Solar Cruiser: Enabling New Vistas for Heliophysics

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ABSTRACT

The NASA Heliophysics Decadal Survey contains multiple references describing the value of solar sails to enable revolutionary new observational capabilities. MSFC is developing the Solar Cruiser mission to mature solar sail technology for use in future Heliophysics missions, as well as missions of interest across a broad user community. Solar Cruiser is a pathfinder for missions that observe the solar environment from unique vantage points such as sub-L1 for advanced warning of solar storms and high inclination solar missions. Observations away from the Sun-Earth line (SEL) present unique opportunities for answering the outstanding science questions of Heliophysics, for improving space-weather monitoring and prediction, and for revealing new discoveries about our Sun and solar system. High solar inclinations are particularly compelling.

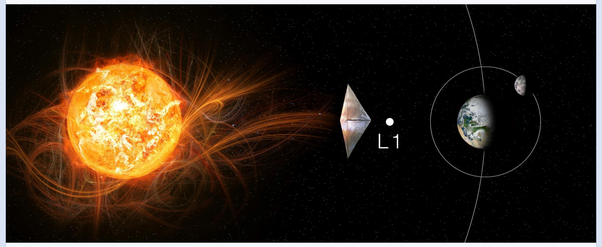
The MSFC-led team (GSFC, Ball Aerospace, NeXolve, and Roccor) are completing for the Science Mission Directorate a Phase A Concept Study Report as one of two competitors for flight in 2024 as a secondary payload on the IMAP mission.

Goals and Objectives

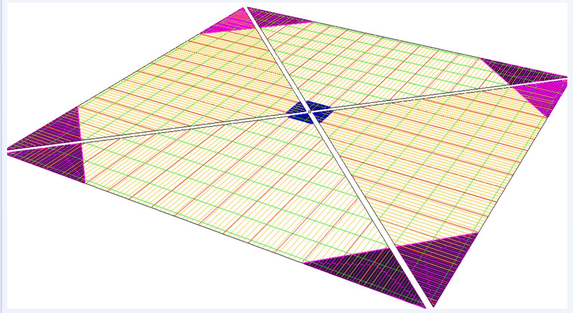
Demonstrate solar sail propulsion technology to enable near- and mid-term Heliophysics science missions up to and including high solar inclination orbits, sub-L1 halo orbits, non-Keplerian solar and other planetary body orbits.

- Show sailcraft operation (acceleration, navigation, station keeping) immediately usable and applicable for near-term mission needs.
- Show scalability of sail technologies (boom, membrane, deployer, Active Mass Translator (AMT) for pitch/yaw momentum management, reflective control devices (RCDs) for roll momentum management) and design to enable more demanding missions, such as high inclination solar imaging.
- Demonstrate that sailcraft pointing control and attitude stability is comparable to that achievable with traditional platforms to validate sailcraft usability with science instruments.
- Demonstrate sail-embedded photovoltaic power generation technology to support future sailcraft systems, and science instrument power needs for long-lived missions.

SOLAR CRUISER'S SOLAR SAIL PROPULSION TECHNOLOGY



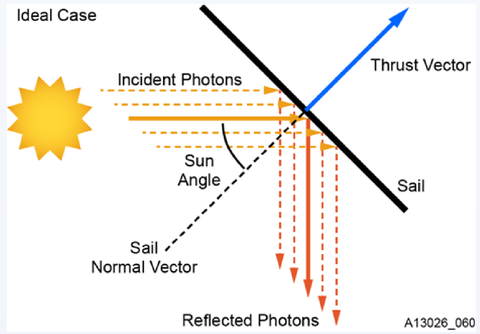
Propellantless solar sails can be used to create artificial equilibria and indefinite station-keeping at locations sunward of L1 along the SEL, or at any desired offset from the SEL leading or trailing the Earth in its orbit. Sails can change the heliocentric inclination of a spacecraft from the ecliptic to as high as solar polar, stopping and remaining at any intermediate inclination orbit in between. Sails can be used to hover over the Earth's poles, using solar photon pressure to offset the Earth's gravitational attraction, creating functional equivalents of geostationary earth orbits.



- Solar Cruiser's sail design is based on the Near-Earth Asteroid Scout solar sail
  - >1600 square meters in surface area
  - Composite booms with excellent strength/weight ratio and thermal stability
  - Embedded RCD's on outer corners of the sail for sailcraft roll control
  - Lightweight Integrated Solar Array (LISA) power generation demonstration

SOLAR SAIL TECHNOLOGY BACKGROUND

Solar sails have the potential to provide essentially unlimited primary ΔV (that is, the propulsion system for getting from one location to another) for many types of missions. A large, ultra-thin, highly-reflective sail made of a lightweight material that reflects sunlight to propel the spacecraft. The continuous photon pressure from the Sun's rays provides thrust and eliminates the need for heavy, expendable propellants employed by conventional on-board chemical and/or electric primary propulsion systems—enabling access to new observational regions and extending mission life on station.



Solar sail versatility enables or enhances many science mission applications by:

1) Accelerating along the existing velocity vector, the orbital energy of the sailcraft is increased, thereby spiraling it away from the Sun, enabling smaller, lower-cost, fly-by missions.

2) Accelerating opposite to the velocity vector, the orbital energy decreases, spiraling inward toward the Sun, a particularly ΔV-intense maneuver that is difficult to achieve on small- or medium-class missions.

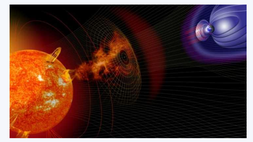
3) Accelerating out of the orbital plane, the sail can change heliocentric inclination, allowing observations from unique, out-of-the-ecliptic vantage points.

4) Carefully managing attitude control, the sail can perform station keeping near-indefinitely, allowing long term observations in locations of interest for Heliophysics and space-weather observations such as sub-L1, long-term station keeping off the SEL or in the Earth's magnetotail, or in vantage points allowing nearly continuous observations of the Earth's polar regions.

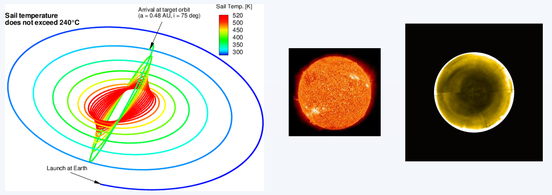
ENABLED MISSIONS

The Solar Cruiser Technology Demonstration Mission will enable multiple future space science and exploration missions for the nation.

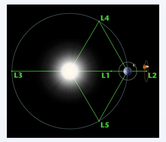
Sub-L1 for Enhanced Solar Storm Warning



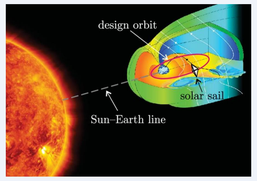
High Inclination Solar Missions



High ΔV Unique Vantage Points



Sustained in-situ observations of the Earth's bow shock and magnetotail



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