



RPW Science Data Validation and Verification Plan

Ref: ROC-GEN-SCI-PLN-00077-LES

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SOLAR ORBITER



RPW Ground Segment

RPW Science Data Validation and Verification Plan

ROC-GEN-SCI-PLN-00077-LES

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Change Record

Issue	Rev.	Date	Authors	Modifications
1	0		X.Bonnin, S.Lion	First issue

Acronym List

Acronym	Definition	Acronym	Definition



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1 GENERAL

1.1 Scope of the Document

The RPW Science Data Validation and Verification Plan (DVVP) presents the activities to perform the validation and the verification of the RPW science data produced and distributed by the RPW Operations Centre (ROC).

The DVVP is a part of the ROC Validation and Verification Plan (RVVP) [AD1].

The validation and verification activities related to the science performance and calibration of the instrument are outside of the scope of this document.

The formal validation of the RPW Low Latency data (LLD) products is operated by the Solar Orbiter Science Operation Centre (SOC), with the support of the ROC team. In consequence, the LLD validation activity is not described in the DVVP.

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	ROC-GEN-SYS-PLN-00040-LES/2/1	ROC Validation and Verification Plan (RVVP)	S.Lion	
AD2	ROC-GEN-OTH-REQ-00081-LES/1/0 (draft-	ROC requirements	M.Maksimo vic	11/01/2019
AD3				
AD4				
AD5				

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	SOL-SGS-TN-0009/2/3	Metadata Definition for Solar Orbiter Science Data	SOC and MADAWG teams	24/09/2018
RD2	ROC-GEN-OTH-NTT-00045-LES/1/1	ROC Glossary of terms	X.Bonnin	08/11/2018
RD3		SOLO-RPW-TN-1989-CNES Calibration test Report	RPW team	TBD
RD4	ROC-PRO-DAT-NTT-00075-LES/1/0	Solar Orbiter RPW Data Product Description Document (DPDD)	X.Bonnin, J.Soucek	
RD5	SOL-SGS-PL-0009	Solar Orbiter Archive Plan	P.Osuna	
RD6	ROC-PRO-DAT-NTT-00006-LES/1/2	ROC Data Products (RDP)	X.Bonnin	
RD7	ROC-GEN-MGT-PLN-00013-LES/1/4	ROC Project Management Plan (PMP)	X.Bonnin	17/11/2017
RD8	SOLO-RPWSY-PT-1235-CNES/1/0	RPW Instrument Calibration Plan	M.Maskimo vic E.Guilhem B.Pontet	11/12/2014



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			Y.de Conchy Analysers teams	
RD9	ROC-GEN-SYS-PLN-00015-LES/2/3	ROC Software Development Plan (SDP)	X.Bonnin	17/11/2017
RD10	ROC-GEN-SYS-NTT-00019-LES/2/1	ROC Engineering Guidelines For External Users	X.Bonnin	
RD11	ROC-GEN-SYS-SPC-00036-LES/01/01	ROC Software System Design Document (RSSDD)	X.Bonnin, S.Lion	



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2 INTRODUCTION

2.1 Context

The ROC is in charge of the science data production for the RPW instrument on-board Solar Orbiter. Especially, the centre shall deliver full-calibrated RPW science data to the Solar Orbiter Archive (SOAR) [RD5], located at the European Space Astronomy Centre (ESAC) in Madrid, Spain.

In this context, the ROC shall:

- Perform RPW science data validation to ensure the compliance with the expected requirements. This activity shall be scheduled during specific campaigns, in agreement with the Solar Orbiter and RPW ground segment development planning.
- Implement workflows to verify the science data consistency and science quality. This activity shall be done as a continuous task during the in-flight exploitation of the RPW instrument, starting during at the cruise phase.

Section 3 and 4 present respectively the plan related to the RPW science data validation and verification.

2.2 Perimeter

The science data validation and verification processes gather all of the RPW science data, from the L0 to the L3 data processing levels (see [RD1] for the data processing level definition).

Nevertheless, intermediate data products, i.e., LZ, HK and L1R (see [RD6] for details), will be also generated but are not expected, at this stage of the project, to be delivered to the SOAR. Since they are directly involved in the RPW science data production, their validation and verification are also presented in the DVVP.

2.3 Definitions

2.3.1 Terminology

The definitions of terms used in the present document, e.g., validation, verification, are listed in the ROC glossary of terms [RD3].

In the framework of this document:

- The ROC (team) defines the people in charge of the RPW science data processing activities at LESIA.
- The RPW data software teams define other people in charge of developing and/or maintaining the software that generates RPW science data products. This definition includes here the Lead CoI teams in charge of delivering to the ROC, the RPW Calibration Software (RCS). The RCS will be run by the ROC team at LESIA to produce RPW science data files at levels L1R et L2.

2.3.2 RPW data and metadata definition

The standards related to the Solar Orbiter science products are defined in [RD1], including the convention for the file naming, data processing levels and metadata. The RPW science data



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products to be archived in the SOAR are presented in the RPW Data Product Description Document (DPDD) [RD5].

Additional LZ, HK and L1R intermediate data products are described in the ROC Data Products (RDP) document [RD6].

2.4 RPW data processing approach overview

The science data validation and verification activities are deeply linked to the RPW data processing.

The RPW data processing key personnel responsibilities are presented in the ROC Project Management Plan (PMP) [RD7] and the software development/exploitation strategy in the ROC Software Development Plan (SDP) [RD9].

The overall approach is:

- The ROC shall be in charge of producing LZ, L0, L1, HK and related quick-look data products at LESIA.
- The L1R and L2 data products will be generated by the ROC at LESIA, running the dedicated RPW Calibration Software (RCS) delivered by the Lead CoI teams in charge.
- The L3 data products will be produced by the teams in charge, and then delivered to the ROC.

The ROC will be the single point of contact with the European Space Agency (ESA), concerning the RPW telemetry (TM) raw data retrieval, and with the Solar Orbiter data distribution and archive centres, e.g. SOAR.

3 RPW SCIENCE DATA VALIDATION PLAN

3.1 Approach overview

The RPW data validation can be decomposed in two processes:

- Validation of the data technical specification – hereafter also named “technical validation”, which shall ensure the data format and metadata are compliant with the expected definition [RD1, RD6]. This process can be fully automated, as explained in the section 3.3.
- Validation of the science data content – hereafter also named “science validation” -, which shall ensure that the science data content is as expected, i.e., science calibration and quality. This task may require human intervention.

The data validation activity shall be performed during dedicated test campaigns, as presented in the section 3.4.

3.2 Responsibilities

The ROC will have the overall responsibilities of the RPW data validation. Especially, it shall:

- Supply the RVVP and DVVP
- Supply the test plans, as well as the tests and validation reports related to the data validation campaigns



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- Provide expected inputs to perform the data validation at levels LZ to L2.
- Prepare and run the tests during the validation campaigns
- Perform the full validation of the RPW LZ, L0, L1 and HK data products.
- Perform the technical validation for the RPW LZ, L0, L1, L1R, L2 and HK data products.

The RPW data software teams shall:

- Participate to the validation campaigns, by providing the expected inputs and support the ROC in the analysis of the tests results and possible anomaly investigations.
- Ensure the calibration for their RPW equipment, as specified in [RD8]
- Perform the science validation of their L1R and L2 data products
- Perform the technical and science validation of their L3 data products (TBC)
- Write test reports related to the L1R/L2/L3 science validation (TBC)
- Verify the campaign validation reports

The RPW PI shall approve the DVVP and science data validation reports generated after each campaign (TBC).

3.3 Proposed implementation

The RPW data validation activity shall be described in details at each step of the validation into the dedicated campaign test plan, as explained in the RVVP.

Nevertheless the overall implementation shall:

- Use the ROC infrastructure at LESIA to perform the technical validation at levels LZ, L0, L1, L1R, L2 and HK.
- Use the RPW data software teams infrastructure to perform the science validation at levels L1R, L2 and L3.

3.3.1 RPW data technical validation implementation

The data technical validation will consist of ensuring the data format and metadata are compliant with the expected definition [RD1, RD6].

To perform this validation, the ROC team shall run the data technical verification process described in the section 4.3.2.3, on well-identified and representative enough samples of RPW data files.

The choice of the RPW data samples will depend of the validation campaign objectives.

3.3.2 RPW data science validation implementation

The RPW L1R, L2 and L3 data science validation shall be done by the RPW data software teams.

The detailed implementation is TBD.

Mainly run the science verification processes defined in section 4.3.3, using the instrument data acquired on-board during the commissioning and cruise phase. Probably done from



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representative enough L1 and extra (e.g., HK, L1R, ANC) data products generated and distributed by the ROC.

Science data calibration validation:

- For data validation campaigns prior to the launch, already done during on-ground thermal calibration campaigns, see [RD8, RD3]
- For data validation campaigns after the launch, the calibration plan is detailed in [RD8]

Science data quality validation:

- Science data quality validation for on-ground products is not relevant. Nevertheless, the infrastructures in support, and more particularly the science data quality verification processes (see section 4.3.3.2) will have to be validated before the launch.
- In-flight science data quality validation: validate the process and ensure that data quality is as expected from the instrument data acquired on-board during the commissioning and cruise phase.

3.4 Schedule

According to the RVVP, the following data validation campaigns shall be scheduled:

- On-ground (before launch):
 - RSS3VC: This campaign will be a “rehearsal” of the RSS4VC. It will only involve the ROC team and only concern a partial set of LZ, L0, L1 and HK data products.
 - RSS4VC: This campaign shall validate the LZ to L2 data technical specification. The implementation of the baseline workflows and procedures to operate the science data verification will be also validated during this campaign, with the support of the RCS teams. But no formal data science validation will be performed, since ground calibration campaigns have already been done [RD3].
- In-flight (after launch):
 - RSS5VC: This campaign shall validate first science data acquired during the commissioning phase. It should be organized just before the beginning of the Cruise Phase.
 - At least one other data validation campaign shall be planned before the beginning of the nominal phase (TBC) to fully validate the RPW science data.

3.5 Support infrastructure

The technical validation of the RPW data at levels LZ, L0, L1, L2 and HK will be performed at LESIA using tailored instances of the ROC data verification infrastructure (see section 4.5).

One specific instance shall be deployed for each campaign.

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4 RPW SCIENCE DATA VERIFICATION PLAN

4.1 Approach overview

The RPW science data verification shall be a routine activity planned during the exploitation of the instrument. The data verification process shall be validated during the commissioning phase (expect for SBM1/SBM2 data, TBC), and fully operational at the end of the cruise phase, i.e., before the beginning of the nominal phase.

It shall consist of checking:

- Data integrity
- Metadata and format standards compliance, according to the Solar Orbiter [RD1] and ROC [RD6] standards respectively.
- Calibration
- Data quality

Regarding to the validation approach presented in the section 3.1, the data integrity/metadata/format verifications – hereafter called “technical verification” - can be fully automated, and the calibration/quality verifications – hereafter called as “science verification” – may need human intervention.

4.2 Responsibilities

The overall responsibilities about these activities are given in the PMP [RD7].

The ROC team shall be in charge of:

- Performing the technical verification of the RPW LZ, L0, L1, L1R, L2 and HK data products.
- Providing the inputs required to define the science data quality. Especially, the inputs needed to compute the QUALITY_BITMASK value in the RPW L1 CDF data files.

The RPW data software teams shall be in charge of:

- Ensuring the science verification for the L1R, L2 and L3 data files generated with their software.
- Implementing inside their software the computation of the QUALITY_FLAG index value for the L1R and L2 data files (case of L3 is TBC).
- Ensuring the technical verification for their L3 data products (TBC).

4.3 Proposed implementation

4.3.1 Implementation overview

Except for the L3 level, the RPW data technical verification shall be done at LESIA using the RPW data processing pipeline of the ROC [RD?]. In the nominal case, the ROC pipeline shall perform these verifications systematically after each RPW data file creation. Especially, data



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files that have not successfully passed the verifications shall be moved into a dedicated directory, and the pipeline shall notify ROC about the anomaly.

The RPW data software teams shall do the L1R, L2 and L3 data science verification. Furthermore, at this stage of the project the ROC team does not plan to implement any automated process at LESIA in order to perform the science verifications for these products; it is expected that the cruise phase will serve to optimize the RPW science performances, calibrations and quality data, in prevision of the nominal phase. Provision by the ROC of additional tools and data in support can however be envisaged.

The table below gives an overview of the expected verification processes for each RPW data processing levels. Each process is described in more details in the next sections.

The infrastructure in support to the verification process is presented in the section 4.5.



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RPW Data processing level	Data verification processes	Type of process
LZ	Data integrity Metadata and format standards compliance [RD6]	Fully automated process performed by the ROC pipeline at LESIA
L0	Data integrity Metadata and format standards compliance [RD1]	Fully automated process performed by the ROC pipeline at LESIA
HK	Data integrity Metadata and format standards compliance [RD6]	Fully automated process performed by the ROC pipeline at LESIA
L1	Data integrity Metadata and format standards compliance [RD1]	Fully automated process performed by the ROC pipeline at LESIA
L1R	Data integrity Metadata and format standards compliance [RD6]	Fully automated process performed by the ROC pipeline at LESIA
L2	Data integrity Metadata and format standards compliance [RD1]	Fully automated process performed by the ROC pipeline at LESIA
	Science calibration	Performed by the Lead CoI teams in charge of the RCS delivery
	Science data quality	Performed by the Lead CoI teams in charge of the RCS delivery
L3	Data integrity Metadata and format standards compliance	Performed by the teams in charge of L3 data production (TBC)
	Calibration / Derived “added-value” data computation (e.g., gonio-polarimetry parameters, VxB, etc.)	Performed by the teams in charge of L3 data production (TBC)
	Data quality	Performed by the teams in charge of L3 data production (TBC)

4.3.2 Technical verification

4.3.2.1 Common verification mechanisms

Except for L3, the state of the technical verification shall be automatically flagged by the ROC pipeline, using the dedicated “VALIDATE” metadata as follows:

- VALIDATE = 0, data file has not been verified
- VALIDATE = 1, data integrity verification has been done successfully
- VALIDATE = 2, metadata and format verification have been done successfully

The value of the “VALIDATE” metadata shall condition the delivery of the RPW data products to the Solar Orbiter data archive centres.



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4.3.2.2 Data integrity verification

The data integrity verification shall be the first process to be run just after the file creation.

It consists of performing a checksum operation just after the production of each data product file. This check shall:

- Apply the CDF MD5 checksum mechanism for the CDF format files, i.e., L1, L1R, L2 and HK
- Apply the TBD for the XML format files, i.e., LZ.
- Apply the Fletcher32 checksum mechanism (TBC) for the HDF5 format files; i.e., L0.

If the data integrity verification succeeds, then the “VALIDATE” metadata shall be set to 1.

4.3.2.3 RPW data standards compliance verification

The data standards verification shall be the second process to be run just after the file creation.

The objective is to ensure that the RPW LZ, L0, L1, L1, L2 and HK data products are compliant with the standards defined at Solar Orbiter [RD1] and ROC levels [RD6] respectively.

Only mandatory metadata and data, i.e., zVariables for CDF, Datasets for HFD5 and tags/attributes for XML shall be checked. Moreover, metadata for which a value is expected shall also be verified.

If the data standards verification succeeds, then the “VALIDATE” metadata shall be set to 2.

4.3.3 Science verification

4.3.3.1 Science calibration verification

The verification of the instrument sub-system calibration is outside of the scope of this document. The teams in charge will perform this activity using dedicated tools in support.

Nevertheless, new calibration shall always lead to deliver new calibration table files to the ROC, and potentially new RCS version, as described in [RD10]. Especially, a testing step will be systematically performed by the ROC team with the support of the team in charge, in order to ensure that the new RCS release works as expected, and before being integrated in the operational instance of the ROC pipeline.

Besides, the calibration should be fully verified/validated before starting the nominal phase of the mission.

4.3.3.2 Science data quality verification

The verification of the science data quality is a tricky task that cannot be fully performed in an autonomous way. In practice two mechanisms will be implemented by the ROC and the RPW data software teams, in order to support the evaluation and the verification of the data quality:

- For L2 level data, automated computation of the “QUALITY_FLAG” CDF zVariable (see definition in [RD1]). The value of the “QUALITY_FLAG” zVariable will have to be set by the RCS in an autonomous way, using the information provided by the “QUALITY_BITMASK” zVariable (see definition in [RD1]) and additional extra data (e.g., HK). By default, the “QUALITY_FLAG” value shall be set to the “good quality” (index=4) in the L1 level data, then decreased if necessary when propagating through higher data level products.
- “Manual” verification using support tools and data (e.g., quick-looks).



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N.B. At this stage of the project, it is not planned to implement at LESIA automated verifications and notifications based on statistical thresholds. Nevertheless, like the calibration verification, it is expected that the science data quality will be mainly evaluated and optimized during the cruise phase.

4.4 Schedule

The RPW science data verification nominal process for a given day of data will have to be performed within the proprietary period, i.e., 3 months (TBC), before data has been publicly available at the Solar Orbiter data archive at ESAC.

The main RPW data production and related verification steps are:

1. Every day the ROC pipeline requests for new RPW telemetry (TM) raw data to the Solar Orbiter data dissemination system (DDS), hosted by the European Space Operations Centre (ESOC) at Darmstadt in Germany.
2. New RPW TM data are analysed, identified, sorted and uniquely inserted into the ROC mission database at LESIA. Verifications of the TM are also done at the step (i.e., TM packet integrity check and missing TM identification)
3. From the TM saved into the mission database, the RODP produces the RPW LZ, L0, L1, HK, L1R, L2 and related quick-look preliminary data file for a given day or time range (for SBM1/SBM2 event data and Bias sweeping). This task will be performed at LESIA every 24h. The resulting RPW data files are automatically verified, i.e., technical verifications only, then made available to the RPW teams via the ROC Web site.
4. From these preliminary data files distributed by the ROC, the RCS teams can analyse and check on their side the science data, possibly upgrade and deliver to the ROC their new RCS and/or calibration tables and produce and deliver to the ROC L3 data files. The full process shall not exceed the proprietary period.
5. When the proprietary period ends, verified data (i.e., for which “VALIDATE = 2”) will be sent to the Solar Orbiter data archive centres.

N.B.

The RPW data production cycle at LESIA will include the possibility of performing a full or partial data file re-processing. In case of issue → To be done every month [AD2].

- The delivery of new RCS and/or calibration tables will not automatically trigger the integration into the operational instance of the ROC pipeline → to be done every month (TBD)
- List of data files that have passed or not the verification processes shall be given to the ROC data processing reporting log file. This log file will be updated every day and accessible to the RPW data software teams.

4.5 Support infrastructure

The RPW data technical verification workflow will be directly integrated inside the ROC data pipeline at LESIA, as regression tests.



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Especially, the following modules will be used [RD11]:

- maser4py.utils.cdf.validator (<https://pypi.org/project/maser4py/>), to check the compliance of CDF files against expected standards.

TBW

5 APPENDIX

5.1 RPW science data automated verification steps performed at LESIA: summary list

Step #	Verification process	Success criteria	Verification Results
1	Automated check of the integrity of the incoming RPW telemetry (TM) data. Missing TM are also identified at the stage.		
2	Automated check of the LZ data		
3	Automated check of the L0 data integrity (checksum) and expected format/metadata		
4	Automated check of the L1 and HK data integrity (checksum) and expected format/metadata compliance		
5.	Automated check of the L1R data integrity (checksum) and expected format/metadata compliance		
	Automated check of the L2 data integrity (checksum) and expected format/metadata compliance		

1. Table 1. RPW data verification steps.



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7 DISTRIBUTION LIST

<p style="text-align: center;">LISTS</p> <p>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</p>	Tech_LESIA
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