THE O/OREOS MISSION: ASTROBIOLOGY IN LOW EARTH ORBIT

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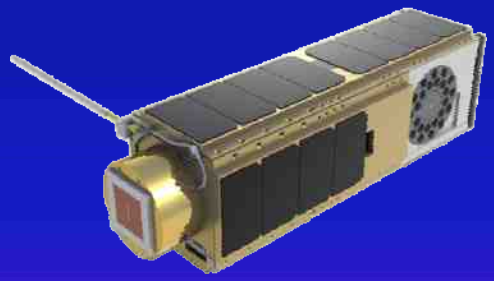

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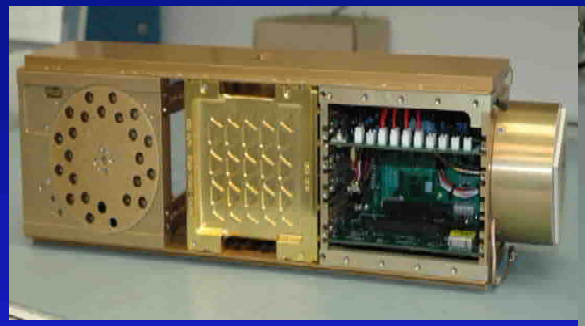
NASA Astrobiology Small Payloads (ASP)

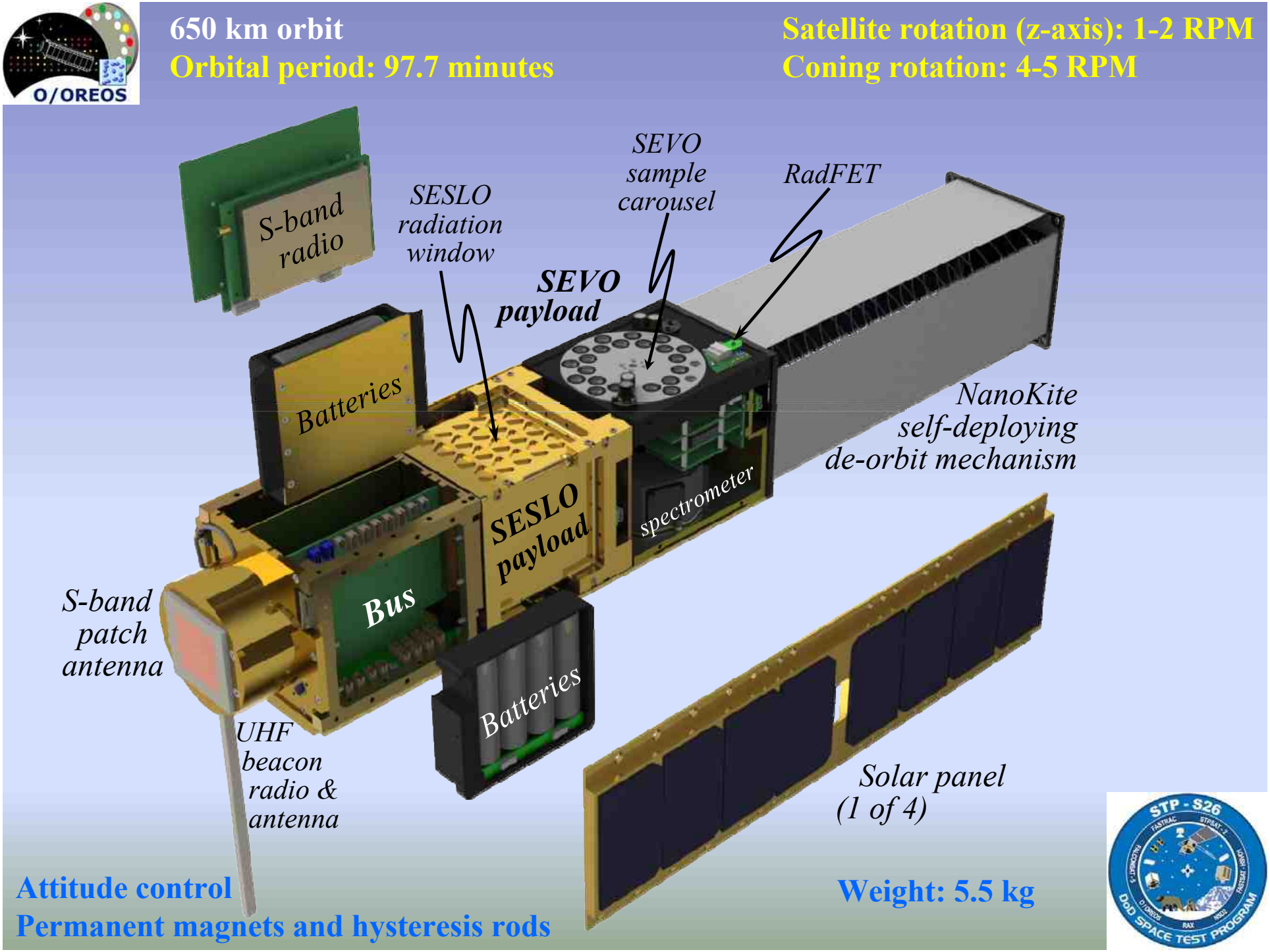
Develop and fly small astrobiology payloads, from single-cube free flyers to suitcase-sized payloads, to address fundamental astrobiology objectives, using a variety of launch opportunities


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
S-band radio
SESLO radiation window
SEVO sample carousel
RadFET
SEVO payload
Batteries
NanoKite self-deploying de-orbit mechanism
SESLO payload
spectrometer
Bus
S-band patch antenna
Batteries
UHF beacon radio & antenna
Solar panel (1 of 4)
Attitude control
Permanent magnets and hysteresis rods
Weight: 5.5 kg

Kodiak lift off

Launch: 19 November 2010

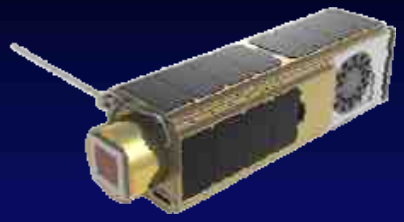
Launch Vehicle: Minotaur IV

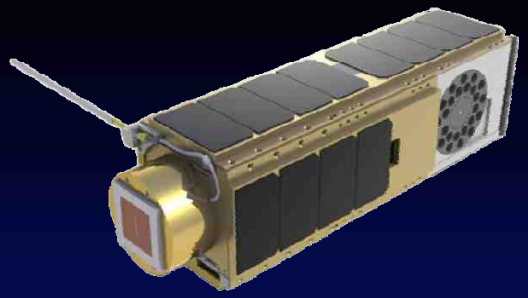
Launch Site: Kodiak, Alaska

Mission duration: 6-12 months

Risk Class D, Category III

($2.5M)





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**

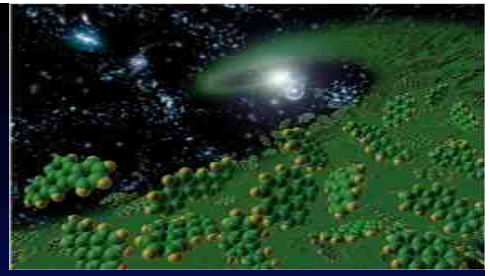
Data downlink: 6 MB

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

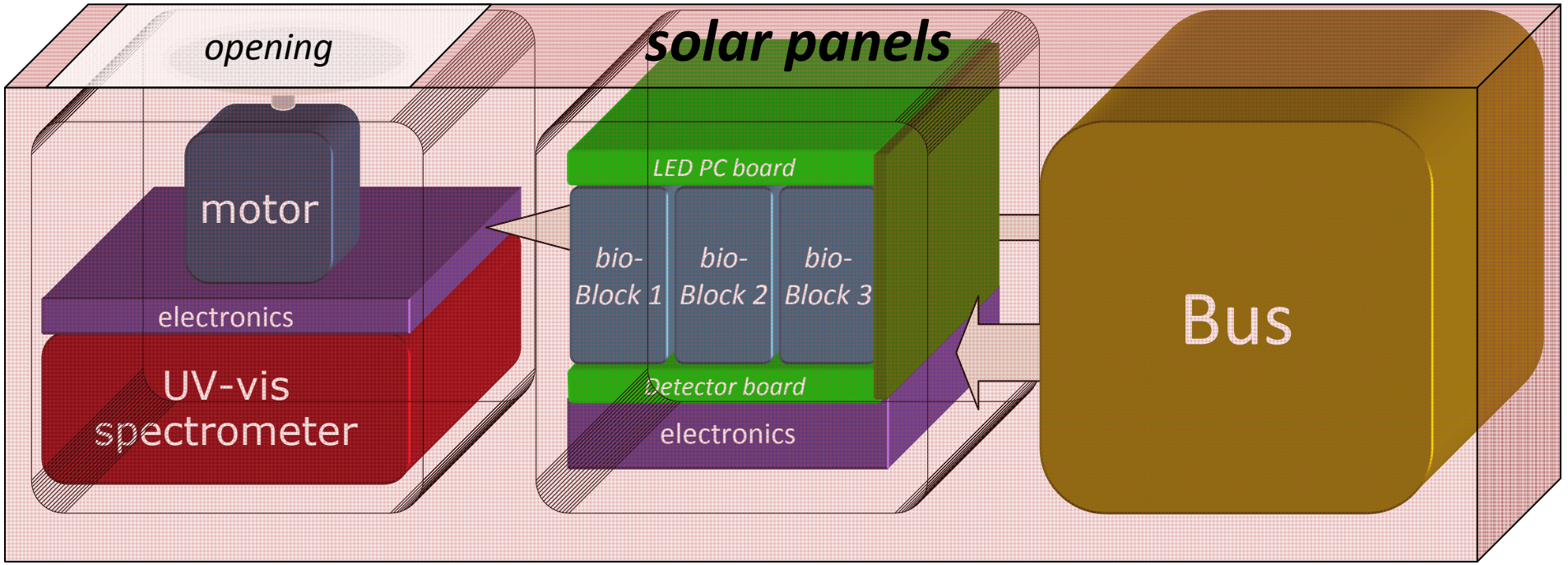
Goal 1: Measure the survival, growth and metabolism of two different microorganisms using **in-situ colorimetry**

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

O/OREOS Dual-Payload Technology Architecture

Astrobiology Small Payloads

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



Organics payload (SEVO)

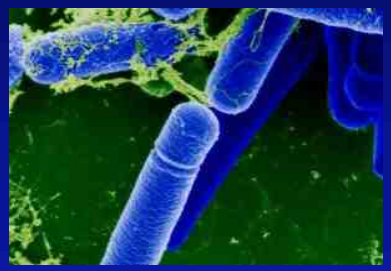
- **4 different organic molecules as thin films**
- **4 reaction-cell-supported environments**
- **UV-visible spectroscopic characterization**

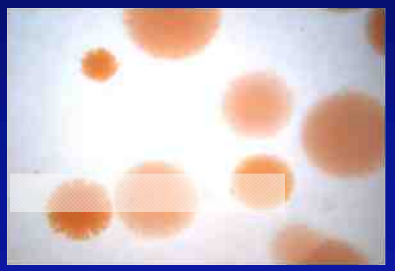
Biology payload (SESLO)

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

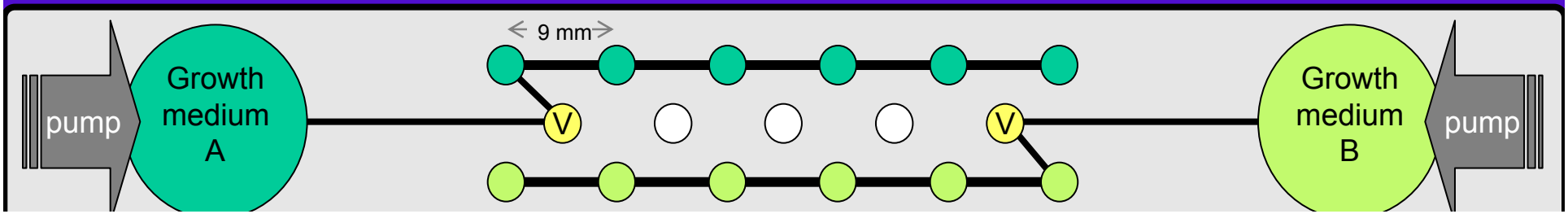
Space Environment Survivability of Live Organisms (SESLO)

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



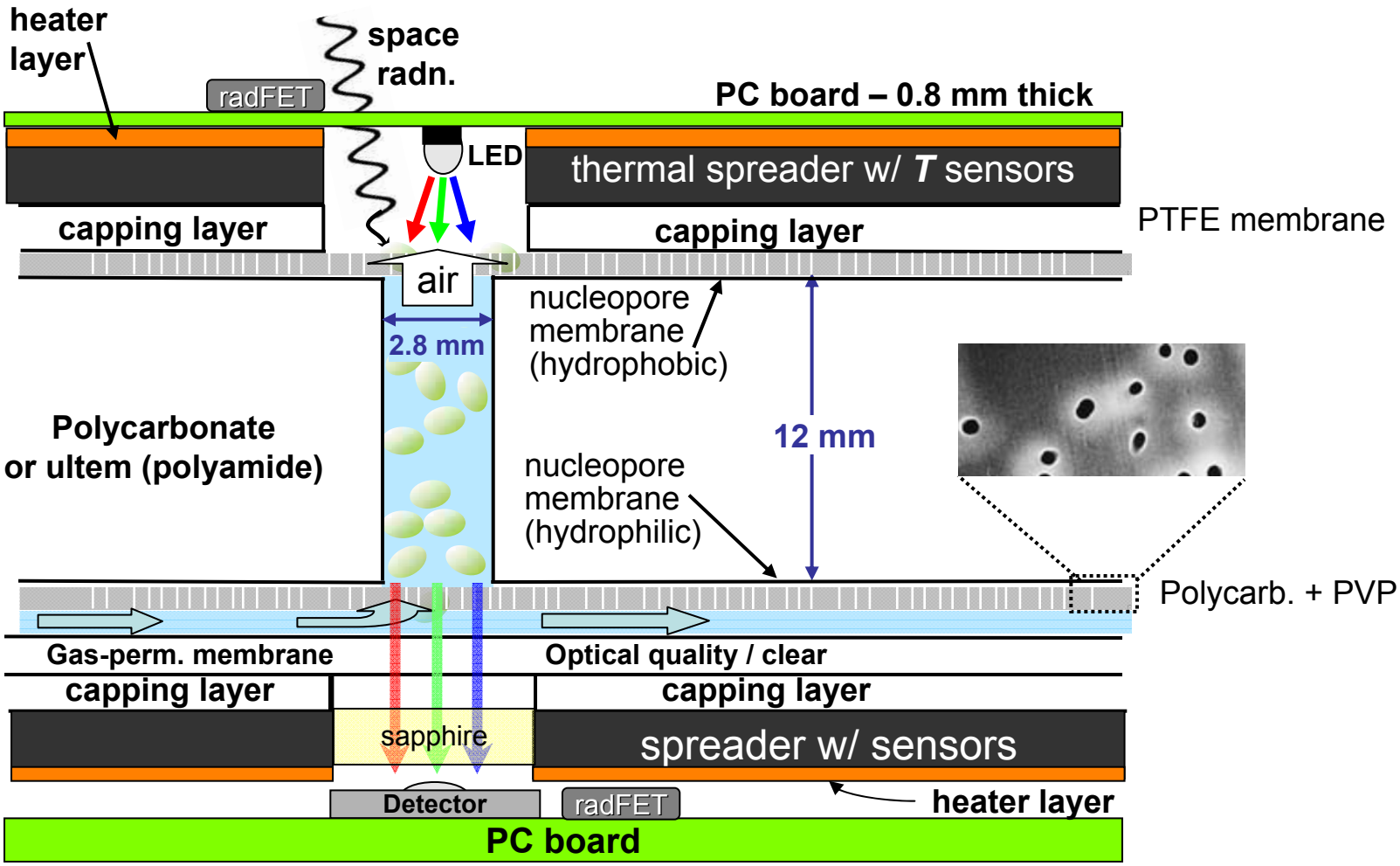


- ***Bacillus subtilis spores & Halorubrum chaoviatoris*** **(each as wild-type and mutant) were launched in a dry state**
- **Rehydration in orbit: fluids were added to micro-organisms containing microwells at 2 weeks after launch, at 3 and 6 months**



SESLO (bio) Fluidic/Thermal/Optical Architecture

Fluidic / optical / thermal cross-section

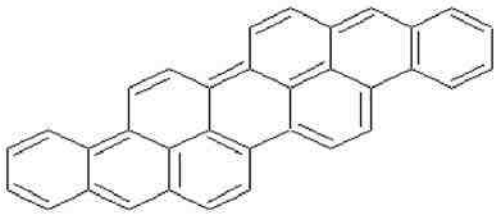


Space Environment Viability of Organics (SEVO)

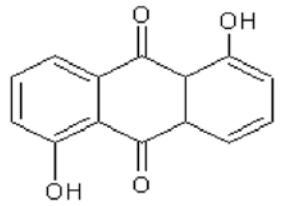
SEVO provides a real-time analysis of the photostability of four classes of organic molecule to the space environment

SEVO houses the organic samples in "planetary micro-environments"

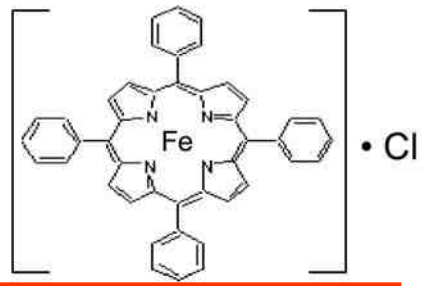
(gas, humidity and mineral substrates are sealed into the individual sample cells)



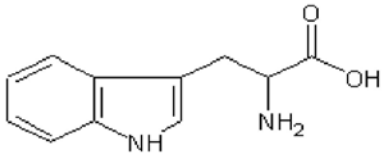
Isoviolanthrene



Anthrarufin

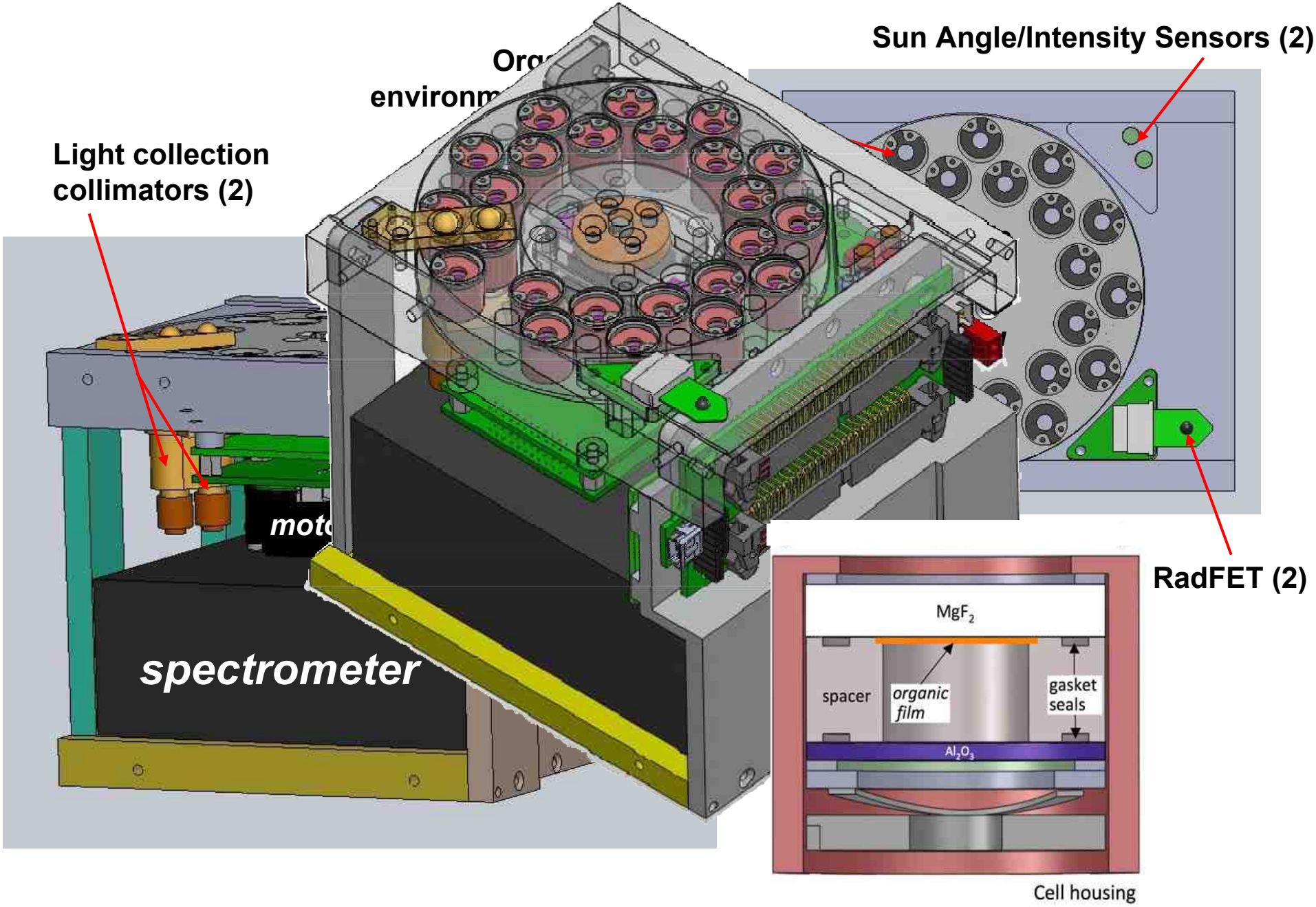


Iron tetraphenylporphyrin chloride

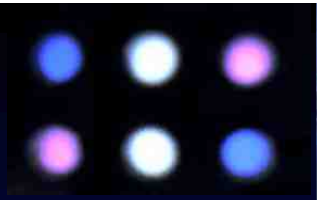


Tryptophan

SEVO: Integrated Instrument & Sample Disk

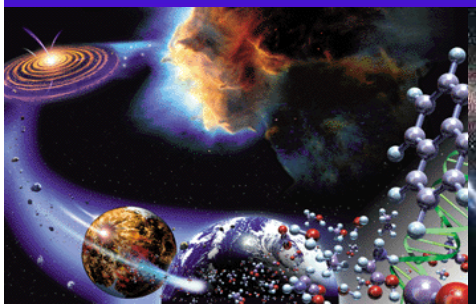


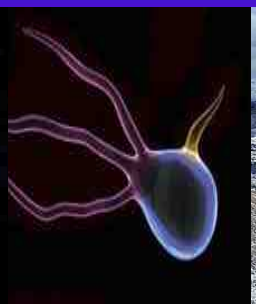
O/OREOS Science Return



- 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.*

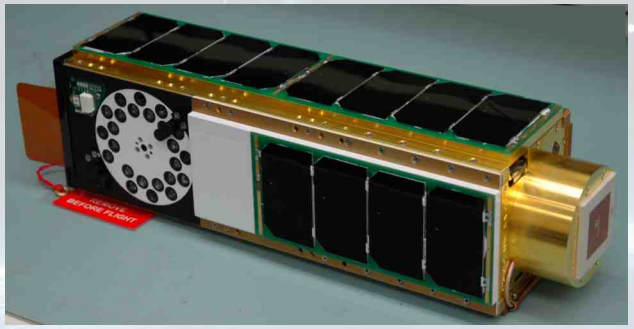
Organisms Experiment Demonstration Medium Success Details:

***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).**

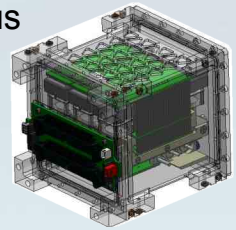
O/OREOS Nanosatellite Mission Update

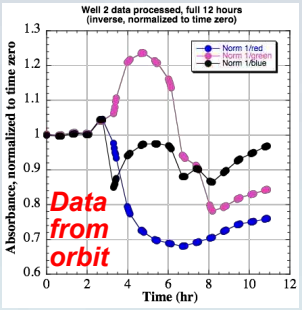
25 May 2011

- **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

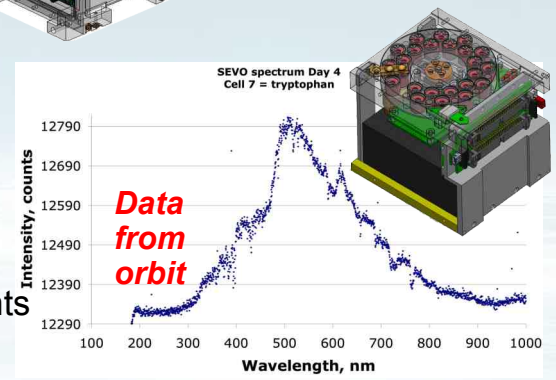


- **Overall Status: Nominal**
  - Full mission success criteria satisfied
  - Rotation rate has slowed from ~ 7 to ~ 1 RPM
  - Autonomous system resets ~ Dec. 27, Feb. 12, May 24
- **Communications Summary**
  - Beacon (EPO): ~ 100,000 packets submitted by amateurs in 22 countries
  - S-band (WiFi): ~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



http://www.nasa.gov/mission_pages/smallsats/oreos/main/ http://ooreos.engr.scu.edu/dashboard.htm

Mission heritage

GeneSat-1

PharmaSat

Space Environment Survival of Living Organisms (*SESLO*)

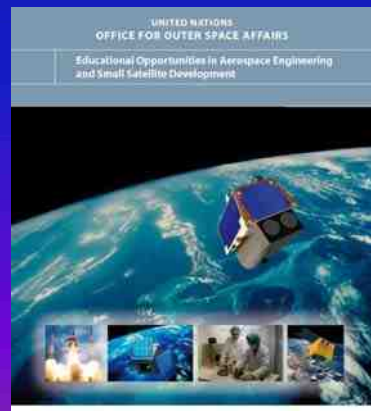
O/OREOS

Space Environment Viability of Organics (*SEVO*)

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

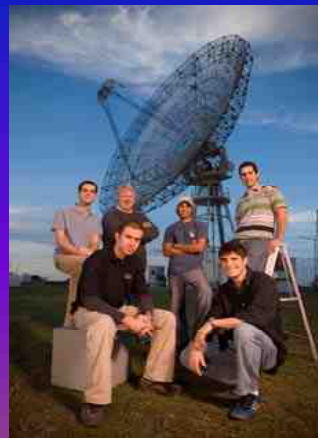
Landers

Impacters

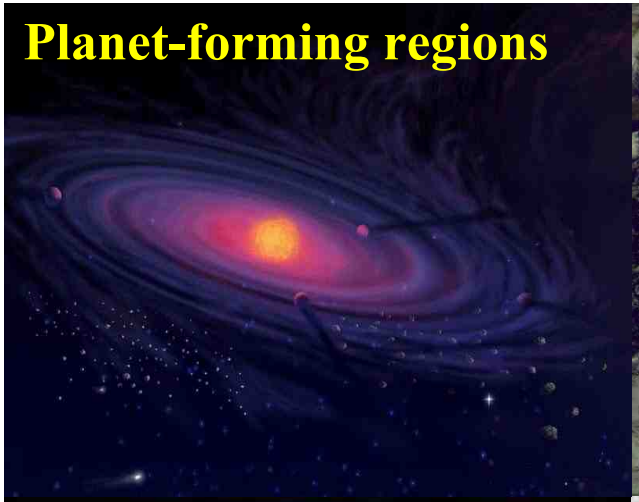
Mission concept to space science results in 18-24 months

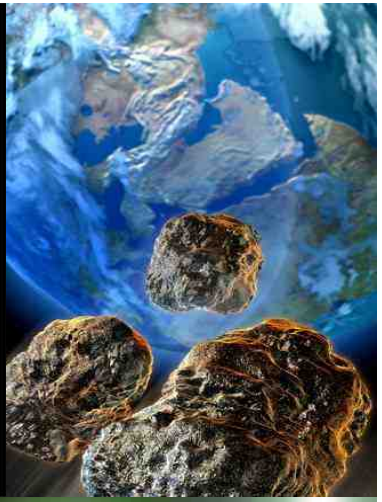
- Frequent access to space
- Ability to execute rapid response missions
- Ability to perform all aspects of a NASA mission
- Comparatively low-cost missions
  - ✓ Small core team with heritage knowledge
  - ✓ Parallel mission architecture (design and cost leveraging)
- Adaptable, modular payload designs

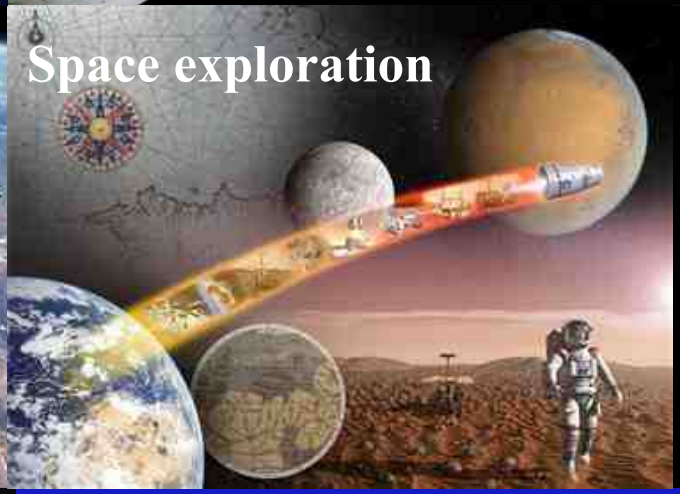
Multi-platform compatibility: Suborbital, ISS, Free Flyers, Planetary Landers/Impacters/Orbiters

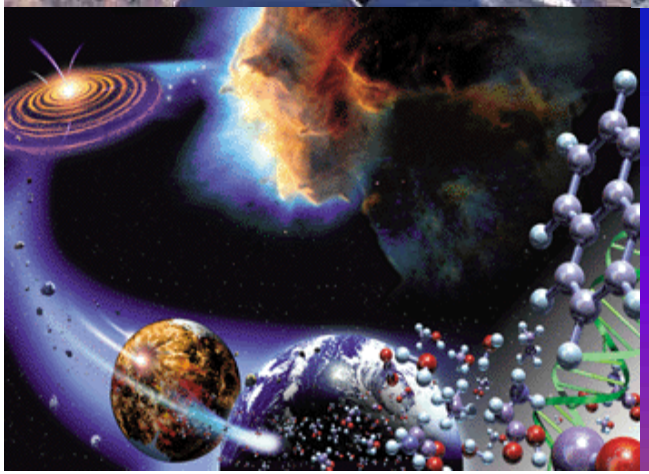


Back-up





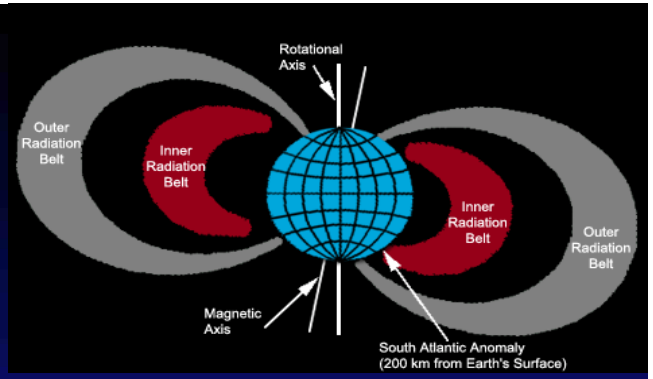




O/OREOS data will address several research avenues:

- 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 ~ 35% of total time = 1500 h
  - 120 - 2800 nm