

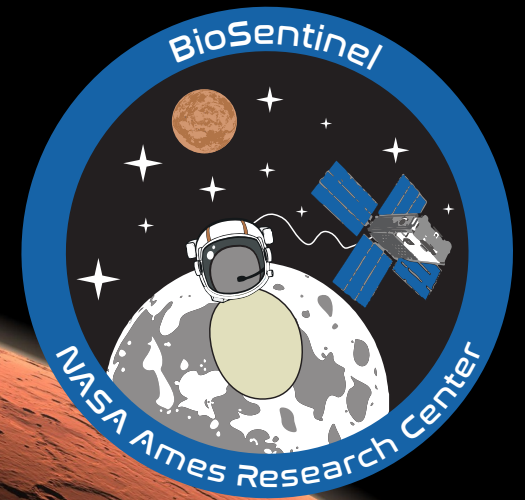


BioSentinel - Spacecraft and BioSensor Flight Unit Development

Bob Hanel
Sergio Santa Maria

Interplanetary Small Satellite Conference 2019
San Luis Obispo, CA
4/29/19

Authors Affiliated with NASA Ames Research Center,
Moffett Field, CA



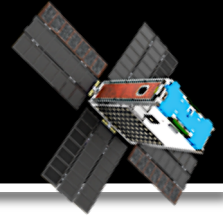
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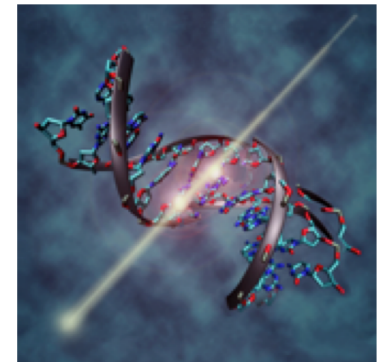
NASA Ames Research Center, Moffett Field, CA



BioSentinel Project Objectives

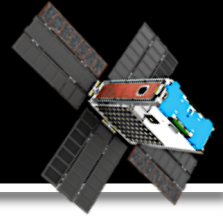


- Advanced Exploration Systems (AES) selected BioSentinel to fly on the Space Launch System (SLS) Exploration Mission (EM-1) as a secondary payload
 - Payload selected to help fill **HEOMD Strategic Knowledge Gaps in Radiation effects on Biology**
 - Current EM-1 Launch Readiness Date (LRD): *6/26/2020*
 - Delivery to Dispenser Integrator, Tyvak: **10/28/2019**
- Key BioSentinel Project Objectives
 - Develop a ***deep space nanosat*** capability
 - Develop a ***radiation biosensor*** useful for other missions
 - Define & validate **SLS secondary payload interfaces and accommodations** for a biological payload
- Collaborate with other EM-1 selected missions (non-biological), particularly:
 - Near Earth Asteroid (NEA) Scout (MSFC)
 - Lunar Flashlight (JPL)

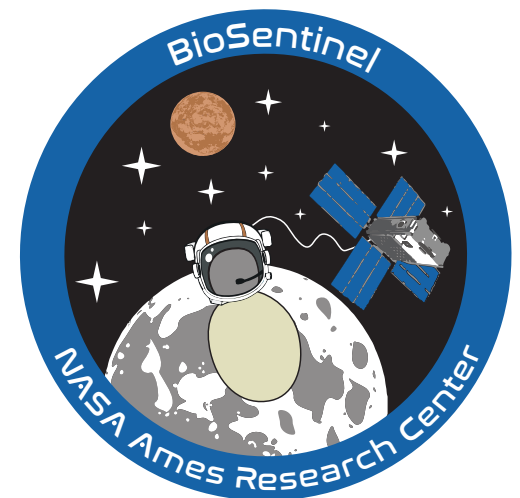
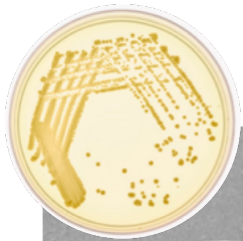
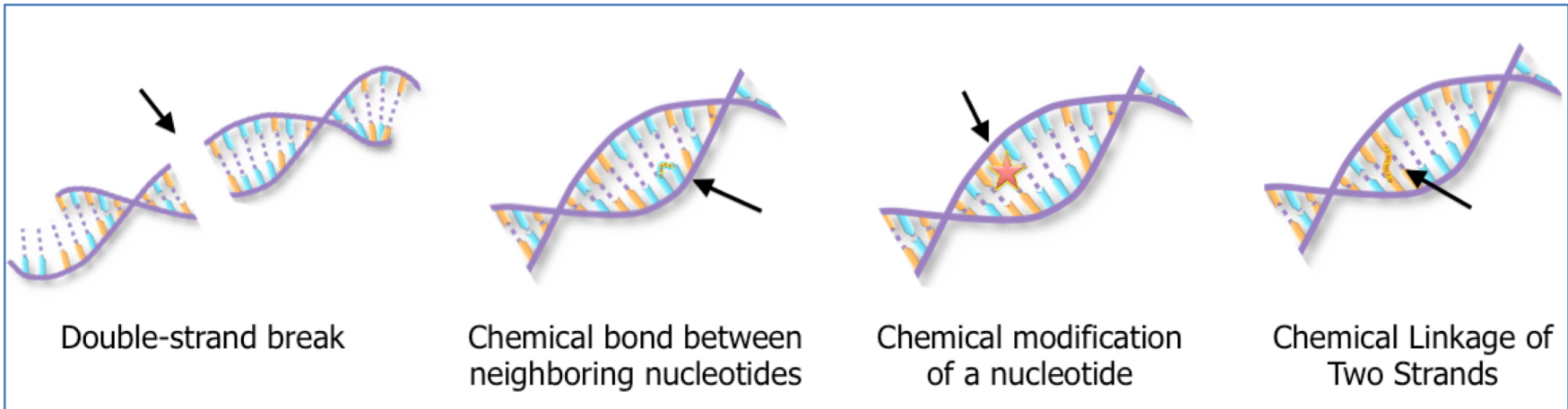




BioSentinel Science

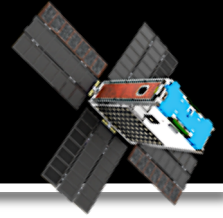


BioSentinel is a yeast radiation biosensor that will measure the DNA damage response caused by space radiation, and will provide a tool to study the true biological effects of the space environment at different orbits.





BioSentinel Science



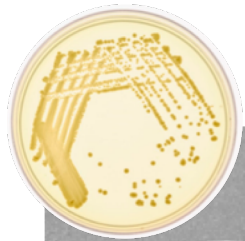
BioSentinel is a yeast radiation biosensor that will measure the DNA damage response caused by space radiation, and will provide a tool to study the true biological effects of the space environment at different orbits.

Why?

Space radiation environment's unique spectrum cannot be duplicated on Earth. It includes high-energy particles, is omnidirectional, continuous, and of low flux.

How?

Lab-engineered *S. cerevisiae* cells will sense & repair direct (and indirect) damage to their DNA. Yeast cells will remain dormant until rehydrated and grown using a microfluidic and optical detection system.

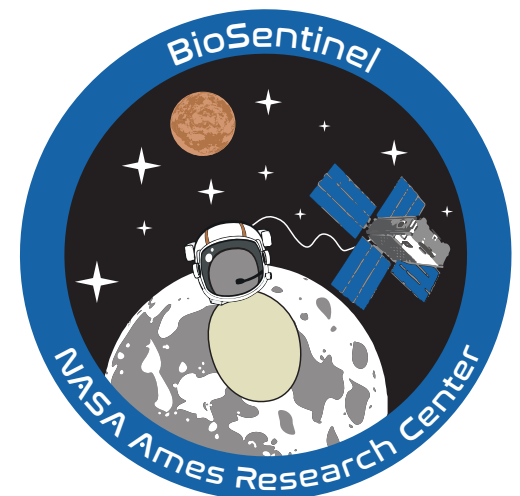


S. cerevisiae
(budding yeast)

Why budding yeast?

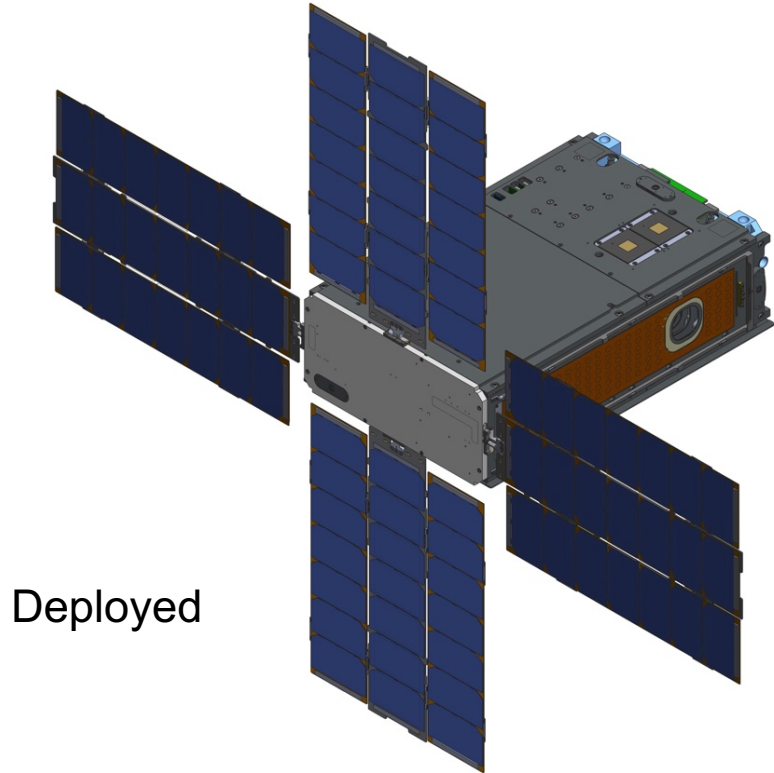
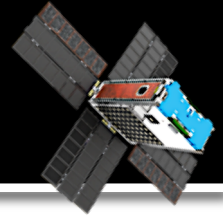
It is an eukaryote (similar to humans);
easy genetic manipulation; assay
availability; flight heritage; ability to be
stored in dormant state

While it is a simple model organism, yeast
cells are the best for the job given the
limitations & constraints of spaceflight

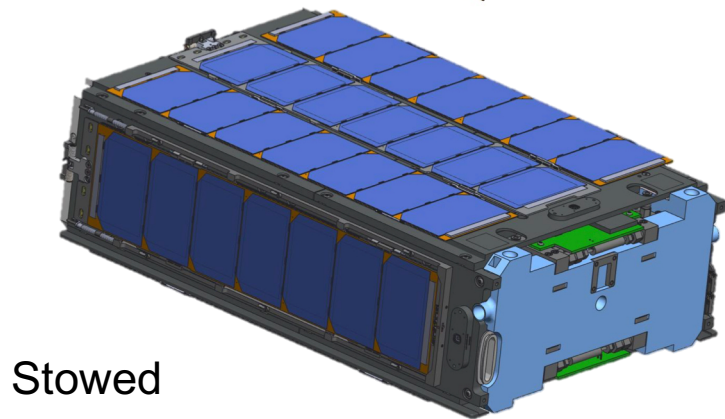




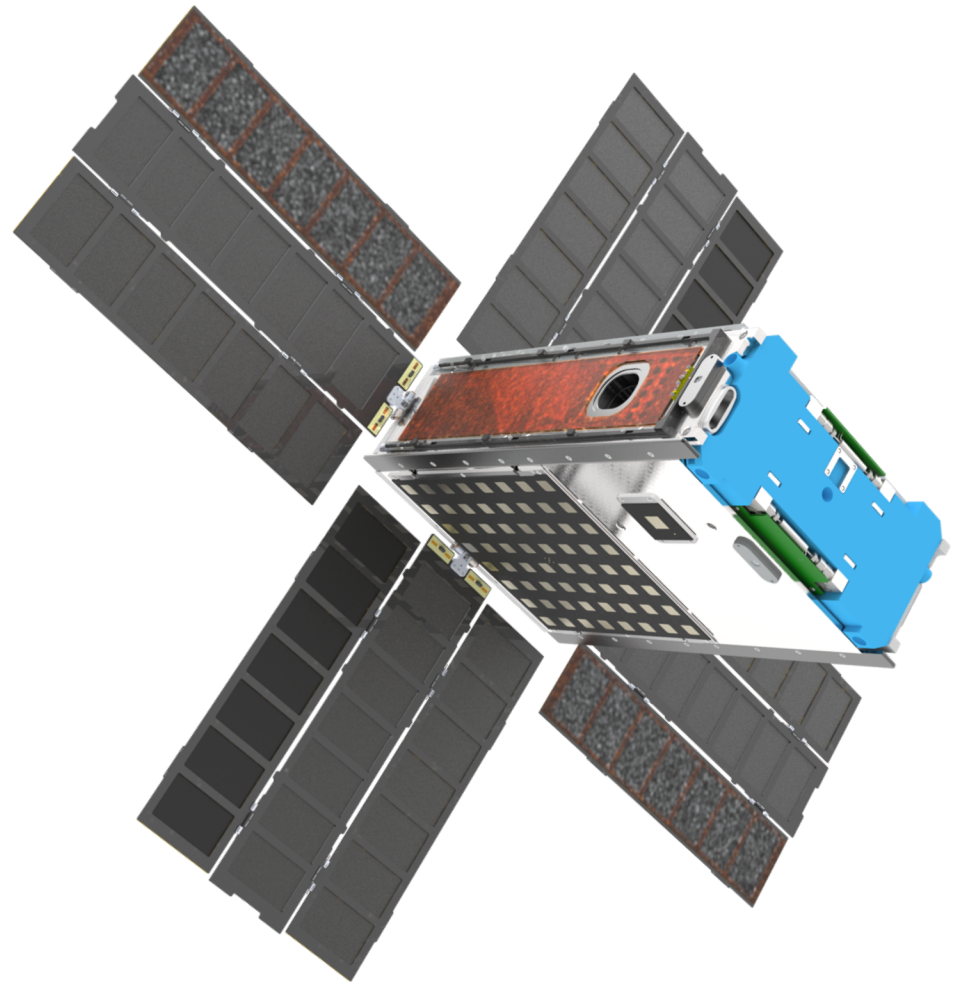
BioSentinel Overview – Deployed & Stowed



Deployed

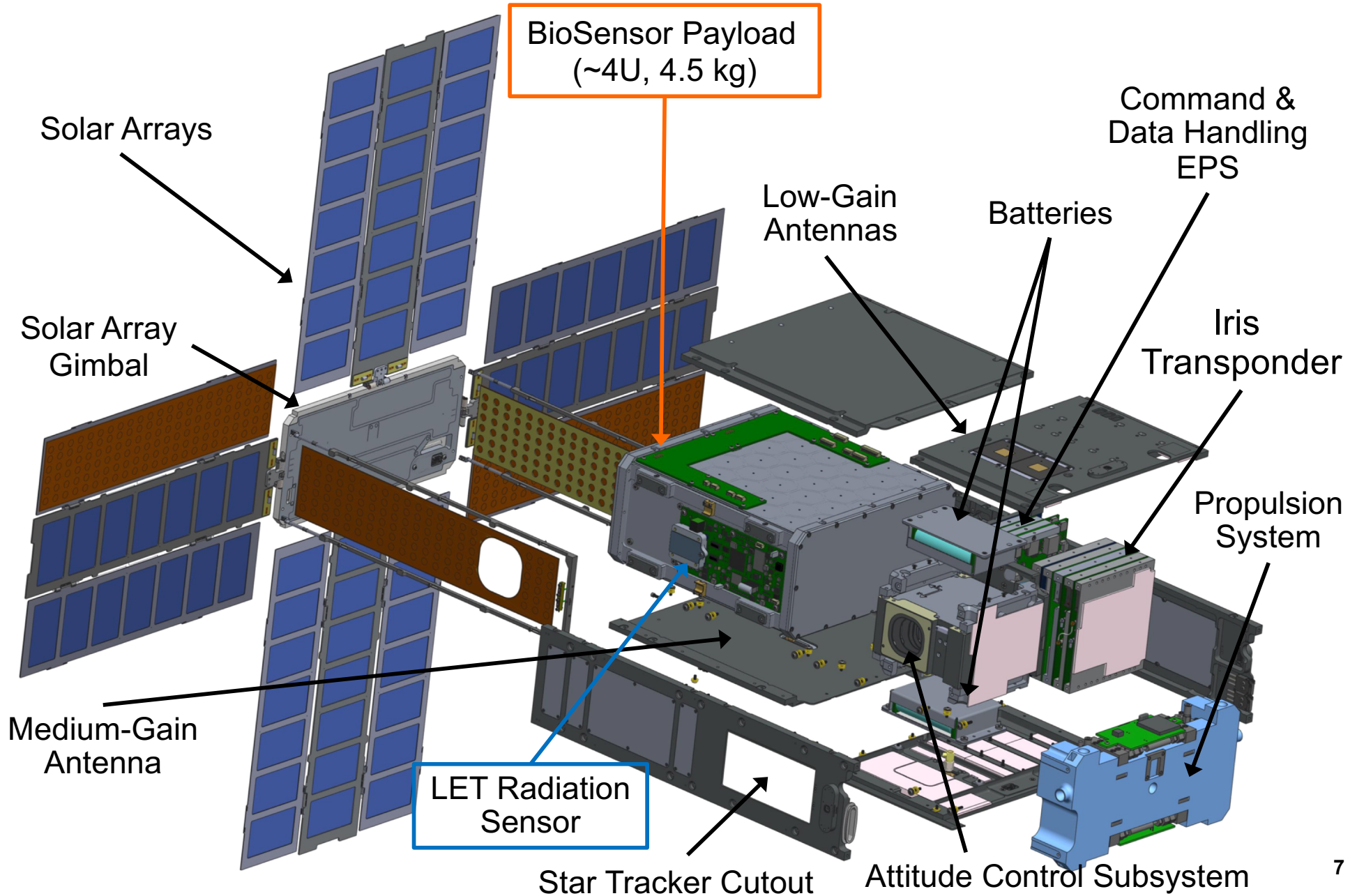
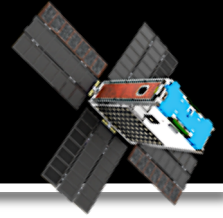


Stowed



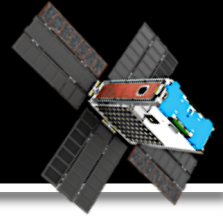


BioSentinel Subsystem Overview

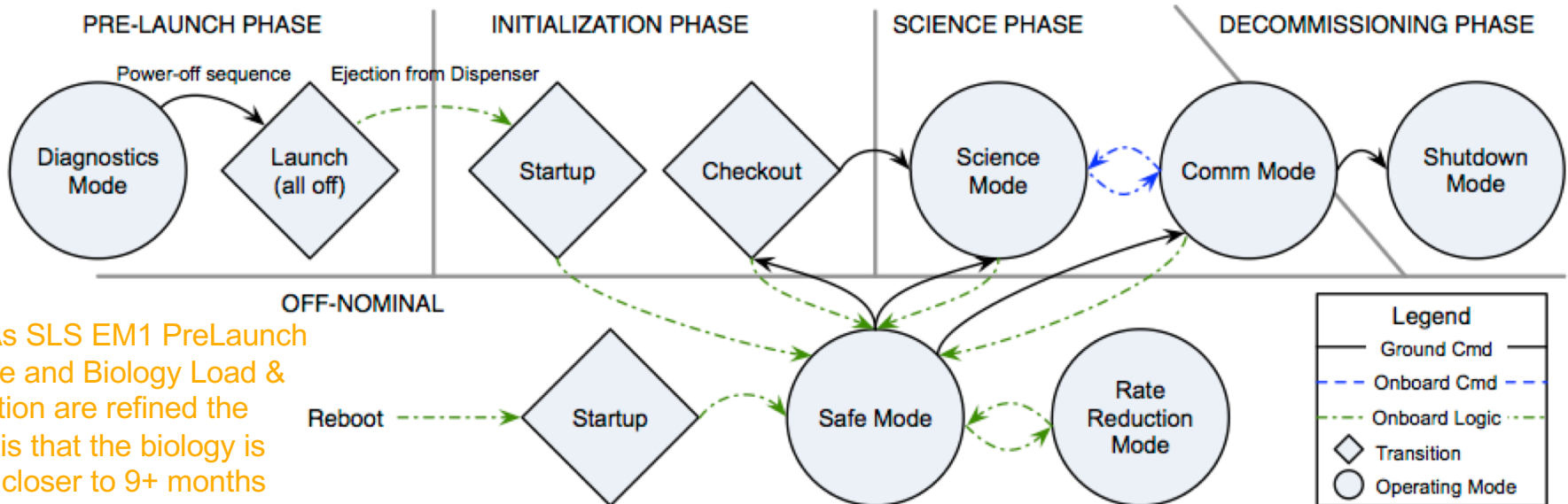
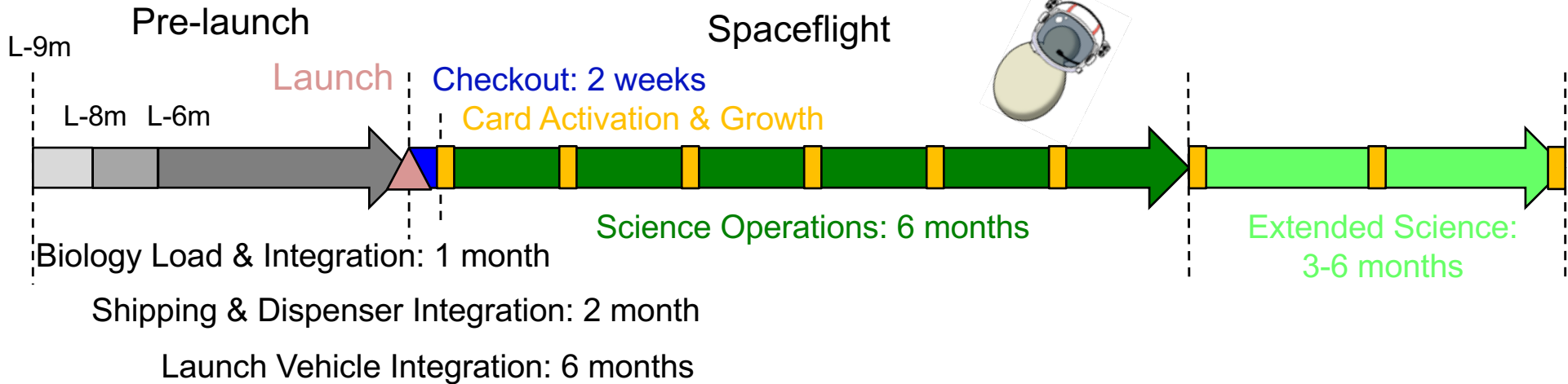




BioSentinel Mission Timeline



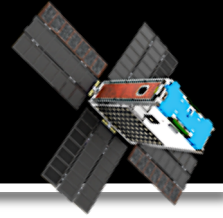
Launch on Space Launch System Exploration Mission #1 (**SLS EM-1**) as a secondary payload



Note: As SLS EM1 PreLaunch Timeline and Biology Load & Integration are refined the impact is that the biology is loaded closer to 9+ months before launch rather than 6 months

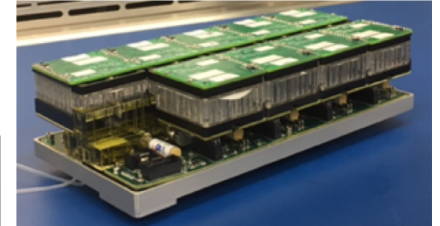
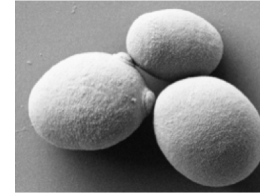


BioSentinel – Science Accomplishments



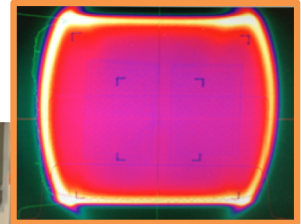
Yeast strain selection:

- Wild type strain (control for unreparable DNA damage & yeast health)
- DNA repair defective mutant (radiation sensitive)



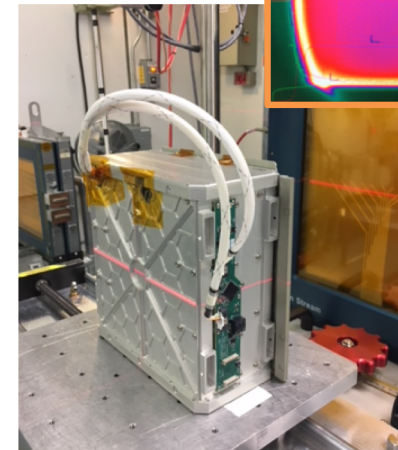
Long-term biocompatibility & other tests:

- Long-term medium & metabolic dye storage ([completed 2-year test](#))
- Long-term yeast desiccation ([completed 2-year test](#)) & desiccation method selection ([completed](#))
- Long-term biocompatibility in fluidic cards ([completed 2-year test](#))
- Card activation sequence: desiccation → stasis → rehydration → metabolic activity & growth
- Sterilization method selection (autoclaving vs. e-beam vs. EtO) ([completed](#))
- Optical data processing & optimization
- Spacecraft EDU assembly, vibration & TVPM tests ([completed](#))
- FlatSat optical calibration tests ([completed](#))
- [Completed EVT & currently assembling protoflight & flight units \(TRL6\)](#)



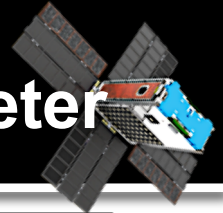
Ongoing radiation experiments:

- Cells irradiated in suspension & in desiccated state (with & without shielding)
- Strain sensitivity via optical readings in microplate readers or GSE optical units
- Sources: gamma (ARC); protons & SPE simulations (Loma Linda); HZE ions & [GCR simulation](#) (NSRL)

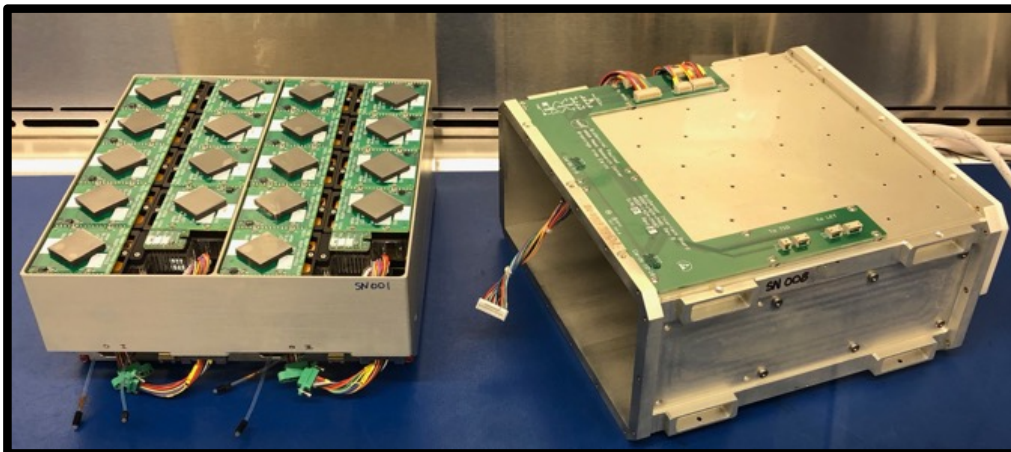




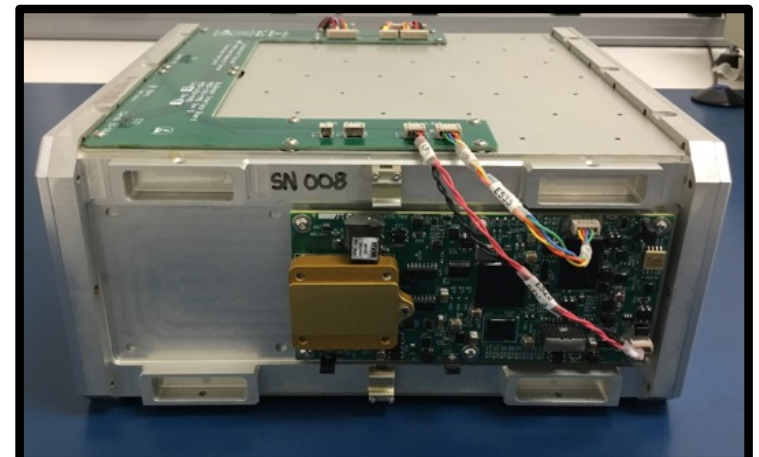
BioSentinel Payload – BioSensor & LET Spectrometer



EDU5 BioSensor being reworked



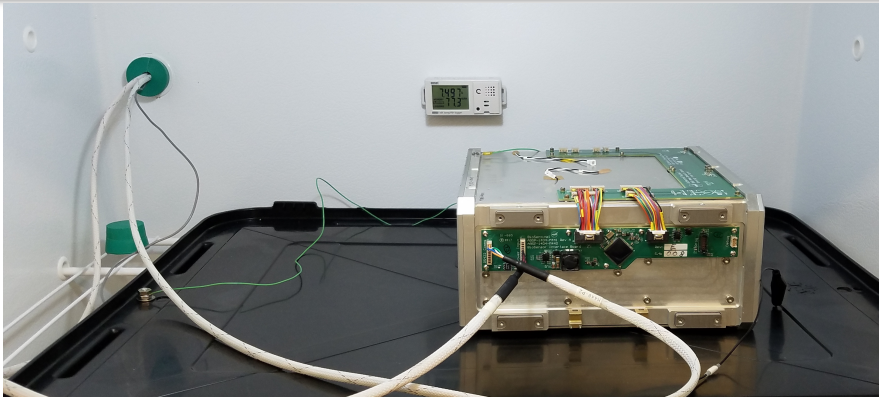
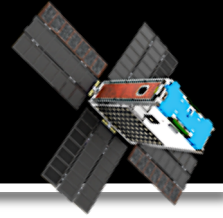
SN01 – Sterile BioSensor During Assembly & Integration



BioSensor & LET Spectrometer Integrated will be used in Spacecraft Protoflight Build



BioSentinel Payload Experiment Verification Test

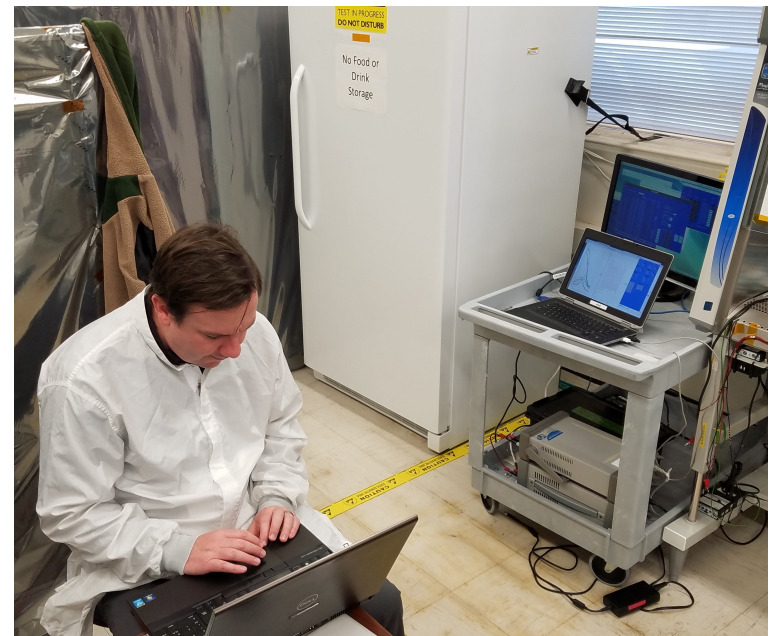


EDU5 in incubator for EVT start

- EVT successfully demonstrated a 6-month BioSensor experiment compressed into a 1-month test (actually 2-months due to shutdown). All 18-cards were filled and science data shows growth of both strains of yeast.



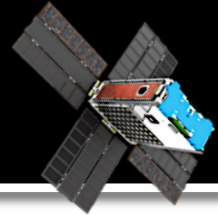
BioSensor Team placing EDU in incubator



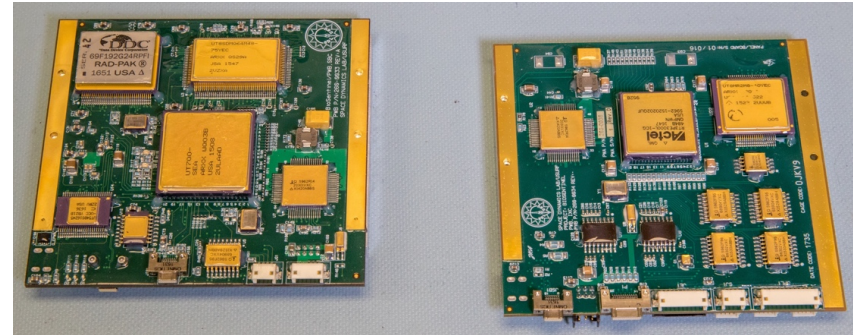
BioSensor Team executing 1 of 9;
2-Card experiments



BioSentinel Spacecraft Flight Hardware Deliveries



Hand-Off of BioSentinel Flight Iris Transponder @ JPL



Flight C&DH Boards: Single Board Computer (SBC) [Left] & Interface eXpansion Card (IXC) [Right] (Provided by SDL)



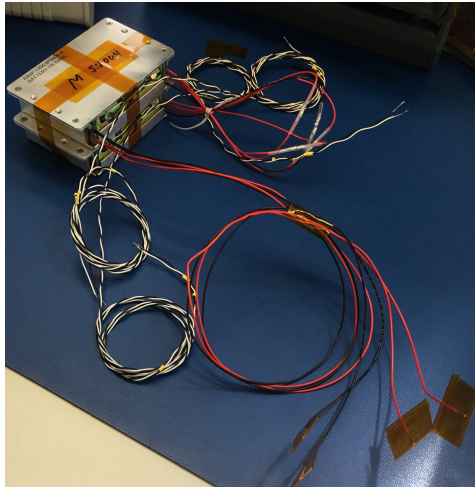
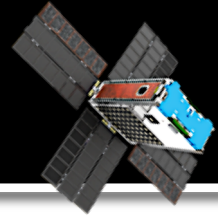
BioSentinel Iris Flight Unit including SSPA & LNA



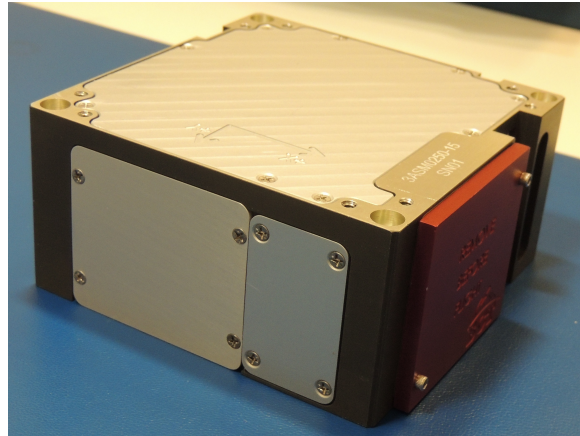
4-Panel Gimbaled Solar Array Ready to Ship (Provided by MMA)



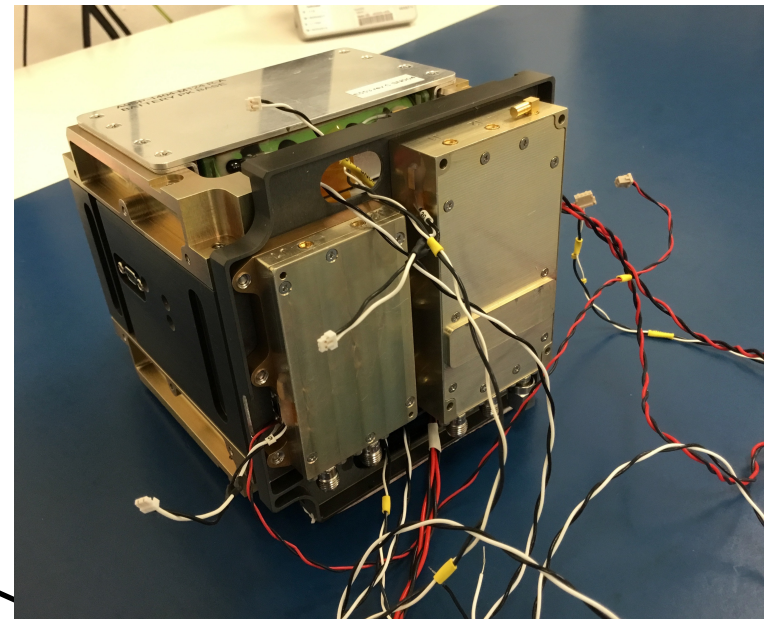
ADCS Module Assembly - Procedure XM044



Batteries
P/N A9SP-1404-M121



BCT XACT
P/N 3ASM0250-15

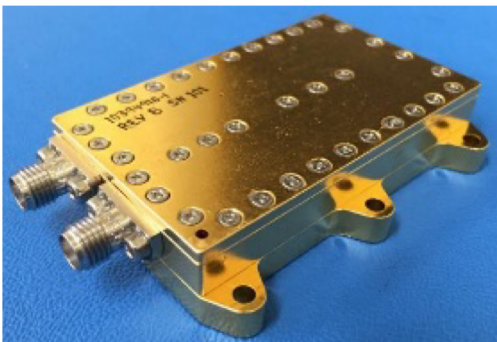


ADCS Module
P/N A9SP-1404-M120

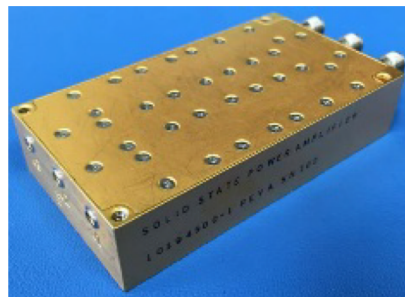
Low Noise Amplifier
P/N 10394916

Solid State Power
Amplifier P/N
10394900

Amplifier Mount
Block Brackets
P/N A9SP-1404-MXXX



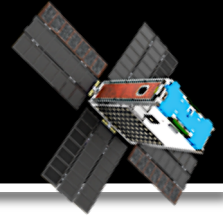
Simulator for Fit Check



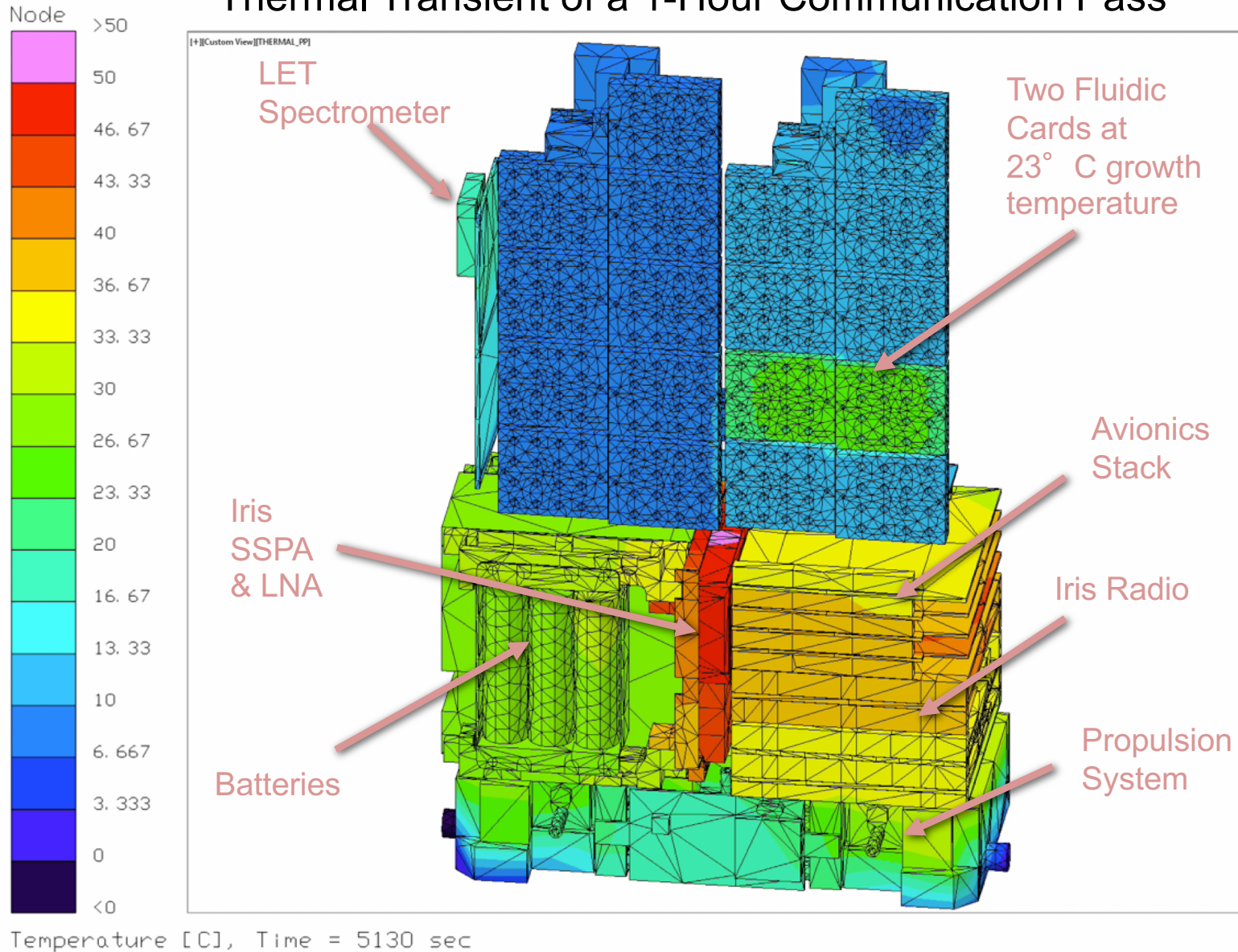
Simulator for Fit Check



Thermal TVPM Data Analysis

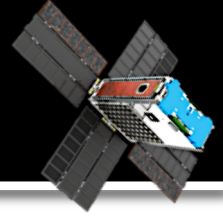


Thermal Transient of a 1-Hour Communication Pass

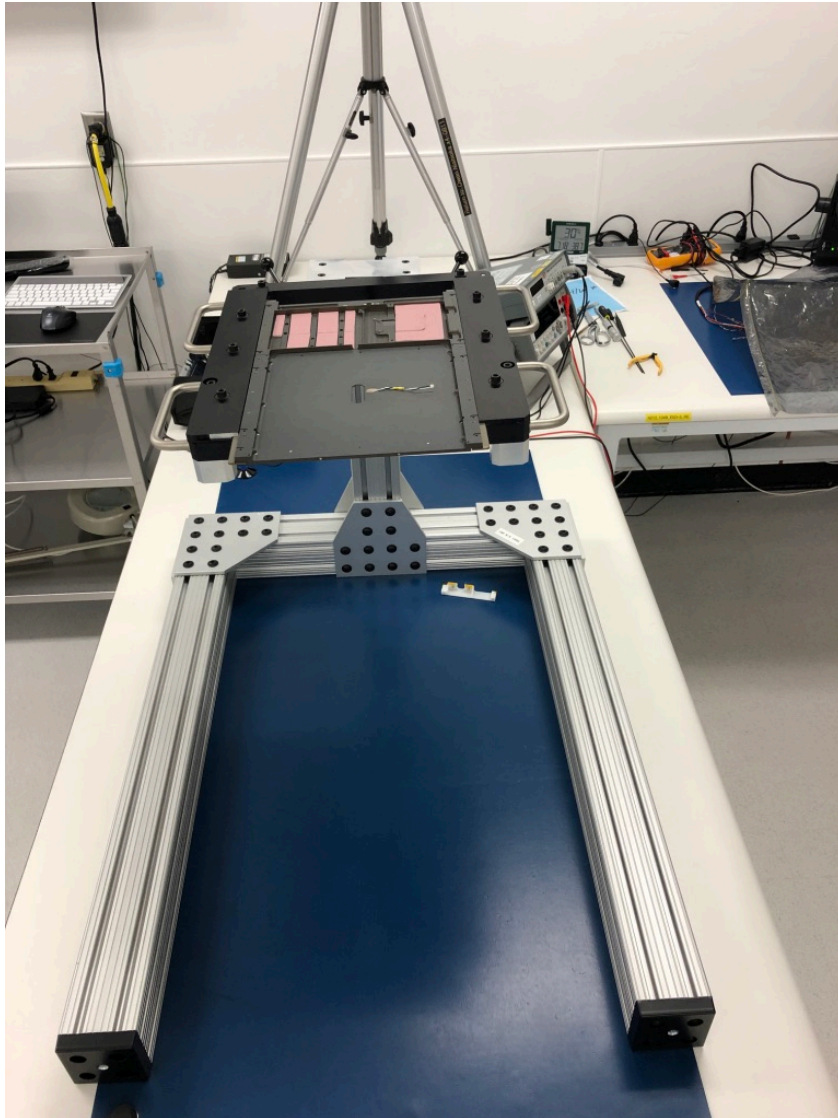




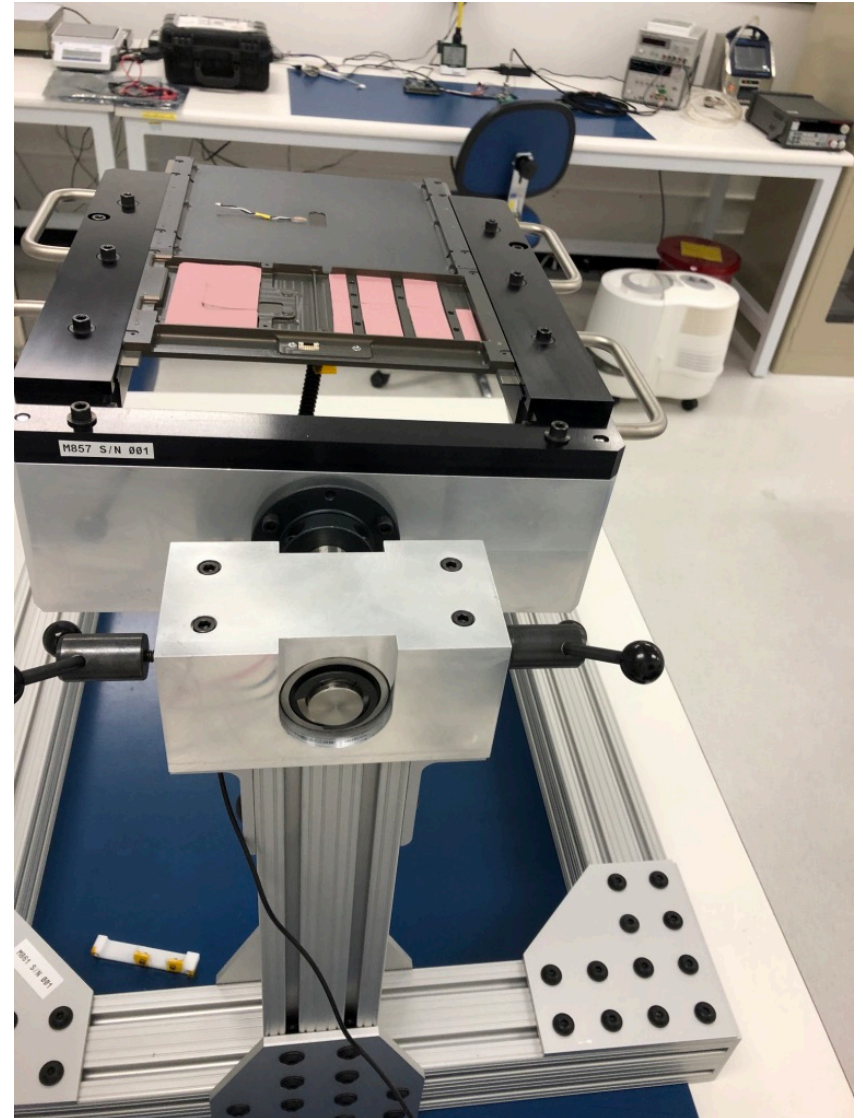
Mechanical Fit Check Progress – Day 2 (11/13/18)



Front View

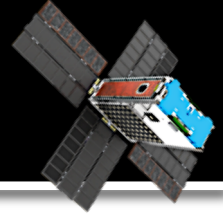


Back View

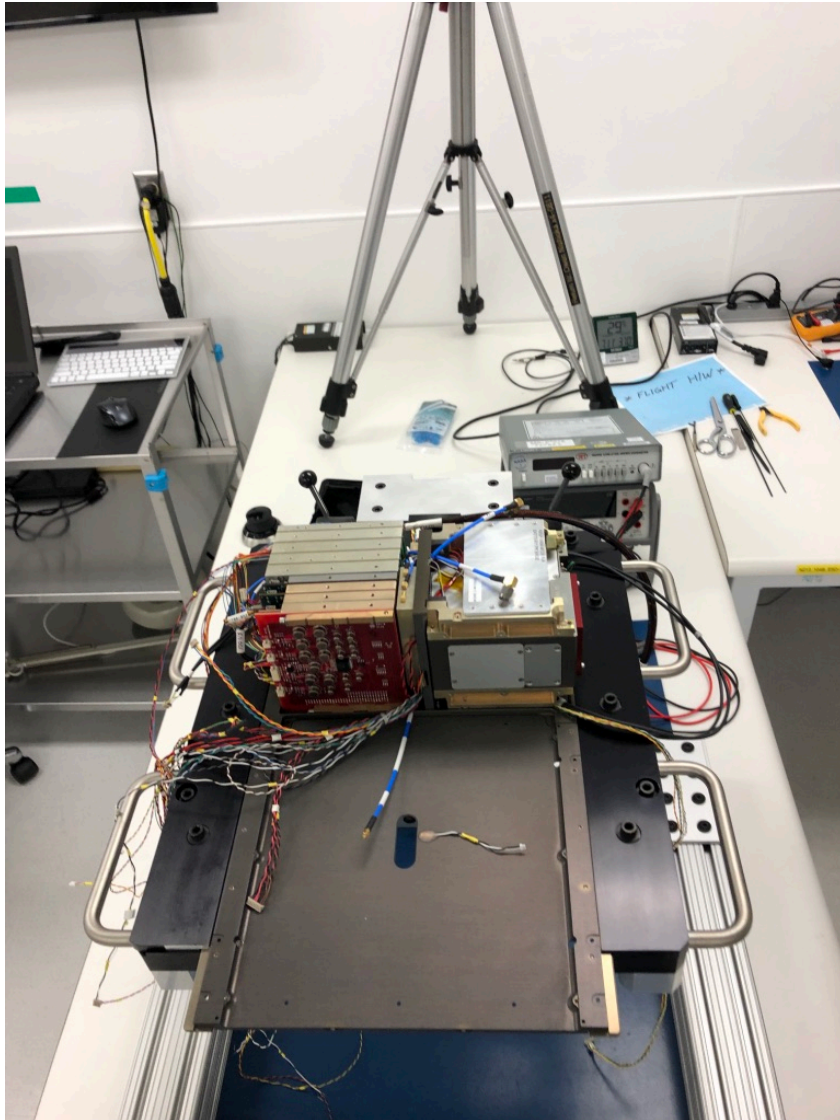




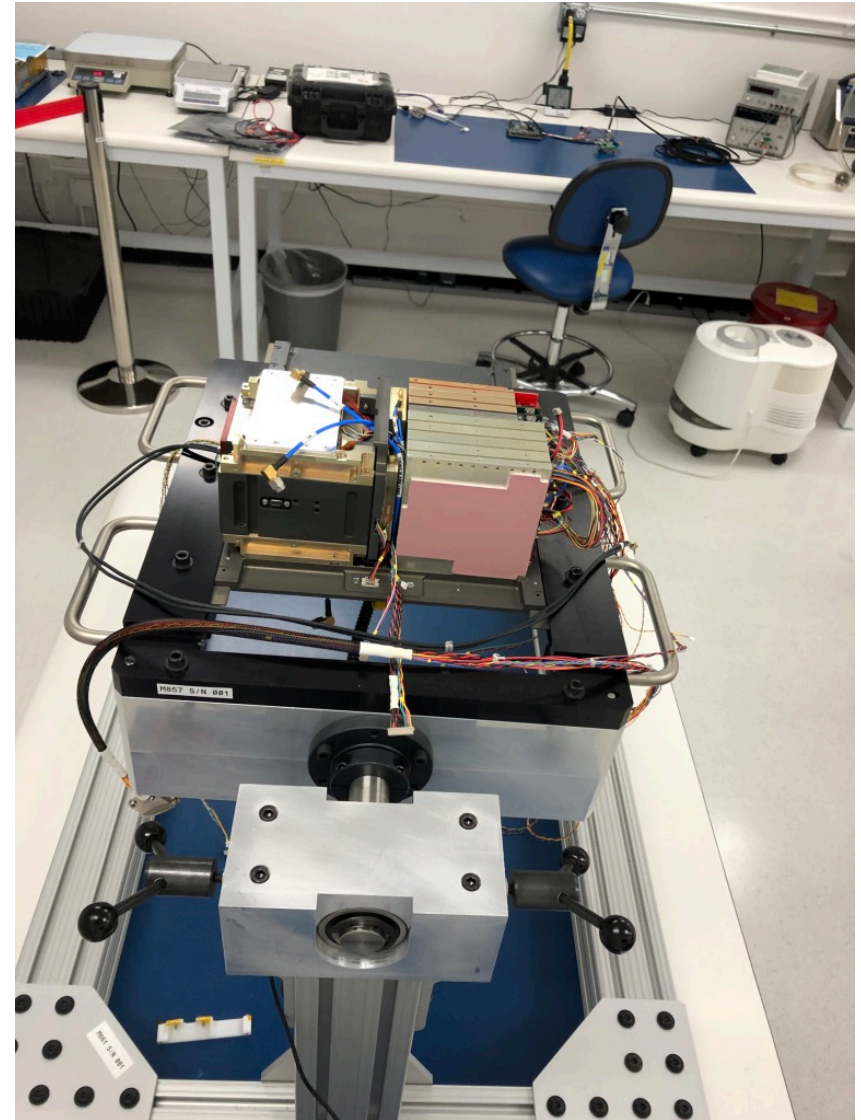
Mechanical Fit Check Progress – Day 3 (11/14/18)



Front View

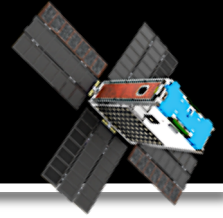


Back View



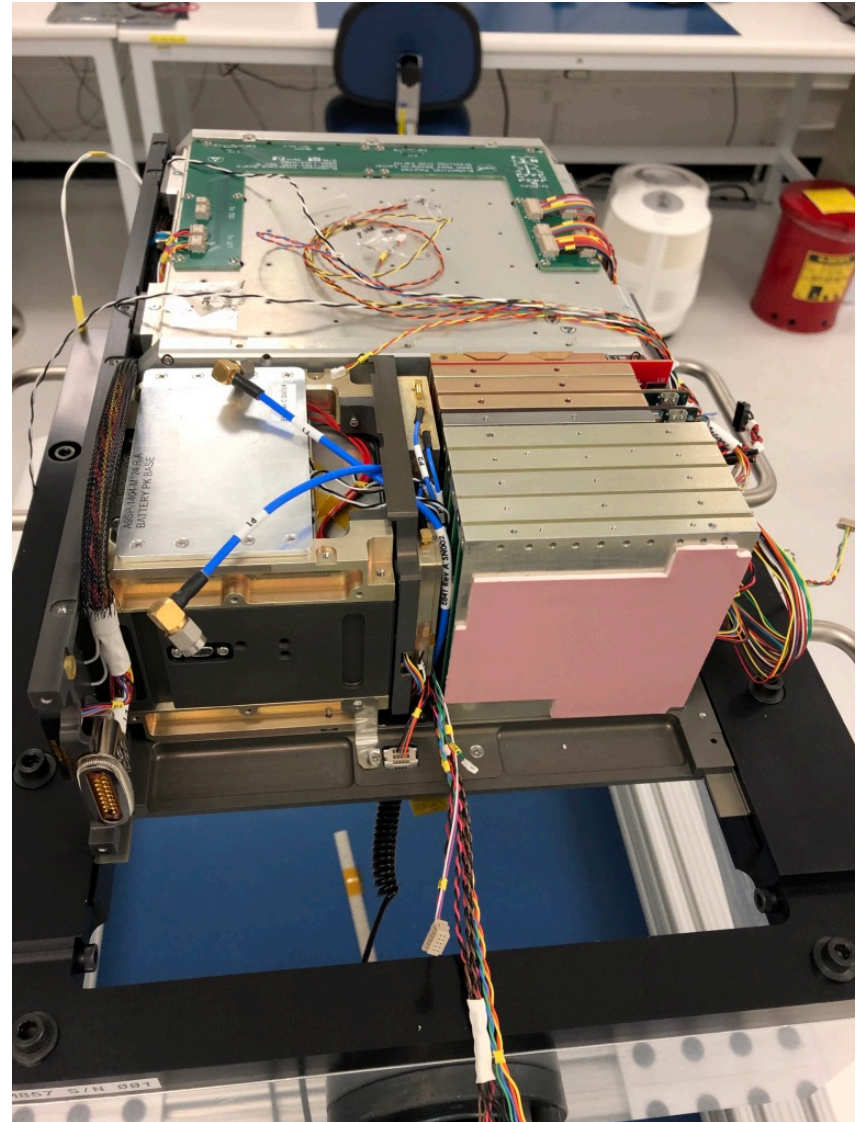
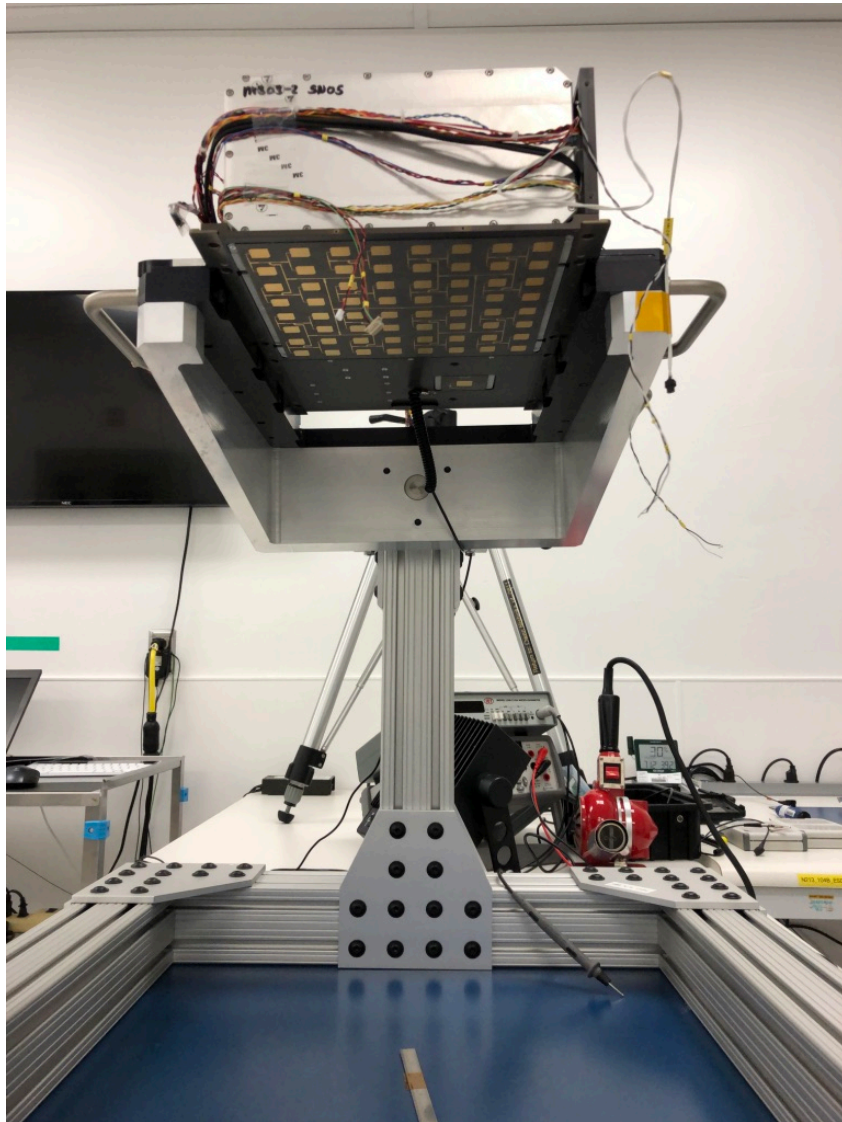


Mechanical Fit Check Progress – Day 6 (11/19/18)



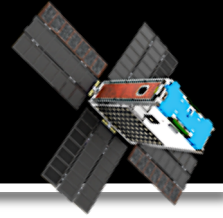
Front - Bottom View

Back View



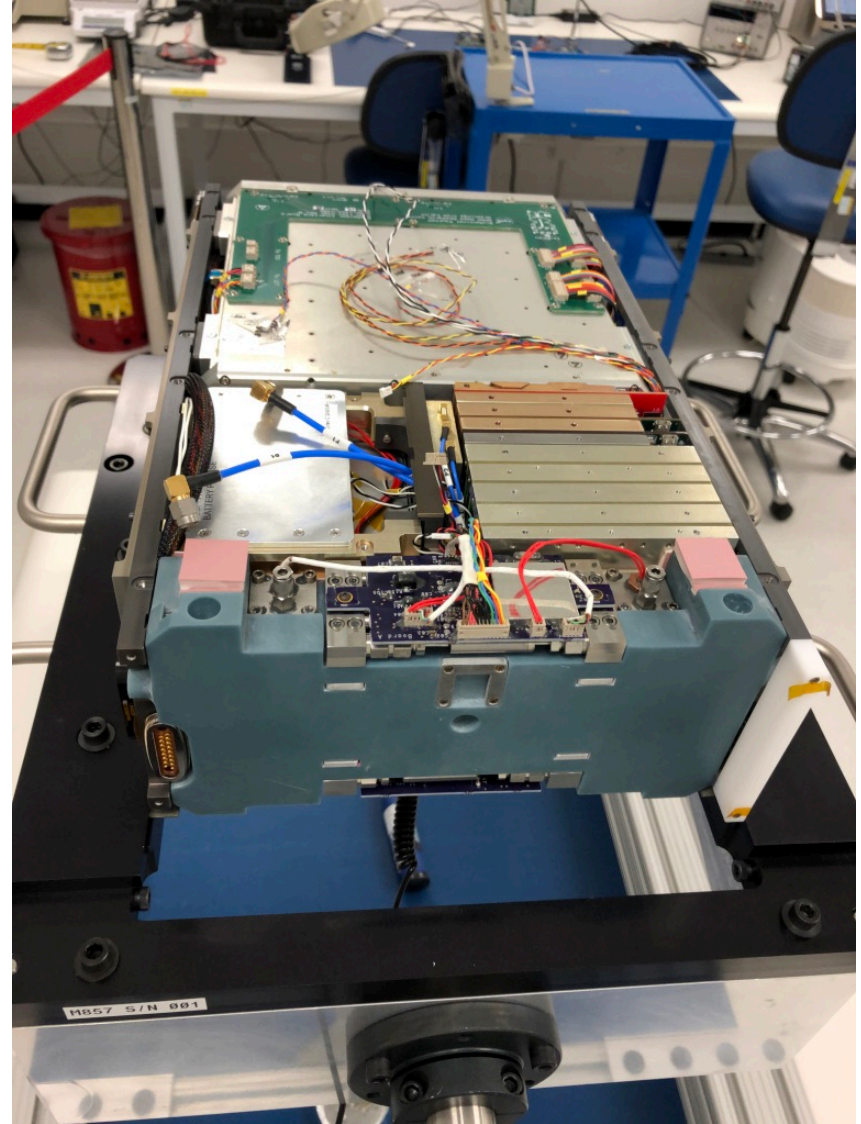
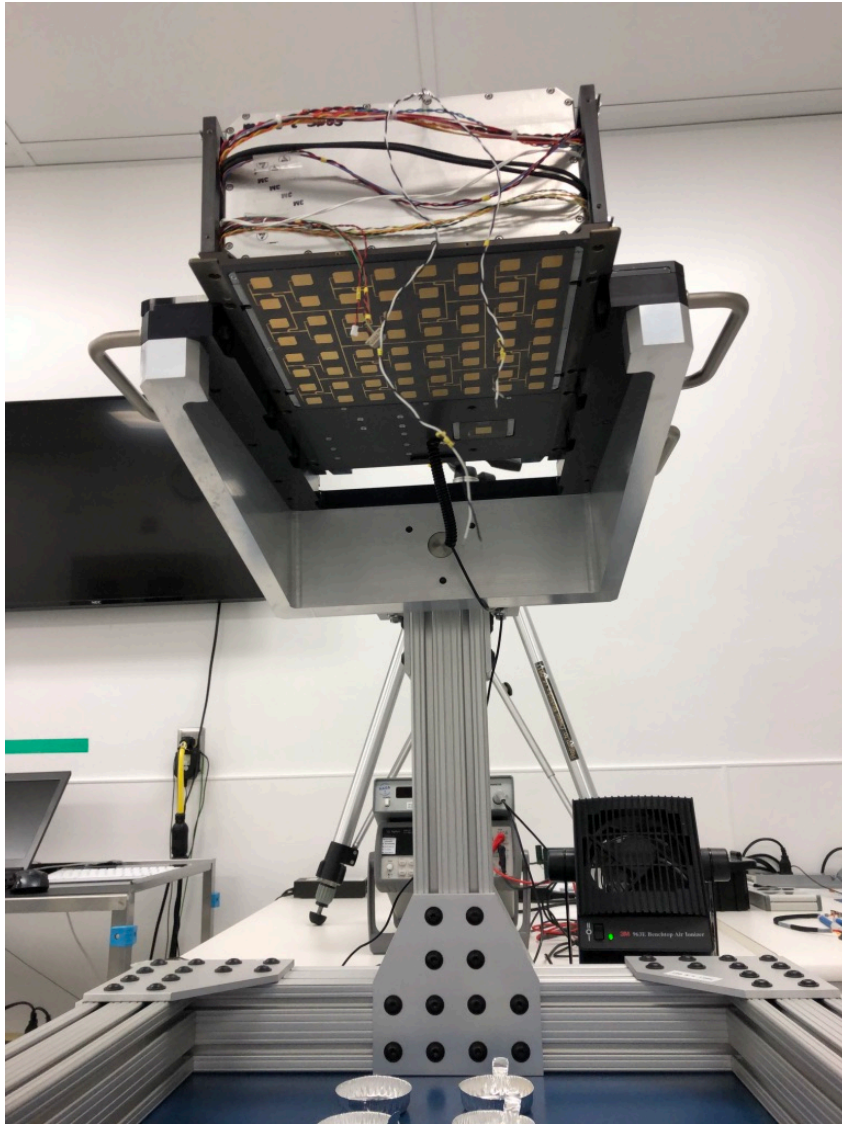


Mechanical Fit Check Progress – Day 9 (11/26/18)



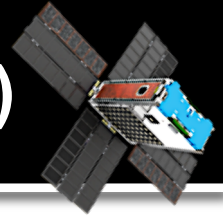
Front - Bottom View

Back View





Mechanical Fit Check Progress – Day 11 (11/28/18)



Front - Bottom View

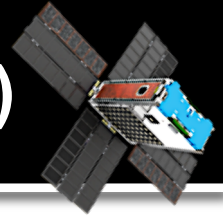


Back View

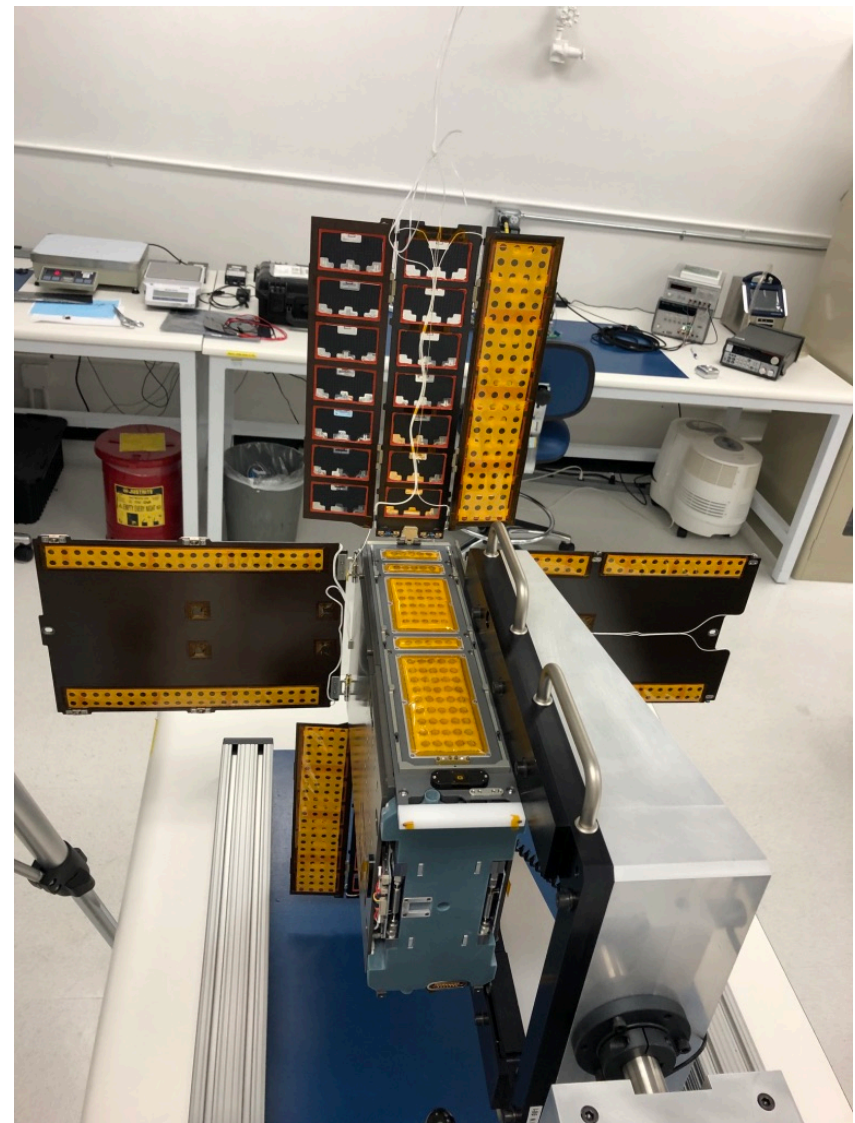
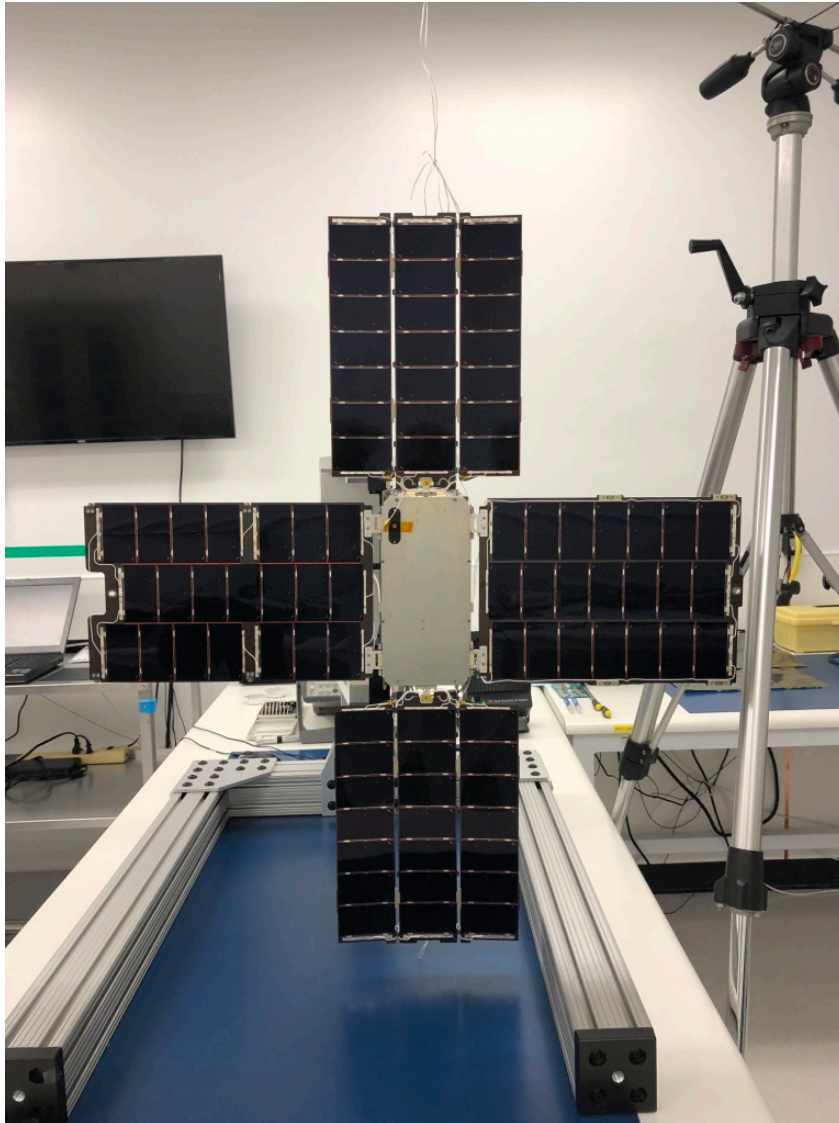




Mechanical Fit Check Progress – Day 12 (11/29/18)

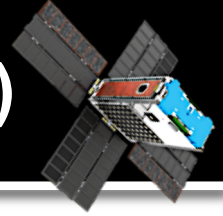


Front - Bottom View Solar Panel Deployed Back View

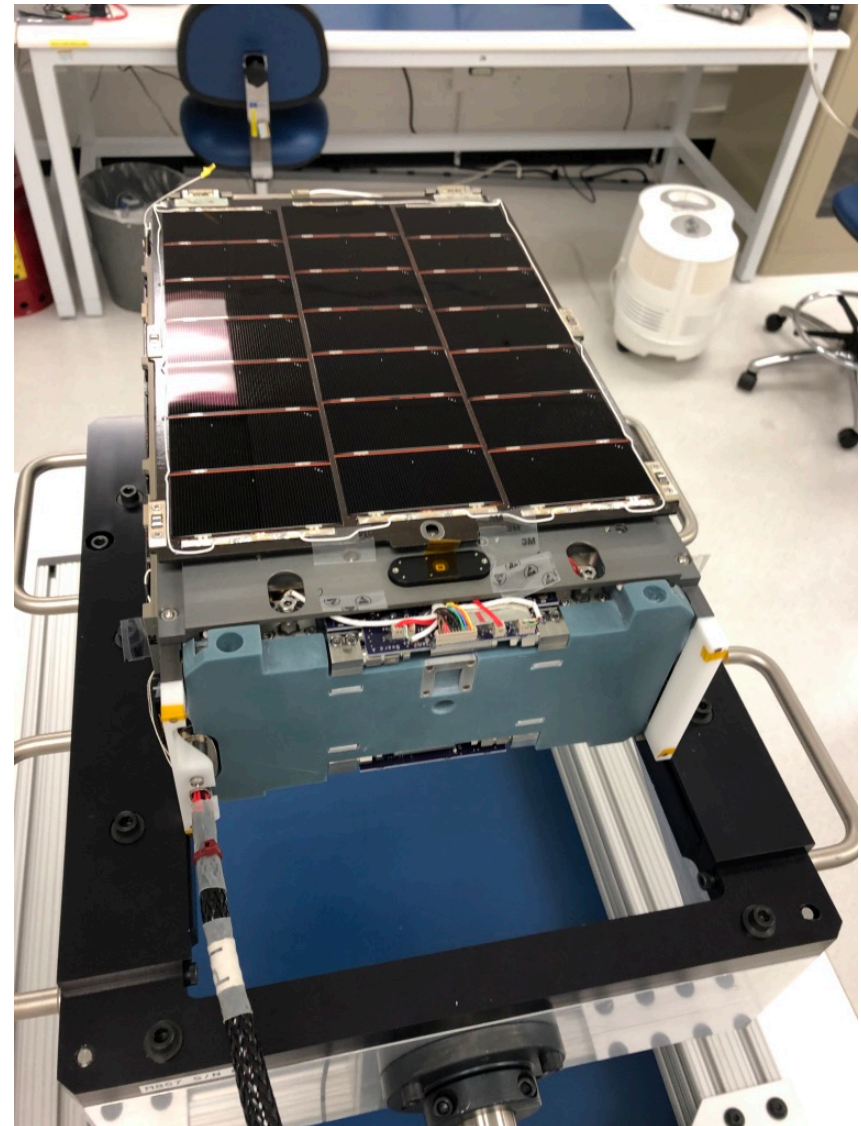
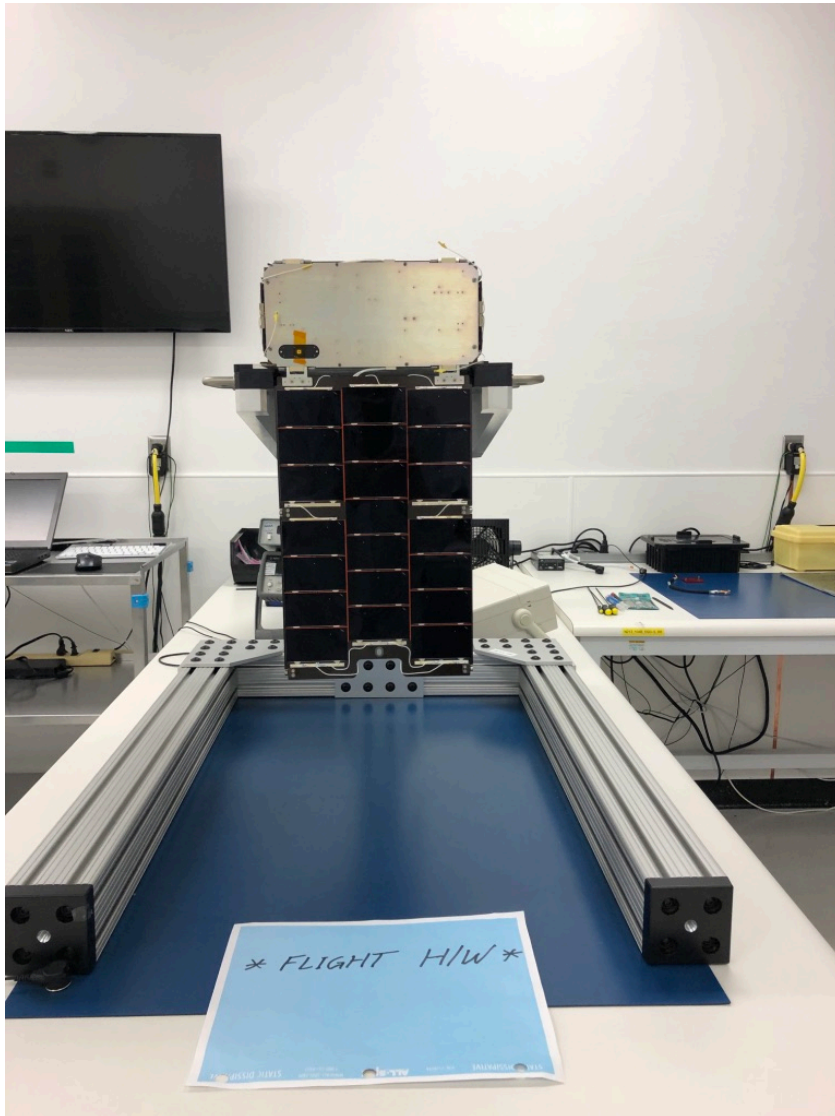




Mechanical Fit Check Progress – Day 12 (11/29/18)

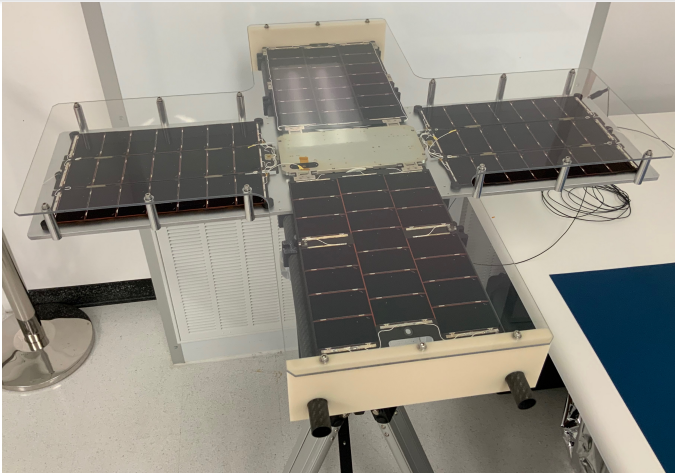
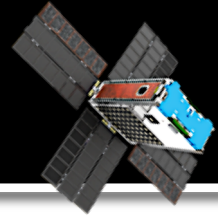


Front - Bottom View Solar Panel Stowed (3 of 4) Back View

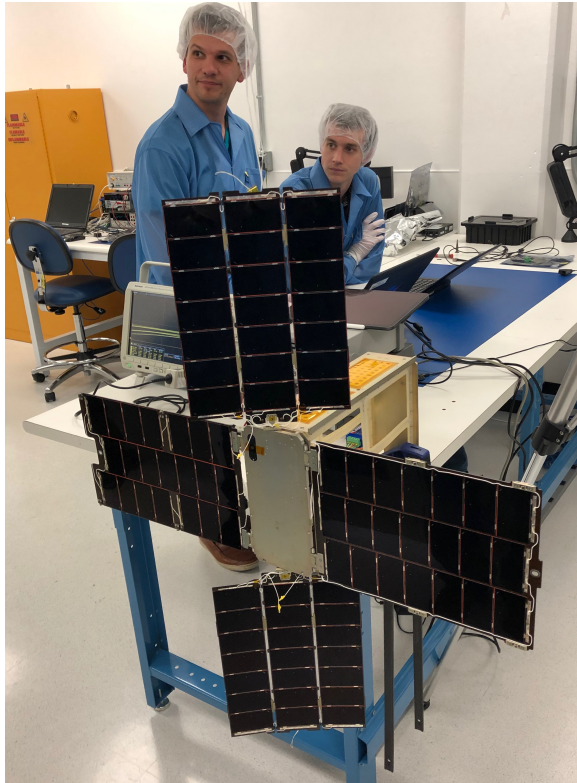




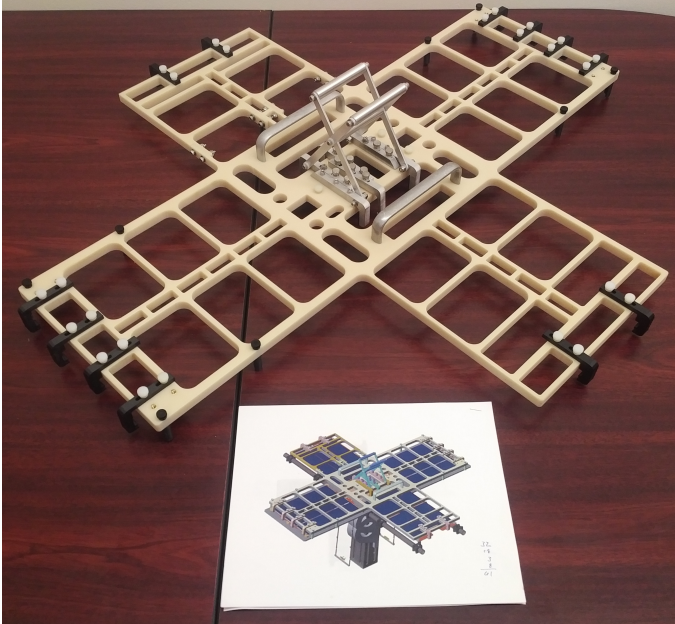
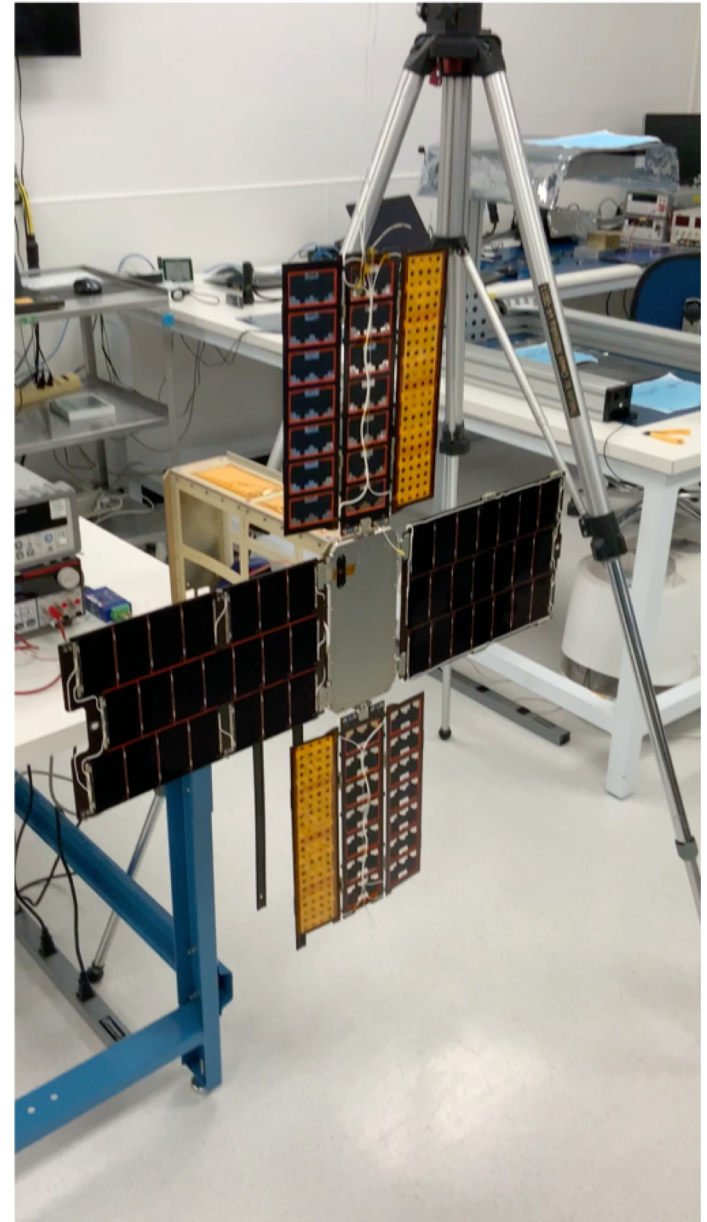
BioSentinel Flight Solar Arrays



Solar Array Support Fixture



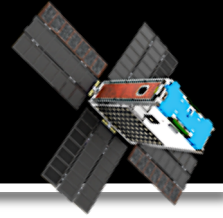
Solar Array Gimbal Testing



Solar Array Grapple Frame Assembly



BioSentinel Back-Up Charts



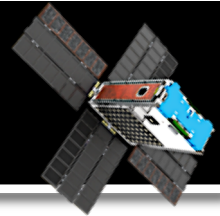
Questions



BioSentinel Leaving Earth



BioSentinel Teaming



- **Mission Management** - Dawn McIntosh, Ben Bradley, Zion Young, Mario Perez, Tara Samuels, Vas Manolescu, Dan Rowan, Mark Shirley Matt D'Ortenzio, Mike Henchske, Nelson Abiva, Bob Hanel, James Chartres, Elwood Agasid
- **Science** - Sharmila Bhattacharya, Sergio Santa Maria, Lauren Liddell, Sofia Tieze, Diana Gentry, Macarena Parra, Tore Straume, C. Mark Ott, Sarah Castro, Greg Nelson, Troy Harkness, Roger Brent
- **Payload** - Tom Luzod, Jeff Homan, Rich Bielawski, Mike Padgen, Lance Ellingson, Dzung Huang, Tony Ricco, Travis Boone, Aaron Schooley,, Dayne Kemp, Eric Tapio, Scott Wheeler, Susan Gavalas, Edward Semones
- **Spacecraft and Bus** – Stephen Walker, Luke Murchison, Terry Stevenson, Jesse Fusco, Philip Shih, Craig Pires, Shang Wu, Abe Rademacher, Josh Benton, Nathan Benz, Rudy DeRosse, Matt Knudson, Matthew Sorgenfrei, Hugo Sanchez

Affiliations

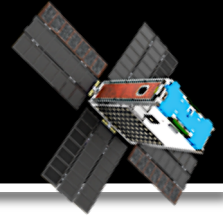
NASA Ames, NASA JSC - RadWorks, Loma Linda University Medical Center (LLUMC), Univ. Saskatchewan

Support

NASA Human Exploration and Operations Mission Directorate (HEOMD); Advanced Exploration Systems Division – Jitendra Joshi - Program Executive.



Acronyms

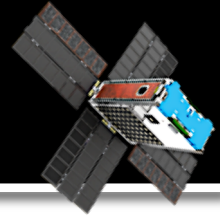


ADCS–Attitude Determination Control System
AES – Advanced Exploration System
BNL – Brookhaven National Laboratory
CR – Continuing Resolution
C&DH – Command & Data Handling
dPM – Deputy Project Manager
EDU – Engineering Development Unit
EM-1 – Exploration Mission One
EPS – Electrical Power System
ER&T-Exploration Research & Technology
ESS – Environmental Stress Screening
EVT - Experiment Verification Test
GSDO - Ground Systems Development & Operations
HR – Hazard Report
IRB - Interface Requirements Baseline (ISS)
ISS – International Space Station
LET - Linear Energy Transfer

LGA – Low Gain Antenna
LLUMC – Loma Linda Univ Medical Center
LOP-G Lunar Orbiting Platform - Gateway
LRD - Launch Readiness Date
LSR – Lightsey Space Research
MGA – Medium Gain Antenna
NET – No Earlier Than
ROM – Rough Order of Magnitude
SABL – Space Automated Biproduct Laboratory
SBC - Single Board Computer
SDL- Space Dynamics Lab (C&DH Boards)
SDP-Safety Data Package
SLS – Space Launch System
SPE – Solar Particle Event
SSTP – Small Satellite Technology Program
TVPM – Thermal Vacuum Power Management
XACT – ADCS Subsystem



BioSentinel – I&T Accomplishments & Activities



- **Remove BioSentinel Payload EDU**
 - Operate 1 bank of Payload, take apart and inspect
- **Reassemble with new BioSentinel Payload EDU and functional tests**
 - Some anomalies required rework, others judged to be acceptable for EDU TVPM
- **Spacecraft Engineering Development Unit (EDU) Thermal Vacuum Power Management (TVPM) Test**
 - TVPM plan is to run the timeline (below), 24/7 test planned for 14 days.
 - As delays pushed us closer to the Holidays we ran the Pump Down (PD) through 1st Thermal Cycle (C1) and then Vented (V) leaving the chamber powered off and at ambient conditions
 - This occurred 12/15 thru 12/20/18
 - After a Team quorum returned from the Holidays the chamber was pumped down again, the final 3 thermal cycles were run and chamber vented.
 - This occurred 1/3 thru 1/8/18
 - Spacecraft EDU returned to clean room and major subsystems disassembled and for inspection and some additional anomaly testing

