Herschel
FLIGHT OPERATIONS PLAN

VOLUME 1

Mission Management

PT-HMOC-OPS-FOP-6001-OPS-OAH

Issue 3.1

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European Space Agency
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ESOC

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CHANGE SUMMARY

Date	FOP Issue	Version	Modification Description	Author	SPR Ref
29/07/2008		1	Created	M. Schmidt	
04/08/2008		2	Initial version - not yet completed	M. Schmidt	
05/08/2008		3	Updated for Issue 1.0	mvoegele-hp	
05/08/2008	1.0	4	Added borders to CRS	mvoegele-hp	
02/02/2009	2.0	5	Updated change control history for Issue 2.0	mvoegele-hp	
06/03/2009	2.1	6	Updated change control history for Issue 2.1	mvoegele-hp	
26/03/2009		7	(no check-in comment)	M. Schmidt	
26/03/2009		8	(no check-in comment)	M. Schmidt	
26/03/2009	2.2	9	Updated change control history for Issue 2.2	mvoegele-hp	
23/04/2009	2.3	10	Updated change control history for Issue 2.3	mvoegele-hp	
06/05/2009	2.4	11	Updated change control history for Issue 2.4	mvoegele-hp	
07/10/2009		12	(no check-in comment)	dbleakle-hp	
07/10/2009		13	Updated Authorization page and distribution list; brought back version to updated version 2.4, reflecting now the Mission Rules, Reporting, etc as agreed prior to launch	M. Schmidt	
08/10/2009	2.5	14	Updated change control history for Issue 2.5	dbleakle-hp	
13/04/2010	3.0	15	Updated change control history for issue 3.0	mvoegele-hp	
06/09/2011	3.1	16	Updated change control history for issue 3.1	mvoegele-hp	

CHANGE RECORD SHEET

Change No.	Type of Change	Date of Issue	Section Affected
1	1.0	06/08/08	All
2	2.0	02/02/09	Volume 1 – Complete re-print for Issue 2.0 Volume 2, Volume 3, Volume 4, Volume 5, Volume 6, Volume 7 and Volume 8 complete re-print for Issue 2.0
3	2.1	06/03/09	Volume 1: Front Page, Distribution List, Change Summary and Change Record Sheet updated. Complete re-print for Issue 2.1 Volume 2, Volume 3, Volume 4, Volume 5, Volume 6, Volume 7 and Volume 8 complete re-print for Issue 2.1 New books added: Volume 4 HIFI FCP's, Volume 4 PACS FCP's and Volume 4 SPIRE FCP's
4	2.2	26/03/09	Volume 1: Complete re-print for Issue 2.2 Volume 2, Volume 3 Chapter 2 and 3, Volume 4 Chapter 2, Chapter 3.1 to 3.3, 3.5, 3.6, Volume 6 Chapter 2.1, 2.2, 2.3, 2.4, 2.6, 3.3, 3.4, 3.5, 3.6, Volume 7 Chapter 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 3.3, Volume 8
5	2.3	23/04/09	Volume 1 – Complete re-print for Issue 2.3 Volume 2, Volume 3, Volume 4, Volume 5, Volume 6, Volume 7 and Volume 8 complete re-print for Issue 2.3
6	2.4	06/05/09	Volume 1 – Front Page, Change Summary and Change Record Sheet replaced. Volume 3 Chapter 2, Volume 4 Chapter 2 and 3, Volume 6 Chapter 2.2, 2.3, 2.4, 2.5, 2.6, 3.4, Volume 7 Chapter 2.1, 2.2, 2.3, 2.4 2.5, 2.6
7	2.5	07/10/09	Volume 1: Complete re-print for Issue 2.5 Volume 3 Chapter 2, Volume 4 Chapter 2 and 3, Volume 6 Chapter 2.2, 2.3, 2.4, 2.5, 2.6, 3.3, 3.4, 3.5, Volume 7 Chapter 2.1, 2.2, 2.3, 2.4 2.5, 2.6, 3.5, 3.6, Volume 8.
8	3.0	13/04/10	Volume 1 – Complete re-print for Issue 3.0 Volume 2, Volume 3, Volume 4, Volume 5, Volume 6, Volume 7 and Volume 8 complete re-print for Issue 3.0
9	3.1	05/09/11	Volume 1 – Front Page, Change Summary and Change Record Sheet replaced. Volume 4 Chapter 3.5, 3.6, Volume 6 Chapter 2.2, 2.3, 2.4, 2.6, 3.4, 3.5, 3.6 Volume 7 Chapter 2.1, 2.2, 2.3, 2.4 2.5, 2.6, 3.4, 3.5, 3.6 Volume 8

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Applicable Documents

[AD-1] Herschel Planck Mission Implementation Plan, PT-MGT-MIP-1001-OPS-OA

[AD-2] Herschel Planck MOC Configuration Management Plan, PT-CMOC-MGT-PL-1203-OPS-CQ

Reference documents

The following documents, though not formally part of this document, amplify or clarify its content:

[RD-1] Herschel Planck Satellite User Manual, H-P-1-ASP-MA-0693

Chapter 1 Introduction to Herschel and Mission Overview

1.2 BACKGROUND AND MISSION OBJECTIVES

The Herschel Space Observatory is an observatory mission. It will perform photometry and spectroscopy in the far infrared and sub-millimetre part of the spectrum, covering the 60-670 µm band. Herschel is the only space facility dedicated to this wavelength range.
The Herschel science objectives target the “cold” universe. Black-bodies 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. The key science objectives emphasise specifically the formation of stars and galaxies, and the interrelation between the two.
Herschel will be launched together with Planck by Ariane 5 into a transfer orbit to a large Quasi-Halo orbit at the L2 point. The transfer time will be in the order of 50 days. The transfer is directly into the operational orbit, subject to a Trajectory Correction Manouevre to remove the launcher dispersion and the deterministic effects implied by other constraints of the launch window.
Science operations (in which commissioning and PV are included) can start during the transfer to L2. In order to achieve the higher data rates Herschel may have to orient the high gain antenna to the earth. There may be some freedom at the lower data rates to relax the pointing constraints for data transfer.
The routine phase, planned to last at least 3.5 yrs at L2, will be conducted with observations interspersed with periods of 3 hours Daily Telecommunication periods, during which the attitude of the spacecraft will be restricted.

1.3 SYSTEM OVERVIEW

TBW

1.4 MOC OVERVIEW

TBW

1.5 Ground Station Network

For the routine phase Herschel makes use of New Norcia (NNO) or Cebreros (CEB), with Kourou (KRU) retained as an emergency station.

For the early Herschel Operations Phases, in the nominal case, the following scenario applies:

- During the first two days of LEOP operations, Herschel will utilise the Ground Stations New Norcia (NNO), Kourou (KRU) and Cebreros (CEB) to maximise the ground station coverage for the Trajectory Correction Manoeuvre (TCM) preparation and conduct. Maspalomas (MAS) and Perth (PER) shall be available as back-up. All above ground stations need to be shared between Herschel and Planck.
- For day 3 to day 14 of the Mission Elapsed Time, Herschel will reduce ground station coverage to 10 hours per 24 hours, which shall be accommodated via the NNO ground station.

- As of day 14 until two month into the mission (to be confirmed, depending on the progress of the Commissioning activities), the ground station coverage will be reduced furthermore to 5 hours per 24 hours, using the NNO ground station.
- Towards the end of the Commissioning Phase Herschel will base operations on 3 hours ground station coverage, which is the same operations principle applied during the Routine Phase (i.e. 3 hours DTCP – Daily Telecommunication and Commanding Phase). This shall be accommodated via NNO [prime option] or CEB [back-up], depending on the utilisation of the ESA Deep Space network by other missions in nominal mission operations phase (Rosetta, Planck).

1.6 SATELLITE OVERVIEW

Please refer to [RD-1] (Spacecraft User Manual).

1.7 MISSION PHASES

The Herschel mission is composed of the following major phases:

- Pre-launch operations, which consist of monitoring launch site operations, initialize Ground Segment systems appropriately with the final spacecraft status prior to launch.
- LEOP phase, which starts at the first AOS following separation and ends with the completion of the first major transfer TCM – Trajectory Correction Manoeuvre. This phase includes the verification of the correct configuration of the CCU, switch-off of the SPIRE Launch Lock, the monitoring of the (passive) cool-down on the Cryogenic Cooling System, and the preparation and the execution of the TCM. During the LEOP phase all commanding to the S/C is done manually.
- Commissioning phase. Commissioning of the SVM and instruments. This phase follows LEOP. The commissioning phase extends past the opening of the Cyro Cover (at temperature around 120 K) until the operational temperature of the Cryogenic System is reached and instrument functionality has been verified. Already early in the Commissioning Phase the manual commanding activities are interleaved with Mission Planning driven commanding for early instrument activities. The Mission Planning driven activities will gradually increase in volume until the end of the Commissioning Phase when all activities are assumed to be planned via the Mission Planning process. The In-Orbit Commissioning Review – IOCR formalises the status of the Commissioning activities.
- Calibration and Performance Verification (CPV) phase. CPV phase follows commissioning and comprises the instrument calibration activities as outlined in the Herschel Performance Verification Plan.
- Routine phase.

The Herschel Spacecraft is “directly” injected onto a stable manifold of the target Quasi-Halo-Orbit around L2. As soon as Instrument Commissioning and Calibration and Performance Verification are completed, Herschel will start Routine Operations.

Chapter 2 FOP Structure

This section provides an overview of the complete FOP structure and contents, as currently foreseen. The following paragraphs summarise the contents:

2.1 Volume 1: Mission Management

Volume 1: Mission Management provides and overall introduction to the FOP, the HERSCHEL satellite, its mission and how this mission is to be conducted.

- **Chapter 1 Introduction to Herschel and Mission Overview:** Provides a summary of the HERSCHEL satellite design, the HERSCHEL mission objectives and the Flight Operations Segment. Also provides a summary of the mission profile.
- **Chapter 2 FOP Structure**: Provides a description of the structure and contents of the FOP
- **Chapter 3 Mission Rules**: Describes a set of rules governing the mission operations for HERSCHEL, covering both the spacecraft and the ground segment, for each of the mission phases, e.g. LEOP, Commissioning, Performance Validation and the Routine Operations Phase.
- **Chapter 4 Mission Operations Management**: Presents the organization, roles and responsibilities of the various parties involved in supporting the HERSCHEL flight operations for each mission phase.
- **Chapter 5 Reporting:** Defines the reporting of spacecraft and MOC ground segment operations. Covers both nominal and anomaly reporting.
- **Chapter 6 Configuration Management and Change Control:** Describes the procedures used to initiate, approve, implement and control any changes to the HERSCHEL Flight Operations Segment during operations.
- **Chapter 7 FOP Production and Validation:** Provides guidelines and rules for the production and validation of the FOP and, in particular, the procedures contained within the FOP.

2.2 Volume 2: Mission Phases

Volume 2: Contains an overview of the Mission Phases Operations and Timelines

- **Volume 2.01 LEOP Phase:** This chapter provides the LEOP timeline determining all operations for this mission phase.
- **Volume 2.02 Commissioning Phase:** This chapter provides a summary of the objectives of and operations to be performed within the HERSCHEL SVM and Instruments Commissioning Phase and a reference to the Commissioning Plan.
- **Volume 2.03 Performance Verification Phase:** This chapter provides a summary of the objectives of and operations to be performed within the HERSCHEL Instrument Performance Verification Phase and a reference to the Performance Verification Plan.
- **Volume 2.04 Routine Operations Phase:** This chapter provides a summary of the objectives of and operations to be performed during the Routine Operations Phase.

2.3 Volume 3: LEOP Related Nominal Flight Control Procedures

Volume 3 contains the LEOP Phase related SVM and Instrument Flight Control procedures.

2.4 Volume 4: COP Related Nominal Flight Control Procedures

Volume 4 contains the Commissioning Phase related SVM and Instrument Flight Control Procedures.

2.5 Volume 5: PVP Related Nominal Flight Control Procedures

Volume 5 is reserved for the Performance Verification Phase related SVM and Instrument Flight Control Procedures. Please note that none has been identified due to the fact that the PV Phase will be driven entirely by the Mission Planning Cycle, i.e. input from the Herschel Science Centre is solely received via Mission Planning Products, no dedicated manual procedures are foreseen to be run during the Performance Verification Phase.

2.6 Volume 6: FCP Related Nominal Flight Control Procedures

Volume 6 contains all nominal Flight Control Procedures, for SVM and Instruments operations.

2.7 Volume 7: CRP Related Nominal Flight Control Procedures

Volume 7 contains all Contingency Recovery Procedures, for SVM and Instruments operations.

2.8 Volume 8: Mission Support Procedures

Volume 8 contains the Mission Support Procedures, comprising Mission Planning Procedures, External Interface Procedures and Ground Specific Procedures.

2.9 FOP Table of Contents:

The summary of the previous sections can be seen in Table 2-1 below:

- FOP Herschel
  - Volume 1 Mission Management
    - Chapter 1 Introduction
    - Chapter 2 Misison Rules
    - Chapter 3 Mission Operations Management
    - Chapter 4 Configuration Management and Change Contro
    - Chapter 5 FOP Production Guidelines
    - text pages
  - Volume 2 Mission Phases
    - text pages
    - Volume 2.01 LEO Phase
    - Volume 2.02 Commissioning Phase
    - Volume 2.03 Performance Verification Phase
    - Volume 2.04 Routine Operations Phase
  - Volume 3 LEOP Related Nominal Flight Control Procedures
    - Chapter 1 Introduction
    - Chapter 2 Platform Flight Control Procedures
    - Chapter 3 Payload Flight Control Procedures
    - text pages
  - Volume 4 COP Related Nominal Flight Control Procedures
    - Chapter 1 Introduction
    - Chapter 2 Platform Flight Control Procedures
    - Chapter 3 Payload Flight Control Procedures
    - text pages
  - Volume 5 PVP Related Nominal Flight Control Procedures
    - Chapter 1 Introduction
    - Chapter 2 Platform Flight Control Procedures
    - Chapter 3 Payload Flight Control Procedures
    - text pages
  - Volume 6 FCP Related Nominal Flight Control Procedures
    - Chapter 1 Introduction
    - Chapter 2 Platform Flight Control Procedures
    - Chapter 3 Payload Flight Control Procedures
    - text pages
  - Volume 7 Contingency Flight Control Procedures
    - Chapter 1 Introduction
    - Chapter 2 Platform Flight Control Procedures
    - Chapter 3 Payload Flight Control Procedures
    - text pages
  - Volume 8 Mission Support Procedures

Table 2-1: FOP Table of Contents

Chapter 3 Mission Rules

3.1 Scope

The purpose of the mission rules is to define unambiguously the framework within with the mission operations will be conducted. They apply to both the ground and the space segment. They give the overall approach to nominal and contingency operations and define the generic and mission specific constraints applicable to the operations.

For contingency scenarios which might result from a combination of anomalies and are not covered by contingency procedures in the FOP, the Mission Rules give the guidelines for the preparation of appropriate timelines and procedures as required when the non-nominal situation occurs.

3.2 General Rules

Mission Rule 1 – Conduct of Operations

1. The overall responsibility for the HERSCHEL mission resides with the HERSCHEL Project Manager until end of phase E1, and with the Mission Manager for the remaining of the mission, both positions appointed by D/SRE. In the following paragraphs this overall responsibility is called Mission Director for simplicity reasons. The Mission Director nominates the Project Representative (Project Rep) who resides at ESOC during the LEOP, parts of the commissioning phase and other critical operations and leads the Project Support Team. The Project Rep has delegated authority and acts on behalf of the MD as concerns the remaining Mission Rules.
2. The responsibility for conducting all operations lies with the Flight Operations Director nominated by D/OPS during the LEOP, Commissioning and s/c emergency phases. For the routine phases of the mission the Spacecraft Operations Manager (SOM) assumes the responsibilities.
3. Procedures documented in the Network Operations Procedures (NOP) document provide all instructions and guidelines for the operations of the Ground Stations. These cover both nominal and contingency cases.
4. Procedures documented in the Flight Operations Plan provide all instructions and guidelines needed to conduct spacecraft flight operations. These cover both nominal and contingency cases.
5. No deviation from the FOP is allowed without the express permission of the Flight Operations Director, who shall seek the concurrence of the Mission Director.
6. In the event that conditions arise that are outside the scope of the FOP, the Mission Director, in collaboration with the Flight Operations Director, shall establish a contingency recovery plan. This plan shall be executed only with the express approval of the MD and OD.
7. For any non-nominal or failure case on board the satellite that is not covered by the FOP, it is the responsibility of the Mission Director (and his project support team) to provide the Flight Operations Director with a recommended course of action.

Explanation: *Standard ESOC approach to conduct of operations*

Mission Rule 2 – Mission Termination or Re-definition

1. The Mission will be declared terminated if the mission objectives cannot be achieved using the plans and facilities developed for the operations. Responsibility for declaring "Mission Termination" resides exclusively with the Mission Director.
2. If parts of the mission objectives can still be achieved it is the responsibility of the Mission Director, in collaboration with the Flight Operations Director and the Mission Control Team, to define a new mission, to specify any new facilities and procedures required to execute it and to arrange for their implementation.
3. From the above, a revised Flight Operations Plan shall be developed by the Mission Control Team that shall govern the operations of the new mission.

Explanation: *Standard ESOC approach to Mission Termination*

Mission Rule 3 – Spacecraft or MOC Emergency

1. In case the health and safety of the satellite is jeopardized the Flight Operations Director or SOM (depending on the mission phase) will declare a "Spacecraft or MOC Emergency". These situations include (but are not limited to):
   - critical SVM situations (loss of ACMS capabilities, CDMS or ACMS safe mode, critical power situation, etc),
   - reduced spacecraft capability to achieve ground contact,
   - loss of both ESTRACK Deep Space Stations (NNO, CEB)
   - loss of MOC at ESOC
2. Based on the type of emergency the OD or SOM will define additional ground station coverage requirements, requirements for additional facilities or manning in ESOC. For emergencies related to the Satellite the MD, in collaboration with OD and SOM, will define and provide requirements for additional ESTEC, industrial support and or Herschel Science Centre support (organizing support of the instrument teams if required). The OD or SOM will also provide an estimated duration for the S/C emergency.
3. The initiator of the request for Spacecraft Emergency (OD or SOM) will ensure that all support requirements are conveyed to H/OPS-O, H/OPS-G, H/OPS-E, the Mission Director, ESTRACK and the Scheduling Office.
4. SOM or his deputy (and in their absence the on-call engineer) shall inform H/OPS-O, H/OPS-OA, and mission management about the situation by phone or short e-mail, including the planned recovery actions.

Explanation*: Standard ESOC approach to emergency situations.*

Mission Rule 4 – Use of Redundant Spacecraft Units

1. No checkout of cold redundant spacecraft units will be performed unless checkout/use of the redundant unit is explicitly specified in this Flight Operations Plan for the Commissioning phase. Specifically no operations

involving FDIR level 3 or 4 reconfigurations (no ACMS or CDMS reconfiguration) shall be planned as part of the commissioning. Only redundant equipments that are not considered safety critical as per SUM FDIR definition shall be tested. At this moment, the commissioning of the following redundant units is planned:

- SAS
- CRS
- AAD
- STR
- Telecommunication Units
- TCS heaters
- All 4 gyro channels

1. A redundant unit can be used in accordance with the Contingency Recovery Procedures in this plan if the prime unit shows performance which is non-compliant with its operational requirements and affects the monitoring and control function of the satellite. If the switch to the redundant unit is ground initiated (i.e. no autonomous on-board FDIR reaction was triggered) then approval by an MRB/ARB is required.
2. Other reconfigurations to redundant units for e.g. science or performance issues need to be agreed by an ARB with all relevant parties involved, with final authorization by the Mission Director before execution.
3. The reconfiguration back to the nominal unit after a failure has been discarded or for investigation reasons needs to be agreed by an ARB with all relevant parties involved, with final authorization by the OD/SOM depending on the mission phase and the Mission Director.

Explanation: *the strategy against checkout of redundant units during the SVM commissioning phase in detail shall be followed as described in the Commissioning Plan.*

Mission Rule 5 – External Command Data

1. It is the responsibility of the Herschel Science Centre to ensure the correctness and completeness of the command data (either Mission Planning inputs or calibration results) provided to the MOC with respect to the planned operation.
2. It is the responsibility of the MOC to ensure that these telecommand data is scheduled either via the Mission Planning System or a procedure specified in this FOP and uplinked to the satellite at the appropriate time.
3. It is the responsibility of the Satellite Prime to ensure the correctness and completeness of the Memory Image data provided for any update of the onboard SW.

3.3 Orbit Acquisition and Control Related Rules

Mission Rule 6 – Non-nominal Injection/Delay of Trajectory Correction Manoeuvre

The reference document for this Mission Rule is GFA Working Paper No 537 "Herschel/Planck Mission Analysis: on Orbit Contingencies at Launch and in Early Orbit Phase"; PT-PMOC-MGT-TN-2717-OPS-GFA; issue 2.0; May 2009.

The rules for a non-nominal injection by the Ariane launcher or for a delay of the Trajectory Correction Manoeuvre can be summarized in the following table [Working Paper No 537; chapter 7]:

Injection apogee	**Herschel**
$r_a > 1000000$ km	Possible delay of first orbit correction up to day 7.
	If no execution up to day 7 stay in orbit and do parking orbit insertion at next perigee pass (one year delay).
$900000 \text{ km} < r_a < 1000000$ km	Assess first orbit correction: -cost < 100 m/s $\rightarrow$ execute nominal. -cost > 100 m/s $\rightarrow$ stay one revolution.
$700000 \text{ km} < r_a < 900000$ km	- Stay one revolution in eccentric orbit. - Perform perigee raising if needed. - Insertion manoeuvre in 2 arcs close to second perigee passage.
$600000 \text{ km} < r_a < 700000$ km	
$450000 \text{ km} < r_a < 600000$ km	Stay in eccentric orbit. Assess cost of insertion manoeuvre close to second perigee: - cost > 100 m/s $\rightarrow$ assess Moon resonant orbits.
$350000 \text{ km} < r_a < 450000$ km	Try to establish Moon resonant orbit for subsequent close Moon fly-by.

To summarize in words, the following can be concluded [Working Paper No 537; chapter 7]:

- For some contingency cases, namely nominal injection but failure to execute manoeuvre at day 2 or slight under-performance of the launcher, the nominal mission design can still be carried out utilising the propellant margins
- If in these cases the day 2 manoeuvre cannot be executed within 7 days for Herschel, the mission can only be recovered with one year delay.
- For other contingency cases, with low insertion apogee radii, a rather straight forward recovery strategy is possible. This recovery strategy implies remaining one revolution in orbit around the Earth and then performing the transfer injection manoeuvre close to perigee rather than on day 2.
- For both spacecraft this perigee manoeuvre has to be done in two parts, one before perigee and the other one after.

The problem of radiation damage and Earth infrared radiation at the perigee passes is to be adressed.

Mission Rule 7 - Abortion of Manoeuvres

No direct criterion for abortion of an on-going manoeuvre which would not be covered by the autonomous on-board FDIR was identified. No Telecommand Sequence shall be loaded in parallel to an on-going manoeuvre for an immediate abort.

For the Trajectory Correction Manoeuvres (TCM 1a and TCM 1b) Project will analyse trends and may inform the Spacecraft Operations Manager about any observation. Any abortion of an on-going manoeuvre shall be approved by Flight Operations Director.

Also a manoeuvre shall not be aborted in case on-ground contingencies (fire-alarm, MCS un-availability, etc).

Mission Rule 8 – Update of ACMS OBDB parameters related to manoeuvres

Depending on the expected thrust level determined through the remaining tank pressure, the on on-board torque matrix needs to be updated according to FQAR recommendations. This shall be achieved by splitting the overall size of the manoeuvre into adequate blocks, which allows update of the torque matrix in OCM, but without a manoeuvre on-going.

The Herschel LEOP timeline has been tailored for the case of splitting the Trajectory Correction Manoeuvre 1a into maximum two parts in case the size of the manoeuvre is greater than 30 m/s. This criterium (split if > 30 m/s) shall be applied strictly and forms the baseline for the Herschel Orbit planning.

3.4 LEOP Rules

Mission Rule 9 – Launch Hold Criteria

The following conditions are mandatory for the MOC to be declared ready for the Herschel/Planck launch:

1. **Voice contact with the Mission Director (DMS) at Kourou from H0-60 min onwards**. If this capability is not available then the DMS at Kourou shall request launch hold.
2. **TM & TC functions at OCC and at the LEOP ground stations Perth and New Norcia including data & voice links available**: The capability to receive, process and display satellite telemetry at the OCC, the capability to generate and transmit telecommands to the satellite from the OCC and at least a single voice link is available for the above ground stations.
3. **Ranging and Doppler functions available for Perth and New Norcia and available (or predicted to be available for LEOP) for at least two of three stations, i.e. Maspalomas, Cebreros and Kourou; auto-tracking function available in Perth**: The capability to auto-track the satellite in Perth and the ability to provide radiometric data to the ESOC Flight Dynamics System is available from the above ground stations. For Maspalomas, Cebreros and Kourou launch is permissible as long as no catastrophic failure has occurred, which would prevent availability of at least two of these stations for the critical LEOP activities, i.e. latest H0+6 hours for Maspalomas and Cebreros and latest H0+8 hours for Kourou.
4. **TM & TC functions at OCC and at the LEOP ground stations available (or predicted to be available for LEOP) for at least two of the three stations, i.e. Maspalomas, Cebreros and Kourou, including data & voice links**: The capability to receive, process and display satellite telemetry at the OCC, the capability to generate and transmit telecommands to the satellite from the OCC and at least a single voice link is available for the above ground stations. For Maspalomas, Cebreros and Kourou launch is permissible as long as no catastrophic failure has occurred, which would prevent availability of at least two of these stations for the critical LEOP activities, i.e. latest H0+6 hours for Maspalomas and Cebreros and latest H0+8 hours for Kourou.
5. **Flight Dynamics System at ESOC available**: The Flight Dynamics System at ESOC is able to process satellite trajectory measurements for orbit determination, to produce orbit predictions and antenna pointing information and to process near-real time telemetry and to generate AOCS commands required for LEOP (e.g. for emergency manoeuvres, etc).
6. **ESOC No-Break Power Supply is operational** as a back-up to the public power supply[1].

[1] Note if this requirement cannot be met then the Flight Operations Director and Mission Director at Kourou can decide jointly to waive it. This decision will take into account potential causes of public power supply interruption, such as the prevailing weather conditions over Darmstadt, on-going work close to public power supply lines, etc.

Explanation: These are the MOC facilities required to support critical contingency operations during LEOP. Voice link to Kourou is required to provide MOC launch readiness status and DMS H0 report. The station network has been selected to ensure the minimum TM,TC and tracking capabilities required in support of this complex two satellite LEOP scenario.
The launch hold conditions above are common conditions for H and P.

Mission Rule 10 – Attitude anomaly during AOS

In case an attitude anomaly has occurred prior to AOS, though the ACMS related separation straps are as expected, i.e

a. separation straps 3 and 4 = SEPARATED
b. ACMS in SAM
c. Attitude outside the allowed solar constraints

then as a last resort a ACMS PM reset as per steps 2.2 of procedure H_CRP_SYS_PATA (system procedure, to cover also AIR flagged to CDMS) shall be applied.

Note that this is a fundamental failure case, which in principle leads to “end-of-mission”. In case the ACMS PM reset recovers the S/C attitude, an overall system and CCU assessment will determine the impact on the mission.

For a failure case when the ACMS related separation straps (straps 3 and 4) are not set correctly, please refer to Mission Rule 9.

Mission Rule 11 – No Separation Detected

The failure of separation not being properly detected by the S/C due to wrong reading of the separation straps is covered in the Herschel LEOP timeline via procedure H_CRP_SYS_CSEP called immediately after expected AOS.

Procedure H_CRP_SYS_CSEP covers both, the CDMS related separation straps 1 and 2 and the ACMS related separation straps 3 and 4:

d. Separation straps 1 and 2 = NOT SEPERATED
e. CDMS mode = Launch Mode

and

f. separation straps 3 and 4 = NOT SEPARATED
g. ACMS in SM

and overwrites the separations straps by manual commanding.

Though the failure to detect separation for the ACMS may lead to an anomalous attitude with mission critical consequences as described in Mission Rule 8, due to stable attitude after physical separation gives good chances to recover the attitude without major impact on the thermal behaviour, and therefore with potentially minimal impact on the mission.

Mission Rule 12 – continuation on redundant units

In LEOP and Routine phase it is acceptable to attempt to continue the mission on a B-unit, before the A-side problem/failure is fully analyzed and before the possibility of roll-back-to-A is assessed. The rationale for this is

- In LEOP, the need to complete the time critical activities
- In Routine phase, continuity of science

[The same approach may be acceptable also in Comm. But here the rationale is less clear – the problem would need to be addressed at Comm. Review, and the commissioning phase offers enhanced support to assess the problem and to implement roll-back if possible]

This continuation-on-B approach is allowable, providing

- exposure to a common failure, and
- damage caused by the way the unit was driven

can both be excluded.

Following the stabilization on B, a decision needs to be made about whether to allow onboard FDIR to reconfigure back to the A-unit in contingency. As an immediate measure in order to increase resilience to further spurious failures/events, reconfiguration by FDIR to the currently working configuration shall be considered. In general terms, if the unit is FAILED, such reconfiguration will be disallowed; whereas if it is DEGRADED or SUSPECT then such reconfiguration will normally be allowable, depending on the severity of the degradation, and the assumed likelihood of false FDIR trigger taking the SC to the A-unit.

Some examples to help clarify the above text

1. CDMU acquisitions failures traced to HW failure within CDMU data acquisition board. Continuation of the mission on PM-B is allowed, there is no exposure of the PM-B to the failed acquisition units. Since CDMU-A is only DEGRADED it is a legitimate candidate for FDIR reconfiguration.
2. DoD. Before continuation-on-B is allowed, common elements (e.g. Battery, instruments etc.) must be excluded as the cause. Otherwise restarting the mission threatens to cause another DoD. Reconfiguration options are restricted until the cause is determined.

Mission Rule 13 – RFDN operations

Whilst the CDMU is in **AFS**, RFDN configuration changes resulting in a change to the transponder in-use (TM+TC) path shall be protected by

1. loading a “protection TC” into the MTL approx 60 minutes into the future, to return the RFDN to it’s current configuration
2. executing the RFDN configuration change
3. deleting the protection TC

[RFDN switches in AFS risk to have an RF switch left in a neutral position. This is protected by the 60-hour-TC-timeout onboard FDIR, but in early mission phases 60 hours outage may be unacceptable].

It does include

- the LEOP switch BBBB->BBAB (configuring MGA to Tx2 for redundancy)
- the switch from LGA1-prime to MGA-prime that will occur in commissioning (typically in transfer after (i) the off-axis angle of the earth wrt to the +z axis in permanently inside ~15 deg and (ii) all ACMS related commissioning activities not compliant with the MGA constraints are completed)
- a potential switch back to configure the LGA1-prime, if need arises during the commissioning activities (for instance LGA nominal selection for ACMS PTG check, currently done after the dedicated TTC commissioning activities have started).
- the entry to NOM from SAM (assuming the NOM RFDN config is not yet in place)
- potentially any other TTC changes made in Comm. for calibration or to support out-of-MGA pointings prior to the setting of AFO

3.5 Commissioning Phase Rules

Mission Rule 14 - Mission Planning Turn-around times in Commissioning Phase

The Mission Planning System, involving Mission Planning tools on Herschel Science Centre level, MOC Flight Dynamics Mission Planning level and MOC Flight Control Team Mission Planning level, will be in use already very early in the Commissioning Phase (MTL active for a reduced number of hours already as of day 12).

The Mission Timeline driven activities will gradually increase in time per 24 hours, until a point in time, still during the Commissioning Phase, all instrument activities will be fully driven by the Mission Planning Process.

In principle the same turn-around times as during Routine Phase operations apply for the Mission Planning Cycle within Commissioning (see Mission Rule 13). Nevertheless, ESOC accepted shorter turn-around times for Mission Planning activities, i.e. later reception of POS (Planned Observation Sequence) files from the Herschel Science Centre due to the following facts:

- during Commissioning Phase increased Mission Planning Support within the MOC is available (not only office times)
- there is the need to wait for outcome of Instrument Commissioning Activities before being able to proceed with subsequent Instrument Commissioning Activities.

In exceptional cases, when specifically requested and highlighted as such in the Commissioning Plan, the short turn-around times (<24 hours) may lead to a situation when only 24 hours worth of Mission Timeline may be stored on-board when going into LOS (typically MOC is required to ensure 48 hours of Mission Timeline to be loaded prior to LOS). The Herschel Science Centre and Project is aware of the risk involved in this approach (missed DTCP may lead to 24 hours of idle time, since no active MTL is on-board) and have accepted this.

3.6 Routine Phase Rules

Mission Rule 15 - Mission Planning Turn-around times in Routine Operations Phase

The Mission Planning Cycle and it's interactions between the various parties involved is described in the MOC compiled "Herschel Mission Planning Concept" TN; PT-HMOC-OPS-TN-6601-OPS-OGH; issue 2.2 and the "SGS-MOC Interactions Document"; HERSCHEL-HSC-DOC-0939; draft 0.9.

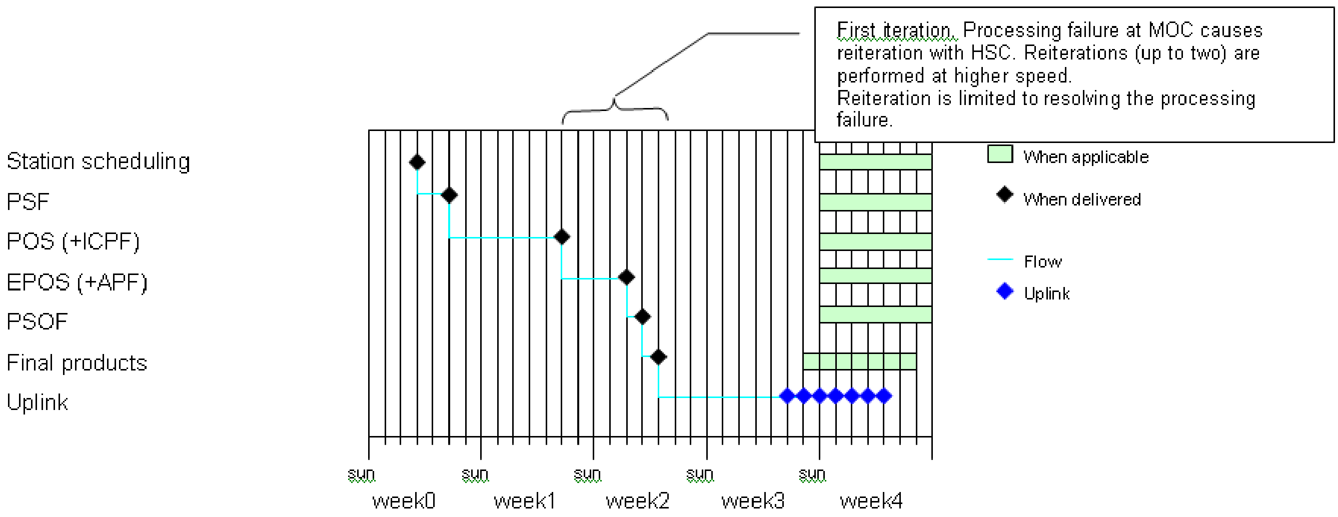
MOC generates Orbit Event Files (long term and short term) and Planned Skeleton Files (PSF) which are routed to the Herschel Science Centre for Planned Observation Sequence (POS) generation.

The POS files will be sent back to ESOC, Flight Dynamics to allow the generation of Enhances Planned Observation Files (EPOS) to be routed to the Flight Control Team for generation of Mission Timeline Uplink Units.

Herschel mission planning may therefore be regarded as occurring in 3 phases:

Phase	Involving	Cycle rate	Completed
1	Station scheduling and production of PSF	Weekly	15 working days prior to uplink
2	Production of POS	Weekly	10 working days prior to uplink
3	Production of final products	Weekly	6 working days prior to uplink, nominal

The timing for product deliveries shall be as follows:



3.7 Contingency Operations Rules

Mission Rule 16 – Handling of Contingency Situations

1. Contingency Operations shall be performed as per Volume 7 of the Herschel Flight Operations Plan.
2. Recovery operations which are not time critical and are performed for the first time in-orbit shall be exercised on the simulator before uplink to the satellite.
3. Any anomaly or contingency situation shall be reported via the Instrument Malfunctions or Operations Problems interface as per chapter 2.1.2.1 of the Consolidated MOC/SGS ICD list [PT-CMOC-OPS-ICD-6101-OPS-OGH; issue 3.2; July 2008]

Chapter 4 Mission Operations Management

4.1 Responsibilities

During critical mission phases (LEOP, Trajectory Correction Manoeuvres [TCM], Early Commissioning phase, S/C emergencies) the responsibility of managing the space and flight operations segment rests with the Herschel/Planck Flight Operations Director. For Herschel operations, he is assisted by the Herschel Spacecraft Operations Manager, the Ground Operations Manager, the Herschel Flight Dynamics Co-ordinator, the Herschel/Planck Project Representative and their support teams.

The Herschel Mission Control Team is composed of the following personnel, located at the Flight Operations Control Centre in ESOC:

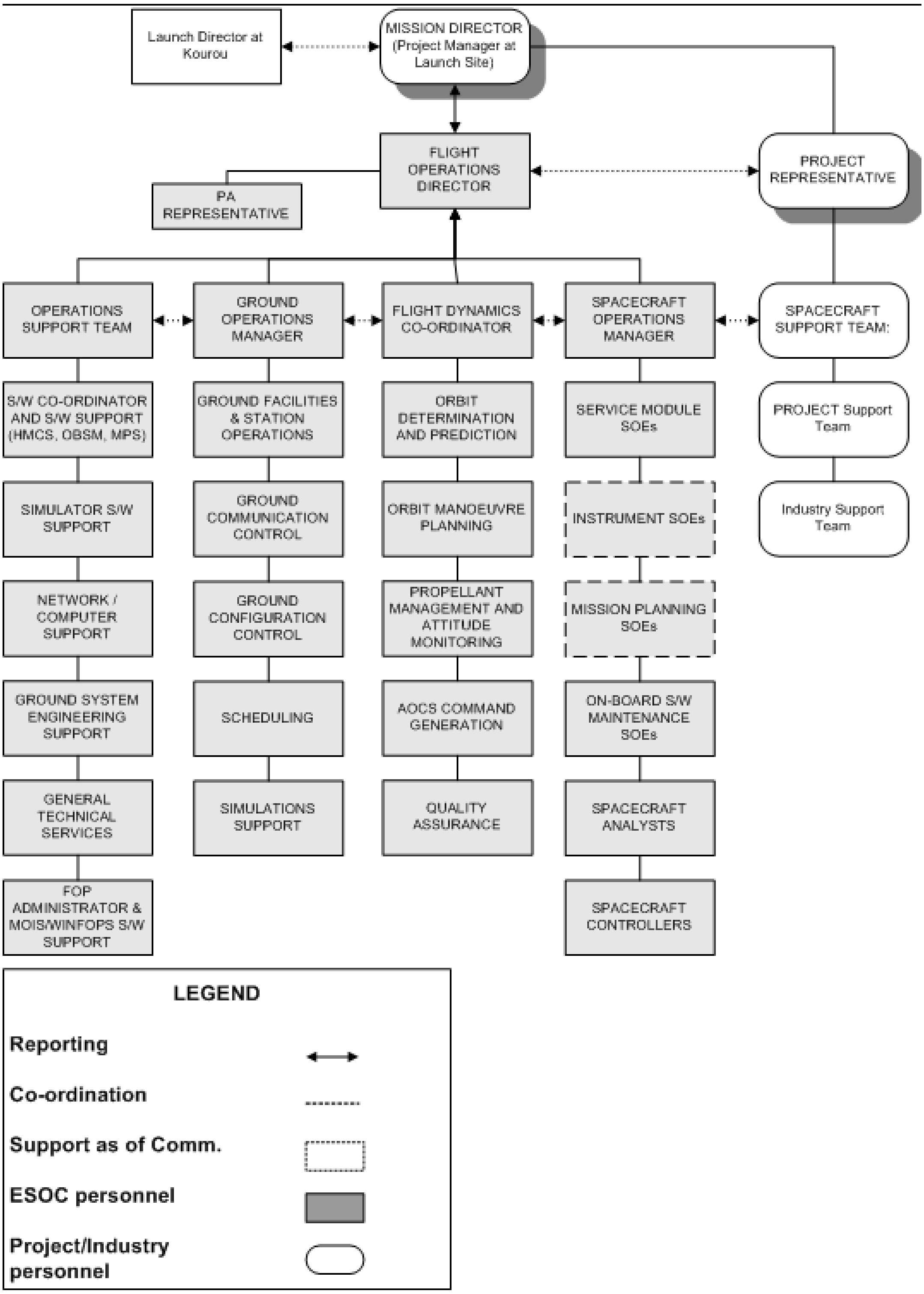
Position	Call Sign (if applicable)	Comment
Flight Operations Director	OD	Responsible for Herschel Mission operations during all critical phases.
Herschel Spacecraft Operations Manager	SOM	
Spacecraft Operations Engineers	CDMS ACMS EPS/TTC/TCS /CCU OBSM	Responsible for one or several subsystems or aspects of the spacecraft and/or ground system.
Spacecraft analysts		Responsible for the Operational Database and for the SPACON team (S/C analyst).
Spacecraft Controllers	SPACON	Responsible for day-to-day monitoring and control of the satellite; interacting with the spacecraft operations engineers during the critical phases (LEOP, Commissioning Phase)
Ground Operations Manager	OM	Responsible for the operations of ground stations and communications.
Ground Configuration Controllers	NETWORK	
Ground Communications Controllers	COMMS	
Software Co-ordinator	SOFTWARE	Leads HMCS S/W support team.
Software Support Engineers	SOFTWARE SUPPORT	
Flight Dynamics Co-ordinator	FLIGHT DYNAMICS	Leads the Flight Dynamics Team.
Flight Dynamics Engineers		
PA Representative		Responsible for al PA aspects, in particular Observation and Anomaly Reporting, Organisation of Anomaly Review Boards (ARB), etc
Project Representative	PROJECT REP	Represents and acts on behalf of the Mission Director at ESOC during critical mission phases. He leads the Project support team.
Project Support Engineers	PROJECT SUPPORT	

The full Mission Control Team is responsible for conducting all mission operations for the duration of the critical mission phases: LEOP, the early Commissioning Phase (while driven by manual commanding activities), S/C emergencies and End of Mission.

During the first two days of the LEOP phase, the full Mission Control Team will operate with 2 teams (A and B) and in 2*13 hour shifts (for exact team hand-over times refer to the LEOP timeline as per Vol.2 of the H FOP).
During the later LEOP phase and the early Commissioning Phase (i.e. from day 3 to day 14), operations will be run in one 12 hour shift, comprising members of the A-Team and the B-Team, depending on the actual support required. The 12 hour shift ideally shall be accommodated using the NNO physical visibility period, which allows the work to be done during day time (Darmstadt local time).
After day 14, Commissioning activities continue with DTCPs [Daily Telecomunication and Commanding Phases] of 5hours per day, to be accommodated during NNO ground station coverage.
During Routine Phase, the SPACON team will perform the day-to-day monitoring and commanding during the DTCP [Daily Telecomunication and Commanding Phase]. The DTCP will be 3 hours per day. Depending on the ground station availability, the DTCPs shall be accommodated on NNO [prime option] or CEB [back-up].

After IOCR (In-Orbit Commissioning Review) at end of phase E1, the responsibility of the overall mission will be transferred to the Mission Manager (located in ESAC, Spain) whereas the responsibility for spacecraft operations is transferred to the Herschel SOM (located in ESOC, Darmstadt, Germany) who leads the Flight Control Team (FCT). Support from all other components of the original Mission Control Team continues to be provided on an off-line basis (periodic or on-call support) to the Herschel SOM for the entire duration of the mission.

4.2 Mission Control Team Organization During Special Phases



Chapter 5 Reporting

5.1 Operations Reporting

Operations reports on the status of the spacecraft, the ground segment, the mission operations and the results of any special operations are prepared by the ESOC mission control team and submitted to the ESA and ESOC management, the HERSCHEL mission manager and project, and other interested parties.

5.1.1 Routine Reports

Table 5-1 provides the list of routine reports, the frequency of generation and the position responsible for its preparation.

Report	Frequency	Prepared by
Shift reports	Daily; end of Every SPACON shift, i.e. end of DTCP	SPACON
Instrument Malfunctions or Operations Problems	On event, i.e. in case of unplanned unavailability of instrument or S/C subsystems (e.g. after an anomaly on-board)	SPACON/Engineers
Weekly Mission Operations reports	Once per week	SOM
Monthly Mission Operations reports	Once per month	SOM
Quarterly Mission Operations reports	Once every 3 months	SOM

Table 5-1 Routine Reports Summary

In the following the content and purpose of the routine reports are explained in more detail:

Shift report	The shift log is for FCT internal use and is a running log of events or information that should be passed on to other shifts and the Spacecraft Analysts. The Log shall provide an overview of the Herschel operations performed during each DTCP. Furthermore, the log shall include a record of all ground segment problems and, depending on the severity, the actions taken. All Spacecraft anomalies and the actions taken (e.g. CRP's executed) shall also be recorded. The log serves as a record of all operation activities carried out during a DTCP. It will be used as input to the weekly report.
Instrument Malfunction or Operations Problem	Any SVM or instrument malfunction will be reported via the "Instrument Malfunction of Operations Problem" interface as described in the "Consolidated MOC/SGS ICD list [PT-CMOC-OPS-ICD-6101-OPS-OGH; issue 3.2; July 2008]
Weekly Mission Operations Report	During all phases of the Herschel mission (except LEOP) the weekly reports shall provide the following information: • Summary of mission operations • Status and performance of the spacecraft including platform and payload during the reporting period. • Spacecraft orbit

- Status and performance of the Flight Operations Segment elements during the reporting period.
- Mission Planning
- Forecast of operations planned for the next period

As part of the status report a list of anomalies per subsystem that have occurred during the reporting period shall be included. Also, a list of major events that have had an impact on the planned operations will be provided.

Monthly Mission Operations Report — This report provides a summary of the weekly reports and serves as input to the OPS-O monthly report. It includes availability figures for the MOC.

Quarterly Mission Operations Report — This report is a summary of the monthly reports and serves as input to the ESOC mission operations report. It includes a summary of major operational events and activities and of the mission performance (products and services). Note approx. every 6 months a more detailed performance analysis will also be provided for all subsystems. The status of any life limited items or consumables shall be included in this more detailed 6 monthly report. A list of anomaly and problem report and availability statistics for the MOC shall also be included.

5.1.2 Special Reports

Special reports will be issued for specific critical mission phases:

Report	Frequency	Prepared by
LEOP Mission Operations Report	Approximately daily (after major events)	FOD
LEOP Report	Once, after end of LEOP	SOM
Commissioning Phase Report	At the end of the Commissioning Phase	SOM
End of Mission Report	Once, after end of mission	SOM

Table 5-2 Special reports summary

In the following the content and purpose of the special reports are explained in more detail:

LEOP Mission Operations Report	This report provides the following information: • Summary of mission operations • Status and performance of the spacecraft • Spacecraft orbit • Status and performance of the Flight Operations Segment elements • Forecast of operations planned for the next reporting period
LEOP Report	This report summarises the LEOP mission operations and its major events. It uses the LEOP Mission Operations Reports as input. It includes an engineering analysis of the spacecraft and Flight Operations Segment during this phase.
Commissioning Phase Report	This report summarises the commissioning mission operations and its major events. It uses the weekly Mission Operations Reports as input. It includes an engineering analysis of the

	spacecraft and Flight Operations Segment during this phase.
End of Mission Report	This report summarises the end of mission operations. It provides also a summary of the operations experience with the satellite and its subsystems acquired by the Flight Control Team during the mission.

Table 5-3 Special report contents

Chapter 6 Configuration Management and Change Control

The configuration management for HERSCHEL (and PLANCK) is defined in the HERSCHEL/PLANCK Configuration Management Plan [AD-2]

6.1 FOP Change Request Procedure

Changes to any Procedure included in the FOP are handled via a change request. The relevant steps are:

- The engineer fills in a change request form explaining the change, the reason and what type of re-validation is considered necessary. He/she distributes it to the deputy SOM and SOM. The format of the HERSCHEL change request form is:

<table>
<tr><td colspan="6">HERSCHEL FOP CHANGE REQUEST</td></tr>
<tr><td colspan="2">Global Reference Number:</td><td colspan="2">Approved by:</td><td colspan="2">Approval date:</td></tr>
<tr><td colspan="2">Originator:</td><td colspan="4">Date:</td></tr>
<tr><td colspan="6">Procedure(s) affected:</td></tr>
<tr><td>Proc ID</td><td>Title</td><td>Current Version</td><td>Author</td><td colspan="2">New Version</td></tr>
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<tr><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="6">Change description / reason for change:</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">Re-validation required? (rerun on SIM, load sequence(s) on MCS, inspection only, no):</td></tr>
<tr><td colspan="2">Implemented by:</td><td colspan="4">Date:</td></tr>
</table>

Sequences to be imported:	Sequences to be removed:
Sequences imported/removed by:	Date:

- Until the freeze before launch, the deputy SOM (who is also the system engineer) or the SOM authorise the change or discuss with the requestor in case of doubts. Due consideration needs to be taken of whether the change is such that could affect other procedures/timelines that call this procedure.
- During the freeze, the mechanism is the same but in addition all change requests have to be approved by the CCB, chaired by the Flight Director. The SOM or his deputy will provide to the CCB the list of changes, together with a recommendation.
- Once in flight and after the end of the freeze, the Change Control Board (CCB) chaired by the SOM or his deputy will take up the same role
- The DCR is assigned a sequential number and kept both by the system engineer and in the Herschel shared drive at ESOC.
- If approved the change is implemented.

Chapter 7 FOP Production and Validation

7.1 FOP Production Rules and Guidelines

The HERSCHEL Flight Operations Plan (FOP) is a large document written by different members of the flight control team from the inputs provided by Industry.
The purpose of the FOP Production Rules and Guidelines Document is to define rules and guidelines that ensure a homogeneous, unambiguous and readable FOP, consistency between the Subsystem and System FOP Volumes and allow proper configuration control of the FOP. The members of the HERSCHEL Flight Control Team (FCT) shall follow these rules in the preparation and maintenance of the FOP. For all aspects of FOP Production, Configuration Control and Validation the MOIS tool will be used.

7.2 FOP Validation

Validation of the FOP contents is critical to ensure safe and efficient execution of the mission.

All satellite nominal and contingency procedures that are formulated for inclusion into the FOP will be validated through the following approach:

1. Selected flight control procedures and contingency recovery procedures or their building blocks are tested in SVT’s and, as a general principle, verified on the simulator before execution on the real spacecraft. As far as practically possible, procedures for SVT's will be written as Flight Procedures with clear identification of SVT specific steps or activities. The SVT’s are also used to collect reference data for development and validation of the simulator.

2. Following SVT's, the SVT test reports will be used to identify any required changes to procedures which will be made using the source flight procedure, thereby ensuring the validation of SVT procedures has been directly fed back into the flight procedures.

3. All satellite procedures and timelines, which cannot be executed during an SVT due to time constraints or cannot be adequately verified with the satellite in its AIT configuration on the ground, will be tested using the satellite simulator. Note it is expected that this will be the majority of all FOP procedures. If only building blocks of a procedure have been validated during an SVT these procedures will also require re-validation either with the simulator or (in exceptional cases of only minor modifications or for lead type procedures) by review. Validation will be performed nominally by the Operations Engineer who authored the procedure. Note (in particular instrument) procedures which cannot be adequately verified with the simulator and could not be run with the S/C due to configuration constraints on the ground or for reason of test time rely on review by external parties.

4. All procedures shall be reviewed by the relevant external parties (ESTEC project team, S/C or Instrument manufacturer).

5. If an already validated procedure is modified the following approach will be applied:
   - If TC items have been modified a re-validation on the simulator will be necessary. This is true in particular for procedures, command or external command sequences containing a lot of parametric information (FDS commands, OBSM external command sequences, command sequences taking input from internal or external Parameter Tables).
   - If TM items have been modified then a re-validation will be necessary if the changes are significant; otherwise verification by review will be performed.

- If the logic of the procedure is changed significantly (e.g. branching or decision steps) then re-validation is necessary.

The method to be applied for re-validation (i.e. complete or partial re-run on simulator or visual review) will be decided depending on the significance of the modifications introduced. This will be assessed on a case by case basis between the responsible parties (normally S/C Operations Engineers and SOM). Validation results will be recorded in MOIS and reported by the FOP Administrator for every FOP release.

Mission Support procedures will be validated during the course of normal work in the preparation activities and support for the various Interface tests, SVT's, SOV's and the pre-launch simulation campaign.