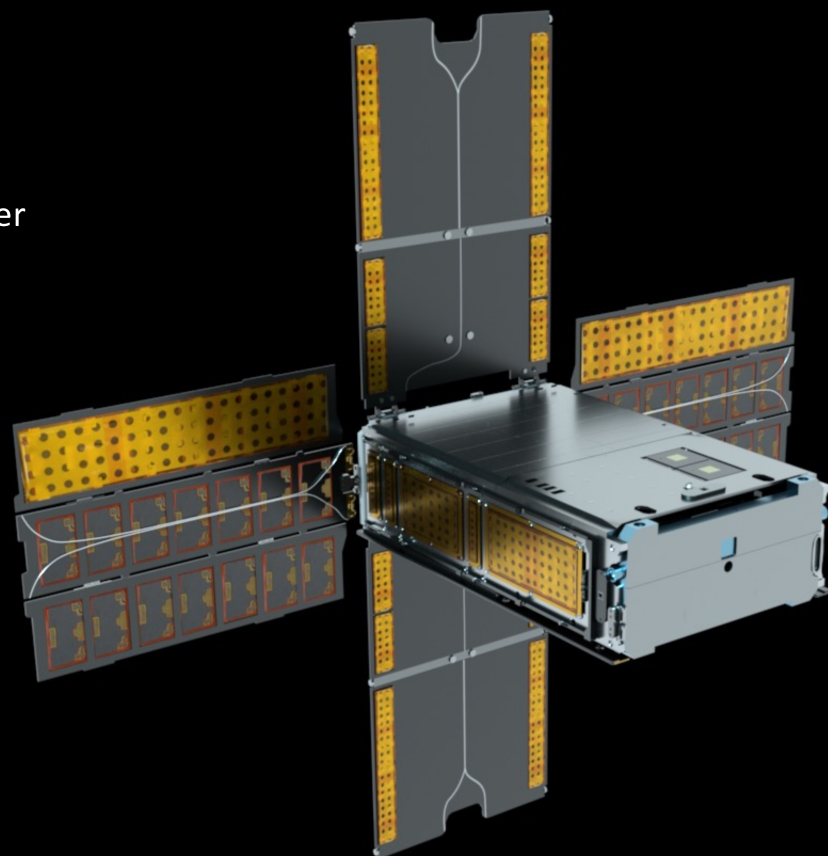
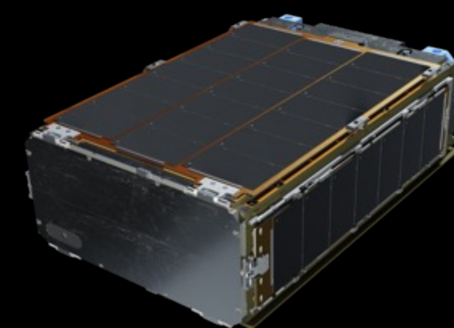
BioSentinel: The first deep space biology CubeSat mission

Ben Bradley
NASA Ames Research Center





NASA/Daniel Rutter

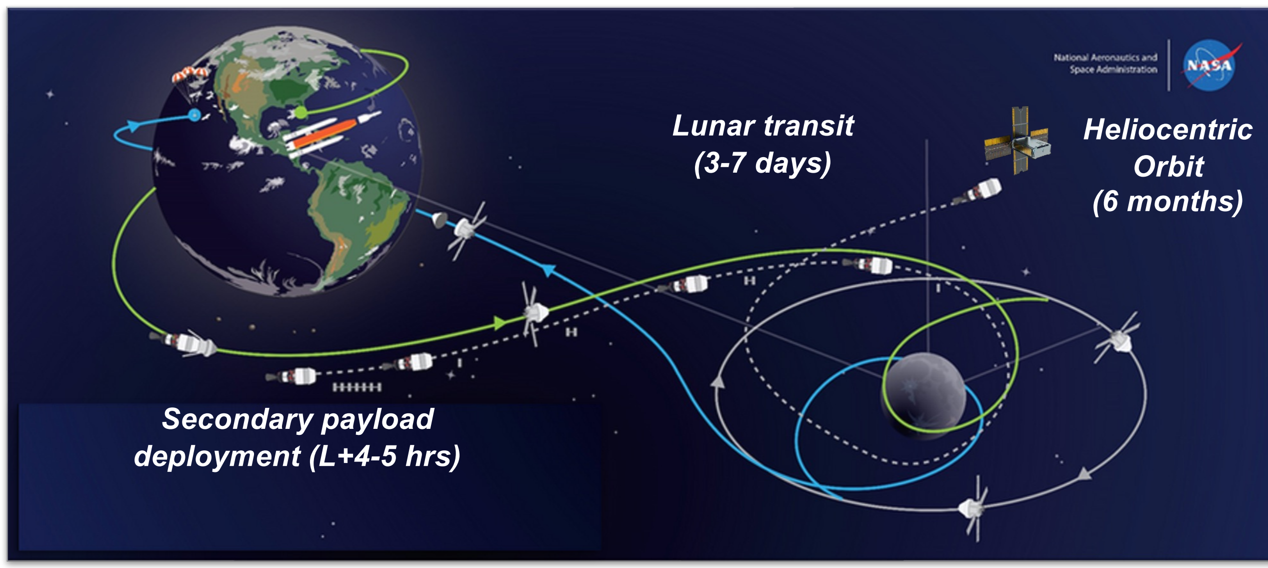
BioSentinel Mission

HQ Directorate: Exploration Systems Development Mission Directorate Mars Campaign Office (ESDMD-MCO)
SMD Heliophysics

Objective: Study the biological effects of the deep space radiation environment on eukaryotic organisms

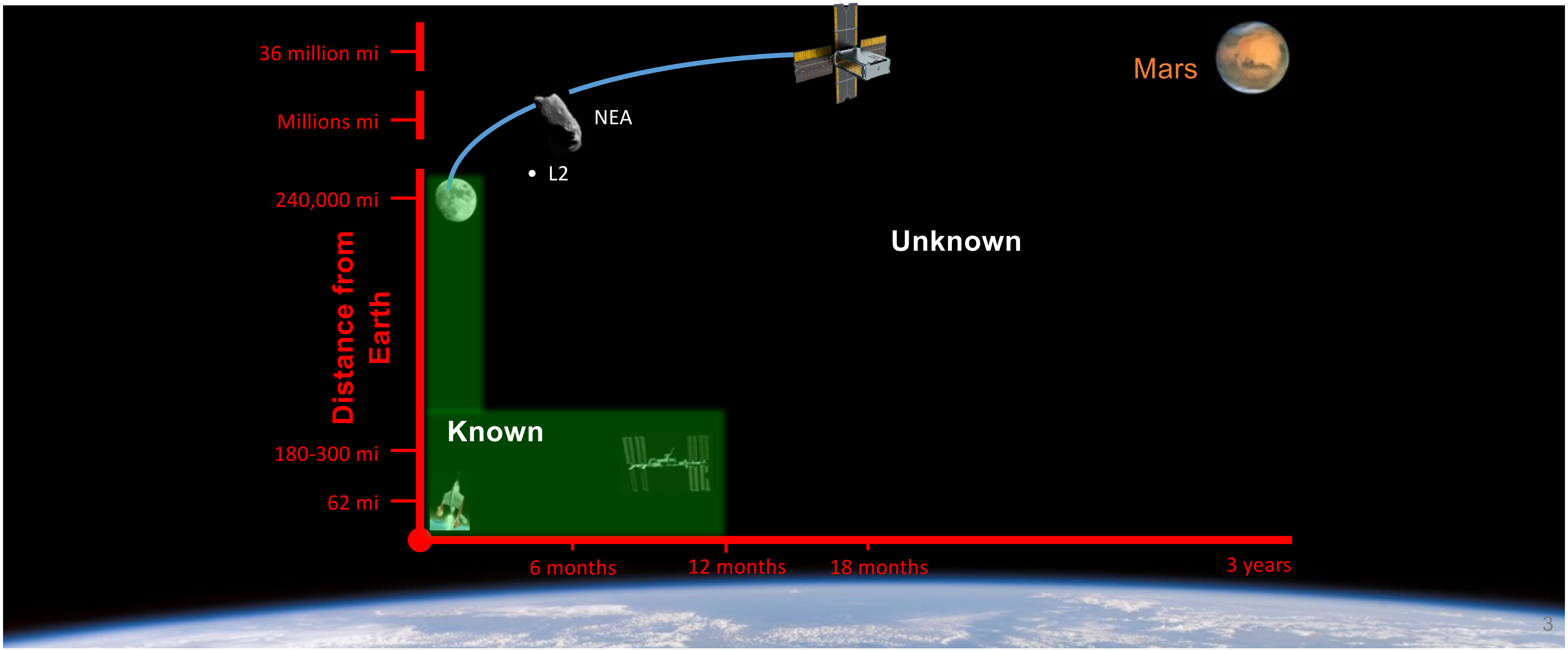
NASA's first biological study in interplanetary deep space:

- Combine bio studies with autonomous capability & dosimetry beyond Low Earth Orbit (LEO)
- Beyond the protection of Earth's magnetosphere
- Compare radiation environments (deep space, LEO, Earth)



BioSentinel: Sending biology further than ever before

The limits of life in space – as we know it – is 12.5 days on a lunar round trip or 1.2 years in LEO. As we send people further into space, we need to understand the biological risks and how they can be addressed



NASA Ames pioneering biological space missions




GeneSat-1 (2006 / 3U): ***gene expression***

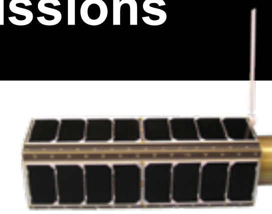
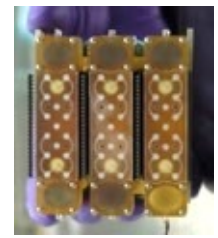
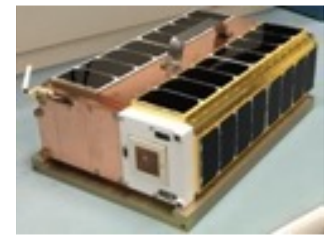
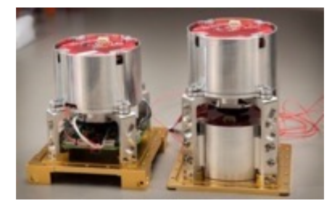
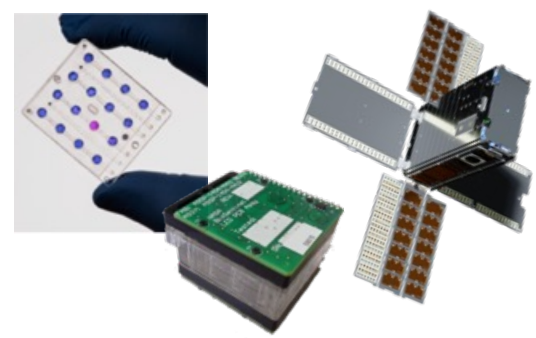
PharmaSat (2009 / 3U): ***drug dose response***

O/OREOS* (2010 / 3U): ***survival, metabolism***

SporeSat-1 (2014 / 3U): ***ion channel sensors, microcentrifuges***

EcAMSat (2017 / 6U): ***antibiotic resistance***

BioSentinel (2022 / 6U): ***DNA damage response from deep space radiation***

What is BioSentinel?

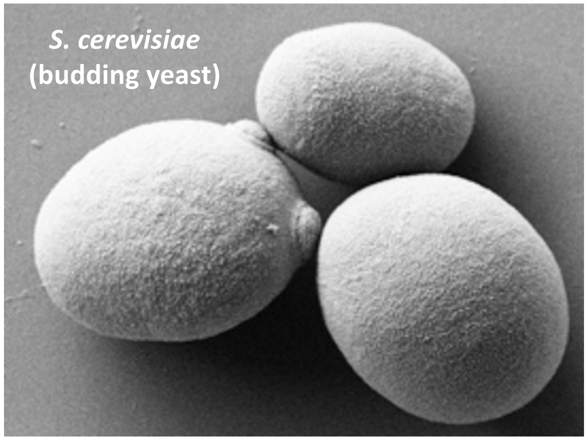
BioSentinel is a yeast radiation biosensor designed to measure the DNA damage response caused by space radiation with the goal of providing a tool to study the true biological effects of the space environment at different orbits.

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?

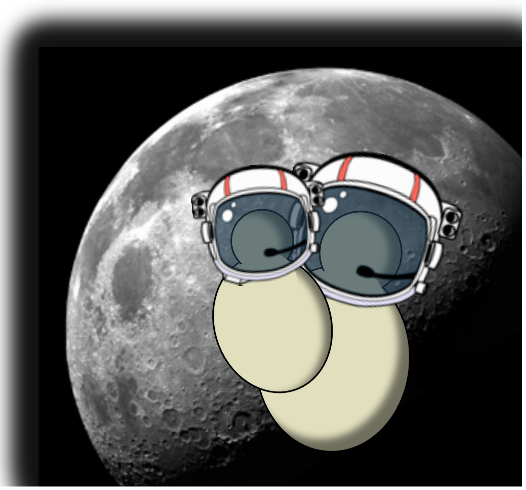
Lab-engineered *S. cerevisiae* cells will sense & repair direct (and indirect) damage to their DNA. Yeast cells remain dormant until rehydrated. They grow inside a microfluidic and optical detection system which uses LEDs and light sensors to detect growth rate, which is a proxy for the overall health of the cells.



Why budding yeast?

It is a eukaryote; easy genetic & physical 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: One Mission in Four Parts

BioSentinel will perform the first long-duration biology experiment in deep space. Its six-month science investigation will study the effects of deep space radiation on a living organism, yeast. There are three segments to the project:

Freeflyer Spacecraft - deep space experiment on Artemis 1

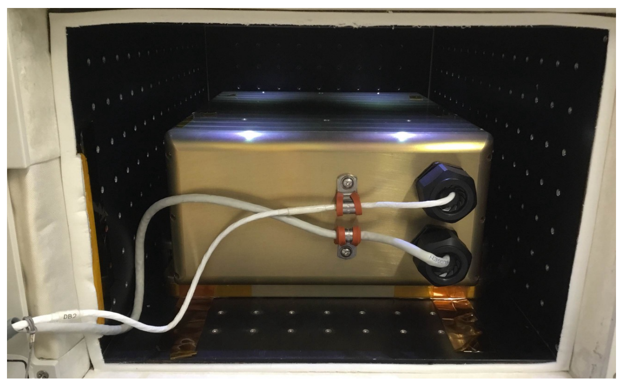
ISS Segment - control experiment in Low Earth Orbit

Ground Segment – control experiment on ground

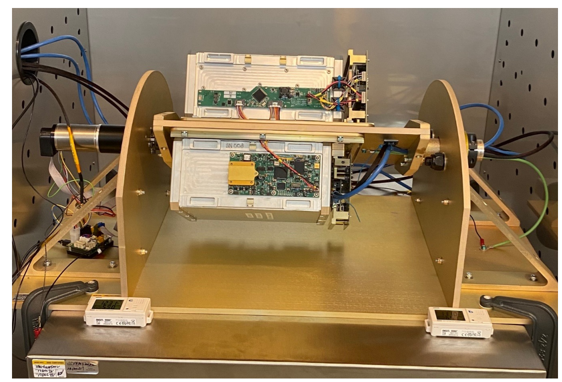
The three segments are all part of the BioSentinel mission and share identical BioSensors.

BioSentinel Install on ISS

Freeflyer Spacecraft

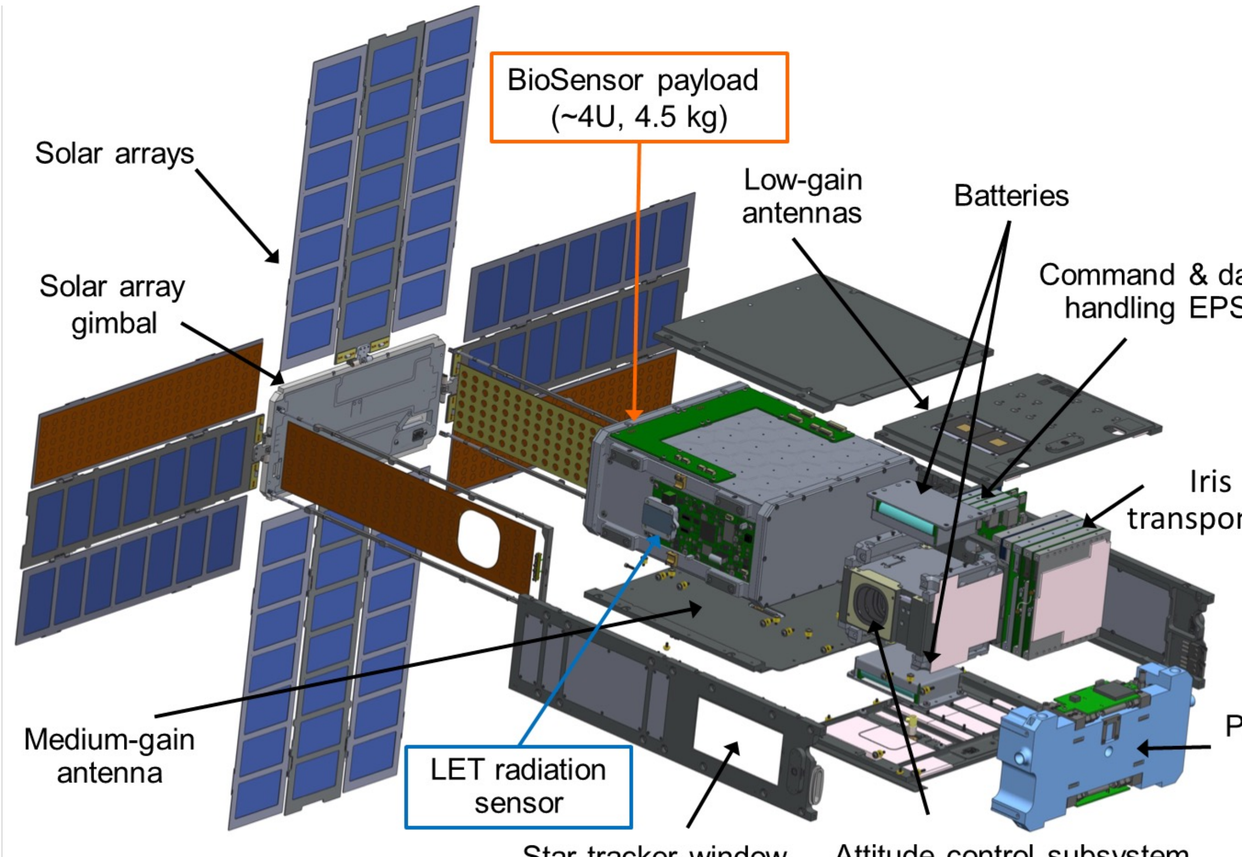


ISS Segment

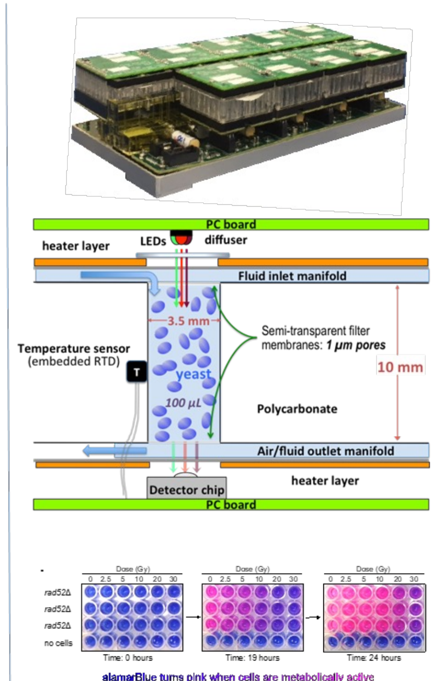


Ground Segment

BioSentinel: 4U experiment in a 6U CubeSat



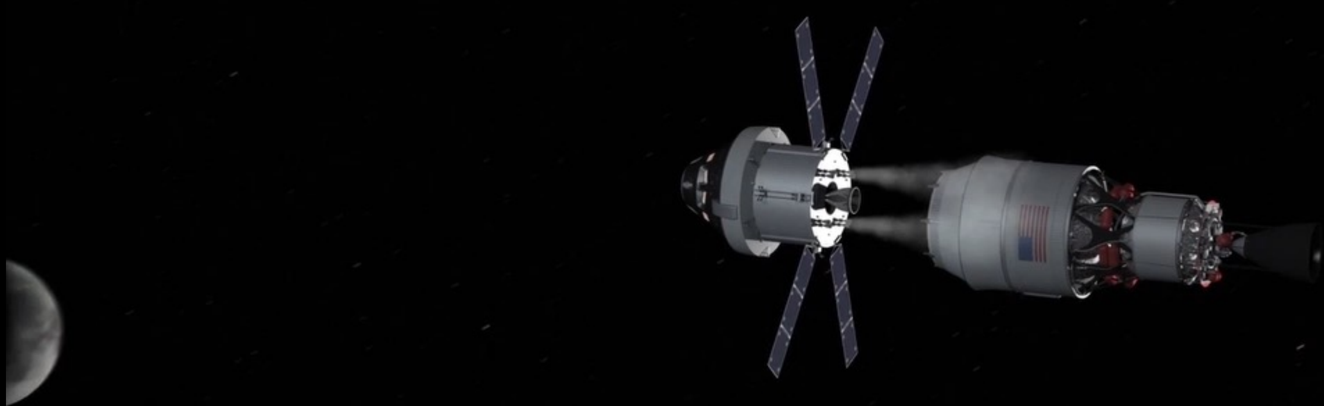
microfluidics delivery system



Launch and Deployment: November 16, 2022

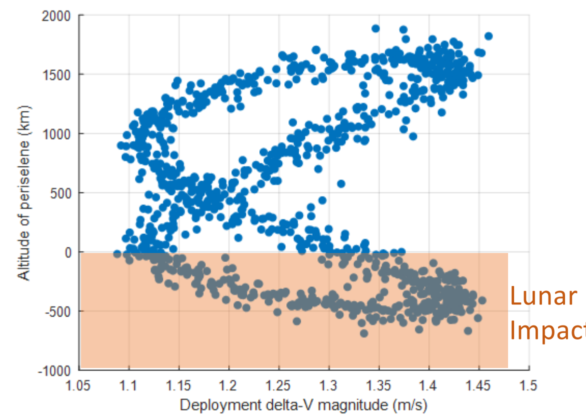
NASA/Bill Ingalls

Deployment

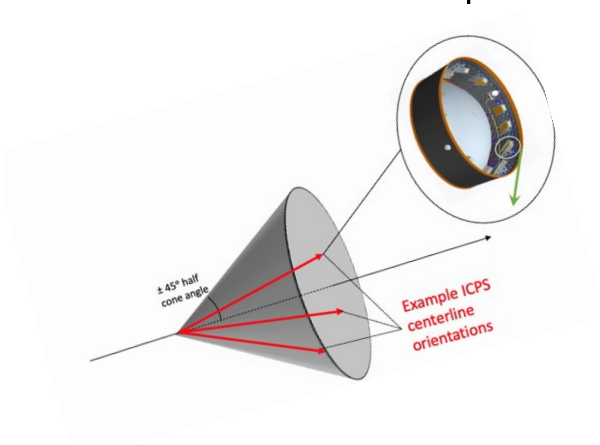


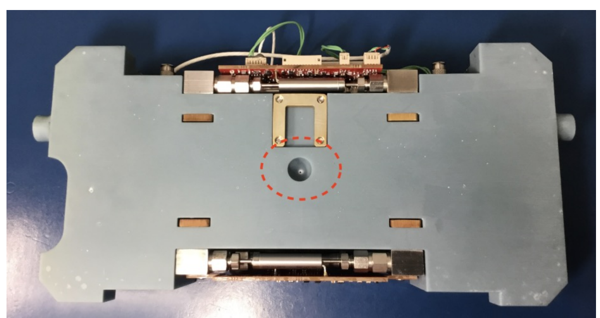
Trajectory Uncertainty: Keeping Perilune Altitude Positive

- Baseline CONOPS did not have a dV maneuver planned. Initial lunar impact risks of <10% was deemed an acceptable risk.
- However, VERY high probability of lunar impact for new launch dates:
  - Aug 29th - 30%, Sept 2nd - 54%, Sept 5th - 56%, Nov 16th - 14%
- Avoiding this impact requires a dV maneuver shortly after deployment
- Prop Subsystem:
  - The capability for dV ~ 4.2 m/s is possible because the propulsion system fortuitously included extra fuel and an extra rear nozzle that had not been planned for the nominal mission.



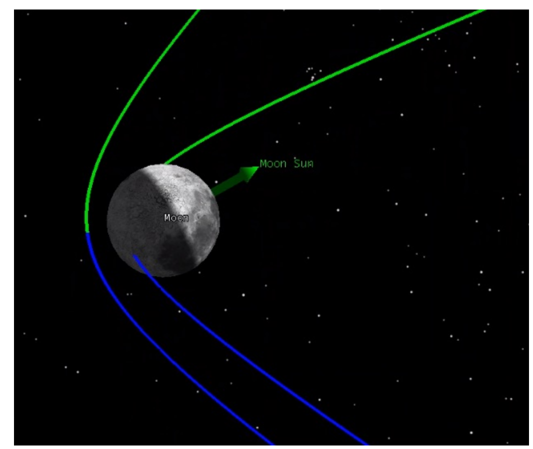
August 29th Launch Deployment Variability





Propulsion Rear nozzle

Image:Terry Stevenson



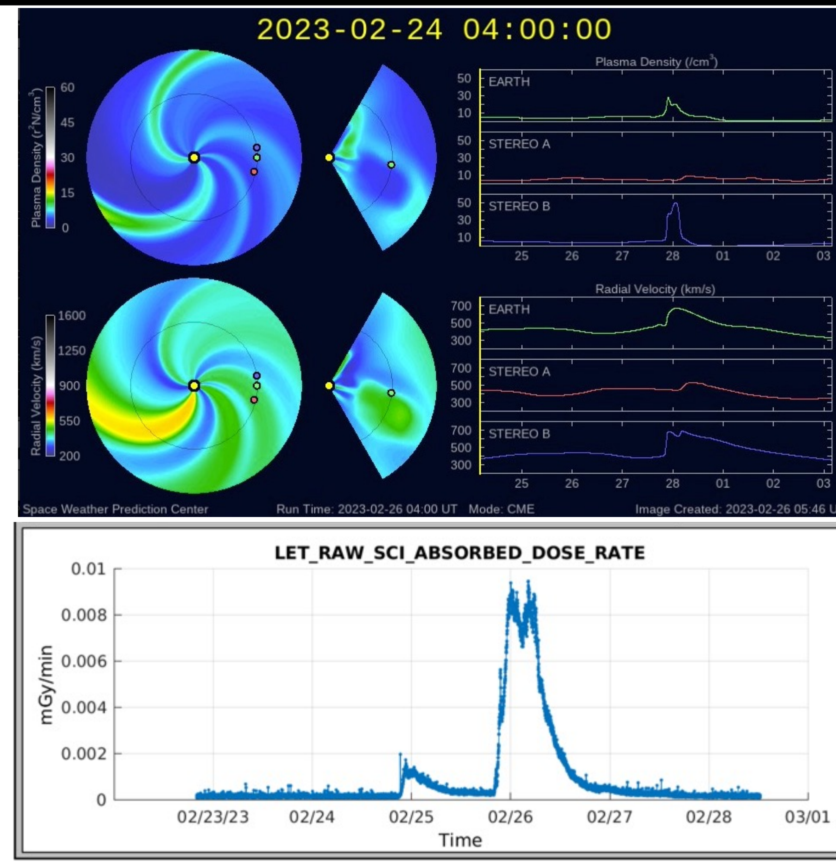
Deep Space Science Operations

BioSensor Payload

- Performed 4 sets of biology experiments on the spacecraft. No growth observed in cell samples and similar results were observed on the ground control unit. The cell viability was affected by long delay between cell encapsulation and launch, along with environmental factors.
- The BioSensor payload technology was demonstrated in deep space and learnings will be utilized in future mission including CLPS project, LEIA.

Linear Energy Transfer (LET) Spectrometer Payload

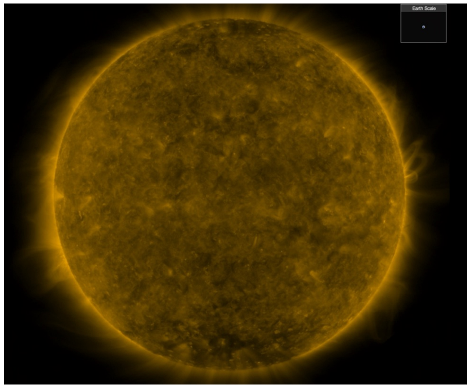
- Continues to gather radiation dosimetry
- Has captured solar events including coronal mass ejections



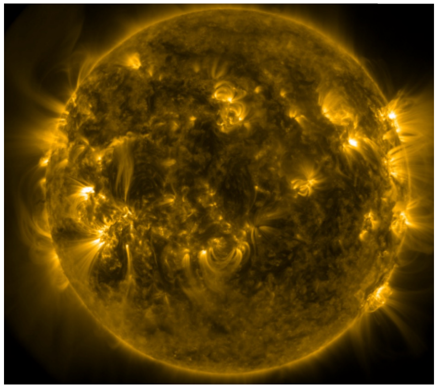
Flux measurements from the GOES satellite (top) and BioSentinel LET spectrometer (bottom) recorded for a pair of Coronal Mass Ejection events on Feb. 24 and 25, 2023

Solar Maximum

1. **Characterize solar energetic particle (SEP) events**, especially as we head deeper towards **solar maximum**. Such measurements will provide valuable information to the heliophysics community for the development of SEP models.
2. Provide space **radiation characterization** in multiple environments using the same radiation detector, including heliocentric orbit, low Earth orbit, cis-lunar space, and on the lunar surface.
3. Monitor galactic cosmic radiation (GCR) flux rates in a unique location while transitioning into the solar cycle maximum period.



Spotless Disk During Solar Min Feb 2019 (SDO AIA Imagery, 171 nm)



~Solar Max, Feb 2024 (SDO AIA 171 nm)

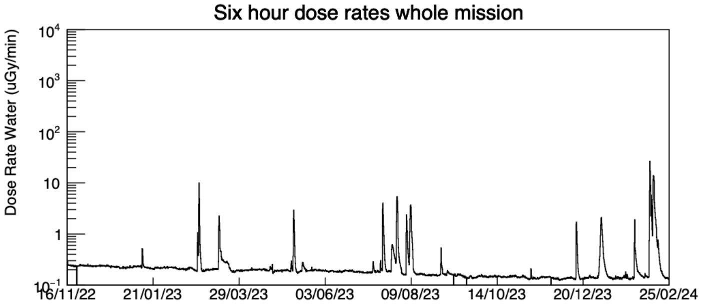
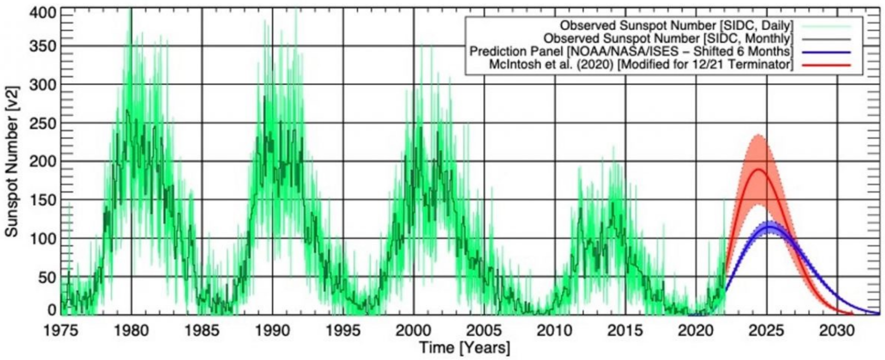
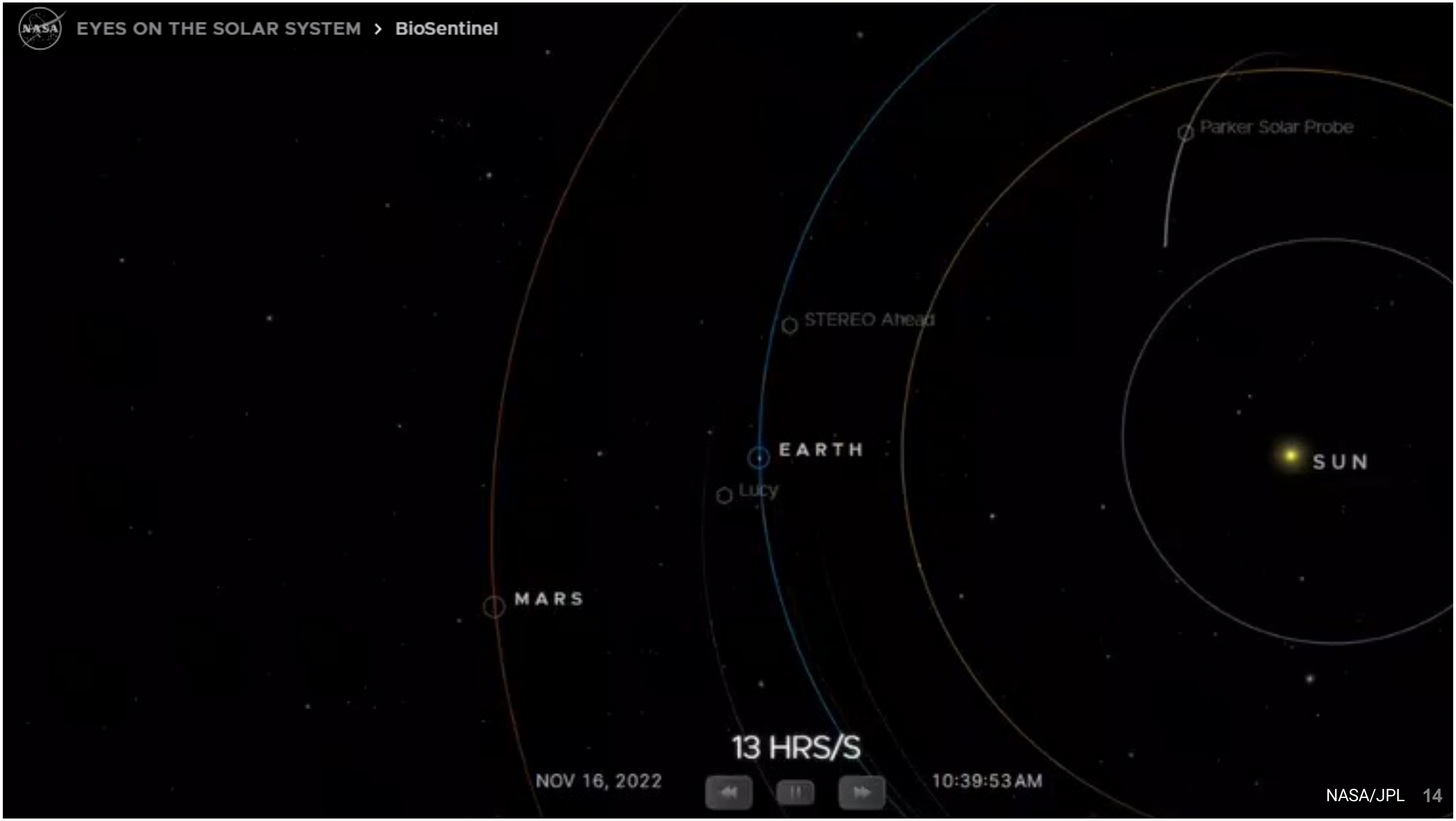


Figure 5: BiosentinelAbsorbed dose rates in water averaged on six hour cadence since mission start

BioSentinel Flight Data
Captured over 18 solar events

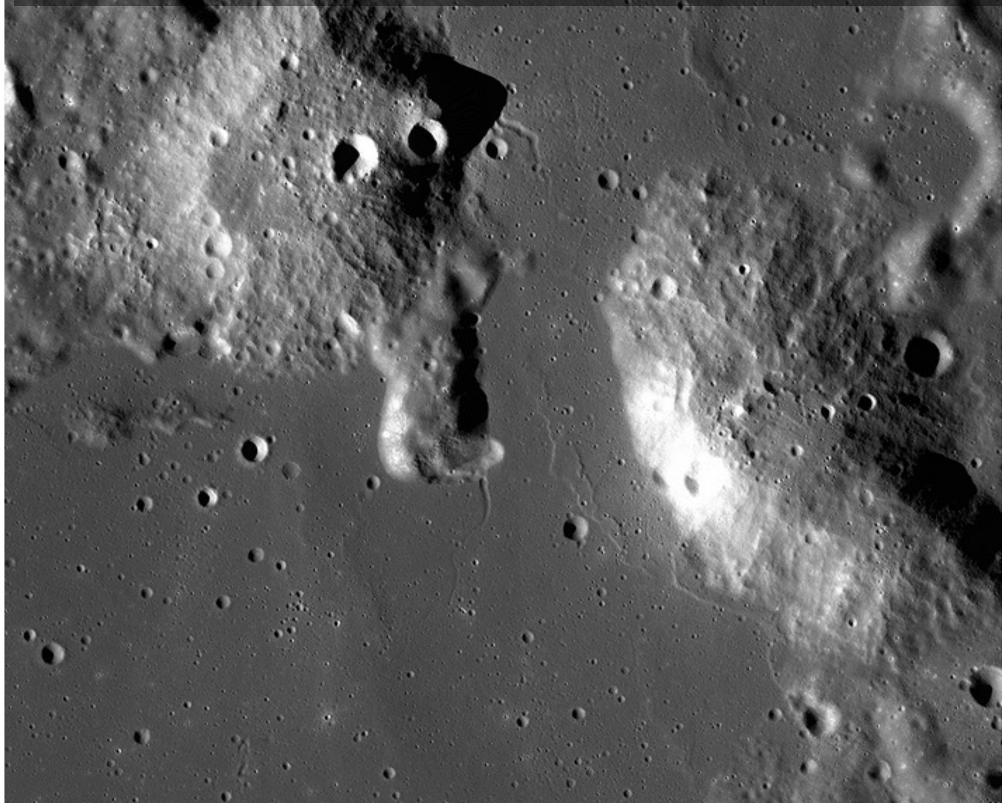


Solar Cycles

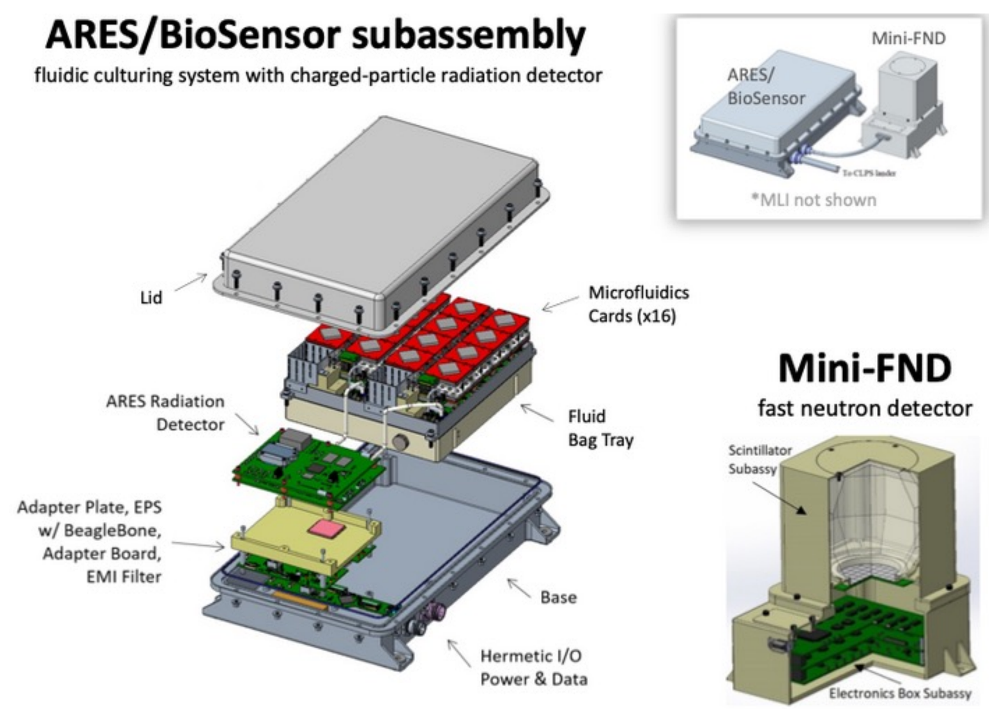

NASA
EYES ON THE SOLAR SYSTEM > BioSentinel
Parker Solar Probe
STEREO Ahead
EARTH
Lucy
SUN
MARS
13 HRS/S
NOV 16, 2022
10:39:53 AM
NASA/JPL

What's Next…

Lunar Explorer Instrument for space biology Applications (LEIA)

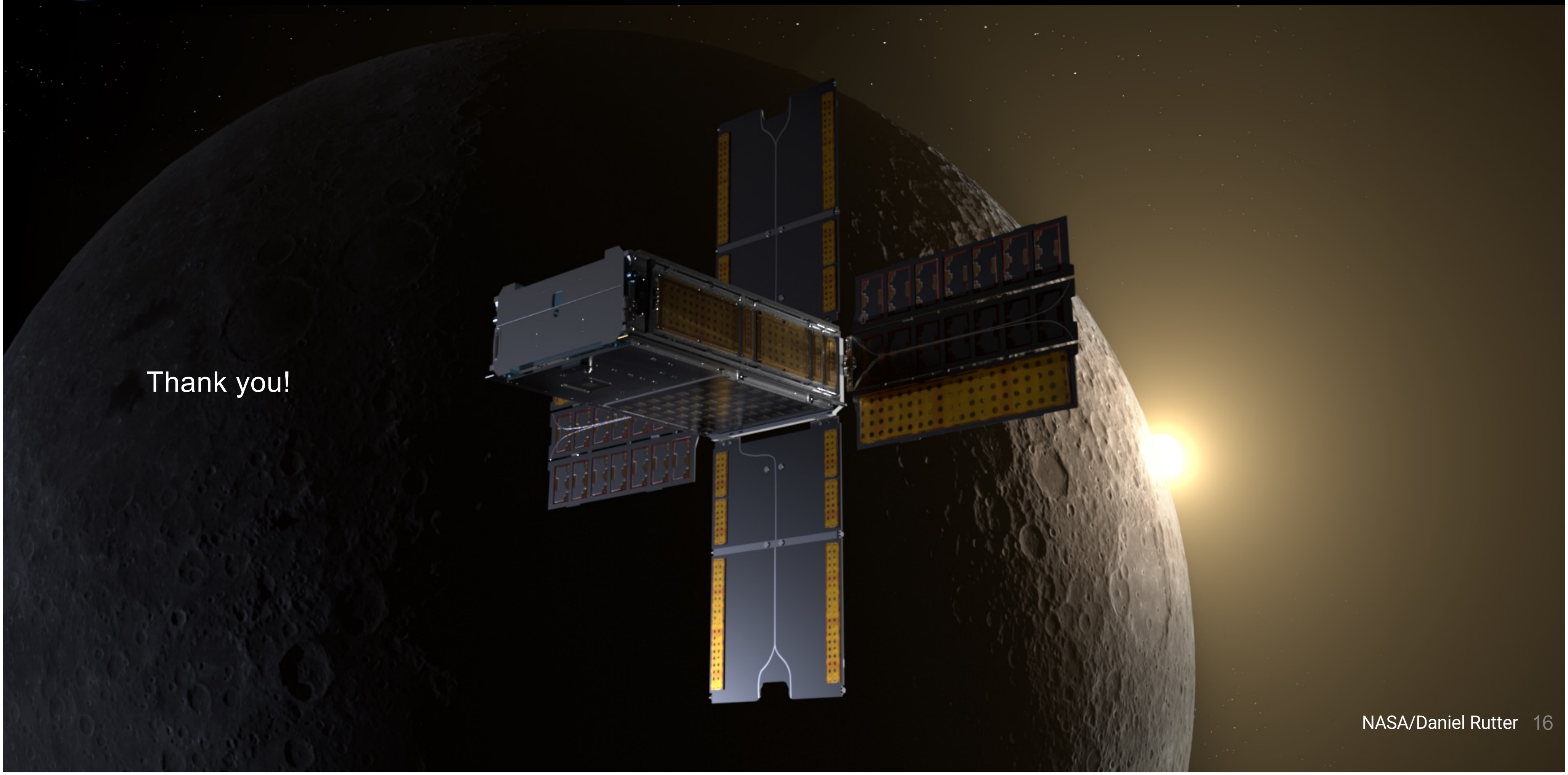


Credits: NASA/GSFC/Arizona State University



Drawings of the hardware components comprising LEIA — the ARES/Biosensor subassembly and the Mini-FND. The image at the top on the right depicts how these two components are connected to form LEIA. (ACRONYM KEY: MLI = Multi-Layer Insulation, EPS = Electrical Power System, EMI = Electromagnetic Interference)

Thank you!



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