ALCATEL SPACE

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# NOTE

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**Objet : Herschel Planck Data Rates**

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# 1. SCOPE

The purpose of this note is to identify if the data rates requested by the instruments are compatible with the MIL-1553 bus and ESA Packet Structure Protocol and with the mass memory and RF downlink constraints.

This technical note provides the first assessment of the data traffic on the MIL-1553 data bus on the Herschel and Planck satellites.

In addition the maximum data rates on the MIL-1553 bus have been identified assuming the absolute minimum of non-payload data traffic, allowing the payloads almost the full capacity of the bus for use in special "burst mode" situations.

# 2. DOCUMENTS

## 2.1 APPLICABLE DOCUMENTS

### 2.1.1 ESA Applicable Documents

AD-1 Instrument Interface Document Part B Instrument PACS SCI-PT-IIDB/PACS-02126 Issue 1/1 MPEO

AD-2 Instrument Interface Document Part B Instrument HIFI SCI-PT-IIDB/HIFI-02125 Issue 1/0

AD-3 Instrument Interface Document Part B Instrument SPIRE SCI-PT-IIDB/SPIRE-02124 Issue 1/0

AD-4 Instrument Interface Document Part B Instrument HFI SCI-PT-IIDB/HFI-04141 Issue 1/0

AD-5 Instrument Interface Document Part B Instrument LFI PL-LFI-PST-TN-012 Issue 1/0

AD-6 Instrument Interface Document Part B Sorption Cooler PL-LFI-PST-TN-011 Issue 1/0

AD-7 Instrument Interface Document Part A SCI-PT-IIDA-04624 Issue 1/0

AD-8 FIRST/PLANCK System Requirements Specifications SCI-PT-RS-05991 Issue 1/0

AD-9 Packet Structure Interface Control Document SCI-PT-ICD-7527 Issue 1/0

### 2.1.2 Other Applicable Documents

AD-10 Aircraft Internal Time Division Command/Response Multiplex Data Bus MIL-STD-1553b

# 3. INTRODUCTION

There are three factors which affect and limit the internal bus datarate, 1) the MIL-1553 and the ESA packet Structure, 2) the size of the mass memory and 3) the RF downlink capacity and contact time with ground.

Strictly speaking only point 1 limits the internal bus datarate, however points 2 and 3 will determine for how long this data may be sustained before filling the mass memory or having so much data on-board that it cannot be downlinked within the available ground contact time.

This note will justify the size of the mass memory, and propose the maximum amount of storage data area for the instruments. This memory allocation coupled with the knowledge of the nominal and maximum burst capacities of the MIL-1553 databus and packet structure should permit the instruments to determine the best use of the on-board resources and enable them to propose instrument operating modes.

## 3.1 DATA BUS

The present requirements for the datarates is expressed in kbps (kilobits per second). This method is not totally correct for a MIL-1553 bus due to it's protocol overhead. The number of bits per second on the data bus may be high, the number of useful bits (real data) will be lower due to the overhead due to the packet control. This situation is further aggravated by the application of another packet structure (as defined by ESA) on top of the MIL-1553 bus protocol. Hence there may be confusion when the data rate is expressed in kbps – does this mean useful data or the total data rate including the overheads due to the packetization ?

The following chapters will present the subframe concept for the implementation of the 1553 protocol (as defined in AD-9), and will conclude with subframe allocation per instrument. Datarates in kbps are also shown, but these figures assume that all available subframe capacity is full of useful data, these kbps figures are only provided to give a cross check with the requirements to demonstrate that the proposed allocation is in-line with the original requirements.

## 3.2 MASS MEMORY

The driver which has been used for the Mass Memory sizing is : the Mass Memory shall be capable to store the maximum average data rate from instruments (science+HK) and spacecraft over 48 hours.

This note will detail the amount of storage memory currently implemented, and the average data rate which corresponds to this amount.

## 3.3 DOWNLINK

The driver for the downlink sizing is : the downlink performance shall permit the transmission in the allocated time period (less than 3 hours (typically 2hrs 20mins) per satellite) of the data acquired and stored over the past 24 hours. It shall also cope with the simultaneous transmission of the data acquired in real time.

The following will recall the link performance figures, in line with the Mass Memory sizing.

# 4. OVERVIEW OF PACKET STRUCTURE

While AD-9 and AD-10 provide full details of the MIL-1553 data bus and the superimposed ESA packet protocol the following paragraphs provide the reader with the Alcatel understanding of the specifications.

The MIL-1553 bus is a serial, full multiplex bus running at 1Mb/s. At 1553 level data is moved around as 20 bit words, of which 16 bits are useful data, the other 3 bits are for synchronisation and 1bit for parity check. The MIL-1553 protocol requests control words and data words. A control word will be a word which may specify the type of data for up to the next 32 MIL-1553 words. A MIL-1553 message may be up to 32 words long, that means 32 x 20 bits = 640 bits of which only 16/20 bits are useful = 512 bits. In addition to the control word overhead there are also delays on the bus which are identified as TBD in AD-9. However AD-9 simplifies the life for the bus user and insulates the user from the MIL-1553 constraints by specifying a higher level protocol. AD-9 introduces the notion of Frames, Subframes and Message Slots.

From AD-9 a 1 second interval is defined as 1 FRAME. This FRAME is divided by 64 to produce a subframe, the resulting time duration of a subframe is 15.625mS.

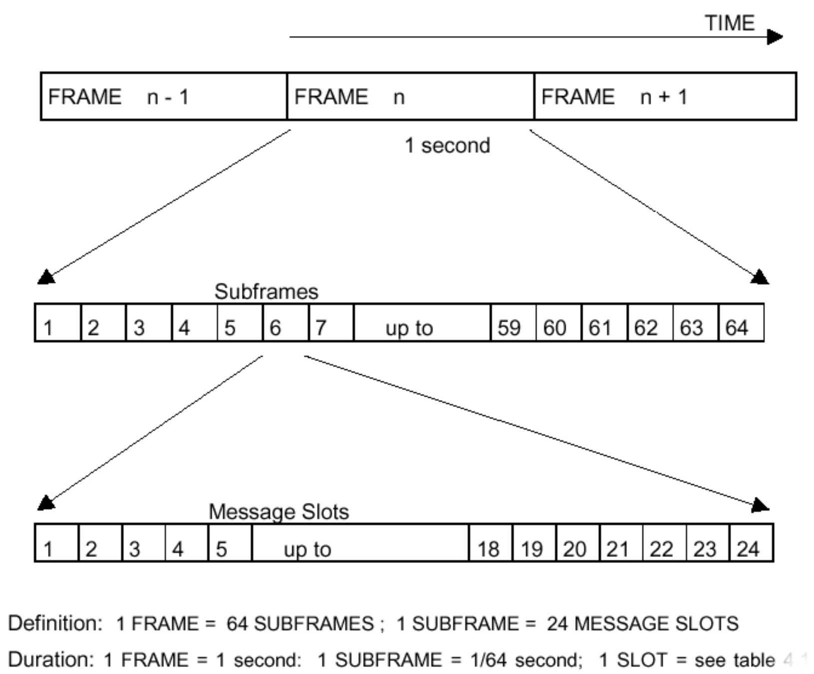


Figure 4-1 Frame, Subframe & Slots

| Slot No. | Content/ Purpose | Duration in micro seconds |
|---|---|---|
| 1 | Subframe synchronization | 150 |
| 2 | Command/ Acquisition Slot | 750 |
| 3 | Command/ Acquisition Slot | 750 |
| 4 | Command/ Acquisition Slot | 750 |
| 5 | Packet transfer | 750 |
| 6 | Packet transfer | 750 |
| 7 | Packet transfer | 750 |
| 8 | Packet transfer | 750 |
| 9 | Packet transfer | 750 |
| 10 | Packet transfer | 750 |
| 11 | Packet transfer | 750 |
| 12 | Packet transfer | 750 |
| 13 | Packet transfer | 750 |
| 14 | Packet transfer | 750 |
| 15 | Packet transfer | 750 |
| 16 | Packet transfer | 750 |
| 17 | Packet transfer | 750 |
| 18 | Packet transfer | 750 |
| 19 | Packet transfer | 750 |
| 20 | Packet transfer | 750 |
| 21 | Packet control (e.g. polling) | 150 |
| 22 | Packet control | 150 |
| 23 | Packet control | 150 |
| 24 | Regulation Slot | ≤ 775 |

Figure 4-2 Slot Allocation within each Subframe

Each subframe is divided (not equally) as 24 slots, some slots are for subsequent subframe control and low level TC/TM, however the majority of these slots (16) are reserved for Packet Transfers.

Each Packet Transfer Slot has a duration of 750uS, which is enough time for 1 complete MIL-1553 message (with the control word and bus delay times), i.e. 512 useful bits of data can be sent in one Packet Transfer Slot, so since there are 16 slots per subframe there can be a maximum of 8192 bits of Packet transfer data sent per Subframe. (8192 bits just happens to correspond to 1kbyte or 1 ESA packet of the maximum size) !

We can conclude that each subframe can be used to transfer up to 1kbyte to/from one user per subframe, so if we want to increase the user data rate we should increase the number of subframes allocated to that particular user.

It should be noted that a particular subframe is dedicated to a particular user for the packet transfer of data, if the user fills the subframe with data then the data rate will be optimised, if the user selects to transfer very small packets then the effective data rate will be low. Only one packet shall be sent per subframe, this simplifies the allocation of the subframes since in this way we can guarantee that there is no risk of trying to send several packets (each one could be of different length) with the result that the last packet is too long and would be truncated. The users should be encouraged to use packets of the maximum size to ensure the most effective datarates.

# 5. ASSUMPTIONS

This section recalls the assumptions on the 3 parameters affecting the data flow requirements on board Herschel and Planck :

- the maximum data production rate stated by the instruments, conditioned by the 1553 data bus specified protocol and the Packet Services specified in the Packet Standard ICD.
- the mass memory size
- the data downlink capability

These assumptions shall be used to establish, for each instrument :

- the maximum average data rate over a one day period, driven by the Mass Memory and Downlink performance
- the maximum peak data rate, driven by the bus type and specified protocol. Section 6 provides proposal for data bus protocol implementations in typical cases.

## 5.1 INSTRUMENT REQUIREMENTS

### 5.1.1 Housekeeping Telemetry

The data rate requirements for the instruments have been taken from the appropriate IIDB. It is not always clear in the IIDB if the datarate requested is inclusive of instrument housekeeping, and whether the housekeeping has the same rate when the instrument is in standby. It is intended that 1 subframe per second (8kps) is allocated per instrument. The instrument is free to chose which Housekeeping telemetry is downloaded within the subframe, it is not necessary that two consecutive HK subframes from the same instrument contain the same TM data or format. For example the instrument may chose to download a set of temperature TM in one subframe, while in the following HK subframe (one second later) status, current or voltage TM could be downloaded. This allocation for the HK gives a far greater allocation than requested by the instruments, but the instrument must remember that this HK will also have to be stored in the mass memory, if they chose to download large quantities of TM then their Science data will be reduced accordingly.

### 5.1.2 Science Data

The sizing case for the nominal Herschel mission is where one instrument is operating. Parallel mode is not considered to be the sizing case since the total data in parallel mode is less than for the nominal mode. It has been assumed that all instruments are producing HK packets.

The sizing case is when PACS is operating in and requires a data rate of 100kbps.

It has been assumed that HIFI and SPIRE will produce 0 science data when PACS is operating.

The worst case burst mode is for up to 400kps for the Herschel databus as requested by PACS. It is assumed that in burst mode the SPIRE and HIFI instruments are not producing any science data only HK TM data.

It is assumed that for PLANCK both instruments are operating at the same time. Both instruments and the sorption cooler will be producing HK data, so 1 subframe has been allocated to each for HK TM.

The nominal TM data rate for LFI scientific data from AD-5 is 30kbps (including margin) although a burst mode of up to 100kbps is requested. It is assumed that HFI is operating nominally when LFI is in burst mode and both instruments and Sorption Cooler are producing HK TM data.

The nominal TM data rate for HFI scientific data from AD-4 is 48kbps.

## 5.2 SERVICE MODULE TM/TC DATARATE NEEDS

### 5.2.1 TC Needs

AD-9 states that 4 subframes per second are reserved for TC distribution. This is considered to be adequate for the commanding of the instruments and the service module. However since it is expected that the AOCS will require significant TM/TC overhead another subframe has been allocated dedicated for the AOCS. AD-9 requires that a TC verification packet is transmitted in response to each TC packet. Therefore a subframe dedicated to the TC verification packet has been allocated for each TC distribution packet, this makes 5 TC subframes + 5 TC Acknowledge subframes.

### 5.2.2 Low Level Commanding

In addition to the dedicated TC packets as described above, AD-9 defines that three slots within each subrame are reserved for command/acquisitions. It is intended that these commands are used for low level applications such as controlling the PCDU and the Cryostat Control Unit (for Herschel). This control is not done at packet level. If we have 3 commands or acquisition slots available per subframe then this means that we have 3x64=192 commands/acquisitions per second. Since we have to balance each TC with a corresponding TC acknowledge this means that we will have up to 96 commands per second which is considered adequate for normal PCDU management.

## 5.3 POLLING STRAGEGY

With the scheme of having a number of dedicated subframes per user and the number and "location" of the subframe is fixed for each system configuration without any requirement to reallocate the bus resources, there is no need for the bus controller to poll the instruments in advance to see if there is data (science or housekeeping), since if the instrument is operating there should always be data to retrieve during any pre-assigned subframe.

However the instrument may need to indicate to the controller of an asynchronous event, in order to detect this event, the CDMU will poll each 1553 Bus user periodically during one of the Packet Control Slots 21 to 23 (see Figure 4-2). If the Bus user has indicated that there is an asynchronous event then the bus controller can acquire the asynchronous TM packet in a subsequent Subframe.

The Packet Structure ICD has allocated three slots per subframe for packet control (e.g. polling), and one asynchronous TM per subframe. If we assume that only one user per subframe is polled then in the worst case situation is where there are six 1553 Bus users (3 instruments + 3 platform), so each user could be polled each 93mS. This assumes that all users have equal priority, another system could be implemented where more than 1 user per subframe is polled but this would lead to a rather more complex priority scheme within the CDMU should both users have an event since only 1 asynchronous TM per subframe can be retrieved.

The time delay between polling the user and actually acquiring the data has not been clearly defined in the Packet Structure ICD. The baseline is that the user is polled in one subframe and the data retrieved in the following subframe.

### 5.4 PACKET SERVICES IMPLEMENTATION

The Packet Structure ICD defines a number of mandatory services that have to be supported by the users (and CDMU). In the Subframe allocation a dedicated subframe has been allocated for the TC acceptance report, and for the Time Management (one of the reserved TC subframes), however all other reporting (TC execution report, event report, exception report, Error/Alarm report) has been considered to be handled via the asynchronous TM system as described in paragraph 5.3. If dedicated subframes were to be allocated for each of these then the number of subframes available for science data would be severely reduced, there would be more subframes dedicated to telemetry and event reporting than for science !

### 5.5 UNSPECIFIED PROTOCOL LEVEL

It is assumed that there is a handshake mechanism whereby science data is validated by the CDMU and an acknowledge is returned to the user. Upon the acknowledge the user will have to update the pointers to the next set of data to be sent and corresponding status word.

If the CDMU does not send an acknowledge signal or sends a non-acknowledge due to corrupt data, then the user will have to re-send the data on the next allocated subframe, which implies that the user will have to be capable of handling a number of buffers.

The timing of this mechanism, in particular the updating of the status word by the user, is not clearly defined in the Packet Structure ICD, it will have to be discussed with the instruments to find a common understanding and definition that will be acceptable by all parties.

### 5.6 MASS MEMORY SIZE

The assumptions for the Mass Memory sizing are very simple :

The autonomy requirements ask to cope with a nominal mission for 48 hours without ground contact; this means that the Mass Memory, at a minimum, shall be able to store the maximum data rate from the instruments, science+housekeeping, and the allocation for the satellite housekeeping.

The actual Mass Memory sizing has been performed with margin, and ALCATEL design offers a 25Gbits End Of Life capacity. This is sufficient to acquire the following useful data (rates shown are not inclusive of overheads):

- up to **140kbps** average over 24hours from the instruments : science+housekeeping for all instrument together,
- up to **5kbps** average over 24hours for the spacecraft housekeeping, as specified.

### 5.7 DOWNLINK CAPABILITY

The downlink is required to permit the transmission of data collected over 24hours, during the specified ground visibility period.

In order to have a consistent and robust approach, it has actually been designed to cope with the transmission of half of the Mass Memory content (12.5Gbits EOL) during one allocated pass, plus the data acquired in real time during this pass (max average rate of 145kbps).

With a useful transmission rate to ground of 1.5Mbps for both satellites, and the amount of data discussed above, the resulting downlink duration is 2.6hours, thus well within the specified 3hours max.

# 6. DATA BUS ALLOCATION PROPOSAL

The results of the subframe allocation (and corresponding datarates) are given in the following tables. The tables show the allocated subframes and the corresponding data rate assuming that all the packets can be utilised 100%.

## 6.1 PLANCK SUBFRAME ALLOCATION

Table 6-1 shows the allocation for the data rates as requested in the IIDBs, these data rates may be achieved while maintaining a adequate margin.

Table 6-2 shows the allocation if 12 Subframes were allocated for nominal LFI Science data, this is in response to a technical note made by Laben which shows that 12 subframes dedicated to science data could be suitable to minimize their buffering constraints. Once again this does not cause any problems, and there is still a healthy margin for the number of subframes available.

Table 6-3 shows that even if 100kbps burst mode is possible, the table shows that the maximum burst mode data rate could be 32 subframes (262kbps) while still maintaining a comfortable margin in terms of subframe allocation.

| PACKET Budget for IIDB issue 1 scenario | | |
|---|---|---|
| | Subframe/s | kb/s |
| | | |
| TC reserved | 4 | |
| TC Acknowledge | 4 | |
| | | |
| HFI Science | 6 | 49.152 |
| LFI Science | 4 | 32.768 |
| HFI HK | 1 | 8.192 |
| LFI HK | 1 | 8.192 |
| Sorption Cooler HK | 1 | 8.192 |
| | | |
| **Total Payload Science+HK** | **13** | **106.5** |
| | | |
| AOCS TM | 2 | |
| PCDU TM | 1 | |
| CDMS - AOCS TC | 1 | |
| CDMS - AOCS TC ACK | 1 | |
| | | |
| Margin | 38 | |
| | | |
| Total | 64 | |

Table 6-1

| PACKET Budget for LFI request of 12 Subframes | | |
|---|---|---|
| | Subframe/s | kb/s |
| | | |
| TC reserved | 4 | |
| TC Acknowledge | 4 | |
| | | |
| HFI Science | 6 | 49.152 |
| LFI Science | 12 | 98.304 |
| HFI HK | 1 | 8.192 |
| LFI HK | 1 | 8.192 |
| Sorption Cooler HK | 1 | 8.192 |
| | | |
| **Total Payload Science+HK** | **21** | **172.03** |
| | | |
| AOCS TM | 2 | |
| PCDU TM | 1 | |
| CDMS - AOCS TC | 1 | |
| CDMS - AOCS TC ACK | 1 | |
| | | |
| Margin | 30 | |
| | | |
| Total | 64 | |

Table 6-2

| PACKET Budget for HFI Burst mode | | |
|---|---|---|
| | Subframe/s | kb/s |
| | | |
| TC reserved | 4 | |
| TC Acknowledge | 4 | |
| | | |
| HFI Science | 32 | 262.14 |
| LFI Science | 6 | 49.152 |
| HFI HK | 1 | 8.192 |
| LFI HK | 1 | 8.192 |
| Sorption Cooler HK | 1 | 8.192 |
| | | |
| **Total Payload Science+HK** | **41** | **335.87** |
| | | |
| AOCS TM | 2 | |
| PCDU TM | 1 | |
| CDMS - AOCS TC | 1 | |
| CDMS - AOCS TC ACK | 1 | |
| | | |
| Margin | 10 | |
| | | |
| Total | 64 | |

Table 6-3

## 6.2 HERSCHEL SUBFRAME ALLOCATION

Table 6-4 shows the allocation for the data rates as requested in the IIDBs for PACS operation. This configuration can be handled by the system while maintaining an adequate margin.

Table 6-5 shows the allocation is the request from PACS to increase the nominal data rate to 120kbps is considered. This is resolved by allocating to PACS 15 subframes per Frame for Science Data (which actually means 122kbps if all the subframes are completely full of data). With this scenario there is still a comfortable margin for allocated subframes.

Table 6-6 shows that even if the margin is eliminated then if the HK TM is maintained from each instrument, the maximum number of subframes which could be allocated to an instrument (PACS in this example) is 48 which yields a data rate of 393kbps which is slightly less than the requested 400kbps, (although it is not clear if the requested 400kbps is only for Science data or for Science data + HK TM).

| PACKET Budget for IIDB issue 1 scenario | | |
|---|---|---|
| | Subframe/s | kb/s |
| | | |
| TC reserved | 4 | |
| TC Acknowledge | 4 | |
| | | |
| HIFI Science | 0 | 0 |
| PACS Science | 13 | 106.5 |
| SPIRE Science | 0 | 0 |
| HIFI HK | 1 | 8.192 |
| PACS HK | 1 | 8.192 |
| SPIRE HK | 1 | 8.192 |
| | | |
| **Total Payload Science+HK** | **16** | **131.072** |
| | | |
| AOCS TM | 2 | |
| PCDU TM | 1 | |
| CDMS - AOCS TC | 1 | |
| CDMS - AOCS TC ACK | 1 | |
| | | |
| Margin | 35 | |
| | | |
| Total | 64 | |

Table 6-4

| PACKET Budget for PACS request of 120kbs | | |
|---|---|---|
| | Subframe/s | kb/s |
| | | |
| TC reserved | 4 | |
| TC Acknowledge | 4 | |
| | | |
| HIFI Science | 0 | 0 |
| PACS Science | 15 | 122.88 |
| SPIRE Science parallel | 0 | 0 |
| HIFI HK | 1 | 8.192 |
| PACS HK | 1 | 8.192 |
| SPIRE HK | 1 | 8.192 |
| | | |
| **Total Payload Science+HK** | **18** | **147.456** |
| | | |
| AOCS TM | 2 | |
| PCDU TM | 1 | |
| CDMS - AOCS TC | 1 | |
| CDMS - AOCS TC ACK | 1 | |
| | | |
| Margin | 33 | |
| | | |
| Total | 64 | |

Table 6-5

| PACKET Budget for PACS Burst mode | | |
|---|---|---|
| | Subframe/s | kb/s |
| | | |
| TC reserved | 4 | |
| TC Acknowledge | 4 | |
| | | |
| HIFI Science | 0 | 0 |
| PACS Science | 48 | 393.22 |
| SPIRE Science parallel | 0 | 0 |
| HIFI HK | 1 | 8.192 |
| PACS HK | 1 | 8.192 |
| SPIRE HK | 1 | 8.192 |
| | | |
| **Total Payload Science+HK** | **51** | **417.79** |
| | | |
| AOCS TM | 2 | |
| PCDU TM | 1 | |
| CDMS - AOCS TC | 1 | |
| CDMS - AOCS TC ACK | 1 | |
| | | |
| Margin | 0 | |
| | | |
| Total | 64 | |

Table 6-6

## 7. CONCLUSIONS

It must be stressed that the data rates as given in the tables in paragraph 6 **must** be considered in conjunction with the mass memory and RF downlink constraints. A maximum average data rate of 140kps has to be considered for the **total of all** instruments for both HK+science data for each satellite

The nominal data rates for both satellites can be accommodated by the data bus and still have comfortable margins. Even if the data rates needed to be increased then this could still be managed.

Burst mode upto 400kbps cannot be managed, a burst mode of 300kbps may be possible but the data rate needs of the SVM should be consolidated before promising the higher data rate burst modes to the instruments, since this mode leaves us with no or very little margin at subframe level.

The requirements for the data rate should be simplified and expressed as the number of available subframes for Science plus the amount of allocated mass memory. It would then be up to the instruments to decide how to allocate between the instruments the overall science data subframes depending upon the operating mode.

It is proposed that the following subframe allocation is made for nominal conditions (not burst mode):

PLANCK

| | |
|---|---|
| HFI HK | 1 Subframe per second |
| LFI HK | 1 Subframe per second |
| Sorption Cooler HK | 1 Subframe per second |
| HFI+LFI Nominal Science Data | 18 Subframes per second |

HERSCHEL

| | |
|---|---|
| HIFI HK | 1 Subframe per second |
| PACS HK | 1 Subframe per second |
| SPIRE HK | 1 Subframe per second |
| HIFI+PACS+SPIRE Nominal Science Data | 18 Subframe per second |