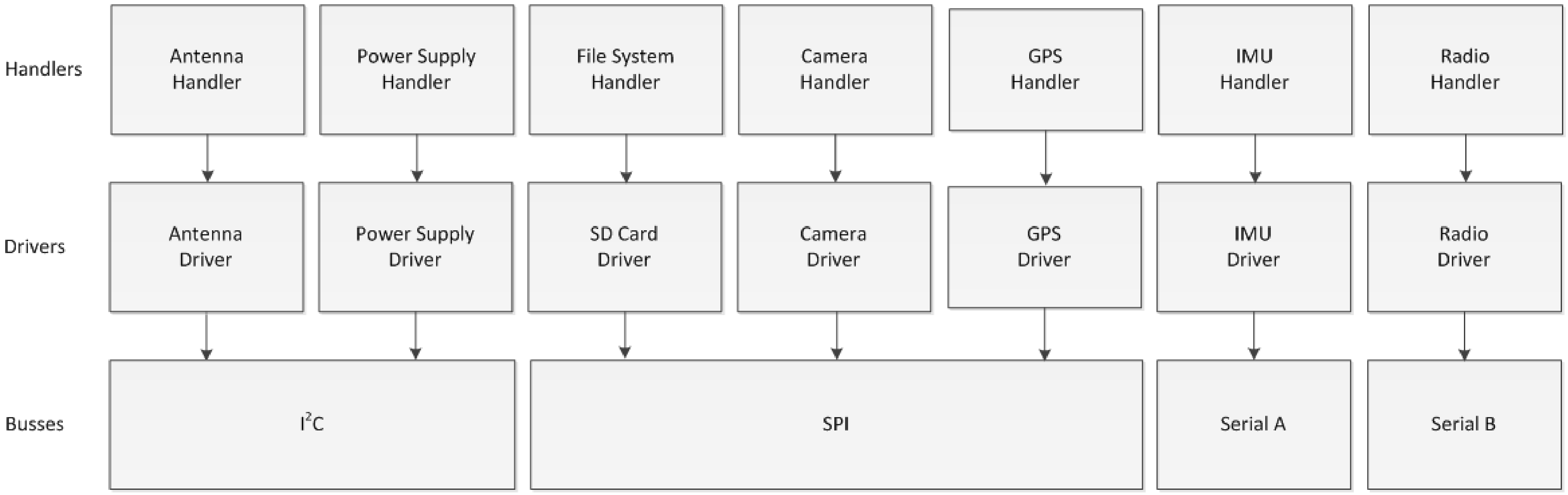
System Design



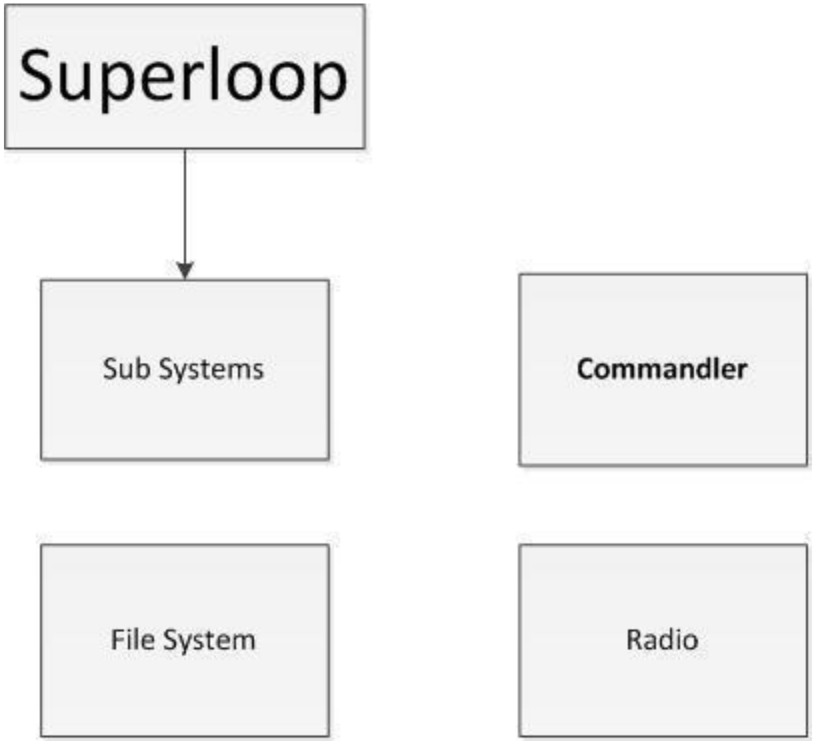
System Design



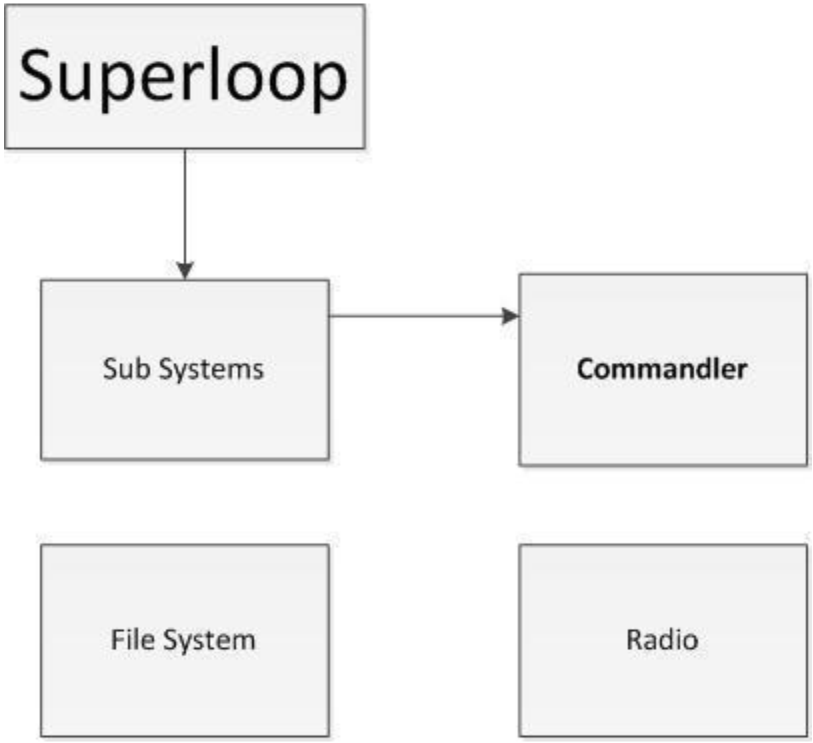
Subsystems


Handlers
Antenna Handler
Power Supply Handler
File System Handler
Camera Handler
GPS Handler
IMU Handler
Radio Handler
Drivers
Antenna Driver
Power Supply Driver
SD Card Driver
Camera Driver
GPS Driver
IMU Driver
Radio Driver
Busses
I^2C
SPI
Serial A
Serial B

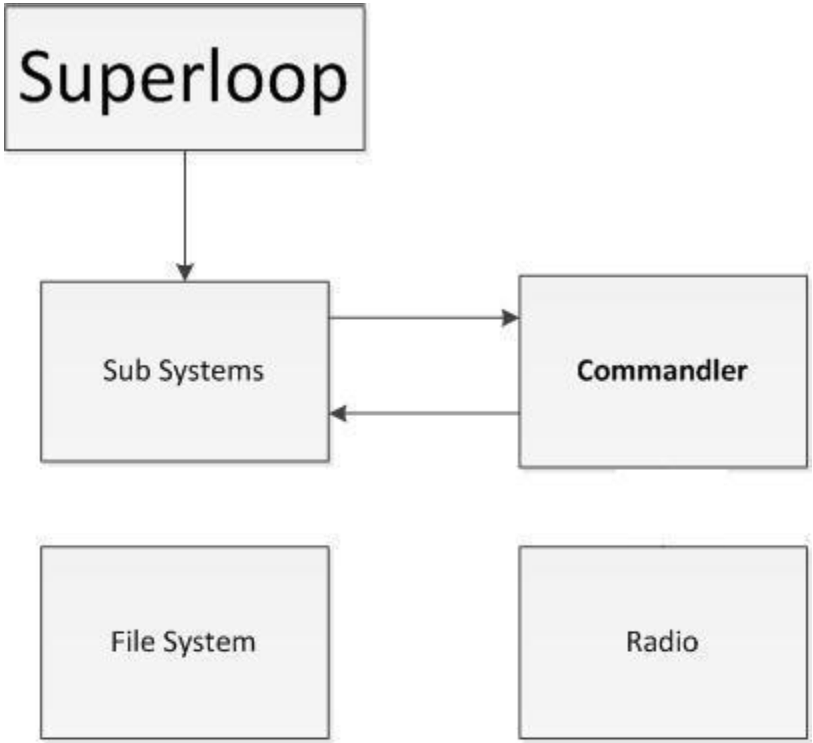
Superloop/Subsystem Interaction



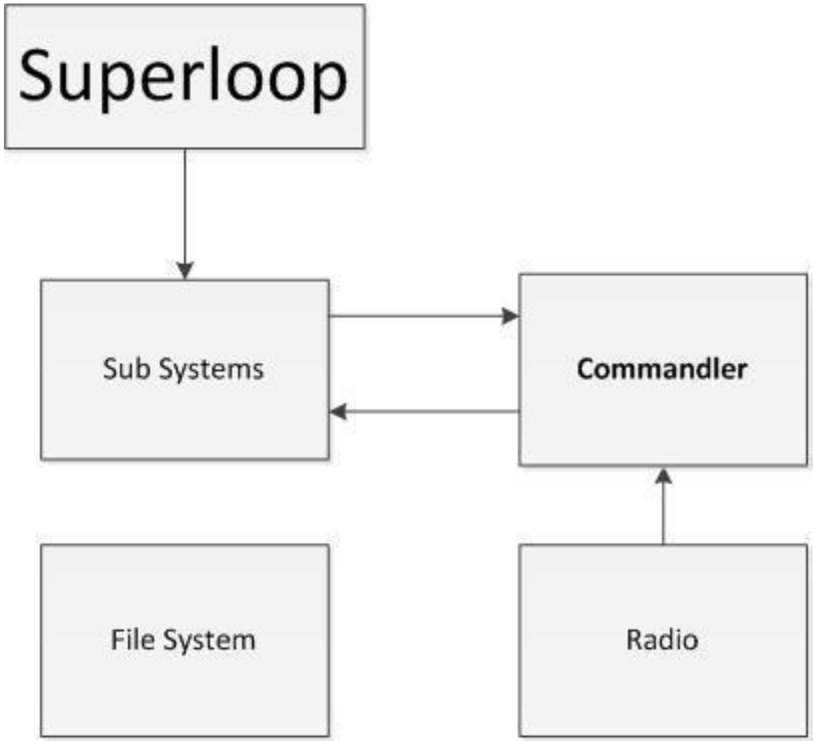
Superloop/Subsystem Interaction



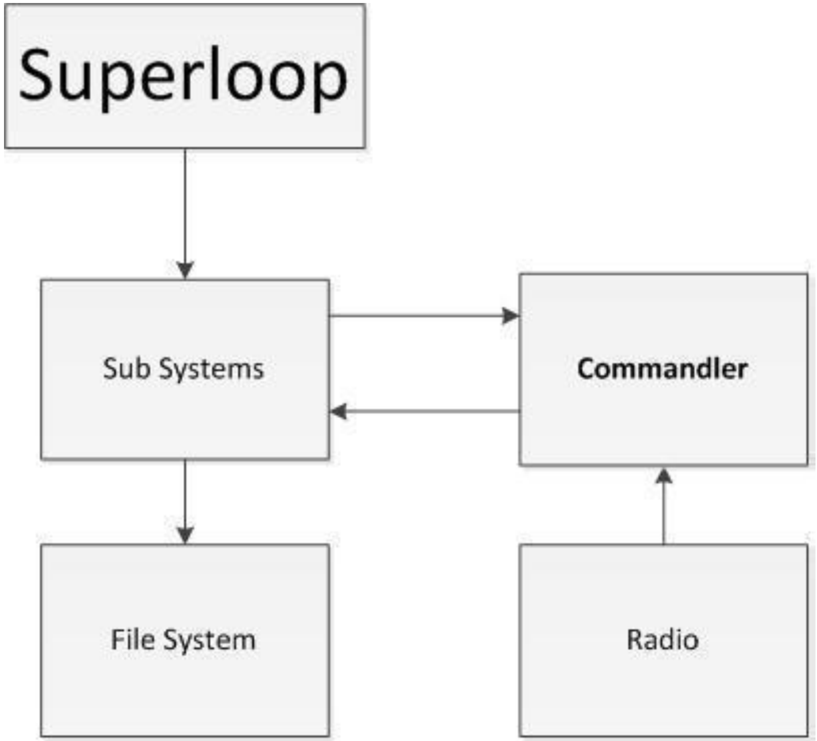
Superloop/Subsystem Interaction



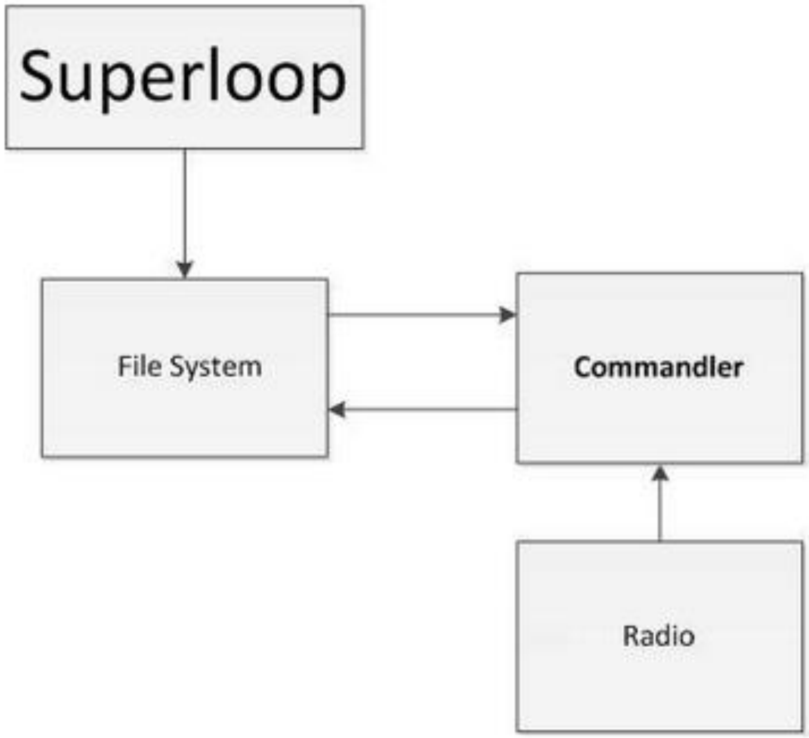
Superloop/Subsystem Interaction



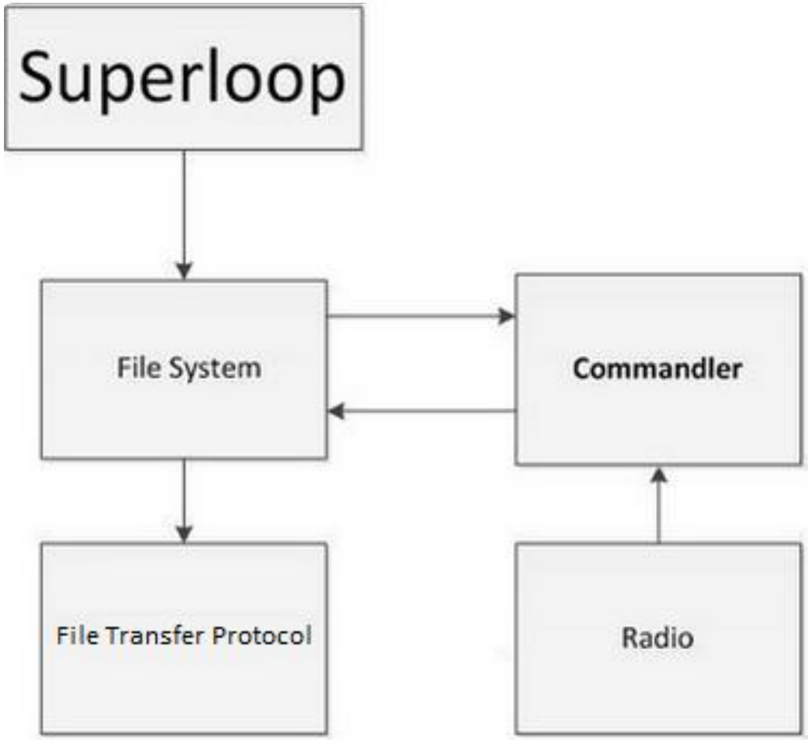
Superloop/Subsystem Interaction



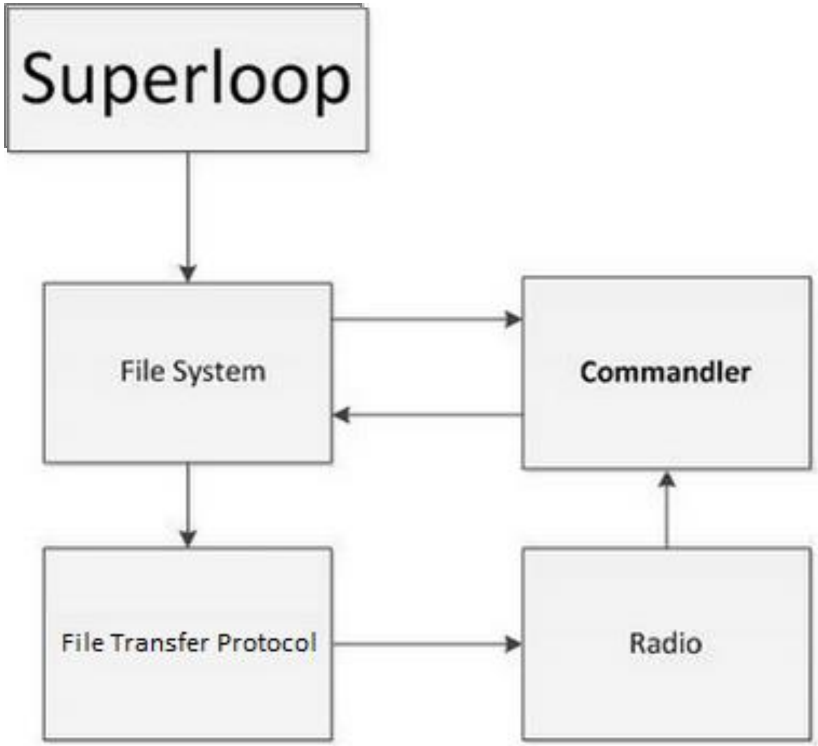
Superloop/Subsystem Interaction



Superloop/Subsystem Interaction



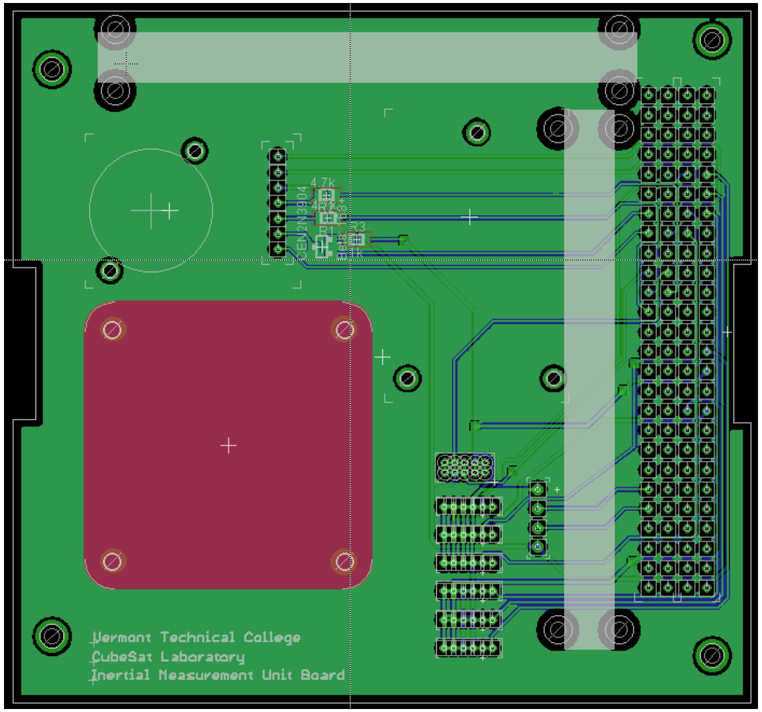
Superloop/Subsystem Interaction

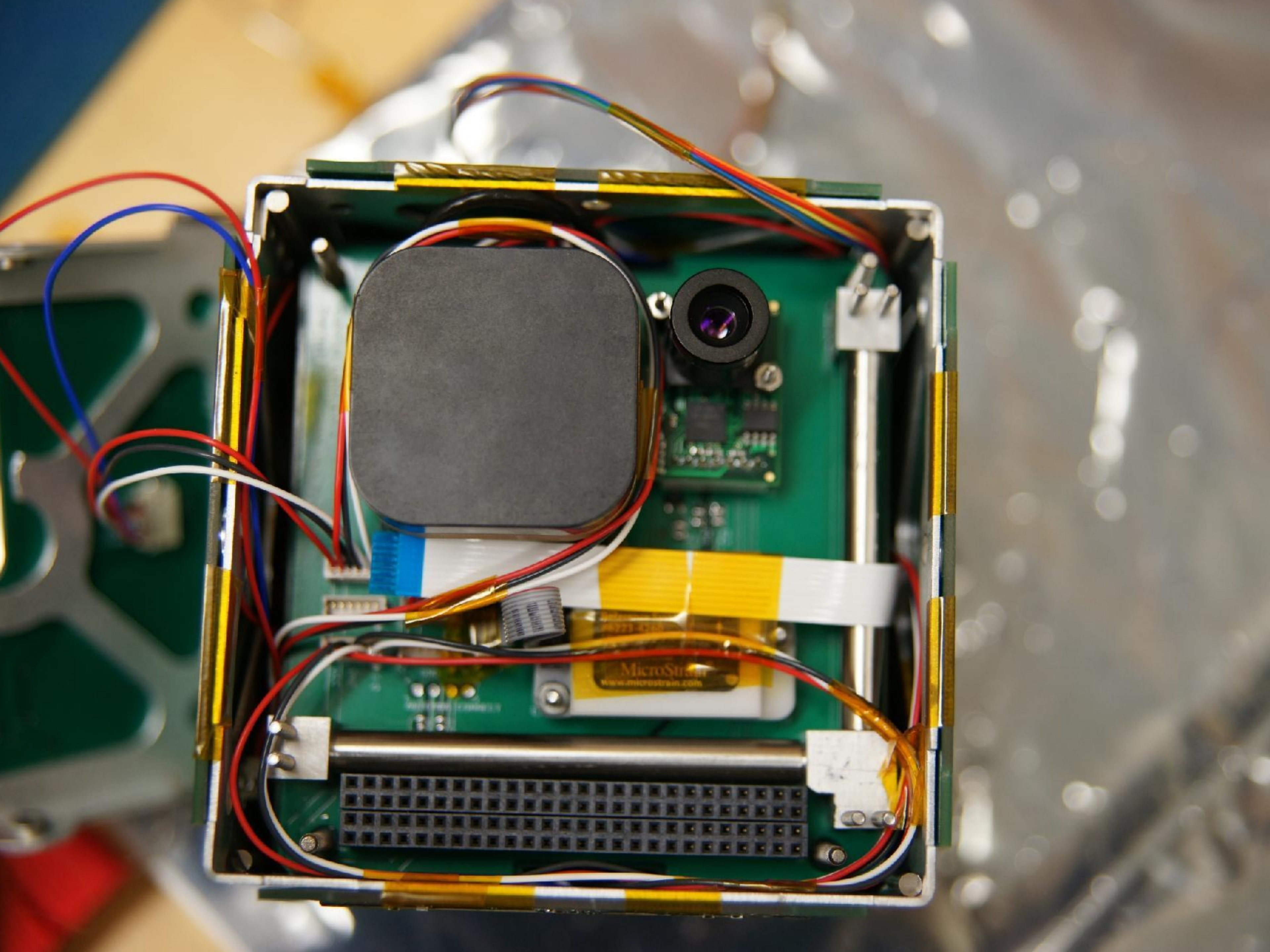


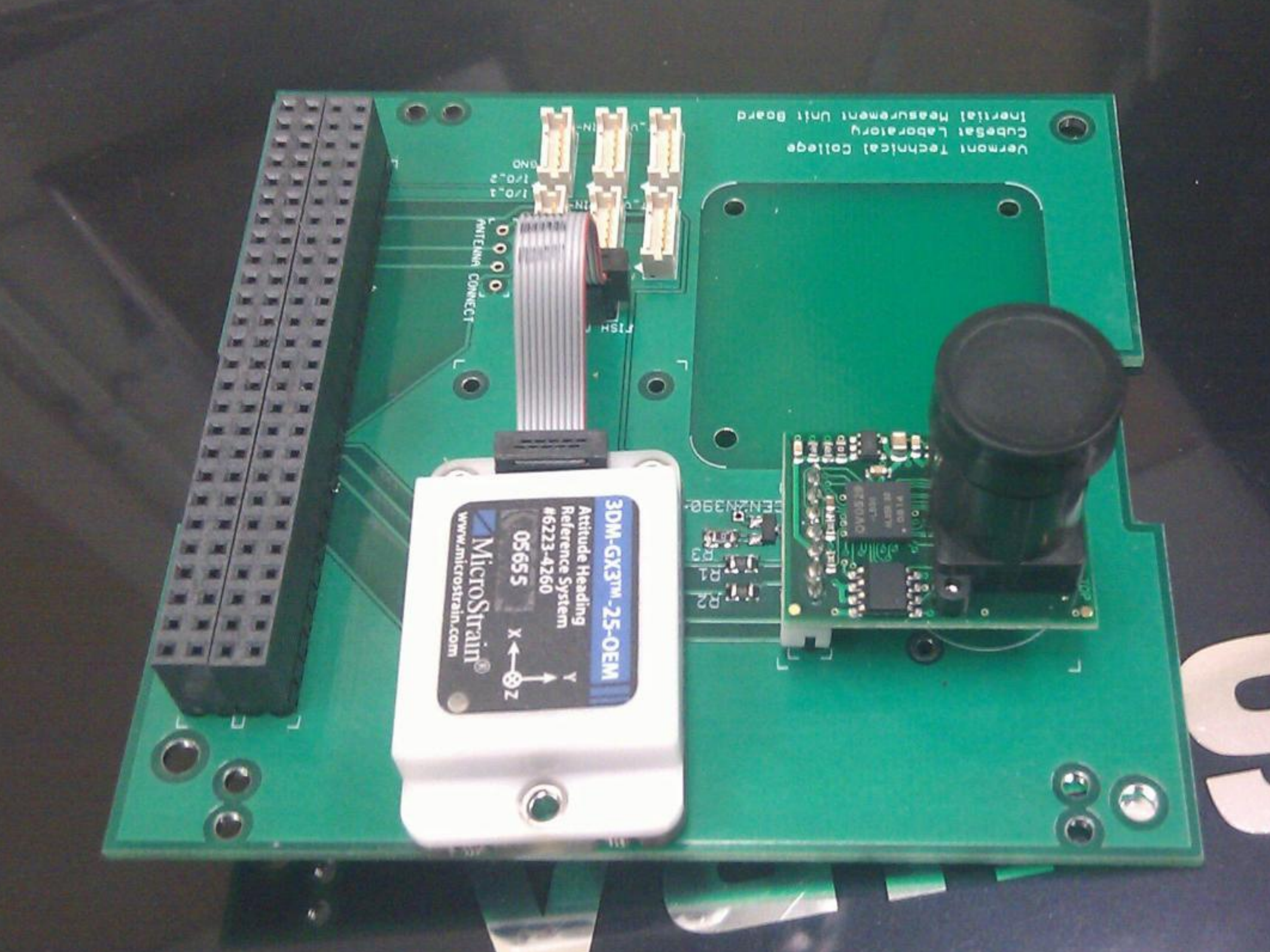
Custom IMU Board

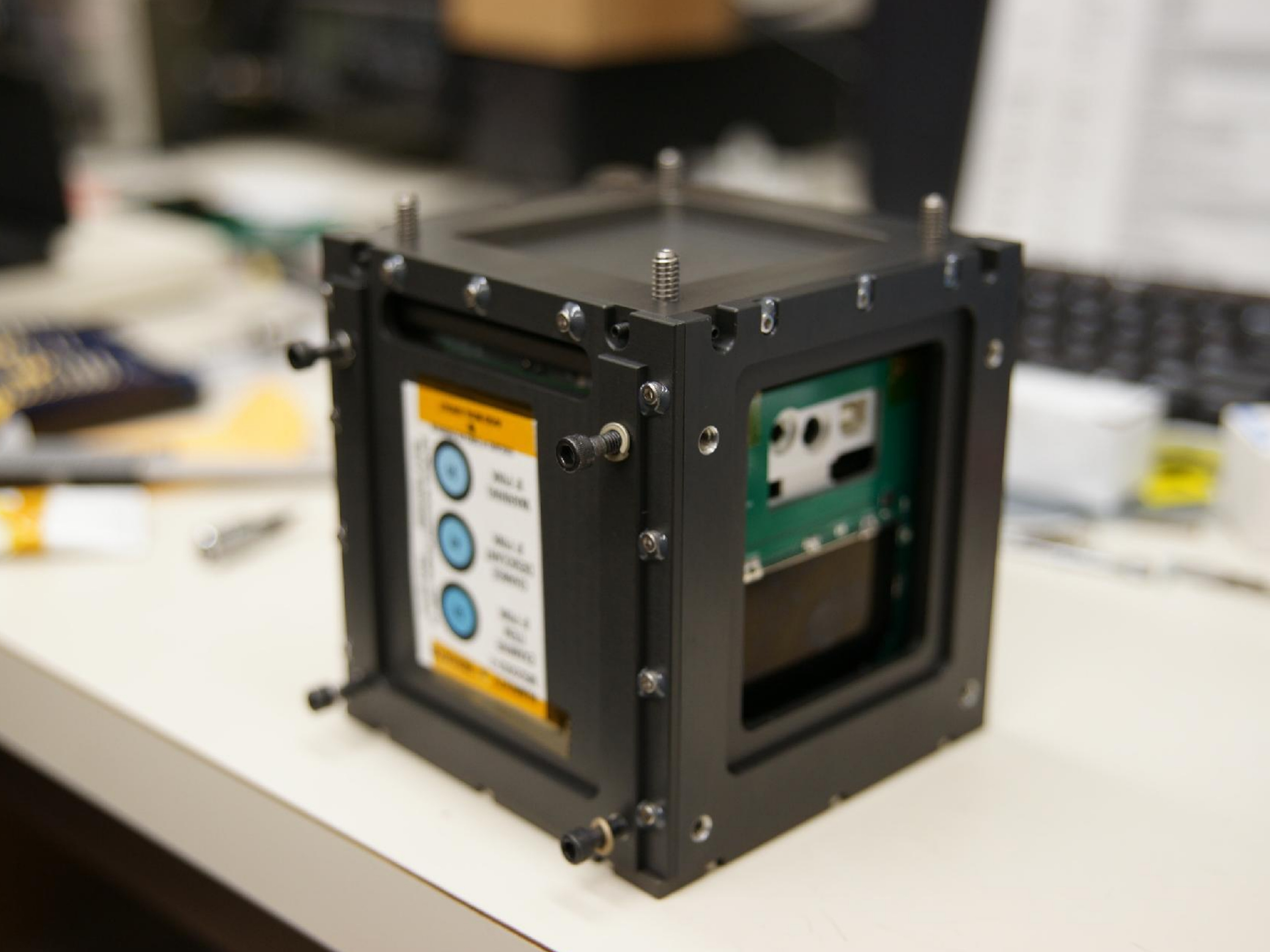
Components:

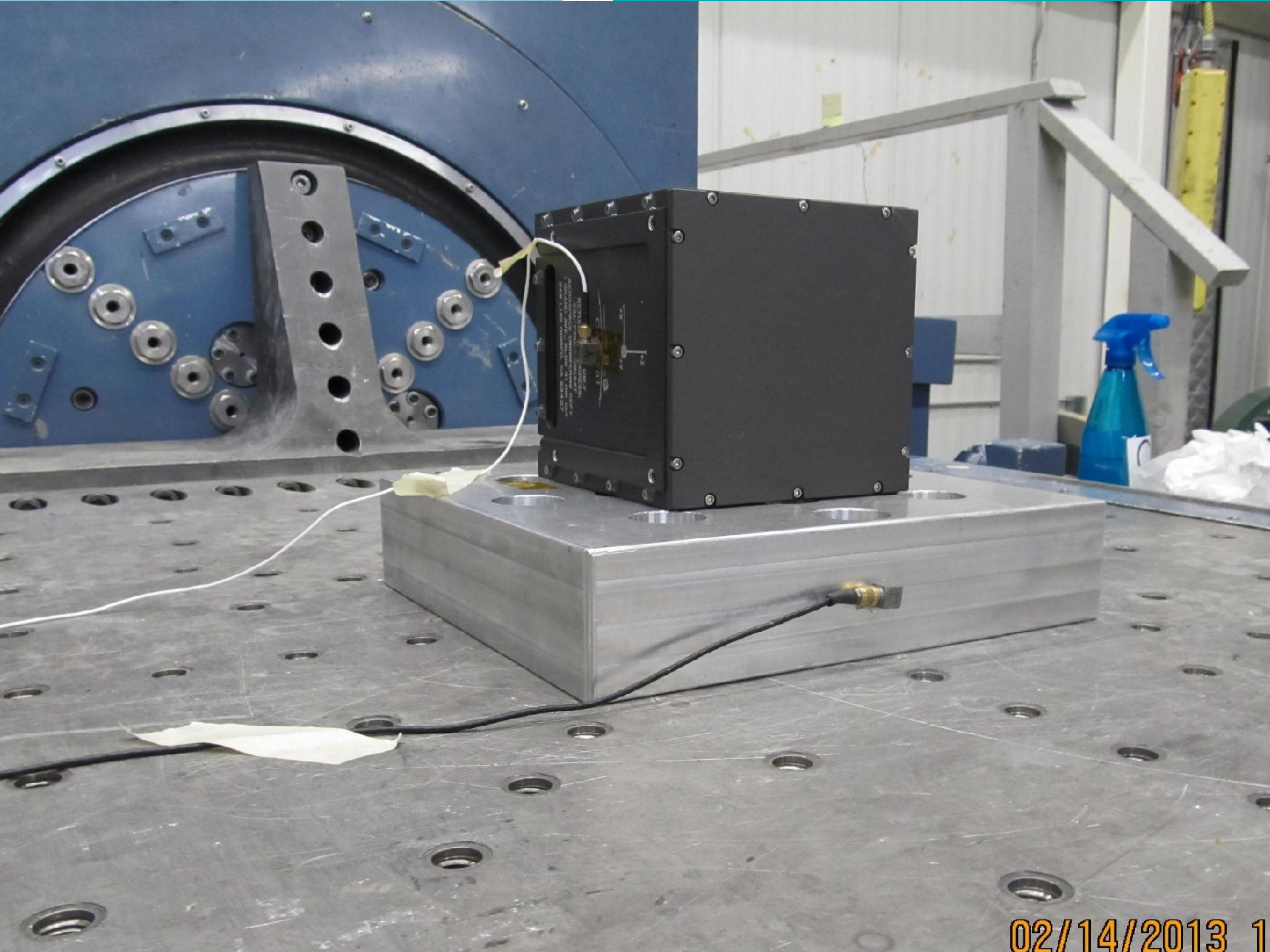
- IMU
- Camera (with camera shutoff circuitry)
- GPS Antenna
- Hysteresis Rods
- Antenna I²C lines
- 6 headers of LEDs

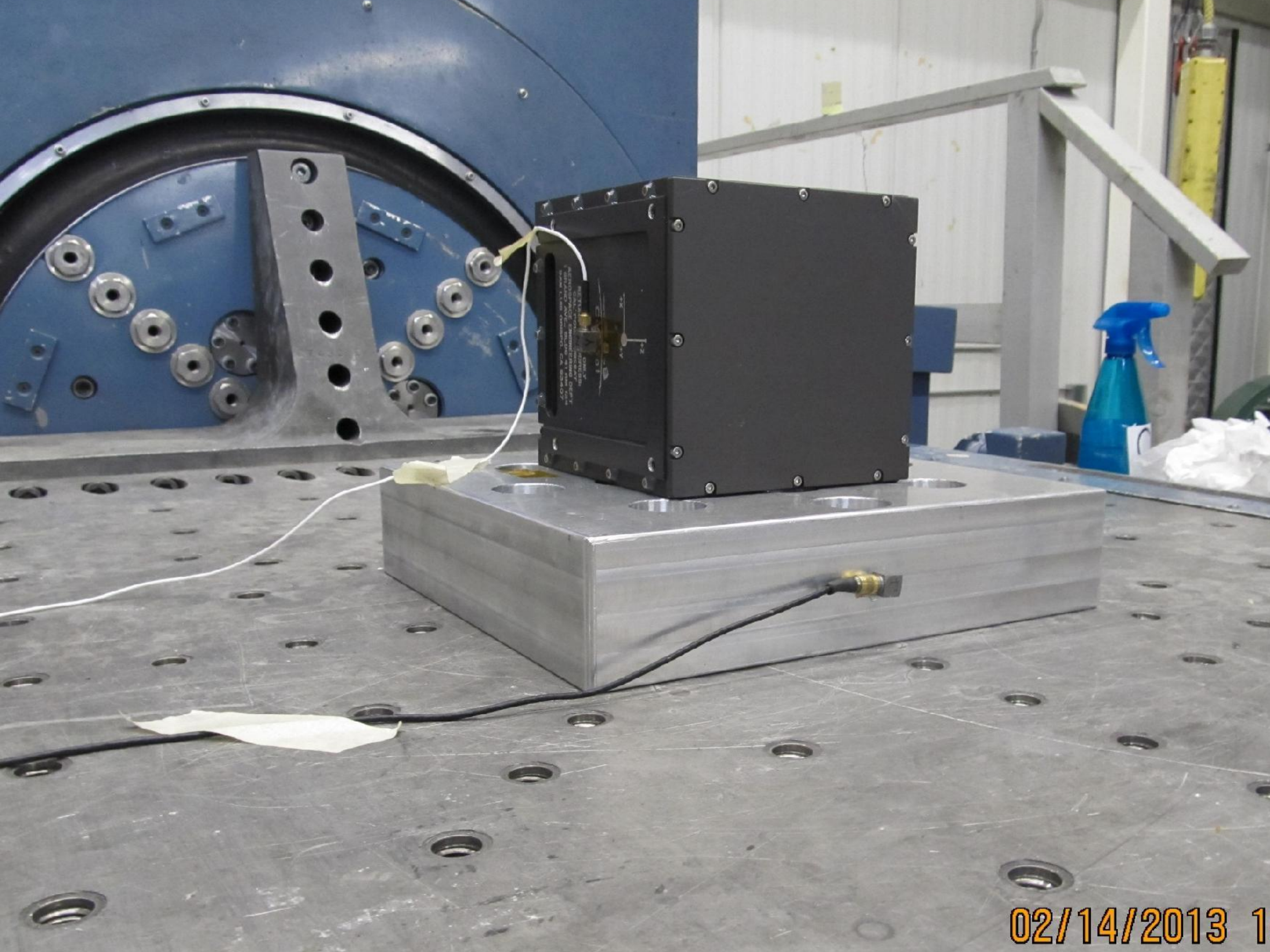



MicroStrain
www.microstrain.com


Vermont Technical College
CubeSat Laboratory
Inertial Measurement Unit Board
ANTENNA CONNECT
3DM-GX3™-25-OEM
Attitude Heading
Reference System
#6223-4260
05655
MicroStrain
www.microstrain.com
X
Y
Z
R1
R2
R3

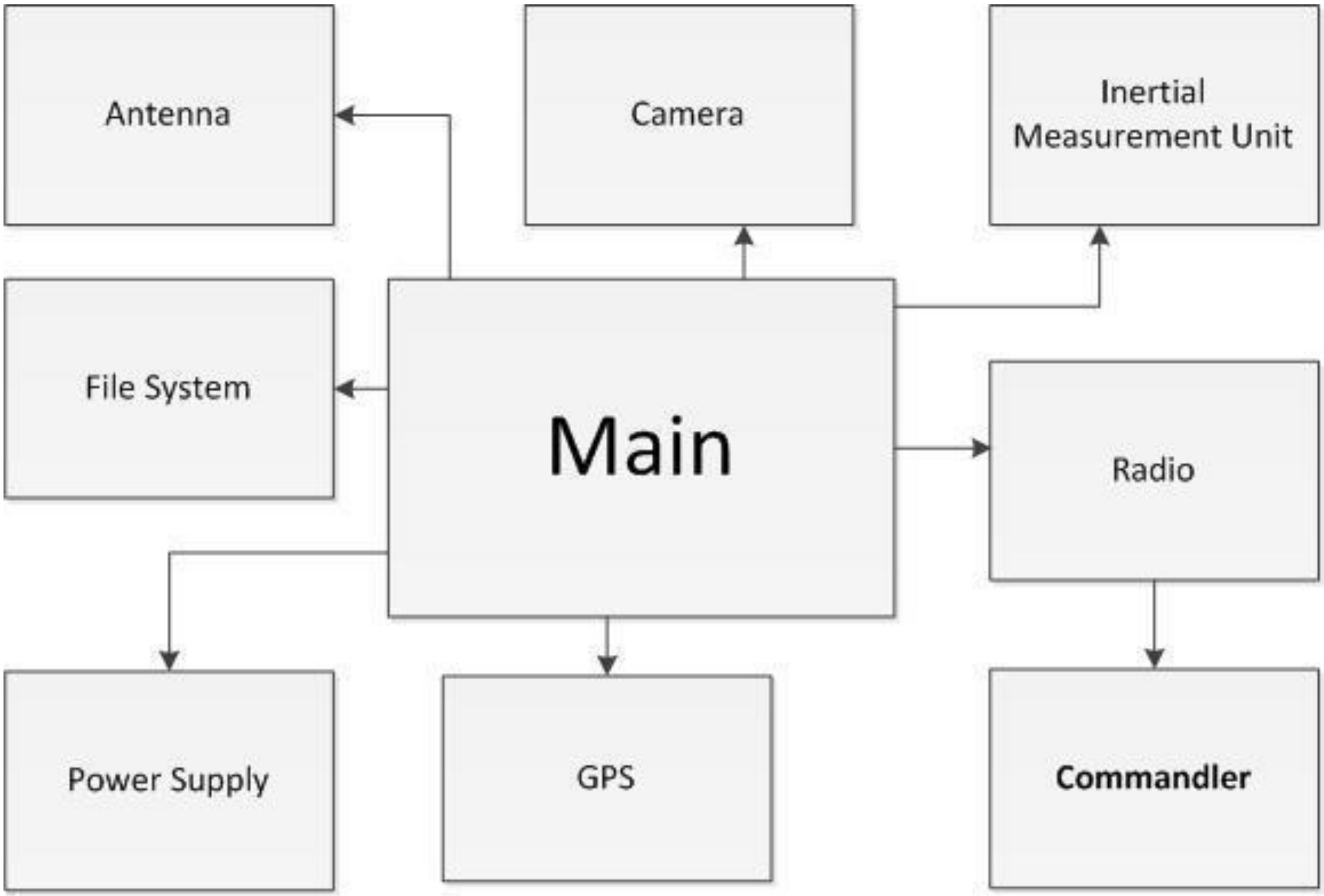



+X
+Y
+Z
02/14/2013 1

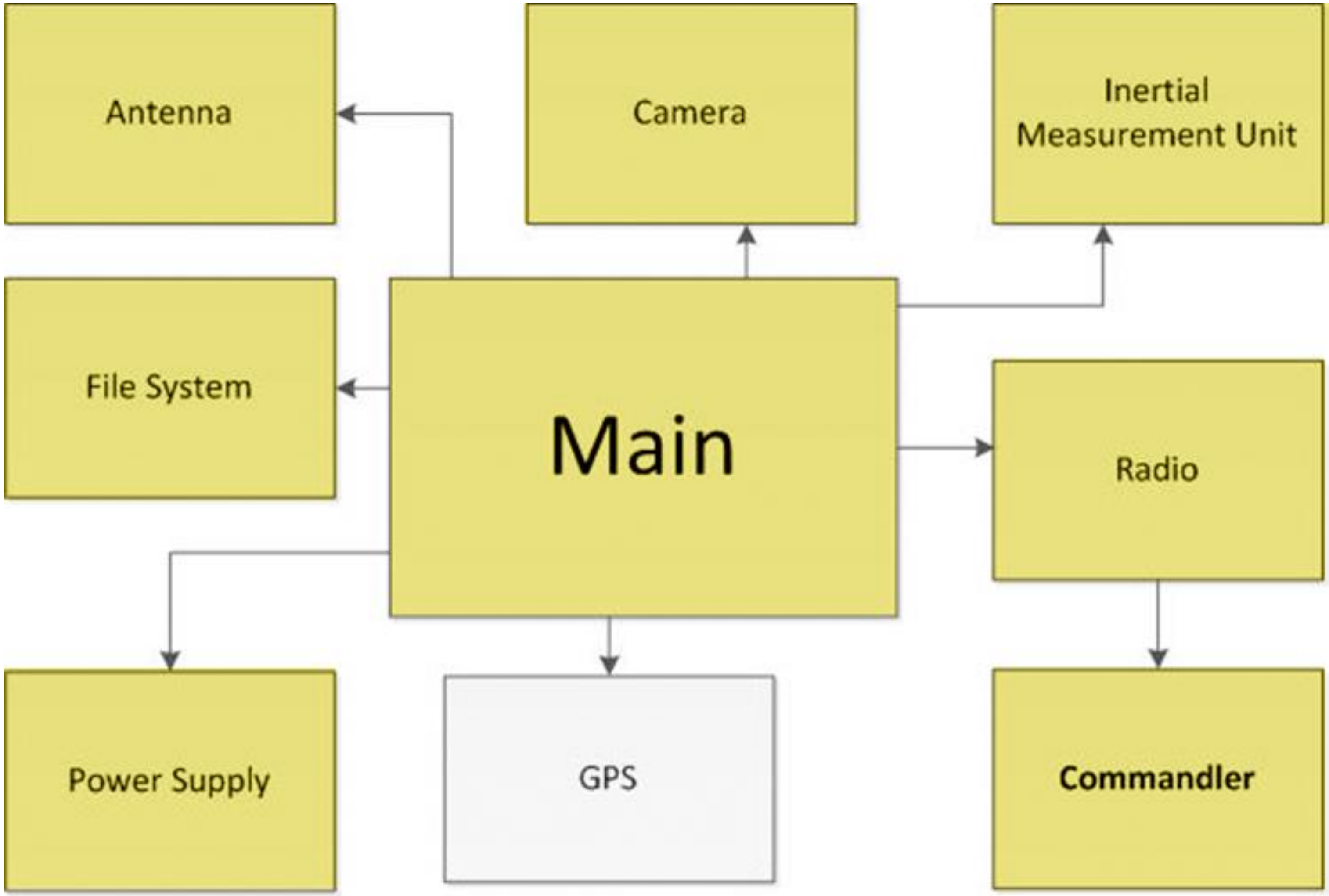


02/14/2013 1

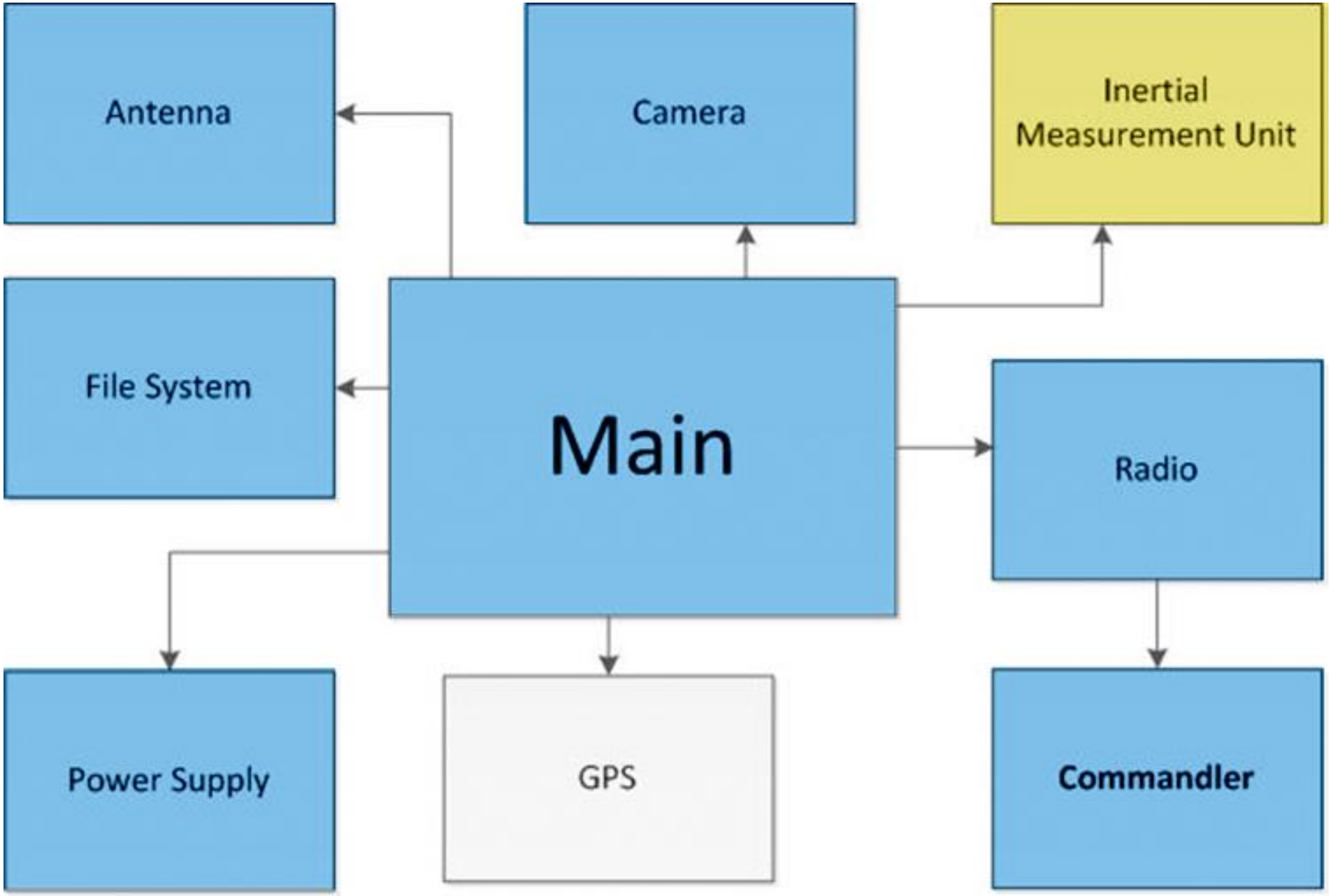
Software Completion



Software Completion



Spark Examinable Software

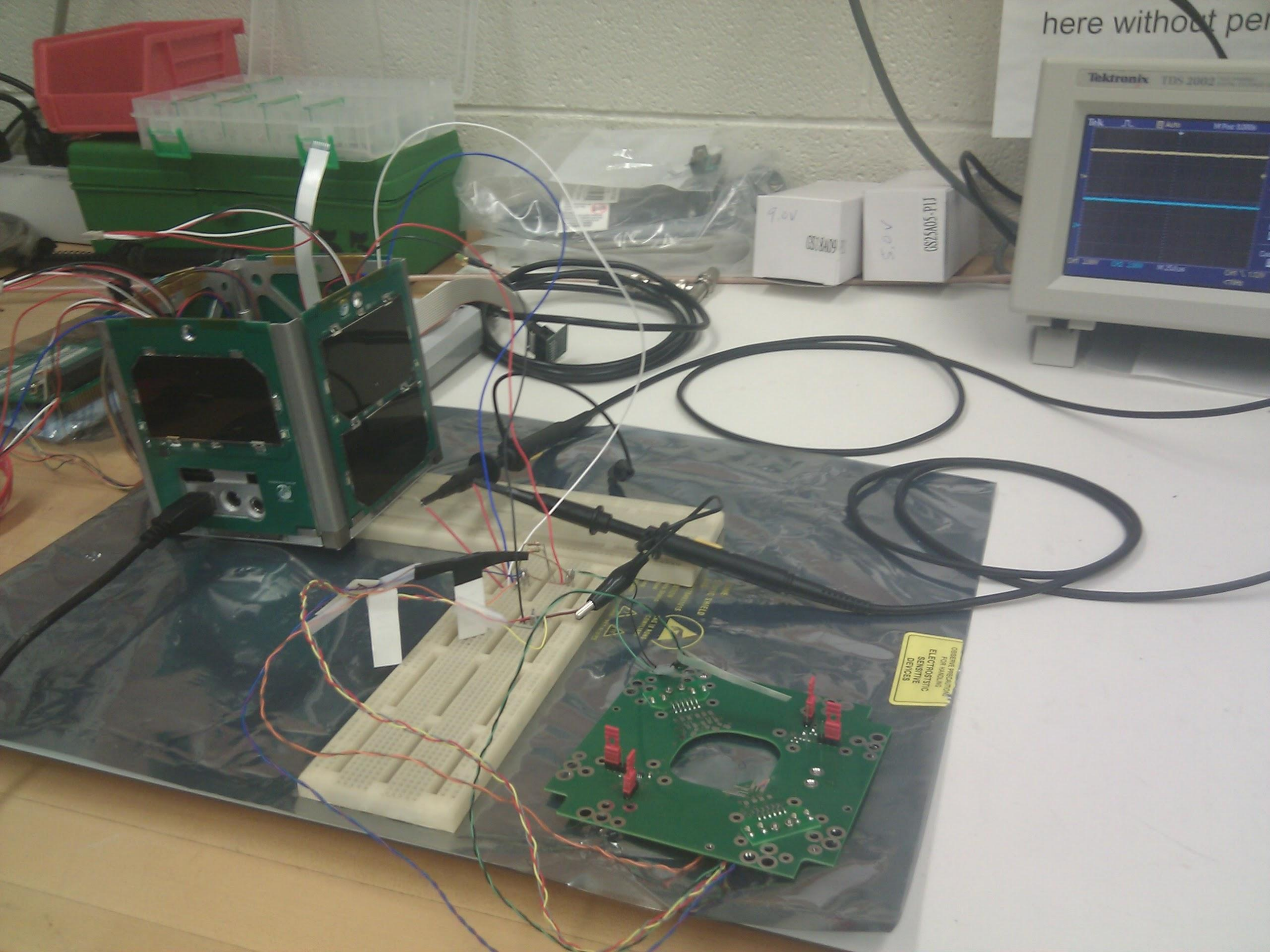


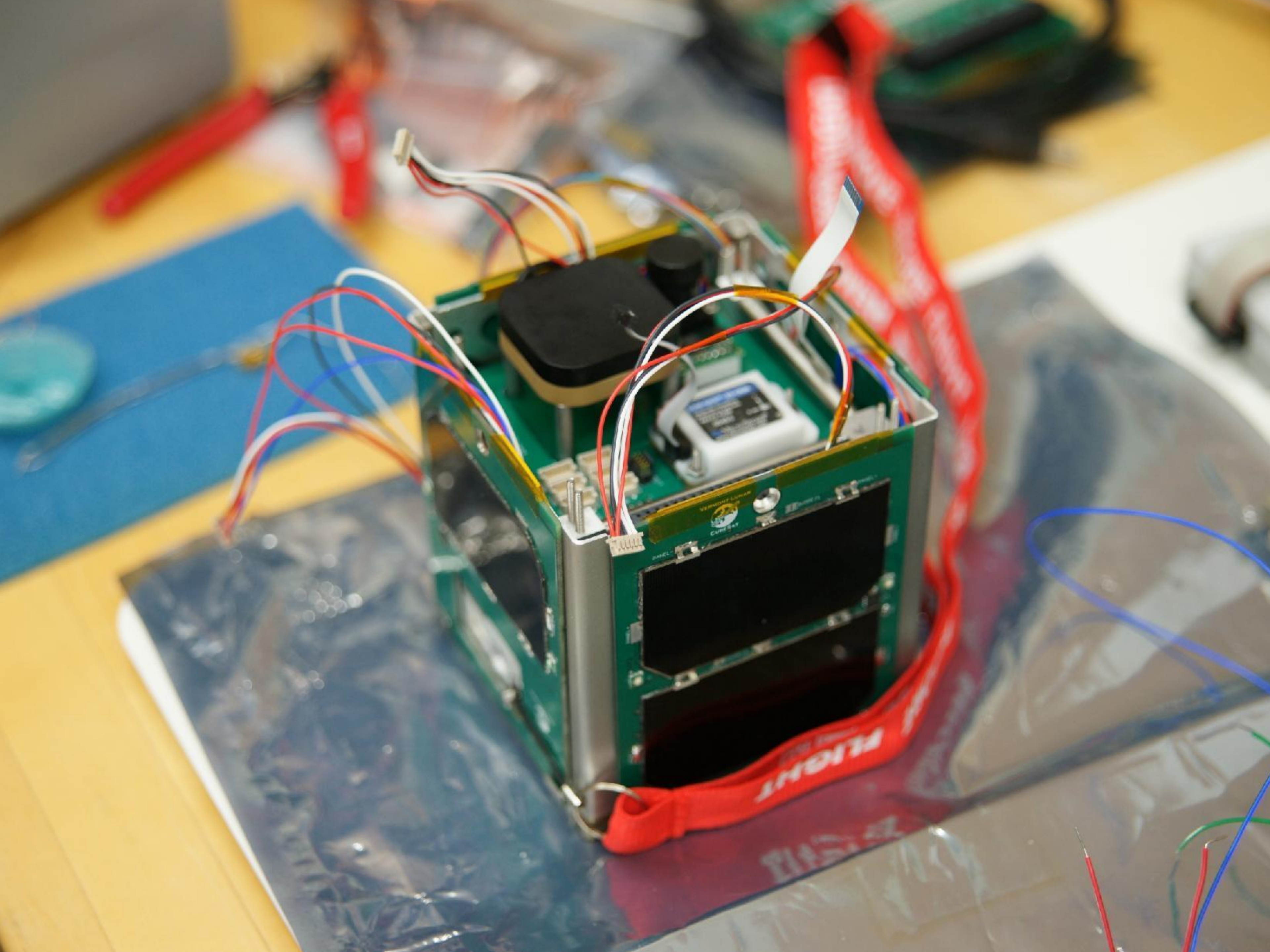
Current Status

- The CubeSat hardware is complete and has passed the ShakeN Bake

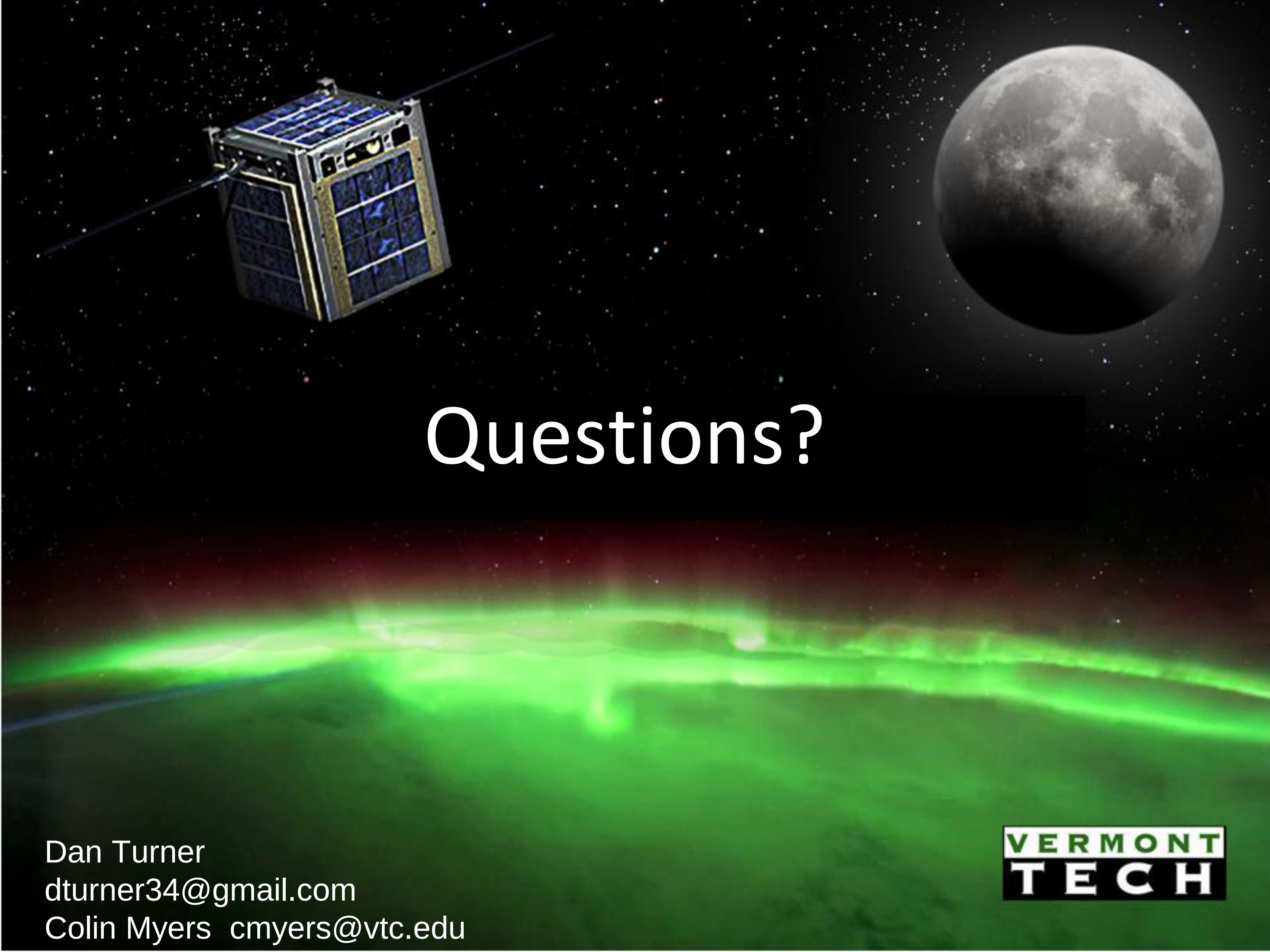
- Other than the GPS and some miscellaneous protocol procedures, the flight control system is done, although it could use more Spark testing.

- We're currently working on setting up a ground control station for our launch at the end of September.


here without per
Tektronix TDS 2002
9.0V
5.0V
OBSERVE PRECAUTIONS FOR HANDLING ELECTROSTATIC SENSITIVE DEVICES


VERMONT LUNAR
CUBESAT
FLIGHT

PUMPKIN
PUMPKIN
SC1
SC2
UHF T'S
UHF PANEL
UHF PANEL
RF ELBOW
RF CONN
PANEL JACK
JACK
RF BARREL CONN.
RT STRAP
N PANEL
PANEL RECP
BNC STRAIGHT
TEK
ADAP
H.P.
ADAPTERS
100 g
500 g
TRIPLE BEAM
700/800 SERIES



Questions?

Dan Turner
dturner34@gmail.com
Colin Myers cmyers@vtc.edu

VERMONT TECH