SOLAR ORBITER
Linking the Sun and Inner Heliosphere
Outline

- Science goals of Solar Orbiter
- Focus of HELEX joint mission
- Mission requirements
- Science payload
- Status update
Top level scientific goals of Solar Orbiter

- Determine the properties, dynamics and interactions of plasma, fields and particles in the near-Sun heliosphere
- Investigate the links between the solar surface, corona and inner heliosphere
- Explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun’s magnetized atmosphere
- Probe the solar dynamo by observing the Sun’s high-latitude field, flows and seismic waves

Combination of remote sensing + in-situ
Focus of HELEX Joint Mission

HELEX (Heliospheric Explorers) = Solar Orbiter + Solar Sentinels

Primary Objectives:

1. Determine the sources, acceleration mechanisms and transport processes of solar energetic particles
2. Determine how coronal mass ejections (CMEs) evolve from the Sun to the inner solar system
3. Determine the origins of solar wind streams and interplanetary magnetic fields
Identify the Sources of Energetic Particles

**Problem:**
The relative importance of acceleration processes due to flares and CME-driven shocks cannot be determined at 1 AU due to particle mixing.

**Solution:**
Simultaneous in-situ measurements of energetic particles within ~1 mean-free-path (~0.35 AU) of their acceleration site and magnetically connected to flare site + shock fronts by the three Sentinels and Solar Orbiter.

**Plus:**
Concurrent remote imaging of flares, wide field-of-view coronagraphy of CMEs and spectroscopic identification of the CME-driven shocks from Solar Orbiter.
Localize the Sources of Solar Energetic

**Problem:**
Multiple SEP events easily separated close to the Sun as demonstrated by Helios, but are all mixed together by the time the SEPs reach Earth orbit.

**Solution:**
- **Sentinels:** near-Sun energetic particle observations to distinguish separate events
- **Solar Orbiter:** provide information on solar structures to establish their connection to solar source regions

How is the structure of ICMEs related to their origin?

**Problem:**
- Models: All interplanetary CMEs (ICMEs) should be flux ropes, independent of initiation
- Observations: not true at 1 AU for > 50% of ICMEs

**Solution:**
- Solar Orbiter: track CME as it travels over Sentinels
- Sentinels + Solar Orbiter: measure CME properties in situ
  → Relate white light structures and spectroscopic plasma diagnostics to local plasma properties
  → Identify the various solar sources of the CME structures.

SOHO/LASCO C2 image showing the classic three-part structure of a CME
Structure and Evolution of Transients

Example: An ICME strikes Comet Encke

Problem:
Line-of-sight ambiguities do not allow definitive determination of solar wind transient structures.

Observed:
ICME passing over Comet Encke illustrates the value of in-situ observations made in FOV of a white-light imager.

Solution:
Remove line-of-sight ambiguities from Solar Orbiter remote observations by multi-point Sentinels in-situ observations → Determination of ICME structure and evolution.

STEREO/HI observation, 4/20/2007
What are the origins of solar wind streams and the heliospheric magnetic field?

**Problem:**
Origin of the slow solar wind is hotly debated.
Possible source regions:
- edges of streamers
- boundaries of coronal holes
- tops of streamers

**Observed:**
Considerable structure inside streamers. However, these structures are completely washed out at 1 AU.

**Solution:**
A combination of near-Sun in-situ observations with concurrent remote imaging will allow the tracing of narrow slow solar wind streams to their origination sites.

Solar Orbiter Mission Requirements

**Orbit:**
- Reach orbit with perihelion between 0.2 and 0.25 AU
- Increase inclination w.r.t. Sun’s equator to:
  - $\geq 30^\circ$ for nominal mission (goal)
  - $\geq 34^\circ$ for extended mission (goal)

**Launch:**
- 2015 (2017 as back-up):
  - NASA-provided launch (Atlas V or Delta IV) as baseline
  - Soyuz-Fregat 2-1b from Kourou as back-up
  
  N.B. Sentinels to be launched separately (~ 2 years later)

**Science Payload:**
- Mass: 180 kg max. incl. maturity margin
- Power: 180 W max. incl. maturity margin
2015 launch: Spacecraft Trajectory

Ecliptic View
2015 launch: Spacecraft Trajectory

Solar Latitude as function of time

Latitude as function of S/C-Sun distance
2015 launch: Spacecraft Trajectory

Sun-Earth fixed
Science Payload

ESA Announcement of Opportunity
- Released 18 Oct 2007
- 12 replies received by the 15 Jan 2008 deadline
- Another 2 (US-led) proposals received by 6 Feb 2008 (deadline extended specifically for this purpose)

NASA SMEX Focused Opportunity for Solar Orbiter
- Released 28 Oct 2007
- Deadline 1 Feb 2008
## Solar Orbiter Instrument AO

### Proposals received by ESA

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Proposal Acronym</th>
<th>Reference Payload Acronym</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Wind Plasma Analyzer</td>
<td>SWA</td>
<td>SWA</td>
</tr>
<tr>
<td>Radio and Plasma Wave Analyzer</td>
<td>RPW</td>
<td>RPW</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>MAG</td>
<td>MAG</td>
</tr>
<tr>
<td>Energetic Particle Detector</td>
<td>EPD</td>
<td>EPD</td>
</tr>
<tr>
<td>Energetic Particle Telescope</td>
<td>EPT</td>
<td>EPD</td>
</tr>
<tr>
<td>Dust Particle Analyzer</td>
<td>SODA</td>
<td>DPD</td>
</tr>
<tr>
<td>Visible Imager &amp; Magnetograph</td>
<td>PHI</td>
<td>VIM</td>
</tr>
<tr>
<td>EUV Spectrometer</td>
<td>METIS/EUS</td>
<td>EUS</td>
</tr>
<tr>
<td>EUV Imager</td>
<td>EUI</td>
<td>EUI</td>
</tr>
<tr>
<td>Coronagraph</td>
<td>METIS/COR</td>
<td>COR</td>
</tr>
<tr>
<td>Spectrometer/Telescope Imaging X-rays</td>
<td>STIX</td>
<td>STIX</td>
</tr>
<tr>
<td>Neutral Solar Wind Detector</td>
<td>SCENARIO</td>
<td></td>
</tr>
<tr>
<td>Solar Luminosity and Irradiance Monitor</td>
<td>SLIM</td>
<td></td>
</tr>
</tbody>
</table>
Recent and on-going Activities

• HELEX Joint Science & Technology Definition Team report released in Sep 2007
• Parallel heat shield and system assessment studies:
  Final presentations in Oct 2007
• ESA and NASA instrument AOs released in mid-Oct 2007
• Industrial phase B1 (18-month definition phase):
  started in mid-March 2008
  • Industry team led by EADS/Astrium, sub-contractor Thales-Alenia
• Instrument proposal evaluation in progress
Recent and on-going Activities

heat shield
breadboard
The End