L1 Constellation: A Collaborative Research Activity with Operational Dividends

Presented to CGMS-53, Space Weather Coordination Group
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Executive summary of the WP

NOAA's Space Weather Follow On – Lagrange 1 (SWFO-L1) and NASA's Interstellar Mapping and Acceleration Probe (IMAP) are scheduled for launch this year. After they reach the Sun-Earth Lagrange 1 (L1) point and complete their commissioning, there will be a total of six spacecraft (including Aditya-L1 and the legacy ACE, DSCOVR, and Wind missions) in the same location of space and measuring the solar wind plasma, particle, and magnetic parameters simultaneously.

This unprecedented spatial coverage of the solar wind can be the basis for improving our understanding of the solar wind and its structures (CMEs, CIRs, shocks, etc.) at 1 AU, particle acceleration processes, and their relation to their coronal and/or photospheric origins. For operational purposes, the dataset can be used to develop more accurate solar wind/IMF time series; optimized numerical-propagation methods to the bow shock where the data can be used as inputs to geospace NWP models; and more effective coupling functions.

This paper summarizes the need for coordination in data pre-processing and archiving procedures and the steps taken among stakeholders up to this point.

Intercalibration at L1

- The advent of up to six missions at the Sun-Earth Lagrange 1 point (L1) provides an unprecedented opportunity for heliospheric science and an improvement of the accuracy and other aspects of quality for operational datastreams.

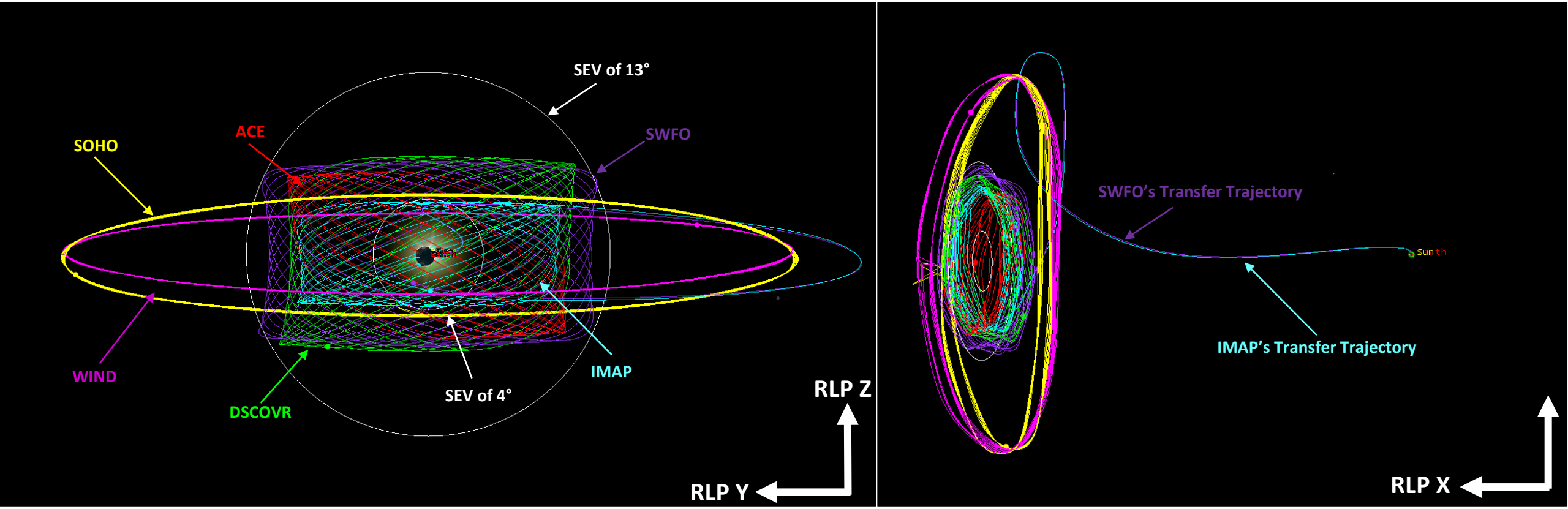
The missions are:

- Three legacy missions: Wind (l. 1994), ACE (1997), and DSCOVR (2015)
- ISRO's recent mission: Aditya-L1 (2023)
- To be launched in 2025: SWFO-L1 and IMAP
- All carry comparable sensors for measurements of plasma (density, velocity, temperature) and IMF parameters. In addition, several missions carry particle sensors for suprathermals, SEPs, and electrons.

Orbits are divided into two types:

- Halo (farther away from S-E line, rounder): Aditya-L1 and Wind
- Lissajous (closer, elliptical): remaining 4 s/c

Orbit Synoptic View



*SEV = Sun-Earth Vehicle Angle
*RLP = Rotating Libration Point

[Webster and Folta, March 16, 2025]

Intercalibration at L1

Selected science topics:

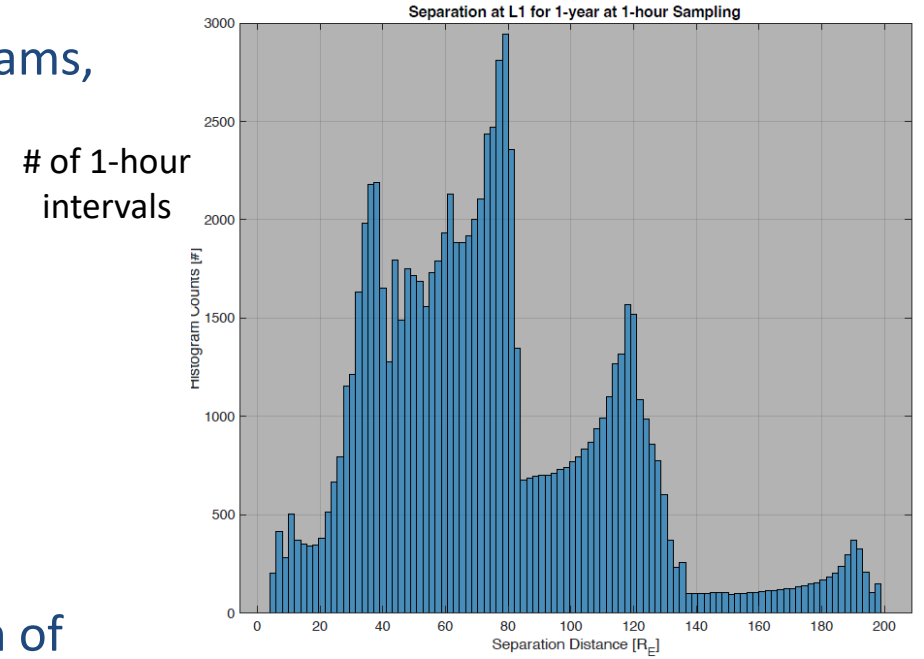
- Correlation scales in the 1-AU solar wind
- 3D configurations of interplanetary structures (CMEs, CIRs/SIRs/streams, IP shocks, etc.)
- Particle acceleration
- Turbulence (at low wavenumbers)

Multiple contributions expected for the HelioSystems Laboratory (HSL) proposed by the Decadal Survey for Heliophysics (12/2024)

Operational dividends:

- Optimized input to geospace models; coupling functions
- “Ground truth” for accuracy; fewer data gaps; improved propagation of SW parcels to bow shock/Mpause
- Calibration techniques (e.g., alfvenic calibration for the B-field)

Resolving Spatial Scales in the Solar Wind



Separation distance (0-200 RE)

[Turner and Horbury, February 17, 2025]

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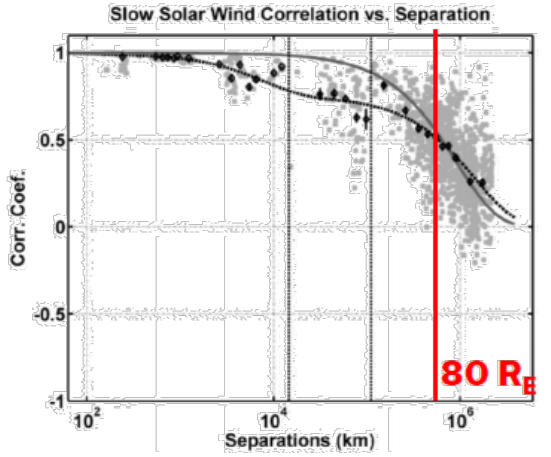
Science Objectives

Solar wind 3D structure
- 3D structure at the correlation scale
- A switchback in 3D?
- Turbulence near the outer scale

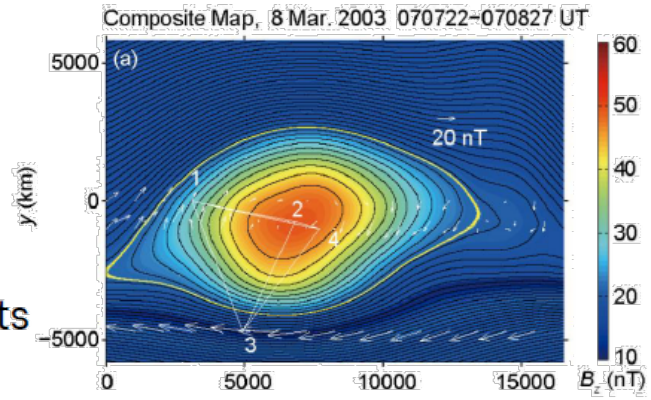
Collisionless shocks
- Response to varying upstream conditions
- Rippling, reformation
- Foreshock variability

Energetic particles
- Shock acceleration and foreshock variability
- Flux tube dropouts

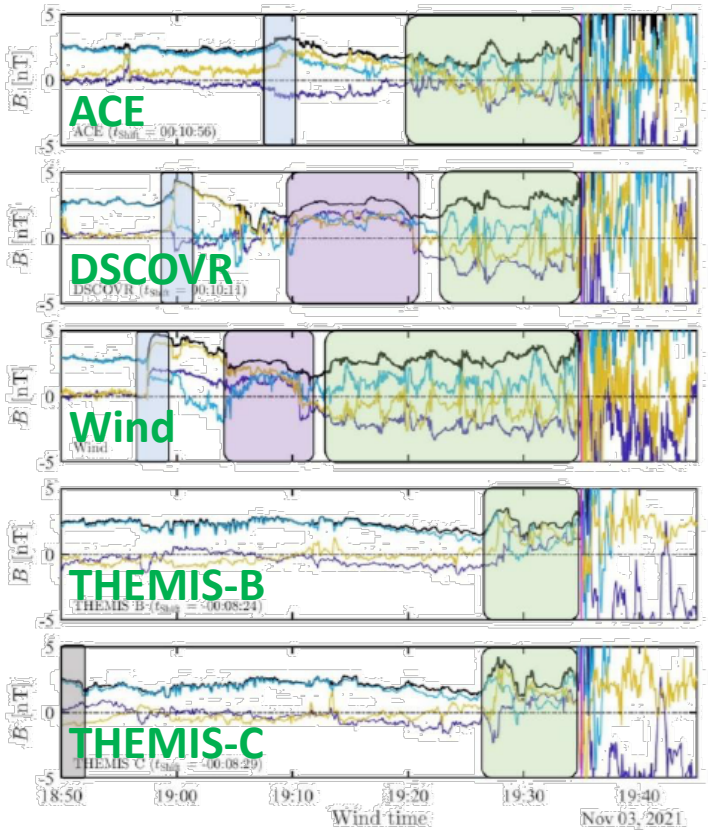
Structured solar wind arrival at magnetosphere
- Beyond the paradigm of radial phase fronts
- Driving geomagnetic activity below the global scale



Weygand et al., 2011



Sonnerup et al., 2004



Trotta et al., 2023

[Turner and Horbury, February 17, 2025]

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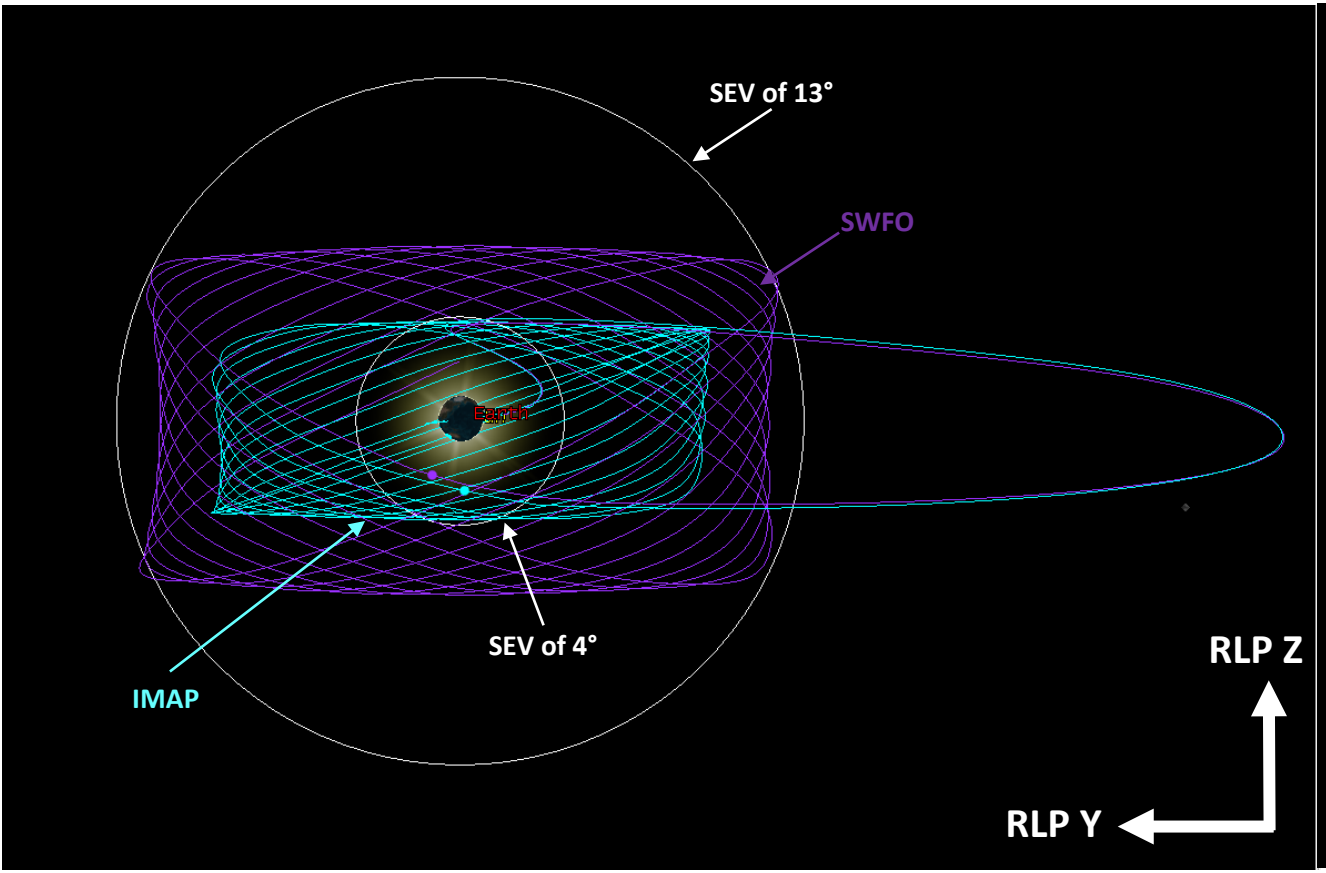
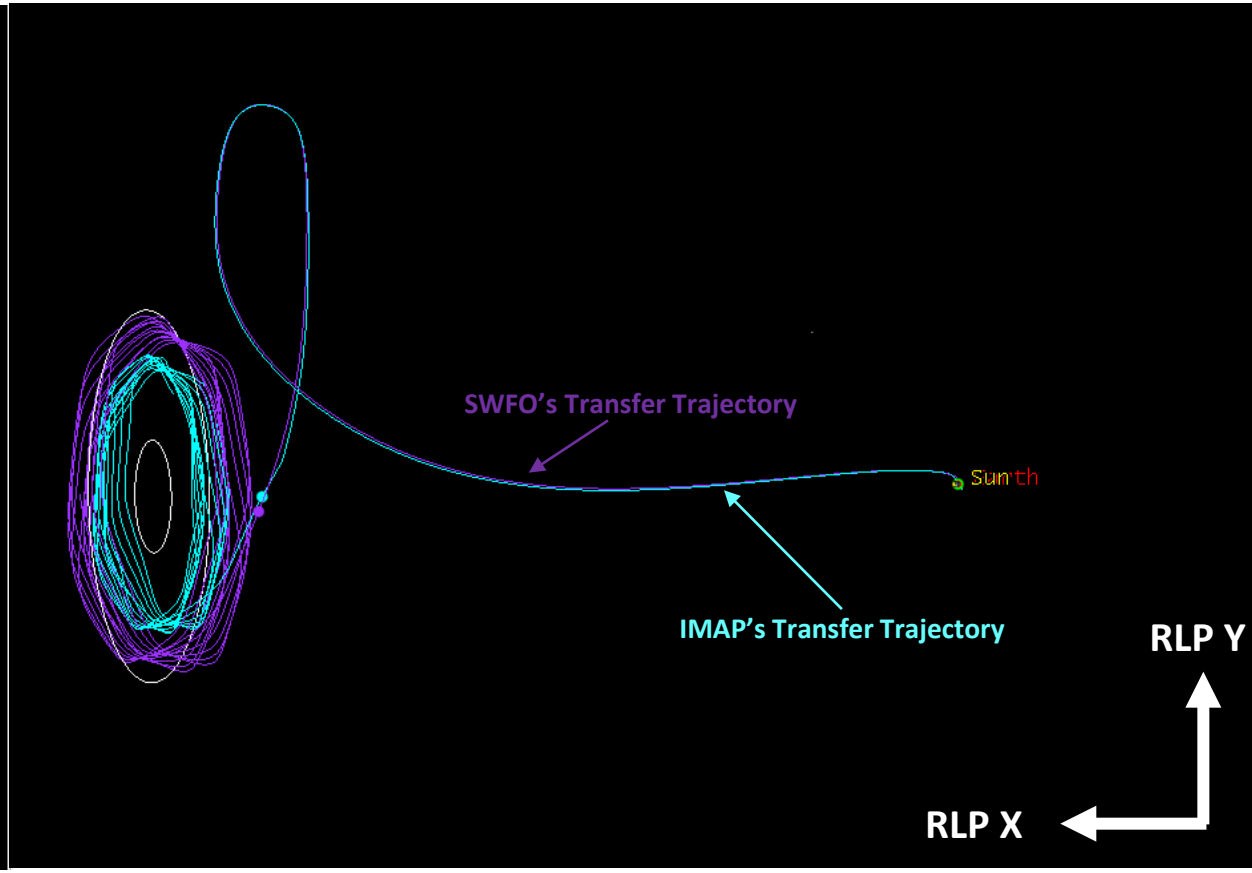
Coordination Activities

Several initial actions have been taken in the coordination between the six missions:

- Communications between project scientists (especially between SWFO-L1 and IMAP), other stakeholders
- AGU 2024 session SH11F New Missions at Lagrange 1: Space Weather Observations and Heliospheric Research (December 9, 2024; 18 papers, primarily on SWFO-L1)
  - Informal meeting among teams from 5 missions on December 11, 2025 after IMAP session
- Science and operational objectives have been listed in a draft white paper
- The IMAP team at APL and the SWFO-L1 team at GSFC have conducted analyses of the available predicted trajectory data. They have calculated pairwise distances for the spacecraft and identified intervals of closest approach.
- A draft white paper has been outlined and allocated.
- A workshop is being planned and NASA and NOAA leads have been identified.

SWFO-L1 and IMAP: Orbits





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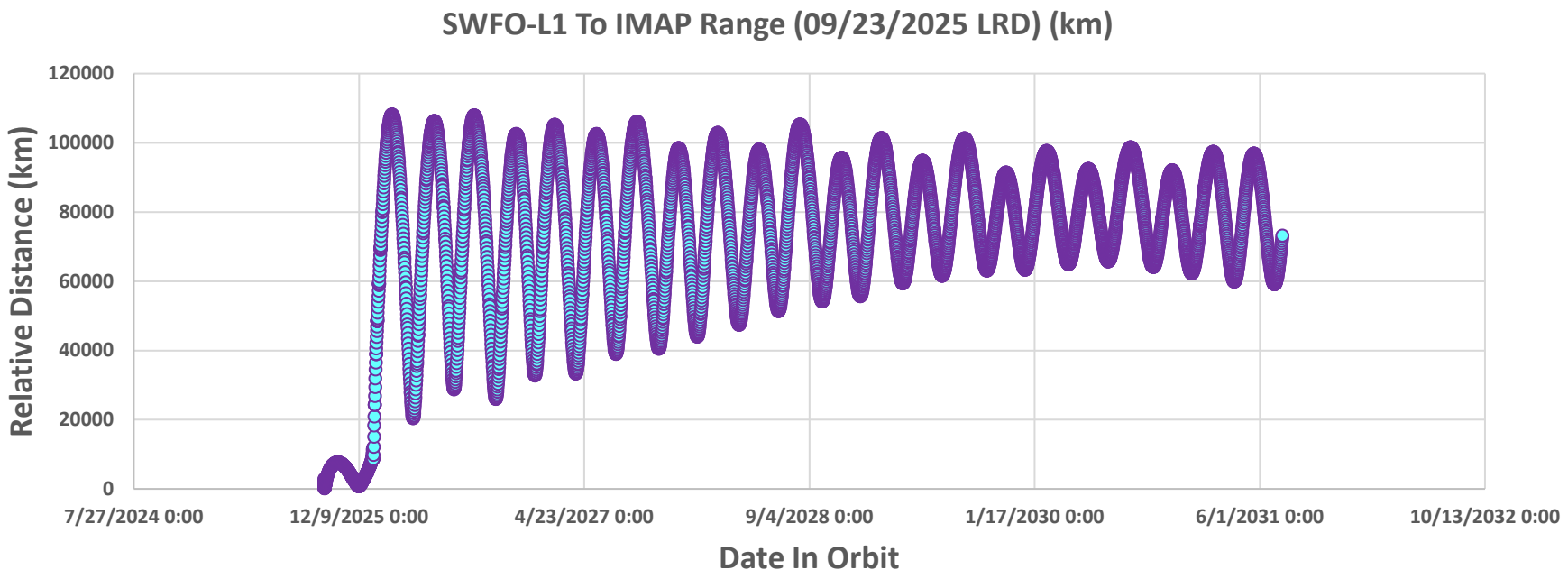
SWFO-L1 and IMAP: Range calculations



Statistic	Relative Range (km)
Min	202.5436 (in transfer) 8489.79 (in orbit)
Max	108230.1
Mean	71991.36 (transfer included) 7700.79 (mission orbit only)
Mode	N/A

[Webster and Folta, March 16, 2025]

Next Steps

A number of follow-up activities are being planned:

Programmatic:

- Continue coordination between project scientists and other stakeholders.
- Increase advocacy for support to NASA legacy missions for intercalibration tasks
- Include operations-relevant measures of activity to support/improve SWPC products (e.g., detailed modeling of magnetic-field fronts; ACE-type >45-keV ion flux, etc.)
- Ensure participation of Aditya-L1 PIs and other scientists

Technical:

- Compile SPICE kernels for all missions for coordinate transformations
- Ensure consistency of data files, compare Level 2 formats
- Conduct comparison/calibration analysis [e.g., Loto'aniu et al., 2022].
- Create a Python package ("L1Py") with search/pre-process functions
- Other needed steps

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Key issues of relevance to CGMS:

- The intercalibration of satellite data is one of the tasks coordinated by the SWCG. In addition, the activity is of interest to the GSICS SWx subgroup which has expanded its scope to include intercalibration among Lagrange-1 missions.

- Relevance to HLPP 2024-2028: The following are objectives to which the L1 project has specific contributions.
  - 4.1 Establish a fully consistent calibration of relevant satellite instruments across CGMS agencies
  - 6.3 Advance the integration of Space Weather coordination activities into the relevant CGMS working groups

To be considered by CGMS:

- For endorsement: project updates to be regularly presented to an SWCG task group and/or the GSICS intercalibration subgroup for awareness/actions.
- For actioning: NA