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DOCUMENT

Solar Orbiter Instrument Operation Request Interface Control Document (IOR ICD)

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CHANGE RECORD

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Table of contents:

1 INTRODUCTION

This document defines the mission planning interface between Instrument Teams and the Solar Orbiter SOC, by which the planned operations for each instrument are submitted for routine operations. The files passing across this interface are called "**Instrument Operational Requests**" or **IORs**. This commanding interface is active in Cruise Phase, NMP and EMP (i.e. after NECP).

The format of the ICD is derived from the Solar Orbiter PLID [RD-1], which is in turn a tailoring of the generic ESOC infrastructure mission planning document "Planning Files Interface Control Document" [RD-2].

This ICD is not strictly a "tailoring" of [RD-1] because formally the PI-SOC interface lies outside the scope of the PLID. However it is sensible to maintain these interface formats as common as possible. It is acknowledged that there are fields within this ICD that are redundant when viewed solely within the scope/context of the IOR. This is a consequence of maintaining consistency with the generic ICDs.

1.1 IOR context

Outside of NECP and dedicated special operations and/or contingency recoveries, the instrument operations for Solar Orbiter are integrated into a single consistent plan at SOC and then forwarded to the OGS. This occurs in Medium-Term Planning (MTP) and Short-Term Planning (STP) cycles[1].

In these phases instrument teams plan their operations

- According to the scientific goals of the specific period, types of pointing target (for RSWs) and data quotas as decided by the SWT and as elaborated in i) the Science Activity Plan, and then ii) the SOOPs at a greater level of detail.
- According to the windows and constraints communicated in the planning skeleton file, and resource allocations communicated by corresponding files.

The instrument teams submit their planned instrument commanding to the SOC in an **IOR**. For commonality reasons this interface retains the same general format as the PDOR interface with OGS, but implements a restricted subset of functionality[2].

At the SOC the plans are integrated together and checked for consistency and resource constraints (example: power consumption, predicted SSMM usage). Problems at this stage are resolved, normally by discussion with the Instrument Team and submission of a revised IOR.

[1] The LTP process is different, being driven more by coordination than by detailed commanding products.

[2] Some elements of the PDOR interface are necessarily excluded. For example all IOR commanding is directed to the MTL.

Within NMP and EMP phases the scope of the planning cycles the IOR is used as follows:

<table>
<tr><th>Planning cycle</th><th>Use of IOR</th></tr>
<tr><td>LTP</td><td>No IOR.
LTP is performed without this level of detail of specific instrument commanding inputs.</td></tr>
<tr><td>MTP</td><td>Preliminary MTP IORs are created as preparation for the SOWG MTP meeting.
Main MTP IORs are refined as necessary following the SOWG MTP meeting.

Only the main IORs are fed downstream from SOC to the MOC.
The MTP IORs are used to come to an integrated and robust set of operations. Once this is done the instrument resource envelopes are considered frozen[3].</td></tr>
<tr><td>STP</td><td>The STP IORs are processed into telecommands that are uploaded to the spacecraft. These IORs are required to fit the resource profile of the final MTP IORs.</td></tr>
<tr><td>VSTP</td><td>VSTP commanding is not covered in this version of the ICD. A limited ability to add commanding at VSTP will be added in a future issue with the following caveats:
Covers a restricted list of pre-agreed sequences only
Only addition of new commanding is allowed (no change whatsoever to the submitted STP commanding)
Resource neutral activity only (power, data, EMC noise)
No criticality if sequences not sent (VSTP commanding is best-effort and not guaranteed, e.g. station failure).
In lieu of proper ICD coverage, the following points can be made
We expect any VSTP IOR to be a delta-IOR, in that is only contains the new sequence calls (it does not repeat what was already delivered in STP).
We expect that the empty time-slots where VSTP commanding will/may occur have already identified at STP in the STP-IOR according to some TBD new element.</td></tr>
</table>

[3] Part of the rationale here being to prevent that tuning of one instrument's planned ops between MTP and STP causes another instrument's un-tuned MTP plan to become invalid at STP.

1.2 Reference Documents

[RD-1] "Solar Orbiter Planning Interface Control Document (PLID)", Luca Michienzi (ESOC), SOL-ESC-IF-05010, v1_0, May 2013
[RD-2] "Planning Files Interface Control Document", Arek Kowalczyk (ESOC), MDS-MCS-SW-ICD-1001-OPS-GD, v3_1, Oct 2012

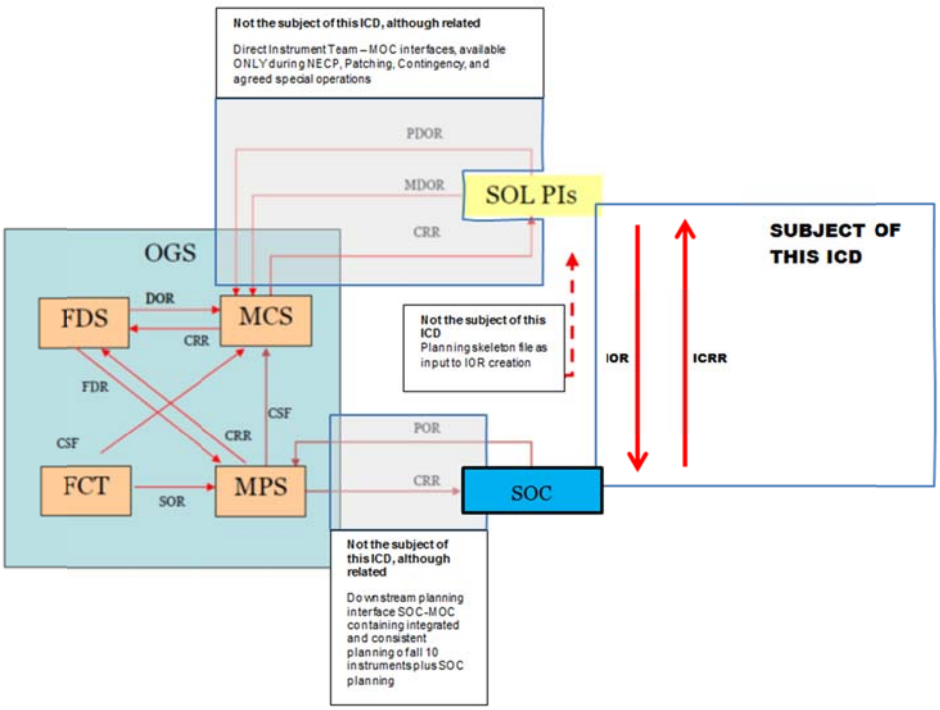

Figure 1, IOR interface in context (derived from PLID figure 2)

2 DELIVERY ASPECTS

2.1 Delivery mechanism

It is foreseen that the GFTS mechanism is used to transfer IORs from Instrument Teams to SOC.

2.2 Delivery timing and time-span

2.2.1 NMP and EMP

MTP IORs are 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[4]. Working backwards from the start of execution of this period, T:

- Final MTP IORs are delivered to SOC at T-6 weeks.
- The SOWG meeting where the initial MTP IORs are iterated is scheduled sometime within a 4 week window between T-8 weeks and T-12 weeks.
- Preliminary MTP IORs are delivered to SOC at T-16 weeks

STP IORs are delivered in a batch to cover a time-range of 1 week, except for RSW periods, where the time-range is extended such that the whole 10 day period shall be delivered together[5].

This time-range of execution begins on a Saturday, at the **end of the pass** (as recorded by the Planning Skelelton), and extends to the equivalent start point of the next time-range. Instrument-teams shall ensure that all commanding delivered for a given planning cycle shall lie exclusively inside the relevant time-range. This constraint applies both at the level of:

- The sequence call times contained in the IOR
- The individual command times that result once the sequences are expanded to commands

Additionally instrument-teams shall ensure

- The time-range constraints shall be met also once Section 6 is taken into account. Practically-speaking this can be easily achieved by ensuring that the final 1 second of the time-range is clear of all commanding.

The STP IOR files shall be delivered to SOC on the Tuesday 10 days prior to this Saturday. This gives time to process the IORs and iterate if necessary with Instrument Teams prior to delivery to MOC at 4 days prior.

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[4] 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.

[5] N.b. Since the RSWs are not necessarily aligned to Saturdays, the extended range of a single RSW could be up to 16 days. If the same approach is maintained for two concatenated RSWs then the maximum range becomes 26 days.

2.2.2 Cruise Phase

In principle the Cruise Phase mission planning works the same way as NMP/EMP. The one difference is because of the nature and wide separation of RSCWs, for the six RS-instruments no STP is considered necessary.

3 DETAILED FORMAT

Each IOR file is an XML file with structure as defined in the following subsections.

Within the tables the following abbreviations are used:
E/A Element/Attribute

Need
M Mandatory
O Optional
Q Qualified, the need for the field depends on other elements, as described

3.1 Command Request File Format

3.1.1 Header

Field	**E/A**	**Type**	**Description**	**Need**
type	A	string	Enumerates the filetype. For IORs this shall be set to "**IOR**"[6]	M
formatVersion	A	integer	"1"	M
genTime	E	string	File generation time in format YYYY-DDDThh:mm:ss Z *Subseconds are not supported in the IOR*	M
validityRange	E	complex	See below	M

The validity range complex element contains the following:

Field	**E/A**	**Type**	**Description**	**Need**
startTime	E	string	YYYY-DDDThh:mm:ss Z *Subseconds are not supported in the IOR*	M
stopTime	E	string	YYYY-DDDThh:mm:ss Z *Subseconds are not supported in the IOR*	M

3.1.2 Occurrence List

Within the IOR every occurrence is a sequence call. The sequences called are defined in the instrument MIB.

First an occurrence List is defined

Field	**E/**	**Type**	**Description**	**Need**

[6] N.b. this is not an allowed enumeration within the [PLID]. As mentioned before the IOR ICD is not strictly a tailoring of the PLID.

	A			
count	A	integer	A count of the number of sequence calls contained in the occurrence list	M
creationTime	A	string	The creation time of the occurrence list in absolute time format YYYY-DDDThh:mm:ss Z	M
author	E	string	Used to identify the user that created the IOR. For the internal use of the instrument-team.	M

Then each occurrence contains the following:

Field	E / A	Type	Description	Need
name	A	string	The name of the sequence. This must match exactly the 8 character CSF_NAME of the sequence in the MIB	M
passID	E	string	To be left blank	M
uniqueID	E	string	See section 3.1.3[7]	M
source	E	string	Indicates the Instrument Team "SOED" EPD "SOEU" EUI "SOMG" MAG "SOMT" METIS "SOPH" PHI "SORP" RPW "SOSP" SPICE "SOHI" SOLO-HI "SOSX" STIX "SOSW" SWA	M
destination	E	string	"R" meaning routine	M
executionTime	E	complex	See below	M
crfParameterList	E	complex	See below. Mandatory if the sequence call requires parameters.	Q

The executionTime complex element is composed of the following:

Field	E / A	Type	Description	Need
actionTime	A	string	Absolute time at which the sequence is	M

[7] To be noted that this ID reference is not available onboard (it is not part of the CCSDS TC structure that is uplinked).

			requested to be begun onboard. YYYY-DDDThh:mm:ss Z *Subseconds are not supported in the IOR* *See also section 6*	

The crfParameterList complex element is composed of the following:

Field	**E / A**	**Type**	**Description**	**Need**
count	A	integer	A count of the number of parameters to be specified for the sequence call.	M
crfParameter	E	Complex	One element for each formal parameter of the sequence in question. These shall be ordered in the same order as the formal parameters of this sequence in the MIB (i.e. according to the CSP_FPNUM)	M

The crfParameter complex element is composed of the following:

Field	**E / A**	**Type**	**Description**	**Need**
name	A	string	This field must exactly match the MIB CSP_FPNAME	M
position	A	integer	Defines the position of the parameter in terms of the ordering specified in the database if applicable. This is so there is no ambiguity in case a given sequence has multiple instances of a given parameter. The first parameter shall have position 1.	M
unit	A	string	For engineering parameters: if the unit is given in the MIB database then the same unit must be specified here, and if the unit is not present in the database then it must also be absent from the CRF file.	Q
description	E	string	Comment field	O
value	E	string	If this field is omitted then the default value (specified in the MIB) will be used, unless no default is defined in which case the IOR is invalid. The format to be used to specify the parameter value shall comply with the parameter type for raw values, and with the calibration type for engineering values.	Q

			This field is **mandatory** if the representation is specified.	
representation	A	string	This field specifies whether the value is supplied in the native format of the parameter, or in a calibrated form. • "Raw": The value is supplied in uncalibrated form, i.e. no decalibration is needed to encode the parameter into the uplink. N.b. Raw parameters are not necessarily unsigned int. It depends on native format of the parameter defined via the MIB CPC_PTC and CPC_PFC. • "Engineering". The value is supplied in a calibrated form, which assumes decalibration prior to encoding on the uplink. Depending on the type of parameter calibration (e.g. textual or numeric) the engineering value can be different formats.	Q
radix	A	string	The radix must be specified for all Raw parameters. It must be omitted for all engineering parameters. For **unsigned integer** raw parameters it can take one of the following • "Decimal" • "Hexadecimal" • "Octal" For **all other** raw parameter types it must be "Decimal"	Q

3.1.3 Unique ID

The usage of the Unique ID is not finalised. This section gives the preliminary baseline.

The following rules shall be followed for the definition of the Unique ID.

- It shall be limited to 20 characters
- The first 4 characters shall identify the source (same as for the subsequent field[8])
- The last (up to) 16 characters shall contain a numeric value, unique for this source

[8] This redundancy of source information is necessary to allow the planning system to search on a single field.

The Unique ID is a facility of the IOR with two general goals:

- To help SOC and MOC to track the evolution between MTP and STP in terms of "what has moved? " and "what is new?"
- To help instrument teams track "observations" between planning products and TC History.

The concept for this ID is that it identifies a self-contained scientific "observation" or meaningful macro-level unit of science acquisition[9]. It is accepted that this definition is vague and the details of the Unique ID usage will vary instrument to instrument. For some instruments it could be considered an "Observation-ID". Often it will be that a group of consecutive sequences share the same ID because they work together to achieve a particular operation. Depending on how the instrument's operations are organised it may or may not be the case that the Unique ID is redundant with the IOR granularity concept of Section 5.

Conceptually the idea is that the same Unique ID should be maintained between MTP and STP planning cycles when the "operation" that the ID belongs to is still present, even if parameter details or execution time have changed. Newly inserted operations at STP, of course require new unique IDs.

The Unique ID appears in the Telecommand History data provided by OGS. This provides one means for instrument teams to find the commanding status (once the commands have been dispatched to the Spacecraft)[10]. Note that the unique IDs are not uplinked and are therefore not available onboard[11].

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[9] I.e. not necessarily, or not usually, unique per sequence.

[10] Of course for the Solar Orbiter mission only very minor time-shifting of IOR timings occur within the planning stream so equally the executionTime provides a key to search for specific operations

[11] Although nothing stops command parameters communicating an "observation ID" to the instrument to use onboard. Instruments that have foreseen functionality like this may find it useful to match the IOR unique ID to their onboard ID.

4 USE OF IOR RESOURCE PROFILES

In common with ESA planetary mission planning approach, spacecraft resource usage will be checked at MOC/SOC. These resources include

- Data production onto Spacewire
- Power
- EMC quietness

For Solar Orbiter, the baseline approach is to perform these checks by processing the IORs submitted by the instrument teams, using a SOC model of the instrument behaviour derived from IUMs and discussion.

For certain instruments this parsing of the IOR to deduce approximate resources may be impossible. Therefore, on **a case-by-case basis**, and in agreement with MOC and SOC, instruments may be permitted to submit their own resource estimate(s), as a substitute for the independently computed resource estimate, as a component of the IOR. Where such is agreed it is recorded below.

4.1 SOLO-HI use of IOR resource profiles

SOLO-HI operations run from a schedule within the instrument, elements of the schedule being loaded as an instrument-level file transfer. This creates two problems

- resource usage implicit in the IOR is completely opaque
- the MTL execution times are not directly connected to the resource usage times, being the time the schedule file is transferred to the instrument across Spacewire, not the time that the schedule will execute.

Therefore it is agreed to support SOLO-HI profile definitions as follows:

4.1.1 SOLO-HI Profile definition

SOLO-HI profiles exist within a dedicated sequence call (i.e. occurrence element), those sole role is to carry the profile data. This sequence containing the profiles shall not be defined in the MIB and carries no commanding. This sequence has name=*TBC*.

There shall be one such profile-dedicated sequence call per IOR file. This sequence call contains only a single profileList complex element containing a series of <time, data> pairs in increasing time order, where the time is a relative time with respect to the executionTime of the sequence. For SOLO-HI this execution time is special in that it shows the time of the operation in SOLO-HI that consumes resources (other SOLO-HI executionTimes are the time of the transfer of the schedule file from OBC to SOLO-HI across SpW).

Each pair also has a type indicating “SOHI_Data” or “SOHI_Power”. These two types are interleaved within the list to ensure monotonic increasing time. No two pairs of the same type shall have the same time offset value. The offset times shall be positive, and limited to the time validity range of the IOR – this has consequences for the placement of the profile carrying sequence within the IOR time validity range since no profile pair can precede this.

For Data points

The proposed baseline is one point per day (equivalent to one point per IOR file). A more graduated set of data points could be agreed if useful. Each point represents the total **science** data volume written to SpW since the previous point. Units shall be MiB.

For Power points

A new point shall be present at each significant change in (5 min average) power consumption, plus one point corresponding to the start time. Units shall be Watts. The power is as drawn from the spacecraft primary (i.e. including convertor losses). It is assuming nominal SC bus voltage.

Example:

```
<profileList count=”4”>
        <profile type=”SOHI_Power”>
                <timeOffset>00:00:00</timeOffset>
                <value> 12.9 </value>
        <profile type=”SOHI_Power”>
                <timeOffset>03:00:00</timeOffset>
                <value> 8.8 </value>
        <profile type=”SOHI_Power”>
                <timeOffset>15:00:00</timeOffset>
                <value> 12.9 </value>
        <profile type=”SOHI_Data”>
                <timeOffset>23:59:59</timeOffset>
                <value> 222.1 </value>
```

5 IOR GRANULARITY AND TIMELINE-REENTRY

During a contingency condition on an instrument, commands to the instrument may be lost. Some instruments will have complex commanding in the MTL, where current commands assume the successful execution of preceding commands. In these cases the point of re-entry into the running MTL for an instrument that was in contingency cannot be performed arbitrarily, and has to be done at a suitable point.

i. For instruments requiring control of the re-entry into MTL, the granularity of the IOR shall be used to convey this information. I.e. the start of a new individual IOR file is used to indicate a usable re-entry point. It is recommended that **at least** one such point occurs each day of nominal operations to reduce delays in restarting an instrument's science operations. Where this approach is used, the first IOR file of a planning period must also be a legitimate re-entry point. This is the one-point in each planning period where the positioning of a re-entry point is time-constrained.
ii. For instruments that don't require any control of the re-entry into the MTL, a granularity of one individual IOR file every 24 hours is proposed.

It is assumed that instruments will make clear in their User Manuals (and specifically their contingency recovery procedures) whether their re-entry into the MTL needs to be controlled in this way or not.

6 TIME-TAGGING AND MTL LOADING

6.1 MTL-load levelling

The spacecraft MTL has a limit on the number of TCs that can exist within a single execution slot in the MTL[12]. In order to avoid that any MTL overload situation can occur in-flight, the following approach is adopted.

- The sequences calls shall be time-tagged only in whole seconds
- The sequences called in the IORs contain command delta-times in the database only in whole number of seconds[13]

- The SOC shall apply a specific time-offset (<1 second) to each instrument's timestamps to spread the commands of the various instruments. See Table 1.

Time offset applied at SOC	Instrument
0 (no offset)	EPD, MAG
+0.125 sec	EUI
+0.250 sec	METIS
+0.375 sec	PHI
+0.500 sec	RPW, SWA
+0.625 sec	SOLO-HI
+0.750 sec	SPICE
+0.875 sec	STIX

Table 1, Provisional allocation of time-offsets applied at SOC

Consequences of this approach:
- The actual execution time of an operation will not exactly match the UTC given in the IOR (but with offset less than 1 second)
- In general instruments cannot arrange to execute a particular MTL-commanded operation at exactly the same instant[14].

6.1.1 Aside on clock drift

A fine detail also worthy of note in this context:-
The execution slots in the IOR exist in "UTC ticks". The onboard execution slots exist in "OBT ticks". The mapping between these time systems in performed transparently within the MOC. Inevitably this means that besides the deterministic time offset described above,

[12] Max 5 TCs within a given execution slot. Slots occur every 0.125 seconds.
[13] This means that the optional millisecond sub-field within CSS_EXTIME of the MIB shall be set to "000" or not used.
[14] The mechanism used by certain IS instruments to synchronise acquisitions according to a modulo operation applied on the raw OBT (as seen at the instrument) is not MTL-commanded, and is not affected by this constraint.

there can be up to a +/-0.0625 sec offset in the actual execution time of a command introduced in the mapping from UTC ticks to OBT ticks. Normally speaking this UTC->OBT offset is consistent and 1:1, but occasionally the onboard clock will have drifted such that it is approximately half-way between UTC ticks. As the clock drifts across this midpoint there can be a point in time where the mapping “flicks” from e.g round-up to round-down, and in this instant the mapping is not 1:1.

This is not foreseen to be a problem.

- This was the reason in Table 1 to separate the execution slots which contain two instruments such that they are not adjacent. This minimises the max. TC load that can occur (arising from IOR commanding) instantaneously in this special case to 3 TCs in a single slot.
- The ordering of TCs per instrument is still preserved, even in this special case, thanks to the restrictions on 1 second commanding. The actual delta time between two TCs nominally separated by 1 sec could (rarely) drop to 0.875 sec (or equivalently increase to 1.125 sec) due to this effect.