Solar Orbiter

Exploring the Sun-Heliosphere Connection

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This Talk

- Brief mission overview in 15 minutes

Solar Orbiter

- First medium-class mission of ESA’s Cosmic Vision 2015-2025 programme, implemented jointly with NASA
- Dedicated payload of 10 remote-sensing and in-situ instruments measuring from the photosphere into the solar wind
Science Objectives

How does the Sun create and control the Heliosphere – and why does solar activity change with time?

1. What drives the solar wind and where does the coronal magnetic field originate?
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?

Mission Summary

Launch: October 2018
Cruise Phase: 2.3-3 years
Nominal Mission: 3.5-4 years
Extended Mission: ~3 years
Orbit: 0.28–0.91 AU (P=135-180 days)
Out-of-Ecliptic View:
Multiple gravity assists with Venus to increase inclination out of the ecliptic to >24° (nominal mission), >32° (extended mission)

Reduced relative rotation:
Observations of evolving structures on solar surface & in heliosphere for almost a complete solar rotation
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Remote-sensing windows (10 days each)
High-latitude Observations

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Mission Profile
October 2018 Launch: Solar Distance

Oct 2018/Option E
October 2018 Launch: Solar Latitude

Oct 2018/Option E
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The Spacecraft
Three-axis stabilized spacecraft, Sun pointing
- Closest Sun encounter: 0.28 AU
- Heat shield to protect spacecraft and payload
- Overall mass: ~1800 kg
- Maximum power demand: ~1100W
- Re-use of BepiColombo unit designs and technology
- NASA-provided launch vehicle
### Payload

#### In-Situ Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
<th>PI</th>
<th>Nationality</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPD</td>
<td>Energetic Particle Detector</td>
<td>J. Rodríguez-Pacheco</td>
<td>Spain</td>
<td>Composition, timing and distribution functions of energetic particles</td>
</tr>
<tr>
<td>MAG</td>
<td>Magnetometer</td>
<td>T. Horbury</td>
<td>United Kingdom</td>
<td>High-precision measurements of the heliospheric magnetic field</td>
</tr>
<tr>
<td>RPW</td>
<td>Radio &amp; Plasma Waves</td>
<td>M. Maksimovic</td>
<td>France</td>
<td>Electromagnetic and electrostatic waves, magnetic and electric fields at high time resolution</td>
</tr>
<tr>
<td>SWA</td>
<td>Solar Wind Analyser</td>
<td>C. Owen</td>
<td>United Kingdom</td>
<td>Sampling protons, electrons and heavy ions in the solar wind</td>
</tr>
</tbody>
</table>

#### Remote-Sensing Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
<th>PI</th>
<th>Nationality</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUI</td>
<td>Extreme Ultraviolet Imager</td>
<td>P. Rochus</td>
<td>Belgium</td>
<td>High-resolution and full-disk EUV imaging of the on-disk corona</td>
</tr>
<tr>
<td>METIS</td>
<td>Coronagraph</td>
<td>E. Antonucci</td>
<td>Italy</td>
<td>Visible and UV Imaging of the off-disk corona</td>
</tr>
<tr>
<td>PHI</td>
<td>Polarimetric &amp; Helioseismic Imager</td>
<td>S. Solanki</td>
<td>Germany</td>
<td>High-resolution vector magnetic field, line-of-sight velocity in photosphere, visible imaging</td>
</tr>
<tr>
<td>SoloHI</td>
<td>Heliospheric Imager</td>
<td>R. Howard</td>
<td>United States</td>
<td>Wide-field visible imaging of the solar off-disk corona</td>
</tr>
<tr>
<td>SPICE</td>
<td>Spectral Imaging of the Coronal Environment</td>
<td></td>
<td></td>
<td>EUV spectroscopy of the solar disk and near-Sun corona</td>
</tr>
<tr>
<td>STIX</td>
<td>Spectrometer/Telescope for Imaging X-rays</td>
<td>S. Krucker</td>
<td>Switzerland</td>
<td>Imaging spectroscopy of solar X-ray emission</td>
</tr>
</tbody>
</table>
Payload Accommodation
Solar Orbiter = Linking in-situ and remote-sensing observations
Science Operations

Science Data Acquisition

- Complete payload suite will observe during three 10-day windows per orbit, typically centered around perihelia and min./max. heliolatitude
- In-situ instruments will operate continuously, starting in cruise phase

Operational Constraints

- Limited telemetry due to orbital characteristics (baseline: 595 Gbit/168-day orbit)
- Variable telemetry rates and data latency due to large variations in S/C–Earth distance (0.4-2.0 AU) → Need for long-term planning of top-level science operations
- Payload will be operated as a suite (all instruments co-pointed)
Synergy between Solar Orbiter and other Observatories

**Solar Orbiter:**
+ unique orbit (solar distance, inclination, longitude)
+ comprehensive payload suite
- limited telemetry due to orbital characteristics

**Solar Probe Plus:**
+ unique orbit (min. perihelion $\approx 10 \text{ R}_\text{Sun}$)
- payload mass constrained by orbital characteristics, mostly in-situ instrumentation

**Near-Earth assets:**
+ much higher data return (e.g. SDO, DKIST)
- limited to Sun-Earth line
Synergy between Solar Orbiter and other Observatories

• Solar Orbiter improves coverage of the Sun over (Near-) Earth view by about 45%

→ Depending on orbit, Solar Orbiter data can be complemented by high-res/high-cadence co-spatial data from other observatories or data with additional spatial coverage, e.g. for helioseismology

Courtesy W. Thompson/O.C. St. Cyr (NASA GSFC)
Development Status

• **Payload:**
  - Critical Design Reviews (CDRs) of 9 out of 10 instruments completed.

• **Spacecraft:**
  - System-level CDR: Board Meeting on 17 June 2015: CDR goals not achieved yet → Delta CDR will follow
  - Spacecraft Structural Thermal Model (STM) test campaign on-going
  - Heat Shield STM successfully passed 10 solar constants flux test in ESTEC’s Large Space Simulator

• **Ground Segment:**
  - Requirements Reviews successfully completed.
  - Design Review of Science Ground Segment successfully completed.

• **Launch Vehicle:**
  - NASA awarded contract (Atlas V 411) in March 2014, progress nominal
Summary

• Solar Orbiter will address a central question of heliophysics: How does the Sun create and control the heliosphere?

• Solar Orbiter will perform
  • In-situ measurements of the solar wind plasma, fields, waves and energetic particles as close as 0.28 AU from the Sun
  • Simultaneous high-resolution imaging and spectroscopic observations of the Sun in and out of the ecliptic plane (up to ~33°).

• The combination of in-situ and remote-sensing instruments, together with the new, inner-heliospheric perspective, distinguishes Solar Orbiter from all previous and current missions, enabling new science which can be achieved in no other way.

• Solar Orbiter has unique synergies with Solar Probe Plus, DKIST and other new observatories.