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DOCUMENT

Solar Orbiter Science Implementation Requirements Document (SIRD)

Solar Orbiter SIRD

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INTRODUCTION

1.2 Scope of the Document

The Science Implementation Requirements Document (SIRD) is the highest-level document after the Science Management Plan (SMP, [AD01]) defining the requirements for the scientific operations of the Solar Orbiter mission and the requirements for establishing the Solar Orbiter data archive. Scientific operations of the Solar Orbiter payload and establishing the Solar Orbiter archive, based on inputs from the Instrument Teams and authorised by the Project Scientists[1], will be the responsibility of the Solar Orbiter Science Operations Center (SOC). The SOC comprises the ESA elements of the Solar Orbiter Science Ground Segment (SGS), which in addition includes the PI teams and potentially other parties taking part in the science operations of the mission. The SIRD also defines the related responsibilities and tasks of the various participants in the Solar Orbiter project of ESA's science programme.

The SIRD encompasses all tasks required for the preparation of the necessary Solar Orbiter science operations and archiving facilities during the definition and implementation phase. During the post-launch phases, the SIRD encompasses all tasks required to carry out the scientific operations in the optimal way compatible with the available resources. For all phases, the detailed activities required to support the scientific operations, data handling and archiving will be covered in the relevant operations and archiving-related documents which will be subordinate to the SIRD. For the post-operations and archiving phase the SIRD encompasses all tasks required to maintain the long-term Solar Orbiter archive, which will be the ultimate legacy of the Solar Orbiter mission.

Any modification to the SIRD requires formal approval of the Solar Orbiter Project Manager (Mission Manager for post-launch phases) and the ESA Project Scientist, as well as to be agreed by the Operational Ground Segment (OGS) and SGS Managers. The SOC's response to the SIRD will be presented in the Science Implementation Plan (SIP), authored by the Solar Orbiter SGS Development Manager, supported by all entities responsible for the implementation, namely the overall Solar Orbiter SGS and the ESA and NASA Project Scientists. They shall clearly identify the tasks and resources required to fulfil the SIRD requirements.

The document tree in Figure 1.1 illustrates the relation of the various relevant documents. In particular, the SMP, Science Requirements Document (SciRD, [AD02]) and Experiment Interface Documents (EID-As [AD03] and EID-Bs [AD04]) are applicable documents to the SIRD.

[1] For this joint ESA/NASA mission, the ESA Project Scientist is formally responsible for all science-related matters under ESA purview, and the NASA Project Scientist is formally responsible for all science-related matters under NASA purview. In this document, which describes the requirements for the ESA elements of the Solar Orbiter Science Ground Segment, the term "Project Scientists" (plural) is used for items of joint responsibility, e.g. chairing of the Science Working Team (SWT), while the singular refers to the ESA Project Scientist.

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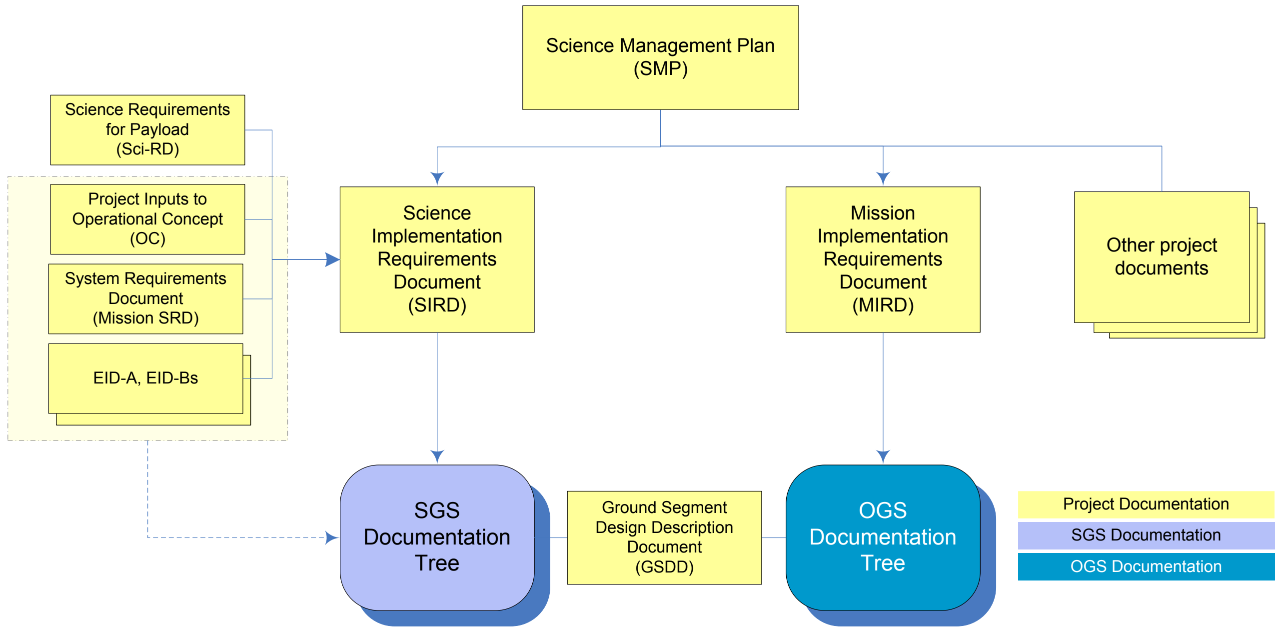

Figure 1.1 Illustration of the documentation tree (from [RD08]).

1.3 Applicable / Reference Documents

1.3.1 Applicable Documents

[AD01] Solar Orbiter Science Management Plan, SMP (ESA/SPC(2012)2)
[AD02] Solar Orbiter Science Requirements Document, SciRD (SOL-EST-RS-1858)
[AD03] Solar Orbiter EID Part A (SOL-EST-RCD-0050, Issue 3)
[AD04] Solar Orbiter EID Part B for Instruments (latest agreed versions)
[AD05] Solar Orbiter Instrument User Manuals (TBW)

1.3.2 Reference Documents

[RD01] Mission Implementation Plan, MIP (SOL-ESC-PL-00001, Issue 1)
[RD02] Mission Implementation Requirements Document, MIRD (SOL-EST-RS-02909, Issue 1)
[RD03] Technical Note: Solar Orbiter Pointing Strategy during Remote-Sensing Windows: Science Requirements (SOL-EST-TN-4020)
[RD04] Representations of World Coordinates in FITS (Greisen & Calabretta, *Astron. Astrophys. 395, 1061*, 2002)
[RD05] Representations of Celestial Coordinates in FITS (Calabretta & Greisen, *Astron. Astrophys. 395, 1077*, 2002)
[RD06] Coordinate Systems for Solar Image Data (Thompson, *Astron. Astrophys. 449, 791*, 2006)
[RD07] Consolidated Report on Mission Analysis, CReMA (SOL-ESC-RP-05500, Issue 3, Revision 1)
[RD08] Generic Science Ground Segment Documentation Tree (SRE-OD-TN-0001, Draft)
[RD09] Roles of the Project/Study Scientists (D/SRE-XXXX, Draft, 8 Dec 2012)

[RD10] Solar Orbiter Mission Planning Workshop, Minutes of Meeting (SOL-ESC-MN-10002, 25 Jan 2013)
[RD11] Solar Orbiter Science Operations Implementation Agreement (SOIA, SOL-ESC-IA-05002, Draft, 12 Feb 2013)

2 MISSION OVERVIEW

Solar Orbiter's mission is to address the central question of heliophysics: ***How does the Sun create and control the heliosphere?*** This, in turn, is a fundamental part of the second science question of ESA's Cosmic Vision programme: ***"How does the solar system work?"*** Solar Orbiter is specifically designed to identify the origins and causes of the solar wind, the heliospheric magnetic field, solar energetic particles, transient interplanetary disturbances, and the Sun's magnetic field itself.
Over the past two decades, an international effort to understand the Sun and heliosphere has been undertaken with an array of spacecraft carrying out both remote observations at visible, UV, and X-ray wavelengths, as well as in-situ observations of interplanetary plasmas, particles, and fields. Combined and coordinated observations from missions such as Ulysses, Yohkoh, SOHO, TRACE, RHESSI, Hinode and STEREO have resulted in an enormous advance in our understanding of the Sun and heliosphere, and have proven that critical progress in understanding the physics requires both remote and in-situ observations working together.
Solar Orbiter's scientific mission can be broken down into four top-level science objectives:

- What drives the solar wind and where does the coronal magnetic field originate from?
- How do solar transients drive heliospheric variability?
- How do solar eruptions produce energetic particle radiation that fills the heliosphere?
- How does the solar dynamo work and drive connections between the Sun and the heliosphere?

Common to all of these questions is the requirement that Solar Orbiter makes in-situ measurements of the solar wind plasma, fields, waves, and energetic particles close enough to the Sun that they are still relatively pristine and have not had their properties modified by dynamical evolution during their propagation. Solar Orbiter must also relate these in-situ measurements back to their source regions and structures on the Sun through simultaneous, high-resolution imaging and spectroscopic observations both in and out of the ecliptic plane.

The near-Sun phase of the mission will enable the spacecraft to approach the Sun as close as 0.28 AU during part of its orbit. The angular speed of a spacecraft at this distance approaches the rotation rate of the Sun, so that the remote sensing instruments will be able to track a given point on the Sun surface for many days. During the out of ecliptic phase of the mission, the spacecraft will reach higher solar latitudes (up to 34° close to the end of the mission), making possible detailed studies of the Sun's polar caps thanks to the remote sensing instruments.

The Solar Orbiter Science Requirements Document [AD02] provides a more detailed discussion of the top scientific goals of the Solar Orbiter mission, their translation into specific scientific questions and derived basic scientific requirements. The document addresses also the scientific synergies between Solar Orbiter and the NASA's Solar Probe Plus mission.

2.1.1 Solar Orbiter Spacecraft

The Solar Orbiter spacecraft comprises a 3-axis stabilised platform that is Sun-pointed during all mission phases after LEOP and a heat shield that provides the platform and sensitive equipment with protection from the extremely high levels of solar flux. The heat shield also contains cut-outs with feed-throughs (and doors), which provide the remote-sensing instruments with their required fields-of-view to the Sun. The spacecraft structure includes internal shear panels providing mounting locations for the remote-sensing instruments and bus units. External mounting locations are provided on face panels, as well as on a dedicated instrument boom, for the in-situ payload elements. Solar arrays provide the capability to produce the required power throughout the mission over the wide range of Sun distances experienced, using rotation about their longitudinal axis to control the solar aspect angle in order to manage the array temperature throughout the mission and in particular during close approach to the Sun.

The launcher interface ring is located on the opposite face of the structure to the heat shield, such that the heat shield is uppermost when the spacecraft is mated to the launch vehicle. No main engine is included as the overall delta-V requirements of the mission are comparatively modest. Rear-panel thrusters are complemented by additional thrusters on side panels in order to provide the capability to perform delta V manoeuvres whilst maintaining a Sun-pointing attitude when close to the Sun, a critical capability for Solar Orbiter.

An articulated high-temperature high-gain antenna provides nominal communication with the ground station, and a medium-gain Antenna and low-gain antennas are included for use as backup and during the Launch and Early Orbit Phase (LEOP).

2.1.2 The Solar Orbiter Payload

The Solar Orbiter payload consists of the following 10 instruments:

2.1.2.1 The In-Situ Instruments:

- The Solar Wind Analyser instrument suite (SWA, Principal Investigator (PI): C. J. Owen, UK) will fully characterize the major constituents of the solar wind plasma (protons, alpha particles, electrons, heavy ions) between 0.28 and 1.4 AU.
- The Energetic Particle Detector experiment (EPD, PI: J. R. Pacheco, Spain) will measure the properties of suprathermal ions and energetic particles in the energy range of a few keV/n to relativistic electrons and high-energy ions (100 MeV/n protons, 200 MeV/n heavy ions).
- The Magnetometer experiment (MAG, PI: T. S. Horbury, UK) will provide detailed in-situ measurements of the heliospheric magnetic field.
- The Radio and Plasma Waves experiment (RPW, PI: M. Maksimovic, France) will measure magnetic and electric fields at high time resolution and determine the characteristics of electromagnetic and electrostatic waves in the solar wind from almost DC to 20 MHz.

2.1.2.2 The Remote-Sensing Instruments:

- The Polarimetric and Helioseismic Imager (PHI, PI: S. K. Solanki, Germany) will provide high-resolution and full-disk measurements of the photospheric vector magnetic field and line-of-sight velocity as well as the continuum intensity in the visible wavelength range.

- The Extreme Ultraviolet Imager (EUI, PI: P. Rochus, Belgium) will provide image sequences of the solar atmospheric layers from the photosphere into the corona.
- The Spectral Imaging of the Coronal Environment EUV Spectrograph (SPICE, European-led instrument with contributions from ESA member states and ESA) will provide spectral imaging of both the solar disk and in the corona to remotely characterize plasma properties of regions at and near the Sun.
- The Spectrometer/Telescope for Imaging X-rays (STIX, PI: S. Krucker, Switzerland) provides imaging spectroscopy of solar thermal and non-thermal X-ray emission from ~4 to 150 keV.
- The Multi Element Telescope for Imaging and Spectroscopy Coronagraph (METIS, PI: E. Antonucci, Italy) will perform broad-band and polarized imaging of the visible K-corona and narrow-band imaging of the UV corona.
- The Solar Orbiter Heliospheric Imager (SoloHI, PI: R. A. Howard, USA) will image both the quasi-steady flow and transient disturbances in the solar wind over a wide field of view by observing visible sunlight scattered by solar wind electrons.

2.2 Ground Segment Facilities and Services

The Solar Orbiter ground segment will make maximum reuse of the ESA/ESOC infrastructure for Deep Space missions, and in particular those developed and used for the BepiColombo and Rosetta missions. The overall ground segment architecture reflects the standard architecture of a typical interplanetary scientific mission, the main components being:

- The Operational Ground Segment (OGS):
    - The Ground Stations, belonging to the ESA network.
    - The Mission Operations Centre (MOC), located in ESOC, Darmstadt, in charge of all mission operations planning, execution, monitoring and control. The Mission Operations Centre includes infrastructure and computer hardware as well as the flight control system compressing data processing and flight dynamics software.
- The Science Ground Segment (SGS):
    - Science Operations Centre (SOC), located in ESAC, Villafranca, in charge of scientific operations planning, Principal Investigators (PI) coordination, data archiving and scientific analysis support.
    - The PI teams.
    - Other parties taking part in the science operations of the mission, e.g. a TBD entity for the facility instrument SPICE that will assume equivalent responsibilities of the PI team of a PI-led instrument.
- The Communications Network, linking the various remotely located centres and stations to support the operational data traffic.

2.2.1 Ground Stations and Communications Network

The Solar Orbiter mission will nominally be supported by a single ESA ground station, except in critical mission phases, where multiple ground station support will be required. There will not be a dedicated ground station, but any of the three ESA deep-space terminals can be used (New Norcia in Australia, Cebreros in

Spain and Malargüe in Argentina), shared with other missions depending on the visibility pattern and availability profile. For the sake of simplicity, however, and considering the potential parallel operations with BepiColombo, it is expected that the Malargüe station will be mainly used for Solar Orbiter.

Where additional tracking support is required, e.g. for delta-Differential One-way Ranging (delta-DOR) tracking in critical phases, one of the other ESTRACK deep space antennas will be used in addition. No NASA-Deep Space Network (DSN) support is planned for nominal and contingency operations. Nevertheless, the spacecraft shall be compatible with the DSN for possible emergency operations
Malargüe will be used over the full visibility (ca. 10 hours/pass, daily passes) through the Near Earth Commissioning Phase (NECP, duration: 90 days [RD07]). During the cruise phase, passes from Malargüe will be taken 3 times per week to dump both science telemetry as well as spacecraft housekeeping data. Daily passes will be taken during the cruise phase's payload check-out windows (twice per year). During the nominal mission phase, i.e. after Venus/Earth GAM-2, the Malargüe station will be used for daily passes as described in [RD01].

All ESA stations will interface with the control centre in ESOC (Darmstadt) via the OPSNET communications network. OPSNET is a closed Wide Area Network for data (telecommand, telemetry, tracking data, station monitoring and control data) and voice.

2.2.2 Mission Operations Centre

The Solar Orbiter mission will be operated by ESOC, and it will be controlled from the Mission Operations Centre (MOC) which basically consists of the Main Control Room (MCR) augmented by the Flight Dynamics Room (FDR), Project Support Room (PSR) and other specific multi-mission support rooms during launch and LEOP. During NECP, cruise, and the science operations phase, mission control will be conducted from a Dedicated Control Area (DCA), which will be an adaptation of, or may be shared with, the existing ones of the other interplanetary missions like Rosetta, Mars Express, ExoMars or Bepi Colombo.

The MOC is equipped with workstations giving access to the computer systems used for different tasks of operational data processing. It will be staffed by dedicated Solar Orbiter spacecraft operations staff, and experts in spacecraft control, flight dynamics and network control who will be shared with other ESA missions.

The computer (hardware and software) configuration used in the Mission Operations Centre for the Solar Orbiter mission will be derived from the existing infrastructure, consisting of:

- A mission dedicated control system used for real time telemetry processing and for command preparation and execution, telemetry and command log, archiving, and also for non real-time mission evaluation;
- A mission planning system supporting command request handling and planning and scheduling of spacecraft and payload operations.
- Workstations hosting the flight dynamics system (ORATOS), which supports all activities related to attitude and orbit determination and prediction, preparation of slew and orbit manoeuvres, spacecraft dynamics evaluation and navigation in general;
- Workstations hosting the science telemetry data distribution and instrument command reception system (Data Disposition System, DDS). The data disposition system supports the acquisition and storage of raw scientific, housekeeping and auxiliary data to be accessible at remote locations.

- System simulator, providing a realistic software simulation of the ground station and spacecraft for pre-launch ground segment verification, staff training and procedure validation throughout the mission.

All computer systems in the MOC will be redundant with common access to data storage facilities and peripherals. All computing systems will be connected by a Local Area Network (LAN).

The external connections to the SOC and PI institutes will use commercial/public networks.

2.2.3 Science Operations Centre

The SOC is responsible for science operations planning. The instrument operations requests (IORs) generated by the individual PI teams will be collected at the SOC and merged into a single, conflict-free payload operations request (POR) to be submitted to the MOC on a periodic basis, as part of the mission planning process. The MOC will be in charge of including the requests in the overall mission operations timeline to be uplinked periodically to the spacecraft.

The SOC will process the auxiliary data received from the MOC and produce auxiliary data products that will be provided to the Instrument Teams in support of the science operations planning process as well as interpretation of instrument data. These auxiliary data products include orbit and attitude profiles (both as NAIF SPICE kernels, daily files), event predictions, time correlation details and other mission specific information (see detailed requirements in Section 4).

The SOC will also construct a mission data archive, which includes all data received from the MOC (e.g. spacecraft raw data and auxiliary data) as well as all data received from the Instrument Teams. NASA will mirror the science part of the Solar Orbiter archive.

The SOC will pre-process a reduced set of science telemetry (science telemetry downlinked with low latency) with the use of PI-provided quicklook software to convert data with specific telemetry Application Process IDs (APIDs) into usable data for SOC/SOWG planning purposes.

2.2.4 Principal Investigator Teams

The roles and responsibilities of the PI teams are defined in [AD01] and summarized in Sect. 3.5 of this document. As far as the science ground segment is concerned, these responsibilities include (cf. Sect. 2.7.1 of [AD01]):

- 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.
- Participate in the definition of the science operations and data handling, and support the Science Operation Centre.
- Provide the scientific data (raw data, calibrated data, and higher level data), including relevant calibration software and/or products, and associated documentation, 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.
- Provide quicklook software to convert data downlinked with low latency into usable data for SOC planning purposes.

- 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.
- 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.
- 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.

In addition, it is the responsibility of the PI teams to support the mission planning cycle (described in Sect. 2.3.5) by providing the required data products on the required time scales. In particular, this includes the prompt processing and analysing of all data related to the short-term and very-short-term planning process, e.g. precursor observations. Before and during Remote-Sensing Windows (RSW, see Sect. 2.3.3), the required turn-around time is on the order of one day.

For the SPICE instrument, which due to its nature of a facility instrument does not have a Principal Investigator, the SPICE Science Steering Committee (SSC) will have overall responsibility of the scientific aspects [AD01]; the implementation, up to and including the In-Orbit Commissioning Review (IOCR), is the responsibility of the SPICE instrument consortium. After successful IOCR, it is envisaged that a TBD entity will assume responsibilities equivalent to those of the PI team of a PI-led instrument.

2.3 Mission Operations Concept

2.3.1 Principles

The main principles that are driving the Solar Orbiter operations concept can be summarised as follows:

- General:
  - The remote-sensing operations will follow an encounter mission philosophy, i.e. the remote-sensing instruments will primarily operate during 30 days per orbit, typically split into three 10-day Remote-Sensing Windows (RSW) centered around perihelion and maximal northern and southern heliolatitude.
  - Exploitation of commonality with BepiColombo to the extent possible, both in the area of ground segment tools and facilities and in the sharing of manpower and expertise in the development and operations teams.
- Pre-launch:
  - Joint approach to pre-launch spacecraft system level testing between the spacecraft manufacturer and the spacecraft operations team.
  - Synergy between spacecraft manufacturer and operators in the preparation of operational documentation, spacecraft user manual, operations database, etc.
- In-Flight:
  - Maximisation of off-line operations (planning, on-board schedule execution, minimisation of the need for real-time interaction).
  - Hierarchical mission-level science planning: long lead-time planning where possible, short lead-time planning where necessary. Outside the RSWs, only the in-situ instruments will

nominally be operating, the S/C will be disk-center pointed and the S/C pointing stability requirements are lower than during RSWs, which simplifies the operations during this phase of each orbit. During the RSWs, on the other hand, the entire payload is operated and the S/C will frequently be commanded from ground to locations on the solar surface in order to track features, e.g. sunspots, that evolve over time, while the solar surface rotates differentially (the average rotation rate depends on solar latitude). Given the limited fields-of-view of Solar Orbiter's remote-sensing instruments, this results in a requirement for short lead-time planning as described in detail in [RD03].

- Spacecraft Operability: Full, consistent and intelligent use of the packet telemetry and telecommand concepts in the spacecraft avionics architecture. Given that the science return of the mission is limited by its telemetry, it is required that the on-board data management and Solid State Mass Memory (SSMM) architecture support selective downlink of subsets of data stored in the SSMM and to be able to cope with orbital periods of highly constrained telemetry downlink (large S/C-Earth distance, conjunctions).

2.3.2 Spacecraft Operations Approach

Due to the long signal propagation delay, the spacecraft will be required to support off-line operations. After the initial spacecraft commissioning, all telecommands required to carry out the mission will be loaded in advance on the Mission Timeline for later execution. All telemetry generated on-board will be stored for later retrieval by ground.

In order to support the off-line operations approach required for a deep-space mission, the following autonomy capabilities have been specified for the spacecraft:

- To support On-board Control Procedures (OBCP), as a way to autonomously execute complex procedures including decision loops which ground cannot support due to the propagation delay. On-board Control Procedures also provide the required flexibility to adjust procedures defined pre-launch to the environment while in the routine orbit around the Sun and the aging spacecraft, as is the case with ground procedures.
- To detect and autonomously recover any single failure, and to reconfigure itself to a safe back-up mode in case the detected failure is not recoverable.

In order to provide the necessary flexibility in allocation of on-board SSMM areas to different payload users and in the retrieval of engineering and science data according to the priority of the on-going operations, the storage on board will be organised in so-called Packet Stores. Dedicated Packet Stores will be created and assigned to each instrument for science telemetry packets. This will allow allocation of storage resources according to the individual instrument requirements without risk of interference across instruments in case of telemetry generation exceeding the assigned and planned resources. Provisions shall be made for a number of package stores to be shared by several instruments to support, e.g., achieving orbit-specific science goals that require additional data sets from specific instruments.

As stated in the previous section, it is required that the on-board data management and SSMM architecture support selective downlink of subsets of data stored in the SSMM and to be able to cope with orbital periods of highly constrained telemetry downlink (large S/C-Earth distance, conjunctions).

The nominal radio frequency link to/from the spacecraft will be degraded when the Sun-Earth-Spacecraft angle becomes lower than 5° (based on X-band experience). Degradation of the signal also affects tracking measurements. For this reason the mission shall be designed such that critical navigation activities (e.g. manoeuvres, planet swing-bys) do not take place within 5° (TBC) angular separation from the Sun as seen from Earth. The spacecraft will be able to operate autonomously during the solar conjunctions, although the regular daily passes will not occur. Consequently during these periods the quick-look processing on ground will be suspended.

2.3.3 Payload Operations Approach

All scientific operations will be conducted under the coordination of the Science Operations Centre.

During the cruise phase, i.e. starting at the end of NECP (L+97 days), the in-situ instruments will be operated, according to the PI teams' requests and following the regular planning process. In this phase of the mission, the remote sensing instruments will, as a baseline, be inactive, and only operated for a short, non-interactive functional checkout of a few days per year. Exceptionally, if operational and resource constraints permit, the remote-sensing instruments may be operated on a best effort basis for limited periods to support high-priority science campaigns (this should not drive development requirements).

After Venus/Earth GAM-2, the Nominal Mission Phase (NMP) starts. During NMP, the in-situ instruments will be operated continuously, while the remote-sensing instruments will primarily operate during 30 days per orbit, typically split into three 10-day Remote-Sensing Windows (RSWs) centered around perihelion and maximal northern and southern heliolatitude. A hierarchical mission-level science-planning scheme, as outlined in Section 2.3.5, is foreseen.

Payload instruments contingencies, as well as maintenance and troubleshooting activities (e.g., on-board software updates, anomaly investigations) will be handled outside the normal planning process and with a direct interface between the PI teams and the MOC. Presence of the PI teams' experts at the MOC will also be possible, where required to support near-real time decision processes.

2.3.4 Data Delivery

All telemetry data are received at ESA/ESOC and filed in a central archive in form of raw TM packets. Access to this archive by the users community (restricted to the SOC, PI institutes and authorised science institutes), is provided via the ESOC Data Disposition System (DDS) infrastructure and the interface is described in the Data Delivery Interface Document (DDID), SOL-ESC-IF-05011 (TBW). The SOC will automatically retrieve all S/C TM data, reformat those into standard formats and make them available to the PI teams, thus avoiding the need for every PI team to develop raw TM reformatting software.

Auxiliary mission information (e.g., orbit and attitude profiles, event files, telecommand history, mission planning information, etc.) will be produced at ESOC and made available to the authorised external users community via the DDS.

The raw telemetry data will be processed by the Instrument Teams, who will in turn provide calibrated data and higher-level data products to the SOC for distribution to the worldwide community. The responsibilities of the PI teams are formalised in Sect. 4.4 of the SMP [AD01]:

"Solar Orbiter data will be made available according to the following procedure. Reduction of science data is under the responsibility of PI teams for PI-led instruments. In the case of SPICE and SIS, this task will be

the subject of a separate ESA AO. Following in-orbit commissioning, the PIs of PI-led instruments 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 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 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."

2.3.5 Mission Planning

While the mission planning approach for all the routine science operations phases will be built on the experience of the precursor planetary missions Mars Express and Venus Express, a fundamental difference with respect to planetary missions is the highly dynamic nature of the Sun. Given the short time-scales on which the targets of remote-sensing observations (e.g. solar active regions) change, together with the narrow fields-of-view of the high-resolution imaging telescopes (which cover less than 3% of the solar disk at perihelion), turn-around times between defining the pointing and executing the observations of at most three days is required during the Remote-Sensing Windows, as described in [RD03].

The resulting requirements on the science operations planning for Remote-Sensing Windows are described below. The envisaged mission planning cycle and its levels are the results of a collaborative effort between the OGS, SOC and PS at a Solar Orbiter Mission Planning Workshop [RD10] and were subsequently consolidated by all parties involved.

A typical mission planning cycle starts with the Science Working Team (SWT) defining the top-level science goals for a given orbit. Given this input, the Science Operations Working Group (SOWG) defines a coherent mission-level observing plan for this orbit. In this task, they will be assisted by the SOC, which will provide detailed information on the resources available (e.g., on-board memory management, telemetry downlink). In turn, the PI teams provide, at fixed deadlines and with a fixed periodicity, inputs to the SOC for the requested science operations, which implement the observing plan defined by the SOWG. The SOC passes a consolidated request to the MOC which checks the requests against mission, environmental and resource constraints. A baseline science plan, which already takes into account the major constraints, will have to be established long before submitting the final science operations requests to the Mission Planning process.

It is important to stress that top-level science operations planning for the mission needs to be done well before launch due to the severe constraints on Solar Orbiter's data downlink volume and on-board storage in the Solid State Mass Memory (SSMM). In particular, this entails feasibility studies of planned operations taking into account the expected time-dependent telemetry downlink profile as well as SSMM load levels.

The mission planning cycle for the routine science operations phase will therefore be divided into different levels:

a) *Long-Term Planning (LTP)* will fix the trajectory and the ground station schedule. This process typically will take place once for each mission phase (covering the entire mission phase) until the start of the nominal mission phase (NMP), and once for every orbit around the Sun, covering the full revolution, after the start of NMP. In each orbit, this process will in general commence after the end of the last Remote-Sensing Window, counted from aphelion. At LTP level, event skeleton fields are provided by the OGS to the SGS, which will contain all the information required by the SGS to conduct science planning.

b) *Medium-Term Planning (MTP)* will fix the usage of spacecraft resources. This process will typically take place once for each of the LEOP and NECP mission phases, covering the whole mission phase, at shorter intervals during Cruise Phase, and once per orbit during NMP, covering the entire orbit. At MTP level, the top-level science operations plan for the entire orbit is defined and a default pointing profile for Remote-Sensing Windows is defined (with possible updates at STP level, see below).

c) *Short-Term Planning (STP)* will generate detailed schedules of commands for the spacecraft and for the ground stations. This process will take place typically every week covering one week: The SOC planning will take place on Mon-Tue of each week, with subsequent processing and command upload by the MOC and start of execution every Saturday, covering one week. The SOC will provide detailed instruments operations requests, which are imported by the MOC in a single plan, and will undergo final detailed resource and constraints checks. At STP level, the instrument activities can be modified, provided they fit into the resource envelope defined at MTP level.

d) In the case of Remote Sensing Windows, *Very-Short-Term planning (VSTP)* may be performed. This planning level, with turn-around times of max. three days between observations and execution of the new Pointing Request (PTR), is required for RSWs in which features on the solar disk, e.g. active regions, shall be tracked over time. This is due to the short lifetimes and non-deterministic motion of targets on the Sun [RD03] and the relatively large (compared to the fields-of-view of the high-resolution imaging telescopes) and temperature-dependent absolute pointing error (APE) of the spacecraft. This VSTP consists of (i) initial target selection and (ii) updates to the pointing.

    i. Prior to the start of an RSW, a limited set of precursor observations with the full-disk imaging telescopes of the EUI and PHI instruments is performed and downlinked with high priority. Based on the returned data, the target for the start of the RSW will be defined. This step is required to make a decision on the pointing of the spacecraft and, in turn, the high-resolution imaging telescopes. In case the orbital constellation permits making this decision by means of other observations (e.g. using ground-based telescopes), this step can be omitted.

    ii. During the course of an RSW, a limited set of daily VSTP data, consisting of full-disk and high-resolution images, will be downlinked with high priority. Based on the evaluation of these images, the pointing will be updated by means of uploading a PTR. The final science target selection (and retargeting) shall be responsibility of a person nominated by the SOWG, who shall make him/herself available according to the schedule required by the planning process. Refinement of the tracking of this target shall be done by SOC, according to a set of rules established by the SOWG.

2.4 Science Operations Planning and Data Selection Tools

As outlined in the previous section, being able to select targets and to update pointing requests based on visual inspection of image data returned with low latency is an important requirement during the RSWs due to the highly dynamic nature of the Sun. This requires a *Science Operations Planning Tool* capable of displaying image data (at least) of those instruments involved in the target selection process (expected to be EUI and PHI) downlinked with high priority returned as part of the STP/VSTP process.[2]

In addition, several instruments onboard Solar Orbiter generate orders of magnitude more data than can be downlinked and therefore require the capability to selectively downlink the scientifically most relevant data. As a key aspect of the mission is to acquire joint data sets of remote-sensing and in-situ instruments, a *Visual Context Data Browsing and Selection Tool* is required to make a decision on the specific data sets to be selected for downlink.

2.4.1 Science Operations Planning Tool

The SOC shall design and implement a Science Operations Planning Tool that fulfils the following requirements. The Science Operations Planning Tool shall:

- Enable the SOC to generate Payload Operations Requests (PORs), based on input from the SOWG and the Instrument Operations Requests (IORs) generated by the individual PI teams
- Display the following data sets:
    - Image data returned as part of the STP/VSTP process for target selection and defining pointing requests by the SOC and SOWG-representatives (the latter likely to be located outside SOC premises[3]).
    - Recent solar synoptic remote-sensing data from a limited set of ground-based (and potentially other space-based) assets to assist in the STP/VSTP process in case no data from Solar Orbiter is available.
- Enable SOC and SOWG-representatives (the latter likely to be located outside SOC premises) to perform target selection and define pointing requests
    - Based on image date returned as part of the STP/VSTP planning process
    - Without using Solar Orbiter data, e.g. in cases in which no telemetry from Solar Orbiter is available on the required time scale. This implies the capability to ingest image data in standard format (e.g., FITS with WCS-compliant metadata) from ground-based or other assets and the requirement to implement a World Coordinate System (WCS, [RD04-06])

  The output of the target selection and pointing definition shall be in a format agreed to by the OGS, e.g. using Carrington coordinates [RD06].

[2] The term Science Operations Planning Tool is used here in the general sense. The task of creating PTRs based on data that has been downlinked with low latency is not strongly coupled to the task of creating payload operations requests, i.e. does not necessarily need to be accomplished within the same piece of software if properly justified.

[3] This requirement suggests that a split between the software performing the actual science operations planning and the one enabling external representatives to define pointing requests might be desirable.

- Provide up-to-date information about the spacecraft resources relevant to instrument operations, e.g. the SSMM usage and data allocation per instrument.

2.4.2 Visual Context Data Browsing and Selection Tool

The SOC shall design and implement a Visual Context Data Browsing and Selection Tool for that fulfils the following requirements:

- Interactively display and overlay the following quantities in an integrated tool:
    - Synoptic observations from all Solar Orbiter instruments (to be provided by the Instrument Teams in standard formats)
    - Quicklook data from all Solar Orbiter instruments (processed by the SOC using software provided by the PI teams) to enable the Instrument Teams to assess instrument health and performance.
    - Highly compressed and/or low-resolution data used to determine which part of the selective telemetry is to be downlinked.
    - Synoptic data from near-Earth assets (both in standard formats, e.g. FITS with WCS-compliant headers for image data) to enable the Instrument Teams to make decisions on which data sets to select for downlink.
    - Solar Orbiter's trajectory
    - Models of the coronal and heliospheric magnetic fields and the heliospheric current sheet to establish the connection between in-situ and remote-sensing measurements (data to be provided to the SOC in standard file formats).
    - Coronal hole maps
    - Solar event markers indicating the occurrence and position of recent solar events, e.g. flares and CMEs

- Implement a World Coordinate System (WCS, [RD04-06]) and enable the user to switch between the relevant coordinate systems.
- The tool shall be usable on all major computer platforms (Windows, Mac, Linux, standard versions at time of SOC commissioning) and shall be made available to the Instrument Teams and all other parties involved in the instrument science operations (per download via ESA web pages).

For illustrative purposes, Figure 2.1 shows an example of an existing ESA tool for solar data, JHelioviewer, (http://jhelioviewer.org) that allows image data from different instruments and missions to be displayed along with 1-D data (e.g. fluxes or in-situ data), which the user can interactively browse in space and time. This software, which already incorporates a WCS, coronal hole maps and solar event markers, could easily be adopted and extended by the SOC at low cost to meet the requirements for a Visual Context Data Browsing and Selection Tool.

At Solar Orbiter Science Operations WG Meeting #5 (July 2014), the current development status of JHelioviewer, which now also offers a 3D representation of solar image data (Figure 2.2), was presented to the SOWG, and the SOWG unanimously agreed that further development and maintenance of this tool would meet the requirements for a Visual Context Data Browsing and Selection Tool for Solar Orbiter. It was seen as additional advantage that (a) JHelioviewer has become one of the most widely used tools in the solar physics community and (b) two Solar Orbiter PI institutions are already actively involved in the development of JHelioviewer and have expressed strong interest in continuing their work and (c) the entire software is open-source, which facilitates contributions by the community.

The development of JHelioviewer has been funded since 2008 by ESA SRE-S and SRE-O as a research activity with an annual budget of 70-90 kEuro (led by the Solar Orbiter Project Scientist), with additional prototyping work being performed in 2013-2014 under an ESA GSTP activity, and it is expected that continued funding around this comparatively low level will be sufficient to maintain the software and add Solar Orbiter-specific functionality.

- Develop a Low Latency Data Visualization tool to support science operations planning, the assessment of instrument health and performance by the Instrument Teams, and the preparation of selective downlink telemetry requests for the periods of the mission where this capability is possible.

- Support with manpower, limited funding for ESA-external software development, expertise and coordination the development and maintenance of the JHelioviewer software to ensure that it can be used with Solar Orbiter data and the Mission Archive.

This approach is supported by the Project Scientist.

For general information, a public web page shall be implemented that allows spacecraft and planet positions to be displayed for user-specified time intervals (see Figure 2.3 for an example from the STEREO mission, http://stereo-ssc.nascom.nasa.gov/where.shtml).

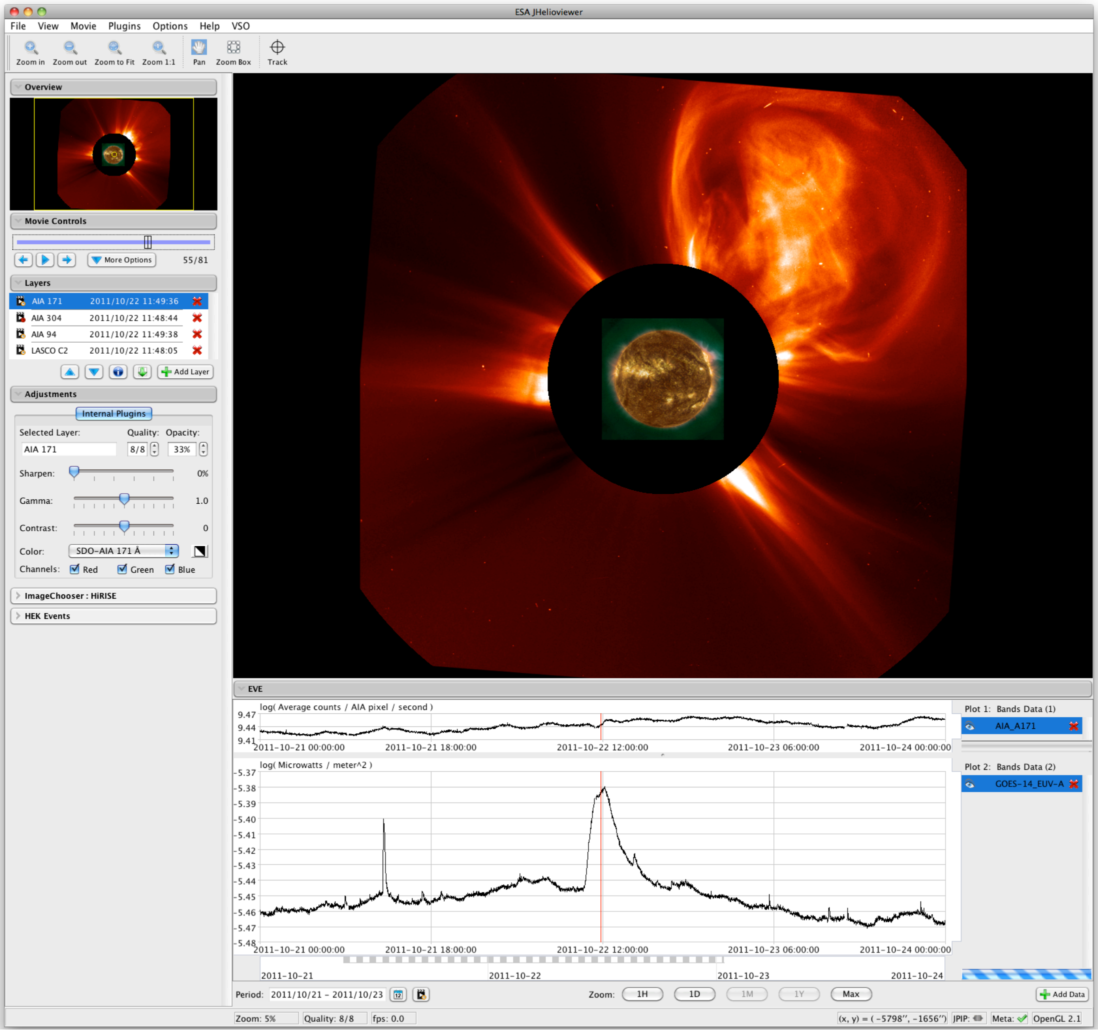

Figure 2.1. Example of an interactive visual browse tool for solar data (ESA JHelioviewer). Image data from different instruments are displayed along with 1-D data and can be navigated in space and time.

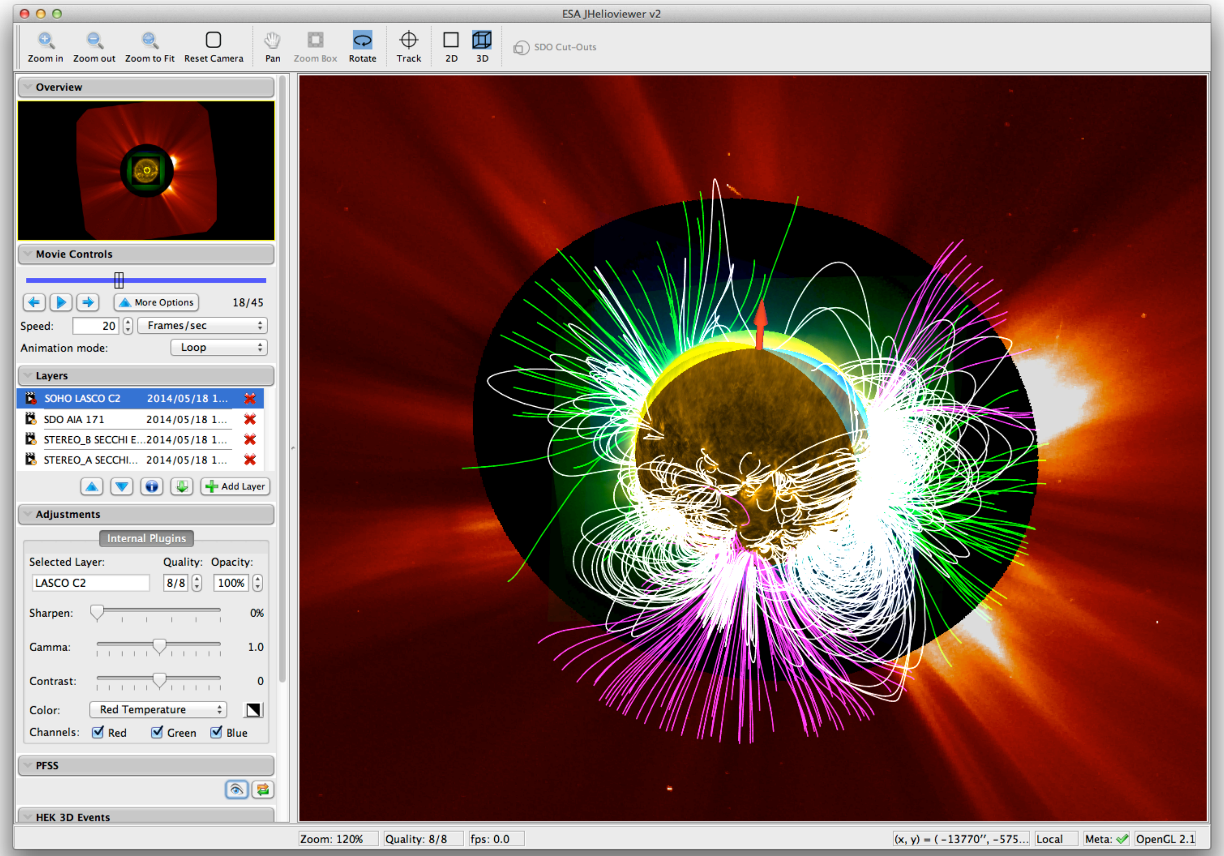

Figure 2.2. Screenshot of JHelioviewer 3D, showing rendering of solar image data, together with field lines from a time-dependent global magnetic field model of the Sun (PFSS). The three different colors of field lines differentiate between lines connecting back to the solar surface (white) and 'open' field lines of different polarities (green and magenta).

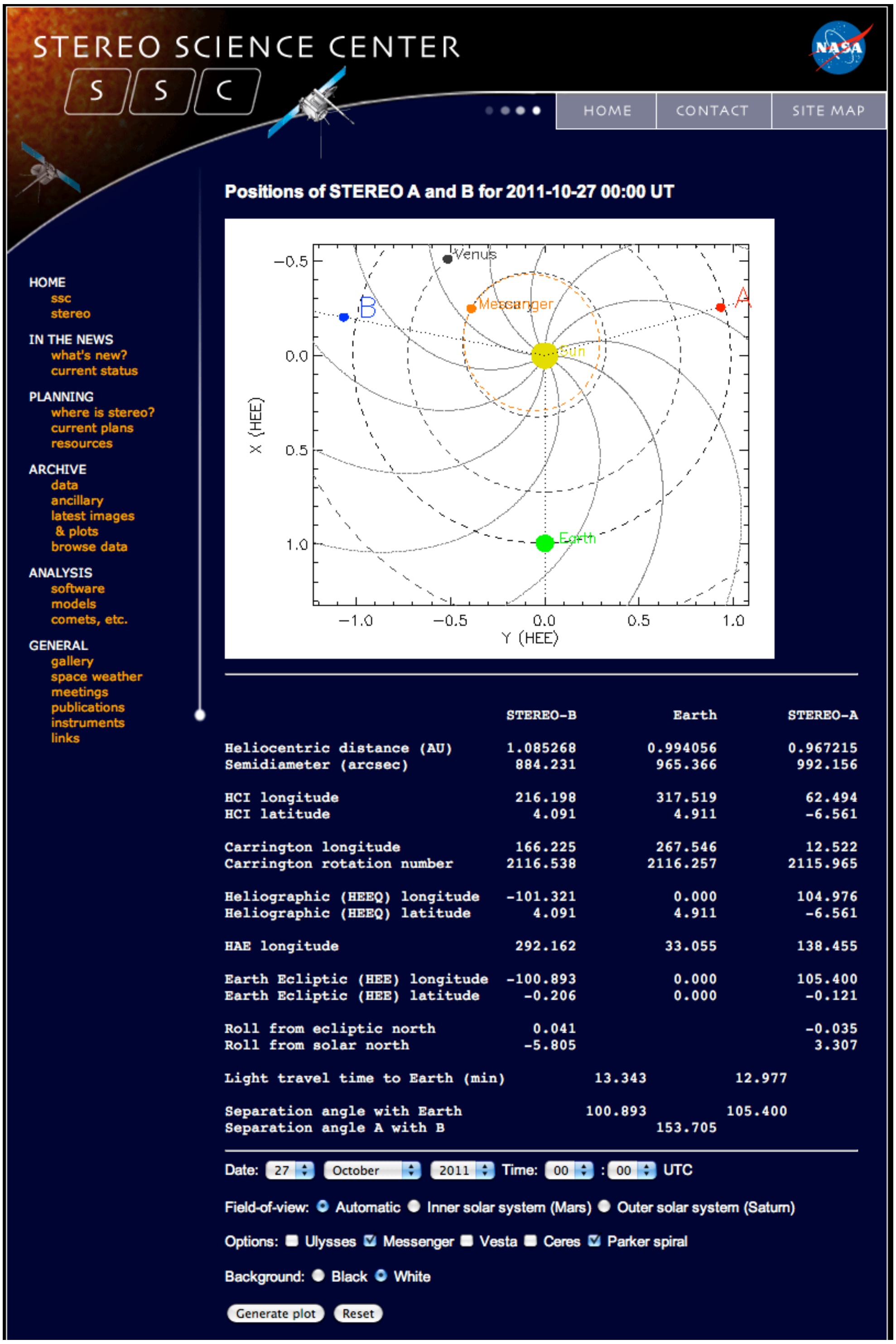

Figure 2.3. Web front-end: spacecraft and planet positions for user-specified time (example from STEREO mission, http://stereo-ssc.nascom.nasa.gov/where.shtml).

3 RESPONSIBILITIES

3.1 Global Responsibilities

ESA's Director for the Scientific Programme (D/SRE) has the overall responsibility for all phases of the Solar Orbiter project.

During definition and implementation phase, the Project Manager (SRE-PS) manages the Solar Orbiter project.

SRE-S is responsible for the implementation of all scientific aspects of the Solar Orbiter mission. In the pursuance of his responsibilities, SRE-S interfaces with the scientific community and other Directorates, at project level, with Member States and International Agencies, within the framework of the respective international Memoranda of Understanding (MoU) and Inter-Agency Agreements, whenever applicable. The Project Scientist (SRE-SM) represents the interests of the scientific community for all phases of the mission.

OPS-OP is responsible for the development, implementation and operation of the Solar Orbiter Ground Segment and execution of all mission operations and will report to the Project Manager/Mission Manager.

SRE-O is responsible for the management of the Solar Orbiter mission once successfully commissioned. At that time a dedicated Mission Manager is nominated by the SRE-O.

SRE-OD will report to the Project Manager and to the Project Scientists (with respect to science aspects) for the development and implementation of the Solar Orbiter Science Ground Segment (SGS), which comprises the Science Operations Center (SOC) and the PI teams.

The SOC coordinates and performs the scientific operations planning based on PI inputs and will be responsible for archiving the science data. The SGS will also be responsible for establishing the Solar Orbiter archive and will assist NASA in mirroring this archive.

The following sections define the detailed responsibilities of involved parties with respect to the Solar Orbiter SGS development and operations. They cover:

- The Solar Orbiter Project Manager (PM)
- The Solar Orbiter Project Scientists (PS)
- The Solar Orbiter Mission Manager (MM)
- The Solar Orbiter Principal Investigator (PI) Teams
- The Solar Orbiter Ground Segment Manager (GSM)
- The Solar Orbiter Spacecraft Operations Manager (SOM)
- The Solar Orbiter Science Ground Segment Development Manager (DM)

3.2 Solar Orbiter Project Manager Responsibilities

The Solar Orbiter Project Manager has ultimate responsibility for the operational elements of the Solar Orbiter Ground Segment.

Specifically:

- Establish the overall mission requirements.
- Establish the concepts to ensure compatibility, commonality, and maximum re-use of hardware and software between all phases of the project.

- Assume overall coordination for the definition and implementation of the elements of the Solar Orbiter ground segment and mission operations.
- Generate the MIRD and the SIRD, update as required and keep under Configuration Control.
- Approve all changes to the Mission Implementation Plan (MIP).
- Define the interface for the scientific instruments' on-board software design.
- Monitor flight operations procedures development (spacecraft and instruments).
- Establish and maintain the overall Ground Segment development.
- Organize (jointly with OPS-OPB, SRE-SM and SRE-OD) all major ground segment and mission operations reviews.
- Provide the instruments' inputs to the Telemetry and Telecommand (TM/TC) database.
- Assume overall responsibility for the definition and execution of the Near-Earth Commissioning Phase.
- Collect payload, Solar Orbiter Project and Solar Orbiter Prime Contractor information in form of documentation, photographs, videos and other information source in a central database that shall be accessible via state-of-the-art technology including controlled user access.
    - Items within the central repository shall be attributed and be under revision control.
    - Documentation attributes used within the Solar Orbiter Project Team and other document providers shall be preserved within the central repository.
- After Near-Earth Commissioning, on request by the Mission Manager, ad-hoc specialist support shall be provided by SRE-P.
- Coordinate with the NASA Project Office on matters concerning the NASA-provided payload elements and the launch vehicle.

Note: Most of the Solar Orbiter Project tasks are carried out in close collaboration with the other parties who have delegated responsibilities for the ground segment and operations.

3.3 The Solar Orbiter Project Scientist Responsibilities

During all phases of the mission, i.e. implementation phase until the end of the exploitation phase, the ESA Solar Orbiter Project Scientist, supported by an ESA Solar Orbiter Deputy Project Scientist, will be responsible for managing the Solar Orbiter scientific program, safeguarding the scientific interests of the science community, and maximizing the scientific return of the mission. The general roles and responsibilities of the PS are described in [RD09]. Specifically, the responsibilities of the PS include the following:

- Acting as the main interface with the scientific community for science related issues, inter alia by chairing the Science Working Team (SWT).
- In close collaboration with the SWT (and with support from SRE-O as required, and where relevant to the SGS), defining the top-level Science Plan, monitoring and approving its implementation in science operations plans (as chair of the Science Operations Working Group, SOWG) during all mission phases, and mediating in the resolution of scientific conflicts.
- Liaising with the Solar Orbiter Project Manager (PM) and the Project Team in the development phase and to coordinate all scientific issues with them. In particular the PS advises the Solar Orbiter Payload Manager on technical matters when they affect scientific performance.
- Defining the requirements and following the implementation of an efficient and cost-effective science operations centre, which is responsible for science operation planning (including adaptation

of planning tools), scientific data handling and archiving.
- Supporting the definition of the Solar Orbiter knowledge management concepts.
- Supporting payload knowledge management with respect to instrument science operation and science relevant issues after handover over the entire mission duration.
- Following the development of the experiments and take an active role during instrument team progress meetings and reviews.
- Reviewing the Flight Operations Plan (FOP) for science operations related aspects.
- Consolidation of data processing plan.
- Coordinating with the NASA Solar Orbiter Project Scientist at NASA GSFC.
- Defining requirements for science data products definition and the Solar Orbiter science data archive.
- After completion of the in-orbit operations, monitoring the transition into the post-operational phase.
- Chair the SPICE SSC as described in [AD01].

During all phases of the mission, the Project Scientist is supported by a number of SOC Instrument Operations Scientists (IOSs, under the line management of SRE-OD) in fulfilling their tasks of safeguarding the scientific interests of the science community and maximizing the scientific return of the mission. There will be a working interface with the IOSs to cover items where the SGS activities could overlap with areas under PS responsibility.

3.4 Solar Orbiter Mission Manager Responsibilities

After successful completion of the Near-Earth Commissioning Phase, the Science Operations Department (SRE-O, via its Solar System and Astronomy science operations divisions, SRE-OS and SRE-OA) is responsible for the overall management of the mission and for the execution of the science operations of the Directorate's missions, following scientific requirements set by the respective Project Scientists. Once commissioned, the mission is managed by the Solar Orbiter Mission Manager with a scientific and operational background and an understanding of the scientific goals of the mission.

The main duties of the Solar Orbiter Mission Manager are:
- Overall responsibility for all aspects of operations. Special emphasis must be given to the science requirements. The Project Scientists (from SRE-S) will advise the Mission Manager on how to optimize the science output of the mission.
- Organization and overall management of the science operation teams and staff assigned to the mission as well as coordination of ad-hoc support from other Directorate elements.
- Interfacing to Operational Ground Segment (OGS) personnel regarding the delegated responsibility for the OGS.
- Overall project planning (scientific, technical, financial and programmatic) including maintenance of the project CaC and planning for any mission extensions.
- Full responsibility for the project budget including delegation to SRE-SM of those elements necessary to support the Project Scientists in his/her activities.
- Organisation of the SGS readiness review.
- Ensuring that information on the project's experiences ("lessons learnt") is appropriately made available to future projects.

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3.5 Principal Investigator Team Responsibilities

For the implementation of the SGS, the PI teams are expected to:

- Support the definition of the science operations.
- Provide inputs for the definition and implementation of the science operations planning, data handling and archiving concepts.
- Support the preparation of the instrument operation timelines.
- Support the definition and implementation of the Solar Orbiter scientific data archive, as part of the pre-launch tasks.
- Agree on a long-term science activity plan and define the scientific priorities of scientific goals.
- Monitor and optimise instrument performance.
- Deliver calibrated and high level data, including relevant calibration products, to the Solar Orbiter scientific archive.
- Provide to ESA unlimited access to all processed and analysed data for public relation purposes during the 3-months proprietary period.
- Provide summaries of the main scientific results at regular intervals.
- Maintain the instrument flight software.

For the SPICE instrument, which due to its nature of a facility instrument does not have a Principal Investigator, the SPICE Science Steering Committee (SSC) will have overall responsibility of the scientific aspects [AD01]; the implementation, up to and including IOCR, is the responsibility of the SPICE instrument consortium. After successful IOCR, it is envisaged that a TBD entity will assume responsibilities equivalent to those of the PI team of a PI-led instrument.

A coherent science operations programme for the mission shall be prepared by the SOWG and endorsed by the SWT, under the overall responsibility of the ESA and NASA Solar Orbiter Project Scientists. In particular, the SOWG will be charged with the definition of dedicated campaigns and sequences of observations, in compliance with their respective resource allocations and overall constraints.

3.6 Directorate of Human Spaceflight and Operations (D/HSO) Responsibilities

The Operations Department (HSO-OPS) at ESOC, acting on behalf of the Director of Human Spaceflight and Operations (H/HSO), has overall responsibility for the design, implementation and operation of the operational ground segment. This responsibility is discharged to an operational ground segment design team, led by a Ground Segment Manager (GSM), which shall, in close collaboration with the Solar Orbiter Project Team, define the operational ground segment and its interfaces to the satellite and its payload, as well as other entities forming the overall Solar Orbiter Ground Segment.

D/OPS will be delegated with the definition, implementation and execution of all mission operations activities. This includes operations preparation, generation of flight operation plans and procedures, planning and execution of spacecraft operations, on-board software maintenance and in-orbit mission evaluations. As far as the science instruments are concerned, this includes instrument monitoring and maintenance of health and safety, instrument command and monitoring interfaces, instrument engineering troubleshooting and maintenance activities, as well as the implementation of end-to-end processes in support of science operations. In this role, the D/OPS Mission Control Team interfaces directly with the payload teams for any aspect related to the above, and at system level coordinates all mission operations aspects within ESOC, with the PI teams and SGS.

The Mission Control Team is led by the Spacecraft Operations Manager (SOM). The SOM will be responsible for the build-up and management of the flight control team (engineers, analysts, controllers), who will support him in the execution of his tasks. Functional support to the SOM will be provided by the other elements of the Operational Ground Segment (OGS), i.e. ground station operations, Flight Dynamics, Software Support teams.

3.7 Science Ground Segment Development Manager Responsibilities

The Science Ground Segment Development Manager (DM) is responsible for the overall development of the Science Ground Segment, following scientific requirements defined in this document and approved by the Project Scientist. The main duties are:

- Overall responsibility for all aspects of science ground segment operations development. Special emphasis must be given to the science requirements. The Project Scientists (from SRE-S) will advise the Development Manager on how to optimize the science output of the mission.
- Organization and overall management of the teams and staff assigned to the SO-SGS.
- Overall project planning (scientific, technical, financial and programmatic) including maintenance of the SGS CaC.
- Development of the overall Solar Orbiter archive.

4 SOC IMPLEMENTATION REQUIREMENTS

This chapter lists the requirements for implementation of the Solar Orbiter SOC.

In the following table the letters in the second column are define as follows:
T = Title; C = Chapter; D = Definition; R = Requirement; DT = Descriptive Text;
O= Open Item (for discussion)

No.	T	SOC Functional Requirements
1	**C**	**1 Mission Phasing and SOC architecture**
1.0-1	D	This requirement summary is structured in line the following phasing of the overall mission: • Development Phase, up to and including Near Earth Commissioning Phase (NECP), during which the SOC is being commissioned • Operational Phase including o Cruise Phase (CP) o Nominal Mission Phase (NMP) o Extended Mission Phase (EMP) • Post-Operations Phase
1.0-2	D	The Science Ground Segment (SGS) comprises the ESA Science Operations Centre (SOC), the PI teams and potentially other parties taking part in the science operations of the mission.
1.0-3	R	The Architecture of the SOC shall cover the following functionalities: • Science Operations Planning • Preparation of Payload Operations Requests (PORs) and Pointing Requests (PTRs), based on input from the SOWG and the Instrument Operations Requests (IORs) generated by the individual PI teams • Visualization of data returned as part of the STP/VSTP operations • Visualization of data for quick-look purposes (data processed using software provided by the PI teams) and for selecting data for selective downlink • Long-Term Archiving • Data Archive and Retrieval • Generate and distribute auxiliary data products: o Orbit data (NAIF SPICE kernels, daily files) o Attitude data (NAIF SPICE kernels, daily files) o Time correlation o Command history

No.	T	SOC Functional Requirements
		○ Spacecraft mode ○ Instrument data production estimates ○ Instrument data transferred to SSMM ○ SSMM configuration ○ SSMM fill status (estimates and actuals) ○ Data on ground (estimates and actuals) ○ Power usage (estimates and actuals)

2	**C**	**2 Development Phase Requirements**
2.1	**C**	**2.1 SOC Architectural Requirements**
2.1.1	C	2.1.1 Science Operations Planning
2.1.1.0-1	R	Design and implement an SOC planning system to fulfil the scientific requirements of the mission defined in the Science Requirements Document [AD02] (assuming the spacecraft and instrument performance will be as specified).
2.1.1.0-2	R	The SOC shall support the capability to plan science data return and advise the SOWG on science planning alternatives, based on instrument models and resource availability inputs provided by OGS and according to processes/interfaces to be defined in collaboration with OGS and the Instrument Teams as part of the Mission Planning Concept
2.1.1.0-3	R	The system shall always be able to allocate and validate spacecraft resources relevant for science operations (in particular SSMM usage and fill levels) based on resource availability inputs provided by OGS.
2.1.1.0-4	R	The SOC shall design and implement a Science Operations Planning Tool (cf. 2.4.1 in the text) able to: • Display data returned as part of the STP/VSTP process for target selection and generation of Pointing Requests (PTRs) by the SOC and SOWG-representatives (the latter likely to be located outside SOC premises); • Enable SOC and off-site SOWG-representatives to perform target selection and generate pointing requests (a) based on image date returned as part of the STP/VSTP planning process (b) without using Solar Orbiter (SO) data (e.g. in cases in which no telemetry from SO is available on the required time scale). The latter implies the capability to ingest and display image data in standard format (e.g., FITS with WCS-compliant metadata) from ground-based or other instruments (of course, the SOC is not responsible for their existence or

		suitability to the task). • Support the identification of problems and issues relevant to science planning and return (e.g. monitor data quality, instrument performance, instrument parameter settings verification, etc.) in order to allow corrections or rescheduling as permitted as part of the STP/VSTP process.
2.1.2	C	2.1.2 Preparation of Payload Operation Requests and Pointing Requests
2.1.2.0-1	R	The SOC shall define and implement a system that allows the preparation and validation of the Payload Operation Requests (PORs) and Pointing Requests (PTRs) for the OGS to uplink.
2.1.3	C	2.1.3 Visual Context Data Browsing and Selection Tool
2.1.3.0-1	R	Define and implement a Visual Context Data Browsing and Selection Tool (cf. 2.4.2 in the text) capable of: • Interactively displaying and overlaying the following quantities in an integrated tool: o Synoptic observations from all SO instruments (to be provided by the Instrument Teams in standard formats) o Synoptic data from near-Earth assets (in standard formats, e.g. FITS with WCS-compliant headers for image data) to enable the Instrument Teams to make decisions on which data sets to select for downlink. o Solar Orbiter's trajectory o Models of the coronal and heliospheric magnetic fields and the heliospheric current sheet to establish the connection between in-situ and remote-sensing measurements (TBD by the Project Scientist) o Coronal hole maps o Solar event markers indicating the occurrence and position of recent solar events, e.g. flares and CMEs (TBD by the Project Scientist) • Implement a World Coordinate System (WCS, [RD04-06]) and enable the user to switch between the relevant coordinate systems. • The tool shall be usable on all major computer platforms (Windows, Mac, Linux; standard versions available at time of SOC commissioning) • The tool shall be made available to the Instrument Teams and all other parties involved in the instrument science operations per download via ESA web pages.

2.1.3.0-1	DT	At Solar Orbiter Science Operations WG Meeting #5 (July 2014), the current development status of the ESA JHelioviewer software was presented to the SOWG, and the SOWG unanimously agreed that further development and maintenance of this tool would meet the requirements for a Visual Context Data Browsing and Selection Tool for Solar Orbiter. It was seen as additional advantage that (a) JHelioviewer has become one of the most widely used tools in the solar physics community and (b) two Solar Orbiter PI institutions are already actively involved in the development of JHelioviewer and have expressed strong interest in continuing their work and (c) the entire software is open-source, which facilitates contributions by the community. The development of JHelioviewer has been funded since 2008 jointly by ESA SRE-S and SRE-O as a research activity with an annual budget of 70-90 kEuro (led by the Solar Orbiter Project Scientist), with additional prototyping work being performed in 2013-2014 under an ESA GSTP activity. It is expected that continued funding around this comparatively low level will be sufficient to add the required Solar Orbiter-specific functionality and maintain the software. Given the expertise required and potentially high cost to develop ESA-internally a new tool that meets the mission-specific requirements and is capable of working with data not only from Solar Orbiter but from other current and future solar observatories as well as current and future theoretical models, the ESA SOC has proposed to • Develop a Low Latency Data Visualization tool to support science operations planning, the assessment of instrument health and performance by the Instrument Teams, and the preparation of selective downlink telemetry requests for the periods of the mission where this capability is possible. • Support with manpower, limited funding for ESA-external software development, expertise and coordination the development and maintenance of the JHelioviewer software to ensure that it can be used with Solar Orbiter data and the Mission Archive. This approach is supported by the Project Scientist.
2.1.4	C	2.1.4 Data Archiving Preparation
2.1.4.0-1	D	Definition of data levels: • Level 0: Telemetry with time ordered packets and sorted by APIDs.

		• Level 1: Uncalibrated data converted into engineering units in standard formats (i.e. FITS, ASCII, CDF or similar). • Level 2: Calibrated data. • Level 3: Higher-level data.
2.1.4.0-2	R	The SOC shall define and implement software modules to ingest all science data to be received from the MOC (content equivalent to Level 0), as well as all Level 1-3 data (to be delivered by the Instrument Teams) into the science archive.
2.1.5	C	2.1.5 Auxiliary Functions
2.1.5.0-1	R	Generate and distribute auxiliary data products: • Orbit data (SPICE kernels, daily files) • Attitude data (SPICE kernels, daily files) • Time correlation • Command history • Spacecraft mode • Instrument data production estimates • Instrument data transferred to SSMM • SSMM configuration • SSMM fill status (estimates and actuals) • Data on ground (estimates and actuals) • Power usage (estimates and actuals)
2.2	**C**	**2.2 SOC Operations Definition**
2.2.0-1	R	Support the definition of the SO mission planning and science operations concept for the science phases in collaboration with the OGS.
2.2.0-2	R	Define the routine operations procedures for the SOC.
2.2.0-3	R	Establish a plan for SOC operational facilities, equipment & services (including hardware).
2.2.0-4	R	Support the definition of the operational interfaces to OGS, implement and maintain the defined interfaces on SOC side.
2.3	**C**	**2.3 Instrument Operations Definition**
2.3.0-1	R	Support the definition of instrument science configurations; this includes the definition of instrument science modes, the set-up parameters, and the logic to switch from one mode to another.
2.3.0-2	R	Support the Instrument Teams, in collaboration with the PS and the SO Project, in the definition of pre-launch calibration data and its analysis where relevant to the overall SGS tasks.
2.3.0-3	R	Support the PS in advising the SO Project and the Instrument Teams on science performance related issues relevant to the overall SGS tasks.

2.3.0-4	R	Author the science elements of the instrument commissioning plans during NECP in coordination with all parties involved.
2.3.0-5	R	Coordinate instrument characterization and calibration plans during CP.
2.4	**C**	**2.4 Near-Earth Commissioning Phase**
2.4.1	C	2.4.1 Science Operations Planning
2.4.1.0-1	R	Support the instrument commissioning on a best-effort basis (given the parallel commissioning activities of the SOC).
2.4.2	C	2.4.2 Command Preparation
2.4.2.0-1	D	During this phase no additional requirements apply to the SOC.
2.4.3	**C**	**2.4.3 Data Browsing and Visualization**
2.4.3.0-1	R	Test the Visual Context Data Browsing and Selection Tool with instrument commissioning data (science test data sets). Test the Science Operations Planning Tool with test data or data coming from commissioning activities.
2.4.4	**C**	**2.4.4 Auxiliary Functions**
2.4.4.0-1	R	Test auxiliary functions (cf. 2.1.5).
2.4.5	**C**	**2.4.5 SOC Commissioning**
2.4.5.0-1	R	Test pre-processing tools with instrument commissioning data. Commission the SOC in coordination with the OGS.
2.5	**C**	**2.5 Interface Requirements**
2.5.0-1	R	Support the definition of the interface to the Solar Orbiter Operational Ground Segment (OGS), in coordination with the OGS and to be consistent with the MIRD and the SOIA.
2.5.0-2	R	Define the interface between the SOC to the Instrument Teams for planning purposes. *Note: This is an Interface Control Document (ICD) between PI teams and SOC.*
2.5.0-3	R	Define the interface between the SOC to the Instrument Teams for data archive and retrieval purposes. *Note: This is an ICD between PI teams and SOC.*

3	**C**	**3 Operational Phase Requirements**
3.1	**C**	**3.1 Cruise Phase**

3.1.1	C	3.1.1 Science Operations Planning
3.1.1.0-1	R	Establish the long-term instrument operations planning in accordance with the science activity plan agreed by the SWT and supported by the PI teams.
3.1.1.0-2	R	Ingest the planning files provided by OGS to be used in the science planning process.
3.1.1.0-3	R	Plan the execution of agreed, PI-requested payload operations of in-situ instruments.
3.1.1.0-4	R	Support and coordinate checkout periods of remote-sensing instruments, which are planned as if they were regular RS operations.
3.1.1.0-5	R	Support the cruise activities by using the Science Operations Planning Tool to support high-priority science campaigns (cf. Sect. 2.3.3 in text).
3.1.1.0-6	R	Implement a public web page that allows spacecraft and planet positions to be displayed for user-specified time intervals.
3.1.1.0-7		Pre-process a reduced set of science telemetry (science telemetry downlinked with low latency) with the use of PI-provided quicklook software to convert data with specific telemetry Application Process IDs (APIDs) into usable data for SOC/SOWG planning purposes.
3.1.2	C	3.1.2 Command Requests Preparation
3.1.2-1	D	Prepare and validate the Instrument Teams' operations requests (by checking for resource and constraints violations) and prepare Payload Operations Requests (PORs) and, when required, Pointing Requests (PTRs), for uplink by the OGS.
3.2	**C**	**3.2 Nominal Mission Phase Operations**
3.2.1	C	3.2.1 Science Operations Planning
3.2.1.0-1	R	Ingest the planning files provided by OGS to be used in the science planning process.
3.2.1.0-2	R	Establish the actual instrument science plans in accordance with the all mission planning cycles. *Note: The definition of scientific priorities is part of the PS and SWT activities.*
3.2.1.0-3	R	Verify the resource allocations to the instruments as function of the different mission phases and instrument operational modes using inputs provided by OGS and the Instrument Teams.
3.2.1.0-4	R	Support the RS instruments characterization and calibration plans.
3.2.1.0-5	R	Maintain the Science Operations Planning Tool.

3.2.1.0-6	R	Maintain the Visual Context Data Browsing and Selection Tool and make it available to the Instrument Teams and all other parties involved in the instrument science operations per download via ESA web pages.
3.2.1.0-7	R	Provide support for selective telemetry downlink in science operations planning and SSMM management for those periods and circumstances where mission design makes it possible (i.e. when compatible with SSMM unused storage volume, available TM downlink bandwidth and any other requirements on instrument operations and data return).
3.2.2	C	3.2.2 Command Requests Preparation
3.2.2.0-1	R	Prepare and validate the Instrument Teams' operations requests (by checking for resource and constraints violations) and prepare Payload Operations Requests (PORs) and, when required, Pointing Requests (PTRs), for uplink by the OGS.
3.2.3	C	3.2.3 Monitoring
3.2.3.0-1	R	Retrieve all satellite and instrument data including the auxiliary data from the OGS.
3.2.3.0-2	R	Support the Instrument Teams in assessing the performance of the payload.
3.2.3.0-3	R	Support the Instrument Teams in identifying payload anomalies (e.g. incorrect instrument settings)
3.2.4	C	3.2.4 Archiving and Data Processing
3.2.4.0-1	R	Ingest Level 0 TM data into the archive.
3.2.4.0-2	R	Ingest Level 1-3 data products into the archive based on agreements with individual PI teams.
3.2.4.0-3	R	Process the auxiliary data provided by OGS for use by the scientific community.
3.2.5	C	3.2.5 Auxiliary Functions
3.2.5.0-1	R	Support the Instrument Teams during in-flight calibration campaigns on SOC related items (e.g. data retrieval, data formatting).
3.2.5.0-2	R	Support the resolution of anomalies and the optimisation of instrument parameters (excluding the on-board software) in a joined effort between the Instrument PIs, the OGS, the PS and their respective teams.
3.2.5.0-3	R	Generate SOC anomaly reports when payload and ground segment anomalies are detected within the SOC. *Note: Anomalies in the spacecraft, payload or operational ground segment that are detected by the SOC shall be reported to the OGS for*

		tracing in their anomaly reporting process.
3.2.5.0-4	R	Receive and assess anomalies reports raised by the OGS.
3.2.5.0-5	R	Include and verify in the SOC system any relevant instrument database update.
3.3	**C**	**3.3 Archiving Requirements**
3.3.0-1	D	In this section, all requirements on data archiving during the whole Solar Orbiter mission starting from the calibration of instruments on ground through in flight calibration and science data generation are summarized.
3.3.0-2	R	In collaboration with the PS, define and implement the long-term archive concept for the SO instruments such that it is compatible with the evolution of ESAC architecture for scientific missions archives by launch.
3.3.0-3	R	Define and implement a data retrieval system for internal (Instrument Teams) and external users to acquire data from the SO archive, according to the science data rights defined in the Science Management Plan.
3.3.0-4	R	Archive instrument data from all mission phases (for pre-launch calibration data pending clarification of delivery by PI teams in EID-A and EID-Bs).
3.3.0-5	R	Archive instrument and spacecraft auxiliary data relevant to science data analysis into the long-term archive according to the guidelines agreed with the PIs.
3.3.0-6	R	Maintain the data retrieval system for external users and provide a helpdesk (during normal working hours) to support solving problems related to (a) the usage of the data retrieval system and (b) retrieving actual data.
3.3.0-7	R	It is required that the SOC is capable of archiving all calibration data (on ground, cruise, science phase) and science data when they become available (for pre-launch calibration data pending clarification of delivery by PI teams in EID-A and EID-Bs).
3.3.0-8	R	To provide support, when necessary and on a best-effort basis, to the PS and PI teams in the definition and creation of the scientific datasets resulting from external processing pipelines for archiving and distribution to the scientific community.
3.3.0-9	R	Assist NASA in setting up a copy of the science part of the archive.

4	**C**	**4 Post-Operations Phase Requirements**

4.1	C	4.1 Archiving
4.1.0-1	R	Ingest Level 1-3 data products into the archive based on agreements with individual PI teams.
4.1.0-2	R	Archive instrument data from all mission phases.
4.1.0-3	R	Archive instrument and spacecraft auxiliary data relevant to science data analysis into the long-term archive according to the guidelines agreed with the PIs.
4.1.0-4	R	Maintain the data retrieval system for external users and provide a helpdesk to support solving problems related to (a) the usage of the data retrieval system and (b) retrieving actual data.
4.1.0-5	R	To provide support, when necessary and on a best-effort basis, to the PS and PI teams in the definition and creation of the scientific datasets resulting from external processing pipelines for archiving and distribution to the scientific community.

5	**C**	**5 Performance, Availability & Security Requirements**
5.1	**C**	**5.1 Science Operational Performances**
5.1.0-1	R	Provide re-planning inputs to the OGS as defined in the SOIA.
5.1.0-2	R	During RSWs in which VSTP is performed, support the turn-around times required by the VSTP cycle.
5.1.0-3	R	Support the detection of science operational anomalies (e.g. wrong instrument setting) and report and coordinate with OGS and PIs for recovery and re-planning inputs (updated parameter inputs) to the OGS (within 1-3 working days during NMP, 5 working days during CP).
5.1.0-4	R	Store Level 0-3 products in the archive and make them publicly available after the proprietary period (3 months after receipt of Level 0 data by the PI teams).
5.2	**C**	**5.2 Availability**
5.2.0-1	R	Define, implement and provide a minimum SOC system, with details to be agreed between the OGS, SOC, PS, and PIs, for ground-segment-level tests TBD months before launch. *Note: Interface tests OGS-SOC are planned in the last TBD months before launch. At this stage the TM processing/archiving function of the SOC can be used with OGS.*
5.2.0-2	R	Define, implement and provide a minimum operational SOC system, i.e. one that supports regular in-situ operations and remote-sensing checkout windows, with details to be agreed between the OGS, SOC,

		PS, and PIs, for ground-segment-level tests TBD months before launch. *Note: The requirement for the readiness date for a minimum operational SOC system is later than the date for a minimum SOC system (Req. 5.2.0-1), but should in any case be before launch, given that regular in-situ operations start at L+97 days (start of CP).*
5.2.0-3	R	Design, implement and operate an SOC with a 95% time availability of the data distribution system to the Instrument Teams, within normal working hours (5 days/week, 8h/day, except for VSTP periods during RSWs – see next requirement).
5.2.0.4	R	During RSWs in which VSTP is performed, provide the 7 days/week availability required by the VSTP cycle.
5.2.0-5	R	Design, implement and operate an SOC archive that makes the whole data volume (Level 0-3) publicly available after the proprietary period.
5.2.0-6	R	Ensure that SOC facilities, procedures & services are validated and ready to support the mission TBD months before start of nominal science operations.
5.2.0-7	R	Define and implement contingency arrangements to cover critical unavailability of any aspect of the SOC (e.g. in case of fire) in line with the disaster recovery plans of the OGS.
5.3	**C**	**5.3 Security**
5.3.0-1	R	Ensure all aspects of the SOC system security during development and operations (this includes security of data, software and access to SOC facilities).

6	**C**	**6 Validation & Verification Requirements**
6.0-1	R	Define and maintain an overall SOC Verification, Validation & Integration Plan (SVIP), covering at least: • SOC system test approach (including software test approach), as defined by the pre-launch and post-launch implementation plan • Support of the OGS/SOC I/F testing before launch (DDS interface tests) • Support of the OGS/SOC I/F testing in preparation of the nominal science phase (including relevant OGS SOVs) • Tests of interfaces between SOC and Instrument Teams • Performance of storage and long-term data archives
6.0-2	R	Support the production of the overall test plans and procedures

		(prepared by the OGS) for the OGS System Operations Validation tests, which include the SOC.
6.0-2.1	R	Review the Instrument User Manuals generated by the Instrument Teams to ensure completeness and up to date status.
6.0-3	R	Support instrument calibration campaigns and instrument pre-launch reviews to gain knowledge on instrument operations, ensure Instrument-SOC interface validation, and support science performance validation.
6.0-4	R	Support any OGS System Operations Validation Tests that include the SOC.

7	**C**	**7 Management Requirements**
7.1	**C**	**7.1 Definition of Responsibilities**
7.1.1	C	7.1.1 Development Phase Responsibilities
7.1.1.0-1	R	In cooperation with the Project Scientist, the Science Ground Segment Development Manager (DM) shall be responsible: • For the definition and validation of the entire SGS system, i.e. including external interfaces. • For the implementation of the SOC, i.e. the ESA part of the SGS.
7.1.1.0-2	R	The DM shall be responsible for integration and testing of additional software packages developed under PI responsibility that will be used in the SOC, e.g. for quick-look data processing, having been delivered tested and documented to agreed standards.
7.1.1.0-3	R	The DM shall establish a dedicated team to fulfil the requirements stated is this document.
7.1.1.0-4	R	The SOC team shall establish and maintain the overall system design, including the definition of the hardware architecture and the software development environment.
7.1.1.0-5	R	The SOC shall implement the use of the relevant (tailored) ESA standards.
7.1.1.0-6	R	The SOC shall define guidelines and standards for, and monitor the development of the software (architecture, standards, commonality, configuration control).
7.1.1.0-7	R	The SOC shall provide and validate all software necessary to support SGS activities during development and operations phases.
7.1.1.0-8	R	The SOC shall support the development of external ICDs involving

		SOC and approve them (e.g. PLID and DDID).
7.1.1.0-9	R	The SOC shall define and maintain the ICD between the Instrument Teams and the SOC.
7.1.1.0-10	R	Provide support to the ESA and NASA Project Scientists on tools and tasks under SGS responsibility (e.g. SSMM usage).
7.1.1.0-11	R	Support the ESA and NASA Project Scientists in following the development of the scientific instruments and whether their operational concept is compatible with the SO resources. Support the PSs in the interface work with the Instrument Teams by participating in relevant team meetings (reviews, definition of science operation interfaces, etc.) and by reviewing of relevant documents.
7.1.1.0-12	R	Support the PSs in preparing the SGS inputs required for the definition of science-related documents and Calls for Proposals.
7.1.1.0-13	R	Support the PSs in liaising with the Instrument PIs and the instrument team in the development and operational phase of the mission on science operational matters.
7.1.1.0-14	R	Support the PSs in providing overall science coordination. Create and analyze ideas to optimize the science return.
7.1.1.0-15	R	Support the PSs in conducting Science Working Team meetings in regular intervals, where related to the definition and planning of observations/operations and in the area of archiving.
7.1.1.0-16	R	Assure that there is a good understanding within the SOC of the instrument commanding system from the beginning to ensure effective development of the SOC and to acquire and maintain knowledge of instruments' scientific performance, instrument operations and science data products. Assure instrument calibration and operations knowledge preservation based on experience gained and best practices by knowledge management and documentation with adequate support from the Instrument Teams. Become familiar with the analysis of the instrument science datasets.
	C	7.1.2 Near Earth Commissioning Phase Responsibilities
7.1.2.0-1	R	During Near Earth commissioning phase, the DM shall be responsible for the generation of instrument operations plans, while the coordination and execution of the ground segment activities will be under MOC responsibility during this phase (the SOC will be commissioned during NECP).
7.1.3	C	7.1.3 Science Operations Responsibilities
7.1.3.0-1	R	During the science phase, the PS shall be informed of and directly

		involved in all communications on science topics.
7.1.3.0-2	R	During the science phase, the SGS Operations Manager shall be responsible for the overall coordination and execution of the science ground segment operations.
7.1.3.0-3	R	The SOC shall elaborate the science operations timelines and provide visibility to the PS.
7.1.3.0-4	R	The SOC shall submit any change requests to the baselined science operations timeline to the PS for approval.
7.1.3.0-6	R	The SOC shall support Science Operations Working Group meetings.
7.1.3.0-7	O	The SGS Operations Manager shall take over the responsibility and the maintenance of the Operational Knowledge Management System as prepared by the SO Project Team, while the PS is responsible for the payload science knowledge management.
7.2	C	7.2 Project Control
7.2.0-1	R	Implement project control systems and procedures focusing on the definition, maintenance and reporting of schedule, costs and configuration information.
7.2.0-2	R	Establish and maintain the overall SGS development and implementation schedule.
7.3	**C**	**7.3 Planning Documentation**
7.3.0-1	R	A Science Implementation Plan (SIP) shall to be issued in response to the requirements specified in this document.
7.3.0-2	R	The SIP shall be approved by the SO Project Manager and Project Scientist and agreed by the OGS and SGS Management.
7.3.0-3	R	The contents of the SIP shall outline: • Assumptions on which the implementation is based • Science operations and the science archiving proposal • SOC development, operations and post-operations phase activities • SIP-to-SIRD compliance • Management structure of the SOC, the assigned responsibilities, project control, progress monitoring scheme, meetings and reviews • Product and documentation trees • Top-level Work Breakdown Structure • Overview of the development schedule • Deliverables and receivable items • Approaches to product and quality assurance, configuration control management, development

		management and risk management • Verification and validation strategy
7.4	**C**	**7.4 Documentation Requirements**
7.4.0-1	R	For each interface, an ICD shall be written which shall be approved and signed both by the representative of the SGS and the representative of the other side of the interface.
7.4.0-2	R	The document numbering and file names shall follow the standards defined within SRE-O for use by SRE SGSs both in the development and operational phases.
7.4.0-3	R	All documents produced by the SGS shall be stored in one central place accessible via a password-protected internet page. This web site shall be easily accessible from the World Wide Web with access rights to be agreed with the PM/MM and PS.
7.5	**C**	**7.5 Reporting**
7.5.0-1	R	The status of the SOC shall be reported to SRE-PS (during the development phase) and SRE-O (during the operations phase) on a three-monthly basis. A status report shall be circulated before each meeting.
7.5.0-2		During the science operations and post-operations phases, the SOC shall report on a monthly basis on the following topics: • Status of the overall SGS system • Status of the Planning/Commanding subsystem • Status of the Planning/Commanding database • Operational activities • Status of the Science Operations Planning • Status of the Quick-look system • Documentation • Management issues (staff, contracts, resources, status of action items, etc.)
7.6	C	7.6 Reviews
7.6.0-1	R	The SOC shall support all mission-level reviews.
7.6.0-2	R	The SOC shall support all Ground Segment reviews and ensure timely implementation of any review recommendations applicable to the SOC.
7.6.0-3	R	The SOC shall support all Payload Reviews.

5 ACRONYMS

AD	Applicable Document
AIV	Assembly, Integration, and Verification
APE	Absolute Pointing Error
APID	Application Process ID
CaC	Cost at Completion
DDID	Data Delivery Interface Document
DM	Development Manager
DDS	Data Disposition System
Delta DOR	Delta Differential One-way Ranging
DSN	Deep Space Network
ECSS	European Cooperation for Space Standardization
EID-A	Experiment Interface Document, Part A
EID-B	Experiment Interface Document, Part B
EMP	Extended Mission Phase
EPD	Energetic Particle Detector
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESOC	European Space Operations Centre
EUI	Extreme UV Imager
FITS	Flexible Image Transport System
FCP	Flight Control Procedure
ICD	Interface Control Document
IOCR	In-Orbit Commissioning Review
IOR	Instrument Operations Request
IOS	Instrument Operations Scientist
IS	In-Situ
LEOP	Launch and Early Orbit Phase
MAG	Magnetometer
METIS	Multi-Element Telescope for Imaging and Spectroscopy
MGS	Mission Ground Segment
MIRD	Mission Implementation Requirements Document
MOC	Mission Operations Centre
NAIF	NASA's Navigation and Ancillary Information Facility
NAIF SPICE	NAIF Observation Geometry System for Robotic Space Science Missions
NECP	Near-Earth Commissioning Phase
NMP	Nominal Mission Phase
OBCP	On-board Control Procedures
OGS	Operational Ground Segment
OIRD	Operations Interface Requirements Document
OPS-PS	Operations Department Solar Orbiter
PHI	Polarimetric and Helioseismic Imager
PI	Principal Investigator
PLID	Payload Interface Document
PM	Project Manager

POR	Payload Operations Request
PS	Project Scientist
PTR	Pointing Request
RD	Reference Document
RPW	Radio and Plasma Wave Instrument
RS	Remote-Sensing
RSSD	Research and Scientific Support Department
RSW	Remote-Sensing Window
SciRD	Science Requirements Document
SDHAS	Science Data Handling and Archiving System
SGS	Science Ground Segment
SIP	Science Implementation Plan
SIRD	Science Implementation Requirements Document
SMP	Science Management Plan
SO	Solar Orbiter
SOIA	Solar Orbiter Science Operations Implementation Agreement
SOC	Science Operations Centre
SoloHI	Solar Orbiter Heliospheric Imager
SOWG	Science Operations Working Group
SPICE	Spectral Imaging of the Coronal Environment
SRE-PS	Solar Orbiter Project Team
SRE-SM	Solar Systems Missions Division of SRE
SRE	Science and Robotic Exploration Directorate
SRD	System Requirements Document
SSC	Science Steering Committee
SSMM	Solid State Mass Memory
STIX	Spectrometer/Telescope for Imaging X-rays
SVIP	SGS Verifying, Validation & Integration Plan
S/W	Software
SWA	Solar Wind Analyser
SWT	Science Working Team
TBC	To Be Confirmed
TBD	To Be Determined
TM/TC	Telemetry and Telecommand