DOCUMENT

Herschel pointing accuracy and calibration procedures

Herschel / Planck Project

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				Change in peak-up applicability: The offset must also be valid for a subsequent inertial fixed **raster** command.
11 November 2003	1.0	2	Page 7 Page 8 Page 12 Section 5.2.3	Figure 2 + 3 updated. Figure 4 updated. Typos removed. Peak-up procedure clarified.
5 december 2003	1.0	3	Table 1 page 10	Update of table.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Background

The Herschel attitude pointing and measurement accuracy is of outmost importance to ensure the scientific return of the observatory. This technical note will describe this performance, the inputs to the performance budgets and the in-orbit calibration procedures needed to support those performance figures.

Additionally this note will give indications on how to achieve the pointing goals, both for the spacecraft design and for the planning of the calibrations, and their relation to the observations.

1.2 Scope

The section outline and scope of this technical note is:

- To discuss the Herschel attitude pointing and measurement requirements and goals, section 3.
- To describe the predicted performance including the main contributors to the error budget, section 4
- To describe possible scenarios under which the goals can be meet, section 4.7
- To describe the alignment and calibrations needed before and during the mission, section 5
- To outline the in-orbit calibration phase, and to propose some operational conditions which can be used to improve the pointing performance and scientific return of the observatory, section 6

All performances and calibrations described within this note are performed within ‘Science Mode’ (SCM), as this is the only mode with high-accuracy pointing performance.

1.3 Acronyms

ALoS	Around Line of Sight
AME	Absolute Measurement Error
APE	Absolute Pointing Error
BOL	Beginning of Life
EOL	End of Life
FM	Flight Model
FoV	Field of View

LoS	Line of Sight
RPE	Relative Pointing Error
RSS	Root Sum Square
PDE	Pointing Drift Error
SAA	Sun Aspect Angle
SRPE	Spatial Relative Pointing Error
STR	Star Tracker

2 Reference Documents

RD-1 System Requirements Specification, SCI-PT-RS-05991, Issue 3.1
RD-2 Instrument Interface Document, Part A, SCI-PT-IIDA-04624, Issue 3.0

3 Pointing Requirements and Definitions

For Herschel, the pointing requirements as specified in RD-1 are applicable to each LoS of each instrument.

Definition: *The LoS of an instrument is defined as the direction on the observed sky of the geometric centre of an FPU entry beam's far field pattern as projected by the telescope.*

Since each instrument has several LoS, the pointing direction will be corrected with a fixed offset, dependent on the 'active' LoS. This is further described in section 5.

The pointing error specifications are expressed as half-cone angles of the LoS and half-sector angle around the LoS. They are specified at a temporal probability level of 68%, which implies that the error will be less than the requirement for 68% of the time for each pointing direction.

RD-1:
MOOF-030 H *During all scientific observation modes requiring periods of stable pointing or scanning, the pointing requirements with the goals as specified in the table below shall be met.*

ERROR	*LoS (arcsec)*	*Around LoS (arcmin)*	*Goals for LoS (arcsec)*	*Goals around LoS (arcmin)*
APE pointing	3.7	3.0	1.5	3.0
APE scanning	3.7 + 0.05 w	n.a.	1.5 + 0.03 w	n.a.
PDE(24 hours) pointing	1.2	3.0	n.a.	n.a.

RPE (1 min) pointing	0.3	1.5	0.3	1.5
RPE (1 min) scanning	1.2	1.5	0.8	1.5
AME pointing	3.1	3.0	1.2	3.0
AME scanning	3.1+0.03*w	3.0	1.2+0.02*w	3.0
AME slew	10	3.0	5	3.0

Notes : *w is the scan rate in arcsecond / second .*
APE scanning mode requirements and goals around LoS are covered by MOOF-085 (ARE : Absolute Rate Error about scan axis) to be less that 1 % of scan rate with minimum of 0.1 arcsec/sec.

In addition there is a requirement on Spatial Relative Pointing Error (SRPE):

> **Definition SRPE:** *the angular separation between the average actual LoS direction and a desired LoS direction which is defined relative to an initial reference direction.*

MOOF-040 H — *In consecutive pointings within 4 deg. x 4 deg. spherical area, the* ***SRPE*** *of all pointings following the initial pointing, as referred to the average (barycentre) pointing direction of the first pointing shall be* ***less than 1 arcsec*** *(68% probability level).*

A visual interpretation of the SPRE can be found in Figure 1

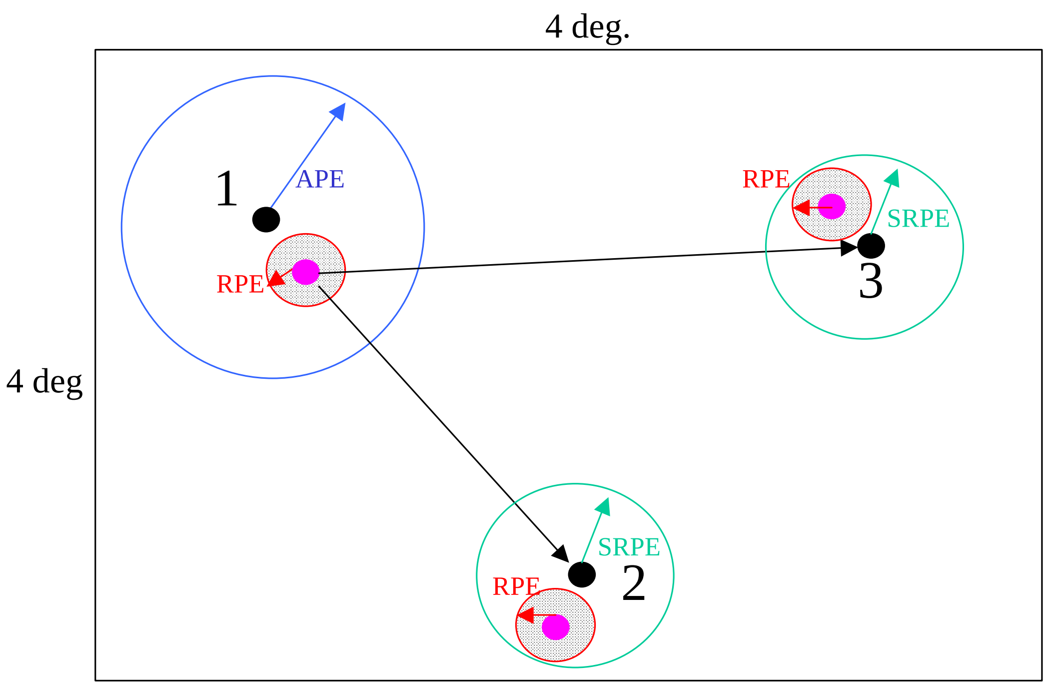

Figure 1: Illustration of SRPE and its definition. The initial commanded direction (black dot no 1) is achieved within the APE accuracy (blue circle). The actual pointing of the spacecraft (dotted area within red circle) has an average direction (purple dot). New directions are commanded (black dot 2+3) relative to initial actual direction (purple dot 1) and are met within the SRPE requirement.

SRPE applies for raster pointing and raster with an offset. However for consecutive inertial fixed pointings, the SRPE does not apply. Additionally it must be assumed that the spacecraft is at a thermal equilibrium at the initial pointing.

3.1 Goal Interpretation

Goals are to be fulfilled under special but specified conditions while requirements are to be satisfied also under worst-case conditions from BOL to EOL.

Examples of such special conditions are:

- 18 or more recognisable stars in the star tracker field of view
- Observations within a narrow sun aspect angle range as experienced during calibrations

In Section 4.7 some initial considerations are given which so far are guidelines for meeting the goals. As the project evolves those means to meet the goals will be continuously refined by industry.

4 PREDICTED POINTING PERFORMANCE

4.1 Overview

The spacecraft design is targeted to the performances of the main error contributors as identified below, i.e. the star tracker (STR) accuracy, the structure thermo-elastic stability and the residual noise in the attitude control loop. This section will describe those main contributors and show the overall predicted performance based hereon, added also the minor contributors.

4.2 Main Error Contributors

For APE and AME four main error contributors can be identified:

- Position dependent bias within the Star Tracker (pixel to pixel variation).
- Residual from calibration.
- Thermo-elastic stability of the structural path between the star tracker and the focal plane units.
- Accuracy in determining the absolute attitude of an instrument line of sight, other than PCASE blue photometer array.

For PDE the dominating error contributor is the thermo-elastic stability of the structural path between the star tracker and the focal plane units. The PDE is defined over 24 Hours, and for the figures in section 4.6, the thermo-elastic effect of a worst-case slew prior to the 24 hours is conservatively included. This means that the maximum thermal distortion is included, simulating a slew from –30 to + 30 deg just prior to the PDE measurement.

For RPE the main error contributor is the input noise to the attitude controller. This noise is composed of star tracker noise and gyro noise merged and attenuated through a Kalman filter.

4.3 Star Tracker Performance

The star tracker is a high precision optical instrument with autonomous inertial attitude determination capability, using a built-in star catalogue. The Star catalogue is based on the Hipparcos catalogue, but is filtered in order to eliminate clusters or stars, stars with close neigbours, stars outside the specified magnitude limit etc. The approximate number of stars in the catalogue will be in the order 3000 to 3500.

Two main requirements leading to the choice of STR were:

- Ability to determine the inertial position from being 'lost in space'.
- Providing high accuracy measurements during scientific pointing.

The first requirement requests a large STR Field of View (FoV) in order to see as many stars as possible, and to use those for determining the pointing direction on the sky. The second requirement requests a small FoV, tracking one or two stars, as done on for example ISO. In this manner the main guide star can be strongly defocused on the CCD and very small variations can be detected.

The best compromise of the two above requirements was the autonomous star tracker build by Galileo Avionica.

This STR has a FoV of 16.4x16.4 deg^2 and is using between 3 and 9 stars to determine the inertial attitude at 4 Hz. 9 stars is a HW limitation on the maximum number of stars, which can be tracked on the CCD by an ASIC, and 3 stars is the minimum number under which the algorithm can uniquely find the inertial attitude.

With the data above a simulation has been performed to determine the availability of stars in the FoV over the entire sky[1]. The statistics is show in Figure 2. From the figure the following can be read:

- Average number of stars in FoV is above 14.
- Probability of 9 stars is >90 % (For the used catalogue the exact value is 96.2 %).
- Minimum number of stars in FoV is 3.
- A step size of 2 deg was used, resulting in a total of 16200 pointings.

[1] The simulations has been performed by ESA with an ESA tool and based on an ESA generated star catalogue filtered with similar criteria as used by Galileo Avionica. The data has been correlated with similar simulations performed by Galileo Avionica, but the flight on-board catalogue will not be delivered before delivery of STR FM's.

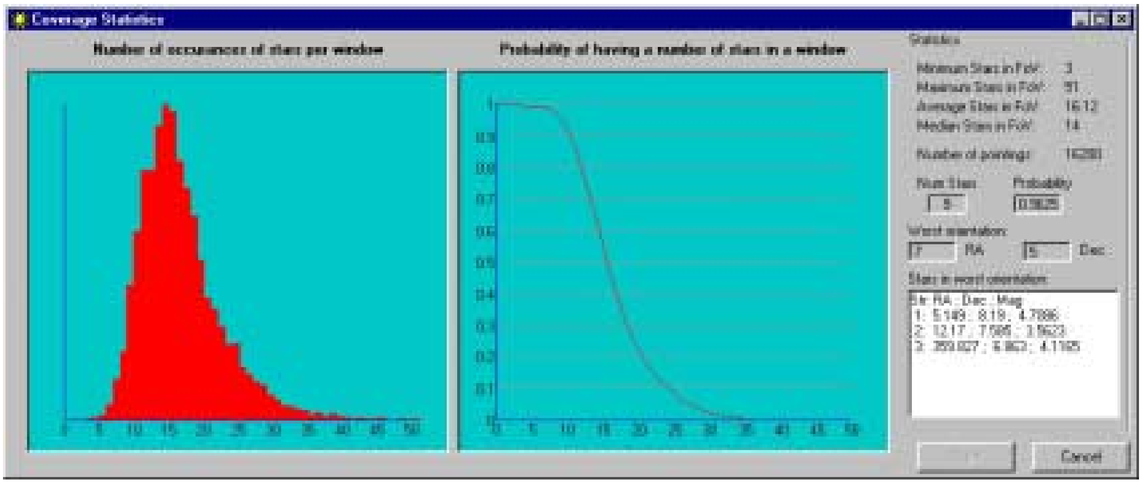

Figure 2: Statistics of available guide stars in the FoV over the entire sky. Field of View is 16.4 times 16.4 deg2.

The distribution of the stars over the entire sky is shown in Figure 3, including the percentage of the coverage with <7, 7,8 and >=9 stars.

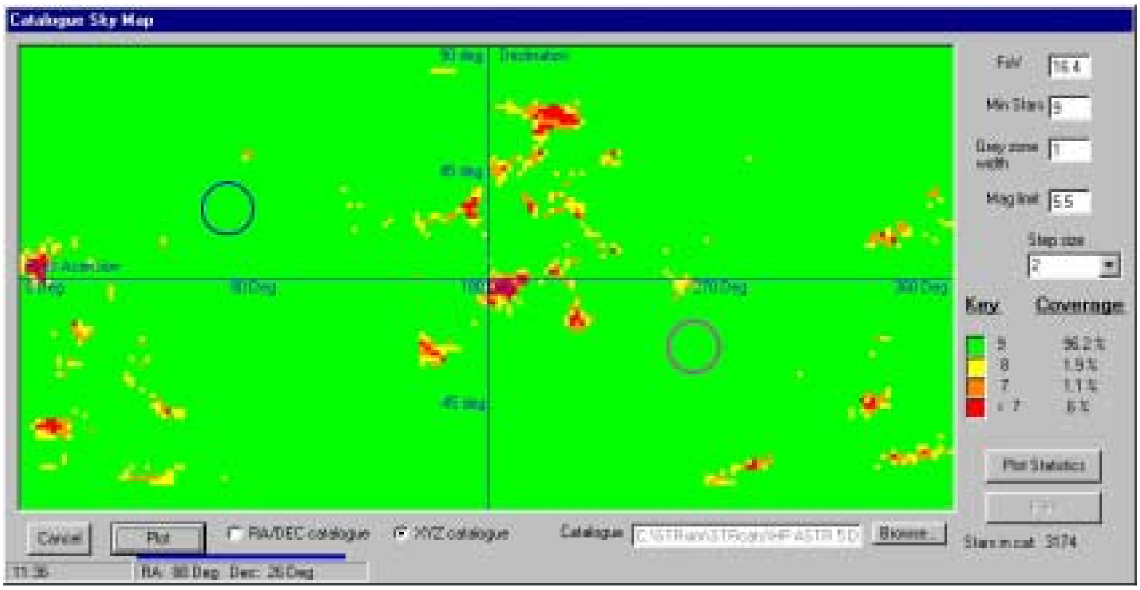

Figure 3: Distribution of stars over the entire sky expressed in RA,DEC coordinates. Green areas indicates that 9 or more stars are available, yellow is 8 stars, orange is 7 and red is below 7 stars. Notice that the telescope is oriented 180 deg away from the STR LoS.

An enhance performance mode, “interlaced mode”, has been introduced to take advantage of attitude directions where more than 18 recognisable stars are present in the field of view. In this mode the STR is sampling at twice the sampling rate, but is tracking two sets of 9 stars, hence the need for more than 18 stars.

Interlacing can be commanded at any time, but using this mode when less than 18 stars are available will not provide any improvement and might even decrease the performance.

Instead the STR will indicate in the TM to the on-board computer (attitude control computer) the predicted number of stars available for tracking in the next cycle. In case more than 18 stars are available the STR will be commanded into interlacing mode. Therefore from an instrument point of view, this is an autonomous process, which will be indicated in TM when exercised.

A simulation has been performed to show areas on the sky with more than 18 stars in the FoV. The result is shown in Figure 4.

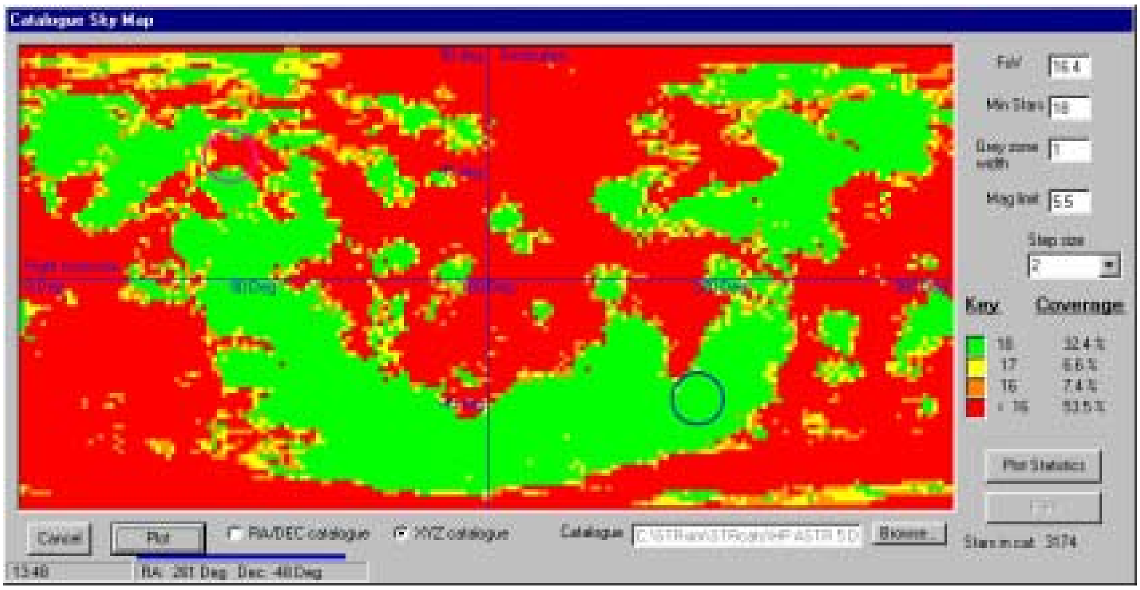

Figure 4: Sky map of availability of 16 or more stars in the FoV. This is important knowledge when planning observations, since areas with more than 18 stars can benefit from the STR interlacing option. Notice however that the STR LoS is oriented 180 deg away from the instrument LoS.

A summary of the main performance parameters are given in the table below (68% probability over the entire sky):

	LoS (arcsec)		*Around LoS (arcsec)*	
	Non-interlaced	Interlaced*	Non-interlaced	Interlaced*
bias at fixed pointing:	0.8	0.6	4.5	3.7
noise equivalent angle:	0.6	0.4	6.5	4

*: when >=18 recognisable stars in the Field of View

From the table it is clear that the LoS performance is one order of magnitude better that around LoS (ALoS). It is therefore essential that the LoS of the STR is aligned with the instrument LoS to avoid the coupling of the worse STR ALoS performance. Since it is unfeasible to place the STR parallel to the telescope, the STR is oriented 180 deg away from the instruments LoS and placed in the center of the service module (SVM). This is illustrated in Figure 5.

The final contribution to the STR error budget is the accuracy of the STR datation. The timing accuracy of the STR data with respect to the CDMU synchronization pulse is 160 us, and is random.

4.4 Thermo-elastic Stability of the Structure

In order to minimize the thermo-elastic path from the STR to the FPU, the star trackers are mounted on a carbon fibre (CFRP) platform that is suspended by struts from the lower dome of the cryostat vacuum vessel (CVV). The struts are partly made of glass fibre (GFRP), to minimise the conducted heat input to the CVV, and partly of carbon fibre (CFRP), to minimise the thermo elastic distortions. An illustrative sketch of this is shown in Figure 5.

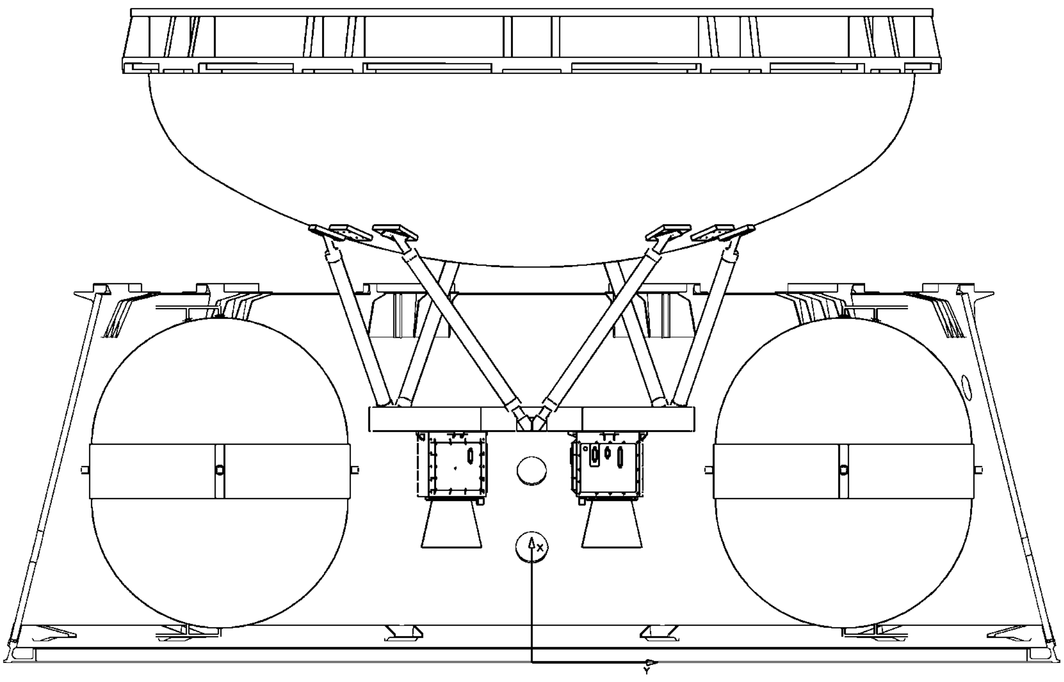

Figure 5 shows an illustrative sketch of the two redundant STR mountings below the CVV. The thermal path is hereby shortened from the STR to the FPU.

The structural path between the CVV lower dome and the instrument focal plane assemblies is very stable thanks to small thermal variations of the CVV over time. For the same reason, small thermal variations over time, the alignment stability between the telescope and the optical bench is high. A typical stability breakdown is given below:

	Solar Aspect Angle	
	-30 <> 0	**0 <> +30**
Star tracker	0.1”	0.1”
Platform – struts	0.2”	0.1”
CVV – FPU	0.2”	0.2”
FPU – telescope	0.2”	0.2”
RSS of errors	**0.36’’**	**0.32’’**

Table 1 illustrating a typical example of the thermal elasticity of the spacecraft. This effect will contribute to the drift of the instrument over 24 hours.

4.5 Noise in the Attitude Control Loop

The high frequency noise (frequencies faster than 1 minute) in the control loop influence the RPE and should be suppressed. The main noise sources are:

- Star Tracker noise equivalent angle
- Gyro noise and short term drift.
- Reaction wheel torque command resolution

The Star Tracker and Gyro data is fed into a Kalman filter which is estimating drift and filtering noise. From the STR the main noise contributor at fixed pointing is the ‘shot noise’ arising from the changing number of photons collected, contributing with approximately 0.6 arcsec.

The Gyro has several noise contributors, main contributor being the internal control loop with an approximately profile of 0.003 arcsec/sqrt(Hz).

By filtering the STR and the GYR data the noise level is reduced to about 0.1 arcsec during fixed pointing.

The reaction wheels introduces additional noise within the digital to analog conversion, as a quantization effect. The influence of this quantization is approximate 0.033 arcsec.

With the above figures it must be remembered that the different frequency contributors, bias, drift and noise must be linearly added to achieve an overall figure[2].

[2] Calculating error contributors and adding them is performed according to ‘ESA pointing error handbook’.

4.6 Predicted Performance

With the above described error sources, and also including the minor contributors, an overall summary of the pointing performance can be presented as shown in the table below.

In the table the requirement and the predicted performance is indicated for LoS and ALoS. The table has been generated based on predicted and simulated performances for each error contributor within the system.

From the table the following is observed:

- All around LoS requirements are met.
- Of all the LoS requirements only the SRPE is non compliant.
- Of the goals only the AME pointing goal is non-compliant.

For the SRPE, two figures are presented, one in the requirement column and one in the goal column. The goal prediction is based on the STR bias and STR thermal interface goal values. However this still leaves a non-compliance of 0.11 arcsec, which can not be removed without reducing the confidence level of 68 %.

Herschel pointing requirements. SRS 3.1

	LoS (arcsec)		Around LoS (arcmin)		LoS Goals	
Name	**Req**	**Performance**	**Req**	**Performance**	**Performance**	**Notes**
APE pointing	3.7	2.83	3.00	0.36	n.a	
APE pointing GOAL	1.5	n.a	n.a	n.a	1.50	**a**
APE scanning	3.7	3.33	n.a	n.a	n.a	
APE scanning GOAL	1.5	n.a	n.a	n.a	1.50	**b**
PDE (24 hours)	1.2	1.14	3.00	0.11	n.a	
RPE (1 min)	0.3	0.16	1.50	0.11	n.a	
RPE (1 min) scanning	1.2	1.00	1.50	0.11	n.a	
RPE (1 min) scanning GOAL	0.8	n.a	n.a	n.a	0.80	**c**
AME pointing	3.1	2.78	3.00	0.36	n.a	
AME pointing GOAL	1.2	na.	n.a	n.a	1.40	**d**
AME scanning	3.1	2.30	3.00	0.45	n.a	
AME scanning GOAL	1.2	n.a	n.a	n.a	1.19	**e**
AME slew	10	4.22	3.00	0.46	n.a	
AME slew GOAL	5	n.a	n.a	n.a	3.69	**f**
SRPE	1	1.49	n.a	n.a	1.11	**g**

	Notes	
a	1. Thermo elastic <0.15" all axis	2. Calibration residual <0.5"
b	1. Thermo elastic <0.15" all axis	
c		
d	1. Thermo elastic <0.1" all axis	2. Calibration residual <0.5"
e	1. Thermo elastic <0.15" all axis	2. Calibration residual <0.5"
f		
g		
ALL	**1. STR thermal goals**	**2. STR bias goals (interlacing).**

Colour code	**Interpretation**
(light blue)	Descriptive name
(yellow)	External requirement/input.
(green)	Performance figure, Compliant.
(red)	Performance figure, NON-Compliant
(light green)	Copy of an input, to be edited somewhere else.

4.7 Goal performance and constraints

For each of the predicted goal performances the following has been taken into account:

- STR interlacing.
- Goal values for thermal stability of the structure.
- Goal value of the thermal interface of the STR.

Additionally for each of the goals which remained non-compliant with the above assumptions the following has been assumed:

- **APE Goal:** Thermo-elastic effects are below 0.15'' about y and z axis (nominal value is 0.8'' about y and z axis) and a calibration residual below 0.5'' about y and z axis (nominal value is 0.65'' about y and z axis).
- **APE scanning Goal**: Thermo-elastic effect below 0.15'' about y and z-axis.
- **AME Goal:** Thermo-elastic below 0.1'' and calibration residual below 0.5''.
- **AME Scanning Goal:** Thermo-elastic effect below 0.15'' and calibration residual below 0.5''.

Of the above list it seems realistic to be able to define sun aspect angles under which the thermo elastically effects remains below 0.15'' and reducing the calibration residual to 0.5. However realistic means to meet the 'AME Goal' has not been found and seems unlikely to be achieved.

It must however be remembered that the above conditions are suggestions and indications only. It will be the choice of industry to finally define the goal conditions and make the correlation between thermo-elasticity and sun aspect angle (SAA).

Such refined analyses will be available at the system CDR.

5 ALIGNMENT AND CALIBRATION

When the spacecraft is in orbit, the objective of the ACMS subsystem is to point the active instrument LoS towards a given target. To achieve the high-performance figures quoted in section 4.6 and 4.7, on-ground alignment and in-orbit calibration must be performed.

This section describes how ground alignment and in-orbit calibrations are carried out.

5.1 Ground Alignment (pre-launch)

There are three main domains for the ground alignment activities with respect to pointing:

- Each FPU alignment with respect to the telescope
- Instrument internal LoS alignment with respect to PACS blue photometer array[3].
- Star tracker alignment with respect to PACS blue photometer array.

The requirements on the first item is expressed by the PIs and reflected in RD-2. The requirement for the latter is governed by the need for the initial calibration targets to be observable within the field of view of PACS, i.e. < ~1.75 arcmin.

The PI's shall provide the alignment knowledge of each instrument entry beam's far field pattern with respect to its focal plane unit master cube. The built standard of the focal plane units are such that no shimming is required to fulfil the alignment requirements with respect to the optical bench. During ground alignment with the CVV in open configuration, the optical bench will be aligned with respect to the telescope and the LOU by the use of a master optical reference on the CVV. This alignment will pre-compensate for the CVV shrinkage during subsequent evacuation and cooling down. The adequate alignment will be verified during thermal vacuum test by means of a dedicated alignment camera system using optical references on the HIFI-FPU, HIFI-LOU and telescope support frame (TBC).

The star tracker LoS will also be accurately measured with respect to the master optical reference on the CVV. Again it is expected that the precision in the built standard will be such that no shimming is required.

Each instrument contains several LoS, between 4 and 14. The relative alignment of each LoS within each instrument is measured on ground. When observations are planned, this fixed offset must be included within the pointing commands send to the ACMS subsystem, thus added by ground to the requested pointing direction.

5.2 In-orbit calibration

In-orbit calibrations are performed in order to validate the ground alignment of the STR towards the focal plane and to compensate for changes during launch and over the lifetime.

Three types of calibrations are foreseen in orbit.

[3] PACS blue photometer array is chosen since it provides the highest accuracy during the calibration and thus is the easiest instrument to calibrate towards in orbit.

- 'Main calibrations', which results in an update of the offset of the STR versus the instrument.
- 'Weekly calibration check' to confirm the current offset[4].
- 'Peak-up mode', which is a calibration valid for the next pointing command.

Initially -off launcher-, a 'main calibration' is needed to determine the fixed offset. However at the very first calibration major offsets might exists from the launch which could imply that the instrument would not see its calibration source.

To ensure that a target is visible by the instrument it is foreseen to perform a raster pointing about the calibration direction and when a rough offset correction is found, the 'main calibration' is performed.

Below is described calibrations performed after such an initial calibration has been performed.

5.2.1 Main calibrations

Main calibrations are performed to update the offset between the STR LoS and the (nominally) PACS blue photometer array. The remaining non-compensated offset is called 'calibration residual'. The size of the calibration residual is dependant only on the performance within the instrument, the STR and the conditions under which the calibration is performed.

The data processing to determine the instrument LoS attitude in inertial space will nominally be performed on ground by the PACS instrument team. The "as measured" absolute attitude, referenced in right ascension and declination, will be provided for each calibration attitude and forwarded to flight dynamics team at MOC. Here the data will be correlated with the STR data and calculation of the offset between the two LoS will be performed.

It is the responsibility of flight dynamics at MOC to maintain the applicable offset (in form of transformation matrices) and to generate the telecommand parameters to the spacecraft (attitude quaternions) corresponding to individual instrument pointing requests.

For the in-orbit calibration it is important to identify suitable reference targets, which are well spread over the sun aspect angle range. As a minimum three targets should be available for each calibration, at approximately +30, +/-0 and – 30 deg sun aspect angles. The reason being that the SAA has a direct influence on the thermal elasticity and that the instrument and STR has position dependent biases; all errors which must be averaged/minimized during a calibration by choosing several sources.

[4] In the SRS daily calibration checks are requested. It is however expected that need and the duration to analyse the calibration data only will require a weekly check.

It is important to understand (for target catalogue generation) that the thermal stability is not influenced by the angle around the sun line, only the sun aspect angle. Therefore a small circle of 360 deg is always available about the sun vector, for the specific case of sun-vector aligned with z-axis (0 deg SAA angle), it is a great circle.

Calibration duration
The thermal time constant of the spacecraft is high, especially for the cryostat. It is therefore recommended to remain at a constant sun aspect angle (<+/- 1 degree) for at least 48 hours before collecting the relevant calibration data[5]. After 48 hours both star trackers shall be calibrated in their operational configuration, i.e. one star tracker ON and one star tracker OFF. Each configuration should be maintained for at least 10 hours to establish thermal equilibrium. This is done in order to guarantee the performance of the spacecraft even in case of a STR failure leading to a usage of the redundant STR. The different offset between the two STR must be available on-board and applied by the SW as part of the FDIR procedure.

In summary the duration of the main in-orbit alignment calibration phase will be:

$$3*(48+10) = 180 \text{ hours, i.e.} \sim 1 \text{ week}$$

Obviously other instrument performance verifications can be carried out in parallel to these alignment calibrations.

The ground alignment knowledge between the various LoS of HIFI, SPIRE and PACS should be sufficiently high to allow the definition of offsets between each of the star trackers and the respective instrument LoS based solely on the PACS measurements. Obviously cross alignment calibration of the internal LoS using the same target would be an advantage to confirm the ground alignment knowledge.
Since the beams are relatively close together no thermo-elastic settling time is required between such observations.

For confidence it is proposed to perform an alignment check on one or two targets just before the start of the routine phase.

Calibration accuracy
When performing calibration, data must be available from both the STR and the instrument (nominally PACS).

The output of the calibration is an estimate of the offset from the STR to the instrument. The size of the calibration residual / the accuracy of the calibration is dependent on five main factors:

[5] This is naturally only possible if the Earth is within the field of view of the medium gain antenna. Otherwise the spacecraft should be slewed back to the border of the antenna FoV during the DTCP and back towards the calibration direction immediately after the DTCP.

1. Accuracy of the STR raw data
2. Thermo-elastic stability
3. Accuracy of the instrument raw data
4. Number of samples at each calibration point
5. Number of observations within each calibration (different SAA)

The accuracy of the STR data is mentioned in section 4.3.

The following formula and assumptions has been used when estimating the calibration residual:

Instrument bias error of each observation in the functional reference frame of the instrument: $\Phi_{ib}(68\%)$
Instrument noise in each read out sample: $\Phi_{in}(68\%)$
STR bias error of each observation: $\Phi_{sb}(68\%)$
STR noise in each read out sample: $\Phi_{sn}(68\%)$

Number of observed calibration sources: n_{obs}
Number of samples per observation: n_{samp}

The residual calibration error is then given by:

$$\Phi_{rc}(68\%) = SQRT[(\Phi_{ib}^2 + \Phi_{sb}^2)/n_{obs}] + SQRT[(\Phi_{in}^2 + \Phi_{sn}^2)/ n_{samp}]$$

The values used for the STR are reported in section 4.3, for the instruments requirements from the IIDA section 5.12 is used as:

- Bias: 0.9 arcsec LoS
- Drift 0.05 arcsec LoS
- Noise 0.05 arcsec LoS

Additionally 100 samples at each observation and 3 observations with different SAA are used.

5.2.2 Weekly calibration check

Weekly calibration check is carried out to perform trend analysis and long term calibration residual validation. The check can be done either in the DTCP period or during the observation phase where a larger part of the sky is available, and when the nominal operation permits (PACS is ‘ON’ and a calibration source is within short distance to the planned observation).

Only one source is needed and the duration can be as short as 10 minutes excluding slews. The check is performed to ensure confidence within the attitude data and to catch slow changes in thermal elasticity to, for instance, solar seasons and ageing.

When the trend of the weekly calibration indicate that the current offset compensation ‘in use’ is outside a specified boundary, a new ‘main calibration’ will be planned within the four weeks by ground. It is however foreseen to perform this ‘main calibration’ only once during the performance validation phase, any other ‘main calibration’ campaign should be regarded as contingency planning.

The instrument data from the calibrations will be provided to the instrument teams, which after processing will supply those data to MOC. At MOC the processed data will be correlated with the STR data and the validation of the current offset calibration is performed.

The duration of the processing loop (instruments and MOC) should be kept shorter than ten days.

5.2.3 Peak-up mode

Peak-up mode is a specific calibration, which is valid only for the next pointing, which is commanded and used by SPIRE and HIFI.

The peak-up procedure is commanded from the Mission TimeLine (MTL) and is roughly as follows:

1. To determine pointing corrections typically a small raster is commanded to instrument and ACMS S/S. (There will be no limitation from ACMS side on what type of pointing is performed for the purpose of determining these corrections.)
2. After 'end of pointing(s)', the ACMS S/S keeps the S/C pointing at the last raster point. (If the command was performed in SSO the S/C continue slewing, pointing at the last point).
3. During this 'idle' of the S/C, the instrument calculates the offset.
4. Instrument sends this offset to the ACMS S/S.
5. From MTL, a new pointing direction is commanded. This can be ‘fixed pointing’ or ‘raster’ either in inertia pointing or in SSO tracking (scans are excluded). In case a ‘scan’ is commanded the peak-up offset is deleted.
6. The ACMS S/S adds the offset to the new position and performs either 'fixed pointing' or ‘raster pointing’ (either in inertial or in SSO tracking mode).
    a. For fixed pointing the target quaternion is modified with the peak up offset.
    b. In case of a Raster Pointing, the commanded quaternion(s) are modified in accordance with the peak up quaternion. This means that the peak up applies to all points in the raster INCLUDING the off-position.

7. At the next commanded pointing / raster etc. the offset will be deleted. That is, it is not possible to send sequential pointing TC's with the same offset applicable.

The above procedure is illustrated in Figure 6.

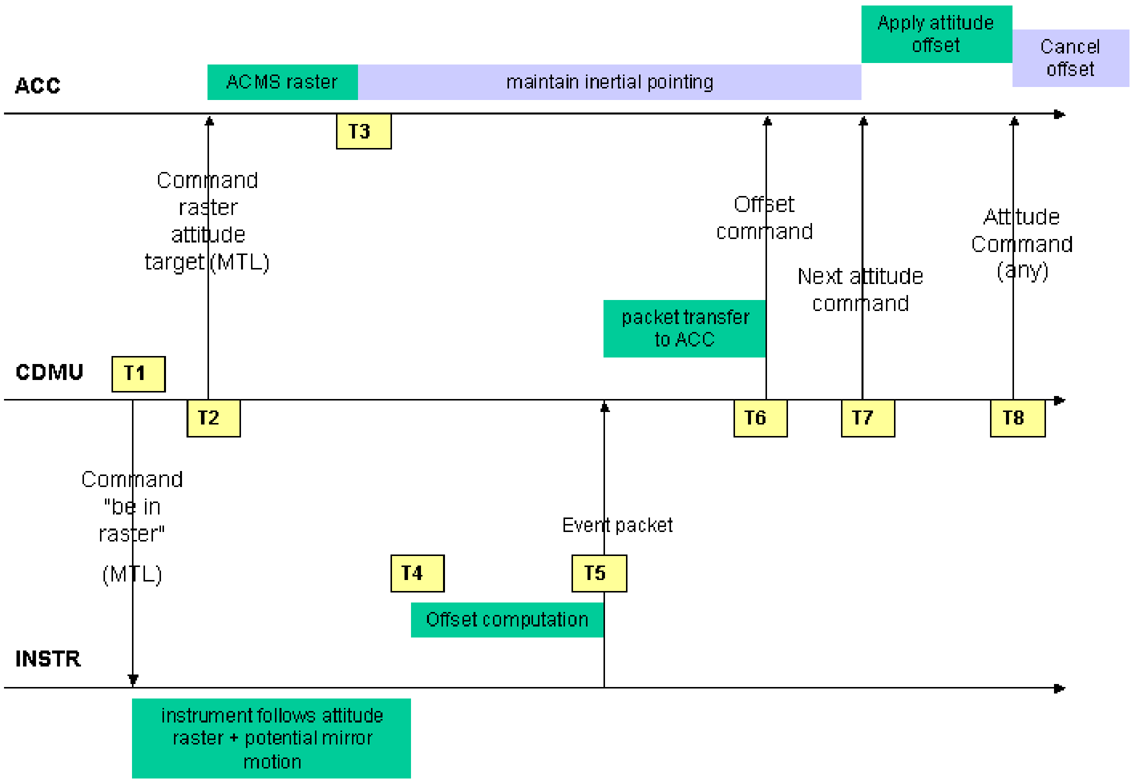

Figure 6 is illustrating the flow of information during a peak-up procedure.

6 SCIENCE TARGET SELECTION AND PLANNING

Although the spacecraft design is compliant with the requirements over the full observable sky at any time (except the SRPE), it is from the above discussion evident that by grouping observations around a limited sun aspect angle a better performance will be achieved. This is especially important to get close to the SRPE requirement, which already assumes a very low thermal drift during the raster pattern.

Examples of simple planning strategies to be applied are:

- Avoid large slews before high performance is needed.
- Select off-target positions on the small circle around the sun-vector.
- Long scan line or big raster observations (>15 degrees) to be scheduled, when feasible, such that their main dimensions are within similar SAA

- When goal performance is needed, calibrate within same SAA direction as the observation.

7 CONCLUSIONS

This paper has discussed the driving requirements for the Herschel observatory in terms of attitude pointing and measurement accuracies. An outline of the main design drivers and the corresponding performances was given. An overview of the ground and in-orbit calibration means has been presented and finally some science target selection and planning rules have been established.