Deployment Technology of a Heliogyro Solar Sail for Long Duration Propulsion

Peerawan Wiwattananon, National Institute of Aerospace, (in Residence at NASA Langley Research Center, USA)

Peerawan.Wiwattananon@nasa.gov

Robert G. Bryant, NASA Langley Research Center, USA

William W. Edmonson, North Carolina Agricultural and Technical State University, NC, USA

William B. Moore, Hampton University, VA, USA

Jared M. Bell, National Institute of Aerospace, VA, USA

4th Interplanetary CubeSat Workshop, Imperial College London, United Kingdom, 26-27 May, 2015
Solar Sail Missions

Heliogyro Solar Sail Mission: 2-bladed 6U Form Factor

Deployment Technology

Current Focus

Benefits

Summary
Square-Shaped Solar Sailing ➔ Heliogyro Solar Sail

1969
1993
Znamya [1]

1993

2010

2015

LightSail-1

NEA Scout
LUNAR Flashlight
Heliogyro Solar Sail
2-Bladed Heliogyro Orbital Platform in Space (HOPS²B)

Future Mission


2-Bladed Heliogyro Orbital Platform in Space Mission (HOPS²B)

- Anti-Jamming Technology
- Re-Usable Locking/Release Mechanism
- Solar Sail: 2 µm thick Polyethylene Naphthalate (PEN)
- Large Solar Sail Area (~ 720 m²)

Heliogyro-Configured: 6U Form Factor

- No fuel
- Mass ~ 8 kg
- Retractable Solar Sail System: Control CM/CP*, avoid thermal heat flux

CM = center of mass, CP = center of pressure

Validation and Demonstrate Heliogyro Solar Sail Deployment/Retraction

Attitude Control

Station-Keeping

Acceleration

Interplanetary Travel
HOPS$^2$B – Deployment Technology & Concept

Solar Sail
Rolling of Solar Sail
Motor
Tip Rod

To scale model

100 mm
200 mm

Image Credit: NASA
Image Credit: NASA
Image Credit: NASA
Image Credit: NASA


Background Image Credit: NASA
HOPS$^2$B – Hardware + Expected Performance

Hardware

<table>
<thead>
<tr>
<th>Components</th>
<th>Vendor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Angle Gearhead Deployment Motors</td>
<td>CDA Intercorp, USA</td>
</tr>
<tr>
<td>Spacecraft Door Release Mechanism</td>
<td>Avior Control Technologies, Inc, USA</td>
</tr>
<tr>
<td>Photodiode Linear Speed Sensor</td>
<td>Aeroflex, USA</td>
</tr>
<tr>
<td>Coated Solar Sail 2 μm thick</td>
<td>Astral, USA</td>
</tr>
<tr>
<td>Uncooled Microbolometer</td>
<td>Sofradir EC, Inc., USA</td>
</tr>
<tr>
<td>Hybrid-Ceramic Bearings</td>
<td>CEROBEAR GmbH, Germany</td>
</tr>
<tr>
<td>Batteries</td>
<td>Clyde Space, UK</td>
</tr>
<tr>
<td>Solar Panels</td>
<td>Vanguard Space Technologies, USA</td>
</tr>
</tbody>
</table>

Expected Performance

<table>
<thead>
<tr>
<th>Solar Sail Mission</th>
<th>IKAROS$^1$</th>
<th>NanoSail-D$^2$</th>
<th>LightSail-1$^3$</th>
<th>CubeSail$^4$</th>
<th>HOPS$^2$B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration</td>
<td>Custom</td>
<td>3U</td>
<td>3U</td>
<td>3U</td>
<td>6U</td>
</tr>
<tr>
<td>Total sail area [m$^2$]</td>
<td>200</td>
<td>10</td>
<td>32</td>
<td>25</td>
<td>717</td>
</tr>
<tr>
<td>Total mass [kg]</td>
<td>310</td>
<td>3.99</td>
<td>5</td>
<td>3</td>
<td>~8</td>
</tr>
<tr>
<td>Characteristic Acceleration* [mm/s$^2$]</td>
<td>0.0053</td>
<td>0.02</td>
<td>0.05</td>
<td>0.068</td>
<td>0.74</td>
</tr>
</tbody>
</table>

*Calculated at 1 AU


HOPS$^2$B – Current Focus

- **Navigation Control** – attitude determination and control, navigation of the spacecraft
- **Deployment and Spin Control** – deployment of solar sails, spin rate of the spacecraft
- **Location and Speed** – location of the spacecraft and its speed
- **Communication** – communication between the spacecraft and the Earth
- **Dynamics** – dynamics of the solar sail and spacecraft

Benefits

• Future spacecraft can have a heliogyro-configured solar sail installed on board for fuel-less in-Space navigation and propulsion.

• Orbiting CubeSat heliogyro(s) can be sent to assist spacecraft that require additional power to achieve a different orbit.

• Missions: long mission period such as interplanetary travel, multi-missions, station keeping, asteroid field mapping, and interception of micrometeoroids can be performed.

• Perform a precision de-orbit by imposing solar/aerodynamic drag. This has been proven by analysis to be a more cost effective approach to de-orbiting than carrying extra fuel to achieve the same goal.¹,²

---

¹ Vaios Lappas et al., CubeSat: A low cost CubeSat based solar sail demonstration mission, Advances in Space Research 48 (2011) 1890–1901
² Walker et al., Update of the ESA Space Debris Mitigation Handbook, ESA, 14471/00/D/HK

Background Image Credit: NASA
2-Bladed Heliogyro Orbital Platform in Space Missions (HOPS$^{2B}$)

**Summary**

- **Deployment Demonstration:** Polar Orbit beyond 35,000 km
  - Validate and Demonstrate Heliogyro Solar Sail Deployment/Retraction
  - Attitude Control
  - Station-Keeping
  - Acceleration
  - Interplanetary Travel

- **Heliogyro-Configuration**
  - 6U CubeSat Form Factor, ~ 8 kg
  - Solar Sail Fully Deployed Area ~ 720 m$^2$
  - Calculated Characteristic Acceleration ~ 0.74 mm/s$^2$
  - Re-Usable Locking/Release Mechanism
  - Solar Sail Anti-Jamming
