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Extract of Solar Orbiter section

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4.8 Solar Orbiter

Introduction

Solar Orbiter is the next solar-heliospheric mission in the ESA Science Programme. The mission is devoted to solar and heliospheric physics and will provide unprecedented closeup and high-latitude observations of the Sun. The Sun's atmosphere and the heliosphere represent uniquely accessible domains of space, where fundamental physical processes common to solar, astrophysical and laboratory plasmas can be studied under conditions impossible to reproduce on Earth or to study from astronomical distances. The results from missions such as Helios, Ulysses, Yohkoh, SOHO, TRACE and RHESSI, as well as the recently-launched Hinode and STEREO missions, have significantly advanced our understanding of the solar corona, the associated solar wind and the three-dimensional heliosphere. Further progress is to be expected with the launch of the first of NASA's Living With a Star (LWS) missions, the Solar Dynamics Observatory (SDO). Each of these missions has a specific focus, being part of an overall strategy of coordinated solar and heliospheric research. An important element of this strategy, however, has yet to be implemented. We have reached the point where further *in situ* measurements, now much closer to the Sun, together with remote-sensing observations from a near-Sun and out-of-ecliptic perspective, promise to bring about major breakthroughs in solar and heliospheric physics. ESA's Solar Orbiter will, as part of the joint ESA–NASA Heliosphysical Explorers (HELEX) programme that also includes NASA's Solar Sentinels mission, provide many of the required observations.

Scientific goals

Within the framework of the global strategy of coordinated solar and heliospheric research outlined above, the top-level scientific goals of the Solar Orbiter mission as originally formulated by the Solar Orbiter Science Definition Team are to:

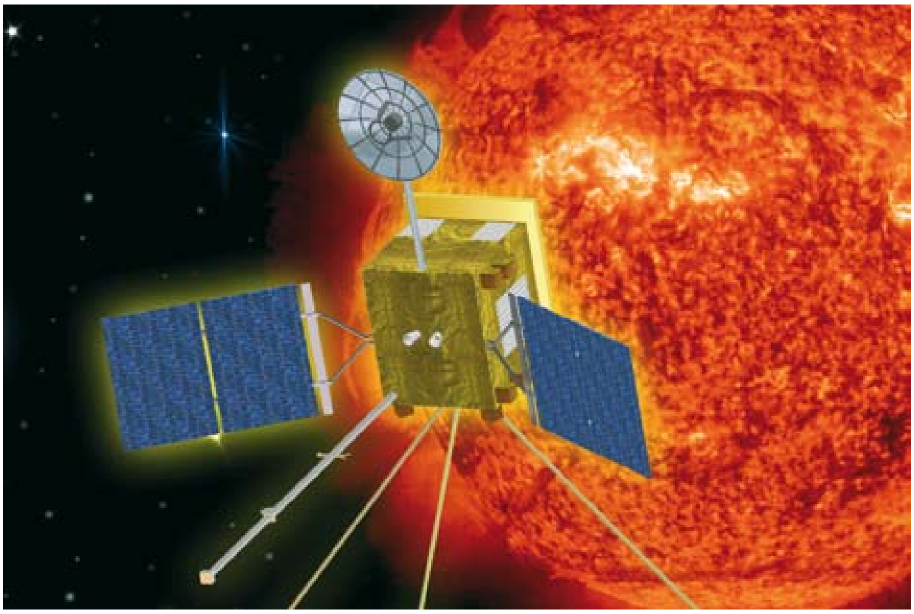
- determine the properties, dynamics and interactions of plasma, fields and particles in the near-Sun heliosphere,
- investigate the links between the solar surface, corona and inner heliosphere,
- explore, at all latitudes, the energetics, dynamics and fine-scale structure of the Sun's magnetised atmosphere, and
- probe the solar dynamo by observing the Sun's high-latitude field, flows and seismic waves.

In order to address these objectives, a mission profile for Solar Orbiter has been developed that will, for the first time, make it possible to:

- explore the uncharted innermost regions of our solar system using both *in situ* and remote-sensing instruments,
- study the Sun from close up (48 solar radii or 0.22 AU),
- fly by the Sun tuned to its rotation and examine the solar surface and the space above from a near co-rotating vantage point, and
- provide images and spectral observations of the Sun's polar regions from out of the ecliptic.

By bringing together and augmenting the unique capabilities of Solar Orbiter (near-Sun and out-of-ecliptic *in situ* plus remote-sensing observations) with those of the Sentinels (*in situ* observations from multiple platforms arrayed at varying radial distances in the ecliptic plane) in the joint HELEX scientific endeavour, ESA

Figure 4.8.1. Solar Orbiter near perihelion.



and NASA have created an unprecedented opportunity for coordinated, correlative measurements, resulting in a combined observational capability that far outweighs that of either mission alone. Within the context of the broader objectives formulated for Solar Orbiter, the overarching questions that will be answered by this joint programme are:

— What are the origins of the solar wind streams and the heliospheric magnetic field?
— What are the sources of energetic particles?
— How do coronal mass ejections evolve in the inner Solar System?

In order to answer these questions, it is essential to make *in situ* measurements of the solar wind plasma, fields, waves, and energetic particles close enough to the Sun that they are still relatively pristine. It is also necessary to make simultaneous *in situ* measurements at multiple locations in order to capture the spatial structure and temporal evolution of the phenomena being observed and to perform remote-sensing observations of the source regions on the Sun simultaneously with the *in situ* measurements. Taking into account the science requirements of HELEX, the following instruments are now included in the baseline reference payload of Solar Orbiter:

— heliospheric *in situ* instruments: solar wind analyser, radio and plasma wave analyser, magnetometer, energetic particle detectors.
— solar remote sensing instruments: visible-light imager and magnetograph, EUV imager, EUV spectrometer, X-ray spectrometer/telescope, coronagraph, wide-field imager.

The baseline mission, which is planned to start mid-2015, utilises a ballistic trajectory combined with planetary Gravity Assist Manoeuvres (GAM). An optimised transfer trajectory leads to a 150-day science orbit with a minimum perihelion radius of 48 solar radii. Repeated gravity assist manoeuvres with Venus on a 3:2 resonant orbit are employed to raise the orbit inclination without use of propulsion. The duration of the ballistic transfer to the second Venus GAM is about 3 years. The end of the nominal mission occurs 6.2 years after launch, after the fourth Venus GAM, when the orbit inclination relative to the solar equator exceeds 25°. The inclination may be further increased during an extended mission phase using additional GAMs, reaching a maximum of 34°.

Science operations will be conducted predominantly in an encounter-like mode, whereby the full payload will operate only during certain key portions of each 150-day science orbit. As a baseline, these will comprise 10-day periods centred on perihelion, and highest northern and southern latitude. A subset of the payload (nominally the *in situ* instruments) will operate throughout the entire orbit, within the constraints imposed by spacecraft operations (e.g. telemetry downlink sessions). In addition, it is envisaged to acquire synoptic remote-sensing observations at a cadence determined by the available telemetry downlink.

Status

At the November 2007 SPC meeting, the Executive presented a way forward for the optimised implementation of Solar Orbiter with a view to bringing the mission back into a cost envelope of 300 MEuro to ESA and to maintain the possibility for a launch mid-2015. This plan, which was approved by SPC, was based on the results of complementary industrial and internal studies performed in 2006 and 2007. A key element in this plan is the cooperation between ESA and NASA resulting in a joint Solar Orbiter/Sentinels mission scenario whereby Solar Orbiter will be launched by an Atlas V from Cape Canaveral (with Delta IV as a possible backup) into a trajectory closely matched to that previously provided by the Soyuz Fregat 2-1B. A joint Science and Technology Definition Team (JSTDT), comprising scientists and engineers appointed by ESA and NASA, was formed in 2007 to support the development of this scenario. The JSTDT report was issued in September, and on 18 October, ESA issued an Announcement of Opportunity for the scientific payload of Solar Orbiter, with proposals due mid-January. This was followed a short time later by an Announcement by NASA for a so-called Focused Opportunity for Solar Orbiter instruments in the framework of the Small Explorer (SMEX) programme. The industrial Phase B1 was kicked off in March 2008.