MEETING

Meeting Date	05/05/2014	**Ref**	SOL-SGS-MN-0020
Meeting Place	Meudon, France	**Chairman**	Luis Sanchez
Minute's Date	08/05/2014	**Participants**	Milan Maksimovic Yvonne De Conchy Philippe Plasson Bernard Pontet Xavier Bonnin Yannis Zouganelis Jayne Lefort Andrew Walsh Chris Watson Ignacio Tanco
Subject	RPW Operations meeting	**Copy**	Filippo Marliani Catherine Laffaye

Agenda

Minor rearrangement for people's availability:

Intro / RPW Needs for Selective Downlink	RPW
Update on Communicating SWA-PAS Sweep times to RPW	ALL
EM TM/TC Database	RPW/MOC
Downlink rate variability and its consequences	SOC
Lunch	
Telemetry Generation Corridors & Planning	SOC
Proposed Selective Downlink Scheme for Nominal and Extended Mission Phases	SOC
Reconciling RPW selective needs with telemetry and SSMM constraints	ALL
HK parameter for monitoring SCM heater current	ALL
Antenna Calibration Rolls	RPW/MOC

RPW Selective Downlink

Science background:
Designed for the collection of shock crossings and type-3 bursts.
1 shock every 5 days based on Helios – expected to be underestimate for Solar Orbiter/RPW => two shocks per day as current crude working assumption.
Besides shocks and type-3 it is possible to trigger on other features (e.g. "discontinuities"). This is a possible in-flight extension of these operations and could lead to the capture of new physics.
Scientifically there are no concrete drivers for setting the period over which to select events

RPW Presentation (appended):
Flow of bursts onto the SSMM is somewhat slower than the "realtime" acquisition speed.
Commandable burst acquisition also possible – would also go to the store-2. (N.b. This is independent from the scheduled burst ("Survey burst mode") that belongs with the survey data).

SBM-1 of 13 mins compression ratio 2, 0.2 Gbit, assumed chosen 1 every 5 days (average)
SBM-2 of 30 min compression ratio 2, 0.25 Gbit, assumed chosen 1 every 40 days (average)
SBM-2 of 120 min compression ratio 2, 1 Gbit, assumed chosen 1 every 40 days (average)
(duration of the SBM-2 is configurable. Above are two possible examples)

Store volumes in this presentation are previous RPW assumption and not endorsed volumes (e.g. shown survey volume is inadequate for the poor comms periods).

Write rates are not well known – RPW desire is for 50 SBM-1 and 4 SBM-2 of storage. Cruise phase allows possible tuning of the detection algorithms in order to obtain the correct mean write rate in practise. (N.b. an additional factor is the variability away from the mean, which cannot be tuned in this way – it is agreed that if the sun is especially active then some written events might be overwritten before they can be chosen or downlinked).

It is confirmed that it is possible to run the detection algorithms (with the corresponding service 5 TM) without directing the corresponding bursts to the spacecraft - this is advantageous for Cruise Phase => validation of the triggering without actual selection process occurring. See the SOC summary of cruise phase S-20 validation (appended).

In terms of predictability of downlink of survey (which depends on how much selective is downlinked), RPW agree that they are able to respect a short–term fixed volume of selective downlink, such that the RPW survey data backlog behaviour is fully independent and predictable. The short-term fixed volume doesn't have to exactly match the request period. In the meeting a volume of **3 bursts (SBM-1) per two weeks** is specified. Some care with this is needed because SBM-1 and SBM-2 can be different sizes (although if SBM-2 is 30minutes then the sizes of SBM-1 and SBM-2 are nearly equivalent).
Post-meeting note: This would mean that the 120 min version of SBM-2 is already excluded. SBM-2 would need to be order of 60 mins or less, otherwise a single SBM-2 becomes incompatible with respecting the two week downlink volume.

SOC caution that choosing bursts out-of-time order will introduce extra constraints on how the scheme can be implemented. There may be consequences for robustness to SSMM contingencies.

Downlink variability and its consequences

SOC presentation (appended).
RPW agree their ability to follow a corridor for their survey data production. Survey data volume is predictable (except for compression factor). RPW is able to vary its survey data rate to adapt to both increases and decreases in allowable rate. Small reductions below 5.5 kbps total for a period (e.g. 5.1 kbps) are acceptable, but big reductions (to e.g. 3 kbps) have to be avoided.

Selective proposal

SOC presentation (appended).
RPW agree with the overall concept and state that the minimum selective buffer fits well with their needs. This corresponds to approx. 50 SBM-1 events present in the buffer at any moment (**N.b.** not all of which are available for downlink because of the end-to-end turnaround – assuming two SBM-1/day then only ~**8** are actually available in any given weekly request period).

Calibration rolls

MOC summary of operational constraints:

- Rotation around arbitrary axis is excluded
- Roll around X with arbitrary +X pointing is excluded.

The principle problem is that sun illumination of the spacecraft radiator on the +/- Y panels is a problem.

- Sun-point +X and roll around X – is broadly OK.
- Off-pointing +X from the sun and roll – may be ok for smaller off-pointing angles (few degrees) depending on thermal situation and transient (e.g. 30 min) illumination of SC radiators, currently uncertain. Few degrees buys RPW little => ignore for now.
- Sun-point +X initially and then **pitch** around Y. This avoids illumination of the radiators, but requires solar arrays to rotate to track the sun => full revolutions not possible, mech. configuration not stable (requested by RPW), and anyway operationally undesirable due to both excess SA actuation and illumination of normally cold surfaces close to a GAM => ignore for now.

Discussion of +80deg, -120 deg "night side" constraint, Figure 43 of RPW EID-B. The Earth poles are tilted (by season) compared to the GSE XY plane (within which, broadly, the path of the spacecraft will lie). Thus it can be that the region around one or other Earth pole may sometimes be visible outside of the constraint as shown. Perhaps the constraint should be relaxed? – this could potentially extend the usable encounter path on the trajectory plots beyond what is shown, possibly allowing RPW to make use of both inbound and outbound legs of a given GAM. Note: Generally the nightside constraint (when combined with +X sun-pointing) makes it difficult to calibrate the –X hemisphere.
Also for the minimum distance constraint it is not clear why it should be mandatory that both pole regions need to be visible together.

Working assumption is 8 hrs per day potentially available for roll, within the GAM reserved period, which is broadly consistent with the 1000 earth radii max distance constraint. Assume 1 rev per hour rolling rate for now.
Action: RPW will take these assumptions, and then trajectory plots from Andrew Walsh (appended), and with the calibration experts

i) Assess the ability to calibrate based on these and the simple <sun-point and roll around X> scenario,

ii) Review the applicability of the EID-B RPW constraints ("night-side", min distance).

[1st June]

SCM heater telemetry

RPW confirm that the SCM heater current parameter is in HK TM.
Action RPW will send the SCOS-2000 parameter name to SOC. [15th May]

Post meeting note: Action completed prior to issue of the minutes. The parameter is HK_PDU_HEATER_CURRENT {NIW00106}
It is confirmed that this is SCM heater only and unaffected by antenna heaters.

_ SWA-PAS sweep-time to RPW _

Action: Andrew to send a proposal to SWA and RPW about how to communicate the timing of PAS sweeps based on the already existing SWA OBT heartbeat and a number of seconds until the next sweep or sweeps and information about the mode PAS is operating in. [8th May]

Post meeting note: Action completed prior to issue of the minutes.

Goal is to meet with SWA and RPW during ESOC FDIR meeting next week.

Action: Luis to deliver a new version of S20 TN7 by the end of May with whatever information can be checked against the flight model instrument TM/TC ICDs. [End May]

Final recap of selective

Review of RPW CDR RID-38 points:

Points 1), 2), 3), 4) are closed with the clarification of the discussions in the meeting .
Point 5) Principle of no active selective in Cruise is agreed. Main goal of CP is to validate the response of the detection algorithm (via service-5 and LLD). RPW state they would like "a couple" of SBM-1 events during cruise brought to ground (to see the data is ok). SOC hear the request but state that such cannot yet be agreed. Closed.
Point 6) is given up. => Closed.

As discussed earlier, RPW are targeting

- 1 week request period
- Stable volume of chosen events going into the downlink, when averaged over two request periods (three SBM-1 every two weeks).
- Variability of write rate accepted to sometimes overwrite events prior to decision/downlink
- Multiple opportunities to downlink a specific burst where the write rate of new events allows this

Question on the details of the TM budget wrt how much is survey, how much is downlinked selective. RPW clarify that the "TM Budget" submitted at instrument-CDR is the reference. UM will be brought into line as normal work.

AoB

Autocompatibility campaign. NECP is led by Project. Autocompatibility needs agreement with other instruments as well.
Informal-only SOC comments on RPW proposed autocompatibility campaign

- Switch-on/switch-off cycle on the other instruments seems aggressive. Couldn't instead each instrument be left on once it has been added?
- Campaign seems quite long. To be discussed at EMC-WG and SOWG.
- Probably autocompatibility itself can assess simple "base-level" contribution of each new instrument, without needing to drive the new instrument through its full range of modes and transients. Detailed mode-by-mode characterisation of noise-contributing instruments maybe can be achieved by having RPW run during other instruments commissioning?

Action summary

Description	Action	Due Date
RPW will take the assumptions, trajectory plots	RPW_OPS-01	1st June 2015

Description	Action	Due Date
from Andrew Walsh, and with the calibration experts i) Assess the ability to calibrate based the simple <sun-point and roll around X> scenario, ii) Review the applicability of the EID-B RPW constraints ("night-side", min distance)		
RPW will send the SCOS-2000 parameter name for SCM heater current to SOC.	RPW_OPS-02	15th May
SOC (Andrew) to send a proposal to SWA and RPW about how to communicate the timing of PAS sweeps.	RPW_OPS-03	8th May
SOC (Luis) to deliver a new version of S20 TN7 by the end of May with whatever information can be checked against the flight model instrument TM/TC ICDs	RPW_OPS-04	End May

l'Observatoire de Paris | LESIA

Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

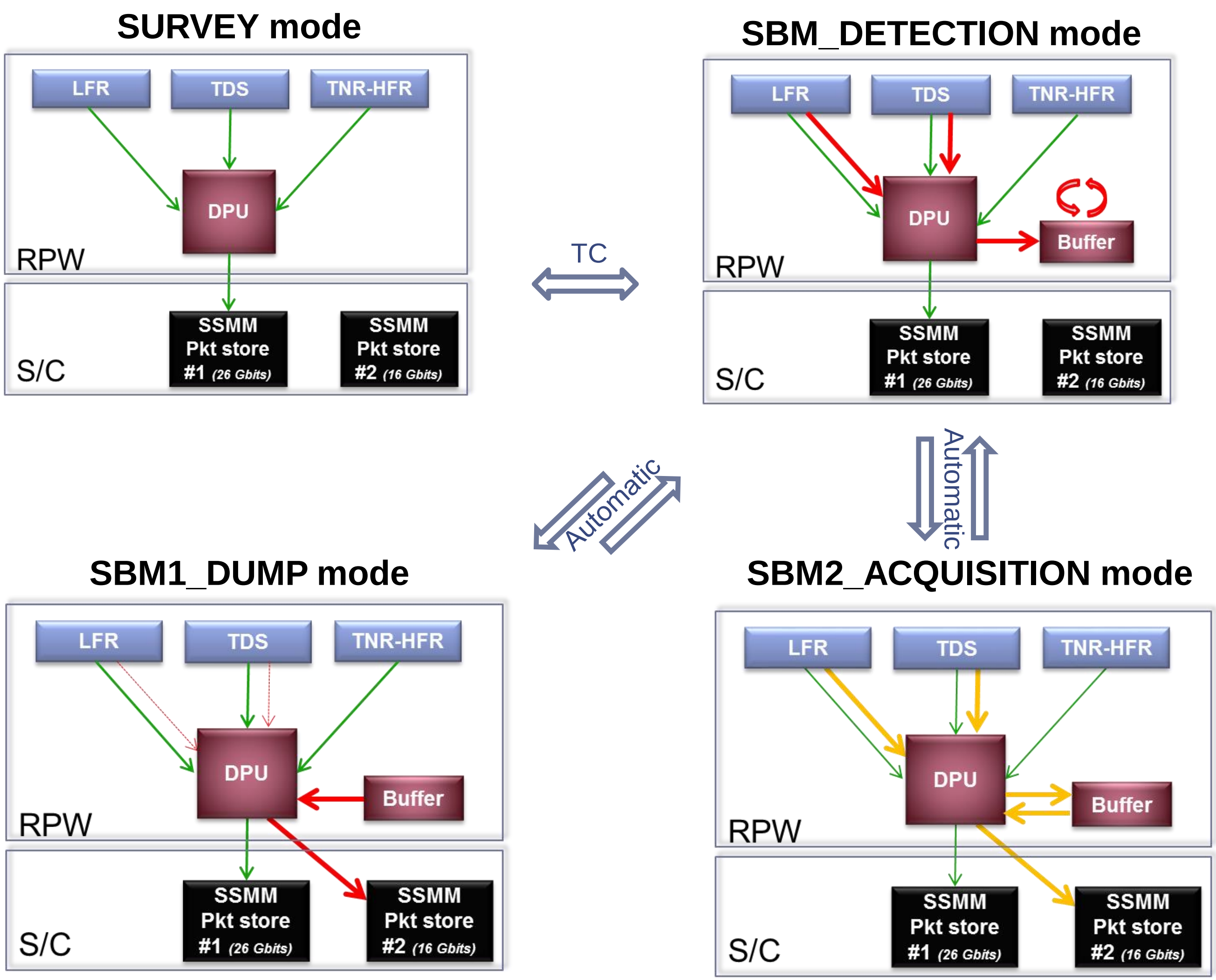
LESIA, Meudon
5 May 2015

RPW Selective Downlink

Philippe Plasson (RPW Software Architect) and the RPW team

RPW

RPW Science Modes and Data Flow



= NORMAL flow = Low cadence (4-40 kbps)

= SBM1 flow = High cadence (200-500 kbps)

= SBM2 flow = High cadence (100-300 kbps)

SSMM Pkt Store #1 = normal downlink (SURVEY data)

SSMM Pkt Store #2 = selective downlink (SBM data)

Interplanetary shock crossing

In-situ Type III

RPW Science Modes and Data Flow

- The dump of the SBM detection buffer (SBM1 data) can also be triggered by the TC_DPU_ENTER_SBM1_DUMP command {ZIW00041}.
  - For test purpose.
  - For acquiring SBM1 on demand (the detection algorithm are by-passed).
- The SBM2 data can be also acquired on demand using the TC_DPU_ENTER_SBM2_ACQ command {ZIW00042}.
- These both commands force the transition to the SBM1_DUMP mode or the transition to the SBM2_ACQUISITION mode.

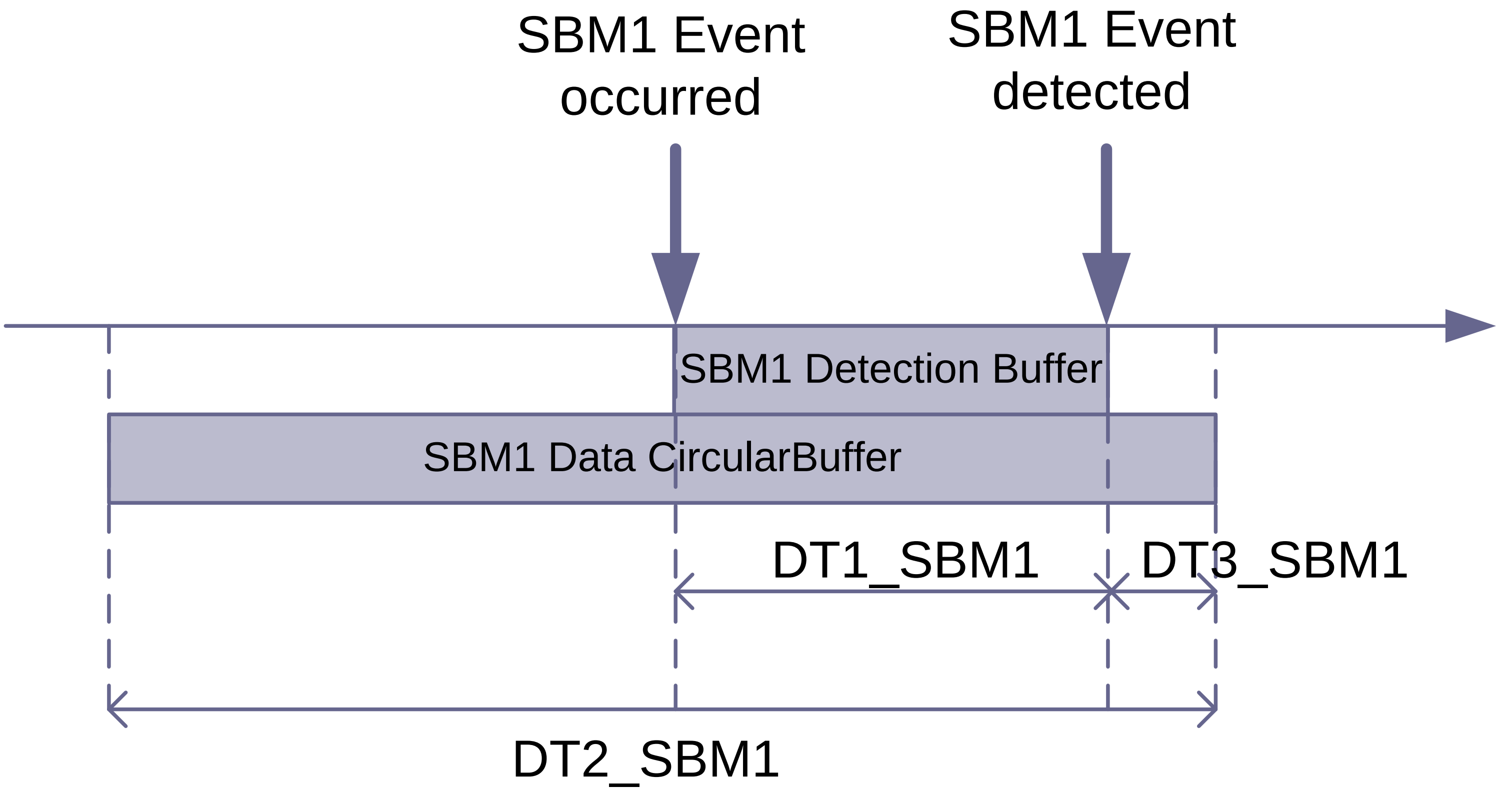
SBM event size and occurrence

- SBM1 events (shocks)
  - The size of one 13-minutes SBM1 event is: 0.2 Gbits (compression ratio = 2)
  - Downlink occurrence (averaged over the orbit) = 1 every 5 days
  - Event occurrence (stored in SSMM) = 1 every day
- SBM2 events (type III)
  - The size of one 30-minutes SBM2 event is: 0.25 Gbits (compression ratio = 2)
  - The size of one 120-minutes SBM2 event is: 1 Gbits (compression ratio = 2)
  - Downlink occurrence (averaged over the orbit) = 1 every 40 days
- The size of the packet store PS#2 (selective downlink) shall allow to store up to 50 SBM1 events (compressed data with a compression factor of 2, 13-minutes duration events) and 4 SBM2 events (compressed data with a compression factor of 2, 120-minutes duration events); this corresponds to a size of about: 14 Gbits.

Selective downlink management

- Auxiliary information provided to the ground segment by RPW for selecting and retrieving the SBM1 data
  - When RPW has detected a shock (SBM1 event), it sends a progress event TM (S5,1) TM_DPU_EVENT_PR_DPU_SBM1 {YIW00304} containing the features of the SBM1 event: copy of the SY_DPU_SBM1_ALGO parameter, shock occurrence time (TShock), value of Q at Tm (SBM1_Q), DT1_SBM1, DT2_SBM1, DT3_SBM1.
  - When RPW enters in the SBM1_DUMP mode, it sends a progress event TM (S5,1) TM_DPU_EVENT_PR_DPU_MODE {YIW00073}
    - The time T1 of this first TM (S5,1) packet allows to determine in the packet store #2 (selective downlink) the generation time of the first SBM1 packet.
  - When RPW leaves the SBM1_DUMP mode, it sends a progress event TM (S5,1) TM_DPU_EVENT_PR_DPU_MODE {YIW00073}
    - The time T2 of this second TM (S5,1) packet allows to determine in the packet store #2 (selective downlink) the generation time of the last SBM1 packet.
- Same mechanism for selecting and retrieving the SBM2 data.

Selective downlink management



Selective downlink management

- Thanks to the information conveyed by the progress event TM pakcets, the RPW ground segment is able to know what are the SBM events stored in the S/C SSMM (type, location, etc.).
- The RPW ground segment will maintain a “map” of the SBM events stored in the S/C SSMM (packet store #2).
- The management of this map will be automated thanks to a specific software tool which will help to determine what is the best event to dump.

Selective downlink management

- When it is the best moment, **in coordination with the SOC**, the RPW ground segment decides, using the SBM event map and the event quality factor, in addition to the RPW, **MAG, SWA & EPD survey data already downloaded to ground**, what SBM event shall be dumped.

- The SBM event is dumped thanks to the **"bound data retrieval" service** proposed by the S/C (PUS service 15): the SBM event is retrieved using the following function: "retrieve all packets between two packet generation times (T1 and T2) specified in the start data retrieval command".

Selective downlink management

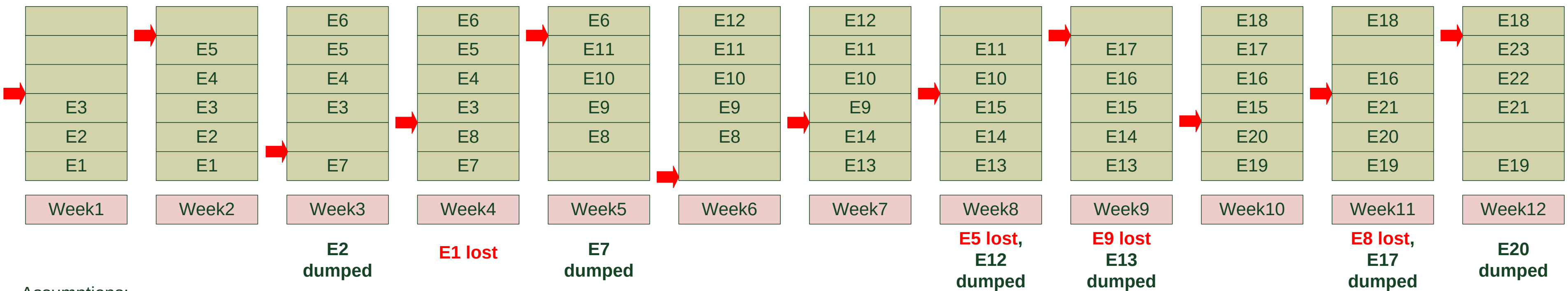
								E16	E16	E16	E16
							E15	E15	E15	E15	E15
						E14	E14	E14	E14	E14	E14
						E13	E13	E13		E13	E13
					E12	E12					
				E11	E11	E11	E11	E11	E11	E11	E11
				E10	E10	E10	E10	E10	E10	E10	E10
				E9	E9	E9	E9				
			E8	E8	E8	E8	E8	E8	E8		
		E7	E7								E23
		E6	E6	E6	E6	E6	E6	E6	E6	E6	E22
	E5	E5	E5	E5	E5	E5				E21	E21
	E4	E4	E4	E4	E4	E4	E4	E4	E20	E20	
E3	E3	E3	E3	E3	E3	E3	E3	E3	E19	E19	E19
E2	E2								E18	E18	E18
E1	E1	E1						E17	E17		
Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12
		E2 dumped	**E1 dumped**	**E7 dumped**			**E5, E12 dumped**	**E9 dumped**	**E13 dumped**	**E8, E17 dumped**	**E20 dumped**

Assumptions:
- Event occurrence (average) = 2 / week
- Event downlink (average) = 1 / week
- Packet store size = 16 events (4 Gbits)
- Non time ordered downlink
- End-to-end turnaround = 3 weeks

= packet store cursor

RPW position:
Maximize the size of the RPW selective downlink PS for making more efficient the RPW selection process.

Selective downlink management



Assumptions:
- Event occurrence (average) = 2 / week
- Event downlink (average) = 1 / week
- Packet store size = 6 events (1.5 Gibts)
- Time ordered downlink
- End-to-end turnaround = 3 weeks

= packet store cursor

ESAC position:
Minimize the size of the RPW selective downlink PS for making more efficient the Solar Orbiter overall TM downlink management.

- Baseline for RPW selective downlink (SBM1) = downlink 3 events every 2 weeks = 0.6 Gbits / 2 weeks

RPW Data Generation and Downlink

Andrew Walsh and Jayne Lefort
RPW Operations Workshop
LESIA, Paris
05 May 2015

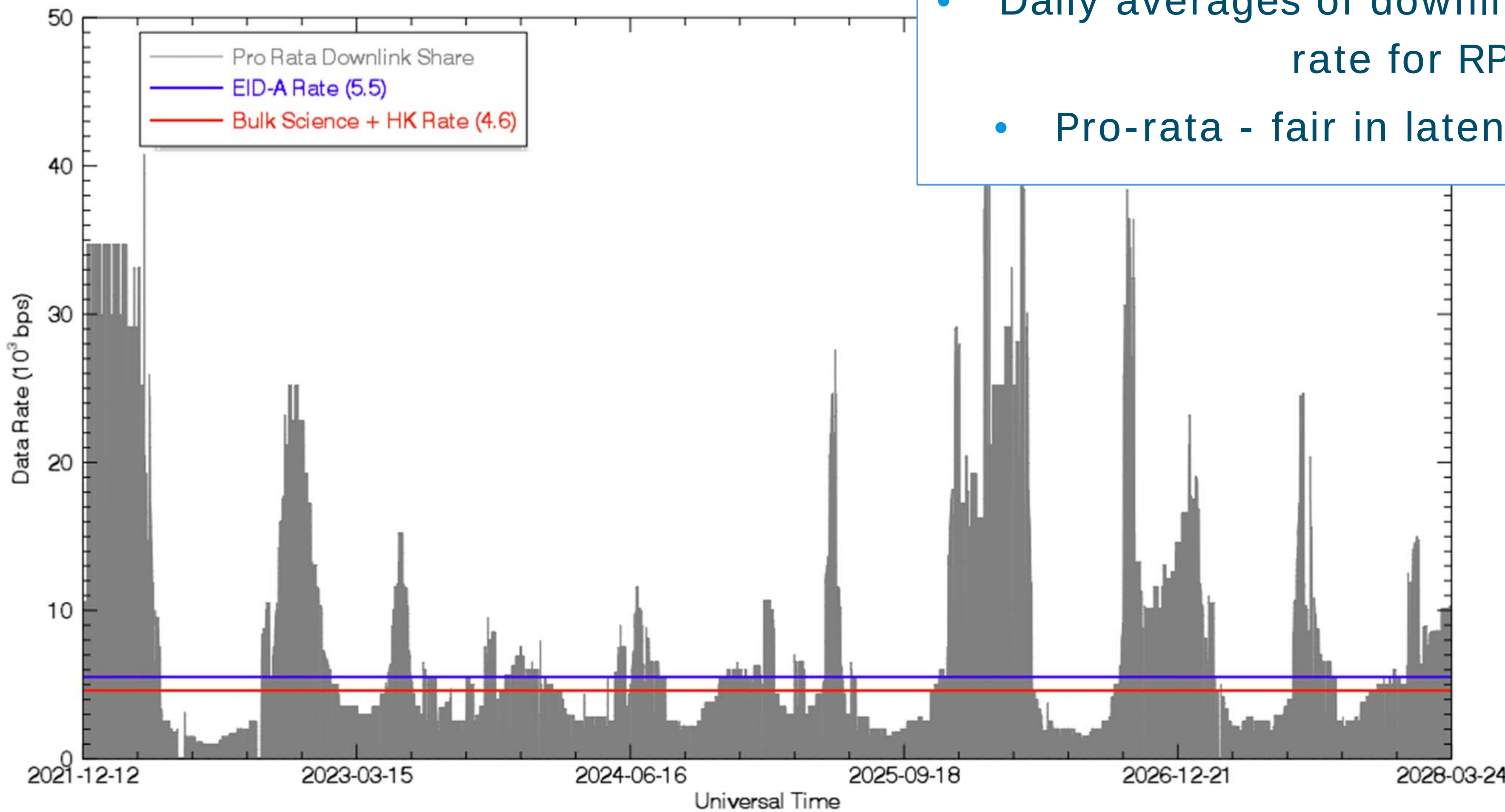
Things to Remember

- Solar Orbiter is a highly downlink constrained mission.
- Communications performance varies a lot over the mission.
- At times, the payload will generate data faster than it can be downlinked.
- The SSMM is there to act as a buffer during these periods of poor communications performance.
- The store sizes in the EID-A were calculated assuming 60 days' data would need to be stored during conjunctions. In reality we may need to store ~150 days' data. This will more or less fill the SSMM.
- This makes implementing selective complicated, but we think we have come up with a scheme that will work **some of the time*.*

Objective of This Presentation

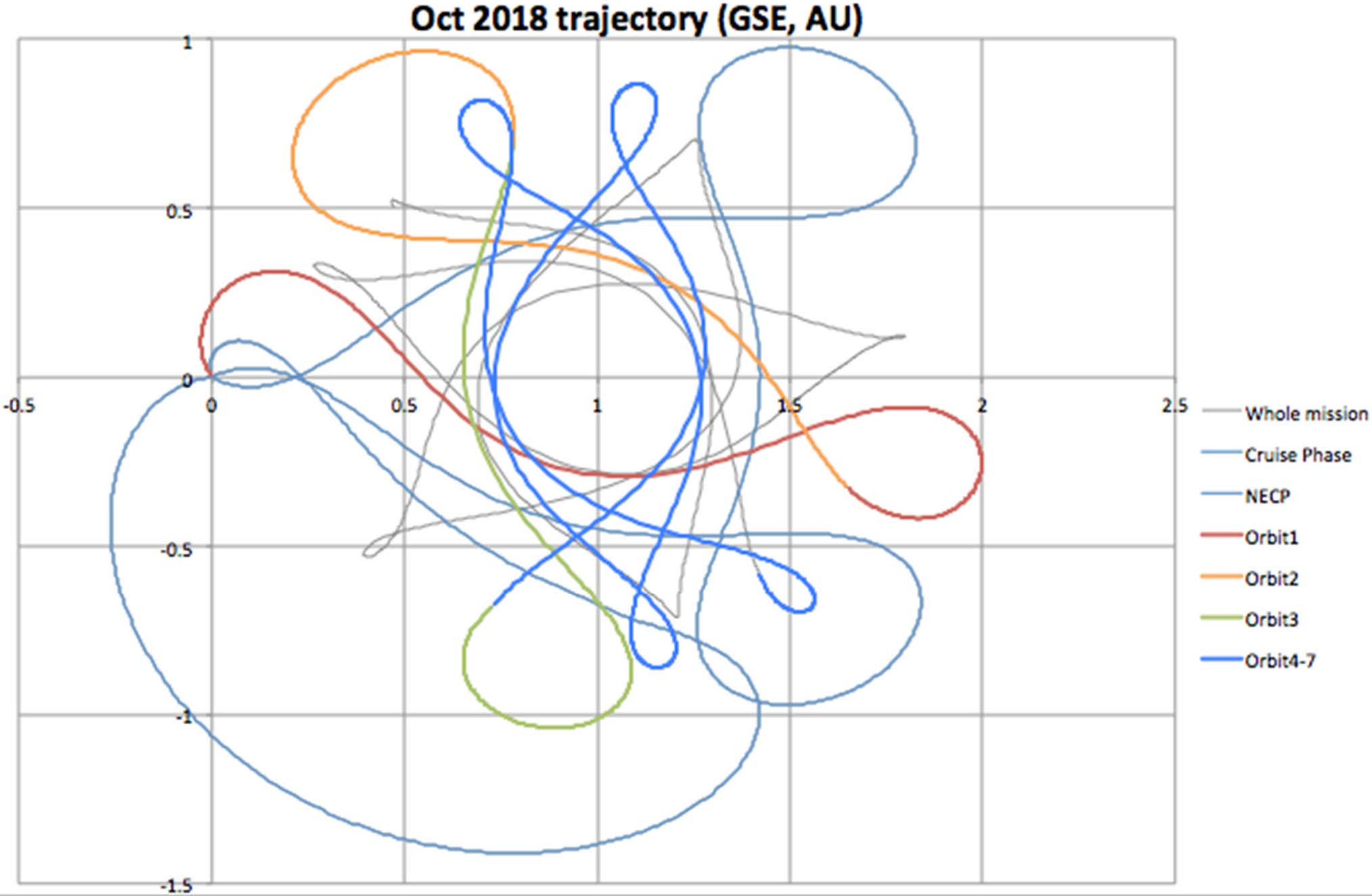
- Make sure everyone understands the downlink situation before we discuss selective this afternoon.
    - Illustrate how variable the downlink is.
    - Explain why it is so variable.
- What are the consequences for RPW?
- Without selective, what flexibility can we give you for when you generate your data.
- Consequences of overruns and underruns

Downlink profile Oct '18

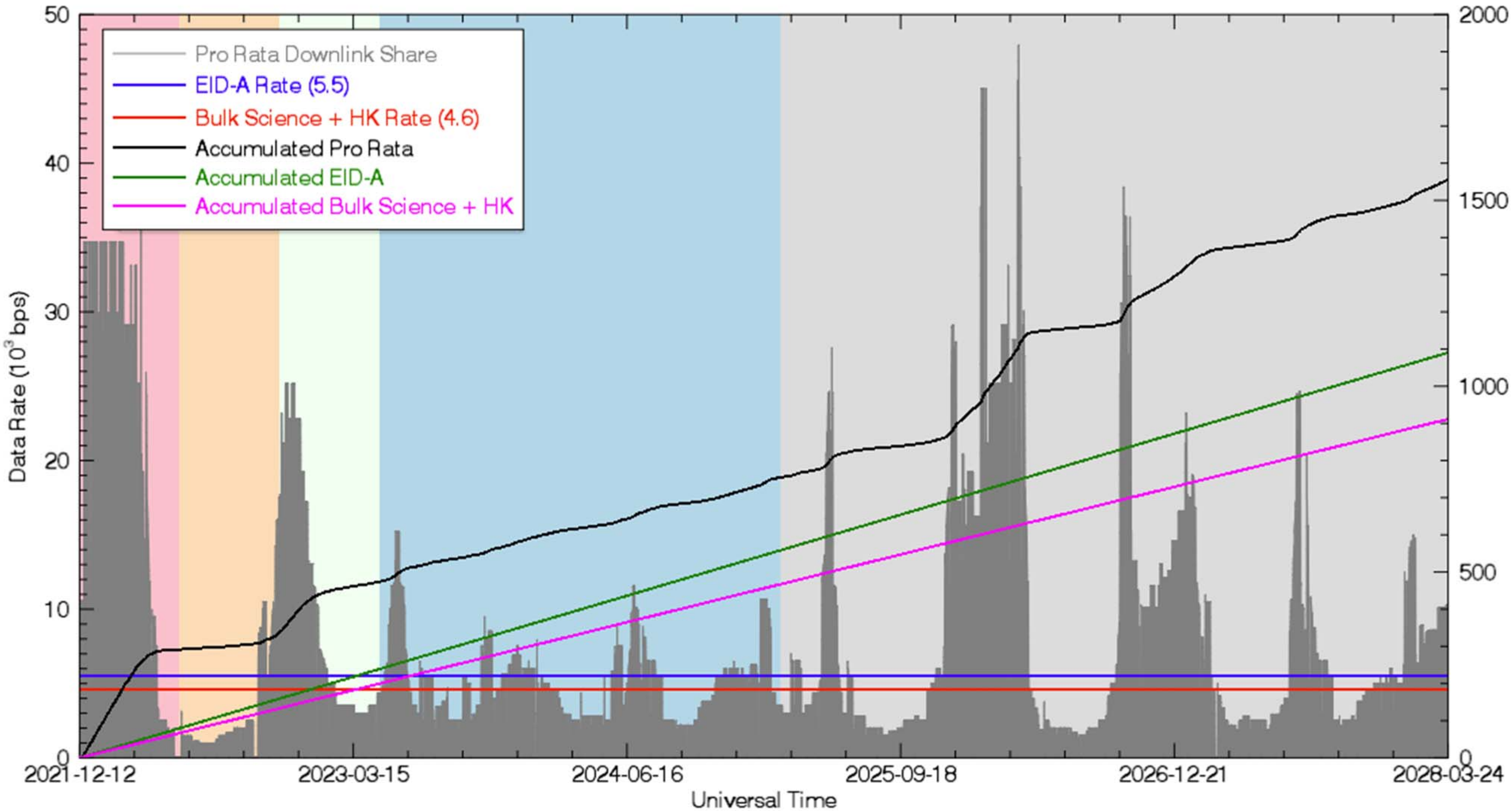


- Daily averages of downlink rate for RPW
  - Pro-rata - fair in latency

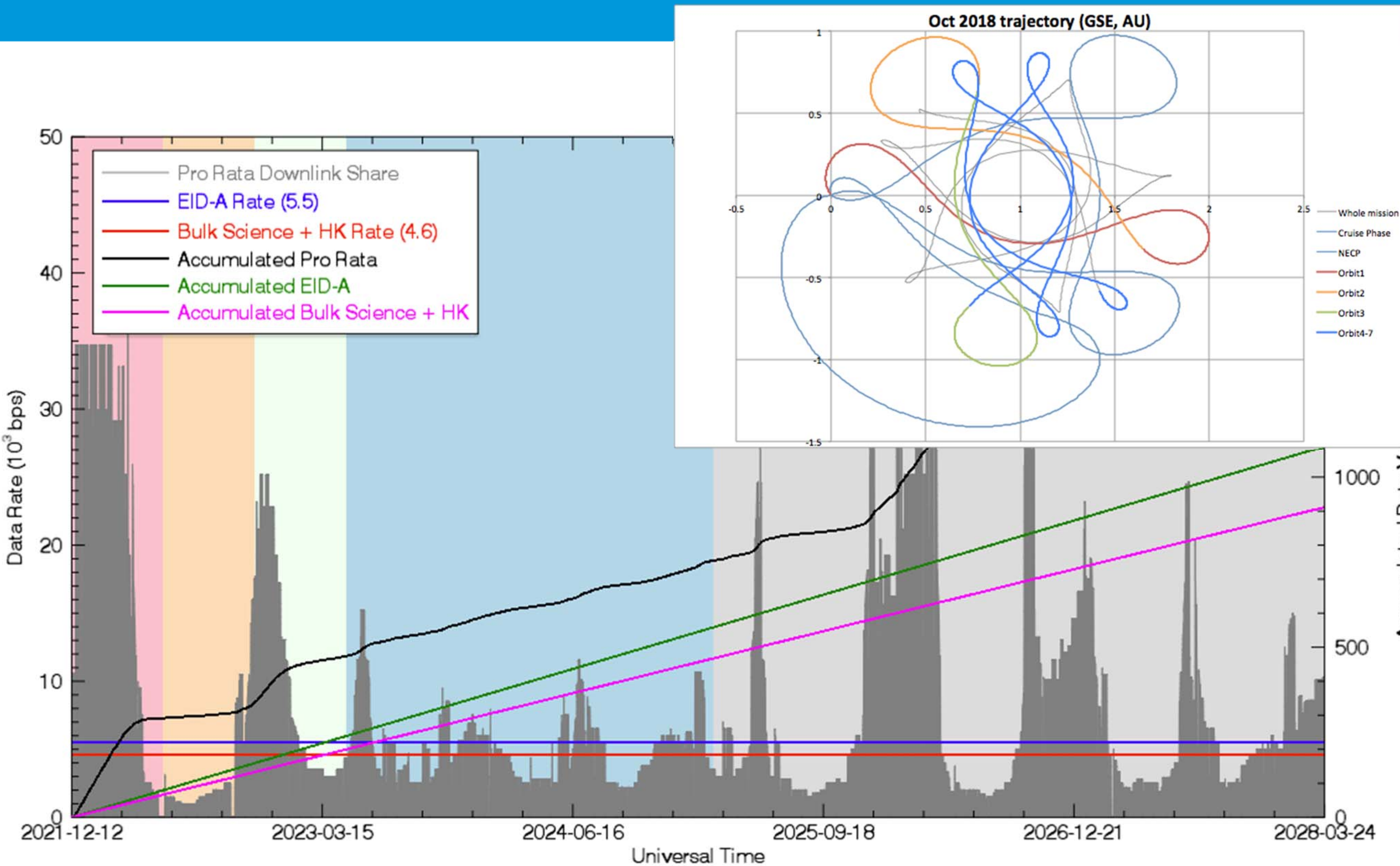
Reason for Variable Downlink



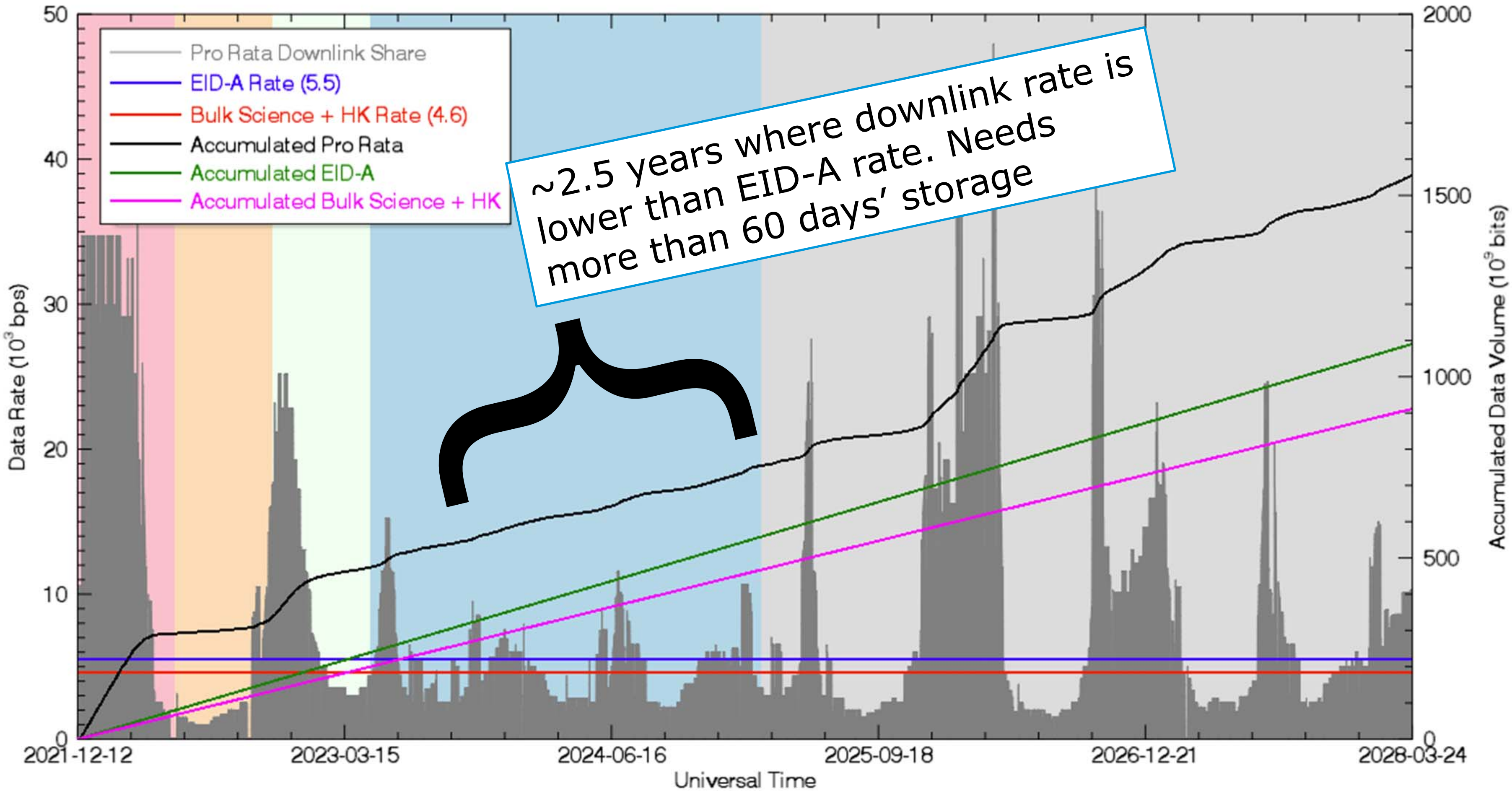
Impact of Variable Downlink on RPW



Impact of Variable Downlink on RPW



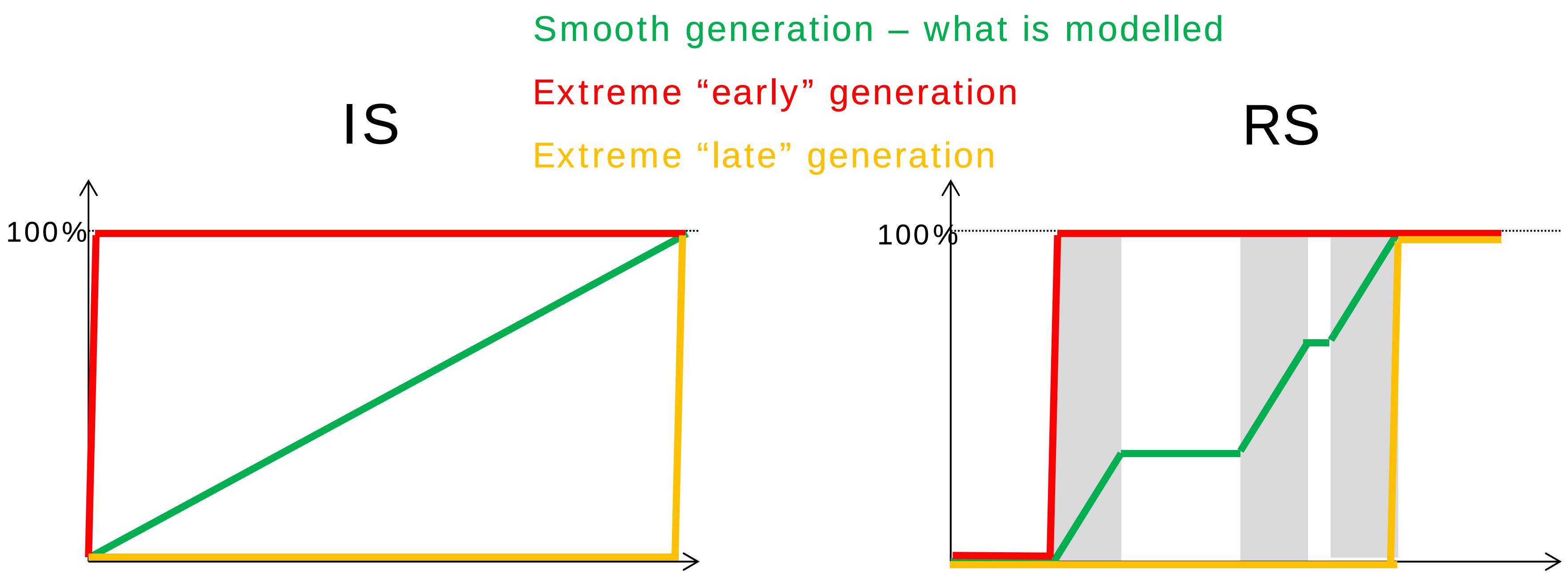
Impact of Variable Downlink on RPW



Data allocations

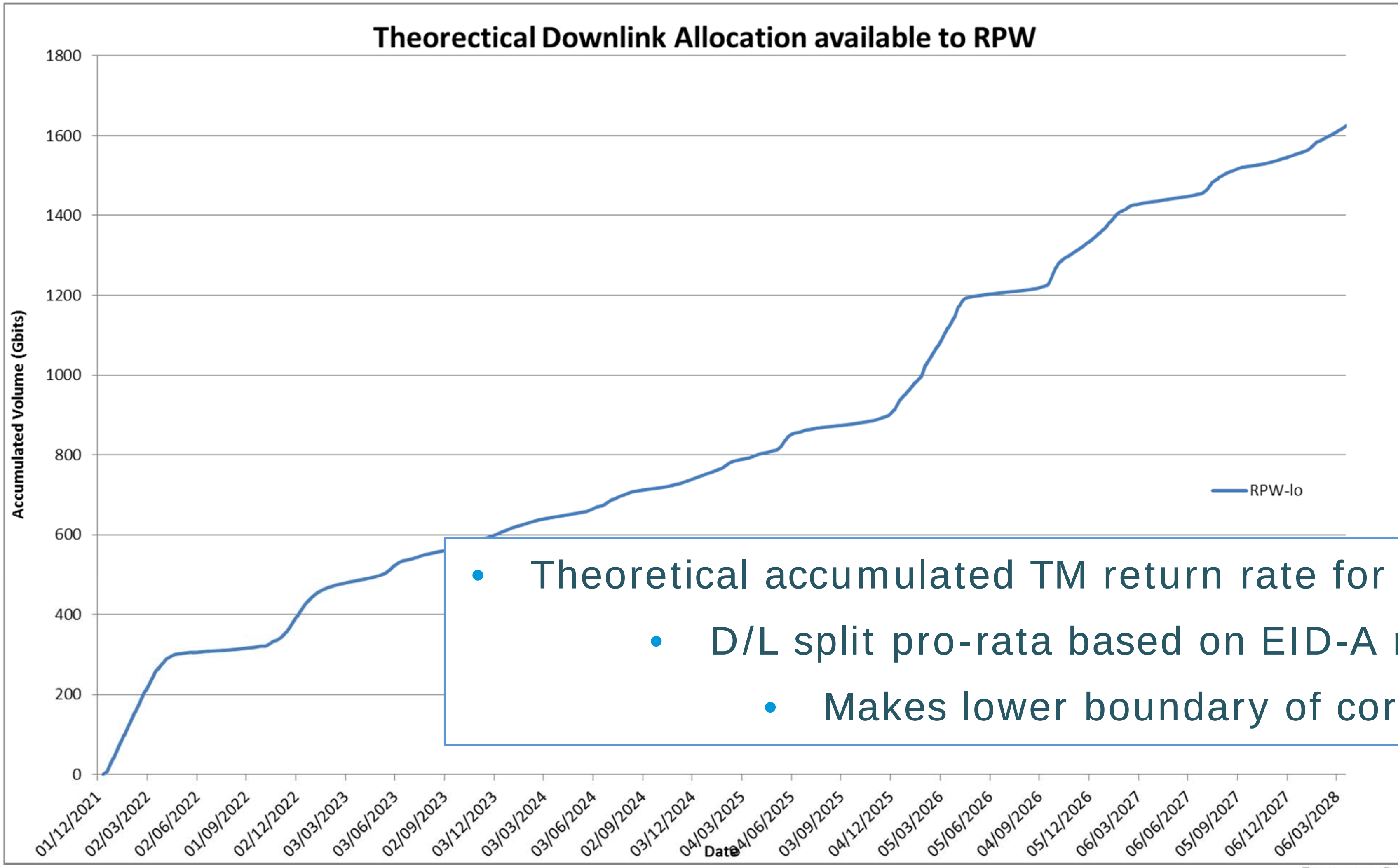
- Super-optimistic interpretation of allocation - “I can generate my data allocation whenever I like in the orbit”

- Super-optimistic interpretation is not true. Simply cannot work with this level of flexibility



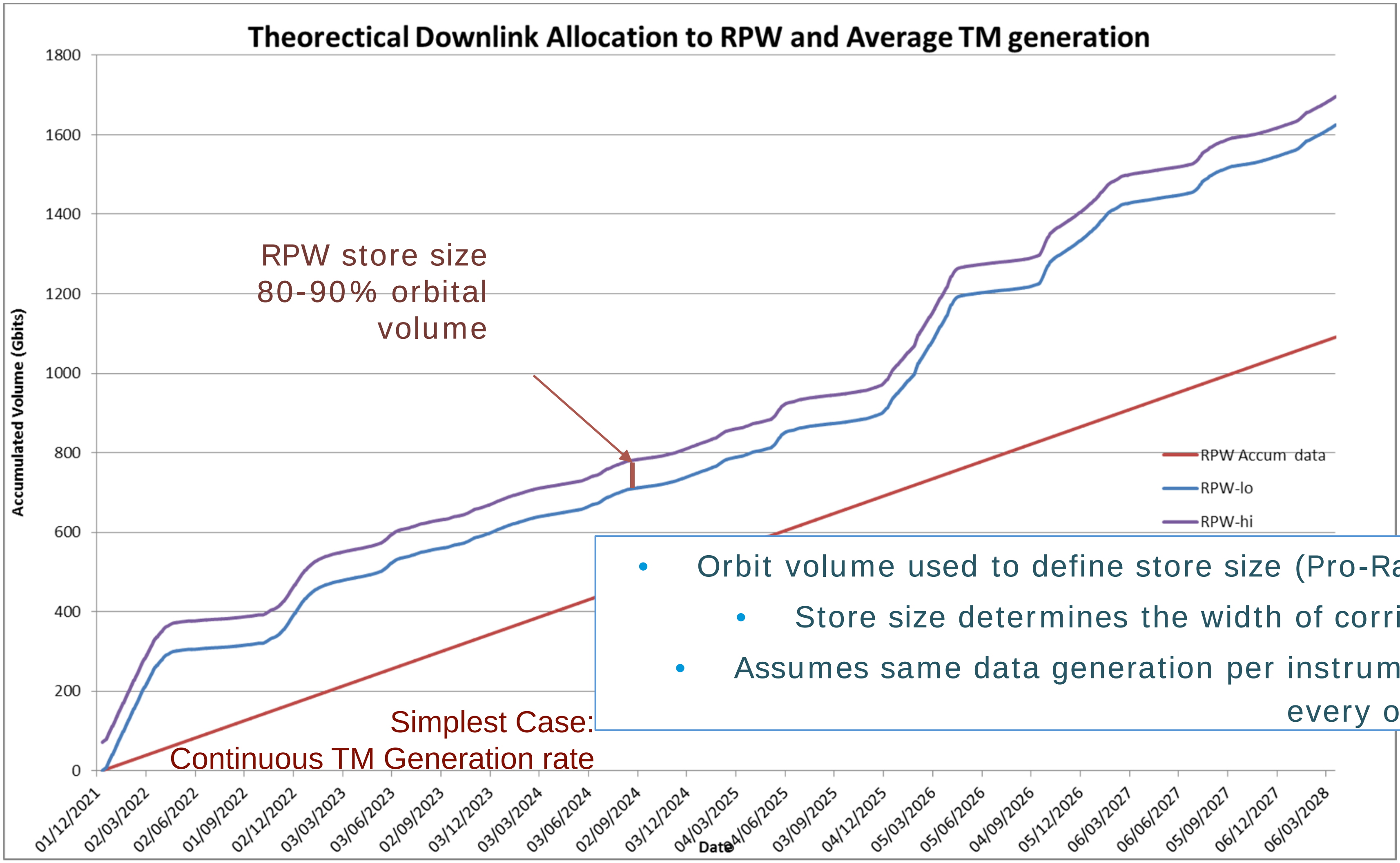
Cumulative TM generation over an orbit

RPW Downlink profile Oct ’18
Construction of TM Corridor



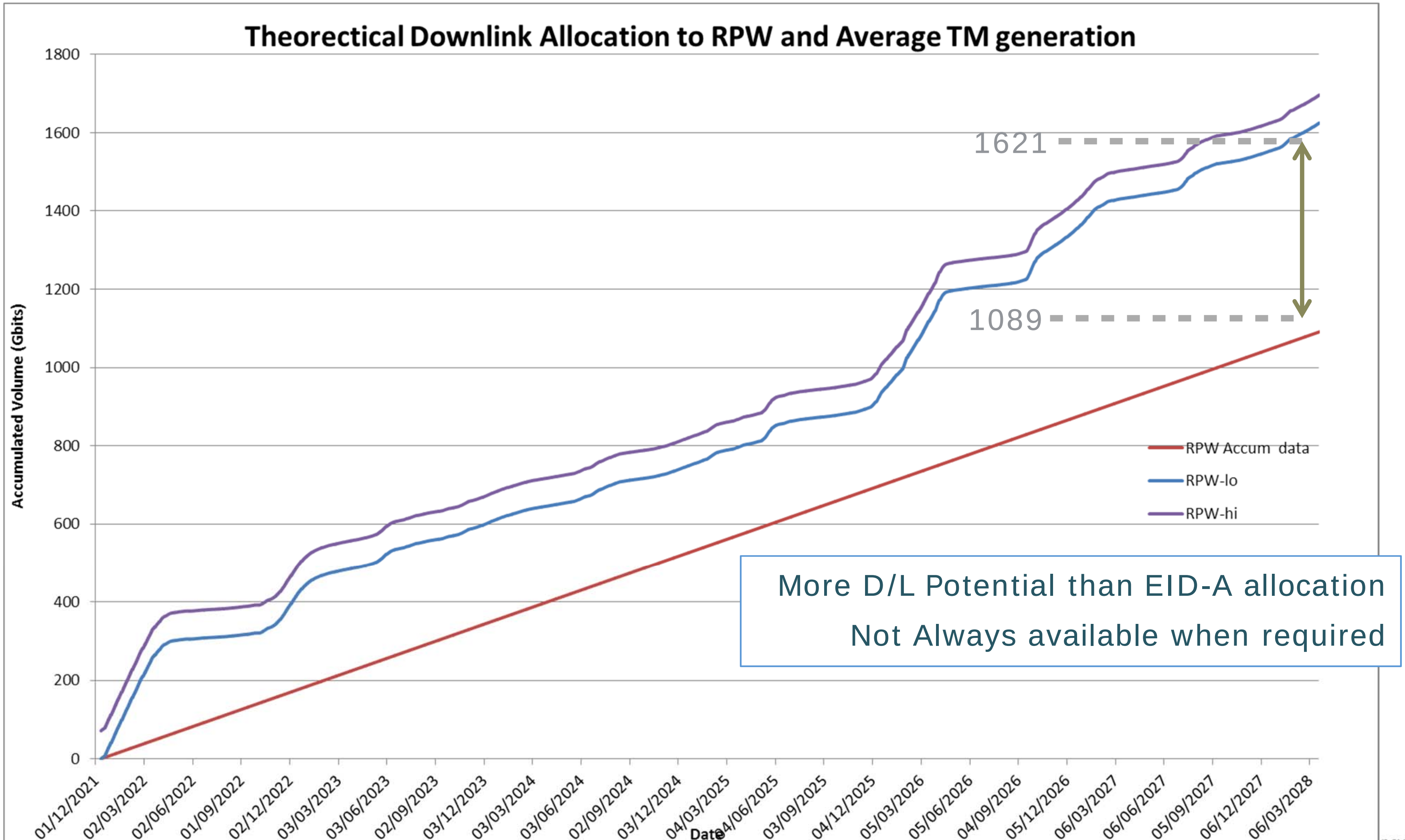
- Theoretical accumulated TM return rate for RPW
  - D/L split pro-rata based on EID-A rates
    - Makes lower boundary of corridor

Construction of RPW TM Corridor EID-A Average RATE

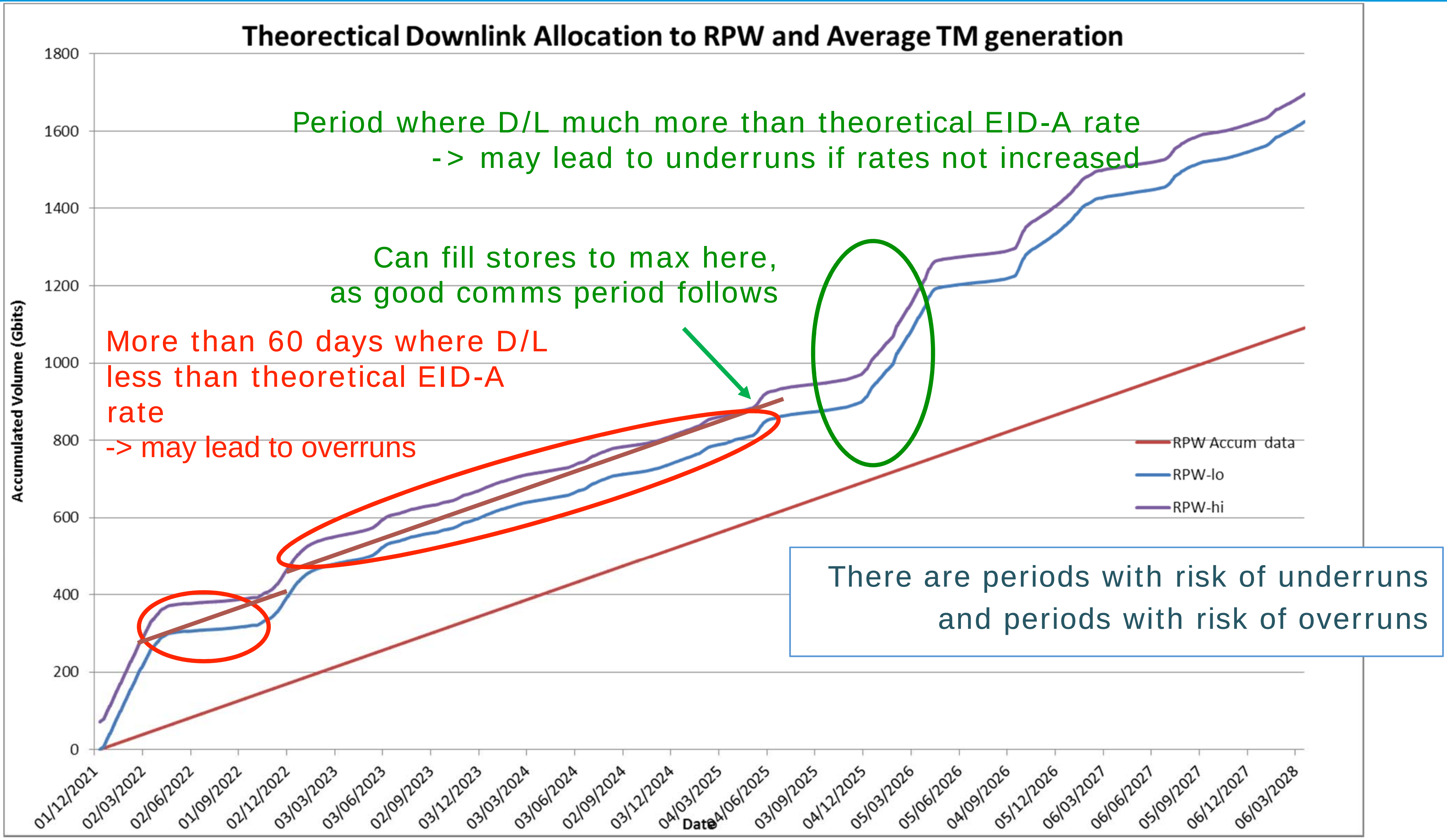


- Orbit volume used to define store size (Pro-Rata)
  - Store size determines the width of corridor
- Assumes same data generation per instrument every orbit

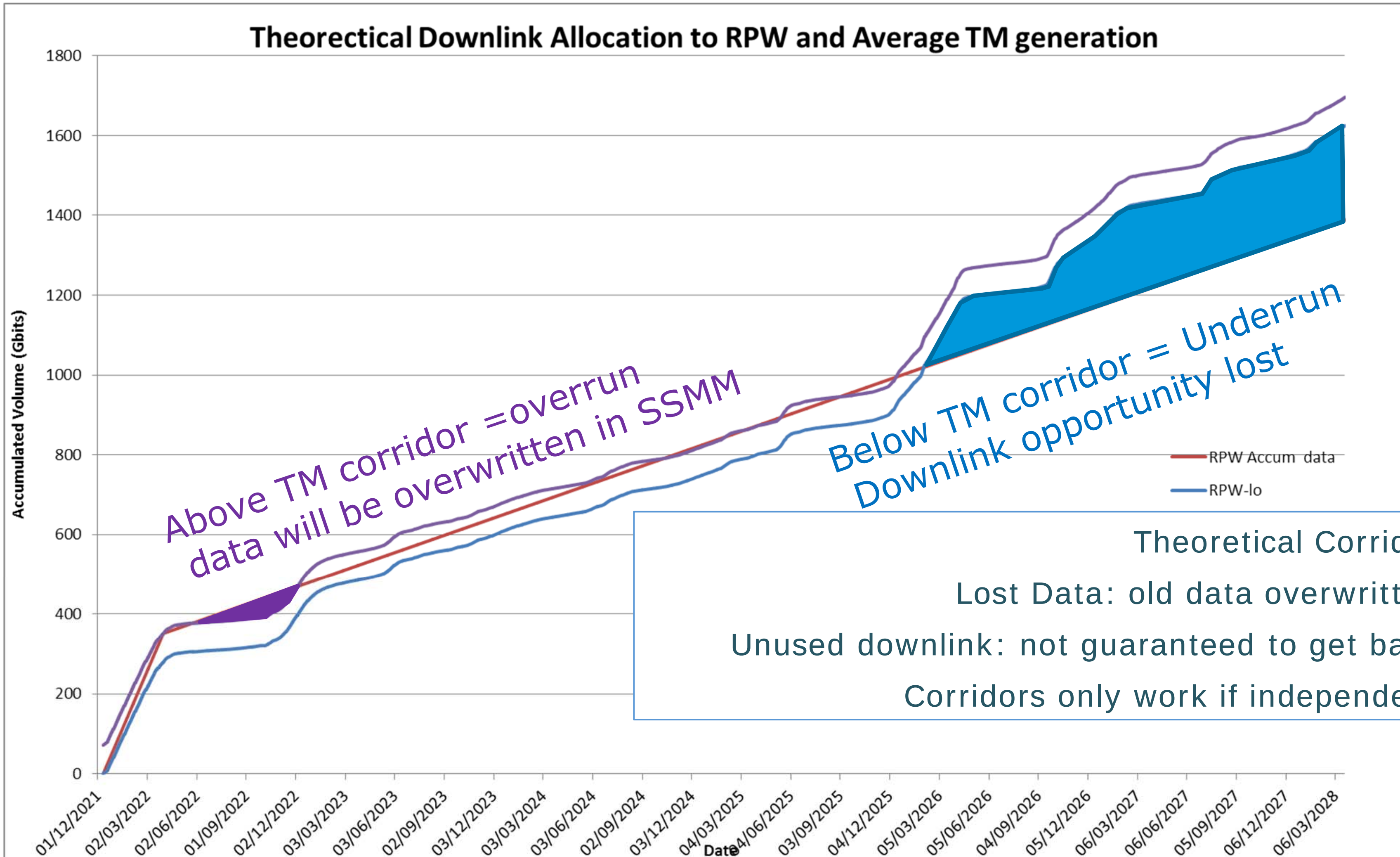
RPW's theoretical data generation



RPW theoretical TM corridor & EID-A allocated average rate



Downlink & Storage limitations



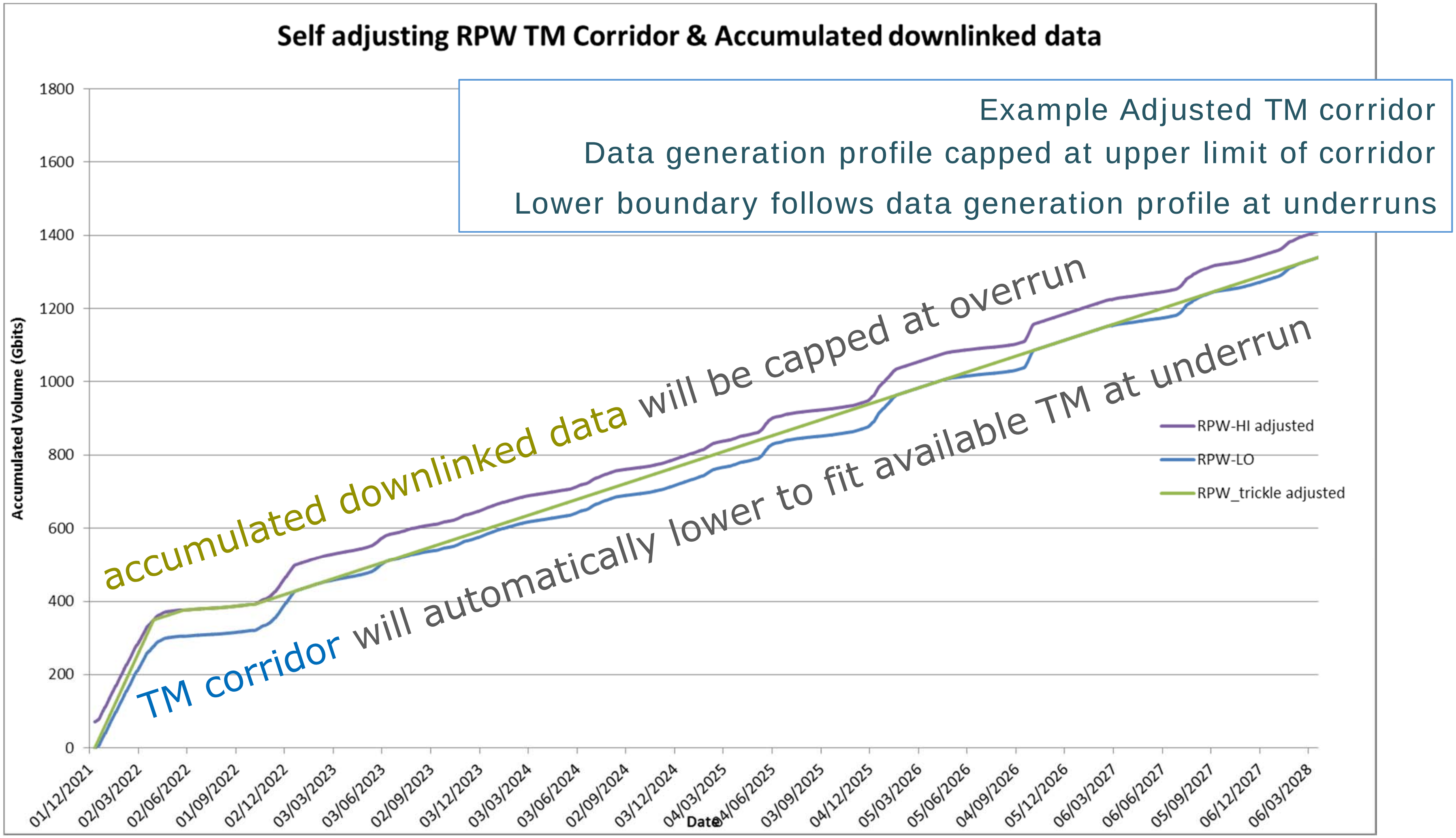
Theoretical Corridor

Lost Data: old data overwritten

Unused downlink: not guaranteed to get back

Corridors only work if independent

Downlink & storage limitations



Summary for simple case

- Downlink rate changes significantly over the mission
- SSMM storage gives some flexibility but this is limited (<orbital volume)
- TM Downlink + SSMM cannot easily accommodate arbitrary, highly variable rates of data and TM generation
- Packet store overruns lead to lost data
- Packet store underruns lead to lost downlink opportunity
- This was only the simple case of continuous TM production

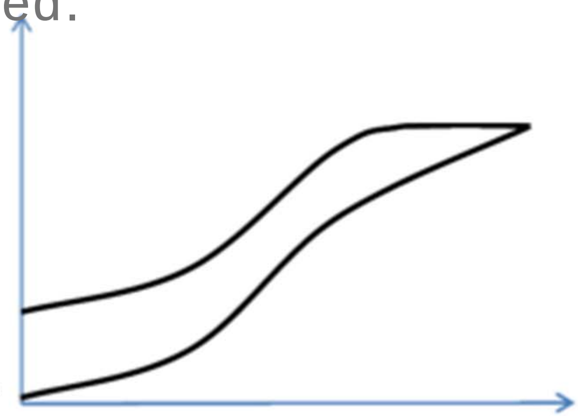
TM corridors as planning tool

1. SOC plans to produce instrument-specific TM corridors for each 6-months planning cycle (starting end LTP)

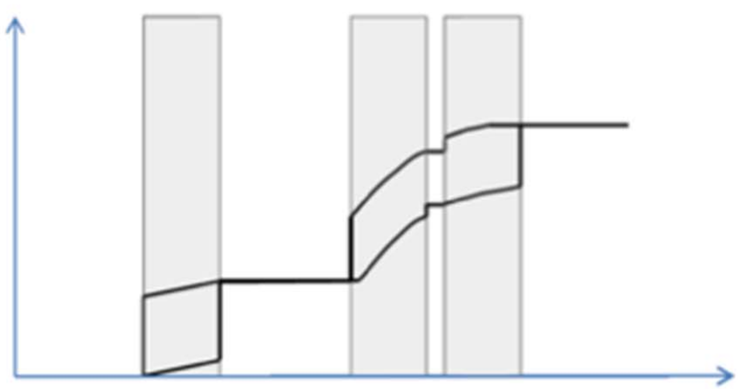
2. Displays your downlink share and TM generation flexibility, based on SWT and SOWG decisions

3. Zero flexibility at planning boundaries and certain events

4. TM generation corridors at STP, with actual SSMM data over plotted.

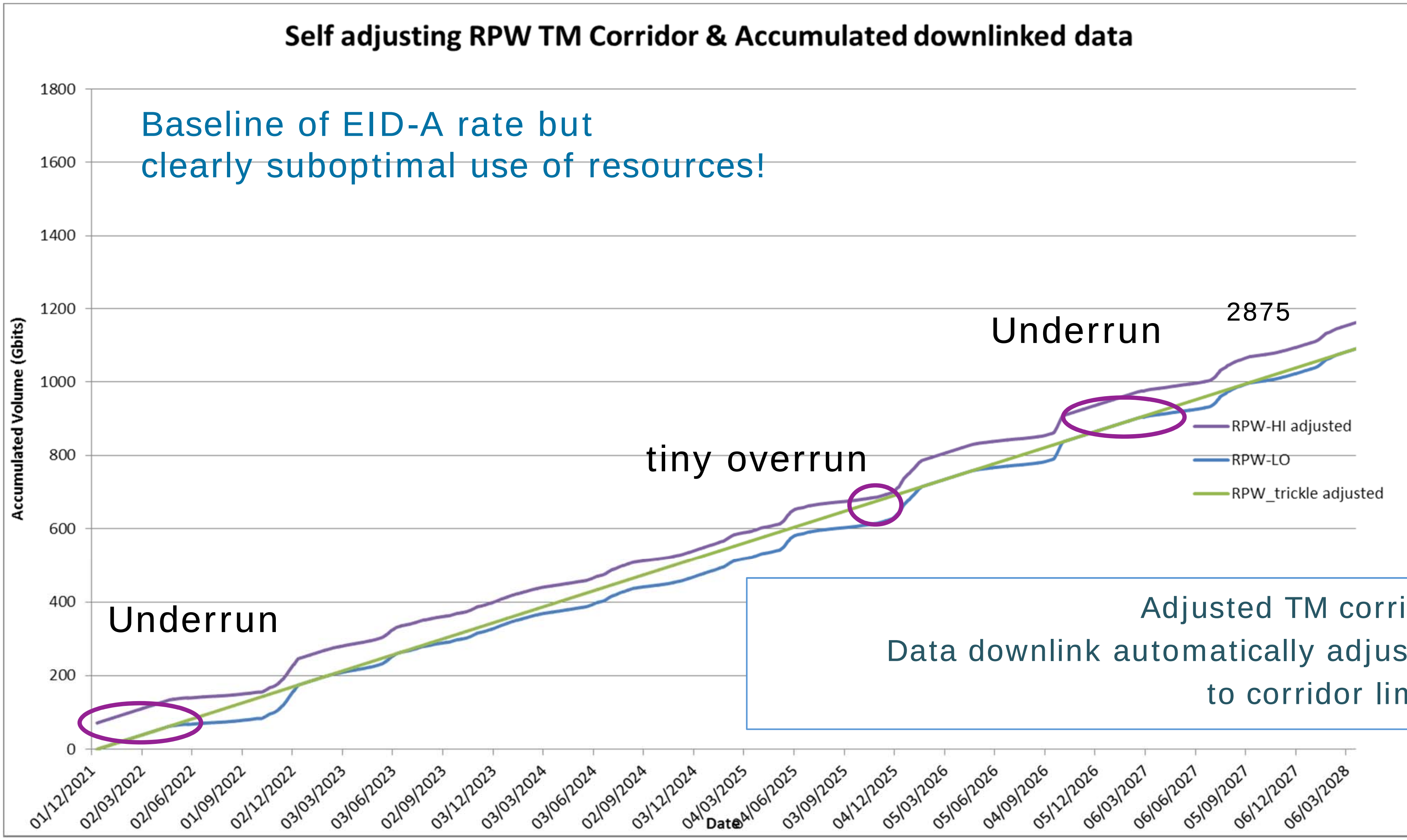


in-situ



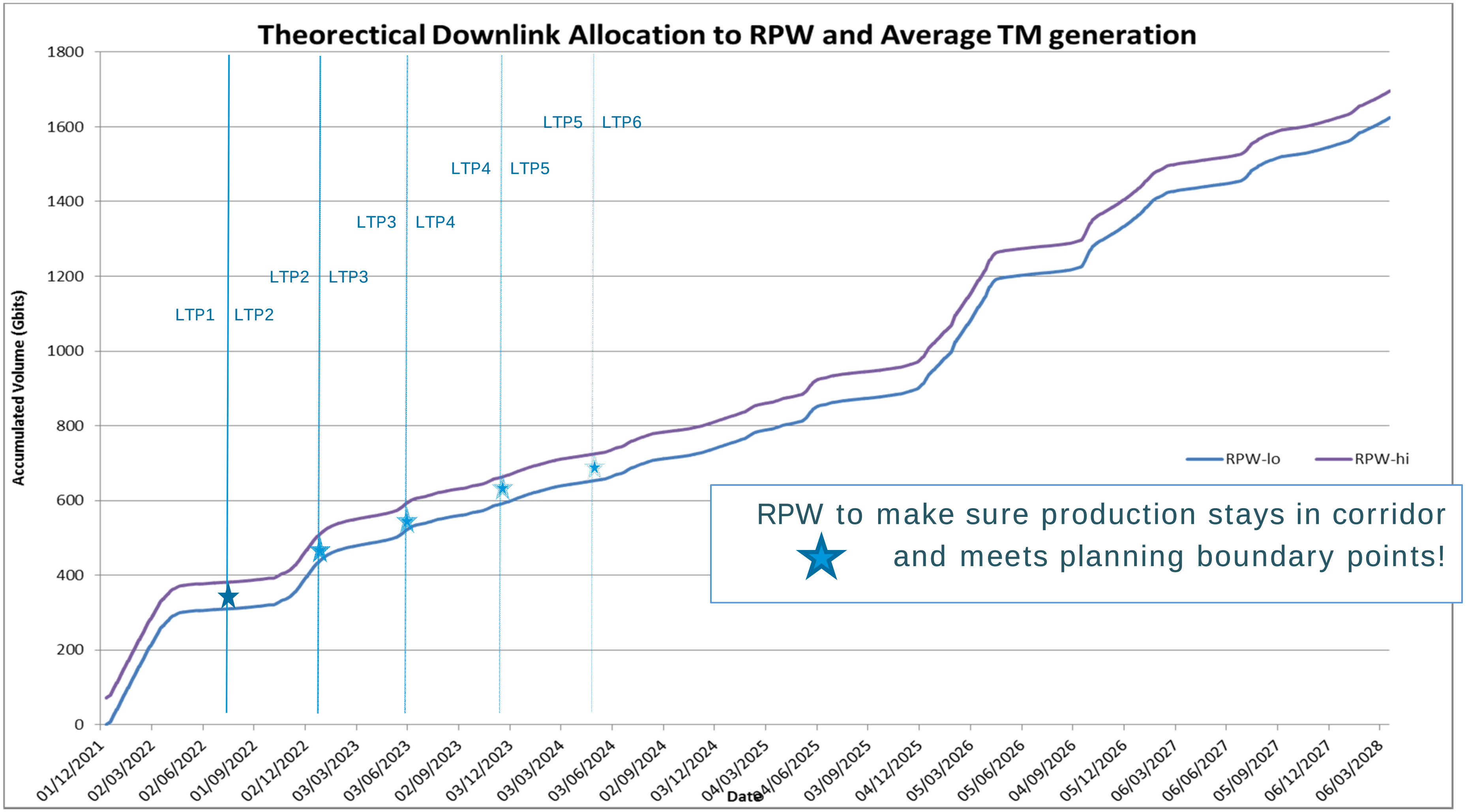
remote-sensing

Adjusting RPW Rates Using EID-A Rate

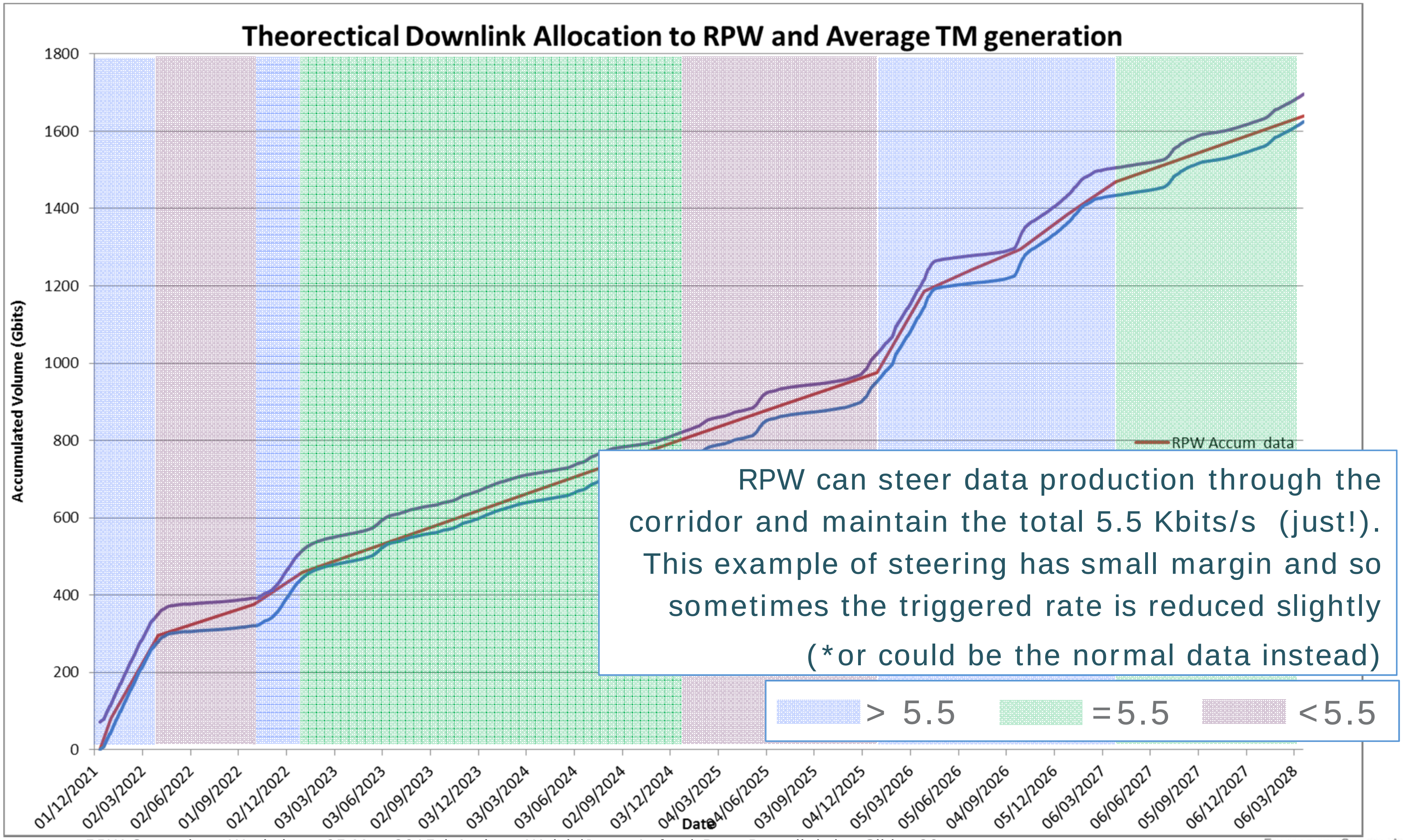


Adjusted TM corridor
Data downlink automatically adjusted to corridor limits

Adjusting RPW rate to navigate the TM corridor



Adjusting RPW generation rate to navigate the TM corridor



Adjusting RPW rate to navigate the TM corridor

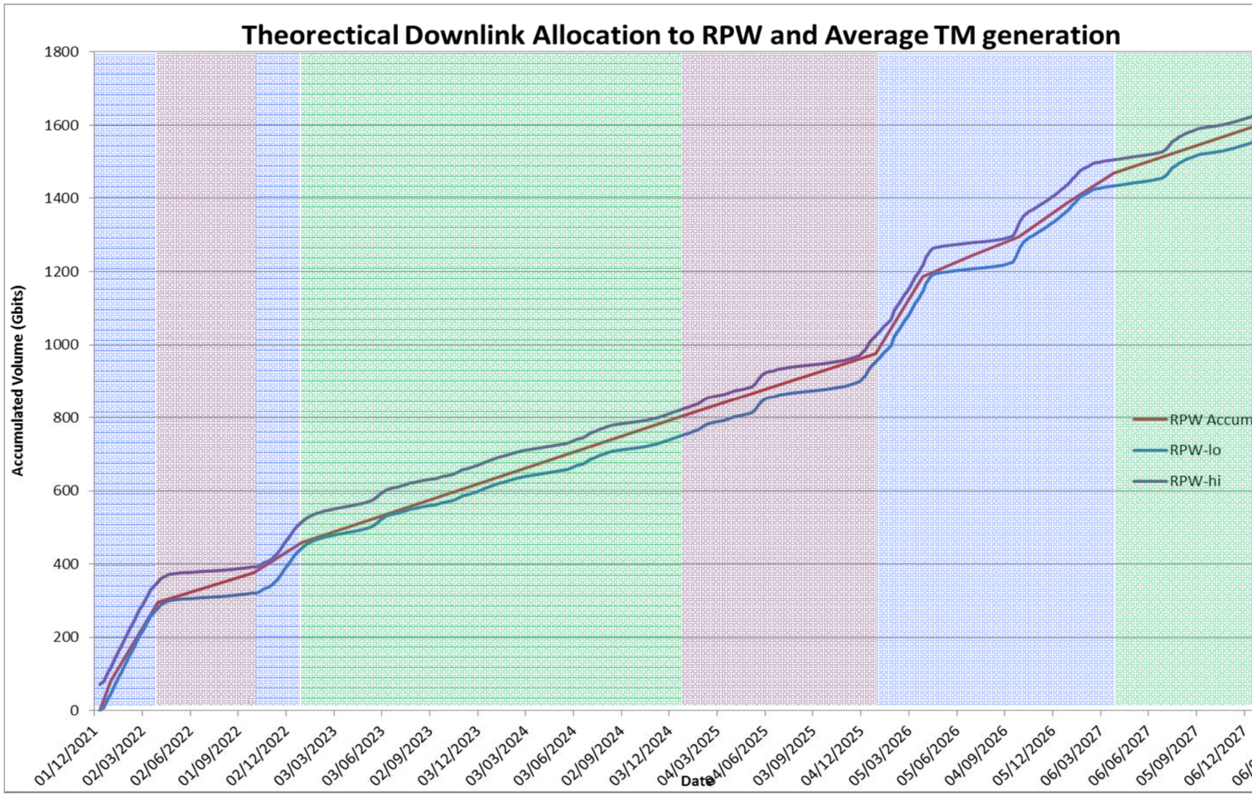


Table of Rates

Date (LTPs and half L	Nominal Data	Burst Mode	Total Rate
11/12/2021 00:00	4.6	40	44.6
01/01/2022 00:00	4.6	23	27.6
01/04/2022 00:00	4.6	0.5	5.1
01/07/2022 00:00	4.6	0.5	5.1
01/10/2022 00:00	4.6	5.8	10.4
01/01/2023 00:00	4.6	0.9	5.5
01/07/2023 00:00	4.6	0.9	5.5
01/01/2024 00:00	4.6	0.9	5.5
01/07/2024 00:00	4.6	0.9	5.5
01/01/2025 00:00	4.6	0.8	5.4
01/07/2025 00:00	4.6	0.7	5.3
01/10/2025 00:00	4.6	0.8	5.4
01/01/2026 00:00	4.6	22.5	27.1
01/04/2026 00:00	4.6	2.5	7.1
01/07/2026 00:00	4.6	2	6.6
01/10/2026 00:00	4.6	7	11.6
01/01/2027 00:00	4.6	6	10.6
01/04/2027 00:00	4.6	0.9	5.5
01/07/2027 00:00	4.6	0.9	5.5
01/01/2028 00:00	4.6	0.9	5.5
24/03/2028 10:00	4.6	0.9	5.5

Rates Used:

Assumes Normal Data is always the same and Triggered Burst Data is tweaked

> 5.5 =5.5 <5.5

To note….

- Mission profile and SSMM cannot easily handle RS data generation profiles (stepping accumulation), it can be difficult for RS instruments to navigate through the corridors (under-runs and overruns are more likely)….

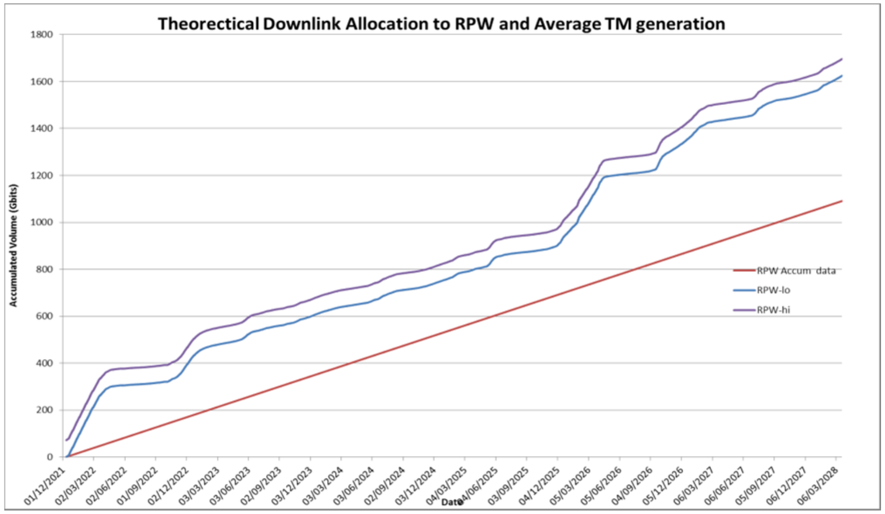
- ….May need to give more downlink to RS instruments around RSWs and then more to IS instruments away from RSWs. This would change the corridor, but it would be known in advance.

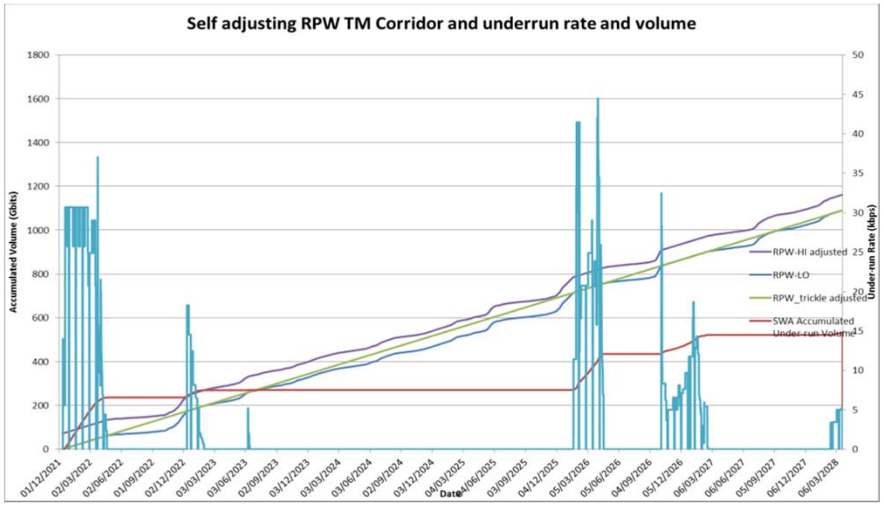
- Store size is an example, depends on other factors (size of LL, HK SD, TAC Stores). After sizing of these stores, the remaining is divided prorata according to science data allocation left from EID-A rates.

- SWT and SAP planning may decide to deviate from the EID-A orbit averages.

More on underruns

- Periods close to Earth hold vast amounts of extra TM
  Can be used to empty buffered data in the mass memory, but as store size relatively small, compared to under run volume
- Opportunities to do more?!
- SOC explores way of maximising downlink exploitation, SWT & SOWG decide!





Crude overview of proposed implementation of selective

Background / assumptions

- Prompt stores (HK, LL) are sized for the conjunction
- Conversely the bulk stores are sized **empirically** by SOC based on a simulation over the mission. This because the necessary space depends on the relationship between RSWs and bad comms in a non-simple way (On current simulations/trajectories the total SSMM volume is marginal to supply instruments with what they need to maintain data return)
- All downlinked TM contributes to allocation
- Selective has to be done in an SSMM-neutral way.
- Selective requires that the Instrument Team actively and promptly monitors LLD and submits selective requests for the chosen bits of data.

- We are also assuming that the chosen subset of the selective data is downlinked promptly and not stored with latency in a bulk-like way.
    - This introduces an extra constraint but also avoids two potential problems
    - It is not fundamental to most of the presented concept (exceptions)
    - Would require use of the SSMM copy functions and there is an ongoing discussion inside ESA on “copies considered harmful”
    - We can discuss this at the end

Crude overview of proposed implementation of selective

Implementation of selective

- No extra SSMM given (over the empirically-determined need ignoring selective) . Instead we split each instrument's bulk allocation into two stores:
    - Store 1: "Undersized bulk store"
    - Store 2: Dual purpose "selective buffer" / "overflow bulk store"
- In periods of good comms (low backlog), the store 1 suffices for bulk, and the store 2 works as a selective buffer, from which chosen periods can be downlinked.
- As the comms becomes worse, the undersized bulk store fills eventually reaching the point where it becomes full (less a margin). At this point
    - Selective capability has to be **disabled**
    - SOC adjust the routing of the bulk data to the store 2 which becomes the overflow bulk store
    - Bulk downlink capability is similarly redirected (by SOC) to the store 2

Crude overview of proposed implementation of selective

Continued implementation of selective

- As the comms becomes good again, there comes a point where store 2 is empty:
  - Bulk downlink moved back to store 1
  - Bulk routing moved back to store 1
  - Selective capability re-enabled
- N.b. This is introducing a non-FIFO aspect to the return of bulk data (bulk science routed via the store 2 comes to ground earlier than preceding backlog in the store 1)
- Selective **also** has to be disabled or restricted when the comms capability is not sufficient to downlink the chosen selective data in a prompt way. In other words, RPWs share of the available downlink after HK and LLD has to correspond to at least 0.9 kbps generation capability
  - Broadly we expect some correlatation between this constraint and the fill-state one, since poor comms => large backlog. However there is some phase-shift between the effects so the constraints will not be perfectly correlated.

Crude overview of proposed implementation of selective

Note

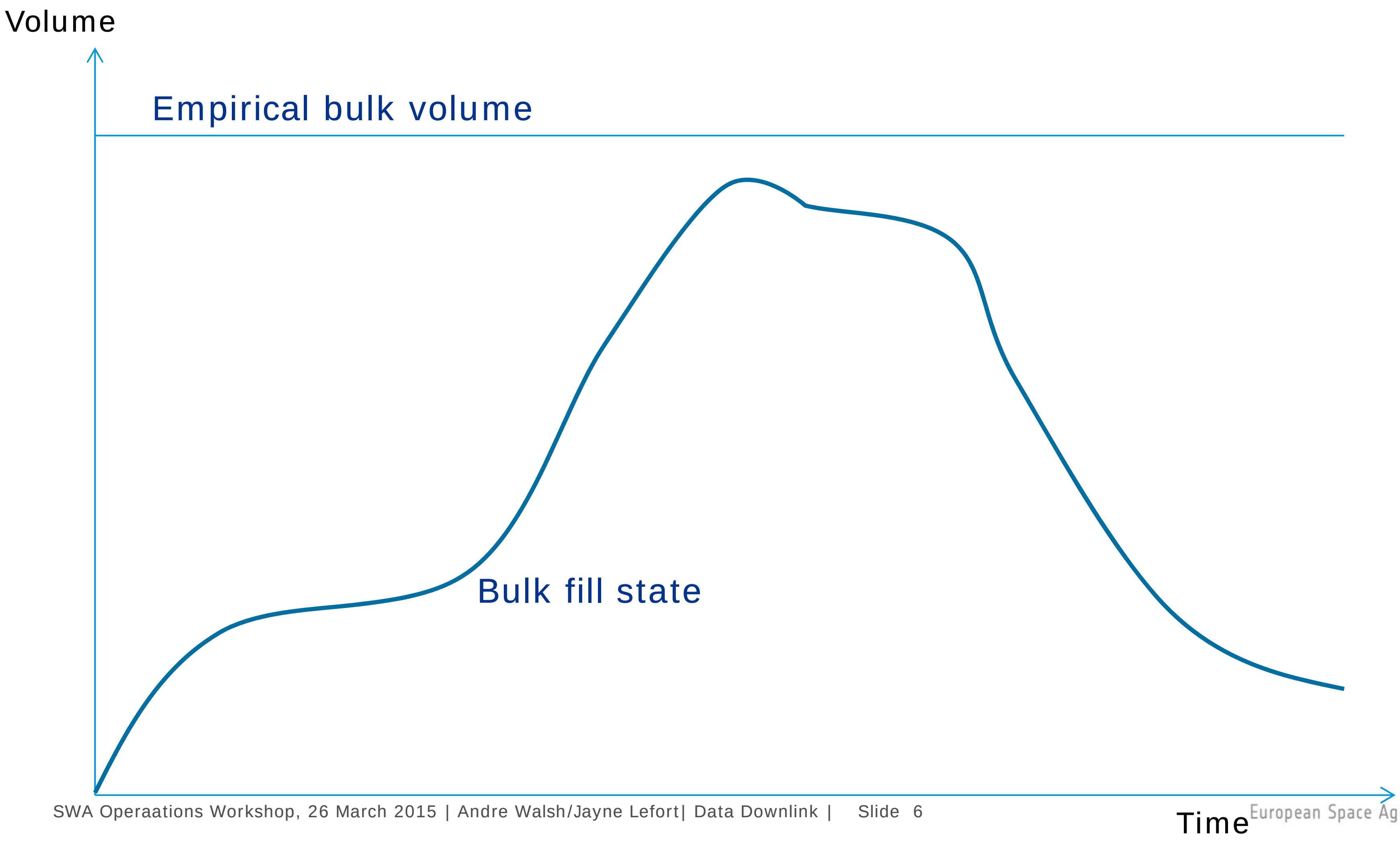
- The division point of the two stores is driven by the need of the selective buffer:
    - Write rate
    - And duration = Period over which “choosing” decision is applied, plus 3 weeks (TBC) end-to-end turnaround time
- Thus there is a trade-off between
    - Selective capability (i.e. write rates and “choosing” period)
    - How often selective has to be disabled
- The amount of selective has to be a small fraction of total science (as indeed in the RPW approach). Otherwise
    - store 2 big => store 1 small => that the selective can almost never run.
    - The part of the selective that is actually downlinked will overload the prompt downlink capability, after HK and LL.

Crude overview of proposed implementation of selective

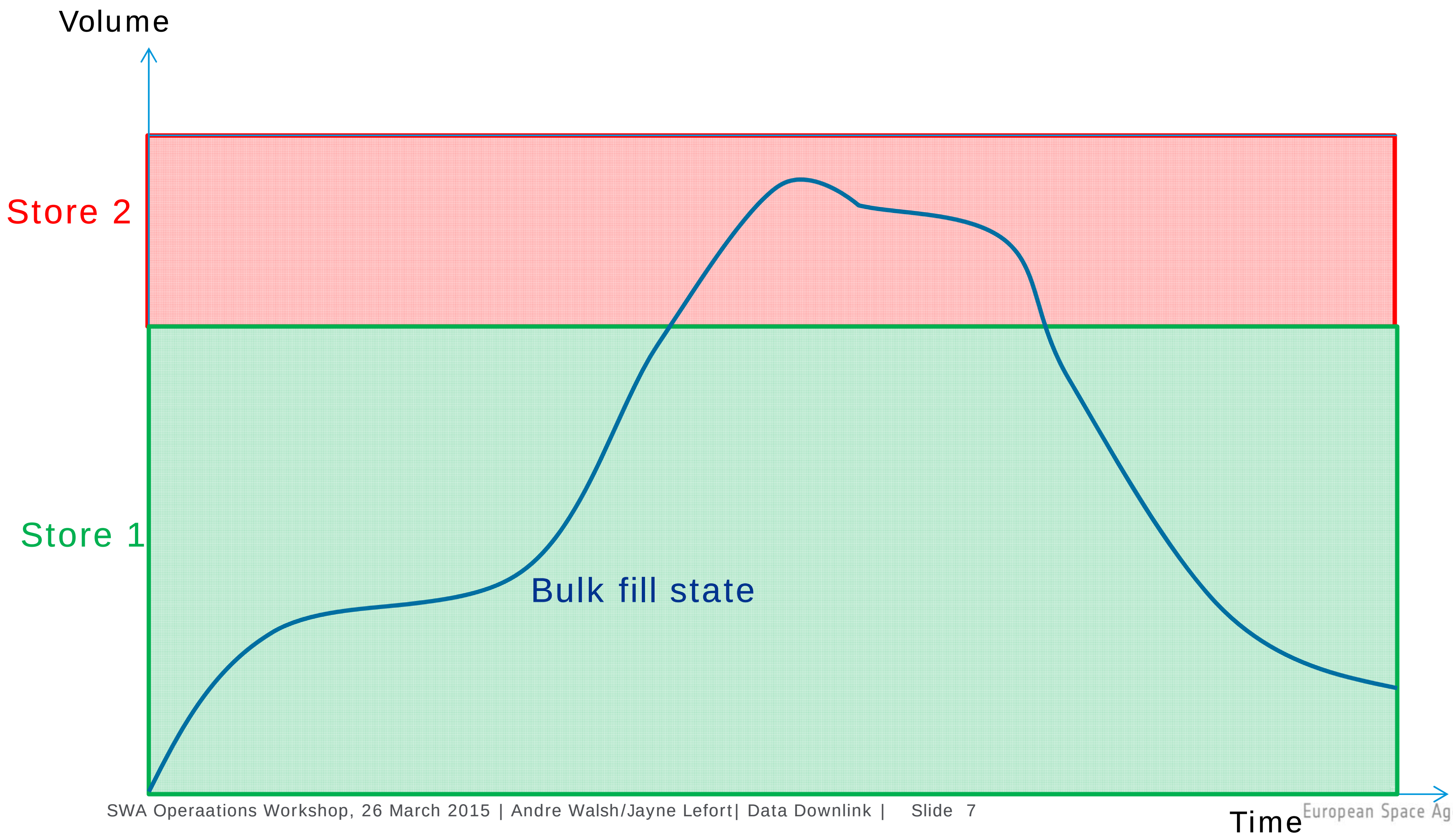
Note

- The scheme probably can't be made to work for RS-instruments. They go from empty to full very rapidly within RSWs, too fast for decisions about what to downlink and for swapping the routing.

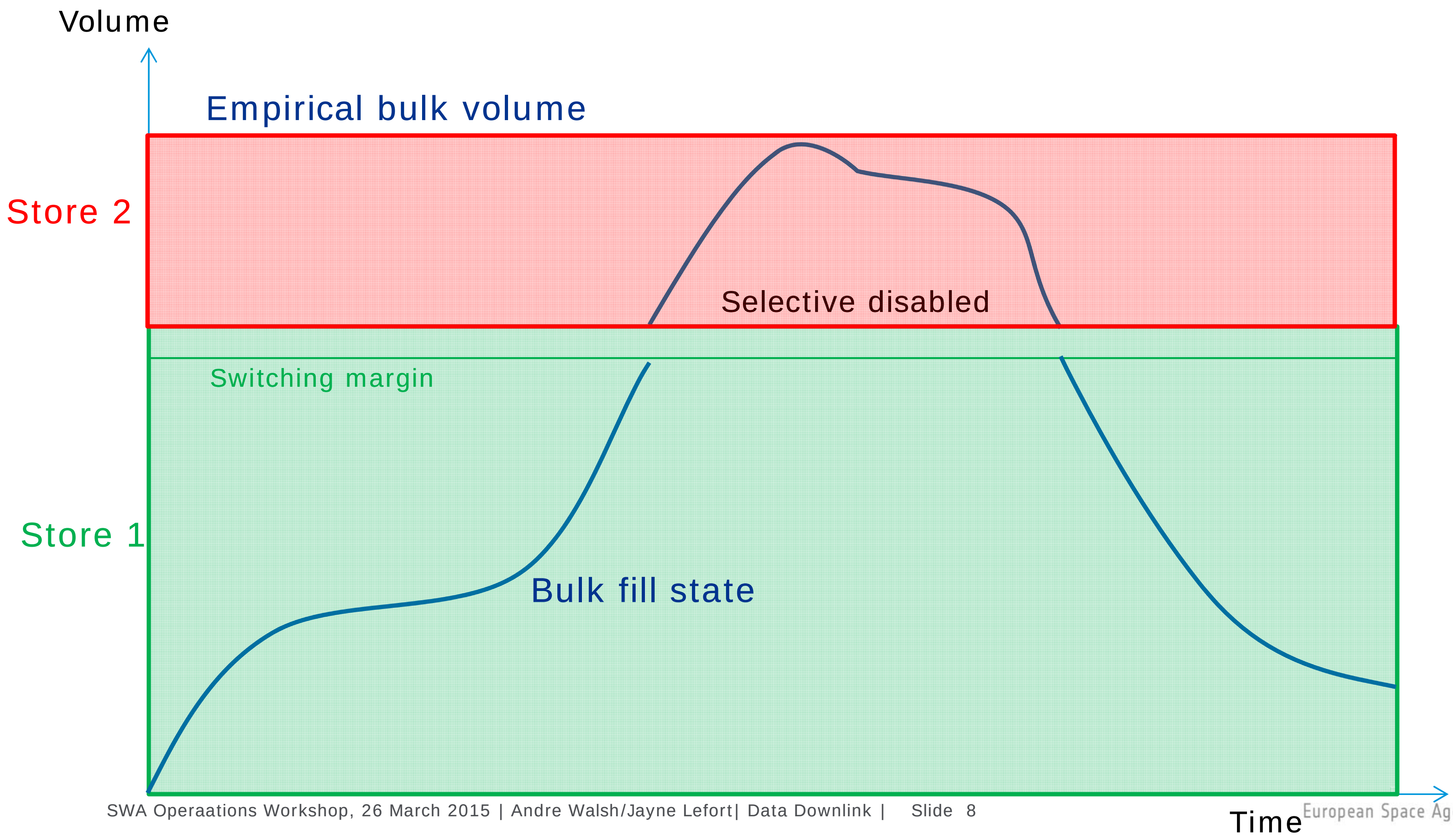
Crude overview of proposed implementation of selective



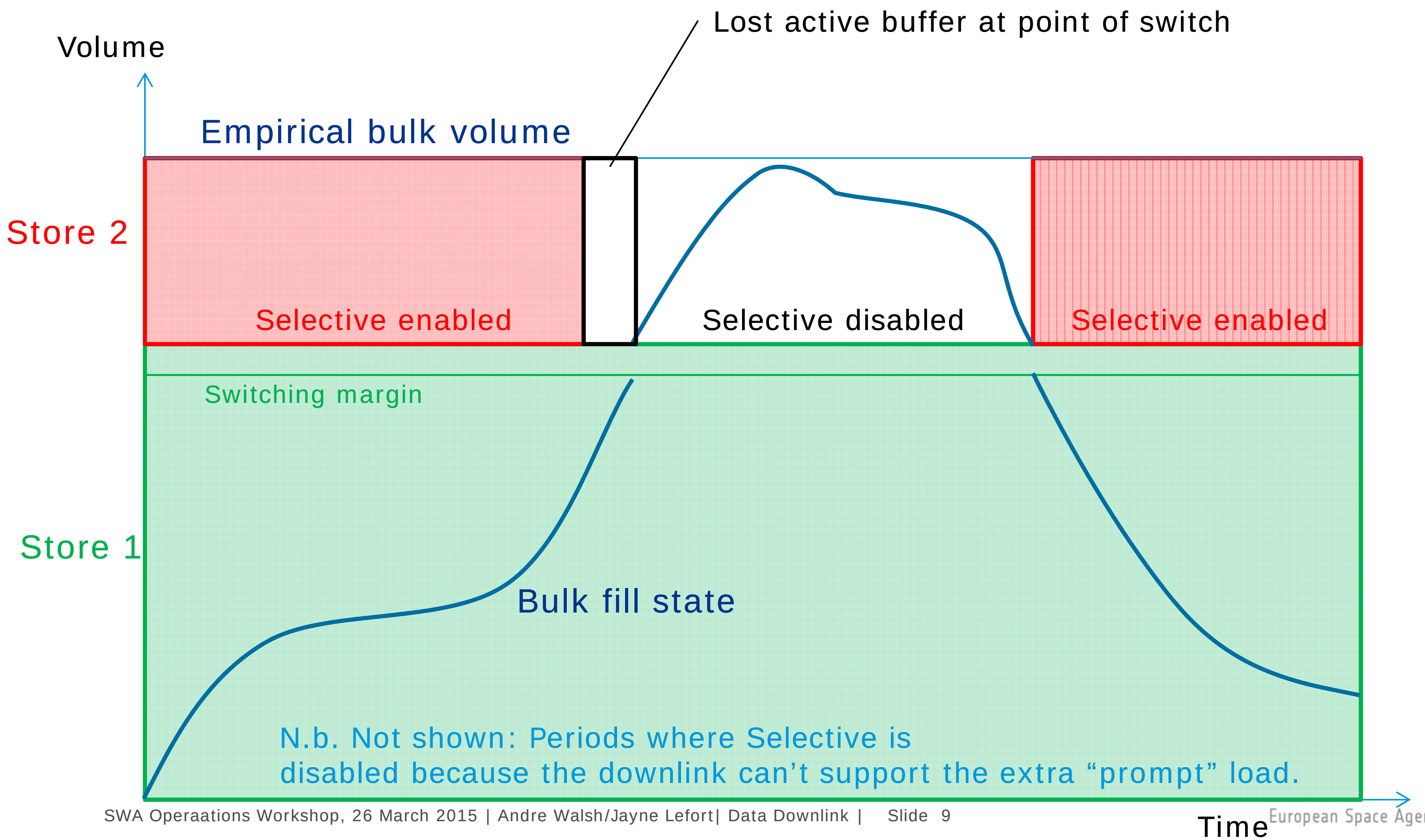
Crude overview of proposed implementation of selective



Crude overview of proposed implementation of selective



Crude overview of proposed implementation of selective



Selective input to RPW ops meeting - preliminary concept and questions

This is a discussion document. It is not a guarantee of any particular implementation or level of service.

Starting assumptions

1) RPW describe performing selective on both SBM-1 and SBM-2 events, and their concept has an **assumed write rate into any selective buffer** of **5.1 kbps**, being the weighted combination of expected frequency/volumes of the two events (3.9 kbps for SBM-1 and 1.2 kbps for SBM-2). The assumed **selective data that is chosen contributes 0.9 kbps to the downlink** (of 5.5 kbps total RPW allocation).

This is based on

- SBM1, each event 300kbps over 15 mins, choosing 8 from 50 events obtained in 40 days
- SBM2, each event 146kbps over 120 mins, choosing 1 from 4 events obtained in 40 days

2) End-to-end turn-around (E2E) on selective processing is assumed to be **three weeks**. This includes

- download and distribution through the ground segment of low-latency data
- Instrument team decision on what data is chosen for downlink
- Periodic forwarding of instrument request to SOC
- Consolidation of requests, and integration into overall downlink plan
- Forwarding of downlink plan to MOC as part of STP
- Integration of the downlink plan into the overall MTL commanding by MOC
- Upload to the spacecraft

Additional to the end-to-end turn-around we have to consider as well the "**decision period**" that the instrument wants to use. This is the time-interval over which any given selective event choosing decisions are made, independent of the E2E. The decision period and the E2E define the minimum neccesary lifetime of data in the selective buffer. In other words: Selective can be described as choosing the best N from M events. It matters to the process the interval that this N from M decision is made over. The least storage overhead occurs for a decision period of 1 week. Conversely the most powerful selection process would be to wait to the end of the mission before choosing the best events, but clearly this is infeasible for storage volume.

In defining this decision period, we are assuming that this is there is only a **single opportunity** to request each event, and that the decision period is therefor directly related to the effective lifetime of data inside the selective buffer (which is important for sizing).

> It is possible to envisage a more complex scheme, where perhaps requests are sent to SOC e.g. once-a-week, but there would normally be e.g. three opportunities to choose a particular event. In practice this approach is almost the same as having a decision period of three weeks, and one should read this note in this sense. I.e. decision period = requesting period * number of opportunities. We are going to call this particular variant **"multiple opportunity"**, and we will refer to to it specifically where relevant below.

3) We are going to assume that it is necessary for the selective scheme to operate inside both

- RPW's nominal footprint on the SSMM
- RPW's fair-share of the bulk downlink (what is left after HK and LLD)

It is possible to operate the selective in a less constrained way than described here, if RPW were somehow guaranteed extra SSMM or Downlink. However this would be controversial, and need SOWG agreement. We prefer to define a concept that does not depend on these external factors.

4) We assume that the RPW's footprint on the SSMM is determined **empirically** by the SOC.

RPW allocated store size in this example is taken from the data-return presentation of SOWG-6, taking the **Oct 2018 scenario 2** corresponding to the mission baseline of 19 extra passes per orbit.

Results are **indicative** only, in that this analysis is done with certain assumptions and without input from SAP to refine science goals or RSWs beyond the EID-A baseline. (Not also that this Oct scenario 2 was not supporting the "reserve" data rate).

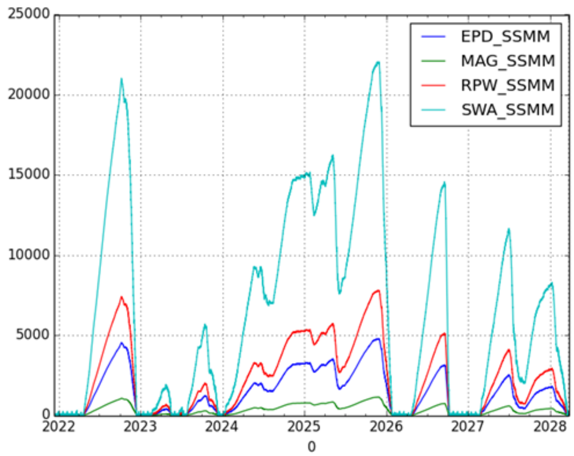


Figure 25, Store fill-states, Y-axis in MB, RED curve is the RPW fill-state which is relevant for us.

We assume an RPW allocation equal to the peak usage in the simulation. => **7.4 GiB** (manually read directly from graph). I.e. for now none of the very limited margin is assigned directly to RPW. We do this because we prefer that margin is (largely) maintained as margin, and as far as possible not "spent" implicitly within the selective concept. N.b. This volume is what is **needed** to ensure data-return is maintained through the poor comms periods in this scenario, assuming 5.5 kbps total RPW generation with no selective.

5) We are going to assume that the chosen selective data makes its way into the downlink without being directly merged with the bulk science. I.e. it is **not copied into the bulk store**, from where it would subsequently be downlinked (with latency). This **copy-into-bulk** approach is avoided because it creates seriously non-time-ordered data inside the bulk store - for nominal FIFO dump of the bulk store this would not matter, but it is liable to make any contingency recovery impossible. **Copy-into-bulk** has a second difficulty which is that the target for a copy cannot be active for any other form of data-write during the copy operation (and of course IS instruments are in principle writing bulk at all times). This aspect is not necessarily insurmountable (e.g. one could route both bulk and chosen data into via copies into a general "downlink" store), but it raises the operational complexity and potentially wastes SSMM.

Additionally there is also an operations discussion within ESA along the lines of "copy considered harmful" to be resolved.

Thus **prompt-downlink** is used for the chosen selective data, where chosen data is not subject to long latency onboard. This has consequences for when selective can operate (see below).

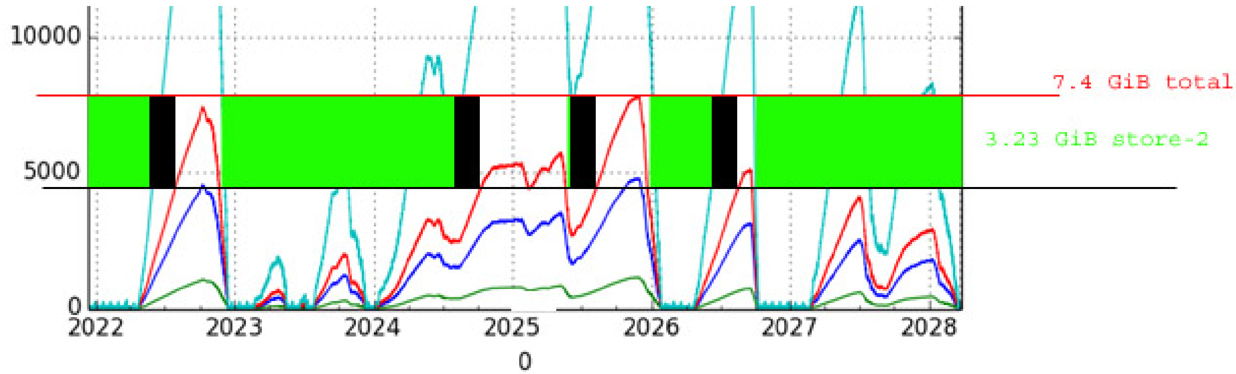
Counter-intuitively both the **prompt-downlink** and the **copy-into-bulk** both lead the same levels of absolute bulk store fill-volume (providing RPW-bulk and RPW chosen data are sharing the same RPW total downlink allocation). This occurs because if the selective chosen data is moved promptly into the downlink, it "steals" this prompt capability that would otherwise be eroding the fill level in the bulk store. Whereas if the chosen data is copied into the bulk, then more data flows in total into the bulk store, but more data is leaving the bulk store as well because more prompt capability is available to bulk.

Initial sizing

Full-sized selective buffer case

The RPW description of selective asks for a "40 day selective buffer". If we assume that 40 days is the requested decision period, and that E2E turn-around has to be added. So we convert 40 days to 42 days to synchronize it with the weekly process and add the 21 days E2E, coming to **63 days** required size.

63 days at 5.1 kbps => **3.23 GiB store-2**



Green periods represent the periods where selective can run, covering about **65% of the NMP/EMP** in this example.

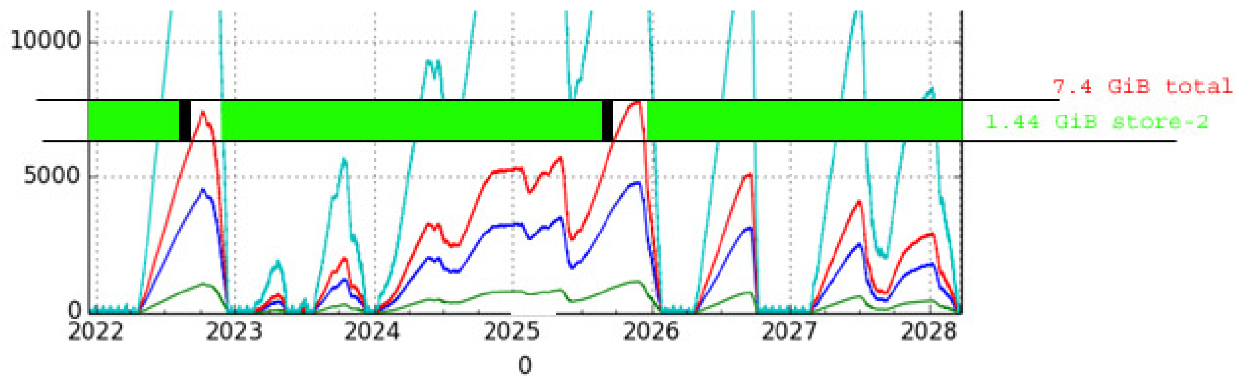
Black periods are the loss of the active buffer at the point where it is re-purposed for bulk storage is performed.

Outside of the green/black period the selective buffer acts instead to store bulk. No margin for the point at which the switch is made has been considered.

Minimum selective buffer case

As an alternative we present as well a minimally sized selective buffer. We assume that RPW can live with a 1 week decision period. So we add 7 days to the 21 days E2E, coming to **28 days** required size.

28 days at 5.1 kbps => **1.44 GiB store-2**



Green periods represent the periods where selective can run, now **86% of the NMP/EMP** in this example. They occupy more of the time (because there is now less time where the selective buffer has to be re-purposed for bulk storage. Black periods are both fewer and shorter (because of fewer switches and because the buffer has less duration to lose on any given switch).

First refinement

Distribution of chosen events within a decision period, or "outrunning the steamroller"

The time needed to downlink of the chosen requests within the selective period has not been considered within the E2E. Part of the reason for this is that the time needed depend on the decision period.
For **evenly distributed** requests over a decision period, and based on the assumptions that

- SOC will schedule the downlink of the oldest requests first, and
- That the budgeted selective downlink rate (0.9 kbps in the case of RPW) is what is actually made available to downlink specific requests (i.e. **it takes a decision period worth of passes to downlink a decision period worth of requests**)

then **typically** the dump operations will advance across the store at broadly the same rate as the write pointer.

However nothing guarantees that requests will be evenly distributed in a decision period, and it must happen sometimes that they are not. If we want to guarantee that the worst case set of requests (i.e. all the chosen bursts reside within the start of the decision period), then we need to **do**

uble the decision period contribution to the buffer size. When this is considered:

- Full-sized buffer would add 42 days, extra 2.15 GiB => 5.3 GiB total store size, which is prohibitively big
- Minimal buffer would add 7 days, extra 0.36 GiB => 1.8 GiB total => disable-behavior intermediate between the minimal and full-sized cases
- Intermediate case, (21 + E2E) + 21 days, extra 0.72 GiB => 3.23 GiB total => same overall disable-behavior as the full-sized buffer was when we were ignoring chosen event distribution

So obviously this mean that the %avaliability of selective presented above has to be modified by this consideration.

N.b. An alternative would be for RPW to accept that arbitrary distribution of chosen events can not always be supported. This might be more acceptable in a "**multiple opportunity**" variant where the later repeat opportunities would not be guaranteed and would be undertaken "at risk". At the moment there is no clear way for RPW to know for sure whether specific "at risk" requests would succeed or not, so very likely RPW would run the risk of wasted downlink allocation in the case an "at risk" request failed.

Second refinement

Occupation of prompt downlink capability

As discussed above the baseline for the routing of selective data to ground is that each chosen period goes promptly into the downlink.

However it means that there always has to be sufficient headroom on the prompt capability (even in periods of poor downlink) such that the selective data that is chosen can be moved (**after HK+LLD is allowed for**).

As a sizing example, looking at the total remaining prompt capability (which would not go entirely to RPW) we assume

- Worst case downlink performance 43 kbps. Less 2 kbps RT => **41 kbps available to dump data**.
- 6 hours of dump within the pass
    - Not really conservative when one considers that pass time is inefficiently spent at in the bad comms periods - that is, ignoring other constraints, we would **like** to reduce pass duration in these periods, in order to spend the same hours more effectively elsewhere.
- 24 hour interval since previous dump (not worst case)
- HK+LLD corresponding to SC+IS+RS of HK: 2+5=7 kbps and LLD: 1.2 kbps continuous over the previous interval. => 4.8 hours to dump HK+LLD => 1.2 hours left for selective
    - Assumes RS-instruments operating.

Gives approx 2 kbps remaining prompt capability for bulk across all instruments. RPW's fair share of this capability is much less than 0.9 kbps, thus selective could not operate in this period.

Very crudely mean total instrument production over the orbit is 42 kbps, of which RPW is 5.5 kbps, which (ignoring subtleties like HK contribution) means RPW can expect 13% of capability. So 0.9 kbps means an overall remaining prompt capability needed of something like 7 kbps. This is achieved when the downlink performance gets to about **61 kbps** (assuming still 6 hour pass, 24 hour interval).

N.b. This analysis is not allowing for the superposition of the selective requests into the downlink, in that these requests perhaps cannot be packed optimally into a specific slot reserved for RPW data. E.g. S-15 by-time dumps cannot be queued up and take a not-completely predictable time to complete. S-13 by times dumps can be queued, but are also not completely predictable and introduce a 2x OWLT protocol closure time between successive requested bursts (since often bursts will be small transactions). One should also be aware of "request granularity" where perhaps one does not pack right up to the maximum out of desire not to segment individual burst requests over passes (however this seems mandatory, for RPW SBM-2 at least).

Other operational aspects

Blackout periods / Conjunction

We believe it is inappropriate to size the selective buffer to cope with the rare conjunction occurrences (when of course the E2E turn-around cannot be obtained). Thus conjunctions represent another period where selective would be unavailable. This has not been assessed above, but will not have huge impact on the overall % availability of selective.

Non-time-ordering of bulk

The re-purposing necessarily introduces a discontinuity in the order that bulk flows to ground. Bulk written into a re-purposed store-2 will arrive on ground prior to the bulk resident in the store-1 at the time of the switch. (n.b. this is not affecting time-ordering inside of a store, just flow-to-ground).

Last packet of any chosen period lost

Because of the details of how the SSMM performs a search operation, the last packet of any chosen period will be lost. This was discussed in SOWG-5.

Precision of the swap between store-1 and store-2

In the diagrams above the swap between store-1 and store-2 is shown as if it was instantaneous. In fact there is no autonomous function onboard to do this, and it would have to be done re-actively. This may imply delay of a couple of weeks (if done via STP) which is not represented in the diagrams. Furthermore:

- On the "way up" swapping bulk storage from store-1 to store-2, we foresee applying a store-swap margin on the fill-state of store-1 (such that we disable selective and re-purpose store-2 once we see store-1 reach a given fill state less than 100%).
- On the "way down" the detailed approach still has to be elaborated. There may be extra delay or minor downlink loss at the swap.

This switching margin is a second way we are spending assumed margin on the store sizing. We have to be careful that in these factors do not erode the margin to zero.

Stability of chosen volume in each decision period

In the simplest management of selective data, the same selective load into the downlink is always present. This allows bulk and selective for RPW to be budgeted/simulated independently.

This seems reasonable for a decision period of 42 days, where (we assume) there will always be some events worth downlinking.

It may be more difficult for a decision period of only 1 week (suppose there are virtually no events that occur in a specific week). Either RPW has to manage to still request the same chosen selective volume in each 1 week period, OR a more complex joint-accounting of selective and bulk has to be done - this will place more of the planning/prediction responsibility in the hands of RPW.

Note also that the introduction of the store-3 imposes a hard maximum limit on the chosen volume of any decision period.

Variability of the write rate

In all this analysis 5.1 kbps is assumed to be a stable rate at which events are written to the buffer. But of course actual burst occurrence is stochastic. It's not clear to us

- the amount of variability that could occur on this mean rate.
- whether the 5.1 kbps is the real expected average, or whether some sensible conservatism has already been assumed

Clearly if the events are written faster than expected into the buffer then some chosen events might be overwritten before they can be downlinked. Especially for events that make it through the SOC processing but are actually overwritten by the time this request gets implemented on the spacecraft it will be impossibly difficult to account/reallocate this "wasted" downlink back to RPW.

Instrument team knowledge of burst volumes

Follows on from the previous two points.

The HK coming from the SSMM will be too crude to resolve the volume written into the selective store by any specific burst. Thus for the purposes of respecting the correct chosen volume in a decision period, the instrument team must have an reasonably accurate awareness of the volume of each burst they choose. They are also expected to communicate this estimated volume of each chosen burst to the SOC, when submitting the requests for a decision period, in order to allow SOC to correctly plan the copy and downlink operations. Errors in these estimates, if significant, may cause loss of chosen bursts or poor control of bulk.

Representativity of fill-state simulation curves when selective concept is superimposed

The store-fill curve used as input was generated assuming RPW bulk production of 5.5 kbps (and no selective).

These curves remain representative in the **periods where selective is running**.

> Crudely 5.5 kbps downlink is still generated so the backlog between generation and downlink stays the same, even though it is different "slices" through the RPW science that are going first into the available downlink in each case.

In the **periods where Selective is disabled**, the curves may or may not be representative depending on the details of operations in these periods

- If, at each re-purposing, RPW maintains bulk production as before, then in these periods the total downlink load is dropping to 4.6 kbps (=5.5-0.9 kbps). Then the curves as shown are somewhat conservative, and fill-state will drop more rapidly back below the store-2 boundary
- If, at each re-purposing when selective is disabled, RPW adjusts bulk production to bring it up to 5.5 kbps, then the simulation curves are

fully representative.

N.b. The latter bullet is more operationally complex, especially considering that the re-purposing is expected to be done reactively at SOC and is not directly coupled with RPW STP planning. Such an approach would entail an STP-cycle delay on RPWs adjustment of rates wrt the selective switch.

Questions

RID close-out

We should go point-by-point through the six points of the RPW-CDR RID answer that triggered this meeting, and minute the outcome.

General thoughts on trade-off between selective capability and how often it is disabled

Any RPW feedback? Does the choice of the decision period drive the choice, or v.v.?

Write rates - variability, conservatism

Are the rate assumptions OK? RPW UM says 4.3 kbps survey data, whereas 0.9 kbps for selective assumed here => 4.1 kbps, so there seems to be an inconsistency somewhere.

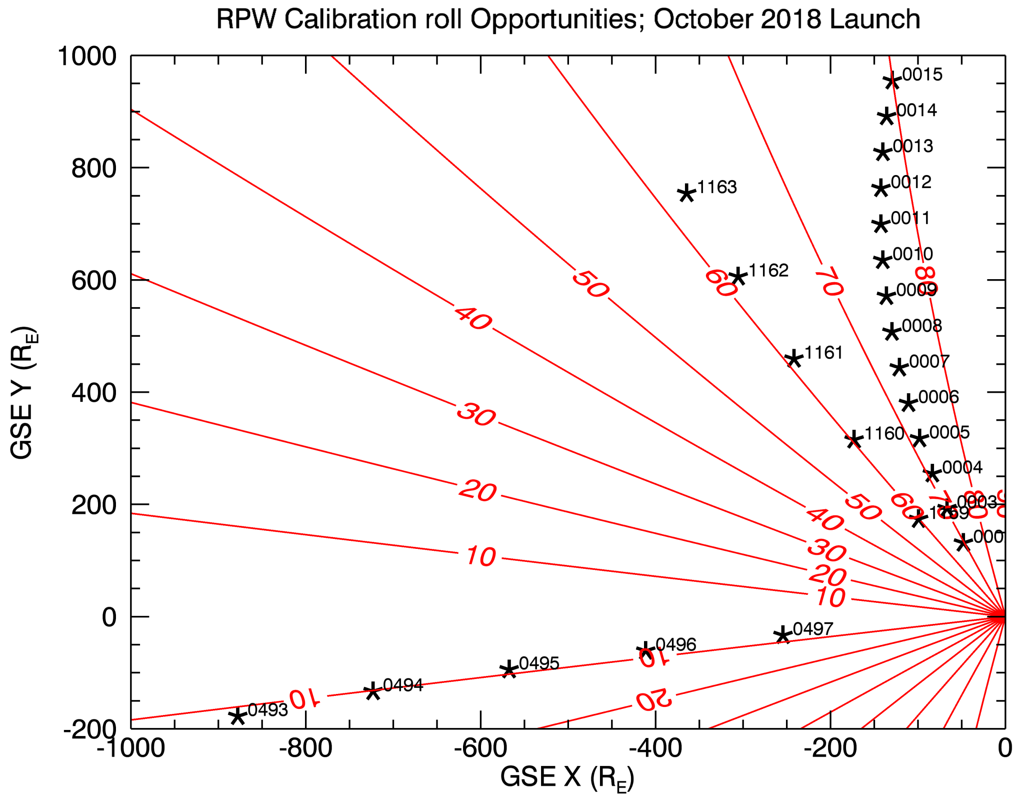
In practice the rate of burst production will vary. How do we cope with that?
 - Do we accept that events can sometime get overwritten and downlink wasted, or do we need to size for something other than the average rate? If yes, what "worst case" rate shall we size for?
 - Or is there some conservatism already applied in the write rate?

Decision period

What decision period do you want? We discussed once a week in the past, but I believe this was probably not "single opportunity" but rather some sort of multiple opportunities scheme (decision period = requesting period * number of opportunities)?

Do you envisage respecting a fixed volume of chosen-data every time you send us a set of requests?
 - This will be easier for the planning with respect to your bulk (survey) production, but obviously constraints your requests (what happens if there are zero interesting events in a decision period?)
 - Depending on the requesting period the granularity of events may make this difficult (e.g. SBM-2s are quite big)

Or, do you expect the ability to vary how much data you choose in a given decision period?
 - This makes the selective more flexible obviously, but
 - This will impact the downlink that goes to your bulk store. You will need to pay more attention to this - "navigating the corridor" becomes complex depending also on how you are loading the selective.



GSE XY projection of Solar Orbiter trajectory (October 2018 CREMA) during those days where the spaceraft is within the position constraints defined for RPW antenna calibration rolls in the user manual (issue 1, rev 0, pp 98-99). The * symbols represent the spacecraft position on the day after launch marked to the right of each symbol.

The red lines are contours of constant angle between the Sun-spacecraft line and Sun-Earth line. Assuming Sun-pointing is maintained, the plane of the antennae (essentially the spacecraft YZ plane) would to be pointing at Earth while the spacecraft is rolled around the spacecraft X axis along the 90 degree contour. For the October 2018 CREMA trajectory, the closest fit to this is immediately after launch, rather than during an Earth GAM.

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European Space Astronomy Centre
P.O. Box 78
28691 Villanueva de la Cañada
Madrid
Spain
T +34 91 8131 100
F +34 91 8131 139
www.esa.int

DOCUMENT

In Flight Validation of In-situ Inter-Instrument Communication and Burst Mode Triggers

Prepared by	**Andrew Walsh**
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APPROVAL

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CHANGE LOG

Reason for change	Issue	Revision	Date

CHANGE RECORD

Issue 0	**Revision** 1		
Reason for change	**Date**	**Pages**	**Paragraph(s)**

Table of contents:

1 INTRODUCTION

This document describes a proposed mechanism by which in-flight validation inter-instrument communication (usually referred to as Service 20), and specifically burst mode triggering, can be accomplished for the in-situ payload during the cruise phase. This document does not impose any requirements on the payload but instead represents a suggested way forward, giving ground visibility of the behaviour of trigger algorithms, both during a validation campaign and beyond, with a minimum overhead in telemetry and loss in science return.

1.1 Reference Documents

RD01 RPW Instrument Software System Specification, 3.1, RPW-SYS-SSS-00013-LES
RD02 Solar Orbiter TM-TC and Packet Structure ICD, issue 7, SOL.S.ASTR.TN.00079
RD03 RPW TM Budget Report 2.0 SOLO-RPW-TN-285-CNES

1.2 Acronyms and Abbreviations

EPD	Energetic Particle Detector
MAG	Magnetometer
RPW	Radio and Plasma Waves
SBM1	Survey Burst Mode 1
SBM2	Survey Burst Mode 2
SOC	Science Operations Centre
SSMM	Solid State Mass Memory
SWA	Solar Wind Analyser
TC	Telecommand
TM	Telemetry

2 RATIONALE

In situ burst mode data is high in volume and will rapidly fill the SSMM packet stores dedicated to triggered burst data if burst mode triggers are issued and responded to more frequently than has been predicted. Since the stores will operate cyclically and data latency is often high, this could lead to the loss of valuable data if the payload responds to spurious triggers: Spurious burst data could overwrite bona fide data that are still waiting to be downlinked, or selected for downlink if and when selective downlink is feasible. Furthermore, those instruments that autonomously control TM generation may simply not respond to a real trigger if a spurious trigger has been issued.

While testing of inter-instrument communication and triggering algorithms on the ground is of course necessary, it will be unknown exactly how the algorithms will respond in flight to anomalous measurements corresponding to platform or payload activities, and indeed the form that these anomalies will take. As such, SOC believes that in-flight validation of triggering algorithms will be needed in order to tune their sensitivity and minimise the number of spurious triggers that are issued and reacted to. Given the limited TM downlink potential in the cruise phase, during which the use of burst mode will not always be feasible in any case, it is an excellent opportunity to perform extended validation of triggering algorithms while burst mode itself is disabled without suffering a negative impact to overall science return.

3 PROPOSED VALIDATION SCHEME

The simplest way to validate burst triggers in flight would be to telemeter and analyse all of the burst mode data that are generated when any trigger is received, however telemetry is far too constrained for this to be feasible, particularly during the cruise phase. An alternative approach could be to downlink the Service 20 packet distributed to the payload that contains the burst triggers, and the parameters passed between the instruments that are used in their calculation, and directly track their performance. However, Service 20 packets are not routinely stored or buffered on board, and although in principle this is possible it would have to be scheduled and commanded in advance, and doing so for long enough to validate trigger algorithms would produce too large a storage and telemetry overhead for it to be a feasible or desirable solution.

Instead, SOC proposes a scheme whereby trigger algorithms can be validated and fine-tuned with a minimum overhead in telemetry and loss in science return by giving ground (ideally prompt) visibility of the behaviour of burst trigger algorithms while triggered burst modes themselves are disabled. Here the concept is illustrated through use of TM(5,1) events and low latency and/or normal mode science telemetry, which SOC believes is a sensible option. In practice ground visibility could also be accomplished through including equivalent parameters in housekeeping or even normal science telemetry, although in the latter case some of the benefits of having prompt visibility of trigger behaviour (see section 3.2) would be lost. How the scheme would operate on board is summarised in Figure 3.1.

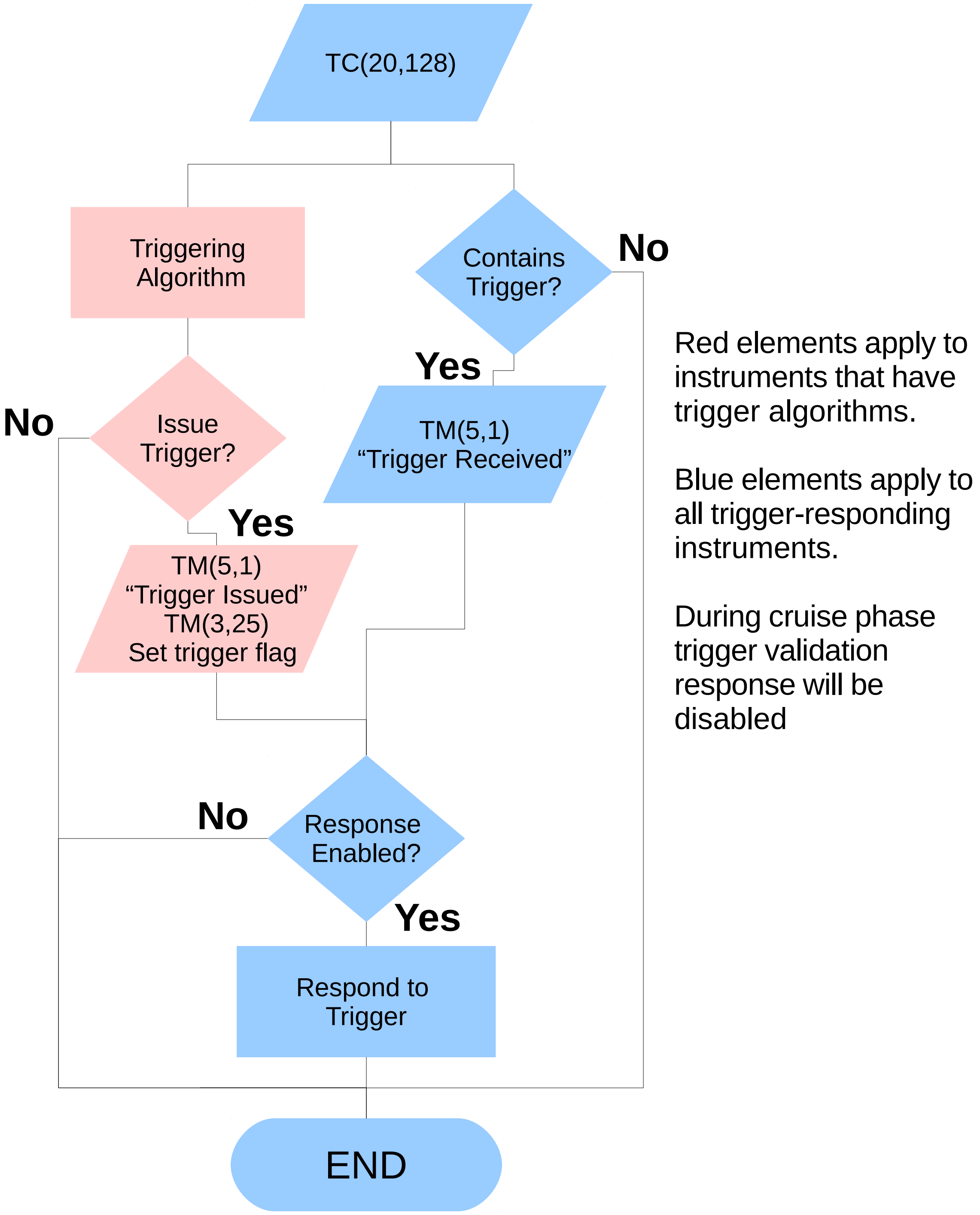

Figure 3.1 Representation of the in-flight trigger validation scheme.

During the validation campaign, any detection algorithms that issue triggers, any processes that set trigger flags in the TM(3,25) packet used for inter-instrument communication, and any processes that check for triggers in the TC(20,128) packet would be active. However, instruments would also be configured such that any responses to triggers (freezing and dumping of buffers, changes of mode, etc.) that originate both internally to that instrument and from other instruments are disabled. On ground visibility of triggering would be provided through TM(5,1) events that are issued by an instrument whenever its triggering algorithm makes a positive detection *that they would normally respond to*, i.e. taking into account quality factor thresholds, minimum fluxes, etc. and also through TM(5,1) events that are issued whenever an instrument receives a trigger via TC(20,128). This is straightforward for binary flags, but if an instrument is monitoring a continuous variable they a decision would have to be made as to what constitutes a significant enough increase in flux (for example) to issue an event. Using the relatively simple case of the RPW SBM1 (shock) trigger [RD01] as an example, the broad sequence of events would be as follows:

1. RPW reads magnetic field, density and velocity parameters from the TC(20,128) packet and provides them as input to its SBM1 detection algorithm.
2. The SBM1 detection algorithm decides that a shock has passed by the spacecraft.
3. RPW issues a TM(5,1) event indicating it has made a positive SBM1 detection.
4. RPW includes its SBM1 flag in the appropriate TM(3,25) packet which is then distributed to EPD, MAG and SWA via TC(20,128).
5. EPD, MAG and SWA each read the SBM1 flag and issue TM(5,1) events indicating that they have received an SBM1 trigger.
6. The TM(5,1) events are downlinked with payload housekeeping during the next pass, along with low latency data and platform housekeeping.
7. Instrument teams with the support of SOC check if the detection algorithms triggered on a real shock or anomalies in the data through analysis of low latency, Normal Science and housekeeping telemetry.

Note that depending on the cruise phase trajectory of the spacecraft, the validation scheme described about might not allow for the optimisation of triggering algorithms to conditions at the closest perihelion, so further tine tuning may be necessary.

3.1 Estimated Telemetry Overhead

The minimum size of a TM(5,1) packet it 8 bytes, including the packet header [RD02], so even assuming that triggers will occur two orders of magnitude more frequently than currently estimated [RD03], implementing the proposed validation scheme throughout the entire mission represents a negligible telemetry overhead for each in-situ instrument: 160 bytes per day per instrument for SBM1 (shock triggers) and 8,000 bytes per instrument per year for SBM2 (in situ type 3) triggers. Assuming mission duration of 10 years, this amounts to 664 kilobytes per instrument. Note that the telemetry associated with this validation scheme, while small, is not additional to existing instrument allocations, but instead would come from current TM budgets.

3.2 Additional Benefits During Nominal Operations

As well as maximising the utility of burst mode triggers, by relying on the diagnosis of the source of a trigger (natural or anomalous) initially using only the low latency data, the validation campaign would help test if good decisions about which events to select for downlink can be made using the low latency data as it is currently defined (or will be defined during cruise). Furthermore, should the TM(5,1) events continue to be issued after the end of the validation campaign, throughout the nominal and extended missions, as is envisioned, this information could be easily visualised with the low latency data in the SOC low latency visualisation tool, allowing an at-a-glance overview of what happened on board, potentially streamlining decisions whether or not to downlink a certain event.

4 DESIRABLE INSTRUMENT FUNCTIONALITY

In order to implement the validation scheme described above, some flexibility in how instruments deal with trigger algorithms and the receipt of burst mode triggers would be important, such that different aspects of their response to triggers and positive detections from detection algorithms could be enabled or disabled independently of each other. The following functionality would be needed:

1. The ability to disable the freezing of buffers, the transfer of burst mode science telemetry to the SSMM and the changing of instrument mode in response to the receipt of a trigger, either internally or via TC(20,128).
2. The ability check the content of TC(20,128) for triggers even when responses to those triggers is disabled.
3. The ability to issue a TM(5,1) event on receipt of a trigger via TC(20,128) even when other responses to the receipt of that trigger are disabled.
4. The ability to keep detection algorithms active even when responses to those algorithms are disabled.
5. The ability to issue a TM(5,1) event when a positive detection is made by a detection algorithm, even when other responses to that detection are disabled.
6. The ability to write a trigger flag to the TM(3,25) packet used for inter-instrument communication when a positive detection is made by a detection algorithm, even when other responses are disabled.

5 SUMMARY

The validation scheme described above is illustrated more graphically in Figure 5.1 below. This figure also includes an additional TM(5,1) event giving visibility of actions instruments take in response to triggers beyond that in standard housekeeping (both in green on the figure). This isn't strictly necessary for the validation campaign but would aid any necessary debugging in flight.

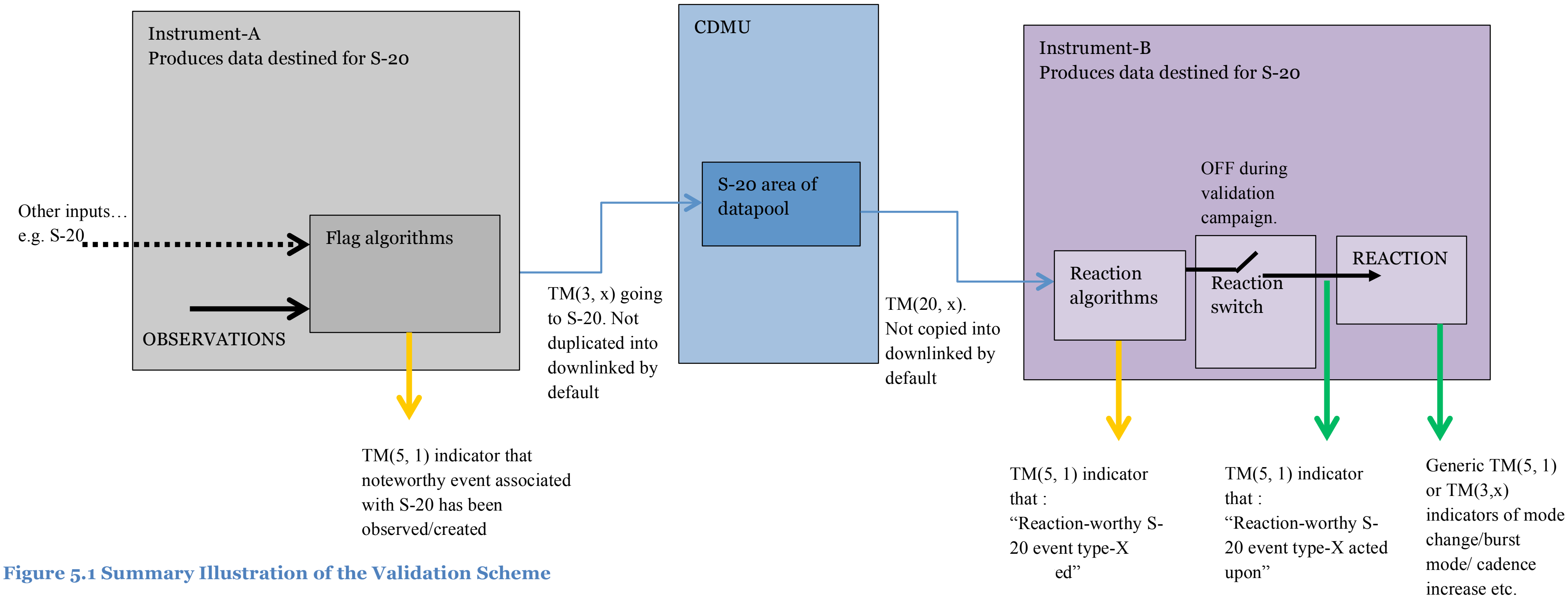

Figure 5.1 Summary Illustration of the Validation Scheme