

RPW Operations strategy

Outline

- Mission science operations planning concept
- RPW science operations plan
- Possible synergy with FIELDS/PSP

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Science Operations Planning Cycles

- *Mission-level Planning*
  - *Science Working Team (SWT) defines top-level science activities for the entire mission (Science Activity Plan, SAP), as well as detailed science goals for each orbit.*
- *Long-Term Planning (LTP)*
  - *Covers 6 months, planned ≥ 6 months before execution (~ 1 orbit; fixes ground stations allocation)*
  - *Given input from SWT, the Science Operations Working Group (SOWG) defines a coherent mission-level observing plan for a given orbit. They will be assisted by the SOC, which will provide detailed information on the resources available.*
- *Medium-Term Planning (MTP)*
  - *Covers 6 months, fixed 4 weeks before execution (defines top-level science operations per orbit: fixes S/C resources, instrument modes, default pointing)*
- *Short-Term Planning (STP)*
  - *Covers 1 week, planned ~1 week before execution (generates detailed schedules of commands for S/C and payload; last opportunity to modify instrument ops. modes)*
- *Very-Short-Term Planning (VSTP)*
  - *For subset of remote-sensing windows only: update S/C fine pointing to track features on solar disk*
  - *Opportunity for fine-pointing updates: once per 24h, time between pointing definition and execution ≤ 3 days*

From Y.Zouganelis, SOWG8



Science Activity Plan

The Science Activity Plan (SAP) describes in a structured way all scientific activities to be carried out by the instruments throughout the cruise and nominal phases in order to fulfill the Science Requirements of the mission.

Top-level science objectives

↓

Detailed science objectives

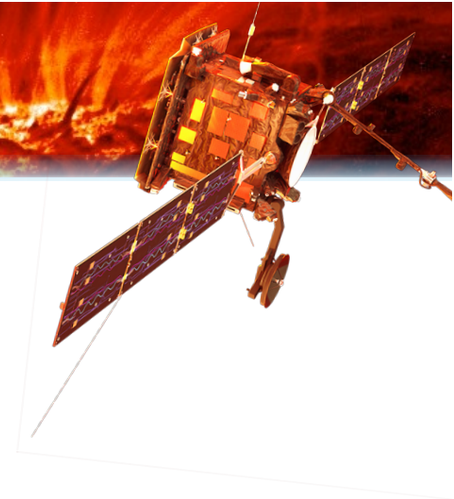
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Specific Science Activities

↓

Science Orbits

From Y.Zouganelis, SOWG8



How to build a SAP

How to build a mission-long SAP?

SolO's (sub)objectives

SOOPs

SOOP A

SOOP B

SOOP C

SOOP D

Step 1

Step 2
Strategy

EPD normal+burst
EUI/HRI AR mode
MAG Normal
Metis GLOBAL
PHI/HRT NOM 0
RPW normal+burst
…

10 instruments, many modes

- EPD
  - EPD Normal Mode
- EUI
  - EUI/FSI Synoptic mode (S)
  - EUI/FSI reference synoptic mode (R)
  - EUI/FSI Global eruptive event mode (G)
  - EUI/HRI Coronal hole mode (C)
  - EUI/HRI Quiet Sun mode (Q)
  - EUI/HRI Active Region mode (A)
  - EUI Beacon mode
  - EUI/HRI Eruptive Event mode (E)
  - EUI/HRI Discovery mode (D)
- MAG
  - MAG Burst Mode
  - MAG Normal Mode
- METIS
  - METIS standard modes
  - METIS special modes
  - METIS observing mode characteristics
- PHI
- RPW
- SoloHI
- SPICE
- STIX
- SWA

10 years mission timeline



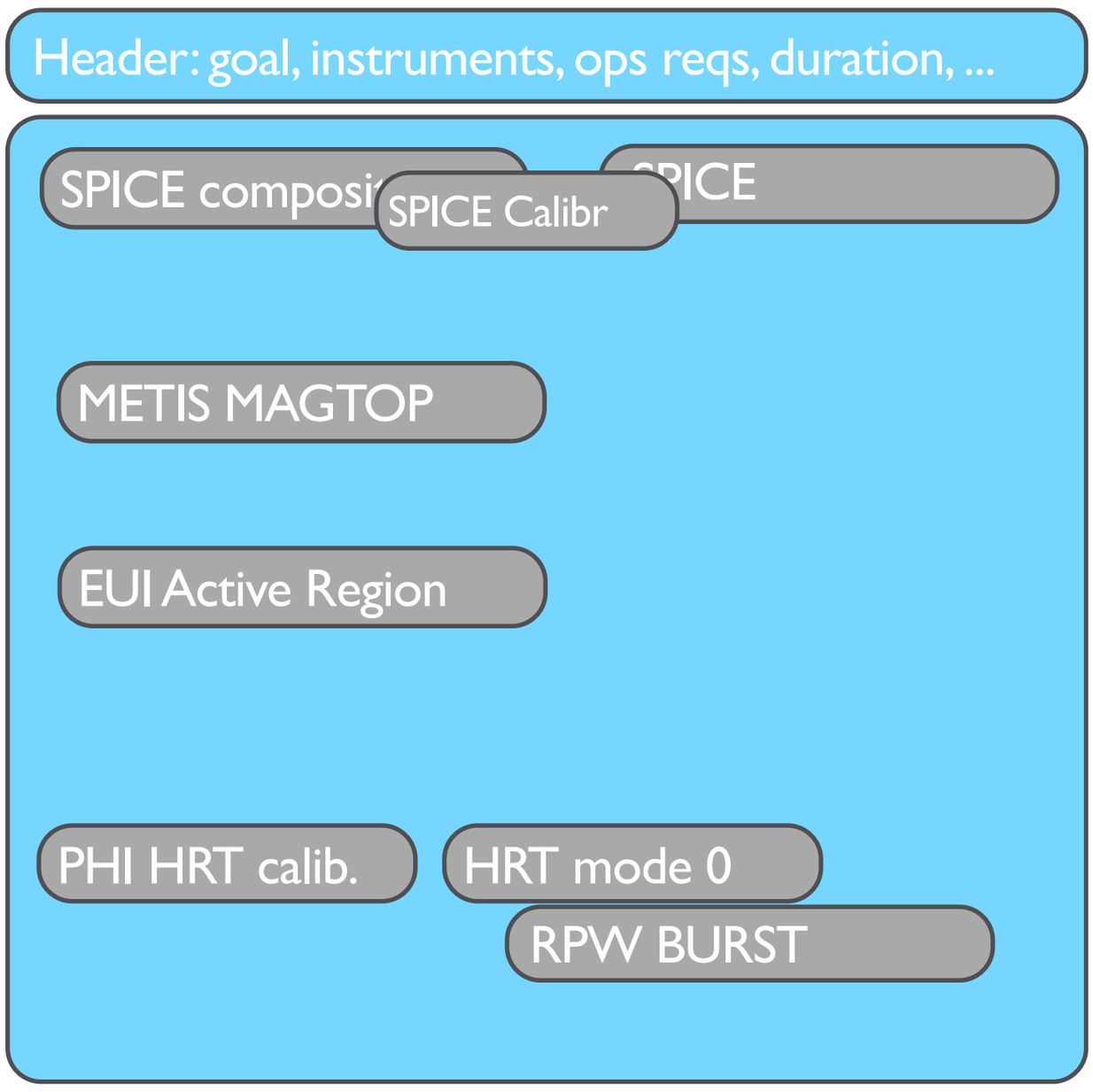
To be checked against mission constraints

Step 3
Simulation

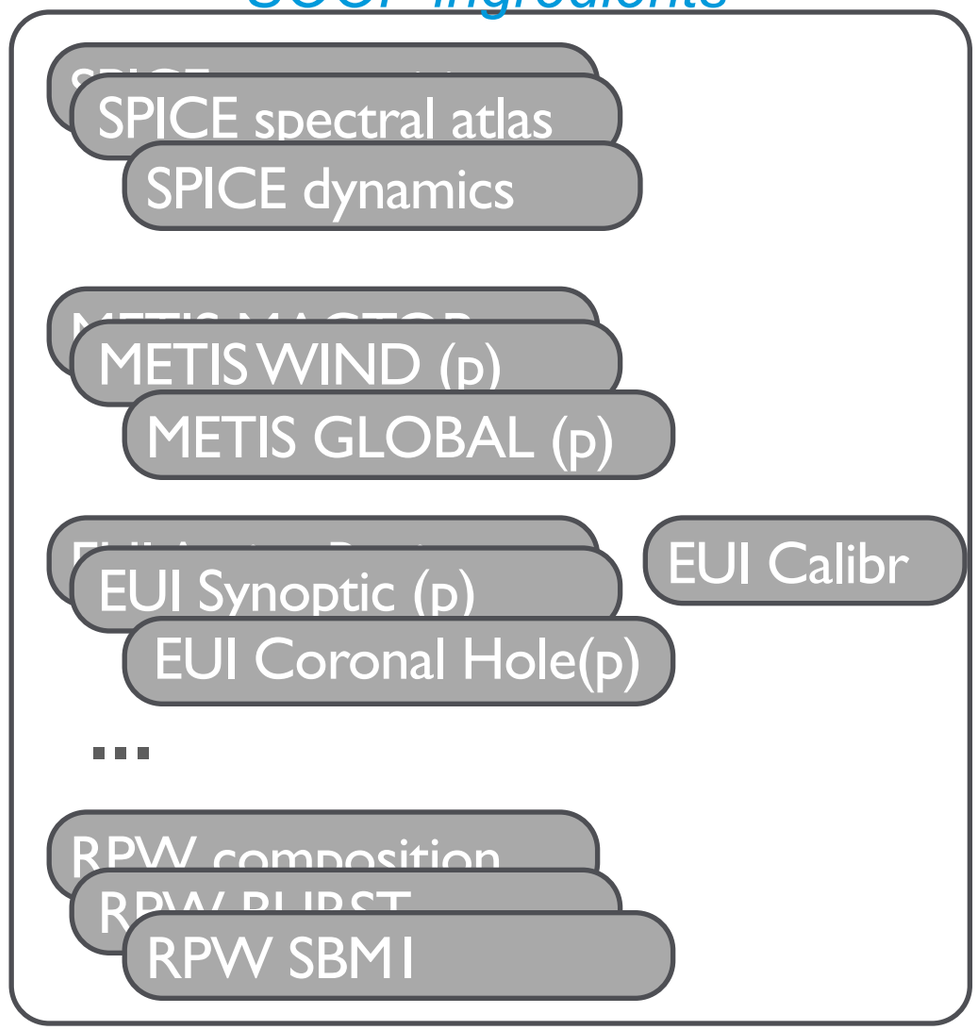
From Y.Zouganelis, SOWG8

LTP & SOOP concept

- SOOP = collection of instrument operations that belong together, i.e serve a common science goal *(or calibration goal during manoeuvre)*



Library of science & aux. modes
'SOOP ingredients'



+ Metadata: **average** power, TM **rate**, conflicts & dependencies

- High-level ops, no time-stamping, durations (~resources) can be tweaked

From SOC, SOWG5

Science operations MTP life-cycle

In preparation to each MTP (6-months planning-cycle ~ 1 orbit), SOC will deliver to the Instrument Teams (IT):

- Resource allocation profiles by instrument:
  - Telemetry Corridor (TMC)
  - Power consumption constraint (TBD)
- Flight event planning skeleton (E-FECS)
- Predictive Orbit/attitude/time data (SPICE kernels)

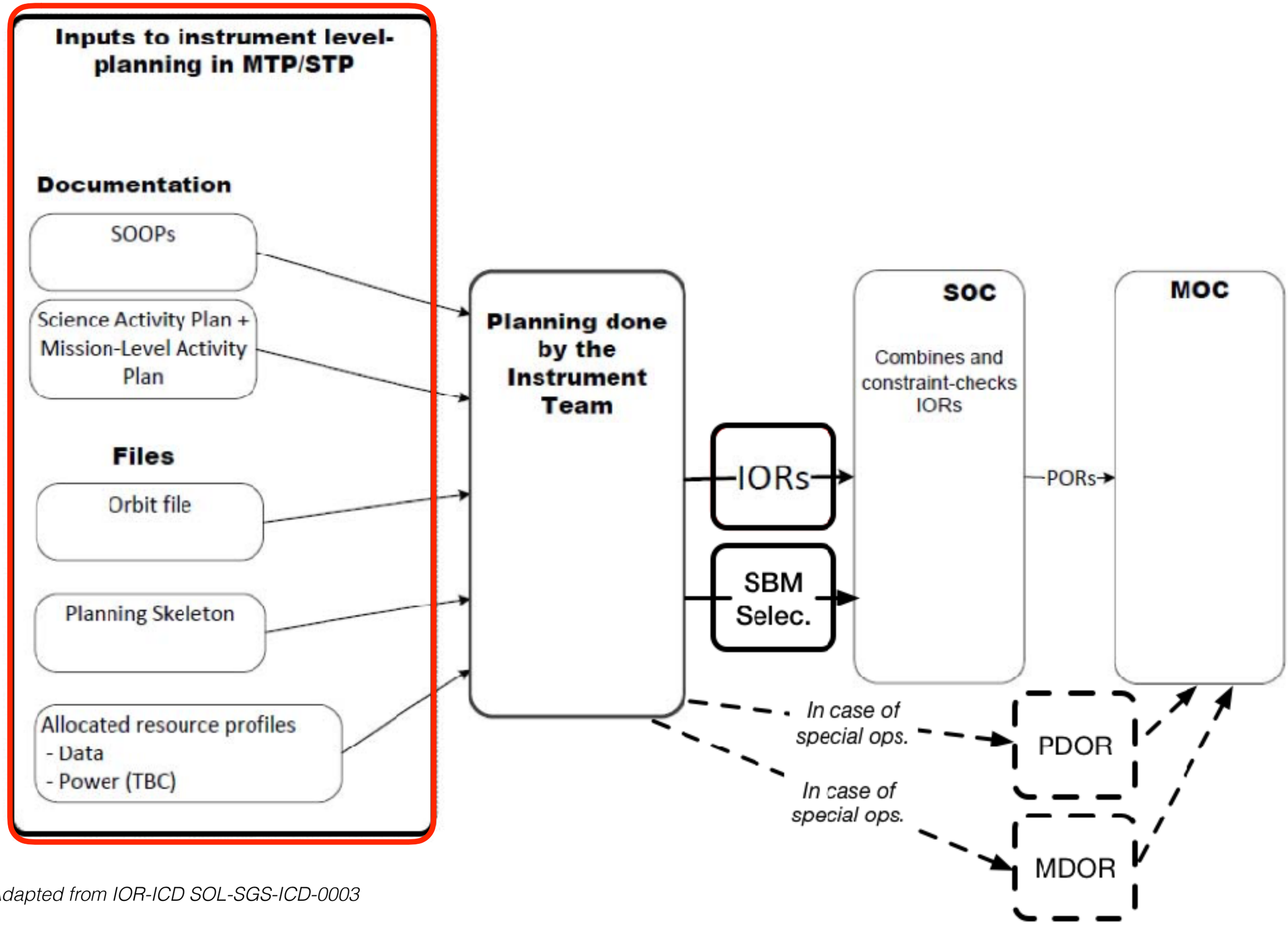
Inputs will be refreshed by SOC during the MTP as soon as real data are available (including actual SSMM data volume)

MTP-related SOOPs will be fixed during SOWG according to the mission constraints

From MTP inputs, each IT will generate and submit to the SOC "Instrument Operations Requests" (IORs), containing a first 6-months timeline of TC sequences

MTP IORs can be refined during STP/VSTP-cycle, but without modifying resource allocations.

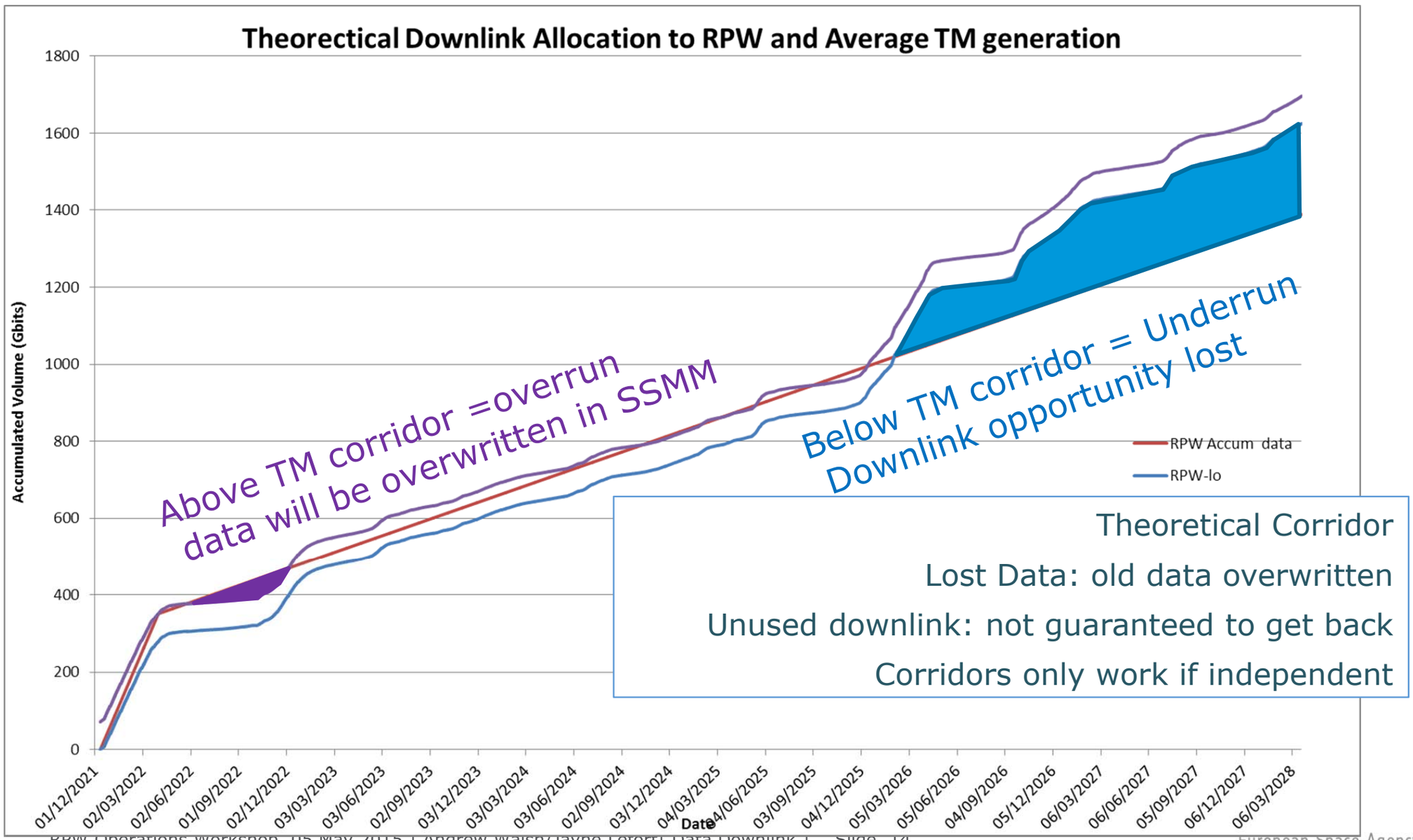
SOC/MOC IT Operations Interfaces



Adapted from IOR-ICD SOL-SGS-ICD-0003

IT operations inputs: TMC

Downlink & Storage limitations



RPW Operations Workshop, 05 May 2015 | Andrew Walsh/Jayne Lefort| Data Downlink | Slide 14

European Space Agency

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RPW th. downlink allocation = 5.5 kb/s (~60 MB/day)

SOC SOOP Kitchen tool

Tool used by the SOC and IT to prepare MTP operations timeline

- Can load and view E-FECS
- Can load and view IORs from ITs
- Can compare IORs against allocation resources (TMC)

Demo : https://solarorbiter.esac.esa.int/soopkitchen/#/planning/DEMO_PLAN_SOWG

Outline

- Mission science operations planning concept
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- Possible synergy with FIELDS/PSP

Flight Operations Concept: Commanding

- Routine Instrument operations will be off-line. No real-time commanding.
  - Instrument commanding prepared in advance.
  - Operations built in atomic sequences, uplinked as safe end-to-end activities. These activity cycles will speed up return to science.
  - At the boundaries of the activity cycles are the so-called re-entry points.
  - Instrument User Manuals must define operations in terms of sequences:
  - In-situ example:
    - Default Mode -> Adjust operational parameters -> Command Mode X -> Return to Default
  - Remote Sensing example:
    - Switch ON -> Warm up detector -> Adjust operational parameters -> Command Mode X -> Go back to Stand-by

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RPW Flight Control Procedures (FCP)

Flight Control Procedures (FCP) contain sequences of TCs with relative timing

FPC shall cover 90% of the needs during the mission

They can be as much as possible re-used for commissioning and recovery operations

ROC has started to prepare FCP with the support of the CNES and RPW sub-system teams for:

- Timeline re-entry (including « science ready » state)
- « Science default » state

Science default state

Instrument Teams must define a so-called « science default » state (cf. « Instrument Commanding Workshop » at MOC on Sept. 2016)

This state must be the baseline for operation cycle (i.e., first science config. when re-entrying the timeline, cycle operations shall return to this state.)

Most cover the main science objectives

Is initially based on the data rate defined in the EID-A (5.5 kbps for RPW) — But it will be actually constrained by the real allocated data rate (cf. TMC), power, EMC quiet periods, …

Science default state

Parameters to define			
	Duration of Burst Mode		10
	Time between 2 snapshots	LFR Waveforms	300
	Measurement time (sec)	LFR basic param	4
	Compression rate		2

RPW operation mode	bit rate (uncompressed) kbit/s	bit rate (compressed) kbit/s	duty cycle min/day	occurrence per day	occurrence per week	# of events	duration of event (min)	% of time (with respect to the day)	Mbits (uncompressed)	Bit rate (uncompressed) kbit/s	Mbits (compressed)	Bit rate (compressed) kbit/s
Normal Mode	6,51	4,30	1 430,00					99,31%	558,62		369,34	
Burst Mode	33,73	21,47	10,00					0,69%	20,24		12,88	
Low Latency normal	0,01		1 430,00					99,31%	0,46		0,01	
Low Latency burst	0,03		10,00					0,69%	0,02		0,03	
Housekeeping	0,50		1 440,00					100,00%	43,20		0,50	
Selected Burst Mode SBM1-Shocks	0,89	0,47	2,60	0,2000		1 every 5 days 360 in 5 years	13	0,18%	0,14	7,21	0,07	4,43
Selected Burst Mode SBM2-In-Situ Type III & LW (to verify)	0,12		0,82	0,0274		100 events in 10 years	30	0,06%	0,01		0,01	
THR Calibration	0,35		1		1	1 event per week	7	0,07%	0,02		0,02	
TDS/LFR Calibration	included in normal mode		1		1	1 event per week		0,07%				
Mbits									622,71		382,86	
Bit rate corridor										7,21		4,43

Science default state

Default configuration for LFR

LFR Normal Mode		nb sensor or signals	frequency channels	measurement time (sec)	snapshots /day
LFR Waveforms	LF E(1V+2E) 16HZ	3	1	0,0625	
	LF E(1V+2E) + 3B 256Hz	6	1	300	288
	LF E(1V+2E) + 3B 4kHz	6	1	300	288
	LF E(1V+2E) + 3B 25kHz	6	1	300	288
LFR basic param					
	set 1 : B^2 & E^2	2	11 (F0), 13 (F1), 12 (F2)	4	
	set 1 : wave norm vector	1			
	set 1 : param ellipticity	1			
	set 1 : deg of polarization	1			
	set 1 : Poynting flux	1			
	set 1 : Phase speed	1			
	set 2 : spectral matrices Bi^2, Ei^2	5	11 (F0), 13(F1), 12 (F2)	20	
	set 2 : spectral matrices	20			
	LFR High res Full spec mat / Auto	5	88 (F0), 104 (F1), 96 (F3)	3600	
	LFR High res Full spec mat / Real	10			
	LFR High res Full spec mat / Im	10			

Science default state

Default configuration for LFR

LFR BURST Mode		nb sensor or signals	frequency channels	measurement time (sec)
LFR Waveforms	LF E(1V+2E) +3B 256HZ	6	1	0,00390625
LFR basic param	set 1 : B^2 & E^2	2	22 (F0), 26 (F1)	5
	set 1 : wave norm vector	1		
	set 1 : param ellipticity	1		
	set 1 : deg of polarization	1		
	set 1 : Poynting flux	1		
	set 1 : Phase speed	1		
	set 2 : spectral matrices Bi^2, Ei^2	5	22(F0), 26(F1)	5
	set 2 : spectral matrices	20		

Science default state

Default configuration for TDS

TDS Normal Mode	nb sensor or signals	frequency channels	measurement time (sec)	snapshots /day
TDS regular snpashots	4			288
TDS triggered snapshots	4			64
TDS statistics			10	8640
TDS histogram 1D	4	64	300	288
TDS histogram 2D	1	4096	1800	48

1D histo:

Xaxis: LOG_HIST_64

Yaxis: PEAK_W_AMP, RMS_W_AMP, RMS_S_AMP, MAXAMP_CH1

2D histo:

Xaxis: LOG_HIST_128

Yaxis: HISTA_32

Zaxis: DA_VS_RE

Science default state

Default configuration for TDS

TDS Normal Mode	nb sensor or signals	frequency channels	measurement time (sec)	snapshots /day
TDS regular snpashots	4			288
TDS triggered snapshots	4			64
TDS statistics			10	8640
TDS histogram 1D	4	64	300	288
TDS histogram 2D	1	4096	1800	48

1D histo:

Xaxis: LOG_HIST_64

Yaxis: PEAK_W_AMP, RMS_W_AMP, RMS_S_AMP, MAXAMP_CH1

2D histo:

Xaxis: LOG_HIST_128

Yaxis: HISTA_32

Zaxis: DA_VS_RE

Science default state

Default configuration for TDS

TDS BurstMode	nb sensor or signals	frequency channels	measurement time (sec)	snapshots /day
TDS Triggered snapshots	4			64
TDS MAMP	3		0,031250775	
TDS statistics			10	8640
TDS histogram 1D	4	64	300	288
TDS histogram 2D	1	4096	1800	48

- Same configuration as normal mode for Triggered snapshots, statistics and histograms
- Added TDS MAMP; decimation factor 4x

Default configuration for TNR-HFR

THR Normal Mode		
CH1/CH2	Bands	Cross
E1/E2	A,B,C,D/A,B,C,D	Yes
E2/E3	A,B,C,D/A,B,C,D	Yes
E1/E3	A,B,C,D/A,B,C,D	Yes
E1-E2/HF	A,B,C,D/HF	No

Measurement time = 12s

Direction findings

THR Burst Mode		
CH1/CH2	Bands	Cross
Bmf/E1	A,B,C,D/A,B,C,D	No
E1-E2 or E2/Bmf	A,B,C,D/A,B,C,D	No
Bmf/E3	A,B,C,D/A,B,C,D	No
E1-E2/HF	A,B,C,D/HF	No

Measurement time = 2s

Magnetic field measurements

SBM selective downlink

SBM Packet Store #3 - 12.3 GBits Cyclic mode (42 SBM1 events of 13 min. and 4 SBM2 events of 120 min.)

The way the SBM selective downlink operations will be performed between ROC and SOC has not known in details yet (must be ready for the NMP)

ROC will select SBM events data to downlink every STP-cycle (i.e., every week)

Must be in agreement with allocation resource

ROC plans to develop a specific Web tools to view and select the events detected on-board

This tool will be open in read-only access to the people involved

RPW Operations timeline overview

LEOP

- ANT & Boom deployments

NECP

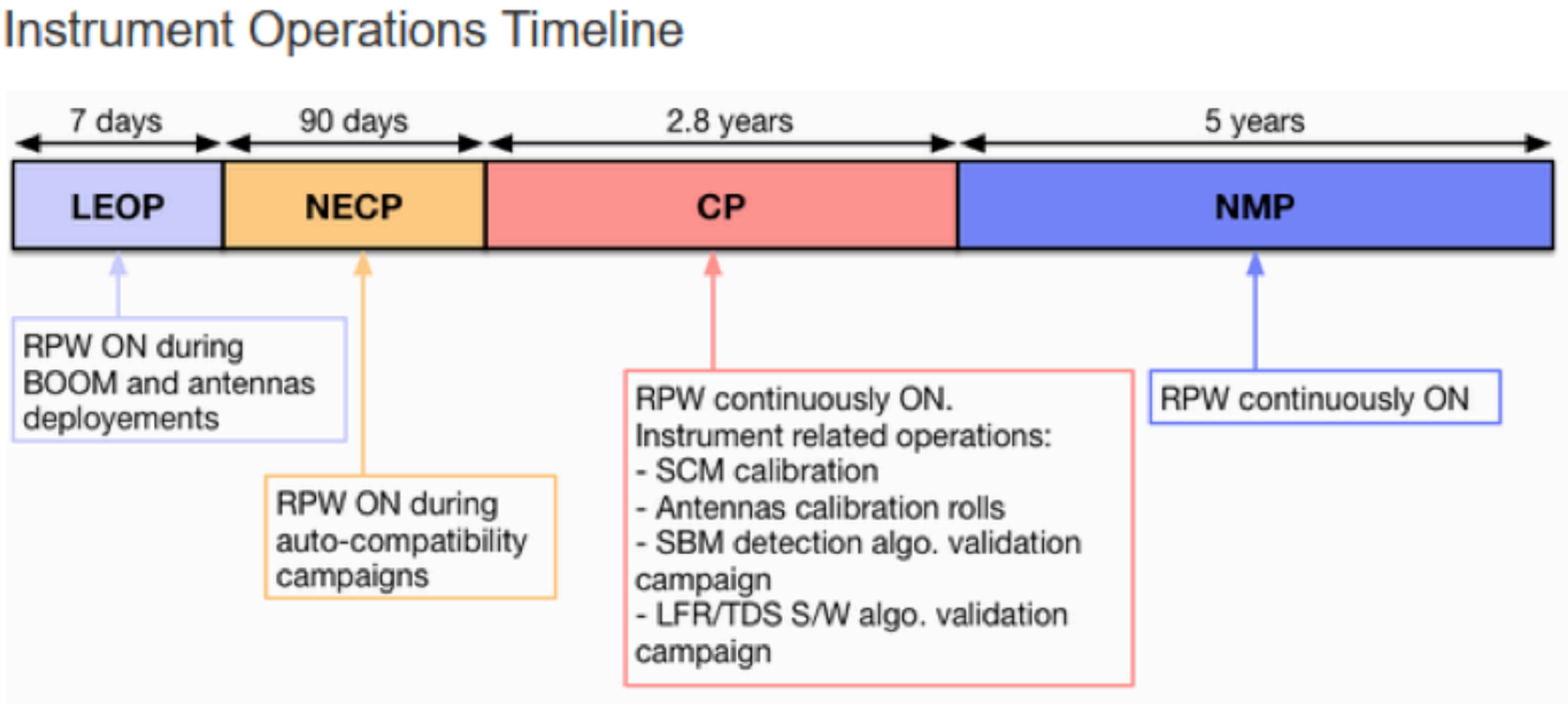
- Instrument auto-compatibility interference campaign
- RPW-PAS filtering tune campaign

CP

- Calibration rolls campaign
- SCM noise campaign
- TDS/LFR internal algo. validation campaign
- SBM algo. validation campaign (TBC)

NMP (+ EMP)

- Routine operations (including regular Bias current setting and SBM selective downlink)



Investigation of the SPICE HSD on the Z-ANT binding will be also performed during the CP and NMP

From current RPW User Manual

RPW Routine Operations

Weekly on-board operations calendar (first draft)

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
02:00 - BIAS cal. (10 min.) 06:00 - BIAS sweeping (10 min.) 18:00 - Starting burst mode (10 min.)	02:00 - THR internal cal. (10 min.) 18:00 - Starting burst mode (10 min.)	02:00 - SCM TDS - LFR internal cal. (10 min.) 18:00 - Starting burst mode (10 min.)	18:00 - Starting burst mode (10 min.)	18:00 - Starting burst mode (10 min.)	18:00 - Starting burst mode (10 min.)	18:00 - Starting burst mode (10 min.)

STP IORs are delivered in a batch to cover a time-range of 1 week. Limited to 150 TCs/day, but SOC asks to have as much as possible 150 TCs per STP IOR

This time-range of execution begins on a Saturday

The STP IOR files must be delivered to SOC on the Tuesday 10 days prior to this Saturday

The BIAS current setting will be done once a week

Triggering of Burst mode windows will have to be synchronized with other in-situ instruments (window center times provided in the E-FECS)

Defining ROC activity planning on-ground is in progress (first draft available in the RPW User Manual)

Outline

- Mission science operations planning concept
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Synergy with FIELDS

At mission level

- Defining and submitting specific SOOPs
- Must be discussed with the SOC and ITs
- (Conjonction with PSP in E-FECS)

At instrument level

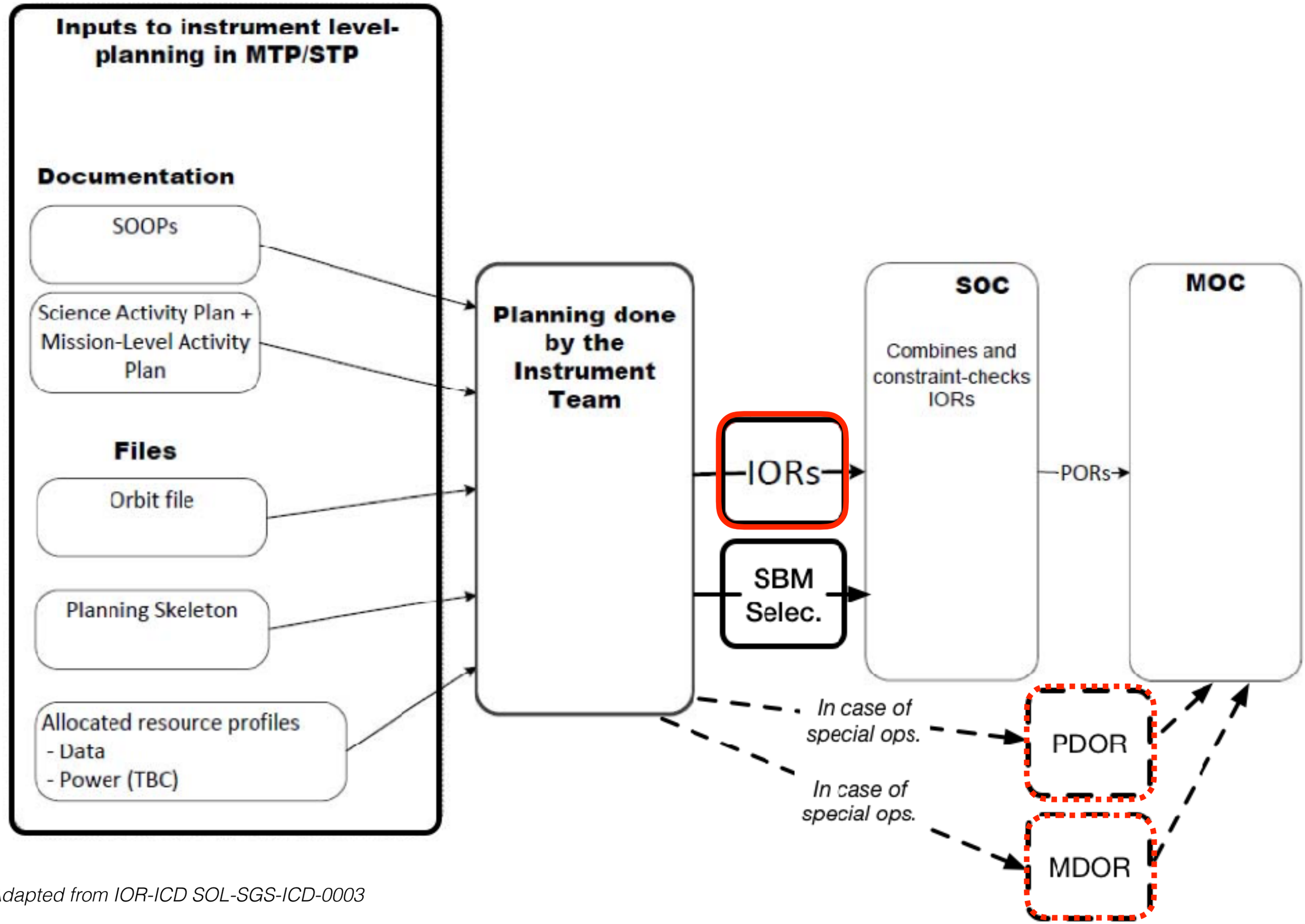
- Defining specific instrument modes — Can be done at procedure level (⚠) or at IOR level using formal parameters

  (more flexible, but we should start asap to think about it)

- SBM selective downlink

Extra slides

SOC/MOC IT Operations Interfaces



Adapted from IOR-ICD SOL-SGS-ICD-0003

SOC/MOC IT ICD

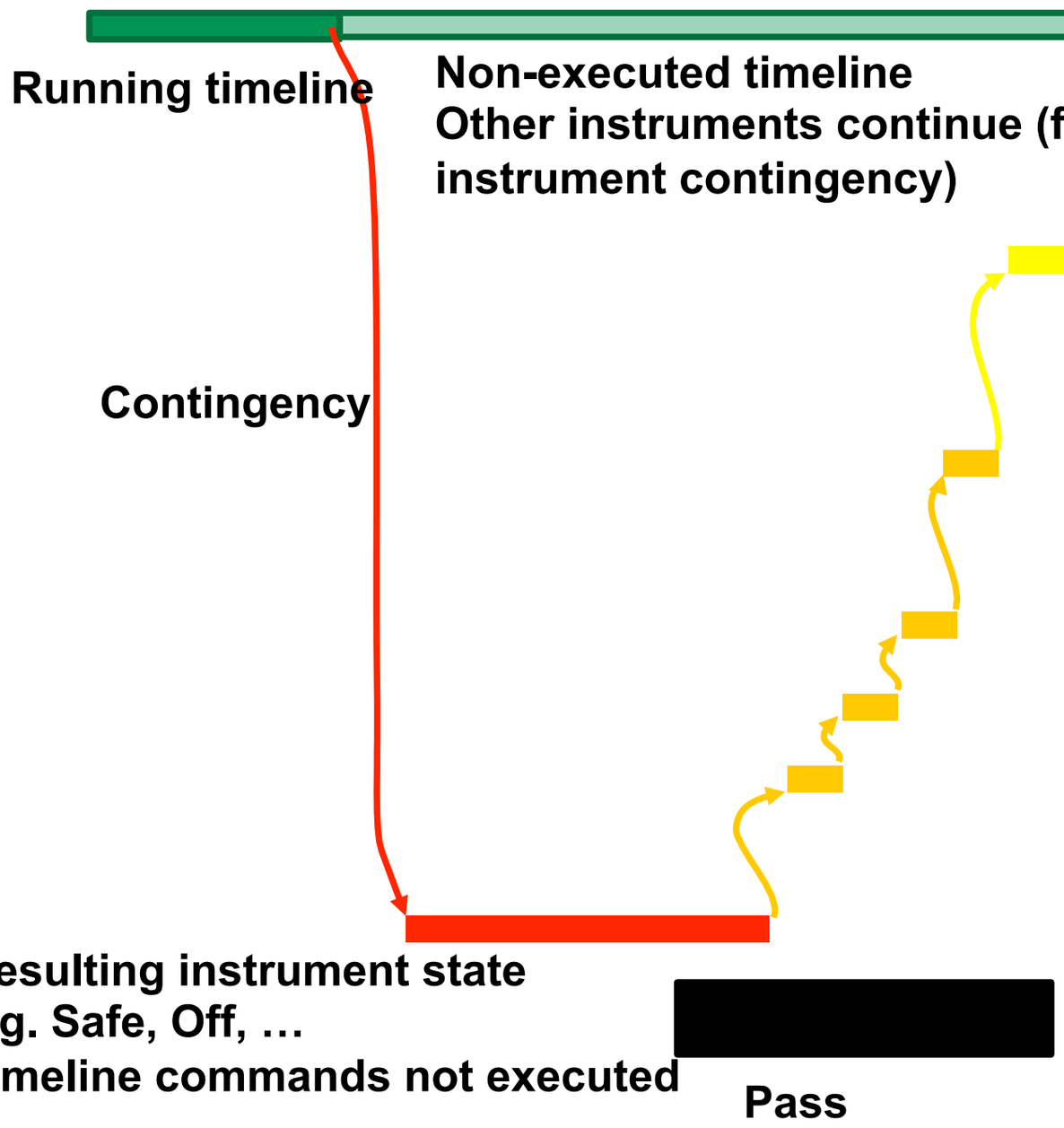
Flight Procedures

- Contains generic sequences of TCs to be used during the whole missing
- 3 categories : Flight Control Procedure (FCP), Contingency Recovery Procedure (CRP), Commissioning procedure (COM)
- Must be delivered by the IT to the MOC in the MOIS import format (Excel 97-2003 format) [SOL-ESC-IF-10002_FOP-ICD]
- Must be validated by the MOC to be integrated into the Flight Operation Plan (FOP) [SOL-ESC-PL-10001_FOPPP]
- Except for identified TC parameters (i.e., « formal » parameters), the values of TC parameters must be fixed in the procedures!

Operation Requests (IOR/PDOR/MDOR)

- In practice, IT will do not submit procedures directly, but the list of procedures to be uplinked
- For routine operations, the IT will be submitted the so-called « instrument operation requests » XML files (IOR) to the SOC (at MTP and STP levels) [IOR-ICD SOL-SGS-ICD-0003]
- For non-routines operations, the IT will interact directly with the MOC using specific XML format files: Memory Direct Operation Request (MDOR) for operations linked to memory, i.e., on-board software patches, and Payload Direct Operation Request (PDOR) for other special operations (NECP, contingency,…) [SOL-ESC-IF-05010_PLID]

Timeline re-entry Graphically…



At re-entry into the timeline we need that the detailed instrument state is consistent with planned timeline

In other words, if the timeline is expecting commands in the outage period to have executed then a simple re-entry does not work

Operation preparation planning at ESA level: SVT

System Validation Tests (SVT)

- **SVT-0** — From a first set of instrument FOP procedures — planned on [*2017-08-22/24*]

- **SVT-1a/SVT-1** — Systematic test of instrument FOP procedures — planned on [*2018-01*, *2018-05-09/18*]

- **SVT-2** — Re-test of any anomalies found during the SVT-1a — planned on [*2018-07-06/13*]

Ref: https://confluence-lesia.obspm.fr/display/ROC/Instrument+Commanding+Workshop

Expected Support of Instrument Teams up to SVT-1

Instrument User Manual Complete [L – 1 year]: All the inputs required for Near Earth Commissioning Phase and Cruise Phase (timeline and procedures). Instrument Teams to provide inputs and support iterations as necessary.

Inputs for System Validation Test [L – 1 year]: All inputs required to test on the PFM to validate as far as possible instrument database and procedures. Instrument Teams to provide all test inputs.

SVT-1 [L – 9 months]: Instrument Team with decision authority to support test at test site. Up to two instruments tested in parallel.

Ref: https://confluence-lesia.obspm.fr/display/ROC/Instrument+Commanding+Workshop

Expected Support of Instrument Teams after SVT-1

Instrument Commanding IF Test [around L-9 months]: Instrument teams to test all commanding interfaces to MOC: PORs, MDORs, PDORs. To be coordinated with MOC&SOC.

Cruise Operations end-to-end test [around L-6 months]: IS Instrument teams to validate end-to-end routine operations planning process, including both TM and TC chains. To be coordinated with SOC.

SVT-2 [L-4 months]: Retest of any problems found with Instruments during SVT-1.

FOP approval [L-3 m]: Instrument teams for review and formally approve all procedures as defined in the Flight Operations Plan (FOP).

NECP [L to L+3 months]: Instrument teams to support commissioning operations. Co-location at ESOC expected, including delivery of any support equipment.

Ref: https://confluence-lesia.obspm.fr/display/ROC/Instrument+Commanding+Workshop

Operation preparation planning at ESA level: SOV

System Operation Validation (SOV)

- **SOV-0** — MOC DDS tests (Test Instrument TM & Command Request transfer capability — [L - 10 months]

- **SOV-1** — MOC Interface Test (Systematic verification of all file change (PDOR, MDOR) — [L - 9 months]

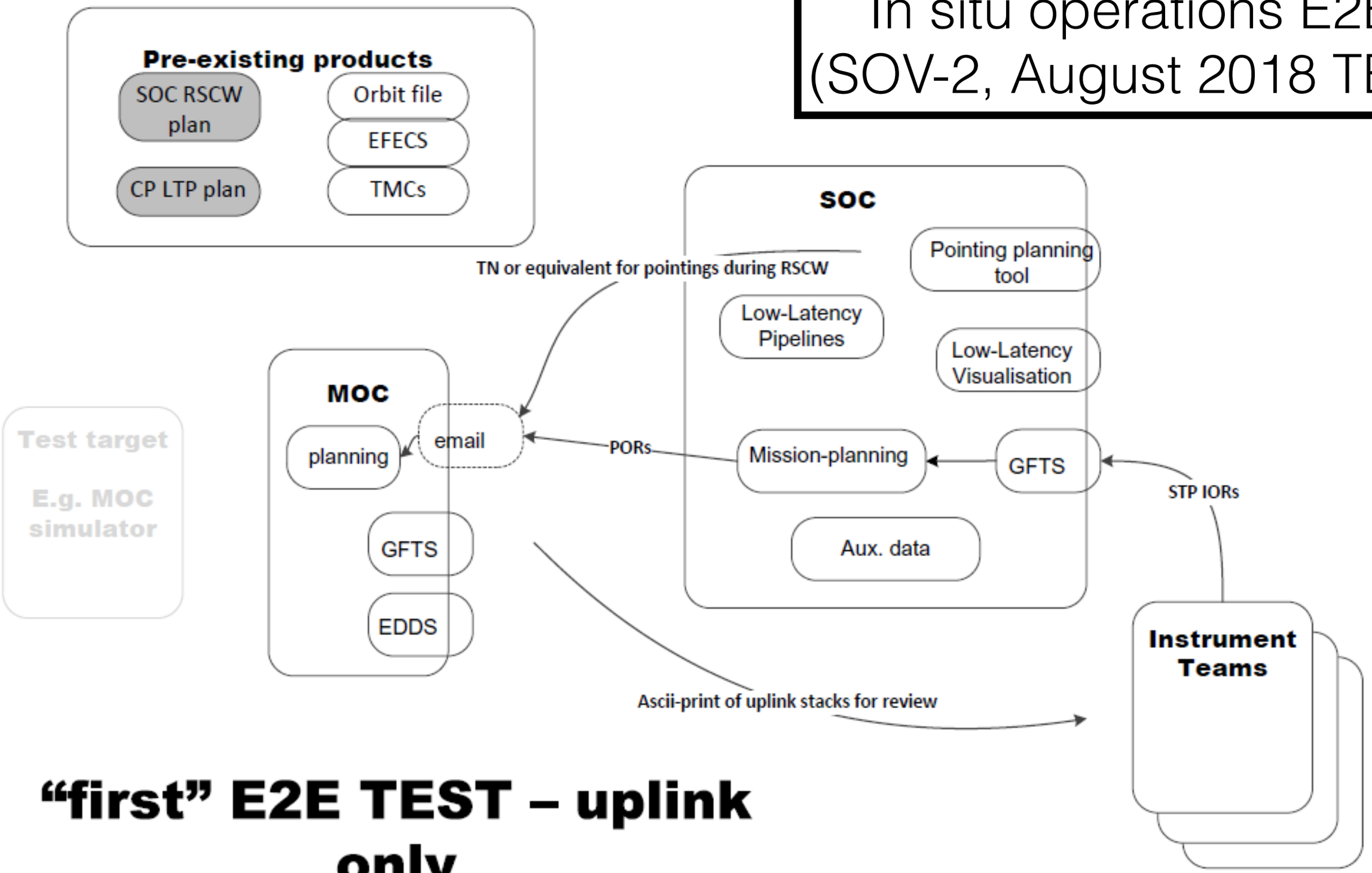
- **SOV-2** — In-Situ Operations E2E (Processing of a realistic CP STP data request. IT submit to SOC, and SOC to MOC) — [L - 6 months]

- **SOV-3** — Checkout window E2E (Same as above, but including RS operations for a checkout window) — [L - 6 months]

Ref: https://confluence-lesia.obspm.fr/display/ROC/Instrument+Commanding+Workshop

Operation preparation planning at ESA level

In situ operations E2E
(SOV-2, August 2018 TBC)



"first" E2E TEST – uplink only

As executed at STP

RPW Operation Management Plan

For engineering operations preparation (LEOP, NECP)

- Specific working groups coordinated by the ROC and CNES

For science routine operations preparation

- Timeline re-entry and science default procedures in progress (first set was tested during deltacal. Cf. Antonio/Yvonne' slides)
- Bias routine operations working group (cf. splinter session)
- Which strategy for defining instrument configurations for science?
  - Same strategy than SOOP, but at RPW level (based on SAP)?
  - SAP and science default state could be good starters

Anomalies

- Organization and procedures at RPW level needs to be clarified
- Role of CNES during mission in case of anomalies?

GSE capability/availability during the mission

- ROC needs to test its procedures and operation requests (IOR/MDOR/PDOR) before submission at MOC/SOC
- GSE capability in case of anomaly investigation