RPW Operations Centre

RPW Instrument State Model

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Change Record

Issue	Rev.	Date	Authors	Modifications
1	0	06/12/2017	A.Vecchio	First issue
1	1	16/02/2018	A.Vecchio	Change
1	2	23/04/2018	D. Bérard	Add of data rate of different configurations
1	3	22/05/2018	D. Bérard	Corrections and add of data rate values for each configuration
1	4	16/07/2018	D. Bérard	Add data rate values calculated with the Calculator 2.1 Add use case of Table 4
		27/09/2018	D. Bérard	Invert Cold/ Hot cases in section 2.6.1
		05/10/2018	D. Bérard	Add low rate config data rate Add a discussion about loading configurations in section 2.5
1	5	07/02/2019	D. Bérard	Correct sequence names with the new convention naming Remove DPU RESET to go to SAFE mode. Only STANDBY mode. Remove AIWF001A and AIWF010A as possible transition sequences Correct data rate for TNR HFR Burst mode to 1730 bits/s
1	6	23/05/2019	D. Bérard	Update data rates using calculator 2.8 Add High Rate and commissioning configurations
1	7	11/07/2019	D. Bérard	Complete transition sequences list (table 3)
1	8	12/09/2019	D. Bérard	Update data rate table using new python calculator
1	9	08/05/2020 02/06/2020	D. Bérard	- Update data rate table using python calculator vs real data and new configurations - Correct table of mode changes - Update data rate with compression using real estimation of compression rate per products

Acronym List

Acronym	Definition
AU	Astronomical Unit
COM	Commissioning procedure
CRP	Contingency Recovery Procedure
DAS	DPU Application Software
DBS	DPU Boot Software
DPU	Data Processing Unit
FCP	Flight Control Procedure
HK	HouseKeeping
ISM	Instrument State Model
MOC	Mission Operations Centre
OBC	On-Board Computer
OMM	OBC Mass Memory
PA	Pre amplifier
PW	Power
ROC	RPW Operations Centre
RPW	Radio and Plasma Waves experiment
SCM	Search Coil Magnetometer
SSMM	Solid State Mass Memory
S/W	Software
TC	(Tele)command
TM	Telemetry
TMC	TM corridor

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1 GENERAL

1.1 Scope of the Document

This document describes the instrument state model (ISM) for RPW.

The ISM provides the RPW instrument states, allowed transitions between states as a function of power consumption and data rate, and the corresponding telecommand (TC) sequences.

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				
AD2				
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-ESC-TN-12000/1/2	Solar Orbiter – Mission Planning Concept	SOL FCT	27/06/2014
RD2	SOLO-RPW-TN-116/8/1	RPW Electrical Power Budget	E.Lorfevre	30/05/2017
RD3	RPW-SYS-SSS-00013-LES/4/3	RPW Software System Specification	P.Plasson	14/12/2016
RD4	SOLO-RPW-TN-285-CNES/2/0	RPW TM budget report	G.Campos Garrido	02/12/2014
RD5	SOL-SGS-ICD-0007/1/0	Solar Orbiter Telemetry corridor ICD	C.Watson	14/03/2017
RD6	ROC-OPS-SYS-NTT-00059-LES/1/1	RPW instrument state transition matrix	A.Vecchio	16/02/2018
RD7	SOL-ESC-PL-10001/1/2	Solar Orbiter FOP Preparation Plan (FOPPP)	I.Tanco	18/01/2017
RD8	SOLO-RPWSY-TN-1160-CNES/2/3 (draft)	RPW instrument User Manuel	RPW team	06/06/2017
RD9	ROC-OPS-SFT-BDG-00044-LES_Iss02Rev01_Calculator_TM_RPW_User_Manual	RPW data rate Calculator User Manual	D. Bérard	13/07/2018

2 INTRODUCTION

2.1 Context

For all the Solar Orbiter instruments, the MOC will define a state model, in which each state is related (e.g. by a fixed offset) to the execution of a specific TC sequence [RD1]. The states are linked to concrete levels of resource usage (power, data rate), allowing the definition of transient states.

Initial values for these models will be provided individually by each instrument team, and will be later updated with actual flight data. It is possible to distinguish within instances of the same sequence, at sequence parameter level, for different state triggering - however not at the level of TC fixed parameters – when this is the case, the resource usage modelling shall be established by SOC and passed via dedicated interface.

2.2 Perimeter

The main purpose of RPW ISM is to provide inputs to the MOC and SOC for their respective instrument state resource modellings.

In the current model, MOC is essentially interested in resource constraints related to the power consumption. Concerning the data rate, MOC only cares about HK telemetry (TM) bit rate that goes to the OMM; ideally a fixed number and not more than 50 bps, which is the case for RPW [RD4]. The SOC is interested in the instrument data rate constraints related to the on-board SSMM storage.

2.3 Definitions

In order to clarify this current document, several definitions are given in Table 1.

Name	Definition
Software mode	Mode of the RPW DPU; detailed in section 2.3.1.
Software sub-mode	Sub-mode in the science software mode (SURVEY_NORMAL, SURVEY_BURST, SBM_DETECTION).
Instrument mode	Set of software modes with the same power consumption. In practice, the RPW electrical power profile is pretty stable over a given S/W mode. The instrument modes hence match well with the S/W modes. Nevertheless, this is not true for the SERVICE S/W mode, when the power consumption can differ significantly depending of the state ON/OFF of the RPW equipment units. In this specific case, and in order to simplify the model, it is assumed that the instrument mode is still the same (i.e., RPW_SERVICE) even if the equipment units are all OFF. **Finally, in this document, we will hence identify software and instrument modes and called them modes.**
Configuration	The configuration of an analyzer is a set of fixed parameters that will define the data recording in science modes (observed frequences, time between two snapshots, length of packets…). These configurations are loaded using TC_*ANA*_LOAD_XXX_PAR,

	where *ANA* is an analyzer (TDS, THR, LFR or BIA) and XXX is the type of parameters (NORMAL, COMMON, CALIBRATION…).
Intrument state	A software mode (or sub-mode) and a given configuration, with constant power consumption[1], and constant data rate.

Table 1 : Definitions

2.4 RPW modes and allowed transitions

Figure 1 gives the RPW modes and allowed transitions. The modes are detailed in [RD3] and summarized in Table 2.

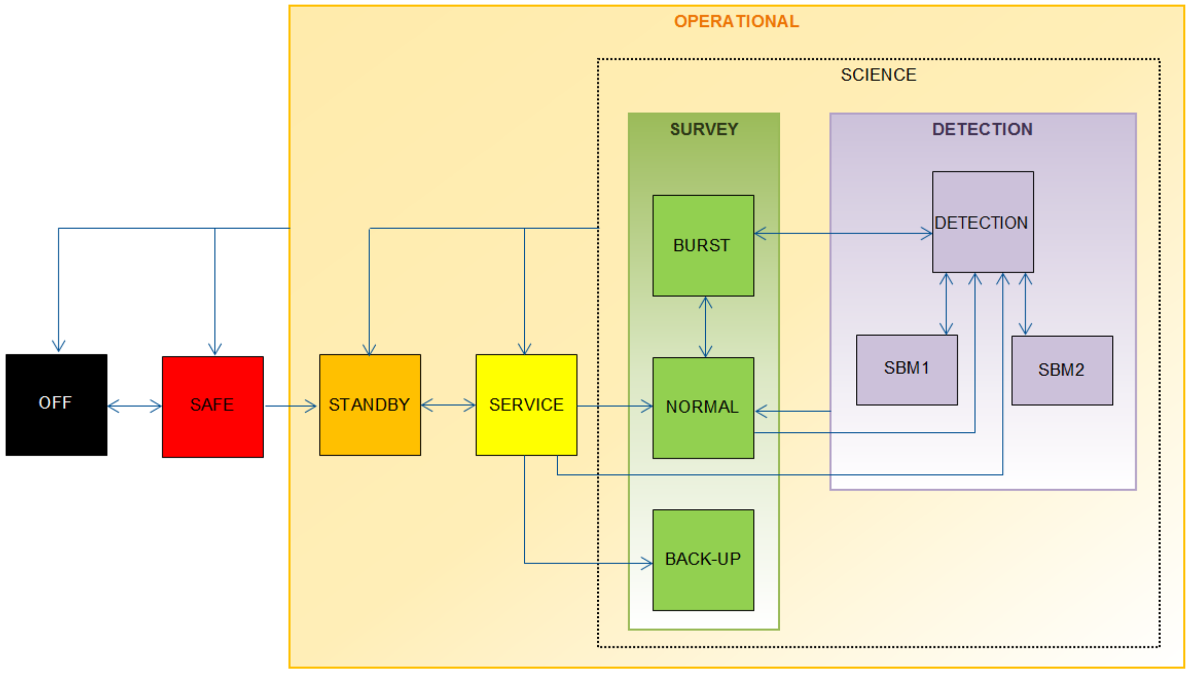

Figure 1. RPW modes.

When in SAFE mode, only the DPU boot S/W (DBS) is executed in the DPU. Once the DPU application S/W (DAS) is loaded, the operational mode (STANDBY sub-mode) is entered. Next, SERVICE mode allows, among other tasks, the configuration and switching ON/OFF of equipment units (i.e., analyzers, Bias and sensors PA). The SCIENCE mode is the main mode of RPW in which the measurements are active.

RPW software mode	Description
RPW_OFF	RPW is OFF
RPW_SAFE	RPW DBS is in SAFE mode
RPW_STANDBY	RPW DAS is in STANDBY mode
RPW_SERVICE	RPW DAS is in SERVICE mode. The equipment units can only be switched-on/off in this mode. However, it is assumed that all equipment units are always ON in the RPW_SERVICE mode.
RPW_SCIENCE	RPW DAS is in the SCIENCE mode, with one of the

[1] The TM bit rate can change significantly depending of the RPW analyzers'configurations.

	following sub-modes triggered from ground: SURVEY_NORMAL, SURVEY_BURST or SBM_DETECTION
RPW_BACKUP	RPW DAS is in SURVEY_BACKUP mode

Table 2 : RPW software modes

2.5 RPW configurations

RPW can have an infinite number of configurations for each software science sub-mode. However, in practice the instrument can be operated through only few well-defined configurations. The latter might cover 99% of the needs related to the science operations, planned during the cruise and nominal phases (commissioning phase might require specific configurations). These configurations are:

- *Default Science* : used the majority of time, it is the nominal configuration for each sub-mode. The corresponding TM rate has been defined in EID-A (5,5kbits/s),
- *Low Rate 1 or 2* : used in case of low TM rate (40% of EID-A = 2,2kbits/s), there are two different configurations : one with SBM DETECTION active, one without, leading to two different data rates.
- *High Rate 1 or 2* : used in case of high TM rate (several times EID-A). In the first configuration, every sub-system is producing more data. In the second one, TDS is producing a lot of data, and other sub-system less.
- *Galaxy* : used in a specific case : only TNR-HFR receiver is switched on in order to measure the radio spectra of the galaxy (high frequency mode).
- *Commissioning configurations* : used in the specific cases of commissioning activities (deployments of antennas, i-Boom, SCM Noise campaign, antennas rolls calibration campaign, inter-instrument campaign).

Additional configurations may be added during the mission, in order to fulfill new needs in terms of operations.

In order to change the configuration of a software science mode, RPW can be in every mode (science or service mode) except in the concerning mode. Meaning that to change the configuration for NORMAL mode for example, RPW could be in SERVICE, or BURST mode. The new configurations will be applied when RPW enter the concerning mode. Thus the following steps present an example of changing the configuration for NORMAL mode :

- RPW in SERVICE mode
- Load of configuration 1 for NORMAL mode
- Enter RPW in NORMAL mode
- Acquire data in NORMAL mode with configuration 1
- Enter in RPW Service mode
- Load configuration 2 for NORMAL mode
- Enter in NORMAL mode
- Acquire data in NORMAL mode with configuration 2

- Load configuration 3 for BURST mode
- Enter BURST mode
- Acquire data in BURST mode with configuration 3

2.6 Electrical Power and telemetry budgets

A given instrument state will have a given electrical power consumption and a given telemetry rate. This link is the main purpose of the instrument state model.

2.6.1 RPW electrical power budget

The RPW electrical power budget is provided in [RD2].

During SAFE and STANDBY modes, antenna and SCM pre-amplifiers (PA) heaters are controlled by the spacecraft through the same hardware used for survival thermal control. In SERVICE and SCIENCE modes the heating power is part of RPW power allocation (only the power of SCM heaters is controlled by RPW) and thus included in RPW power budget.

PA heating power consumption varies, depending on the distance of Solar Obiter from the Sun:

- When Solar Orbiter is far from the Sun, RPW antennas shall be heated. The reference case is the operational hot case at 1.2 AU.
- When Solar Orbiter is near to the Sun, RPW antennas are not heated. The reference case is the operational cold case at 0.28 AU. At this distance a lower heating power is needed.

The RPW power budget is thus divided into 2 parts: a cold case, when the spacecraft is closer to the Sun, without heating the antennas and a hot case, farther from the Sun, with heating power for the antennas. On the other hand, SCM heater shall be activated during the whole mission.

2.6.2 RPW Telemetry budget

The RPW TM budget is given in [RD4].

For the MOC, the TM budget only concerns here the HK that goes to the OMM. For RPW the related TM bit rate is always lower or equal to 50 bps, and can be thus ignored in the ISM.

Nevertheless, the TM bit rate constraint must be taken into account, when defining the instrument configurations within the Solar Orbiter science operation timeline. Especially, the volume of instrument TM that will go to the SSMM, will be controlled by the SOC via the Telemetry corridor (TMC) mechanism [RD5]. As this TM budget depends on the loaded state, ROC decided to define several common states for each analyzer, and then an associated data rate.

3 RPW INSTRUMENT STATE MODEL (ISM)

3.1 RPW flight sequences summary list

The full list of flight sequences for RPW can be found in the section 5 of the RPW User Manual [RD8].

3.2 RPW instrument modes allowed transitions and corresponding power consumption

The table below presents for each RPW instrument mode, the power consumption in Watts (W), as well as the allowed transitions (i.e., sequences) from other modes. The power consumption is given for both the hot (i.e., PA heaters are off) and cold (i.e., PA heaters are on) cases.

RPW instrument Mode	Hot/Cold Power Cons. (W)	Transition to Mode via Sequence	Allowed Transition from Mode	Remarks
RPW_OFF	0/0	AIWF002A (UNIT_A and UNIT_B, manual)	RPW_STANDBY	Switch off both prime and redundant units
		AIWF001A (OBCP)	RPW_STANDBY	Switch off both prime and redundant units
RPW_SAFE	4.5/4.5	AIWF011A (UNIT_A, manual)	RPW_OFF	Nominal case
		AIWC015A (UNIT_B, manual)	RPW_OFF	Non nominal case
		AIWC046A	RPW_SCIENCE RPW_STANDBY RPW_BACKUP	Non nominal case
RPW_STANDBY	5.3/5.3	AIWF030A	RPW_SAFE	
		AIWF045A	Any mode (except RPW_OFF and RPW_SAFE)	When executing AIWF045A, the RPW equipment units, which are ON, are properly switched-off by the DPU (see [RD3] for details)
RPW_SERVICE	15.2/16.6	~~AIWF031A~~ ~~3.2.1.1.1.1~~	~~RPW_STANDBY~~ ~~3.2.1.1.1.2~~	~~3.2.1.1.1.3 AIWF031A allows RPW to go~~

				~~from RPW_STANDBY to RPW_SERVICE mode and switch on all equipment straight.~~
		AIWF043A	RPW_SCIENCE or RPW_BACKUP or RPW_STANDBY	
		IW-FCP-047	RPW_SERVICE	Each sequence of IW-FCP-047 allows to switch off one equipment only.
		AIWF033G	RPW_SCIENCE (NORMAL, BURST or SBM_DETECTION)	
		AIWF033I		
RPW_SCIENCE_SURVEY_NORMAL	17.7/19.1	AIWF035A	RPW_SERVICE	
		AIWF033A	RPW_SCIENCE (NORMAL, BURST or SBM_DETECTION)	

		AIWF033B AIWF033D	RPW_SERVICE	
RPW_SCIENCE_SURVEY_BURST	17.7/19.1	AIWF035B	RPW_SERVICE or RPW_SCIENCE (NORMAL or SBM_DETECTION)	
RPW_SCIENCE _SBM_DETECTION	17.7/19.1	AIWF035C	RPW_SERVICE or RPW_SCIENCE (NORMAL or BURST)	
RPW_BACKUP	17.7/19.1	AIWF044A	RPW_SERVICE	This is the same value of all science modes since it represents the maximum power consumption in Survey Backup mode (i.e. TDS could be on but not working properly)

Table 3. Operational hot/cold cases (the heating average power is considered)

Notes:

- The active thermal control system of the RPW PA heaters is controlled by the S/C both in operational and survival modes (see [RD8] for details).
- The active thermal control system of the RPW SCM heaters is controlled by the MEB in operational mode and by the S/C otherwise (see [RD8] for details).

3.3 RPW instrument mode transition matrix

Figure 2 shows the possible transitions between RPW software modes (or sub-modes) and the corresponding sequences.

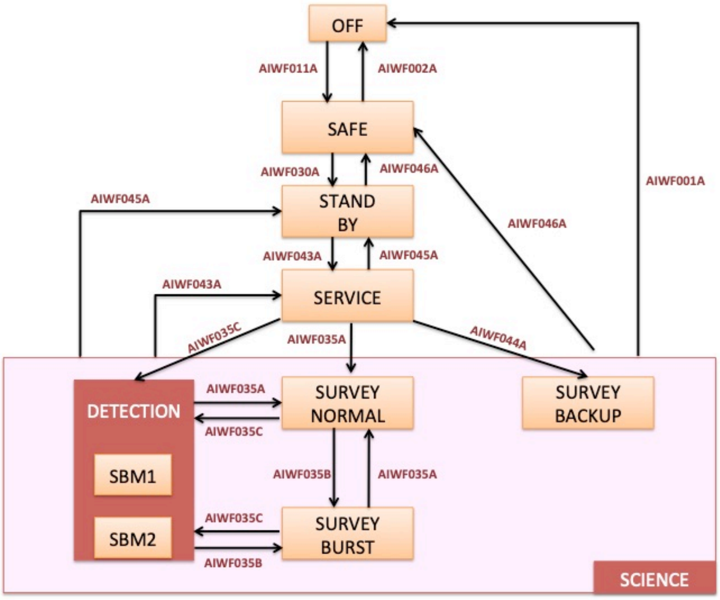

Figure 2 : Allowed transitions between RPW software modes and corresponding sequences

The transition matrix, which presents the instrument mode versus the RPW flight sequences is given in [RD6].

3.4 RPW instrument state data rates

For each instrument state, a data rate can be estimated based on a ground model data (see the calculator user manual [RD9]) and will be updated with real measurements during the mission. Table 4 details the **instantaneous** data rate **with or without compression** in function of the configuration and the sub-mode for each analyzer.

<table>
<tr><th rowspan="3"></th><th colspan="6">Instantaneous data rate (bits/s) without compression (with compression)</th></tr>
<tr><th rowspan="2">Instrument mode
Configuration</th><th rowspan="2">NORMAL</th><th rowspan="2">BURST</th><th colspan="2">SBM DETECTION</th><th rowspan="2">BACK-UP</th></tr>
<tr><th>SBM1</th><th>SBM2</th></tr>
<tr><td rowspan="2">HK</td><td>All except Galaxy</td><td colspan="5">757</td></tr>
<tr><td>Galaxy</td><td colspan="5">705</td></tr>
<tr><td rowspan="7">LFR</td><td>Default</td><td>4250 (2345)</td><td rowspan="5">31812 (14258)</td><td rowspan="5">410091 (213483)</td><td rowspan="5">31812 (19524)</td><td rowspan="5">0</td></tr>
<tr><td>Low rate 1</td><td>1883 (1086)</td></tr>
<tr><td>Low rate 2</td><td>1390 (703)</td></tr>
<tr><td>High Rate 1</td><td>30337 (16473)</td></tr>
<tr><td>High Rate 2</td><td>22096 (8232)</td></tr>
<tr><td>Galaxy</td><td colspan="5">0</td></tr>
<tr><td>Calibration</td><td colspan="5">87382 (73593)</td></tr>
<tr><td>TDS</td><td colspan="6">TSWF are not taken into account in TDS below data rate calculations. For each dumped TSWF, the produced data rate is : 1062 kBits (797 kBits compressed)</td></tr>
</table>

	Default	965 (670)	2590 (1099)	66592 (33472)	1061248 (530816)	13911 (9699)
	Low rate 1	228 (178)	2590 (1099)			
	Low rate 2	289 (265)	2724 (1233)			
	High Rate 1	13448 (7340)	2847 (1356)			
	High Rate 2	17610 (8342)	2737 (1245)			
	Galaxy	0				
THR	Default	507 (507)	1724 (1724)	NA	NA	507 (507)
	Low rate 1	254 (254)				254 (254)
	Low rate 2					
	High Rate 1	850 (850)				785 (785)
	High Rate 2					
	Calibration TNR-HFR	685 (685)				
	Galaxy	499 (499)	0			
Others	Calibration Bias	1547 (396)				
	Sweep Bias	773 (198)				

Table 4 : Data rate of each pre-determined state without compression (in black) and with compression (in blue). NA = Not Applicable

<u>Notes:</u>

- Calibrations and sweeps are negligeable in first approximation and are not taken into account in the global calculations
- TDS Trigerred snapshots (TSWF) are not taken into account in TDS data rate global calculation as it depends on a manually required dump. The table 4 gives the size of one TSWF. The user must take into account how many TSWF are dumped in one day and thus calculate the data rate to be added to the global TDS data rate (see example below).
- In SBM DETECTION mode, the data rate of NORMAL mode always applies. When an event is detected the SBM1 (or SBM2) data rate needs to be applied in addition to the normal mode.
- The daily average data rate should be inferior at the EID-A data rate (5.5 kbits/s). In case of low telemetry, this average daily data rate must decreased down to 40% EID-A (2.2 kbits/s).
- TDS default configurations are multiple. The data rate given in Table 4 is the higher rate from sequences AIWF038K or L. AIWF038M creates a data rate of 670 bit/s.

<u>How to use Table 4 to calculate an average daily data rate :</u>

1. The user should determine the timeline of the day (how long RPW will be in each mode during the day and how many TSWF will be dumped).
2. For each mode, add the corresponding data rate for each analyzer (and HK), multiply by the total duration of this science mode to obtain the data size.

3. If TSWF dumps have been required (with AIWF034B or as indicated in Soop Kitchen) : number of TSWF in each dump * data rate for one TSWF (see table 4) * number of dumps per day * 24h
4. Sum all those data rates and divide by one day in seconds (24*3600 =86400s).

Practical example :

Let's assume RPW is in BURST mode 10 min per day, and that all instruments are in SBM DETECTION the rest of the time. As a SBM1 event (shock) is expected every 5 days and last 13 minutes, and ten SBM2 events (Type III) are expected every year and last 30 minutes each, we can say that RPW is in average :

- In BURST mode 10 min/day
- In NORMAL mode : 24*60 – 10 = 1430 min/day (because in SBM DETECTION, Normal mode still applies)
- In SBM1 detection 13 / 5 = 2.6 min/day
- In SBM2 detection 30 x 10 / 365 = 0,82 min/day

Assuming 4 dumps of 16 TSWF per day (nominal dumping rate during the nominal phase), the data size produced in one typical day with no compression is:

Data size = 1430 x 60 x (4250+965+507)	**NORMAL**
+ 10 x 60 x (31812+3608+1724)	**BURST**
+ 2.6 x 60 x (410091+66592 + 507)	**SBM1**
+ 0.82 x 60 x(31812+1035364+507)	**SBM2**
+ 757 x 3600 x 24	**HK**
+ 4 x 16 x 1062 x 1000	**TSWF (4 dumps of 16 TSWF during 24h. One dump = 1062 kBits)**

= 490 947 600 + 22 286 400 + 74 441 640 +52 530 004 + 65 404 800 + 67 698 000

= 773 308 444 bits

And thus the corresponding data rate is 773 308 444 /(24*3600) = 8950 bits/s

List of TBC/TBD/TBWs

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

4 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-]Cols
		Science-Cols

INTERNAL

LESIA CNRS			LESIA CNRS		

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