SOLAR ORBITER

RPW Operation Centre

ROC Concept and Implementation Requirements Document

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Change Record

Issue	Rev.	Date	Authors	Modifications
0	0	17/09/2014	Yvonne de Conchy	First draft
0	1	06/01/2015	Xavier Bonnin	Second draft
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1	0	24/06/2015	Xavier Bonnin	First release
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1	4	17/11/2017	Xavier Bonnin	Major modifications: • Adding section about the Solar Orbiter Ground Segment design • Remove sections about ROC activities and add sections about ROC responsibilities • Upgrades the implementation requirements

Acronym List

Acronym	Definition
AIT	Assembly Integration Test
AIV	Assembly Integration Validation
ANT	(Electrical) antennas
APID	Application Process ID
CDPP	Centre de Données de Physique des Plasmas
CIRD	Concept and Implementation Requirements Document
CNES	Centre National d'Etudes Spatiales
CNRS	Centre National de Recheche Scientifique
CoI	Co Investigator
CP	Cruise Phase
DDS	Data Dissemination System
DPU	Digital Processing Unit
EDDS	EGOS Data Dissemination System
EID-A	Experiment Inteface Document - Part A
EMP	Extended Mission Phase
EPD	Energetic Particles Detector
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESOC	European Space Operation Centre
FDIR	Failure Detection Isolation and Recovery
FOP	Flight Operation Plan
GIGL	Groupe d'Informatique Générale du LESIA
HFR	High Frequency Receiver
HK	Housekeeping parameters
IAP	Institute of Atmospheric Physics
ID	Identifier
IOR	Instrument Operation Request
IT	Instrument Team
IOP	Instrument Operation Planner
IOR	Instrument Operation Request
LEOP	Launch & Early Operations Phase
LESIA	Laboratoire d'Etudes Spatiales et d'Instrumentations en Astrophysiques
LFR	Low Frequence Receiver
LLVM	Low Latency Virtual Machine
LPC2E	Laboratoire de Physique et Chime de l'Environnement et de l'Espace
LPP	Laboratoire de Physique des Plasma
LVPS-PDU	Low Voltage Power Supply - Power Distribution Unit
MDOR	Memory Direct Operation Request

MOC	Solar Orbiter Mission Operation Centre
NECP	Near Earth Commissioning Phase
NMP	Nominal Mission Phase
OGS	Operations Ground Segment
OS	Operating System
PDOR	Payload Direct Operation Request
PI	Principal Investigator
PMP	Project Management Plan
POR	Payload Operations Request
RFP	RPW Flight Procedure
RGS	RPW Ground Segment
ROC	RPW Operation Centre
RPW	Radio and Plasma Waves
RSR	RPW Science Requirements document
RSS	ROC Software System
RSW	Remote-sensing Window
SDP	Software Development Plan
S/C	Spacecraft
S/W	Software
SBM	Selective Burst Mode
SCM	Search Coil Magnetometer
SGS	Science Ground Segment
SGSE	Software Ground Support Equipment
SIRD	Solar Orbiter Science Implementation Requirements Document
SOC	Solar Obriter Science Operation Centre
SOOP	Solar Orbiter Operation Plan
SOV	System Operation Validation
SOWG	Science Operations Working Group
SSL	Space Science Laboratory
SSMM	Solid State Mass Memory
SVT	System Validation Tests
TC	Telecommand
TDS	Time Domain Sampler
TM	Telemetry
TNR	Thermal Noise Receiver
VM	Virtual Machine

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1 GENERAL

1.1 Scope of the Document

The ROC Concept and Implementation Requirements Document (CIRD) presents the RPW Operations Centre (ROC) objectives, overall organization, responsibilities and design.

It also addresses the top-level requirements about to the ROC implementation, w.r.t. the higher level requirements at mission and instrument levels.

Especially, the CIRD must comply the requirements defined in the Experiment Interface Document Part A (EID-A) [AD1]. It is also expected to be consistent with the Solar Orbiter Science Management Plan (SMP) [RD8], the Solar Orbiter Science Implementation Requirements Document (SIRD) [RD9] and the RPW Science Requirements document (RSR) [RD12].

The ROC is in charge of the ground segment activities for the Radio and Plasma Waves (RPW) instrument [RD1] on-board Solar Orbiter spacecraft (S/C).

1.2 Applicable Documents

This document responds to the requirements of the documents listed in the following table:

Mark	Reference/Iss/Rev	Title of the document	Authors	Date
AD1	SOL.EST.RCD.0050/05/00	Experiment Interface Document Part A (EID-A)	Erik de Witt	16/03/2015
AD2				

1.3 Reference Documents

This document is based on the documents listed in the following table:

Mark	Reference/Iss/Rev	Title of the document	Authors	Date
RD1	SOLO-RPWSY-IF-55-CNES_0401.pdf/05/02 (=EID-B)	Experiment Interface Document Part B (EID-B) for RPW	RPW Team	29/07/2015
RD2	RPW-SYS-SSS-00013-LES/03/05	RPW Software System Specification	Philippe Plasson	03/06/2015
RD3	SOL-ESC-PL-00001/1/1	Solar Orbiter Mission Implementation Plan	Ignacio Tanco	31/01/2013
RD4	SOL-ESC-IF-05011/1/0	Solar Orbiter Data Delivery Interface Control Document	Luca Michienzi	10/09/2013
RD5	SOL-SGS-ICD-0003/0/2	Solar Orbiter Instrument Operation Request Interface Control Document	Christopher Watson	19/08/2014
RD6	SOL-SGS-TN-0009/2/2	Metadata Definition for Solar Orbiter Science Data	A. de Groof	23/07/2015
RD7	SOL-SGS-ICD-0009/0/3	Solar Orbiter File-Transfer SOC<->Instrument Teams ICD	Emilio Salazar, Christopher Watson	20/01/2017
RD8	SOL-EST-PL-00880/02/02	Solar Orbiter Science Management Plan	Richard Marsden	16/02/2012
RD9	Solar_Orbiter_SIRD_v1.2_DM_2013-03-18	Solar Orbiter Science Implementation Requirements	Daniel Müller	18/03/2013

		Documents (SIRD)		
RD10	SOLO-RPWSY-PT-1235-CNES/1/0	RPW Instrument Calibration Plan	Milan Maksimovic RPW teams	11/12/2015
RD11	RPW-GEN-PLN-00130-LES/02/00	RPW Operations Concept	Milan Maksimovic	08/03/2012
RD12	RPW-SYS-SRD-00040-LES/02/01	RPW Science Requirements	Milan Maksimovic	16/06/2015
RD13	RPW-SYS-SOW-001518-LES/01/01	RPW Science Performance	Milan Maksimovic	12/06/2015
RD14	SOL-SGS-PL-0009/0/2	Solar Orbiter Archive Plan	Pedro Osuna	01/07/2015
RD15	SOL-ESC-PL-10001/1/2	Solar Orbiter FOP Preparation Plan	Ignacio Tanco	18/01/2017
RD16	ROC-GEN-SYS-CVM-00049-LES/01/00	ROC top-level traceability matrix	Xavier Bonnin	17/11/2017

1.4 About this document

1.4.1 Access policy

This document is accessible without any restriction.

Any modification of the CIRD requires formal approval of the RPW Ground Segment Project Manager before publication.

2 INTRODUCTION

2.1 RPW Science objectives

RPW will make key measurements in support of the first three, out of four top-level scientific questions, which drive Solar Orbiter overall science objectives:

- How and where do the solar wind plasma and magnetic field originate in the corona?
- 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?

Here is the summary of the specific RPW Science Objectives.

Solar & Interplanetary Radio Burst

- What is the role of shocks and flares in accelerating particles near the Sun?
- How is the Sun connected magnetically to the interplanetary medium?
- What are the sources and the global dynamics of eruptive events?
- What is the role of ambient medium conditions on particle acceleration and propagation?
- How do variations and structure in the solar wind affect low frequency radio wave propagation?

Electron density & temperature measurements with the Quasi-Thermal Noise spectroscopy

- Precise measurement of both the electron density and temperature, with accuracies respectively of a few % and around 10 %, at perihelion.

- Study the non-thermal character of the electron distributions at perihelion.

Radio emission processes from electron beams: Langmuir waves and electromagnetic mode conversion

- Measurements for the first time in the Solar Wind of both the electric and magnetic field waveforms at high time resolution (up to 500 kSs).
- Study of the mode conversion from Langmuir to electromagnetic waves.
- Study of the energy balance between electron beams, Langmuir waves and e.m. radio waves at several radial distances

Solar wind microphysics and turbulence

- Measure of the waves associated with the plasma instabilities that are generated by temperature anisotropies in the solar wind.
- First DC/LF electric field measurements in the inner heliosphere and over a large radial distance in the solar.

Shocks, Reconnection, Current Sheets, and Magnetic Holes

- Identification & study of the reconnection process in current sheets with thickness down to the ion scales and smaller.
- Determination of the interplanetary shock structure down to the spatial and temporal scales comparable and smaller than the typical ion scales.
- Determination of different particle energisation mechanisms within shocks and reconnection regions.
- Distinguish different radio burst generation mechanisms.

Interplanetary Dust

- Determination, in combination with the EPD instrument, the spatial distribution, mass and dynamics of dust particles in the near-Sun heliosphere, in and out of the ecliptic.

To cover its specific Science Objectives, RPW will measure magnetic and electric fields at high time resolution using a number of sensors, to determine the characteristics of electromagnetic and electrostatic waves in the solar wind. More precisely, RPW will:

- Make the first-ever high accuracy, high-sensitivity and low noise measurements of electric fields at low frequencies (below ~1 kHz) in the inner Heliosphere.
- Measure the magnetic and electric fields of the solar wind turbulence with high sensitivity and dynamic range along the spacecraft trajectory.
- Store high-resolution data from scientifically interesting regions such as in-situ shock crossings, in-situ Type III events and others.
- Measure the satellite potential with high temporal resolution permitting to estimate the density fluctuations in the solar wind and allowing higher accuracy particle instrument measurements.
- Measure the quasi thermal noise and Langmuir waves around the local plasma frequency

- Measure for the first type the high frequency magnetic counterpart of Langmuir waves associated with in-situ Type III bursts
- Observe the solar and interplanetary radio burst
- Observe the radio counterpart of dust particle impacts
- Detect on-board in-situ shock crossings and store the corresponding data
- Detect on-board in-situ Type III events and store the corresponding data

2.2 RPW instrument

RPW will provide *in situ* and remote sensing measurements of both electrostatic and electromagnetic fields and waves in a broad frequency range, typically from a fraction of Hertz to a few tens of MHz.

RPW is developed by a consortium composed of the following institutes/agencies:

- LESIA, Observatoire de Paris, CNRS, UPMC, Université Paris Diderot, Meudon, France
- CNES, Centre Spatial de Toulouse, France
- LPP, CNRS, Ecole Polytechnique, UPMC, Université Paris Sud, Palaiseau, France
- LPC2E, CNRS, Université d'Orléans, Orléans, France
- IAP (Institute of Atmospheric Physics), Academy of Sciences, Prague, Czech Republic
- Astronomical Institute (AsI) of the CSRC, Prague, Czech Republic
- IRF-U (Swedish Institute of Space Physics, Uppsala) and KTH (Royal Institute of Technology, Stockholm) Sweden
- Space Research Institute (IWF), Gräz, Austria
- Space Sciences Laboratory (SSL) of the University of California Berkeley

In addition, the SSL is strongly contributing to the RPW science through the science synergy with the FIELDS instrument on the NASA Solar Probe Plus mission.

Table 1 presents the instrument sub-systems.

Name	Short name	Description	Responsible
Time Domain Sampler	TDS	TDS captures waveform up to 500 kSPS. LFR redundancy module	IAP
Thermal Noise and High Frequency Receivers	TNR-HFR	Electron measurements at the local plasma frequency and remote detection of radio emissions. TNR-HFR will provide electric power spectral densities from 4 kHz up to 16 MHz and magnetic power spectral densities from 10 kHz up	LESIA

		to 500 kHz.	
Low Frequency Receiver	LFR	LFR covering both in-situ electric and magnetic measurements from DC to about 10 kHz. LFR will provide both waveform and power spectral densities in this frequency range.	LPP
Biasing unit	BIAS	BIAS will allow DC electric measurements. The BIAS drive a constant current to the electric antennas allowing reliable DC/LF electric field and satellite potential measurements.	IRF/KTH
Digital Process Unit	DPU	DPU will handle commands, data and communication with S/C.	LESIA, IWF
Low Voltage Power Supply - Power Distribution Unit	LVPS-PDU	Since the LVPS unit produces the secondary voltages, the PDU distributes the output voltages toward the various RPW subunits.	AsI
Search Coil Magnetometer	SCM	The SCM is an inductive magnetic sensor. It is made of a core in a high permeability material (ferrite or perm-alloy) on which are wound a main coil with several thousand turns and a secondary coil with a few turns.	LPC2E
Electrical antennas, Pre-Amplifiers	ANT, PA	Each ANT monopole serves as a simple voltage sensor. At low frequencies, an antenna is coupled to the local plasma potential through a photoelectron sheath. Successful measurement of DC/low frequency plasma electric fields requires that the antenna be biased (as described below). At sufficiently high (radio) frequencies, an antenna behaves as if in a vacuum. Each monopole is connected to the inputs of both: A low frequency and high frequency preamplifiers.	CNES, SSL

Table 1. RPW sub-systems.

2.3 Solar Orbiter mission overview

2.3.1 Solar Orbiter mission phases

Erreur ! Source du renvoi introuvable. presents an overview of the Solar Orbiter mission timeline.

The mission has five phases for an expected total duration of 10.35 years:

- The Launch and Early Operations Phase (LEOP), starting at launch and during 7 days. It is reserved for critical platform operations. Especially the Boom and RPW electrical antennas (ANT) will be deployed during this phase.
- The Near-Earth Commissioning Phase (NECP), following the LEOP and lasting 90 days. The payload is switched on and characterized during this phase.
- The Cruise Phase (CP), which lasts ~2.8 years. Only the in-situ payload will be continously operational during this phase. The remote-sensing payload will be on during specific check-out windows.
- The Nominal Mission Phase (NMP) will lasts around 5 years, when the in-situ payload will be continously on and the remote-sensing payload will be on during specific windows, named "Remote-sensing Windows" (RSW). 3 RSW per orbit is planned.
- The Extended Mission Phase (EMP) is planned to last 2.5 years.

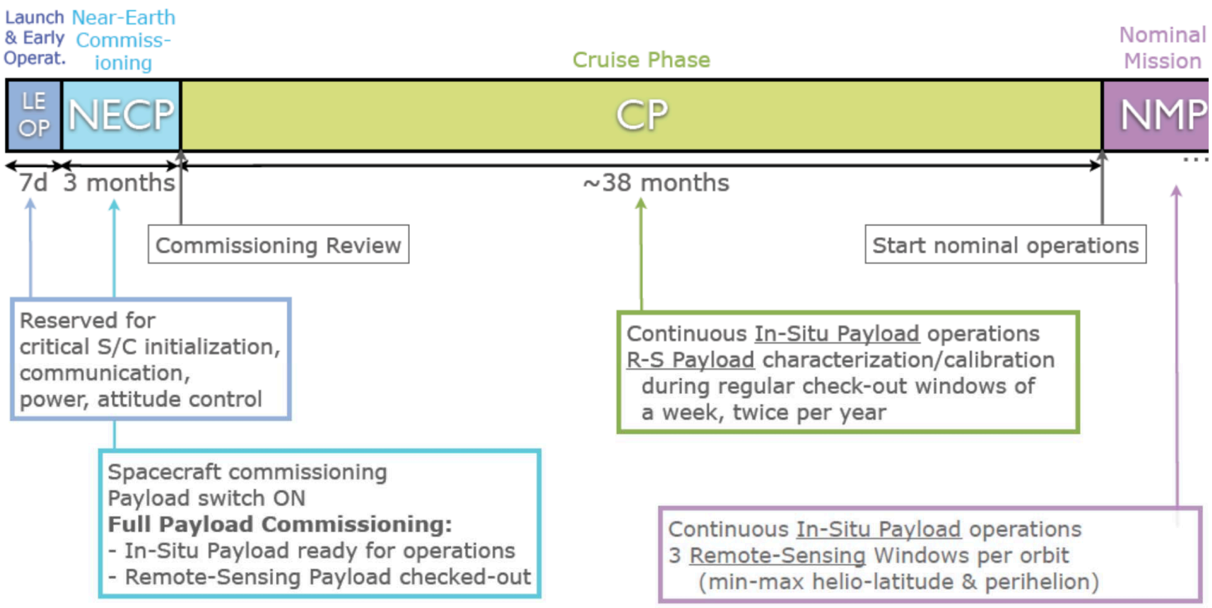

Figure 1. Solar Orbiter mission phases and main operations timeline.

The RPW Ground Segment Project Manager and PI shall ensure that the RPW operation planning is in agreement with this mission timeline.

Besides, the CNES will be in charge of supervizing instrument validation activities until the end of the NECP.

2.3.1 Solar Orbiter mission operations concept and plan

The mission operations concept and plan for Solar Orbiter are respectively presented in [RD9] and [RD3].

3 SOLAR ORBITER GROUND SEGMENT DESIGN OVERVIEW

3.1 Ground segment overview

The Ground Segment for Solar Orbiter in the operational configuration consists of the following elements:

- The Operational Ground Segment (OGS) that includes the Mission Operations Centre (MOC) located at ESOC and the Ground Stations and Communication Network (ESTRACK).
- The Science Ground Segment (SGS) that includes the Science Operations Centre (SOC) located at ESAC and the PI facilities used to manage their respective instruments and perform data processing.

Figure below shows the main components of the SGS and the OGS, and the interactions between them.

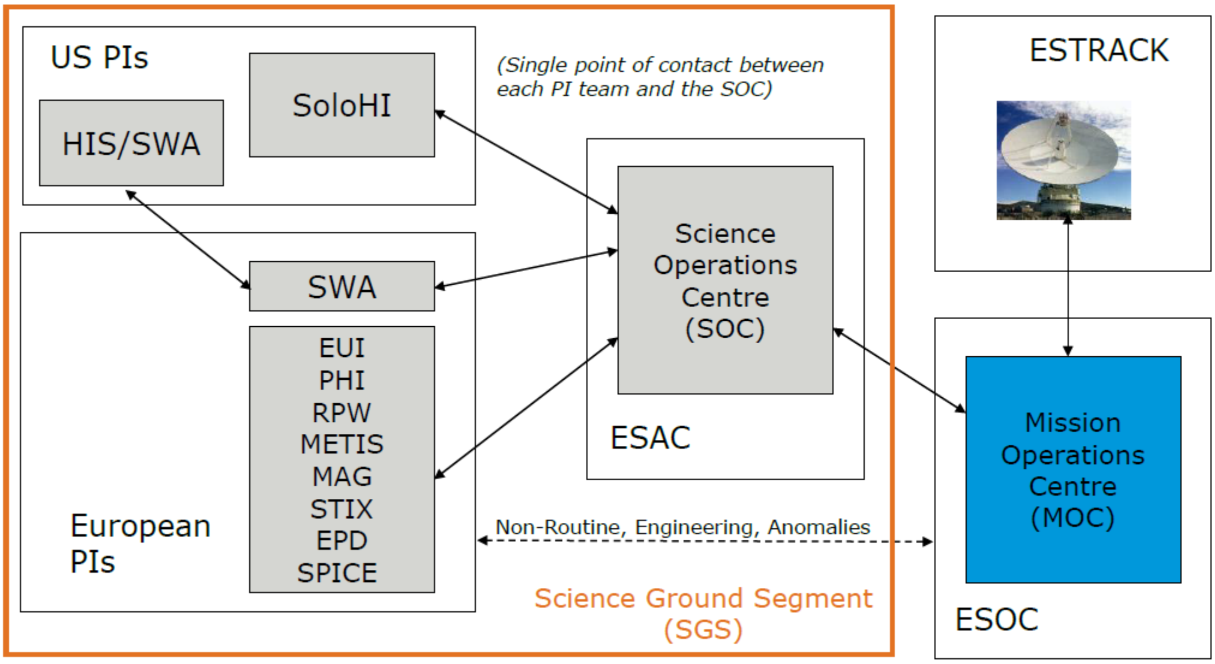

Figure 2. A schematic drawing of the SGS and OGS main components.

3.2 Mission Operation Centre (MOC)

The MOC is a part of the OGS, responsible for all mission operations planning, execution, monitoring and control activities [RD3].

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

- Overall mission planning
- Provision of instrument raw data, spacecraft housekeeping and auxiliary data to the SOC and Instrument Teams (IT), via the Solar Orbiter Data Dissemination System (DDS) [RD4] in a timely manner and in an agreed format
- Performing anomaly (out of limit) checks on a set of payload parameters
- Notifying payload anomalies to the SOC/PIs.

Non-routine, engineering and anomalies payload operations are directly managed between the MOC and IT. It concerns more particularly all of the operations before the Cruise Phase (CP).

3.3 Science Operation Centre (SOC)

The SOC is responsible for supporting the planning of science operations and the coordination of the science operations plans of the IT to generate a conflict-free science operational timeline [RD9]. This timeline will be prepared from inputs provided by the Instrument Teams and by the MOC, with feedback to the Science Operations Working Group (SOWG), which is responsible for top-level science operations planning. All nominal instrument planning and commanding activities after commissioning will take place through the SOC.

The instrument operations requests (IOR) generated by the individual PI teams will be collected at the SOC, and merged in a single 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 IT 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.

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 IT. NASA will mirror the Solar Orbiter archive.

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

3.4 RPW Operation Centre (ROC)

The ROC supervizes one the ten Solar Orbiter instrument ground segment. It gathers the functions usually supported by both the operations and data centres for the RPW instrument.

According to [AD1, RD8, RD9, RD10, RD11, RD12, RD13, RD14, RD15], the ROC is expected to:

- Agree on a long-term science activity plan and define the scientific priorities of scientific goals.
- Support the definition of the science operations.
- Provide inputs for the definition and implementation of the science operation planning, data handling and archiving concepts
- Support the definition and implementation of the Solar Orbiter scientific data archive, as part of the pre-launch tasks.
- Supervise the preparation of the instrument operation timelines, in agreement with the planning at the mission level
- Prepare and submit to the MOC the sequences of telecommands (TC) – inside flight procedures - to be used during the mission.
- Prepare and submit the science instrument operation requests to the SOC during the mission
- In case of non-routine/special operations, prepare and submit directly to the MOC the instrument operation requests
- Control and monitor the instrument state during the different phases of the mission
- Monitor and optimize the instrument performances and the science data return
- Maintain the instrument flight software
- Retrieve and process the telemetry (TM) packets for RPW
- Deliver calibrated and high level processing data, including relevant calibration products, to the Solar Orbiter scientific archive within 3-months.
- 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
- Be present at MOC site during the commissioning phase, in order to support MOC in the RPW-related operations.
- Develop, deliver to the CNES AIT/AIV team and maintain a Software Ground Support Equipment (SGSE), in support to the RPW ground calibration campaigns data post-mortem analysis.

Most of the ROC tasks are carried out in close collaboration with the other parties, who have delegated responsibilities for the ground segment and operations.

The ROC is located at the "Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique" (LESIA) at Meudon (France), which is also the RPW PI-ship laboratory.

4 ROC DESIGN OVERVIEW

4.1 RPW ground segment design overview

Figure 3 presents an overview of the RGS design.

As seen in the section 3.1, the ROC will be the main interface with the Solar Orbiter MOC and SOC during the mission. In addition, the ROC will rely on several teams inside the RGS consortium, as explained in the next sections, to achieve its objectives.

It must be noticed that the CNES participation to the RGS activities will end at the beginning of the mission cruise phase.

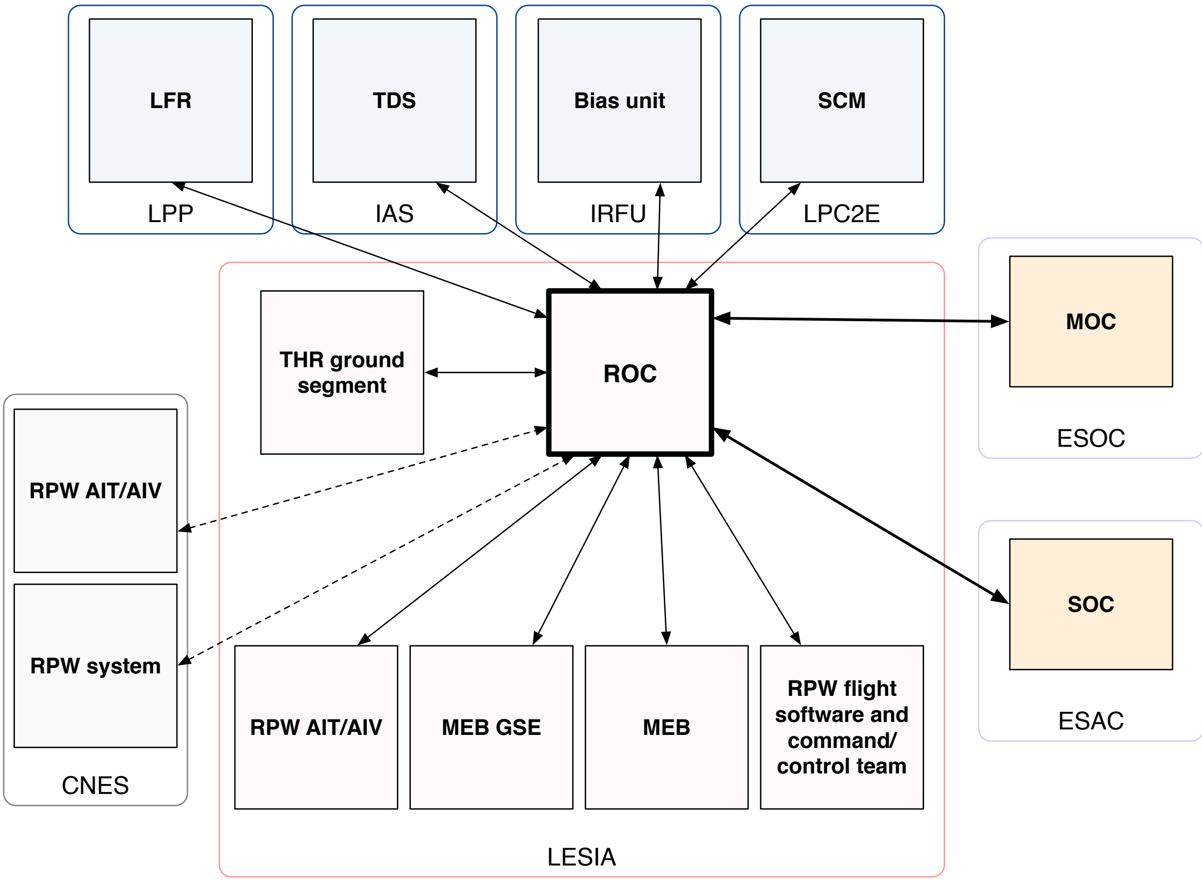

Figure 3. RPW ground segment overall design.

4.2 ROC staff overview

4.2.1 Involved Institutes

The institutes involved in the RGS and the overall functions are given in the table below.

Institute	Overall function
CNES (Toulouse, France)	RPW project manager (until the end of commissioning phase only)
ESAC (Madrid, Spain)	Solar Orbiter Science Operation Centre (SOC)
ESOC (Darmstadt, Germany)	Solar Orbiter Mission Operation Centre (MOC)
IAP (Pragues, Czech Republic)	- TDS Lead CoI-ship laboratory
IRF-U (Uppsala, Sweeden)	- Bias Lead CoI-ship laboratory
IWF (Graz, Austria)	- Antennas calibrations (rheometry)
LESIA (Meudon, France)	- RPW PI-ship laboratory - ROC manager - RPW MEB / PA manager - DPU Flight S/W & control/command manager - TNR-HFR Lead CoI-ship laboratory - In-flight effective antennas calibration - RPW MEB E-GSE/SGSE manager
LPC2E (Orléans, France)	- SCM Lead CoI-ship laboratory
LPP (Palaiseau, France)	- LFR Lead CoI-ship laboratory

Table 2. Institutes involved in the RPW Ground Segment.

4.2.2 Key personnel and teams

Figure below presents the organization of the key personnel and teams involved in the ROC and RGS.

The ROC has five main teams:

- The "RPW data processing team", in charge of the data centre activities, i.e., RPW data retrieving, processing (e.g., TM packet analysis, science data calibration and higer level data production), dissemination and archiving
- The "RPW operations team", in charge of the operations centres activities. It consists of preparing the instrument planning and managing the operations (i.e., requesting sequences of TCs and controlling the instrument state and resources).
- The "Quality/Product Assurance team", which ensure the quality of the software development over the project. This team is led by the RPW Ground Segment Software Product Assurance Manager.
- The "Ground Support Equipment team", which develops and maintains the ROC GSE

In addition to the ROC, the RGS activities are supported by the following teams:

- RPW CNES team, as a RPW project manager entity until the end of the commissioning phase
- RPW MEB team
- RPW sub-systems teams, which regroup people from analysers (TDS, LFR, THR), sensors (ANT, SCM), Bias unit, DPU and PDU.
- RPW flight software & command/control teams
- RPW MEB GSE team
- RPW E-GSE team

The centre is under the responsibility of the RPW Principal Investigator (PI) and the RPW Ground Segment Project Manager.

The responsibilities of the ROC key personnel are given in the section 4.3.

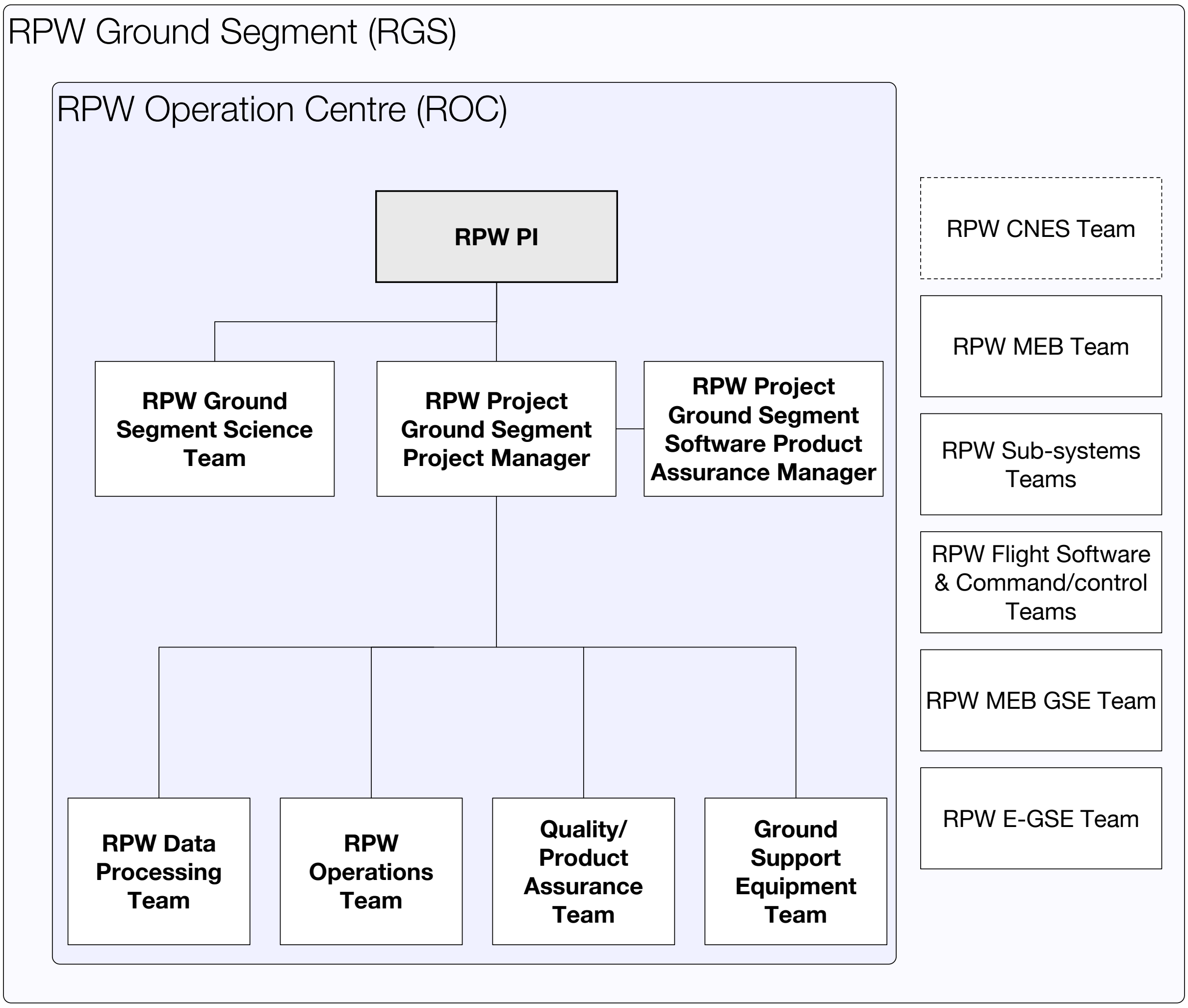

Figure 4. Key personnel and teams involved in the RPW ground segment.

4.3 The ROC infrastructure

The ROC shall rely on a dedicated infrastructure in order to support the RPW ground segment activities. Especially, this so-called ROC Software System (RSS) will have to ensure the following main tasks with minimal human intervention:

- RPW data retrieval and processing (i.e., analysing of TM packet data and production of the higher level science data products)
- RPW science data dissemination and archiving
- RPW data visualization, including HK and event reporting
- Instrument flight procedures edition, pre-validation and submission to MOC
- Instrument science operations requests generation, pre-validation and submission to SOC
- Instrument direct payload/memory operations requests generation, pre-validation and submission to MOC
- Mission planning visualization

- SBM1/SBM2 event data visualization and selection
- Support processing and visualization of RPW GSE data products (i.e., RPW TM/TC packet and E-GSE stimuli data)
- Support simulation of the SBM1/SBM2 event detection algorithms, for validation and detection rate optimization on-ground/in-flight.

The main instance of the RSS will have to be hosted and run at the LESIA site.

5 RESPONSABILITIES

5.1 ROC responsibilities

This section presents the responsabilities, and related tasks, to be supported by the ROC before, during and after the Solar Orbiter mission.

5.1.1 ROC science activity responsibilities overview

The ROC shall support the following science activities:

- Preparing and updating the RPW science activity plan and the resulting operations planning in accordance with the Solar Orbiter mission science and operations plans.
- Producing RPW science data compliant with the data formats defined in [RD6].
- Ensuring the validation and the quality assessment of the RPW science data products.
- Providing full access to the RPW science data products to the RPW Consortium and the SOC.
- Delivering the required RPW science data products at the SOC mission data archive at ESAC and the Centre de Données de Physique des Plasmas (CDPP)[1] at Toulouse (France).
- Ensuring the long-term storage of the RPW science data products archived at the LESIA.
- Ensuring that the documentation related to the science activities at the ROC is up-to-date and available.

5.1.2 ROC operations activity responsibilities overview

As soon as the on-board RPW instrument is swichted-on, the ROC shall ensure the sustainability of the following routine operations activities at the LESIA:

- Monitoring the instrument health and performance.
- Optimizing the instrument performances and science data returns.
- In agreement with the mission operation planning and constraints at the Solar Orbiter level:
  - Preparing and commanding the RPW flight operating modes
  - Controlling the RPW on-board data storage and power consumption
  - Controlling the RPW TM/TC data rate.
- Maintaining and upgrading the on-board DPU software
- Controling the on-board BIAS current
- Optimizing the SBM1/SBM2 algorithms detection rates on-board.
- Managing the SBM1/SBM2 event data selection and downlink

[1] Deliverying data to the CDPP is not a high level requirement.

- Monitoring the instrument science and engineering data validatity and consistency
- Providing full access to its instrument science and engineering data archive to the RPW Consortium and the SOC/MOC.
- Being the main interlocutor with the SOC/MOC in case of non-routine procedures (e.g., anomalies, flight software updates).
- Supervizing the instrument anomaly verification and resolution.
- Ensuring that the documentation related to the RPW instrument operations activities at the ROC is up-to-date and available.

5.1.3 ROC specific pre-launch-related activity responsibilities

Before the launch, the ROC shall:

- Develop, test, validate and deliver to the CNES and LESIA AIT/AIV teams a SGSE in support to the RPW ground calibration validations. The ROC shall also ensure the maintenance and the possible upgrades of this SGSE.
- Develop, test, validate, deliver and run software tools to support the RPW flight software team in the validation of the SBM1/SBM2 detection algorithms. The ROC shall also ensure the maintenance and possible upgrades of these tools after the launch.
- Support the definition of data formats for the science products (contributor in the Modeling and Data Analysis Working Group for Solar Orbiter, MADAWG)
- Define, prepare and validate the RPW science and operations data products.
- Define, prepare and validate the RPW operation planning concept for the different phases of the mission. This task shall be done in agreement with the Solar Orbiter mission planning.
- Prepare the RPW commissioning and cruise phase activities and dedicated support software, data and documentation, including dedicated RPW flight procedures (RFP).
- Specify, design, develop, test, validate, deliver and run facilities related to the RPW operation planning, the instrument monitoring and commanding, and the data processing. These tools shall be fully operationnal at the launch. The maintenance and the possible upgrades are under the responsibility of the ROC.
- Design, develop, test, validate and deliver to the SOC, a Low Latency Virtual Machine (LLVM) for RPW, according to the SOC tevhnical specification and delivery planning.
- Participate to the writing of the RPW user manual to be delivered by the CNES to the MOC before the launch.
- Participate to the System Validation Tests (SVT) and System Operation Validation (SOV) campaigns at the MOC/SOC levels.
- Participate to the SOC<->IT interface tests
- Participate to the MOC<->IT interface tests
- Participate to the Low latency test schedule of the SOC.
- Retrieve and implement the RPW subsystems calibration software that will be developed in the Lead CoI institutes. It concerns more specifically the following sub-systems:
    - ANT Estimation of Leff in BF (SPIS simulation,E=-VXB), estimation of Leff in HF (CNES& Austrian simulations, use of Rolls)
    - SCM Transfer functions & calibrations, merging with MAG data
    - LFR Transfer functions & calibrations
    - BIAS Determination of BIAS current depending on R

- TDS Transfer functions & calibrations
- TNR-HFR Transfer functions & calibrations

5.1.4 ROC specific Launch and Early Operation Phase (LEOP)-related activity responsibilities

The following operations related to RPW will be realized during the LEOP:

- i-Boom deployment
- ANT deployments

RPW will have to be switched-on prior to these operations.

During the LEOP, the i-Boom and ANT deployments will be triggered and controlled by the MOC it-self. Nevertheless, the presence at ESOC of people from the RPW team, ROC and CNES, will be required to monitor operations execution and validate the deployments at the instrument level.

The verifications and validations relative to RPW during these operations will be under the CNES responsibility.

5.1.5 ROC specific Near Earth Commissioning Phase (NECP)-related activity responsibilities

The RPW instrument will be switched-on during the NECP in order to perform:

- The inter-instruments interference campaign
- RPW instrument characterization and performance validation (including TDS/LFR flight software algorithm validation and RPW-PAS filtering tune)

Like for the LEOP RPW-related operations, the RPW team, ROC and CNES, is expected to be at ESOC during the NECP operations to monitor operations.

The verifications and validations relative to the RPW instrument performance durning the NECP will be under the CNES responsibility.

5.1.6 ROC specific Cruise Phase (CP)-related activity responsiblities

During the Cruise Phase (CP), the ROC shall perform the following specific tasks:

- Evaluating, validating and optimizing the RPW on-board data storage, power consumption and TM/TC data rate. This task will be done in collaboration with the SOC team, which in charge of providing to IT periodic information about available data rates (e.g, “corridor” data).
- Evaluating, validating and optimizing the instrument scientific return
- Evaluating, validating and optimizing the on-board SBM1/SBM2 detection algorithms and the SBM1/SBM2 events data downlink management
- Evaluating, validating and optimizing the BIAS current setting
- Participating to the ANT calibration rolls and to the analysis of the resulting data. The roll campaigns shall lead to the delivery of direction and length parameters of the flight effective ANT vectors.
- Preparing, requesting operations related to the SCM noise measurement in the Earth magnetic lobes and coordinating resulting data analysis
- Ensuring the standard operations as defined in the sections 5.1.1 and 5.1.2.

5.1.7 ROC specific Nominal Mission Phase (NMP) and Extended Mission Phase (EMP)-related activity responsibilites

During the Nominal Mission Phase (NMP) and the Extended Mission Phase (EMP), the ROC team shall ensure the routine operations, as defined in the sections 5.1.1 and 5.1.2.

In addition, scientific cooperation with other mission teams (e.g. FIELDS/Solar Probe Plus) needs to be reinforced.

5.1.8 ROC specific post-operation phase-related activity responsibilities

At the end of the mission, the ROC shall:

- Finalize the science data processing and archiving for all of the mission phases.
- Maintain the data access interface for ESAC, CDPP and RPW Consortium users and provide a helpdesk to support solving problems related to (a) the usage of the data retrieval system and (b) retrieving actual data.

5.2 ROC key personel responsibilities

5.2.1 RPW Principal Investigator responsibilities

In the framework of the RPW ground segment, the RPW PI shall be in charge of:

- Supporting the Solar Orbiter science operation definition.
- Defining the RPW science operation planning for all phases of the mission in accordance with the Solar Orbiter mission planning.
- Approving the ROC CIRD and Project Management Plan (PMP).
- Approving the financial and technical proposal document
- Validating RPW science data calibrations.
- Assuming overall responsibility about the RPW science data in terms of quality, dissemination and archiving.
- Share overall responsibility with the RPW Project Manager at the CNES for the definition and execution of the RPW operations during the NECP.
- Assume overall responsibility for the definition and execution of the RPW operations during the CP, the NMP and the EMP.
- Supervising the selection of SBM event data to be downlinked from the SSMM. This activity shall be performed in collaboration with other instrument PIs involved.
- Being the main interlocutor between the RPW ground segment and the Solar Orbiter consortium concerning RPW science operation planning at S/C level.
- Approving the instrument operations reports released after each in-flight phase
- Liasing with the science community concerning the RPW science data exploitation.
- Liaising with the NASA Solar Probe Plus FIELDS PI team in common development and data processing.

5.2.2 RPW Ground Segment Project Manager responsibilites

The RPW Ground Segment Project Manager is responsible of supervising the RPW ground segment activities.

Especially she/he shall:

- Establish the overall RPW ground segment activities and RSS capabilities implementation 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 ROC.
- Establish the ROC PMP.
- Establish the technical and financial proposal document (PTF).
- Assume overall responsibility for the ROC infrastructure availability during all phases of the mission
- Assume overall responsibility for the RPW ground segment configuration and documentation management, in terms of consistency and accessibility policy.
- Write the CIRD, update as required.
- Approve all changes of the RPW Software Development Plan (SDP).
- Ensure the instrument operations comply the science and operation planning at both payload and S/C levels.
- Supervise the RFP preparation, validation and delivery.
- Assume overall responsibility for the remote control of the RPW operational modes. It includes the SOOP to IOR/PDOR/MDOR translation as well as the IOR/PDOR/MDOR preparation, validation and transmission to the SOC/MOC.
- Coordinate the RPW routine and anomaly operations.
- Assume overall responsibility for the RPW performances during all in-flight phases of the mission.
- Ensure the monitoring of the RPW performance as well as on-board data storage and power management.
- Coordinate the instrument failure and anomaly operation management.
- Establish and maintain the overall RPW ground segment development and sustainability.
- Act as the main interface with the RPW Lead CoI ground segment teams.
- Act as the main interface with the MOC and SOC about RPW operations, data processing and archiving technical issues. Especially, the RPW Ground Segment Project Manager should participate to the Science Operations Working Group (SOWG).
- Supervising and participating to the RSS development and validation, more particularly the ROC SGSE, RPW science operation planning tools, data processing pipelines, instrument monitoring tools as well as the software interfaces with the MOC/SOC.
- Ensuring the sustainability, the availability and the maintenance of the RSS during all phases of the mission.
- Issue instrument operations reports after each in-flight phase.
- Establishing the ROC SDP, the ROC Software System Specification (SSS), the Software Design Documents (SDD) and Interface Control Documents (ICD) concerning the RSS.
- Coordinating the writing and delivery of Software User Manuals (SUM) for the RSS.
- Establishing guidelines about RPW ground segment engineering development, including procedures for testing, validating, delivering, executing and maintaining applications to be run by the ROC.

- Being the main interlocutor between the ROC and the LESIA in terms of hardware/software logistic support.
- Ensuring the archiving and accessibility of the RPW ground segment documentation
- Liaising with the RPW Lead CoI ground segment teams about RPW sub-system science data processing software and data to be implemented in the RSS.

Depending of the context, a part of these tasks may be supported by a deputy project manager if required.

5.2.3 RPW Ground Segment Scientist Team responsibilites

The RPW Ground Segment scientits are in charge of supporting the RPW science activities in the ROC, and maximazing the scientific return of the instrument. Their main tasks shall consist of:

- Ensuring the RPW performance fulfilled the science requirements [AD6].
- Participating of the RPW science data format definition.
- Supervising the validation of the RPW science data calibrations.
- Optimizing and validating the SBM detection algorithms.
- Ensuring the quality of RPW science data produced during the mission.
- Participating to the preparation of the science operations for RPW.
- Participating to the discussions concerning the RPW science in the dedicated working groups (e.g., Modelling And Data Analysis Working Group, MADAWG)

5.2.4 RPW Lead Co-Investigator teams

In the framework of the RGS, the Lead Co-I team shall:

- Ensure the calibration of its RPW sub-system.
- Support the RPW sub-system data product definition
- Support the validation of its RPW sub-system science data.
- Ensure the quality of its RPW sub-system calibrated science data.
- Provide expertise support in case of failure or anomalies involving its RPW sub-system.
- Assume the development, test, validation, delivery and maintenance of the software that produce science data for their RPW sub-system. These software shall be designed to be runnable in the RSS.
- Participate to the preparation of the RPW operations.

6 ROC IMPLEMENTATION REQUIREMENTS

This section lists the requirements related to the ROC implementation.

Requirement Number	Description
ROC infrastructure	
REQ-ROC-CIRD-0001	The ROC shall implement a so-called "ROC Software System" (RSS), which supports minimal human intervention and gathers all of the equipment to perform the RPW ground segment tasks.

REQ-ROC-CIRD-0002	The main instance of the ROC software system shall be hosted and run on the LESIA site (Meudon, France).
REQ-ROC-CIRD-0003	The ROC shall be capable of deploying and using a secondary instance of its software system at the MOC site, during the LEOP/NECP RPW-related operations. Depending of the needs, all or only a identified part of the system may be required.
REQ-ROC-CIRD-0004	The ROC shall support promptly delivering of a fully operational and up-to-date RPW LLVM to the SOC during the mission. The LLVM design and data products will have to be as expected by the SOC.
Data retrieval and processing capabilities	
REQ-ROC-CIRD-0005	The ROC Software System shall be able to promptly retrieve from the MOC DDS and analyse the RPW TM raw data.
REQ-ROC-CIRD-0006	The ROC Software System shall be able to promptly retrieve from the GFTS and analyse, the Solar Orbiter mission ancillary data (e.g., SPICE kernels) provided by the SOC during the mission.
REQ-ROC-CIRD-0007	The ROC Software System shall support the capability of producing RPW HK parameter digest files for the RPW Lead CoI teams.
REQ-ROC-CIRD-0008	The ROC Software system shall be able of producing RPW L1 uncalibrated science data files.
REQ-ROC-CIRD-0009	The ROC Software System shall be able of producing RPW L2 calibrated science data files.
REQ-ROC-CIRD-0010	The ROC shall support the verification and the validation of the quality of RPW L2 calibrated science data.
REQ-ROC-CIRD-0011	The ROC Software System shall produce RPW science data summary plots at L1 and L2 levels.
REQ-ROC-CIRD-0012	The ROC Software System shall support the On-board Time (OBT) to UTC time conversion.
REQ-ROC-CIRD-0013	The ROC Software System shall be able of displaying processing status of data products
REQ-ROC-CIRD-0014	The ROC Software System shall be able of producing LL01 low latency data products for RPW.
Instrument monitoring capabilities	

REQ-ROC-CIRD-0015	The ROC Software System shall support prompt visualization of: • RPW TM/TC packet downlink/uplink flows • On-board event reporting • In-flight instrument and sub-systems status • RPW flight software version and status • Science data and HK parameters • RPW Low Latency data • Ancillary data • TM/TC statistics • List of SBM1/SBM2 events detected on-board for instrument monitoring
REQ-ROC-CIRD-0016	The ROC Software System shall support the verification of TC ack. and expected TM flow.
REQ-ROC-CIRD-0017	The ROC Software System shall support the capability of generating and publishing, regular summary reports about the instrument state on-board to the ROC operations team.
REQ-ROC-CIRD-0018	The ROC Software System shall support automated alert notifications to the ROC operations team, in case of anomalies reported on-board by the DPU.
REQ-ROC-CIRD-0019	The ROC Software System shall support the capability of monitoring the BIAS current applied on-board
REQ-ROC-CIRD-0020	The ROC Software System shall supply an up-to-date map of the SBM1/SBM2 events detected on-board, with their current status (e.g., “selected”, “downlinked”, “deleted”, “close to being deleted”, etc.)
REQ-ROC-CIRD-0021	The ROC Software System shall permit to monitor the operations executions in near-real time, during the LEOP/NECP RPW-related operations at the MOC site.
Instrument operations planning and commanding capabilities	
REQ-ROC-CIRD-0022	The ROC shall be able to control the on-board instrument operating modes, at the minimal VSTP-cycle operation request time cadence.
REQ-ROC-CIRD-0023	The ROC Software System shall permit to create and submit to the SOC, the IORs for the MTP/STP/VSTP cyles, in the expected format and with the expected

	interfaces
REQ-ROC-CIRD-0024	The ROC shall support approval or rejection of the IORs by the SOC
REQ-ROC-CIRD-0025	The ROC Software System shall permit to create and submit to the MOC, the PDOR/MDOR in the expected format and with the expected interfaces
REQ-ROC-CIRD-0026	The ROC shall support approval or rejection of the MDOR/PDOR by the SOC
REQ-ROC-CIRD-0027	The ROC Software System shall permit to generate/edit and submit RPW flight procedures to the MOC, in the expected format and with the expected interface
REQ-ROC-CIRD-0028	The ROC shall support approval or rejection of the RPW flight procedures by the MOC
REQ-ROC-CIRD-0029	The ROC Software System shall support the automated verification of the RPW flight procedures, in terms of content consistency and format compliance.
REQ-ROC-CIRD-0030	The ROC Software System shall support the automated verification of the IOR/MDOR/PDOR, in terms of content consistency and format compliance.
REQ-ROC-CIRD-0031	The ROC Software System shall support the capability of verify the resource allocation (data rate and power consumption) against the instrument modes over the planning.
REQ-ROC-CIRD-0032	The ROC shall be able to test the execution of the operation requests and related flight procedures – with dedicated facilities (e.g. S/C simulator or GSE).
REQ-ROC-CIRD-0033	The ROC shall be able to control the Bias currents on-board.
REQ-ROC-CIRD-0034	The ROC shall support the prompt selection and submission to the SOC of the SBM1/SBM2 event data to downlink (at a STP-cycle time cadence).
REQ-ROC-CIRD-0035	The ROC Software System shall support the visualization of the mission planning cycles (MTP, STP, VSTP) and related-data (E-FECS, TMC)
REQ-ROC-CIRD-0036	The ROC Software System shall support the visualization of the RPW operations timeline, including: • Planned/submitted/executed instrument science operation requests to the SOC • Planned/submitted/executed direct instrument

	non-routine operation requests to the MOC • Instrument configuration states and resources (predictive/real TM rate and power consumption).
REQ-ROC-CIRD-0037	The ROC shall be able to prepare, request and verify flight software patching on-board.
REQ-ROC-CIRD-0038	The ROC shall support the capability of analysing and optimizing the SBM1/SBM2 algorithms detection rates on-board.
Data dissemination and archiving capabilities	
REQ-ROC-CIRD-0039	The ROC shall ensure the availability within few days of the RPW HK and L1 science preliminary data, to the RPW Lead CoI and the Solar Orbiter PI teams.
REQ-ROC-CIRD-0040	During the cruise, nominal and extended phases, the ROC shall be able to distribute within 3 months the RPW L1, L2 and L3 science data products to the ESAC data archive.
REQ-ROC-CIRD-0041	The ROC shall have the capability to store at the LESIA site, the RPW data produced before, during the mission and post-operations phases.
REQ-ROC-CIRD-0042	The ROC shall ensure access to its data processing software, the science models and instrument data calibrations to the SOC, MOC, RPW Lead CoI and Solar Orbiter instrument PI teams.
REQ-ROC-CIRD-0043	The ROC shall ensure public access to the documentation relative to: • RPW science data description and calibration • ROC public facilities (e.g., user libraries, tools and public services on-line)
Ground Support capabilities	
REQ-ROC-CIRD-0044	The ROC shall supply a dedicated post-mortem SGSE tool, allowing the RPW AIT/AIV teams to view and analyse RPW and E-GSE data, generated during instrument calibration campaigns on-ground.
REQ-ROC-CIRD-0045	During the instrument calibration campaigns on-ground, the ROC shall provide interface allowing the RPW sub-system teams, to promptly retrieve and analyse the RPW TM/TC and E-GSE stimuli data.
REQ-ROC-CIRD-0046	During the mission, the ROC shall maintain a SGSE capable of processing and analysing data from a

	instrument "spare" model on-ground.
System validation and monitoring capabilities	
REQ-ROC-CIRD-0047	The ROC shall support the capability of performing the validation of the critical functionalities of the ROC software system.
REQ-ROC-CIRD-0048	The ROC shall support the capability of monitoring the ROC software system equipment state.

8 HIGH LEVEL REQUIREMENTS APPLICABLE TO THE ROC IMPLEMENTATION

The ROC implementation must comply the high level requirements listed in the table below. For each requirements, the number, description and the origin are provided.

Requirement Number	Description	Origin
EIDA R-354	The PI shall make available the necessary resources to support the science operations conducted from the SSOC	[AD1]
EIDA R-355	The PI shall deliver the Level 1b, Level 2, and Level 3 data to the Solar Orbiter Archive.	[AD1]
EIDA R-359	The PI shall deliver to the SSOC and maintain the software implementing the data processing pipelines to Level 1b and Level 2.	[AD1]
EIDA R-360	The PI shall make available the necessary resources to support the installation and the maintenance of any relevant software at the SSOC.	[AD1]
EIDA R-371	The PI shall issue instrument operations reports after each in-flight phase.	[AD1]
EIDA R-372	The PI shall make available the necessary resources during NECP for the installation of instrument EGSE equipment at the SMOC to monitor the operations execution in near-real time and to support GO/NOGO decisions at predefined steps in the procedures.	[AD1]
EIDA R-373	The PI shall submit operations requests to the SSOC.	[AD1]

EIDA R-376	The PI shall maintain the instrument on-board software throughout the mission.	[AD1]
EIDA R-380	The PI shall be responsible for the verification of correct loading of the instrument software updates, since science telemetry processing will not be performed at the SMOC.	[AD1]
EIDA R-382	The PI shall provide inputs to the SSOC for the requested science operations for integration in the mission planning products.	[AD1]
EIDA R-389	The PI shall make available the necessary resources to support the procedure definition, the procedure approval, the text execution, the results analysis and the anomaly investigation/resolution for the Data Disposition System Interface Test (DDSIT).	[AD1]
EIDA R-697	The PI shall be responsible for Level 1b, Level 2 and Level 3 processing.	[AD1]
EIDA R-698	The PI shall identify a single point of contact for instrument planning activities and for data deliveries to the Solar Orbiter Archive.	[AD1]

Table 3. High level requirements.

9 Traceability Matrices

The traceability matrices for the ROC are given in [RD16].

10 List of TBC/TBD/TBWs

TBC/TBD/TBW			
Reference/Page/Location	Description	Type	Status

11 DISTRIBUTION LIST

LISTS See Contents lists in “Baghera Web”: Project’s informations / Project’s actors / RPW_actors.xls and tab with the name of the list or NAMES below		Tech_LESIA
		Tech_MEB
		Tech_RPW
		[Lead-]CoIs
		Science-CoIs

INTERNAL

LESIA CNRS		

LESIA CNRS		

EXTERNAL (To modify if necessary)

CNES		C. FIACHETTI
		C. LAFFAYE
		R.LLORCA-CEJUDO
		E.LOURME
		M-O. MARCHE
		E.GUILHEM
		J.PANH
		B.PONTET
IRFU		L. BYLANDER
		C.CULLY
		A.ERIKSSON
		SE.JANSSON
		A.VAIVADS
LPC2E		P. FERGEAU
		G. JANNET
		T.DUDOK de WIT
		M. KRETZSCHMAR
		V. KRASNOSSELSKIKH
SSL		S.BALE

AsI/CSRC		J.BRINEK
		P.HELLINGER
		D.HERCIK
		P.TRAVNICEK
IAP		J.BASE
		J. CHUM
		I. KOLMASOVA
		O.SANTOLIK
		J. SOUCEK
		L.UHLIR
IWF		G.LAKY
		T.OSWALD
		H. OTTACHER
		H. RUCKER
		M.SAMPL
		M. STELLER
LPP		T.CHUST
		A. JEANDET
		P.LEROY
		M.MORLOT