OREOcube: ORganics Exposure in Orbit

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Astrochemistry:
• Carbon chemistry in space and planetary environment
• Understand details & distribution of prebiotic chemistry - chemical building blocks
• Tracing the chemical processes towards the origin of life

Astrobiology:
• origin, evolution, distribution, & future of life in the universe of life
• Study potential for life to adapt/survive in extraterrestrial environments
• Search for (signs of) extant or extinct non-terrestrial life
• Find habitable environments in our solar system & beyond

Why: fundamental understanding of life & the universe
Rationale - Why “SmallSats”?

SmallSats are ever more capable: *Miniature/micro/nano technologies*

- bioengineered organisms; fabrication; materials; optics; sensors; actuators; MEMS; fluidics; electronics; communications; instrumentation; data handling & storage
- Power generation & storage density up; power needs down

**Access to space:** *Low-cost* launches as secondary payloads

- *military, government, commercial*; US, Russia, Europe, Canada, India, ...
- *Multiple flights possible* - test, learn, iterate

**Excellent education vehicle:** Significant academic participation worldwide

**Autonomous operations:** Less reliance on human-tended experiments

**Technology migration:** ISS; landers/orbiters for moon, Mars, other planets
## Mission heritage

<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>
</tr>
</thead>
<tbody>
<tr>
<td>Fund. biology / Tech. demo.</td>
<td>2U payload, 1U bus (4.4 kg)</td>
<td>Gene expression</td>
<td><em>E. coli</em></td>
<td>OD; green fluorescence</td>
<td>10 wells</td>
<td><em>T, p, RH, accel., radiation flux</em></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><em>B. Subtilis, H. Chaoviatoris</em></td>
<td>RGB absorbance, metabolic indicator</td>
<td>3 x 12 wells</td>
<td><em>T, radiation dose</em></td>
<td>Nov. 2010, Minotaur IV (72° inclination, 650 km)</td>
<td>Mission success; subsystems operational Anticipated deorbit ~ 2032</td>
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<td>Solar UV-induced organic degradation</td>
<td>PAH, amino acid, porphyrin, quinone</td>
<td>UV-vis spectroscopy</td>
<td>4 µenvironments</td>
<td>24 sample cells</td>
<td><em>T, radiation dose, intensity/sun angle</em></td>
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**Mission heritage**

- **GeneSat-1**: Space Environment Survival of Living Organisms (SESLO)
- **PharmaSat**: Space Environment Viability of Organics (SEVO)
- **O/OREOS**
Key facts:

O/OREOS (NASA Astrobiology Small Payloads):
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)
• first technology demonstration
• space environment as well as space biology relevant to Moon and Mars missions.
• precursor for experiments on small satellites, the ISS, future free-flyers and lunar surface exposure facilities.

SESLO (Space Environment Survivability of Live Organisms)
• understanding of the environmental limits of life
• space biology and planetary protection.

SEVO (Space Environment Viability of Organics)
• carbon chemistry in space environments,
• extraterrestrial delivery processes
• prebiotic chemistry on the early
Key Facts:

Proposed to the International Research Announcement for Research in Space Life Sciences ILSRA 2009 and selected for Definition Phase by the European Space Agency (ESA)

OREOCUBE: SEVO (Space Environment Viability of Organics) of O/OREOS Nanosat, a 10-cm cube containing a highly capable UV-visible spectrometer and 24-sample carrier

- OREOCUBE provides the capability of daily in-situ monitoring of flight samples
- Comparative low cost, low power requirements, high functionality, full autonomy, and small size of an already-built nanosatellite payload instrument at technology readiness level (TRL) 8
- Development of standardized (“plug & play”) analytical instrumentation
- Inexpensive-to-develop, space-qualified instrumentation for use in (or on the outside of) the ISS, planetary orbiters and landers, lunar platforms and future free-flyers

Launch 2015/6, potentially SpaceX, Cape Canaveral, Florida
OREOCUBE:

2 integrated “single-cube” UV/visible/near-IR spectroscopy systems

Simulation of planetary micro-environments: any gas/humidity composition can be sealed into the individual sample cells

Measurements in the radiation environment of the ISS to understand the carbon chemistry in space environments, extraterrestrial delivery processes and prebiotic chemistry on the early Earth

Real-time analysis of the photostability of organics and biomarkers in the UV and ionizing radiation environment of the ISS

Elucidation of the kinetics and evolution of organic materials in planetary micro-environments

Demonstration of in-situ UV-visible spectrometer technology on exposed samples on the ISS, with the two spectrometers remaining available for future experiments

Isomolarthrene

Tryptophan

Anthrarufin
<table>
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<th><strong>OREOcube-SEVO: Key Specifications</strong></th>
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<td><strong>Solar exposure wavelengths</strong></td>
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<tr>
<td><strong>Exposure time</strong></td>
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<td><strong>Spectrometer wavelength range</strong></td>
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<tr>
<td><strong>Spectral resolution</strong></td>
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<td><strong>Grating specs. &amp; slit width</strong></td>
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<tr>
<td><strong>Integration time</strong></td>
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<td><strong>On-board spectral averaging</strong></td>
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<td><strong>Temperature range (samples)</strong></td>
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<td><strong>Temperature sensors</strong></td>
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<td><strong>Cell leak rate/Sealing method</strong></td>
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<td><strong>Operational sequence</strong></td>
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<td><strong>Normalization/calibration</strong></td>
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<td><strong>Acquisition criterion</strong></td>
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Free-Flyer (in LEO) vs. Hitchhiker (on ISS)

**Free-Flyer:**
- In-situ monitoring
- Autonomous
- Propulsion/Attitude control/self-deorbiting

**Hitchhiker**
- In-situ monitoring plus sample return
- Autonomous (astronaut installation possible)
- No Propulsion/Attitude control
Space conditions @ 650 km, 72° inclination

**Biology:** Particle radiation and microgravity
- 0, 3 mo, 6 mo space exposures
- \(< 10^{-4} \times g\)
- \(~1.3\) Gray total dose over 6 months
  - 0.1 Gy is GCR, 1 Gy is trapped protons

**Organics:** Particle and UV radiation
- 12-17 month exposure of organics to space
- Solar exposure \(~ 30\% \) time = 3600 h
  - 120 - 2800 nm (Lyman \(\alpha\) = 10 eV photons)
- \(~ 55\) Gray total ionizing dose over 12 months
  - 0.2 Gy is galactic cosmic radiation, 50 Gy is trapped electrons

*Total radiation dose ~ 15x dose at ISS for similar shielding*
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, astrochemistry, 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**
Lunar and Interplanetary Developments

LuBiC (Lunar Biosentinel Cube):
- Effect of the lunar radiation environment on living organisms by measuring DNA double-strand breaks, cell membrane damage, oxidative stress response and protein alterations.
- LuBiC will help to improved radiation countermeasures and biosentinel dosimetry strategies by helping to assess pathogenicity and evaluate/improve radiation damage models & ground studies.

RASIR (Reactivity Analyzer for Soil, Ices, and Regolith):
- Represents a next generation SEVO cube, modified for regolith/dust analyses using thin-film chemical sensors in combination with fluorescence, luminescence and/or UV-Vis Reflectance measurements.
- RASIR will enable characterization of sample reactivity levels by monitoring reactive oxygen and hydrogen species in soil, ices and regolith.
Future perspectives

- Astrobiology/Astrochemistry experiments in higher elliptical orbits, Lagrange points or to other planets (free-flyer or hitchhiker)

- Further development of analytical instrumentation for in-situ monitoring

- Adaptation of off-the shelf technology, Inexpensive-to-develop, space-qualified instrumentation for use in (or on the outside of) the ISS, planetary orbiters and landers, lunar platforms and future free-flyers

- Intensified collaboration between academia and industry for future cubesat platforms
Conclusions

• **Nanosats / cubesats can do real science in space!**
  • Tools, devices, sensors of bio / nano / micro technologies are key enablers
  • Integration & automation and a remarkable multi-disciplinary team
  • Real-time, *in-situ* measurements provide insights on dynamics of reactions & processes not available with expose-and-return strategies
  • More launch opportunities, lower cost than conventional space platforms, no reliance on crew training / availability
  • Interplanetary cubesat missions would offer great potential for astrochemistry and astrobiology