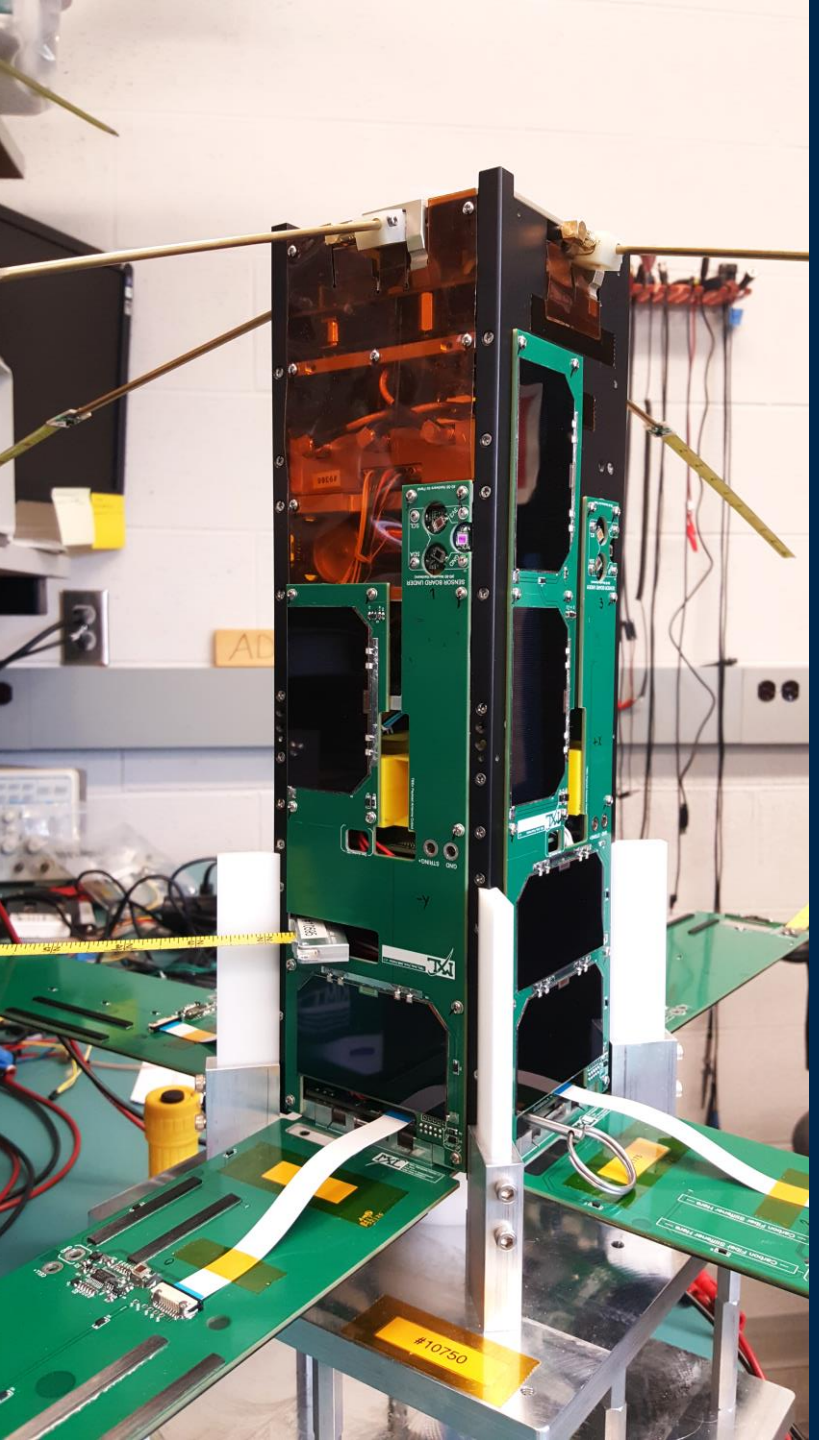


AEROSPACE ENGINEERING
UNIVERSITY of MICHIGAN ■ COLLEGE of ENGINEERING

SRI International

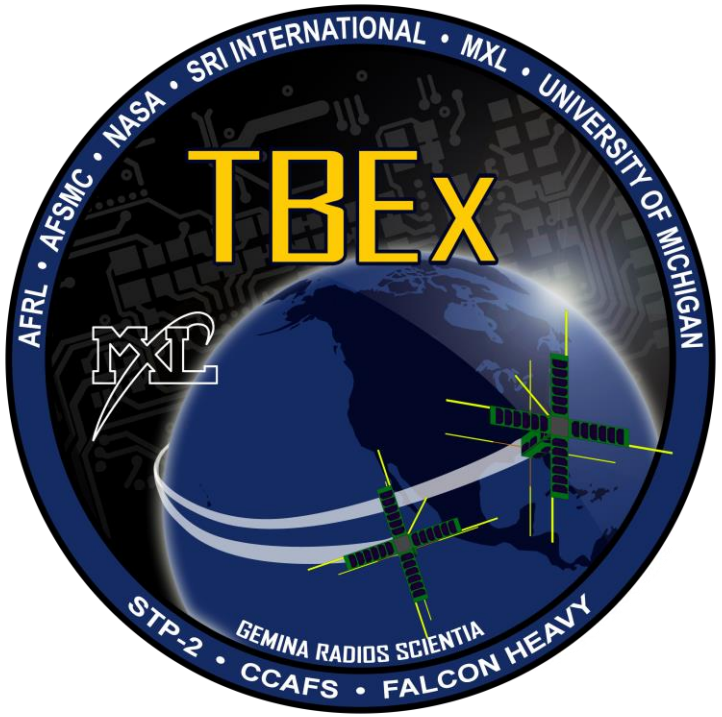
MXL

Tandem Beacon Experiment - TBEx
Design Overview and Lessons Learned

CubeSat Workshop

Nathanael England
James Cutler
Srinagesh Sharma

04/30/2018



Mission Overview and Organization

Project Organization

Black - Student
Blue - Faculty / Staff / Gov

NASA SMD – National Aeronautics and Space Administration Space Science Mission Directorate
AFRL – Air Force Research Laboratory
AF SMC – Air Force Space and Missile Systems Center
SRI – SRI International
UofM – University of Michigan

NASA SMD
Dr. Dan Moses
Dr. David Pierce

AFRL
Dr. David Cooke

AF SMC
Capt. Alan Kotomori

SRI

Principal Investigator / Science Management
Dr. Roland Tsunoda

Co-Investigator: Payload / Project Management
Dr. Rick Doe

Payload / GRBR Station Developer
Mr. John Buoncore

Payload Antenna Developer
Dr. Mike Cousins

Payload Software Designer
Mr. Roman Novoselov

UofM

Co-Investigator: Spacecraft
Dr. Jamie Cutler

Project Manager for Bus Development
Nathanael England

ADCS
Prince Kuevor
Alex Walsh

C&DH
Rohan Punnoose
Justin Shetty
Michael Wilson

COMM
Srinagesh Sharma

EPS
Daniel Gu

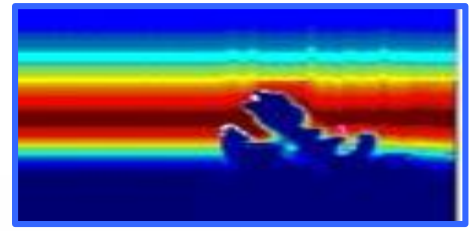
OPS
Valerie Chen
Adrian Gamboa

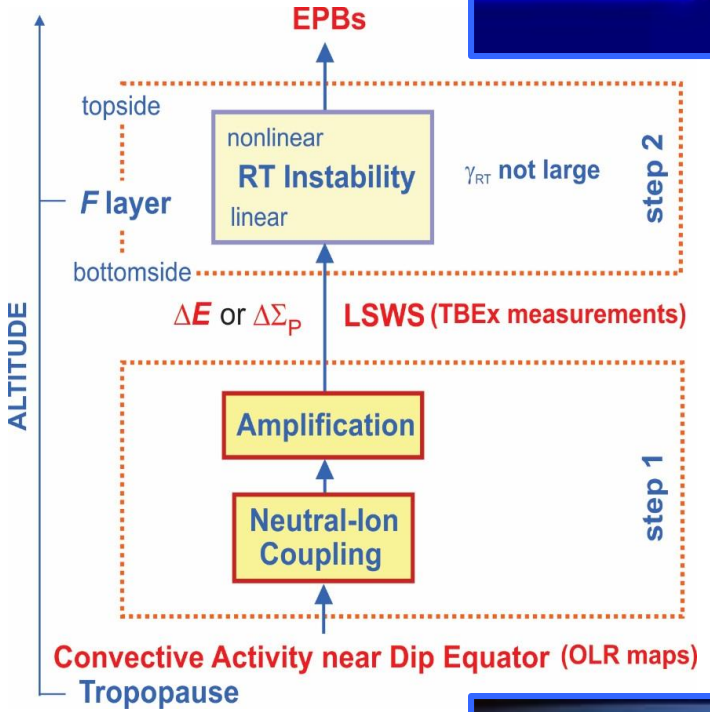
STR
Jeffrey Poon

Science Questions and Motivation

- How does forcing from the lower atmosphere via tidal, planetary, and gravity waves, influence the ionosphere and thermosphere
  NASA 2009 Heliophysics Roadmap Research Focus F3

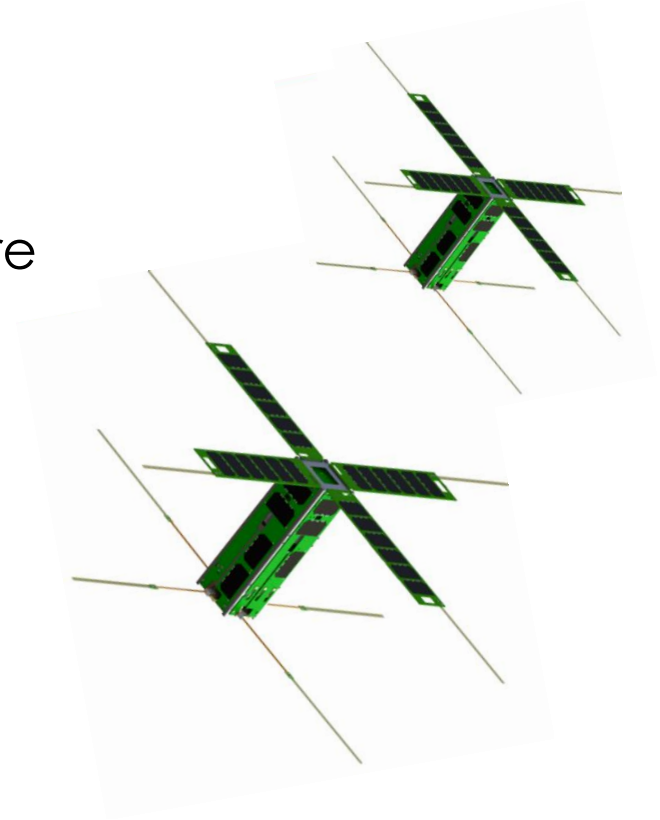
- Insight into large scale weather structure generation of EPBs will greatly improves
  - Ionosphere Forecasts
  - GPS robustness
  - Storm time transmission capacity





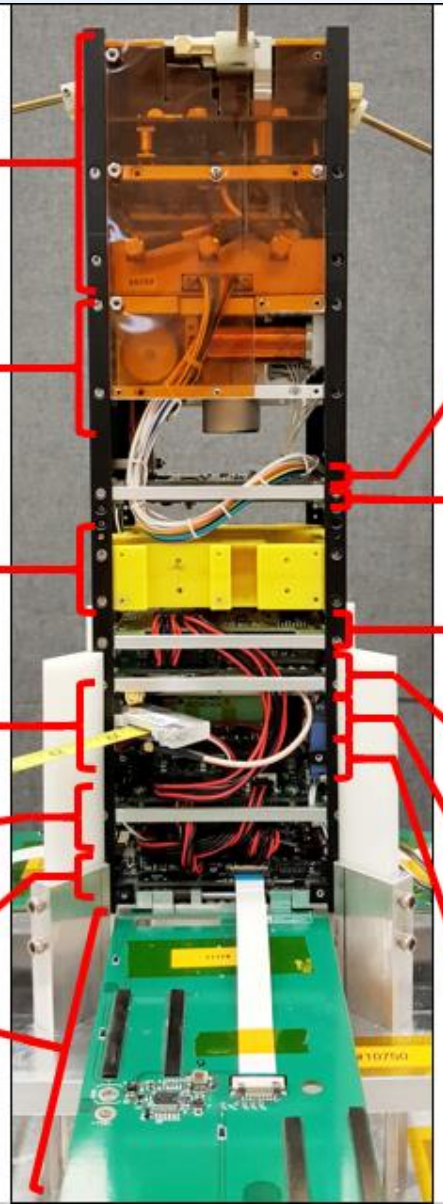
CubeSat Project Overview
Mission Concept

- Fly two identical CubeSats with triple band transmitter in low inclination, nadir-pointing orbit
  - 1 GHz band blocked by FAA. Still flying 100 and 400 MHz capabilities
- Use drag profiles to gain ~15 to 45 minute separation
- Measure phase delays from payload transmissions to measure ionosphere properties with ground stations in Central Pacific
- Back out EPB formation and evolution by comparing CubeSat transmissions



Satellite Design

The CubeSat



TBEx Acronyms

TCB: Torquer Controller Board

MCB: Motor Controller Board

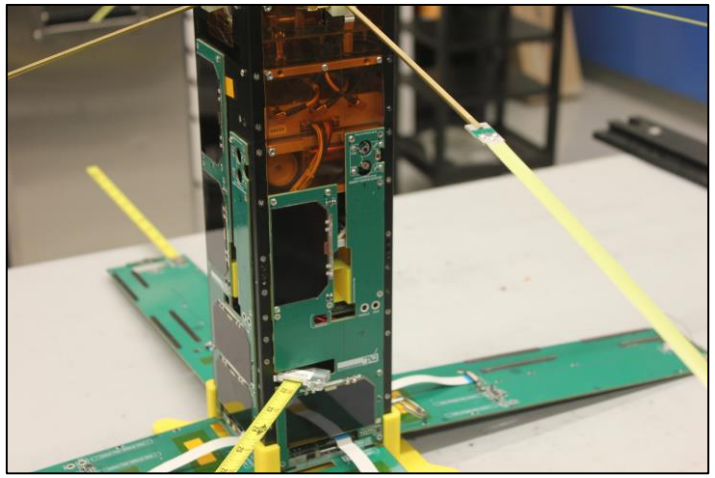
ACPU: ADCS Central Processing Unit

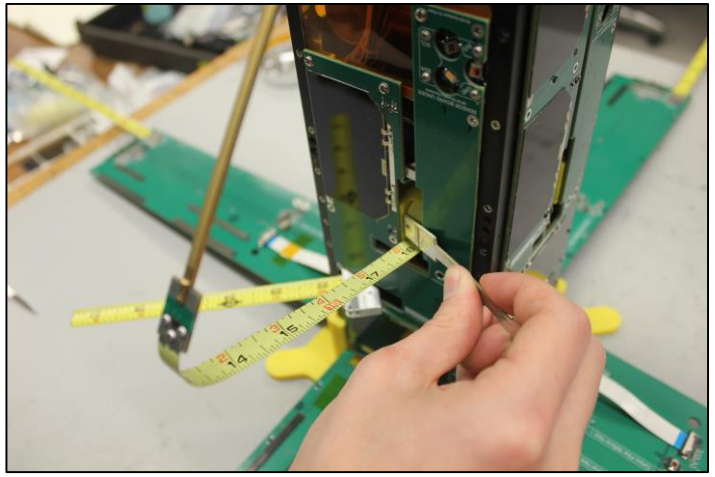
FCPU: Flight Central Processing Unit

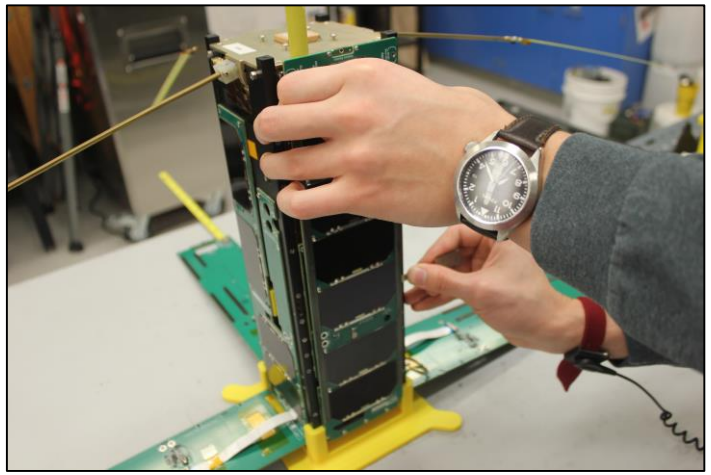
EPS: Electrical Protection System

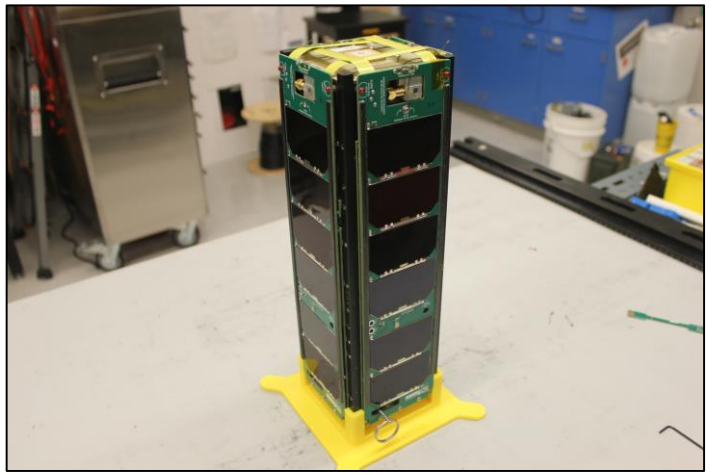
MZINT: -Z Integration Board

Stowing Scheme and Burn Circuit

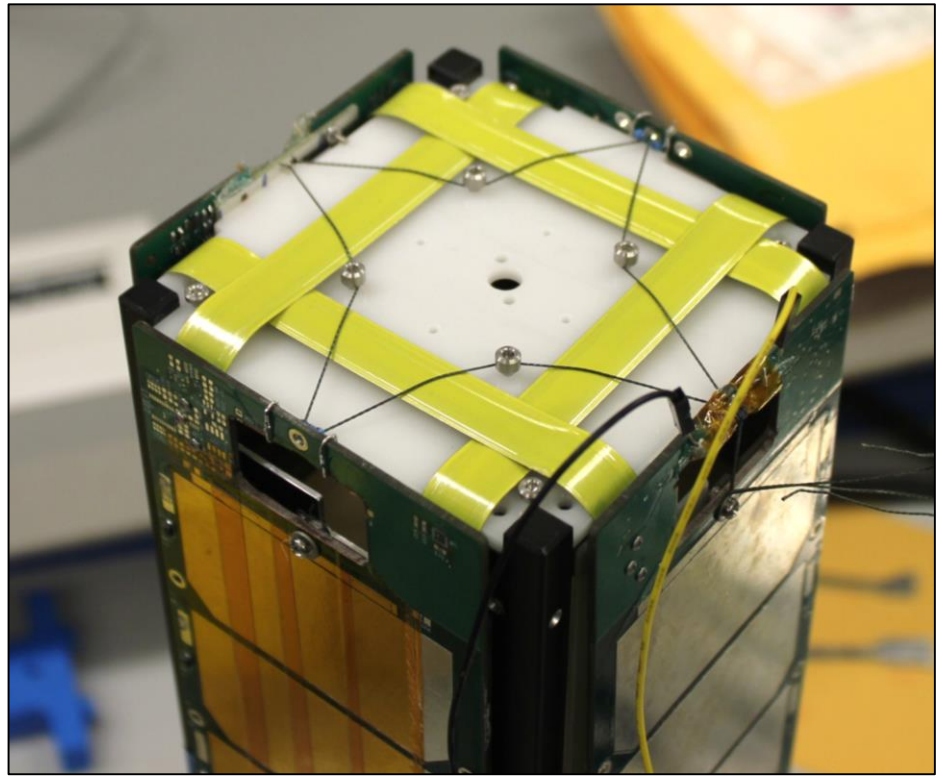






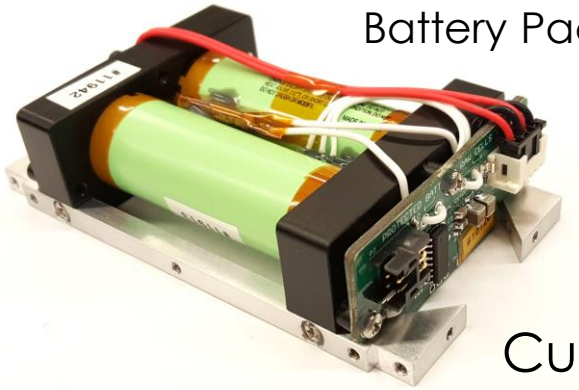


Payload UHF/VHF antennas coil up into pocket block through body panel cutouts

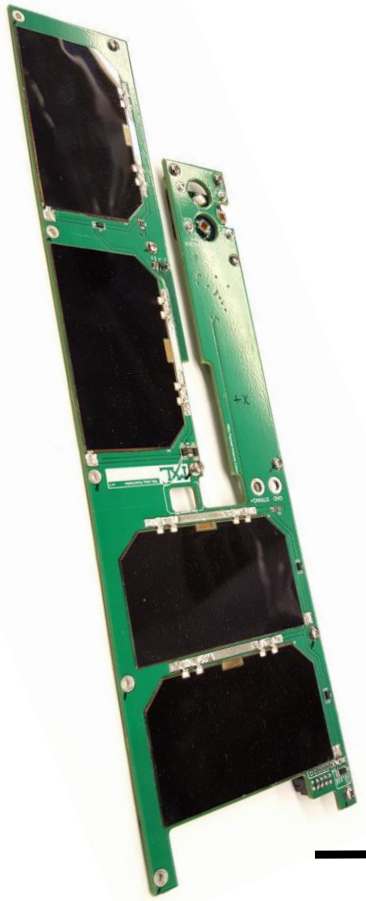


4x redundant burn resistor circuit design with robust deployment-checking script

Power Generation and Storage



Battery Pack



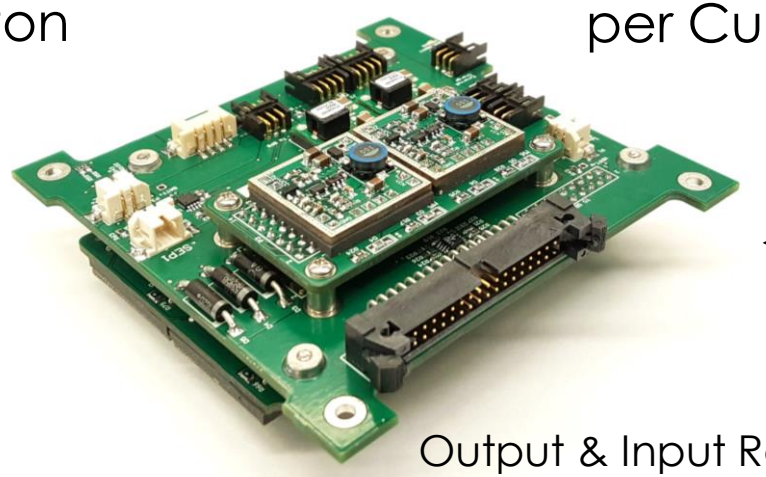
Body Panel

Power distributed to Vbatt, Watchdog, 5v0, and 3v3 power rails

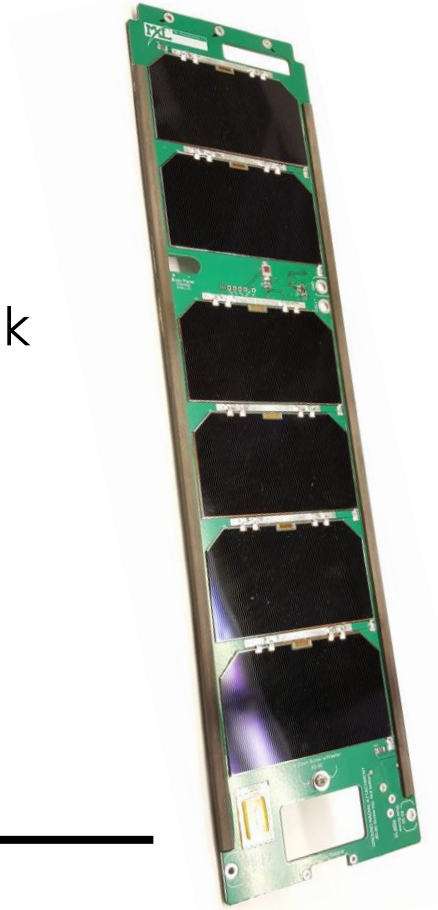
Emcore GaAs triple junction solar cells adhered with kapton

Custom boost and buck regulator boards for peak power tracking into batteries

Facilitates power inhibits per CubeSat standards



Output & Input Regulation



Deployable Panel

Flight Processing and TT&C

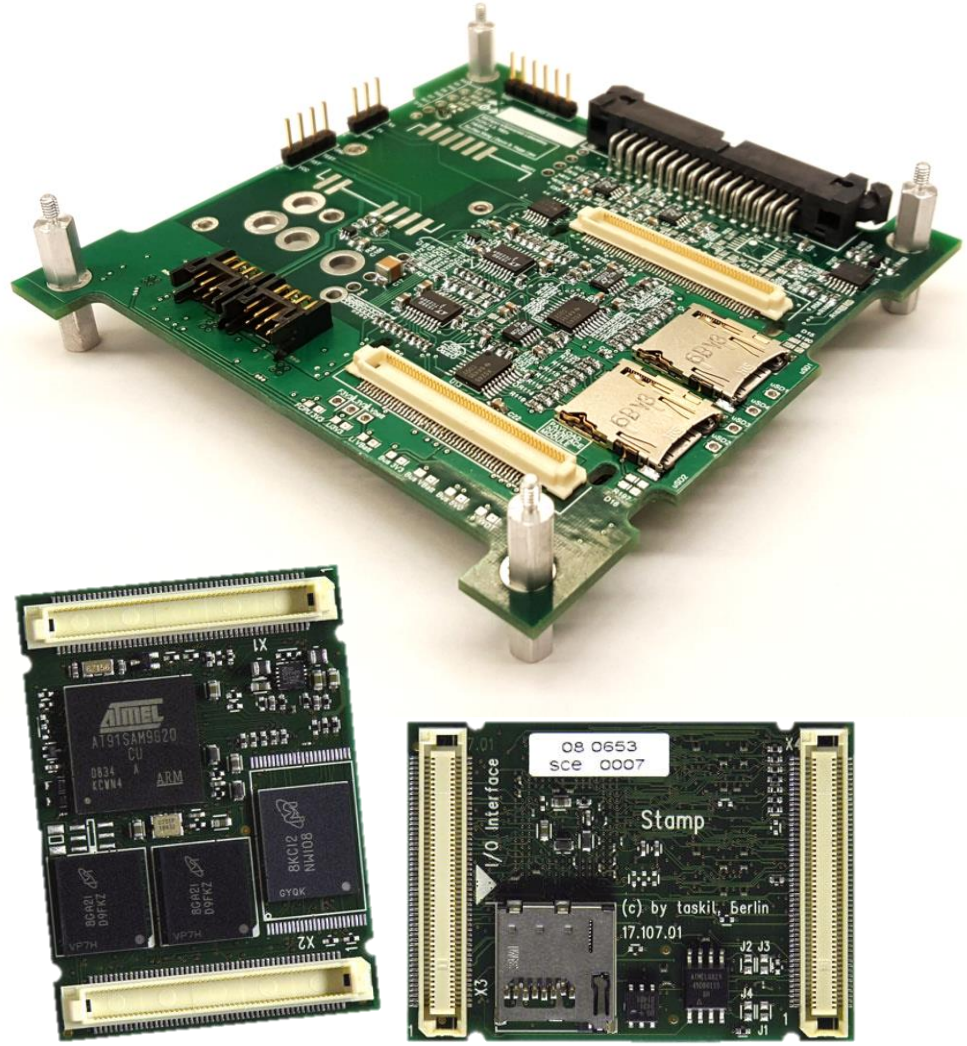
Stamp9G20 with Linux BusyBox for main CubeSat processor

Lithium v2.0 for UHF ground communications

4x SD card slots for online data storage

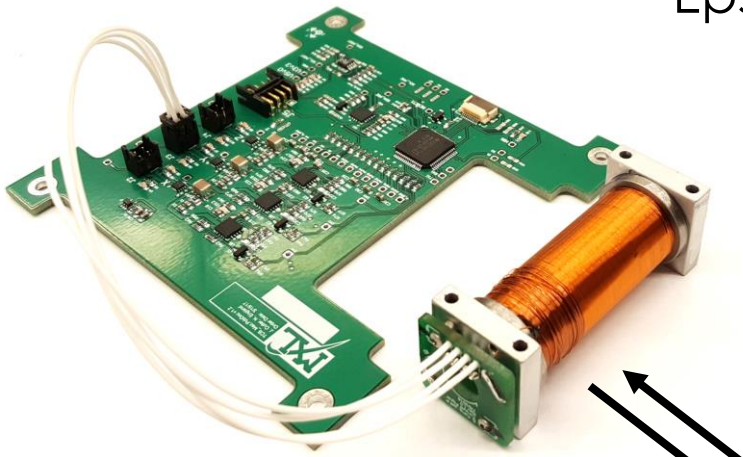
Custom MSP430-based WDT

Responsible for main attitude determination and controller code evaluation

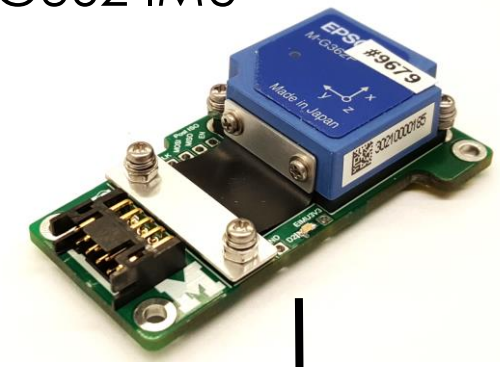


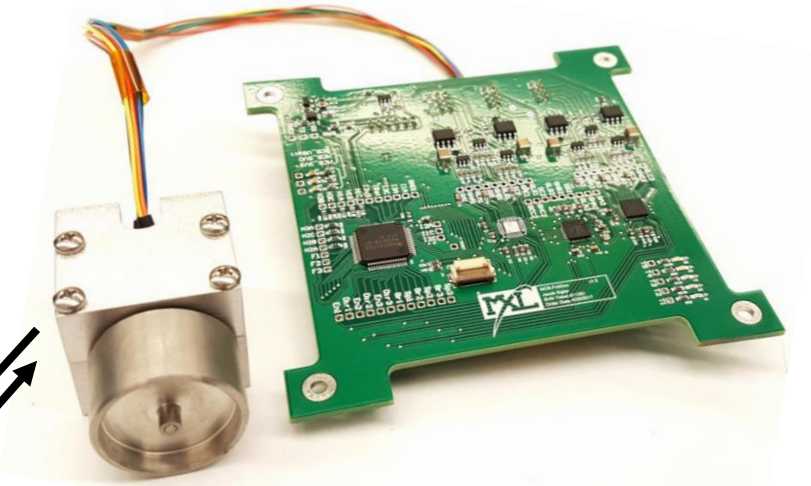
Attitude Determination and Control

Epson M-G362 IMU



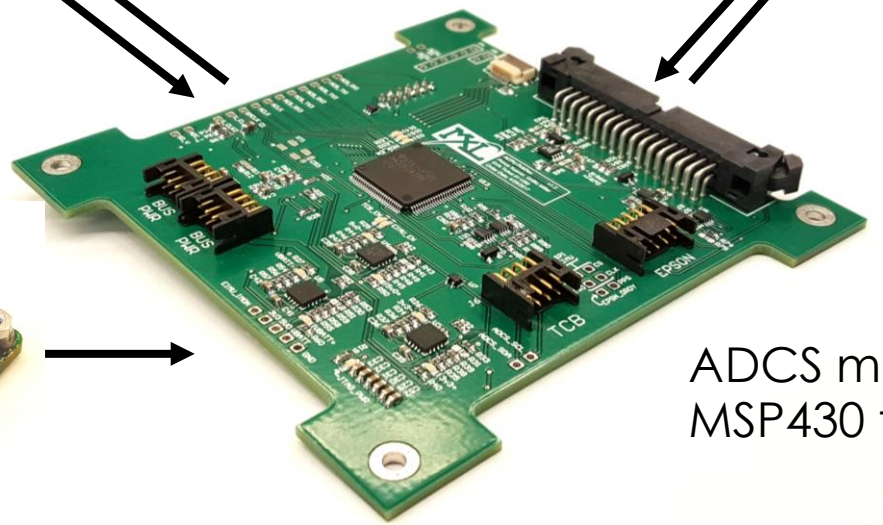
Magnetorquers designed for ~0.35 Am^2 dipole at 200 mW





Reaction wheels designed by The Aerospace Corporation and built by MXL driven with MSP430

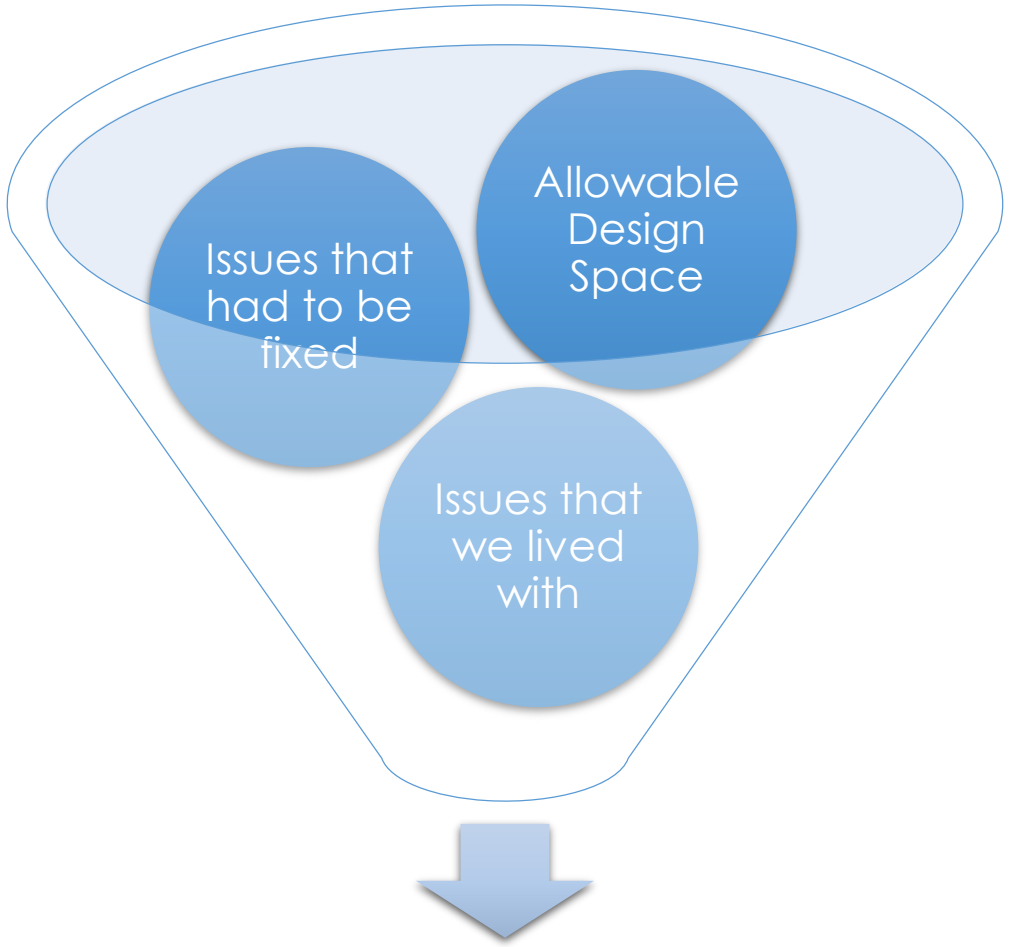
5x “Triclops” sensor suites with 3 photodiodes and Honeywell magnetometer each



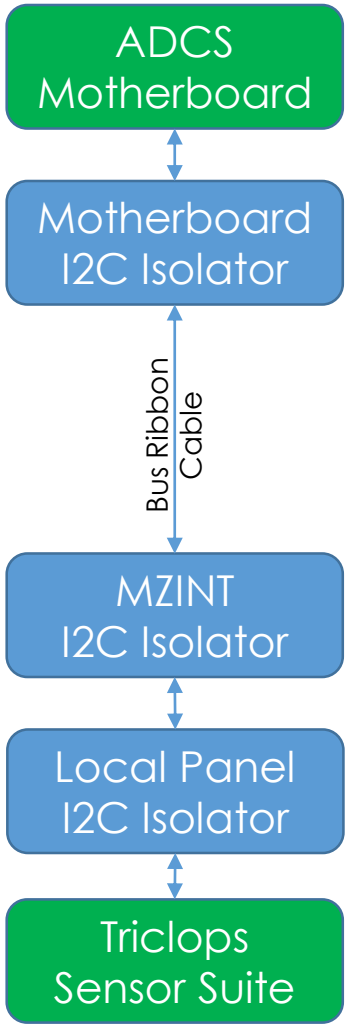
ADCS motherboard with MSP430 to run Salvo RTOS

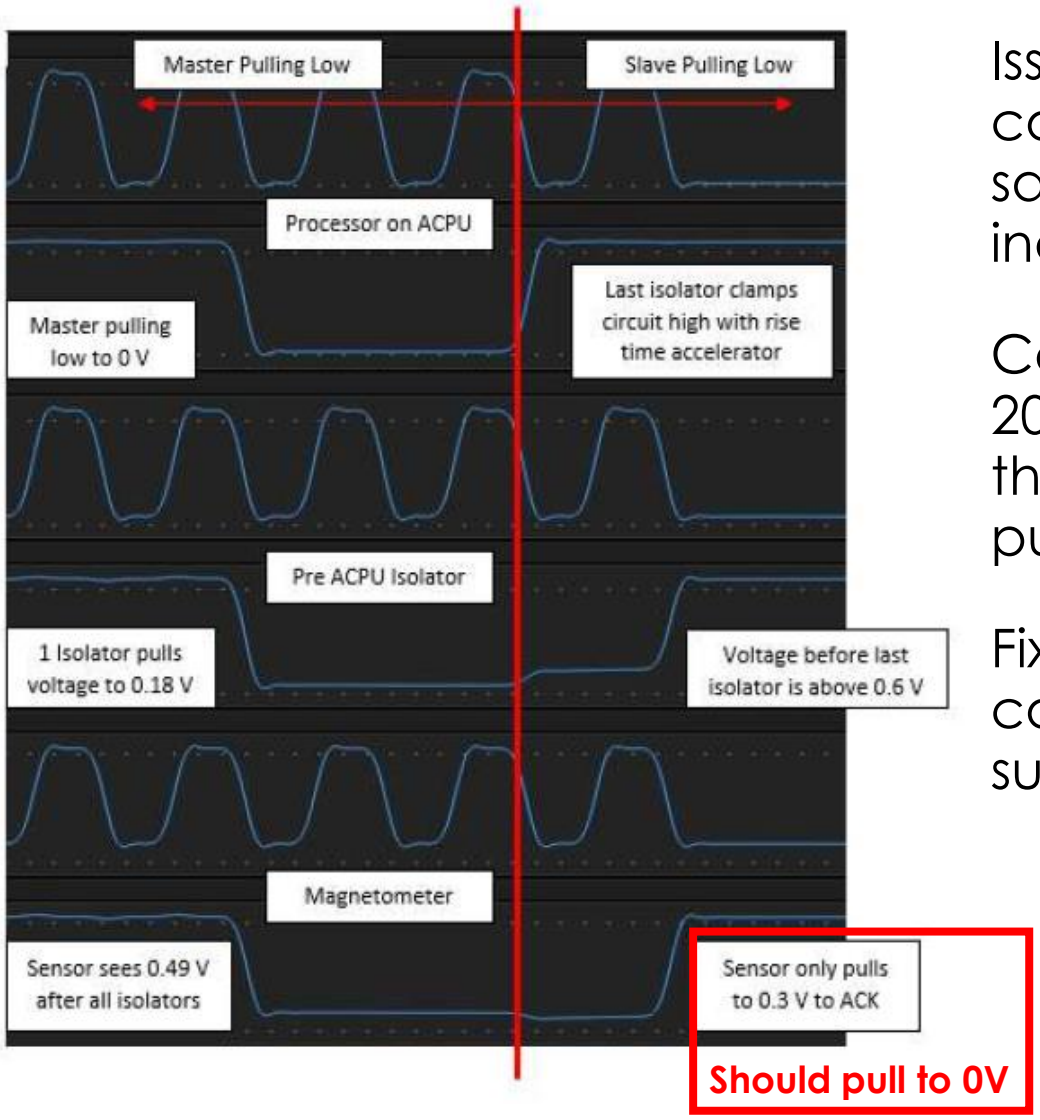
Lessons Learned

Goal: Extract broader lessons from mission development and known issues



Major Lesson: Always Check Signal Integrity





Issue: Triclops magnetometer not communicating on I2C in integrated satellite but would work during individual checkout

Cause: Data isolators (LTC4300) cause 200 mV increment when passing through a signal and device only pulled to 0.3 V on slave side

Fix: Probe data lines during I2C communication checkout to make sure all devices pull to GND sufficiently

Major Lesson: Process Development Needed for In-House Board Population

Known issue list for "Discovered and Resolved" section

- TBEx I2C lock up on flight models
- Epson gyroscopes not communicating with ACPU (poorly soldered TPS switches)
- EDU FCPU stopped booting up after a couple months post-vibe
- EPS_3v3 on 10855 wouldn't work first time testing
- 10855 had shorted VBatt and GND lines
- EPS ASB wouldn't communicate over I2C
- Regulator modules failed efficiency testing
- FCPU SPI RTC circuit would hang at 1.5 volts when disabling
- Reaction wheels would periodically stick
- A couple MCBs didn't work because of incorrect population
- Peripheral sensor data collection system didn't work with I2C isolators used on sensor boards
- EPS external charging connector populated incorrectly on ORB
- EPS battery connector on ORB populated backwards
- TCB early rev used PWM0 wired to one of the coils but you can't do this per MSP User guide and how the PWM module works on an MSP
- Solar panels had scratches from manufacturing and caused short on EDU body panel
- MZINT wouldn't communicate on I2C (I think?) (resistor R38, R39 issue)
- Flight payload on flight unit B wouldn't communicate with FCPU (PIM soldering)
- Gyroscopes would send intermittent weird values during checkout (fixed with flight code)
- One of the torque rods on the flight models actuates a different way when you drive a forward command
- Payload VHF extensions were angled and couldn't stow in body panel when coiled up
- One reaction wheel harness came out of MCB connector during testing
- TCB shape had to change drastically to allow MCB harnesses to be plugged in
- MCB was routed backwards so it didn't fit together with TCB on early revs
- Li_VBatt power switch could not get enabled (FX8 pin soldering)
- UHF antennas not trimmed to optimal length prior to flight integration
- EPS battery pack didn't fit snugly in structure due to countersinks
- Flight payload didn't fit in walls because of spring set screws
- Magnetometers not working on EDU
- EDU walls anodized incorrectly the first time around by Alpha metal

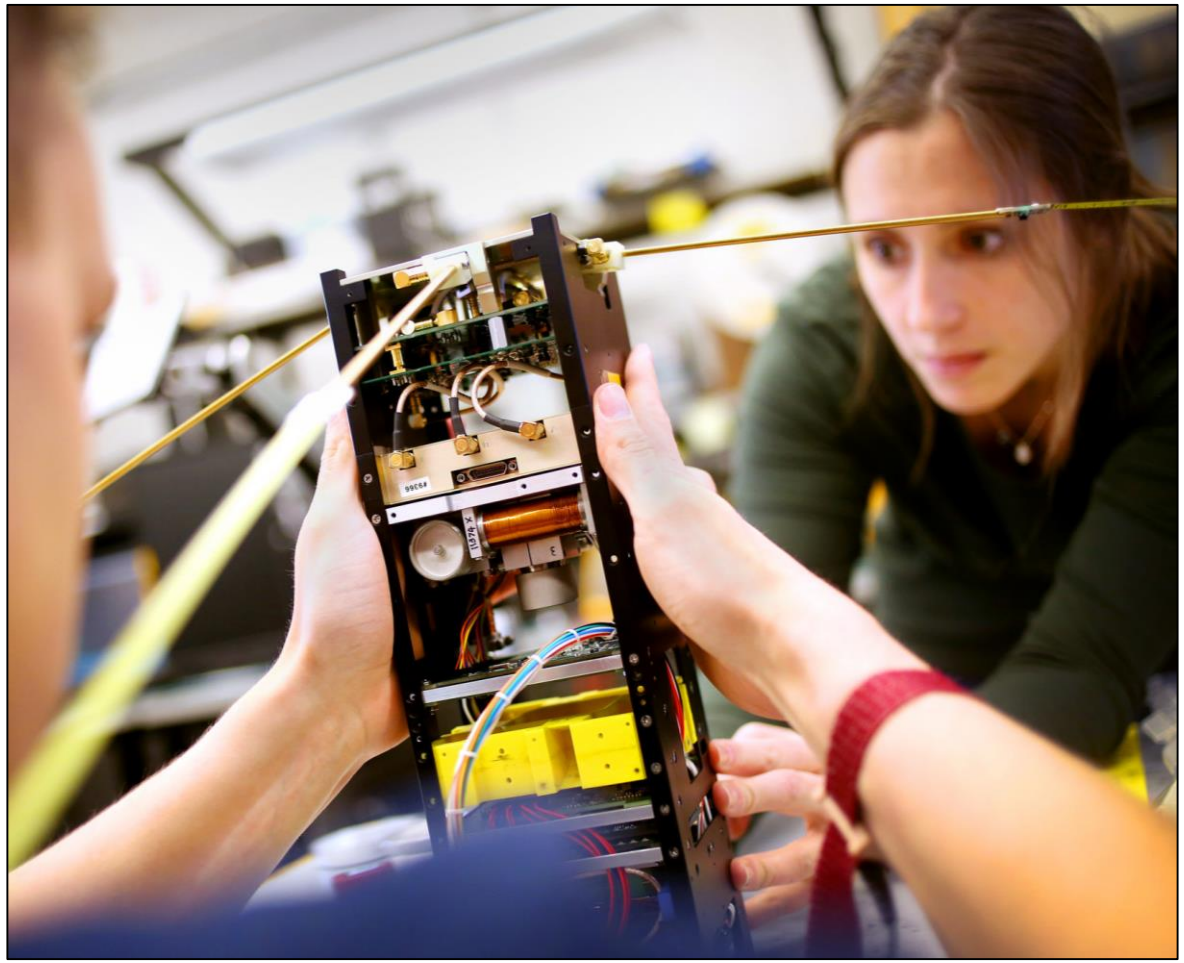
Red Underline = Population Related

Issue: Numerous population errors throughout EDU and flight production phases

Cause: Population BOMs intended to be more flexible for system development. Resultant document was hard to read and verify correct population for each board

Potential Fixes: Outsource large population orders or create better procedure docs for population

Major Lesson: Recruiting and Knowledge Transfer Need More Attention

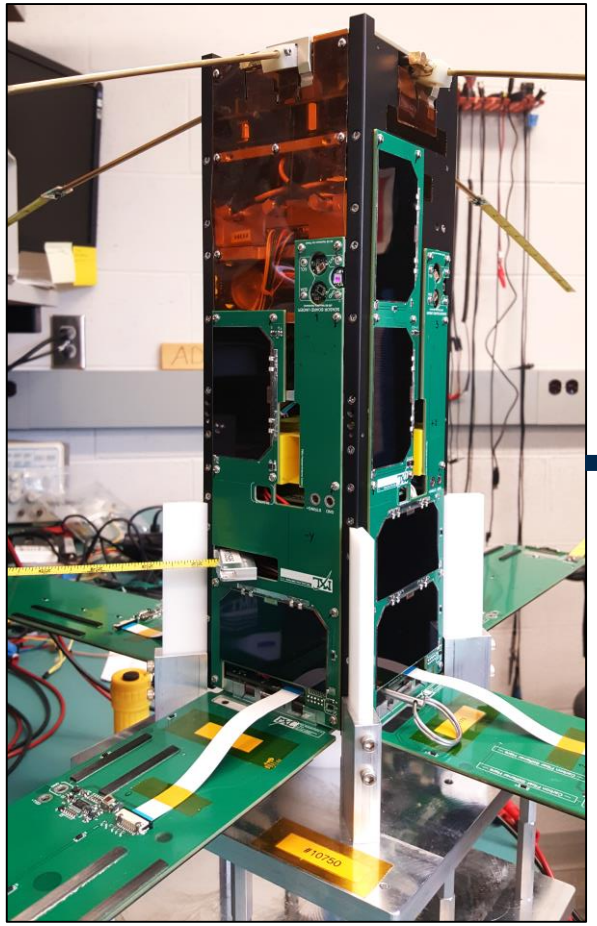


Issue: MXL knowledge tends to live with the "experts" and has a large learning curve for transferring to new people

Cause: Small lab numbers drives people to work on tasks over documenting existing systems and knowledge

Potential Fix: Refocus recruiting efforts and external collaborations to build stronger, larger team allowed by existing funding

What's Next?



Close out remaining action items from Mission Readiness Review

Launch on Falcon Heavy with STP-2 mission

Run operations at UMICH and other locations until deorbit

Acknowledgements

Faculty

John Van Noord – Testing

SPRL Technicians

Graduate Students

Tyler Rose

So-Hee Kang

Ari Porter

Joshua Synoweic

Jeffrey Poon

Emanuella Della Bosca

Jacob Winnick

Charles Lacy

Dae Young Lee

Prince Kuevor

Alex Walsh

Daniel Spatcher

Undergraduate Students

Daniel Gu

Rohan Punnoose

Adolfo Apolloni

Justin Schacter

Jacob Sigler

Others

Rick Doe – SRI

Roland Tsunoda – SRI

Terry Larrow – UMICH

Vidur Kaushish – Tyvak

All past MXL alumni

Feel free to follow up with any questions or collaboration interests

engnatha@umich.edu