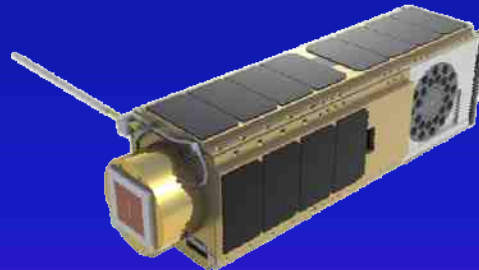




THE O/OREOS MISSION: ASTROBIOLOGY IN LOW EARTH ORBIT

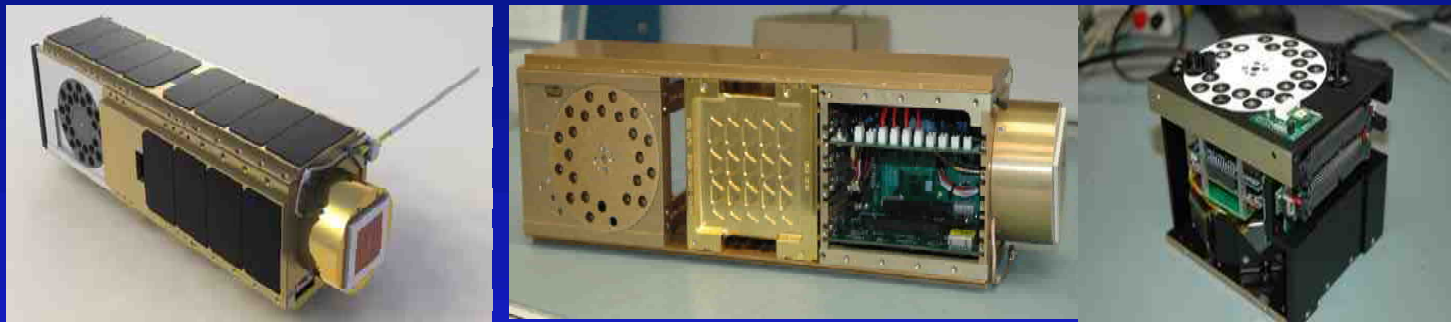
P. Ehrenfreund¹, A.J. Ricco², D. Squires², C. Kitts³, E. Agasid², N. Bramall²,
K. Bryson⁴, J. Chittenden², C. Conley⁵, A. Cook², R. Mancinelli⁴, A. Mattioda²,
W. Nicholson⁶, R. Quinn⁷, O. Santos², G. Tahu⁵, M. Voytek⁵, C. Beasley²,
L. Bica³, M. Diaz-Aguado², C. Friedericks², M. Henschke², J.W. Hines²,
D. Landis⁸, E. Luzzi², D. Ly², N. Mai², G. Minelli², M. McIntyre²,
M. Neumann³, M. Parra², M. Piccini², R. Rasay³, R. Ricks², A. Schooley²,
E. Stackpole², L. Timucin², B. Yost², A. Young³



¹Space Policy Institute, Washington, DC, USA, ²NASA Ames Research Center, Moffett Field, CA, USA, ³Robotic Systems Laboratory, Santa Clara University, Santa Clara, CA, USA, ⁴Bay Area Environmental Research Institute, Sonoma, CA, USA, ⁵NASA Headquarters, Washington DC, USA, ⁶University of Florida, Gainesville, FL, USA, ⁷SETI Institute, Mountain View, CA, USA, ⁸Draper Laboratory, Cambridge, MA, USA

NASA Astrobiology Small Payloads (ASP)

Develop and fly small astrobiology payloads, from single-cube free flyers to suitcase-sized payloads, to address **fundamental astrobiology objectives**, using a variety of launch opportunities



SEVO

O/OREOS (Organism/Organics Exposure to Orbital Stresses) is the first technology demonstration mission for ASP

Launched: November 19, 2010

Nominal performance in orbit, 6 months

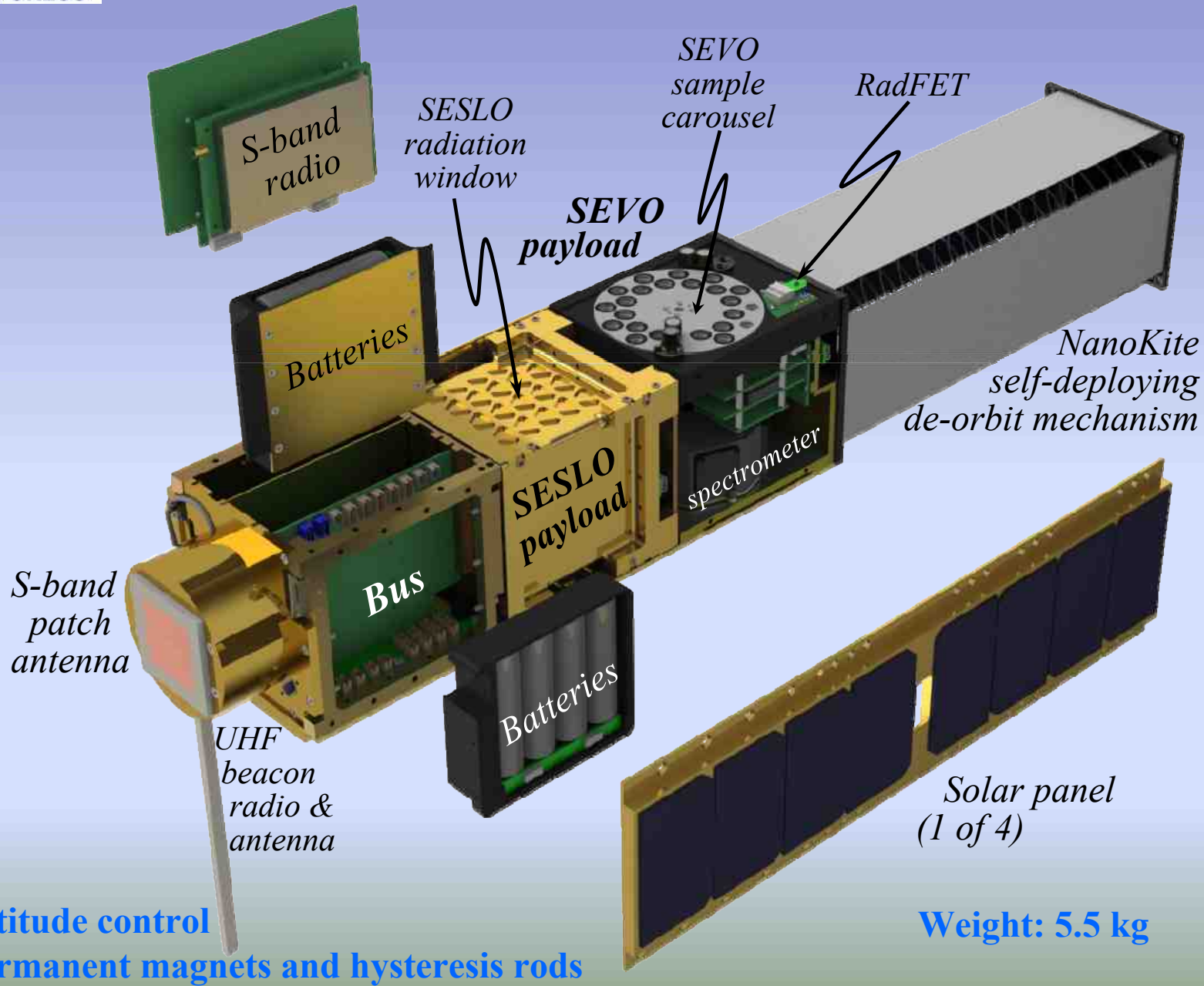
<http://ooreos.engr.scu.edu/dashboard.htm>





650 km orbit
 Orbital period: 97.7 minutes

Satellite rotation (z-axis): 1-2 RPM
 Coning rotation: 4-5 RPM



Kodiak lift off

Launch: 19 November 2010

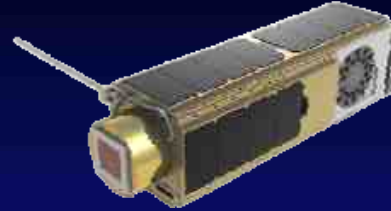
Launch Vehicle: Minotaur IV

Launch Site: Kodiak, Alaska

Mission duration: 6-12 months

Risk Class D, Category III

(\$2.5M)



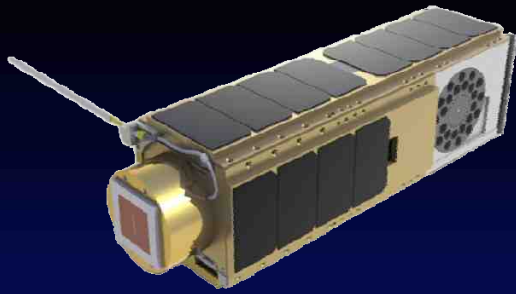
Minotaur IV



Kodiak Launch Complex, AK

57° 25' N

152° 21' W



Spacecraft Operations

O/OREOS beacon sends an AX.25 packet every 5 seconds; the packet contains data about the spacecraft systems operation

Single 3-meter Dish Operations:

- Useful Contacts per day: **2 good contact**
- Average time per contact: **~ 2 min**

Data downlink: 6 MB

EPO: Beacon signal → public operators

S-Band station: standard command and telemetry operations for O/OREOS

Santa Clara University



Mission science goals



O/OREOS Dual payload:

Monitor how exposure to space radiation and weightlessness changes biology and organic molecules



Goal 1: Measure the survival, growth and metabolism of two different microorganisms using **in-situ colorimetry**

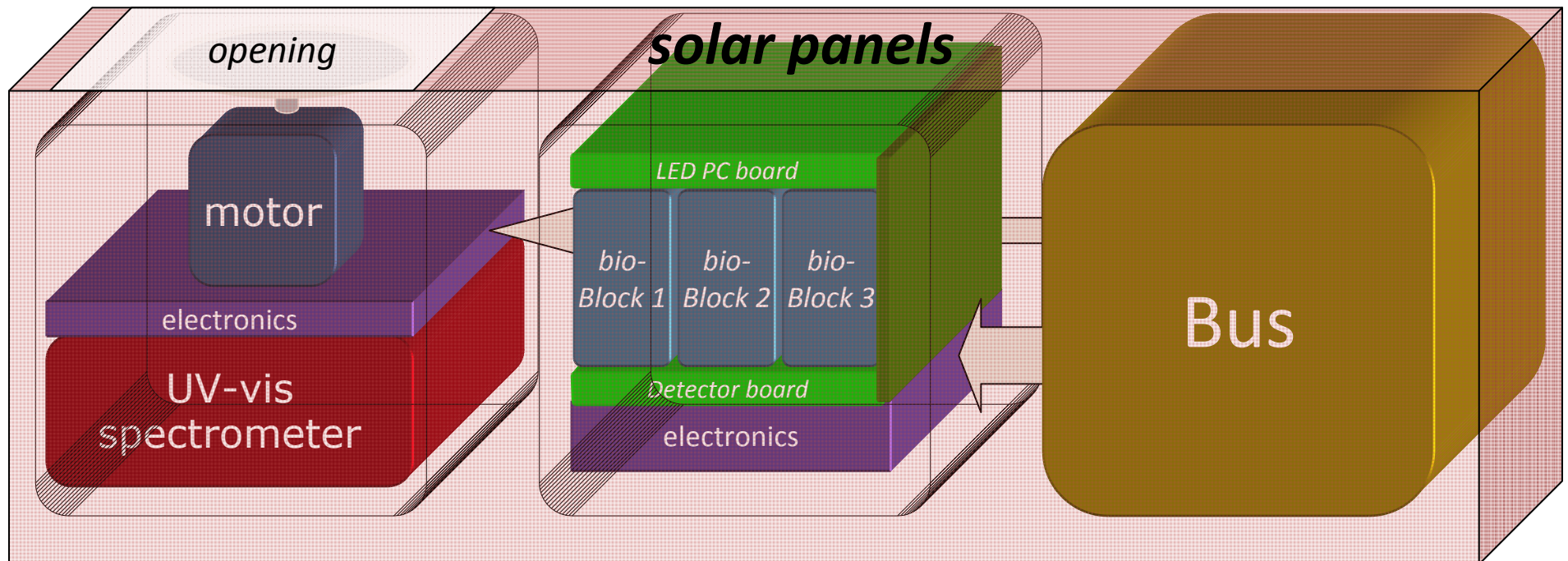
Goal 2: Measure the changes induced in molecules and biomarkers using **ultraviolet and visible spectroscopy**



O/OREOS Dual-Payload Technology Architecture



Each payload experiment-plus-instrument contained in a single 10-cm cube



Organics payload (SEVO)

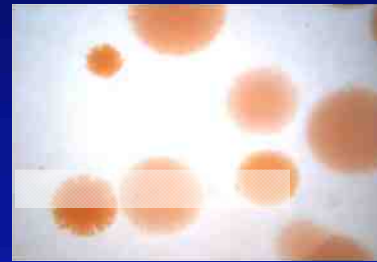
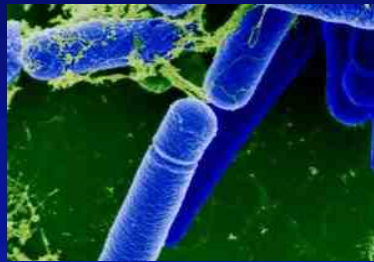
- 4 different organic molecules as thin films
- 4 reaction-cell-supported environments
- UV-visible spectroscopic characterization

Biology payload (SESLO)

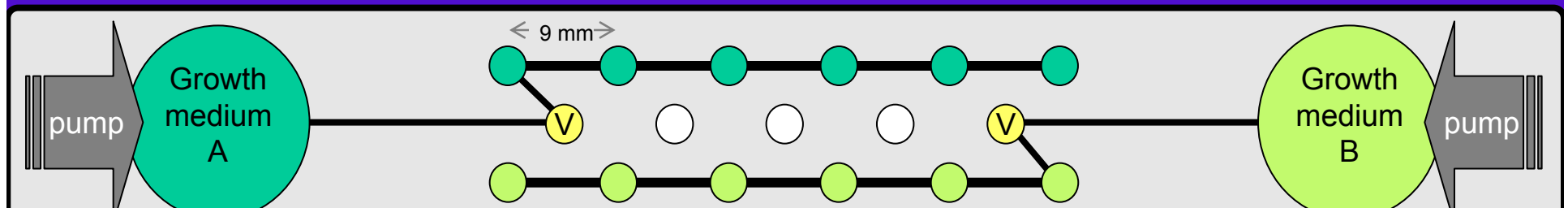
- 2 different biological specimens
- 3 growth initiation times (test periods)
- optical measurement of growth, metabolic activity

Space Environment Survivability of Live Organisms (SESLO)

SESLO collected 3 datasets on the survival and metabolic activity for two micro-organisms during the 6-month mission

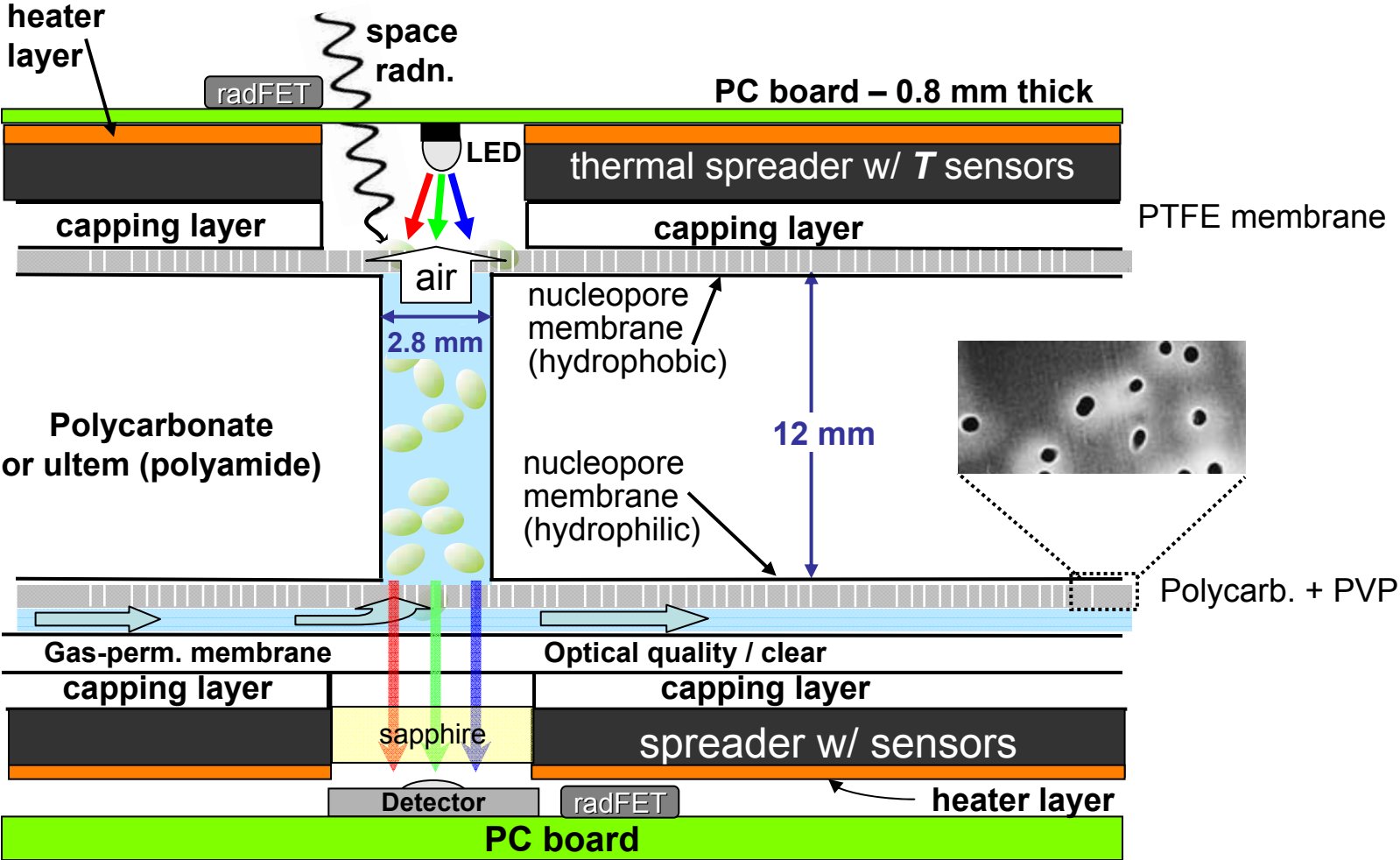


- *Bacillus subtilis* spores & *Halorubrum chaoviatoris* (each as wild-type and mutant) were launched in a dry state
- **Rehydration in orbit:** fluids were added to micro-organisms containing microwells at 2 weeks after launch, at 3 and 6 months



SESLO (bio) Fluidic/Thermal/Optical Architecture

Fluidic / optical / thermal cross-section

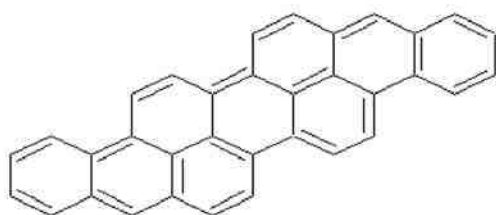


Space Environment Viability of Organics (SEVO)

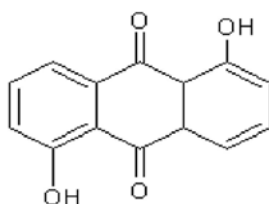
SEVO provides a real-time analysis of the photostability of four classes of organic molecule to the space environment

SEVO houses the organic samples in “planetary micro-environments”

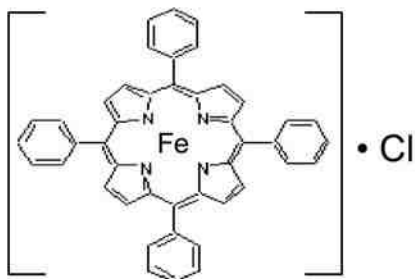
(gas, humidity and mineral substrates are sealed into the individual sample cells)



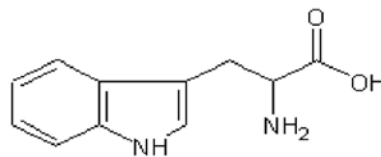
Isoviolanthrene



Anthrarufin



Iron tetraphenylporphyrin chloride



Tryptophan



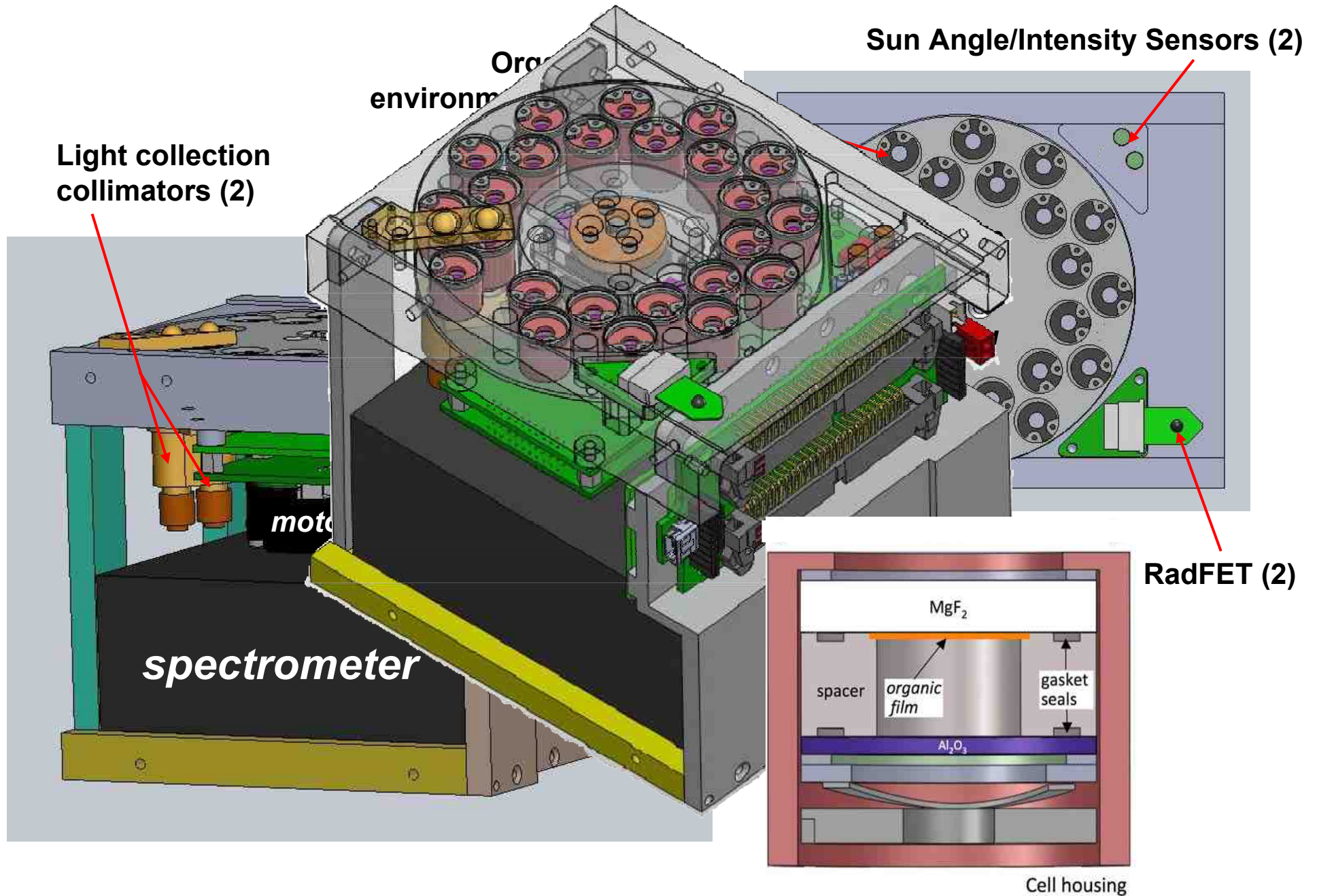
SEVO spectrometer



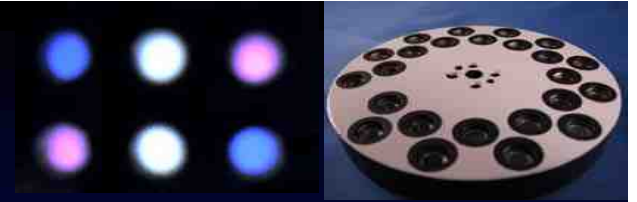
8 cm



SEVO: Integrated Instrument & Sample Disk



O/OREOS Science Return



- SESLO data contribute to our understanding of the **environmental limits of life** and will address many aspects of space biology and **planetary protection**
- SEVO data allow us to better understand **the carbon chemistry in space environments**, **extraterrestrial delivery processes** and prebiotic chemistry on the early Earth





O/OREOS





Medium & Full Success Criteria



Medium Success (TRL 7) includes minimum success outcomes plus *completion of ground experiments for establishing pre-flight experimental data baselines.*

Organics Experiment Demonstration Medium Success Details:

Measure the degradation of (bio) organic molecules in at least one of the relevant space environments.

Organisms Experiment Demonstration Medium Success Details:

Demonstrate the ability for biology to survive in a 3-month mission, *maintaining stasis for up to 4.5 months.*

Full Success (TRL8) includes minimum and medium success outcomes plus *launch, successful operation of the O/OREOS-Sat payload, and delivery of collected mission data to program management.*

Organics Experiment Demonstration Extended Success Details:

Measure the degradation of (bio) organic molecules in all *4 selected space environments.*

Organisms Experiment Demonstration Medium Success Details:

Demonstrate a third time series organism growth test that will be executable after 6 months on orbit. In this demonstration some of the organisms will have to be maintained in *stasis for up to 7.5 months* (1.5 months pre-launch, 6 months in space).

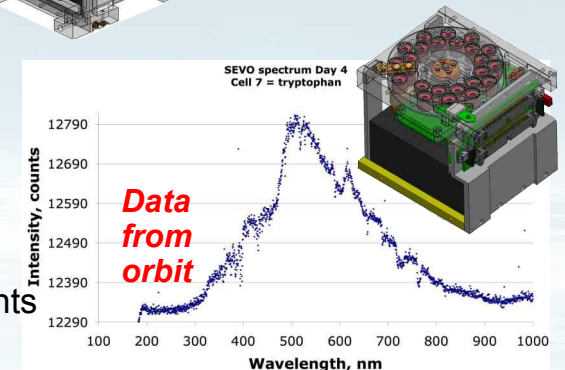
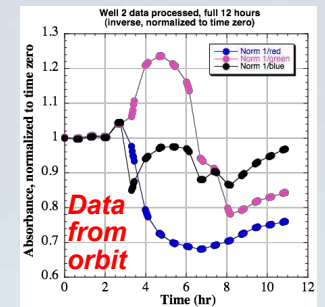
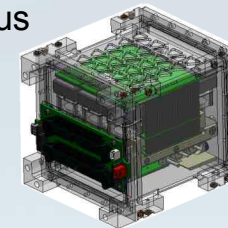
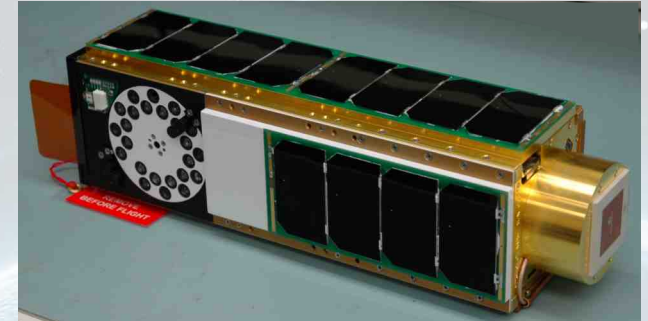


O/OREOS Nanosatellite Mission Update



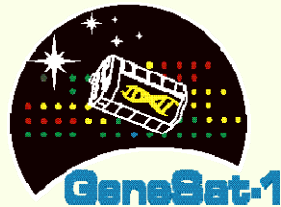
25 May 2011

- **Launch: Nov. 19, 2010, Minotaur IV**, Kodiak Launch Complex, Alaska
 - 5.5 kg nanosat deployed from PPOD @ 650 km, 72°, 98-min orbit
 - 1st science nanosatellite above the thermosphere
- **Overall Status: Nominal**
 - Full mission success criteria satisfied
 - Rotation rate has slowed from ~ 7 to ~ 1 RPM
 - Autonomous system resets ~ Dec. 27, Feb. 12, May 24
- **Communications Summary**
 - Beacon (EPO): ~ 100,000 packets submitted by amateurs in 22 countries
 - S-band (WiFi): ~6 MB downlinked by Santa Clara University team
 - Radiation dose, rotation data, temperatures, health, downlinked from bus
 - Multiple command uplinks successful to tune operational parameters
- **P/L 1: Space Environment Survival of Living Organisms**
 - $t = 2$ wk, 3 mo, 6 mo Biomodule exp'ts.: Dec. 3, Feb. 18, May 19
 - Asynchronous ground controls: Jan. 11, Apr. 5, July 5
 - Germination/growth of *B. subtilis* spores in all biowells; stable temp.
- **P/L 2: Space Environment Viability of Organics**
 - Nominal spectrometer function: 22 sets of 24 UV-vis spectra recorded
 - > 500 spectra from 4 organics in 4 microenvironments downlinked to date
 - Acquisition parameters tuned: best [signal - background] now > 7500 counts





Mission heritage



Space
Environment
Survival of
Living
Organisms (*SESLO*)



Space
Environment
Viability of
Organics (*SEVO*)

<i>Mission type</i>	Fund. biology / Tech. demo.	Fund. biology / Science	Astrobiology / Tech. demo. / 6-month experiment duration	
<i>Configuration</i>	2U payload, 1U bus (4.4 kg)	2U payload, 1U bus (5.1 kg)	2 x 1U independent payloads, 1U bus (5.5 kg)	
<i>Experiment</i>	Gene expression	Antifungal dose response	Microbe survival & activity	Solar UV-induced organic degradation
<i>Specimen</i>	<i>E. coli</i>	<i>S. cerevisiae</i>	<i>B. Subtilis</i> <i>H. Chaoviatoris</i>	<i>PAH, amino acid,</i> <i>porphyrin, quinone</i>
<i>Measurement</i>	OD; green fluorescence	RGB absorbance, metabolic indicator	RGB absorbance, metabolic indicator	UV-vis spectroscopy 4 μ environments
<i>Sample n</i>	10 wells	48 wells (3 conc's.)	3 x 12 wells	24 sample cells
<i>Sensors</i>	<i>T, p, RH, accel.,</i> radiation flux	<i>T, p, RH,</i> radiation flux	<i>T, p, RH,</i> radiation dose	<i>T, radiation dose,</i> intensity/sun angle
<i>Launch (Orbit)</i>	Dec. 2006 Minotaur I	May 2009 Minotaur I (430 km)	Nov. 2010, Minotaur IV (72° inclination, 650 km)	
<i>Outcome</i>	Mission success Re-entry 2010	Mission success De-orbit ~ 2013	Mission success; subsystems operational Anticipated deorbit ~ 2032	

CubeSat “Demographics”



- Total 55 of cubesats launched since 2003
 - Most are university satellites
 - Many launched for nominal fee < \$100k, some launched “free” on government launch vehicles
- Since 2000, ~ 100 universities have developed or are active in the field of cubesats
- Since 2000, twelve new businesses/startups
- UN Basic Space Technology Initiative





Payload Technologies: Cross-Cutting Applications

PAYLOADS

Biology—grow & characterize survival, space environment effects: *cells, microbes, plants, multicellular organisms*

Chemistry—characterize *in situ*: *dust, soil, regolith, atmosphere*

Space environment—consequences for materials: *engineering, astrobiology*

Sensing: *radiation, space weather, atmospheric studies*

Spectroscopy: *atmospheres, exospheres, soil volatiles, materials, molecules*

Imaging & astronomy: *Solar system bodies, stars, galaxies, interstellar medium*

PLATFORMS

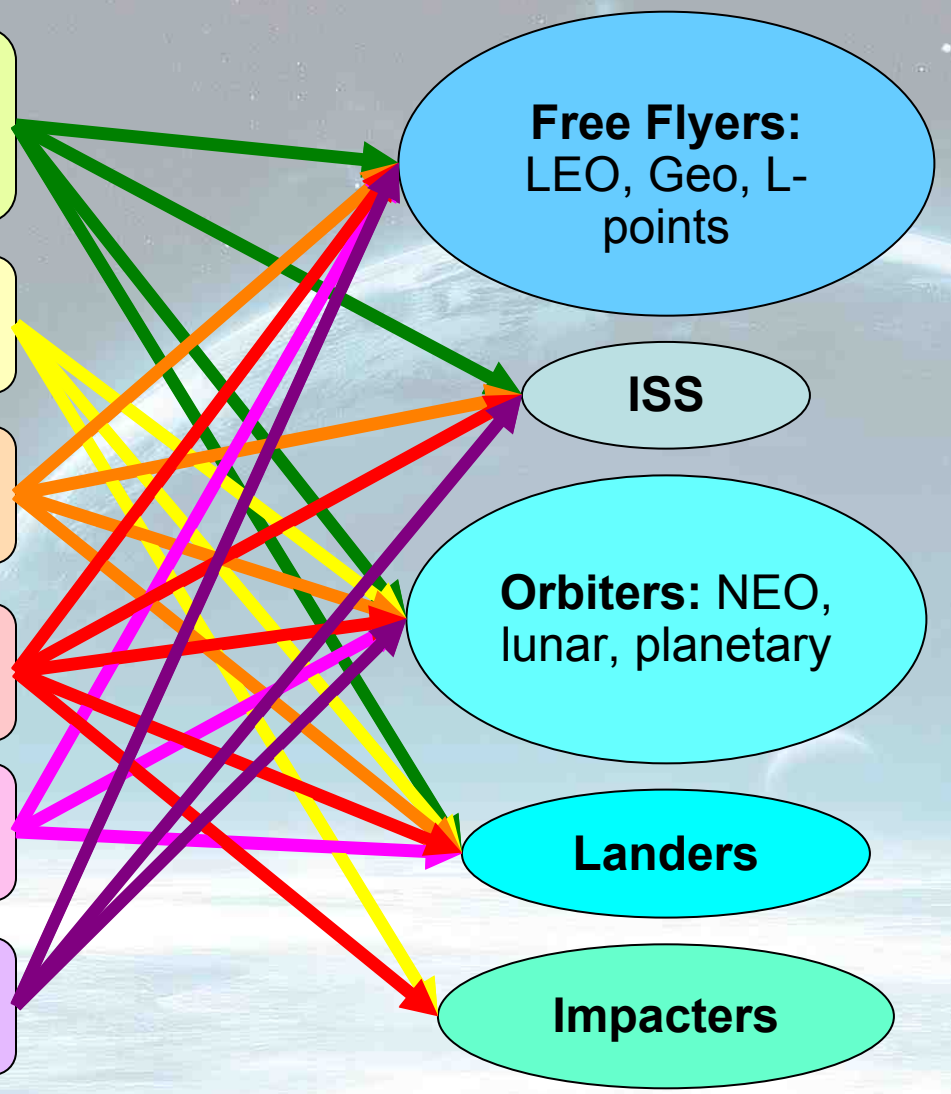
Free Flyers:
LEO, Geo, L-points

ISS

Orbiters: NEO, lunar, planetary

Landers

Impactors

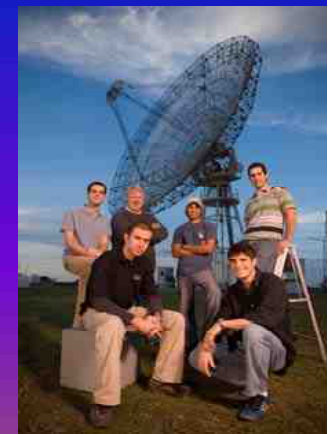


Mission concept to space science results in 18-24 months



- Frequent access to space
- Ability to execute rapid response missions
- Ability to perform all aspects of a NASA mission
- **Comparatively low-cost missions**
 - ✓ Small core team with heritage knowledge
 - ✓ Parallel mission architecture (design and cost leveraging)
- **Adaptable, modular payload designs**

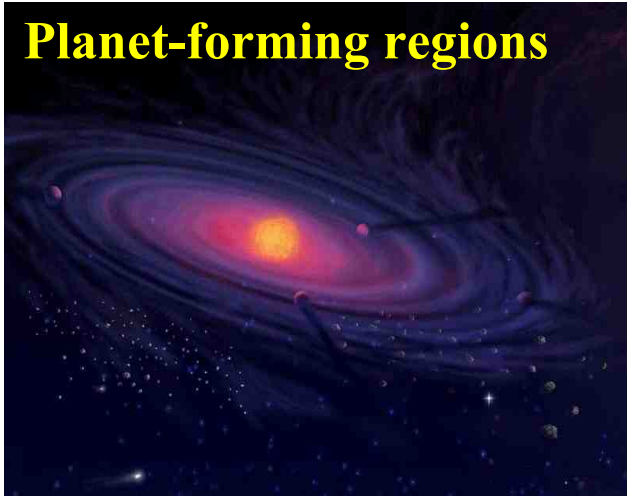
**Multi-platform compatibility: Suborbital, ISS, Free Flyers,
Planetary Landers/Impactors/Orbiters**



Back-up



Planet-forming regions



Earth-Moon-Mars Space



LEO



Space exploration

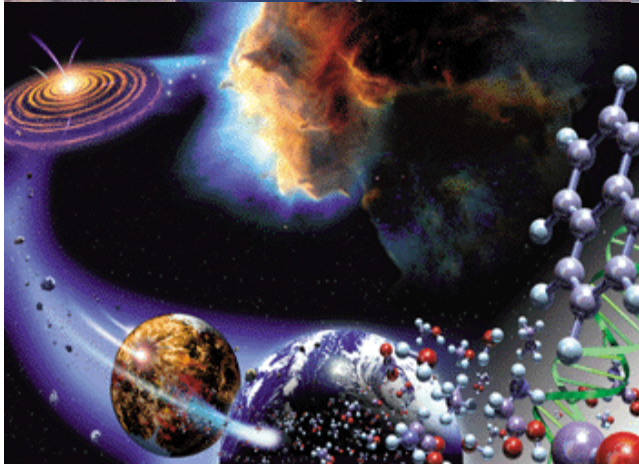


Earth science

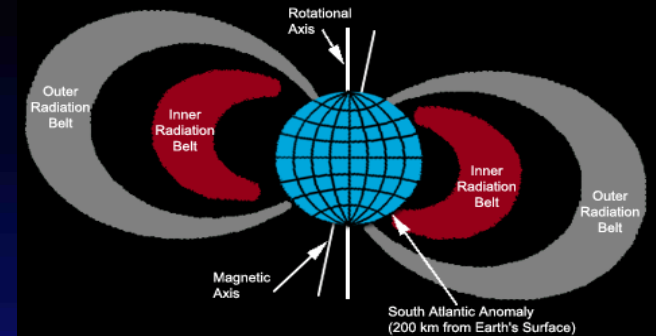


O/OREOS data will address several research avenues:

- Organic chemistry in space**
- Extraterrestrial delivery processes**
- Adaptation of life to space environment**
- Planetary protection**
- Space exploration**
- In situ monitoring technology**



Space conditions



- **Biology: Particle radiation and microgravity**
 - $< 10^{-3}$ g
 - 1.3 Gy total dose over 6 mo
 - 0.1 Gy is GCR, 1 Gy is trapped protons
- **Organics: Particle and UV radiation, microgravity**
 - $< 10^{-3}$ g
 - ~ 15 Gy = 1.5 krad
- 6-month exposure of organics to space
- Solar exposure $\sim 35\%$ of total time = 1500 h
 - 120 - 2800 nm