



National Aeronautics and Space Administration

SPORESAT

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Project Manager
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May 30, 2014



HUMAN EXPLORATION

NASA's Path to Mars



EARTH RELIANT

MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS



Mastering fundamentals
aboard the International
Space Station

U.S. companies
provide access to
low-Earth orbit

www.nasa.gov

PROVING GROUND

MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS



Expanding capabilities by
visiting an asteroid redirected
to a lunar distant retrograde orbit

The next step: traveling beyond low-Earth
orbit with the Space Launch System
rocket and Orion spacecraft



MARS READY

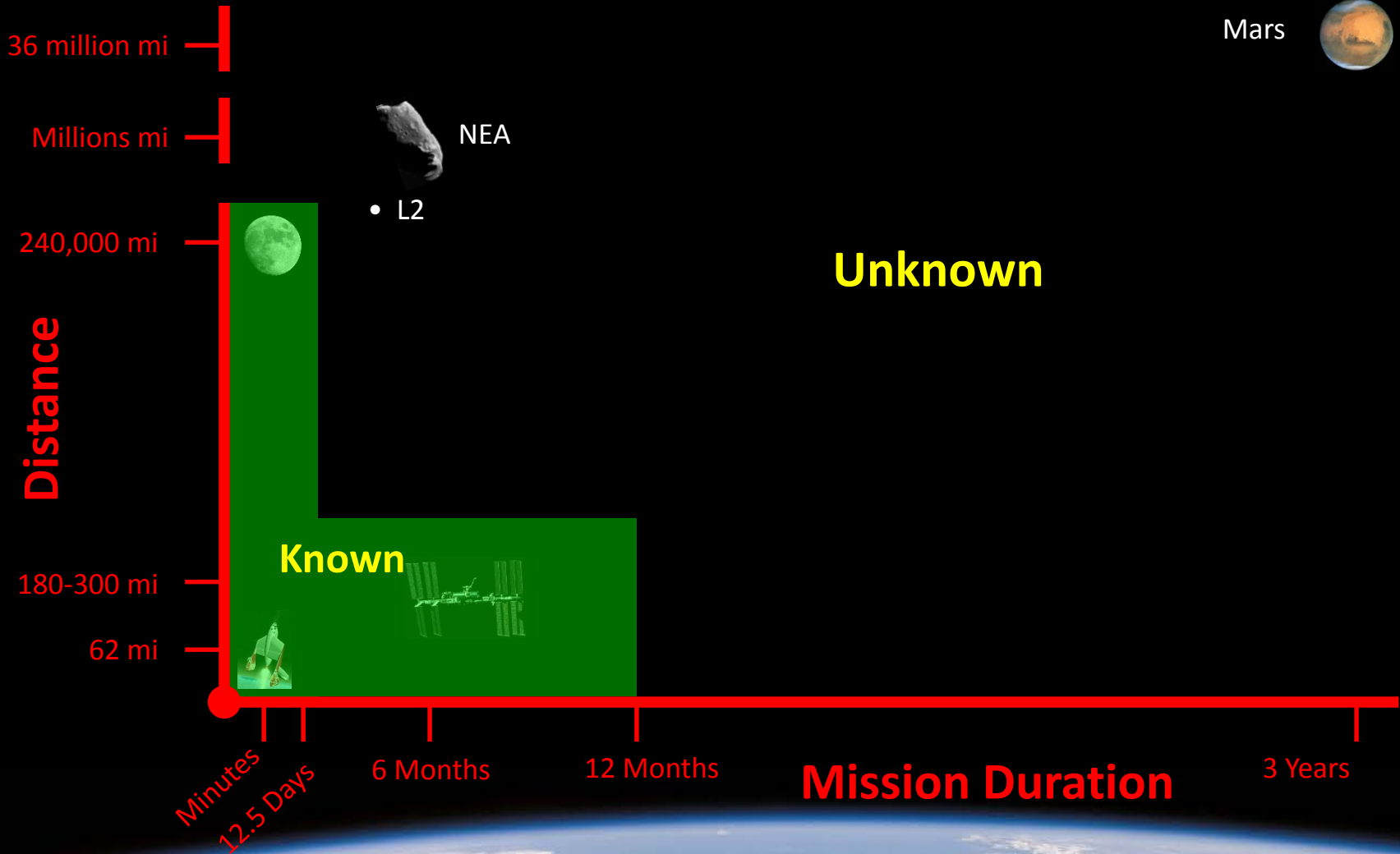
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS

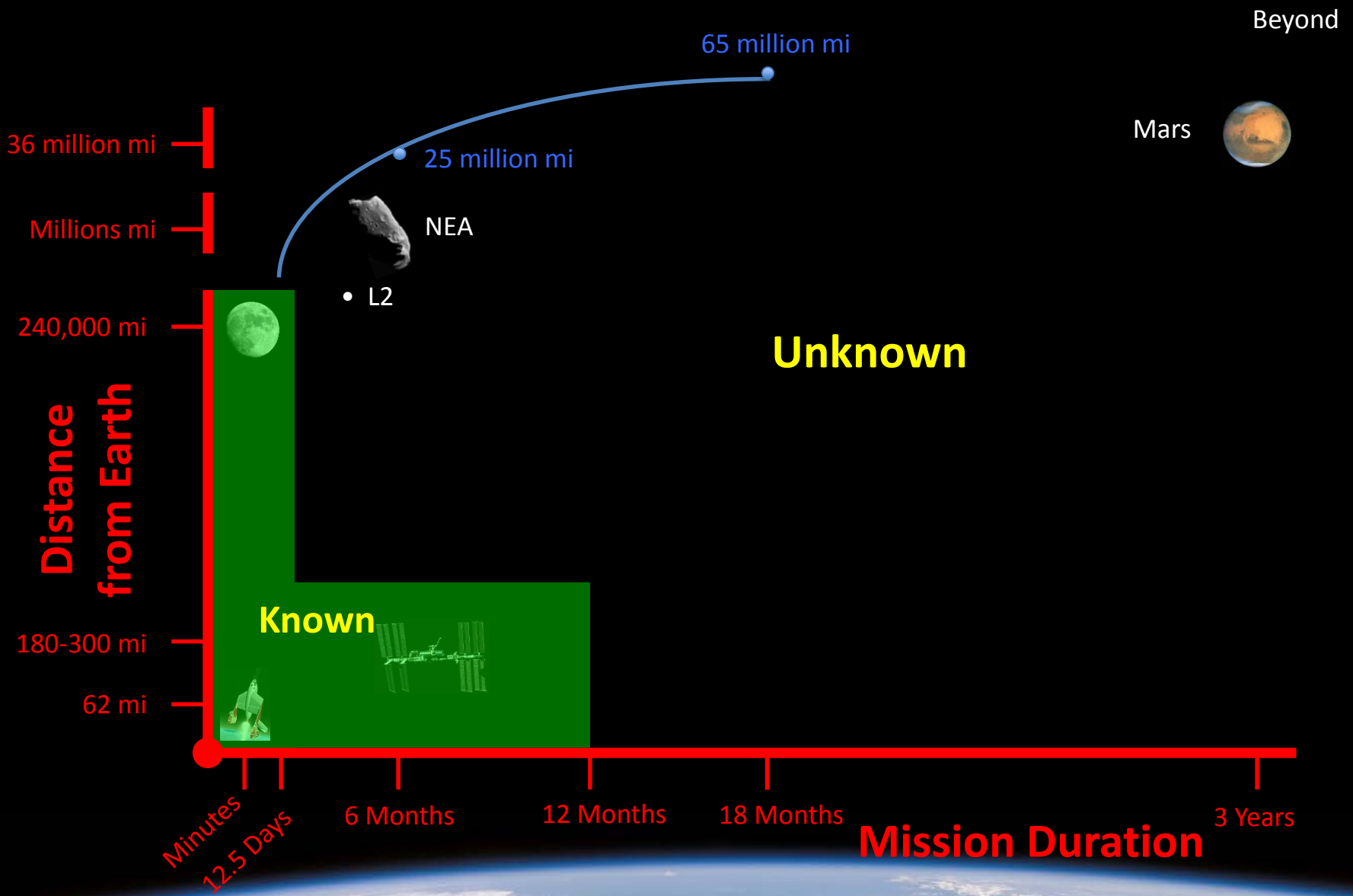


Developing planetary independence
by exploring Mars, its moons and
other deep space destinations

Why Study Space Biology?

The limit of life in space, as we know it, is 12.5 days on a lunar round trip and 1 year in LEO. As we send people further into space, we have to use other organisms to understand the biological risks and how they can be addressed.





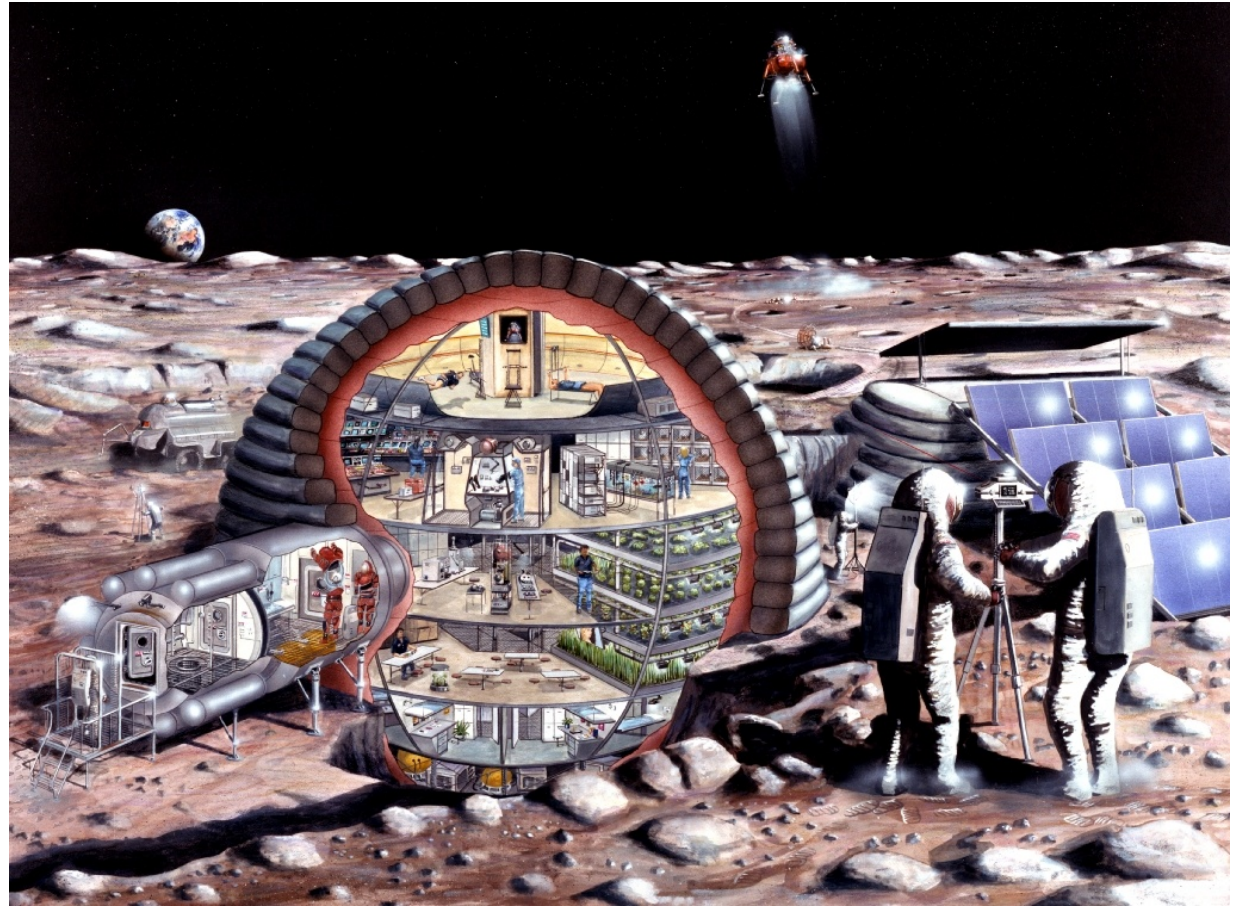


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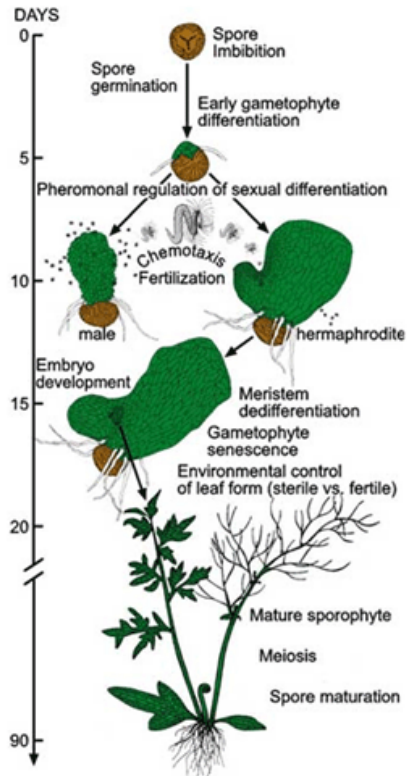
Motivation

If humans are going to live in space or on the moon, we need to understand the basic biological effects of lower gravity—not only on our own bodies, but on plants that may be used for food or to help clean the air or water in a life support system.



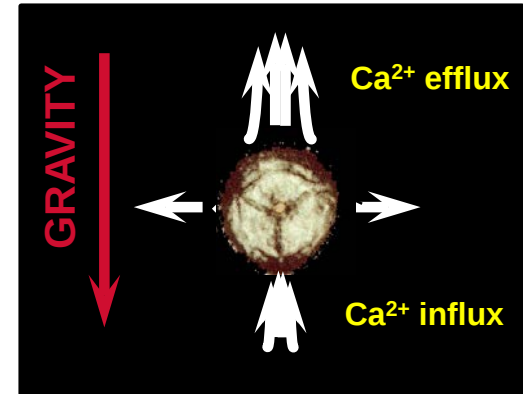
Background

Biologists have studied for decades, through hypothesis and experiment, how certain plants and their spores sense and respond to gravity.

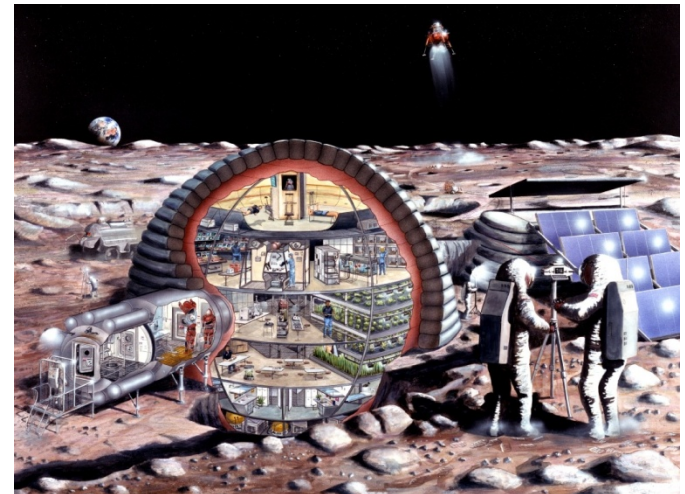


Spores of the fern *Ceratopteris richardii* are among the most studied.

But they have not yet been studied in the microgravity environment of outer space, nor across a range of gravity levels lower than Earth's -- like gravity fields equivalent to the Moon or Mars.



One spore of the fern *Ceratopteris richardii*.
It's 2 – 3x the diameter of a human hair.





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Introduction

Project Overview: SporeSat is a fundamental space biology science space mission to investigate biophysical mechanisms of plant gravity sensing using a “lab-on-a-chip” experimental approach. The unicellular germinating *Ceratopteris richardii* fern spore will be studied in outer space.

Science Objective: SporeSat shall determine gravity thresholds for calcium ion (Ca^{2+}) channel activation in wild-fern spores.

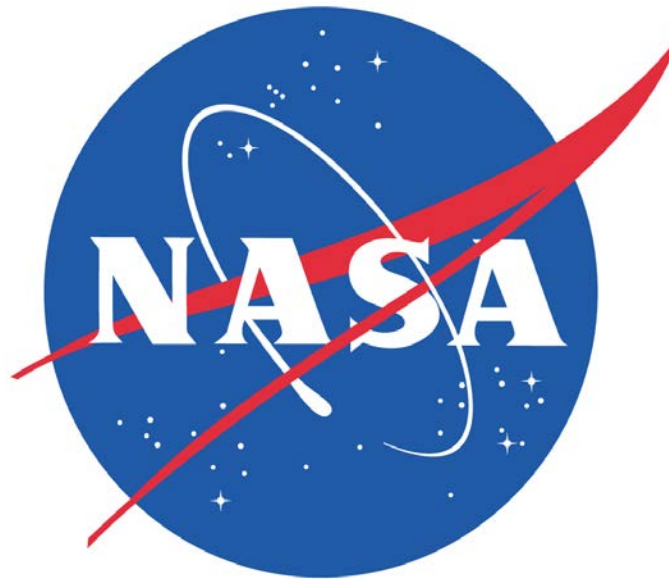
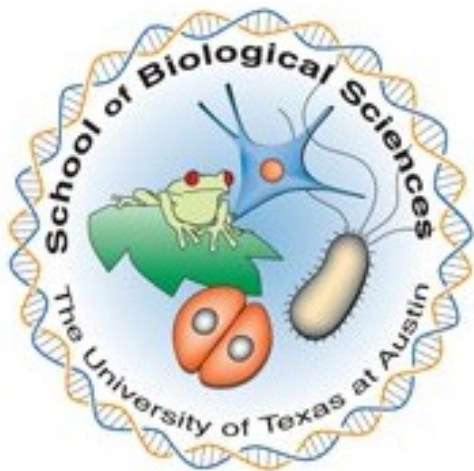
Why This is Important: Ion channels are critical to the functioning of biological organisms, including humans. Ion channels are key components of the nervous system as well as cardiac, skeletal, and smooth muscle function, transport of nutrients and ions, T-cell activation, and pancreatic beta-cell insulin release. *Ion channels are often the target of the search for new drugs.*



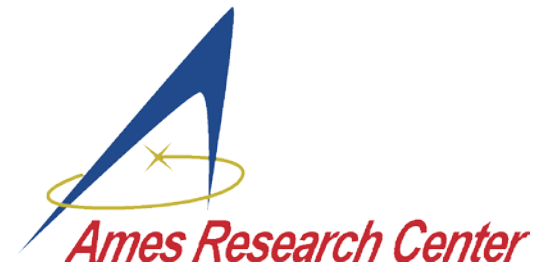
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NASA and Academia Collaboration



ELaNa
Educational Launch of Nanosatellite







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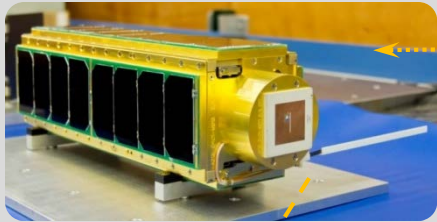
Mission Data Architecture



SpaceX-3 (Falcon 9)
Cape Canaveral, FL
April 14, 2014
325 km circular orbit

Launch

SporeSat



UHF for early
ops and E/PO



S-band
Primary
2-way Comm.



Santa Clara University Mission Operations Center (MOC)

Ground Communications



Principal Investigators
and Co-I

Ground Control
Experiment

S/C Health

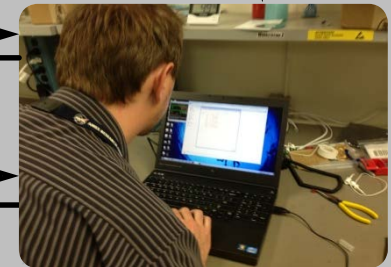
Science Data

Processed
Science Data

Data Request
& Ops
Concurrence

S/C Health & Status

Data Request



(Virtual) Science Operations Center
(vSOC)

Science Operations

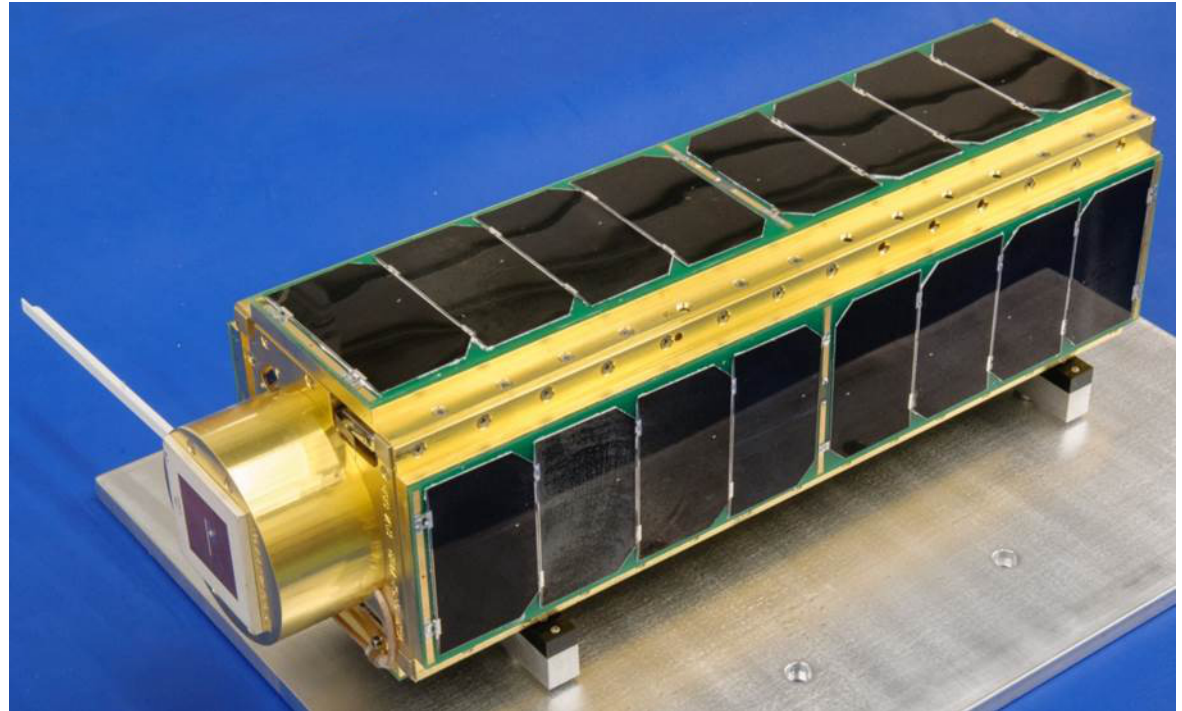


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3U Spacecraft Overview

Ames standard 3U
design leveraging
heritage spacecraft
components from
PharmaSat,
O/OREOS, and
GeneSat missions.





Exploded View Spacecraft

1. Solar Body Panels 4ea.

2. Close Out Panel

3. Bus Interface PCB

4. Front Panel Assembly

5. Hermetic Enclosure

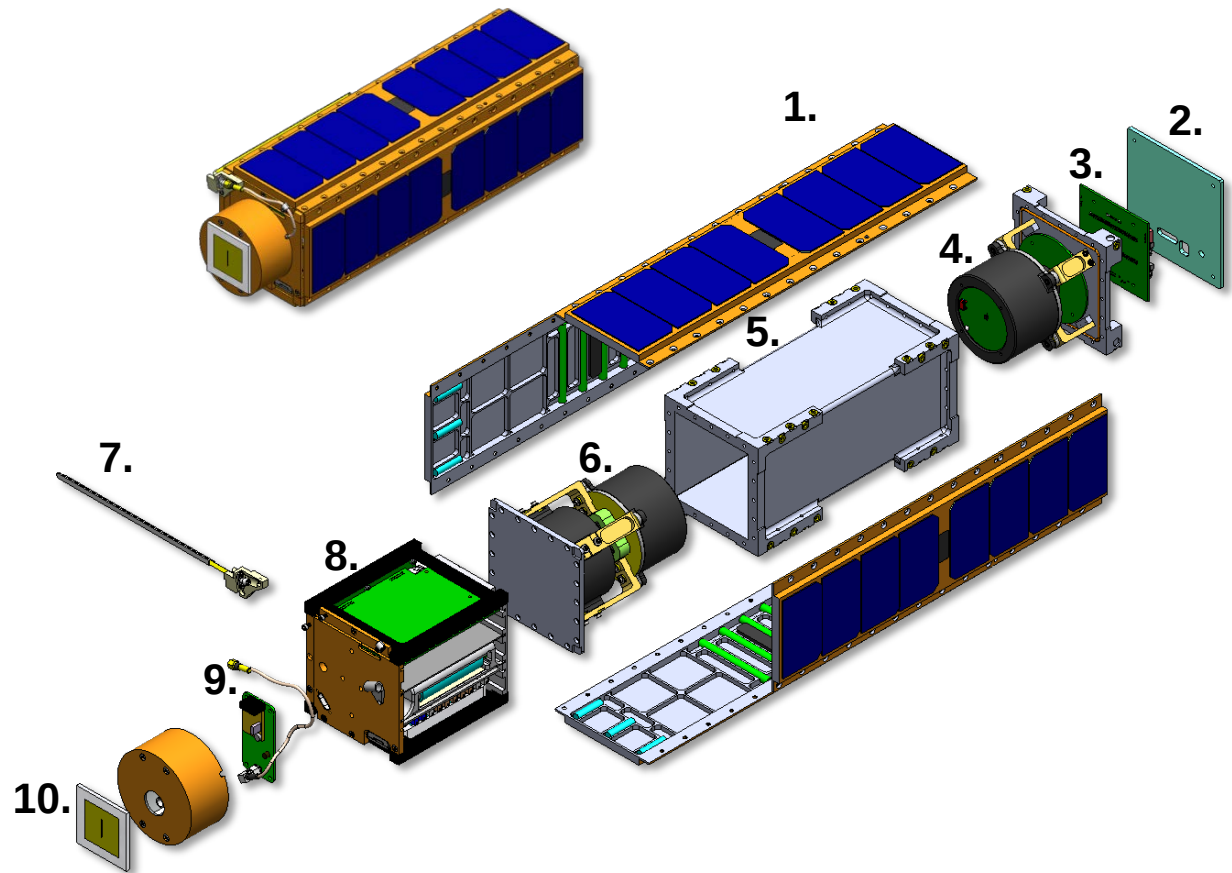
6. Back Panel Assembly

7. Transponder Antenna

8. Avionics Bus

9. Transponder PCB

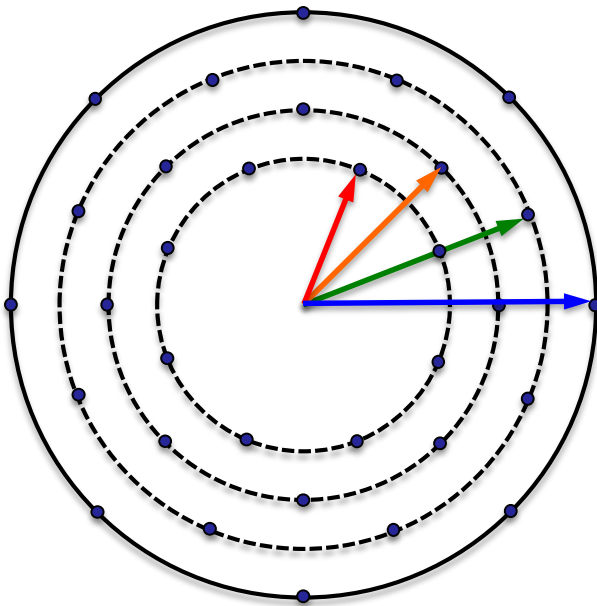
10. Patch Antenna



Centrifugal Gravity on bioCD

$$g = \frac{R}{9810} \left(\frac{\pi}{30} \omega \right)^2$$

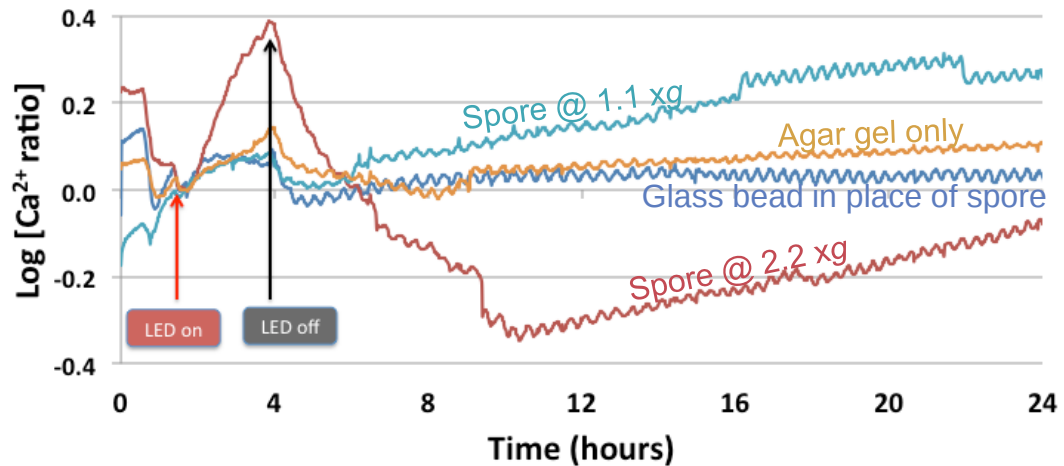
- g: decimal fraction of Earth gravity
- R: radius from rotation axis (mm)
- ω : rotating speed (rpm)



32 spores - 8 spores at each radii

Rotation rate		Gravity at R (mm)			
(rpm)	(Hz)	R ₁ =9	R ₂ =12	R ₃ =15	R ₄ =18
80	1.38	0.06 x g	0.09 x g	0.11 x g	0.13 x g
112	1.87	0.13 x g	0.17 x g	0.21 x g	0.25 x g
158	2.63	0.25 x g	0.34 x g	0.42 x g	0.50 x g
223	3.72	0.50 x g	0.67 x g	0.83 x g	1.00 x g
315	5.25	1.00 x g	1.33 x g	1.66 x g	2.00 x g

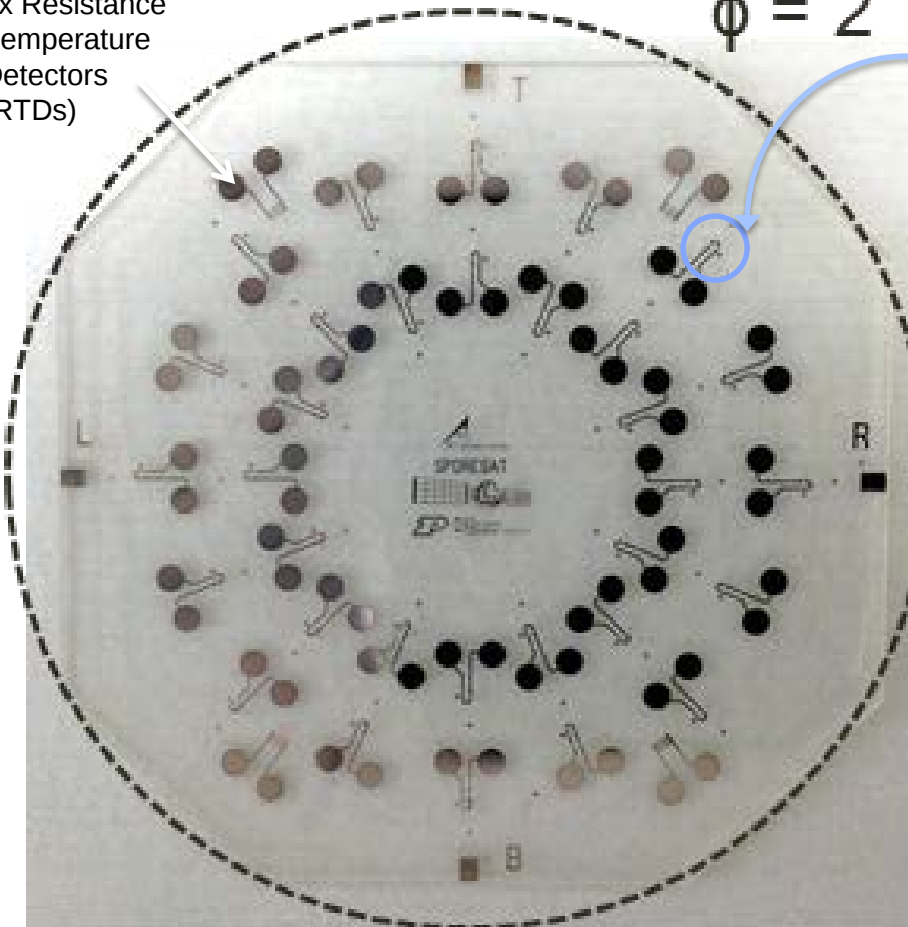
Measured Response of Fern Spores during Ground Testing



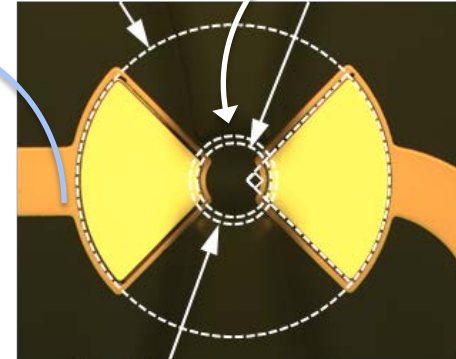
Biology Compact Disc (bioCD)

4x Resistance Temperature Detectors (RTDs)

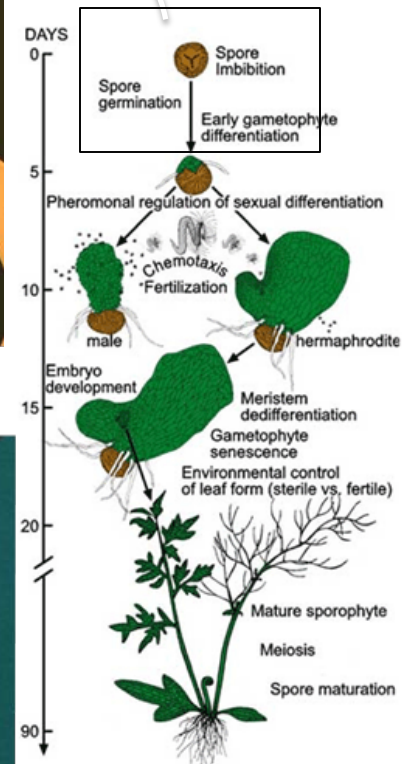
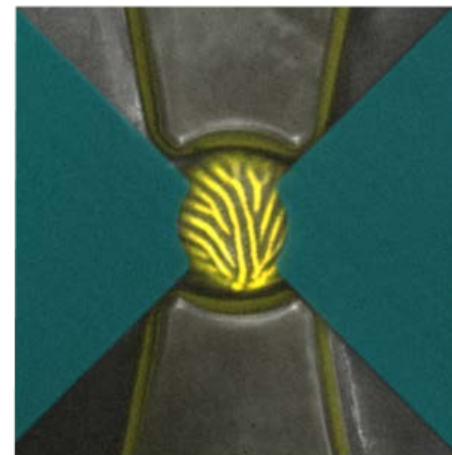
$\phi = 2''$



$r = 230\mu\text{m}$ $r = 50\mu\text{m}$



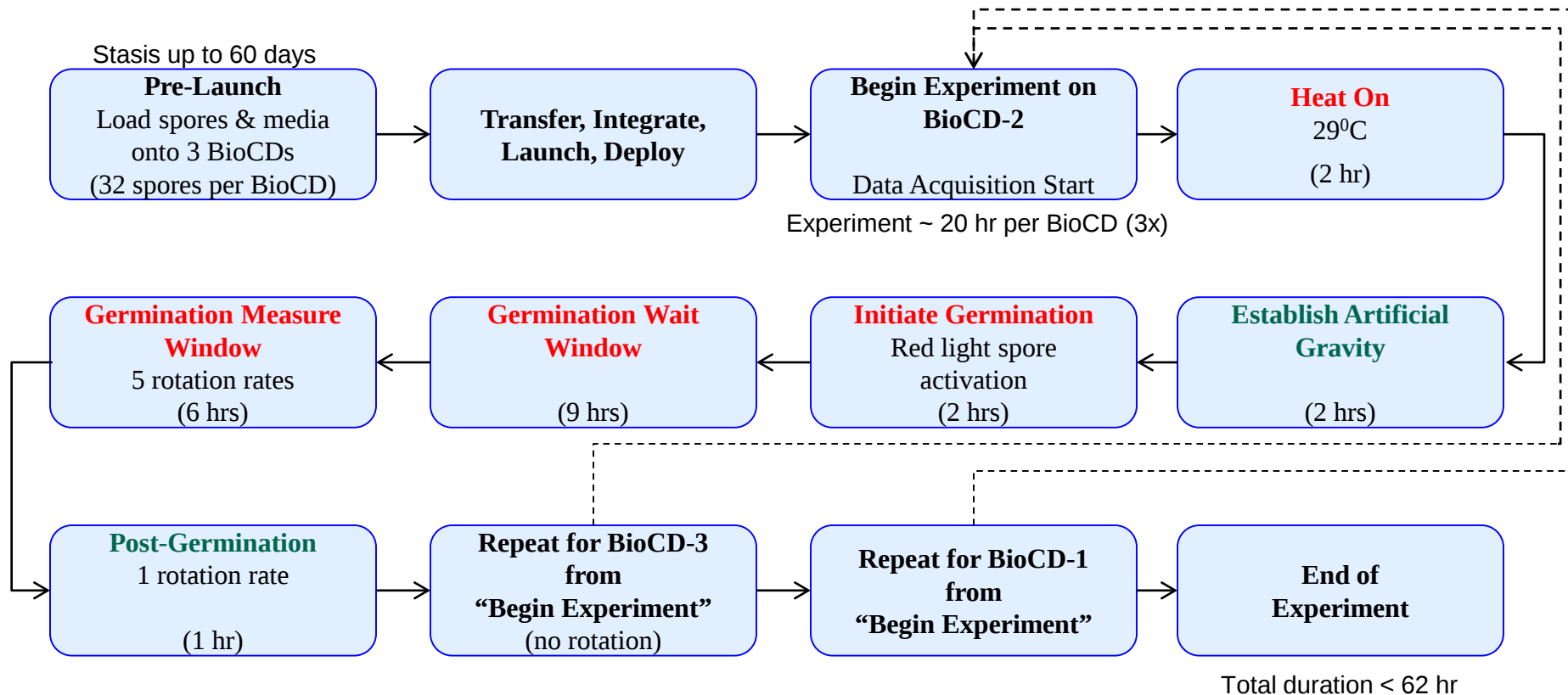
$\phi = 126\mu\text{m}$



32 pairs of Silver – silver chloride Electrodes with Ca Ion Selective Membrane (ISM)



Experiment Protocol

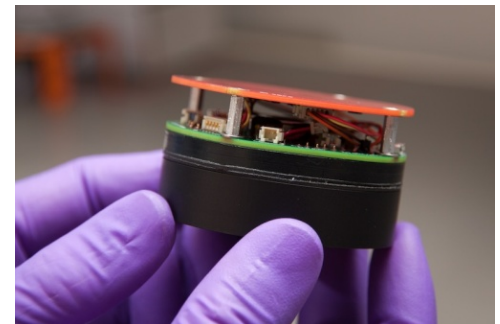
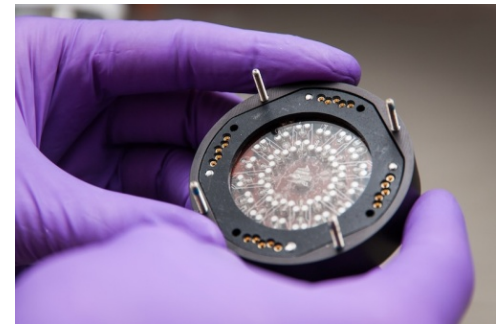
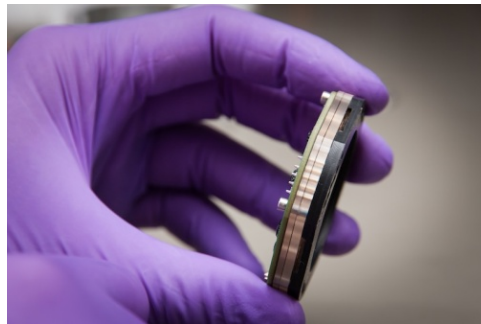
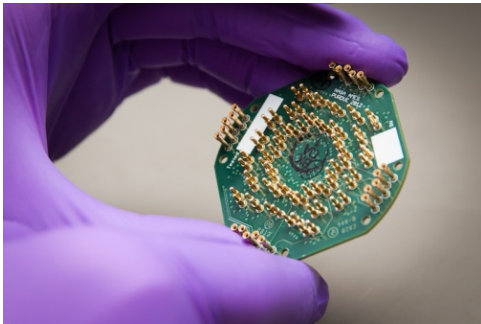
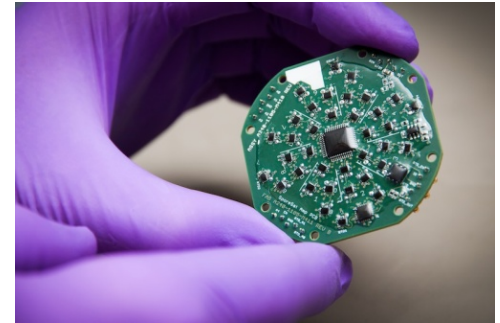
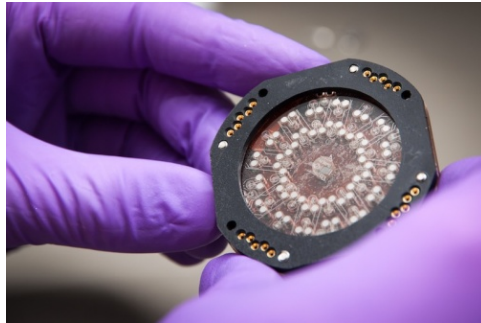
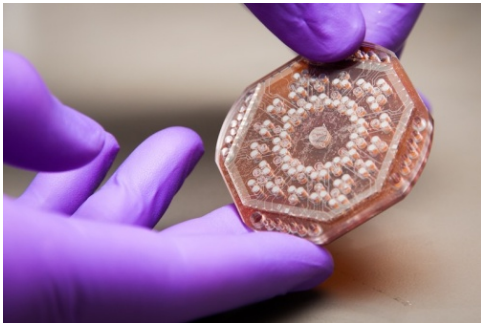




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Assembling bioCD Measurement Electronics

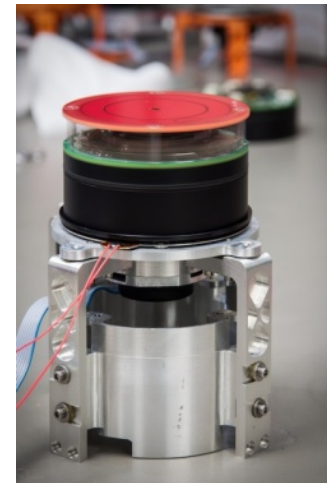
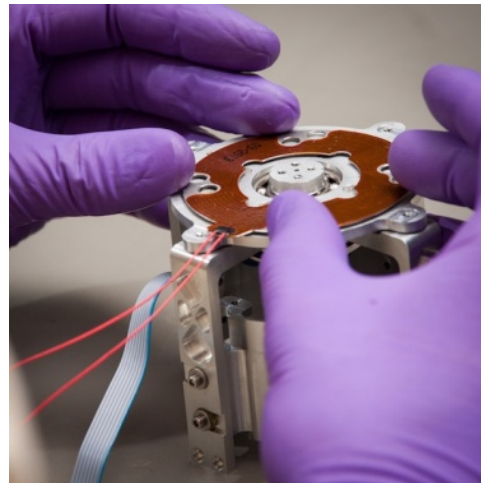
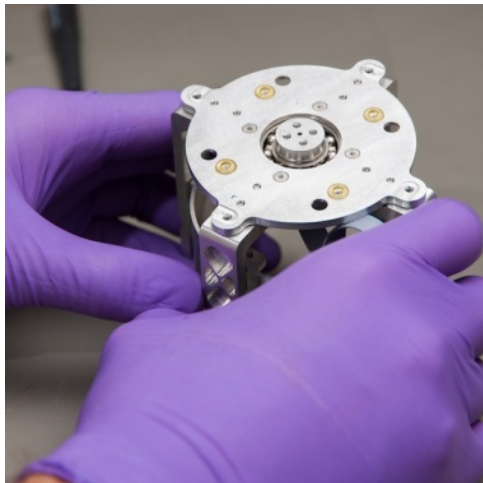
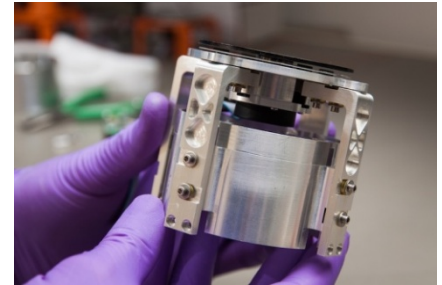
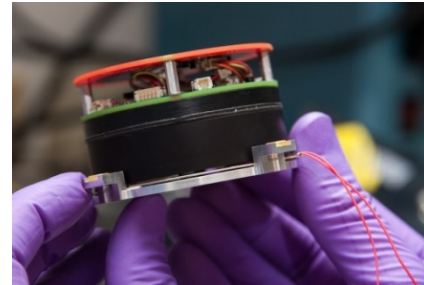
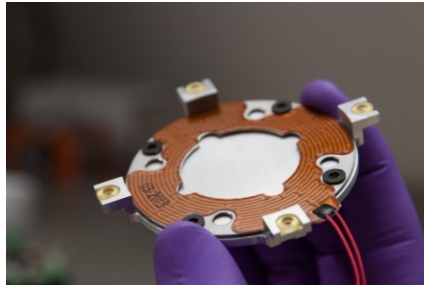




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Integrating bioCD Rotating Assy. & Motor

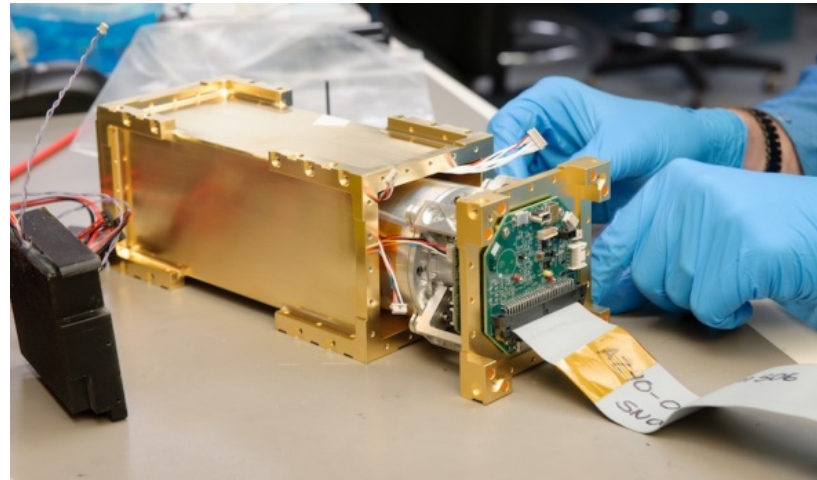
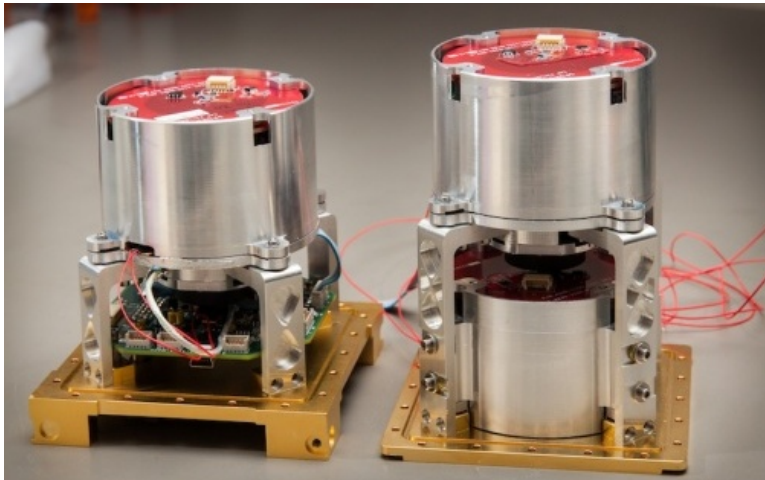
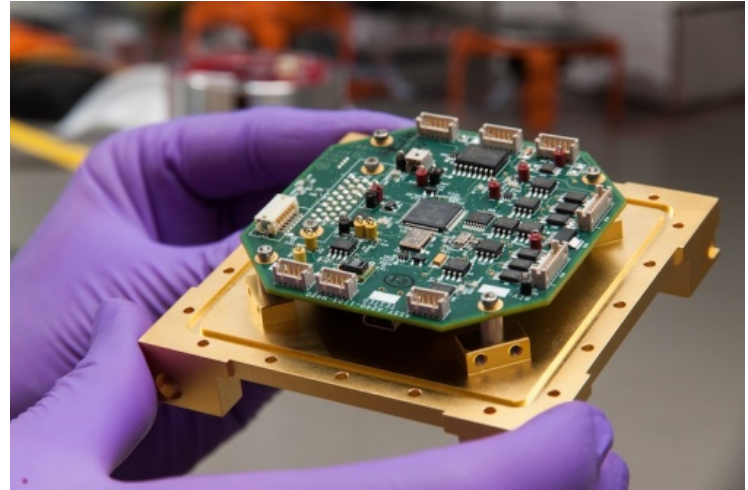
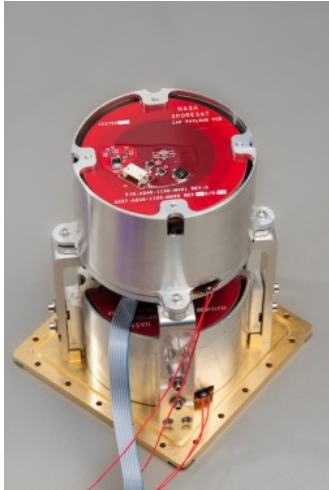




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Integrating bioCD/Motor in P/L Vessel





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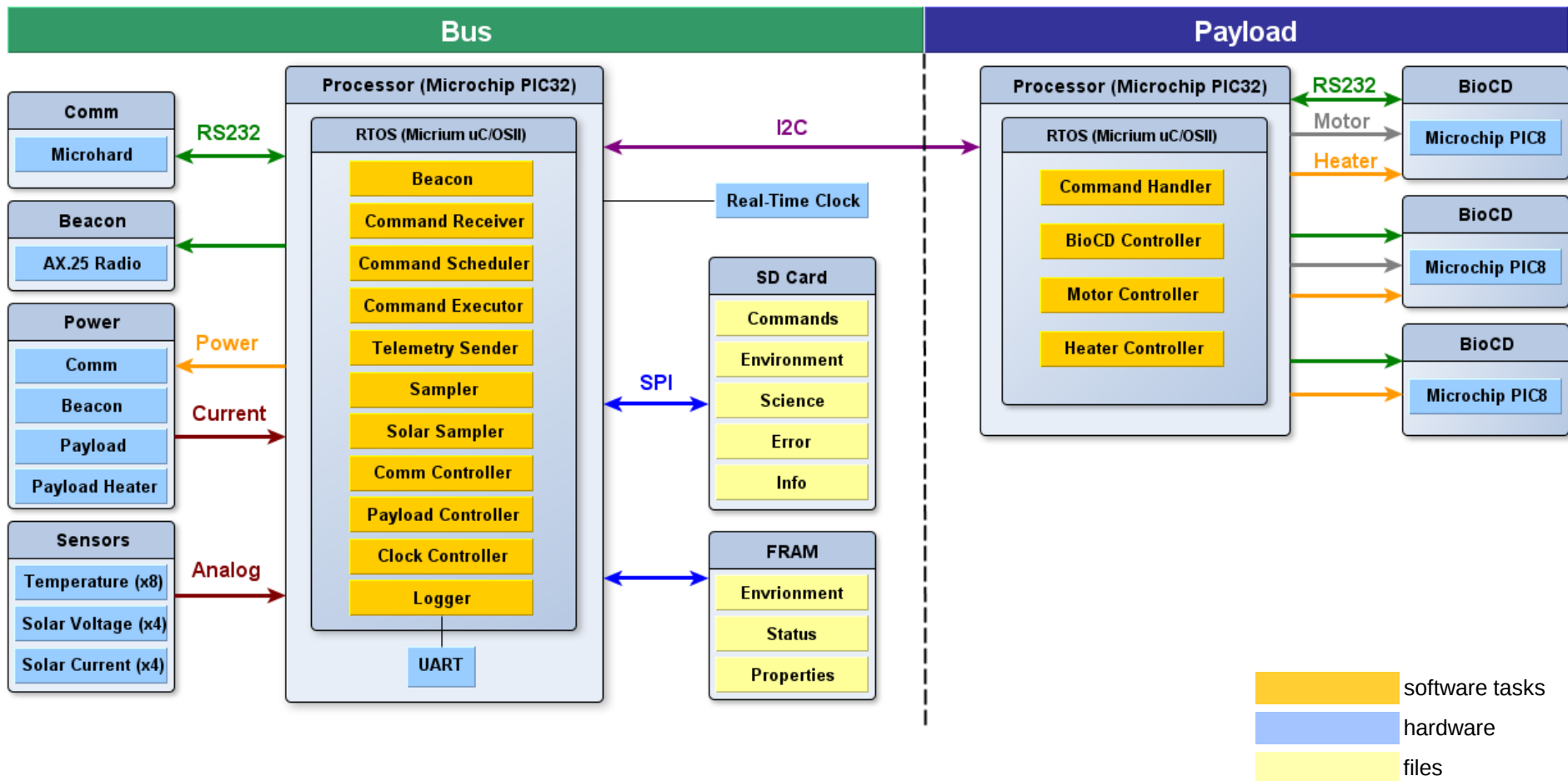


Avionics Bus

- **Three main PCBs – EPS, C&DH, and Backplane**
- **Leveraging heritage from previous missions... but now:**
 - Faster CPU - PIC32
 - RTOS Micrium μ C/OS-II
 - Memory microSD (2GB), and 3Mbit FRAM
 - Self tracking ICs on every PCB
 - One-wire interface
 - 5 line switches for payloads (2A each)
 - Bus draws less than 50mA (without radios)
 - 2 radios - 1 Microhard 2420, 1 Stensat beacon
 - Passive attitude control magnet and hysteresis rod
 - Fixed body mounted triple junction solar panels
 - 80 Watt hours of Battery



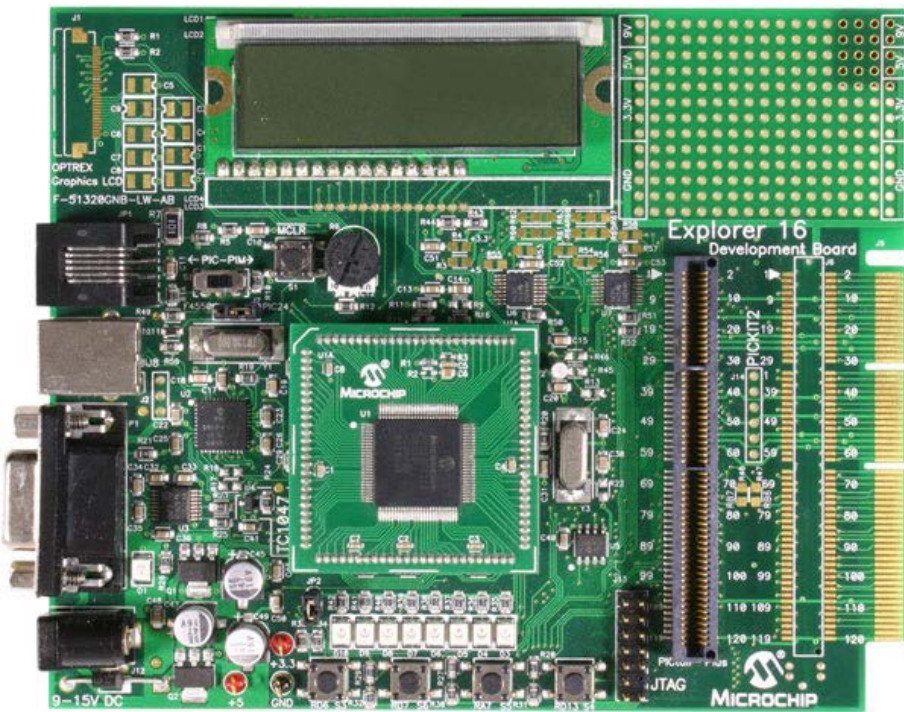
Flight Software



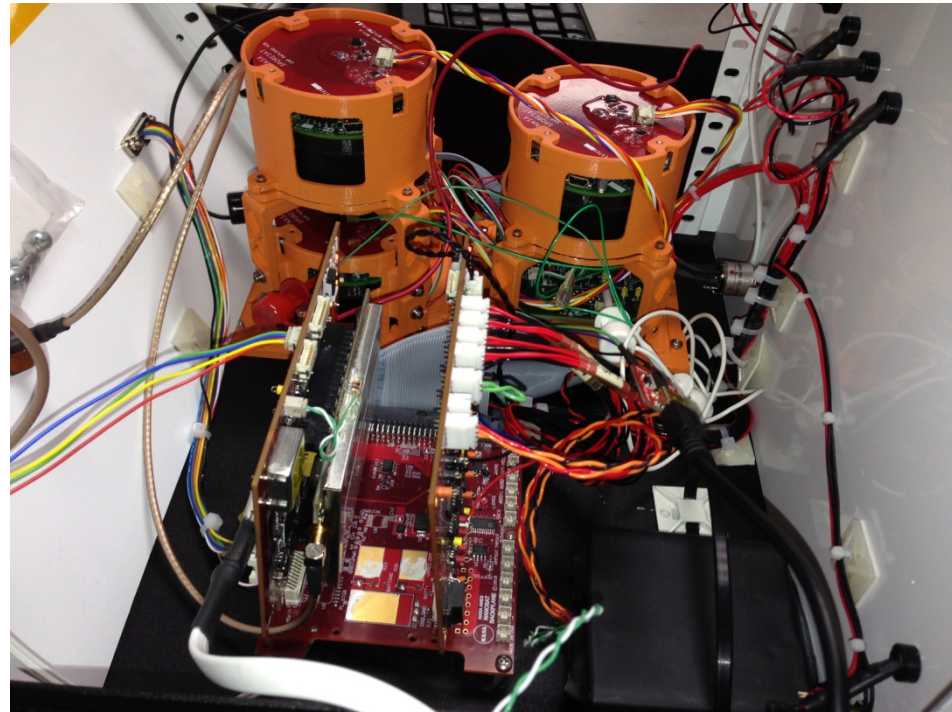


Software Development

Developed using Explorer 16 board first, then ported to EDU practically overnight!



Explorer 16 Development board



SporeSat - Engineering Development Unit (EDU)



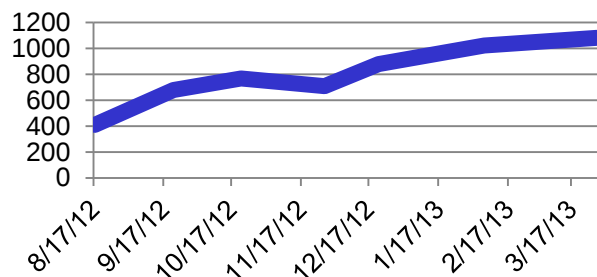
Software Engineering

- **Subversion**: Configuration management of documents and code
- **Jira**: Issue tracking and management
- **Virtual Box**: Consistent development environment
 - **PC-Lint, Uncrustify**: Static analysis and formatting
 - **Python**: Test harness. Build and test preparation
 - **MPLAB X**: Development environment
 - **Unity**: Test framework
 - **Doxygen**: Documentation tool. Captures detailed design
 - **yEd**: Drawing tool
- **Target hardware**: Flight hardware and Explorer 16 board

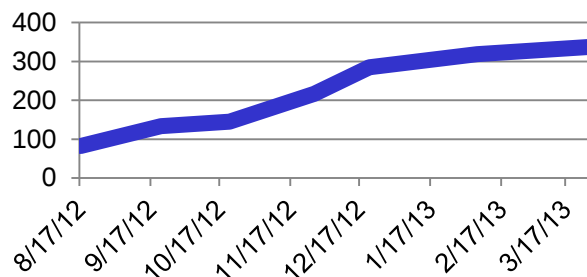


Software Metrics and Margins

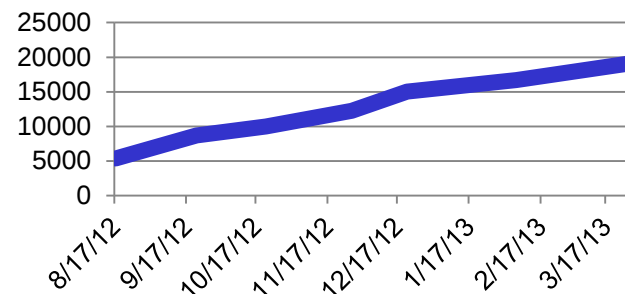
Doxygen Pages



Test Cases



Lines of Code



Resource	Margin
CPU utilization	17%
RAM	74%
Flash memory	79% (35% for COTS file system)

Sub-system	Design	Ported to prototype	Ported to flight-like EDU	System test
Bus	✓	✓	✓	✓
Payload	✓	✓	✓	✓
Master PCB	✓	✓	✓	✓

✓
○

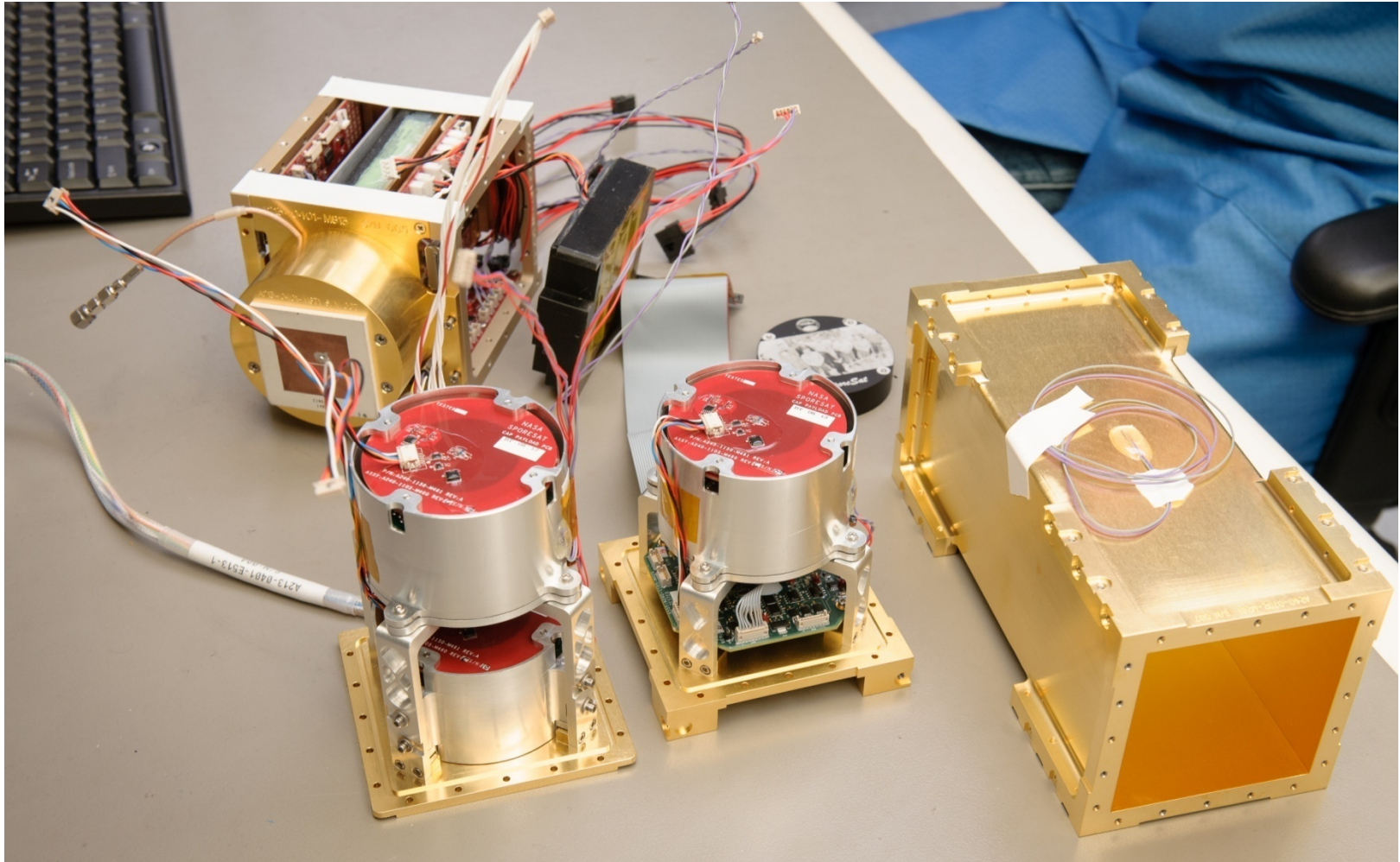
(> 90%. Remaining tasks captured in Redmine.)
(Captured in Integrated Master Schedule.)



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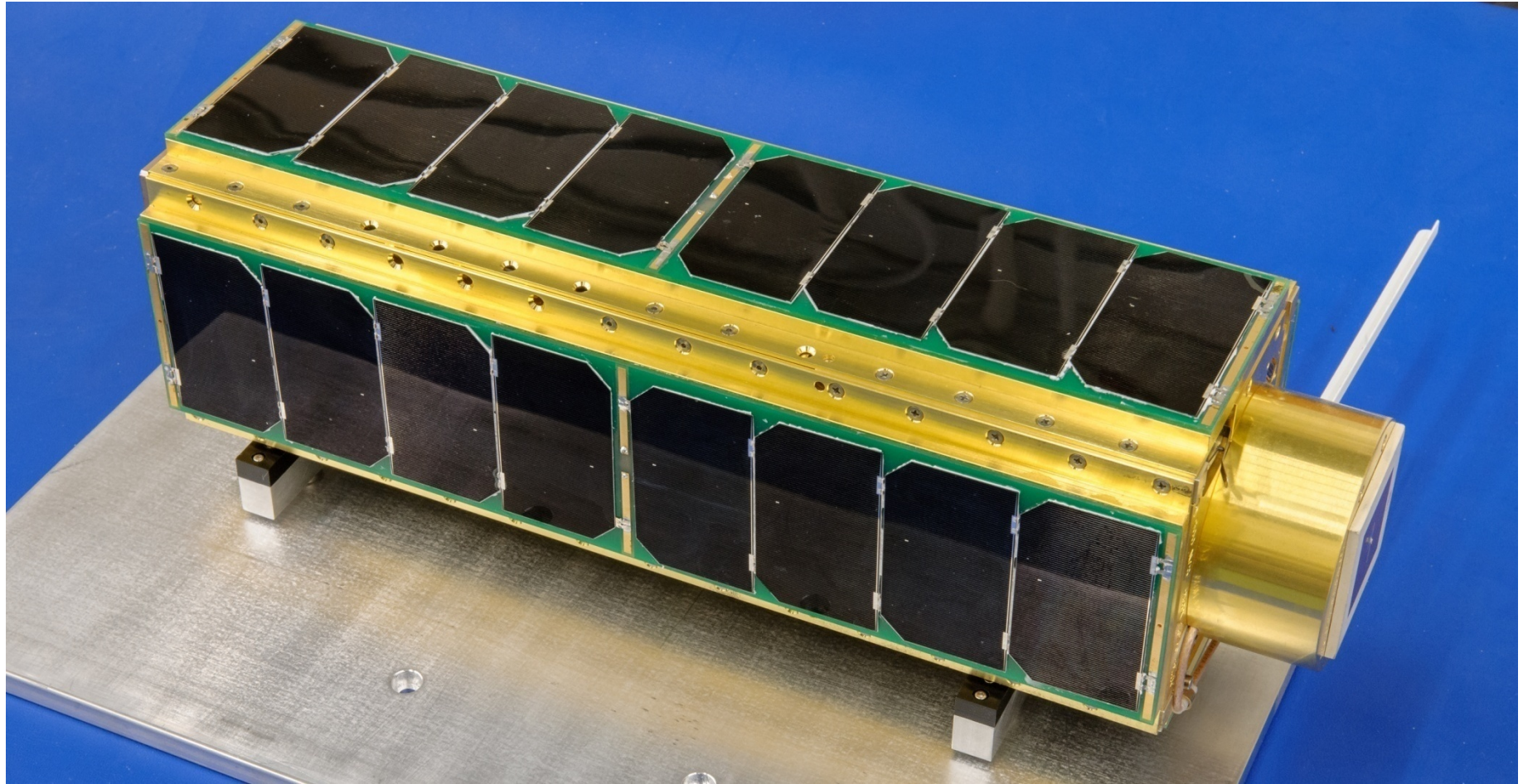


Ready for Integration





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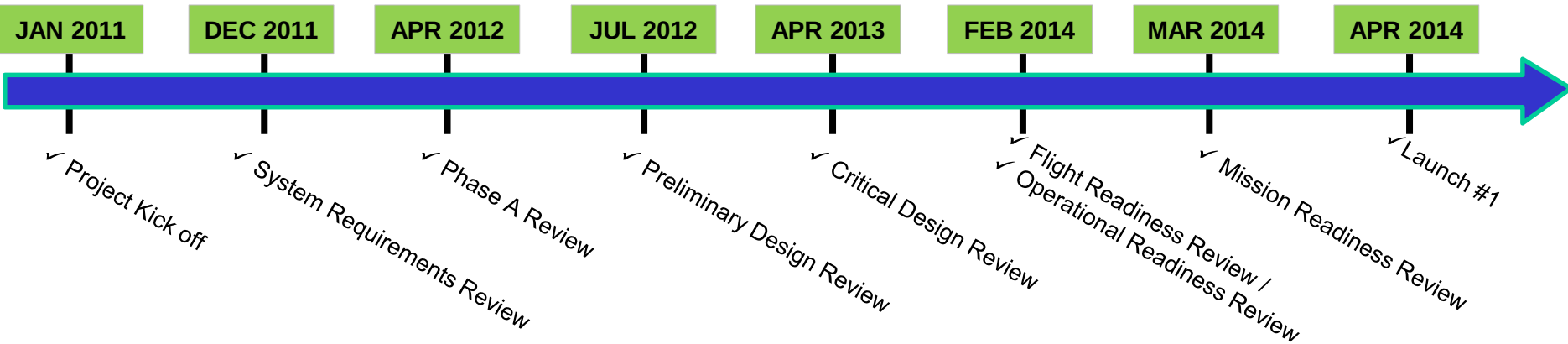
SporeSat-1



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Project Milestones



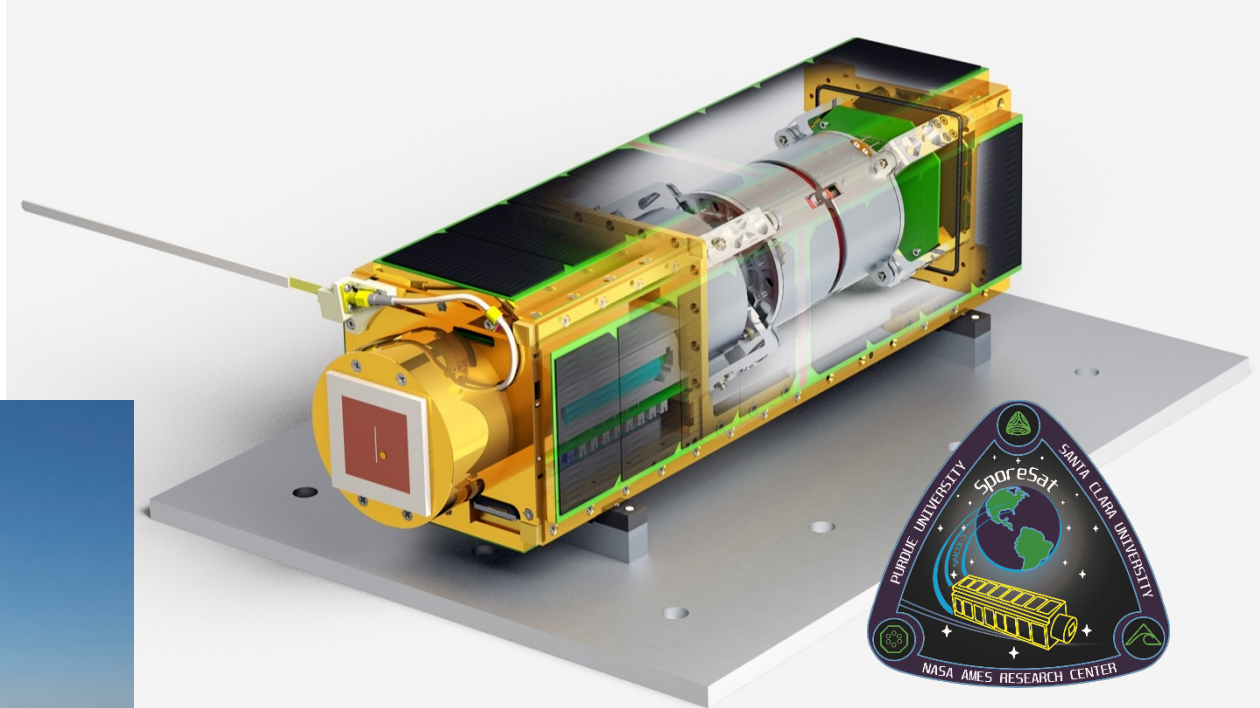


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Current Status:

Launched at 3:25 pm (EDT) on April 18, 2014 on SpaceX-3 – now in Low Earth Orbit

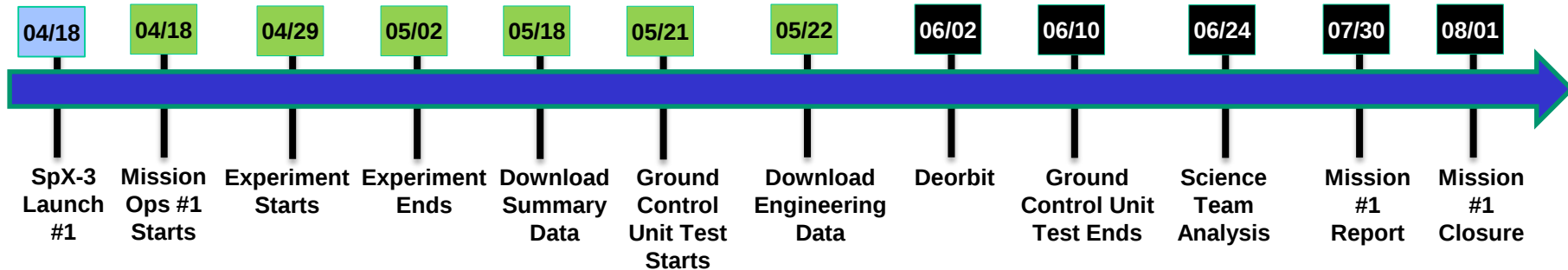




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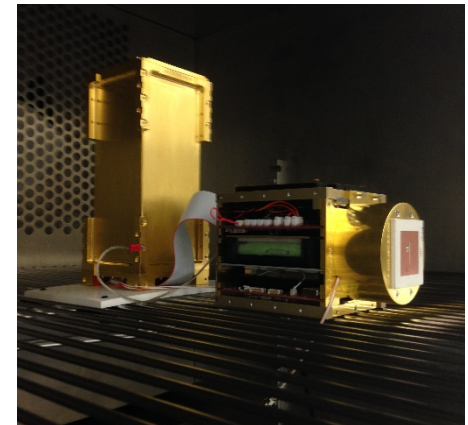
SporeSat-1 Mission Operations



Two Line Element Set (TLE):

```
1 39681U 14022B 14126.91979341 .00283955 41986-4 76519-3 0 461
2 39681 051.6463 299.0935 0022529 332.3199 027.6507 15.93385135 2889
```

<http://www.n2yo.com/satellite/?s=39681>



SporeSat Ground Control Test - NASA ARC
Engineering Evaluation Laboratory (EEL)



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Upcoming Milestones

- Complete Ground Control Test
- Analyze data (science and engineering) and prepare Mission #1 report - July 2014
- Assess SporeSat-1 performance and identify critical areas (HW/SW) to improve – Summer 2014
- Implement prioritized changes and prepare SporeSat-2 for Flight – Fall 2014
- And do it all over again!

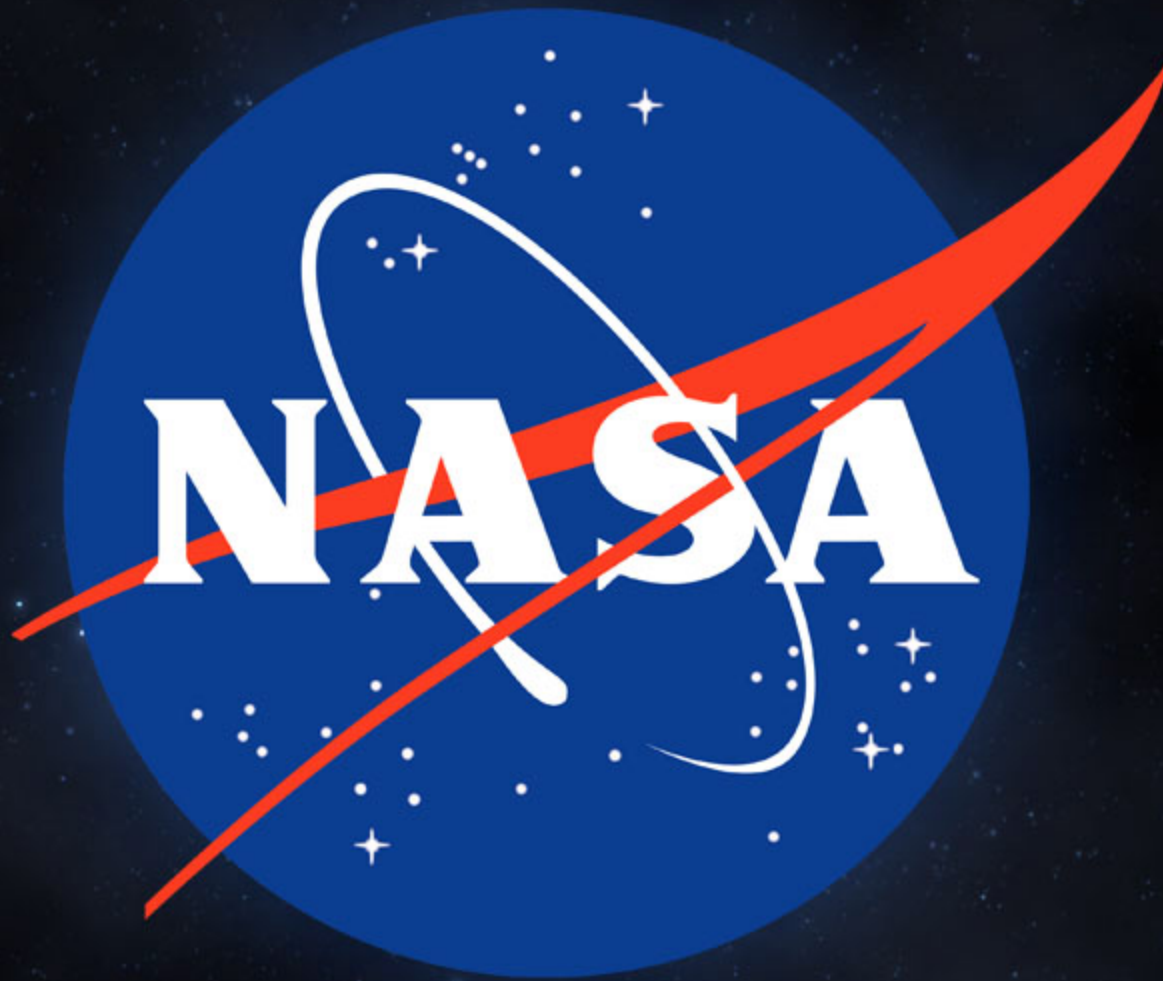
**SporeSat-2 manifested on
ORB-4 – JAN 2015!**



Conclusions

- Sophisticated science experiments can be implemented in small spacecraft to study phenomena uniquely accessible in the outer space environment.
- We will use SporeSat to study the gravity response of ion channels, particularly at low (sub-terrestrial) gravity levels that cannot be simulated on Earth.
 - The SporeSat experiment measures the responses of Ca^{2+} ion channels, which are common to many forms of biology, including humans.
- Ion channels control how ions like sodium, potassium, and calcium move in and out of cells: they are a means of regulation and control for cells.
 - Ion channels control our heart rhythm and blood pressure
 - Ion channels help some plants -- for example the fern spores that are onboard SporeSat -- figure out which way is up, so they send their roots and shoots in the right directions
- SporeSat results will link modulation of Ca^{2+} ion channel activity to the level of gravitation for fern spores
- SporeSat is a first-of-its-kind small science satellite that couples novel miniaturized technology to novel biological science: a variable-rate centrifuge allows testing the response of Ca^{2+} ion channels from microgravity to hypergravity!

This is what's exciting!



<http://www.nasa.gov/sporesat>