The Multiview Observatory for Solar Terrestrial Science (MOST)

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#55 SHINE 2022

Introduction

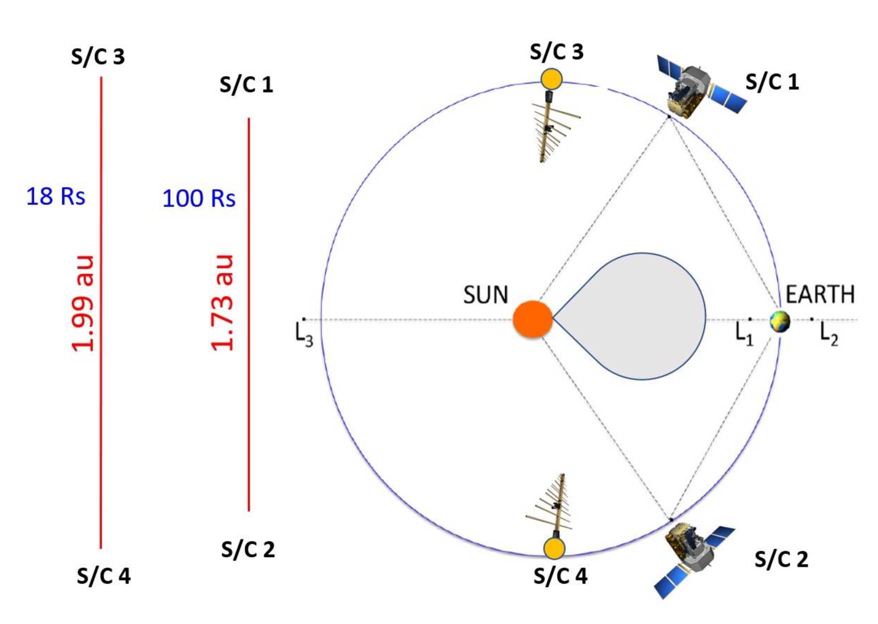
The heliosphere is defined and structured by the magnetic field that emerges through the solar surface. To understand the magnetic coupling between the Sun and the 3-D heliosphere, we need to obtain the magnetic flux over the entire surface of the Sun, not just the 60-degree wedge observable from the Sun-Earth line. Simulations show that magnetic field measurement over a larger solar surface including the poles dramatically improve modeling of solar wind structures (Petrie et al. 2018; Pevtsov et al. 2020).

Solar events such as flares, jets, coronal mass ejections (CMEs), and solar energetic particles are all powered by solar magnetic energy released in the corona, yet we have a very limited set of magnetic field measurements: in the photosphere from the Sun-Earth line and in-situ observations in the solar wind.

The Multiview Observatory for Solar Terrestrial Science (MOST) will provide comprehensive imagery and time series data needed to understand the magnetic connection between the solar interior and the solar atmosphere.

MOST will build upon the successes of SOHO and STEREO with new views, instrumentation, and capabilities from Sun-Earth L4 and L5 and their vicinities.

The MOST Mission Overview



MOST is a four-spacecraft mission. Two large spacecraft each with seven remote-sensing and three in-situ instruments will be stationed at Sun-Earth L4 and L5. Two additional, smaller S/C drifting ahead of L4 and behind L5 will carry Faraday rotation radio package to measure the magnetic field in solar wind structures between the Sun and 0.5 au during the prime mission and the entire inner heliosphere in the extended mission. MOST will generate the following science data products: magnetograms, dopplergrams, EUV images, hard X-ray images, coronagraph images, heliospheric images, radio dynamic spectra and time series, Faraday rotation time series, time series of solar wind plasma parameters, solar wind magnetic field vectors, and solar energetic particle intensity and spectra.

References

Gopalswamy et al. 2011, JASTP 73, 658
Petrie, G J D et al. 2018, Solar Phys 293, 88
Pevtsov, A. et al. 2020, Space Weather, 18 (7), e02448
LASCO: Brueckner et al., 1995
WAVES: Bougeret et al., 1995; 2008
STEREO: Howard et al. 2008; Kaiser et al. 2008

Science Goal and Objectives

The primary science goal: understand the magnetic coupling of the solar interior to the heliosphere in 3-D.

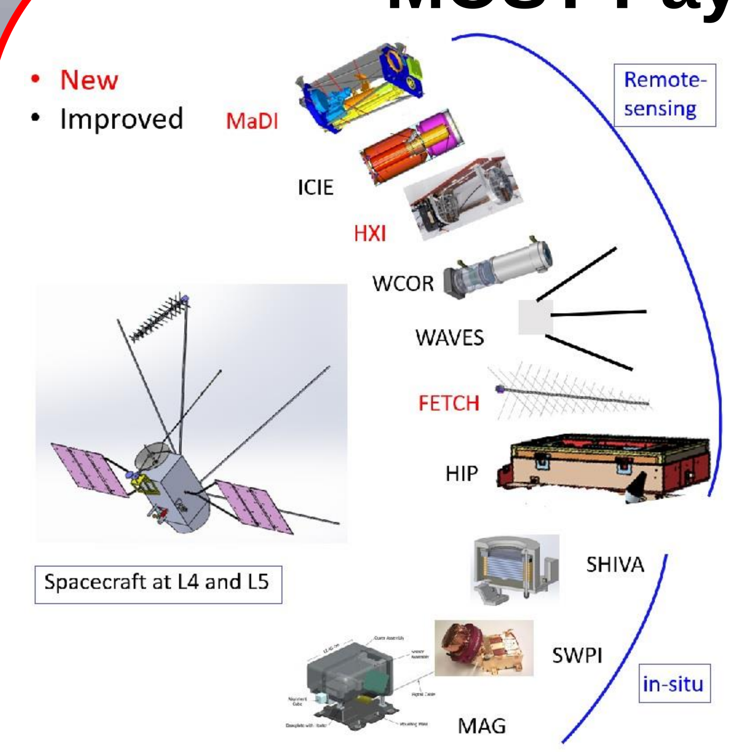
The science objectives:

How do CIR magnetic fields evolve in the inner heliosphere and accelerate particles?
- Track the longitudinal evolution of corotating interaction regions (CIRs) from L5 to Earth to L4
- Determine if interchange reconnection between active region and coronal hole field lines provides seed particles to CIR particle accelerator

How do CME flux ropes accelerate, drive shocks, and evolve from near the Sun into the heliosphere?
- Characterize and track 3-D CME acceleration and the evolution of the CME-shock complex through the outer corona and young solar wind; determine forces acting on CMEs
- Reconstruct and track flux ropes and flare structures from eruption data

How do active regions evolve before and after emerging to the solar surface?
- Derive the physical properties of the convection zone
- Determine the complete life-cycle of active regions
- Determine the global magnetic field distribution on the Sun for solar wind modeling

MOST Payload



FETCH is a cutting-edge instrument delivering magnetic field information on solar wind structures via radio-sounding Faraday rotation observations. Towards this goal, electron density information is utilized both from the signal itself (e.g., ranging) as well as HIP Thomson scattering images. Details in Poster **#131 Chip Manchester**

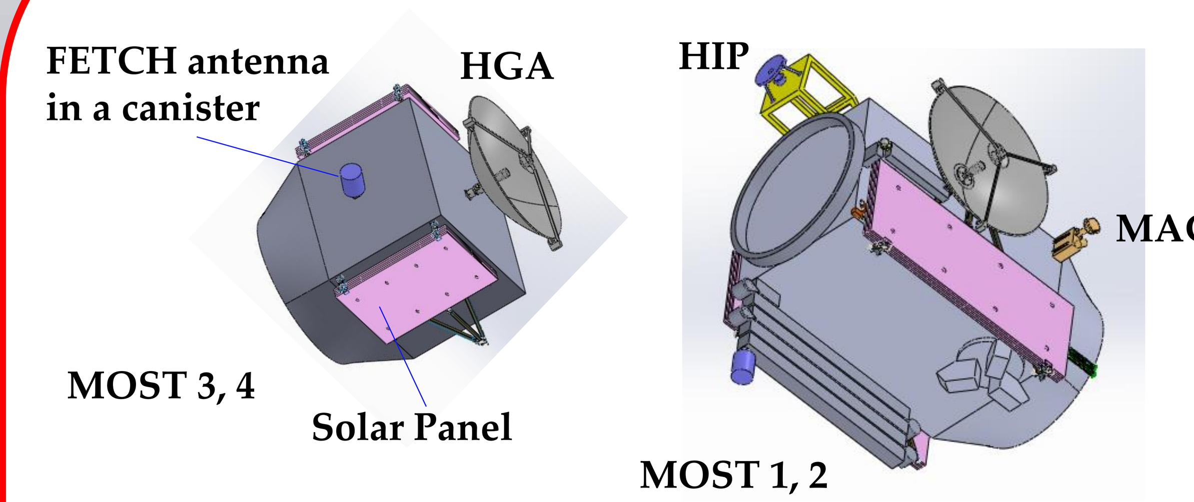
- Magnetic and Doppler Imagers (MaDI): surface and subsurface magnetism by combining magnetic and Doppler measurements.
- Inner Coronal Imager in EUV (ICIE): study active regions, coronal holes, post-eruption arcades, coronal dimming by capturing the magnetic connection between the photosphere and the corona
- Hard X-ray Imager (HXI): image thermal & non-thermal components of flares
- White-light Coronagraph (WCOR): track quiescent and transient coronal structures seamlessly from ICIE FOV
- Heliospheric Imager with Polarization (HIP): track solar features into the heliosphere and their impact on Earth; provide line-of-sight electron column densities for FETCH analysis
- Radio and Plasma Wave Instrument (WAVES): track shocks and electron beams from Sun to 1 au
- Faraday Effect Tracker of Coronal and Heliospheric Structures (FETCH): novel radio package to determine the magnetic field structure and evolution within 0.5 au
- Solar High-Energy Ion Velocity Analyzer (SHIVA):Energetic particle detector to determine the spectra of electrons and ions from H to Fe at multiple spatial locations and use energetic particles as tracers of magnetic connectivity
- Solar Wind Magnetometer (MAG): heliospheric magnetic structures at 1 au, CME and CIR evolution
- Solar Wind Plasma Instrument (SWPI): to infer solar wind plasma structures at 1 au, CME and CIR evolution

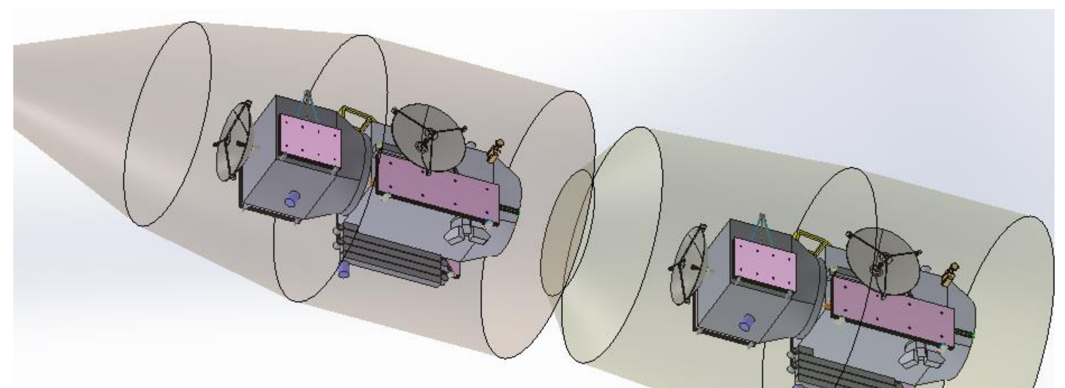
Synergy among Instruments

The instrument suites provide imagery and time series data to reveal magnetic connectivity across boundaries. Various instrument combinations are needed to achieve the science objectives. For example, to track the CME flux rope evolution we need the following combinations:

- MaDI magnetogram and ICIE post-eruption arcade images need to be combined to get the flare connected flux that determines the flux-rope magnetic properties
- ICIE, WCOR and HIP provide geometrical properties of the flux rope- FETCH magnetic field measurements provide verification of the flux-rope magnetic content halfway between Sun and Earth
- In-situ data provide ground truth

MOST Launch Configuration



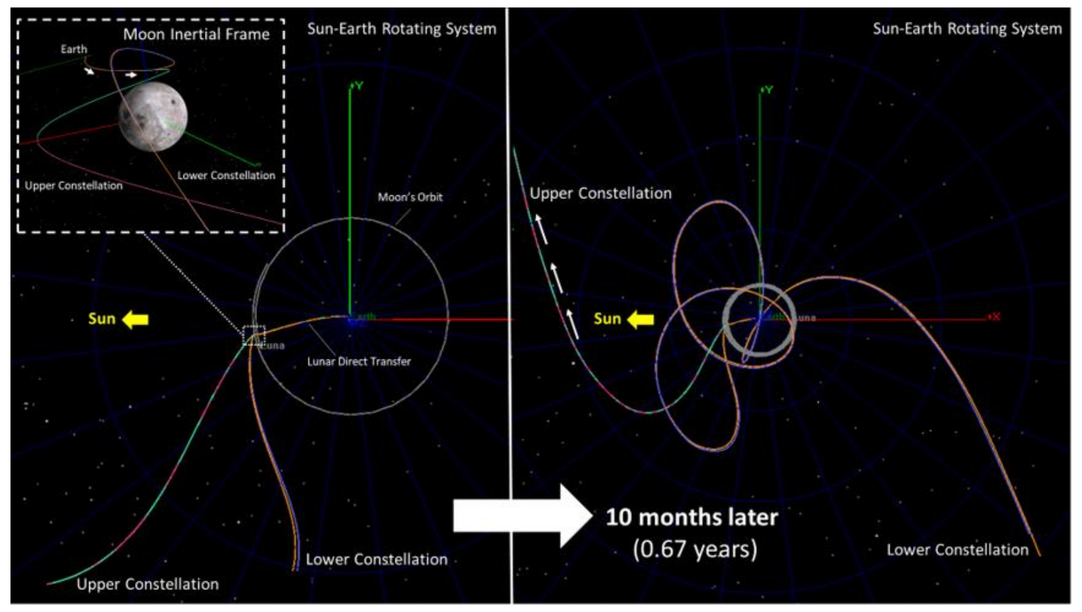


MOST 1-4 mounted in the Vulcan split manifest fairing

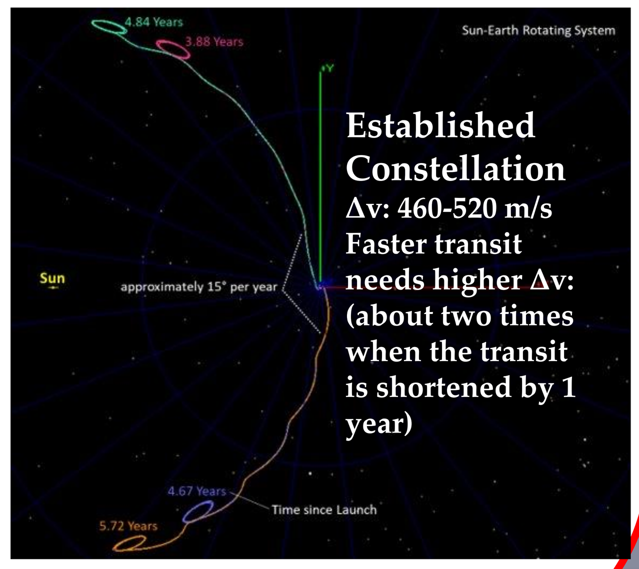
- Stowed configuration for MOST 1-4 and how they are mounted in the fairing. The High Gain Antenna (HGA) points to Earth (Ka and/or X-band comms).
- MOST 1&3 form the upper constellation; MOST 2&4 form the lower constellation
- Upper constellation FETCH antennas point to lower constellation antennas
- Sun-pointed remote-sensing instruments are not visible in the presented view
- The FETCH antennas and the WAVES antennas (not shown) will be deployed after launch
- S/C design based on EASCO (Gopalswamy et al. 2011)

Flight Dynamics

Lunar flyby performed to place the spacecraft into heliocentric orbits out to Sun-Earth L4 or L5 (similar to STEREO)
High thrust (chemical propulsion) and low trust (ion propulsion) considered.
Dwell Phase: Spacecraft remain at desired locations. Spacecraft can remain at desired locations with minimum station-keeping propellant.
Drift Phase: MOST-1/2 stay at Sun-Earth L4/L5 indefinitely while MOST-3/4 begin an approximate 10-year drift campaign to drift back towards Earth and switch position.



- All four spacecraft are launched together into a direct lunar transfer (5-day transfer period)
- Each spacecraft will perform a Trajectory Correction Maneuver (TCM) in order to plan a particular lunar flyby
- The flybys place two spacecraft groups (upper and lower constellation) into heliocentric drift-away orbits towards the L4 point (upper constellation), while the other two spacecraft (lower constellation) are directed towards the L5 point



- Low thrust option requires ~11 kg of mass consumption per S/C

Summary

MOST is focused on two things: Observing subsurface magnetic flux concentrations ahead of emergence through the photosphere and understanding the global impact of the emerging flux from the inner corona out to 1 au. Such a comprehensive study needs a great observatory with a complete set of instruments.

FETCH is a novel concept requiring the analysis of spacecraft-to-spacecraft radio signals.

Flight dynamics studies indicate that ion propulsion is a viable option. More trade studies will be performed between chemical and ion propulsion.

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