Earthshine
A Deep Space Mission Using Small Satellite Technology

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Science #1

- Links between solar and climate variability have, in the past, been discounted because the power extracted from the solar wind is much lower than the power delivered by solar UV, visible and IR radiation (2e11 vs. 1.7e17 Watts).
- However, recent work has caused a re-evaluation of some possible links between solar and climate variability.
- The power output from the Sun per unit area at the Earth has been shown to vary by 0.1% during the solar cycle. This variation is thought to be due to the effects of solar magnetic fields.
- 0.1% is not enough to account for some of the observed changes, but there is growing evidence that the effects of this variation in solar irradiance on Earth’s climate are somehow amplified.
- Possible mechanisms proposed include:-
  - Large variability in UV has disproportionate effect via the chemistry of the middle atmosphere.
  - Total Solar Irradiance variations drive changes in Earth’s albedo
  - Galactic cosmic rays induced ions grow into cloud condensation nuclei and thus contribute to the production of clouds.
  - GCRs influence global electric thunderstorm circuit
Science #2 - Terrestrial Energy Budget

Albedo $\approx \frac{1}{3}$
Science #3 – Objectives

• To measure variations in global cloud cover in relation to solar variations
• Continuously monitor Earth albedo over a range of scattering angles
• Make observations of the heliospheric environment near Earth.
• To measure the incident GCR flux outside the Earth’s magnetosphere
Meeting the Science Goals

• Continuous view of Sun and daylight side of Earth for albedo measurements.
• Orbit diameter large enough to cover range of scattering angles (140 to 170º)
• GCR must be measured outside of Earth’s magnetosphere.
• 3-D observations of heliospheric structure and GCR scattering (synergy with other missions).

➢ All of above point to an orbit about the L1 Lagrange point.
Scientific Payload

• Four instruments selected.

- Amon-Ra Albedo Monitor & Radiometer
- Isis – Interplanetary Strahl and Ion Sensor
- Atem – a three axis magnetometer
- Horus – a cosmic ray experiment
## Instrument Budgets

<table>
<thead>
<tr>
<th>Unit</th>
<th>Mass (kg)</th>
<th>Power (W)</th>
<th>Size (m)</th>
<th>Data (bps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amon Ra</td>
<td>10.9</td>
<td>10.0</td>
<td>0.15x0.16x0.3</td>
<td>471</td>
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<tr>
<td>Horus +</td>
<td>2.45</td>
<td>5.0</td>
<td>0.2x0.2x0.01</td>
<td>8.3</td>
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<td>Electronics</td>
<td></td>
<td></td>
<td>0.14x0.25x0.1</td>
<td></td>
</tr>
<tr>
<td>Atem sens. +</td>
<td>0.25</td>
<td>-</td>
<td>0.05x0.11x0.07</td>
<td>9</td>
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<tr>
<td>Electronics</td>
<td>0.35</td>
<td>0.8</td>
<td>0.14x0.25x0.1</td>
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<tr>
<td>Isis 1</td>
<td>1.0</td>
<td>1.88</td>
<td>0.13x0.13x0.1</td>
<td>4.6</td>
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<tr>
<td>Isis 2</td>
<td>1.0</td>
<td>1.88</td>
<td>0.13x0.13x0.1</td>
<td>4.6</td>
</tr>
<tr>
<td>Boom &amp; Harnesses</td>
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<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harnesses</td>
<td>1.1</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>18.8</td>
<td>19.6</td>
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<td>497.5</td>
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</table>
Atem & Isis

Atem- Sensor

Isis-1 Sensor
Payload Design Drivers
Payload Design Drivers

- Isis-1 fov direction must point normal to spin axis
- Isis-2 fov parallel to spin axis
- Both have to be rotated so that the 3D structure of the heliosphere can be measured.
- Atem sensor has to be mounted on a 1m boom to reduce influence of spacecraft magnetic field.
Mission Philosophy

- Low cost mission meaning,
  - Small design margins
  - Limited redundancy
  - EEE parts quality consistent with expected environment
  - Use flight qualified hardware where possible
  - Minimise development activities
  - Shared launch (piggy back)
  - Protoflight approach
  - Minimise documentation
Mission Analysis

Short transfer - delta V 1190 m/s

Long transfer - delta V 850 m/s
Spacecraft Subsystems

• Propulsion
  – Large fuel tank for delta V and station keeping. Oxidiser tanks also required.
  – 20N thruster (Isp=290s)
  – Smaller 0.5N monopropellant thrusters for station keeping.
  ➢ All COTS items.

• Ion thrusters considered, but high power requirement meant large solar arrays needed.
Spacecraft Subsystems

• Structure/Thermal
  – Filament wound carbon fibre design permitting direct attachment of hardware
  – Stiff panels used to close ends
  – Design qualified
  – Passive thermal control (foil heaters)
  – MLI blankets on outside.
Spacecraft Subsystems

• Data Handling System & AOCS
  – Unionics dual high-performance processor performs all on-board processing (payload and spacecraft)
  – Spacewire and RS422 protocols
  – Miniature, autonomous star tracker and 3 axis gyro packaged together
  – Fixed momentum wheel
  – 2 axis course Sun sensor (for recovery from AOCS failure).
## System Budgets

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Mass (kg)</th>
<th>Power - LEOP (W)</th>
<th>Power - L1 (W)</th>
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<tbody>
<tr>
<td>Payload</td>
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<td>Propulsion</td>
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<td>1</td>
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<td>Power</td>
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<tr>
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<td>AOCS</td>
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<td>Comms</td>
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<td>6.5</td>
<td>6.5</td>
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<td>Thermal</td>
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<td>0</td>
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<td>Structure</td>
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<td>Totals</td>
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At PCDU

<table>
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<th>Subsystem</th>
<th>Total (W)</th>
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<td>Propellant</td>
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<tr>
<td>Totals</td>
<td>135.97</td>
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System margin 18.05
Configuration
Configuration
Summary

- By careful choice of payload, it is possible to do really useful science with a small spacecraft at L1.
- The phase A study shows a low-cost approach, using mainly COTS equipment, is feasible with acceptable levels of risk.