



# RPW Calibration Software Interface Control Document

Ref: ROC-PRO-PIP-ICD-00037-LES  
Issue: 01  
Revision: 07  
Date: 24/04/2024

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SOLAR ORBITER



## RPW Operation Centre

# RPW Calibration Software Interface Control Document

ROC-PRO-PIP-ICD-00037-LES  
Iss.01, Rev.07

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## Change Record

Issue	Rev.	Date	Authors	Modifications
0	0	08/07/2015	Manuel Duarte	First draft (inherits from the RCS ICD for ROC-SGSE, ROC-TST-GSE-ICD-00023)
1	0	09/11/2016	Xavier Bonnin	First release
1	1	12/10/2017	Xavier Bonnin	<ul style="list-style-type: none"><li>- RCS CDF outputs path is now passed via the CLI specific input parameters, and not returned by the software in the stdout.</li><li>- "outputs.release" attribute removed from the descriptor file</li><li>- Add "outputs.template" attribute in the descriptor file</li><li>- Rename "Exceptions and errors" section to "Exceptions handling" and update the content</li><li>- Add section 4 on RCS-related data</li><li>- Remove section on the interface from the pipeline side (this section is copied into the ROC Software System Design Document)</li></ul>
1	2	05/06/2019	Xavier Bonnin	<ul style="list-style-type: none"><li>- Add section 3.3 "ROC reserved environment variables"</li><li>- Add software version convention in section 3.2.2.2 "Release"</li><li>- Add icd_version attribute in section 3.2.2.1 "Identification"</li><li>- Rename url attribute to source in section 3.2.2.2 "release"</li><li>- Simplify the sections 3.2.2.4.1 "Inputs" and 3.2.2.4.2 "Outputs"</li><li>- Update descriptor example and schema in appendix</li><li>- Add Data_version in the list of attributes to be updated by the RCS</li><li>- Add section 4.1.3.1 about QUALITY_FLAG</li></ul>
1	3	19/05/2020	Xavier Bonnin	<ul style="list-style-type: none"><li>- Add RD9</li><li>- Rename section 3.4.3 to "RCS exit status convention"</li><li>- Update content of section 3.4.3</li><li>- Add SPICE_MK_PRED_PATH and SPICE_MK_FLOWN_PATH variables in table 1</li></ul>



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				<ul style="list-style-type: none"> <li>- Add SPICE_KERNELS global attribute definition in table 4</li> <li>- Add section 5.4 about Solar Orbiter SPICE kernel processing</li> </ul>
1	4	20/10/2020	Xavier Bonnin	<ul style="list-style-type: none"> <li>- Update list of items in table 4 (RCS output CDF metadata)</li> <li>- Add section "RCS output CDF variable setting convention"</li> <li>- Rename and update section "RCS science data quality setting"</li> <li>- Add section "RPW Calibration Table (RCT) description"</li> <li>- Update RD and AD</li> </ul>
1	5	29/06/2021	Xavier Bonnin	<ul style="list-style-type: none"> <li>- Add SKELETON_MODS attribute definition in table 4</li> <li>- Add format convention for MODS in table 4</li> </ul>
1	6	04/10/2023	Xavier Bonnin	<ul style="list-style-type: none"> <li>- Update AD1 issue and date</li> <li>- Add L3_QUALITY_BITMASK optional zVar</li> <li>- Make Parent_version attribute obsolete</li> <li>- Change default value for QUALITY_FLAG to 3</li> <li>- Be RPW Calibration Table CDF filename compliant with Solar Orbiter Archive standard</li> <li>- Change several RPW Calibration Table section titles</li> </ul>
1	7	24/04/2024	Xavier Bonnin	<ul style="list-style-type: none"> <li>- Update AD1 issue and date</li> <li>- Add DOI global attribute</li> </ul>

## Acronym List

Acronym	Definition
BP	Basic Parameters
CDF	Common Data Format
CLI	Command Line Interface
CSV	Comma Separated Values
DOI	Digital Object Identifier
ICD	Interface Control Document
ID	Identifier



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I/F	Interface
I/O	Input/Output
JSON	JavaScript Object Notation
ROC	RPW Operation Centre
RODP	RPW Operation and Data Pipeline
RPW	Radio and Plasma Waves instrument
SCM	Search Coil Magnetometer
SGSE	Software Ground Support Equipment
S/W	Software
TDS	Time Domain Sampler
LFR	Low Frequency Receiver
THR	Thermal Noise and High Frequency Receivers
WF	Waveform
XML	eXtended Markup Language



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## 1 GENERAL

### 1.1 Scope of the Document

The RPW Calibration Software Interface Control Document (RCS ICD) describes the interface to be implemented in the RPW Calibration Software (RCS), in order to be autonomously run by the RPW data processing pipelines.

The RCS definition covers all of the programs that produce RPW calibrated science data at both analyzer and sensor levels.

It is the responsibility of the teams in charge to deliver to the RPW Operations Centre (ROC) a RCS fully compliant with this ICD. The way the software (S/W) and associated materials shall be delivered to the ROC is described in the “ROC Engineering Guidelines for External Users” (REGU) document [RD4]. The REGU should be hence read in complement to the present document.

### 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-SGS-TN-0009/2/6	Metadata definition for Solar Orbiter science data	SOC team	16/04/2024
AD2	ROC-PRO-DAT-NTT-00006-LES/1/3	ROC Data Products	X.Bonni n	08/01/2020
AD3	ROC-GEN-SCI-PLN-00077-LES1/0	RPW science Data Validation and Verification Plan (DVVP)	X.Bonni n	27/05/2019
AD4				

### 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	ROC-GEN-SYS-SPC-00036-LES/1/1	ROC Software System Design Document	X.Bonnin, S.Lion	09/01/2017
RD2	ROC-TST-GSE-SPC-00004-LES/1/0	ROC SGSE Software Design Document	X.Bonnin	14/02/2016
RD3	Deleted			
RD4	ROC-GEN-SYS-NTT-00019-LES/1/3	ROC Engineering Guidelines for External Users	X.Bonnin	19/05/2020
RD5	ROC-TST-GSE-SPC-00004-LES/1/1	ROC-SGSE Software Design Document	X.Bonnin	15/04/2016
RD6	ROC-GEN-SYS-NTT-00008-LES/1/3	ROC engineering guidelines	X.Bonnin	17/11/2017
RD7	ECMA-404.pdf/1 <sup>st</sup> edition	The JSON Data interchange format	ECMA	10/2013
RD8	ROC-TST-SFT-SUM-00027-LES/1/1	RCS Interface Validation Tool User Manual	M.Duarte	06/05/2016
RD9	SOL-SGS-TN-0017/0/4	SOC-Provided ancillary data for Solar Orbiter	A.Walsh	04/12/2019





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## 2 CONSIDERATIONS & OBJECTIVES

### 2.1 RPW Calibration Software (RCS) implementation philosophy

During the Solar Orbiter mission, the ROC will be in charge to regularly produce and deliver to ESA calibrated science data for the RPW instrument. The task will be performed in an automated way by the ROC Operations and Data Pipeline (RODP) [RD1]; the main RPW data processing pipeline hosted on the ROC server at LESIA (Meudon, France). Nevertheless, it is the role of the RCS to calibrate the instrument science data and to generate the resulting output data files. Such functionality requires RCS to be integrated into the RODP.

Since the RCS programming language can differ from a S/W to another, the integration shall be done in a standard way. It implies to use a dedicated common interface in order to: (i) minimize the human intervention, (ii) ensure the traceability of S/W and its data products, (iii) mitigate the possible points of failure in the RODP.

In addition, the RCS will be also integrated into the ROC-SGSE [RD5]; the ROC pipeline in charge of processing the RPW data stored into the MEB Ground Support Equipment (GSE) database. In both cases, the RODP and ROC-SGSE, the same interface will be used, and the present ICD is thus applicable.

### 2.2 RCS deliverables

RCS will be supplied to the ROC by teams in charge. It is strongly recommended to reduce as much as possible the number of S/W to be delivered by each team in order to optimize the delivery, installation, execution and maintenance processes.

A single S/W by team, but producing several RPW data products, should be the optimal solution. Additionally, a given data product should be as much as possible generated by a given class or function in the RCS.

### 2.3 RCS data products

The RCS will produce RPW calibrated science data files at processing levels higher than level 1 (L1) and in the Common Data Format (CDF), as defined in [AD1]. Especially, the ROC does not expect that its pipelines handle other RCS data products than these data sets. RCS should not hence be used to generate derived science data products, such as summary plots. If it is the case, the RCS shall include an option to trigger the production of derived products separately.

The standards for the Solar Orbiter science data products (e.g., file naming, processing levels, data format and metadata description) are given in [AD1].

### 2.4 Objectives related to this document

In order for the teams to deliver RCS to be run by the ROC pipelines, it is necessary to define in detail the specification of the interface, and more particularly:

- How the RCS shall be called in a standard way
- How a ROC pipeline will identify and call the RCS
- How a ROC pipeline will identify and provide to RCS the required input data



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- How and where the RCS will store the generated data products
- How a ROC pipeline will check that RCS run without error, and the resulting data products were correctly written.

This will be the purpose of the next sections. Section 3 describes the interface to be implemented by teams in charge on the RCS side. Section 4 presents conventions related to the RCS data.

## 3 DESCRIPTION OF THE INTERFACE TO BE IMPLEMENTED IN THE RCS

This section presents the interface that shall be found in the RCS, in order to be autonomously run by a ROC pipeline. This interface is composed of two main elements:

- A command line interface (CLI), that allows a ROC pipeline to call the RCS in a standard way
- A descriptor file (also called “descriptor”), that provides relevant information about the RCS to a ROC pipeline. The descriptor shall help the pipeline to identify the RCS, its inputs/outputs and to build the CLI calling sequence.

Besides, the RCS shall support the loading of reserved environment variables, as explained in the section 3.3.

### 3.1 Description of the RCS command line interface (CLI)

The RCS CLI is detailed in this section, namely: the general convention and the calling sequence formalism. A full example of such a CLI call is given in the appendix 5.1.

#### 3.1.1 CLI executable convention

The CLI shall comply the following convention:

- The ROC pipelines shall be able to run the RCS by calling an executable - binary or script – file only.
- There shall be a single executable file per S/W.
- A team in charge of a RCS shall ensure that the executable file can be launched on the ROC server environment: a Linux Debian Operating System (OS) with Bourne-Again Shell (BASH), as a primary shell.
- The name of the executable file shall contain alphanumeric characters only. Only the “\_” underscore and “-“ hyphen characters must be used as delimiters to separate two fields in the name.

According to the convention above, every RCS CLI calling sequence shall start as:

**\$EXECUTABLE**

Where **EXECUTABLE** is here the name of the executable.

Notes:

- **The interface does not work in the case where the executable is split in several words (for example, IDL batch commands usually work running “idl -e program -args [...]” calling sequence). In such a situation, the actual RCS launch command shall be wrapped into a BASH script. This script will be seen as the main**



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**RCS executable from the ROC pipelines point of view, and shall be thus compliant with this ICD.**

- In the case where the executable is a Python script, a dedicated virtual environment shall be pre-installed by the ROC team with the support of the RCS team. The virtual environment shall be then activated prior to the software execution in a way defined by both teams.

### 3.1.2 CLI input parameters

The CLI input parameters to be used to call the RCS executable, are described in the next section.

#### 3.1.2.1 RCS function name

Each RCS shall contain one or more functions (or classes), which are used to create output data files. Each function has its own set of inputs/outputs that shall be known by the ROC pipelines to call it correctly. This will be the purpose of the S/W descriptor file, as explained in the section 3.2.

In order to allow the ROC pipelines to launch a given function of the S/W from the CLI, the executable shall provide the name of this function as a first argument.

It means that every calling sequence of a RCS executable shall start as followed:

```
$EXECUTABLE func1
```

Where **EXECUTABLE** is here the name of the executable, and func1 is the name of the S/W function to run.

Note that this syntax is not mandatory in the specific case where input keywords are called, as explained in the section 3.1.2.4.

#### 3.1.2.2 Common input parameters

In addition to the name of the function as a primary argument, the RCS executable calling sequence shall accept at least the following common input parameters:

**--log [/path/to/logfile]**: the absolute path **/path/to/logfile** to the log file

**--config [/path/to/configfile]**: if required, the absolute path **/path/to/configfile** to the S/W configuration file.

These input parameters shall take only one argument.

#### 3.1.2.3 Specific input parameters

The specific input parameters shall permit to pass as input arguments, the path of the RCS input/output RPW data files.

The specific input parameters shall be called in the CLI following the convention above:

- The specific input parameter calling sequence shall be formed by a “*--flag value*” pair, where “*flag*” must be a lowercase string, containing only alphanumeric characters and the underscore ‘\_’ as a separator, and preceded by the double hyphen prefix ‘--’. The “*value*” is the parameter argument value to be passed to the S/W function.
- The “*flag*” name shall be unique for a given S/W function calling sequence.

A typical RCS call, mixing common and specific parameters of a given func1 function, looks like:



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```
$EXECUTABLE func1 --input_1 /path/to/inputfile1 --input_2 /path/to/inputfile2 --output_1 /path/to/outputfile1 --log /path/to/logfile
```

The order of the input parameters is not important, except the function name, which shall be always the first argument to be called.

The way a ROC pipeline automatically identifies a function and its inputs/outputs from information in the descriptor file, and how it builds the corresponding calling sequence is explained in [RD1].

Notes:

- **The path to the master CDF or calibration table files, shall not be passed as input arguments to the CLI, but shall be loaded by the S/W using the dedicated environment variables (see section 3.3).**
- The path to the configuration file can be provided, using the dedicated `--config` input parameter.

### 3.1.2.4 Input keywords

The RCS executable calling sequence shall support at least the following input keywords:

**--identification:** return information about the S/W. The format and content of the returned stream shall correspond to the `"identification"` JSON object in the S/W descriptor file. (See the section 3.2 for more details about the descriptor file.)

**--version:** return information about the current S/W release. The content of the returned stream shall comply the `"release.version"` attribute value in the S/W descriptor file.

**--help:** display a help message, containing information about how to call the S/W.

For instance, to get information about the current version of the S/W:

```
$EXECUTABLE --version
```

Where **EXECUTABLE** is name of the executable file.

Note:

- Input keywords shall not take argument.
- Calling the input keyword shall not require to provide the function name `func1` as a first argument.

## 3.2 RCS descriptor file specification

The RCS descriptor file (or simply descriptor) is the second key element of the interface with the CLI. It contains information about the RCS that helps the ROC pipelines to automatically identify:

- The S/W it-self (e.g., name, identifier, description)
- The release (e.g., version number, release date, author)
- The execution environment (e.g., setup script, executable, configuration, etc.)
- A detailed description of the output files produced by the S/W (name, identifier, description, release, etc.)



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- The list of calling sequences for each S/W function and the corresponding inputs and outputs

The information is used, among others, by the ROC pipelines to automatically build the CLI calling sequence for a given RCS function, and to monitor the outputs creation.

The content of the descriptor is checked and inserted into the ROC pipeline database during the registration step (see [RD1] for more details). A ROC pipeline is hence not able to run a RCS delivered without or with a badly formatted descriptor file.

An example of such a descriptor file can be found in the appendix 5.1.

## 3.2.1 General convention

The descriptor files shall be delivered with the RCS, following the convention below:

- The descriptor file shall be written in the JSON format [RD7]
- The descriptor file shall be placed in the S/W main directory
- There shall be only one descriptor file per S/W
- The descriptor file shall be named “*descriptor.json*”
- All of the paths defined in the descriptor file shall be relative to the S/W main directory. No absolute path shall be defined in the descriptor.

## 3.2.2 Descriptor file structure

The structure of the descriptor file is detailed in the following sections.

### 3.2.2.1 Identification

Each S/W shall be identified in the pipeline by the attributes provided in the “*identification*” JSON object:

- “*project*”: name of the project. It shall be “ROC”.
- “*name*”: full name of the RCS, to be human readable.
- “*identifier*”: a name used as a unique reference by the ROC pipeline to identify the S/W. This ID shall contain alphanumeric uppercase characters only. The hyphen or underscore characters shall be used separators only. The list of possible ID is: “THR\_CALBAR”, “LFR\_CALBUT”, “TDS\_CALBA”, “SCMCAL” and “BICAS”.
- “*description*”: Short description/purpose of the S/W.
- “*icd\_version*”: Version (i.e., issue.revision) of the RCS ICD

### 3.2.2.2 Release

The “*release*” object shall inform about the current S/W release. It shall contain the following attributes:

- “*version*”: Current version of the S/W. The RCS version shall be a unique number sequence identifier “X.Y.Z”, where “X” is an integer indicating the release (major changes, not necessarily retro-compatible), “Y” is an integer indicating the issue (minor changes, necessarily retro-compatible) and “Z” is an integer indicating a revision (e.g., bug correction). The first stable release of software (S/W) must have its major number



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“X” equals to 1, its minor number “Y” equals to 0 and its revision number “Z” equals to 0 (i.e., “1.0.0”). S/W preliminary versions (e.g., alpha, beta, etc.) must have their version number “X” equals to 0 and must not have a character as a prefix/suffix (“0.Y.Zb” for the 0.Y.Z beta version for instance). In all cases, any change in the S/W must lead to update the version number.

- **"date"**: Date of the release of the S/W in the format ‘YYYY-MM-DD’, where ‘YYYY’, ‘MM’ and ‘DD’ are respectively the year, month and date of the release.
- **"author"**: Name of the person, team or entity responsible of the release
- **"contact"**: contact of the author (e.g., email or address)
- **"institute"**: Name of the institute that delivers the release
- **"modification"**: a string containing the list of S/W modifications in the current release.

In addition, the **"release"** object can provide the following optional attributes:

- **"reference"**:reference for the RCS user manual documentation
- **"source"**:indication for an online URL of the RCS source files (e.g., Git repository URL).

### 3.2.2.3 Environment

The attributes defined in the object **"environment"** are used for setting the RCS environment variables, and reset it to the initial state. It shall contain:

- **"executable"**: Relative path to the S/W executable file to be called by the ROC pipeline via the CLI. It corresponds to the **EXECUTABLE** in the calling sequence example given in the section 3.1.2.3.

In addition, the **"environment"** object can contain the following optional attributes:

- **"configuration"**: Relative path to a possible configuration file that it is required by the S/W to run correctly. Note that if the **--config** common input parameter is provided in the CLI, it supersedes the value given in this attribute.
- **"activation"**: Relative path to the directory containing script(s) used to set up the environment, or to be run prior to the S/W execution. The script(s) shall work in the BASH shell and shall run without any input argument.
- **"deactivation"**: Relative path to script(s) used to reset the environment to its initial state. The script(s) shall work in the BASH shell and shall run without any input argument.

### 3.2.2.4 Modes

The **"modes"** element is a JSON objects array, which contains the list of S/W functions that can be run by the pipeline, when it calls the executable.

For each S/W function, its name, its purpose and the list of input/output RPW data to be read/saved shall be supplied. It allows the pipeline to build the S/W function input calls automatically, and to control if the expected output data files are correctly saved.

Each function listed in the **"modes"** object shall contain the following attributes and JSON arrays:

- **"name"**: The name of the function. It shall be unique. It corresponds to the **func1** in the calling sequence as presented in the section 3.1.2.1.
- **"purpose"**: A short description of the purpose of the function





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- **"inputs"**: A JSON array containing the list of the RPW dataset(s), to be provided as input argument(s) to the function
- **"outputs"**: A JSON array containing the list of the output RPW dataset(s) to be produced by the function.

The purpose and the content of the **"inputs"** and **"outputs"** objects are detailed in the two next sections.

### 3.2.2.4.1 Inputs

The **"inputs"** JSON array contains the list of input RPW dataset(s) to be passed to a given function `func1` of the RCS.

The following rules shall be applied for the **"inputs"** array entries:

- There shall be one entry in the array per specific input parameters found in the RCS CLI. E.g., one entry for **"--input\_1"** and one entry for **"--input\_2"**, in the RCS CLI example of the section 3.1.2.3.
- The name of an entry shall be the same than the specific input parameter keyword used in the RCS CLI, but without the **"--"** prefix. E.g., the name of the **"--input\_1"** and **"--input\_2"** entries are **"input\_1"** and **"input\_2"** respectively, in the RCS CLI example of the section 3.1.2.3.
- Each entry shall be a JSON object containing the mandatory attribute **"identifier"**. This attribute shall provide the RPW dataset ID of the input data file, passed to the corresponding RCS CLI specific input parameter keyword.

According to the example of CLI calling sequence in the section 3.1.2.3, the **"inputs"** array will be structured as followed:

```
"inputs":[
  "input_1":{
    "identifier":"RPW_DATASET_ID1"
  },
  "input_2":{
    "identifier":"RPW_DATASET_ID2"
  }
],
```

Where **"RPW\_DATASET\_ID1"** and **"RPW\_DATASET\_ID2"** are the RPW dataset ID of the input data files, to be passed to a given function `func1`, respectively as `--input_1 /path/to/inputfile1` and `--input_2 /path/to/inputfile2` in the RCS CLI calling sequence.

Notes:

- The list of RPW dataset ID are presented in [AD2].
- **The "inputs" array shall not contain any path to an input data file.** The input data file path will be automatically built and passed to the RCS CLI by the ROC pipelines them-selves, from the information provided in the descriptor file.



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- The teams are in charge to define the list of inputs for their S/W in the descriptor file. This work shall be done in collaboration with the other teams and the ROC. Especially, the ROC shall supply as soon as possible information required to develop and maintain the RCS and their descriptor file, including an up-to-date list of the RPW datasets ID and versions used by the RCS.
- The pipeline will not run a given function of the S/W in the case where, at least one of the input files of the expected RPW input dataset, as defined in the **"inputs"** of the descriptor, is not found. It should be taken into account in the S/W architecture design, especially when defining the number of available modes.

### 3.2.2.4.2 Outputs

The **"outputs"** JSON array has the same objective than the **"inputs"** JSON array, but for the software outputs. It contains the list of output RPW dataset(s) generated by a given function `func1` of the RCS. Additionally, it provides descriptive information about the output RPW dataset(s) saved by the RCS.

The following rules shall be applied for the **"outputs"** array entries:

- There shall be one entry in the array per specific input parameters found in the RCS CLI. E.g., one entry for **"--output\_1"**, in the RCS CLI example of the section 3.1.2.3.
- The name of an entry shall be the same than the specific input parameter keyword used in the RCS CLI, but without the **"--"** prefix. E.g., the name of the **"--output\_1"** entry is **"output\_1"**, in the RCS CLI example of the section 3.1.2.3.
- Each entry shall be a JSON object containing the attributes listed below.

Each entry listed in **"outputs"** shall contain the following mandatory attributes:

- **"identifier"**: The RPW dataset ID of the output data file(s), passed to the corresponding RCS CLI specific input parameter keyword.
- **"name"**: a more human-readable name for the dataset, not necessarily unique.
- **"description"**: a short description of the dataset.
- **"level"**: the processing level of the dataset. The authorized values are **"L1R"** or **"L2"**.

In addition, the **"outputs"** object can contain the following optional attributes:

- **"template"**: file name to reference a data schema used for the output generation, as an indication for the ROC team. It should provide the master CDF name.
- **"reference"**: Any reference (paper, note, Web site) giving a description of the output (e.g., RPW Data Product Description Document reference).

According to the example of RCS CLI calling sequence in the section 3.1.2.3, the **"outputs"** array will be structured as followed:

```
"outputs": [
```





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```
"output_1":{  
    "identifier":"RPW_DATASET_ID3"  
},  
],
```

Where "RPW\_DATASET\_ID3" is the RPW dataset ID of the output data file, generated by a given function func1 and for which the target path /path/to/outputfile1 is passed as --output\_1 /path/to/outputfile1 in the RCS CLI calling sequence.

Notes:

- The list of RPW dataset ID are presented in [AD2].
- The **"outputs"** array shall not contain any path to an output data file. The output data file path will be automatically built and passed to the RCS CLI by the ROC pipelines them-selves, from the information provided in the descriptor file.
- The ROC pipeline will perform an automated validation of the S/W descriptor file at each new release, in order to check that the content of the file is consistent with the information in the pipeline database. In particular, it will verify that the datasets declared in the **"modes"** object are all defined in the descriptor and across S/W.

### 3.3 ROC pipeline reserved environment variables

The table below gives the list of environment variables that shall be set by the ROC pipelines only. RCS shall be thus not allowed to define or modify the value of these variables.

Environment variable	Description	Need	Comment
ROC_PIP_NAME	Name of the ROC pipeline. Must be "RGTS" for the ROC-SGSE and "RODP" for the RODP	M	This variable allows the RCS to identify which pipeline is running. Especially, it allows to select which datasets to use between the ROC-SGSE and the RODP.
ROC_RCS_CAL_PATH	Absolute path to the directory containing the RCS calibration table files.	M	This variable allows the RCS to load the calibration tables.
ROC_RCS_MASTER_PATH	Absolute path to the directory containing the RCS master CDF files	M	This variable allows to the RCS to use the master CDF files.
SPICE_MK_PRED_PATH	Absolute path of the Solar Orbiter SPICE predictive	M	Can be used by the RCS to load Solar Orbiter SPICE



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	meta-kernel MK file		Kernels labelled as “predictive”. (See 5.4 section for more details)
SPICE_MK_FLOWN_PATH	Absolute path of the Solar Orbiter SPICE “as-flown” meta-kernel MK file	M	Can be used by the RCS to load Solar Orbiter SPICE Kernels labelled as “as-flown”. (See 5.4 section for more details)
ROC_PIP_VERSION	ROC pipeline version	O	Can be used by the RCS to identify the version of the ROC pipeline
ROC_RCS_ABS_PATH	Absolute path to the directory containing the RCS	O	Can be used by the RCS to know the absolute path of the RCS main directory

Table 1. RCS environment variables.

## 3.4 RCS exception handling mechanism

The RCS shall include a mechanism to handle exceptions that can occur during the execution. The exceptions to be notified to the ROC pipelines, and the expected actions to be performed by the RCS are explained in this section.

### 3.4.1 RCS exception level definition

Table below gives the definition of the exception levels to be implemented in the RCS.

Exception level	Definition
Medium	It is a “warning” exception level. It alerts about a potential issue, but does not necessarily require stopping the execution.
High	It is an “error” exception level, which requires aborting the execution.

Table 2. RCS exception levels.

In both case the “medium” and “high” exception levels, the RCS shall return a message detailing the reason why the exception has been triggered.

In addition, a WARNING/ERROR level event shall be also reported by the RCS into its log file for each “medium”/”high” event (see the section 4.3.1 for the definition of log levels).



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## 3.4.2 Identified exceptions

A RCS shall raise an exception if it encounters one of the following events.

Event	Exception level	Comment
Input(s) data file(s) cannot be found or read correctly	High	
Input(s) file(s) inconsistency	High	It concerns the case where the input file(s) is/are not as expected.
Additional file(s) cannot be found or read correctly	High	It can concern configuration file, master CDF and/or calibration table file(s)
Output(s) file(s) cannot be written correctly	High	e.g., bad write permissions, output directory not found, etc.
Log file cannot be written correctly	High	e.g., bad write permissions, output directory not found, etc.
S/W execution environment not defined	High	e.g., environment variables required by the RCS are not defined correctly
Inconsistencies of metadata for current output dataset	Medium	The metadata of the input files or master CDF are not as expected

Table 3. RCS exception list.

## 3.4.3 RCS exit status convention

If the exit status returned by a RCS is 0, the ROC pipeline will consider that the execution has succeeded. Any other exit status value returned by the RCS will be interpreted by the ROC pipeline as an error.

Especially, if a “high” level exception is raised, the RCS shall return an exit status equals to 1. The error information (i.e., type of error and message) shall be written in the standard error (*stderr*). Error messages shall not be passed to the standard output (*stdout*).

Upon reception of a non-null exit status, the ROC pipeline shall:

- Stop the running process
- Catch the message passed into the standard error (*stderr*) for reporting
- Copy/Move any input/output CDF files as well as software log files into a location accessible to the RCS teams for future investigations

Procedures relative to the RCS failure reporting and recovery must be described in [RD4].

## 4 RCS DATA CONVENTIONS

This section gives the rules related to the RCS data.



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## 4.1 RCS output CDF data convention

### 4.1.1 General convention and metadata definition.

The RCS output CDF data must comply the convention described in [AD1].

### 4.1.2 RCS output CDF metadata setting convention

The table below gives the list of CDF metadata – global and variable attributes - that shall be created or updated by the RCS, when producing the output CDF files using the master CDF.

N.B. All the global attribute entries shall be stored using the CDF\_CHAR data type

Attribute name	Attribute type	Definition	Comment
CAL_ENTITY_NAME	Global attribute	Entity (person or team) in charge of the calibration table generation	There must be one entry for each entry in the CALIBRATION_TABLE attribute
CAL_ENTITY_AFFILIATION	Global attribute	Affiliation of the entity in charge of the calibration table generation	There must be one entry for each entry in the CALIBRATION_TABLE attribute
CAL_EQUIPMENT	Global attribute	The name of the RPW equipment (e.g., "TDS", "LFR", "TNR", "SCM", ...) which is calibrated when applying the corresponding calibration table	There must be one entry for each entry in the CALIBRATION_TABLE attribute
CALIBRATION_TABLE	Global attribute	File basename of the calibration table(s) required to calibrate data in the current file	There must as many as entries than the number of calibration table files required to calibration data inside current file.



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CALIBRATION_VERSION	Global attribute	Version of the calibration table.	There must be one entry for each entry in the CALIBRATION_TABLE attribute
Data_version	Global attribute	See [AD1]	Shall be updated by the RCS from the version field in the CDF file name (i.e., extract the "XX" in the "VXX" field of the input file name)
Datetime	Global attribute	Datetime field as provided in the CDF file name	e.g., "20200301" (for a daily file)
DOI	Global attribute	RPW ESA DOI	Shall be " <a href="https://doi.org/10.57780/esa-3xcjd4w">https://doi.org/10.57780/esa-3xcjd4w</a> "
Generation_date	Global attribute	See [AD1]	
Logical_file_id	Global attribute	See [AD1]	
MODS	Global attribute	See [AD1]	It shall be at least one entry for each release of the RCS software that brings significant change in the data content. Entry format shall be "YYYY-MM-DD -- VX.Y.Z -- change #1 short description   change #2 short description", where YYYY, MM and DD are respectively the year, month and day of the new RCS release. Then followed by the software version "VX.Y.Z" and the change descriptions, which shall be separated by the pipe character (" ")
OBS_ID	Global attribute	See [AD1]	Shall be a recopy of the L1 parent CDF OBS_ID attribute entries.
Parents	Global attribute	See [AD1]	See [AD1]
Parent_version	Global attribute	Version of the parent file(s)	Attribute is obsolete since RCS ICD 1.6
TIME_MAX	Global attribute	See [AD1]	



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TIME_MIN	Global attribute	See [AD1]	
SCALEMAX	Variable attribute	See [AD1]	
SCALEMIN	Variable attribute	See [AD1]	
Software_name	Global attribute	Name of the RCS	Should be the value provided in the identification.identifier field of the descriptor file
Software_version	Global attribute	See [AD1]	Version of the RCS, using the "X.Y.Z" convention
SOOP_TYPE	Global attribute	See [AD1]	Shall be a recopy of the parent CDF SOOP_TYPE attribute entries.
SPECTRAL_RANGE_MAX	Global attribute	See [AD1]	
SPECTRAL_RANGE_MIN	Global attribute	See [AD1]	
SPICE_KERNELS	Global attribute	If any, names of the SPICE MK meta-kernel files used to compute L2 data.	There must be one entry by SPICE MK kernel. Only dated/versioned MK files must be provided. The first entry must contain the name of the SPICE SCLK kernel file used to compute Epoch time (this information can be found in the input L1/HK CDF files).

**Table 4. RCS output CDF metadata setting.**

## NOTES:

- The "File\_ID", "Generated\_by", "Pipeline\_name" and "Validate" global attributes will be updated by the ROC pipeline, just after the creation of a RCS output CDF file.
- The "SKELETON\_MODS" global attribute can be used to give the history of changes for the associated skeleton table. It shall be one entry for each new skeleton table version.
- The use of "CAL\_\*" global attributes is not mandatory for RPW L3 CDF files, but it is highly recommended when it is applicable.

### 4.1.3 RCS output CDF variable setting convention

The table below gives the list of CDF zVariables that can be created or updated by the RCS, when producing the output CDF files.

zVariable name	Data type	Definition	Comment
CALIBRATION_TABLE_INDEX	CDF_UINT1	Index of the calibration	Each CDF record must contain 2 elements: the



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		table(s) value required to generate L2 CDF files.	first element must gives the index of the associated CALIBRATION_TABLE entry (i.e., 0 for the first entry, 1 for the second, etc.). The second element must refer to the index of the value to be used inside the calibration table file.
L2_QUALITY_BITMASK	CDF_UINT2	Optional zVariable that can be used to store bitmask information relevant to the RCS output L2 CDF files	The bitmask meaning values can be different from a RCS to another or from a RCS output CDF to another, depending of the purpose.
L3_QUALITY_BITMASK	CDF_UINT2	Optional zVariable that can be used to store bitmask information relevant to the RCS output L3 CDF files	The bitmask meaning values can be different from a RCS to another or from a RCS output CDF to another, depending of the purpose.

**Table 5. RCS output CDF variable setting.**

## NOTES:

- The use of “CALIBRATION\_TABLE\_INDEX” zVariable is not mandatory in RPW L3 CDF files, but it is highly recommended when it is applicable

### 4.1.4 RCS science data quality setting

The “QUALITY\_FLAG” value shall be set to “good quality” (index=3) in the L1 level data files by default.

From information in parent input files (e.g. QUALITY\_BITMASK), the RCS shall take the decision to keep or downgrade (index < 3) the QUALITY\_FLAG value in the output L1R/L2/L3 data files.



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The RCS shall take the decision in an autonomous way. It is the responsibility of the RCS teams to implement the algorithms that set the QUALITY\_FLAG values in the RCS output CDF files.

Additionally, the optional L2\_QUALITY\_BITMASK zVariable can be set by the RCS to provide any relevant information in the output L2 CDF files. (The same remark can be applied for L3\_QUALITY\_BITMASK).

## 4.2 RPW calibration table (CAL) description

### 4.2.1 Definition

The RPW calibration table files (CAL) are used by the RCS to calibrate the instrument science data.

They contain support data (e.g., gains and phases) required by the RCS to produce RPW L2 output CDF files from L1/HK parent CDF files.

They shall be provided by the RCS teams following the procedure described in [RD4].

### 4.2.2 Data format

The RPW CAL file shall be written using CDF format.

### 4.2.3 File naming

The RPW CAL file shall comply the following file naming convention [AD1]:

solo\_[LEVEL]\_[Descriptor]\_[Datetime]\_V[CALIBRATION\_VERSION].cdf

Where:

- [Descriptor] is the prefix of the Descriptor CDF global attribute value (before ">"). It shall be of the form rpw-[equipment]-[\*], where is the name of the RPW equipment, e.g., "tds", "lfr", "bia", "scm", ... and [\*] is an optional field that can be used to specify the content of the file (e.g., "bias-f0")
- [LEVEL] is the RCT data processing level as defined in [AD1]. It shall be "CAL".
- [Datetime] gives the date when the RCT CDF file has been released. The format is "yyyymmdd".
- [CALIBRATION\_VERSION] is a 2-digit number of the version of the calibration table file (e.g., "01").

### IMPORTANT:

- Each field in the file name shall be separated by an underscore "\_" (use hyphens "-" inside each field to distinguish sub-strings).
- The RPW CAL file shall use lower case convention, except for the level and the version.

### 4.2.4 Data versioning

The version of a RPW CAL CDF file is a 2-digit number, which shall be iterated each time a new version of the file is released for a given descriptor and date.

Initial version number shall be "01".

In the RPW CAL filename, the version number shall appear with the "V" prefix in capital letter (e.g., "V02").





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The value of the CALIBRATION\_VERSION global attribute (see next section) shall be set with the file version number.

## 4.2.5 Release policy

There is no specific rule concerning the cadence of RPW CAL file delivery.

New RPW CAL file(s) shall be generated by the RCS team in charge and delivered to ROC, each time modifications have been made to the calibration data (e.g., gain or phase values).

## 4.2.6 RPW CAL file metadata description

The content of a RPW CAL CDF file can differ from a RPW sub-system to another and the teams in charge are free to define the content. Nevertheless, the file shall at least contain the following global attributes:

Name	Type	Description	Comment
CAL_ENTITY_NAME	Global attribute (CDF_CHAR)	Entity in charge of the calibration (person or team)	Same definition than for RCS output CDF metadata
CAL_ENTITY_AFFILIATION	Global attribute (CDF_CHAR)	Affiliation of the entity in charge of the calibration	Same definition than for RCS output CDF metadata
CAL_EQUIPMENT	Global attribute (CDF_CHAR)	RPW equipment associated to the calibration table.	Same definition than for RCS output CDF metadata
CALIBRATION_TABLE	Global attribute (CDF_CHAR)	Filename of the calibration table, without the “.cdf” extension.	Same definition than for RCS output CDF metadata
CALIBRATION_VERSION	Global attribute (CDF_CHAR)	Version of the calibration table.	Same definition than for RCS output CDF metadata
Descriptor	Global attribute (CDF_CHAR)	Same definition than [AD1].	See convention in previous section.
LEVEL	Global attribute (CDF_CHAR)	Level of the calibration table. Must be “CAL”.	
MODS	Global attribute (CDF_CHAR)	Same definition than [AD1].	
Project	Global attribute (CDF_CHAR)	Same definition than [AD1].	



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Source_name	Global attribute (CDF CHAR)	Same definition than [AD1].	
-------------	-----------------------------	-----------------------------	--

Table 6. RCT CDF metadata setting.

## 4.3 RCS log file convention

This section describes the convention concerning the log file, to be generated by the RCS during its execution at the ROC site.

### 4.3.1 General convention

Teams in charge shall follow the following log file related general convention:

- There shall be one log file per S/W.
- The S/W it-self shall create the log file, from the path and name provided by the argument of the **--log** input parameter. If a log file with the same name already exists in the log directory, the S/W shall not create a new log file, but must append new entries into the existing file.

Note that the ROC might need at some points to move an existing log file from the log directory. In this case, the S/W will then create a new log file.

### 4.3.2 File naming convention

The RCS log file shall follow the file naming convention:

*[rcs\_name].log*

Where *[rcs\_name]* is the name of the RCS in lower case characters, with only hyphens “-“ or underscores “\_” as separators (e.g., tds\_calba.log).

N.B In practice this naming convention is only applicable to the ROC team, since the log filename is an input argument of the RCS.

### 4.3.3 Format and content

The log file shall be an ASCII format file. It shall contain enough information about the execution of the RCS, in order to allow the ROC and the teams in charge to monitor the S/W behaviour and to diagnose unexpected events.

Each line of the file shall start with the following prefix:

*[YYYY:MM:DD] [hh:mm:ss] -- [log\_level] -- [message]*

Where *[YYYY:MM:DD]* and *[hh:mm:ss]* are the date (*YYYY*=4-digits year, *MM*=2-digits month and *DD*=2-digits day of month) and time (*hh*=2-digits hours, *mm*=2-digits minutes and *ss*=2-digits seconds) of the log event. *[log\_level]* is the level of severity of the log event (see table in the next section) and *[message]* is a one line description of the log event.

### 4.3.1 Log event severity levels

Table below gives the list of event severity levels to be used in the RCS log file.



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Severity level	Definition	Actions to be performed by the RCS
DEBUG	Debug event (only used in debug mode)	No specific action
INFO	Normal event (e.g., RCS start/end times, routine tasks information, etc.)	No specific action
WARNING	Event that requires attention, but does not compromise the software execution or data production	No specific action
ERROR	Event that requires special attention, and compromises the data production or the software execution (e.g., unexpected values in the data, not input data file found, env. variable not well defined, etc.)	Stop the software execution and exit with an exception (error code 1)

Table 7. RCS log event severity levels.

## 5 APPENDICES

### 5.1 Example of a RPW S/W descriptor file

Here is an example of a RPW descriptor file for the THR Calibration software (THR\_CALBAR) RCS.

```
{
  "identification": {
```



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```
"project": "ROC",
"name": "THR CALBAR",
"identifier": "THR_CALBAR",
"description": "The RPW TNR-HFR CALibration softwARE (THR-CALBAR)
produces RPW TNR-HFR calibrated science data",
"icd_version": "1.2"
},
"release": {
  "version": "1.1.0",
  "date": "2015-07-29",
  "author": "Antonio Vecchio",
  "contact": "antonio.vecchio@obspm.fr",
  "institute": "LESIA",
  "modification": "Update tnr_l2_calibration function",
},
"environment": {
  "activation": "scripts/setup_thr-calbar_env.sh",
  "deactivation": "scripts/unset_thr-calbar_env.sh"
  "executable": "bin/thr-calbar-api",
  "configuration": "config/thr-calbar_configuration.json"
}
"modes": [
  {
    "name": "tnr_l2_cal",
    "purpose": "Produce calibrated science TNR data file at analys
er level (L2)",
    "inputs": {
      "input_l1_tnr": {
        "identifier": "SOLO_L1_RPW-TNR-SURV"
      }
    },
    "outputs": {
      "output_l2r_tnr": {
        "identifier": "SOLO_L2_RPW-TNR-L2-SURV",
        "name": "RPW TNR L2 survey data",
        "description": "RPW TNR L2 science data in survey mode
",
        "level": "L2",
        "template": "SOLO_L2_RPW-TNR-SURV_V04.cdf ",
      }
    }
  },
  {
    "name": "hfr_l2_calibration",
    "purpose": "Produce calibrated science HFR data file at analys
er level (L2)",
    "inputs": {
      "input_l1_hfr": {
        "identifier": "SOLO_L1_RPW-HFR-SURV"
      }
    },
    "outputs": {
```



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```
        "output_l2_hfr": {
            "identifier": "SOLO_L2_RPW-HFR-SURV",
            "name": "RPW HFR L2 survey data ",
            "description": "RPW TNR L2 science data in survey mode
",
            "level": "L2"
            "template": "SOLO_L2_RPW-HFR-SURV_V04.cdf ",
        }
    }
}
]
```

## 5.2 Examples of a CLI calling sequence

With the following configuration, the pipeline will call the S/W for the calibration mode `tnr_l2_cal` as (assuming that the environment as been setup previously and that the path to the S/W directory is contained in the `$ROC_RCS_ABS_PATH` variable):

```
$$ROC_RCS_ABS_PATH/bin/thr-calbar-api tnr_l2_cal --input_l1_tnr
/path/to/input_l1_tnr_cdf \
    --output_l2_tnr /path/to/output_l2_tnr_cdf --log /path/to/log \
    --config $SW_ROOT/config/configuration.file
```

If the S/W ends without error, then the pipeline will search for a file at `/path/to/output_l2_tnr_cdf`.

If an error occurs, the S/W must stop with an error code greater than 0 and a relevant message in `stderr`. If the error can be caught by the pipeline, it will store not necessarily useful information.

For the identification command, the S/W will return the following JSON message in the `stdout`:

```
$$ROC_RCS_ABS_PATH/bin/thr-calbar-api --identification
{
    "project": "ROC",
    "name": "THR CALBAR",
    "identifier": "THR_CALBAR",
    "description": "The RPW TNR-HFR CALibration softwARE (THR-CALBAR)
produces RPW TNR-HFR calibrated science data",
    "icd_version": "1.2"
}
```

And for the version command:

```
$$ROC_RCS_ABS_PATH/bin/thr-calbar-api --version
{
    "version": "1.1.0"
}
```



## 5.3 ROC S/W descriptor file validation

A JSON format file, as for XML, can be validated against a schema. A JSON schema is following the specifications from <http://json-schema.org/draft-04/schema>. Dedicated documentation can be found at <https://spacetelescope.github.io/understanding-json-schema>.

The JSON schema for the RCS descriptor file is described below. It will be used by the ROC pipeline to automatically validate a S/W descriptor file after delivery.

A copy of the RCS descriptor JSON file “cawa-schema.json” can be found in the RCS folder of the <https://gitlab.obspm.fr/ROC/DataPool> Git repository. Teams are free to download and use this file to verify that their descriptor is compliant.

```
{
  "$schema": "http://json-schema.org/draft-04/schema#",
  "definitions": {
    "input": {
      "type": "object",
      "patternProperties": {
        "^[A-Za-z][\\w-]+$": { "$ref":
"#/definitions/input_dataset" }
      },
      "additionalProperties": false
    },
    "output": {
      "type": "object",
      "patternProperties": {
        "^[A-Za-z][\\w-]+$": { "$ref":
"#/definitions/output_dataset" }
      },
      "minProperties": 1,
      "additionalProperties": false
    },
    "mode": {
      "type": "object",
      "properties": {
        "name": {
          "type": "string",
          "pattern": "^[A-Za-z][\\w-]+$"
        },
        "purpose": { "type": "string" },
        "inputs": { "$ref": "#/definitions/input" },
        "outputs": { "$ref": "#/definitions/output" }
      },
      "required": [ "name", "purpose", "inputs", "outputs" ],
      "additionalProperties": false
    },
    "release": {
      "type": "object",
      "properties": {
        "author": { "type": "string" },
        "date": {
```



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```
        "type": "string",
        "format": "date-time"
    },
    "version": {
        "type": "string",
        "pattern": "^((\\d+\\.\\.?)?(\\d+\\.\\.?)?(\\d+))$"
    },
    "file": {"type": "string"},
    "institute": {"type": "string"},
    "reference": {"type": "string"},
    "url": {
        "type": "string",
        "format": "uri"
    },
    "contact": {
        "type": "string",
        "format": "email"
    },
    "modification": {"type": "string"}
},
"required": ["author", "date", "version"],
"additionalProperties": false
},
"output_dataset": {
    "type": "object",
    "properties": {
        "identifier": {
            "type": "string",
            "pattern": "^[\\w-]+$"
        },
        "name": {"type": "string"},
        "level": {"enum": ["LZ", "L0", "L1", "L1R", "L2", "L3",
"ANC", "LL01", "LL02", "HK"]},
        "description": {"type": "string"},
    },
    "required": ["identifier", "name", "level", "description"],
    "additionalProperties": true
},
"input_dataset": {
    "type": "object",
    "properties": {
        "identifier": {
            "type": "string",
            "pattern": "^[\\w-]+$"
        },
    },
    "required": ["identifier"],
    "additionalProperties": false
}
},
"type": "object",
"properties": {
```



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```
"identification": {
  "type": "object",
  "properties": {
    "project": {"type": "string"},
    "name": {"type": "string"},
    "identifier": {"type": "string"},
    "description": {"type": "string"},
    "icd_version": {"type": "string"},
  },
  "required": ["project", "name", "identifier", "description",
"icd_version"],
  "additionalProperties": false
},
"release": {"$ref": "#/definitions/release"},
"environment": {
  "type": "object",
  "properties": {
    "activation": {"type": "string"},
    "deactivation": {"type": "string"}
  },
  "additionalProperties": false
},
"executable": {"type": "string"},
"configuration": {"type": "string"},
"modes": {
  "type": "array",
  "items": {"$ref": "#/definitions/mode"}
}
},
"additionalProperties": false,
"required": ["identification", "release", "environment", "executable",
"modes"]
}
```





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### 5.4 Solar Orbiter SPICE kernel RCS processing implementation

Producing RPW L2 CDF files will require to use the Solar Orbiter SPICE kernels [RD9].

Before running a RCS, the ROC pipeline shall hence ensure:

- The environment to run SPICE toolkit with the RCS is setup. For IDL, the SPICE “ICY” toolkit must be used ([https://naif.jpl.nasa.gov/naif/toolkit\\_IDL.html](https://naif.jpl.nasa.gov/naif/toolkit_IDL.html)). For Python, the “spiceypy” module must be used (<https://pypi.org/project/spiceypy/>).
- The solo\_ANC\_soc-pred-mk.tm and solo\_ANC\_soc-flown-mk.tm files are replaced by symbolic links pointing toward the expected dated/versioned MK files (e.g., solo\_ANC\_soc-pred-mk\_VNNN\_YYYYMMDD\_XXX.tm and solo\_ANC\_soc-flown-mk\_VNNN\_YYYYMMDD\_XXX.tm). It allows the RCS to retrieve the names of the MK files used to process L2 CDFs and store them as entries of the dedicated SPICE\_KERNELS global attribute (see table 4).
- The SPICE\_MK\_PRED\_PATH and SPICE\_MK\_FLOWN\_PATH environment variables are defined and point toward the path of the solo\_ANC\_soc-pred-mk.tm and solo\_ANC\_soc-flown-mk.tm symbolic links respectively.

The ROC pipeline shall unpacked and make available any new Solar Orbiter SPICE kernel data pack delivered by the SOC within 24 hours after reception.





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## 7 DISTRIBUTION LIST

<p style="text-align: center;"><b>LISTS</b></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
	Tech_MEB
	Tech_RPW
	[Lead-]Cols
	Science-Cols

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LESIA CNRS	

LESIA CNRS	

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