The High Inclination Solar Mission (HISM)

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PRESENTED AT:

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GOAL & BACKGROUND

Introduction

HISM is a concept design by the MSFC Advanced Concepts Office. The goal is to design a mission based on the solar sail technology for Solar Cruiser, which recently completed a Phase-A design study.

Goals:

- ~10 yr mission to >75° heliographic inclination
- Observing the Sun from >75° heliographic inclination
  - → Sun-pointing observing platform
  - → ~2' pointing accuracy & ~20" pointing stability
- Helioispheric observations & measurements at >75° heliographic inclination
  - → Instrument boom for magnetometer & solar wind instruments

How to get to high inclination:

- Gravity Assist:
  - Jupiter gravity assist used by Ulysses
  - Resulting orbit is far from Sun, with long period (Ulysses: 6.2 yr orbital period, perihelion 1.35 AU)
- Solar Electric Propulsion (Ion Drive)
  - Significant fraction of spacecraft mass taken by propellant
  - Ion drive may interfere with in-situ measurements
- **Solar Sail**
  - **No propellant, indefinite delta-V**
  - **In development**

Current State of Solar Sail Technology:

– Nanosail-D2 (NASA MSFC): Successful deployment of 10 m2 sail in 2010

– IKAROS (JAXA): Successful sail deployment and flight

– LightSail-1 (The Planetary Society): Successful deployment

– CanX-7 (Canada): Successful Deployment

– InflateSail (EU / Univ. of Surrey): Successful Deployment

– NEA Scout (NASA MSFC): Planned for 2021 launch, 86 m^2 sail

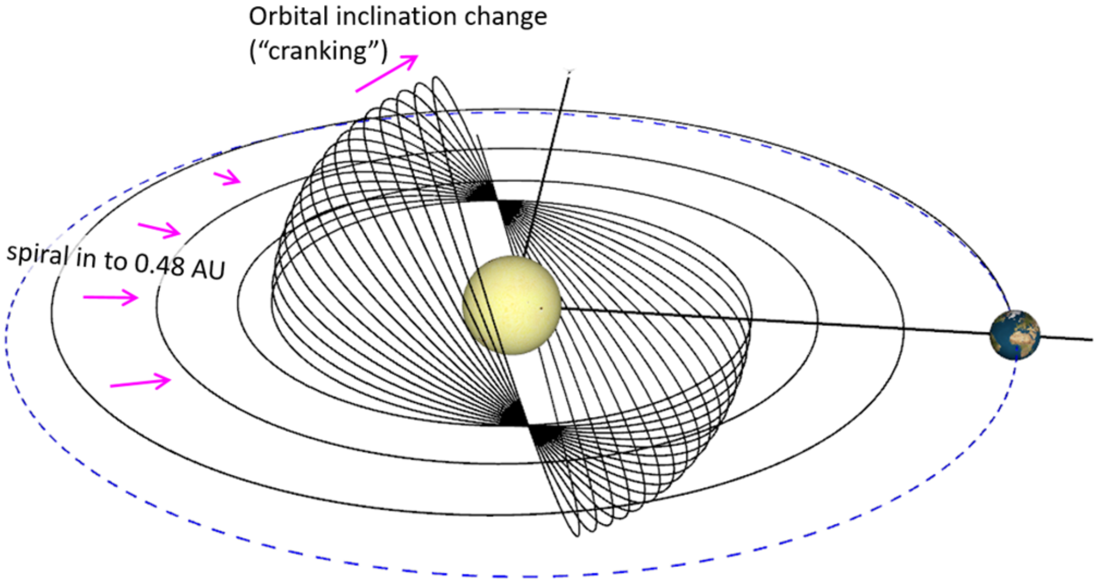
– Solar Cruiser (NASA MSFC): In Phase-A Design, 1,653 m^2 sail

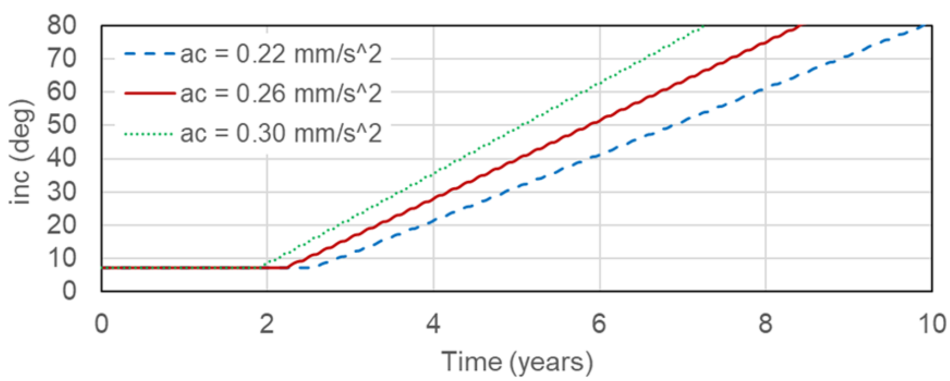
References:

•Kobayashi et al. 2020 (https://arxiv.org/abs/2006.03111)

•McIntosh et al. 2019 (https://doi.org/10.1007/s11207-019-1474-y)

MISSION DESIGN



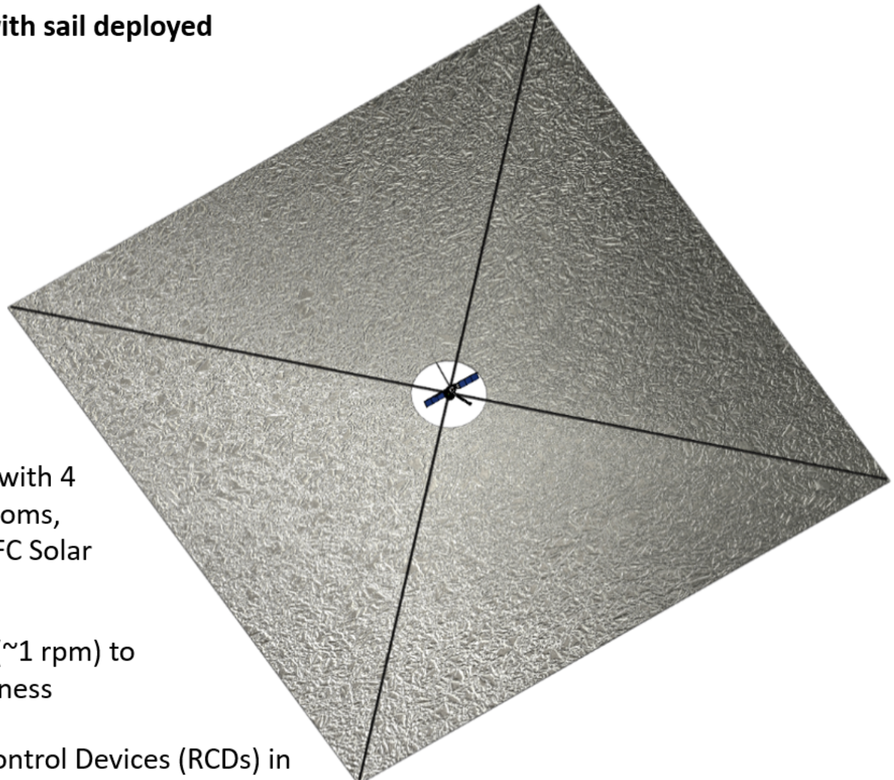


A_C=0.26 mm/s^2 corresponds to the HISM concept design without mass margin (0.30 mm/s^2 with margin).

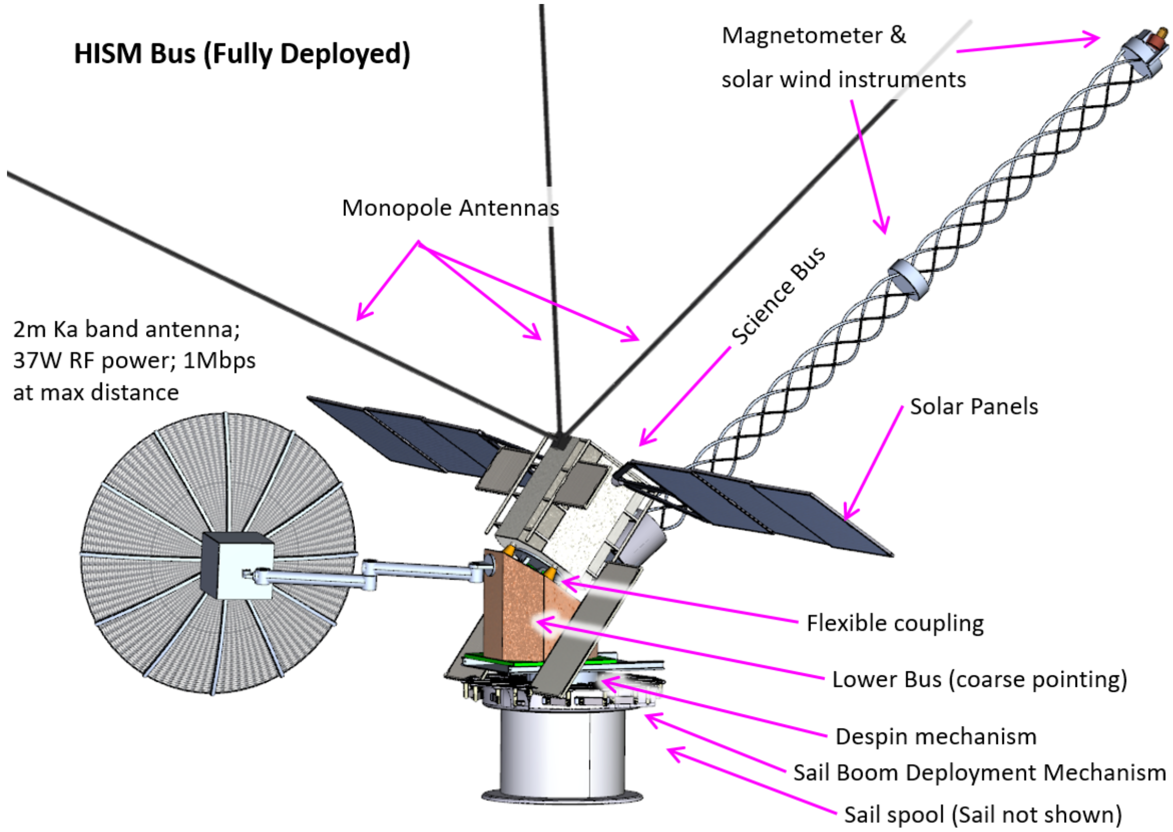
The mission design is based on the Solar Polar Imager study. The mission consists of a spiral-in phase to 0.48 AU ecliptic orbit, followed by a cranking phase to gradually increase the orbital inclination. **Full science observations start at the beginning of the cranking phase.**

SPACECRAFT DESIGN

HISM sailcraft with sail deployed



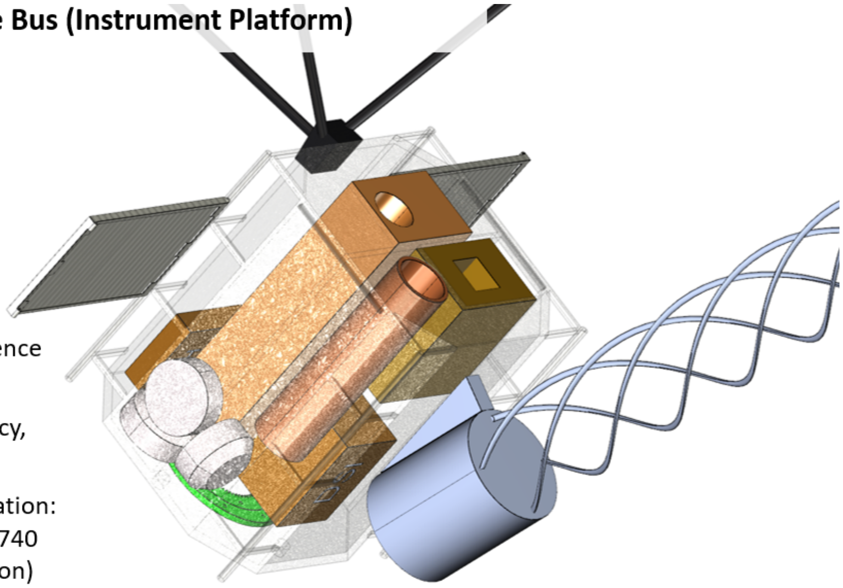
- 7,000 m^2 sail with 4 composite booms, based on MSFC Solar Cruiser
- Spinning sail (~1 rpm) to augment stiffness
- Reflectivity Control Devices (RCDs) in each corner used for roll control & desaturating momentum wheels (all axes)



Total sailcraft mass: 233 kg bus + 65 kg sail

SCIENCE BUS

HISM Science Bus (Instrument Platform)



- The Science Bus is a fine pointing platform for science instruments.
- 2-arcmin pointing accuracy, 20"/10-sec stability
- Science instrument allocation: 46 kg mass, 94W power, 740 MB/day (after compression)
- Shown here are a magnetograph / helioseismology instrument, coronagraph, deployable boom with magnetometers and solar wind / ion instruments, and electrical antennas.

CONFIGURATION

Guidance/Navigation/Control:

- No thrusters (-> no consumables)
- Reaction wheels inside Science Bus for fine pointing
- Reflectivity Control Devices (RCD) on sail used for sail attitude control & for de-saturating reaction wheels

Power:

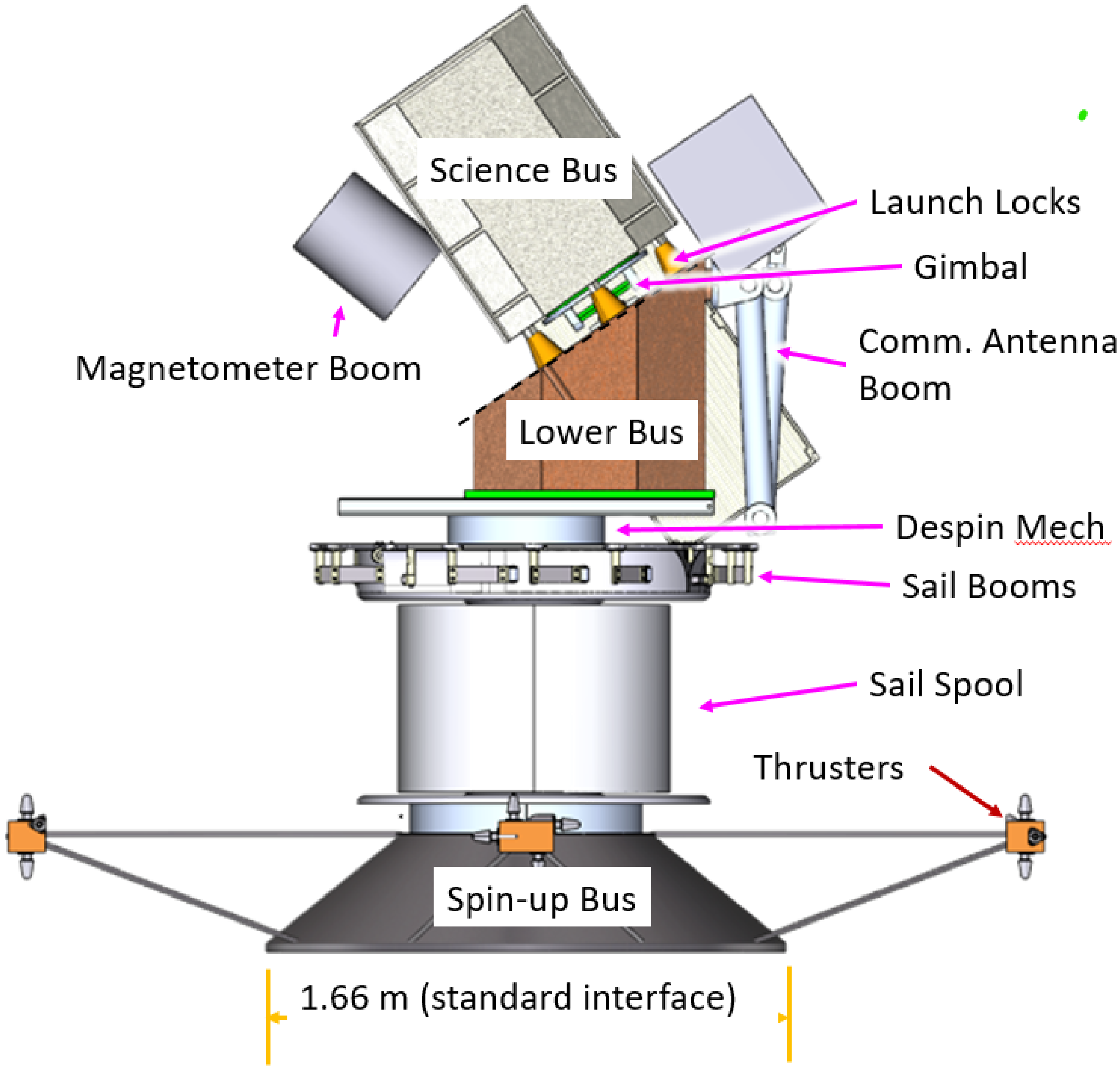
- 2 conventional solar panels + 4 high-temperature (low efficiency) panels
- Initial power at 1 AU: 702W (incl. 320W for instrument survival heaters)
- Cranking/science phase: 540W

Thermal design:

- Deployable radiators on both the Lower Bus & Science Bus, sized for 0.48 AU
- Additional heaters required at 1AU

Communications & Avionics

- 1 Mbps downlink capability throughout mission, using 2-meter deployable Ka-band antenna & 38 watt RF power
- 2.2 hr / day downlink required to meet science requirement



Dedicated launch assumed. Spin-up Bus contains a propulsion system for initial attitude control & sail spin-up. It is jettisoned after sail deployment.

ABSTRACT

The High Inclination Solar Mission (HISM) is an out-of-the-ecliptic solar sail mission concept for observing the Sun and the heliosphere. The mission profile is based on the Solar Polar Imager concept: initially spiraling in to a 0.48 AU ecliptic orbit, then increasing the orbital inclination at a rate of up to 10° degrees per year, ultimately reaching a heliographic inclination of >75°. The orbital profile is achieved using solar sails based on the sail design for the Solar Cruiser mission, currently in Phase-A study at NASA Marshall Space Flight Center.

An initial instrument complement was assumed for the study, consisting of a combination of remote, in-situ, and plasma wave instruments with a total mass of 66 kg. These provide a comprehensive suite of instruments to study the solar polar regions and connections to the heliosphere.

The 7,000 m^2 sail used in the mission assessment is a direct extension of the 4-quadrant 1,666 m^2 Solar Cruiser design and employs the same type of high strength composite boom, deployment mechanism, and membrane technology. The sail system modeled is spun (~1 rpm) to assure required boom characteristics with margin. The spacecraft bus features a fine-pointing 3-axis stabilized instrument platform that allows full science observations as soon as the spacecraft reaches a solar distance of 0.48 AU. The spacecraft provides 95W power to science instruments and 8 Gbit/day downlink capability.