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| ——— | Solar Orbiter Project | ——— |
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| NECP In-Situ Inter-Instrument Communication Campaign | | |
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| MAG Magnetometer Instrument | | |
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# Scope

This document collects the necessary inputs from the Solar Orbiter in-situ instruments (EPD, MAG, RPW and SWA) ahead of the delivery of sequences of commands (in the form of PDORs) for the in-situ inter-instrument communication (IS-IIC) campaign to be performed in flight during the Near Earth Commissioning Phase (NECP). This activity is referred as IM-IIC in [RD01], as a placeholder of 3 hours duration.

The following table shows for every of the in-situ instruments (according to [RD02]) whether they process other ins-situs’ data present in TC(20,128). The rows represent each instrument’s data destination/processing node, while the columns represent the instrument’s source of data. A shaded cell means that the destination instrument does not process the origin instrument’s data:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Origin** | | | |
|  | **EPD** | **MAG** | **RPW** | **SWA** |
| **EPD** |  | No | Yes | No |
| **MAG** | No |  | Yes | No |
| **RPW** | Yes | Yes |  | Yes |
| **SWA** | No | Yes | Yes |  |

Table 1‑1 SO in-situ instruments IIC data paths

To avoid confusion, from the previous table, EPD and MAG process RPW data; RPW processes EPD, MAG and SWA data; while SWA processes MAG and RPW data. Furthermore, EPD, RPW and SWA also process platform data present in TC(20,128).

Additionally, the following table summarizes the process that every instrument performs on the in-situ data present in TC(20,128):

|  |  |  |
| --- | --- | --- |
| Instrument | Source of data | Processing |
| EPD | RPW | Burst trigger based on the RPW survey burst mode 1 and 2 algorithms (SBM1 and SBM2). |
| MAG | RPW | Burst trigger based on the RPW survey burst mode 1 algorithm (SBM1). |
| RPW | EPD | SBM2 algorithm requires electron flux. |
|  | MAG | SBM1 algorithm requires the magnetic field magnitude. |
|  | SWA | SBM1 algorithm requires the solar wind density and velocity. |
| SWA | MAG | 2D burst mode product (SWA-EAS) generation requires the magnetic field vector. |
|  | RPW | Trigger mode based on the RPW survey burst mode 1 algorithm (SBM1). Only for SWA-EAS. |
|  | RPW | Calculation of on-board moments of the electron distribution function requires of the spacecraft potential measurement. |

Table 1‑2 SO in-situ IIC processing and NECP campaign

The rest of the document contains, in section 3, the capabilities offered by every instrument to manipulate or modify the data included in TC(20,128), as well as the capabilities of dumping the data present in TC(20,128); section 4 lists the different sub-activities intended to be performed during the IS-IIC campaign. It is expected that a future release of the present document includes a flow diagram of the entire IS-IIC campaign, which could be used by each in-situ instrument team as a reference to provide the necessary inputs to ESOC (PDORs).

# Reference and applicable documents

|  |  |  |  |
| --- | --- | --- | --- |
| **Item** | **Reference** | **Description** | **Issue/Revision/Date** |
| RD01 | Payload\_Commissioning\_Needs\_&\_Planning\_16082019\_InstrumentTeams | Solar Orbiter NECP timeline for instruments | 16 August 2019 |
| RD02 | SOL-EST-TN-14523 | Solar Orbiter Instruments Inputs for Inter-Instruments Communication (IIC) Test | Issue 2 Revision 3  04 April 2017 |
| RD03 | RPW-SCI-NTT-000243-LES | Definition of the In-Flight Burst Modes Detection Algorithms | Issue 2 Revision 0  09 December 2013 |

Table 2‑1 Reference and applicable documents

# Instruments TC(20,128) capabilities

The following table summarizes the capabilities offered by each of the in-situ instruments to manipulate or dump the data present in TC(20,128). These information has been taken from [RD02] (for more details, refer to that document). Note that TC(20,128) is produced by the Solar Orbiter On Board Computer (OBC) based on the contents of IIC TM(3,25) packets sent by each instrument (each instrument produces one packet of this type at a certain frequency):

|  |  |  |
| --- | --- | --- |
| Instrument | TC(20,128) data manipulation | TC(20,128) dump |
| EPD | EPD can feed EPD IIC TM(3,25) packet with a test pattern data. | EPD does not offer the capability to dump the contents of TC(20,128). However, EPD can dump the content of the EPD IIC TM(3,25) packet. |
| MAG | MAG can modify the contents of MAG IIC TM(3,25) in two different ways:   * By enabling the Ramp mode. This way the X, Y and Z components of the magnetic field vector take the value of a counter which is incremented at 1920 Hz. * By applying the MAG on-board calibration matrix to the magnetic field vector. This capability allows to modify the module, direction and offset of such vector. | MAG does not offer the capability to dump the contents of TC(20,128). |
| RPW | RPW can feed RPW IIC TM(3,25) packet with a test pattern data. | RPW can dump EPD, MAG, RPW and SWA IIC parameters received via TC(20,128), as well as Platform parameters, at 1Hz, through dedicated TM(3,25) packets. |
| SWA | SWA can feed SWA IIC TM(3,25) packet with a test pattern data. | SWA can dump RPW and MAG IIC parameters received via TC(20,128), as well as Platform parameters, at 1Hz, through a dedicated TM(3,25) packet, containing the data of the last 8 TC(20,128) packets received. |

Table 3‑1 Capabilities of the in-situ instruments to modify and dump TC(20,128) data

# NECP IS-IIC campaign sub-activities

The following table summarizes the sub-activities to be performed during the IS-IIC campaign, additional details are provided in the sections below:

|  |  |
| --- | --- |
| Sub-activity | Description |
| IS-IIC-1 | Reaction of EPD/MAG/SWA on RPW **SBM1 triggered by TC** |
| IS-IIC-2 | Reaction of EPD on RPW **SBM2 triggered by TC** |
| IS-IIC-3 | **SWA-EAS** reaction to **MAG** magnetic field changes |
| IS-IIC-4 | Reaction of EPD/MAG/RPW/SWA to **SBM1** triggered by a discontinuity in the **MAG** vector magnitude |
| IS-IIC-5 | Reaction of EPD/RPW on **SBM2** triggered by **EPD** electron flux |

Table 4‑1 IS-IIC sub-activities

Most of the IS IIC data paths are covered during the IS-IIC campaign, as showed in the next table:

|  |  |  |
| --- | --- | --- |
| Processing node | Source of data | Sub-activity |
| EPD | RPW – SBM1 | IS-IIC-1 and IS-IIC-4 |
|  | RPW – SBM2 | IS-IIC-2 and IS-IIC-5 |
| MAG | RPW – SBM1 | IS-IIC-1 and IS-IIC-4 |
| RPW | EPD – Electron flux | IS-IIC-5 |
|  | MAG – Magnetic field | IS-IIC-4 |
|  | SWA – Density and velocity | n/a |
| SWA | MAG - Magnetic field | IS-IIC-3 |
|  | RPW – SBM1 | IS-IIC-1 and IS-IIC-4 |
|  | RPW – S/C Potential | n/a |

Table 4‑2 Coverage of the IS-IIC campaign

As per the previous table, the following data paths won’t be exercised during the IS-IIC campaign:

* RPW SBM1 trigger based on SWA proton number density and bulk speed vector: SWA can’t produce a discontinuity on these two parameters. SWA can feed the contents of the SWA IIC TM(3,25) with a varying pattern (see [RD02] for more details). In principle, this varying pattern (16 bits counters) could produce a discontinuity after a certain period (every time the counters overflow). However, due to the time constraints of the IS-IIC campaign, it has been agreed not to include a sub-activity to cover this case.
* SWA calculation of on-board moments of the electron distribution function based on the local spacecraft potential measurement given by RPW: provided there is a value in the TC(20, 128) with the local spacecraft potential (V\_SC), SWA’s processing will work. It will be studied over the entire NECP if RPW V\_SC is useful to SWA on-board processing or not.

## IS-IIC-1 RPW SBM1 TC triggered. EPD, MAG and SWA reaction.

The four in-situ instruments will be involved in this sub-activity, that is, EPD, MAG, RPW and SWA, according to the following steps:

1. **RPW**,by feeding the IIC TM(3,25) with test pattern data, can set the SBM1 algorithm parameters to shock detected values.
2. **EPD, MAG and SWA** should react to the RPW shock detection algorithm SBM1. Depending on the instrument:
   1. **EPD:**
      * Has two burst modes which react to RPW SBM1, modes 2 and 3.
      * For mode 2, two sensors go into burst mode (EPT and STEP); for mode 3, one additional sensor (HET) goes into burst mode.
      * Those two modes are triggered when the RPW SBM1 flag is equal to 1, and the RPW SBM1 quality factor (SBM1\_QF) is larger than the configured instruments’ threshold. Additionally, EPD requires that the particle flux measured by EPD is larger than an internal instrument’s threshold.
      * Ideally, modes 2 and 3 should be triggered in isolation during the sub-activity.
      * EPD can configure the minimum time necessary among two consecutive triggered burst modes, through the configuration parameter ‘idle time’. For an ‘idle time’ equals to 30 minutes, for example, the triggered burst modes could trigger every 30 minutes (given that SBM1 algorithm parameters remain in detection values). The default value for the ‘idle time’ of modes 2 and 3 is 15 minutes.
      * Besides disabling the reaction to the RPW SBM1 algorithm, EPD can disable the generation of burst telemetry to the S/C (the latest method is the preferred in case that for some reason the reaction of EPD to RPW SBM1 needs to be disabled).
   2. **MAG**:
      * A transition to burst mode from MAG is expected when RPW SBM1 flag rises from 0 to 1, and RPW SBM1 quality factor (SBM1\_QF) is larger than the configured instruments’ threshold.
      * MAG stays in the triggered burst mode for a configurable amount of time, which by default is equal to 10 minutes.
      * Additionally, when triggered into burst mode, MAG sends burst data for the last 6 minutes, which is stored in an internal buffer.
      * MAG has no limitation in the number of times it triggers into burst mode, so every time it is not in burst mode and the trigger condition is met, MAG triggers.
   3. **SWA**:
      * A transition to trigger mode from SWA is expected when the RPW SBM1 flag rises from 0 to 1, and the RPW SBM1 quality factor (SBM1\_QF) is larger than the configured instruments’ threshold.
      * The trigger mode only affects SWA-EAS.
      * SWA-PAS can react to RPW SBM1, however this reaction will be kept disabled during the IS-IIC campaign.

Different cases may be defined, for example one with a threshold value of 0 within each instrument, to ensure the trigger reaction; and another one with a threshold set to the maximum value, to avoid the trigger reaction.

## IS-IIC-2 RPW SBM2 TC triggered. EPD reaction.

RPW and EPD will be involved in this sub-activity, according to the following steps:

1. **RPW**,by feeding the IIC TM(3,25) with test pattern data, can set the SBM2 algorithm parameters to those obtained when an in-situ Type III burst is observed. By default, RPW would remain in SBM2 mode for 120 minutes, once triggered. The duration of SBM2 should be reduced however, because the IS-IIC campaign is time limited. A duration of 15 minutes has been proposed.
2. **EPD** should react to the RPW shock detection algorithm SBM2, according to the following bullet points:
   * EPD has one burst mode which react to RPW SBM2: mode 5 burst.
   * Mode 5 burst is triggered based on RPW SBM2 data in TC(20,128) only, i.e., it does not perform any additional check on EPD data, as burst modes 2 and 3 do (see section 4.1 for more details).
   * EPD can configure the minimum time necessary among two consecutive triggered burst modes, through the configuration parameter ‘idle time’. For an ‘idle time’ equals to 30 minutes, for example, the triggered burst mode could be triggered every 30 minutes. The default value for mode 5 idle time has not been confirmed, but 15 minutes seems reasonable.
   * Besides disabling the reaction to the RPW SBM2 algorithm, EPD can disable the generation of burst telemetry to the S/C (the latest method is the preferred in case for some reason the reaction to RPW SBM1 needs to be disabled).

Different cases may be defined, for example one with a threshold value of 0, to ensure the trigger reaction; and another one with a threshold set to the maximum value, to avoid the trigger reaction.

## IS-IIC-3 SWA-EAS reaction to MAG magnetic field changes

MAG and SWA will be involved in this sub-activity, according to the following steps:

1. **MAG**, by updating the on-board calibration matrix, can change the magnitude and direction of the magnetic field vector present in TC(20, 128), according to the following bullet points:
   * MAG populates IIC TM(3,25) with the measured magnetic field in S/C coordinates in units of nT. To that end, the measured magnetic field is calibrated on-board the instrument according to the following formula:
   * The terms C and O can be updated by telecommand.
   * By making the calibration matrix a zero matrix, the value of the magnetic field vector in TC(20, 128) can be pre-set to the value of the offset vector O.
2. **SWA-EAS** reads the TC(20,128) MAG magnetic field vector 8 times every second. When SWA is commanded into Burst Mode, SWA-EAS will use this vector to determine which EAS look direction to use.

During this sub-activity, EPD, MAG, RPW and SWA reactions to RPW SBM1 trigger should be disabled, to avoid undesired triggers at this point.

## IS-IIC-4 RPW SBM1 MAG triggered. EPD, MAG, RPW and SWA reaction

All the in-situ instruments (EPD, MAG, RPW and SWA) will be involved in this sub-activity, according to the following steps:

1. **MAG**, by updating the on-board calibration matrix (see section 4.3) can produce a discontinuity in the TC(20, 128) magnetic field vector magnitude.
2. **RPW SBM1**, in accordance with [RD03], can detect a shock ΔT\_Buffer (see [RD03] nomenclature) minutes after a discontinuity in the TC(20, 128) magnetic field vector magnitude is observed. To that end, RPW needs to change the coefficients in the triggering criterion to ensure a trigger based on the magnetic field discontinuity (independently of the values of the proton number density and the bulk speed vector provided by SWA within the TC(20, 128)). Coefficients values of alpha=1, beta=0, gamma=0 (see [RD03]) should make RPW to ignore SWA data. Followed by the shock detection RPW will, according to [RD03]:
   1. Send to the S/C the RPW burst data of interest, stored in a rolling buffer internal to the instrument with a length of 13 minutes maximum, centred at the time of the shock occurrence.
   2. Set the SBM1\_FLAG in the TC(20, 128) to 1.
   3. Set the value of the quality factor SBM1\_QF in the TC(20, 128).
3. **EPD, MAG and SWA** should react to the RPW shock detection algorithm SBM1, in accordance with section 4.1.

## IS-IIC-5 RPW SBM2 EPD triggered. EPD and RPW reaction

EPD and RPW will be involved in this sub-activity, according to the following steps:

1. **EPD**, by feeding IIC TM(3,25) with a test pattern data, can set the EPD parameters in TC(20,128) to any desired value (including the electron and proton fluxes, see [RD02] for more details). The following restrictions apply:
   1. The parameter ‘Heartbeat’ in the EPD IIC TM(3,25) will be increased in every packet, independently on whether the remaining parameters have been previously set by TC or not.
   2. The ‘validity flags’ parameters present in the EPD IIC TM(3,25) indicate whether the electron and proton fluxes present in IIC TM(3,25) have been updated since the generation of the last packet or not. If the fluxes have not been updated (by TC, for example), the ‘validity flags’ will take a value of 0.
2. The **RPW SBM2** detection algorithm isperformedin two distinguish steps (in accordance with [RD03]):
   1. RPW, after Δ*TEPD* minutes (20 minutes by default), will enter into SBM2 mode, given certain values in the EPD TC(20,128) fluxes parameters. RPW will remain in this mode for a duration of Δ*TSBM2* (120 minutes by default).
   2. Once RPW is in SBM2 mode, in order to notify through TC(20,128) that an in-situ Type III burst has been observed, the quantification of the Langmuir Waves activity by RPW-TDS should exceed a configurable threshold. For the purpose of this sub-activity, setting RPW *NLW-tresh* to 0 would lead to a SBM2 detection of RPW after Δ*TLW* minutes (20 minutes by default) of entering SBM2 mode. After a SBM2 detection, RPW will:
      * Stay in SBM2 mode for the remaining duration of Δ*TSBM2.*
      * Notify of the SBM2 detection through TC(20,128).
3. **EPD** should react to the RPW SBM2 detection, in accordance with section 4.2.