Science Demonstration Phase Implementation

Herschel/HSC/MEM/1312_v1.1

Göran Pilbratt, 19 January 2009

1. Introduction and Scope of this Memo

This document describes the background to, the objectives of, and the implementation of the Science Demonstration Phase (SDP) for Herschel, and solicits observations to be executed as part of the SDP. The SDP will take place just before commencing the routine science operations phase.

The present version (v1.0) is intended for the soliciting of KP GT observations for the SDP.

The outline of this memo is as follows:

- Section 2 provides the background and overview of the SDP.
- Section 3 provides a discussion of the objectives and consequences of the SDP.
- Section 4 provides the implemention guidelines and applicable rules of the SDP.
- Section 5 provides the process for the selection of the SDP observations, with schedule.

This document has been written by the Herschel Project Scientist (PS) following definition of the relevant policies by the Herschel Science Team (HerschelST). The PS is the custodian of the document and the present version (v1.1) has been endorsed by the HerschelST for circulation, after the incorporation of a few modifications discussed in HerschelST#36.

2. Background and overview of the SDP

The original motivation for the SDP was to generate high quality Public Relations/Communications (PR&C) material. The HerschelST has emphasised the need to consolidate the lessons learned from the in-flight Commissioning and Performance Verification Phases (CoP and PVP), to take stock of where we are at that point, and to confirm and/or update the existing observing programmes as appropriate before going into the 'production phase' of the mission - the routine science operations phase. Herschel is a cryogenic consumables lifetime-limited mission and we cannot allow precious helium/lifetime to be spent on observations (or even observing programmes) that do not deliver.

The existence of a dedicated mission phase to address these issues has been introduced into the Herschel Science Management Plan (SMP), the top level document governing Herschel, and has been approved by the Science Programme Committee (SPC). For information and convenience Section 6 of the SMP is attached as an Appendix, the SDP is addressed in (sub-)Section 6.4. It should be noted that exceptionally Section 6 in the SMP is 'for reference only' and the actual definitions and durations of the various mission phases will be given in other documents; this memo fulfils that role for the SDP.

The objectives of the SDP observations can be summarised as (see further Section 3):

- to demonstrate the actual scientific capabilities of the observatory to (potential) observers;
- to demonstrate what can be learned from observations performed successfully;
- to produce material for PR&C purposes.

In addition the HerschelST has identified a fourth and major objective of the SDP:

- to provide the basis for the updating (as necessary) of accepted observing programmes.

These objectives will be addressed mainly by performing a small fraction of a variety of approved observing programmes, using the recently gained in-flight knowledge and observe in the manner intended for the routine phase, and to reduce and share the results with the general astronomical community. In addition, special

additional observations will be carried out if the necessary aspects of Herschel performance cannot be demonstrated using observations from already approved programmes.

The SDP observations will be carried out after the PVP, but before commencing the routine phase. An important and integral part of the SDP is the organisation of a major workshop to communicate the findings to the community at large, and also to provide a nice PR&C opportunity. Furthermore, it will be necessary to update all existing observing programmes and associated observations (AORs) incorporating the in-flight knowledge, before releasing for execution in the routine phase. It is conceivable that this could involve drastic modifications to certain observing programmes. The information gained will also be incorporated into the AO to be released shortly afterwards for the Cycle 1 Open Time regular call.

3. Objectives and Consequences

As outlined in Section 2 above there are objectives associated with the actual observing to be conducted in the SDP, and there are additional objectives associated with the processing, interpretation and assessment of these observations, and the implications in terms of implementing necessary modifications to existing observations and/or observing programmes.

3.1 Observations and observing programmes

The observing objectives fall in four categories:

- **To demonstrate the actual scientific capabilities of the observatory to (potential) observers.**

There is a need to demonstrate both to existing and potential new Herschel observers what the real demonstrated in-flight observing capabilities of the observatory are.

For existing observers there is a need to consolidate their observing programmes based on demonstrated in-flight actual observatory performance. Such consolidation may be limited to the ‘tweaking’ of the AORs based on the now verified AOTs with updated calibration tables etc, this should be relatively straight forward unless there are very major differences compared with the pre-launch knowledge and predictions. If the required changes are more significant further reaching modifications may be required.

- **To demonstrate what can be learned from observations performed successfully.**

There is a need to ascertain that observations successfully carried out and processed, are actually suitable to address the scientific objectives that were provided to motivate them, i.e. that their science rationale is valid and realistic in the ‘real world’.

It is also important to conclude what cannot be achieved, and the necessary consequences will need to be accepted.

- **To provide the basis for the updating (as necessary) of accepted observing programmes.**

In the case of major differences in scientific capabilities compared with the pre-launch situation, such as e.g. AOTs that will have to be withdrawn (and possibly replaced by new ones), very significant sensitivity/observing time updates and the like, more drastic modifications of affected observing programmes could be required. Such modifications should normally be covered by the ‘robustness’ information provided in the proposal; should this not be the case involvement of the HOTAC will be necessary.

Should the original science goals, or part of them, not be realistic in the light of the in-flight performance and lessons learned an observing programme may have to be modified to concentrate on a subset of the original scientific objectives, with resulting updates to the observations to be released for scheduling in the routine phase. The PS is responsible for assessing whether the proposed modifications clearly go beyond the robustness of the proposal and refer such proposals to the HOTAC for review; in an extreme case an entire observing programme could be declared infeasible and would be cancelled. For a GT programme the observing time cut in this process would go back to the GT owner, for an OT programme the time would be lost.

- **To produce material for communications purposes.**

This is still a valid objective, however, it is considered neither to be a major driver to the selection of observations to be carried out nor to the implementation of the SDP in general. Observations in the PV phase as well as the SDP can be used for PR&C.

3.2 Workshop - looking towards the routine phase and the release of the AO

The SDP workshop will include a review, from a scientific perspective, of the Commissioning, PV, and SD phases and lessons learned, illustrating a variety of facets of the mission. It will also be an important event for PR&C.

The detailed planning will be done in early 2009. Sessions - of widely varying durations - that are foreseen in the workshop include:

- **Herschel press session.**

It is planned to use the fact that a major Herschel workshop is conducted presenting the capabilities and some first results also to promote Herschel in the press/media by organising a dedicated press/media session. This session could be planned at the opening or at some other time during the workshop. Communications people in both ESA/ESTEC and JPL/IPAC are aware of and enthusiastic about this idea.

- **Current status of Herschel.**

Information to the community about Herschel early in-flight phases, emphasizing the aspects that are of interest to astronomers who need to update their programmes for release for scheduling in the routine phase, and for potential proposers in the forthcoming AO.

- **Overview of the SDP, conducted observing programmes, and early results.**

A summary description of the SDP, its objectives and implementation. Then a number of individual presentation by members of the KP consortia whose observations have been implemented, providing information about the objectives of the programmes, the observations conducted and why, and finally the early observational and scientific results.

- **In-flight instrument performance and AOT status.**

This will deal with updates to AOTs (including new, not yet released, and withdrawn AOTs, as appropriate), calibrations, sensitivities/observing time estimates, and other parameters. In addition ‘best practices’ can be illustrated giving advice on how to best utilise a particular AOT for a given purpose.

- **Demonstrated scientific capabilities of Herschel as a facility available to the community.**

This will rely on the SDP observations carried out (see above). It will be important to illustrate both what Herschel can do well, and what it cannot do so well as the case may be.

- **Lessons learned about choosing the mode for the job.**

Best practices on the choice of how to use Herschel for particular tasks, e.g. choices between raster and on-the-fly mapping, between frequency and load switching, what to keep in mind for solar system object observations, how often to include calibrations etc as appropriate for the different instruments and AOTs.

- **Updating of existing observations (AORs) for routine phase release.**

There will undoubtedly be minor, and perhaps some major differences between pre-launch and routine phase AOTs, and these will be incorporated in the routine phase version of HSpot. Observations to be performed in the routine phase must be submitted using the routine phase version of HSpot.

- **HOTAC review of the Herschel Key Programmes.**

The process and timescale for HOTAC review of the science programme based on in-flight performance of Herschel will be explained.

- **Lessons learned about data processing.**

This is not a data processing workshop, but results will presented and therefore the initial lessons learned in the processing of the PVP/SDP observations can be shared. Information about data processing software releases and workshops planned as appropriate.

- **Information about the forthcoming and future AOs.**

Timing and contents of the coming and future AOs as currently planned. This will include information about ‘rules’, Herschel observers’ manuals, and the tools that must be used to propose.

The intention is that the workshop should be of interest both to existing Herschel observers - who will have to update the observations/observing programmes to go into routine phase - as well as potential proposers in the forthcoming AO to be released shortly. After the workshop all existing observing programmes should be consolidated/updated and all AORs (re-)generated with the routine phase HSpot.

4. Implementation - guidelines and applicable rules

The SDP activities will take place after the successful conclusion of the PVP, but before the start of the routine science operations phase - the 'production phase' of the mission. It thus 'bridges' the two and serves to take stock and confirm or modify plans as necessary and appropriate at a critical phase during the in-flight mission. This is done in order to ensure that all observations about to be scheduled and executed in upcoming the routine phase will represent good use of Herschel observing time - a scarce resource - both in terms of being executed correctly and proven to deliver in terms of science.

4.1 Total duration of the SDP

The nominal overall duration of the SDP suggested by the SMP (2.5 months) is considered excessive, **as a guideline up to 2 weeks per instrument has been adopted as a reasonable starting point for the SDP planning**. The maximum would then be 250 hr of observing per instrument or 750 hr in total, which if - for illustration only - evenly distributed over the 42 accepted KPs would amount to just less than 18 hr per programme.

The observations to be carried out will be dictated by the objectives as outlined in Section 3.1, and the overall duration will be no longer than necessary to achieve these objectives. There is no guarantee that the maximum amount of time will actually be utilised, nor that it will be evenly distributed over all programmes (which in fact is unlikely). In the event of nominal or near-nominal performance, it is hoped that considerably less than six weeks in total will be needed.

4.2 Observing programmes

The SDP is functional phase, thus in principle any observation could be constructed and used. However, since the objective is science demonstration, the accepted idea is to preferentially use observation requests (AORs) from 'real' approved (by the HOTAC) observing programmes.

KP observers will be offered to assign a (small) fraction of their programmes for implementation in the SDP. It is not compulsory to participate, but it is encouraged. **These observations must be a subset of the existing observations**. The SDP cannot and must not be used to 'sneak in' additional or different observations.

An important factor is the capability of the observers to perform the necessary data processing of their observations and derive scientific results in a timely manner, as dictated by the objectives of the SDP given in Section 3.1 and the workshop described in Section 3.2. At this early time in the mission this will likely favour the observers with strong connections to the instrument teams or the observatory, often they will be GT observers. However, all KP observers will be invited to participate in stages, in the first instance the KP GT observers will be invited, then followed by the KP OT observers for capabilities not covered by the GT observations. Should the HerschelST conclude that there are still important remaining gaps in the overall SDP programme, observations will need to be defined for the purpose of filling these gaps.

4.3 Eligible observation requests

For the SDP only 'released' AOTs/observing modes of the observatory will be used. All SDP observations (AORs) will be executed in a 'routine phase manner'. They might not be generated by the routine phase version of HSpot - as it may not yet be available - but they should be 'identical' to what is intended to be generated by the routine version HSpot. In practice - depending on the 'success rate' of the PVP - this may mean that not all observatory capabilities can be included in the SDP.

Although it is not the intention to 'duplicate' demonstrations of various observational or scientific capabilities, it will be advantageous - at least initially - to have 'oversubscription' of the SDP since source visibility during the SDP will depend on the actual launch date. Furthermore, if for some reason certain observing modes/AOTs are not verified in the nominal PVP, they cannot be included in the nominal SDP.

4.4 Deliverables and data rights

The deliverables by SDP observers will consist of 'quantitative' or 'non-quantitative' data, the choice is made by the observer, and has ramifications for observing time reimbursement (as described in Section 4.5).

'Quantitative data' include the raw data and processed data products in the form of e.g. FITS files, i.e. what would normally be made available to the observer in the Herschel Science Archive plus the 'user-processed' final data products (e.g. images and/or spectra). Information on how the data have been processed will be important too.

'Non-quantitative' data refers to reduced data products such as files depicting final images and/or spectra but without 'raw' data or processed data products, intended to demonstrate the scientific capability of the observatory, but not to provide scientifically publishable material.

In formulating the SDP plan there will be a preference for observations for which full 'quantitative' data and data products are provided - but not an absolute requirement. In order to encourage the delivery of 'quantitative' data this defines whether the observing time spent is reimbursed or not (see Section 4.5).

Furthermore, by making a proposal to the SDP the data owner explicitly agrees to the rule that all SDP data, data products, and results are embargoed and must not be released until a date to be communicated by the PS. This embargo will also apply to any observations specifically designed for incorporation into the SDP.

Any observations specially designed for incorporation into the SDP must not interfere with any of the existing programmes (GT or OT), all data and data products will be made available for the general community, at the date when the SDP embargo is lifted.

4.5 Reimbursement of observing time

KP holders who allow observations from their programmes to be made in SDP will be providing a valuable service to all (potential) Herschel users through assisting in the optimization of the Herschel mission and providing community information.

In order to stimulate the provision of 'quantitative' data (see Section 4.4) **KP time holders who agree to such release from their SDP observations will have the observing time used reimbursed, to be used in the same programme according to the 'robustness' criteria provided in the observing proposal**. This adjustment will be part of the overall revision that will be performed using the in-flight validated version of HSpot before releasing the programme for observation in the routine phase. **KP time holders releasing 'non-quantitative' data will not get reimbursed**.

5. Soliciting and selecting observations - response and schedule

With the issue of the present document observations for the SDP are solicited. As part of the solicitation process this document will be sent to the HerschelST which includes all the 10 owners of Herschel GT.

The general rules and guidelines are provided in Section 4 above. Note that within the instrument consortia the instrument PIs may want to impose/introduce internal procedures before the submission of proposals to ESA.

5.1 Proposal contents

The response - the 'proposal' - to the solicitation **must contain the following information**:

- **The name of the PI and associated observing programme**.
- **Brief outline of the proposed SDP observations**, sources/fields, AOTs/AORs, noise level or SNR to be achieved, total duration, and any other relevant information.
- **Brief outline of the expected results**, why they are important and appropriate for the SDP, with reference to the objectives as described in Section 3.1.
- **Identification of the individuals responsible for planning the observations and providing the AORs**. It is likely that the AORs to be executed will have to generated at short timescale close to the actual implementation of the SDP.
- **Identification of the individuals responsible for the data reduction**, and confirm that the timescale for data reduction is appropriate to the SDP which will be very short, of order one or a couple of weeks.
- **Any other information considered appropriate**.

The total length of the response should be maximum 2 (two) A4 pages (using 11pt font and minimum 2 cm margins), excluding the listing of the AORs as currently defined which should also be provided.

The responses should be sent in PDF format to the Herschel PS by email to <gpilbratt@rssd.esa.int> on the schedule provided in Section 5.3 below. When a deadline date is mentioned 12:00 UT on that date is always implied.

5.2 Observations selection

The responses will be scrutinised by an *ad hoc* subcommittee of the HerschelST, chaired by the PS, which will generate a draft SDP plan. This will be endorsed (and possibly adjusted) by the HerschelST in its entirety.

HOTAC involvement is not required but they will be kept informed by the Herschel PS.

5.3 Timescale for KP GT SDP observations selection

For the KP GT SDP observations the formal solicitation will issued on 19 Dec 2008 using a preliminary approved version of this memo. The final wording will be (re-)approved by the HerschelST in its meeting 12-13 Jan 2009, however, no major modifications are to be expected.

The schedule will be as follows:

- Formal solicitation on 19 Dec 2008, reconfirmation on 14 Jan 2009.
- Internal procedures as appropriate within the instrument teams as defined within the teams.
- Delivery to ESA on 19 Feb 2009.

A preliminary selection of KP GT observations will be performed on a timescale of mid-Mar 2009. An update of this document (adding at least Section 5.4 providing the provisional outcome of the KP GT SDP process, and Section 5.5 providing the schedule for the KP OT process) will then be added, and the memo issued to the 21 KP OT PIs providing about a month to respond.

6 In-orbit mission phases

The overall *Herschel* in-orbit mission comprises a minimum of 3.5 years (as set by the cryostat lifetime requirement, cf. section 5.1), providing a 'routine science operations' phase duration of 3 years.

The instruments will be tested, characterised, and calibrated at instrument level before delivery, and verification of their proper functioning will be performed at system (satellite) level after integration, before and after environmental qualification. However, fully accurate scientific performance knowledge will only be obtained by in-orbit operation.

Below follow short descriptions of the objectives and activities performed in the various mission phases, leading up to the routine science operations phase. This section is meant to be for reference only and to provide additional background for section 5.

6.1 Launch and early operations phase

Herschel will be launched (together with *Planck*) by an Ariane 5 launcher into a transfer orbit towards a large Lissajous orbit around the L2 point. The final top-up of the *Herschel* superfluid liquid helium tank will take place 4 days before the launch. *Herschel* will separate from the launcher about half an hour after launch, followed by *Planck,* they will then proceed independently to their respective orbits.

The 'launch and early operations phase' (LEOP) will comprise approximately the first two weeks of the mission. The LEOP operations will be centred on the check-out of the spacecraft subsystems, the acquisition of the 'attitude control and measurement system' (ACMS) nominal mode, and the performing of transfer trajectory corrections for a proper orbit insertion around L2.

During LEOP the spacecraft will be transmitting only 'housekeeping' (HK), and the payload will not produce any 'telemetry' (TM). The LEOP is considered to last until the 3rd trajectory correction (scheduled for day 12) has been made, thereafter the transfer phase begins. During the transfer towards L2 the spacecraft commissioning followed by the spacecraft and science payload 'performance verification' (PV) phases will take place.

6.2 Spacecraft commissioning phase

The spacecraft commissioning (and performance verification) phase commences immediately after the end of the LEOP. It is to some extent intertwined with the science payload commissioning and PV phase, the boundary between the two phases is not absolute. Nominally, the (science payload) PV phase starts at the end of the (spacecraft) commissioning and PV phase.

The spacecraft commissioning includes a complete check-out of spacecraft functions and verification of all subsystems performance, ensuring that the satellite can be operated safely in 'autonomy' mode, and verification of the spacecraft/instrument interface. The spacecraft performance verification is seen as an extension of the spacecraft commissioning and addresses in particular ACMS and ACMS sensor calibration. The nominal duration of this phase is 2 weeks, the cumulative time since launch at the end is thus 4 weeks.

6.3 Science payload performance verification phase

The instrument (commissioning and) performance verification (PV) phase nominally commences after the conclusion of that of the spacecraft. However, in practice they will to some extent overlap in time.

6.3.1 Instrument commissioning

The instrument commissioning includes initial switch-on and functional check-out. During check-out, a subset of the test procedures used in ground tests will be repeated to confirm that the instruments have survived the launch.

Instrument HK parameters will be monitored by the MOC and the 'Instrument Control Centre' (ICC) teams co-located at the MOC will analyse the data in order to establish the status of their instruments. The instrument operations teams at the corresponding ICCs will perform further detailed analysis of these data. Instrument check-out shall verify that the basic functions required to support science operations are available.

Instrument commissioning and check-out does not require a specific target or pointing, in fact it does not even require the cryostat lid to be open. The nominal duration of this phase is 2 weeks, the cumulative time since launch at the end is thus 6 weeks, which corresponds to when the telescope temperature will be approaching its operational temperature and the cryostat cover can be opened.

6.3.2 Instrument performance verification

The instrument performance verification includes all activities necessary to validate and/or optimise instrument operational and calibration parameters so that the identified instrument operating 'modes' (offered to the users in the form of AOTs) can be used for scheduling 'real' observations. In particular the PV phase includes:

- Instrument performance determination and calibration.
- Instrument focal plane geometry calibration.
- ACMS to instrument calibrations
- Verification/optimization of instrument operations including the verification and tuning of the AOTs and associated instrument command sequences.

Due to the complexity of the instruments this phase will be considerably longer than the preceding ones. It will be carried out according to an instrument PV plan generated by the HSC with participation of the instrument teams.

The objective is that at the end of the PV phase all spacecraft and instrument nominal configurations have

been established and all tunable spacecraft and instrument parameters have been set to their optimal operating values. Thus, at the end of the PV phase all instrument AOTs should be scientifically validated and ready to be used for the routine scheduling of observations.

In the real world unexpected problems/issues will probably occur, but all planning and preparation should be directed towards obtaining full PV completion. It is clear that the telescope temperature will be somewhat elevated and slowly decreasing throughout this phase, and the sky accessibility will be somewhat more restricted compared to around L2 (larger angle between Earth and Sun), and depending on the exact launch date the observability of various calibration sources will vary.

After the initial PV phase described above periodic calibrations/re-calibrations of both spacecraft and instruments are expected to be required during the routine phase. The extent and frequency of these operations will be established in the course of the PV phase. The corresponding calibration operations will be carried out as normal routine phase operations thereafter.

A first determination of the remaining helium mass in the main tank is planned to take place. The nominal duration of this phase is 2 months, the cumulative time since launch at the end is thus about 3.5 months.

6.4 Science demonstration phase

Assuming that the PV phase has been successfully completed the operation of *Herschel* should now be ‘routine phase’ like. The objective of the science demonstration phase is threefold:

- There is a need to demonstrate to (potential) observers in the astronomical community what the actual scientific capabilities of the observatory are; i.e. demonstrate what *Herschel* can do, and also state what it cannot. In this sense this phase can be seen as the ‘crowning’ of the PV phase activities.
- Conversely, a second objective of the science demonstration phase is to learn what we can learn about the universe from observations performed successfully from a technical point of view; thus to demonstrate that identified science objectives can be addressed with the actual performance of the observatory.
- This phase was originally motivated and introduced by a need to produce ‘pretty pictures’ for communications purposes, which remains one of the objectives.

A very important activity connected to this phase is the organisation of a workshop. In this workshop the actual performance of *Herschel* will be demonstrated and explained, enabling already selected observations to be optimised before being scheduled in the routine phase. In addition, the information for proposing can be updated to reflect actual - rather than predicted - performance ahead of the issue the OT part of the ‘Cycle 1’ AO (cf. section 5.4).

The nominal duration of this phase is 2.5 months (there is a trade-off with the duration of the PV phase), the cumulative time since launch at the end is thus about 6 months - the foreseen start of the routine science operations phase.

6.5 Early failure protection observations

It is foreseen to identify a limited set of observations that every effort should be made to execute in the event that the lifetime of the mission for some unforeseen reason is much less than expected. These predefined observations would then be scheduled upfront in order to provide the maximum science return given the circumstances.

Such a scenario could be due to a technical problem of some sort, e.g. a leak or an unwanted thermal conductance. Depending on the severity of the problem, most likely only a limited PV phase would be executed restricted to dealing with the instrument modes necessary to execute the observations identified for this phase.

6.6 Routine science operations phase

The routine science operations phase will commence after the conclusion of the science demonstration phase. Initially, the observing schedule will be entirely dominated by ‘Key Project’ (GT and OT) and GT programmes.

The programmes scheduled early should be those that most likely will require follow-up *Herschel* observations, but it is also of importance that a number of smaller regular GT observation programmes involving the community support staff get observed so that these people get ‘trained on the job’. If necessary observations that allow validation/optimization of remaining non-validated AOTs and improved calibration also warrant early scheduling.

The nominal duration of this phase is 3 years, the cumulative time since launch at the end is thus 3.5 years, which is the specified cryostat lifetime. Should spacecraft and other constraints allow, the duration of this phase will be extended for as long as is possible; also the durations mentioned of all other phases are subject to optimization.