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

IKAROS: Image Credit: JAXA [3]

2010

Heliogyro Solar Sail

2015

2-Bladed Heliogyro Orbital Platform in Space (HOPS²B)

Future Mission

NEA Scout

LUNAR Flashlight

LightSail-1

NanoSail-D

Heliogyro Solar Sail

http://news.bbc.co.uk/2/hi/science/nature/271224.stm


http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110023680.pdf

Background Image Credit: NASA


Background Image Credit: NASA
2-Bladed Heliogyro Orbital Platform in Space Mission (HOPS²B)

Anti-Jamming Technology

Re-Usable Locking/Release Mechanism

Solar Sail: 2 \( \mu \)m thick Polyethylene Naphthalate (PEN)

Large Solar Sail Area ( \( \sim 720 \text{ m}^2 \) )

Heliogyro-Configured: 6U Form Factor

- No fuel
- Mass \( \sim 8 \text{ kg} \)
- Retractable Solar Sail System: Control CM/CP*, avoid thermal heat flux

CM = center of mass, CP = center of pressure

Background Image Credit: NASA  
HOPS²B Mission

Interplanetary Travel

- Validate and Demonstrate Heliogyro Solar Sail Deployment/Retraction
- Attitude Control
- Station-Keeping
- Acceleration

>35,000 km

Image Credit: NASA

HOPS$^{2B}$ – Deployment Technology & Concept

Right Angle Gearhead Deployment Motor

Solar Sail Roll

Solar Sail Spindle

Bearing

Solar Sail Roll

Camera & Uncooled Microbolometer

Photodiode Linear Speed Sensor

Guiding Gap

Tip Rod Lock Mechanism

Control Unit:
Communication, Data Handling, ADCS, EPS, Instrument Package

Camera & Uncooled Microbolometer

Solar Sail Tip Rod

Camera & Uncooled Microbolometer

Background Image Credit: NASA
HOPS\textsuperscript{2B} – Deployment Technology & Concept

Solar Sail

Rolling of Solar Sail

Motor

Tip Rod

To scale model

Background Image Credit: NASA

HOPS\textsuperscript{2B} – 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\textsuperscript{[1]}</th>
<th>NanoSail-D\textsuperscript{[2]}</th>
<th>LightSail-1\textsuperscript{[3]}</th>
<th>CubeSail\textsuperscript{[4]}</th>
<th>HOPS\textsuperscript{2B}</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\textsuperscript{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\textsuperscript{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


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

Questions?

Image Credit: NASA

Peerawan.Wiwattananon@nasa.gov