SpinSat

A flexible payload system for studying the effects of radiation and variable gravity in space

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https://www.nasa.gov/ames-studies-current/spinsat

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Motivation

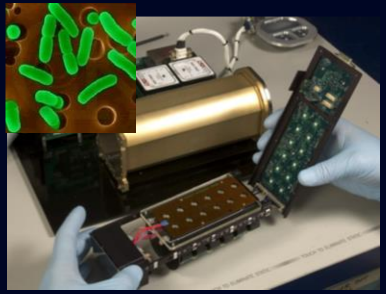
Current capabilities for studies of the effects of space radiation and reduced gravity are limited:

- Radiation: terrestrial accelerators are impractical for studying long-duration, low dose rate exposures; ISS orbit is substantially shielded from GCR; complex internal shielding adds to uncertainty in dose to payload; limited opportunities.
- Reduced gravity: available on ISS but limited in potential experiment configurations, and without simultaneous deep-space radiation exposure.

ISS does not meet needs for studying BLEO effects. Gateway and Commercial LEO Destinations facilities are still undefined and likely to offer limited access at high cost.

Technology heritage: biological cubesat payloads

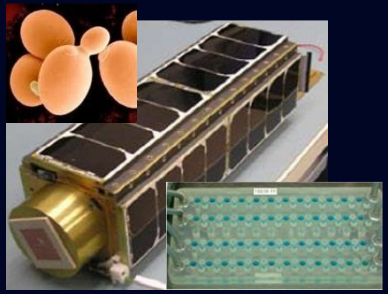
GeneSat-1 *(3U)*



2006

- *E. coli* (bacterium)
- Microgravity effects on gene expression
- 12-well fluidic card
- LED-excited fluorescence for GFP expression, + LED light scattering for cell population
- 1st fully automated self-contained biological experiment on a cubesat

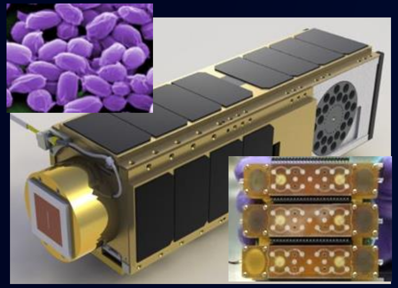
PharmaSat *(3U)*



2009

- *S. cerevisiae* (yeast)
- Microgravity effects on antifungal response
- 48-well fluidic card
- In-situ preparation of multiple drug dose levels from concentrate
- 3-color LED optical detection system
- alamarBlue indicator dye

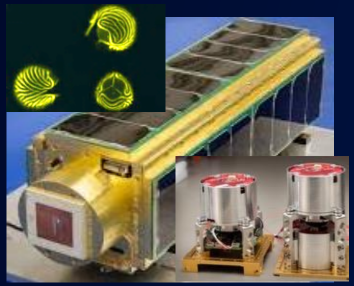
O/OREOS *(3U)*



2010

- *B. subtilis* (bacterium)
- 1st demo of 2 distinct experiment payloads on one autonomous satellite
- Microgravity & LEO + radiation effects
- 3-LED optical detection; solar UV-vis spectrometer
- 1st time dried organisms rehydrated in orbit: enables multi-timepoint activation

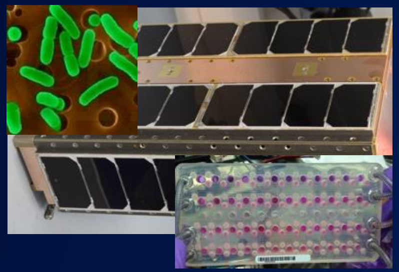
SporeSat-1 *(3U)*



2014

- *C. richardii* (aquatic fern spores)
- Variable gravity effects on spore germination *via* calcium ion transport
- 1st time artificial gravity capabilities in cubesat, 0 – 2x g
- 1st micro-centrifuges as well as Lab-on-Chip electrochemical sensors in a cubesat
- Deployed by re-supply mission *en route* to ISS

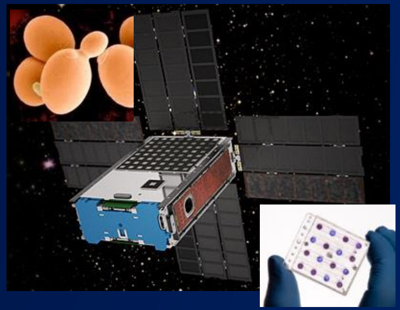
EcAMSat *(6U)*



2017

- *E. coli* (uropathogenic bacterium)
- Microgravity effects on antibiotic response
- 48-well fluidic card
- 3-LED optical detection; variable-dose drug delivery
- 6U format for 50% more solar power
- 1st bio cubesat deployed from ISS

BioSentinel *(6U)*



2022

- *S. cerevisiae* (yeast)
- Microgravity & deep-space radiation effects on DNA damage/repair
- 1st use of monolithic multilevel fused manifolds
- 18 x 16-well cards: 288 samples
- 1st deep-space bio cubesat: 2° payload on *Artemis-1*
- Onboard radiation spectrometer (LET)

SpinSat Platform

A standardized NASA Class D (high risk tolerance, medium to low complexity) “plug-and-play” platform utilizing standard open-source form factors and interface.

- Provides power, comms, avionics--PIs can focus on experiment-specific hardware.

- Offers increased flight opportunities for experiments studying combined effects of deep space, lunar or Mars radiation environments and gravity.

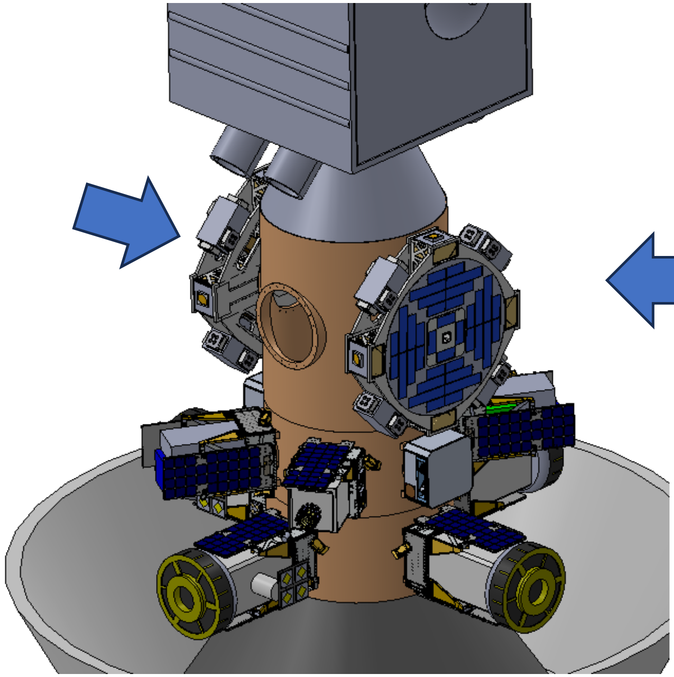
SpinSat Platform

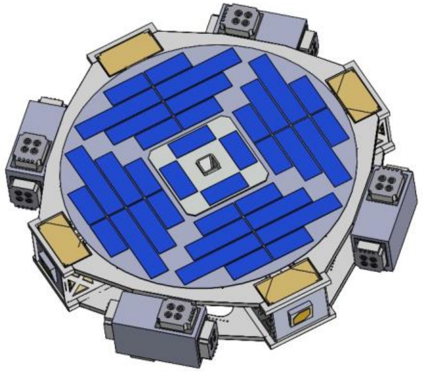
- Low cost per experiment
- Frequent access to space
- Duration: weeks to > 1 yr
- Launch vehicle and orbit agnostic
- Many experiments can be hosted on a single platform
- Possibility for reduced gravity and 1g control simultaneously
- Base configuration uses CubeSat form factor and interface. (Other configurations not precluded.)
- Easy integration and payload access
- Potential for late loading

SpinSat Platform

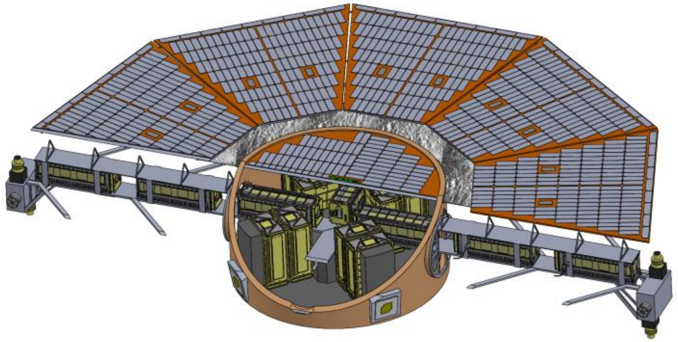
Two SpinSat configurations

1.5m ESPA* port mounted (x2 shown)



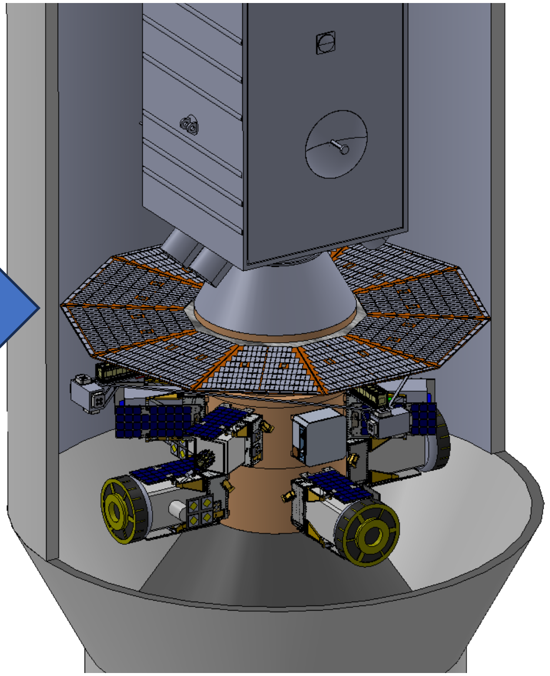


Can host > 48“U” worth of experiments



Can host ~300“U” worth of experiments

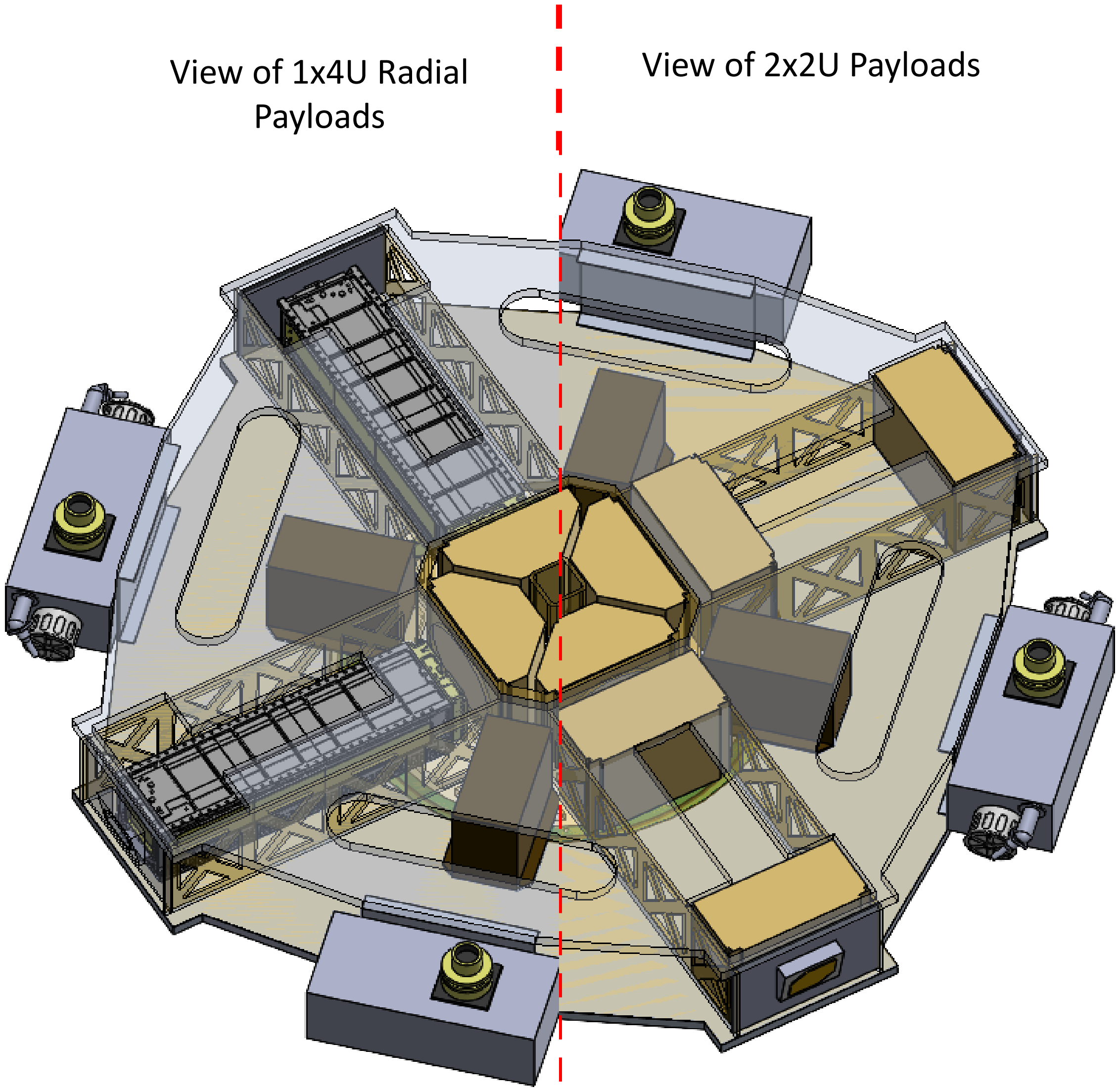
4.5m ESPA* In-line stack



experiments can be mounted axially, radially, or azimuthally w.r.t. the spin axis for both approaches

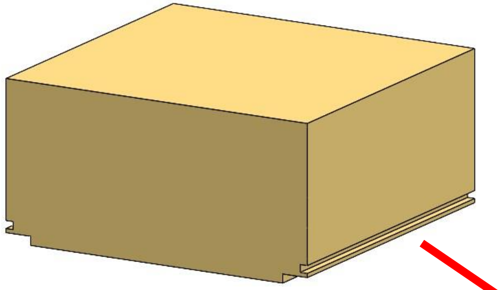
***EELV Secondary Payload Adapter**

1.5 m



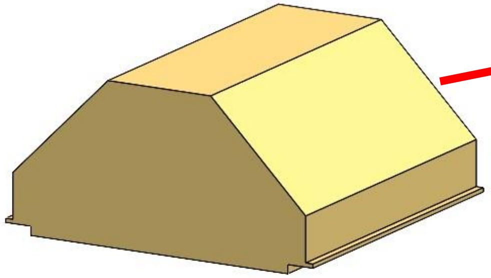
Top View – Solar Arrays Removed

1/6g - 1g simulation



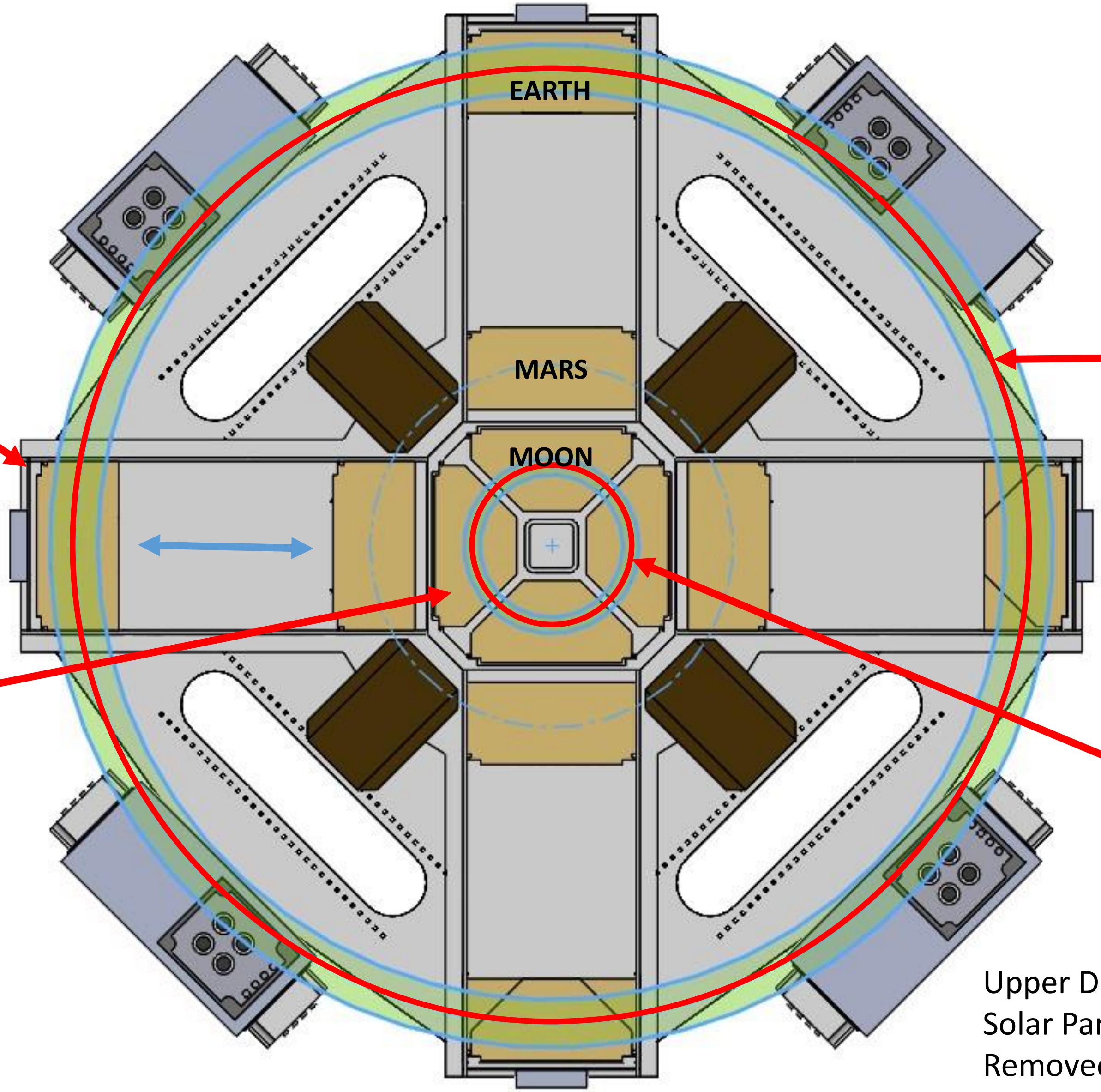
2x2U Standard Payload (4X)

4 Earth-g, 4 Mars-g Shown



2x2U Wedge Payload (4X)

Allows tighter packing near spacecraft axis for Moon-g



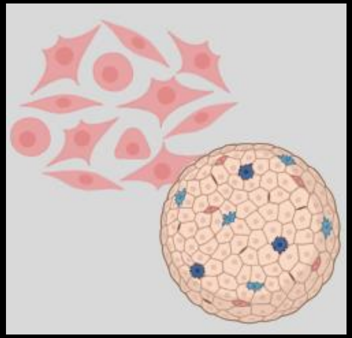
1g Ø 1.35m

1/6th g Ø 0.225m

Upper Deck and Solar Panels Removed

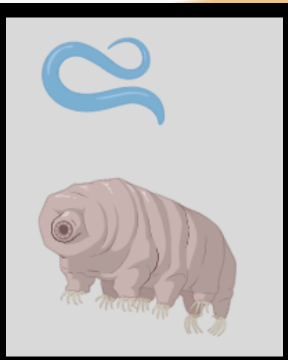
Science Opportunities

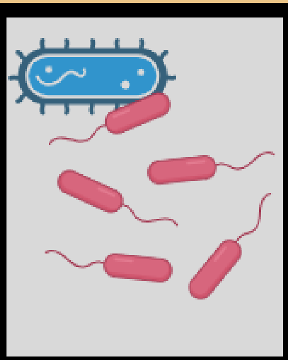
Human Cells



- Stem cells
- Neurons/glia
- Intestinal cells
- Cancer cells

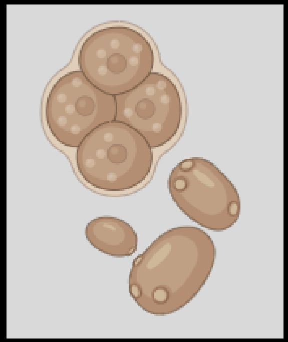
Model Organisms and Communities





- C. Elegans
- Tardigrades

- Microbiome
- E. coli
- B. subtilis



- S. Cerevisiae
- S. Pombe
- Saccharomyces

- Microalgae
- Cyanobacteria
- Arabidopsis

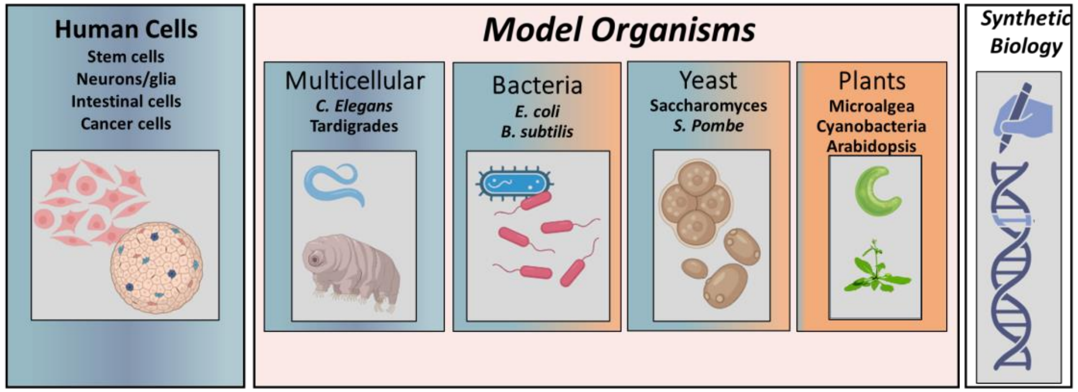
Synthetic Biology

- Central Nervous System
- Cancer
- Bone and Muscle Health
- Pathogenesis and Wound Healing
- Microbiomics
- Pharmacologics
- Food Sources
- Environmental Control and Life Support

Observables: DNA damage | Protein damage | Cell membrane damage | Mitochondrial damage | Germination | Growth | Tropisms | 2° metabolite production

Potential Experiment Concepts

- Biological and Astrobiological Sciences
  - Microbial survival in non-terrestrial conditions (high-fidelity simulation of Mars, lunar, or transit conditions)
  - Prebiotic chemistry in relevant environmental conditions
  - Model organisms: response to radiation and gravity conditions relevant to crewed exploration of deep space
  - Evolutionary studies: communities/microbiomes; models
  - Testing countermeasures to deep space stressors



- Planetary Sciences
  - Behavior of regolith at lunar gravity
  - Behavior of small-scale particle interactions during early growth of small bodies (regime where electrostatics is more important that gravity)
- Physical Sciences
  - Flame propagation studies at Lunar & Mars gravities
  - Heliophysics applications of electric field and in-situ magnetometer measurements

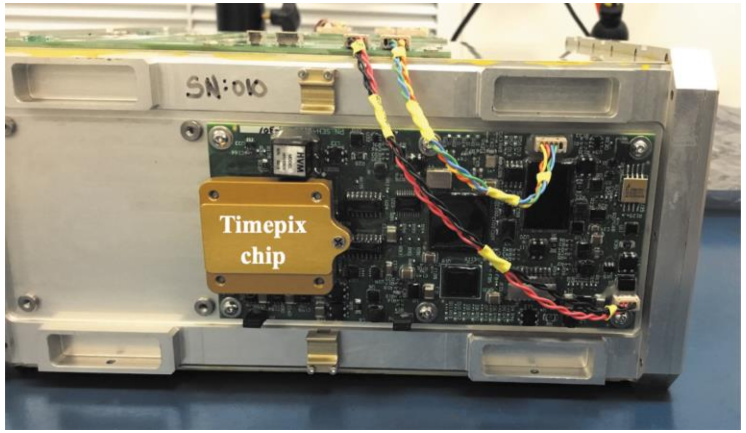
Radiation instruments

Cubesat “U” form factor allows room for dedicated active dosimetry for individual payloads as well as vehicle dosimetry.

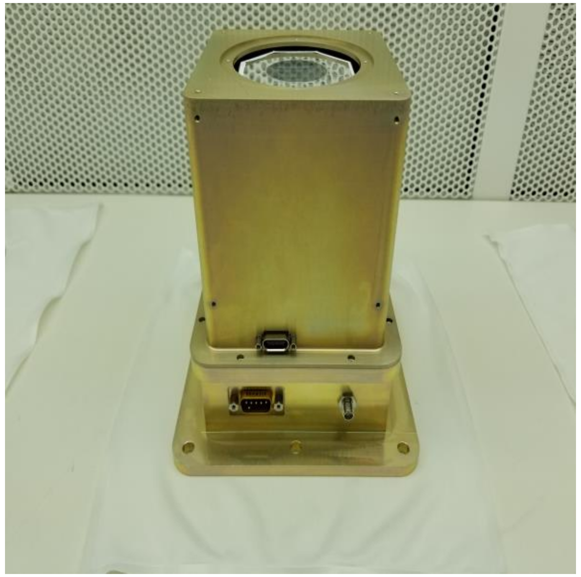
Example: charged particle + neutron measurement suite

LET spectrometer (BioSentinel, LEIA)

LET (in H_2O) = 0.1 - 300 keV/μm

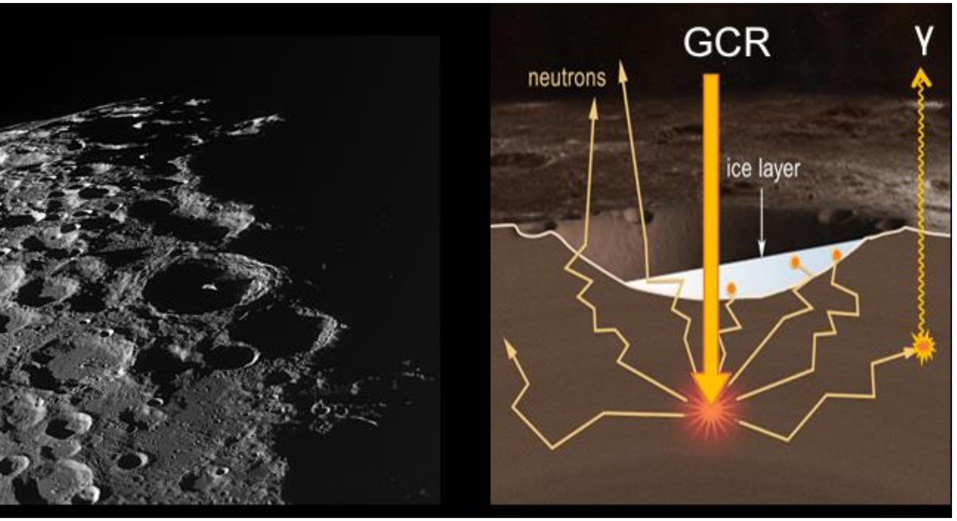


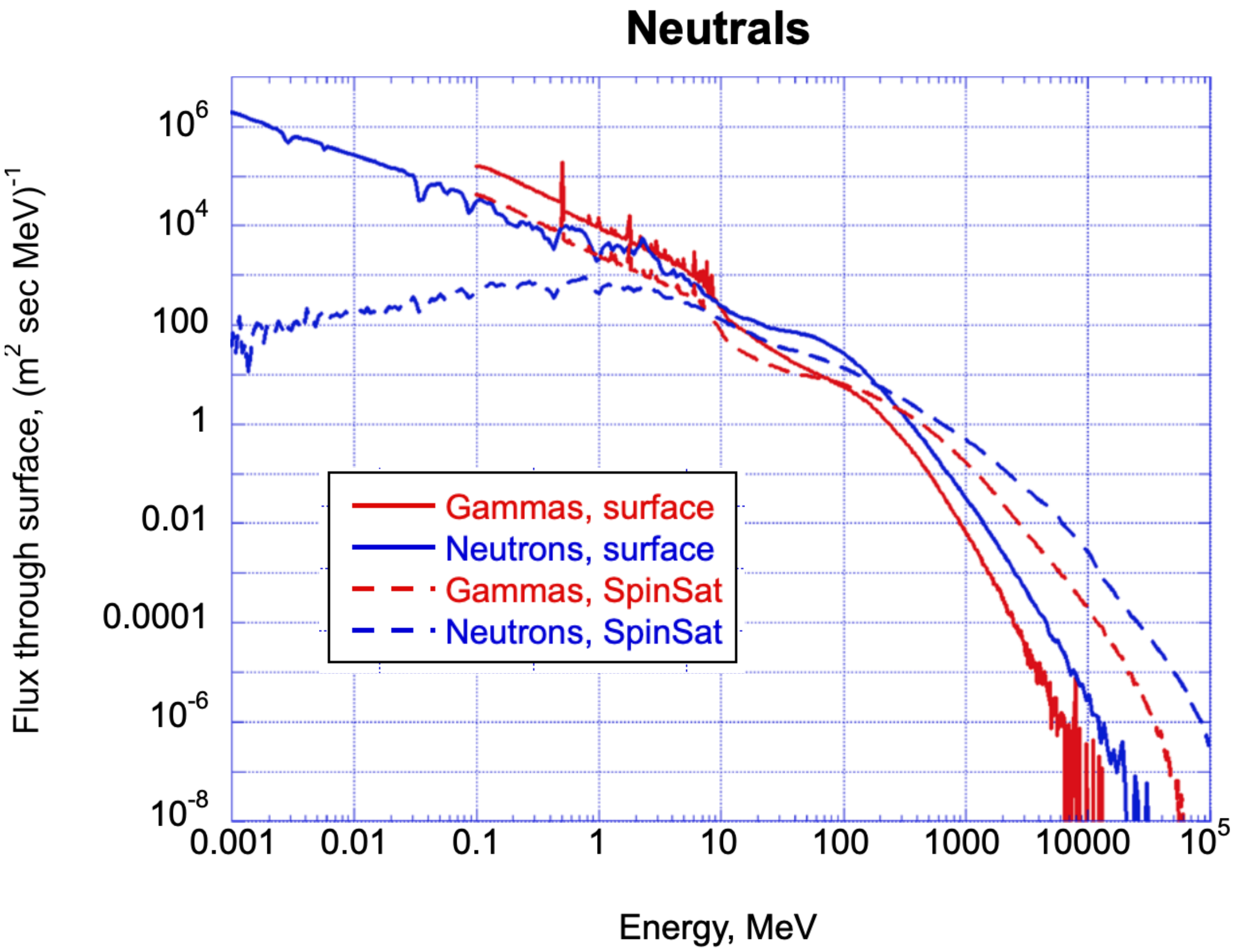
Mini-FND (LEIA)



- Neutron energy range: 0.5 to 10 MeV
- 1.3 kg
- 1650 cm^3 (10.5 x 10.5 x 15.0 cm)

Simulation of the Lunar Radiation Environment



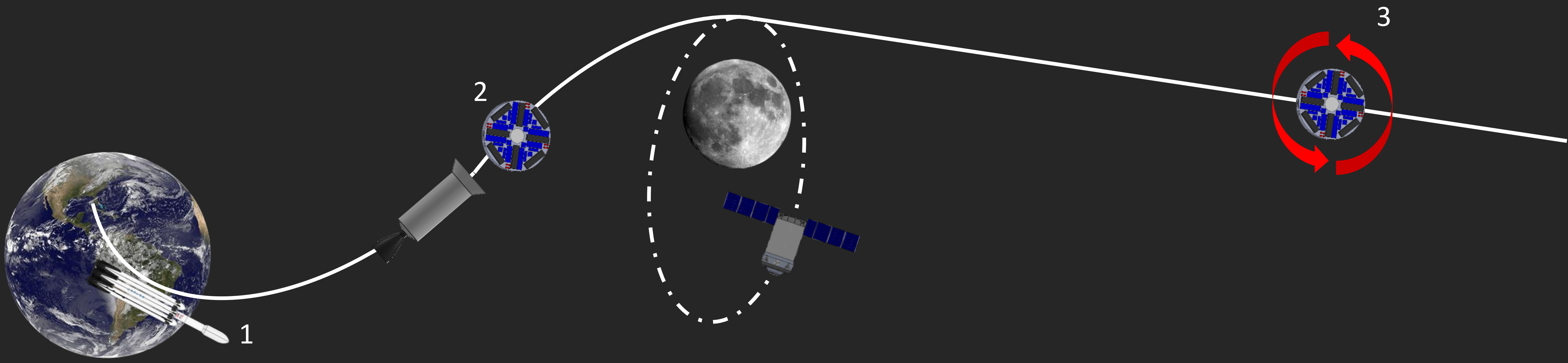


- Fast neutrons cause direct cellular damage and also produce ionizing radiation
- SpinSat can simulate the lunar neutron environment by including regolith in the payload.
- Right: GEANT4 simulation* of a **3x1U block of 2 g-cm^{-2} ferroan anorthosite (FAN)** bombarded isotropically by GCR; tabulated all particles except neutrinos coming out of the block.

* M. Looper, Aerospace Corp.

1. Launch on CLPS/DLS rideshare, on escape disposing stage
2. Separate at appropriate bus-stop
3. Once at appropriate environment, spin up and start science

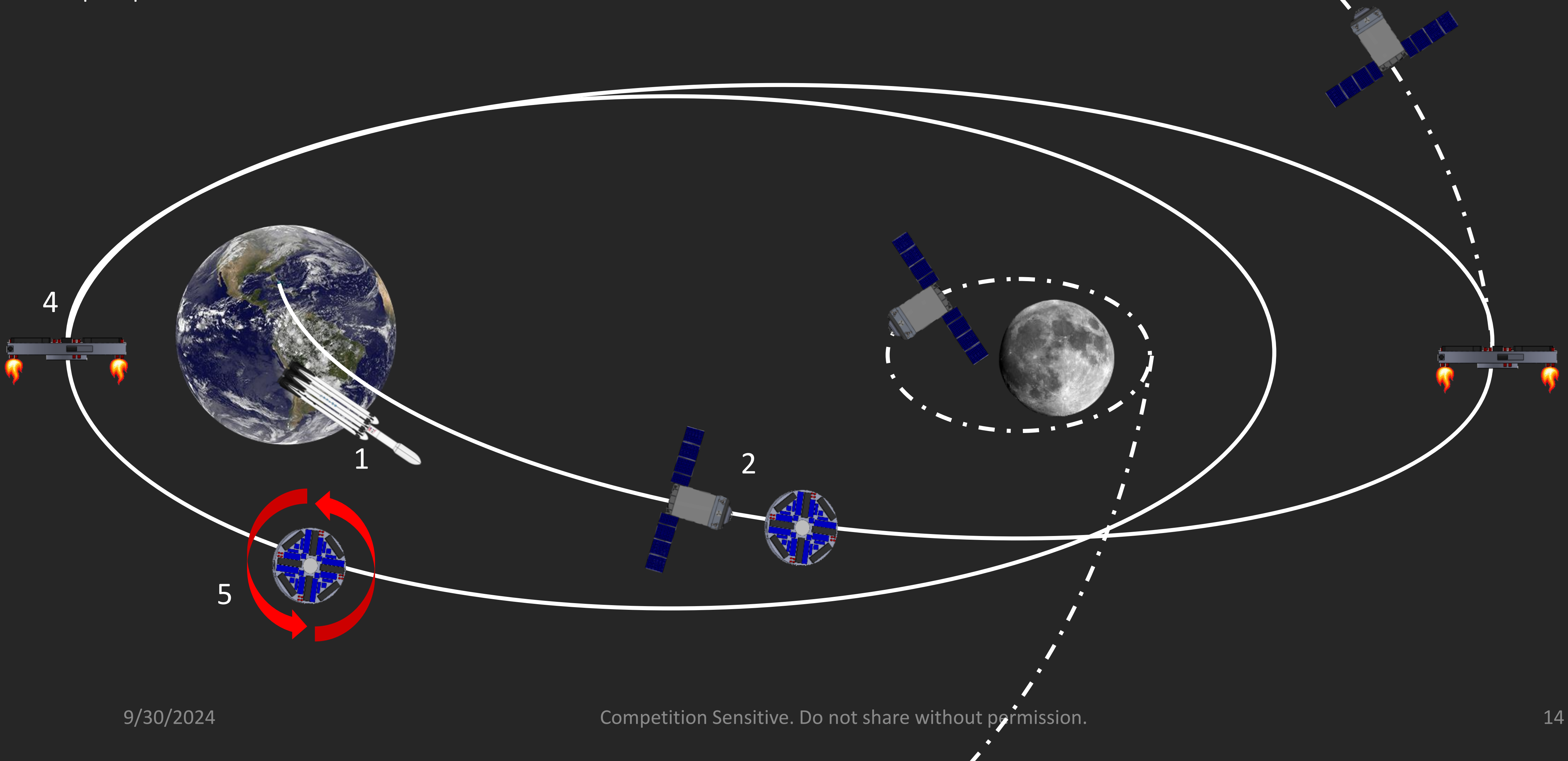
Con-Ops: Earth Trailing



Not to scale

Con-Ops: High Earth Elliptical

1. Launch on CLPS/DLS rideshare with TLI or BLT trajectory
2. Separate prior to apogee TCM
3. At apogee, burn to raise perigee above VAB
4. Apogee lower maneuver
5. Spin up and start science



Status

Design process

- Architecture study and trades completed by Ames Mission Design Center
- Initial funding provided by Earth-Independent Operations (EIO), led by the Mars Campaign Office (MCO)
- Design in progress for LEO Demo flight and Deep Space Missions

Key Studies underway for LEO & Deep Space

- Thermal Analysis, Comms, Dynamic Balancing
- Extendable Solar Panels, Radiation, Regolith Simulant Requirements, Rad Sensor Requirements, Sensor Placement

Operational demo flight (LEO) targeted for 2028*; Annual launches thereafter.

*pending funding

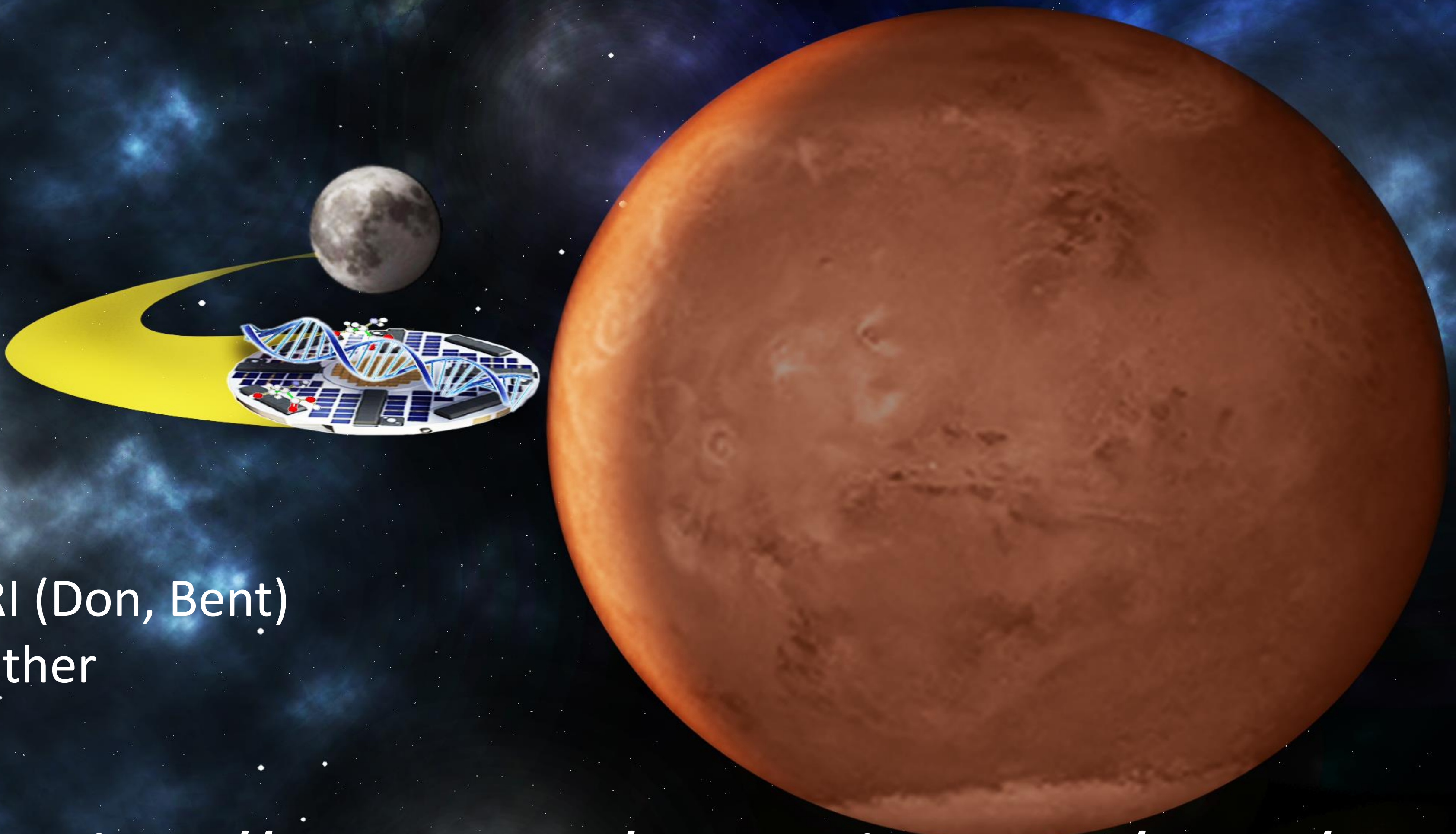
Status

Science community engagement

- **Requirements Workshop held at Ames, 3/8/24**
  - Broad science and engineering participation (~75 people)
- **Request For Information issued on SAM.gov**
  - Seeking input from the space sciences community and instrument developers for future missions

https://www.nasa.gov/spinsat-rfi/

Thank you*



*SwRI (Don, Bent)
Günther

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- **Design in progress for LEO Demo flight and Deep Space Missions**
  - Agnostic STM developed
  - MTM partially developed
  - Requirements traced to Level 1 Requirements
  - Initial MELs generated for LEO Mission with Deep Space Exception Tracked
  - 1.5m – ESPA port mount; 4.5m – ESPA stack mount
- **Key Studies underway for LEO & Deep Space**
  - 3D s/c printing, Thermal Analysis, Comms, Dynamic Balancing, Extendable Solar Panels,
  - Radiation, Regolith Simulant Requirements, Rad Sensor Requirements, Sensor Placement

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  - We want to hear from you!

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Notional launch schedule

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Annual launches thereafter

Status

Architecture Study & Trades Completed by NASA-Ames Mission Design Center

- No significant technical challenges identified

Requirements Workshop and RFI

- Broad science and engineering participation (~75 people)
- RFI issued to solicit requirements from a wider range of PIs – on SAM.gov

LEO Demo & Deep Space Mission & SC Design in Progress

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