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Solar Orbiter Science Management
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EUROPEAN SPACE AGENCY

SCIENCE PROGRAMME COMMITTEE

Solar Orbiter Science Management Plan

Summary

Delegations will find attached the Science Management Plan (SMP) for the Solar Orbiter mission. It describes the implementation of those aspects of the project, up to and including the post operational phase, that are required to ensure the fulfilment of the mission's scientific objectives, and to optimize its scientific return, with special emphasis on payload procurement, science operations and data management.

This SMP has been used as a reference document, subject to SPC approval, in the Solar Orbiter Announcement of Opportunity issued on 18 October 2007. Any changes agreed by SPC prior to approval will be circulated to proposers.

The revised Solar Orbiter Science Management Plan (SMP) includes comments expressed by delegations as of 19 November 2007.

Required decision

The SPC is invited to approve the Solar Orbiter Science Management Plan.

Voting rights and majority required

Simple majority of Member States.

Recommendation of advisory committees

The document has been presented to the SSWG at its 125th meeting held at Paris on 11-12 October 2007 and has been unanimously recommended after incorporation of SSWG comments. It has also been presented and discussed at the SSAC during its 120th meeting of 16-17 October 2007, held at Paris, and was unanimously recommended for presentation to SPC.

Legal basis

SPC Terms of Reference, Section (b)
ESA Convention, Article XI, 6 (d).

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SOLAR ORBITER

SCIENCE MANAGEMENT PLAN

date of issue/*date d'édition* 4 December 2007

Solar Orbiter Mission Summary	
Mission Objectives	<ul style="list-style-type: none"> • Explore the uncharted innermost regions of our solar system • Study the Sun from close up (48 solar radii or 0.22 AU) • Fly by the Sun tuned to its rotation to examine the solar surface and the space above from a quasi-corotating vantage point • Provide images of the Sun's polar regions from latitudes in excess of 30°
Reference Payload	<ul style="list-style-type: none"> • Heliospheric <i>In-Situ</i> Instruments: • Plasma Package (ion and electron solar wind analysers) • Fields Package (radio and plasma wave analyser, magnetometer) • Particles Package (energetic particle detectors, interplanetary dust detector) • Solar remote sensing Instruments: • Visible-light imager and magnetograph • EUV full-Sun and high-resolution imager • EUV spectrometer • X-ray spectrometer/telescope • Coronagraph • Heliospheric Imager/Wide Field Coronagraph
Mission Profile	<ul style="list-style-type: none"> • Launch on Atlas V (Delta IV and Soyuz-Fregat 2-1B as back-ups) • Interplanetary cruise with chemical propulsion and gravity assists at Earth and Venus. • 3:2 Venus resonance orbit with multiple gravity assists to increase inclination
Spacecraft	Single element, 3-axis stabilised, 2 adjustable solar arrays
Orientation	Sun-pointing (heat shield)
TM band	X/Ka
Data volume per orbit	Ranging between 380 and 430 Gbit
Launch vehicle	Atlas V (or Delta IV and Soyuz-Fregat 2-1B as back-ups)
Launch date	mid-2015
Nominal Mission duration	6.2 yr
Ground TM station	New Norcia (Australia) or Cebreros (Spain), 35m - Antenna, 4 to 8 hrs/day (effective)
Programmatic	<ul style="list-style-type: none"> • ESA is responsible for the Solar Orbiter spacecraft, transfer to nominal science orbit, mission operations. • NASA is responsible for launch vehicle provision and launch operations.

TABLE OF CONTENTS

1	SUMMARY AND SCOPE	5
2	MISSION OVERVIEW	5
	2.1 Introduction	5
	2.2 Historical Background.....	6
	2.3 Scientific Objectives.....	7
	2.4 Mission Description	7
	2.5 International Cooperation.....	8
	2.6 Payload Consortium Confirmation Process.....	9
	2.7 Modes of Participation	9
	2.7.1 Principal Investigator.....	10
	2.7.2 Co-Principal Investigators	11
	2.7.3 Co-Investigators.....	12
	2.7.4 Guest Investigators	12
	2.7.5 Interdisciplinary Scientists	12
3	SELECTION PROCESS.....	13
	3.1 Instrument Selection.....	14
	3.1.1 Payload Review Committee	14
	3.1.2 Evaluation Criteria and Selection Principles	14
	3.2 Selection of Guest Investigators.....	16
	3.3 Selection of Interdisciplinary Scientists	16
4	SCIENCE AND ESA PROJECT MANAGEMENT.....	17
	4.1 The Project Scientist.....	17
	4.2 Science Working Team	17
	4.3 The Project Office	17
	4.4 Monitoring of Instrument Development.....	18
5	SCIENCE OPERATIONS AND DATA.....	19
	5.1 Solar Orbiter Operations Concept	19
	5.2 Mission Operations Centre	19
	5.3 Science Operations Centre	19
	5.4 Data Rights.....	21
	5.5 Communication and Public Outreach.....	21
	5.5.1 Public Outreach	21
	5.5.2 Science Communication	22
	ACRONYMS.....	23
	ANNEX.....	25

1 SUMMARY AND SCOPE

Solar Orbiter is the next solar-heliospheric mission in the Science Programme of the European Space Agency (ESA). The mission is devoted to solar and heliospheric physics and will provide unprecedented close-up and high-latitude observations of the Sun. The mission will be carried out as an ESA mission open to the worldwide science community.

The Solar Orbiter baseline configuration consists of a 3-axis stabilized, single element spacecraft that will be launched from Cape Canaveral on an Atlas V (with Delta IV and a Soyuz-Fregat 2-1B from Centre Spatial Guyanais, Kourou (CSG) as possible back-ups). The launch date is mid-2015.

The Solar Orbiter Science Management Plan (SMP) describes the implementation of those aspects of the project, up to and including the post operational phase, that are required to ensure the fulfillment of the mission's scientific objectives, and to optimize its scientific return, with special emphasis on payload procurement, science operations and data management.

The SMP first summarizes the main aspects of the mission, followed by a description of how the scientific community will be associated with the mission, focusing in particular on the selection of the instruments that will constitute the Solar Orbiter scientific payload. The plan outlines the role of the Solar Orbiter science advisory structure, and the ESA science management tasks from instrument selection to data distribution and archiving. The SMP also addresses the duties and rights of the Solar Orbiter investigators, as well as their interaction with the Solar Orbiter Science Working Team.

2 MISSION OVERVIEW

2.1 *Introduction*

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 advanced significantly 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 Heliospherical Explorers programme that also includes NASA's Solar Sentinels mission, provide many of the required observations.

2.2 *Historical Background*

Ideas for an ESA Solar Orbiter mission were first discussed at the workshop “A Crossroads for European Solar and Heliospheric Physics”, held on Tenerife in March 1998. Following a pre-assessment study carried out in ESTEC in 1999, the mission was proposed to ESA in the framework of the Flexi-mission F2/F3 Call for Proposals in 2000. Based on the results of the pre-assessment, and a further “delta” assessment study conducted between April and June 2000, the mission was selected in October 2000 by ESA's Science Programme Committee (SPC) for launch in the 2008-2013 time-frame.

In May 2001 the First Solar Orbiter Workshop was held in Tenerife, at the same location where the “Crossroads” meeting took place 3 years earlier. Following the reassessment of the ESA Science Programme in spring 2002, the selection of Solar Orbiter was confirmed by ESA's SPC in May 2002 for implementation with BepiColombo as a single project. Launch was foreseen in 2011 or 2012. Subsequently, as a result of the ESA's Cosmic Vision re-construction activity in 2003, it was considered necessary to obtain further formal re-confirmation of the mission by the SPC. This occurred in June 2004, with SPC requiring that the mission be implemented within a tight budget envelope by maximising the commonality with the BepiColombo mission to Mercury, with the objective of a launch preferably in 2013, but no later than 2015.

Between January 2004 and October 2005 the Solar Orbiter underwent an extensive assessment phase with the aim to maximise the scientific performance, through optimisation of the payload complement, while attempting to reduce costs and programmatic risks. The preferred mission scenario that had emerged was to launch Solar Orbiter on a Soyuz Fregat 2-1B in May 2015. To achieve this with adequate resource margins the payload had to be highly optimised while ensuring the mission's scientific competitiveness was maintained. This was achieved by defining, from the analysis of the scientific objectives, the corresponding payload complement and resulting instrument requirements. An optimised reference payload suite was defined, which was compatible with the science objectives as well as with the available resources. In addition to a detailed payload optimization industrial study, two parallel industrial Mission Assessment Studies were conducted that led to a technically feasible mission profile with associated costs and programmatic analyses.

The international scientific community has been closely involved throughout the extended assessment phase of Solar Orbiter, in particular through membership of the Payload Working Groups (PWG), and/or the Science Definition Team (SDT).

In 2006, taking due account of overall ESA science directorate programmatic constraints, ESA's Science Programme Committee directed the Executive to present in November 2007 a way forward for the optimized implementation of Solar Orbiter, to bring the mission back into a cost envelope of 300 MEuro to ESA and to maintain the possibility for a launch mid-2015.

This was accomplished in the course of complementary studies performed in 2006 and 2007. Cooperation between ESA and NASA resulted in a mission scenario whereby Solar Orbiter will be launched by and Atlas V from Cape Canaveral (with Delta IV as a possible back-up) into a trajectory closely matched to that previously provided by the Soyuz Fregat 2-1B. [Compatibility with Soyuz-Fregat will be technically maintained so as to keep it as a technically possible back-up as well.] Improved trajectories may be developed later in the program if launch vehicle performance is available. In the course of 2007, a joint Science and Technology Definition Team (JSTDT) comprising scientists and engineers appointed by ESA and NASA has studied the benefits to be gained by combining ESA's Solar Orbiter mission and NASA's Solar Sentinels into a joint programme. The final report of the JSTDT captures the key science goals of the joint missions, the need for multi-spacecraft measurements from different vantage points, strawman instrument payload and possible implementation approaches.

2.3 *Scientific Objectives*

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 magnetized atmosphere;
- 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 co-rotating vantage point;
- Provide images & 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 a joint scientific endeavour called Heliospheric Explorers, ESA 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.

Detailed information on these core objectives is given in the Joint Science and Technology Definition Team report. Additional objectives for the joint programme that may be achieved if resources allow, are addressed in the Solar Orbiter Science Requirements Document.

2.4 *Mission Description*

The baseline mission is planned to start mid-2015 with an Atlas V launch from Cape Canaveral, including 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. Science operations (with *in-situ* instruments and where possible,

remote-sensing instruments) can however start after spacecraft commissioning and continue during the initial part of the trajectory. End of 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°.

The optimised reference payload of the Solar Orbiter is given in Table 1 of the Annex. 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.

2.5 *International Cooperation*

Solar Orbiter is considered to be ESA's primary contribution to the International Living With a Star (ILWS) initiative. In its original concept the mission always had important synergies with NASA's Solar Sentinels Mission.

This fact has now been explicitly recognized by both agencies and (also to overcome budgetary constraints in both missions) ESA and NASA have recently agreed on a common programme called Heliospheric Explorers (HELEX), comprising Solar Orbiter and the Solar Sentinels into one synergistic two-mission concept. Elements of this common programme are the provision of a launch and parts of the payload for Solar Orbiter by NASA, and the provision of remote sensing capabilities from Solar Orbiter to the Sentinels in-situ observation during the simultaneous part of the two missions. While ESA prefers to maintain a launch date in mid-2015 for scientific and programmatic reasons, the Solar Sentinels are planned to be launched by NASA in 2017, thereby coinciding with Solar Orbiter during parts of both the ecliptic and out-of-ecliptic phases of the mission.

A common European-US "Joint Science and Technology Definition Team" (JSTDT) has assessed the synergistic opportunities arising from this common ESA/NASA programme, and has recommended an optimized core payload for both missions. The payload review committees for both missions in both agencies will use the JSTDT report as a top level document, together with the original S(T)DT reports.

2.6 *Payload Consortium Confirmation Process*

ESA will issue an Announcement of Opportunity (AO) to the Scientific Community for the Solar Orbiter payload that will be based on the optimised reference payload (Table 1, Annex). The AO will call for provision of instruments from individual scientists or science consortia willing to participate.

The proposals for the instruments shall be compatible foremost with the scientific and operational objectives of the Solar Orbiter mission and also with its design and operational capabilities as defined in the Experiment Interface Document (EID-A). Each proposal for an instrument must identify a single Principal Investigator (PI) heading the instrument consortium and carrying final responsibility for all aspects of the provision of the instrument. It follows that the PI must be fully backed by the national funding agency of her/his country, henceforth called “Lead Funding Agency” for the instrument. In some countries, various organisations or institutions may provide resources. In this case the Lead Funding Agency will be the organisation providing representation to the ESA Science Programme Committee or, for non-ESA member states, be represented by a national space agency. The Lead Funding Agency is expected to provide the majority element of the funding for the respective instrument and have prime science and industrial responsibility through the PI and Instrument Manager.

It must be stressed that an instrument proposal submitted by a PI will only be selected if accompanied by a Letter Of Endorsement (LOE) providing for financial support for the Definition Phase, accompanied by a time-line showing milestones leading to full commitment, from the relevant national funding agency, representing all institutes participating in the proposal. Responses will clearly need to spell out the character and level of participation together with the nature of the management structure and financial commitments within each instrument consortium. This LOE will constitute a preliminary agreement between ESA and the Lead Funding Agency until formalization of the Multi-lateral Agreement (MLA) between all participating agencies (or Memorandum of Understanding (MOU) in the case of non-ESA member states) at completion of the Definition Phase.

The ESA AO is open to European and non-European scientists, and to other scientific communities with which reciprocity or specific agreements exist.

It is anticipated that an Announcement of Opportunity for participation of a number of Guest Investigators will be issued after launch.

2.7 *Modes of Participation*

The possible modes of participation to the Solar Orbiter programme are:

- (1) Principal Investigator (PI), heading an instrument consortium providing an instrument (see section 3.2.1);
- (2) Co-Principal Investigator (Co-PI) may be appointed if a major development is carried out in a country/institution different from the one of the PI; A Co-PI will have similar rights as a PI, but the PI will remain the formal interface to the Project Office (see section 3.2.2);
- (3) Co-Investigator (Co-I), a member of an instrument consortium providing an instrument (see section 3.2.3);
- (4) Guest Investigator (GI), by participating in the data collection and analysis of one or more instruments (see sections 3.2.4).
- (5) Interdisciplinary Scientist (IDS), an expert in specific overarching science themes connected with solar and heliospheric physics (see sections 3.2.5).

2.7.1 Principal Investigator

The PI (where applicable, in coordination with the Lead Funding Agency) will have the following responsibilities:

(1) Management

- (i) Establish an efficient and effective managerial scheme, which will be used for all aspects and through all phases of her/his instrument programme.
- (ii) Organise the efforts, assign tasks and guide other members of the instrument consortium.
- (iii) Ensure that plans are established, implemented and analysed such that the status reporting complies with the requirements of the ESA Project Office.
- (iv) Provide the sole formal managerial and technical interface of the instrument to the industrial prime via the ESA Project Office.
- (v) Support ESA management requirements (e.g. investigation progress reviews, programme reviews, change procedures, product assurance, etc.) outlined in the Experiment Interface Document (EID).
- (vi) Where applicable, be responsible for ensuring compliance with all ITAR regulations in a timely manner. Surveillance requirements arising from ITAR regulations shall be reported to ESA and any costs associated with such requirements shall be borne by the PI.

(2) Science

- (i) Monitor the compliance of the instrument design to the scientific requirements outlined in the Sci-RD.
- (ii) Attend meetings of the Science Working Team and Groups, as appropriate; report on instrument development, and take a full and active part in their work.
- (iii) Provide the formal scientific interface of the instrument consortium with the ESA Project Office.
- (iv) Ensure adequate calibration of all parts of the instrument, both on the ground and in space. This includes the provision of all required calibration data and software to the ESA SOC along with a full instrument technical and science user manual for use by the general science user community.
- (v) Participate in the definition of the science operations and data handling, and support the Science Operation Centre (where applicable in coordination with the ESA Liaison Scientist(s)).
- (vi) Exploit the scientific results of the mission and assure their diffusion as widely as possible.
- (vii) Provide the scientific data (raw data, calibrated data, and higher level data), including relevant calibration software and/or products, to the Solar Orbiter archive (in a format that will be agreed with the ESA SOC for application by the general science community) upon delivery to, and verification by, the PI team.

(3) Hardware

- (i) Define the functional requirements of the instrument and auxiliary test equipment (e.g. MGSE, EGSE, CGSE, etc.)
- (ii) Ensure the development, construction, testing and delivery of the instrument. This shall be performed in accordance with the technical and programmatic requirements outlined in the AO including its annexes such as the EID-A, and subsequently reflected in the PI response, EID-B.
- (iii) Ensure that the instrument is to a standard that is appropriate to the objectives and lifetime of the mission, and to the environmental and interface constraints under which it must operate.
- (iv) Deliver adequate verification models (EQM's, STM's, etc.) of the instrument to the prime contractor, as required to verify system interfaces. The envelope of this delivery is ruled by the EID-A, in accordance with technical programme needs.
- (v) Deliver a Flight Model and Flight Spare kit in accordance with the technical requirements defined in the EID-A, together with the relevant Ground Support Equipment.
- (vi) Support the system level integration and test activities related to and involving the instrument.

- (vii) The PIs shall provide the necessary equipment to process their data as agreed with ESA and specified in the EID-A.
- (viii) Ensure that all procured hardware is compliant with ESA requirements, through participation in technical working groups and control (e.g. cleanliness) boards, as requested, and that the hardware allows system level performance compatibility to be maintained.
- (ix) Provide the overall documentation during the project, as defined in the EID-A.

(4) Software

- (i) Ensure the development, testing and documenting of all software necessary for the control, monitoring and testing of the instrument, in accordance with the rules and guidelines established in the EID-A.
- (ii) Specify and then support the development, testing and documenting of all software necessary for the testing, operation and data reduction/analysis of any parts of the instrument provided under ESA responsibility, in accordance with the rules and guidelines established in the EID-A.
- (iii) Ensure the delivery to ESA of any instrument-specific software that is required for testing or operations and its documentation to ESA, or elsewhere, in accordance with approved ESA guidelines, procedures and schedules. This includes the provision of software required in the ESA SOC as agreed in the Science Operations Requirements Document.
- (iv) Maintain and update all PI provided instrument software and its documentation until the end of the mission, at which point it is to be delivered to the SOC as part of the final archive.

(5) Product Assurance

Provide product assurance functions in compliance with EID-A requirements.

(6) Operations

Provide support for preparation and implementation of the mission and science operation up to the end of the mission including delivery of a user manual and data base inputs in accordance to the EID-A requirements.

(7) Financial

The financial status of the PI teams will have to be guaranteed by the Lead Funding Agency. The Lead Funding Agency will be considered responsible vis-à-vis ESA for all what concerns financial matters related to the selected investigations. Co-I teams are required via their national funding agencies to seek agreement with the Lead Funding Agency, which retains full responsibility for the instrument development and is the sole contact with ESA with respect to the required Letter Of Endorsement (LOE).

(8) Communications and Public Relations

Support science communications and public relations activities of ESA (and where applicable, the Lead Funding Agency), and provide suitable information and data in a timely manner, as outlined in the Science Communication Plan (see section 5.5.2).

2.7.2 Co-Principal Investigators

Although not a preferred arrangement, in some exceptional circumstances, a Co-PI may be appointed. The single point interface to the Project Office will remain the PI.

Co-PIs are responsible for their own funding which is guaranteed via their national funding agencies and must be underwritten by formal interagency agreements with the Lead Funding Agency, representing the PI and which holds overall fiscal responsibility with respect to instrument development and delivery to ESA.

2.7.3 Co-Investigators

Members of each PI-led consortium may be proposed as Co-Investigators. Each Co-I should have a well-defined role either with regard to hardware/software delivery or with regard to scientific support of the investigations within the instrument consortium. The PI-led consortium may review the status of its members regularly and implement changes if required. The Lead Funding Agency will however not change during the development of a given instrument.

Co-Is are responsible for their own funding which is guaranteed via their national funding agencies and must be underwritten by formal interagency agreements with the Lead Funding Agency, representing the PI and which holds overall fiscal responsibility with respect to instrument development and delivery to ESA.

2.7.4 Guest Investigators

Guest Investigators (GIs) are individual scientists who wish to make use of the data collected by one or more instruments. Their proposals shall be submitted to ESA. Their tasks shall be agreed with the PIs, with concurrence of the ESA Project Scientist.

Guest Investigators will be selected after launch and will be expected to participate in the activities of the Science Working Team, including science communications.

2.7.5 Interdisciplinary Scientists

To ensure a top-level oversight of mission science, a number of Interdisciplinary Scientists (IDS) will be selected through an open AO process. These IDSs should not reflect instrument specific domains, but rather cover specific science themes. IDSs will take part in the analysis of data from different onboard instruments, and have the same data rights as members of PI-led instrument consortia. Proposals submitted by IDSs must describe clearly their scientific case, the relevance of their contribution to the mission and the instrument data sets needed to carry out their research programme. Financial endorsement by the national funding agencies, should they require funds for their activity, is also required. The IDSs, like the PIs, are expected to provide adequate support to the communications activities of ESA.

The Agency may release additional AOs at a later stage for specific mission phases.

3 SELECTION PROCESS

The approach to be adopted for the selection, funding and development of the Solar Orbiter payload aims at taking into account the limited funds available for the payload procurement, and the need to preserve an efficient procurement of a highly optimised payload to ensure maximised science return from the mission with minimum resources. It is also essential that the payload will not eventually drive the cost at completion of the mission that is currently based on the reference payload (Table 1, Annex). This requires that the payload must be solidly defined technically, financially and programmatically, in order to fit smoothly into the overall mission development schedule, and strictly within the available spacecraft resources, with minimum risk to ESA and the various instrument funding agencies.

Through the iteration of the arrangements for the payload procurement, there clearly needs to be a guardian of the payload's scientific capability. A Payload Review Committee (PRC) of independent experts will perform this essential role. The terms of reference of the PRC are defined in section 3.1.1.

ESA will issue an AO calling for the provision of the instruments from institutes and funding agencies willing to participate. This AO will call for the identification of both a Principal Investigator (PI) and Lead Funding Agency for each instrument. AO responses should come from the PIs themselves and shall include a Letter Of Endorsement (LOE) from their Lead Funding Agency as referred to in section 2.6. The intention is that the response to the AO will not only establish the technical character and design maturity of the instrument, but also the level of involvement, together with the nature of the management structure and financial commitment. This LOE will constitute a preliminary agreement between ESA and the Lead Funding Agency until formalization of the Multi-lateral Agreement (MLA) or Memorandum of Understanding (MOU) in the case of non-ESA member states.

The PRC will be asked to review and confirm the scientific acceptability of each instrument proposal. The assessment of the PRC is particularly important in the cases where a proposal does not fully cover the scientific requirements or departs significantly from the reference payload. If competing instrument proposals are submitted by different PI-teams and Lead Funding Agencies, the PRC will be asked to make a recommendation on which proposal should be selected. In parallel with the work of the PRC, ESA shall undertake an internal technical, financial and management review of each proposal to establish the overall proposal integrity. The deliberations of both the PRC and ESA internal review will be submitted to the ESA Advisory Structure (SSWG, SSAC and SPC) for approval.

The aim of the Payload Review Process is to provide all parties with a minimum risk strategy, while safeguarding the scientific integrity and oversight of the mission within an agreed mission envelope. ESA will prepare all data packages with the documentation relevant for the PRC.

The technical requirements (including EID part A) will be available together with the formal issue of the AO, to ensure the timely specification of clear technical interfaces. It is essential that a solid cost and programmatic analysis can be completed between ESA, instrument consortia and Funding Agencies in their response to the AO, which will permit in a timely manner the relevant parties to focus on the provision of instruments.

The involvement of the funding agencies themselves in the consortia organisation and definition of the undertakings is mandatory and should lead to an in-depth analysis of the managerial and financial arrangements as well as risk aspects before submission to ESA. It should be understood that ESA will not propose to commence the implementation phase without the agreement by the SPC of the character, structure and funding commitment of the instrument consortia. The timetable of events leading to this approval is envisaged as follows:

- ◆ October 2007: Issue of the ESA AO.
- ◆ January 2008: Receipt of PI-led proposals with Lead Funding Agency Letters Of Endorsement in response to the AO.
- ◆ February –October 2008: Selection of instrument consortia.
- ◆ Autumn 2009: Payload confirmation and MLA signature.

3.1 *Instrument Selection*

3.1.1 Payload Review Committee

To ensure that the scientific return of Solar Orbiter is of the highest quality, an independent international Payload Review Committee (PRC) shall assess the mission in close cooperation with internal ESA technical, financial and management teams. The Executive shall appoint the Payload Review Committee members, after consultation with and agreement of the SSWG and SSAC.

The terms of reference of the Payload Review Committee are as follows:

The PRC shall perform, after receipt of all instrument proposals in response to the AO, a review in close cooperation with ESA technical, programmatic and financial analysis teams, supported by the potential prime contractors, in order to:

- ◆ Ensure that all science objectives are satisfied within the overall AO response.
- ◆ Ensure that each instrument proposal satisfies the science requirements in terms of sensitivity and performance, as specified in the relevant documents, to achieve the specific science objectives.
- ◆ Ensure compatibility of each instrument against the optimised reference payload.
- ◆ Identify clear alternatives in case of too high a development risk and/or incompatibility with available spacecraft resources or interfaces.

The Payload Review Committee will work in close collaboration with internal ESA review teams consisting of selected personnel of the Agency and its contractors as well as invited specialists. For each instrument proposal, in financial and programmatic areas, ESA will consult extensively with funding agencies and provide, via the appropriate internal review team, the Payload Review Committee with input on the implementation feasibility and risk assessment.

The “No Conflict of Interest” rule will apply, i.e. no potential PI for any instrument can be a member of the PRC, nor be involved in the selection procedure. Proposing Co-Is may be accepted as PRC members, if strictly necessary. They will have no voting right for their own investigation and other competing investigations.

3.1.2 Evaluation Criteria and Selection Principles

The individual instrument proposals will be evaluated by the PRC (in close collaboration with internal ESA technical, managerial and financial review teams) on the basis of the AO and using the following preliminary criteria:

- ◆ Relevance of the scientific objectives and their compatibility with the global objectives of the whole mission;
- ◆ Adequacy of the measurements to fulfil the stated objectives and capability of the instrument to perform the required measurements as indicated in the JSTDT report and the Sci-RD;
- ◆ Feasibility and heritage of the proposed technical solutions;
- ◆ Development status of the instrument;

- ◆ Availability of relevant technologies and the need for the development of new technologies. The development status of such “new” technologies should also be evaluated based on the AO response. All ITAR-related approval aspects shall be clearly identified and included in the planning.
- ◆ Compliance with the interfaces specified through the EID-A.
- ◆ Instrument development plan including test and validation programme.
- ◆ Compatibility of the instrument with the mission environment, spacecraft resources, accommodation and mission constraints;
- ◆ Operational complexity;
- ◆ Quality of data analysis plan;
- ◆ Management plan and its adequacy with the instrument complexity; this specifically includes the complexity of the management interfaces within a consortium.
- ◆ Continuity of human and institutional resources to ensure a timely execution of instrument development, calibration and associated tasks, and to support post launch operation and data analysis. The manpower funding profiles, at the science institute level within each consortium, backed by the appropriate funding agency and confirmed through the Lead Funding Agency should be analysed for all mission phases including science exploitation and archive.
- ◆ Competence and experience of the team in all relevant areas (science, technology, software development, management and outreach/science communications);
- ◆ Credibility of costing; This will be performed by ESA staff experienced in instrument cost analysis acting in close cooperation with the relevant funding agencies and coordinated with the Lead Funding Agency through which the proposal was submitted.
- ◆ Compliance with ESA applicable management, engineering, reporting and product assurance requirements and standards;
- ◆ Possible financial impact of the proposed instrument upon ESA;
- ◆ Commitment of all the national funding agencies to provide the correct level of support to member institutes within the consortium under the overall responsibility of the Lead Funding Agency which represents at a minimum the PI-institutes participation in the consortium.
- ◆ Commitment of the PIs funding agency to become the Lead Funding Agency and agree to the LOE.

The composition of the overall payload carried by Solar Orbiter will take into account the following criteria:

- ◆ Evaluation of individual instrument proposals (see above);
- ◆ Potential scientific achievement within the global mission objective;
- ◆ Compatibility with the reference payload.
- ◆ Compatibility with system resources, mission and programme constraints, and financial envelope imposed by national agencies.

The PRC in close cooperation with the ESA review teams will recommend a Solar Orbiter payload complement which must fulfil the science requirements for the mission and be fully compatible with the allocated spacecraft resources. The recommendation will be subject to endorsement by the Solar System Working Group (SSWG) and Space Science Advisory Committee (SSAC), and finally submitted to the Science Programme Committee (SPC) for approval.

3.2 *Selection of Guest Investigators*

The selection criteria for Guest Investigators (GIs) will be established later, at the discretion of the instrument teams, in consultation with the SWT (see 2.7.4 and 4.2). The formal appointment will be made by SPC upon recommendation by SSWG and SSAC.

3.3 *Selection of Interdisciplinary Scientists*

Interdisciplinary Scientists (IDS) will be selected through an open AO process (see 2.7.5). The proposals will be evaluated through an independent Peer Review. Each IDS will be selected on the basis of the scientific quality and value of the investigation proposed. The proposed research shall not require additional resources or any redesign of the payload. The selection will take place after the completion of the Solar Orbiter payload confirmation procedure. The formal appointment will be made by SPC upon recommendation by SSWG and SSAC.

4 SCIENCE AND ESA PROJECT MANAGEMENT

4.1 *The Project Scientist*

ESA nominates the Solar Orbiter Project Scientist (PS). The PS is located at ESTEC within ESA's Research and Scientific Support Department (SCI-S) and is the Agency's interface with the Principal Investigators for scientific matters. The PS will chair the Science Working Team (SWT) and coordinate its activities.

During all phases of the mission, i.e. implementation phase until the end of the exploitation phase, the Solar Orbiter Project Scientist will be responsible for all scientific issues within the Project. During the development phase, the PS will advise the ESA Project Manager (SCI-P) on technical matters affecting scientific performance. The PS will monitor the state of implementation and readiness of the instrument operations and data processing infrastructure. A small team will support the PS in the above-mentioned tasks. The Science Operations Department located at ESAC (SCI-O) and Science Operations Development Division located at ESTEC (SCI-SD) will provide support on science operations and archiving.

After the in-flight commissioning phase, a Mission Manager within SCI-O will take over the responsibility for the mission throughout the exploitation phase. The Mission Manager will have overall responsibility for the delivery of the scientific output of the mission as approved within assigned constraints. The PS will continue his/her activity as the main interface with the scientific community and the main scientific interface with the MOC and SOC. The PS will coordinate the creation of the scientific products, their archiving and distribution to the scientific community.

4.2 *Science Working Team*

The executive membership of the Solar Orbiter Science Working Team will consist of the Principal Investigators and the Project Scientist. Co-Investigators, Guest Investigators, Interdisciplinary Scientists and other interested scientists will be invited to participate in SWT meetings. The Solar Orbiter Project Scientist will chair the SWT.

The SWT will monitor and advise ESA on all aspects of the Solar Orbiter mission that will affect its scientific performance. It will assist the PS in maximizing the overall scientific return of the mission within the established boundary conditions. It will act as a focus for the interests of the scientific community in Solar Orbiter.

4.3 *The Project Office*

ESA will establish a Solar Orbiter Project Office at ESTEC, headed by a Project Manager, which will fulfil its function until the completion of the spacecraft initial commissioning phases. ESA, via the Project Manager and later by the Mission Manager, will retain overall responsibility for the mission through all phases.

The Project Office will be responsible for the mission design and implementation.

Within the executive mandate of the project and with regards to the Solar Orbiter Investigator teams, the Project Office will be responsible for:

- ◆ The procurement of Solar Orbiter (including the payload)
- ◆ The launch preparation and procurement.
- ◆ The commissioning of the system in the early transfer phase.

The ESA Project Manager will periodically call Project Reviews, which will include all aspects of the mission including the development status of the Solar Orbiter. In particular the Solar Orbiter Team will have to show compliance with schedule, resources, interfaces, safety and any other relevant aspect of the Solar Orbiter implementation.

Following completion of the in-flight commissioning, the Mission Manager will assume responsibility for management of the Solar Orbiter project: organisation and overall management of teams and staff assigned to the Solar Orbiter project, of the science operations team and the mission operations teams.

Specifically this will include the overall responsibility for:

- ◆ Insertion of the Solar Orbiter into its initial science orbit
- ◆ Checkout of Solar Orbiter prior to first perihelion passage
- ◆ Science operations
- ◆ Archiving of Solar Orbiter data products.

The Mission Manager will be supported by the Project Department with respect to spacecraft system engineering issues.

4.4 Monitoring of Instrument Development

The ESA Project Office will monitor the progress of the design, development and verification of all Solar Orbiter instruments. The instrument consortia will have to demonstrate to ESA (and where applicable, the Lead Funding Agency), in regular reports and during formal reviews, compliance with the scientific mission goals, the spacecraft system constraints, the spacecraft interfaces and the programme schedule as defined in the mutually agreed Experiment Interface Document (EID).

5 SCIENCE OPERATIONS AND DATA

5.1 *Solar Orbiter Operations Concept*

ESA will be responsible for the launch and operations/checkout of the spacecraft.

ESA will establish the Solar Orbiter Mission Operations Centre (MOC), located at the European Space Operations Centre (ESOC). ESA will also establish a Science Operation Centre (SOC), located at the European Space Astronomy Centre (ESAC).

5.2 *Mission Operations Centre*

The Solar Orbiter Mission Operations Centre (MOC) will be responsible for the operation and control of the spacecraft.

The Solar Orbiter Project Office will define, in agreement with the MOC, the requirements and responsibilities for mission operations, on the basis of a Mission Implementation Requirement Document (MIRD) and a Mission Implementation Plan (MIP).

The MOC will, in particular, be responsible for the following tasks, relevant to science operations:

- ◆ Overall mission planning
- ◆ Supplying, in a timely manner, the Principal Investigators with raw data from their instrument, and spacecraft housekeeping and auxiliary data in an agreed format;
- ◆ Providing the SOC with a subset of payload data and spacecraft housekeeping and auxiliary data in an agreed format;
- ◆ Providing an agreed subset of key scientific parameters for space weather monitoring purposes (so-called “beacon data”) in near-real time (when spacecraft operations allow);
- ◆ Performing anomaly (out of limit) checks on a set of payload parameters;
- ◆ Notifying payload anomalies to the SOC/Pis.

5.3 *Science Operations Centre*

Science operations will be conducted in close coordination between ESA and the PI teams.

Key science operations responsibilities and functions include:

- ◆ Optimisation of the science return from the Solar Orbiter mission by defining and implementing an efficient and cost-effective science ground system and operational scheme for all mission phases;
- ◆ Preparation of the long-term and short-term payload operations plan based on input from the SWT chaired by the PS, to be implemented by the Mission Operations Centre;
- ◆ Preparation of guidelines supported by the PI teams, to create the Solar Orbiter science data archive.

The specific responsibilities of the Science Operations Centre are:

- ◆ Definition and implementation of efficient and cost-effective science operations planning, data handling and archiving concepts;
- ◆ Act as the sole interface seen from the MOC perspective on any matter related to routine instrument operations and mission planning;

- ◆ Provision of Liaison Scientists where applicable;
- ◆ Support of instrument operations during commissioning, nominal and extended mission phases ;
- ◆ Coordination of the science planning;
- ◆ Coordination of science-related inputs and updates for the Flight Operations Plan (FOP);
- ◆ Consolidation of the instrument operation timelines before their submission to the MOC;
- ◆ Analysis of critical science data required for science operations purposes related to spacecraft navigation and orbit insertion;
- ◆ Preparation with the Solar Orbiter investigators of summaries of scientific results at regular intervals and for mission highlights;
- ◆ Preparation of guidelines for science data archiving and creation of the Solar Orbiter scientific data archive;
- ◆ Support to Public Relations activities;
- ◆ Ensure the Knowledge Management over the long mission duration;
- ◆ Provide software support to the PI teams for payload operations;
- ◆ Support the MOC in the preparation of the payload operations before the end of the commissioning phase;
- ◆ Follow up the development of the experiments and participate in tests;
- ◆ Archiving of non-scientific data needed for instrument calibration, e.g. from check-outs during cruise phase;
- ◆ Distribute pre-processed instrument data and supporting information

The specific responsibilities of the PIs are:

- ◆ Support the definition of the science operations;
- ◆ Provision of inputs for the definition and implementation of the science operations planning, and data handling and archiving concepts;
- ◆ Support the preparation of the instrument operation timelines;
- ◆ Provide expert support at the MOC and/or SOC during payload commissioning and critical operations
- ◆ Support of the definition and implementation of the Solar Orbiter scientific data archive, as part of the pre-launch tasks;
- ◆ Provision of support required by the Science Operations Centre and other PIs for science planning purposes, as mutually agreed within the SWT;
- ◆ Monitoring and optimisation of instrument performance;
- ◆ Deliver raw, calibrated, and high level data, including relevant calibration products and/or software, to the Solar Orbiter scientific archive (see also 5.4);
- ◆ Provision to ESA with unlimited access to all processed and analysed data for public relation purposes;
- ◆ Provision of summaries of the main scientific results at regular intervals.

The science operations will be defined by the Solar Orbiter Project Scientist and the SWT. This process will include the production of a Science Implementation Requirements Document (SIRD) and Science Implementation Plan (SIP).

The SOC will be implemented in a cost-effective manner making use of facilities like Internet, electronic communications, video conferencing etc., and its functionality may be augmented by national data centres that act as local sites and, where appropriate, provide specialised data processing and other user services. In order to fulfil their responsibilities with respect to science operations during all phases of the mission (both pre- and post-launch), PIs will require adequate support from their funding agencies. Such support must be clearly specified in the response to the AO and agreed by all funding agencies.

5.4 *Data Rights*

Solar Orbiter data will be made available according to the following procedure. Reduction of science data is under the responsibility of PI teams. Following in-orbit commissioning, the PI teams retain exclusive data rights for the purpose of calibration and verification for a period of 3 months after the receipt of the original science telemetry and auxiliary orbit, attitude and spacecraft status information. Upon delivery of data to the ESA SOC it will be made available to the scientific community at large through the ESA science data archive. It must be stressed that PI teams must clearly indicate in their proposal the level of resources allocated to the task of ensuring science data enters the ESA science archive in a timely manner. These resources must be agreed by the funding agencies involved.

The PI teams will also be required to share data with the GIs and IDSs so as to enhance the scientific return from the mission, in accordance with procedures to be agreed and formalised within the SWT.

The PI teams will provide records of processed data with all relevant information on calibration and instrument properties to the ESA science data archive. The format for the spacecraft data shall be compatible with those defined for the ESA science data archive. The ESA science data archive will be the repository of all mission products. The ESA science data archive will be compatible with NASA's National Space Science Data Center.

Scientific results from the missions will be published, in a timely manner, in appropriate scientific and technical journals. Proper acknowledgement of the services supplied by ESA (and where applicable, the Lead Funding Agency) will be made.

The PI teams will provide ESA (and where applicable, the Lead Funding Agency) with processed and useable data for Science Communication purposes as soon as possible after their receipt.

5.5 *Communication and Public Outreach*

5.5.1 *Public Outreach*

The Solar Orbiter mission is expected to attract much public interest. Hence, the mission will be given proper importance and exposure within the framework of the communication activities of the Science Programme. Each Solar Orbiter Investigator must provide material and information for Public Relations to ESA (and where applicable, to the Lead Funding Agency).

During the development phase of the mission, ESA will set up web pages on the Solar Orbiter mission as an information tool for the general public and the media. With the progress of the mission the web pages will be enriched with more material and features related to the mission.

The active cooperation of all scientists involved in the Solar Orbiter mission in providing relevant information and results to ESA (and where applicable, to the Lead Funding Agency) is expected for the success of the related communication activities.

5.5.2 Science Communication

The Solar Orbiter Mission will be included in the overall ESA Communications Plan and a detailed Solar Orbiter Communication Plan will be drafted in due time with inputs from the Project Scientist.

The Project Scientist will initiate and publish project related progress reports and reviews of scientific results from the mission. Scientific articles suitable for public release will be provided by the members of the SWT, upon their own initiative or upon request from the Project Scientist, at any time during the development, operational and post-operational phases of the mission.

ACRONYMS

3-D	3-Dimensional
AO	Announcement of Opportunity
Co-I	Co-Investigator
Co-PI	Co-Principal Investigator
CGSE	Calibration Ground Support Equipment
COR	Coronagraph
CSG	Centre Spatial Guyanais
DPD	Dust Particle Detector
D/SCI	Director of the Scientific Programme
EGSE	Electrical Ground Support Equipment
EID	Experiment Interface Document
EID-A	EID-Part A
EID-B	EID-Part B
EM	Engineering Model
EPD	Energetic Particle Detector
ESAC	European Space Astronomy Centre
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
EUI	EUV Imager
EUS	EUV Spectrometer
FM	Flight Model
FOP	Flight Operations Plan
GAM	Gravity Assist Manoeuvre
GI	Guest Investigator
GSE	Ground Support Equipment
HI/WFC	Heliospheric Imager/Wide Field Coronagraph
IDS	Interdisciplinary Scientist
JSTDT	Joint Science and Technology Definition Team
LOE	Letter Of Endorsement by Lead Funding Agency
MAG	Magnetometer
MGSE	Mechanical Ground Support Equipment
MIP	Mission Implementation Plan
MIRD	Mission Implementation Requirements Plan
MLA	Multi-lateral Agreement
MOU	Memorandum of Understanding
PI	Principal Investigator
P/L	Payload
PDD	Payload Definition Document
PRC	Payload Review Committee
PS	Project Scientist
RPW	Radio and Plasma Wave Analyser
RSSD	Research and Scientific Support Department of ESA
S/C	Spacecraft
Sci-RD	Science Requirements Document
SIP	Science Implementation Plan
SIRD	Science Implementation Requirements Document
SMP	Science Management Plan
SOC	Science Operation Centre
SPC	Science Programme Committee
SSAC	Space Science Advisory Committee
SSWG	Solar System Working Group
STIX	Spectrometer Telescope Imaging X-rays

SWA	Solar Wind Analyser
SWT	Science Working Team
VIM	Visible Imager and Magnetograph
WWW	World Wide Web

ANNEX**Table 1: Solar Orbiter Reference payload**

<i>Instrument</i>	ACRONYM	<i>Science goals</i>
Solar Wind Plasma Analyzer	SWA	Investigation of kinetic properties and composition (mass and charge states) of solar wind plasma
Radio and Plasma Wave Analyzer	RPW	Investigation of radio and plasma waves including coronal and interplanetary emissions
Magnetometer	MAG	Investigation of the solar wind magnetic field
Energetic Particle Detector	EPD	Investigation of the origin, acceleration and propagation of solar energetic particles
Dust Particle Detector	DPD	Investigation of the flux, mass and major elemental composition of near-Sun dust
Visible Imager & Magnetograph	VIM	Investigation of the magnetic and velocity fields in the photosphere
EUV Spectrometer	EUS	Investigation of properties of the solar atmosphere
EUV Imager	EUI	Investigation of the solar atmosphere using high-resolution and full-Sun imaging in the EUV
Coronagraph	COR	Investigation of coronal structures using polarized brightness measurements
Spectrometer Telescope Imaging X-rays	STIX	Investigation of energetic electrons near the Sun, and solar x-ray emission
Heliospheric Imager/Wide Field Coronagraph	HI/WFC	Investigation of outer coronal and inner heliospheric structures using white-light imaging

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EUROPEAN SPACE AGENCY

SOLAR SYSTEM WORKING GROUP

Recommendation on the Science Management Plan of Solar Orbiter

At its 125th meeting held on 11-12 October 2007 at ESA Headquarters, Paris, the Solar System Working Group (SSWG) received a presentation on the Science Management Plan (SMP) on the Solar Orbiter mission. The SSWG endorses the SMP subject to the adoption of minor changes.

In addition, the SSWG supported the principle of an open Announcement of Opportunity for the payload and its composition. The SSWG also supports the removal of any proprietary period for data delivered by the selected payload. The SSWG recommends that selected Principal Investigators are allocated adequate funding to support this approach.