From SOHO to Solar Orbiter Science Operations

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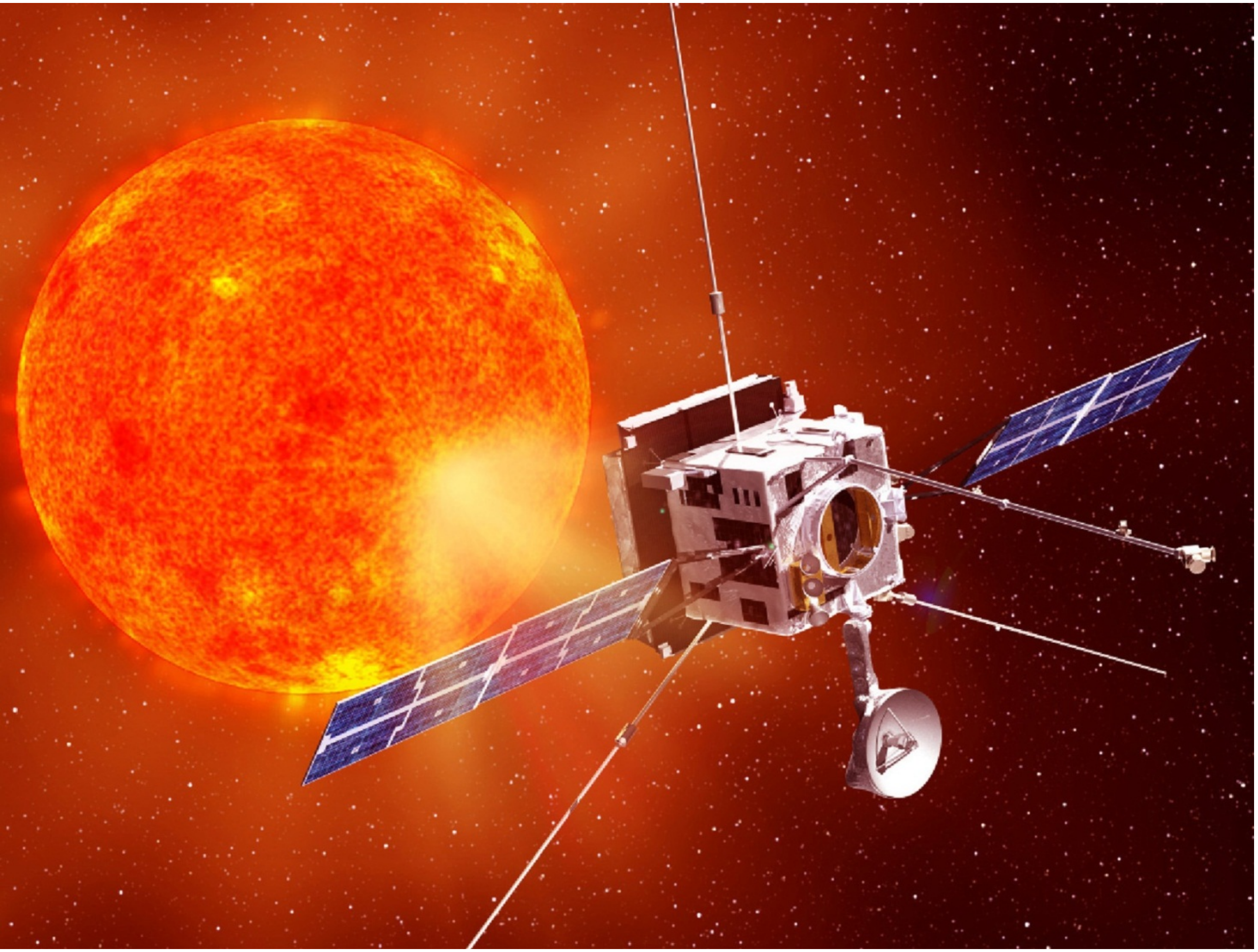
Solar Orbiter mission overview

- Selected as the M1 mission of the ESA Cosmic Vision Science Programme in October 2011.
- Solar Orbiter will address the central question of heliophysics: How does the Sun create and control the heliosphere?
- Scientific objectives:
    1. What drives the solar wind and where does the coronal magnetic field originate from?
    2. How do solar transients drive heliospheric variability?
    3. How do solar eruptions produce energetic particle radiation that fills the heliosphere?
    4. How does the solar dynamo work and drive connections between the Sun and the heliosphere?
- Coordinated payload observations are key to address the mission scientific objectives.

Solar Orbiter mission profile

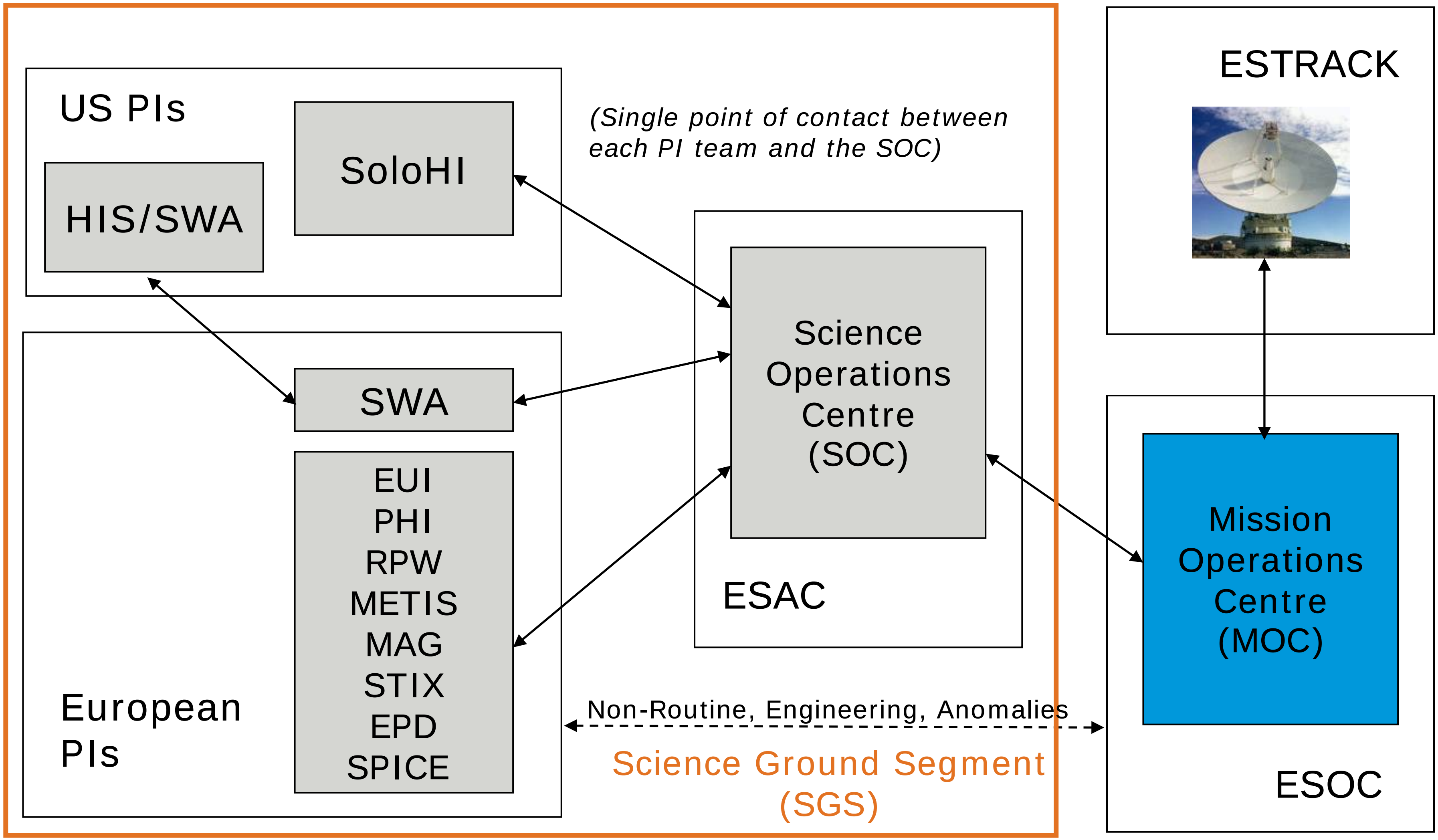


- BepiC HW inheritance
- 3 axis stabilized
- Sun-pointing
- Heat shield
- 2 solar arrays
- Dual X-band
  - 150 kbps@1AU
- Launch 2017 NASA EELV
- 7 years (3.5 yr cruise, 3.5 yr nominal)
- GS: ESTRACK network
  - 8h/day sci dumps
- 10 instruments, PI model
  - 6 remote sensing
  - 4 in-situ
  - S/C pointing only

Mission overview animation

Mission overview video

Solar Orbiter Science Ground Segment



Science Operations Centre

Science Operations Centre (SOC) responsibilities:

- Support of instrument development, calibration and characterization.
- Support of science data analysis.
- Coordination of overall mission planning.
- Coordination of individual instrument science operations.
- Auxiliary and “quick-look” data production and distribution.
- Data, software and documentation archiving, distribution and preservation.
- Feedback to the Project Scientist and SWT of information about the fulfilment of the mission scientific objectives.

The SOC is the single point of contact for the Instrument Teams for nominal science operations.

The SOC coordinates a conflict free schedule of payload operations that forwards to the Mission Operations Centre.

From SOHO to Solar Orbiter

SOHO

1. Sun-Earth L1 halo orbit ~0.01 AU from Earth
2. Constant TM rate
3. Almost no data latency
4. Limited data processing on board
5. Realtime operations
   - Reaction to solar events is easy
6. Few inter-instrument operational constraints
   - Instrument independent pointing

Solar Orbiter

1. Heliocentric eccentric orbit ~0.4 – 2 AU from Earth (0.28 AU perihelion, up to 34° tilted out of the Ecliptic).
2. TM rate varies by a 25x factor
3. Data latency will be months at times.
4. Sophisticated on-board data processing
5. Off-line operations (encounter model)
   - Reaction to solar events difficult
6. Significant inter-instrument operational constraints
   - No instrument independent pointing
   - EMC effects

Inheritance from SOHO - 1

Instruments and Instrument Teams.

Coordination of payload science operations - SOHO Joint Observing Programs concept to be reused:

- Coordinated observations that target a specific scientific objective.
- Scientific Leader coordinates with support of Science Ops Centre.
- Potential participation of other ground and space based observatories.
- Provides very visible feedback to Project Scientist and SWT about accomplishment of scientific objectives.
- Resulting scientific data set is easily identifiable and re-analysed.

Production of a “Quick look” data set.

- To be implemented in Solar Orbiter as a small Low Latency data set.
- Downloaded with minimal latency (next ground station pass).
- Processed and distributed by the Science Operations Centre.
- Supports:
  - Planning of science operations, in particular pointing determination.
  - Assessment of instrument performance.
  - Decisions on selective telemetry download.

Inheritance from SOHO - 2

Concept of inter-instrument communication:

- Allows for limited autonomous instrument operations reacting to each other observations of solar events.
- Not very much used with SOHO, as realtime operations provided enough flexibility.

Reuse of the experience accumulated on archiving solar data.

- Single archive to distribute science data and science operations (no split between operations and long term science archive).
- Solar Orbiter archive to be built on the ESAC infrastructure of other solar and heliospheric archives (SOHO, Ulysses, PROBA2).

Lessons learned from a long lived mission:

- Flexibility to react to changes in the technology and tools used in the ground segment.
- Flexibility to accommodate changes in the PI teams and PI institutions.
- Need to plan beforehand for long term data and software preservation.

Inheritance from other projects

Planetary missions (MEX, VEX, Rosetta, BepiColombo…):

- Reuse of the concept of science operations planning cycles synchronized with Mission Operations:
    1. Long term planning (one year to six months before ops).
    2. Mid term planning (orbit per orbit).
    3. Short term planning (weekly cycle).
- Reuse of existing tools:
    1. Experiment Planning System (modelling TM return already now).
    2. SoLab for geometry visualization.

Astronomy missions (Herschel, Planck…)

- Concepts for software development.
- Integration of PI software in data production pipelines.

Science operations planning model

The result is a “cascade” model for science operations which refines operations as they approach in time:

1. SWT plans at the highest level (Science Activity Plan).
2. SOWG refines the plan at the mid level (Joint Observing Plans level)
3. Instrument Teams plan their individual observing sequences (Instrument Operations Requests).

The SOC supports every planning level providing feasibility assessments and conflict resolution.

This inherited concept has been refined with specific features to address the peculiarities and challenges of Solar Orbiter:

Addressing Solar Orbiter science operations challenges

Telemetry heavily constrained:

- Pre-planning of the whole mission to assess TM return.
- On-board selection of telemetry.
    1. Within instrument memory buffers.
    2. At spacecraft SSMM level.
- Ground station pass optimization on good communication periods.

Fast reaction times to solar events are difficult to accomplish:

- Implementation of a Very Short Term Planning loop to update pointing as fast as possible.
- Usage of inter-instrument communications.

Close coordination of science observations to address scientific objectives.

- EMC characterization and monitoring of instrument and S/C subsystems
- Definition of EM quiet periods for magnetic field science observations

Designing together spacecraft, instruments and operations is key to success: Close collaboration with MOC, the Project, Instrument Teams and Project Scientist is a must.