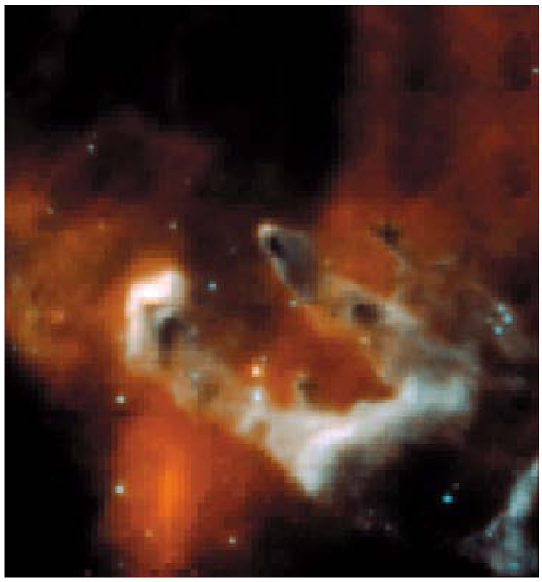
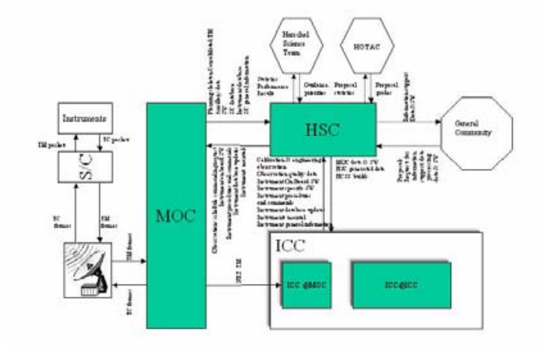
HERSCHEL SPACE OBSERVATORY

OPERATIONS SCENARIO DOCUMENT





Ref: Herschel/HSC/DOC/0114

Date: 17 March 2002

Issue: 1.2

DOCUMENT APPROVAL

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DOCUMENT STATUS SHEET

Issue	Revision	Date	Reason for change
		14 Nov 1999	Initial collation of inputs provided by a multitude of authors as agreed in the first two 'Scenario meetings' held on 4-7 July 1999 (A la bonne idée) and on 13-15 October 1999 (Vilspa).
		22 Dec 1999	As updated after the 3rd 'Scenario meeting' held on 16 December 1999 (ESTEC).
		14 Jan 2000	As updated in the 4th 'Scenario meeting' held on 11-14 January 2000 (Vilspa).
Draft 0.9		24 Jan 2000	'Consolidated' draft issued for soliciting comments for 'last' major round of updating.
Draft 0.95		22 Feb 2000	As updated in response to extensive comments from all parties on draft 0.9. Intended to be issue 1.0, but decided to produce another draft for soliciting comments from the (then) FIRST Science Team (FST) to be incorporated before releasing issue 1.0.
1	0	12 Nov 2000	Draft 0.95 circulated to the (then) FIRST Science Team (FST), and within SCI-SA including the ISO Data Centre (IDC). It was discussed in FST#5 held on 7-8 March 2000 (ESTEC) and agreed that it can be issued as 1.0 after incorporating FST comments. Additional comments were provided by staff in IDC and in SCI-SA in an internal review. The actual updating and issuing in the end only took place in preparation for the HCSS SRR (and concurrent v0.1 PDR) review(s) held Nov/Dec 2000. Comment: The 'content date' is spring 2000.
1	1	Sep 2001 (not issued)	As updated after the SRR review Nov/Dec 2000 Board Report (18 Dec 2000) and the RID disposition by the CCB (20 Feb 2001). A few minor comments that should have been included already in issue 1.0 were also incorporated. The name of FIRST was changed to the 'Herschel Space Observatory' by R. Bonnet on 12 Dec 2000 in Toledo. Comment: The 'content date' is spring 2001.

1	2	17 Mar 2003	In the Herschel HSC/ICC status review held in Nov/Dec 2002 it was reiterated that the top-level documents, including the present document, need to be signed and formally issued. No new updates were formally required as a result of his review. However, a version with earlier required updates had not been issued, and the Board charged the PS to update the document in order to establish a 'baseline' and to be formally signed off. Document approval scheme revised, and 'source document' label introduced.

DOCUMENT CHANGE RECORD

Document Issue/Revision Number: 1.1

Section	Change
All	Changes as a result of Recommendations made by the SRR Board are labelled 'SRR Rmm-n'. Changes resulting from SRR RIDs accepted by the CCB are labelled 'RID SR-xxx-mm'. Purely typographical changes, including the name change from FIRST to Herschel, FSC to HSC, etc. are not recorded here.
1.1	Text and figure updated to reflect the change of status to Applicable Document, rather than Reference Document, following SRR R03-2.
1.3	Added Reference Documents number 8, 9, 10, and 11.
1.4	The 'List of Acronyms' has been updated.
1.5	The 'Glossary' has been moved to a separate document.
2	Assumptions 12 and 15 rephrased following RIDs SR-CCB-64 and -65.
3.1, 3.2	Scope of the descriptive text expanded due to the change of status to Applicable Document, and its location above the SIRD in the document tree.
3.3	Section title updated, subsection 3.3.1 Telescope inserted, forcing renumbering of the already existing very slightly updated 3.3.n subsections to 3.3.n+1.
3.4	Figure 3.1 updated, sections 3.4, 3.4.1, 3.4.2 slightly updated.
3.5	Section added, cf. sections 3.1, 3.2 above.
3.6, 3.6.1, 3.6.2	Old sections 3.5*. The duration of the active archive phase has been increased from 24 to 48 months, following RID SR-CCB-67. The schedule tables have been updated.
4.1	Section title improved.
4.2, 4.3.1	Reference to NASA Herschel Science Center updated.
4.4	Text updated following RID SR-CCB-68.
5.2	Text updated following RID SR-CCB-70.
5.4.2	Text updated following RID SR-CCB-73.
5.7.9	Text updated following RID SR-CCB-74.

5.8	Text updated following RIDs SR-CCB-75, 76, and 77.
5.9	Text updated following RID SR-CCB-78. Link to original proposal text modified.
5.10.4	Text updated following RID SR-CCB-79.
5.11.2	Text updated following RID SR-CCB-80.
6.5.2.3	Text updated following RID SR-CCB-82.
6.7	Text updated to cover additional objectives.
7.3.2	Text updated following RID SR-CCB-83.
9	Text to be extensively updated following RID SR-CCB-xx (not yet implented).

Document Issue/Revision Number: 1.2

Section	**Change**
All	DocRef updated from FIRST/FSC/... to Herschel/HSC/.... . Minor descriptional updates, additions to the list of acronyms, correction of typos etc. are not recorded here.
0	Document approval sheet updated following agreement.
1.2	Source document replacing applicable document status for SMP and current document.
3.2.3	Reference to the existance of the HCalSG included.
3.4	Minor updates to text, Fig. 3.1 updated.
3.6.1	Actual past and agreed future dates updated.
3.7	Concept of ESA Science / RSSD archive introduced.
4.2	Fig. 4.1 updated.
5.7.1, 5.7.5	Average science data production rate increased from 100 to 130 kbit/s.
6.1.2, 6.1.3	Modernising of text and Fig. 6.1 as per actual developments.
6.2.2, 6.2.3	Modernising of text and Fig. 6.2 as per actual developments.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Scope and Structure

The present document, the ‘Herschel Space Observatory Operations Scenario Document’, provides a top-level, self-contained overview of all aspects of Herschel (formerly known as FIRST - the Far InfraRed and Submillimetre Telescope) operations, including ground tests and community interaction. It elaborates on the ideas presented in the (then FIRST) ‘Science Management Plan’ (SMP = [AD1]), and describes how operations will be conducted, breaking them down to indicate the range of activities within the purview of each ground segment element during each mission phase. It identifies top-level interfaces between the parties involved (the Herschel/Planck Project, the Mission Operations Centre (MOC), the Herschel Science Centre (HSC), the Instrument Control Centres (ICCs), the associated NASA Herschel Science Center (NHSC), and the astronomical community) and necessary mechanisms for co-ordination. It provides a scenario for operations, but is not meant to specify implementation although possible implementations may occasionally be described.

This document serves as the source document for the production of the formal top-level requirements documents: the (Herschel and common part) ‘FIRST/Planck System Requirements Specification’ document [RD6], as well as other space system specification documents, the Herschel ‘Science Implementation Requirements Document’ (SIRD), the Herschel/Planck ‘Mission Implementation Requirements Document’ (MIRD), and the ‘Interface Requirements Document’ (IRD), as is illustrated in Figure 1.1 below.

It reflects the current concept of Herschel operations. The level of detail in this document is uneven, mainly reflecting the current state of definition and the perceived need of detail for producing lower level documents.

The Herschel mission is introduced in section 3 and its ground segment in section 4. The overall goal is to enable scientifically productive and efficient routine phase operations, thus this mission phase is described upfront in section 5. However, there will by necessity be additional drivers to the ground segment originating from the other mission phases described in section 6. The various users – or rather user roles – of the ground segment are described in section 7, science communication and PR activities are briefly described in section 8, and finally the top-level management structure is outlined in section 9. All sections are based on the assumptions given in section 2, as well as additional assumption given per section.

1.2 Source Document

SD1: (FIRST) Science Management Plan (SMP) (ESA/SPC(97)22, rev 1 = FIRST/FSC/DOC/0019)

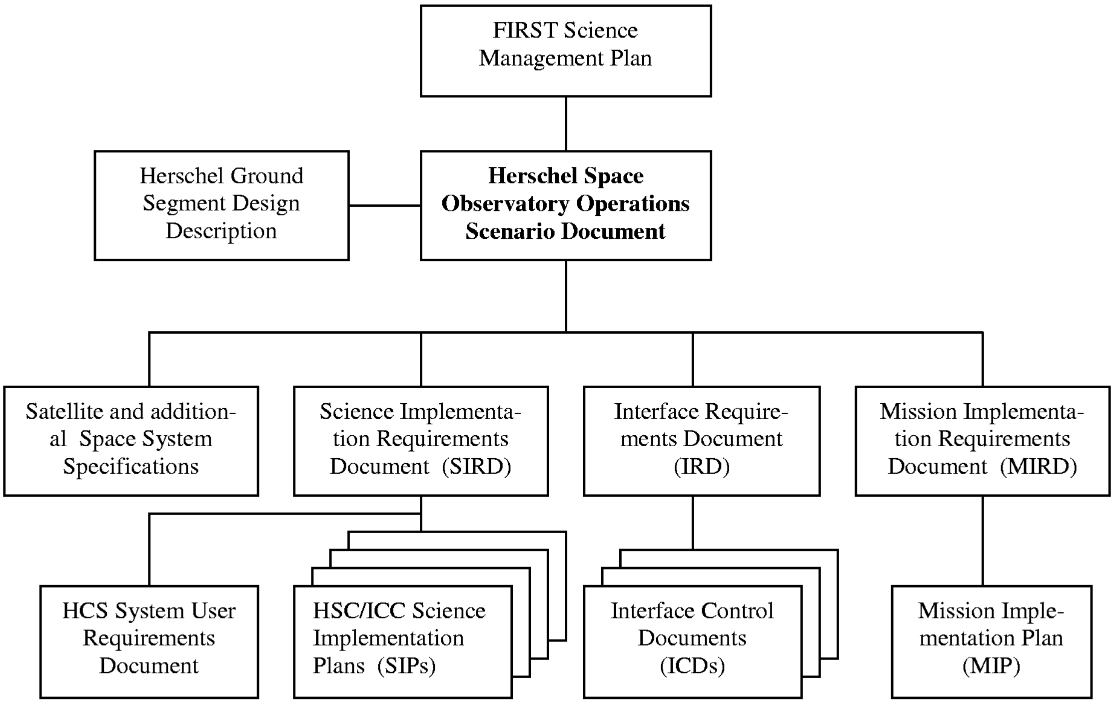

Figure 1.1 *Top level document tree for the Herschel mission. The (FIRST) Science Management Plan (SMP) has been approved by the Science Programme Committee (SPC). The* ***current document*** *(usually referred to as the '****Scenario Document****') is a narrative elaboration of the ideas presented in the SMP, approved by the SPC, serving as the source document for the formal requirements documents in the third level, including notably the SIRD. In the fourth level the responses to the formal requirements in third level can be found.*

1.3 Reference Documents

RD1: FIRST Science Operations Concept and Ground Segment Document (SCI-PT-3056)
RD2: The FIRST Announcement of Opportunity (AO) documentation
RD3: The HIFI Instrument Proposal
RD4: The PACS Instrument Proposal
RD5: The SPIRE Instrument Proposal
RD6: The FIRST/Planck System Requirement Specification (SCI-PT-RS-5991) (FIRST and common sections)
RD7: The FIRST/Planck Operations Interface Requirements Document (SCI-PT-RS-7360)
RD8: HCSS Glossary of Terms (FIRST/FSC/DOC/0120)
RD9: Proc. of the Symposium 'The Promise of the Herschel Space Observatory' (ESA SP-460)
RD10: Herschel/Planck Ground Segment Review Plan (SCI-PT-8690)
RD11: Herschel Ground Segment Description Document (FIRST/FSC/DOC/0146)

1.4 Acronyms

AAS	American Astronomical Society
AGN	Active Galactic Nucleus
AIV	Assembly Integration and Verification
AO	Announcement of Opportunity
AOCS	Attitude and Orbit Control System
AOT	Astronomical Observing Template
APID	Application Program IDentifier
CCB	Configuration Control Board
COTS	Commercial Off-The-Shelf
CRP	Contingency Recovery Procedure
CS4	(ESA) CornerStone 4 (= Herschel)
CSG	Centre Spatial Guyannais
CUS	Common Uplink System
DBMS	DataBase Management System
DDS	Data Distribution System
DE	DEclination
DHSS	Data Handling SubSystem
DPU	Data Processing Unit
DTCP	Daily TeleCommunication Period
EAS	European Astronomical Society
EE	End-to-End
EGSE	Electric Ground Support Equipment
EMC	Electro-Magnetic Compatibility
ESA	European Space Agency
ESOC	European Space Operations Centre
ESTEC	European research and Space TEchnology Centre
FD	Flight Dynamics
FDIR	Fault Detection Isolation and Recovery
FIRST	(ESA) Far InfraRed and Submillimetre Telescope (former name of Herschel)
FOM	Figure Of Merit
FOP	Flight Operations Procedures
FPU	Focal Plane Unit
FTS	Fourier Transform Spectrometer
GS	Ground Segment or Ground Station
HCalSG	Herschel Calibration Steering Group
HEB	Hot Electron Bolometer
HIFI	(Herschel) Heterodyne Instrument for the Far Infrared
HK	HouseKeeping
HOTAC	Herschel Observing Time Allocation Committee
HSC	Herschel Science Centre

HSCOM	HSC Operations Manager
H/W	HardWare
IA	Interactive Analysis
IAU	International Astronomical Union
ICC	Instrument Control Centre
ICC@MOC	ICC at MOC
ICD	Interface Control Document
IDA	Instant Data Access
I/F	InterFace
ILT	Instrument Level Test
IRAS	InfraRed Astronomy Satellite
IRD	Interface Requirements Document
ISO	(ESA) Infrared Space Observatory
IST	Integrated System Test
JFET	Junction Field Effect Transistor
L2	2nd Lagrangian point (in the Earth-Sun system)
LEOP	Launch and Early Operations Phase
LHe	Liquid Helium
LO	Local Oscillator
LOS	Line-Of-Sight
MCR	(ESOC) Main Control Room
MCS	Mission Control System
MIP	Mission Implementation Plan
MIRD	Mission Implementation Requirements Document
MOC	Mission Operations Centre
MTL	Mission TimeLine
NASA	(US) National Aeronautics and Space Administration
NCTRS	(ESOC) Network Control Telemetry Receiver System
NDIU	Network Data Interface Unit
NHSC	NASA Herschel Science Center
NRT	Near Real Time
NTD	Neutron Transmutation Doped
OBDH	OnBoard Data Handling
OD	Operational Day
ODB	(MOC) Operational Data Base
PACS	(Herschel) Photodetector Array Camera and Spectrometer
PDR	Preliminary Design Review
PDU	Poer Distribution Unit
PV	Performance Verification
PI	Principal Investigator
PLM	PayLoad Module

PM	Project Manager
PR	Public Relations
PS	Project Scientist
PSF	Planning Skeleton File
PSR	(ESOC) Project Support Room
PUS	Packet Utilisation Services
QLA	Quick Look Assessment
RA	Right Ascension
RID	Review Item Discrepancy
RSSD	(ESA) Research and Scientific Support Department
RTA	Real Time Assessment
S/C	SpaceCraft
SCOE	Spacecraft Check-Out Equipment
SCOS	(ESOC) SpaceCraft Operations System
SCR	Software Change Request
SED	Spectral Energy Distribution
SiC	Silicon Carbide
SIP	Science Implementation Plan
SIRD	Science Implementation Requirements Document
SIRTF	(NASA) Space InfraRed Telescope Facility
SIS	Superconductor-Insulator-Superconductor
SMP	Science Management Plan
SOFIA	(NASA/DLR) Stratospheric Observatory For Infrared Astronomy
SPACON	(ESOC) SPAcraft CONtroller
SPC	(ESA) Science Programme Committee
SPIRE	(Herschel) Spectral and Photometric Imaging REceiver
SPR	Software Problem Report
SRR	System Requirements Review
SSO	Solar System Objects
SSR	Solid State Recorder
SVM	SerVice Module
SVT	System Validation Test
S/W	SoftWare
TBC	To Be Confirmed
TBD	To Be Determined
TC	TeleCommand
ToO	Target of Opportunity
TM	TeleMetry
TMP	TeleMetry Processor
URD	User Requirements Document
VC	Virtual Channel

WFE Wave-Front Error

XMM (ESA) X-ray Multi Mirror (now XMM-Newton)

1.5 Explanations of Terms

The contents of this section have been transferred and made into a separate document, the ‘HCSS Glossary of Terms’ ([RD8]).

2 ASSUMPTIONS

This section serves the purpose of a place holder for assumptions made. Many assumptions have now been worked into the appropriate sections, however, this process is not yet completed. Thus, the assumptions below are left here for the moment, now grouped into subject sections.

Overall schedule:

1. The overall schedule for the implementation of the Herschel mission is given in section 3.5.

Proposing:

2. It is assumed that proposals will be submitted in two stages.
3. HOTAC assign grades to observations (not proposals) and not just a yes/no decision.

Mission planning:

4. No backup schedules will be produced. It is felt that the implementation of the capability to produce backup schedules is not cost effective because (i) the loss of data due to instrument malfunction is small (estimated once per instrument per year), (ii) replanning can be performed within one working day, thus resulting in an estimated loss of around 1% of observing time.
5. (i) The Mission Planning System shall allow scheduling constraints to be specified in such a way that e.g. calibration observations will be scheduled in a predictable order and at a predictable time (period). (ii) It shall be possible for the ICCs to access the Mission Planning system and produce working schedules. (iii) The responsibility for producing the final schedules always rests with the HSC.
6. (i) ‘Periodic’/’repetitive’ observations do not exist as a special class of observations. It is believed that only a very small number of such observations will exist which can be implemented using ‘fixed time’ observations and a facility to copy observations. (ii) It shall be possible to concatenate observations. (iii) “Linked” observations do not exist.
7. Observation duration is independent of the epoch of observation but instrument command parameter values depend on the epoch of observation for HIFI (exact LO frequency).
8. The Mission Planning System has to take into account that there may be forbidden transitions between AOTs.
9. Shadow tracking and offset tracking for SSO observations need to be possible (requirements on the Mission Planning System, with possible impacts on the I/F to Flight Dynamics, need to be established for the procedure by which this will be implemented).
10. Tracking of position and radial velocity of specified points on SSOs needs to be possible (requirement on Mission Planning System with possible impacts on the I/F to Flight Dynamics).
11. Observations of planetary moons at specified points in their orbits, e.g. maximum elongation, are foreseen.
12. Peaking up does not have an impact on the HCSS other than adding to the duration of an observation plus sending some additional instrument commands.

13. During DTCP the X-band high gain antenna has to point into the Earth direction +/- 10 degrees (which leads to the assumption that proposed observations can be executed during DTCP).
14. The visibility constraint checking tool has to be able to accommodate the transfer phase to L2 (during which the Earth constraint does not lie entirely within the Sun constraint).
15. It has to be possible to produce a long range plan for one year in less than 24 hours. The long range plan may treat ‘fixed time’ observations as ordinary observations. SSO observations are allowed to be ignored in the long range plan.

Data:

16. Observations will be marked by a ‘cycle number’ identifying which AO they come from. This includes pre-launch cycles (ILTs, ISTs, etc.)
17. The observer/archive researcher will be provided with (i) raw data with quality flag information, (ii) quick-look output, (iii) on-demand data processing capability (locally at the user’s site or at the HSC).
18. Quality information will be derived systematically at the HSC for each observation. (i) The observation has executed nominally, (ii) all data generated are available in the archive, (iii) quality control processed without problem, (iv) quick-look output available.

Other:

19. Key programs do not generate any specific requirements on the GS.
20. Cross-calibration of instruments does not have an impact on the system by generating specific requirements. The HSC has ultimate responsibility for cross-calibration activities.

3 OVERALL HERSCHEL MISSION DESCRIPTION

3.1 Introduction

The Herschel Space Observatory is a multi-user ‘observatory type’ mission targeting the far infrared and submillimetre part of the spectrum. It will perform photometry and spectroscopy covering approximately the 57-670 μm band.

The key science objectives emphasize current questions connected to the formation of galaxies and stars, however, having unique capabilities in several ways, Herschel will be a facility available to the entire astronomical community. Because Herschel to some extent will be its own pathfinder, the planning and implementation of the overall observing programme as well as the issue of instrument calibration and data processing timeliness have special importance.

Once operational Herschel will offer a minimum of 3 years of routine observations; roughly 2/3 of the available observing time is open to the general astronomical community through a standard competitive proposal procedure.

Herschel is one of the original four ‘cornerstone’ missions in the European Space Agency (ESA) ‘Horizon 2000’ long term science plan. The ESA Science Programme Committee (SPC) decided to implement Herschel - then called FIRST - as Cornerstone 4 (CS4) in its November 1993 meeting.

3.2 Science Objectives

Herschel is the the only space facility dedicated to this wavelength range. Its vantage point in space provides several decisive advantages, complementing the capabilities of other available facilities by offering space observatory capabilities in the far infrared and submillimetre for the first time. Thus, Herschel will provide new and unique observing opportunities for its users, but also places special requirements on the instrument calibration and data processing.

3.2.1 The Cool Universe

The Herschel science objectives target the ‘cool’ universe, for an extensive discussion see [RD9]. Blackbodies with temperatures between 5 K and 50 K peak in the Herschel wavelength range, and gases with temperatures between 10 K and a few hundred K emit their brightest molecular and atomic emission lines here. Broadband thermal radiation from small dust grains is the most common continuum emission process in this band. These conditions are widespread everywhere from within our own solar system to the most distant reaches of the Universe!

Herschel - being a unique facility in many ways - has the potential of discovering the earliest epoch proto-galaxies, revealing the cosmologically evolving AGN-starburst symbiosis, and unraveling the mechanisms involved in the formation of stars and planetary system bodies. The key science objectives emphasise specifically the formation of stars and galaxies, and the interrelation between the two. Example observing programmes with Herschel include:

- Deep extragalactic broadband photometric surveys in the 100-600 μμm Herschel ‘prime’ wavelength band and related research. The main goals will be a detailed investigation of the formation and evolution of galaxy bulges and elliptical galaxies in the first third of the present age of the Universe.

- Follow-up spectroscopy of especially interesting objects discovered in the survey. The far infrared/submillimetre band contains the brightest cooling lines of interstellar gas, which give very important information on the physical processes and energy production mechanisms (e.g. AGN vs. star formation) in galaxies.

- Detailed studies of the physics and chemistry of the interstellar medium in galaxies, both locally in our own Galaxy as well as in external galaxies, by means of photometric and spectroscopic surveys and detailed observations. This includes implicitly the important question of how stars form out of molecular clouds in various environments.

- Observational astrochemistry (of gas and dust) as a quantitative tool for understanding the stellar/interstellar lifecycle and investigating the physical and chemical processes involved in star formation and early stellar evolution in our own Galaxy. Herschel will provide unique information on most phases of this lifecycle.

- Detailed high resolution spectroscopy of a number of comets and the atmospheres of the cool outer planets and their satellites.

All astronomy missions and observatories - ground, air, and space based - to varying degrees rely on, and complement, each other; in this respect Herschel is not an exception. A major strength of Herschel is its photometric mapping capability for performing unbiased surveys related to galaxy and star formation. Redshifted ultraluminous IRAS galaxies (with spectral energy distributions (SEDs) that ‘peak’ in the 50-100 μm range in their rest frames) as well as class 0 proto-stars and pre-stellar objects peak in the Herschel ‘prime’ band. Herschel is also well equipped to perform spectroscopic follow-up observations to further characterise particularly interesting individual objects.

From past experience, it is also clear that the ‘discovery potential’ is significant when a new capability is being implemented for the first time. Observations have never been performed in space in the ‘prime band’ of Herschel. The total absence of (even residual) atmospheric effects - enabling both a much lower background for photometry and full wavelength coverage for spectroscopy - and a cool low emissivity telescope open up a new part of the phase-space of observations. Thus, a space facility is essential in this wavelength range, and Herschel will be breaking new ground!

3.2.2 A Phased Approach

Bringing the Herschel capabilities into space for the first time has an important consequence, which can easily be seen by making a comparison with the ISO situation. When the ISO observing programmes were being planned by the various future observers the data resulting from the all sky survey performed by IRAS, in its four photometric bands all within the ISO spectral coverage, were available. With ISO one could thus plan to build on the IRAS observations when extending the coverage in phase-space offered by the much more powerful ISO capabilities.

Herschel has no IRAS. While benefitting from IRAS itself and ISO, and hopefully by the SIRTF observations and the Japanese Astro-F all sky survey yet to be conducted, as well as other space and ground based work, clearly at least to a certain degree it will need to be its own pathfinder. Given this fact and the science objectives of Herschel, it was anticipated already in [AD1] that large ‘Key Projects’ in the form of large photometric and spectral ‘survey’ type programmes would constitute an important part of the overall observing programme. Because only Herschel itself can perform some of the necessary follow-up observations, the key projects must be carried out early in the mission; this was referred to as a ‘phased approach’.

Furthermore, because it can be anticipated that the total amount of time devoted to performing Key Project observations will require a substantial part of the overall mission, they should be selected in response to a separate call for proposals open to the entire community.

3.2.3 Timescales - a Herschel Challenge

Herschel observers will want to build on and follow-up their own observations, which put stringent timescale implications on being able to successfully process Herschel data in a timely manner, and thus by implication, on the calibration of Herschel instruments and the indentification and characterization of suitable astronomical calibrators.

Obviously, in order to build on its own observations, it must be possible to properly calibrate and process Herschel data on a timescale significantly shorter than the mission lifetime. But the real requirement is actually even much more stringent. It is currently planned to carry out unbiased ‘large’ observing programmes early on in the Herschel mission. To follow up on these observations, it is necessary not only to have the capability to process these data immediately, but in order to collect them in an optimal fashion it must be possible to properly process and assess the data collected in the performance verification phase before proceeding to decide just how to perform these large programmes.

It is thus necessary to be able to process Herschel data - at least for the observing modes to be selected for performing the large unbiased programmes - just a few months into the in-orbit phase of the mission. This is a challenging task, especially considering the wide range of Herschel instrument detector technologies (see below). This is where the legacy of ISO (and eventually SIRTF) will be crucial for Herschel in providing a guideline on how to successfully accomplish this task. The Herschel Science Team has instigated the ‘Herschel Calibration Steering Group’ (HCalSG) to address important aspects of this issue.

3.3 Telescope and Science Payload

In order to fully exploit the favourable conditions offered by being in space Herschel needs a precise, stable, low background telescope, and a complement of capable and reliable science instruments. The telescope will be passively cooled to maximise size, while the instrument focal plane units (FPUs) will be housed inside a superfluid helium cryostat to maximise sensitivity.

3.3.1 Telescope

The Herschel telescope must have a total wave-front error (WFE) of less than 6 μm - corresponding to 'diffraction-limited' operation at 90 μm - during operations, and a very low emissivity. Being protected by a fixed sunshade, it will radiatively cool to an operational temperature in the vicinity of 75 K in orbit.

The telescope will be a Cassegrain design with a 3.5 m diameter primary, and an 'undersized' secondary. The telescope is will be provided by Astrium-EF (Toulouse, France) and will be almost entirely constructed of silicon carbide (SiC). The primary mirror will be made out of segments that are 'brazed' together to form a monolithic mirror that can be polished to the required accuracy. Since the accuracy of the manufacturing of the primary mirror is the driver in the overall telescope WFE budget, the control of this parameter is important.

Special care will be taken to design the entire optical path, from the telescope and its surroundings to the instrument detectors, for minimum straylight and emissivity.

3.3.2 Principal Investigators

The Herschel science payload has been conceived and optimised for the primary science goals in mind, but additionally it offers a range of capabilities for the general observer. It will be provided by Principal Investigator (PI) consortia, which have been selected through an Announcement of Opportunity (AO) process during 1997-98, and consist of the following three instruments:

- The **Photodetector Array Camera and Spectrometer (PACS)** instrument; **PI: A. Poglitsch**, MPE, Garching, Germany, with Co-PI C. Waelkens, KU Leuven, Belgium.
- The **Spectral and Photometric Imaging Receiver (SPIRE)** instrument; **PI: M. Griffin**, Cardiff University, Cardiff, United Kingdom with Co-PI L. Vigroux, SAp, Saclay, France.
- The **Heterodyne Instrument for the Far Infrared (HIFI)**; **PI: Th. de Graauw**, SRON, Groningen, The Netherlands, with Co-PIs E. Caux, CESR, Toulouse, France, T. Phillips, Caltech, Pasadena, USA, and J. Stutzki, University of Köln, Germany.

The PI consortia provide these instruments, and their associated Instrument Control Centres (ICCs) under their own funding, to ESA in return for guaranteed observation time.

3.3.3 PACS - the Photodetector Array Camera and Spectrometer

PACS is a camera and low to medium resolution spectrometer for wavelengths in the range ~57-210 μm. It employs in total four detector arrays, two bolometer arrays and two Ge:Ga photoconductor arrays. The bolometer arrays are dedicated for photometry, and the Ge:Ga detector arrays are to be employed exclusively for spectroscopy. PACS can be operated either as an imaging photometer, or as an integral field line spectrometer.

PACS has three photometric bands with R~2. The short wavelength 'blue' array covers the 60-90 and 90-130 μm bands, while the 'red' array covers the 130-210 μm band. In photometric mode one of the 'blue' bands and the 'red' band are observed simultaneously. The two bolometer arrays both fully sample the same 1.75x3.5 arcmin field of view on the sky, and provide a predicted point source detection limit of ~3 mJy (5σ, 1 hour) in all three bands. An internal ^{3}He sorption cooler will provide the 300 mK environment needed by the bolometers.

For spectroscopy PACS covers 57-210 μm in three contiguous bands, providing a velocity resolution in the range 150-200 km/s and an instantaneous coverage of ~1500 km/s. The two Ge:Ga arrays are appropriately stressed and operated at slightly different temperatures - cooled by being ‘strapped’ to the liquid helium - in order to optimise sensitivity for their respective wavelength coverage. The predicted point source detection limit is ~$3x10^{-18}$ Wm^{-2} (5σ, 1 hour) over most of the band, rising to ~$8x10^{-18}$ Wm^{-2} for the shortest wavelengths.

3.3.4 SPIRE - the Spectral and Photometric Imaging REceiver

SPIRE is a camera and low to medium resolution spectrometer for wavelengths ~200-670 μm. It comprises an imaging photometer and a Fourier Transform Spectrometer (FTS), both of which use bolometer detector arrays. There are a total of five arrays, three dedicated for photometry and two for spectroscopy. All employ ‘spider-web’ bolometers with NTD Ge temperature sensors, with each pixel being fed by a single-mode 2Fλ feedhorn, and JFET readout electronics. The bolometers are cooled to 300 mK by an internal ^{3}He sorption cooler.

SPIRE has been designed to maximise mapping speed. In its broadband (R~3) photometry mode it simultaneously images a 4x8 arcmin field on the sky in three colours centred on 250, 350, and 500 μm. Since the telescope beam is not instantaneously fully sampled, it will be required either to scan along a preferred angle, or to ‘fill in’ by ‘jiggling’ with the internal beam steering mirror. The SPIRE point source sensitivity is predicted to be in the range 7-9 mJy (5σ, 1 hour). Since the confusion limit for extragalactic surveys is estimated to lie in the range 10-20 mJy, SPIRE will be able to map ~0.5 square degree on the sky per day to its confusion limit.

The SPIRE spectrometer is based on a Mach-Zender configuration with novel broad-band beam dividers. Both input ports are used at all times, the signal port accepts the beam from the telescope while the second port accepts a signal from a calibration source, the level of which is chosen to balance the power from the telescope in the signal beam. The two output ports have detector arrays dedicated for 200-300 and 300-600 μm, respectively. The maximum resolution will be in the range 100-1000 at a wavelength of 250 μm, and the field of view 2.6 arcmin.

3.3.5 HIFI - the Heterodyne Instrument for the Far Infrared

HIFI is a very high resolution heterodyne spectrometer. It offers velocity resolution in the range 0.3-300 km/s, combined with low noise detection using superconductor-insulator-superconductor (SIS) and hot electron bolometer (HEB) mixers. All mixers are cooled to their operating temperatures by strapping to the helium in the cryostat.

The focal plane unit houses seven mixer assemblies, each one equipped with two orthogonally polarised mixers. Bands 1-5 utilise SIS mixers that together cover approximately 500-1250 GHz without any gaps in the frequency coverage. The two highest frequency bands utilise HEB mixers, and target the 1410-1910 GHz region.

The FPU also houses the optics that feeds the mixers the signal from the telescope and combines it with the appropriate local oscillator (LO) signal, as well as provides a chopper and the capability to view internal calibration loads.

The LO signal is generated by a source unit located in the spacecraft service module (SVM). By means of waveguides it is fed to the LO unit, located on the outside of the cryostat vessel, where it is amplified, multiplied and subsequently quasioptically fed to the FPU. The SVM also houses a complement of backend spectrometers, consisting of wideband acousto-optic and digital auto-correlator spectrometers.

HIFI is not an imaging instrument, it provides one pixel on the sky (with a gaussian 'beam' that has full width at half maximum of ~1.2λ/D), but has very high frequency multiplexing. Each mixer band views a (slightly) different position on the sky. The focal plane chopper moves this position up to 3 arcmin peak-to-peak, enabling a differential measurement with a stable spacecraft pointing. Imaging with HIFI is performed by continuous slow scanning while observing, which is often referred to as 'on-the-fly' mapping, or (in certain cases) by raster mapping; both of which are performed by repointing the spacecraft.

3.3.6 Instrument Operating Constraints

For various reasons, including e.g. thermal, EMC, telemetry bandwidth, and pointing requirements, the instruments can only be operated under certain constraints. At this point in time, the constraints identified are not all well defined, and additional constraints are likely to be found. These constraints might have a significant impact on the Herschel operations.

- All instruments face (to varying degrees) data 'rate' constraints. The overall requirement here is that the total amount of data generated during an operational day (OD) must not exceed what can be stored and downlinked. This forces restrictions on operational modes used, and on possible multi-instrument (parallel etc.) modes.

- It is assumed that operation of (the) HIFI (local oscillator) will preclude operation of any other instrument.

- Operation of SPIRE requires that the internal cooler has been recycled. The recycling time is 2 hours, enabling 46 hours of subsequent operations. The very same constraint applies to the operation of PACS in photometric mode.

- It is assumed that HIFI cannot perform any astronomical observations when the spacecraft transmitter is operating, i.e. during the DTCP.

- Operation of a HIFI specific band requires that the appropriate local oscillator (LO) power for that band is available, each mixer band has two LO bands. This requires (i) that the LO source unit is operational (requiring of order 15 min (TBC) of 'stabilisation' when turning HIFI from standby to prime), and (ii) that the LO power amplifier/multiplier chain is operational (requiring 5-15 min (TBC) of 'stabilisation' time when changing LO band).

- HIFI operation will require knowledge of the radial velocity between Herschel and the target with an accuracy down to (a few) tens of m/s in extreme cases. This will have implications especially for the scheduling of solar system object observations.

- At the time this document was intially written there was a stated requirement that no more than 24 hours have elapsed between the most recent PACS vs. star-tracker boresight calibration and the beginning of a requested observation that uses PACS, with a similar requirement for HIFI observations. The actual need and frequency of this calibration need further assessment, particularly in the light of the fact that the PACS photometer now requires a recycled cooler to operate.

As time progresses this list will grow, and the level of detail and confidence will increase. The various constraints must be captured as requirements on the various affected operations subsystems, which indicates that (separate from this document) a list of these constraints and their implications should be kept and properly maintained. The HCalSG has taken on the task to capture, document, and keep updated, a detailed list of instrument operating constraints.

3.4 Spacecraft and Mission Implementation

In addition to providing the cryostat and telescope, the Herschel spacecraft needs to provide all necessary infrastructure for the proper operation of the instruments; including pointing, power, commanding, monitoring, onboard data handling, and communication with the ground. An improvement of the well-proven ISO superfluid helium cryostat technology will be used to advantage for Herschel. In order to enable efficient passive cooling and a thermally stable environment with good sky visibility an operational ‘orbit’ around L2 has been chosen, which also enables sharing an Ariane 5 launcher with Planck.

3.4.1 Spacecraft Design

Following the selection of Alcatel (Cannes, France) as prime industrial contractor, and Astrium GmbH (Friedrichshafen, Germany) and AleniaSpazio (Torino, Italy) as main subcontractors, the detailed design phase (phase B, cf. Section 3.6.1) started in April 2001. The Herschel design shown in Figure 3.1 illustrates the design at the time of the PDR in the summer of 2002. The spacecraft is modular, consisting of the payload module (PLM), comprising the superfluid helium cryostat based on ISO cryostat technology - housing the optical bench with the instrument FPUs - which supports the telescope, star trackers, and some payload associated equipment; and the service module (SVM), which provides the ‘infrastructure’ and houses the ‘warm’ payload electronics.

3.4.2 Launch and Orbit

Herschel will share an Ariane 5 launcher with Planck which will inject both satellites into a transfer trajectory towards the second Lagrangian point (L2) in the Sun-Earth system. They will then separate from the launcher, and subsequently operate independently from orbits of different amplitude around L2.

The L2 point is situated 1.5 million km away from the Earth in the anti-sunward direction. It offers a stable thermal environment with good sky visibility. Since Herschel will be in a large orbit (which is strictly not stable, demanding infrequent orbit maintenance manoeuvres) around L2, which has the advantage of not costing any ‘orbit injection’ Δv, its distance to the Earth will vary between 1.2 and 1.8 million km. The transfer to the operational orbit will last approximately 4 months; after cooldown and outgasing have taken place, it is planned to use this time for commissioning, performance verification, and science demonstration (cf. Sections 6.5, 6.6, 6.7). Once these crucial mission phases have been successfully accomplished, Herschel will go into the routine science operations phase for a minimum duration of 3 years.

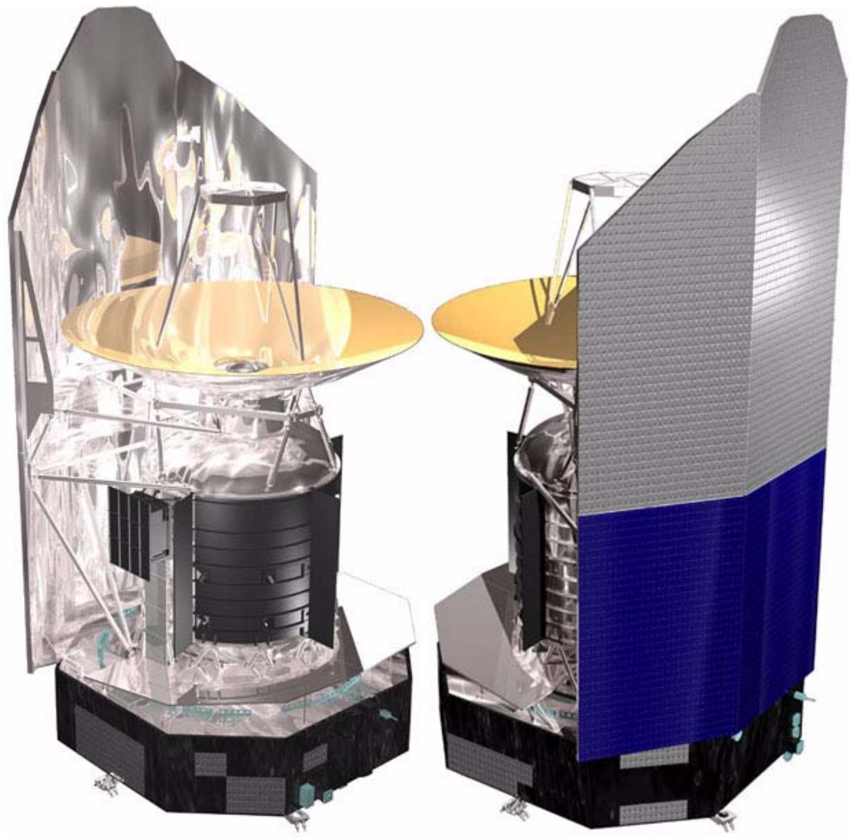

__Figure 3.1__ The Herschel design as illustrated by Alcatel measures approximately 9 m in height, 4.5 m in width, and has an approximate launch mass of 3200 kg. The 3.5 m diameter Herschel telescope is protected by the sunshade, and will cool passively to around 75 K. The Herschel science payload focal plane units are housed inside the cryostat, which contains superfluid helium at 1.65 K. Fixed solar panels on the sunshade deliver about 1.5 kW power. The local oscillator unit for the heterodyne instrument and the waveguides connecting it to its source unit in the service module are visible on the outside of the cryostat vacuum vessel.

3.4.3 Spacecraft Operating Constraints

Herschel is a three-axis stabilised satellite that must point (or in fact execute a desired pointing pattern that could be a sequence of pointings or scans) accurately to specific objects, including solar system objects (SSOs), selected for observation. It will be observing autonomously controlled by an onboard Mission TimeLine (MTL), collecting science and housekeeping data and storing them in a solid state recorder onboard, for the duration of an Operational Day (OD) of 24 hours. During the Daily TeleCommunication Period (DTCP), nominally 3 hours, the health of the spacecraft and its scientific instruments will be assessed, stored data will be transmitted to the ground, and the future observation programme will be uploaded. It is foreseen that Herschel will be conducting observations also during the ground contact period; however, the sky visibility will be constrained by the requirement that the high-gain downlink antenna has to be pointed towards the earth.

From the instrument point of view, a number of spacecraft services are particularly important, including the ones discussed in the following subsections.

3.4.3.1 Ground Station Coverage

The 34 m New Norcia (in the vicinity of Perth, Australia) ground station will be the only ground station used by Herschel in the routine operations phase. The ground station visibility is in the range 8-14 hours a day; however, the foreseen ground contact time (DTCP) is 3 hours per 24 hours, at approximately 24 hour intervals. Thus, the normal satellite operating mode is autonomously, governed by the MTL.

3.4.3.2 Mission Timeline Reception and Execution

The onboard Data Handling SubSystem (DHSS) receives the MTL from the MOC. The MTL is time-keyed with a granularity of 1 second; subsystem commands will be distributed from the DHSS to the intended recipients with negligible delay (<<1 sec) at the time specified in the timeline. At the time the nominally 3 hours ground contact is resumed, the DHSS still contains 27 hours of commanding schedule. Should a ground station pass be missed for whatever reason, execution of the command schedule will continue until the next pass over the ground station. In the nominal case the schedule for one day in the future (which starts execution at T_0+27 hours if T_0 denotes the start time of a nominal ground station pass) is uplinked during the ground station pass. In case (an) important on-board instrument failure(s) are indicated by high priority TM, new schedules which do not use the failed instrument will be produced as fast as possible (~ 1 day), and will be executed until a proper assessment of the instrument failure has been done and corrective action has been taken.

3.4.3.3 Attitude Control

The satellite's Attitude and Orbit Control System (AOCS) provides a number of services ('pointing modes') in support of science data taking. These services are described in the Herschel/Planck System Requirement Specification ([RD6]), and are listed below:

- Fine pointing,
- Nodding,
- Position switching,
- Raster pointing,
- Raster pointing with OFF position,
- Line scanning,
- Line scanning with OFF position.

To enable observations of Solar System Objects (SSOs), all of the above AOCS modes are to be implemented also for a moving 'reference position'. However, observations of SSOs are also foreseen to require additional pointing sequences such as e.g. 'shadow tracking' (observing the point on the sky where the SSO will be/have been fairly close in time) and 'offset tracking' (observing a point defined with respect to the SSO itself e.g. a certain position in a cometary tail)

A calibration of the line-of-sight (LOS) of all instrument arrays/beams with respect to the nominal 'spacecraft' LOS as determined from the AOCS system will have to be performed as part of the performance verification phase, and regularly (frequency TBD) checked. In addition, a 'peak-up' mode will be available (TBC) whereby an instrument can perform a small map around a nominal position and then derive a small (order arcseconds) 'pointing correction' to the nominal position, for a particular observation. This will require the instrument to be able to autonomously determine the appropriate correction and to communicate it to the spacecraft AOCS.

3.4.3.4 Onboard Telemetry Storage

The DHSS provides mass storage for all on-board generated telemetry for up to 48 hours in the form of a solid state recorder (SSR). During a scheduled ground station pass, all TM is downlinked from the satellite to the ground station at of order ten times the speed at which it was recorded from the satellite subsystems (24 hours of on-board data collection compressed to approximately 2 hours of the satellite-to-ground station downlink time). The DHSS is programmed to downlink the TM from the SSR in a prioritised manner, first event packets, followed by HK TM, followed by instrument science TM. This data is forwarded from the ground station to the MOC at a reduced speed (compared to reception from the spacecraft), such that all TM for 24 hours worth of on-board data taking is available at the MOC within at most 16 hours (TBC) of reception at the ground station.

3.4.3.5 Support to Instrument Autonomy

In line with the PUS (Packet Utilisation Services) that will be agreed to apply to the Herschel mission (Herschel/Planck Operations Interfaces Requirements Document; [RD7]), the DHSS will offer a number of monitoring functions to the instruments to support their autonomous operation; in the event that an instrument itself or the DHSS detects a serious instrument malfunction/contingency, the DHSS will initiate a simple series of actions, most likely a controlled shutdown of (the operations of) the affected instrument.

3.5 Science Operations

As alluded to in Sections 3.1 and 3.2 Herschel is an observatory facility with guaranteed and open time in approximate fractions 1/3 and 2/3 respectively, as described in detail in the SMP ([AD1]). The observing programmes are foreseen to be implemented in a 'phased approach' (cf. Section 3.2.2).

The 'Key Projects' will be selected first, before any observing time allocations have been made. The actual observing programmes will be solicited by a dedicated call for observation time proposals for these programmes only; this call will be open for the entire community. Only after the 'Key Projects' have been selected will the guaranteed time programmes be selected, and finally the initial round of open time programmes. Both guranteed and open time observing programmes will be selected in response to observing proposals, to be evaluated by the Herschel Observing Time Allocation Committee (HOTAC).

The Herschel Science Centre (HSC), supported by the associated NASA Herschel Science Center (NHSC), will be the point of contact for information requests and community support for all pahses of the mission, including the proposal phase. The calls for observation proposals will be issued by the HSC.

Once Herschel has been succesfully launched and injected into the transfer trajectory towards the operational orbit and the spacecraft commissioning will commence. During the initial 2-3 weeks of spacecraft cooldown the telescope will be heated to prevent from acting a cold trap. It is estimated that the cryostat lid can opened approximately 6-8 weeks into the mission, after which operation of the scientific payload will start, and the mission progresses into the performance verification (PV) phase. The goals of the PV phase include validation of the instrument observing modes and the calibration and data processing of the resulting data (cf. Section 3.2.3).

In the science demonstration phase, immediately following the PV phase, the goals include pushing the observing capablities to the limits in certain parts of the observation capability phase space, and to evaluate and optimise the observation strategies. This is done in order to decide upon how to perform the 'Key project' observations in the optimum manner, and to demonstrate the capabilities of the Herschel observatory to the astronomical community and also for public relations purposes.

Once the goals of the PV and science demonstration phases have been met, the routine operations phase commences. Early on there will be mostly guaranteed and 'Key Project' observing programmes performed. In order to be folled up obviously the 'Key Projects' will have to be performed early, but this also enables the guaranteed time holders of the HSC to obtain real data of their own to work on, in order to further prepare for providing community support to the open time observers by having go through the entire observing chain from submitting proposals to accessing and reducing the resulting data.

All observers will be able to ‘track’ the whereabouts of their proposals, and will be notified when the resulting data can be accessed.

3.6 Mission Phases and Milestones

The following overall timelines for the implementation and subsequent operation of the Herschel mission have been used as working assumptions in this document. They all correspond to actual dates in the past, and to current planning. Only the ‘mission level’ reviews and a selection of the most important dates vis-à-vis the instrument and spacecraft hardware as well as the calls for observing time are listed.

In addition to the mission level reviews there is a set of reviews for each of the instruments, the satellite system, and the ground segment, as well as separate reviews for components of the ground segment, as described in detail in the ‘Herschel/Planck Ground Segment Review Plan ([RD10]).

3.6.1 Development Phase

Release of Announcement of Opportunity (AO)	October 1997
Scientific payload complement selection	May 1998
Scientific payload complement approval	February 1999
Release of Invitation To Tender (ITT)	September 2000
Start of Phase B	April 2001
Start of Phase C/D	Q3 2002
Mission level Preliminary Design Review (M-PDR)	January 2003
Instrument Avionics Model deliveries	October 2003
Instrument Cryogenic Model deliveries	October 2003
Call for ‘Key Project’ observation time proposals (L-36 months)	February 2004
Mission level Critical Design Review (M-CDR)	May 2004
Instrument Proto-Flight Model deliveries	January 2005
Call for ‘Guaranteed Time’ observation time proposals (L-24 months)	February 2005
Call 1 for ‘Open Time’ observation time proposals (L-12 months)	February 2006
Mission level Flight Acceptance Review (M-FAR)	Q3 2006
Mission level Flight Readiness Review (M-FRR)	January 2007
Launch	L = 15 February 2007

3.6.2 Post Launch Timeline

The assumed schedule (the unit of time is month) post-launch. Note that additional call(s) for open observation time proposals are foreseen, dates are TBD and not explicitly listed here. Note also that the expected time to reach the vicinity of L2 is approximately 4 months.

Launch	L = 15 February 2007
Commissioning phase (1 month)	L => L+1
Performance verification phase (2 months)	L+1 => L+3
Science demonstration (1 month)	L+3 => L+4
Mission level In-Orbit Commissioning Review	June 2007
Herschel routine observations (minimum 36 months)	L+ 4 => L+>40 = Boil-off = B
Run-down phase (3 months)	B => B+3
Mission consolidation phase (6 months)	B+3 => B+9
Active archive phase (48 months)	B+9 => B+57
Archive consolidation phase (6 months)	B+57 => B+63 = **End** of Herschel mission
Historical archive phase (indefinite)	B+63 (= **beyond the end** of Herschel mission) => TBD

3.7 Legacy

The ultimate legacy of Herschel will have a tangible component, the historical archive, in addition to the sum of all the knowledge, scientific and technical, already derived from implementing and using Herschel.

The historical archive (cf. Section 6.9) will provide access to all Herschel observations and derived products. The products will all be derived during the archive consolidation during the post-operations phase (cf. Section 6.8) in a consistent manner and to consistent standards using the best knowledge of Herschel instrument calibration and data processing. In addition to the software, ‘written’ information – manuals etc. – and tools will be available from the historical archive.

It is anticipated that the Herschel historical archive will be a ‘component’ of an ESA Science (or RSSD) wide archive with a common ‘overlay’ together with e.g. the ISO, XMM-Newton, INTEGRAL, and Planck historical archives, built using similar multi-tier architecture and subsystems as these. This brings down development costs and risks and not only ensures a common ‘look and feel’ across archives of multiple ESA missions, at the same time simplifying for the user and raising the ESA ‘corporate identity’, but also their early and full integration into the Virtual Observatories initiatives worldwide.

4 OPERATIONS CONCEPT AND GROUND SEGMENT DESIGN

Herschel has been conceived as a multi-user observatory, and it will be open to the entire astronomical community (cf. Section 3.5) . This means that the science ground segment needs to be designed to this effect, including providing an interface for the community at large to keep abreast with Herschel developments as they happen – especially with regard to its predicted scientific capabilities and schedule for the planned calls for observing proposals – and to provide user support at all stages of the mission.

4.1 Science Operations Implementation Overview

In order to implement an efficient science ground segment that minimises resource requirements, clear and logical divisions of responsibility with clearly defined deliveries and interfaces must be established; expertise must be utilised efficiently; operability and data reduction (as well as the cost of the instruments themselves) must be the key drivers for the design, ground test, characterisation, and calibration of the instruments; and commonality between the various instruments and between the ground and flight operational environments is a design goal.

The Herschel science operations concept has been designed with the objective to minimise the total overall operations effort (and thus cost) within the constraints given. The efficiency requirements driving the concept technically were:

- the expertise of all involved must be utilised in a maximum and optimum way with clear predefined areas of responsibility and interfaces,
- the design must give strong incentives to the PIs to develop their instruments with operations and data processing requirements addressed from the very beginning; which is expected to lead to instruments which are less complex to operate and ground testing programs designed with data reduction in mind,
- commonality must be actively pursued; guidelines for instrument design and operational environments were given in the Announcement of Opportunity (AO) to ensure the required level of commonality,
- the ground segment elements have a common development and operational environment, enabling smooth transitions between mission phases,
- the design must minimise overheads, needs of dedicated infrastructure, and needs of relocation of people.

The above considerations have led to a ‘distributed’ ground segment concept; cf. Figure 4.1 below. In times of fast computer links and teleconference facilities, the physical separation between the various building blocks of the ground segment is considered not to be a noteworthy disadvantage, provided these facilities are actually used routinely to coordinate the activities at the different sites.

4.2 Ground Segment Overview

The scientific operations of Herschel will be conducted in a 'decentralised' manner. The proposed ground segment concept comprises five elements:

- a Herschel Science Centre (HSC), provided by ESA. The HSC, supported by the NHSC (see below), acts as the point of interface to the science community and the outside world in general.
- three dedicated Instrument Control Centres (ICCs), one for each instrument, provided by the respective PI. Each ICC will be responsible for enabling the operation of its instrument, and also for the provision of calibration and data reduction tools for all data generated.
- a Mission Operations Centre (MOC), provided by ESA, which will be responsible for the execution of all in-orbit operations.

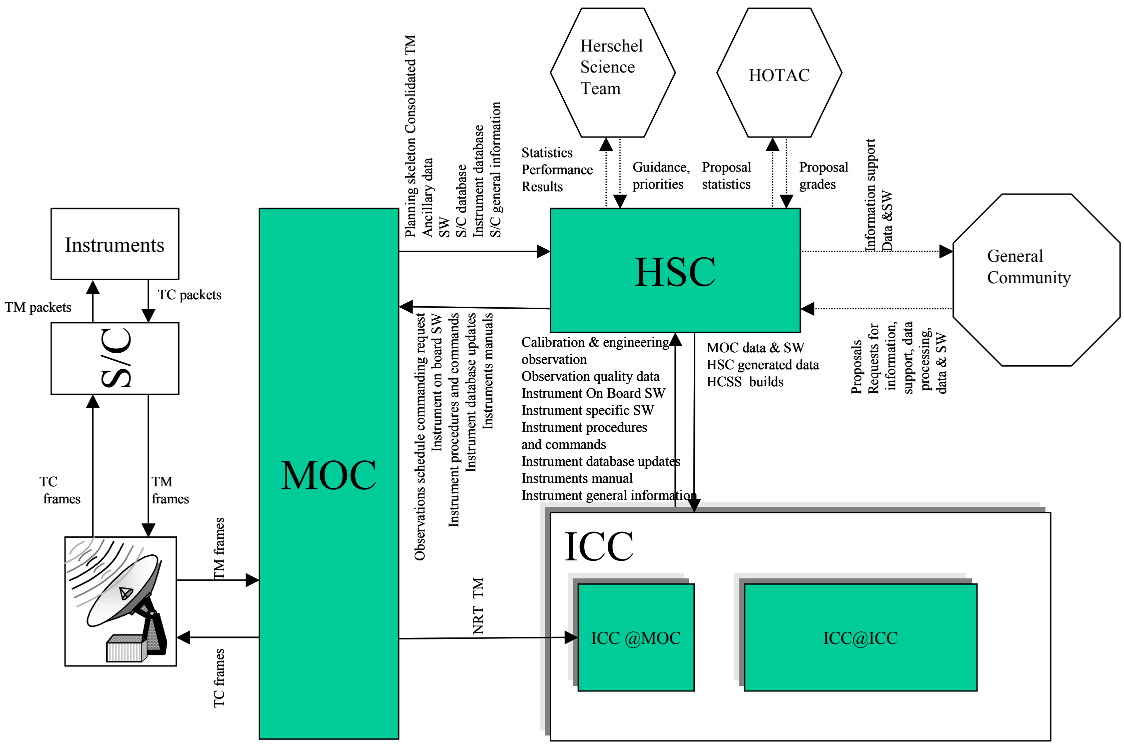

Figure 4.1 Overview of the 'distributed' Herschel ground segment diagram showing data flow.

In addition, it is foreseen that in the future the NASA Herschel Science Center (NHSC) to be located at the (Caltech/JPL) Infrared Processing and Analysis Center (IPAC), Pasadena, CA, will become an associated sixth element, provided by NASA.

4.2.1 Geographical Locations

The Herschel science ground segment is decentralised. The assumptions are that the MOC will be located at ESOC, and the ICCs at (or near) the PI institutes (except for the ICC@MOC setup for real-time analysis of the data, located at ESOC). The HSC will be located at a suitable place in an ESA member state, e.g. Vilspa. The ‘Herschel Common Science System’ (HCSS) will be designed and implemented to enable this decentralised ground segment to work efficiently as a whole.

4.2.2 Communication and Data Interfaces

HCSS is a collection of software and hardware facilities that together act as the common repository for all information, data and software relevant for Herschel operations in the broadest sense. At the same time it provides the backbone for the retrieval and communication of this information for and between all legitimate Herschel users, including ESA (HSC, project, MOC), the science instrument consortia and their associated ICCs, the general astronomical user community, and the interested public.

It is assumed that adequate bandwidth between Herschel GS elements will be available to enable a distributed Ground Segment. The minimum required bandwidth is at least twice (TBC) the on-board data production rate.

4.3 Ground Segment Elements

The elements constituting the Herschel ground segment have well defined responsibilities. Their interfaces will be specified in Interface Control Documents (ICDs) which will be maintained under strict configuration control.

4.3.1 Herschel Science Centre (HSC) Overview

The Herschel Science Centre (HSC) is a single-point interface to the ‘outside’ world – including not only the general scientific community but also the press and general public – for contacting the Herschel observatory.

The HSC will be responsible for all ‘observatory’ aspects of the mission. The HSC shall ensure that the scientific productivity and impact of the Herschel mission is maximised within the given constraints. For this task the HSC will be supported by the Herschel Science Team, and the Herschel Observing Time Allocation Committee (HOTAC).

Specificially, the HSC responsibilities are:

- to perform overall science coordination and scientific mission planning strategy, taking guidance from the Science Team,
- to issue calls for observing time proposals, and the handling of proposals,
- to set up and support the HOTAC for time allocation and proposal rating,

- to provide general community support throughout all mission phases, acting as a single-point input (requests, proposals), output (information, data, software) interface and 'central helpdesk',
- to coordinate cross-calibration between Herschel instruments, and between Herschel and other facilities,
- to give support to ESA PR and science communications activities (cf. Section 8).

In addition, the HSC is responsible for a number of functional tasks, including the responsibility for all HSC software development. In particular, the HSC functional tasks are:

- to perform detailed scientific mission planning,
- to provide quality control information on all observational data,
- HCSS design together with ICCs, development, coordination and maintenance, including the integration of its subsystems according to agreed standards,
- to provide, manage, and maintain the central Herschel data base, and all the HSC software subsystems,
- to populate HCSS with Herschel test, characterisation, science, and operational data,
- to provide the framework and 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,
- to ensure overall ground segment consistency with respect to instrument configuration, including onboard software,
- to provide and maintain the HSC infrastructure, including training of staff,
- to provide cohesion between all Herschel ground segment elements.

The HSC has major functional interfaces with the Instrument Control Centres (ICCs) and the Mission Operations Centre (MOC); in addition the HSC should provide specific support to the Planck mission (TBC). The NHSC is expected to provide community support to the US users of Herschel.

4.3.2 Instrument Control Centre (ICC) Overview

The ICCs are responsible for the successful operation of their respective instruments, and for making possible the processing of the resulting data. The ICCs are responsible for most instrument related operational issues; instrument monitoring and calibration, developing and maintaining instrument specific software and procedures, and supporting operations. Each ICC performs tasks dedicated to their particular instrument. In particular the responsibilities include:

- the monitoring of instrument development, testing, characterisation and calibration.
- status and health monitoring, and maintenance of the instrument.

- the provision of instrument simulators for inclusion into the satellite simulator.
- the provision of instrument ‘time estimators’.
- the provision of instrument command generation facilities. The ICC generates and verifies commands for tests, calibration and scientific validation purposes.
- the maintenance of the instrument onboard software which has been generated and validated by the instrument teams.
- the generation and maintenance of all ground software.
- input to the procedures needed for operating the instruments, and for performing monitoring and trend analysis.
- the provision 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.
- instrument calibration; all aspects of the instrument calibration during all phases of the mission.
- the production of instrument and software manuals, and observer manuals.
- provision of necessary instrument information to the HSC and MOC.
- the definition and scientific validation of AOTs and test modes.
- scientific exploitation. The ICCs play a central role in requiring the instrument consortia to process and scientifically exploit their guaranteed time data, and thereby maximise the scientific return from the mission.
- to support the HSC, when required to the extent mutually agreed, e.g. for quality control of the observations, and community suppport involving the use of ICC delivered software.

There will also be an ICC set-up at the MOC, called the ICC@MOC. It will be used during the commissioning phase (cf. Section 6.5), and potentially for the remainder of the mission during instrument emergencies. It will allow for TM monitoring and commanding (via MOC) of the instruments.

4.3.3 Mission Operations Centre (MOC) Overview

The responsibilities of the MOC include:

- Generating all commands to be uplinked to the satellite based on input from the HSC, the ICCs and its own subsystems.
- Receiving, recording for safekeeping, consolidation of the telemetry data and making these data available to the rest of the Ground Segment.

- Making near real-time telemetry available to the ICC@MOC; providing the ICCs with necessary space etc. for setting up the ICC@MOC.
- Ensuring the health and safety of the satellite and all its subsystems, including that of the science instrument complement.
- Maintaining the instrument and spacecraft databases shared by the MOC, ICCs, and HSC, and of the SCOS-2000 system used (TBC) by the MOC and ICCs.

In the development phase there is very little operational interaction between the MOC and the other ground segment elements. During tests where the MOC is not participating, a component that mimics the role of the MOC shall be present, but it will only be a feed-through entity sending commands and telemetry to and from the satellite and/or the instruments. MOC is present during SVTs, EEs, and simulations.

In operations the detailed observing schedule is created by the MOC by interleaving the science observations with the necessary satellite operations. The final schedule is subsequently translated into an MTL and up-linked via the Herschel ground station. The data stored in the onboard memory are down-linked to the ground station (where they are recorded) and then transmitted to the MOC where they are stored for safe-keeping. At the MOC the house-keeping telemetry is inspected and analysed for possible malfunctions or abnormal operations. If malfunctions are found, these are flagged. When needed, actions for the relevant teams (ICC, HSC and/or MOC) are initiated. The telemetry is stored in the HCSS, and thus becomes accessible for the instrument and science teams for further analysis.

4.4 Smooth Transitions Between Mission Phases

To facilitate transfer of knowledge and procedures, as well as for reducing conversion efforts, it is very desirable to have the same (or at least a similar) environment through all Herschel mission phases from early development to post operations. It is thus desirable that the HCSS is available (in some form) in all these phases to provide a smooth transition starting from Instrument Level Tests (ILTs) all through post operations.

In the ILT phase the ICCs will start performing the first characterisations of their instruments. The initial deliverable version of the HCSS, the HCSS v0.1, will be used to support these tests.

In the subsequent Integrated System Test (IST) phase the integrated satellite system will be tested. In this test phase a special test set-up shall be created to command the satellite and its subsystems (i.e. also the instruments) in a fashion closely resembling the final operational environment. In this phase the HCSS should function like the backbone system it will be in the post launch phases. The IST set-up should subsequently smoothly adapt into the operations environment as sketched in the previous sections.

Finally, in Post Operations the main task of the HCSS will be to provide the user community a stable access point into the Herschel historical archive. The user community should not be adversely affected by any potential updates to the HCSS when going from operations to post operations.

5 ROUTINE PHASE OPERATIONS

The development and subsequent operations of Herschel and its instruments will contain a number of phases and tests. From approximately L-8 hours (8 hours before launch) the following mission phases are defined:

- Launch and Early Orbit Phase (nominal duration: a few days),
- Spacecraft and Instrument Commissioning Phase (nominal duration: 1 month),
- Calibration and Performance Verification Phase (nominal duration: 2 months),
- Science Demonstration Phase (nominal duration: 1 month),
- Routine Phase (nominal duration: minimum 3 years).

The routine phase is the main driver for the Herschel operations. This phase is when the ‘raison d’être’ of Herschel – producing astronomical data – will take place, and consequently also the phase when the ‘customers’ of Herschel – the astronomers – will play a major role in the operations.

This section describes the full ‘life cycle’ of performing a routine phase observation with Herschel, starting from applying for observation time, through the planning of the observation in detail, scheduling and execution of the observation, and ending with obtaining the resulting corresponding science data.

This section also addresses, at top level, satellite and ground segment contingencies as well as providing a brief overview of what needs to happen ‘behind the scene’ in terms of instrument and spacecraft monitoring, as well as on-board software and science ground segment database and software maintenance.

5.1 Obtaining Observation Time

Herschel offers guaranteed and open observation time. The guaranteed time (approximately 1/3 of the total time) is owned by contributors to the Herschel mission, mainly by the PI consortia, but there is also some time belonging to the HSC and the mission scientists; the remainder (thus about 2/3) is open time.

Throughout the entire operational lifetime of the Herschel mission, the observation time will be shared between guaranteed and open time. The guaranteed time observing programmes will be defined by the guaranteed time holders through the submission of observing proposals. The open time will be allocated to the general community (including the guaranteed time holders) on the basis of calls for observing proposals. A small amount of open time will be reserved (discretionary time) for targets that could not have been foreseen at the time of the deadline for a call. The formation of large observer collaborations collectively addressing key scientific topics will be actively encouraged, there will be a special call for ‘key’ projects. All proposals will be evaluated and graded by the Herschel Observing Time Allocation Committee (HOTAC) with respect to scientific merit. All science data are proprietary for a certain period of time (generally for 12 months after being made available to the owner) according to rules laid out in the Herschel SMP ([AD1]), and are subsequently made public.

The first call (cf. the timeline in Section 3.6) for observation time will be the call for 'key' projects, followed by the call for guaranteed time. When the 'key' and guaranteed observation programmes have been established there will follow TBD (but at least 2) calls for observation proposals for the open time.

5.1.1 Announcing a Call for Proposals

ESA, advised by the Herscel Science Team, announces to the community the detailed schedule for proposal cycles and support availability. These announcements are done on the Herschel website, where documents relevant to planning and proposing a research programme are also available, and in the Herschel Newsletter. In addition, the HSC informs the community at international meetings (such as EAS, IAU, AAS, and others), sends envoys to institutions to speak on proposal opportunities, and encourages members of e.g. the science team and the instrument consortia to give mission- or science-oriented colloquia at science institutes.

A call is announced on the Herschel website and by bulk email to members of the astronomical community. The proposal cycle is a two stage process, where the detailed planning of the observations is only taking place in step two, after the HOTAC review. Proposals for targets of opportunity and discretionary time can be submitted at any time, according to special rules.

5.1.2 Proposal Submission

During this period the user is aided by tools accessible on-line through the Herschel website that provide to all observers an integrated and uniform environment for planning their observations. This includes:

- General observing information, including relevant spacecraft documentation (Observer Handbook) and documentation for all instruments (Instrument Observer Manuals).
- Sky visualisation tools (like IRSKY), with online access to available astronomical databases and the resources of other missions (e.g. IRAS, ISO, SIRTF, SOFIA, etc …).
- A sky visibility tool providing information which areas of sky are visible to Herschel at given times.
- PI names, proposal titles, target lists, and observing modes (TBC) for all accepted key, guaranteed, and already observed or 'carried over' programmes from earlier proposal cycles.
- Time Estimators for all instrument modes. The observing modes of the instruments will be kept simple and relatively few, which will simplify the proposal preparation and handling processes as well as homogenize the contents of the Herschel science data archive.

The call for proposals includes examples of filled-in observing modes that can be used for guidance and as proposal templates. In the first stage of submission, each proposal must include the following information:

- Cover sheet (PI name and address, co-I names and addresses, proposal title, abstract)
- Science category

- Science justification
- Target list and associated instrument mode category
- Total observation time applied for
- Status of proposals accepted on previous cycles, and recent publications of relevance

Proposals are to be submitted electronically. At the time it is submitted, each proposal is automatically checked for certain errors or redundancy with already existing programmes as described above. HSC provides the capability to the proposer to modify the submitted proposal up to the submission deadline.

5.1.3 Selection

For each proposal HOTAC determines:

- Science merit,
- Ranking priority based on scientific merit,
- Adjustments to the requested observing time for technical or scientific reasons.

To be able to carry out these tasks, the HSC provides the following support to HOTAC:

- Technical feasibility assessment of proposed observations,
- Notification of object/observing mode redundancy/overlap between different proposals.

In case observations, as originally proposed, fail technical feasibility assessment but are considered to be of high scientific merit by HOTAC, or if certain observations overlap between different proposals, HOTAC advise the HSC how these cases should be resolved in direct contact between HSC and the proposing individuals or teams.

Accepted proposals are made public to the extent (TBC) of listing PI names, proposal titles, target lists, and observing modes. Proposal contents are protected indefinitely.

5.1.4 Detailed Observation Planning

An on-line environment is provided for the users to plan - and fill in - the observation details of their accepted proposals in proposal submission stage 2. The user is able to use the latest measured performance of spacecraft and instruments determined during the calibration and performance verification period or, should performance values change with time, the routine phase; pre-launch, predicted performance values, based on laboratory measurements, will have to be used. The users are allowed to refine their approved stage 1 proposals within specified guidelines, keeping within their awarded observing time. It is planned to require that user changes to accepted observing proposals occur only during specific time periods; however, for proposals submitted pre-launch, this period will extend into the instrument calibration and performance verification phase such that early results from this phase can be fed back into the approved observations.

Observation Time Estimators are available on-line to allow instrument operations to be optimized, using knowledge of background fluxes, stabilisation times, etc. These time estimators will be refined throughout the mission as additional experience is gained.

HSC offers user support via email, phone, and fax throughout all phases of the proposal submission process. The user is also given the option to visit the HSC to get assistance. The HSC Community Support personnel interface directly with designated ICC personnel for question answering and problem solving as may be required; observers are not expected to contact ICCs. Before the end of the observation planning period, the user submits the completed (phase 2) proposal to HSC.

5.1.5 Database Management

HSC manages the observation database resulting from submitted stage 1 and stage 2 proposals. To this end, the HSC has a suite of tools that can act on individual observations as well as classes of observations, e.g. to (fine)tune (or change) observations to reflect the improved understanding of the instruments, or to check that proposals remain within time limits taking into account the latest instrument sensitivities. The HSC has a mechanism to contact all observers, and/or (selected) groups of observers, as the need arises.

5.2 Calibration and Engineering Observations

In operations the ICCs' main tasks are: monitoring instrument health, calibrating the instrument, and the provision of data reduction software. The task of calibrating the instruments can be divided into two parts: calibration planning and calibration analysis. For calibration planning, calibration observations are submitted to the HSC for scheduling, wherever possible using standard AOTs to observe internal or external sources. 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 as an infringement on observation proprietary rights.

Engineering observations are at the lowest level in the sense that these observations do not use the standard command sequences generated by AOTs, but are 'manually' assembled through the editing of scripts that generate commands (in the same way AOTs are defined) 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. All observations, including engineering observations, will be requested through templates.

5.2.1 Planning and Execution of Calibration and Engineering Observations

For every nominal scheduling period the ICCs select and prioritise a set of observations based on their agreed long-term calibration plan. The observations contained in such a set are verified (by the ICCs) to be 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) enter the system as a series of independent observations submitted to the HSC for scheduling. The ICCs and the HSC have a joint responsibility to collaborate to ensure that cross-calibration requirements are fulfilled by the planned instrument specific calibration observations.

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.

5.2.2 Analysis of Calibration and Engineering Data

Calibration and engineering observations are analysed using standard reduction steps (IA tools) to the maximum extent possible. This analysis, which is mostly carried out by instrument specialists from the ICCs or HSC, leads to an assessment of the status and behaviour of the instrument by performing trend analysis, and to the derivation of detailed instrument calibration parameters. Multiple values (e.g. ‘nominal’ and ‘test’) for such parameters are supported by the processing software. Once ‘test’ values for such parameters are accepted as new ‘nominal’ values after ICC/HSC review, they are approved by the CCB, and made available as such 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. When warranted by the results of the ongoing calibration, the long term instrument calibration plan and strategy are adjusted. If necessary, additional calibration sources are selected or more information on available calibration sources is sought (e.g. using additional observations of calibration sources using other Herschel instruments or ground-based facilities).

At regular intervals the larger astronomical community is informed about the status of the instrument calibration and the calibration strategy.

Note: For critical observations, e.g. investigations following an instrument failure, it may be necessary for parts of the ground segment, and in particular for the ICCs 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.

5.3 Mission Planning

The mission planning approach re-uses main generic features which have been successfully implemented for earlier ESA observatory type missions, such as ISO and XMM-Newton.

The following discussion of the mission planning process makes no particular assumptions on the usage of instruments during given periods; indeed, it is assumed that periods during which all instruments are used during the shortest possible planning unit (one OD) can alternate with periods during which a single instrument is used for several contiguous ODs. Possible restrictions to a maximally flexible use of the instruments are currently being assessed with respect to science return and implications on observatory lifetime by the Science Team, and for potential interference between instruments (which may prevent the mixed use of different instruments during the shortest possible planning unit, cf. Section 3.3.6) by the PI teams.

5.3.1 Inputs to the Mission Planning Process

5.3.1.1 The Planning Skeleton File

For a given nominal scheduling period, MOC will provide a set of PSFs (one PSF per OD) identifying e.g.

- The ephemeris (RA and DE) of the Earth as seen from Herschel at the start and at the end of the OD. Because the Herschel high gain antenna has to be pointed approximately at the Earth during the DTCP, this information is required for scientific mission planning as more severe attitude restrictions apply during the DTCP than during the rest of the OD.

- Start and end times of science and non-science windows. Observations can only be scheduled during science windows. Non-science windows are periods of time reserved for spacecraft activities which are incompatible with the taking of science data, e.g. times during which orbit maintenance manoeuvres are executed.

5.3.1.2 The Observation Database

All observations (including also the engineering and calibration observations, in addition to the science observations) to be scheduled by the scientific mission planning system are contained in an observation database, from which they are retrieved for assessment whether they can potentially be scheduled in the OD for which a schedule is being generated.

Because calibration and engineering observations are constantly added, because individual observers may request changes to their not yet executed obervations, because re-scheduling of failed observations and targets of opportunity observations, and because at certain times it will be necessary to automatically update certain observations (e.g. after a significant enough change in instrument sensitivity), the observation database will be far from static. However, it appears reasonable (and operationally necessary) to assume that such changes can be accumulated and be applied at certain times (e.g. once per week) between which the observation database remains stable. In addition, a scheduled observation must be unscheduled before it can be modifed.

5.3.1.3 Rules and Constraints

When considering a particular observation for scheduling, scientific mission planning will take into account rules and constraints which determine whether and when this observation can be scheduled during the OD for which a schedule is being prepared. Restrictions in scheduling that need to be considered include:

- Visibility of a target during the observation duration,
- Constraints provided by the observer,
- Use only of a commissioned and currently available instrument modes,
- Use only of (an) instrument(s) which is/are configured to carry out scientific observations during this OD,

- Unconstrained access to and departure from the target attitude if the observation uses a pointing mode (i.e. validity of the slews connecting an observation to its predecessor and successor observations),
- Unconstrained attitude for the entire slew path for observations that use the slewing mode,
- Compatibility of an observation with its predecessor and successor observations,
- Global compatibility of all observations with spacecraft constraints (e.g. maximum amount of data that may be stored on the SSR during an OD).

There are also specific constraints for the scheduling of observations with specific instruments or instrument modes; the currently identified ones are listed in Section 3.3.6.

5.3.2 The Scientific Mission Planning Process

Conceptually, scientific mission planning can be broken down into two separate activities:

- A scheduling activity, performed by a ‘scheduling engine’, that generates a timed sequence of observations of known duration,

- An activity generating the timed sequence of satellite (spacecraft and instrument) commands that need to be provided to on-board systems to actually carry out this sequence of observations.

When schedules are generated for all or part of the nominal planning period, the scientific mission planning can be used in three modes:

- Manual mode; in this mode the Mission Planner is in sole control of specifying which observations are carried out in which sequence at which times, provided the observations and their sequence do not violate any constraints.

- Automatic mode; in this mode the mission planning software has complete freedom to select and sequence a set of observations for an OD (subject to the above mentioned constraints). Prior to triggering such an automatic scheduling run, the Mission Planner will set a number of parameters, e.g. the instrument(s) to be used during an OD (or set of contiguous ODs) or some other filters to generate a candidate target list for the scheduling period. In automatic mode, scientific mission planning will ‘optimize’ the selection and sequencing of observations by maximizing a user-defined ‘figure of merit’ (FOM) for a schedule or sequence of schedules.

- Mixed mode; in this mode the Mission Planner may manually specify certain observations to be scheduled during a particular OD (or set of ODs) that (s)he wants to have performed if possible but leave it to the mission planning software to e.g. ‘optimise’ the schedule by automatically filling in additional observations that increase the FOM for the schedule which has only been partially filled this way.

The scientific Mission Planning System can also be used in a long range (‘what if?’) planning mode to investigate the scientific impact of different long term observation strategies (e.g. in response to a partial instrument failure, or to provide guidance on how to best resolve the competition between observations that target highly oversubscribed spatial regions on the sky). The long range planning mode is distinct from the mode in which actual schedules are produced. No part of a schedule produced in long range planning mode can be changed to a state in which it could be transferred to the MOC, no timed sequences of satellite commands are generated.

The long range planning mode has the following characteristics:

- It has to produce a schedule of observations for up to one year in less than 24 hours elapsed time,
- It executes fully automatically after the Mission Planner has specified a scheduling scenario for the long range plan (e.g. periods during which specific instruments shall be used),
- It produces a set of outputs/statistics/summaries which allow to quickly assess certain qualitative and quantitative aspects of the schedule that has been generated with this scheduling scenario.
- Fixed time observations can be treated as if they were ordinary observations (which can be scheduled at any time non-temporal constraints allow).
- Solar System Observations do not have to be considered for scheduling in the long range plan.

5.3.3 Output of the Scientific Mission Planning Process

The output of the scientific mission planning process includes:

- a timed sequence of observations; which is to be which is transferred ('committed') from HSC to the MOC,
- a set of time-keyed satellite commands to carry out the scheduled observations and intervening slews,
- modification of certain attributes (held in the observation database) of the observations contained in the schedule (e.g. whether an observation is still schedulable or not; an observation may be contained in several 'draft' schedules until it is contained in a committed schedule) and/or attributes of the schedules themselves (e.g. committing a schedule will make those draft schedules invalid that contain one or more of the observations contained in the committed schedule).

5.3.4 Schedule Review and Approval

Before any observation schedule can be committed (transmitted to the MOC for further processing, including MOC 'approval' and subsequent uplink) it will be reviewed and formally authorized by the Project Scientist or his appointed representative.

To inform observers of the status of their observation, the HSC will provide visibility into which observations have been included in which committed schedule.

5.3.5 Replacement of a Committed Schedule

Replanning of ODs for which a schedule has already been committed is possible under certain circumstances. Such circumstances include:

- Appearance of a Target of Opportunity (ToO) which is to be observed as soon as possible if visibility constraints allow.
- Appearance of an instrument or spacecraft anomaly that does not allow the observations contained in a committed schedule to be carried out.
- On-line investigations into an instrument anomaly, which may require replacement of a committed schedule by a schedule that leaves part of the timeline available for interactive satellite commanding.

Replacement of a committed schedule requires approval of the Project Scientist or his appointed representative and may be subject to further constraints (e.g. a minimum time which needs to be available between resubmission of an already committed schedule to the MOC and the start of the corresponding OD) that should be identified in a ‘HSC-MOC Interaction Document’; however, no ‘backup schedules’ will be systematically produced and committed preemptively to cater for the occurrence of such a contingency. [Rationale: Assuming that (i) replacement schedules for already committed schedules can be produced by HSC and further processed by the MOC within less than 48 hours after detection of an instrument contingency that invalidates a committed schedule, (ii) only a small number (~5) of such contingencies occurs per year, the relative time lost to science is considered to be much smaller than the corresponding increase in complexity and cost of the scientific mission planning system.]

5.3.6 Types of Supported Observations

The following types of observations are supported by the scientific mission planning system:

- **Normal observations:** Such observations can be scheduled at any time when they do not violate non-temporal constraints.

- **Fixed-time observations:** In addition to satisfying non-temporal constraints, fixed time observations must be scheduled to start within a configurable temporal window. Although ‘calibration’ and ‘engineering’ observations are performed for a different purpose than requested celestial observations, they are not distinguished as a separate class of observations; from the point of view of scientific mission planning they form a subset of fixed-time observations.

- **Solar System Object (SSO) observations:** Because Solar System Objects have time-variable target coordinates, SSO observations form a separate class. The scientific mission planning system shall specifically support the following variants of SSO observations:

- Observation of a limited number of planets, planetary moons, asteroids and comets (order of 100 different objects contained in a configurable set) , including knowledge of the radial velocity (relative to Herschel) of these SSOs at the time of observation,

- Observations of specific points on major planets (e.g. latitude and longitude; order of 10 different specific points contained in a configurable set), including knowledge of the radial velocity (relative to Herschel) of these points at the time of observation,

- Observations in which a SSO and a point on the sky relative to this moving object (i.e. at a fixed distance from and position angle relative to the SSO) are pointed at alternatively during the same observation.

Comment: For ISO the SSO observations were handled practically manually, rather than automatically. They were normally entered into the mission planning system through the pre-emption queue as fixed- time observations (though not fixed-time from the observers’ point of view). The reason was the complicated constraints imposed by the observers. A detailed analysis on how best to deal with SSOs in Herschel is needed.

- **Concatenated observations:** A sequence of observations is said to be concatenated if these observations cannot be scheduled independently; concatenated observations have to be scheduled one directly after the other (in time) in exactly the sequence specified by the observer, and thus that the complete sequence must be scheduled as a single 'unit'.

Specifically not supported by the scientific mission planning software are:

- **Linked observations** in which, based on a previous observation having met a particular 'success criterion' a follow-up observation of this target is automatically scheduled. Rationale: Based on ISO experience it is not believed that a sufficient number of such observations will be requested that would make automatic support for such observations more cost efficient than manual scheduling of follow-up observations.

- **Periodic observations** in which, after an initial observation of a target, the same observation is automatically repeated at regular intervals. Rationale: Based on ISO experience it is not believed that a sufficient number of such observations will be requested that would make automatic support for such observations more cost efficient than manual scheduling of periodic observations.

- Automatic flagging for rescheduling of **failed observations**. Rationale: Based on ISO experience it is believed that the reasons why an observation can have failed are so numerous and complex that establishing the cause for the failure cannot, in many cases, be conclusively determined automatically and already requires manual interaction and visual inspection of possibly several data sets.

- **SSO observations** of the same (now 'blank') position in the sky where the SSO was when actually observed at a future epoch in a separate observation. Rationale: It is assumed that this can be covered procedurally by generating a separate, fixed-time observation to be carried out after the SSO observation (cf. comment about SSO observations above.)

5.4 Observation Execution

5.4.1 DTCP

By the start of a DTCP the satellite has been re-pointed (via commands contained in the on-board schedule) such that the high gain downlink antenna points towards Earth. The nominal sequence of interactions between the MOC and the S/C during this period is described in Section 5.6.

5.4.2 DHSS - Instrument Interaction

On-board, the command schedule is executed autonomously by the DHSS. At the times specified in this schedule, TCs are sent to the instruments in the form of TC source packets (i.e. stripped of onboard scheduling information) for immediate execution. This is performed in a 'fire and forget' fashion in the sense that the DHSS (i) does not wait for any packet acknowledgement from the instrument, and (ii) does not interpret any TC verification packets returned by the instruments. Although no handshaking takes place in the transfer of TC source packets from the DHSS to the instrument, the DHSS continuously monitors the instruments for failures by periodically (or when certain criteria are fulfilled (TBD)) sending an 'are you alive' command; if an instrument fails to respond to such a command, the DHSS will take some predefined action (e.g. switch the instrument off). Further information on instrument failures is contained in Section 5.10 below.

At all times instrument source TM packets are retrieved by the DHSS for storage in the SSR and for downlink during the DTCP.

5.4.3 Assumptions

The assumptions relevant in the context of on-board observation execution are:

1. All significant time blocks (idle periods, observations and slews) are considered 'observations' in that they (i) are separately schedulable, (ii) can generate science and/or house keeping data for all instruments and (iii) have their own, unique observation identifier (OBS_ID).
2. It shall be possible to unambiguously attribute any TM packet to an observation execution context (when relevant).
3. At times when one instrument is prime, the others may be observing in parallel, partner, or serendipity mode (cf. section 1.6), deliver only HK data, or no data at all.
4. The instruments always accept the TC packets sent to them by the DHSS.
5. Provided the instrument operates nominally, schedule generation during scientific mission planning will ensure that the command packets sent to an instrument will not overflow the instrument internal packet/command buffers.
6. No command sent to an instrument can endanger the health of the instrument regardless of the state of the instrument at the time the command is received (e.g. also during an 'observation' or when preceding commands are lost for any reason).
7. All science TM packets contain enough information required to process that particular bit of data on the ground (e.g. OBS_ID, relevant instrument parameters).
8. The reaction time in case of problems (from detection of the problem in available TM to having scheduled and/or manual TCs available to investigate or cure the problem) is typically of order 72 hours.
9. DHSS generated commands are formatted according to the ESA packet standard.
10. TC reception and execution verification information will be stored on-board for down-loading during the next DTCP.
11. If an instrument has to be switched on this is always done manually, i.e. under ground control during the DTCP.
12. When an instrument is found to be in a non-nominal state, it is either switched off or configured to safe mode by the DHSS (depending on details of instrument status). There will be **no** attempt to bring the instrument back on-line outside ground control.

5.5 Instrument Monitoring and Evaluation

Each ICC will monitor the health and performance of their instrument throughout Routine Phase. It does this by

(i) collecting instrument anomalies identified by the instrument itself, the DHSS, or reported by the MOC (cf. Section 5.10),
(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 on-board 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).

5.6 Spacecraft Monitoring and Evaluation

During each DTCP, the MOC will go through the following, nominal sequence of interactions with the spacecraft:

1. Acquisition of S/C in low TM rate
2. Confirm S/C attitude is as expected to start DTCP operations
3. Start telemetry transmission in low rate (scheduled on-board)
4. Start Ranging
5. Configure station and switch to high TM rate
6. Enable dump of events and stored HK
7. Enable RT science (if required)
8. Enable dump of stored science
9. Replenish on-board schedule to cover the next 48 hours
10. Terminate dump
11. Configure station and switch to low TM rate
12. Start Ranging
13. End of pass

The various on-board failure modes and corresponding recovery actions (on-board and/or ground; to be taken by MOC or ICCs) will be defined by the Prime Contractor during phase B. The ground segment related failure modes will be defined jointly between the MOC, the HSC and the ICCs, including identification of which GS parties are involved how in the recovery action. For each failure case a thorough analysis will be required, which is outside the scope of this document. The major failure modes are briefly listed in Section 5.10 as far as they can be identified at this early stage.

5.7 TM Delivery

5.7.1 On-board TM Generation Data Rate

Science TM (including instrument HK) is assumed to be generated at an average rate of 130 kbps, the S/C

HK will be in addition to this figure. The assumed allocations for the different on-board TM sources are as follows:

- S/C HK: 2 kbps,
- Instruments HK: 2 kbps,
- Science data: 128 kbps.

5.7.2 TM Mapping to Virtual Channels

TM will be allocated to different VCs (channel numbers are tentative, up to eight are in principle available) to allow easy separation of the data into:

- VC0: Live HK (HK data generated during DTCP), including events, TC verification, and memory dumps,
- VC1: Live science (science data generated during DTCP),
- VC2: Dump HK (HK data from SSR), including events, TC verification, and memory dumps,
- VC3: Dump science (science data from SSR),
- VC4-7: Not used.

5.7.3 Solid State Recorder Data Volume

SSR data storage is to be sized for 2 days of TM data, taking into account that **all** TM data will be recorded on-board (even if it had already been transmitted live during a DTCP) and assuming storage of TM data without any overhead.

5.7.4 Solid State Recorder and Download Data Organization

It is assumed that:

- The SSR can be organised in such a way that the event and TC verification packets can be dumped before the remaining HK data.

- The download of data from the SSR can be prioritised so that data of high interest (e.g. HK) can be dumped first.

- The DHSS is flexible enough to allow any combination of data to be downloaded during DTCP:
  Live HK only,
  Live HK + live Science,
  Live HK + SSR dump,
  Live HK + live Science + SSR dump.

5.7.5 DTCP Duration and Spacecraft to Ground Station Data Downlink Rate

If we assume that:

- TM download from the S/C to the ground station is associated with a 20% (TBC) overhead for both dump and live TM (132 kbps expanding to 0.57 Gbit/hour),

- 24 hours of stored data is downloaded during a single DTCP (11.4 Gbit expanding to 13.7 Gbit for SSR-recorded data due to transmission overhead),
- live and dump TM are downloaded at the same time,
- t_{DTCP} denotes the DTCP duration in hours,

we find the total data volume to be downloaded from the S/C to the ground station during DTCP to be

$$(13.7 + 0.57 * t_{DTCP}) / t_{DTCP} \qquad \text{[Gbit/hour]}$$

which requires a satellite to ground station bandwidth of about 2.1 Mbit/s, if 2 hours are to be used during the (nominally 3 hour) DTCP for the actual downlink, while about 2.8 hours would be necessary for the downlink if the rate would be 1.5 Mbit/s.

5.7.6 Ranging

In the absence of a specific study it is reasonable to assume that ranging will take place during a 5 min period at the beginning and another 5 min period at the end of each DTCP.

5.7.7 Data Transfer from Ground Station to MOC

The ground systems involved in this data transfer are the TMP at the ground station and the NCTRS at the MOC. The TMP will permit the selection of data in two modes: Real time and IDA protocol mode;

- The real time mode ensures that real time S/C data arrives at the MOC in real time. No recovery measures are made for data lost between TMP and MOC.
- The IDA protocol mode ensures the complete transmission of data from the ground station to the MOC. No recovery measures are taken for data lost between the S/C and the ground station.

Real time data has priority over IDA data. The selection of data from the TMP will be based on VC (note that idle frames will be discarded). Thus, for a pass in which data from all VCs will be transmitted, the scheme will be as follows:

1. Connect to the TMP for Live HK (VC 0)
2. Connect to the TMP for Live science (VC 1)
3. Connect to the TMP for IDA dump HK (VC 2)
4. Connect to the TMP for IDA dump science (VC 3)

The bandwidth calculation for the data transfer from the ground station to the MOC should take into account that it is not necessary to transfer 48 hours worth of satellite data (in case the previous DTCP has been missed) over a single physical line. The operational line can be assumed to be backed up so that the bandwidth of the nominal line can be sized for only 24 hours worth of satellite data and both the nominal and the backup line being used in case of having missed the previous DTCP. If the duration of the data transfer from the ground station to the MOC is assumed to be maximum 12 hours (TBC), a bandwidth of ~250 kbit/s between the ground station and the MOC appears sufficient, provided the additional data overhead added by the ground station (e.g. the addition of Earth Reception Time) is small.

5.7.8 TM Made Available by MOC

All telemetry (S/C and instrument) is archived at the MOC in the Data Distribution System (DDS) from which it is made accessible by the HSC through HCSS in the form of TM source packets. Thus, the DDS 'makes available' TM data, but does not 'distribute' data. TM are made available in the DDS by categories (events, HK, science), APID and time period in two modes:

- **Consolidated TM:** TM made available after consolidation. The consolidation process ensures that for a given period all TM correctly downloaded to the ground station are made available in a time ordered manner. Consolidated TM are made available on a time range basis (e.g. one OD). For a given period, events TM will be made available first, followed by the remaining HK TM, followed by science TM.

- **NRT TM:** TM made available almost as soon as received by MOC. As 'unconsolidated' data, NRT TM will appear in the DDS with a latency of approximately one minute after actual reception at the MOC, independent of whether it is live or dumped TM. NRT TM is made available on a TM packets basis.

5.7.9 Ancillary Data Made Available by the MOC

Satellite TM alone will not always be sufficient to fully exploit all Herschel data scientifically; e.g. satellite TM does not contain any orbital position and velocity information, which is e.g. required to accurately account for Doppler shifts in spectra. In other cases it might be very difficult for the average astronomer (or even the HSC/ICCs) to render certain kinds of TM into a format useful for further scientific analysis: although AOCS TM is available on the DDS as part of the S/C HK TM, it takes specialist knowledge to convert this TM into astronomically useful parameters such as RA and DE, and instrument orientation around this boresight as a function of time. The AOCS TM must be documented in such a way as to ensure that at any time during operation or post-operational phase it is possible to regenerate the astronomically useful information starting from the AOCS TM packets.

For this reason the MOC will make available additional, ancillary data on the DDS, including predicted and measured orbital data and a reconstructed attitude history.

5.7.10 Access to Data Stored on DDS by HSC and ICCs

HSC only makes use of consolidated TM and ancillary data which is retrieved from the DDS and ingested into HCSS for later retrieval by HSC, ICCs, and (possibly) general astronomical users (cf. Section 5.8). During routine phase, HSC is expected to retrieve consolidated data from MOC (for each type of TM and ancillary attitude information) on an OD basis.

Under nominal conditions during routine phase, ICCs only make use of consolidated TM data retrieved from HCSS (rather than directly accessing the DDS at the MOC). Consolidated TM for an OD is expected to be available from HCSS on the order of 20 minutes including consolidation by the MOC for HK TM (this includes the time for transfer of this data from MOC to the HSC, physical storage in HCSS and 'indexing' of this data for retrieval); for science TM the corresponding latency is on the order of 16 hours (to which another 16 hours has to be added at the MOC until science data has been consolidated in the

DDS for an OD).

5.7.11 Contingency Cases

In case of an instrument contingency, the corresponding ICC may need to access its instrument live TM data in NRT. This shall be possible in the ICC@MOC. Indeed, if a serious instrument anomaly is detected by the MOC that cannot be dealt with by SPACON using available CRPs, ICC presence at the MOC may be needed for an interactive session with the instrument during a DTCP.

Non consolidated live TM will not be available at the ICCs. However, from an ICC it should be possible to remotely log into the ICC@MOC to be able to support ICC personnel at MOC from the ICC during these sessions. SPACONs, however, are *not* expected to set up, man or maintain any of the ICC@MOC equipment.

5.8 Data Processing and Evaluation

The HSC will routinely query the DDS for new consolidated TM and ancillary data, retrieve these data, and ingest them into HCSS. The current assumption is that no significant conversion of consolidated TM will take place in this process, i.e. TM will be stored in HCSS in the form of source TM packets.

Scientific data processing will be carried out using interactive analysis (IA) packages developed by the ICCs. The IA packages will allow the astronomer who so wishes to start the data processing process from the TM packets stored in HCSS. This does not necessarily imply that the average astronomer will normally choose to start to work from data at this lowest level, because it does require detailed knowledge of the source packet structures and the use of tools that convert raw TM values to calibrated engineering parameters. The IA packages will include routines for transparently (to the astronomer) producing ‘higher level’ starting point(s) for further data reduction.

The IA packages will be available from HCSS and include the best instrument calibration knowledge available at the time; this knowledge is expected to evolve significantly especially during the early phases of the mission. Together with the provision of IA packages through HCSS, the HSC will also be responsible for providing the necessary support for data reduction to the community (cf. below, Section 5.9).

HSC will ensure that all observational data are systematically processed for quality control purposes. The processing will be done by running a set of IA and other dedicated modules in batch mode with appropriate parameters, and will require additional information, such as MOC operational logs, the TM event packets and the RTA logs. As a result of the evaluation, a quality flag will be assigned to each observation, which reflects (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, and (iv) whether the corresponding quick-look output is available. Although it is assumed that the quality flag will be assigned automatically for most observations, all science observations will be visually inspected by an operator, and it is expected that in some cases a deeper analysis by an instrument specialist may be required. 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 (or flags) assigned as ‘failed’ and it will be marked as such in the database. It will be considered for rescheduleding if appropiate.

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(s) from an observer’s point of view. The only assumption an observer can reasonably make in this respect is that the observation has been performed (i) with an instrument mode of operation (AOT) which had been validated, and (ii) with a set of calibration-related instrument parameters that were the best available at the time the observation was performed.

Bulk (re-)processing of all observations in the archive, with generation and storage of all products, will be carried out at during the post-operations phase by HSC for the consolidation of the Legacy archive as necessary.

5.9 Processed Data Delivery

The access to the data by the astronomical community will be done through HCSS, and it will be controlled following the Herschel data policy and in accordance with the data proprietary rights. The basic procedure is that no data will be automatically delivered, but the user will have to request the data. When requesting, the user can make certain choices. The archive interface will allow the user to make queries selecting on all parameters that characterize an observation (e.g. target name, target coordinates, instrument, instrument mode, observation id), and to browse and retrieve the selected data.

An astronomer requesting a certain observation for which he/she has authorized access will be provided with a choice of: (i) ‘raw’ data with quality flag information (cf. Section 5.8 for the qualification of ‘raw’ data in this context), including the quality flag information, (ii) related auxiliary data, (iii) quick-look output, in order to be able to browse the contents of the data, (iv) on-demand data processing capability, which may include both the generation of intermediate standard products to be used as input for the IA tools and the possibility to reduce the data by using the IA packages on-line. These intermediate products will not be permanently stored in the archive. Links to the original proposal and related publications will also be provided.

No mass storage physical media will be sent out, except for special high-volume data such as Serendipity data and surveys. Generally it is assumed that the astronomer will download his/her data.

The astronomer requesting data through the Herschel archive will have access to the necessary documentation for the correct interpretation and analysis of the data (e.g. Data User’s manuals, IA User’s manuals, ‘how to’ documents and recipes, documents on specific calibration issues). Helpdesk will support the archive user by answering questions by e-mail and telephone, and by making a Web page with the questions/answers database available. Further support to those astronomers who will require it, will be given by providing personal assistance on data reduction at the HSC. Other activities for astronomer support include the organization of open workshops and meetings focused on the reduction of certain types of data (e.g., spectra, maps, weak sources).

The access to the Herschel data by the instrument experts is assumed to be done through the general HCSS database query interface.

5.10 Contingencies and Recovery

In the absence of satellite contingencies, observations are carried out automatically (i.e. outside ground station contact and without ground intervention) under the control of the on-board mission timeline (MTL), which is loaded/updated from the ground during the DTCP. Several types of failure occurring on-board may cause this autonomous mode of operations to be abandoned. In addition, GS elements (ground station, MOC, HSC, ICCs) as well as the ground communication network or the space-to-ground link can fail in various modes that affect operations.

The various on-board failure modes and corresponding recovery actions (to be initiated on-board and/or on ground) will be defined by the Prime Contractor during phase B. The GS-related failure modes will be defined jointly between the MOC, the HSC and the ICCs. For each case a thorough analysis will be required, which is outside the scope of this document. The major failure modes are briefly listed here as far as they can be identified at this early stage:

5.10.1 Spacecraft Failure Modes

Survival mode: The S/C will enter ‘survival mode’

(i) automatically, if a major failure is detected by the on-board fault detection logic;
(ii) automatically, if a violation of attitude constraints is detected;
(iii) automatically, if no ground command has been received for a given, ground-programmable time;
(iv) if the ground has commanded the S/C into survival mode.

Upon entering survival mode, the S/C will configure itself and the three Herschel instruments into their respective ‘safe’ modes (possibly switch-off for the instruments) and will abandon execution of the MTL. The S/C will be able to maintain the survival mode for a least seven days without ground contact. The attitude constraints are satisfied while in survival mode. Exit from the survival mode will only be possible via ground command.

Other S/C anomalies: The on-board FDIR (Fault Detection, Isolation and Recovery) logic may detect other on-board failures whose criticality do not require entry into the survival mode, e.g. when switching to a healthy redundant unit is possible. Minor failures (e.g. out of limit conditions) may possibly be rectified by the spacecraft autonomously (e.g. through gain setting adjustment) without the need to switch to redundant units. Minor anomalies might not even require any specific actions apart from reporting their occurrence in telemetry.

In all cases failures and anomalies detected on-board are reported to the ground in the TM via specific ‘event’ packets. In addition, specific events not related to any error condition may also be reported via the ‘event’ packet mechanism (e.g. successful completion of an observation).

5.10.2 Instrument Failure Autonomous Detection and Recovery

It shall be ensured by design that no command is capable of harming the instruments. All commands will be checked by the DPUs for their validity, wrong commands will be rejected and an event packet will be sent to the DHSS (which, however, will not take any action other than storing it on the SSR; cf. Section 5.4.2). Missing commands might influence the data quality related to a particular observation, but should not harm the instruments nor affect the subsequent observation(s). At the end (TBC) of each observation the instruments will be commanded into a default state.

Two types of autonomy functions will be used to control the status and health of the instruments, the first level is handled by the DHSS:

- The DHSS will regularly check important instrument parameters like primary voltages and currents or temperature read-outs controlled by the spacecraft. In case of anomalies or failures, the DHSS will react according to predefined procedures and put the instrument either in a safe state or power it off. Event packets will be issued by the DHSS accordingly.

- The DHSS will regularly check if the DPUs of the instruments are alive. In case of an anomaly the DHSS will react according to predefined procedures, e.g. microprocessor reset (TBC) or power-off.

The second level of autonomy functions will be handled by the DPUs, which will regularly check important instrument parameters. In case of an anomaly they will take corrective actions according to predefined instrument on-board procedures, e.g. changing bias voltages, commanding the subunits into a safe state, or even requesting the DHSS to switch off the instrument. To request such DHSS action the DPUs will use event packets.

The DPUs will also verify the execution of commands or procedures by the instrument subunits, which communicate with the DPUs through event messages. In case of anomalies the DPUs will either take corrective actions themselves or ask the DHSS to switch off the instrument or put it into a safe mode.

Neither the DHSS nor the DPUs will initiate recovery actions in case of major instrument anomalies or power-off. Instead, agreed procedures for detailed failure analysis and recovery will be carried out from ground.

5.10.3 Ground Recovery from Spacecraft and Instrument Failure Modes

At the beginning of the DTCP the ‘event’ packets (S/C and instruments) are downloaded first to allow the ground to assess as quickly as possible spacecraft and instrument health, as well as the status of the operations which were executed outside ground coverage.

Three main types of activities can be carried out on ground depending on the nature of the failures/ anomalies detected (details are TBD):

- implement diagnostic procedures (spacecraft and/or instruments),

- implement corrective action through manual commands from MOC (recovery),

- replan and uplink new schedule (to minimise loss of science until the failure/anomaly has been analysed to a level that diagnostic or recovery action can be attempted).

For all the cases above, approved Contingency Recovery Procedures (CRPs) must be available.

5.10.4 Ground Station Node Failure

- Pass missed: Problems at the ground station or scheduling conflicts with other spacecraft having higher priority than Herschel may cause a pass to be missed (i.e. the DTCP to be cancelled). No data is in principle lost in this case since the Solid State Recorder (SSR) on-board the S/C is dimensioned to store 48 hours of data. Specific provisions would have have to be made in order to recover the data over the subsequent passes (cf. also Section 5.7.6). However, presently the MOC baseline is that such provisions are not the baseline. If more than one pass is missed, data will always be lost. It is likely that in this case (TBD) the ground will command the S/C into survival mode from another station.

- MOC failures: To be described in lower level documents.

- HSC failures: To be described in lower level documents.

- ICC failures: To be described in lower level documents.

All identifiable failure modes listed above must be covered by the corresponding approved Ground Segment Procedures.

5.10.5 Ground Communications Failures

- Ground station-to-MOC link failure: The TM downloaded from the S/C is recorded at the Ground station (nominally Perth). In case of a partial or total failure of the Perth-MOC link (and its back-up), and depending on the duration of the failure, the data recorded at the station will either be re-transmitted when the link is restored or a CD will be written and mailed to the MOC (TBC). It is also conceivable that the low volume TM (HK TM, which includes event and TC verification packets from the S/C and instruments) will be re-transmitted (or transmitted using public networks) while the complete TM is recorded on CD and mailed to the MOC.

- MOC-HSC link failure: To be covered in a MOC/HSC ‘Interface Control Document’ (ICD), which will cover MOC-to-HSC as well as HSC-to-MOC link failures. The ICD will also cover error cases which are not related to a link H/W failure (e.g. missing input, input in the wrong format, etc.)

- HSC-ICC link failure: To be covered in a separate document as above.

Because the MOC-HSC and HSC-ICC links might become operationally critical in contingency situations (not safety critical but critical to achieving the Herschel scientific objectives), suitable backup strategies for a failure of these links need to be investigated.

- HSC-Community, HSC-HOTAC, ICC-ICC@MOC link failures: For the communication between these parties standard internet connections will be used.

For all the failure modes listed above approved Ground Segment Procedures must be available.

5.10.6 Space-to-Ground Link Failure

Space-to-ground link errors may affect the communication between the spacecraft and the ground resulting in lost packets or incomplete packets being received at the ground station (the transmission of TM packets does not involve 'hand-shaking' with the ground). Since all TM generated on-board is stored in the SSR, these failures do not result in loss of data per se. In principle, packets lost in the space-to-ground link could be retrieved from the SSR and dumped during the subsequent pass. This is however a non-trivial operation in terms of planning and consolidation of the MOC Archive (the DDS). It is therefore not in the MOC baseline to recover such data.

5.11 Maintenance

5.11.1 On-board S/W Maintenance

In the event on-board software in an instrument needs to be changed to accommodate an instrument anomaly or for operational reasons, the ICC will be responsible for modifying the code, or on-board tables, as necessary, using the OBS maintenance facility provided by the ICC. 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 available to the ICC before being made available to the Ground Segment. An SPR/SCR will be raised at the time of the anomaly/change arising 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.

5.11.2 Ground Segment S/W Maintenance

Ground segment S/W maintenance will officially start with the S/W transfer phase, which ends with the successful completion of the last EE test. The MOC on one side and the HSC/ICCs on the other side will set-up separate S/W maintenance teams and environments, reflecting the separate way in which the GS S/W has been developed. At the time the GS S/W enters into maintenance, the MOC/HSC and MOC/ICCs S/W and data interfaces are expected to be generally stable, with two possible exceptions:

- Maintenance of the instrument and S/C databases, which are shared by MOC, ICCs and HSC, and which are very likely to change regularly during the early phases of the missions (commissioning and calibration/performance verification).

- Maintenance of the SCOS-2000 system, which is likely to be common to both the MOC and the ICCs.

The maintenance of these two entities is likely to require specific bodies with representatives from MOC, HSC and ICCs (TBD).

Concerning S/W maintenance at the MOC, it is expected that ESOC will make their standard provisions for maintaining Flight Control S/W; in this respect Herschel does not differ from any other ESOC-controlled satellite.

The HSC and ICCs are expected to share COTS products (e.g. DBMS), the HCSS data model, and a large amount of S/W, a significant fraction of which (time estimators, command generators, instrument simulators, IA) is developed by the ICCs but used by the HSC as well as the ICCs. As a consequence, it is expected that the maintenance of all S/W which is shared between the HSC and the ICCs (including S/W and data which may impact the quality of the science data taken by Herschel and the efficiency with which this science data can be obtained) is managed in a centralised fashion. This implies existence of:

- one joint Configuration Control Board (CCB), chaired by the HSCOM, with permanent members from the HSC and ICCs. Only this board has the authority to approve/refuse and plan changes to the HSC/ICCs system that may have an impact on Herschel science data.

- a centralised change control system accessible to all relevant parties.

- 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. These systems are expected to be COTS with little or no specific development.

This set-up is expected to be in place from some time prior to the S/W transfer phase until the end of the Herschel post operations phase.

6 OTHER MISSION PHASES

6.1 Instrument Level Tests

6.1.1 Test Objectives

The objective of the ILTs is to test the functional, environmental and scientific performance, including characterising the instrument, and establishing calibration parameters and procedures, of the various instrument models (with FPUs at LHe temperature). ILTs are carried out on PI premises.

6.1.2 Test Environment

The scheme of the EGSE given in Figure 4 below illustrates the functional elements of the uplink and downlink parts of the test set-up. The goal is to facilitate a smooth transition from one mission phase to the next, by being as compatible with further tests (IST, EE-tests) and in-orbit operations as possible.

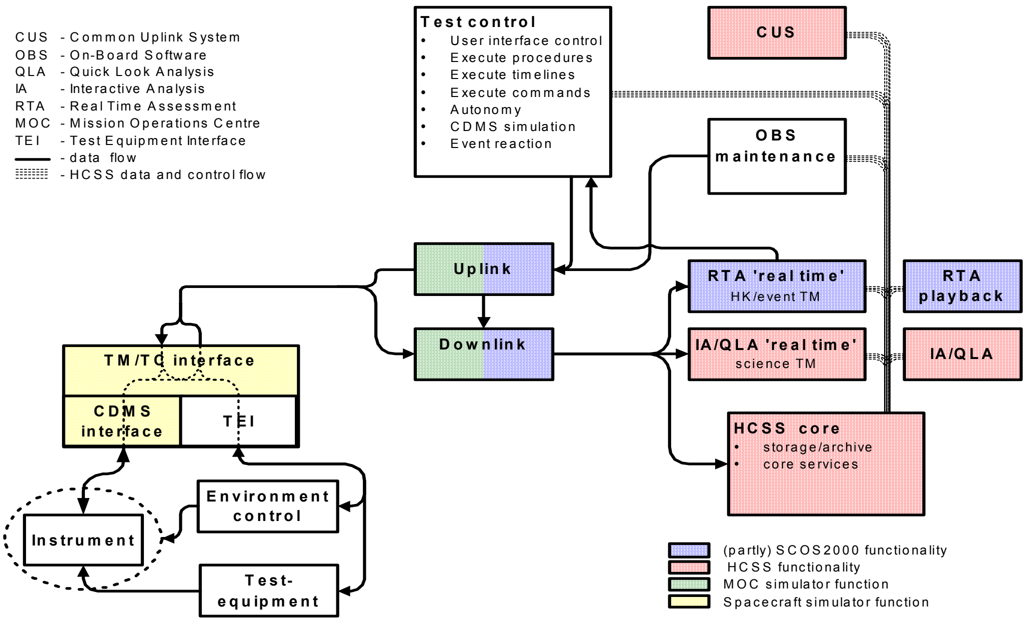

Figure 6.1 *Schematic indication of the different observatory functions required during ILTs.*

To deal with practical constraints like cryogenic hold times, external set-up limitations, and missing elements of the overall ground segment (HSC and MOC), some shortcomings of the ILT scenario with respect to the in-orbit environment have to be accepted. Missing elements will be simulated as far as possible.

The different functions identified in the above figure are expected to be relevant to the different tests and operational phases in the mission. This should help designing a system which can be carried across these different phases at minimal cost. In particular, the functions covered by CUS, OBSM, RTA, QLA, IA, and HCSS core are relevant to all test and operational phases.

The functions which are specific to ILT are:

The **Interface Unit** (consisting of the TM/TC and CDMS interfaces and the Test Equipment Interface) provides software/hardware interfaces to the instrument and the external test equipment required to stimulate the instrument during testing. It simulates (i) the telecommand and telemetry interfaces of the spacecraft data handling system (TM/TC Interface), (ii) the Spacecraft Power Distribution Unit (PDU) and (iii) the thermometry interfaces. PDU simulator, thermometry and external test equipment will be treated as subsystems of the spacecraft as far as commanding and telemetry are concerned; telecommands to these subsystems will be opened and acted upon by S/W in the Interface Unit. Telecommand packets addressed to the instrument will be passed directly to the instrument electronics for further processing.

Test Control provides facilities to (i) generate commands from both test procedures and via interactive user input, (ii) execute test procedures and (iii) control the entire test system. As Test Control can receive and needs to react to events signalled by RTA (e.g. out of limit conditions), it can also provide functionality of the CDMS with respect to instrument monitoring (cf. Section 5.4.2). Note that because of this active feedback loop between RTA and Test Control, instrument data need to be available to RTA with a delay of < 2 seconds during ILTs.

Uplink/Downlink (MOC simulator) provides the facility to translate commands and generate time tagged TC packets. It also generates consolidated TM packets from instrument or test equipment output.

The implementation of the interfaces to these functions are expected to simulate the interfaces in the final implementation of the operational system.

The functions contained in this diagram which are *not* specific to ILTs but need to be available throughout all phases of development and in-orbit operations are:

The **HCSS core** which includes the storage and archiving function of the HCSS and core services, i.e. services neded by several applications and across mission phases, e.g. configuration control, AOT instantiation, generation of command from instantiated AOTs.

The **Common Uplink System (CUS)**, which is used to define new AOTs.

The **On -board Software Maintenance** component, which provides facilities to (i) modify the instrument on-board software, (ii) generate binary images from code in a format suitable for the Uplink component.

The **RTA** and **IA/QLA** data analysis systems are used in different modes. RTA 'real-time' will be fed with data directly from the MOC simulator with a negligible delay and, as a result of the analysis of the HK data, will produce event logs and other reports. QLA 'real-time', is a subset of IA functions to display and characterise detector behaviour with a negligible delay. RTA playback and IA/QLA are only used off-line. For both RTA and QLA, the implementation of the 'real time' modes and off-line modes are expected to be essentially the same.

The acceptable delays between the time the data leave the instrument and the arrival at the different data analysis system are given in Table 1.

All of these permanent functions, which happen to be used in some (not necessarily final) form for the first time during ILTs, require the following common infrastructure (provided through HCSS):

- Permanent storage of all relevant data,
- Retrieval of data,
- S/W configuration control,
- Version control of data and code,
- Document management.

Location ILT	**Data**	**Delay**	**Driver**
Off-line	HK	~1 min.	At the ICC only off-line analysis is carried out on data taken during ILTs. Feedback for tests is given after analysis of complete data sets.
	Science	~1 min.	
Real-time	HK	<2 sec.	Personnel at the EGSE station need to interact directly with the instrument. Feedback is real time.

Ideally it should be possible to create links between these different database items (e.g. link documentation to test procedures and resulting calibration parameters).

6.1.3 Test Scenario

A simple test scenario could be described as follows:

Uplink: An AOT prepared with the CUS will be instantiated and corresponding sequence of commands will be generated by HCSS core from Test Control. Test Control will then translate instrument and TEI commands into time tagged command packets. These will be sent via the Uplink and the Interface Units to the instrument and test equipment. Test Control will control the execution of the test procedures and simulate the spacecraft autonomy functions in checking and reacting to event messages (e.g. out of limit conditions) generated by RTA 'real-time'.

Downlink: All specified types of telemetry packets generated by the instrument or test equipment will be transmitted by the interface and the uplink/downlink units to the different data analysis systems. Finally, all data (test procedures, data produced during the test, test reports and test logs) will be stored in HCSS.

6.2 System Level Tests

6.2.1 Test Objectives

The objectives of the Herschel Integrated System Tests (ISTs) are to (i) verify the functionality of the instruments (with FPUs at LHe temperature) and (ii) validate correct implementation of all interfaces between instruments and S/C on both sides. Following integration of the instruments into the satellite, ISTs provide as flight-representative an environment to the instruments as possible to validate (i) instrument general health, (ii) instrument performance and (iii) compatibility between instruments. As far as the test set-up and 1 g conditions allow, ISTs will cover all aspects of instrument operations, including instrument command execution and validation of engineering observations and astronomical observing modes (AOTs).

ISTs will be conducted on the satellite prime contractor's premises or at ESTEC.

6.2.2 Test Environment

The functional elements of the operational environment during ISTs are shown in Figure 4 below. Compared to ILTs the following differences apply:

The laboratory environment has been replaced by the S/C.
Test control and uplink/downlink functionalities are now covered by the satellite EGSE and as such fall under the responsibility of the prime contractor. The other IST functional elements are expected to be compatible with the ones of earlier (ILTs) and of later phases (SVTs, EE tests and in-orbit operations), which should lead to a similar (if not identical) design.

However, it is clear that due to missing S/C functions (e.g. attitude control) and missing ground segments elements (e.g. MOC), some shortcomings of the IST set-up with respect to the EE test or in-orbit environments have to be accepted; missing elements or functions will be simulated to the extent possible.

Note: The satellite EGSE will probably also contain RTA and archiving functionality. The link between the instrument RTA and test control, which is 'electronic' during ILTs, may be 'human interaction' between an ICC member manning instrument RTA and a test controller in charge of the EGSE during ISTs.

6.2.3 Test Scenario

A simple test scenario could be described as follows:

Uplink: It is expected that test procedures related to instrument commanding will be implemented as

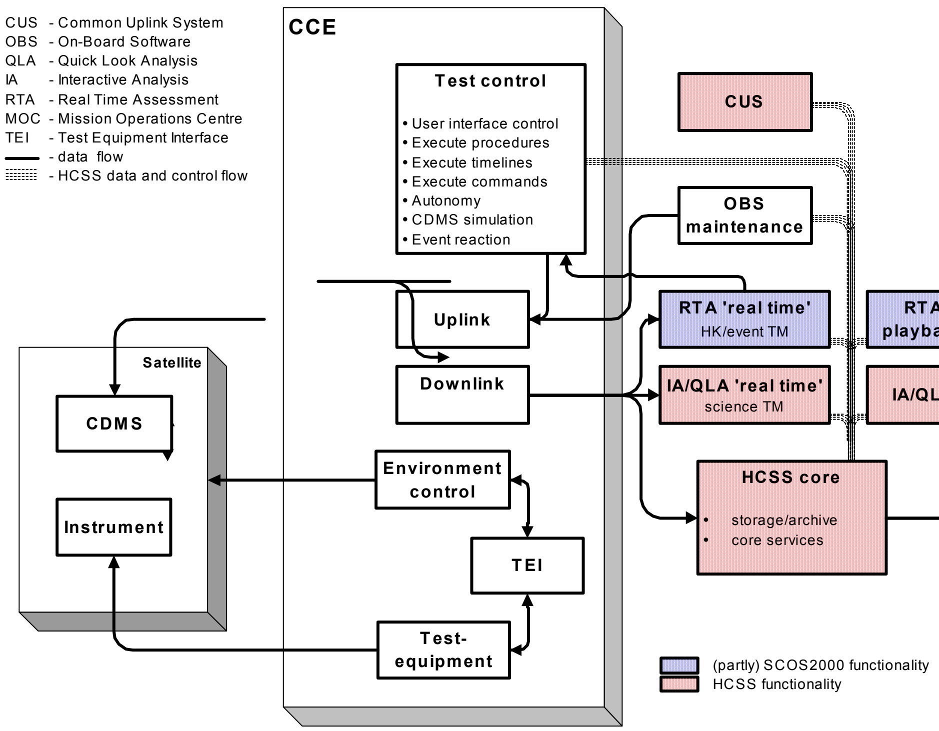

Figure 6.2 *Schematic indication of the different observatory functions required during ISTs.*

observation commanding compatible with the concept of observations as it is used in operations. Commanding of S/C and external test environment will be taken care of at EGSE level. With respect to the figure above, the CUS and HCSS core cover the generation of command sequences and the EGSE covers the generation of the corresponding instruments TCs and mission timeline. The execution of the commanding timeline will be supported by the CDMS on-board scheduling.

Downlink: All specified TM packets generated by the instruments will be transmitted to the EGSE for archiving, and subsequent ingestion into HCSS and analysis by RTA, QLA, and IA.

6.3 Ground Segment Tests

Following the ISTs a series of tests and simulations is carried out, which involve

- the MOC and the real S/C (SVTs),
- the MOC, the real S/C, and the HSC/ICCs (EE tests),
- different configurations of GS elements, during all of which the real S/C is replaced by a satellite simulator.

The overall purpose of these tests and simulations is to prepare all GS centres for in-flight operations individually and as an integrated whole.

6.3.1 System Validation Tests

As a minimum, two System Validation Tests (SVT-1 at L-9 months, and SVT-2 at L-3 months) are carried out in which the MOC is connected to and commanding the real satellite. The satellite is linked to the MOC by a representative part of a standard ESA ground station (the Network Data Interface Unit, NDIU), and to the EGSE.

6.3.1.1 Test Objectives

The purpose of these tests, each of which lasts ~2 weeks, is to validate the MOC Operational Data Base (ODB) contents and Flight Operations Procedures (FOPs) - which up to then have only been exercised against the S/C simulator - against the real spacecraft. These tests are **not** intended to, and **do not** address instrument scientific operability; indeed, SVTs are carried out without MOC to HSC data flow, and they only produce satellite HK data. In particular, the objectives are as follows:

- Validation of the capability of the MCS to correctly communicate with the spacecraft
- Validation of the data base for telemetry, telecommanding and on-board software maintenance
- Validation of MCS and FD processes
- Validation of spacecraft behaviour
- Validation of procedures
- Validation of the MOC spacecraft simulator as a representative test tool by comparison of the behaviour with respect to the 'real thing'
- Collection of data sets for use in further test campaigns

6.3.1.2 Test Environment

For these tests the overall ESOC ground segment is in a configuration that is as close as possible to the operational case, given the development status of the system. Thus, the first SVT may not include all the MOC elements, but ultimately the MOC should be complete at least in the critical areas for the final SVT.

The satellite will be fully integrated and located at either the satellite prime contractor premises or at ESTEC.

6.3.1.3 Test Scenario

SVTs do not involve the HSC or ICCs, except for the ICC@MOC. Test scenarios will be defined by the MOC as a matter of routine work with the aim of maximizing (i) the number of critical flight operations procedures and (ii) the number of commands in the database that are validated against the real S/C.

6.3.2 End-to-End Tests

The HSC and ICCs and their procedures are developed and tested using simulators, the same situation as for the MOC. The Herschel satellite itself is only rarely available to be connected to by equipment other than the spacecraft check-out equipment (SCOE) and instrument electrical check-out equipments (EGSEs). The opportunity of having the real satellite connected to the MOC during SVTs is taken advantage of to append a one-week End-to-End (EE) test to each of the two SVTs. These EEs involve the HSC and ICCs as well.

6.3.2.1 Test Objectives

Complementary to the immediately preceding SVT, the emphasis of an EE-test is on the scientific operability of the instruments and on validating - in as realistic an environment as possible - the I/Fs between the HSC and the MOC and between the ICCs and the HSC. Whereas SVTs mostly use manual commanding, EE-tests rely on and exercise satellite commanding through an automatically generated command schedule. In particular, the main objectives are:

- Validation of the overall ground and space segment behaviour and performance from end-to-end in its different operational configurations.
- Validation of the mission planning process and interfaces
- Validation of the data transfer processes and access mechanisms
- Validation of OBSM interfaces for payload elements
- Validation of the HSC and ICC@MOC capabilities to receive and process all appropriate data from the MOC
- Validation of the HSC and ICC processes and procedures

Except for the Ground Station and antenna, the EE-tests require all the elements of the ground segment interfacing with the MOC to be involved in the testing.

6.3.2.2 Test Environment

During EE tests the satellite is at the same location as during the preceding SVT. The MOC, the HSC, and the ICCs will be at their operational locations (TBC for the HSC location during EE-1).

6.3.2.3 Test Scenario

The test scenario consists of exercising routine mission phase activities for a number of ODs on a compressed time scale (with respect to the nominal planning cycle during routine operations). These activities include:

- Generation and delivery of a PSF from MOC to HSC
- Processing of the PSF into a planned observation schedule at the HSC and delivery to the MOC
- Conversion of the planned observation schedule to a command timeline at the MOC
- Uplink of this timeline to the real satellite
- Execution of this timeline by the real satellite, resulting in satellite TM
- Processing of this telemetry at the MOC, the HSC and ICCs using the operational interfaces and procedures.

6.3.3 Simulations

Simulations have the aim of (i) validating operational procedures and databases, (ii) training operators in nominal and contingency situations, (iii) completing GS system tests at higher levels of integration where several (sub)systems, their data and procedural I/Fs are exercised together. Depending on the roles of the different ground segment elements and the time remaining to launch, several types of simulations can be distinguished.

- MOC stand-alone simulations; these simulations are conducted with a spacecraft simulator that more or less realistically responds to telecommands and environmental effects in terms of producing the corresponding HK telemetry for all spacecraft subsystems and (at reduced fidelity) instruments. No realistic science data are generated during these tests; if such data are produced at all it is for the sole purpose of providing a realistic load of incoming telemetry on the system. Numerous such stand-alone simulations are conducted pre-launch, with the majority concentrating on critical mission phases such as the launch and early orbit phase (LEOP). Neither the HSC nor the ICCs play any role in these simulations.

- HSC stand-alone simulations; these simulations are conducted with a variant of the satellite simulator and a MOC simulator. The satellite simulator is operated in a mode which puts the emphasis on modelling the instrument HK and science telemetry as realistically as possible while the modelling of S/C HK data is rudimentary and limited to essential instrument/spacecraft I/Fs. These simulations bring together individual tests that have been carried out before by running the entire HSC system as one unit for a limited duration in time. It is envisaged that up to two such simulations of up to one week duration each will be conducted before any joint simulations with the MOC or the ICCs.

- ICC stand-alone simulations; these tests simulate the interactions with the HSC expected during the routine operations phase. These interactions take place through the ICC interfaces with HCSS, which is expected to be in place and operational well before these tests are conducted for delivery of telemetry data. Thus the tests will concentrate on the validation of the procedures to be used for delivery of software and data from the ICC to HSC and observation scheduling. ICC interaction with the MOC takes place through the ICC@MOC that was already used in the ISTs. It is expected that this system will be transferred to the MOC at the end of the IST and will therefore not require stand-alone testing.

- HSC/ICC combined simulations; these simulations are conducted with the variant of the spacecraft simulator used during HSC stand-alone simulations. They extend these stand-alone simulations in the sense that they exercise the HSC/ICC data and procedural interfaces.

- MOC/HSC/ICC combined simulations; these simulations are conducted as (i) dry runs for EE-tests, and (ii) to exercise the data and procedural I/Fs between all ground segment elements. It is envisaged to conduct two such simulations (plus another two as EE dry runs), each with a duration of ~1 week, prior to launch, mixing elements of the commissioning phase, of the calibration/performance verification phase and routine phase operations to a different degree.

6.4 Launch and Early Orbit Phase

Herschel will be launched together with Planck by an Ariane 5 into a transfer trajectory towards a large Lissajous orbit around the L2 point. The transfer time will be approximately 4 months, and in that time there will probably be 3 navigation manoeuvres, two close to the launch (L+2 days (40 ms^{-1}) and L+12 days (3 ms^{-1})), and the third close to the injection (Inj. - 10 days (3 ms^{-1})). The transfer is directly into the operational orbit.

The LEOP can be considered to last until the first two trajectory corrections have been made. During this phase the science payload will be off. Following the second navigation manoeuvre, the instruments will be switched on to start payload operations (Commissioning, Calibration/ Performance Verification, Science Demonstration Phases). Herschel should be fully ready to start Routine Phase operations by the time it enters the Lissajous orbit.

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 RT, unless the coverage does not permit this. Data will be stored on-board for the non-coverage periods, and there will be some time spent in the higher data rate modes to dump this data. An outline of the operations for this phase follows:

- establish the correct spacecraft configuration,
- determine the spacecraft attitude/ spin rate,
- correct attitude/spin rate if necessary,,
- determine the orbit
- determine the optimal attitude and magnitude of the trajectory correction manoeuvre
- execute the attitude slews to the firing attitude,
- refine the magnitude and timing of the burn,
- execute 1st trajectory correction,
- determine the orbit,
- determine the optimal attitude and magnitude of the fine trajectory correction manoeuvre,
- execute the attitude slews to the firing attitude,
- refine the magnitude and timing of the burn
- execute 2nd trajectory correction,
- determine the orbit,
- slew to the optimal attitude for the transfer (depends on operations and link budget),
- adjust spin rate,
- start transfer phase operations.

6.5 Commissioning Phase

Satellite commissioning is subdivided into spacecraft commissioning and instrument commissioning. The entire satellite Commissioning Phase is carried out under the responsibility of the Herschel/Planck Project.

6.5.1 Spacecraft Commissioning

A significant part of the spacecraft commissioning is already interleaved with LEOP. Prior to the first trajectory manoeuvre, basic properties of the satellite (centre of mass, moments of inertia) and proper functioning of basic spacecraft subsystems (RF, thermal control, power subsystem, data handling, attitude and orbit control, thrusters, SSR, etc.) will already have been established, at least to the extent these subsystems are required for spacecraft operations.

Spacecraft commissioning will be completed alongside instrument commissioning as and when required by the instrument commissioning plan. This includes verification of:

- Instrument/DHSS I/Fs,
- Additional AOCS modes required for instrument scientific operations,
- Instrument Focal Plane geometry,
- Instrument PDU and thermometry I/Fs,
- Direct instrument/AOCS interactions (‘peaking up’, TBC).

6.5.2 Instrument Commissioning

Note: The contents of this section need further thought/analysis and will remain TBD for some time.

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). In addition, the PACS instrument is likely to play a major role in pointing-related activities, not only to establish its own 'focal plane geometry' like the other instruments, but also to assist generic spacecraft activities like establishing telescope/startracker boresight.

6.5.2.1 Facilities

Real-time contact:

Real time activities will be necessary during this phase. They arise from two slightly different activities:

- During instrument checkout, execution of procedures will depend on decisions based on the analysis of procedures executed immediately before. 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. These activities imply the satellite should be in continuous (high speed, TBC) telemetry contact with the ground

- Pointing activities likely require targets incompatible with the satellite being in real-time contact with the ground (because of the pointing constraint in this mode). A repeated sequence of 'measurement - downlink - measurement - downlink etc.' might emerge, implying several pointings and ground contacts to speed up analysis and feedback loops.

Both types of activities are incompatible with a single short DTCP and require extended ground station contact and data transfer to MOC. Extended ground station coverage is likely to be required.

ICC@MOC:

Most activities will be conducted by ICC staff located at the MOC during this phase. This requires a working ICC software environment at MOC (the ICC@MOC) with:

- the possibility to prepare/modify test/calibration observations and command sequences off line.

- the possibility to run the instrument analysis environment, in particular its real-time RTA/QLA parts (instrument status display etc.). 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. Table 2 lists the amount of delay between receipt of telemetry at the MOC and availability for the ICC that is considered acceptable.

The 'instrument representative' at the MOC will be responsible for conducting the tests, and providing confirmation of their correct execution. It will not be necessary to be in contact with the ICC. Indeed, it is not expected that the 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 ICCs to allow monitoring of the tests by the 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.

Location	Data	Delay	Driver
ICC@MOC	HK	~20 min.	Only off-line analysis with little or no feedback to the tests.
	Science	~20 min.	
ICC@MOC		< 1 min.	Personnel at the instrument station need to monitor the instrument in real time. Similar (the same?) tests will be carried out as in IST, and thus time scale for data to arrive should be the same. Interaction with the instrument is done via the MOC spacecraft operators.

6.5.2.2 Activities

A set of procedures and ‘PCSs’ (fixed command sequences) are defined by the instrument groups and provided to the MOC before the tests begin.

The ‘instrument representative’ starts up the ICC@MOC system and configures it for the tests. This includes connecting to the real-time telemetry data.

The spacecraft controller will issue commands to the instrument (and spacecraft) according to the procedure(s) to be carried out. These may include points at which the spacecraft controller will wait for the 'instrument representative' to confirm that it is OK to start the next stage of the test.

The ‘instrument representative’ will monitor the execution of the test and confirm, when appropriate, the continuation of the test.

Some tests will require off-line analysis to confirm the correct completion of the test. This analysis may be made at the ICC@MOC or at the ICC dependant on the facilities, timescale and expertise required.

6.5.2.3 Contingencies

In the event that a test fails, or another problem arises, the ‘instrument representative’ may decide that the testing cannot continue, and request a termination of the test. The ‘instrument representative’ will notify the relevant ICC of the problem and the action taken.

The resolution of the problem and the recommended course of action to be taken will be decided by the instrument experts at the ICCs. However, it is not expected that these will be available outside normal working hours so the investigation of the problem will probably not start until the beginning of the next day. (The ICCs will be manned 7 days a week, normal office hours, during this phase.)

The final decision on how the overall commissioning plan proceeds in view of an instrument not being ready to continue the test as planned requires additional input from the Herschel/Planck Project, the HSC and the relevant ICC, and the MOC. The final decision will reside with the Flight Director (Project Manager).

6.6 Calibration and Performance Verification Phase

The Performance Verification (PV) phase is intended to obtain in-flight characterisation (and verification or otherwise with respect to ground characterisation) of all instruments e.g. in terms of stability, sensitivity, resolution, timing, and calibration parameter. 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 ICCs and the HSC. The plan contains a description of all planned calibration activities and associated calibration sources (internal and astronomical) required to fully characterise each instrument. It is important that the plan 'stretches' the phase-space of instrument capabilities in order to representatively cover the planned routine phase observation programme, in order to verify or generate new values for observation optimisation parameters.

During Cal/PV there is only limited ground contact but it can be assumed (TBC in further refinement of Cal/PV) to be somewhat relaxed against the stringent DTCP definition that applies during routine phase.

Possible changes in (near) future calibration observations are inserted into subsequent observing schedules. However, such changes are inserted only when detailed analysis shows that the pre-planned schedule is not suitable for further characterisation of the instrument. Schedule changes will be possible on a time scale of TBD days.

Data may be monitored by ICC personnel present at the MOC as these data arrive; most of the detailed analysis, in particular of the science data, is done offline at the ICC using IA facilities.

Table 3 below lists the amount of delay between receipt of telemetry at the MOC and availability for the ICC that is acceptable during the PV phase.

Location	Data	Delay	Driver
ICC@MOC	HK	~20 min.	Only off-line analysis with little or no feedback.
	Science	~20 min.	Only off-line analysis with feedback to the observing schedule on timescale of day(s).
ICC@MOC		< 1 min.	Only for monitoring of live TM, little or no feedback to operations expected.

6.7 Science Demonstration Phase

Building on the results obtained and knowledge gained in the PV phase in this phase the goals include (as alluded to in Section 3.5) pushing the observing capablities to the limits in certain parts of the observation capability phase space, to evaluate and optimise the observation strategies, and at producing early on in the mission science data that are especially suitable for use in public relations and science communications, cf. Section 8. Guided by data taken in the performance verification phase and the status of the data processing software, observations will be scheduled that are likely to produce results that will make an impact in an appropriate way, e.g. that are visually stunning or unique in an obvious way.

The observation programmes scheduled in this phase are foreseen to be primarily ‘real’ programmes, originally selected on the basis of their science objectives. However, in this phase the priority with which they are scheduled is not scientific merit alone, but their suitability for the purposes of this phase will be one of the decisive parameters. Observations dedicated for these purposes are also possible, as is the use of data taken during the performance verification phase e.g. in the case of public relations observations that provided striking or unexpected results. The data owners’ proprietary rights to the data themselves, and their use for scientific purposes remain in force.

From an operational point of view there could be restrictions (in addition to unavoidable scheduling restrictions) when choosing what observations can successfully be used in this phase due to the status of the various instrument observing modes and data reduction software. However, as described in Section 3.2 (specifically in Sections 3.2.2 and 3.2.3) there is a clearly stated objective that by the end of the PV phase these restrictions should be minor. This mission phase thus places requirements on the timely availability of selected observation and data reduction capabilities.

6.8 Post-Operations Phase

The Herschel post-operations phase consists (cf. Section 3.6.2 for the timeline) 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, also after the conclusion of this phase (i.e. in the historical archive phase).

The operations and ground segment of Herschel are designed to provide ‘seamless’ transitions between the various mission phases. For the post-operations phase this means that it should follow the routine operations phase smoothly. Indeed, many activities ‘normally’ associated with this phase will already be ongoing as part of the routine day-to-day activities in the preceeding phase. Specific to this phase is that all these activities will (have to) be concluded, and finally ‘wrapped up’ for posterity in the historical archive which will constitute the ultimate legacy of Herschel.

These tasks and activities include:

- finalisation of the understanding of the satellite and instruments' behaviour (including calibration and cross-calibration) in orbit
- continuing providing support to the astronomical community in using Herschel data during this entire phase by provision of not only of software and data products (interim archive), but also of expertise, information, and as a centre to visit for personal assistance

- preparing and making available the final processing algorithms and data products at various levels
- consolidating and finalising all documentation, manuals, and the like for all aspects of the mission and making these available
- providing a final archive of data, knowledge and software that will permit continued exploitation of Herschel by the astronomical community.

Note that the legacy archive interface will be adapted from the one existing during the Herschel operations, thus for the 'archive user' the difference in 'look and feel' will be insignificant. In the final transitional phase all documentation, software, data, and products will be 'frozen', and also the hardware configuration will be finalised. This includes performing a systematic data processing, using the 'final' data processing software, of all the Herschel data to create a uniform standard astronomical legacy product archive.

At the very end of the phase the HSC and ICCs cease to exist as such, the 'historical archive' being the final result of their combined effort, and indeed, constituting the legacy archive of the Herschel mission.

6.9 The Historical Archive

As already described, the historical archive 'phase' is actually outside the (funded) Herschel mission. This phase commences after the end of the post-operations phase. Through arrangements made in the transfer to this phase, the user will see no difference from earlier phases, except that from the beginning of this phase onwards no further developments of any kind, 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.

7 GROUND SEGMENT USERS

7.1 Astronomers

Members of the astronomical community (including members of various Herschel 'teams' in this role) will use the Herschel ground segment in a variety of ways throughout all phases of the project. Based on ISO experience, it is expected that Herschel will serve in excess of 1000 astronomers. The astronomers are the 'raison d'être' for Herschel.

The most general role that an astronomer will play as a ground segment user is that of enquirer. The ground segment will be the interface to Herschel as seen by the community. Astronomers will use the ground segment to obtain all information they require on the mission, including progress reports, status, news, statistics, descriptions of the facility, observing opportunities, PR events and stories, scientific results, publications lists, relevant conferences, etc. This role exists throughout all mission phases.

Astronomers will use the ground segment information to decide if Herschel is a suitable facility to carry out their science. If yes, they will then use information (instrument and spacecraft operating modes, lists of blocked observations, etc.) and tools (observing time calculators including what-if facilities, entry and editing tools, etc) to prepare and tune up observing time proposals. Acknowledgement of receipt of proposals will be given. This role exists from preparation of the guaranteed time proposals to the end of the final proposal cycle.

Once observing time has been allocated for a proposal, the astronomer becomes an observer. Observers expect to be able to adjust their observations as new information becomes available (revised sensitivities, updated observing modes, results from the initial Herschel observations of their programme, etc.). They expect to be able to track the scheduling status of their programme and to interact with the HSC as needed. They expect to have an easy interface for notification that their data are available. This role exists from preparation of the guaranteed time observations to the end of in-orbit operations.

An astronomer with Herschel data (either from his/her own programme or from the archive) becomes a data user. Data users expect to have a simple-to-use interface enabling them to browse, select, and retrieve data. They expect clear and complete structured documentation to all data products and all tools provided for data analysis. Sets of recipes and guidelines are very valuable. This role exists from launch to the historical archive phase.

7.2 General Public

The general public is also an important Herschel 'customer' with a legitimate right to information. Members of the general public will be offered access to this information through the Herschel ground segment

Herschel general information pages on the Web. These pages will contain information on the mission, its objectives, and achievements in a clear and concise way, in multiple languages. It will provide links to ESA, PI institutes, national agencies, etc. press releases and other sources of information directed towards non-astronomers, e.g. to schools and to the general public.

The emphasis will be put on Herschel discoveries, which will be presented making use of the latest multi-media capabilities. These Web pages should also contain additional sections addressing educational aspects (e.g. material for schools and planetariums, explanations to understand Herschel science in a more general astronomy context).

7.3 HSC Support Providers

The HSC provides support to a variety of Herschel users through support teams drawn from the Project Scientist Team.

7.3.1 Community Support – the ‘Helpdesk’

The HSC community support - the ‘helpdesk’ - is the main ‘human’ interface between the astronomical community and the mission. It is where any member of the community can address any question concerning the mission, spacecraft, instruments, operations, observations, data, scheduling, archive etc. The community should see the helpdesk as a single point of contact for queries and as a single point of replies to questions independently of the complexity of getting the answer compiled at the helpdesk side.

Helpdesk should have the knowledge to answer the question directly or the knowledge where to go to for an answer. Helpdesk should be consistent so that the same question gets always the same answer as long as the circumstances have not changed.

Throughout the mission lifetime, the emphasis of questions will focus on certain topics. Initially questions can be expected to focus on information related to scientific capabilities and performance, to be followed (in time) by issues related to proposal preparation and submission, then about scheduling, observing and proposal updating and later about data products and their quality. Therefore helpdesk should have a direct link at the appropriate time to the persons who can answer the bulk of the questions.

The turn around time and accuracy of information provided by the helpdesk will, to a large extent, determine the impression the astronomical community will have of the project and its staff. Clearly this has to be balanced with the available resources. However, there are always situations where an observer has an urgent question, and is necessary that the helpdesk can cope with this kind of cases.

Helpdesk will use the so-called helpdesk system, which will consist of a collection of software tools to support helpdesk activities. In particular the helpdesk system should be able to track the questions and answers so that one can always know the status of each query. It should provide access to the question/answer database (including an interface to the astronomer), and support the generation/maintenance of Web pages including FAQs. In addition, it should be possible to make statistics of helpdesk questions and answers. Generation and maintenance of mailing lists are also expected from the helpdesk system.

7.3.2 HOTAC Support

HSC will support HOTAC in the selection and grading of submitted proposals. For this purpose it will make use of the ground segment software (e.g., instrument simulators, visibility tool, astronomical tools, access to other observatories data) to provide HOTAC with technical reports on the technical feasibility of all successful proposals. It will also make use of the proposal/observations database to flag duplicated pointings, and to make statistical analysis of the proposal database (e.g. instrument usage, distribution of grades), also on HOTAC request.

7.3.3 General Public Support

ESA has an obligation to provide information specifically aimed for the general public. This task is under the responsibility of the ESA Science Communication service (which is **not** part of the Herschel ground segment), however, some support by the HSC is necessary to provide a good service.

HSC, supported by allocated Herschel science writer(s) provided by the ESA Science Communication service and other PR agencies, e.g. those of the PI consortia institutes and national agencies, will provide the necessary input, review material, support ‘events’, etc. as required to ensure that the general public is offered high quality information.

7.4 Proposal Handlers

The role of the proposal handler is to maintain the ‘proposal database’, and to provide required statistics etc. necessary e.g. for long term planning, HOTAC support, and other areas where it is deemed necessary. An important issue is to interface with the observers when instrument or other observational parameters change to make sure that required changes propagate into existing proposals.

7.5 Mission Planners

In the Herschel ground segment there are two types of mission planners; the MOC mission planners and the scientific (normally HSC) mission planners.

7.5.1 MOC Mission Planners

The role of the mission planner at the MOC is primarily to provide HSC with the input required to prepare scientific observation schedules in the form of the Planning Skeleton. After scientific scheduling by the HSC, the MOC mission planner validates the HSC-provided scientific observation schedules against all operational constraints (those contained in the Planning Skeleton and generic constraints imposed by the spacecraft, e.g. attitude, power consumption, TC and TM bandwidth, etc.). From the validated schedule the MOC mission planner subsequently produces a command schedule of time-keyed commands for on-board execution, to be uplinked by the spacecraft controller.

The process of producing and committing scientific observation schedules does require HSC/MOC interaction which needs to be elaborated in a corresponding interaction document and procedures.

7.5.2 HSC Scientific Mission Planners

The task of the scientific mission planner is to produce scientific observation schedules by filling the MOC provided planning skeleton with observations from the observation database. After appropriate authorisation these schedules are committed to the MOC. To perform the task the mission planner will use a number of tools (e.g. visibility checker, observing and slew time calculators, various constraint checkers etc.), to be able to select schedulable observations from the database. The scheduling process (irrespective of its degree of automation) has to attempt to optimise the schedule in terms of a 'figure of merit', as defined by the Project Scientist (PS).

On request of the PS, the HSC scientific schedulers will generate 'long range' plans of possible observation scenarios, based on the database of approved and as yet unscheduled observations and scheduling preferences provided by the PS.

7.5.3 Other Scientific Mission Planners

In the different development and operational phases of the mission the role of the scientific mission planner can be assumed by different users. In agreement with the responsibilities of the different entities that contribute to the Herschel Ground Segment (cf. Section 4), the following users can be expected to fill this role at one time or another: the HSC Mission Planning Team, the Project Scientist Team, ICC members, the Herschel/Planck Project Team (TBC) and the Ground Segment Integration and Test Team (it is expected that in terms of physical bodies this team will be composed of members of the above teams). Table 4 below indicates when which teams are expected to be taking a mission planning role in the various mission phases.

Whenever there is more than one tick mark in a given row in the above table, this suggests a potential clash arising from the fact that several users may be trying to play the same Scientific Mission Planner role for the same planning period. For planning periods of short duration (IST, EE-tests, commissioning) this is not considered to be a serious problem that can be overcome by co-location and proper coordination.

However, the situation is different for the lower three rows, which require access to the Scientific Mission Planning role for an extended period (from start of Cal/PV onward throughout the mission) and involving different sites. Suitable procedural provisions have to be put in place to avoid excessive coordination requirements across sites. One such provision could be to assign entire scheduling intervals, e.g. operational days, to different teams at different sites for scheduling purposes and provide a locking mechanism that prevents interference between different users trying to schedule science activities for the same or overlapping periods; another possible provision would be to make engineering and calibration observations deliverable items from the ICCs to the HSC with an appropriate ICC I/F to specify scheduling constraints (since it is expected that both fixed time and concatenated observations will be supported by the system, this I/F may already be in place).

	ICC	Herschel/PLANK Project	GS I&T Team	PS Team	HSC mission planners
ILT					
IST					

SVT/EE	4		4		
Launch preparations		4		4	
S/C and instrument commissioning	4	4			
Engineering observations	4				4
Calibration observations	4			4	4
GT/first-light, routine observations					4

7.6 Calibration and Instrument Experts

Members of the calibration and instrument teams will often use the Herschel ground segment in a way similar to what is described in Section 7.1 for astronomers in general. However, there are additional specific needs, which are detailed in this section. Based on ISO experience, it is expected that Herschel will serve some several tens of calibration and instrument experts.

The calibration and instrument experts must have efficient means for identifying and accessing the relevant data in the Herschel database in order to address specific questions, or in order to perform trend analysis. In addition to Herschel in-flight data the database will also contain Herschel data from pre-launch tests, astronomical data from other missions (e.g. ISO, SOFIA, SIRTF, Astro-F, etc) and specific astronomical data compiled expressly for calibration purposes. In addition, there must be easy access to all ancillary spacecraft and instrument data, and to the relevant documentation.

Similarly these experts must have an efficient mechanism to feed back their results into the Herschel ground segment. New calibration and instrument information has to flow back into the system. During operations calibration and instrument knowledge have to be fed back to pending observations so that the remaining programme is executed in an optimal way. Improved calibration and instrument knowledge has to be fed back to data products and documentation for the external astronomical community as well.

In the event of in-orbit problems with an instrument, the calibration and instrument experts will need timely access to the most recent data and will be developing specific diagnostic sequences for the satellite.

During the EE-tests and Simulations the calibration and instrument experts will test and exercise the Ground Segment. They will also participate in the launch campaign for which the standard facilities available at the Centre Spatial Guyannais (CSG) in Kourou as well as the EGSE (relocated to Kourou, and used during the AIV Programme) will be used.

A dedicated instrument monitoring and data analysis room (the ICC@MOC) will be available at ESOC for the instrument experts to support Commissioning phase, PV phase and contingency periods during routine phase. A dedicated machine running RTA, QLA and IA, which will be receiving near real-time telemetry (cf. Section 6) shall be available. A HCSS node to access documentation and data, and to insert newly derived data will also be required. It is assumed that the calibration and instrument experts at the

ICC@MOC will have the possibility of remote access to the machines located at ICC@MOC.

7.7 Quality Controllers

After retrieval of TM and auxiliary data for a particular OD, HSC will access the ground segment to gather all information related to the execution of each observation (see Section 5.8), and make sure that the corresponding data are processed through a predefined set of data analysis modules (IA and others) running in a batch mode with default parameters. This will allow to assess the quality of the observations in the terms defined in Section 5.8, and to assign the corresponding quality flag.

In case of observations with some related anomaly, it is expected that the final assessment of the causes of the problem, the declaration of 'failed observation' and the flagging for re-scheduling will generally require human intervention (HSC operators and/or instrument experts).

7.8 Database/Archive Managers

Has been put in as a place holder at this point.

7.9 Software Developers

Software developers are found in all groups comprising the ground segment. The software developers have the task to design, implement, test and maintain software modules used by ground segment users and/or the various ground segment data models. Most of the interactions of software developers with the Herschel ground segment will actually consist of using HCSS clients and/or developing HCSS components. A developer in particular needs:

- Access to S/W modules
- Access to documentation, e.g. all requirement and design documents, reports, manuals…
- Access to data, i.e. to the data definition (the data model) and the data itself (the objects)
- Access to HCSS (sub)systems, e.g. SPR system, configuration control system…

The developers therefore need access to a number of facilities, tools and/or data provided by HCSS, the details of which will depend on the type of developer and the type of action/task that the developer has to perform.

7.10 Project and Industry

Before launch the Herschel/Planck Project and Industry will become users of the ground segment (or subsets thereof) at various phases during the overall Herschel programme. They are not dedicated users but will use specific facilities as participants in the various activities leading to satellite Integration and Verification as well as overall Integration and Validation of the entire ground segment.

In the early phases (e.g. SVM Module level testing, PLM module level testing, Instrument Level Tests, Integrated System Tests, etc.) the H/W and S/W elements used by Project and Industry (e.g. Central

Check-out Equipment, Communication Equipment, Simulators, etc.) do not strictly speaking pertain to the ground segment as such. However the baseline concept of seamless transition between the various mission phases should lead to early validation of specific H/W and S/W ground segment elements (e.g. Test procedures, Instrument Stations, Simulators, Communication protocols, etc.).

In addition, pre-launch the Project is involved (with Industry support) in all mission preparation activities leading to the generation and formal approval of all Plans ('Mission Operations Plan', 'Flight Operations Plan' , etc.) and Procedures (Flight Control Procedures, Contingency Recovery Procedures, GS Operations Procedures, etc.) necessary to conduct the mission and operate S/C and ground segment. The Project Manager (or his representative) formally approves all Plans and Procedures

As participants in the SVTs, Project and Industry will be users of the MOC facilities. The Project will participate in the End-to-End Tests, which in addition to the MOC will exercise the HSC and the ICCs. For Herschel the EEs will immediately follow the SVTs (TBC). Industry participation in the EE Tests is normally not required.

Jointly with ESOC the Project will be involved in the Spacecraft-to-Ground Station(s) compatibility Tests which demonstrate that the network of ground stations (H/W and S/W) which will support Herschel from count-down to routine phase is compatible with the S/C design.

During the launch campaign Project and Industry will use the standard facilities available at the CSG in Kourou as well as the EGSE (relocated to Kourou) which was used during the AIV Programme.

The Project and Industry will, as participants in the overall Simulations Programme, exercise the entire ground segment.

During LEOP the Herschel Project Manager (as Mission Director) assumes overall responsibility for the mission. A subset of the Project Team coordinates Industry support to the LEOP (from the PSR). Industry support consists mainly in the monitoring of the major S/C subsystems (e.g. OBDH, AOCS, RF, etc.), support to the maneouver activities, and assistance in contingency/emergency situations. The instruments are switched-off during the LEOP. The HSC and ICCs will probably (TBC) receive the S/C TM in order to carry out final tuning of their Ground systems (listen-in mode). These activities will be coordinated by the Project.

The Project is responsible for the planning and execution of the Spacecraft Commissioning Phase. It produces the S/C Commissioning Plan (with inputs from ESOC and the PI Teams) and ensures that it is carried out as planned. During this phase HSC, ICC and Industry support is required. Overall coordination is ensured by the Project Team with the Herschel Project Manager assuming overall responsibility. At the End of the Commissioning phase the Project generates the End of Commissioning Phase Report. This includes Industry contribution and covers both S/C and ground segment.

After the successful conclusion of the satellite Commissioning phase, at a point in time TBD, the Project Scientist will assume the responsibilities of the Project Manager.

During the PV and Routine phases the Project only provides ad-hoc support to the mission. It receives the MOC, HSC and ICCs Operations and Anomaly Reports (covering S/C, Instruments and ground segment) and coordinates whatever support is required from Industry in response to the anomalies .

Post-Launch the Project is involved in all phases of the mission (therefore in the corresponding ground segment operations) with the exception of the Post Operations phase and Historical Archive phase.

A dedicated Project Support Room (PSR) will be available in the Main Control Room (MCR) at ESOC to support Project and Industry activities during the various phases of the mission during which they are GS users. There are no other specific facilities required by Project and/or Industry in addition to the PSR.

8 SCIENCE COMMUNICATIONS AND PUBLIC RELATIONS

HSC is a single-point interface for the astronomical community, the press and the general public to contact the Herschel observatory and to obtain both general information as well as more specific information regarding the status and scientific achievements of the mission.

Strictly speaking, the HSC is responsible for keeping the astronomical community informed, whereas the responsibility for providing the necessary input to the media and keeping the general public informed lies with the ESA Science Communication service (which is **not** part of the Herschel Science Centre or the Herschel ground segment).

HSC is therefore responsible for the communication of the Herschel science directly to the community, and to support the Science Communication service in its role. Examples of how this will done are through:

- Web pages, which will provide information for the astronomical community and (under auspices of the Science Communication service) the general public. They will contain the description of the mission, its status, achievements and main discoveries in a clear and direct way, where appropriate making use of multimedia capabilities. It will also include links to the Web pages of the instrument teams, and other relevant missions and sites. For the astronomical community, it will contain lists (and links, if possible) to Herschel publications in astronomical journals, and information on Herschel conferences and workshops. For non astronomers there should be material tailored for different groups such as for instance the general public, the interested layman, and schools.
- the preparation of a Herschel Newsletter
- the organisation of workshops on specific Herschel topics
- collaborating in the organisation of special Herschel sessions in scientific conferences (e.g. EAS, IAU, AAS, as well as topical conferences)
- the organisation (and/or supporting, cf. below) of press conferences
- (supporting) the preparation of material and, possibly, commissioned articles for amateur astronomer/interested layman magazines
- (supporting) the preparation of material and, possibly, commissioned articles for monthly and weekly magazines

In addition, HSC will provide support to Public Relations, which is not an HSC but an ESA responsibility.

For this purpose, the astronomers in the HSC will work in close collaboration with the Herschel science writer(s), who will be responsible for the preparation of ESA press releases and ESA information notes related to Herschel. The specific HSC Public Relations related tasks are:

- support to ESA communications events,
- support to press releases preparation (e.g. information notes or picture releases with captions)
- support in writing/polishing of Herschel materials to be distributed directly by ESA (e.g. brochures, posters, etc).

9 MANAGEMENT

THIS SECTION WILL BE REWRITTEN.