Deployment Technology of a Heliogyro Solar Sail for Long Duration Propulsion

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

Objectives & Outlines

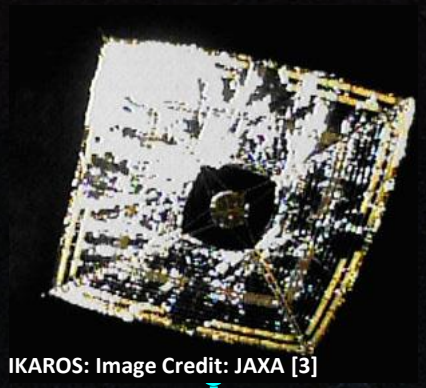
- Solar Sail Missions
- Heliogyro Solar Sail Mission: 2-bladed 6U Form Factor
- Deployment Technology
- Current Focus
- Benefits
- Summary

Image Credit: NASA http://www.nasa.gov/mission_pages/hubble/multimedia/index.html?id=355696

Square- Shaped Solar Sailing → Heliogyro Solar Sail


Image Credit: NASA/JPL

1969


IKAROS: Image Credit: JAXA [3]

1993

Znamya [1]

2010

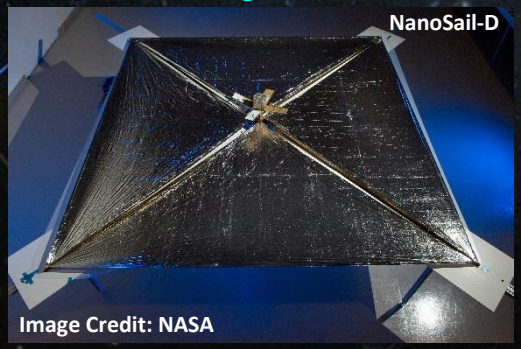


Image Credit: NASA

2015

LightSail-1

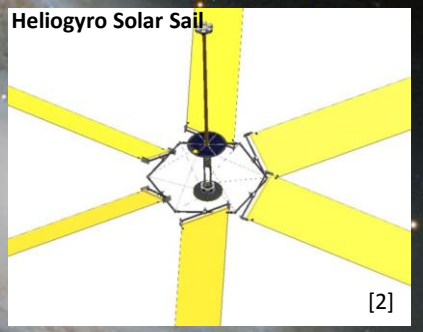
Future Mission

NEA Scout

LUNAR Flashlight

Heliogyro Solar Sail

2-Bladed Heliogyro Orbital Platform in Space (HOPS^{2B})



[1] http://news.bbc.co.uk/2/hi/science/nature/271224.stm
[2] Wilkie K.W. et al., Heliogyro Solar Sail Research at NASA, 3rd Int'l Solar Sail Symp., UK, 2013
[3] http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110023680.pdf
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2-Bladed Heliogyro Orbital Platform in Space Mission (HOPS^{2B})

~2.4 km

Anti-Jamming Technology

Re-Usable Locking/Release Mechanism

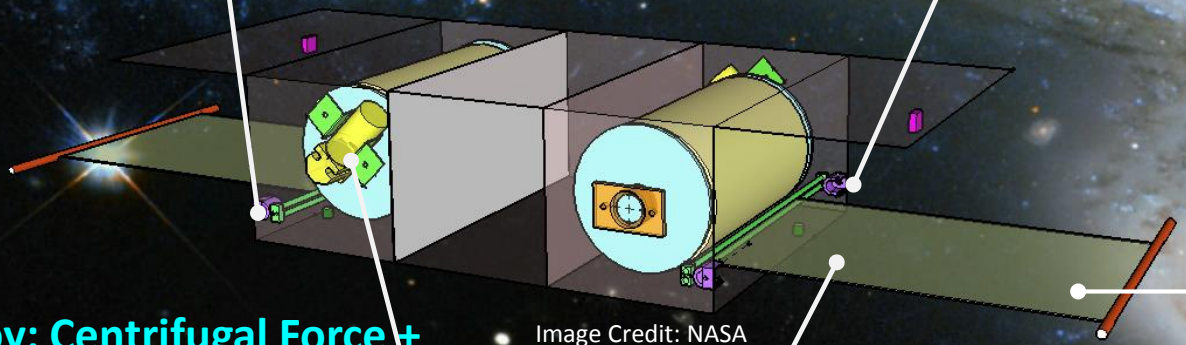

Image Credit: NASA

Solar Sail: 2 µm thick Polyethylene Naphthalate (PEN)

Deploy: Centrifugal Force + Motor Assist

Large Solar Sail Area (~ 720 m^2)

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

Background Image Credit: NASA http://www.nasa.gov/mission_pages/hubble/multimedia/index.html?id=355696

HOPS^{2B} Mission

Interplanetary Travel

>35,000 km

Image Credit: NASA

Validate and Demonstrate Heliogyro Solar Sail Deployment/Retraction

Attitude Control

Station-Keeping

Acceleration

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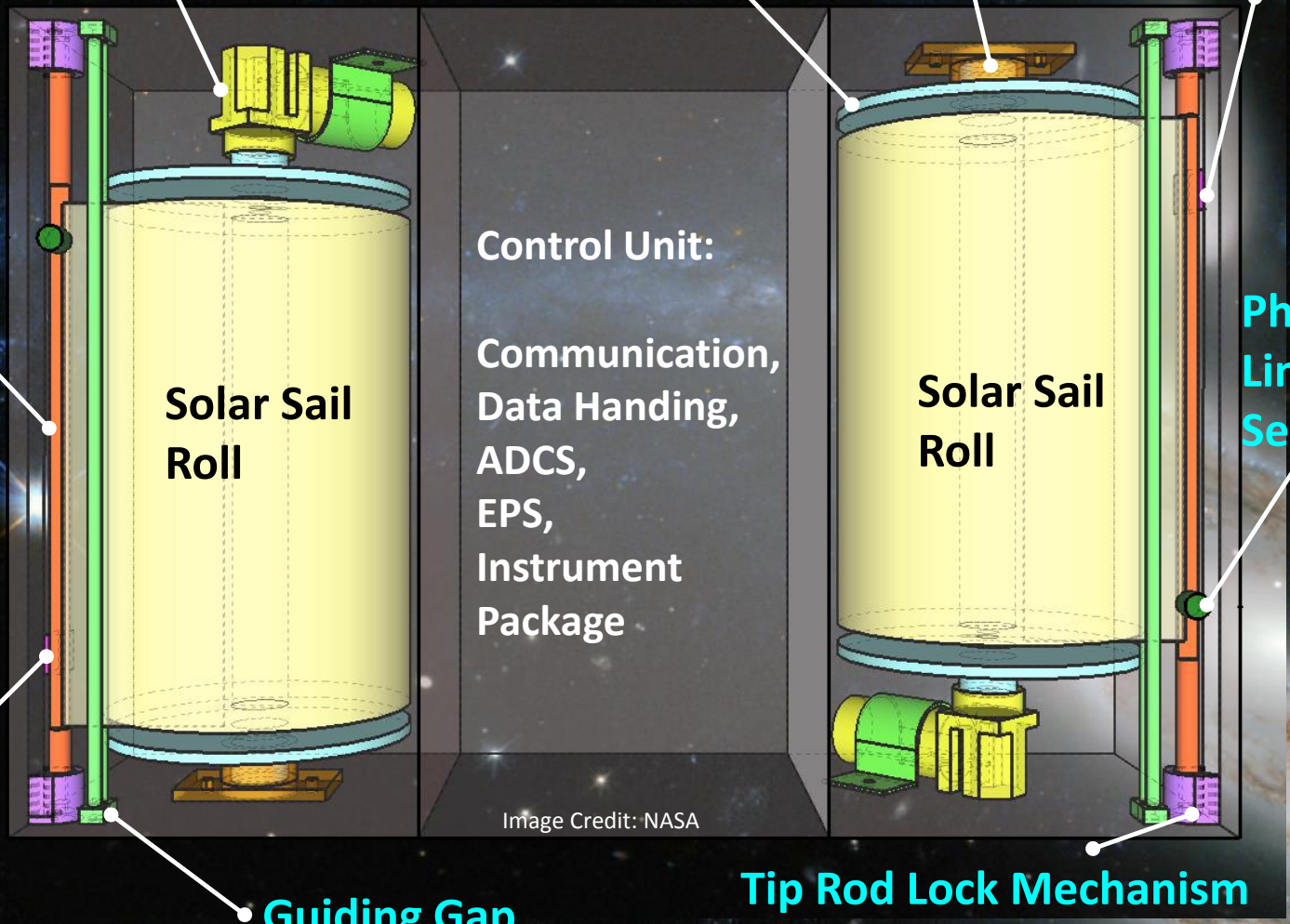
HOPS^{2B} – Deployment Technology & Concept



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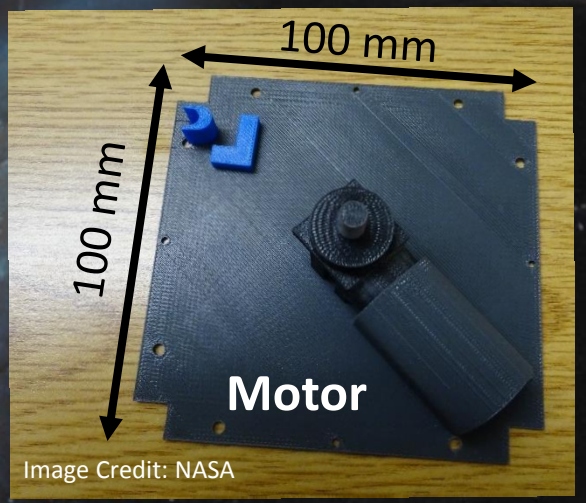
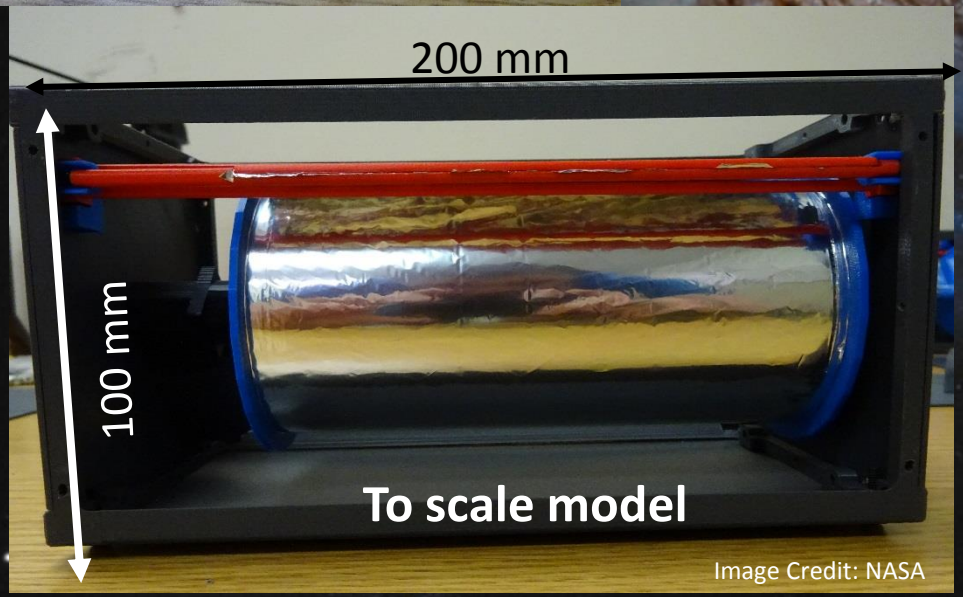
HOPS^{2B} – Deployment Technology & Concept





Background Image Credit: NASA http://www.nasa.gov/mission_pages/hubble/multimedia/index.html?id=355696

HOPS^{2B} – Hardware + Expected Performance

Hardware

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

Expected Performance

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

***Calculated at 1 AU**

[1] http://www.jspec.jaxa.jp/e/activity/ikaros.html
[2] Johnson L. et al., ActaAstronautica, 68(2011)
[3] Chris Biddy and Tomas Svitek, **LightSail-1 Solar Sail Design and Qualification,** *Proceedings of the 41st Aerospace Mechanisms Symposium, JPL, May 16-18, 2012*
[4] Vaios Lappas et al., CubeSail: A low cost CubeSat based solar sail demonstration mission, Advances in Space Research 48 (2011) 1890–1901

HOPS^{2B} – 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

Background Image Credit: NASA http://www.nasa.gov/mission_pages/hubble/multimedia/index.html?id=355696

HOPS^{2B} – Deployment Technology & Concept

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., CubeSail: 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

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

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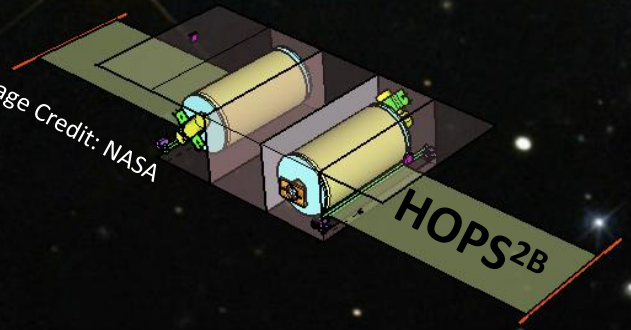

Image Credit: NASA

HOPS2B

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