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DOCUMENT

Solar Orbiter SPICE Out-Of-Field Straylight Calibration TN

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CHANGE LOG

Reason for change	Issue	Revision	Date
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CHANGE RECORD

Issue 0	**Revision** 2		
Reason for change	**Date**	**Pages**	**Paragraph(s)**
Clarification on "East" and "West" variants			2

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1 INTRODUCTION

SPICE requires an out-of-field straylight calibration as defined in [SPICE_CAL] section 4.2.5. The calibration is implemented here as a single long (three hour) dwell on **either** the East or West limb.

This is the SPICE equivalent of the TN-0036 catering for the straylight calibration of METIS and SOLO-HI. Whereas METIS and SOLO-HI achieve their calibration via many short offpoints, the SPICE approach instead keeps the spacecraft stable and achieves movement across the Sun via the SPICE scan mirror.

This note is written for calibrations within Cruise Phase and NMP.

This note defines the calibration pattern but does not record in detail when instances of this calibration are scheduled. Instead scheduling information is found:

- For ITs, in the first instance, on the SOC-public science planning pages https://issues.cosmos.esa.int/solarorbiterwiki/pages/viewpage.action?pageId=34047195
- Later, for FD, in the pre-LTP TN from SOC
- Later still, for ITs, in the EFECS and SOOP-kitchen plan

1.1 Reference Documents

[SPICE_CAL] "SPICE Instrument Calibration Plan", SPICE-RAL-PL-0005, Nov 2018, v8_0

1.2 Acronyms

APE	Attitude Pointing Error
CP	Cruise Phase
EFECS	Enhanced Flight Events and Communication Skeleton *Also called planning skeleton. This is a SOC-extended version of the FECS+PTEL that comes from MOC which details the spacecraft events*
FD	Flight Dynamics *Team at ESOC*
FIFO	First-In, First Out
HK	Housekeeping telemetry
IS	In-Situ
LLD	Low-Latency Data *That "thin-slice" of science data that can always be downlinked promptly to ground*
LTP	Long-Term Planning
MOC	Mission Operations Centre. *For Solar Orbiter this is ESOC in Darmstadt.*
MTL	Mission TimeLine *The onboard time-tagged queue from which nominal operations execute*
MTP	Medium-Term Planning
NMP	Nominal Mission Phase
PTEL	Planning Timeline Events *The planning skeleton produced by Flight Dynamics*
PTR	PoinTing Request *Routine phase RSW mechanism for SOC to request pointings to FD*

RPE	Relative Pointing Error
RS	Remote Sensing
RSCW	Remote-Sensing Checkout Window *The checkout windows for RS-instruments in cruise phase*
RSW	Remote-Sensing Window
SOC	Science Operations Centre *For Solar Orbiter this is ESAC near Madrid*
SOOP	Solar Orbiter Observing Plan
SOOP kitchen	The software tool used for collaborative science planning at LTP
SSMM	Solid State Mass Memory
STP	Short-Term Planning
TAC	Turn-Around Calibration *Complements LLD as prompt science link to ground. Because a "fatter slice" of science can come through this (compared to LLD) it is normally OFF, and only enabled for specific activities that need it (those where there is a mandatory tight space->ground->space loop needed), and then only when the downlink can support it.*
TBA	To Be Agreed
TMC	TeleMetry Corridor
TMC-M	TMC-Measured *TMC plus Measured data of actual write rates seen at the SSMM*
VSTP	Very Short Term Planning

2 OVERVIEW OF THE CALIBRATION

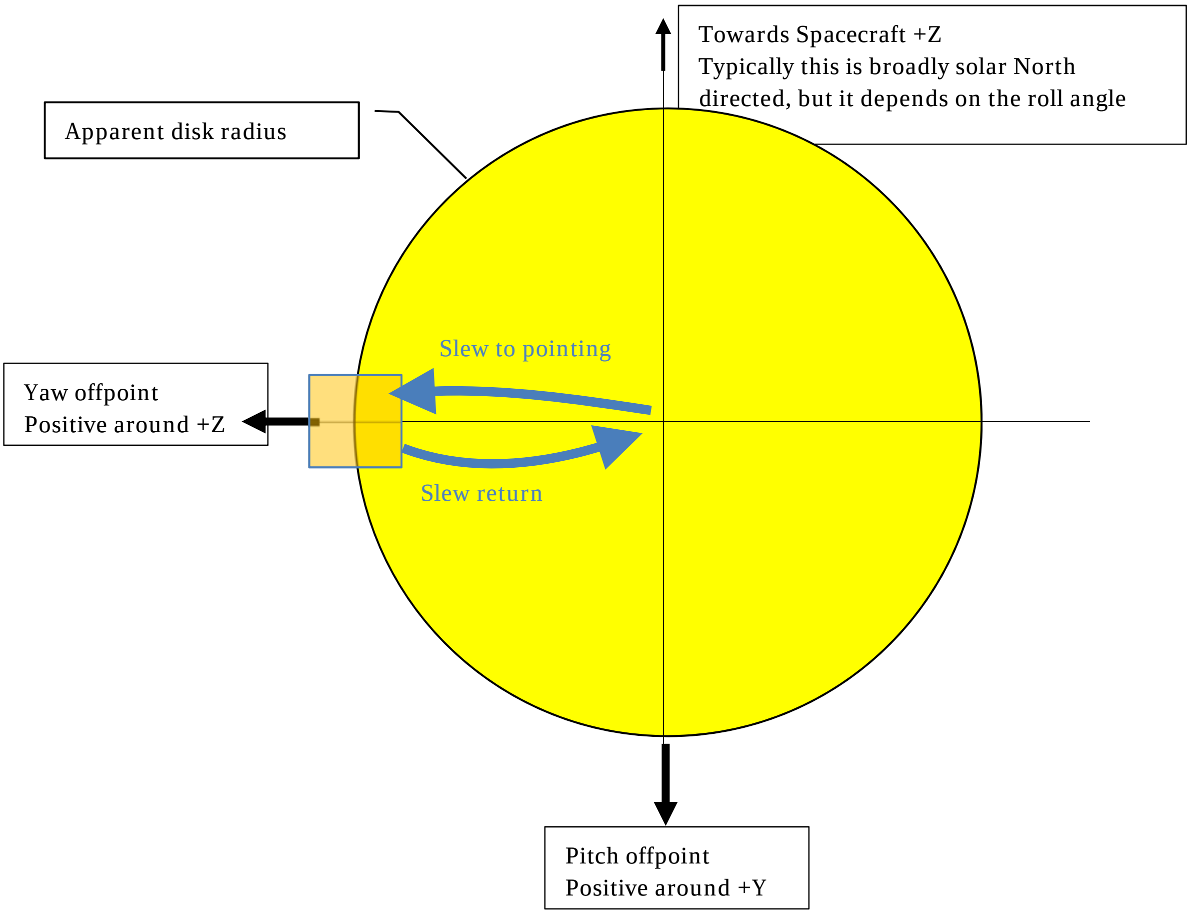

Figure 1, crude off-point diagram of out-of-field calibration if performed on the East limb

Point number	Fraction of apparent sun disk radius in yaw	Fraction of apparent sun disk radius in pitch
1	1	0

Table 1, numeric values for East limb

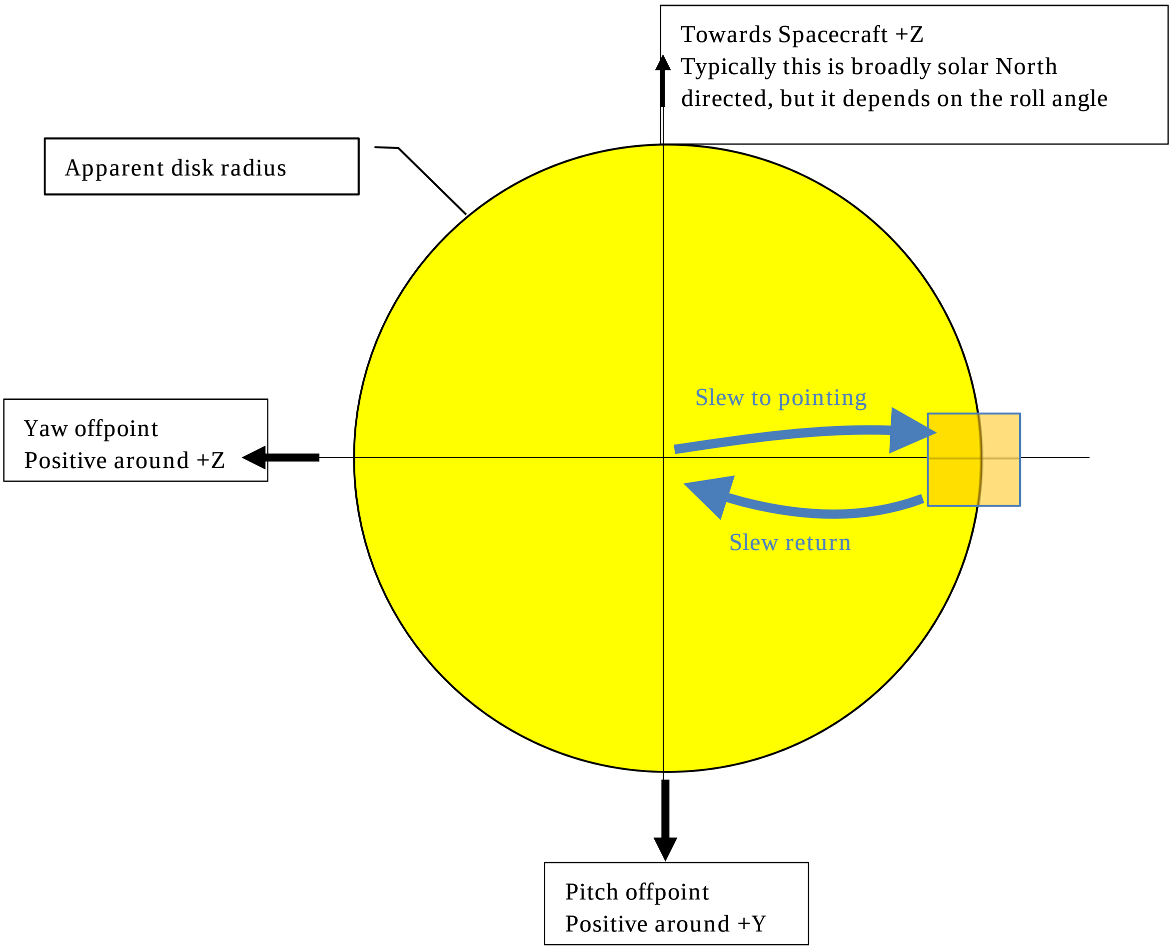

Figure 2, crude off-point diagram of out-of-field calibration if performed on the West limb

Point number	Fraction of apparent sun disk radius in yaw	Fraction of apparent sun disk radius in pitch
1	**-1**	**0**

Table 2, numeric values for West limb

Figure 1 and Figure 2 illustrate the general scheme, former for East limb, latter for West. Table 1 and Table 2 show these off-points numerically. All off-points are defined as a fraction of the limiting angle to the limb.

Clarification on East and West keywords as used in the calibration:
Strictly speaking we are abusing East and West here. The limb position for each variant is defined in SC coordinates – "East" is actually positive yaw and "West" is actually negative yaw. In typical conditions these offpoints do indeed correspond broadly to pointing at the corresponding limb. It's clear that later in the mission when the orbit plane is orientated further from the solar equator then the correspondence is less exact.

Moreover the spacecraft might be at a roll angle of e.g. 180 degrees[1]. In such case the "East" variant will actually point near to the West limb and vice-versa.
In the end "East" and "West" here are just names for the two variants. Each variant preserves the geometry between SPICE axes and how the limb is orientated, regardless of the roll angle.

2.1 Duration

Table 3 shows the timing of the pattern. This timing includes pre- and post- slews.

	Duration (mins)	Start time within pattern (hh:mm)
Slew to 1	5	00:00
Dwell at 1	180	00:05
Slew return	5	03:05
End	-	*03:10*

Table 3, timeline for offpoints

2.2 Placement of the pattern

In Cruise Phase SOC will request the day that the pattern be implemented and FD will place the pattern avoiding

- Passes
- Incompatible platform modes and disturbance events such as wheel-offloadings, appendage movements etc.

The position of the pattern shall be communicated to SOC within the PTEL.
If necessary, SOC will then expand the pattern to component events within the EFECS such that instrument teams can see the individual dwell time explicitly.

2.2.1 Slew time

Solar Orbiter routine planning assumes a fixed worst-case duration for slews. This worst case value is currently assumed to be 5 mins (as visible in Table 3). Any change to this value, e.g. arising during NECP, needs to be communicated from MOC to SOC to ensure that SOC can correctly expand the component parts of the calibration in planning.

2.2.2 Quiescence time

The AOCS includes a flexure filter on the wheel torque demands. If this works correctly then reaction wheel controlled slews will require no quiescence time, so that further overhead (besides slewing) in completing the overall pattern can be avoided. The actual performance of this approach will need to be seen in NECP. As with the previous point, any change in this needs to be communicated MOC to SOC.

2.2.3 As reported in PTEL

PTEL is the planning skeleton that comes to SOC from Flight Dynamics.

[1] The spacecraft can be rolled away from the zero angle for communications reasons. It would be rare, but it can happen that a large roll like this is needed.

Naming of this calibration event is proposed to be CALIB_OFFPOI_OOF
The duration of the calibration event in the PTEL would reflect the duration of the pattern according to Table 3.

An attribute limb_direction is proposed to identify between the two variants. This would have value EAST 0r WEST

2.2.4 As reported in SOOP Kitchen and EFECS pointing enumerations

This particular calibration is simple enough that SOC expansion to atomic POINT_ event s may not be necessary. If it is performed the expansion would be as follows:

- The single pointing is a POINT_LIMB event

3 SIDE ISSUES

The following issues are highlighted to instrument teams for completeness, but are understood not to impact the calibration pattern approach.

3.1 Downlink latency

The scheduling of the pointing pattern does in itself prioritise the science associated to the pattern. By default the science flows through the bulk science store in the normal FIFO way, which may involve significant latency.

In the Cruise Phase for the RSCW-1 the closure of the TM corridor flexibility at the end of the LTP-1 period is expected sufficient to ensure that data comes down adequately before RSCW-2. The later RSCWs of the cruise phase are closer spaced and may require more care. A particular concern here is:

- LTP simulation can be used to establish latency in the modelled scenario. This provides an opportunity to check that data downlink needs prior to next RSCW are met (based on the modelled LTP scenario).
- Subsequently the TM corridors expose flexibility on the TM generation but this flexibility comes at the price of unmodelled increased latency.

In routine phase it is expected that data arising from these calibrations will follow the normal bulk science latency.

In routine the TAC store may be used to "jump the queue" for "turn-around calibrations" but this is not applicable here.

- the calibration is not expected to lead directly to instrument commanding updates
- TAC is subject to significant constraints on when and how it is used. Not least amongst these, the currently foreseen volumes of data on this calibration exceed the baseline sizing of the TAC store.

3.2 APE, RPE etc.

The SC will not succeed to point exactly to where it is commanded, and subsequent knowledge of where it actually went will not be perfect either. This will complicate the analysis of the calibration. Numbers for the specified performance of the spacecraft can be found in the EID-A.

3.3 Aberration

In Cruise phase[2] the calibration is expected to be implemented without correction for aberration. Aberration magnitude in cruise will be similar to that seen from Earth, i.e. ~20 arcsec.

[2] More precisely, whenever the calibration is implemented outside of the PTR mechanism for requesting pointings, which covers the CP, but may also occur in NMP if calibrations are implemented away from RSWs.

3.4 Apparent roll[3] under off-pointing

Apparent roll is **not** expected on this calibration because there is only yaw movement.

[3] Apparent roll is the name given to the (very small) instrument ALOS rotations that can occur within off-pointings.