HERSCHEL / PLANCK

# Instrument Data Rates Allocation
# H-P-1-ASPI-TN-0204

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## ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORDS*

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# 1. SCOPE

The previous technical note regarding the datarate allocation (AD11) dealt primarily with the data rates on the MIL-553 Data Bus, the allocation with the instruments and the compatibility of the MIL-1553 Data Bus and the ESA Packet Structure ICD.

This revised technical note updates the data rate allocations after some clarifications with ESA. The maximum operating limits of the MIL-1553 Bus data rate are considered to identify the maximum downlink datarate and time. The initial baseline mass memory budget is presented, and the impacts upon the mass memory are identified in accordance with the potential increased data rate .

The baseline instrument allocation of 100kbps has been taken as a reference and the maximum average instrument data is calculated considering the baseline system design which resolves to 140kbps.

This note explores the boundary conditions for each datarate and identifies the bottlenecks for each possible configuration.

This technical note is intended to indicate what is possible with the present, it is not intended that the contents of this note are considered to be a contractual nor technical commitment.

# 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 2/0
AD-2 Instrument Interface Document Part B Instrument HIFI SCI-PT-IIDB/HIFI-02125 Issue 2/0
AD-3 Instrument Interface Document Part B Instrument SPIRE SCI-PT-IIDB/SPIRE-02124 Issue 2/0
AD-4 Instrument Interface Document Part B Instrument HFI SCI-PT-IIDB/HFI-04141 Issue 2/0
AD-5 Instrument Interface Document Part B Instrument LFI SCI-PT-IIDB/LFI-04142 Issue 2/0
AD-6 Instrument Interface Document Part B Sorption Cooler PL-LFI-PST-ID-002 Issue Draft/3.3
AD-7 Instrument Interface Document Part A SCI-PT-IIDA-04624 Issue 2/0
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 2/0

### *2.1.2 Other Applicable Documents*

AD-10 Aircraft Internal Time Division Command/Response Multiplex Data Bus MIL-STD-1553b
AD-11 Herschel Planck Data Rates H-P-ASPI-TN-186 Issue 1 29/06/2001

### *2.1.3 Reference Documents*

# 3. INTRODUCTION

There are three factors which affect and limit the overall science return of Herschel and Planck spacecraft,

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, while 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 first quantify the baseline figures, and a packet allocation in line with the baseline will be proposed.

## 3.1 Data Bus

The present requirements for the datarates are expressed in kbps (kilobits per second). This definition needs some additional clarification, it is intended as the data between one user and the CDMU, data meaning science data, HK Telemetry data, Event Message data, all the data types as defined in the AD9. This definition is useful for sizing the mass memory and for ensuring that all data can be downloaded with the specified downlink data rate and within the allocated time, however it must be stressed that this technical note is primarily concerned with the data rate on the internal MIL-1553 databus, so the term “data rate” within this note means the data rate on the internal databus only.
While datarate is a useful parameter, the number of subframes that can be used to transfer this data must also be defined. The number of subframes allocated to a particular instrument not only has to be dimensioned for the average datarate, but should also take into account peak data rates which the instrument may encounter.
This note will define the number of subframes to be allocated for the instruments and the average datarate.

## 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.

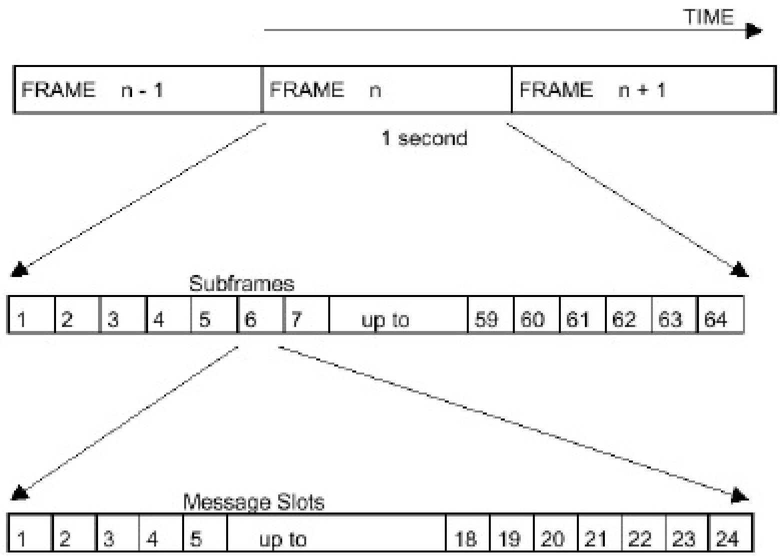
## 3.3 Downlink

The 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 and shall also cope with the simultaneous transmission of the data acquired in real time.

# 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 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.




Definition: 1 FRAME = 64 SUBFRAMES ; 1 SUBFRAME = 24 MESSAGE SLOTS

Duration: 1 FRAME = 1 second: 1 SUBFRAME = 1/64 second; 1 SLOT = see table 4.1

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 |

One full length 1553 message (slots 2, 3, 4)

One full length TM Packet (slots 5 to 20)

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 useful data.
Each Packet Transfer Slot has a duration of 750uS, which is enough time for 1 full length MIL-1553 message (with the control word and bus delay times), i.e. 512 useful bits of data can be sent in one Datat Transfer Slot, so since there are 16 slots per subframe there can be a maximum of 8192 bits of Data transfer data sent per Subframe. (8192 bits corresponds to 1kbyte or 1 Herschel/Planck 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 on the data bus. 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 TM 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. It should be highlighted that the system will allocate a certain number of subframes per user, in the allocation tables these allocations may be broken down to show HK TM, Science data, Event packet etc. This breakdown is only given as an example and sizing case, the user is free to use the subframes as required, they may be used by any combination of Science data, HK etc and the same user subframes in subsequent frames may contain different type of data. e.g. suppose that subframes numbers 10, 20 and 30 are allocated to a user, in Frame1 subframe 10 contains HK TM and 20 and 30 contain Science data, in Frame 2 subframe 10,20 and 30 all contain science data, in Frame 3 subframe 10 and 20 contain science data and subframe 30 contain an Event Packet…. and so on.

Packets control slots have a duration of 150µs which is enough time for 7 words long 1553 message.

In a given TC subframe up to 4 TCs may be issued, however only 1 TC per subframe can be issued to any one user.

## 5. ASSUMPTIONS

This section gives the assumptions on the 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 baseline memory size of 25Gbits has been assumed, which is in line with a baseline downlink of 1.5Mbit/s . The storage unit being sized to buffer up to 48hours of data, it is assumed that 50% of this memory will be available for a 24 observation period hence 12.5Gbits of memory are to be considered
- the data downlink capability – The baseline is 1.5Mbit/s which, associated with a 2.6h downlink time, allows to dowload the 50% of the mass memory content during every daily pass.
- the CDMU processor is able to handle the complete ESA packet ICD requirements at the full data rate and for all the 64 subframes.

The mass memory and data downlink rates are examined in detail in Chapter 6. The following paragraphs establishes the maximum number of subrames which could be allocated to the instruments at this early phase of the program while maintaining an adequate margin.

The assumptions used to establish the max average datarate for each instrument are :

For the instruments :

Four subframes per second are reserved for instrument related Telecommands. These four TC may be distributed between the instruments as required, it is not intended that each instrument has 4 TC/sec (the maximum rate per instrument is 2 TC per sec). For each TC a TC Acknowledge subframe is allocated (see AD9).
One TM subframe per second per instrument (for instrument HK TM). For Planck, the Sorption cooler is allocated 1 subframe per second for HK TM. Therefore each satellite has 3 subframes per second allocated for instrument periodic and non-periodic HK TM.

For the satellite system :

A total of 5 subframes per second allocated for the ACMS

Two subframes per second allocated for ACMS TM.

Two subframe per second allocated for PCDU TM.

One subframe per second allocated for cryostat Control Unit CCU TM.

Margin is defined in this study as the difference between the total available subframes and sum of instrument and system allocation. It is desirable at this stage of the program to maintain as considerable margin (at least 20 subframes) to allow for unforeseen TM/TC needs for the system unit or to allow for the fact that that the CDMU processor may not be able to handle to maximum MIL-1553 data bus datarate. As the program matures this margin may be relaxed, thereby allowing additional subframe allocation for the instruments.

## 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 telemetry is downloaded within the subframe, it is not necessary that two consecutive 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 packet 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 HK 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 is defined that HIFI and SPIRE will produce 0 science data when PACS is operating.
The worst case burst mode is considered as 300kps for the Herschel databus as requested by PACS in AD1. In burst mode the SPIRE and HIFI instruments are not producing any science data, only HK TM data. It is also assumed that there will be no TC to the instruments (and correspondingly no TC Acknowledgement) during the burst mode.
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 54kbps (including margin) although a burst mode of up to 200kbps 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. LFI burst mode still has to be defined, but it is expected that this will be a higher data rate than the nominal mode and in any case the combined PLANCK instrument data rate (including the sorption cooler) will be shared between the instruments to allow for this burst mode and will not exceed the allocated datarate/subframe allocation.
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 ACMS will require significant TM/TC overhead another subframe has been allocated dedicated for the ACMS. 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.

### *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. It is not intended to allocate all of these slots for PCDU and CCU control, at present it is considered that 8 slots per second could be used for the PCDU and CCU control, leaving the rest available for high priority event reporting and control.

### *5.2.3 FDIR*

The FDIR will require access to the bus occasionally, it is not expected to be a sizing case but adequate margins must be maintained in the subframe allocation to cover this need.

## 5.3 Polling Strategy

The Heschel Planck satellites will adopt a polling scheme where one of the last slots within the subframe will be used for polling (interrogation by the CDMU) and another slot within the subframe is used to indicate to the remote terminal that the data has been correctly received by the CDMU.

Two types of polling have to be considered, Nominal mode, and Burst Mode.

Nominal Mode:

With reference to Figure 5.3-1. Slot number 21 will be used for polling control, if the instrument has data to be retrieved then it shall write to this slot, the CDMU will check this slot and if it finds that the instrument needs servicing it will access the data output register of he instrument Remote Terminal and take the data stored there in a subsequent subframe. Note that the baseline is to have the polling and data retrieval in subsequent subframes, however there are no requirements that forbid that one or more subframes are in between polling and retrieval (interlaced polling – see Figure 5.3-2). If the Polling request is not set by the instrument the CDMU will not access the data output register of he instrument Remote Terminal, there will be no data transfer during the subframe associated to the polled terminal.

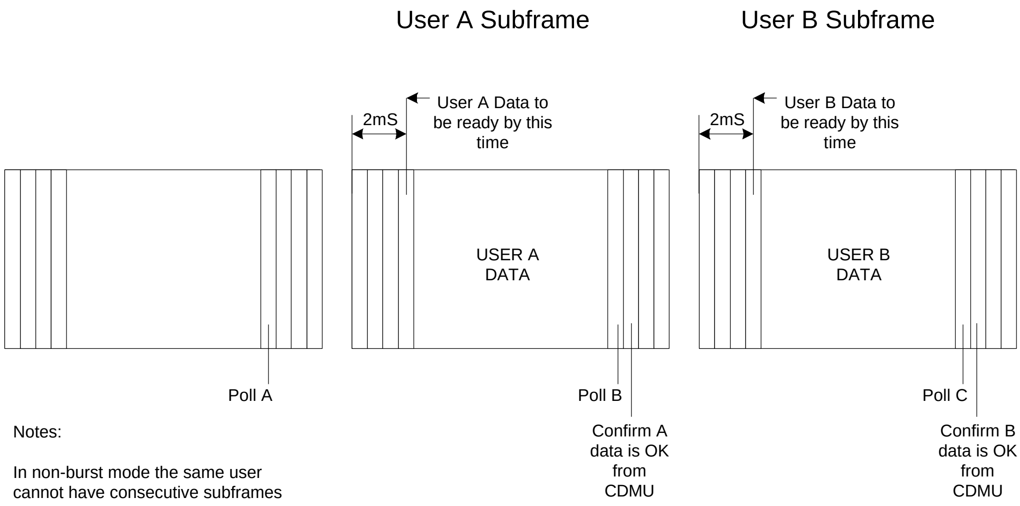
The CDMU will then check the validity of the received data and if found to be correct will set a confirmation flag in slot 22. Upon receipt of this confirmation the Remote Terminal should clear the output register and may prepare for the next transfer. If the CDMU finds that the data transfer was not successful then this confirmation flag will not be set and the instrument should not clear the register but leave the data ready for the next acquisition (polling request will have to be set again).

It should be noted that it is required that the user has all the data ready for transfer within 2mS from the start of the subframe allocated for that transfer .

In this mode it is not intended to have consecutive subframes allocated for the same user.

BURST Mode:

This mode is principally the same as the nominal mode except that the same user is polled in consecutive subframes. In this mode the CDMU will always set the confirmation flag that data has been received correctly (there will be no checking). Burst mode is shown in Figure 5.3-3.




Notes:

In non-burst mode the same user cannot have consecutive subframes

If Poll is not set by user then the CDMU will not access User data register, the bus will be idle for that subframe user data time

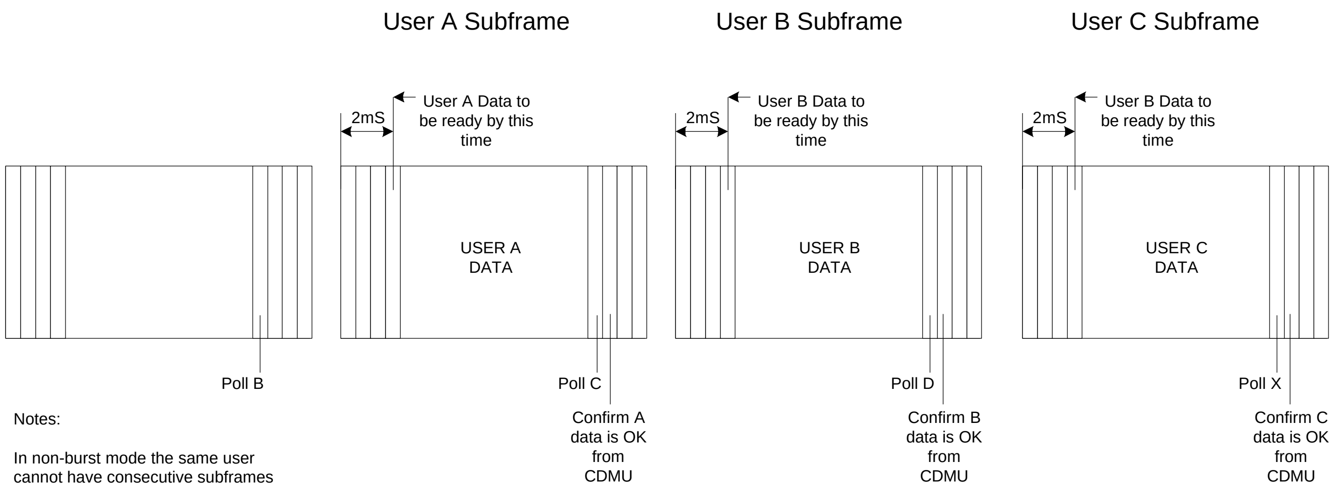
If Poll is set then the CDMU will access the user data register

If the Confirm data is set by the CDMU then the dataregister can be cleared/updated by the User

If the Confirm data is not set by the CDMU then the data transfer has failed and the data register should not be cleared /updated by the User

Nominal Mode Polling
(No interlacing)

Figure 5.3-1

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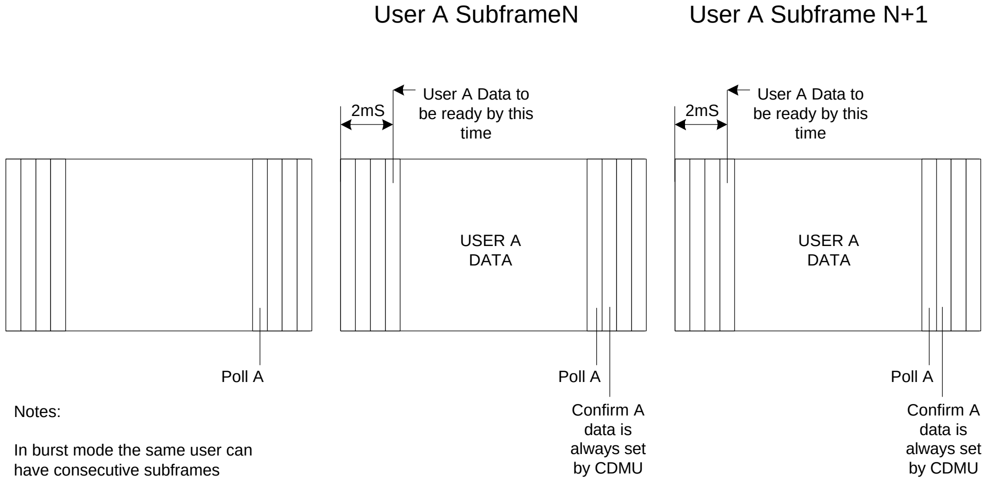
Nominal Mode Polling
(interlacing)

Figure 5.3-2




Notes:

In burst mode the same user can have consecutive subframes

If Poll is not set by user then the CDMU will not access User data register, the bus will be idle for that subframe user data time

If Poll is set then the CDMU will access the user data register

When the Confirm data is set by the CDMU then the dataregister can be cleared/updated by the User

The Confirm data is always set by the CDMU, no check performed in burst mode

Burst Mode Polling

Figure 5.3-3

## 5.4 Mass memory size

The assumptions for the Mass Memory baseline sizing are:
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:

- 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.

The maximum Mass Memory has been calculated for the baseline and is broken down as:

| | | | justification |
|---|---|---|---|
| S/C HK | 864 | Mbits | 5kbps for 24 hours |
| MTL | 38 | Mbits | 100 sets per day of 100 max length TC's |
| Events | 1 | Mbits | 1000 events per day |
| Copy of Flight SW | 16 | Mbits | 2Mbytes |
| | | | |
| SubTotal | 919 | Mbits | |
| Margin | 460 | | 50% margin |
| | | | |
| Total for Satellite System | 1380 | Mbit | |
| | | | |
| Instrument Data 140kb/s for 48hours | 24.192 | Gbit | |
| | | | |
| Total Mass Memory | 25.571 | Gbit | |

## 5.5 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.
With a useful transmission rate to ground of 1.5Mbps for each satellite, and the amount of data discussed above, the resulting downlink duration is 2.6hours, thus well within the specified 3hours max. The difference between the 2.6 hours and the specified 3 hours allows for set-up time by the ground station, and allows to recover data from a previously missed pass. Clearly a missed pass cannot be fully recovered

within this limited time, it will require several days to recover the complete stored data, however this recovery strategy still has to be refined and evaluated.

## 5.6 Assumption Summary

A maximum datarate of 140kb/s is compatible with the baseline mass memory and baseline download datarate.

140kb/s has to be considered as an absolute maximum average of the total of all instruments science + HK TM, over a 24 hour period.

Ground Contact time is 2.6 Hours.

Downlink data rate is 1.5Mbps.

## 5.7 Baseline Dowlink Rate/downlink time/Mass Memory Size/Data Bus rate

The Downlink rate has been specified as 1.5Mbit/s, and the contact duration is specifies as less than 3 hours. A contact duration time of between 2 and 3.5 hours is used in this study, this represents the time when actual data is being downlinked, ie the « useful » downlink time .
The baseline has considered a useful contact time of 2.6 hours, this has been derived from the 3 hours specified less some estimated time for setup and margins.

Table 5.7-1 shows how this study has been performed, the baseline situation is given in this table.

- The 1st Column is self explanatory, the downlink data rate is 1.5Mbits/s.
- The 2nd Column specifies the useful contact time for data download, between 2 and 3 hours, 2.6 hours have been taken as a sizing case in all studies performed to date.
- The 3rd Column, is the downlink time in seconds multiplied by the downlink rate. This gives the Total amount of data that can be downlinked. It should be remembered that the Total downlink data consists of real time instrument data, data from mass memory and satellite HK data.
- The 4th Column calculates how much real time data there would be generated during the contact time and would have to be downloaded during the contact time, it is the product of the contact time and the Max average data rate to fill the mass memory (7th Column).
- The 5th Column gives the absolute minimum size of the mass memory required to store the data for a 24 hour period. It is calculated as the amount of data that can be downlinked during the contact time less the amount of real time data generated and dowlinked in real time during the contact time.
- The 6th Column gives the datarate needed to fill the mass memory within 24 hours. This data rate comprises all the instrument data plus the satellite system housekeeping data.
- The last Column (7th) gives the datarate for the instruments, which is the value in Column 7 less 5kb/s which is allocated for the satellite system HK telemetry.

| Downlink Data rate Mbits/s | Downlink time | Total data can be downlinked (Mbit) | Max Real Time data acquired & to be dowlinked during contact time (Mbit) | Mass Memory data to be downloaded (Total data - real time data) (Gbit) | Max average data rate to fill mass memory within 24 hours (kb/s) | Max Average Data rate allocated to instruments (kb/s) |
|---|---|---|---|---|---|---|
| 1.5 | 2 | 10800 | 831 | 10.0 | 115 | 110 |
| 1.5 | 2.1 | 11340 | 912 | 10.4 | 121 | 116 |
| 1.5 | 2.2 | 11880 | 998 | 10.9 | 126 | 121 |
| 1.5 | 2.3 | 12420 | 1086 | 11.3 | 131 | 126 |
| 1.5 | 2.4 | 12960 | 1178 | 11.8 | 136 | 131 |
| 1.5 | 2.5 | 13500 | 1274 | 12.2 | 142 | 137 |
| 1.5 | 2.6 | 14040 | 1372 | 12.7 | 147 | 142 |
| 1.5 | 2.7 | 14580 | 1474 | 13.1 | 152 | 147 |
| 1.5 | 2.8 | 15120 | 1580 | 13.5 | 157 | 152 |
| 1.5 | 2.9 | 15660 | 1688 | 14.0 | 162 | 157 |
| 1.5 | 3 | 16200 | 1800 | 14.4 | 167 | 162 |
| 1.5 | 3.1 | 16740 | 1915 | 14.8 | 172 | 167 |
| 1.5 | 3.2 | 17280 | 2033 | 15.2 | 176 | 171 |
| 1.5 | 3.3 | 17820 | 2154 | 15.7 | 181 | 176 |
| 1.5 | 3.4 | 18360 | 2278 | 16.1 | 186 | 181 |
| 1.5 | 3.5 | 18900 | 2405 | 16.5 | 191 | 186 |

Table 5.7-1 Baseline Calculations

Examining Table 5.7-1 will clarify and justify the baseline design. 1.5Mbits/s and an available contact time of 2.6 hours yields a max instrument data rate of 142kb/s and will require a mass memory of 12.7Gbits for 24 hour storage.

# 6. DATA BUS ALLOCATION

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%. As highlighted in paragraph 5, and should be stressed again, the proposed allocation of subframes will lead to excess data if all the subframes (Science + HK) are totally full of data. For each instrument, the subframe allocation must be considered together with a TBD Mass Memory allocation which will effectively limit the maximum average datarate of the Science+HK data to 140kps for the total of all instruments. To maintain a minimum system margin for the datarate, **the maximum datarate allocated to the instruments is considered as 130kps.**

## 6.1 PLANCK Subframe Allocation

Table 6-1 shows the allocation for the data rates as which could manage the required LFI Burst mode as defined in the IIDB. The IIDB states that the bus should be capable of managing the short duration peak, this is understood as a burst mode, different to the nominal operating mode. HFI have explicitly requested a maximum of 9 Science TM packets, which has been considered to be the nominal allocated number of subframes, see Table 6-2.

This burst mode could be handled as a separate defined HFI mode where a greater number than usual of subframes are allocated, however it is not the intention to allocate such a high number of subframes for the normal operating mode on the off-chance that HFI may need these subframes to avoid buffering within the instrument.

Table 6-2 shows the nominal allocation for both the instruments, this allocation easily satisfies the requirements as expressed in the IIDB for nominal observation. It should be noted that this allocation is the maximum that can be made to ensure that the average of 130kbs is not exceeded. The total number of subframes for the science data have been divided 50-50, however the Planck instruments should decide between themselves the most suitable division of these subframes.

| PLANCK Burst Mode Subframe Budget Allocation | | | |
|---|---|---|---|
| | Subframe/s | Max equivalent kb/s | Actual equivalent kb/s |
| | | | |
| TC reserved | 0 | | |
| TC Acknowledge | 0 | | |
| | | | |
| | | | |
| HFI Science TM Packet | 9 | 73.728 | 73.728 |
| LFI Science TM Packet | 25 | 204.8 | 204.8 |
| HFI Other TM | 1 | 8.192 | 2 |
| LFI Other TM | 1 | 8.192 | 2 |
| Sorption Cooler Other TM | 1 | 8.192 | 0.5 |
| | | | |
| **Total Payload Science+Other TM** | **37** | **303.104** | **283.028** |
| | | | |
| AOCS TM | 2 | | |
| PCDU TM | 1 | | |
| PCDU TC | 1 | | |
| PCDU TC ACK | 1 | | |
| CDMS - AOCS TC | 1 | | |
| CDMS - AOCS TC ACK | 1 | | |
| | | | |
| Margin | 20 | | |
| | | | |
| Total | 64 | | |
| | | | |
| | | | |

Table 6-1

| PLANCK Subframe Budget Allocation | | | |
|---|---|---|---|
| | Subframe/s | Max equivalent kb/s | Actual equivalent kb/s |
| | | | |
| TC reserved | 4 | | |
| TC Acknowledge | 4 | | |
| | | | |
| | | | |
| HFI Science TM Packet | 9 | 73.728 | 73.728 |
| LFI Science TM Packet | 9 | 73.728 | 73.728 |
| HFI Other TM | 1 | 8.192 | 2 |
| LFI Other TM | 1 | 8.192 | 2 |
| Sorption Cooler Other TM | 1 | 8.192 | 0.5 |
| | | | |
| **Total Payload Science+Other TM** | **21** | **172.032** | **151.956** |
| | | | |
| AOCS TM | 2 | | |
| PCDU TM | 1 | | |
| PCDU TC | 1 | | |
| PCDU TC ACK | 1 | | |
| CDMS - AOCS TC | 1 | | |
| CDMS - AOCS TC ACK | 1 | | |
| | | | |
| Margin | 28 | | |
| | | | |
| Total | 64 | | |
| | | | |
| | | | |

Table 6-2

## 6.2 HERSCHEL Subframe Allocation

Table 6-3 shows the allocation is the request from PACS to increase the nominal data rate to 300kbps is considered. This is resolved by allocating to PACS 37 subframes per Frame for Science Data (which actually means 303kbps if all the subframes are completely full of data). With this scenario there is still a minimum margin for allocated subframes.

Table 6-4 shows the allocation for a nominal observation mode. This table shows that PACS is the observing instrument, however either of the other two instruments could have the same allocation. The important fact to note is that the total number of subframes for science data have been allocated, independent of the instrument or instruments which are observing.

| HERSCHEL Subframe Budget for PACS Burst mode | | | |
|---|---|---|---|
| | Subframe/s | Max equivalent kb/s | Actual equivalent kb/s |
| | | | |
| | | | |
| TC reserved | 0 | | |
| TC Acknowledge | 0 | | |
| | | | |
| | | | |
| HIFI Science | 0 | 0 | 0 |
| PACS Science | 37 | 303.104 | 303.104 |
| SPIRE Science | 0 | 0 | 0 |
| HIFI Other TM | 1 | 8.192 | 2 |
| PACS Other TM | 1 | 8.192 | 4 |
| SPIRE Other TM | 1 | 8.192 | 2 |
| | | | |
| **Total Payload Science+Other TM** | **40** | **327.68** | **311.104** |
| | | | |
| AOCS TM | 2 | | |
| PCDU TM | 1 | | |
| PCDU TC | 1 | | |
| PCDU TC ACK | 1 | | |
| CCU TM | 1 | | |
| CDMS - AOCS TC | 1 | | |
| CDMS - AOCS TC ACK | 1 | | |
| | | | |
| Margin | 16 | | |
| | | | |
| Total | 64 | | |
| | | | |

Table 6-3

| HERSCHEL Subframe Budget Allocation | | | |
|---|---|---|---|
| | Subframe/s | Max equivalent kb/s | Actual equivalent kb/s |
| | | | |
| | | | |
| TC reserved | 4 | | |
| TC Acknowledge/ Event | 6 | | |
| | | | |
| | | | |
| HIFI Science TM Packet | 0 | 0 | 0 |
| PACS Science TM Packet * | 22 | 180.224 | 180.224 |
| SPIRE Science TM Packet | 0 | 0 | 0 |
| HIFI Other TM | 1 | 8.192 | 2 |
| PACS Other TM | 1 | 8.192 | 4 |
| SPIRE Other TM | 1 | 8.192 | 2 |
| | | | |
| **Total Payload Science+Other TM** | **25** | **204.8** | **188.224** |
| | | | |
| AOCS TM | 2 | | |
| PCDU TM | 1 | | |
| PCDU TC | 1 | | |
| PCDU TC ACK | 1 | | |
| CCU TM | 1 | | |
| CDMS - AOCS TC | 1 | | |
| CDMS - AOCS TC ACK | 1 | | |
| | | | |
| Margin | 21 | | |
| | | | |
| Total | 64 | | |
| * Prime Instrument shown, same datarate applies to any Prime Instrument | | | |

Table 6-4

### 6.3 packet allocation 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. With the present baseline for downlink rate and contact time, 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. Clearly there could be more subframes allocated per instrument to cope with the peaks of data but the risk is that the instruments will assume that this allocation can be used and considered for 100% of the time with the consequences that mass memory will be filled quicker and that science data could be lost.

The nominal data rates for both satellites can be accommodated by the data bus and still have margins. Even if the data rates needed to be increased then this could still be managed as long as the average 140kbits/s is respected.

Burst mode up to 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 Other TM + LFI Other TM + Sorption Cooler Other TM + HFI+LFI Nominal Science Data
= 21 Subframes per second

HERSCHEL

HIFI Other TM + PACS Other TM + SPIRE Other TM + HIFI+PACS+SPIRE Nominal Science Data
= 25 Subframe per second

140kb/s has to be considered as a **maximum average** of the total of all instruments science + HK TM, maybe more subframes are allocated which if all the subframes were 100% full then this max average value would be exceeded, therefore in order to provide limits which are flexible and allow for peaks in the data rates it is proposed to give an allocation in terms of both subframes + mass memory, in this way the instrument will be able to manage peak values and memory. In order to provide a minimum of system margin**, it is proposed that the average data rate for all the instrument data is limited to 130kb/s.**