THE O/OREOS MISSION:
ASTROBIOLOGY IN LOW EARTH ORBIT

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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.

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

Weight: 5.5 kg

SEVO payload
SESLO sample carousel
RadFET
NanoKite self-deploying de-orbit mechanism

S-band radiation window
SEVO payload
S-band patch antenna
UHF beacon radio & antenna
Batteries
Batteries
Solar panel (1 of 4)

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Permanent magnets and hysteresis rods

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Attitude control
Permanent magnets and hysteresis rods
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

3 m antenna
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*
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

- Polycarbonate or ultem (polyamide)
- Gas-perm. membrane
- Optical quality / clear
- capping layer
- sapphire
- spreader w/ sensors
- Detector
- radFET
- heater layer
- PC board
- Polycarb. + PVP
- PTFE membrane
- nucleopore membrane (hydrophilic)
- nucleopore membrane (hydrophobic)
- 2.8 mm
- 12 mm
- PC board – 0.8 mm thick
- LED
- heater layer
- radFET
- space radn.
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).

Isovanlanthrene

Anthrarufin

Iron tetraphenylporphyrin chloride

Tryptophan

SEVO spectrometer 8 cm
SEVO: Integrated Instrument & Sample Disk

- Spectrometer
- Motor
- Light collection collimators (2)
- Organic film / environment cells (24)
- Solar source diffusers (2)
- Sun Angle/Intensity Sensors (2)
- RadFET (2)
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
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 (TRL 8) 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

<table>
<thead>
<tr>
<th>Mission type</th>
<th>Configuration</th>
<th>Experiment</th>
<th>Specimen</th>
<th>Measurement</th>
<th>Sample n</th>
<th>Sensors</th>
<th>Launch (Orbit)</th>
<th>Outcome</th>
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</thead>
<tbody>
<tr>
<td>Fund. biology / Tech. demo.</td>
<td>2U payload, 1U bus (4.4 kg)</td>
<td>Gene expression</td>
<td>E. coli</td>
<td>OD; green fluorescence</td>
<td>10 wells</td>
<td>T, p, RH, accel., radiation flux</td>
<td>Dec. 2006 Minotaur I</td>
<td>Mission success Re-entry 2010</td>
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<tr>
<td>Astrobiology / Tech. demo. / 6-month experiment duration</td>
<td>2 x 1U independent payloads, 1U bus (5.5 kg)</td>
<td>Microbe survival &amp; activity</td>
<td>B. Subtilis H. Chaoviatoris</td>
<td>RGB absorbance, metabolic indicator</td>
<td>3 x 12 wells</td>
<td>T, p, RH, radiation flux</td>
<td></td>
<td>Mission success; subsystems operational Anticipated deorbit ~ 2032</td>
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<tr>
<td></td>
<td></td>
<td>Solar UV-induced organic degradation</td>
<td>PAH, amino acid, porphyrin, quinone</td>
<td></td>
<td></td>
<td>T, radiation dose, intensity/sun angle</td>
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<tr>
<td></td>
<td></td>
<td>UV-vis spectroscopy</td>
<td>4 µenvironments</td>
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<td>24 sample cells</td>
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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
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
  - $\sim 15$ Gy = 1.5 krad
  - 6-month exposure of organics to space
  - Solar exposure $\sim 35\%$ of total time = 1500 h
    - 120 - 2800 nm