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DOCUMENT

Solar Orbiter Enhanced Flight Events Communications Skeleton Interface Control Document (E-FECS ICD)

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APPROVAL

Title	
Issue 3	**Revision** 0
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EPD PI	
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RPW PI	
SOLO-HI PI	
SPICE PI	
STIX PI	
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CHANGE LOG

Reason for change	Issue	Revision	Date
Update for NMP	3	0	Oct 2021
Add NEAR_SUN and FAR_SUN events to resolve MAINT variants	2	5	Mar 2021
LTP-4 updates	2	4	Jan 2021
Update for late LTP-02 (>0.95 AU and NAV window) Released as a sub-minor revision to keep the schema v2_3 applicable.	2	3.1	Oct 2020
Update for LTP-03	2	3	July 2020
Draft update of SGS-FD ICD and first PTEL	2	2	April 2020
Various minor changes, post-GSRR	2	1	Oct 2019
Update for E2E-1 including major changes especially across the MOC events	2	0	April 2019
Inclusion of In-Situ burst coordination event as discussed in SOWG-10	1	2	Oct 2017
"Last minute" modification to v1_0 for schema issues	1	1	March 2017
First issue intended for signature round	1	0	March 2017
Update to coincide with release of example file derived from SOWG-8 LTP planning exercise	0	6	April 2016
SOC internal release. Schema only	0	5	
SOC internal release. Schema only	0	4	
Update for SOWG-8	0	3	Jan 2016
Results of internal review - AW comments - RC comments MOC clarification on passes vs. Attitude events Expansion of delivery timing	0	2	June 2015
First draft	0	1	June 2015

CHANGE RECORD

Issue 3	Revision 0		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Comment on pointing decisions and iVSTP reservation			2.3.4
More explicit details of LL timing wrt to passes for EUI, PHI and pointing decisions			2.3.11
Clarification on PTR windows not 1:1 wrt RSWs			2.3.12
New TCS change events			2.3.18, schema
Clarification on TAC routing timing			2.4.8
Fix corner cases in historic EFECSs wrt the schema (these are not expected to recur but it is cleaner to fix them) : Allow power attribute to take value zero (LTP-5)			schema

Issue 2	**Revision** 5		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Remove references to the descoped MTP cycle Remove unused idea of 60 day STPs in Cruise Add NEAR_SUN, FAR_SUN events			many 3.2.2 2.3.17

Issue 2	**Revision** 4		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Revise applicable and reference documents Add RPW calibration rolls Add Out-Of-Field calibration Update NAV window open issue to <resolved>			1.3, 1.4 2.3.5 2.3.5 5.1

Issue 2	**Revision** 3.1		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Removal of MTP cycle New approach to NAV windows Note on albedo MAINT ANY behaviour threshold at 0.95 AU Additional time margins on off-Sun pointings			1.2 2.3.2 2.3.2 2.3.16 2.3.16, 2.3.1

Issue 2	**Revision** 3		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Modify attributes of CALIB_ROLL_RS Notes on CSW patching usage of MAINT ANY			2.3.5, schema 2.3.16

Issue 2	**Revision** 2		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Addition of type attribute to MAINT events Addition of attributes to CALIB_ events MGA_PT and ENG_WIN. Align schema with ICD Update ADs and RDs Resolution of star calibration timing open issue			2.3.16, 2.3.3, schema 2.3.5, schema Schema 1.3, 1.4 5.10

Issue 2	**Revision** 1		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Misspelling of "skeleteon" on title page Grammar. editorial "are"->"is", GSRR RID GD-22 Clarifications on windows and duration attribute Header2 addition Revision of CALIB_ events Two new numerations on the metis_compatibility flag Backup plan switch-point Add PSP events PTR_END rsw_number made optional			Title page 2.1 2.1, schema 2.2, 3.3.1, schema 1.4, 2.3.5, 5.10, schema 2.4.1,2.3.2, schema 2.4.10, 5.3, schema 2.4.11, 5.8, schema Schema only

Issue 2	**Revision** 0

Reason for change	Date	Pages	Paragraph(s)
Major changes in the naming and significance of MOC events Update to ATT_DIST events Filenaming addition to cover back-up plans		many	

Issue 2	Revision 2		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Correct EMC names in the text to reflect schema Add new IS_COORD_BURST event Minor clarifications to MTP cycle and version format			2.3.5 2.3.6 and schema 3.3

Issue 2	Revision 4		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Incorporate MAINT and ENG_WIN events into schema			2.2.12, 2.2.13, 4
Split schema into two .xsd files to ease SOC-internal reuse of elements according to “chameleon namespace” model			4
Correct item in footer			all

Issue 2	Revision 0		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Correct the revision on front page		1, 2	
Add file transfer ICD			1.3, 3.1
Note on leap-second			2.1
Enhanced advice/description wrt pass events			2.2.9
Update STP_BOUND, MTP_BOUND			2.2.10,2.2.11
Add volume attribute to TAC			2.3.7
New heatshield door clarification			2.3.8
Update filenaming			3.3
Update schema			4
New open issue of filename metadata in content			5.7
Change XML usage of hyphen to underscore			

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1 INTRODUCTION

This document defines the mission planning interface by which the global instrument planning constraints are articulated to the ITs, by the SOC, prior to their own planning which leads to IORs in STP.

This interface is called the **E-FECS** (Enhanced FECS). It is also sometimes called the **Planning Skeleton** (more descriptive name, commonly used on other ESA missions for the same approach).

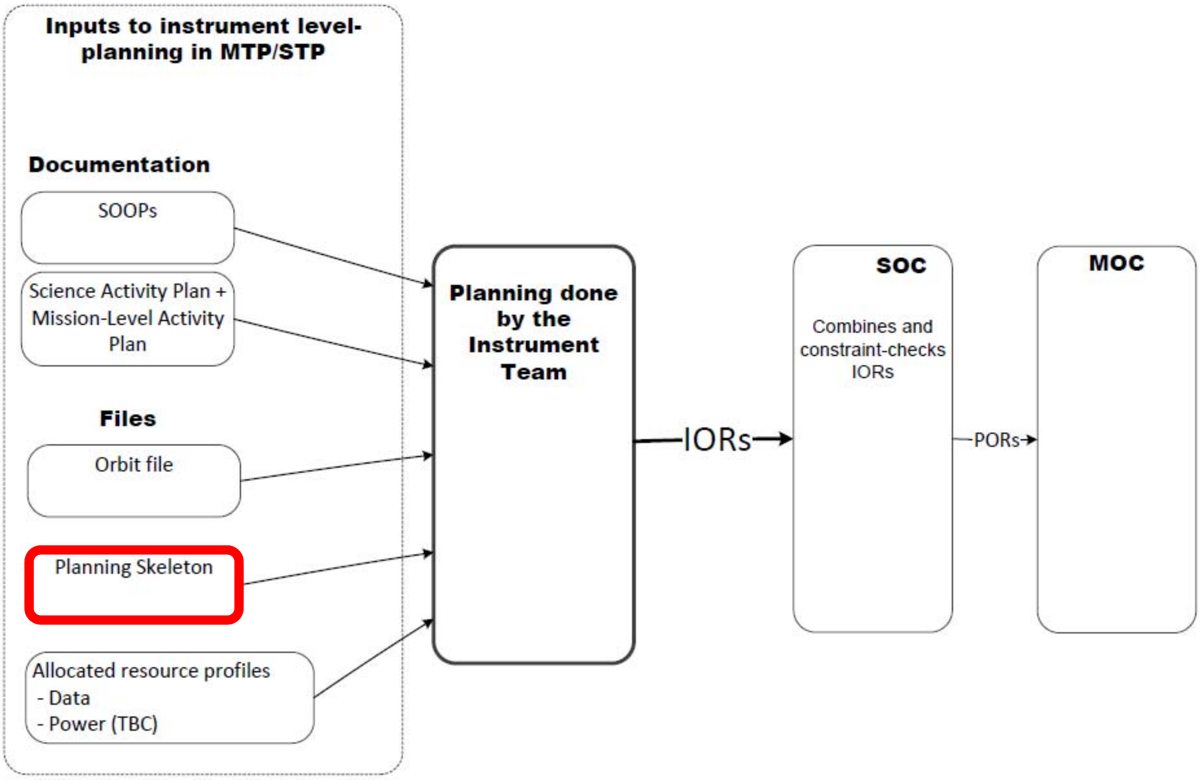

Figure 1, Instrument-team planning in STP

Figure 1 shows the context of the E-FECS. Note that the E-FECS does **not** provide

- "Documentary" planning information.
    - What science goals are covered by specific periods
    - The detailed coordination strategy according to the SOOP planning done at LTP
- Orbit information
- Resource profiles. These are specific to each instrument.

The E-FECS is an **input**, to instrument-level planning at STP. Thus it is not foreseen to iterate the E-FECS to accommodate instrument teams within these cycles. Rather the work of the earlier LTP cycle is to come to a solid coordination strategy, such that such iteration is nominally not needed.

The role of the E-FECS is solely to facilitate planning. Thus, although the E-FECS may give some first crude indications relevant for scientific post-processing[1], this is not its role. A given E-FECS is never re-issued to reflect the actual execution on the spacecraft.

The E-FECS is only used in Cruise Phase, NMP and EMP (i.e. after NECP).

1.1 Relationship E-FECS to MOC inputs

MOC provide planning inputs covering platform activities.

- The FECS is produced by MOC-FCT and is specified in [FECS].
- The PTEL is produced by MOC-FD and is specified in [SGS FD]

In principle these contain **all** spacecraft-level events needed for planning (e.g. when the HGA will move, when thrusters will fire), and **no** scientific-level planning.

The principal science-planning exception in the MOC inputs is the inclusion of the times of the RSWs.

- This is important for the planning of MOC manning and needs to be fixed early
- The SAP therefore needs to firmly define when the RSWs will occur[2].

There is no planning at the level of individual instrument teams where the MOC inputs are used directly.

The MOC inputs are used as an input to the instrument coordination performed at LTP. Use of the inputs in this context is the responsibility of the SOC.

The E-FECS is produced by SOC following the LTP planning. It is based on the MOC inputs, but adds scientific-planning information.

In the main, the E-FECS only **adds** windows to the MOC inputs.
Exceptions to this are:

- Pointing sync points (VSTP_UPDATE) may be removed. *E.g. For RSWs where there is no feature-based pointing[3] (i.e. pointing is well-defined in advance and needs no update) then there is no need for RS-instruments to avoid the sync points as potential disturbance periods since it is clear in advance that these will not be used.*
- Station passes may be removed, where it is clear that the downlink capacity is not needed. *(Exact process to perform this removal is not yet clear)*

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[1] E.g. periods where EMC noise or slewing may be expected.

[2] For example, the default placement of the high/low latitude RSWs of the early phase of the mission is scientifically rather arbitrary (since the obtained latitudes are unremarkable) and these default placements could be changed in the light of factors like conjunctions, comms-rolls etc. It is mandatory that such is done early in the context of SAP and mission-level planning iteration.

[3] And no backup objective requiring features.

1.2 Overview of planning cycles wrt E-FECS

Planning cycle	Relationship to E-FECS
SAP / Mission-level	Minimal. *e.g. SAP sets the RSW times which ultimately end up in the FECS and E-FECS*
LTP	Finalisation of Inputs to the E-FECS production *E-FECS distributed to the instrument teams as an output of the LTP, and used to constrain instrument-team IOR planning.*
STP	Major use by SGS *Same E-FECS remains applicable to STP planning.* *Exceptionally there may be an update of E-FECS between LTP and STP*
VSTP	Minimal. *Same constraints as STP apply, but because of the strict restrictions on VSTP instrument commanding, no new conflict possibility is expected.*

1.3 Applicable Documents

[FECS] "Solar Orbiter PLID Annex B – MOC-SOC ICD", Sylvain Lodiot, SOL-ESC-IF-05012, v2_0, May 2020

[GFTS] "File-Transfer SOC<->Instrument Teams ICD", Emilio Salazar, SOL-SGS-ICD-0009, v1_2, April 2020

[SGS FD] "Solar Orbiter SGS-FD ICD", Clement Aldebert, SOL-ESC-IF-50005, Jan 2021, v2_3

1.4 Reference Documents

[PLID] "Solar Orbiter Planning Interface Control Document (PLID)", Luca Michienzi (ESOC), SOL-ESC-IF-05010, v1_4, Aug 2019

[META] "Metadata Definition for Solar Orbiter Science", SOL-SGS-TN-0009, Jan 2015, v1.0

[OOF] "Solar Orbiter SPICE Out-Of-Field Straylight Calibration TN", Dec 2020, v0_2
[FLAT]"Solar Orbiter EUI/PHI flatfield TN", SOL-SGS-TN-0019, Nov 2020, v0_4
[ROLL] "Solar Orbiter Roll Scheduling Strategy TN", SOL-SGS-TN-0018, Dec 2020, v0_5
[ALIGN] "Solar Orbiter Limb-pointing Alignment Calibration Pattern TN", SOL-SGS-TN-0035, Sept 2019, v0_2
[STAR] "Solar Orbiter Star Calibration TN", SOL-SGS-TN-0037, April 2020, v0_4
[STRAY] "Solar Orbiter Cross-like Calibration TN", SOL-SGS-TN-0036, April 2020, v0_3

1.5 Acronyms

APID	Application Process ID
CSW	Central SoftWare *The main software run by the spacecraft.*
E-FECS	Enhanced Flight Events and Communication Skeleton *The planning skeleton according to which the various instrument teams to do their planning at STP*
EMP	Extended Mission Phase
EUV	Extreme UltraViolet
FCT	Flight Control Team
FD	Flight Dynamics
FDIR	Failure Detection, Isolation and Recovery
FECS	Flight Events and Communication Skeleton *A planning "pre-skeleton" that is defined by MOC*
FoV	Field of View
GAM	Gravity Assist Manoeuvre
HGA	High Gain Antenna
IEO	Inverted External Occulter *For METIS the line between their M0 mirror and their IEO is one way of defining the instrument boresight*
IOR	Instrument Operations Request *The routine instrument commanding product sent from the instrument teams to the SOC*
IS	In-Situ
IT	Instrument Team
iVSTP	That part of VSTP concerning instrument commanding
LLD	Low Latency Data. *That "thin slice" of science TM that is brought promptly to ground.*
LTP	Long Term Planning *The planning done over a six month period that establishes all "coordination" aspects before instrument teams plan their own detailed commanding*
MGA	Medium Gain Antenna
MOC	Mission Operations Centre *ESOC for Solar Orbiter*
MTL	Mission TimeLine
MTP	Medium Term Planning *The planning done (again over a six month period) that contains the first submission of detailed instrument commanding over the interval. Historically this was foreseen as a planning cycle between LTP and STP but it has been removed from the planning concept.*
NECP	Near Earth Commissioning Phase
NMP	Nominal Mission Phase
opt	optional
PLID	PLanning Interface Document *The ICD that defines the routine planning interface between SOC-MOC (and also instrument teams-MOC for non-routine)*
POR	Payload Operations Request *The routine consolidated set of instrument commanding products sent from SOC->MOC . Is in a sense "a set of IORs that have been accepted by the SOC"*
pVSTP	That part of VSTP concerning pointing
RS	Remote Sensing
RSW	Remote Science Window
SA	Solar Array
SAP	Science Activity Plan *The top-level science plan that identifies e.g. use of the individual RSWs*
SC	SpaceCraft
SOC	Science Operations Centre *ESAC for Solar Orbiter*
SOOP	Solar Orbiter Observing Plan *A collection of instrument operations/observations that belong together, e.g. to serve a common science goal.*
STP	Short Term Planning *The planning done (over a typically one week period) that contains the final submission of detailed instrument commanding over the interval*
TAC	Turn-Around Calibration (data) *A mechanism to allow rare/exceptional expedited downlink of science beyond LLD.*
TBC	To Be Confirmed
TBD	To Be Decided
TBW	To Be Written
TCM	Trajectory Correction Manoeuvre
TM	TeleMetry

VSTP	Very Short Term Planning *The planning phase at which* - *Pointings are updated (for those fraction of RSWs where late selection of pointing targets is agreed)* - *A very restricted set of instrument parameters may be updated*
WOL	Wheel OffLoading
wrt	With Respect To

2 DESCRIPTION E-FECS ELEMENTS AND PLANNING CONSEQUENCES

2.1 Time and duration formats

Every event within the E-FECS contains a time. The time format used is the CCSDS ascii time code B (a "day of year"format), of the form

`YYYY-DDDThh:mm:ssZ`

Note that additionally

- The use of subseconds is excluded in the EFECS[4]
- The Z suffix is made mandatory

Often events are used to describe a window of time (e.g. an RSW). Two approaches are used for this:

- For windows considered to typically have "long" durations (multi-day or more) the window is defined by independent start and end events. The idea is to facilitate cases where these windows may span a LTP planning boundary, thus needing some representation in two separate E-FECS files.
- For windows considered to typically have "short" duration (e.g. less than 24 hours) a single event contains a duration parameter. The assumption being that splitting of these windows across LTP planning boundaries will be avoided.

For the later approach, the duration parameter is represented as a **integer number of seconds**.

This philosophy is imperfectly implemented. Special cases are:

- `STP_START`. This looks like it is part of a pair, but it is not. There is no corresponding _END event. It is treated as an instantaneous event.
- `con` conjunction events. Functionally start and end events are present, but structurally these are folded into a single event name, distinguished by attribute. A duration is always present. For the start instances the duration represents the time to the end instance, and for the end instance it is set to zero.
- Some _START/_END pairs have previously been exported in operational EFECSs with duration="0". Where is has happened the current schema defines a duration but sets the attribute `use="optional"` to indicate that the duration is depreciated, whilst maintaining a kind-of backwards compatibility.

Events that are defined as instantaneous, e.g. `IS_COORD_BURST`, have no window. These have no duration.

[4] There is no event where planning should be concerned with timings below a second. Instruments attempting aposterori reconstruction of some particular behaviour requiring high time fidelity are expected to work from HK TM rather than the planning skeleton.

N.b. the legacy planning systems at MOC and SOC do not recognise leap-seconds. Thus durations in practise may last one second longer than indicated in the EFECS, in the case that a leap-second exists inside the timespan of the window.

2.2 Headers

There are two header elements, as defined in the schema.

`header` is a legacy set of fields and defines fundamentals such as the mission, the start and end range of the file and a link to the version of this ICD document issue.

`header2` contains traceability information linked to the LTP plan within SOOP-Kitchen that has created the EFECS, and a duplication of metadata that occurs in the filename, including, where applicable, whether the file is a prime plan or a backup.

2.3 Elements coming from MOC

2.3.1 Planned thruster firings (and sun-illumination of normally-shadowed surfaces)

For instruments having a sensitivity to thruster firings, it is the instrument teams responsibility to plan their IORs such that the instrument is commanded into a safe configuration for the duration of the nominal thruster firing periods identified in the E-FECS.

Explicitly planned thruster firings include both Trajectory Correction Manoeuvres ("`TCM`" event) which occur within GAM windows, and Wheel-offloadings ("`WOL`" event) which occur periodically throughout the mission (with some increased frequency expected typically closer to perihelion).

Then, because TCMs may be performed at non-Sun-pointed attitudes, the some TCM windows have an additional significance related to **illumination of normally-shadowed surfaces**. The event has an attribute type which may be set to "type-2" or "type-1/2". Type-2 indicates that the manoeuvre occurs with normal shadowing (i.e. sun-pointed) and type-1/2[5] indicates that an illumination of normally-shadowed surfaces may occur in line with EIDA R-139.

"Type-1/2" instances, occurring above 0.95 AU, are expected to have safety consequences beyond just thruster-firings for the operating state of **light-sensitive** sensors like SWA-EAS and EPD-SIS. The illumination also has **thermal** consequences, most obviously for other boom-mounted / externally-mounted instruments/sensors and the SORA elements, but also for some internal units on the MY panel since the radical thermal situation also penetrates into the structure to some extent. The thermal consequences are not constrained completely within the TCM window itself (e.g. it takes time for temperature to re-stabilise afterwards) so there are additional time-margins that have to be added – see section 2.3.16 for details.

[5] "type-1/2" is used (not simply "type-1") because even if a TCM with off-pointing is allowed at a particular time, it will not necessarily be needed/selected.

The needed delta-V direction of a TCM is not known at the time the E-FECS is created. Thus in addition to the implicit possible **off-pointing** of “type-1/2”, all TCM events contain an potential implicit and unknown roll.

The TCM event may be book-ended by two slew events. Because these slews are going to/from the TCM attitude, they inherit the same illumination constraints as the TCM.

2.3.2 NAV windows

The “NAV” (navigation) events are extended periods around each GAM, within which thruster firings will occur but without an explicit schedule known at LTP.
RS-instruments should expect to be OFF or in Standby for the entirety of NAV windows.

NAV windows at LTP
At LTP NAV windows are, more-or-less, “anything goes windows” for the purpose of delta-V support activities, and this means the **whole** NAV window has to be considered potentially constraining for sensitive instruments.

At LTP, NAV windows implicitly include the possibility of any and all of the below activities:

- Thruster firings (including either TCM type and WOLs)
- Rolls
- Slews
- SA and HGA movements

NAV windows at STP
At approximately 3 weeks prior to the start of the NAV window an updated EFECS will be circulated to instrument teams. This update will add an explicit schedule of TCMs, WOLs, MAINT etc. windows within the NAV window such that in-situ instruments can maximise their science through the NAV period, only needing to make sensitive units appropriately safe during these newly added constraint windows.

Albedo constraints around closest approach
Certain IS instruments have albedo constraints around the closest approach of a flyby. This includes:

- Illumination constraints from albedo
- Thermal constraints from albedo

There is no EFECS event that covers the albedo / close approach. And currently it is not expected that other events (TCM, WOL, MAINT etc) will impinge on the closest approach period. The detailed approach for handling the albedo constraints will need to be developed, probably with significant responsibility falling to the instrument teams, and will fall outside of the coverage of the EFECS.

2.3.3 HGA/MGA/SA movements

Movements of these elements has consequences for both EMC-quiet and attitude disturbances, however these science consequences are explicitly indicated by SOC-inserted windows.

HGA and MGA movements are detailed by the "HGA_PT" and "MGA_PT" events respectively.

In practise planned MGA_PT events in the MOC inputs may be rare or non-existent. Nominally the MGA stays in a stowed position (it is deployed to a configurable position in the event of e.g. a safe-mode entry, but these contingency events will not be pre-planned).

HGA_PT event frequency may vary significantly with orbital geometry, but at least one event per day should be expected.

The Solar Array movement ("SA_ROT" event) contains a parameter detailing the array angles. This will allow any instruments with any known sensitivity to specific Solar array angles (e.g. thermal, stray-light) to plan accordingly. Each of these events contains the starting angle and the ending angle. These declared angles are the **intended angles according to apriori planning**. Because the performance of the arrays is critical[6] and because the detailed behaviour of the arrays is very likely something that will need to be learnt in-flight, it can happen that the profile of array position over time has to be adjusted between the LTP and the actual execution.
Therefore

- it is **not guaranteed** that the angles in the event are always respected in-flight, although the timing of the movement period **will be** respected[7].
- The EFECS may contain apparently redundant movement events (like e.g. start and end position the same). These may exist to give MOC some flexibility on when to perform a movement.

Note that

- As far as possible the used solar array positions will respect the list of allowed positions defined by Airbus
- Known instrument sensitivities are understood to occur as the array moves between allowed positions.

Therefore it is not expected that this uncertainty in the final SA profile can cause instruments to acquire bad science data in nominal acquisition periods. However it is acknowledged that the nominal acquisition periods are slightly reduced by the redundant movement events, and that, for sensitive IS sensors[8], by the uncertainty of the angle ranges crossed (i.e. any

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[6] There is a need to balance power production and temperature, this being especially tightly balanced close to perihelion.
[7] True for all ground commanded array movements. There is the possibility of contingency autonomous movement if, despite ground control, the arrays go too hot.
[8] For RS, the attitude disturbance effect of the SA movement presumably prevents any movement period being usefully used, regardless of angles crossed.

SA_ROT may potentially cross a bad angle, so if there is a safety issue all SA_ROTs need to be reacted to).

Instruments needing the array position for scientific post-processing reasons will need to take the values from telemetry.instruments/sensors by the fact that any SA movement has to be assumed to cross a problematic angle range[9].

Generally the trend on the array position will reflect the orbit position, with low angles near aphelion and high angles (approaching close to 90 deg) near perihelion. However periodic maintenance activities – lubrication and SA performance characterisation – will insert occasional off-trend movements.

2.3.4 VSTP pointing update markers

During RSWs utilising "feature-tracking" (only), the SOC can update the spacecraft pointing based e.g. on low-latency data, to correct for proper motion, or to choose a new feature over the currently tracked one. This update occurs with a turn-around of several days.

The points in time where this update can be implemented are identified in the MOC inputs by the event "VSTP_UPDATE".

The VSTP pointing update has consequences for pointing stability, since if an update is performed it introduces a slew (albeit possibly quite small angular size for proper motion correction). It is not known until very late which update opportunities will actually be utilised, thus RS-instruments will have to plan their IORs on the assumption that each VSTP update marker is actually used. Thus for the point of view of instrument planning this window is effectively the same as a slew (see section 2.4.3).

The VSTP_UPDATE is special, in that this is a MOC-inserted event, that SOC may **remove** when creating the E-FECS, for those RSWs where LTP planning has shown that no update of pointing will be utilised.

N.b. This keyword is related to pointing VSTP (p-VSTP) and has no direct relation to the instrument-commanding VSTP (i-VSTP) implemented in the IOR. However, for those instruments (e.g. EUI and PHI) who may want to use iVSTP slots to react to pointing decisions the VSTP_UPDATEs are important because they show where a pointing decision could be implemented onboard. As such it makes sense to use the IOR slot reservation at STP to reserve iVSTP slots at the time of the VSTP_UPDATE (i.e. during the implied slew), or at least in any time between the end of the preceding PASS event and the VSTP_UPDATE. In most cases this should work, because the i-VSTP cycle is somewhat faster than the p-VSTP cycle, so that the instrument teams would normally have some small amount of time to deliver a VSTP IOR following the pointing decision. (It does not make sense to place the iVSTP reservation earlier than the end of the preceding PASS event because then an earlier

[9] In any case, taking actual behaviour from TM rather than from planning products is good practise in general (see text in section 1). SOC can assist in identifying the location of relevant parameters.

uplink opportunity would have to be used and this would mean the VSTP IOR delivery would be needed before the pointing decision was taken).

2.3.5 CALIB events

There is a family of events that are containers for attitude related calibration. These imply sets of rolls or offpoints. They are used in periods when the SOC does not have recourse to the direct pointing interface that is available e.g. during RSWs. Principally this occurs during Cruise Phase.

Identified members of this family are:

- "CALIB_ROLL_MAG"
  - This is the continuous period of rolling needed by MAG
  - Defined in [ROLL]
- "CALIB_ROLL_RPW"
  - This is the continuous period of rolling needed by RPW close to Earth-GAM
  - Defined in [ROLL]
- "CALIB_ROLL_RS"
  - This is where the spacecraft is rolled progressively through a set of non-nominal roll angles to allow RS-instruments to acquire with e.g. coronal features rotated into different positions on the detectors.
  - There are attributes that define a list of angles[10] where dwells occur and a single fixed dwell duration that applies to every dwell. Also defined in [ROLL]
- "CALIB_OFFPOI_FLATFIELD"
  - This is flatfield pattern agreed with PHI and EUI, defined by [FLAT]
  - There is a variant for full-disk/sun telescopes and another variant for high-resolution telescopes
- "CALIB_OFFPOI_STRAYLIGHT"
  - This covers the combined METIS/SOLO-HI calibration offpoints for straylight, according to [STRAY]
- "CALIB_OFFPOI_ALIGNMENT"
  - This is the alignment pattern, defined by [ALIGN]
- "CALIB_OFFPOI_STAR"
  - This is inner off-pointing part of the star calibration, defined by [STAR].
  - The star calibration is unique in that the precise timing is dependent on orbit geometry and therefore improved orbit knowledge shortly before the calibration may cause the timing to be updated. Details are in [STAR]. Non-involved instruments (e.g. IS) should be aware only that the component slews inside the CALIB_OFFPOI_STAR window at LTP are indicative only. Although if they move they stay within the LTP-given CALIB_OFFPOI_STAR window. The simple way to view this is that any part of CALIB_OFFPOI_STAR could potentially contain a slew.

[10] Maximum number of angles in the list is 20. Where fewer angles are needed, the surplus angle attributes are omitted.

- “CALIB_OFFPOI_OOF”
    - This covers the SPICE long limb-pointing for out-of-field straylight, according to [OOF]

The CALIB_ events exist mainly to allow MOC and SOC to coordinate these non-RSW pointing activities. Each CALIB_ event type has a set of attributes to record any variables that set the details of the calibration.

For IT constraint checking, these container events and their attributes are not essential because SOC will explicitly insert ROLL and SLEW events into the EFECS to reflect the atomic components of the activity. But the container events can be useful to quickly identify the purpose of a particular group of slews/rolls.

2.3.6 Rolls

Roll events represent an atomic period of “roll-slewing” between the stable roll angles which are maintained otherwise.

The spacecraft will be orientated at zero roll angle (defined by whichever roll-reference is eventually selected[11]), except for periods where deviations are necessary. These can be

- Dedicated calibrations requiring rolling
- Roll to put give the HGA a clear view of the Earth (within allowed HGA positions)
- (TBC) Roll to avoid illumination of RPW’s pre-amplifiers

Each roll slew is identified by the event “ROLL”. Attributes identify the starting roll angle and the ending roll angle. The starting angle should always correspond to the ending angle of the previous roll event (where present). Outside of roll events the roll angle is stable (excepting the “unknown” periods inside of NAV, TCM and MAINT events).

Rolls would not normally be scheduled during passes, because of the impact on HGA pointing.

Because rolls are defined in the MOC inputs, they are an input already at the LTP planning. Thus scientific roll needs have to be explicit (e.g. in the SAP) such that SOC and MOC can schedule them prior to LTP planning (avoiding for example that subsequently rolls need to be superimposed on top of passes).

N.b. Various options for the roll reference have been discussed. Orbit normal is the current assumption. For any roll reference other than the orbit normal, the orientation of the SC +Z at zero roll is not inertially fixed round the orbit, thus in an inertial sense the spacecraft can be very slowly rolling throughout the orbit to maintain the roll reference. This type of “slow continuous roll” is not covered by this event, being a nominal part of the roll reference

[11] Candidates reference directions being: Orbit normal, Solar equatorial normal, Ecliptic normal. For the last two the roll angle=zero location is the closest projection of SC +Z onto this reference, given SC +X disc-centre pointed.

definition. This also means that the "integer number of complete rotations" of the MAG_CAL_ROLL are not exactly inertial complete rotations.

Roll coast rate[12] is assumed to be fixed across all roll events and not selectable. There is therefore no parameter to indicate the rate within the E-FECS since this fixed rate will be known. It is expected to be faster than the off-pointing slew rate. Order of 0.1 deg/sec for roll coast speed is currently assumed, but this depends on the eventual reaction wheel performance. It is therefore to be expected that Rolls cause quite significant violation of nominal pointing performance as well as significant blurring of images. Plausibly the METIS HS door will need to be closed during rolls, although this currently does not seem neccesary.

2.3.7 RSWs

The location of the RSWs are defined in advance from the SAP / mission-level plan.
They are identified in the E-FECS by the two events "RSW_START" and "RSW_END".

Because the E-FECS covers ~six calendar months (broadly [Jan, June] or [July, December]) and is not aligned with the orbit, the E-FECS will not necessarily always contain three RSWs.

The RSW keywords are also used in the Cruise Phase to identify the Remote Sensing Checkout Windows (RSCWs). Recall that the purpose of RSCWs is not science but to check and characterise the RS instruments. Like the normal RSWs, the RSCWs will need to be fixed well in advance to take advantage of appropriate opportunities (e.g. Cruise phase aphelia and perihelia)

2.3.8 Solar conjunction

During Solar conjunctions there is no communication between the spacecraft and the Earth. Instrument operations are planned like normal, and will operate from the MTL during the conjunction. However instrument-teams need to be aware that there will be no low-latency arriving on ground and no possibility of instrument-VSTP commanding updates. For example

- For those instruments utilising selective, this will not be active through the conjunction, and they may consider disabling the generation of selective at instrument level.
- Those IS-instruments navigating their TM-corridors in a reactive way will need to be more conservative (coming nearer the middle of their corridor, or disabling the more unpredictable data generation) prior to the conjunction.

Additionally no possibility of feature tracking can be foreseen during solar conjunctions[13]. However this information is also clear from the pointing enumeration (see section 2.4.2)

[12] Roll duration of course also depends on ramp-up and ramp-down performance, but for large rolls this is a detail.
[13] Theoretically one could identify a feature to track prior to the onset of conjunction (e.g. from the previous solar rotation) and attempt to track this "in the blind" through the conjunction. However in most cases the consequences of uncorrected proper motion on the high-resolution/narrow FoV imagers is going to render this approach unworkable in

Solar conjunctions are identified by the event "con". An attribute conjunctionType identifies either "ES3S" or "ES3E".

- ES3S indicates the **start** of a conjunction period where the **sun-earth-spacecraft** angle falls below 3 degrees.
- ES3E indicates the **end** of the same conjunction period.

The duration of an ES3S event gives an independent way to locate the end of the conjunction. The duration of an ES3E event is not meaningful and is set to zero.

ES3S events correspond to both superior and inferior conjunctions (being close approach of Sun and spacecraft as seen from the Earth). This should be the conjunction event type that drives the communications outages[14].

During solar conjunctions it is possible that HGA_PT and PASS events are maintained throughout (to allow the chance of visibility for MOC for safety purposes) even though planning will always assume that no useful contact occurs in conjunction (i.e. no SSMM_DUMP_xxx, VSTP_UPDATE events).

The details of STP periods in relationship to conjunctions are TBC, but most likely a single extended STP will be defined to span the entirety of the conjunction.

2.3.9 Hibernation [removed]

Hibernation does not occur in any of the current trajectories so this event is retired.

2.3.10 GAMs [removed]

GAM event is subsumed into the more general NAV windows (see also section 5.1).

2.3.11 Pass events

[Largely irrelevant to Instrument Teams]

There are a number of events related to passes and downlink events within the E-FECS. These windows are indicating the general availability of particular downlink services, but not specifying how this availability is applied to specific stores. Therefore they are relevant for SOC downlink planning but are transparent to instrument planning[15]. As such the instrument teams are **advised to ignore** OMM_DUMP and SSMM_DUMP_1WAY and SSMM_DUMP_2WAY. For the specific question of how to guarantee that low-latency data will be downlinked in a particular pass (at the latest) the rule is:

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practise. Furthermore we expect that the SAP and mission-level planning are identifying science goals/activities that need feature-tracking and assigning these to RSWs without conjunction well before E-FECS production occurs.

[14] Or more precisely, the periods where pass outage has to be assumed for the purposes of science planning.

[15] The corresponding instrument-level information is captured in the TM-corridors.

(Excluding special cases like post-conjunction catch-up) any low-latency data that is written to SpW prior to the start of the pass (represented by PASS) will be downlinked in the pass.
Thus, if a reliable minimum latency on LLD is desired, that data should be written to SpW immediately prior to the PASS. This is especially important for EUI and PHI LL that informs pointing decisions in RSWs using p-VSTP pointing updates. Normally the most recent imagery available for these decisions will be the last image written prior to a pass start.

These events are:

"PASS"

"OMM_DUMP"

"SSMM_DUMP_1WAY"

"SSMM_DUMP_2WAY"

The PASS event might plausibly influence EMC-quiet. It is understood that, for reasons of thermo-elastic stability and pointing requirements, the RF chain (deep space transponder and travelling tube wave amplifier) may be retained continuously on.

PASS is also relevant for the delivery constraints for i-VSTP IORs.

These events contain certain attributes (see schema). These are described here **for information only**, since there is no instrument planning that depends on them.

station	three letter code indicating one of the three ESA deep-space stations
tm_rate	frame-level downlink rate in bps
mod	modulation scheme of downlink
rng	whether ranging is enabled onboard
dbcode	MIB code corresponding to the downlink configuration of the transponder (effectively the combination of rate, modulation, rng)

2.3.12 PTR_START and PTR_END

[Largely irrelevant to Instrument Teams]
The events

"PTR_START" and "PTR_END"

indicate to the SOC the periods within which direct pointing requests from SOC are supported by MOC. Broadly these occur during some RSWs and precursors (i.e. not Cruise Phase). Not all RSWs necessarily support PTR windows. Further, there can be reasons to split PTR windows within a PTR-supporting RSW. As such that the relationship between PTR windows and RSWs is not one-to-one.
These events should be irrelevant to the instrument teams because

- They follow directly from the choice of RSW locations already made by the SAP and possibly tweaked by the SWT prior to the LTP.
- The POINT_ pointing placeholder events give a more precise picture of the pointing plan for IOR creation.

Note that these events contain an attribute which provides a count / index number of the PTR window, and that, for historical reasons, this is called rsw_number, although really it is a PTR window number. Instrument teams are advised to **ignore this attribute** because, for reasons above, it will deviate from the number of the RSW from a normal planning perspective.

2.3.13 POWER

[Irrelevant to Instrument Teams]
The event
"POWER"
indicates to the SOC the aggregate power available across all ten instruments. If power restrictions below EID-A allocations apply in-flight (not baseline), then this will be the starting point for addressing this. However it cannot be used-as-is for instrument planning because there would need to a decomposition of this number down to individual instruments – most likely this would be done in the LTP meeting.

2.3.14 STP boundaries

The E-FECS covers the entire six month planning period, but smaller intervals of planning are submitted in each STP. STPs normally cover a week, except for conjunctions where they span the entire conjunction period (TBC).

The STP boundaries are identified in the MOC inputs with the event "STP_START" such that they are explicit already once the EFECS is distributed.

As discussed in SOWG and Instrument FDIR workshop, instrument Teams are required to structure their IOR files such that each individual IOR file identifies a boundary where, for the purposes of contingency recovery the IOR commanding can easily be resumed. The recommendation is that such a boundary occur at least once a day. But additionally these IOR file boundaries also have to align with the edges of the planning period. Thus an STP delivery of IORs will need to match file boundaries to these STP_START events at the start and end of each STP period.

The STP boundaries normally occur on each Saturday, at the end of the corresponding pass.

Beside the time, the STP boundaries contain the following attribute

stp_number	the mission-level count of the STP cycle

N.b. stp_number may be particularly useful ,as this can be used to identify the `[mission-STP-number]` part of the IOR filenaming.

The STP_START event does not have a duration. The implicit STP period belonging to each STP_START lasts until the next STP_START. Since commanding is limited to 1 second granularity the implicit last commanding opportunity of the period can be thought to be one second prior to the next STP_START.

2.3.15 LTP boundaries

Similarly to the STP_START event, there is an LTP_BOUND event.

Beside the time, the LTP boundaries contain the following attributes

duration	time to the next LTP boundary in seconds
l_count	the mission-level count of the LTP cycle
first_stp	the mission-level stp_number of the first STP within the LTP
last_stp	the mission-level stp_number of the last STP within the LTP

The l_count attribute will match the `[mtp-cycle-number]` of the EFECS filename.

Normally it is expected that each EFECS file will contain a single LTP_BOUND event

2.3.16 Attitude maintenance activity windows

These are identified by the event "MAINT". They represent flight-dynamics related maintenance activity for which no other event is provided. They contain a type attribute

type	Description
ZFZT	"Zero Force Zero Torque" manoeuvre. These are like short TCMs but with the intention of providing no deltaV (and no torque), for the sole purpose of purging the "old" fuel exposed to the valves. They are required more often early in the mission. Each event sequentially purges both thruster branches.
SA_RELUBRICATION	These are SA movements not covered by SA_ROT. They are added when the nominal array steering does not move the arrays sufficiently. The arrays move +/-15 degrees (for the arrays starting in a "mid-range" position) and end up in the same place that they started. If the arrays are near one end of the range, the exact excursion has to be modified.
SA_CHARAC	These are SA movements not covered by SA_ROT. The SA is driven to a high incidence angle (typically 79 deg) and back. If done at a sufficient Sun distance this forces the arrays into a peak-power tracking mode for a short period of time. (It also discharges the battery). This allows an assessment of the performance of the arrays to be made.
SA_ENDSTOP	These are SA movements not covered by SA_ROT. This is like the SA_CHARAC, but the array is driven further such that additionally the absolute position of the array can be confirmed by contact with the endstop.
DEICING	This is a 210 deg pitch slew, with the Sun progressively illuminating +X, -Z, -X and then returning. Its purpose is to remove ice from the instrument boom. It can only be run above 0.95 AU. Apart from a validation run during NECP (and a possible re-validation with a modified procedure in Cruise) the

	de-icing is run only if SWT ask for it. This request must come before the LTP planning of the relevant period.
ANY	This is the wildcard MAINT, during which FD can do anything. From an instrument planning perspective they are like short NAV windows at LTP that do not associate with a GAM. N.B. In the LTP-02 a MAINT ANY event has been used to indicate a main computer software update requiring all instruments to be fully OFF for the duration. This is outside the normal/intended scope of a MAINT ANY (in that there could be instruments that are able to remain on for all varieties of attitude impact, that nonetheless have to be turned off for the patching). As of now there is no alternate event to uniquely signal a CSW update, so it can happen again that a MAINT ANY is used in this non-standard way, and the special significance of the particular instance being communicated to the by some other means.

Pointing performances (e.g. AME, RPE etc.) are not guaranteed in any MAINT window. Additionally the following instrument-level consequences apply:

		Nominal potential consequences		
		Thruster firings	Off-Sun pointing	SA movement
MAINT type	ZFZT	Y	-	-
	SA_RELUBRICATION	-	-	Y
	SA_ENDSTOP	-	-	Y
	SA_CHARAC	-	-	Y
	ANY	Y	-	Y

Table 1, MAINT consequences at less than 0.95 AU Sun distance

		Nominal potential consequences		
		Thruster firings	Off-Sun pointing	SA movement
MAINT type	ZFZT	Y	-	-
	SA_RELUBRICATION	-	-	Y
	SA_ENDSTOP	-	-	Y
	SA_CHARAC	-	-	Y
	DEICING	-	Y	Y
	ANY	Y	Y	Y

Table 2, MAINT consequences at equal or greater than 0.95 AU Sun distance

Off-Sun pointings include two classes of consequence (related but not the same):

- Direct illumination of normally shadowed surfaces

- Thermal consequences

Note that two tables of instrument-level consequences are given for clarity, the first that applies for < 0.95 AU Sun distance and the second for >= 0.95 AU. In words, the differences between the two tables are:

- Off-Sun pointings are not allowed below 0.95 AU and therefore the consequences of MAINT ANY windows are different depending on whether they occur above or below this distance threshold
- Similarly de-icing can only be scheduled >= 0.95 AU

These two distance cases can be distinguished using NEAR_SUN and FAR_SUN events described in the following subsection.

During MAINT events in general:

- RS instruments are recommended to avoid integrations
- METIS is required to make itself safe[16].
- Sensitive instruments are required to make themselves safe.

For the SA movement events: Note that since the starting angle is not perfectly known (since the end angle of the previous SA_ROT is only indicative) it is recommended that SA-movement sensitive instruments make themselves safe for any the SA_ events and not try to assess if the movement range in question will affect them or not.

Additional time margins on thermal consequences of off-Sun pointing

As noted above, MAINTS above 0.95 AU of flavour: MAINT-ANY, MAINT-DEICING and TCMs of "Type-1/2" (section 2.3.1) involve, or potentially involve, off-Sun pointings with thermal consequences. In brief, the thermal consequences are that:

- RS instruments need to be OFF (exceptions apply for EUI to avoid full switch-off of the CEB, and for SPICE to allow CMS measurements).
- EPD STEP,HET sensors and the HV of SIS need to be OFF
- Spacecraft-provided decontamination heaters will be turned OFF by SOC for the duration

There are additional time margins that need to be taken (on top of the explicit duration of the event in the EFECS) for the thermal consequences.
Margins are needed because:

- SOC have to apply various FDIR monitoring changes around the event to avoid spurious FDIR reactions
- The thermal situation does not stabilise instantly following the end of the off-Sun pointing

This is an **exception case** in the EFECS as currently formulated, in that the time-period of the user-level effect is not directly represented in the file.

[16] Now that Heat Shield Door events are planned at LTP, the door aspect of this will be handled by the insertion of HSD events around these events.

Currently the additional time margins for thermal consequences are (as trialled on STP-116):

- **60 minutes prior to the start of the event**
- **70 minutes after the end of the event**

2.3.17 Sun distance events

Two events

"NEAR_SUN" and "FAR_SUN"

indicate the **transition** to a new sun distance regime for the purposes of MAINT constraints above. Both are instantaneous events which carry a duration attribute set to zero.

- NEAR_SUN marks the start of a period below 0.95 AU.
- FAR_SUN marks the start of a period above 0.95 AU.

The initial state is not given explicitly in each new EFECS but has to be propagated from the previous planning cycle. Similarly in the very first planning LTP cycle in which these events are introduced there will be a period prior to the first flagged transition that will be neither explicitly marked nor found in previous cycles.

2.3.18 Sun distance-related thermal control events

The spacecraft anomaly SOL_SC-67 led to a period of five months without SWA operations. The anomaly review board has decided to implement thermal control system changes with the goal to stabilise the temperatures at the SWA EB, so to prevent further degradation of the SWA EB A-unit and to protect the B-unit from possible recurrence. Currently (they may be adapted in future) the changes to the spacecraft thermal control thresholds are:

- SWA EB [34,35] degC, MY zone heater [34,35] degC to be applied before the SC exceeds 0.5 AU Sun distance
- SWA EB [-6,-5] degC, MY zone heater [-10,-9] degC to be applied before the SC falls below 0.35 AU Sun distance

N.b. it is not expected that these locations typically run at the extreme temperatures above, rather the control thresholds are being used to effectively force the heater ON or OFF (whilst retaining some protection).

The two thermal lines will be commanded such that they change from being almost-always ON to almost-always-OFF (on the inbound transition, v.v for the outbound transition) somewhere between the two distance thresholds. The SOC will choose the exact point of inserting these thermal changes case-by-case for each orbit, based on the science plan for the upcoming orbit that is available prior to the LTP. This time of the change is then communicated to the instrument teams via events in the EFECS.

These thermal measures maintain the avoidance of routine continuous cycling of the MY panel zone heaters, which were observed to generate thermos-elastic pointing effects during NECP, for the continued benefit of the remote-sensing instruments. This comes at the cost of a large single change (expected to be order of half an arcmin) at each transition. These events are not currently flagged by ATT_DISTs (because we expect an incremental change in alignment rather than requirements violation or jitter).

The two events are

“SWA_TCS_NEAR” and “SWA_TCS_FAR”

the former occurring on an inbound segment and the latter on an outbound segment.
Both are instantaneous events which carry a duration attribute set to zero. The events show the time that the thermal control change is initiated. Thermal stabilisation in the new regime of course extends in time subsequent to each event.
The initial state is not given explicitly in each new EFECS but has to be propagated from the previous planning cycle.

Whilst the name identifies SWA, the thermal step changes involved can be significant, so **all instruments mounted on the MY or PZ panels are recommended to be aware of these events,** especially if they have thermal sensitivities.

Hard ON<->OFF transitions of these heaters have already occurred in-flight, albeit at different Sun distances:

- SWA EB heater 21 May 2021 ~17:34
- MY zone heater 30th June 2020 ~13:08 and 25th Nov 2020 ~12:21

These prior events can be used to obtain a hint at the order of magnitude of the temperature shift expected when these events occur, noting that locations under active thermal control of other TCS lines may mask the shift if it fits inside the control band.

As an aside, some further description of the thermal approach behind these events:

A typical spacecraft thermal line / heater

- Is fully ON in cold conditions (e.g. near aphelion)
- Is fully OFF in hot conditions (e.g.near perihelion)
- Cycles in between the above two conditions

This was the original approach for the M zone heater.
(Often the power status of the unit under control is a contributory factor in whether the conditions above count as hot. This is does contribute somewhat to the MY zone heater but is especially true of the SWA EB heater).

The selected approach seeks both to run the SWA EB warmer and have less cycling, so broadly:

- TCS control thresholds are raised
- The third cycling bullet above is avoided and this period is replaced by a manually-inserted ON<->OFF shift, within the appropriate range where otherwise the lines would cycle

2.3.19 TMTC onboard routing maintenance windows

These are identified by the event “ENG_WIN”. During these windows all TM and TC routing from/to the instrument is suspended/ not guaranteed to allow for maintenance activities affecting SSMM/SpW routing.
Therefore:

- No planned instrument TCs shall be submitted in this interval

- No instrument TM shall be generated in this interval

Practically-speaking it may be that these windows require that the instrument is either SAFE or OFF. This is because

- Spacecraft-provided FDIR actions will not be available (only instrument-internal FDIR can protect the instrument in these periods)
- The absence of instrument heartbeats at the OBC would normally cause the instrument to be turned off[17].
- At instrument-level the continued absence of S-20 would be expected to cause the instrument to prepare for turn-off[18].
- (If the previous two bullets are circumvented) the instrument exposes itself to the risk of an unwarned power-off, if the spacecraft experience a survival mode

2.4 Elements superimposed by SOC

2.4.1 Platform-created Attitude Disturbances

These windows are used to explicitly identify periods where the EID-A pointing performances are not expected to be met. The "ATT_DIST" events identify these periods.

During these windows

- RS instruments are recommended to avoid sensitive (high resolution) integrations

In principle all platform-created disturbances are implicitly due to events already within MOC inputs. Identifying these events with a dedicated pointing disturbance event is:

- More explicit
- Allows the later inclusion of tranquilisation times on top of the root event durations where necessary

Currently this event does not attempt to distinguish the flavour of disturbance, e.g.:

- whether big or small
- affecting RPE or APE (or both)

Most disturbances are likely to affect both APE and RPE to some extent and to need characterising in-flight to reliably understand the magnitude of disturbance. Also it seems likely that most RS-instruments will prefer to avoid integrations during any sort of disturbance regardless of the specific flavour. As such the discussion on ways to identify flavours of disturbance is moved to Open Issues, section 5.11.

METIS protection:

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[17] Unless the SC FDIR is reconfigured for this interval.

[18] Unless the instrument FDIR is reconfigured for this interval

Originally it was foreseen that ATT_DIST could or would be used to identify to the METIS team when to protect METIS from sun-light entering around the occultor. In the current scheme protection via closure of the heatshield door is planned as part of the LTP. As such, the HSD protection is already visible already in the E-FECS rather than being planned in IORs based on the E-FECS. Here the METIS heatshield door would be closed for:

- POINT_ events that are flagged metis-compatible="NO"
  - plus the enveloping slews
- disturbances that cause βtherm to be exceeded (currently only a small subset of overall disturbances)[19]

2.4.2 *Pointing type enumeration*

Whereas the previous element was identifying periods where the nominal pointing performance is disturbed, the "pointing type enumeration" is identifying what the nominal pointing *is*, in terms of the general class of pointing.

A feature of the Solar Orbiter mission is that the choice of a specific solar feature necessarily can come very late in the planning, at a time when the STP instrument operations are already submitted. Thus the pointing type enumeration is intended to identify a class of pointing within the skeleton, sufficient for instrument operations planning without giving the explicit pointing.

Instruments with safety constraints related to pointing will be required to plan according to the worse possible pointing that can occur inside the given enumeration. With this in mind every pointing type contains a flag that identifies whether the pointing is guaranteed compatible with METIS observing or not. This flag has four enumerations:

YES	pointing guaranteed inside **science** performance limit, α_{max}
DEGRADED	pointing guaranteed inside **sun intrusion** limit, β_{max}
NO	pointing not guaranteed inside **sun intrusion** limit
STRAYLIGHT	exception case where limited sun-intrusion is deliberately caused for calibration purposes.

For many cases, and for feature-tracking in particular, the flag is expected to be set simply either YES or NO.
Other enumerations arise as follows:
DEGRADED occurs in the narrow region between α_{max} and β_{max} where science performance is not guaranteed but direct sun intrusion has not yet occurred. METIS could choose to observe in these periods, or not. The door would not normally be closed. Actual occurrences in NMP may be rare, because of the narrowness of the region. However in Cruise Phase several RSCWs occur at ~0.5 AU such that limb-pointing for the other instruments could place us in this zone.
STRAYLIGHT occurs for the calibrations defined in [TN-0036], when this occurs at closer distances. For these calibrations the door must be left open otherwise the calibration is

[19] Many classes of disturbances, like e.g. HGA movement, don't cause βtherm to be exceeded because the disturbance size is smaller than the margin on the POINT_ events where the door will to be closed and where it needs to be closed.

useless. These occurrences might require that METIS adjust the thresholds in their imaging FDIR protection to avoid false triggers, or that they rely solely on thermal-based FDIR – FDIR tuning activities like this are METIS responsibility, via their IORs. There might be other calibrations where we would set this flag, possible example: limb-pointing parts of star calibration in Cruise Phase.

METIS HSD events will be inserted around those enumerations such that the door is closed for NO periods.

As an example of the use of the METIS compatibility flag it is worth to discuss in particular the "feature tracking" POINT_FEATURE enumeration. Here if the SOWG agrees a METIS-compatible pointing enumeration this is the same as agreeing that the available disc be restricted compatible with the METIS observing constraint[20]. Conversely agreeing the POINT_FEATURE event to not have METIS compatibility maximises the freedom of feature tracking but excludes METIS observing (depending on distance).
As with all pointing type decisions, the choice of the pointing type applicable in each period would be an SOWG decision at LTP (guided by the plan of the SAP). It has to be understood that this METIS-compatible feature-tracking can be valuable only at intermediate to far solar distance RSWs, since close to perihelion the METIS constraint is too narrow to accommodate anything other than an essentially disc-centred pointing. In other words, if the SWT wants METIS to operate during a close RSW, it is assumed that they would choose a disk-centre pointing enumeration, with METIS as the prime boresight

A similar decision process applies to the other pointing types, although these are in general simpler in that the actual pointing that will be implemented is more tightly bound.

These windows are identified by the following events

"POINT_CENTRE"	disk centre pointing
"POINT_POLE"	pole pointing
"POINT_LIMB"	pointing somewhere on the limb
"POINT_FEATURE"	tracking of a feature[21].
"POINT_PATTERN"	a single dwell within any «grouped pattern»[22] of pointings
"POINT_OTHER"[23]	

Each instance contains the following information:

[20] I.e. only those features inside the METIS constraint could be chosen and tracked later at p-VSTP. The extent to which this restricts feature selection depends on Solar distance.
[21] In almost all cases the location of the feature will not be known until pVSTP.
[22] POINT_PATTERN is not used in cases where the atomic pointings within a pattern can all be constructed from other existing POINT_ types, like POINT_CENTRE and POINT_LIMB.
[23] Could for example be a geometric pointing at some specific location relative to the sub-satellite point, but not corresponding to the disk-centre nor the pole. It's not clear if such pointings can be needed.

Disk centre
Pole
North
South
Limb
<opt> Solar lat bounding min value
<opt> Solar lat bounding max value
<opt> East/West/North/South[24]
Feature tracking
<opt> Active feature (e.g. Active region, sun spot, base of prominance)
<opt> Quiet feature (e.g. coronal hole/boundary)
Single element with a "pointing pattern"
EUI-PHI flat-field calibration
METIS_SOLOHI_straylight_cal
METIS off-point matrix calibration (depreciated in favour of combined pattern above)
SOLO-HI off-point matrix calibration (depreciated in favour of combined pattern above)
Mosaic
Other

Each POINT_ event in the E-FECS has a parameter indicating which RS-instrument boresight the SOC will attempt to place onto the chosen target. This "prime boresight" is also decided by the SOWG at LTP. One clear use-case for this functionality is the disk centre pointing, where choosing METIS as the prime boresight may be necessary to ensure METIS observing.

N.b. the boresight information itself used by SOC will come from the RS-instruments teams according to a TBW interface. This is envisaged as a static alignment relative to the spacecraft frame, to be delivered infrequently.
Identified prime boresights are

"SC"	Spacecraft +X
"EUI_UV"	EUI High Res. EUV channel
"EUI_1216"	EUI High Res. 1216 channel
"EUI_FSI"	EUI Full Sun
"PHI_HRT"	PHI High Resolution Telescope
"PHI_FDT"	PHI Full Disk Telescope
"SPICE"	SPICE
"METIS"	METIS M0-IEO line
"STIX"	STIX

[24] The limb direction here is mostly descriptive. It does not mean that the limb pointing goes exactly to a particular cardinal direction. Often the limb-pointing occurs relative to the orbital directions which are not strictly aligned with the solar axes. This is the case in cruise phase where these keywords will be used to distinguish the individual limb-pointings inside a calibration pattern, without use of the bounding value. Later, in NMP, we would expect to start using the bounding values, once the limb-pointings are associated to scientific targets, like e.g. the streamer belt.

"Mean_1"	Mean of EUI HRI_1216 and EUI HRI_EUV (I.e. EUI high res. mean)
"Mean_2".	Mean of PHI HRT and mean 1
"Mean_3"	Mean of SPICE and mean 1
"Mean_4"	Mean of PHI HRT and SPICE
"Mean_5"	Mean of Mean 1, SPICE, PHI HRT (i.e. All high res telescopes)

All POINT_ events also have a METIS compatibility flag which, in most cases, is "YES" or "NO". METIS compatibility=YES means that the pointing is guaranteed to meet METIS's science observing needs. Practically the meaning is slightly different for different types of pointing

- For pointings that are purely geometrical, it means that the pointing is known in advance (i.e. within LTP planning) to be compatible with METIS science requirements
- For pointings that depend on later decisions on targeting (i.e. feature tracking or connectivity RSWs), it means that the SOWG agrees to constrain the later pointing choices to remain within the METIS constraint

METIS compatibility needs to be considered also in relation to the prime boresight. For pointings where METIS is not the prime boresight, some additional margin will need to be retained to guard against updated boresight alignments being delivered between LTP planning and execution.

2.4.3 Slews

These are indicated by the event "SLEW".

As with the pointing enumerations, the time that the slew occurs can be defined in the E-FECS, but the actual slew required (i.e. angular distance) may not be known. Consequently a fixed slew duration (5 mins TBC on wheels/AOCS information) is foreseen for all normal on-disk slews. Although fixed the duration is given as a parameter. This is the only additional information contained in the slew.

Here slewing means specifically changes in the off-pointing of the +X axis with respect to the sun. These events are independent from the roll events described earlier.

The SLEW event is unusual in that some instances are defined by MOC based on platform needs, and other instances may be inserted by SOC when enumerating the POINT_ plan (e.g. if splitting one long dwell into two separate POINT_s).

N.B. Slews adjacent to TCM and MAINT blocks can be slews to an **off-disk attitude**, and may have duration longer than the fixed on-disk slew duration discussed above. Therefore these slews inherit the off-disk attitude and illumination of normally shadowed surfaces properties of the adjacent TCM or MAINT.

2.4.4 Summary of attitude-related events

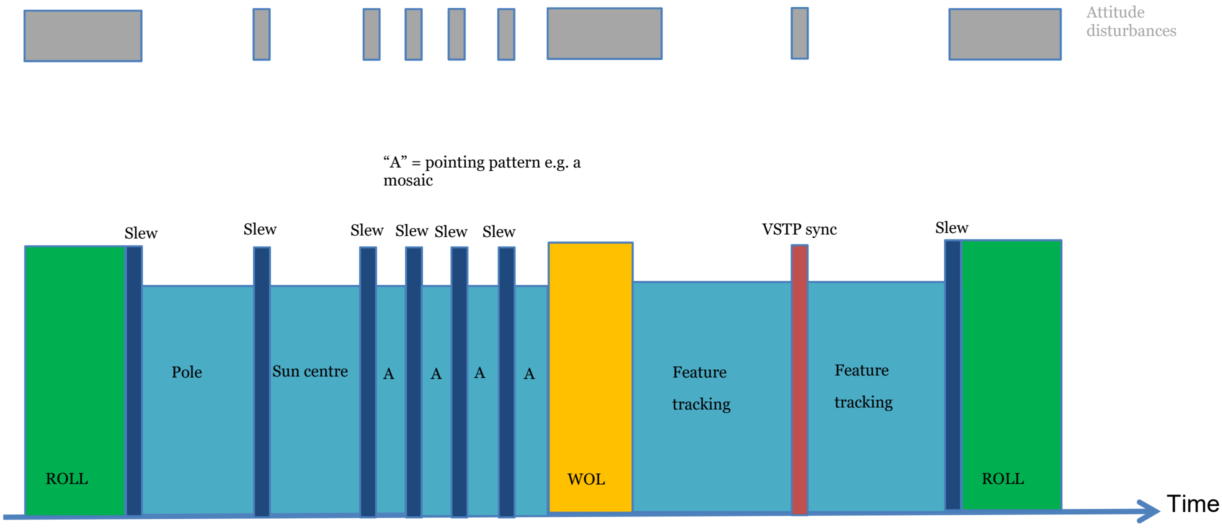

Figure 2, Example of attitude events

Figure 2 shows a complicated example sequence of attitude windows for illustration.

Blue items are SOC-inserted. In particular light blue represents stable pointing periods corresponding to a pointing enumeration. Only the top-level part of the pointing enumeration is shown, but in fact the E-FECS would contain lower-level aspects like prime boresight as well.

Non-blue colours are MOC-inserted and present in the inputs.

Attitude disturbance events are also shown above the attitude events. These disturbance events correlate with the attitude windows, but may not have identical duration. Other types of event beside attitude events can also attitude-disturbances (e.g. HGA movement[25]). These are not represented in the diagram.

WOL events include both the actual off-loading (thruster-firing), and the bounding slews to/from disk centre.

It is TBC whether the ROLL events follow the same approach or not. The latter is shown in the figure. Also we expect that rolls are performed in a fast mode (expected rate 0.1 deg/sec TBC) that have an operational overhead at the end (short period of gyro re-calibration). Similarly it is not clear whether tranquilisation times (when applicable) will be included in all windows. These issues will determine whether the attitude-related events are contiguous in time or whether there can be gaps between the various windows (in any case the attitude-related events will never overlap).

[25] Sometime these may be stacked on top of other attitude disturbances, but this may not be possible in every case.

Relationship of Attitude events to Passes
Certain types of event will perturb the HGA pointing (which is moved in discrete movements and does not track continuously). Some of the events that contribute to attitude disturbances will have large enough magnitude to potentially influence comms as well. The baseline is that these comms-disturbing events will be scheduled outside of passes – this is not expressed as a rule on the format of the E-FECS (since it might change during flight) but rather as an expression of how these windows will typically be scheduled in practise.
The following attitude events are expected to be scheduled only outside of passes on this basis:

- ROLLs
- WOL
- SLEW
- VSTP_UPDATE

The implication is, that most days there will be at least one long pointing type enumeration lasting the full pass duration (typ. 8-9 hours).

Additionally the non-attitude SA_ROT event is also a candidate for scheduling outside of passes.

2.4.5 EMC noisy/quiet windows

This section describes the E-FECS means to control EMC noisy periods. Because the precise instrument operations that contribute noisy events are currently uncertain, the scheme described is quite general.

It should be clear that, for a spacecraft targeting the simultaneous operation of ten instruments, the ability to mitigate these events through operational planning (as described here) is limited, and the only robust solution is for instruments to achieve entirely EMC-quiet behaviour at the design-level.

Where instruments have not achieved quiet behaviour by design, then some means to "steer" the generation of EMC noise is necessary to protect the ability of RPW and MAG to make meaningful measurements. The approach detailed here is a compromise which is attempting to:

- Allowing adequate apriori EMC-quiet periods for the purpose of MAG/RPW planning
- Without imposing overly harsh operating restrictions on those instruments that have routinely noisy operations

Assumption: EMC-noisy operations list
It is expected that a list of instrument operations creating EMC-noisy events (according to the definition of the EID-A) will be created and maintained, to allow the control of these operations in planning. This list will cover both spacecraft and instrument noisy events. The initial version of this list is expected to come from the EMC working group. In-flight the list will have to be updated to

- remove those operations that are found to be quiet in practise
- add those operations that are discovered to be noisy

A first update can be expected as a result of compatibility testing in NECP. Further updates are possible as the mission flies.

Assumption: Platform operation planning goes first, payload planning follows
This is an assumption of the planning skeleton approach. Within the context of EMC, this means that the times of platform noisy operations are declared within the skeleton, and subsequently the instrument operations are fitted around these.

N.b. It could happen that certain types of platform noisy event are unpredictable. If such occurs then obviously this type of event cannot be declared in the skeleton.

Assumption: Limited planning skeleton control of instrument noisy operations
Since the instrument operations that can be EMC-noisy is currently unclear, it is impossible to construct a fully deterministic planning scheme that guarantees in advance both

- achievement of the 70% quiet requirement across each orbit, and
- acceptable/non-blocking operating constraints on an instrument that has noisy operations

Therefore the E-FECS is implementing a flexible scheme to “guide” the placement of noisy events without necessarily constraining ALL noisy operations to pre-defined windows. This scheme is also tuneable, in that the SWT could decide to use it in a way that gives flexibility or in a way that is more directive.

This is done through two distinct types of EMC window:

- “Mandatory quiet” windows
- “Preferred noisy” windows

It is expected that the SWT will define the general principles of how often the two windows are inserted, and with what duration. These general principals would be adapted in each LTP cycle to the specific periods according to the science goals present (perhaps an RSW targeting connectivity has tighter requirements on EMC quiet than an RSW targeting some other science goal). The SOC would insert the windows when building the E-FECS.

If it is found subsequently that the approach does not achieve the 70% quiet requirement over the orbit, then the SWT would need to consider whether to tighten the guidelines on the use of the windows (and consequently tighten the operating constraints on noisy instruments) in subsequent orbits, in order to come closer to 70% quiet.

Mandatory quiet windows
The first type of EMC-related E-FECS window is the “mandatory quiet” window. These are created by the SOC, according to the guidelines of the SWT, and avoiding SC noisy periods.

Because the mandatory quiet windows are potentially highly constraining to noisy instruments, the use of these windows should be moderate, especially during RSWs.

In principle mandatory quiet windows require that all instrument noisy operations are avoided, both

- those that result explicitly from commanding (i.e. "don't command this operation in the quiet window") and
- those that can occur due to autonomous action (i.e. "disable the autonomous action for the duration of the window").

Because of the way EMC quiet periods are defined in the EID-A, it is likely that any mandatory quiet window would always be at least an hour long.

It's possible that certain types of autonomous action could be agreed to be free from this constraint on the basis that the autonomous response is very unlikely to occur within any given window. Potential candidates for an exception could include:

- SIS autonomous iris movement
- STIX autonomous attenuator movement

Preferred noisy windows

The second type of EMC-related E-FECS window is the "preferred noisy" window. These are created by the SOC. Normally these will be "stacked" on top of a Spacecraft-noisy event. Where no suitable spacecraft events are present a "preferred noisy window" can be created without a root spacecraft event. Preferred noisy windows would be placed so as to never overlap with a mandatory quiet window.

Instrument teams should attempt to schedule noisy operations within "preferred noisy" windows where possible, and would be **required** to schedule a particular subset of these noisy operations herein. This subset would be all those operations that are classed as "easily movable" in the sense that

- Their precise timing is not critically important
- They are not tightly interwoven with normal instrument operations

The "easily movable" parameter would be a property of the instrument EMC-noisy operations list.

An example of this type of operation could be (for some instruments) a door movement. It seems likely that door opening and closing will tend to concentrate itself at the beginning and end of remote sensing windows. The provision of windows to guide the placement of these operations avoids that they become unnecessary spread over an arbitrary period.

"Mandatory quiet" and "preferred noisy" windows shall never overlap. Generally, substantial periods that are neither "mandatory quiet" nor "preferred noisy" are possible. Within these periods instrument teams would be neither encouraged nor forbidden to schedule noisy operations. It is expected that some fraction of the time in these intermediate periods ends up contributing to the overall EMC-quiet total, without the specific contributing periods having been pre-planned.

These events are identified as "EMC_MAND_QUIET" (being the mandatory quiet window) and "EMC_PREF_NOISY" (being the preferred noisy window).

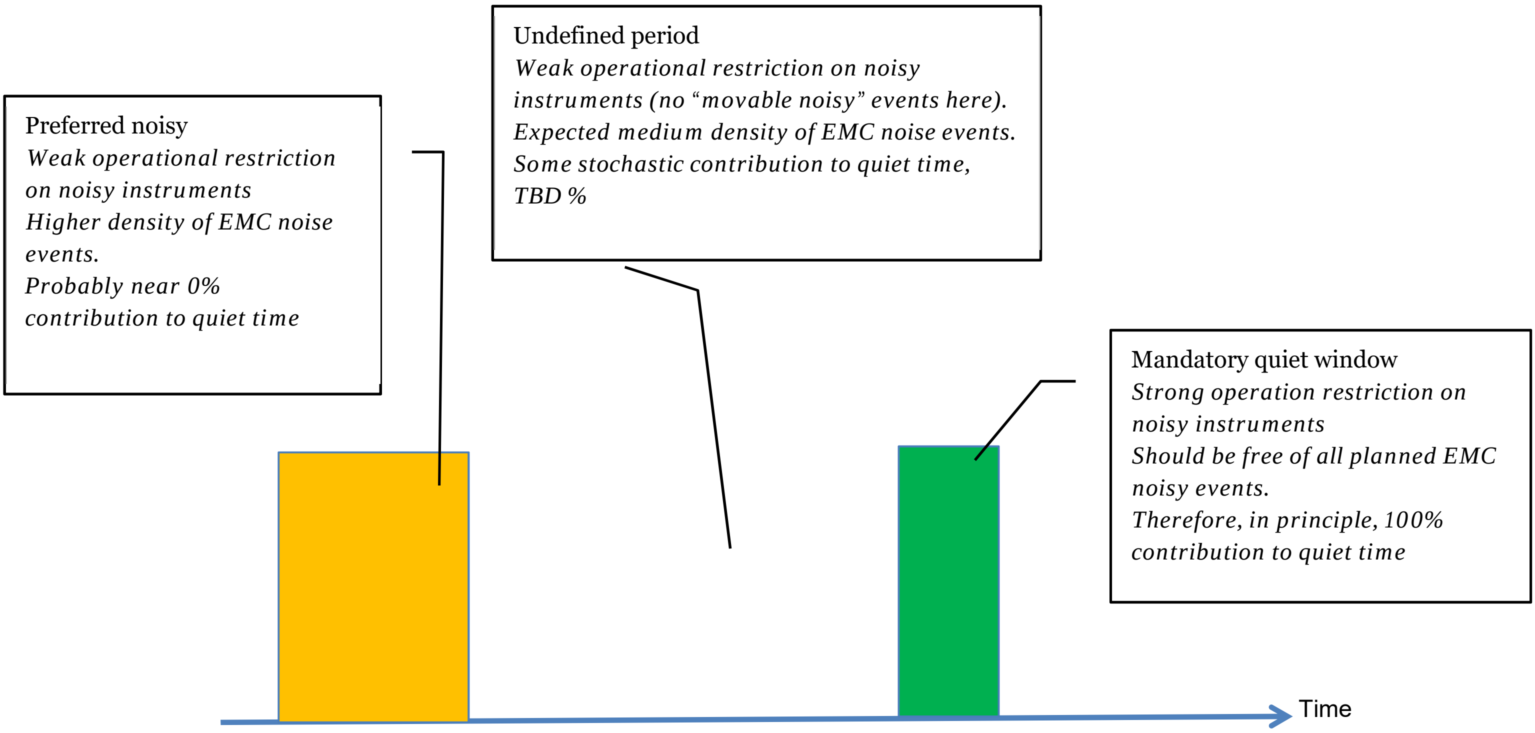

Figure 3, Representation of EMC control

Possible use of EMC windows

As noted above, the scheme is general and would have to be tuned to deal with the specific noisy operations that we will encounter. However it can be instructive to illustrate how these could be used in practise, with some examples

- During RSWs we may face a significant numbers of EMC noisy events. A mandatory quiet window of 1 hour, once per day, would be sufficient to allow IS-instruments to plan scheduled burst modes in periods that are known to be quiet. Depending on the eventual sources of EMC-noisy this sort of window may have acceptably low impact on most RS-instrument operations.
- RSWs specifically targeting connection science are particularly challenging and might need more aggressive mandatory quiet windows. One possibility is a duty-cycling approach crudely based on the expected propagation time, example: unrestricted-RS-activities-for-a-day, quiet-activities-for-a-day, unrestricted-RS-activities-for-a-day, quiet-activities-for-a-day, etc.
- Outside of RSWs, mandatory quiet windows could be strongly extended to cover the majority of each day. This could increase the probability of reaching 70% quiet over the orbit, albeit at the price of restrictions on operations outside of RSWs (like e.g. annealing) if such were noisy.
- Preferred noisy windows of perhaps 15 minutes would most likely be inserted at the order of once a day, and more often if more spacecraft noisy events are present.

Type parameter

An optional type attribute to identify the type of EMC disturbance is included to allow possible future expansion of these windows into different types of disturbance (e.g. E-field versus Magnetic). However, operationally we prefer the simplicity/clarity of an EMC-quiet window that requires all forms of EMC-quietness to be met at the same time. Thus this expansion will only be undertaken if it is demonstrated that operationally the simple window cannot met the needs of the mission.

As for ATT_DIST, see section 5.11 ,an equivalent separation of classes of EMC event would be to create separate events, this approach being more clear for overlapping events.

2.4.6 In-Situ Burst Coordination

The event "IS_COORD_BURST" indicates a period where it is expected that the IS instruments will all perform scheduled bursts. It marks the **mid-point** of the burst (because we are not trying to coordinate the potentially different burst durations across different instruments), as such this event definition has a time but no duration.

This event is for **guidance** rather than mandatory that it be followed. This is because

- The presence of this event does **not** permit instruments to exceed resources or any other established constraint. In particular some instruments are expected to rely significantly on scheduled burst cadence as a way of controlling their overall data production within the limits of the TMC
- Individual instrument operations (e.g. *autonomous* burst mode responses or TM book-keeping) may interfere with the scheduled burst

Often this event will occur inside an EMC_MAND_QUIET window to protect the quality of the scheduled bursts. However this is not imposed by the interface, and may not always be the case.

2.4.7 RS-Extended Windows

These were originally called Precursor Windows. The new name reflects the fact that there may be RS-instrument commanding both before and after a RSW (e,g, PHI post-processing). These windows apply only to the RS-instruments.

These events are identified as "RSW_EXT_*[name]*" where name can be EUI, METIS, PHI, SOLOHI, SPICE , or STIX. In other words there are six discrete flavours of this event, one for each RS instrument.

They indicate instrument-specific periods outside of RSWs where a RS-instrument is allowed to schedule mission-planning commanding. In other words, all instruments may schedule commanding during an RSW, but outside an RSW RS-instruments may only schedule commanding during a RS-extended window identifying their instrument. RS-extended windows are supposed to cover peripheral activities that support the main RSWs.

This covers precursors, but potentially also other periods where the RS-instrument may be commanded. The nature of this commanding is not specified in the E-FECS, but must be consistent with the operations/SOOPs agreed within the LTP[26], where the presence and duration of the RSW_EXT_... windows are decided.

Because RS-Extended Windows are inserted by the SOC (whereas RSWs are inserted by MOC), it is possible that these may contain a higher density of spacecraft events than RSWs.

RS-Extended windows shall not overlap with RSWs. RS-Extended windows belonging to different instruments may overlap with each other.

2.4.8 TAC windows

TAC stands for Turn-around calibration. Some instruments have occasional calibration activities where

- The calibration results fed a commanding update in relatively tight-loop[27]
- the data volume exceeds the capacity of the low-latency data

In order to meet this need a dedicated store is envisaged. This store is small (in order not to "waste" SSMM) and is a shared resource, and therefore

- The use of TAC is limited to those cases where a clear tight-loop commanding consequence of the calibration can be foreseen.
- TAC usage has to be agreed within the LTP planning.
- is controlled by SOC, via the rerouting of normal instrument science APIDs. The window in the E-FECS shows the period over which this re-routing is applicable.
- There will be periods where TAC cannot be supported for downlink reasons[28]. TAC cannot be used to implement a regular prompt always-on downlink to ground – this is the function of low-latency, and the reason that the low-latency volumes are so restrictive is that this is as much as the poor-comms periods can support. Part of the LTP planning decision about assignment of TAC is this assessment of what can feasibly fit promptly into the downlink.

The TAC window in the E-FECS indicates to the relevant instrument team the time-period over which the routing to the TAC store will be applied. It is identified by the "TAC_*[name]*" where *name* can be EUI, METIS, PHI, SOLOHI, SPICE, STIX, EPD, MAG, RPW, SWA.

The current assumption for the routing of the TAC period is that all of the instrument's science APIDs (other than LLD) would be routed to the TAC store. I.e. no need to distinguish

[26] Example: If PHI has an RS-Extended window for the LTP-agreed purposes of onboard data-processing, it shall not use this window to do additional observations.

[27] If the interpretation of the calibration is simple, then providing the means to apply the results autonomously onboard may be an option to avoid the delay and complication of the TAC loop to ground, and back to the spacecraft.

[28] The downlink will always serve HK and low-latency first. In periods where this load largely occupies the available bandwidth, then there is no way to move TAC promptly to ground.

different routing for different bulk-science products within the TAC routing period. This is consistent with TAC windows being associated to an instrument rather than an APID or an APID list.

Each TAC window will include as an attribute a volume that represents the estimated volume of bulk science to be generated within the window. This will be the volume declared at the LTP planning, where the feasibility of providing TAC will have been assessed. This volume will also be used later by SOC to organise the downlink.

N.b.1 TAC data still counts towards TM allocation
N.b.2 When downlinking from the TAC store SOC intend to delay the TAC-using instrument's bulk-science correspondingly, TBC[29].
N.b.3 The commanding updates resulting from the TAC data come are inserted by the instrument team in their normal mission-planning input, making use of the STP IOR, or (in NMP, EMP only) the delta-IOR of the VSTP cycle.
N.b.4 TAC in Cruise Phase:

- Is not foreseen for RS-instruments[30]
- May be applied for IS-instruments, where the downlink in Cruise allows it

It is not excluded that TAC windows for different instruments may overlap, although this is undesirable for TM accounting reasons.

The commanding sequences that implement the routing changes are not strictly instantaneous (for example most instruments have multiple science APIDs to reroute). As such instrument teams are advised to wait 15 seconds after the start of the event to be sure that the TAC routing is fully in place.

2.4.9 Spacecraft Heatshield Door Operations

As discussed in the RSWG of Jan 2016, HSD operations are to be planned within the LTP. The reason to do this is that only a single door can be operated at a time, implying that an element of coordination is needed between the various door requests. Additionally heat-shield door operations are expected to be EMC-noisy, and may be attitude-disturbing.

Remote sensing instrument teams having the need for dark exposures against a closed HS-door are required to take this into account when agreeing the LTP plan, either

- by allowing time for the necessary instrument operations e.g. prior to a single nominal door opening preceding each RSW, or
- by requesting within the LTP additional close-open operations at specific times

[29] Enhanced downlink priority of TAC data necessarily delays other data. The point here is that the user of TAC should fairly be the user whose bulk-science is delayed.
[30] EID-A states that RSCWs are "pre-programmed". In any case it is assumed that in cruise phase these sorts of RS updates are applied between one RSCW and the next. This allowing more detailed ground analysis appropriate to checking out the instrument.

For instruments that foresee routine door closure outside of observing periods, the former approach is strongly preferred in that it minimises door cycles.

For METIS only, additional HS door operations are created based on the METIS compatibility of the various POINT_ and other attitude windows.

The events are represented as
"HSD_*[name]*_*OPEN*" and
"HSD_*[name]*_*CLOSE*"
where *name* can be EUI_FSI, EUI_HRI, METIS, PHI_FDT, PHI_HRT, SPICE

The duration of the event window will be the order of 10 minutes. When multiple doors are operated in sequence the duration of the window may be longer.
Each event indicates a window during which the door movement is guaranteed to occur[31]. It does not represent the actual "moving" time of the door, which will be shorter and which will occur somewhere within the window.

2.4.10 Split point for "backup" LTP plans

Handling of backup plans in NMP is described in 3.3.1. This involves two sets of planning files, that contain identical planning up to some point, after which the plans diverge. The point at which the plans diverge is represented by the keyword "BACKUP_SPLIT".
N.b. This is not the point in time that the decision of which branch to follow needs to be made. This decision needs to be made earlier. The baseline would be to decide early enough that only one set of STP files needs to be delivered and processed which implies the decision is needed approx.. 2 weeks earlier that the split.
This event only occurs in those EFECSs corresponding to LTP plans with an agreed backup plan.

2.4.11 PSP events

[In this issue of the ICD, PSP events are added even though the SOC cannot currently populate these. As such, the definition of the interface is made ready, pending the upgrade to actually provide these events].

It is likely that some parts of the Solar Orbiter mission will run in coordination with Parker Solar Probe (PSP). Where this is the case it needs to be planned properly via the normal cascade of planning cycles. Most likely the bulk of this planning occurs at mission-level and LTP in order to arbitrate the PSP cooperation and implied resource usage against the standard Solar Orbiter goals and RSWs. However it is also clear that at later planning cycles instrument teams would like a reference for where (e.g. within a ten day RSW) a particular support campaign is centred.

[31] Excluding mechanical failure

The EFECS, as a timeline of discrete events, is not the proper place to tabulate arbitrary geometry data. This is much better done by interrogating e.g. NAIF-SPICE for whatever detailed geometry parameters are of interest. However, as a compromise, we add three simple events to the EFECS that act as simple reference timing markers for instrument teams planning their detailed observations around a coordinated window. All of these events are instantaneous.

- PSP_QUAD. Quadrature of PSP wrt Solar Orbiter, i.e. where the Sun-PSP-Solo angle is 90 degrees
    - including an optional attribute indicating whether PSP is leading or lagging wrt Solar Orbiter, i.e. does PSP appear broadly on the Solo +velocity side of the sunward direction or on the –velocity side? This could be important for SOLO-HI for example.
      As formulated here, the "sidedness" attribute is decided from a purely orbital point of view, this should be sufficient providing we are not flying really extreme roll angles.
- PSP_PERI. Perihelion of PSP
    - all perihelia to be included regardless of whether PSP is on same side of the Sun as Solar Orbiter or not.
- PSP_RADA "Radial alignment" of PSP and Solar Orbiter on the same side of the Sun.
    - Because the planes of the two orbits are not identical a true radial alignment is unlikely. As such, this event will represent a sort-of closest approach to radial alignment. Mathematically one could define this to be e.g. any local minimum in the PSP-Sun-Solo angle occurring when PSP-Sun-Solo angle < 10 deg. We include an optional attribute for whether PSP is closer to the Sun or further away than the Solar Orbiter position [32].

Magnetic alignment is also interesting of course, but to define it properly, besides the identical geometry issues as for radial alignment, one additionally needs to apply models and potentially also initialise these models with recent data. As such it is not addressed by the EFECS.

N.b. within this overall approach the assumption is that PSP flies a stable and predictable trajectory, similarly to Solar Orbiter (which seems likely given that it too has a resonant orbit approach with Venus) such that the knowledge at LTP is sufficient for later planning. It is not intended that the EFECS be reissued solely to update the precise timing of PSP events based on post-LTP improvements in orbit knowledge. If this becomes a problem then an alternative would be to deliver these events in a separate file which might allow more streamlined updates.

[32]. Whilst many radial alignments would have PSP closer, there are cases where this is reversed.

3 DELIVERY ASPECTS

3.1 Delivery mechanism

It is foreseen that the GFTS mechanism is used to transfer E-FECSs from SOC to Instrument Teams, according to the ICD [GFTS].

3.2 Delivery timing and time-span

3.2.1 NMP and EMP

The E-FECS is delivered to cover a time-range of a ~six month planning period corresponding to the station scheduling exercise. Approximately this corresponds to one period covering [Jan, June] and one period covering [July, Dec] each year[33]. Working backwards from the delivery of IORs, and using a reference time T which is the start of the onboard execution of this period:

- E-FECS is delivered to the Instrument Teams at T-20 weeks

The STP cycle has no additional issue of an E-FECS. The E-FECS is supposed to be stable between LTP to STP and Instrument teams are to plan their STP based on the corresponding time-range within the E-FECS.

Exceptionally it may be necessary to issue a revised E-FECS. Situations that can lead to this include:

- Mis-performance on a GAM
- Showstoppers discovered within later planning, such that LTP assumptions have to be revised within an SOWG planning meeting

3.2.2 Cruise Phase

Broadly the Cruise Phase mission planning works in a similar way as NMP/EMP.
However

- Control of EMC-noisy and quiet windows is not expected within an RSCW. Most likely an entire RSCW has to be considered potentially noisy.
- The top-level plan for the RSCW placements and allocation of check-out activities to each RSCW is probably not the SAP, but can be a document maintained by the SOC.
- A restricted/simplified LTP activity is probably still necessary every six months. This is needed to adapt plans to the confirmed station schedule.

3.3 Filename

Originally the intention was to adapt the Solar Orbiter metadata standard [META] filenaming to mission planning products. However the metadata standard has not been

[33] Clearly this period is **not** the same an orbit. The above planning period has been chosen to ensure that MTP is always done with a firm station baseline already in place.

designed with planning in mind and, in common with the IOR ICD, it has been decided to move to a more simple filenaming:

`EFECS_M[mtp-cycle-number]_V[version].xml`

`[mtp-cycle-number]` is a two digit decimal number, nn, starting from 01, which increments with each new MTP planning cycle.

`[version]` is a two character alphanumeric. In flight-operations it is a two digit decimal number, starting from 01, which increments each time a new E-FECS for the cycle in question has to be issued (nominally there should be no re-issue).
Version numbers containing alphabetical characters indicate on-ground test files.

The E-FECS will also be delivered to MOC. This is to allow MOC visibility of the METIS compatibility of foreseen POINT_ events for mission-planning safety checking. Most likely a copy of the EFECS (same content, different filename) will be implemented to allow the transfer of the file to the MOC according to MOC conventions.

The E-FECS itself may be delivered in a zip file containing other planning products.

3.3.1 Handling of backup plans

An EFECS belonging to a backup plan will be identified by a B instead of a V prefix before the version field. E.g.

`EFECS_M[mtp-cycle-number]_`**`B`**`[version].xml`

Besides the filename identification of prime/backup plans, there is also a metadata inside the file (attribute within the header2) which repeats the same information, in the form `filename_isPrime = "YES"` or `"NO"`.

Explanation of backup plans:
Sometimes the science goals of a particular RSW may depend critically on the availability of a suitable solar feature that cannot be guaranteed in advance.

The proposed approach to handle these cases is to have two plans at LTP. Firstly a prime plan based on the availability of the hoped-for feature, secondly a back-up plan that can run reliably regardless of the actual solar conditions encountered.

N.b. to prevent an explosion of permutations, only **one RSW** of a given six-month planning period would be allowed to have this dependency. The plans would be identical up to the critical RSW (and perhaps precursor), and would then diverge thereafter.

Both plans would be completed in the LTP planning, dual E-FECSs and TMCs would be delivered to the instrument teams. During the execution of the plan, it is assumed that the availability of the requisite feature can be decided by the SOOP coordinator with ~2 weeks lead time[34], such that only a single chain of STP plans have to be considered.

It is assumed that planning periods having this dependency are rare, since it implies significant additional planning work by both SOC and Instrument Teams

This approach implies the ability to manage parallel prime and backup TMCs, E-FECSs.

[34] This is not implying additional precursor activities. It is assumed that Earth-based assets (and perhaps Solar Orbiter low-latency data from earlier RSWs) is sufficient to decide the availability of a suitable feature.

4 SCHEMA

Available in Confluence next to this ICD.

5 OPEN ISSUES

5.1 Use of routine planning through GAM periods

[RESOLVED] Reissue of the EFECS at ~3 weeks prior to the NAV window as described in 2.3.2

5.2 Heatshield door operations

[RESOLVED] creation of HSD events and including of door ops in LTP .

5.3 Handling “backup” LTP plans

[RESOLVED]
Section 3.3.1 defines the filenaming convention for backup EFECSs. Section 2.4.10 defines the keyword to mark the point at which the two plans diverge in execution.

5.4 MOC maintenance windows

[RESOLVED] creation of MAINT and ENG_WIN events.

5.5 Implementation of packet store resizing opportunities

It is valuable to be able to resize the packet stores during the mission. Examples:

- SAP goals that may lead to strong changes of data allocation in different periods of the mission
- Failure of an instrument, leading to the desire to redistribute memory between stores
- Failure of specific regions of the SSMM memory, leading to the need to redistribute memory between stores

However constraints apply on the resizing operation:

- Data loss occurs if the stores are not empty
- A brief window where no operations in or out of the SSMM memory arrays is required to perform a establish a backup of the new partitioning

Currently the overall concept for advanced-planning resizings is:

- To establish resizing opportunities in the mission-level plan
- To decide if these opportunities are to be used at LTP
- To implement the confirmed opportunities via
  - Restrictions on the TM corridors (to ensure the bulk stores are empty)
  - Restriction on operations close to the resizing itself to
    - Limit non-bulk (HK, LL) data loss around the resizing
    - To guarantee the window for the backup of the partitioning

The details of how to reflect this in the E-FECS have to be decided.
E.g. Some of constraints are close to the ENG_WIN event, but

- ENG_WIN is over-restrictive in that it also prevents TM/TC over the SpW network to/from the OBC
- ENG_WIN is a MOC owned window, whereas we expect the resizing opportunities to be created by SOC

5.6 Control of EMC noisiness arising from power variability

The EMC approach described in 2.4.5 is based on assigning a binary EMC score ("noisy" or "quiet") to specific platform and payload operations, and then controlling according to this. This is appropriate for a mission-planning approach as foreseen for Solar Orbiter that works by first implementing a planning skeleton and subsequently letting the instrument teams plan in isolation. And it is clear that there are certain operations (e.g. many of the motor movements) that are noisy in a binary way.

However, EMC noise also arises (indirectly) from the variability of power consumption. Many instruments have significant power variability in many of their modes. The overall power variability EMC noisiness arises from the aggregate of all the individual contributions. Whilst the EID-A establishes a level for the aggregate performance it has not attempted any instrument-by-instrument budget for power variability.

Currently it is not clear whether the current variability aspects need an enhanced approach or not. If it is necessary then one possible approach is

- To crudely model the power variability of each instrument "mode" associated to the LTP SOOPs
- To use this modelling to check within LTP that EMC quiet periods are also respected in terms of aggregate power variability
- To subsequently impose this LTP division of power variability on STP planning
  - Via a new allocated resource profile (and new ICD) controlling the allowed power variability over time of each instrument
  - Distributing this new product as an output of LTP together with E-FECS, TMC etc.
  - Using this new product as a constraint check on incoming IORs at STP.

However this is complicated and therefore not preferred unless shown to be necessary.

5.7 Metadata of filename also inside the file as content

[Resolved].
Addressed in section 2.2 and via the resolution of the backup planning addressed in section 5.3.

5.8 Support for PSP events

[Resolved].
Addressed in section 2.4.11.

5.9 Impact of RS-synoptics

Details of RS-synoptics are still in discussion.

For many RS-instruments synoptics would require a relaxation of the rule that RS-instruments can only command during RSWs or RSW_EXTs. I.e. Many RS-instruments cannot simply sit in a “synoptic producing” mode without commanding. This relaxation could be total, either

- removing RS_EXTs completely and allowing free RS-commanding equivalent to how IS commanding works
- or equivalently extending RS_EXTs to cover all time outside of RSWs

However there can be good reasons to make a more targeted relaxation and maintain RSW_EXTs as they are

- Synoptic commanding presumably is a small subset of nominal commanding. This subset could potentially be whitelisted within the mission-planning providing the synoptic periods can still be identified in the EFECS.
- The process for inserting the “flat trim” in the TMCs relies on the identification of periods outside of RSWs and RSW_EXTs. Maintaining this “ flat trim” is appropriate because synoptics are supposed to write to LL only.

No decision on approach was taken yet.

5.10 Star calibrations

[Resolved]
Timing uncertainties at LTP and subsequent orbit knowledge improvements that may move the precise timing of the event are addressed in the new issue of [STAR].

5.11 Distinguishing different flavour of ATT_DIST

Currently the ATT_DIST event does not distinguish the type of disturbance (e.g. magnitude, APE or RPE or both). If such distinction is needed this subsection discusses possible ways to do this

Type attribute
Attribute(s) could be added to identify the “disturbance type”. E.g.:
- APE violations versus RPE violations, which may have different durations and affect different instruments
- To potentially allow e.g. METIS to distinguish “small” disturbances that may be tolerable (if of short duration) versus “large” excursions that may require protective action.
- In the same way as for the attitude disturbance windows, a parameter to identify the type of EMC disturbance is included to allow possible future expansion of these windows into different types of disturbance (e.g. E-field versus Magnetic).

Separate events

Another way of achieving the equivalent separation of classes of disturbance would be to create two new separate events, e.g. ATT_DIST_APE and ATT_DIST_RPE. Given that different types of disturbance event would overlap this second approach may be more clear.

However, operationally we prefer the simplicity/clarity of a single type of attitude disturbance window that applies whenever ANY pointing performance is predicted to not met. Thus this expansion will only be undertaken if it is demonstrated that operationally the simple window cannot met the needs of the mission.