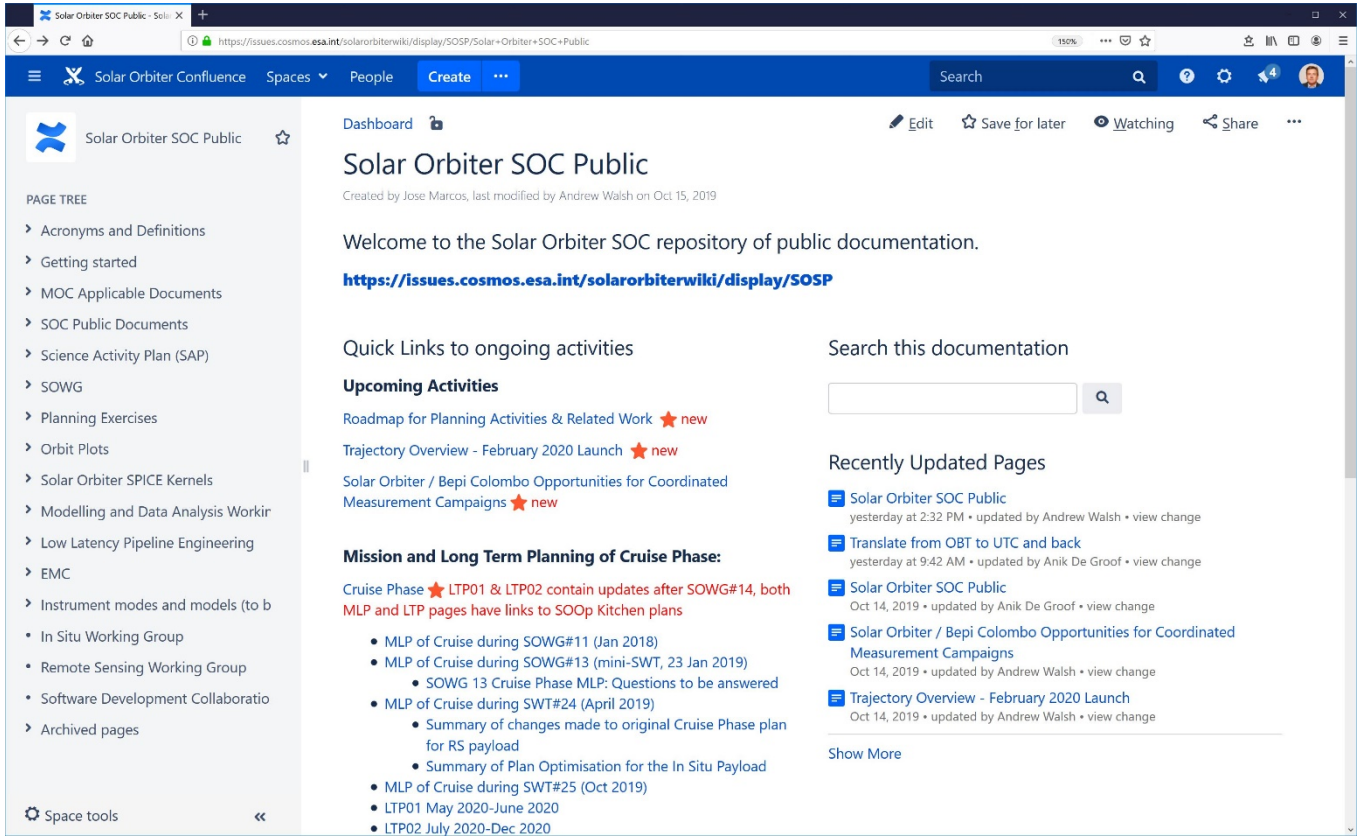
Solar Orbiter Science Operations
7th Metis Workshop - Padova

Luis Sanchez

European Space Agency

All information in our Confluence repository



Solar Orbiter Operations

As usual in ESA science, mission and science operations are separated:

- Mission operations, at ESOC, cover the highly standardized S/C platform operations, navigation and managing the ground station passes.
- Science operations, at ESAC, is the more bespoke aspect of coordinating payload operations with a view to maximize the scientific return of the mission.

Both benefit from prior experience.

- In particular, ESOC is reusing the mission planning and control systems of BepiColombo, while us at ESAC have reused ideas and methods from other Solar System missions (SOHO, planetary orbiters) while providing tools and concepts to upcoming projects (PLATO, JUICE).

Managing expectations

Solar Orbiter is quite different from prior solar and space physics missions:

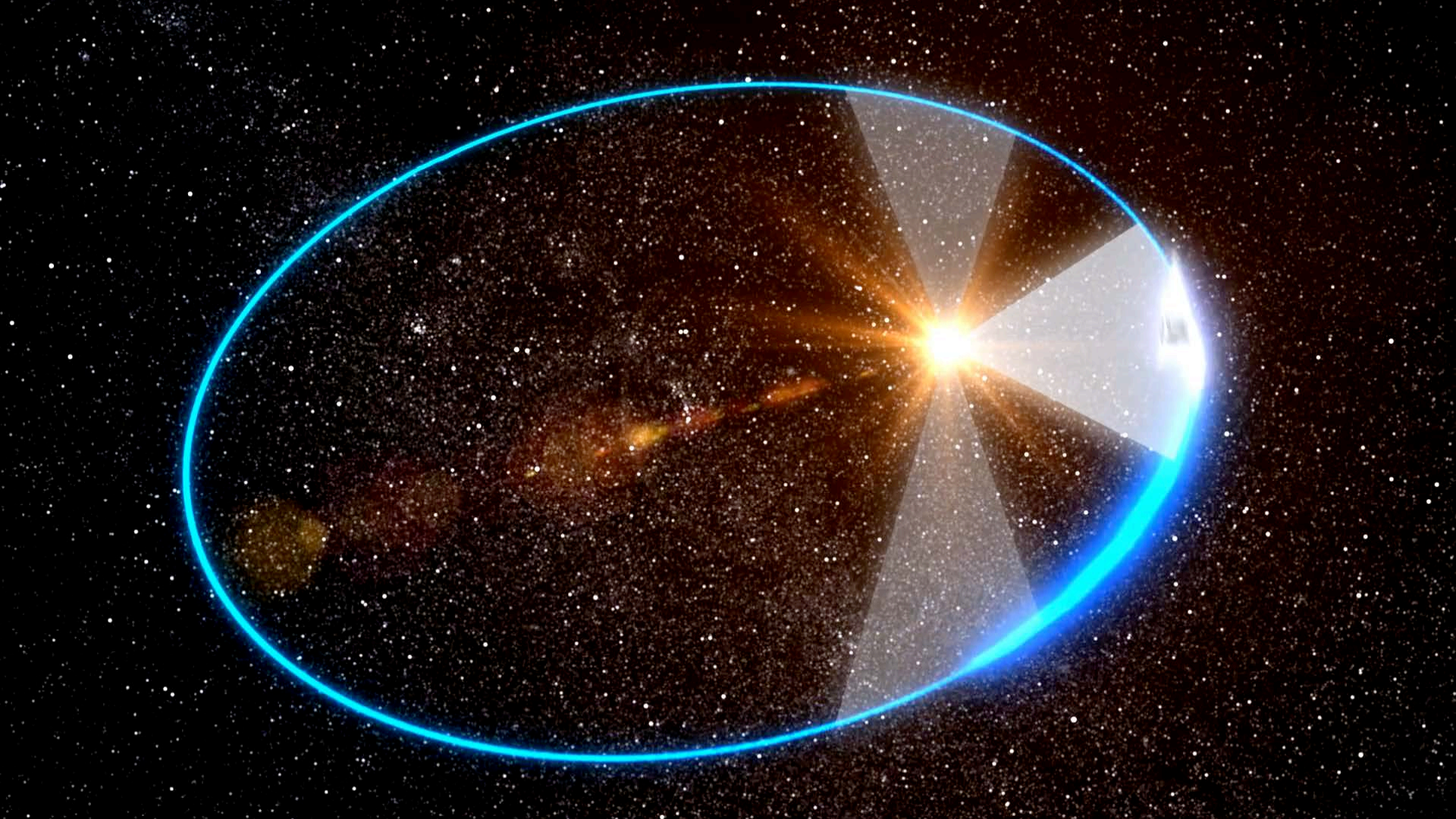
- Not a LEO or L1 mission (familiar to the Solar Physics community).
- Not a spin stabilized spacecraft (the usual in the in-situ community).

Mission design looks to address two often conflicting drivers:

- Heliocentric trajectory very often away from Earth to reach closer perihelia Sun and to incline the orbit away from the ecliptic plane.
- Be responsive to the dynamic Sun we want to study.

Science Management Plan is, therefore, a compromise:

- As one prime objective of Solar Orbiter is connecting in-situ and remote sense science, it concentrates the operations of the whole payload in selected, advantageous periods: perihelia and maximum solar latitude. The mission was designed and selected as an 'encounter mission'



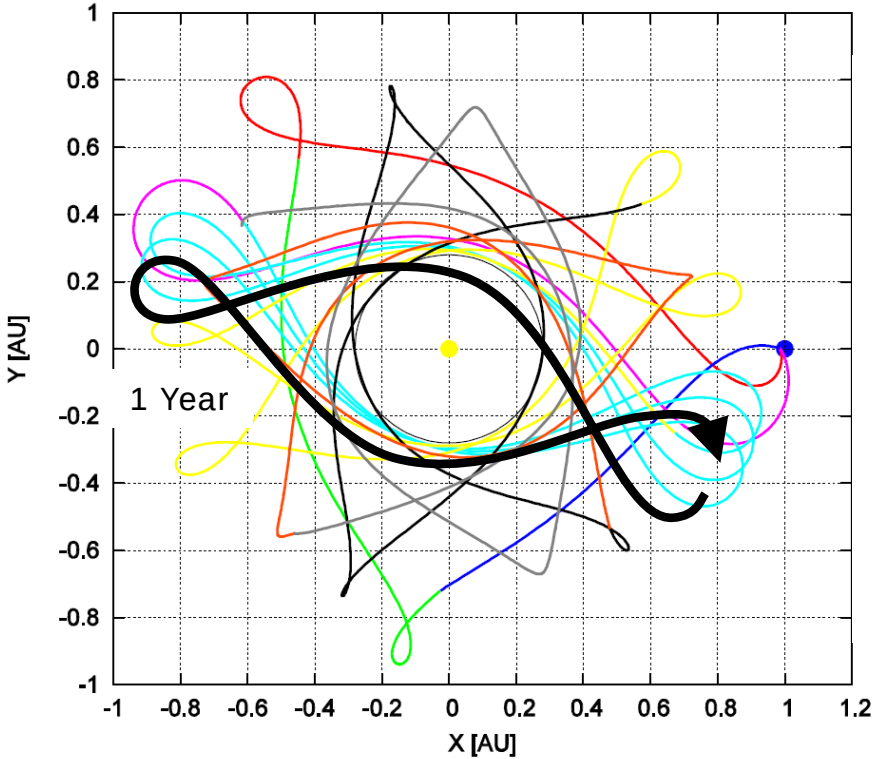
Science Operations

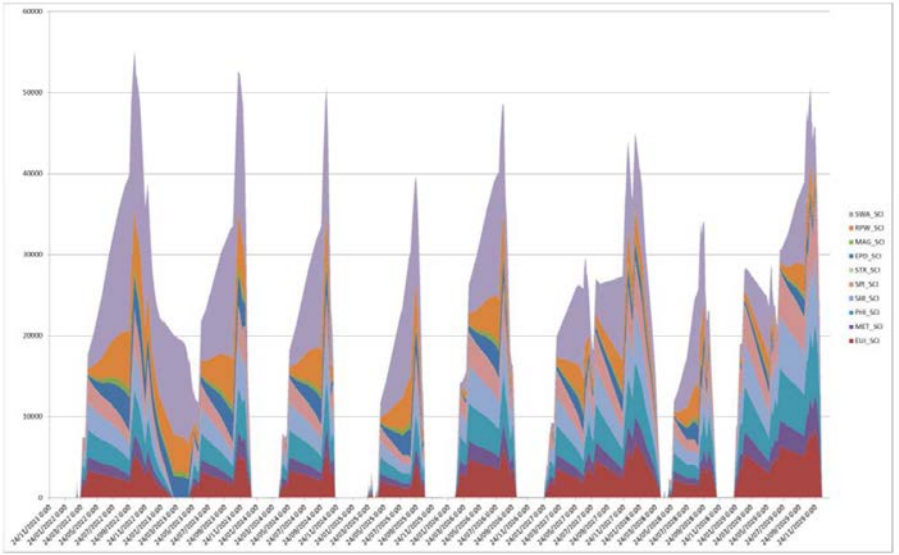
The Science Operations Centre team had the task of coming up with a practical implementation of this Science Management Plan.

This concept and implementation also has to evolve to accommodate:

- Trade-offs between mission design and operations.
- The natural evolution of how the spacecraft and the payload will be used over the coming years.
- The operational constraints, as they will exist at launch but also later on.

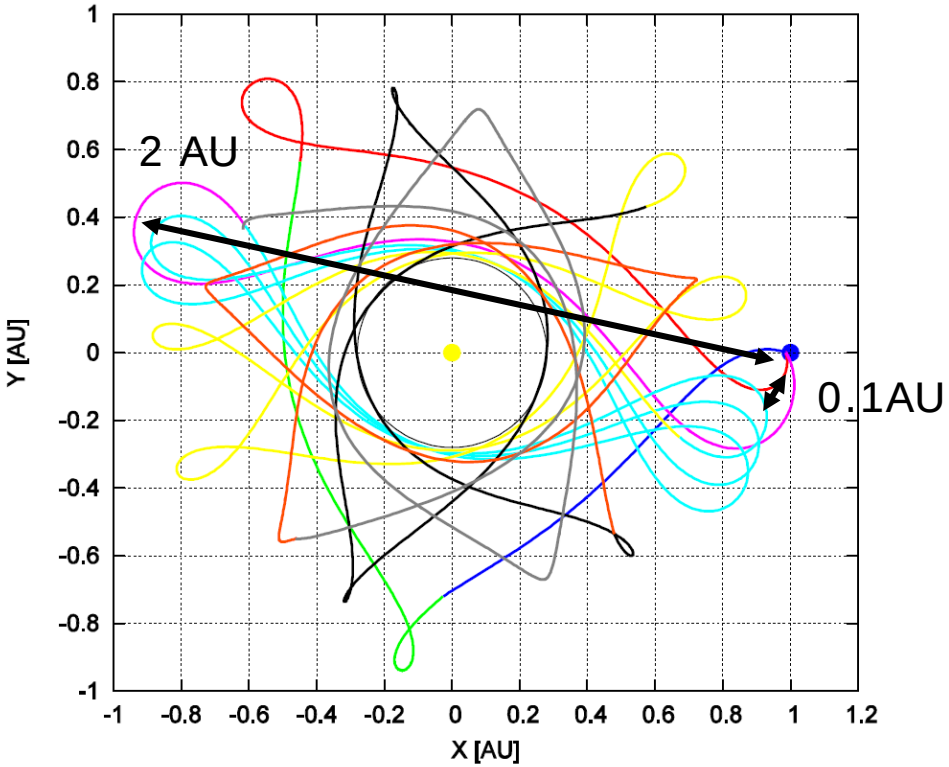
Telemetry downlink optimization and variability





SSMM packet store filling simulation

Operational constraints: Telemetry



In-plane movement only. Earth-rotating system.

The main constraint is telemetry downlink capacity.

But TM downlink is not only restricted:

- Also very variable: Ratio of good to bad comms performance is **23:1** (vs 3:2 – 6:1 for planetary)
- Data has up to 6 months of latency.

We have a 512 Gbit SSMM to cope with it.

Science Operations Concept

- Planning. A lot of planning (more that we would have liked).
  - Science Activity Plan (the entire mission) – SWT decides priorities at this level.
  - Longer Term plan (6 month cadence) – SOWG driven - all payload coordination established here.
  - Short Term plan (weekly cadence, actual instrument commanding) – Individual instruments.
  - Very Short Term plan (for pointing and limited instrument parameter updates) – SOC run.
- Low Latency Data: Very limited dataset (about 1 MB per instrument and day) to be used for at least one of these three purposes.
  1. Assess performance of the instruments (health done via HK).
  2. Determine pointing, for RSW operations.
  3. Inform the decision process for selective downlink.
- Selective telemetry downlink:
  - Limited to two in-situ instruments, because of the size of the SSMM does not work for RS ones.
- Inter-instrument communication:
  - Limited exchange of data across the payload, also triggers to signal solar events (1 sec cadence).

More on planning

Science Activity Plan and Mission Level Planning (SWT):

- Specification of detailed scientific objectives (topical workshops in 2016-17).
- Determination of the types of observations required from each instrument.
- Establishing desirable collaborations with third parties.
- Definition of a timeline of activities taking advantage of the trajectory opportunities.
- We would like to update it early in cruise: Workshop under consideration for Sep 2020.

Long Term Planning (SOWG):

- Detailed coordination of operations across the whole payload.
- Solar Orbiter Observing Programs (SOOPs) used as building blocks.
- Each coordinated campaign will have a scientific coordinator appointed by the SWT.
- Level of resources (telemetry, EMC, power) assigned and fixed here.

Tools developed by the SOC

SOOP Kitchen:

- Main longer term planning tool. Used for SAP and long term planning.
- Campaigns, coordinated observations, etc. are defined here.
- Main building block for planning coordination: Solar Orbiter Observing Program (SOOP).
- Science coordinators for SOOP are to be selected/appointed by the SWT.
- Currently operational (in use for the planning of the Cruise Phase).

Pointing tool:

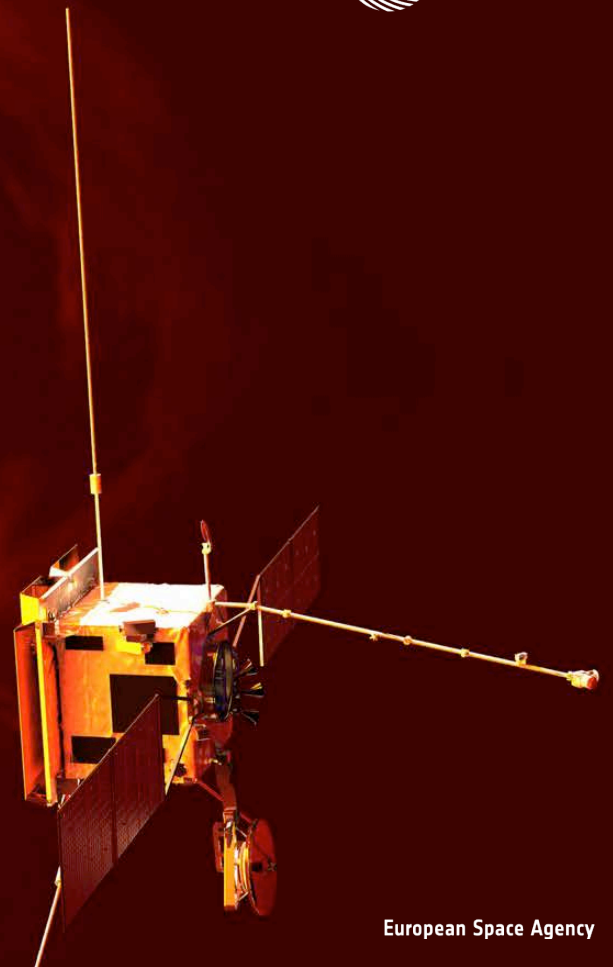
- To be used starting in the Nominal Phase
- Capable of ingesting pointing info coming from other tools (that the SOOP coordinator might use).
- In prototype now.

SSMM management:

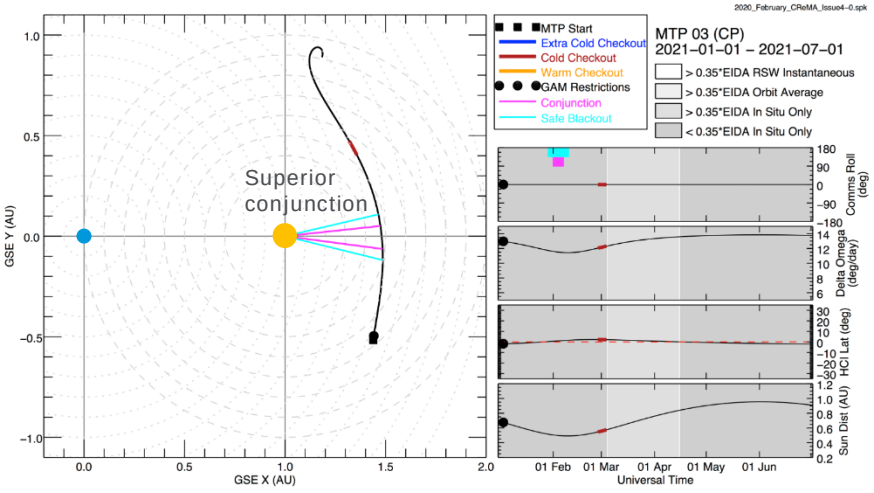
- Internal to SOC for TM corridor generation and checking, downlink management.

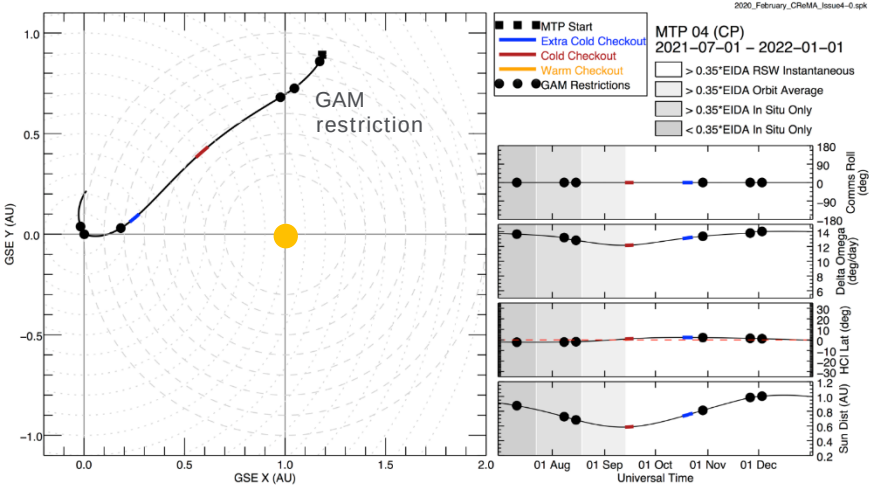
No automatic scheduling but

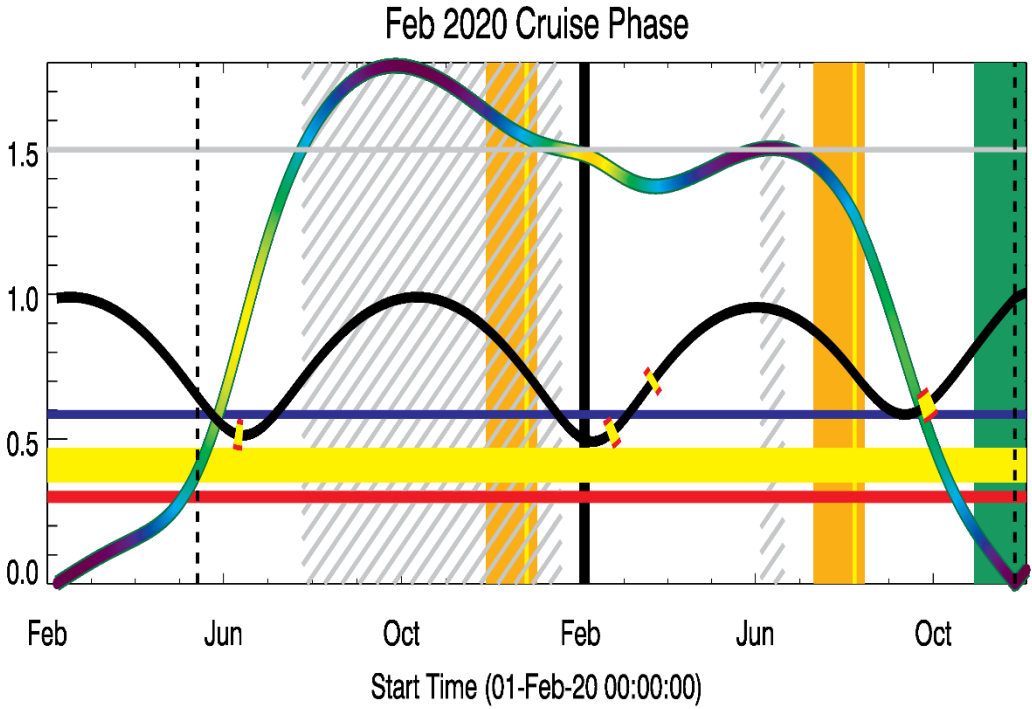
concurrent observations planning



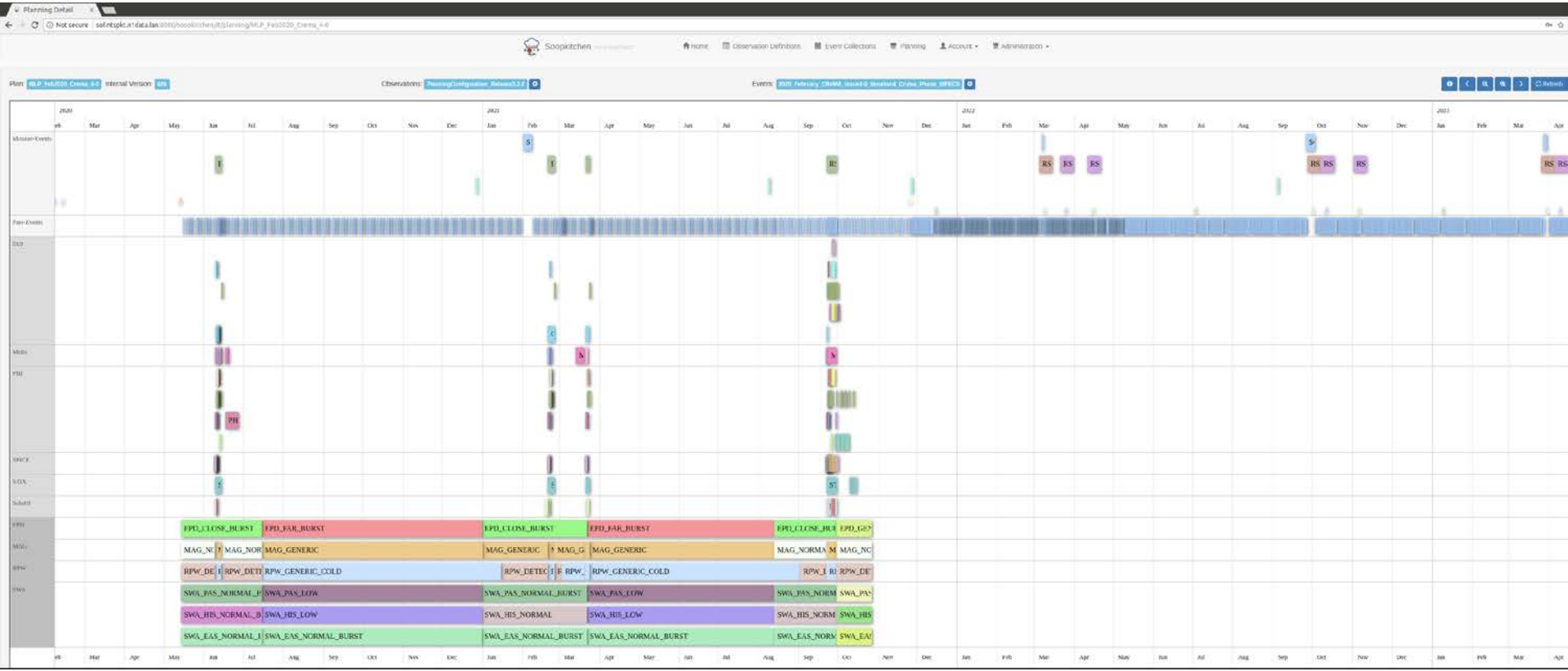
Context & first proposal



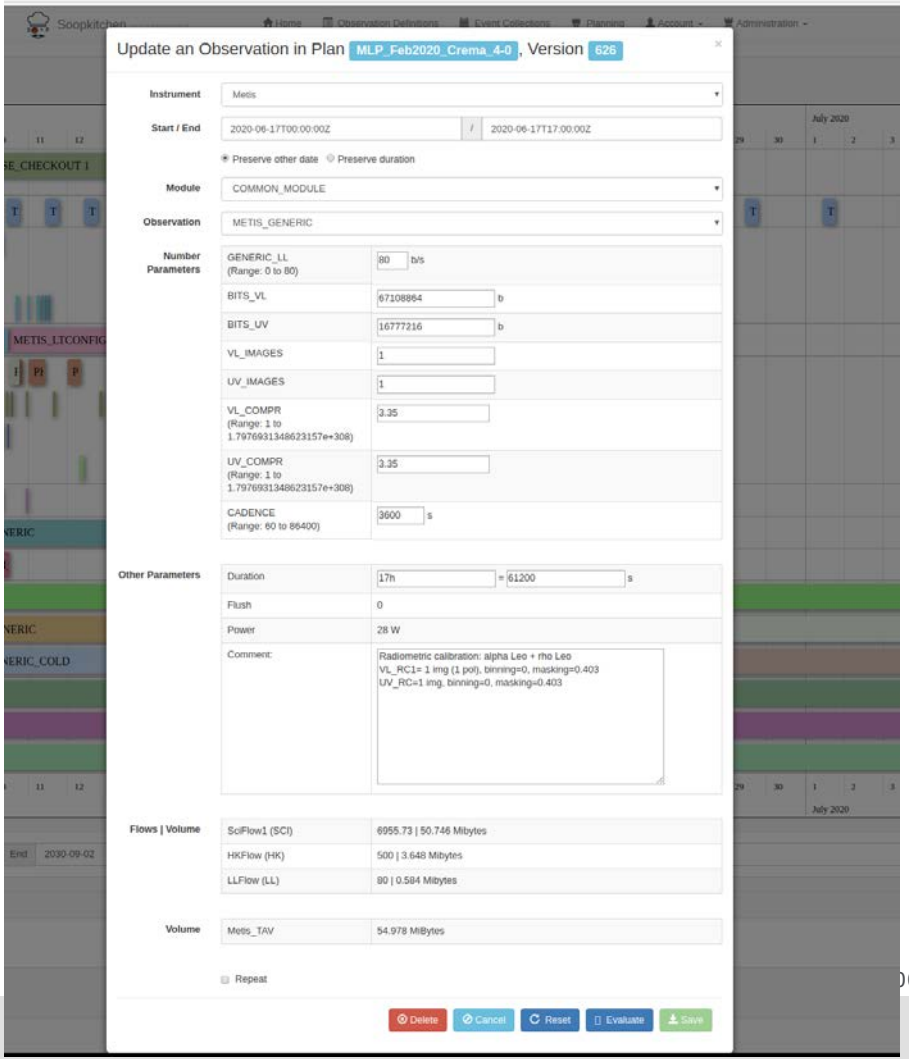




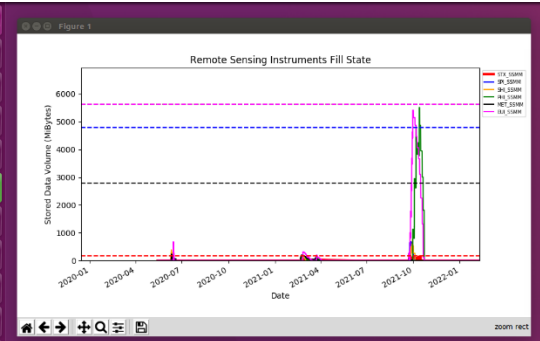
SOOP Kitchen

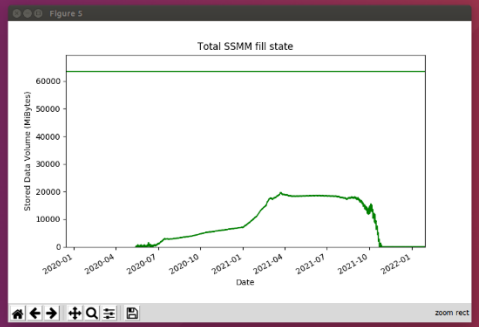


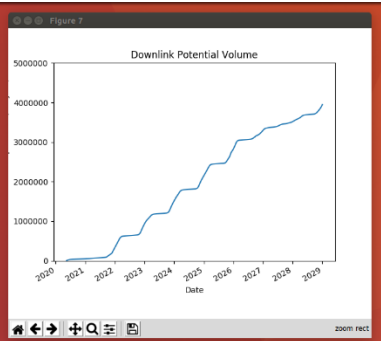
SOOP Kitchen Details

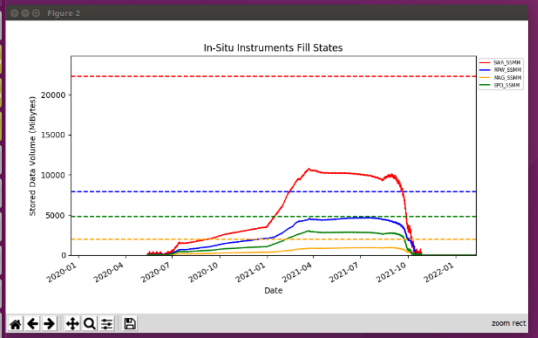


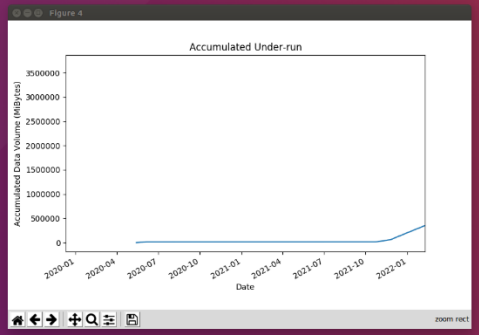
SOOP Kitchen – simulation of resource usage

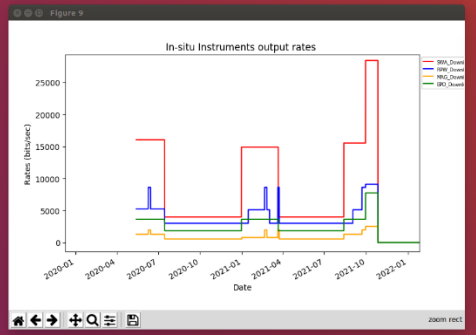


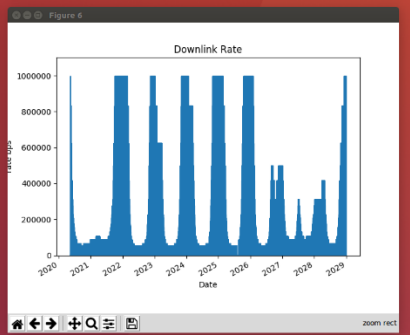












SPROUTS

Synoptic operations of the remote sensing instruments outside of RSWs:

- It would be very advantageous for the scientific output of the mission (in part, for its increased capability to collaborate with other assets, both in space and on ground).
- Already defined by the RSWG in a technical note.
- Structured so it fits existing science operations mechanisms (routine operations, LL data…)
- Compatible with existing Science Management Plan and Flight Control Team operations.

However:

- We need to gain experience on current operations before expanding on them. In particular:
- We need to assess the EM cleanliness of RS instrument operations in the relevant modes.
- We'll find out during the cruise phase.
- A decision will be made before the start of the nominal phase.

Current status of science operations

Ground Segment Readiness Review (23 August – 7 October).

- All objectives achieved. Board declared the review successful.

Science Operations: Cruise Phase planning.

- Overall Cruise Phase planned at mission level (at SWT #24).
- Also planned at LTP until end of 2020 (LTP1+2).
- Agreed with FCT how to transition from commissioning to normal science operations.
    - Will require an update to the LTP planning product which depend on launch date.
    - Will require flexibility, as end of commissioning date is not fixed.

Details:

https://issues.cosmos.esa.int/solarorbiterwiki/display/SOSP/Cruise+Phase

Trajectory overview:

https://issues.cosmos.esa.int/solarorbiterwiki/display/SOSP/Trajectory+Overview+-+February+2020+Launch

An operations area was set up at ESAC: Waiting for you.

Information on Solar Orbiter

http://sci.esa.int/

The science pages are being revamped now, we expect to have the new web site online before launch.
General information about the mission.
Links to instrument pages.

http://issues.esac.esa.int/solarorbiterwiki/

SWT and SOWG related material.
Highly technical and detailed.

You can follow Solar Orbiter on twitter as well: @ESASolarOrbiter

All information in our Confluence repository