Summary of Plan Optimisation for the In Situ Payload

Optimisation Carried Out Prior to SWT 24

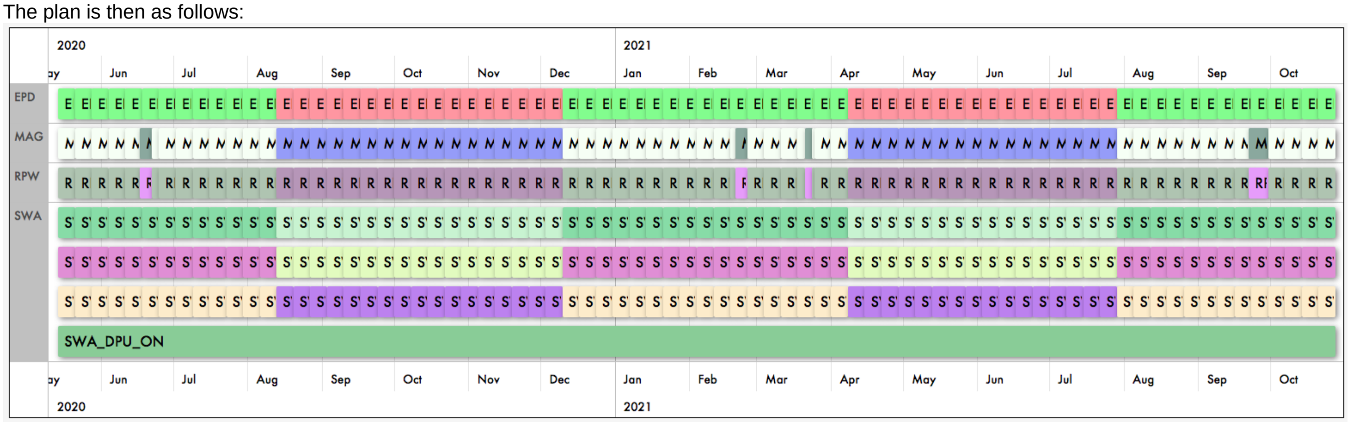
At the mini-SWT during SOWG13 SOC took the action to try and optimise the in situ data return for the cruise phase. Here we present the results of that optimisation, the optimised plan can be found on the SOOP Kitchen: MLP Feb 2020 as of SWT24.

The optimisation was carried out with the goal of minimising the amount of time that the instruments would have to operate with a reduced cadence or resolution of normal mode data, while maintaining a reasonable amount of burst mode and without filling the packet stores more than approximately 90%. Recall that selective downlink will be unavailable during the cruise.

The plan was constructed using only observations definitions that SOC are sure are accurate, i.e. no GENERIC type observations were used. Observations of duration 7 days were added to the plan as follows:

1. Normal mode only at standard cadence and resolution throughout the cruise. This resulted in packet store overruns!
2. Reduced cadence, "low rate" observations replace the default normal mode observations for periods subsequent to the first perihelion when the spacecraft was further than 0.8 AU from the Sun, apart from the end of cruise when the spacecraft will approach Earth.
3. Some minutes per day of burst mode were added to each observation, commensurate with the default amount of burst mode for that observation type according to the observation definition.
4. For RPW and MAG, an additional 8 hours of burst mode (EQUAL128 for MAG) per day were added during each of the Remote Sensing Checkout Windows to allow for detailed EMC characterisation of RS instrument operations.

The plan is then as follows:



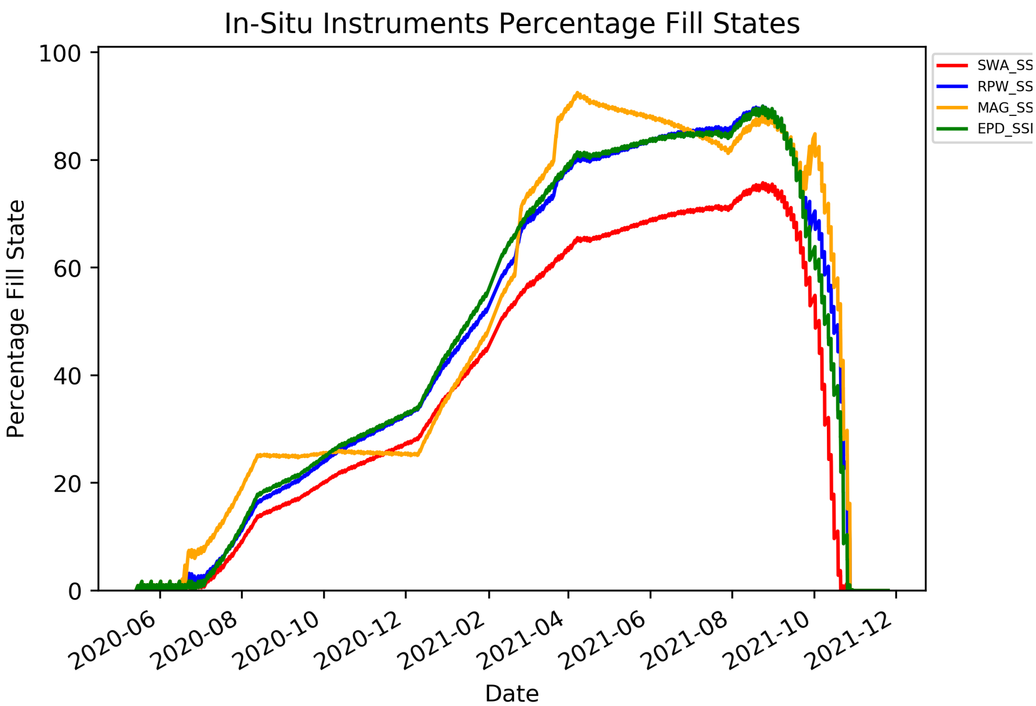
The following observations were used, with minutes per day of burst mode shown in brackets:

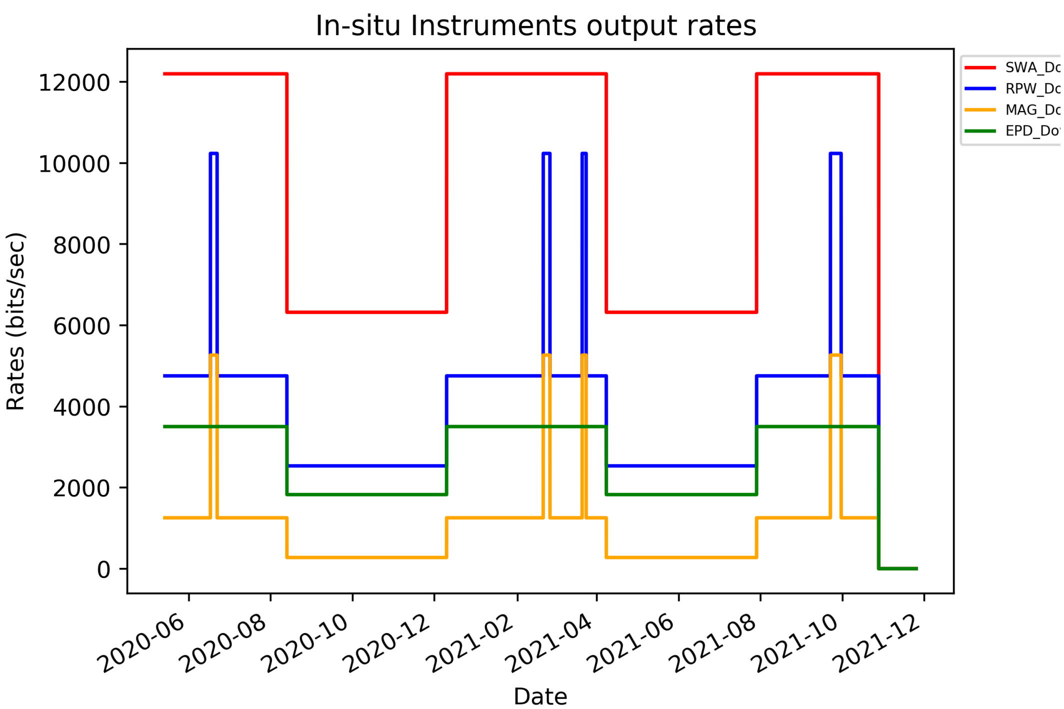
Rate	EPD	MAG	RPW	SWA-EAS	SWA-PAS	SWA-HIS
Nominal (R<0.8)	EPD_CLOSE_BURST (15) **GREEN**	MAG_NORMAL_BURST (120) **WHITE(ISH)**	RPW_DEFAULT_COLD (10) **OLIVE**	SWA_EAS_NOMINAL_BURST (10) **YELLOWISH**	SWA_PAS_NORMAL7_BURST7 (5) **DARKER GREEN**	SWA_HIS_NORMAL_BURST (5) **PURPLE**
Low (R>0.8)	EPD_FAR_BURST (5) **RED**	MAG_LOW_BURST (30) **BLUE**	RPW_LOW1_COLD (10) **PURPLEISH**	SWA_EAS_LOW_BURST (10) **PURPLE**	SWA_PAS_NORMAL11_BURST11 (5) **LIGHTER GREEN**	SWA_HIS_LOW_BURST_HALF (5) **GREEN**

Note that for RPW and MAG different observations were used during RS Checkout Windows.

Downlink was shared pro rata between the instruments according to EID-A allocations. This results in the following output data rates and packet store fill states:

EPD MAG RPW SWA

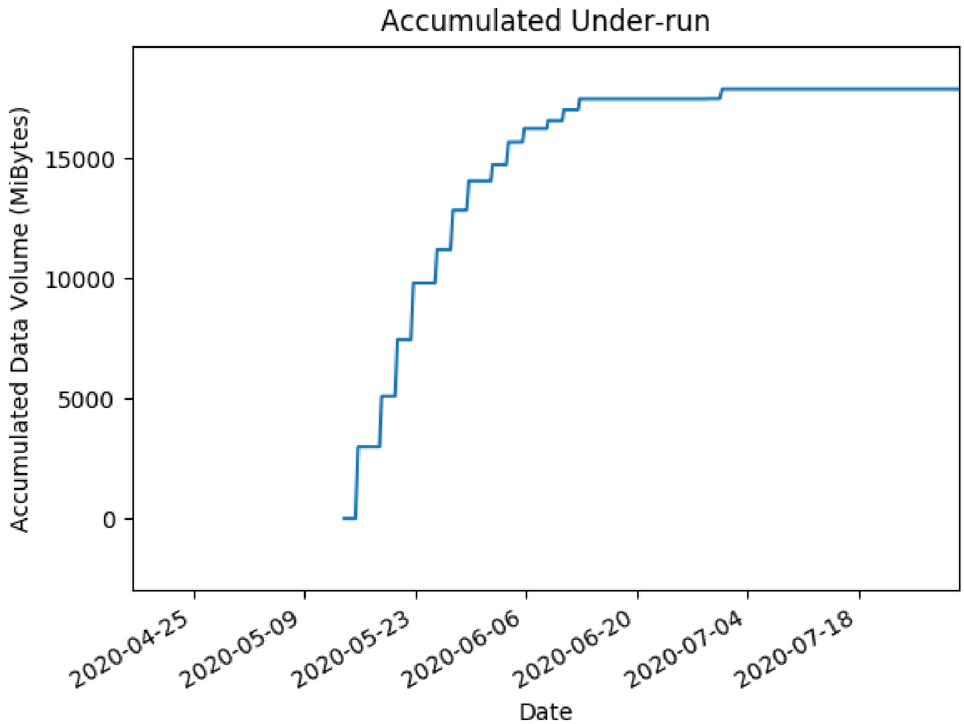


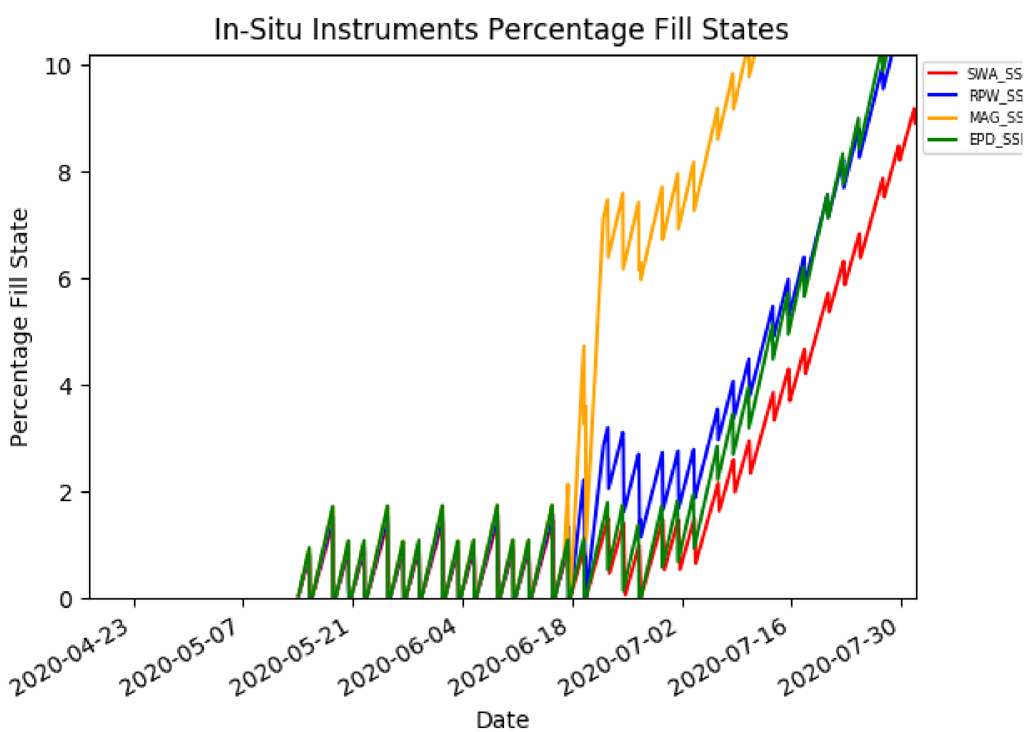


This plan has 33 weeks of low rate mode, compared to ~44 weeks (exact durations vary by instrument) of low rate mode in the Cruise Phase plan agreed during SOWG11.

Scope for Further Optimisation & Target Fill States at the End of LTP 01

Packet stores only start to fill during the first RSCW (17 June 2020) so there is scope for some additional burst mode up to and including the first perihelion. Exact amounts cannot be calculated without knowing the exact times of the communications passes and the true spacecraft trajectory; however, the unused downlink drops dramatically as the spacecraft approaches perihelion so the vast majority of this will have to be earlier. Some burst can be added during LTP.





In order to maintain default cadence and resolution while the spacecraft is within 0.8AU, packet stores shouldn't be more than ~5% full on average at the end of LTP01 (01 July). If higher data generation (e.g. through additional burst mode) is deemed to be desirable during the first perihelion, this could be achieved through increasing the time spent in low rate mode later, or indeed through reducing the amount of burst mode scheduled after 1 July. Conversely, because SSMM stores start to fill so late in the planning period, there is almost no scope to reduce data production during LTP01 in order to increase production later during the cruise, and hence minimise the amount of time in low rate modes. However, should the SWT decide to further minimise the amount of time in low rate modes later in the cruise, this can be accomplished by sacrificing burst mode after 01 July. For example, according to the currently scheduled observation definitions, the following tradeoffs are possible.

- EPD: Sacrificing 180 minutes (12 days at 15 minutes per day) of CLOSE burst mode allows 1 day to be changed from FAR to CLOSE (assuming zero burst on that day).
- MAG: Sacrificing 360 minutes (3 days at 120 minutes per day) of BURST64 allows 1 day to be changed from LOW to NORMAL (assuming zero burst on that day).
- RPW: Sacrificing 150 minutes (15 days at 10 minutes per day) of SURVEY_BURST mode allows 1 day to be changed from LOW1 to DEFAULT (assuming zero burst on that day).
- SWA
    - EAS: Sacrificing 30 minutes (3 days at 10 minutes per day) of BURST mode allows 1 day to be changed from LOW to NOMINAL (assuming no burst on that day).
    - HIS: Sacrificing 100 minutes (20 days at 5 minutes per day) of BURST mode allows 1 day to be changed from NORMAL to LOW_HALF (assuming no burst on that day)
    - PAS: Sacrificing 410 minutes (82 days at 5 minutes per day) of BURST mode allows 1 day to be changed from NORMAL7 to NORMAL11 (assuming no burst on that day)

Scope for Collaboration with Parker Solar Probe

Of the five Parker Solar Probe perihelia that will take place during the cruise phase, three will occur while the plan above has Solar Orbiter's in situ payload operating at nominal cadence (i.e. when the spacecraft is within 0.8 AU), and two will occur while the payload is operating in low rate modes. The plan above can be changed, without affecting its feasibility, such that a week (for example) of nominal rate observations can be exchanged with a week of low rate observations so that the nominal rate observations coincide with PSP perihelion encounters. Similarly, burst mode can be concentrated during these periods (within reason) as long it is moved from elsewhere rather than scheduled in addition to existing burst mode.

The PSP encounters are as follows:

- 7 June 2020: Nominal Rate
- 27 September 2020: Low Rate
- 17 January 2021: Nominal Rate
- 29 April 2021: Low Rate
- 9 August 2021: Nominal Rate

Caveats

Apart from better filling the underruns at the very start of cruise, and should SSMM maintenance activities permit, at the end of cruise, SOC believes this optimisation represents close to the upper limit of what can be achieved, and could in fact be over-optimistic. The following caveats and open points apply:

- Underruns are better filled during the long term planning process, as much as is possible given the uncertainty in exact downlink rates. This uncertainty will not be resolved until the true trajectory is known.
- Sizes of SSMM stores are not yet finalised. If these change such that the proportion of the SSMM allocated to the in situ payload as a whole needs to be reduced beyond what is currently unused at the time of peak storage, some activities will have to be removed (i.e. increased time in low rate mode, or a reduction of burst mode).
- The optimisation was carried out based on downlink being shared pro rata based on EID-A rates between the IS payload for the 3 passes per week. Once the optimised plan was combined with RS plans for the checkout windows, some "IS reserved" downlink was shared with the RS payload between RSCW3 and RSCW 4 to ensure the RS teams have time to analyse RSCW 3 data before RSCW4. This has the effect of increasing IS data latency a little.
- Stores empty in this plan ~2 weeks later than in the previous plan. If this puts too much pressure on SSMM maintenance activities, and stores can't be emptied earlier through optimisation of the pass schedule, some activities may been to be descoped (i.e. reduction in the amount of burst mode, more time spent in low rate mode). This is unlikely, however.