# SPIRE

**SUBJECT:** SPIRE ICC Scenarios

**PREPARED BY:** Tanya Lim

**DOCUMENT No:** SPIRE-RAL-DOC-001195

**ISSUE:** Draft 0.1 **Date:** 14th March 2002

**APPROVED BY:** **Date:**

| Agreed By | | | Date |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

# Distribution

# Change Record

| ISSUE | DATE | |
|---|---|---|
| Draft 0.1 | 11th April 2002 | First draft |

## TABLE OF CONTENTS

**FIGURES**

**TABLES**

## Glossary

| | |
|---|---|
| AVM | Avionics Model |
| CCB | Configuration Control Board |
| CCS | Central Checkout System |
| CQM | Cryogenic Qualification Model |
| CUS | Common Uplink System |
| EGSE | Electrical Ground Support Equipment |
| HCSS | Herschel Common Science System |
| HGS | Herschel Ground Segment |
| HOTAC | Herschel Observing Time Allocation Committee |
| HSC | Herschel Science Centre |
| IA | Interactive Analysis |
| ICC | Instrument Control Centre? |
| IFSI | Istituto di Fisica dello Spazio Interplanetario |
| ILT | Instrument Level tests |
| IST | Integrated System tests |
| MCS | Mission Control System |
| MIB | Mission Information Base |
| MOC | Mission Operations Centre |
| OBS | On-Board Software |
| PFM | Proto Flight Model |
| QLA | Quick Look Assessment |
| RTA | Real Time Assessment |
| SCOS | Spacecraft Operating System |
| STM | Structural Thermal Model |
| TC | Telecommand |
| TEI | Test-Equipment-Interface |
| TFCS | Test Facility Control System |
| TM | Telemetry |

# 1. Scope

# 2. Documents

## 2.1 Applicable Documents

| | | | |
|---|---|---|---|
| AD1 | SPIRE Science Implementation Plan | K. J. King | SPIRE-RAL-DOC-001801 |

## 2.2 Reference Documents

| | | | |
|---|---|---|---|
| RD1 | SPIRE ICC Use Cases | | |
| RD2 | SPIRE QLA User Requirements | T. L. Lim | SPIRE-RAL-DOC- |
| RD3 | FIRST Operations Scenario Document | | FIRST/FSC/DOC/0114 |
| RD4 | SPIRE CQM Instrument Level Test Plan | D. L. Smith | SPIRE-RAL-DOC- |

# 3. INTRODUCTION

This document is a high level description of those activities in the Herschel ground segment which have an involvement by the SPIRE ICC. The next section introduces the Herschel ground segment then the remainder of the document is divided into mission phases and for each phase it describes the main activities of the ICC.

The SPIRE ICC has undergone a definition process, initially the basic requirements, given in section 4, were expanded to user requirements documents. These have then been used as a basis for the more definitive use cases (RD1) which are considered to be the baseline for ICC definition. This document should be considered to be an accompanying high level overview of those SPIRE ICC activities described in the use cases. The SPIRE ICC differs from the two other ICCs in that it is distributed across three locations, RAL, Imperial College and Saclay. The distribution of the ICC activities across the three locations is described in AD1 and will only be addressed in this document in the context of areas where co-ordination is needed.

# 4. THE HERSCHEL GROUND SEGMENT

The Herschel Ground Segment (HGS) consists of three major decentralized components. The Mission Operations Centre (MOC) located at ESOC, the Instrument Control Centres (ICCs) located at (or near) the PI institutes and the Herschel Science Centre (HSC) which will be located at a suitable place in an ESA member state, e.g. Vilspa (Spain).

The MOC is responsible for all aspects of S/C operation as well as the safety of the instruments during in-orbit phase only. This includes generating all commands to be up-linked to the satellite, receiving, recording for safekeeping, and consolidation of the telemetry data and making these data available to the rest of the Ground Segment. It is also responsible for maintaining the instrument and spacecraft databases shared by the MOC, ICCs, and HSC, and of the SCOS-2000 system used by the MOC and the ICCs.

The HSC is the single-point interface to the outside world for all Herschel observatory matters. In particular, it will issue calls for observing time proposals, the handling of proposals, ?providing general community support and giving support to ESA Public Relations and science communications activities. To do this task it will ?provide the framework for the interfaces with the astronomer for all community interaction, e.g. for information gathering, proposing, data browsing and retrieval, on-demand data processing, and generation of quick-look products. It will ?provide, manage, and maintain the central Herschel data base, and all the HSC software subsystems and will also ?populate the Herschel database with characterisation, science, and operational data to ensure overall ground segment consistency with respect to instrument configuration, including onboard software. Another role will be to ?co-ordinate the cross-calibration between Herschel instruments, and between Herschel and other facilities. It will also perform the detailed scientific mission planning and provide quality control information on all observational data.

The Instrument Control Centres (ICC, at least one centre per instrument) are responsible for the successful operation of their respective instruments, and for making possible the processing of the resulting data. Each ICC performs tasks dedicated to their particular instrument. In particular the responsibilities include, the monitoring of instrument development, testing, characterisation and calibration, monitoring the ?status and health of the instrument, and maintenance of the instrument. Each ICC is also responsible for providing to the HSC the instrument 'time estimators' and command generation facilities. Each ICC is expected to maintain the instrument onboard software once it has been generated and validated by the instrument teams and provide of all software required for error correction, calibration, and generally for the scientific processing of the data from the instruments, including interactive analysis tools and scripts and/or 'recipes' allowing the generation of 'standard' data products. Each ICC is also nominally responsible for instrument calibration.

All three components share a common science database and software system known as the Herschel Common Science System (HCSS). The HCSS groups all Herschel Ground Segment (HGS) functionalities that are common to the science and instruments operations. It includes the major following functions.

- Definition of proposals and observations
- Scheduling of observations
- Observations commanding generation
- Analysis of the instrument science data
- Processing and quality assessment of observation science data

- The storage and retrieving of all instrument and science relevant data

Each of these major functions is implemented by an HCSS subsystem or component. The HCSS includes the following subsystems:

- CUS: common uplink system for definition of observation templates and observation commanding generation
- PHS: proposal handling system for definition of proposals and observations
- MPS: mission planning system for scheduling of observations
- CC: configuration control system for HCSS data, software and documentation
- Browsers
- IA: interactive analysis system for an instrument
- QLA: subset of IA used by the ICCs for quick look assessment of science and tests observations
- SPG/QCP: subset of IA for producing standard data products and quality assessment for observation science data

At the heart of the HCSS is an object-oriented database management system (ODBMS) for storage and retrieval (querying) of all the Herschel mission artefacts relevant to science and instruments operations. This ODBMS will act as a data server for each of the HCSS sub-systems defined above as well as for RTA and the OBS Management. All the above HCSS sub-systems will interact directly with the ODBMS or via specific object servers to retrieve and/or store their input and output data.

# 5. INSTRUMENT LEVEL TESTS

The main activity during the instrument level test (ILT) phase will be the assembly and testing of the SPIRE instrument. There will be four models tested during this phase:

- The structural thermal model (STM) is a mechanical form and fit model which will be vibration tested and thermally tested to check that the components can withstand launch and space conditions.
- The warm electronics and commanding scheme will be tested on the avionics model (AVM), which consists of the on-board computer and a simulator for the detector and mechanism readout and control units.
- The cryogenic qualification model (CQM) will be used to characterise and verify the instrument scientific performance with functionally representative cold sub-systems and warm electronics units.
- The Proto-Flight Model (PFM) will be the instrument model that is intended for flight and will be built to full flight quality.

For testing, all models (except the STM?) will require the electrical ground support equipment (EGSE). The EGSE starts with the spacecraft simulator, which simulates in software the telecommanding (TC) and the telemetry (TM) passing through the spacecraft systems between the instrument and the ground. Another part of the EGSE is the spacecraft operating system (SCOS 2000) which is used to generate TC and also provides the real time assessment (RTA). Data storage will be in a local installation of the HCSS database. There will be a copy of the database situated in the test laboratory which will be isolated from the outside world during tests, plus a second copy outside the RAL firewall accessible to all ICC members plus authorised users. The copy outside the firewall will be updated regularly between tests. The Mission Information Base (MIB) is the instrument database and is described in section 5.4. One aspect of the MIB will be to be the storage location of the command mnemonics. The CUS system which uses the MIB, will be used to generate test observations.

## 5.1 Preparation of tests

The tests are defined at high level in overall test plans for each model. Where appropriate these are then specified in more detail in individual specification documents. The test specifications are then expanded further into test scripts.

It is expected that initially the instrument will be commanded using individual command mnemonics defined in the MIB. Once confidence is gained in sending a set of commands, these can be put together in the CUS. To facilitate this building up process the CUS logic allows for the definition of high level commands. These high level commands can be put together to form a ‘building block’, and building blocks can be put together to form observation templates. These three types of CUS component are combined using a simple ‘CUS language’ which is a tailor made language for the CUS. Once observation templates are defined, the CUS can then be run with a set of input parameters (e.g. S/N) to produce observations. The observations are then manually put together into ‘test scripts’.

## 5.2 Real-time running of tests

The test scripts will be run on a Test Facility Control System (TFCS) which will not only allow the instrument to be commanded but also the test equipment e.g. cryostat, telescope simulator, cold blackbody etc. Each test equipment subsystem will be able to receive instructions and/or transmit data to a Test-Equipment-Interface (TEI) that decodes telecommands (TC) received from the EGSE, and compiles telemetry (TM) packets to be transferred to the main EGSE running SCOS-2000. Data packets will be passed between the instrument EGSE and the TFCS via a single TM/TC interface.

The instrument output will be monitored by both the RTA system which allows a check on the housekeeping data and by the Quick Look Analysis (QLA) system which allows a near real time assessment to be made of the scientific quality of the data. The RTA system is part of SCOS 2000 and is common to all instruments. The QLA system is a tailor made system for SPIRE, although the interface to the telemetry router in the EGSE and the QLA infrastructure is common. Both the SPIRE contribution to the HCSS software and QLA development is distributed across all the ICC sites plus Trieste, with a common repository used for developed software and regular meetings to discuss progress.

## 5.3 Off-line Analysis of tests

Test data will be stored in raw form (telemetry packets) in the test facility copy of the HCSS database. Also stored will be 'processed' data produced by data analysis routines within QLA. This data can then be accessed at any time through an interface to the ICC copy of the database which will be accessible from outside the RAL firewall and isolated from the RAL test laboratory. Any authorised user will be able to access this copy from any location.

To support further processing of the test data, the ICC will provide some software tools for offline analysis, which will be formally part of the QLA system, but may have components that will also be used as a basis for Interactive Analysis (IA). Input to these analysis tools from external sources (e.g. IPAC) will be considered as 'algorithm' only and the ICC may recode these inputs before the software becomes part of the 'official' system. Outputs from offline analysis e.g. calibration files, parameter limits, and trend tables will be stored back in the database.

## 5.4 Provision of instrument data-base (MIB)

Sunil to write.

## 5.5 Changes to On-board Software

The on-board software (OBS) is being developed at IFSI and this development is done in close consultation with the instrument team. The software will be first tested on the AVM. What else?

# 6. Integrated System Tests

The Integrated System Test (IST) phase will cover many aspects of instrument operations, from functional tests to the validation of engineering observations and AOTs. During these tests, the main difference with respect to routine operations phase is that there is no MOC. The SPIRE specialists will have an interface to the instrument and its information via the MCS/HCSS, although part its behaviour has to be simulated in IST. These tests will be conducted by industry using the Central Checkout System (CCS). This section is TBC as long as the contracting out of the CCS and with this the interfaces to and from the HCSS are being discussed.

## 6.1 Preparation of tests CUS etc.

These tests will have been defined during ILT and the main aim will be to check that the instrument is still functioning correctly and the performance is nominal. Therefore it is expected that any test script development will be minimal, although some may be required in the case of optimising after a component failure.

During this phase there may also be an opportunity to increase understanding of the instrument and possibly further fine tune observing modes by testing on the flight spare. If this is done, specific test scripts will need to be developed.

## 6.2 Real-time running of tests

The real-time running of tests on the flight model during IST will be done in a similar way to the ILT phase with the main difference being that the real spacecraft is in use rather than a simulator. As no test equipment will be used the only telemetry source will be the spacecraft and instrument, although the shutter telemetry may be in separate packets. The QLA system will continue to be used for IST and is likely to be run via QLA scripts developed in ILT. The development work on the QLA system during IST is expected to be minimal.

Any tests on the flight spare model will be done at RAL with the same lab set up at ILT.

## 6.3 Off-line analysis of tests

IST data will be stored in the data based and analysed offline using tools developed during ILT. As IA will become increasingly mature during this phase it may be possible to use IA for part of the analysis.

One of the main results to come out of the offline analysis will be a final estimate of sensitivities which will allow the Time Estimator software to be completed and delivered to the HSC. This software will be used by Herschel proposers to estimate how much time they will need to carry out their scientific programmes.

## 6.4 Changes to On-board Software

How will this be handled during this phase?

# 7. LAUNCH AND EARLY ORBIT PHASE

The launch and early orbit phase describes the launch and first few orbits where orbital parameters are established. During this phase all Herschel instruments will be switched off and there are no specific ICC activities in this phase.

The LEOP operations will be centred around the check-out of the spacecraft subsystems and the navigation into the correct transfer trajectory. The spacecraft will be transmitting only HK data at low rate, and operations will generally be conducted in real time, unless the coverage does not permit this. Data will be stored onboard for the non-coverage periods, and there will be some time spent in the higher data rate modes to dump this data.

# 8. COMMISSIONING PHASE

The commissioning phase describes the phase where the instruments are first switched on and the instrument (and spacecraft) functionality is fully checked out.

The activities of the instrument commissioning phase will focus on switch on, functional checkout of the (prime) instrument subsystems and their modes, similar to the tests carried out during the Integrated System Tests, plus observations to confirm the instrument/satellite system characteristics (e.g. instrument aperture pointing).

## 8.1 Preparation of tests

The functional tests used for commissioning will be a standard set of tests, which would have been initially developed in ILT and repeated in IST. The observations to characterise the spacecraft characteristics (e.g. to establish focal plane geometry) will be new observations for commissioning phase, however the scope of these will be well known and can be prepared before launch.

If the instrument behaviour is very different to expectations, it may be necessary to change some observations and facilities will be available both at the MOC site and at the ICC sites to do this.

## 8.2 Real-time running of tests

The functional tests will be run by members of the ICC, situated at the MOC location in real-time. The data from these tests will be monitored, as they were for IST, on the RTA and QLA systems.

Instrument parameters (e.g. detector settings) may be required to be updated on the same time scale, determined by the speed of data analysis and decision taking. Following the result of each test the ICC will give a ‘go’ or ‘no go’ for the next test to be performed. If a test fails, a pre-determined course of action will be followed, and in most cases this will involve switching the instrument off until the cause of failure is determined.

## 8.3 Off-line analysis of tests at ICC@MOC

The ICC@MOC is that part of the ICC located at MOC for the duration of commissioning phase. It is likely that the personnel situated at MOC will be those who have participated in the IST and they will have a good general background of instrument behaviour. A working ICC software environment will be available at MOC (the ICC@MOC) allowing the possibility to prepare/modify test/calibration observations and command sequences off line plus the possibility to run the instrument analysis environment, in particular its real-time RTA/QLA parts. The data transfer time from the satellite to the ICC@MOC should allow such activities on a near real time timescale, i.e. not introducing dead periods on timescales significantly larger than the inevitable signal travel time.

The ‘instrument representative’ at the MOC will be responsible for conducting the tests, and providing confirmation of their correct execution. They will not be necessary to be in contact with the ICC@ICC. Indeed, it is not expected that the ICC@ICC will monitor all the tests as they may be carried out at any time of day or night (the staff at the ICC@MOC will work shifts, as required by the timing of the tests). Despite this, the ICC@MOC will be provided with telephone and network links to the ICC@ICC to allow monitoring of the tests by the ICC@ICC and discussion between the instrument experts, at the ICC, and the 'instrument representative' at the MOC.

A communication link from the ICC@MOC to the spacecraft controller is used to provide verbal communication between the instrument representatives and the spacecraft controller during tests.

## 8.4 Off-line analysis of tests at ICC@ICC

The members of the ICC located at the four ICC sites will have access to commissioning data. Depending on expertise, e.g. OBS expertise at IFSI, the ICC@ICC will either have a direct role in detailed analysis of commissioning data or an intermediary role in facilitating instrument experts in their analysis.

## 8.5 Changes to On-board Software

During commissioning phase the OBS may be changed in response to an instrument anomaly or a different instrument behaviour to that on the ground.

In the event that the on-board software needs to be changed, the ICC will use the OBS maintenance facility (provided by the ICC) to update the code or tables. The updated code will be used to generate memory images required to implement the change on board. The updated memory image will be tested on either the Flight Spare instrument or other instrument simulators before being made available to the Ground Segment.

An SPR/SCR will be raised and, when verified, the memory image(s) will be delivered to the HSC with a software release note describing the implications of the change, plus updated documentation reflecting the change. The HSC will validate the updated memory image using the satellite simulator and submit the change to the CCB for approval.

When agreed, the updated memory image will be submitted by the HSC to the MOC for uplink to the satellite. The whole memory image will be transferred to MOC and not only the parts of the memory image which have been modified (patches). It will then be up to MOC to generate the necessary patches to be uploaded to update the on board memory image in accordance with the one received from the HSC. MOC will also be in charge of verifying that the update has been successfully performed.
In the event, where an instrument on board memory needs to be analysed (e.g. following an instrument failure), the ICC may request MOC to dump partially or totally its memory image. The memory dump will be planned by MOC in co-ordination with HSC and the ICC. The resulting memory dump will then be transferred to the ICC via the HSC.

## 8.6 Monitoring of Instrument Health and Safety

The ICC will monitor the health and performance of SPIRE throughout the mission. It will do this by:

(i) collecting instrument anomalies identified by the instrument itself, the data handling system, or reported by the MOC
(ii) identifying unexpected instrument events reported in instrument HK TM
(iii) analysing trend data extracted routinely from instrument HK TM and calibration/scientific AOT products
(iv) periodically dumping instrument on-board memory for comparison with the expected image

In the event of an anomalous situation, the ICC will investigate the problem using data from the observation, previous observations, ground testing; instrument simulators or other software tools; the instrument flight spare; specific diagnostic observations submitted to the satellite; or a combination of these.

A panel of instrument experts will be convened to evaluate the information from the investigation and to recommend a course of action to the CCB chaired by the SCOM. This may be: do nothing, update onboard software, change procedures, etc.

Routine monitoring activities will be carried out as a background task (i.e. there is no requirement to carry out the task each day) although monitoring should not lag behind data reception by more than a few days; instrument anomalies will, of course, be dealt with as soon as possible after they have been reported. In general, the ICC will work five days per week during office hours. It is anticipated that an instrument specialist (who has remote access to the ICC software) will be available on call during weekends (at least during the early parts of the mission).

# 9. PERFORMANCE VERIFICATION PHASE

The Performance Verification (PV) phase is intended to obtain in-flight characterisation of the instrument e.g. in terms of stability, sensitivity, resolution, timing, and calibration parameters. A schedule of astronomical observations and (internal) calibrations, defined and iterated pre-launch, is executed using normal observatory procedures.

This schedule is based upon an agreed in-orbit calibration plan generated jointly by the ICC and the HSC. The plan contains a description of all planned calibration activities and associated calibration sources (internal and astronomical) required to fully characterise the instrument. It is important that the plan ‘stretches’ the parameter space of instrument capabilities in order to cover the parameter space of the routine phase observation programme, and to verify or generate new values for observation optimisation.

During the PV phase there is only limited ground contact but it can be assumed to be somewhat relaxed against the stringent definition that applies during routine phase and the data may be monitored by ICC personnel present at the MOC on arrival. Most of the detailed analysis, in particular of the science data, is done offline at the ICC using IA facilities.

## 9.1 Preparation of ordinary observations

Ordinary observations will be used in PV phase for two purposes:

- to support the calibration of the instrument
- to confirm the instrument is performing as expected and hence the validation and verification of the observing mode

The observations used in PV phase will be planned and scheduled before launch and will be the implementation of the detailed calibration plan. They will demonstrate that the validation of the performance and the calibration can be done by the observations conducted in this phase.

The ICC will select targets based on calibration need and visibility constraints. If detailed analysis shows that the pre-planned schedule is not suitable for further characterisation of the instrument, it will be possible to change (near) future calibration observations which are then inserted into subsequent observing schedules. Such schedule changes will be possible on a time scale of TBD days.

## 9.2 Preparation of calibration/engineering observations

Some PV observations will not be able to be executed using standard AOTs and these will have to done using non-standard tailor-made observations developed using the CUS. These observations will be used for very specific cases of instrument calibration or for instrument diagnostic purposes. They will not use the standard command sequences (generated by AOTs) but will use a ‘manually’ assembled sequence of instrument commands and consisting of ‘blocks’.

## 9.3 Processing & Analysis of ordinary observations

The SPIRE data processing will be done via the interactive analysis system which is developed and maintained under the responsibility of the ICC. The HSC will use the IA to carry out the scientific data processing using the IA in a ‘pipeline’ configuration. As a result of this pipeline processing a set number of reduced data products will be stored in the HCSS.

The IA is likely to have a 'core' IA which will consist of those modules required for processing scientific observations plus additional modules forming a 'calibration' IA which will allow instrument behaviour to be investigated and calibration tables to be derived. Apart from the scientific performance validation observations, it is likely that the ICC will process most observations interactively using the calibration IA system.

The current baseline is that SPIRE IA will be a specific software for all SPIRE data reduction. It will have a distributed development across all ICC sites and will be written in Java with a common (Herschel) infrastructure. The advantage of this approach is that the IA can be run on any platform which will enable members of the ICC located at different sites to work together easily.

## 9.4 Processing & Analysis of calibration/engineering observations

Calibration and engineering observations stored in the HCSS database will be analysed to the maximum extent possible using standard IA reduction steps with further analysis being completed using the calibration IA system. For some engineering observations QLA may also be used. Although most calibration analysis will be carried out by members of the ICC, some calibration analysis may also be done by an instrument specialist at the HSC.

The analysis leads to an assessment of the instrument status and behaviour, and this will be reviewed on a regular basis throughout PV phase (e.g. weekly) by the entire ICC, and the reviews could either be done in ICC meetings or via tele- or video-conferencing. As a result of this review, the analysis, calibration trend tables or specific calibration parameters or tables needed in data processing will be updated in the ICC database. It is also possible that it will be necessary to also update the processing software, although time limitations in a 2-3 month PV phase may not allow this. As calibration tables can be changing on a weekly basis during this phase it is not likely that a formal update of the calibration file/IA system in the HSC will take place until the end of PV phase.

## 9.5 Optimising observing modes/AOT parameters

The observing modes and AOT parameters will have been established in ground testing. The PV phase observations will give an indication of the instrument behaviour and in many cases a direct comparison can be made with how it was behaving on the ground, although some parameters e.g. telescope temperature can only be determined in space. The PV data may indicate that the observing mode templates need to be updated. Reasons for this include:

- the sensitivity has changed,
- calibration parameters determined in space are different to predictions
- instrument anomalies
- a better way of achieving the same science is found

If performance has changed e.g. sensitivities might have changes or mechanism limits might be refined, then an update will be made to the observing mode template by editing the CUS. In the case of a sensitivity change, the time estimator used by SPIRE observers will also need to be updated. Changes to observing modes may also need to be implemented in the MIB and/or the OBS. Any changes to observing modes will have to be implemented via the SPR/SCR system and the HSC will inform observers if they need to update their proposals.

## 9.6 Optimising data processing

The ICC data processing is initially developed and refined using test data in the ILT phase and IST phases. In PV phase it is likely to be refined as a better understanding of the instrument is achieved and/or refinements are made to the observing modes.

Members of the ICC will work on processing algorithms (and associated calibration files). Once a prototype algorithm and, if necessary, the associated calibration file, are ready, this is submitted to a regular meeting of the ICC for discussion. If approved, this will be coded to IA coding standards and enter the software update system described in section 10.7, although release times for IA during this period will be shorter than the nominal 6 months in routine phase.

## 9.7 Monitoring of Instrument Health and Safety

The ICC will continue to monitor the instrument health and safety as described in section 8.6. For critical observations, e.g. investigations following an instrument failure, it may be necessary for parts of the ICC to revert to the setup for the commissioning phase, during which ICC personnel are physically present at the MOC.

## 9.8 Scientific Performance Verification

Once the initial instrument calibration is established, the latter part of PV phase will be used to confirm the scientific performance of the instrument. To do this, observations of a standard set of sources giving a range of astronomical parameters e.g. point-like to extended, faint to bright, and low background to high background are selected before launch, placed in the PV phase plan, then, when approved, entered into the observation planning system and scheduled. These observations are then used to fully exercise each observing mode and its data processing. If this is found to be satisfactory, the ICC will then recommend the release of the observing mode to the HSC.

## 9.9 Scientific Validation of AOTs

Whenever an update to an observing mode or the IA system is made, the update will need to be checked for scientific validity. This is likely to be done via a standard set of observations. These observations will initially be performed in PV phase and the data from these observations will allow the ICC to recommend whether or not a particular observing mode should be released to the community.

# 10. ROUTINE

In operations the ICCs' main tasks are: monitoring instrument health, calibrating the instrument, and the provision of data reduction software. Calibration analysis uses various software tools (such as RTA and IA) to reduce the resulting HK and science data, to relate them to existing observations of the same type and to compare with models and/or data from other facilities. The results of this analysis can then flow back into the next cycle of calibration planning and data reduction. Although calibration observations will normally be specifically requested, the ICCs may use any observation for the sole and explicit purpose of calibrating their instruments without this being considered an infringement of proprietary rights.

## 10.1 Preparation of ordinary observations

Astronomers will have a time allocated to use SPIRE from HOTAC. They will be responsible for planning their own observations using tools supplied by the ICC and HSC. The HSC is responsible for co-ordinating this process and they will provide an on-line environment for the users to plan and fill in the observation details of their accepted proposals.

The user will be able to use the latest measured performance of spacecraft and instruments determined either in ground testing or in-flight. To facilitate this, the ICC will provide an observation time estimator which will be made available on-line. This will allow the instrument operations to be optimized, using knowledge of background fluxes, stabilisation times, etc. The time estimator will be refined throughout the mission as additional experience is gained.

Will the ICC have an additional role of entering observations for key programmes?

## 10.2 Planning and Preparation of Calibration and Engineering Observations

For every nominal scheduling period the ICC will select and prioritise a set of observations based on its long-term calibration plan which is agreed with the HSC. These observations will include observations needed for calibration derivation, calibration monitoring and cross-calibration. It is the joint responsibility of the ICC and HSC to define and agree cross-calibration observations.

The ICC will verify that the selected observations are consistent and schedulable (using time estimators, visibility tools and e.g. the HSC mission planning tools) and handed over to the HSC for scheduling. As part of a calibration or engineering observation, specific scheduling constraints can be provided, such as 'schedule at the start of an operational day', 'schedule observation A 20 minutes after observation B', 'schedule at a specific absolute time', or 'use a specific S/C configuration'. Repetitive calibrations (e.g. to be carried out every Nth day/week) will be entered into the system as a series of independent observations submitted to the HSC for scheduling.

It is envisaged that the majority of observations submitted will use the standard AOTs. However it will be possible to submit engineering observations. These are at the lowest level in the sense that they do not use the standard command sequences generated by AOTs but a 'manually' assembled sequence of instrument commands (generated by the Common uplink System (CUS) and consisting of 'blocks' validated during ILTs). These observations can be used for very specific cases of instrument calibration (which cannot be achieved through AOTs) or for instrument diagnostic purposes.

Normally, calibration and engineering observations are submitted at fixed times within the agreed nominal scheduling cycle. When warranted, e.g. by non-nominal instrument behaviour, a much shorter time scale (3 days – TBC) for the submission and planning of a calibration or engineering observation can be accommodated.

HSC personnel select the proposed calibration and engineering observations and insert them into the observation schedule in agreement with the specified scheduling constraints. The resulting schedule may or may not be a mix of calibration, engineering and normal observations. After submission of the observation schedule to the MOC, the calibration and engineering observations are carried out as normal observations and the resulting data are ingested into HCSS by the HSC according to normal operating procedures. Contrary to failed 'normal' observations, however, the HSC will not undertake to reschedule failed calibration or engineering observation without a specific request from the relevant ICC.

## 10.3 Processing & analysis of ordinary observations

The SPIRE data processing will be done via the interactive analysis system which is developed and maintained under the responsibility of the ICC. The HSC will make the IA package available to the astronomer via the HCSS and it will include the both the 'latest' agreed software and calibration tables. The HSC will use the IA to carry out the scientific data processing using the IA in a 'pipeline' configuration. As a result of this pipeline processing a set number of reduced data products will be stored in the HCSS.

It is expected that most astronomers will start their data reduction of a particular observation with one of these high level products from the pipeline. The IA packages will also allow any astronomer, who so wishes, to start the data processing process from the data frames stored in the HCSS and to facilitate this they will be able to access both the 'latest' software and associated calibration tables.

The HSC will also be responsible for providing the necessary support for data reduction to the community and will ensure that all observational data are systematically processed for quality control purposes.

## 10.4 Processing & analysis of calibration and engineering observations

Calibration and engineering observations are stored in the HCSS database and will be analysed to the maximum extent possible using standard IA reduction steps with further analysis being completed using specific calibration analysis tools developed by the ICC. For some engineering observations QLA may also be used. Although most calibration analysis will be carried out by members of the ICC, some calibration analysis might also be done by an instrument specialist at the HSC.

The analysis leads to an assessment of the instrument status and behaviour, and this will be reviewed on a regular basis by the entire ICC, either by ICC meetings or tele- or video-conferencing. As a result of this review, the analysis, calibration trend tables or specific calibration parameters or tables needed in data processing will be updated in the ICC database. It is also possible that it will be necessary to also update the processing software. Also, if necessary, additional calibration sources may be selected for further observations or more information on available calibration sources may be sought (e.g. using additional observations of calibration sources using other Herschel instruments or ground-based facilities).

Agreed updated parameters or tables will initially be made available to members of the ICC for testing purposes and the ICC database and processing software will support multiple versions (e.g. 'nominal' and 'test'). The results of this test period will again be reviewed and once the 'test' values for such parameters are accepted as new 'nominal' values, the ICC and HSC review the planned update, and this is then they are approved by the CCB. The formal route for this is likely to be through the SCR/SPR system. The new tables are then made available through HCSS for general use, e.g. by the standard product generation software or, when relevant, by the scientific mission planning system.

Relevant conclusions with respect to overall instrument calibration and health are added to the calibration status report, which is periodically produced by each ICC, and if necessary the long term instrument calibration plan and strategy are adjusted.

## 10.5 Optimising observing modes/AOT parameters

Routine phase calibration observations and trend analysis will give an indication of the instrument behaves over the mission from PV phase onwards. Any changes in behaviour may result in the need to change an observing mode. Typical reasons for these changes include a change in internal calibrator behaviour, a change in detector sensitivity or pixels becoming 'dead', and a mechanism movement becoming sub-optimal. Investigations by the ICC into the best way to get the maximum scientific return from the instrument may lead to suggestions for a new observing mode.

If approved by the ICC (and instrument team?), a potential new observing mode will be tested on the instrument simulator and/or flight spare. During this process the changes needed to be made to S/W will be analysed. When a final decision is made by the ICC, a request for a change is made via the SCR system. The change will be formally approved by the CCB.

## 10.6 Optimising data processing

The ICC data processing is initially developed in ILT and IST phases. In PV phase it is likely to be initially refined as a better understanding of the instrument is achieved and/or refinements are made to the observing modes.

During routine phase members of the ICC will continue to work on processing algorithms (and associated calibration files). Once a prototype algorithm and, if necessary, the associated calibration file, are ready, this is submitted to a regular meeting of the ICC for discussion. If approved, this will be coded to IA coding standards and enter the software update system described in section 10.7.

## 10.7 Software maintenance

### 10.7.1 Software supplied to the HSC

The HSC and ICCs will share a large amount of S/W and a significant fraction of this (e.g. time estimators, command generators, instrument simulators, IA) is developed by the ICCs but used by the HSC as well. It is expected that the maintenance of all shared S/W will be managed in a centralised fashion.

This implies existence of one joint Configuration Control Board (CCB), chaired by the SCOM, with permanent members from the HSC and ICCs. Only this board will have the authority to approve/refuse and plan changes to the HSC/ICCs system that may have an impact on the Herschel science data. To track changes there will be a centralised change control system accessible to all relevant parties plus centralised documentation and S/W configuration control systems which are used by all relevant parties.

The CCB is expected to meet at regular intervals (e.g. weekly) to review the pending SPRs, SCRs and to disposition on their analysis, implementation, and installation. Because the different CCB members will not be on the same site, CCB meetings will normally be held via tele- or videoconference.

It is expected that the HSC and each ICC will set up a (small) SW maintenance team in charge of implementing, testing and installing the S/W changes approved by the CCB for the S/W falling under their responsibility (i.e. the S/W they have developed). The different teams will co-ordinate their efforts on a day-to-day basis with the objective of meeting the work plan set by the CCB. The HSC maintenance team leader may act as the co-ordinator. The co-ordination will be facilitated by the centralised change, documentation and configuration control systems, which are expected to be taken over from the development phase.

### 10.7.2 Internal ICC software maintenance

ICC software will be developed on a number of development sites both within the ICC plus possibly some agreed contributing institutes. It is only at the development sites that changes to the system are performed and tested. Once an element is changed, verified and validated, the author of the change places it into an internal ICC configuration control system. This author does not have to possibility to issue a new release of the system. New releases of any system are decided by the ICC configuration control board (one for the developers' release and a larger one for the 'users' release). This ensures that the development site system is not chaotically evolving. Releases to the development site can be rather frequent (typically a month but not less).

**Development site:**
As of today, the foreseen development sites are all within the ICC. However we are open to having more development sites as this holds the potential for faster and better developments of the systems. The privilege of a development site is to always be able to access the latest version of the system. The duty of a development site is to (1) regularly contribute to the development by providing elements of the system, (2) follow the CC convention, (3) install all developers' releases, and (4) participate in the different test stages of a release.

**Developers' releases:**
To perform a release of the development site system (this is the test version), at a given date, CC is freezed (i.e. no more changes, except bug fixes, are allowed, elements under development have to be placed back in CC, even if incomplete) and the current version of all subsystems is released and tested (for a given period, e.g. 1 week). If these tests are good, then this is the new development site release. If not, we stay with the previous release and work out the bugs. On demand, the developers' release can be made available to consortium members. Current baseline for developers' release period is 4 weeks.

**Users' releases:**
Official or users' releases are much less frequent (6 months is the smallest period acceptable for software changes). Their release process is no different from that of the development site except that the CC board is different. Outside users may be frustrated by this slow process. But this minimizes the number of different versions of the system we are sending out in nature, and thus the problems we will have to handle. For safety reasons, the users' release has to be identical to a developers' release.

### 10.7.3 On-board S/W maintenance

It is expected that the need for OBS maintenance during routine phase will be minimal as each change will have an impact on the data processing and calibration of the instrument.

The on-board software maintenance during routine phase will follow the same procedure as for commissioning phase (see section 7.5 for details), with the ICC taking responsibility for the update, for raising an SPR/SCR and for testing the update on the flight spare or simulator. The CCB is in charge of the approval process and the HSC tests the update on the spacecraft simulator and the delivery to MOC.

## 10.8 Monitoring of Instrument Health and Safety

The ICC will continue to monitor the instrument health and safety as described in section 7.6. For critical observations, e.g. investigations following an instrument failure, it may be necessary for parts of the ICC to revert to the setup for the commissioning phase, during which ICC personnel is physically present at the MOC, which is not normally the case during routine phase.

## 10.9 Quality control of data products

The IA system running in the pipeline configuration will produce ‘quality control pipeline’ products in addition to the scientific data products. The quality control data will be evaluated by the HSC and as a result of the evaluation, a quality flag will be assigned to each observation. This quality flag will reflect

(i) whether the observation has executed nominally
(ii) whether all data generated are available in the archive
(iii) whether quality control processing has completed without error messages having been generated
(iv) whether the corresponding quick-look output is available

Although it is assumed that the quality flag will be assigned automatically for most observations, it is expected that in some cases a deeper analysis by an instrument specialist may be required and here it may be possible for the ICC to set criteria for observations it wishes to check.

During the operational phases it is not planned to store the products generated during quality control processing in the archive, with the exception of the quick-look product. If an observation has the final quality flag assigned as ‘failed’, it will be marked in the database to be considered by the scientific mission planning system to be rescheduled.

The above description of quality control processing highlights the fact that assignment of a ‘good’ value to the quality flag is a formal process which says little about the scientific validity of the output product from an observer’s point of view.

## 10.10 Support to the HSC

The ICC will be required to support the HSC in several ways:

**S/W maintenance:**
The ICC will maintain its contribution to the common software in the HCSS system, the QLA software, the IA software and the OBS. Any updates made by the ICC to software will be made via the SPR/SCR system. Approval of SPRs and SCRs will be via a CCB which will convene regularly (e.g. weekly early in the mission) and will include participation by the ICC.

**Attendance at meetings:**
It is likely that the HSC will hold regular operations meetings at which, participation by the ICC is expected.

**Helpdesk enquiries:**

Herschel observers will be able to make enquiries about their observations to the HSC via a helpdesk system. Any enquiries regarding SPIRE data, which can not be dealt with by the SPIRE expert at the HSC will be passed to the ICC for follow up. After investigating the problem the ICC will inform helpdesk the outcome.

**Quality control follow up:**
The HSC will provide quality control information to the ICC. If a set of criteria specified by the ICC are met or the pipeline fails (e.g. because of partial TM loss) the ICC will investigate whether the observation will need re-scheduling and pass their recommendations back to the HSC.

**Outreach:**
The HSC is responsible for outreach activities but it may consult the ICC on suitable material to be used and it may require the ICC to aid in the preparation of publicity material.

# 11. POST-OPERATIONS PHASE

The Herschel post-operations phase consists of the rundown monitoring phase, mission consolidation phase, active archive phase, and the archive consolidation phase (when the transfer into the subsequent historical archive phase takes place), and is the final formal phase of the mission.The goal of this phase is, within the constraints of time and resources, to maximise the scientific return from the Herschel mission by facilitating continuing widespread effective and extensive exploitation of the Herschel data.

The operations and ground segment of Herschel are designed to provide 'seamless' transitions between the various mission phases and, many activities 'normally' associated with this phase will already be ongoing as part of the routine day-to-day activities in the preceeding phase. However, all these activities will (have to) be concluded, and finally 'wrapped up' for posterity in the historical archive. During this phase we would expect a run down of ICC manpower at all sites.

These ICC activities will include:

- finalisation of the understanding of the instrument behaviour (including calibration and cross-calibration) in orbit
- finalisation of data processing development.
- continuing to provide support to the HSC in supporting astronomical community in using Herschel data, by provision of not only of software, but also of expertise, and information

## 11.1 Calibration and Algorithm Development

Calibration tables needed for data processing will continue to be refined by the ICC in the post-operations and it is likely that emphasis will be placed on calibration issues which require a more in-depth investigation. It is likely that these will not have been completed due to operational constraints on the members of the ICC. Also this period allows a final derivation of any time dependent calibration tables.

## 11.2 Software Maintenance

Software maintenance is no longer required on operational systems such as the time estimator and QLA, however the CCB system will continue to be used for updates to the IA system. At certain points in the post-operations phase the HSC will undertake bulk reprocessing of data following updates to the IA system (e.g. on a yearly basis). The ICC may have to undergo a scientific validation exercise following these updates.

## 11.3 Support to the HSC

The HSC will continue to operate a helpdesk system and the ICC will be required to investigate/answer queries from SPIRE users via this system. Also all software updates will continue to be supported, including possible tele-attendance at CCB meetings. Regular ground segment meetings will continue and the ICC may also me required to support the organisation of Herschel related conferences.

## 12. ARCHIVE PHASE

The historical archive 'phase' is actually outside the (funded) Herschel mission but could commence after the end of the post-operations phase. The user will see no difference from earlier phases, except that from the beginning of this phase onwards no further developments, and no updates of the contents, of the archive can be expected to take place. The duration over which the historical archive will be kept available is undecided, as is, its source of funding, location, and 'custodian', but it is foreseen to be an asset of great value to astronomy for a considerable length of time.