Volume VI: MISSION OPERATIONS REQUIREMENTS

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CONTENTS

List of Figures

List of Tables

List of TBC's

Sec. 6.2.10: - First detection is expected at a distance between 400,000 - 250,000 km from the comet

Sec. 6.4.7.2: - Plane of thermal radiators parallel to sun line, however not exceeding ± 30 deg. during certain mission phases

List of TBD's

Sec. 6.4.5: - Visibility duration for DSN in LEOP
- TM bit rates at Asteroid flyby

Sec. 6.6.4.1: - Access to data held on the DDS limited to the PIs (confidentiality agreement)

6.1. OVERVIEW

The development and implementation of the Rosetta ground segment system, and its post-launch operation in conjunction with the space segment, i.e. the Rosetta spacecraft and its payload and Surface Lander have been delegated to the European Space Operations Centre (ESOC). This task includes spacecraft operations required for Mars and Earth swing-bys during the interplanetary cruise phase, the combined spacecraft and payload operations during asteroid fly-bys, the mission execution during comet recovery/approach and near comet phase, the cometocentric orbit phase, and in particular the conduct of mission operations during Lander delivery and relay. Throughout the complete mission duration (from launch up to the end of mission, when ground contact to the spacecraft/payload is terminated), facilities and services will be provided to the scientific community for planning and execution of scientific data acquisition. This will include the generation and provision of the complete raw-data sets and necessary auxiliary data to the Principal Investigators (PIs), and the Rosetta Lander Ground Segment for the Lander.

6.2. MISSION PHASES

The Rosetta mission is divided into distinct mission phases, as defined in table 6.2.1 below

Phase	Start Date	End Date	Dur. (d)	Start Conditions	End Conditions	Remark
LEOP	26/02/2004	29/02/2004	3	Launch	Launch + 3 days (Completion of Trajectory Correction Manoeuvre 1)	
Commissioning (part 1)	29/02/2004	07/06/2004	99	Launch + 3 days (Completion of Trajectory Correction Manoeuvre 1)	Completion of DSM1	
DSM1	05/06/2004					
Cruise 1	07/06/2004	20/09/2004	105	Completion of DSM1	NNO Full passes availability (MEX solar occultation)	
Commissioning (part 2)	20/09/2004	04/11/2004	45	NNO Full passes availability (MEX solar occultation)	End of NNO full passes availability	
Earth Swing-by 1	04/11/2004	04/04/2005	151	End of NNO full passes availability	1 month after Earth Swing-by 1	
DSM2	08/12/2004					
Earth	03/03/2005					
Cruise 2	04/04/2005	06/09/2006	520	1 month after Earth Swing-by 1	1 month before DSM3	Solar occultation (49 days)
Mars Swing-by	06/09/2006	28/03/2007	203	1 month before DSM3	1 month after Mars Swing-by	
DSM3	05/10/2006					
Mars	27/02/2007					
Cruise 3	28/03/2007	16/09/2007	172	1 month after Mars Swing-by	2 months before Earth Swing-by 2	
Earth Swing-by 2	16/09/2007	16/12/2007	91	2 months before Earth Swing-by 2	1 month after Earth Swing-by 2	
Earth	15/11/2007					
Cruise 4	16/12/2007	12/09/2009	636	1 month after Earth Swing-by 2	2 months before Earth Swing-by 3	Solar occultation (11 days) Solar occultation (41 days)
DSM4	24/03/2009					
Earth Swing-by 3	12/09/2009	12/12/2009	91	2 months before Earth Swing-by 3	1 month after Earth Swing-by 3	Solar occultation (10 days)
Earth	11/11/2009					
Cruise 5	12/12/2009	11/01/2011	395	1 month after Earth Swing-by 3	4 months before RVM1	Solar occultation (50 days)
Rendez-vous Manoeuver 1	11/01/2011	11/07/2011	181	4 months before RVM1	Sun Distance of 4.62AU	Solar occultation (39 days)
RVM1	10/05/2011					Start of rendezvous manoeuver 1 burn
Cruise 6 (DSHM)	11/07/2011	23/01/2014	927	Sun Distance of 4.62AU	Sun Distance below 4.6AU and end of solar occultation	
Rendez-vous Manoeuvre 2 and Comet Approach	23/01/2014	22/08/2014	211	Sun Distance below 4.6AU and end of solar occultation	Comet insertion point (92 days after start of RVM2)	Solar occultation (28 days) Near Comet Drift (start with first RVM2 burn): 30d Far Approach: 30d Close Approach: 6d Transition to Global Mapping: 15d Operational Margin: 11d
RVM2	22/05/2014					Start of rendezvous manoeuver 2 burn

Global Mapping and Close Observation	22/08/2014	19/10/2014	58	Comet insertion point (92 days after start of RVM2)	22 days before Lander Delivery	Global Mapping: - 7d dedicated to data collection - 28d for data analysis and selection of 5 potential landing sites Close Observation: - 13d dedicated to data collection (2 days for each landing site + 1 day orbit phasing + 2days to downlink data of last site) - 10d for landing site selection
Lander Delivery	19/10/2014	15/11/2014	27	22 days before Lander Delivery	5 days after Lander Delivery	Lander Delivery Dress Rehearsal: 11d Lander Delivery Preparation: 11d
Lander Delivery	10/11/2014					Sun distance = 3AU
Comet Escort	15/11/2014	31/12/2015	411	Lander Delivery + 5d	Sun Dist. of 2 AU post-perihelion (perihelion reached on 12/08/2015)	

Figure 6.2-1: Rosetta Mission Phases

6.2.1. Launch and Early Orbit Phase

This phase lasts about 3 days, starting from a few hours before launch.

Launch support will start 8 hrs before launch and includes a final readiness test with the stations. At L-4 hrs data flow tests and data confidence tests are performed, the data are flowed from the satellite at the launch site to ESOC. This permits the final verification of the ground system and network readiness one-hour before launch and the final go/no-go decision prior to lift-off. The satellite will be launched by an Ariane 5 launch vehicle.

After spacecraft separation from the launch vehicle, a series of configuration activities will be performed automatically by the spacecraft, including priming of the reaction control subsystem, acquisition of a sun-pointing attitude, deployment of the solar array wing and establishment of a RF contact with the ground stations. The post-launch spacecraft operations will start immediately following Acquisition of Signal (AOS) by the Kourou ground station at approximately L+2 hours. At that time the control centre takes over control of the spacecraft and completes the initial configuration activities, including configuration of the main subsystems (DMS, AOCS) and activation of the most important functions.

In parallel, precise orbit determination is carried out by analysis of the radiometric measurements and the parameters for the first trajectory correction manoeuvre are calculated. The execution of this manoeuvre, about three days into the mission, concludes this phase.

6.2.2. Commissioning Phase

The Commissioning and Verification Phase (CVP) starts at about L+ 3 days and is divided into three subphases, dictated by the availability of the New Norcia station for Rosetta:

- Part 1: from launch until end March 2004. In this phase full New Norcia passes can be utilised for Rosetta support (about 9 hours/day for Science ops);
- Part 2: from April to end of May 2004. In this phase Mars Express has priority on use of the New Norcia station, which can be used for Rosetta only when MEX is out of visibility. This means about 6 hours of NNO coverage per day at the beginning of the period. Towards the end of the period the pass duration decreases to about 4 hours;
- Part 3: in September/October 2004 Mars Express enters a Sun occultation period and New Norcia can be fully used for Rosetta control (about 6 hours per pass for the payload).

The Commissioning Phase includes activation and checkout of the payload, instrument calibration, and verification that the overall system performance meets the requirements. This involves amongst other activities the checkout of the payload interfaces with the spacecraft subsystems, interference measurements between the payload and of subsystem influences on the payload. All subsystems not immediately used entering LEOP are also commissioned at the beginning of this phase.

The HGA is nominally used for RF contact with the ground stations throughout this phase. Reception of telemetry in emergency cases is possible via the Low Gain Antenna (LGA) until about 14 days after launch.

Experiment specialist participation is required at the RMOC for the first experiment switch-on operations and subsequent performance checkout. The mission products and the facilities provided to PIs during CVP are defined in section 8.4 and 9.3 respectively.

Upon completion of the CVP a Mission Commissioning Results Review (MCRR) will be held to assess the actual performance of the satellite/ground segment complement.

The NNO 35m station augmented by DSN will be used throughout the CVP. Kourou 15m might be used for the first period when ground contact with this antenna is still possible, to support commissioning operations over a more extended period of time for a couple of days. NNO 35m gives in this period a daily pass of about 10 hours above 10 degrees elevation, but can only be fully used depending on Mars Express use (see 7.3.2 above for details).

6.2.3. Cruise Phases

There will be six cruise phases in the Rosetta mission. In these phases the spacecraft will be configured in a safe mode in which a minimum level possible of activities will be required, both autonomously on-board and on ground. The exact definition of start and end of each cruise phase is reported in section 4.1.2.

The last cruise phase is also the longest one, about 2.5 years. In this phase the spacecraft reaches the maximum distance of 5.3 AU from the Sun, and therefore its active systems have to be minimized for power reasons. The spacecraft will therefore be spun-up and will be almost completely deactivated, in the Deep Space Hibernation Mode (DSHM).

In the other cruise phases the spacecraft will be put into Near Sun Hibernation Mode (NSHM). This is a 3-axis stabilized, low fuel consumption thruster mode.

The current assumption is that spacecraft monitoring will be required during the NSHM phase with a frequency of one pass of a few hours every month. No routine control activities are assumed to be performed during this phase, except those required to establish the periodic monitoring contacts. In particular all payload science operations are excluded, although limited, regular and simple activation and checkout activities on the payload instruments can be supported. During the DSHM phase no ground contact will be possible, nor any payload operation.

The NNO 35m ground station will be used in this phase whenever ground contact is required.

6.2.4. Mars Gravity Assist

This phase starts 1 month before Deep-Space Manoeuvre #3 - which in turn takes place around 5 months before the Mars encounter - with acquisition of the spacecraft, orbit determination and navigation manoeuvres to get onto course to the proper swing-by point. The swing by event takes place at a distance from the surface of Mars of about 200 Km. The phase ends one month after Mars flyby, when all scientific data collected during the encounter have been successfully downlinked.

During the whole phase, the communications link will be maintained and proper articulation of the High Gain Antenna (HGA) and solar arrays will ensure solar power. After the Mars gravity assist phase time is necessary to perform further orbit determination and deep space manoeuvres and preparations for the subsequent approach to Earth.

The criticality of this phase (tracking difficulty, low swing-by height, orbit manoeuvre) precludes the possibility to give any priority to science during the swing-by. Science and checkout operations of the payload are however requested by the PI teams and a baseline plan of payload activities will be established and included in the Flight Operations Plan, with the understanding that any planned and unplanned spacecraft-related activity in this phase takes absolute priority over payload operations. Any science data generated in this phase will be recorded on-board and down linked during the post-swing by period.

The NNO 35m ground station will be used in this phase. NNO 35m gives in this period a daily pass of about 9 hours above 10 degrees elevation. In addition DSN tracking support is mandatory required during this phase.

6.2.5. Earth Gravity Assists

The three gravity assist phases each start a few months before Earth swing-by with tracking and targeting manoeuvres, and last until about 1 month after the swing-by again concluding with orbit determination and orbit correction manoeuvres and preparations for the following cruise phase.

For a few days around closest approach to Earth the RF link with the spacecraft will be switched from HGA to the LGA at a low bit rate. Some spacecraft operations during the swing-by may have to be performed autonomously. Ground based navigation during this phase is expected to be very accurate.

It is not baselined to conduct any science operation during this phase. However, pre-planned checkout activities and even limited science operations defined and agreed long in advance can be implemented under the condition that they do not conflict nor constrain the critical spacecraft operations related to the Earth swing-by.

The NNO 35m station will be used in this phase

6.2.6. Asteroid Fly-by

The details of the Asteroid Flyby phases will only be defined after launch, when the knowledge about fuel availability will drive the target asteroid selection.

In general, however, the phase will start about 3 months before the encounter, and it will end with the completion of the post-encounter data downlink, about 2 months after the flyby. The spacecraft navigation camera will detect the asteroid when it reaches magnitude 11, and this will be a few weeks before encounter, depending on size and illumination of the selected asteroid. Images of the asteroid against the star background are used on-ground to improve the knowledge of the spacecraft trajectory relative to the asteroid. A sequence of correction manoeuvres will be performed in the last few days before the closest approach in order to achieve the required fly-by distance and orientation in the target plane.

Before the fly-by, a last orbital trim manoeuvre will be performed, after which the spacecraft attitude control will be transferred to asteroid pointing. For a few minutes around the encounter the HGA tracking will have to be suspended, thus interrupting communications with ground. Immediately after encounter an autonomous Earth recovery sequence will be scheduled, which will restore telecommunications with ground.

A baseline plan of payload science operations will be established long before the fly-by. The related timelines and procedures will be included in the Flight Operations Plan. All spacecraft and payload operations for the fly-by will be implemented via time-tagged commands and On-Board Control Procedures uplinked a few days in advance. The presence of PI Teams at ESOC during the last days before the encounter will be required to provide real-time support in case of unforeseen events and, if needed by specific instruments, to carry out fine-tuning configuration activities via near-real-time commanding shortly before the encounter.

All science data collected during the asteroid flyby will be stored on-board the mass memory unit and down linked after the reacquisition of the RF link with the spacecraft. Due to the large amount of data and the limited downlink bandwidth it is expected that it will take up to several weeks to complete the downlink of science data after each asteroid flyby.

The NNO 35m station will be used in this phase augmented by DSN.

6.2.7. Rendezvous Manoeuvre 1 and Hibernation Entry

The rendezvous manoeuvre to match the spacecraft orbit with the comet orbit will be implemented in two legs, one at the beginning and one towards the end of the long aphelion cruise phase. The manoeuvre will be based on ground based navigation only. This manoeuvre will be performed with the spacecraft in a low power mode.

Being the largest manoeuvre of the mission, each leg will be split into progressively smaller burns to mitigate execution errors. The first Rendezvous Manoeuvre Phase (RVM1) will start 4 months before the first burn, at the end of Cruise 5. It will end about 2 months after the manoeuvre, at a Sun distance of 4.6 AUs, with the completion of the hibernation entry activities.

During this phase the power available on-board the spacecraft is very limited. Time sharing of subsystem activation might be required, including possibly the TTC, resulting in an intermittent contact with the Earth even when the ground station is available. Payload operations are of course excluded for the same reason.

The NNO 35m ground station will be used in this phase. DSN 70m support is scheduled for the critical period of hibernation entry.

6.2.8. Rendezvous Manoeuvre 2 and Comet Approach.-

The Rendezvous Manoeuvre 2 and Comet Approach Phase starts with the spacecraft autonomous exit from hibernation at a Sun distance of 4.6 AUs and preparation for the second leg of the Comet Rendezvous Manoeuvre (RVM2), which takes place at a Sun distance of 4 AUs. It ends when the spacecraft reaches the Comet Insertion Point.
During the approach to the comet nucleus after the rendezvous manoeuvre the spacecraft will also come closer to the Sun, and this will allow gradual activation and checkout of payload instruments. For these activities a baseline activity plan will be produced by ESOC and included in the Flight Operations Plan. The result will be a second payload-commissioning phase, which will extend over a large part of the phase. It should be noted that for these activities the PI teams would be required to be present at ESOC to participate in the operations in the same way as in the Commissioning and Verification Phase.

Mission design will ensure that adequate power is available to operate the camera and the attitude control system in a high stability mode while the distance to the Sun is below 4 AU. First detection of the comet is expected at a distance between 400,000 - 250,000 km (TBC) from the comet. Subsequently manoeuvres based upon optical navigation can be performed. The full payload complement can be operated below 3.25 AU from the Sun, when sufficient power becomes available.

The NNO 35m ground station will be used in this phase. DSN 70m stations have been scheduled as back-up support for the critical phase of hibernation exit.

6.2.9. Comet Mapping and Close Observation

The objective of the comet nucleus mapping phase is to define the major parameters of the nucleus such as size, rotation axis and rate, mean density etc. to enable planning for the orbiting strategy. Close observation is required to study features on the surface and subsequently to determine suitable landing places for the Lander.

The phase starts at Comet Insertion Point and ends with the selection of the landing site. The duration of this phase is estimated at about one month for global mapping and selection of potential landing sites plus about one month for close observation of the selected sites and finalisation of the landing scenario.

The routine science mission-planning scheme will be gradually introduced in this phase. In principle all instruments will be allowed to operate in this phase. However it is expected that the Master Science Plan established by the SWT/SOWG for this period will give priority to the imaging instruments in accordance with the main objective of this phase.

Both the Cebreros and NNO 35m ground stations will be used in this phase, to increase the data downlink capability and the flexibility of control operations.

6.2.10. Lander Delivery and Relay.-

Once a suitable landing site for the Lander has been found, the orbiter will be placed into a delivery orbit, which at a pre-set time flies through the separation position at the required altitude. The orbiter will be commanded at a pre-set time before separation to go into the required separation attitude. After separation the Lander will reach the comet surface within about 30 minutes. Meanwhile the orbiter will be manoeuvred into an orbit that optimises communications with the Lander for the following 5 days. The Lander will carry out his initial scientific sequences during this period.

In this phase the operations will be carried out outside of the routine mission-planning scheme, due to the criticality of the activities involved.

Both the Cebreros and NNO 35m ground stations will be used in this phase, to increase the data downlink capability and the flexibility of control operations.

6.2.11. Comet Escorting.-

The Lander will nominally operate on the surface of the comet for several months. During this phase the spacecraft will orbit or escort the nucleus carrying out science operations with the orbiter payload and periodically establish RF contact with the Lander to recover science data collected on the surface and to transmit new operational sequences to the Lander control unit. Average required contact time between the Lander and the Orbiter will be of 15 minutes every 16 hours. In practice the orbital strategy decided in the Master Science Plan will dictate the visibility periods between Orbiter and Lander, which are normally expected to be larger than the required period, giving a higher flexibility in the Lander operations planning. An exception could be the special orbits required performing "excursions" into the coma at large distances from the nucleus, which would result in an excessive distance for the Lander-Orbiter link to be established.

Rosetta will accompany the comet nucleus in its orbit towards perihelion and beyond, up to a distance of 2 AUs from the Sun, reached at the end of December 2015, when mission end will be declared.

In this phase various science objectives will be pursued, involving different orbits around the nucleus and different pointing attitudes. The Master Science Plan established by the SWT/SOWG will give the guidelines for the science operations and the selection of orbit and attitude strategies. The mission planning cycle will further detail the MSP and translate it in operations timelines.

The NNO 35m ground station will be used in this phase.

6.3. GROUND SEGMENT

The Rosetta ground segment will provide capabilities for monitoring and control of the Rosetta spacecraft and payload during all mission phases, as well as for the reception, archiving and distribution of payload instrument data. The ground segment (Fig. 6.3-1) is therefore composed of:

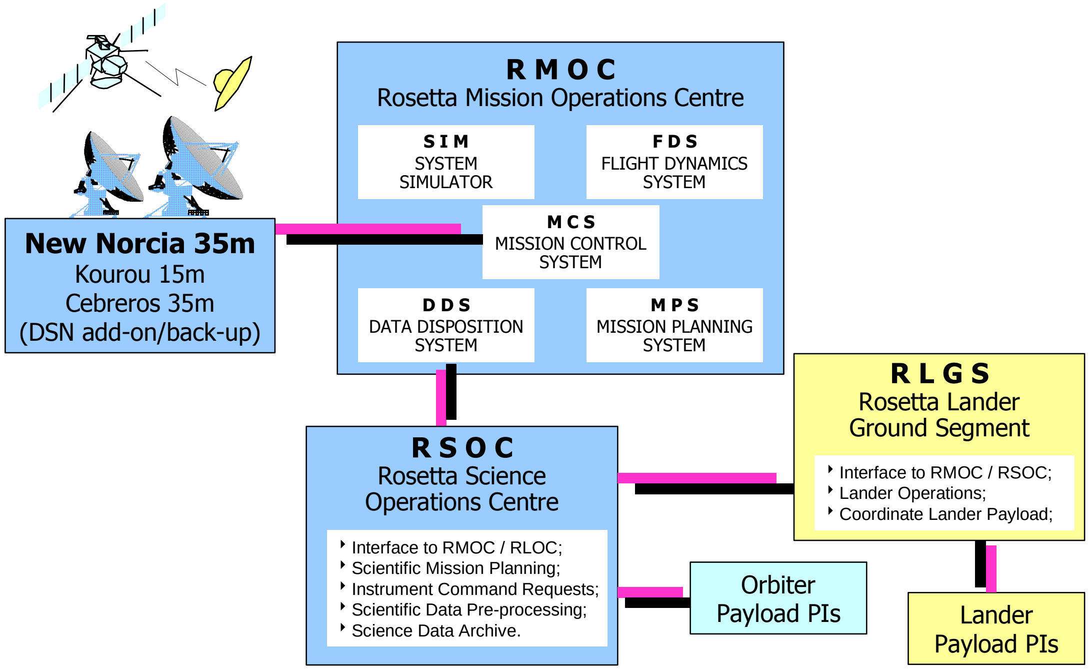

Figure 6.3-1: Rosetta Ground Segment Overview

(a) A Ground Station and Communications Network performing telemetry, telecommand and tracking operations within the S/X-band frequencies. Telecommand will always be in the S-band, whilst telemetry will be switchable between S- and X-band, with the possibility to transmit simultaneously in both frequency bands, only one of which will be modulated (S-band down-link is primarily used during the near Earth mission phases). The ground station used throughout all mission phases will be the ESA New Norcia (NNO 35m) deep space terminal (complemented by the ESA Kourou 15m station during near-Earth mission phases and by the Cebreros 35m deep-space antenna during early comet phases up to Lander delivery). In addition, the NASA Deep Space Network (DSN) 34m and/or 70m network is envisaged for back-up and emergency cases.

(b) A Rosetta Mission Operations Centre (RMOC) located at ESOC, Darmstadt, Germany including:

- the Rosetta Mission Control System, to support with both hardware and software, the data processing tasks essential for controlling the mission, as well as spacecraft performance evaluation and software validation;
- the Rosetta Data Disposition System, supporting the acquisition and interim storage of raw scientific data, to be accessible together with raw housekeeping and auxiliary data from PIs at remote locations;
- the Rosetta Mission Planning System, supporting command request handling and the planning and scheduling of spacecraft/payload operations;
- the Flight Dynamics System, supporting all activities related to attitude and orbit determination and prediction, preparation of slew and orbit manoeuvres, spacecraft dynamics evaluation and navigation in general;
- the Spacecraft Simulator, to support procedure validation, operator training and the simulation campaign before each major phase of the mission.

(c) A Rosetta Science Operations Centre (RSOC), to support scientific mission planning and experiment command request preparation for consolidated onward submittal to the Rosetta Mission Operations Centre (RMOC). The RSOC will make pre-processed scientific data and the scientific data archive available to the scientific community.

(d) A Rosetta Lander Ground Segment (RLGS),), with two centres located at DLR Köln and at CNES Toulouse to support operations of the Lander before and after completion of the landing and relay phase, including Lander landing site selection within mission constraints, by coordinating scientific mission planning and command request submittal to the Rosetta Science Operations Centre (RSOC). The RSOC will merge the submitted lander requests with the ones received from the orbiter payload PIs prior submitting a consolidated schedule to the RMOC.

(e) A General Purpose Communication Network, providing the support services for access to test data obtained during the spacecraft integration and test programme, submittal of command requests to the ESOC/RMOC, retrieval of quick look mission products kept at ESOC, and potentially to further provide for electronic data exchange of scientifically processed data, if required.

6.4. MISSION OPERATIONS

6.4.1. General

The Rosetta Mission Operations preparation, planning and execution will be performed by the Mission Operations Department (TOS-O) at ESOC on behalf of the Scientific Programme Directorate (D/SCI).

All Rosetta Operations will be conducted by ESOC according to procedures laid down in the Rosetta Flight Operations Plan, a comprehensive document prepared by the ESOC Rosetta Flight Control Team based on Project/Industry deliverables (User Manual and Database), the Science Operations Plan and agreements with the PIs. Payload operations specifically will be based on experiment User Manuals, Procedures and Databases which the PI teams will be required to produce and deliver.

Spacecraft operations during all active mission phases (lasting overall about 12 years) will be carried out with an 'off-line' approach, with all activities pre-planned and the resulting telecommands up-linked to the spacecraft for time-tagged execution; telemetry evaluation will also be mainly off-line, with limited possibility of quasi-real-time intervention in selected critical phases and in major contingency cases.

During the mission there will be communications black-out periods due to the spacecraft-Earth-Sun geometry which will prevent RF signal reception. In addition it is planned to put the spacecraft into a safe resource saving mode (hibernation) for at least one period of about 2.5 years duration. In this deep space period no ground contact with the spacecraft is planned, and therefore no on-board activity outside the basic survival mode of operation will be carried out.

The communication turn-around time between ground and the Rosetta spacecraft will be up to 100 minutes. The spacecraft and payload are therefore required to have the capability to conduct corrective actions on short notice in case of autonomously detected on-board anomalies. The contacts between the Rosetta Mission Operations Centre (RMOC) at ESOC and the spacecraft will not be continuous and will be primarily used for pre-programming of autonomous operations functions on the spacecraft, and for data collection for subsequent off-line status assessment. Anomalies will only be detected on ground with a delay which as a minimum corresponds to the light travel time, but typically will rather be in the order of one day. Thus quick reaction will not be supported.

6.4.1.1. Support of Payload Operations

Operations of the scientific instruments on-board of the Rosetta spacecraft will be defined by the PI institutes who have developed the instruments. The primary responsibility for developing the payload operations strategy for the Rosetta Scientific Mission will be with the Rosetta Science Working Team. Payload science operations are baselined around the asteroid fly-bys and during the whole near-comet phase from completion of the Rendezvous manoeuvre until the comet has reached a Sun distance of 2 AU post-perihelion. . Non-interactive science operations can be supported during Mars and the second and third Earth swing-by, with lower priority and on a non-interference basis with the critical spacecraft operations. The payload instruments are also operated for about three months after launch and for two successive months in the first year of flight to carry out commissioning activities.

For the remaining mission phases the instruments will normally remain inactive. However, whenever the spacecraft is active, i.e. outside of hibernation periods, limited payload operations support could be provided as described in the following:

(a) Cruise Checkout:
Several experiment teams have requested to have regular checkouts during the cruise phases. In particular, movement of mechanical parts is requested. Checkout windows will be scheduled with a frequency of once every 6-8 months during all cruise phases in which the spacecraft is not hibernated ([1]). All instruments requiring checkout activities will be operated together within the checkout window which will have a duration less than one week. All checkout operations will be carried out according to pre-defined and agreed procedures by the Rosetta Flight Control Team without interaction with the PI team (except in the case of anomalies).

(b) Cruise Science:
Some experiments (in particular RPC and RSI) have requested Science operations during cruise phases. These are currently not within the mission baseline and will only be considered outside of hibernation periods whereby taking into account Spacecraft (e.g. power) and overall Ground segment resource constraints.

[1] Note that hibernation periods of up to 27 months are foreseen; therefore the instruments shall be able to survive without checkout and maintenance activities for the duration of these periods.

Payload check-outs are planned as depicted in the table below. PIs are requested to furnish relevant expertise on-site at ESOC in support of these periods, also with a view to maintain and preserve knowledge of pertaining Rosetta instrument operations.

Payload Checkouts			
P/L Checkout 1	5d	17/10/2005	22/10/2005
P/L Checkout 2	5d	15/05/2006	20/05/2006
P/L Checkout 3	25d	27/11/2006	22/12/2006
P/L Checkout 4	25d	17/09/2007	12/10/2007
P/L Checkout 5	5d	24/03/2008	29/03/2008
P/L Checkout 6	5d	22/09/2008	27/09/2008
P/L Checkout 7	12d	16/02/2009	28/02/2009
P/L Checkout 8	24d	14/09/2009	08/10/2009
P/L Checkout 9	5d	15/03/2010	20/03/2010
P/L Checkout 10	5d	30/08/2010	04/09/2010
P/L Checkout 11	5d	21/03/2011	26/03/2011

Tab 6.4-2 Payload planned checkout

6.4.2. Operational Approach

The characteristics of the mission, which imply long periods without ground contact and, in some critical phases, a signal travel time of more than 1 hour, dictate a completely off-line mission operations concept, in which all operations are pre-planned and spacecraft health and mission progress monitoring is conducted off-line after late recovery of the required telemetry.

This implies a high level of autonomy to be implemented on-board the spacecraft at system, subsystem and instrument level, in order to achieve the following objectives:

(a) to implement science operations and maintain appropriate prerequisite conditions on the spacecraft outside ground contact under nominal on-board conditions;

(b) to maintain the mission products generation process continuing in case of the occurrence of a first failure affecting a spacecraft function;

(c) to stop mission product generation in case of occurrence of a second failure, but ensuring spacecraft survival until ground intervention.

In case of failures the intervention of the ground will normally take place a long time - variable depending on the mission phase - after the intervention of the on-board systems. The approach on ground will be to collect the necessary information on the failure and the actions already taken autonomously on-board, and, if necessary, to re-configure the spacecraft subsystem or instrument to re-establish the generation of mission products. To this goal, the spacecraft and payload shall provide via telemetry the ground with extensive information on the decision process followed and all the actions autonomously carried out in case of detection of a failure. Reaction to on-board failures from the RMOC will require unambiguous identification of the failure in telemetry, and the related contingency procedures being contained in the experiment user manual.

Operations (for both spacecraft and scientific payloads) will only be conducted in strict compliance with validated event sequences and procedures documented in the Flight Operations Plan. This encompasses all operations i.e. special operations and contingency operations as well as routine operations during the Mission Operations Phase. Principal Investigators shall not request operations for which no validated procedures exist in the FOP.

It is important to emphasise that the Science TM Packets will not be processed at the control centre. This means that any information which the OCC needs in order to carry out nominal and contingency operations on the payload must be included either in the Housekeeping or in the Event TM packets (see also volume 2 for a precise definition of all the TM packet types).

The RMOC will only command a payload instrument according to the agreed nominal and contingency procedures and the accepted mission plan. However, the RMOC shall have the right to switch off any experiment which is deemed to be interfering with or endangering the mission objectives.

6.4.3. Payload Operations Support

Rosetta payload operations will be governed by the rules and guidelines established and periodically discussed by the Science Working Team (SWT). The preparation, coordination and execution of science operations will be carried out differently in the various phases of the mission. Two categories of operations (Fig. 6.4-1) have been identified:

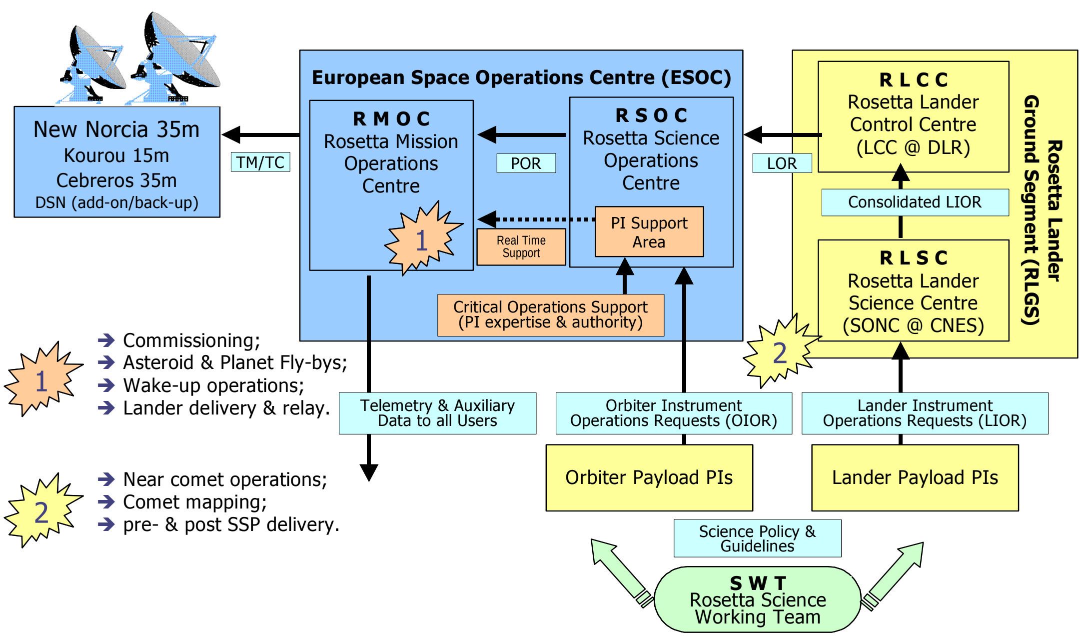

Figure 6.4-1: Rosetta Payload Operations

a) *Critical Operations (Category 1)*

During payload commissioning, asteroids fly-by, planet fly-by, wake-up operations with payload re-activation after the comet rendezvous phase, Lander delivery and relay, as well as any critical activity involving the payload, all experiment operations will be executed at the RMOC using a detailed phase timeline and related procedures established before the start of the phase. Timelines and procedures will be defined by the SWT and the experimenter teams, produced by the ESOC Flight Control Team, reviewed and agreed by the PIs and included in the Flight Operations Plan. In these phases the presence of the PI with his team of experts at the RMOC will be required (for the period in which critical operations of their instrument are carried out).

A dedicated area (PI Support Area) will be available at ESOC, allowing the experimenter teams to install their support equipment. Payload representatives will monitor the operations execution in near-real-time (compatible with the availability of data at the RMOC) and will support GO/NOGO decisions at pre-defined steps in the procedures during the Commissioning and re-activation phases. It will be possible for the experimenter teams to submit change requests to procedures and/or timelines until very close to the execution time (this will not be guaranteed for asteroid and planet fly-by phases). These requests will be discussed with the Flight Control Team in daily operations review meetings under the supervision of the Project Scientist and the Spacecraft Operations Manager. Throughout this phase the Rosetta Lander Ground Segment (RLGS) will support the Lander experimenter team at ESOC.

The Rosetta Science Operations Centre (RSOC) will be co-located at ESOC for all category 1 operation phases, with the function of real-time coordination of the PI inputs to the RMOC.

b) Near-Comet Operations (Category 2)

For all the near-comet operations including the comet mapping, as well as the pre- and post SSP delivery / relay phases, (the Lander delivery and relay phase is a critical operation, carried out as a category 1 activity) - see Fig. 6.4-2 - a Rosetta Science Operation Centre (RSOC) will be established to support the Rosetta Project Scientist in the planning of the science operations schedule and the generation of coordinated operational sequences, the payload command sequences for all Rosetta experiments and their onward transmission to the Rosetta Mission Operations Centre (RMOC).

A dedicated Rosetta Lander Ground Segment (RLGS) will support the RSOC. The RLGS will merge the inputs for science operations from the various lander experiments PIs, check them against Lander system constraints and provide a single, consolidated Lander operations request to the RSOC on a periodic basis, synchronised with the Rosetta mission planning cycles. The RSOC will treat this input at the same level as any other orbiter payload input, and use it to create its consolidated payload operations request to the RMOC.

A centre for Rosetta Lander Science operations Coordination (SONC) which deals with science operations coordination of the Lander payload will assist the Rosetta Lander Control Centre (RLCC), mainly dealing with the Lander systems, by generating the Lander Operations Requests (LOR). In any case, the RSOC will be receiving operation requests for the Lander from a single interface with the RLGS.

All activities in these phases will be carried out *off-line* according to the planning periods and deadlines established in the mission planning concept (see also section 6.4.4 below). The inputs from RSOC will be checked by the Flight Control Team mission planners at the RMOC against the mission rules and constraints and the available spacecraft and environmental resources, iterated if necessary with the RSOC and finally implemented in the mission timeline to be up-linked to the spacecraft.

Since the interface between the RSOC and the RMOC at ESOC occupies a central position in the Rosetta ground infrastructure for payload operations, the detailed responsibilities and operational implementation of the interfaces between the two centres will be defined in a separate RMOC/RSOC Implementation Agreement Document. This document will also include a definition of the various pre-mission tests to be conducted and a description of the related test set-up.

Name	Start	Finish
Global Mapping	**22/08/2014**	**26/09/2014**
Comet Orbit Insertion Point	22/08/2014	22/08/2014
Global Mapping: Data Collection	22/08/2014	29/08/2014
Global Mapping: Data Analysis	29/08/2014	26/09/2014
Close Observation	**26/09/2014**	**19/10/2014**
Close Observation: Data Collection	26/09/2014	09/10/2014
Close Observation: Data Analysis	09/10/2014	19/10/2014
Lander Delivery	**19/10/2014**	**15/11/2014**
Lander Delivery Dress Rehearsal	19/10/2014	30/10/2014
Lander Delivery Preparation	30/10/2014	10/11/2014
Lander Delivery (3AU)	10/11/2014	10/11/2014
Lander Baseline Mission	10/11/2014	15/11/2014

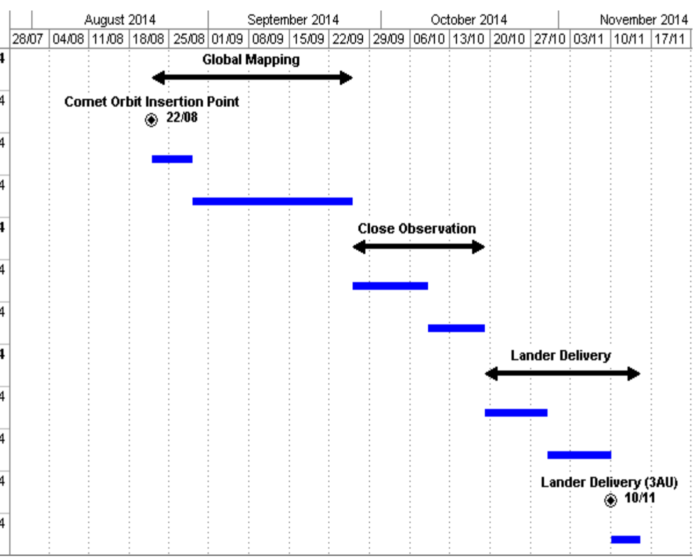

Figure 6.4-2: Rosetta Early Comet Phases and Lander Delivery & Relay Timeline

6.4.4. Mission Planning and Implementation

For category 2 phases, an off-line mission planning concept has been defined, based on cyclic inputs and iterations over planning periods.

In general, inputs for the generation of the complete plan for each mission phase will be required to be submitted several months before the start of the phase. The planning process will then continue at a more detailed level, subdividing each phase in *planning periods*, for each of which a separate deadline for submission of final inputs concerning the details on the operations to be conducted in the period will be given. In any case, due to the characteristics of the mission and the off-line approach of the operations concept, the finalisation of the detailed mission plan for each planning period will be still a few days away from the start of the period.

The above described Mission Planning approach will be adopted for all the near-comet phases, with the exception of the SSP delivery and relay phase which will be treated as a special window within the overall science plan. In a typical Mission Planning scenario the PI teams provide, at fixed deadlines and with a fixed periodicity, inputs to the RSOC for the requested science operations, the RSOC passes a consolidated request to the RMOC which checks the requests against mission, environmental and resource constraints.

For the near-comet phases the timeline of attitude and orbit with respect to the comet nucleus will play a major role in establishing the constraints scenario against which the payload operations plan will have to be checked. This means that the Mission Planning process will have to take into account information coming from the Flight Dynamics System defining the evolution of the relative attitude and relative position of the spacecraft and the comet. Other constraints (already known well in advance) like the distance from the Sun (determining the available power) and to the Earth (defining the maximum data rate) and of course the visibility from the Earth ground stations will have to be taken into account.

The complex set of constraints applicable to the payload operations around the comet indicates that a baseline science plan which already takes into account the major constraints will have to be established long before submitting the final science operations requests to the Mission Planning for release to the front-end Mission Control System. A simulations tool will be available to allow examination of the feasibility of various operations scenarios and to support the creation of baseline science plans for this phase.

The Mission planning scenario for the near-comet phase will therefore be divided into different levels:

- the *long term planning* will deal with the establishment of the baseline science plans; important to note in this phase there will be an input from the SWT and RSOC to the RMOC to define the orbit and attitude timeline based on the scientific objectives to be achieved; typically one long term plan will be defined for each major payload operations phase of the mission, and the final iteration will take place several months in advance of the actual operations of each phase.

- the *medium term planning* will deal with the definition and refinement of an orbit and attitude strategy for the next planning period (typically of the duration of one month). Once the dynamics timeline is defined, the baseline plan will be defined by adjusting the science requests to the resulting constraints;

- the *short term planning* will work on shorter planning periods and produce the detailed timelines of operations. Deadlines for submission of requests in this phase will be in the order of one week to a few days before the event. The planning period will also be in the order of a few days, but the exact duration will be dependent on the dynamic characteristics of the comet and the Rosetta orbit around it. For this reason various planning sub-phases with different planning period lengths might have to be defined.

6.4.5. Acquisition Periods and Bit Rates

The acquisition periods achievable with the available ground stations complement will be varying depending on the mission phase, whereby the distance of the spacecraft from Earth dictates the maximum bit rates. The maximum available telemetry data rates on the space-ground link are summarised in the table below. Of course the figures below give the maximum bandwidth which has to be shared among all payload instruments, subsystems and the Lander when operational, with varying priority depending on the relevant mission phase.

Mission Phase	Ground Station	Daily visibility	Distance to Earth	Max TM Bit Rate (1) (2)	Max TC Bit Rate
Launch and LEOP	NNO 35m Kourou 15m DSN	10 hours 10 hours (TBD)	near-Earth	26 kbps 26 kbps 26 kbps	2 kbps 2 kbps 2 kbps
Commissioning and Verification	NNO 35m	10 hours / 6 hours	near-Earth	26 kbps 26 kbps	2 kbps 2 kbps
Earth assist 1	NNO 35m DSN	9 hours 4 hours	Near-Earth	26 kbps 26 kbps	2 kbps 2 kbps
Mars assist	NNO 35m DSN	9 hours 4 hours	2.1 AU	26 kbps 26 kbps	2 kbps 2 kbps
Earth assist 2	NNO 35m DSN	9 hours 4 hours	Near-Earth	26 kbps 26 kbps	2 kbps 2 kbps
Asteroid fly-by	NNO 35m DSN	12 hours 4 hours	about 3 AU	TBD	2 kbps 2 kbps
Earth assist 3	NNO 35m DSN	9 hours 4 hours	Near-Earth	26 kbps 26 kbps	2 kbps 2 kbps
Comet Rendezvous and Approach	NNO 35m DSN 34m	12 hours 4 hours	4 AU	14 kbps 14 kbps	2 kbps 2 kbps
Comet Mapping and Close Observation	NNO 35m Cebreros 35m	10 hours 10 hours	about 3 AU	26 kbps 26 kbps	2 kbps 2 kbps
Lander delivery and relay	NNO 35m Cebreros 35m	10 hours 10 hours	3.3 AU	14 kbps 14 kbps	2 kbps 2 kbps

(1) assumes the use of on board High Gain Antenna (HGA) and X-band transmission (except for Launch / Commissioning) and maximum on-board transmission power;
(2) assumes cooled X-band receivers and the new Intermediate Frequency and Modem System (IFMS);

Table 6.4-1: Acquisition Periods and Bit Rates

6.4.6. Navigation

Navigation is the function to determine and control the spacecraft trajectory on the basis of measurements and estimation algorithms.

The navigation function for Rosetta will be performed at the RMOC on the basis of radiometric measurements via the TT&C subsystem and astrometric measurements of the comet position. Relative measurements of the Rosetta spacecraft position and velocity with respect to the asteroids or comet nucleus will be refined with the help of processing of images obtained with the optical cameras on-board the spacecraft.

The RMOC will be responsible to define the orbit manoeuvres strategy for the entire mission, including planets and asteroids fly-by, comet detection and approach, nucleus mapping, characterisation and escort, Lander delivery and relay phase. This includes the preparation and maintenance of a comet model (with a longitude and latitude grid) to allow for position identification on the comet.

6.4.7. Attitude Pointing Accuracy and Stability

Refer to Section 2.2.9.2.2 .

6.4.8. Comet Nucleus Orbit and Attitude Constraints

There are a number of constraints on the design of comet nucleus orbits and the spacecraft attitude related to the comet which of course impact on the flexibility in scheduling payload operations during the near-comet phase. This section summarises these constraints.

6.4.8.1. Orbits

The periods of the typical orbit of Rosetta around the comet nucleus will be of the order of days or weeks, however, orbits which result in eclipses are not allowed. In addition such orbits must be stable on a timescale of days so as to ensure Spacecraft safety also during communication outage periods. In particular, no orbit shall lead to collision with the nucleus within less than 7 days. As far as Churyumov-Gerasimenko is known today, approaching to an altitude of 1 km for Lander delivery would be possible while still satisfying this constraint.

6.4.8.2. Attitude

The attitude of the spacecraft body will be defined by pre-set profiles of reference axes in inertial space. This ensures that imaging objectives are met and stability during imaging can be controlled. This objective will be realised by star trackers following star patterns. This approach excludes a direct tracking of the nucleus by closed loop attitude control.

The attitude of the spacecraft will be controlled such that a plane containing thermal control radiators will be kept parallel to the spacecraft-Sun-line. Such radiators might also be used by instruments. This implies that the solar array rotation axis is kept about perpendicular to the Sun. This constraint is applicable throughout the mission apart from some brief periods where it may be violated for less than one hour, for example during Lander delivery, however not exceeding ± 30 deg (TBC).

6.4.8.3. Manoeuvres

In general there will be orbits around the comet which are not stable over a long period (> 2 weeks), and therefore orbit manoeuvres are required.
Orbit manoeuvres near the nucleus can easily result in one of two catastrophic scenarios, impact or escape, because of the low velocity increments involved in such manoeuvres. Orbital manoeuvres to go to a relay orbit will be performed under a maximum extent of ground control.

6.5. EXPERIMENT DOCUMENTATION AND DATA INPUTS

6.5.1. General

The experiment will be operated and controlled in-flight according to the requirements defined in a set of documents. These will be mainly the documents which will govern operations according to the Flight Operations Plan (FOP) and are summarised as follows:

- Experiment On-Board Software ICD (i.e. section 2.8 of EID-Bs / LID-B)
- Experiment / Lander User Manual
- Experiment / Lander Data Operations Handbook

The documentation tree showing the relationship among these documents is given in Fig.6.5-1.

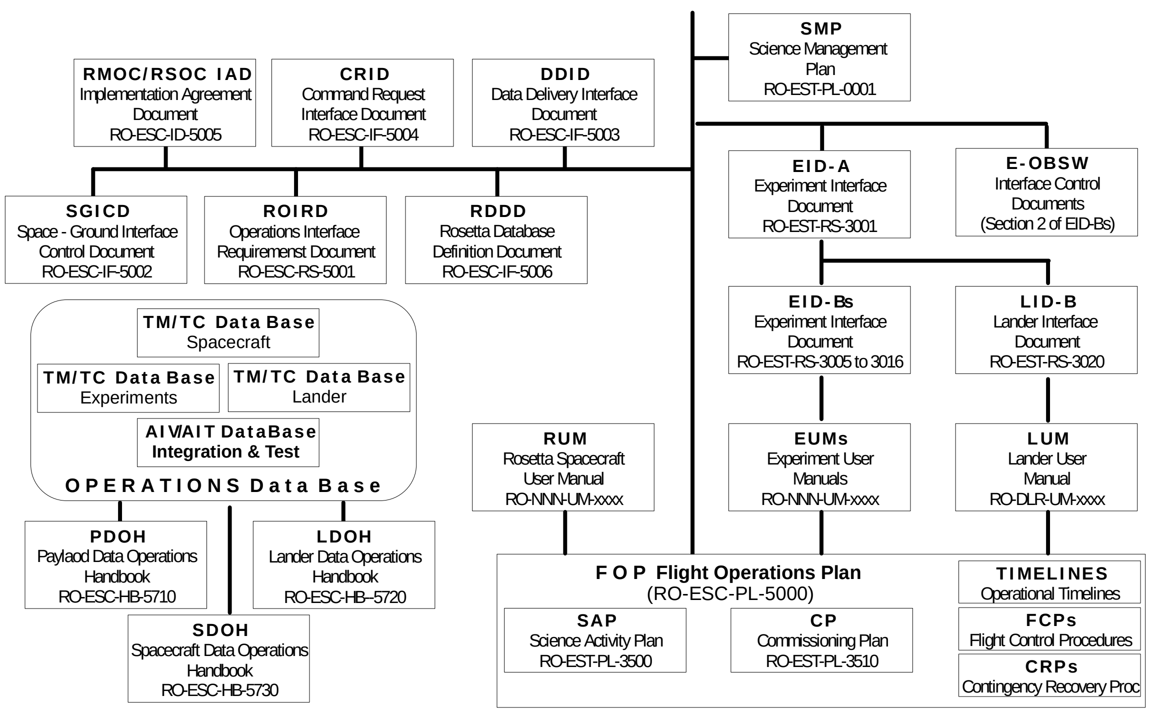

Fig. 6.5-1: Payload Documentation Tree

6.5.2. Experiment Data Base

An Experiment Data Base (EDB) shall be established, maintained and delivered to the project to become part of the Satellite Data Base (SDB). This SDB will be used throughout the different phases of the project starting from payload acceptance bench testing, through spacecraft AIV.
The EDB shall contain a complete definition of telemetry and telecommand data required for the detailed design of the flight control software, for the design of the software simulator and for setting up the operational telemetry and telecommand data files. The EDB shall comply to the Rosetta Database Definition Document (RDDD), RO-ESC-IF-5006 and shall be delivered according to the schedule given in Volume VIII. Delivery of the database shall be in XL sheets format, which should allow to parse it into the SDB.

Maintenance and configuration control of the EDB shall be the responsibility of the PI up to launch, whilst post launch throughout all mission phases this responsibility shall lie with ESOC.

The **Experiment Data Operations Handbook** (ref. EID A, Vol. VIII) will be the hardcopy form of the EDB and provides the formal interface definition to be endorsed by the PI.

6.5.3. On-Board Software Handling

Experiment software development and validation, including the generation of all software updates is the responsibility of the respective Principal Investigator (PI) throughout all mission phases.

Changes to the experiment software proposed by the PI which affect the functioning or the operation of experiments will be implemented only with explicit approval of both the ESA Project Scientist and the ESA/ESOC Spacecraft Operations Manager (SOM). In addition, before the implementation of software changes, any effects related to the ESOC ground software shall be identified by the PI and, if required, modifications will be initiated by the SOM.

Software patch telecommand requests related to the agreed software changes will be provided to ESOC via the RSOC by the responsible PI team. If the experiment supports the standard load memory Telecommands and dump memory Telemetry packets (Optional service as indicated in section 2.7.3), then the PI can request ESOC to verify the correct loading of the software patches. In any case it is responsibility of the PI to verify and confirm the correct functioning of the implemented software modification.

Changes/updates to the experiment software may be required at three different levels as follows:

Level 1: Table updates (configurable) to allow limited fine tuning as necessary;

Level 2: Data compression algorithms, Experiment application software(like macrocommands, packet content tables, etc.);

Level 3: Experiment 'system' code updates/changes

All Level 1 changes/updates will be handled through routine commanding. They will be identified by parameter correlation held in a ground table data base, delivered by the PI and maintained by ESOC. The PI will provide ESOC with ROM and RAM image, parameter IDs (including address, length in bits, ROM default setting) as input into the ESOC data base.

Level 2 and Level 3 changes are considered as contingency cases only because of the limited up-link rate, and require a special request to be approved and scheduled by the project scientist. On-board software maintenance procedures will have to be included in the experiment user manual. ESOC will prepare the relevant flight control procedures from that and use them whenever a software change to the experiment is approved. The changes will be implemented only if such procedures exist for the relevant experiment. The presence of experiment experts at ESOC during the software maintenance activities is recommended but not required.

6.6. MISSION PRODUCTS

Mission products will be made available to the PIs, and will include all spacecraft and experiment telemetry data and auxiliary data as defined in the following.

6.6.1. Science Telemetry

Upon receipt at the RMOC, science data will be extracted and stored as raw data chronologically ordered by Lander and experiment and will include quality data and additional timing data so as to enable the PI to correlate the data with respect to UTC.

Immediately after reception on ground the optical image data from both the navigation camera and the OSIRIS camera shall be available at ESOC/RSOC for navigation purposes and further dissemination of data to the Experimenters. All information on the formatting and data compression algorithms shall be provided to ESOC/RSOC.

Further processing of science data (e.g. calibration) and verification of correct functioning of experiments will not be performed by the RMOC and is considered to be fully a PI responsibility.

6.6.2. Other Telemetry

All other telemetry packets (typically housekeeping and diagnostic packets, telecommand acceptance, execution reports, event messages and anomaly reports, memory dump packets, etc.) will be treated in the same way as science data, and will also be stored as raw data.

In addition to the above, the capability exists at the RMOC to process the above telemetry data in near-real time for spacecraft control purposes. The HK and event packets, including the traditional binary and analogue parameters and event messages, will be processed using e.g. calibration curves to convert them into engineering and/or functional parameter values needed to monitor the status of the spacecraft subsystems and payload and to recover anomalies, if any. Special telemetry packets like diagnostic, command acceptance and execution reports, memory dump packets, will also be processed to carry out additional functions like command verification, performance assessment and trouble shooting and on-board software maintenance as required.

6.6.3. Auxiliary Data

Auxiliary data provided to PIs will comprise data not contained in the telemetry data, to enable PIs to fully analyse the science data. The auxiliary data will be correlated with respect to UTC and will be available under subject headings. It is foreseen to include:

- spacecraft ephemeris with respect to Sun and Earth, planet (at swing-by), asteroid (at fly-by) and with respect to comet (starting before detection);
- navigation products (e.g. comet shape model);
- spacecraft attitude prediction/reconstitution;
- command history data;
- time relation history (OBT/UTC);
- mission planning information.

Auxiliary data will be provided in a format and within coordinate systems to be jointly defined between ESA and the PIs through the relevant SWT. Auxiliary data will be stored in a similar way as science data.

6.6.4. Data Access / Command Request Handling

6.6.4.1. Data Access via DDS

During the entire mission a Data Disposition System (DDS) at ESOC allows for quick access to the most recent data available over communication lines on a call-up basis. The data will include telemetry and auxiliary data, as well as related catalogues.

Telemetry data (spacecraft and payload) are provided as raw data, i.e. time-stamped packets individually stored on logical files according to Application ID (Process Identifier and Data Type).

Auxiliary data generated by the ESOC/RMOC will contain information needed to assist in processing and analysing the science data, and also to support the mission planning and command request generation. The data may be stored on different files according to their nature.

The DDS catalogues will contain a full record of all data sets available on the DDS and the time period to which each data set pertains.

The DDS is a near real-time processing system which provides data access on a demand-driven basis, i.e. the PIs or delegated representatives are responsible for respective data requests. The data/message transmission will be via file transfer only.

DDS data access for PIs is either possible at the ESOC/RMOC or from a remote location. Taking into account line capacity and computer resource limitations, only a small amount of data can be transmitted via a communication line. For the same reasons access to the data held on the DDS is limited to the PIs, among which a confidentiality agreement (TBD) will apply. The complete data set is distributed to each PI on a raw data medium (see below).

File transfer requires network functions and protocols to be compatible with FTP (TCP/IP). The PIs are responsible for providing the required terminals or work stations at the remote host site, and the leasing/rental of public lines.

DDS Interfaces will be governed by the Data Disposition Interface Document (DDID). This document will be issued and agreed with all PIs. It will be put under configuration control as ESOC's formal delivery commitment. The DDID will describe the formatting of delivered data down to the necessary level of detail to enable users to retrieve science data and any required housekeeping or auxiliary data.

As the DDS is a multi-project software and is the only interface between RMOC and the Pis for data access, a DDS status (including listing the SPRs status) will be distributed regularly by the RMOC to the Pis during the whole mission preparation phase and during the mission.
Access to the DDS before launch will be provided regularly to the Pis, such as interface tests and operational validation can be achieved and maintained.

It should be noted that the DDS will be part of the pre-launch freeze, occurring at about L-4 weeks. From that moment until end of freeze (normally occurring at the end of LEOP), no changes to the software nor to the configuration will be allowed unless specifically authorised by the ESOC Rosetta Configuration Control Board.

For reasons of safety of the launch and LEOP operations, all non-essential computer systems will be disconnected and/or disabled from L-1 3 days until end of LEOP (nominally L+3 days). The DDS will therefore not be available for the Pis during this disconnection period.

6.6.4.2. Command Request Handling

In addition to the data access capability the DDS allows for transfer of consolidated command requests from the RSOC to the RMOC as inputs to the mission planning system during near-comet operations. The DDS will support approval, authentication, and authorisation of command requests. After validation the ESOC/RMOC will incorporate the command requests into the mission planning system which generates the final command schedule for uplink to the spacecraft. This interface will be governed by the Command Request Interface Document (CRID).

6.6.4.3. Critical Payload Operations (Category 1)

A Principal Investigator Support Area (PISA) will be provided at ESOC to accommodate PI provided EGSE to be used during commissioning and for special campaigns during the mission (e.g. asteroid fly-by, payload re-activation before comet approach, Lander delivery and relay). The PISA will enable data access and commanding capabilities, as well as communication with remote locations.

At the PI Support Area an interface with the DDS (identical to the remote interface) will be available to support both the telemetry delivery services to the experiment EGSEs and special command requests from PIs to the ESOC/RMOC.

6.6.5. Raw Data Long Term Archiving

Raw telemetry and auxiliary data will be archived by ESOC throughout all post launch mission phases. ESOC will keep the data and related retrieval service available until one year following the end of the mission. The archive medium will be kept off-line. A table of content of the archive will be available in form of a catalogue, however, no processing, data selection or other value-added services will be provided.

Retrieval from this archive will require 10-20 days and should present an identical data format as described above, i.e. copies of particular RDMs in the archive will be made. Requests for retrieval will require authorisation from ESA and should identify start/stop of pertinent time periods. This interface will be governed by the Data Disposition Interface Document (DDID).

6.6.6. Data Delivery Formats

Each data delivery request to the DDS will result in a transfer of a block of data containing three main areas:

- an acknowledgement, including request details and status
- a catalogue entry giving identification details of the requested data actually supplied (e.g. experiment, date, time)
- the requested data itself.

A simple packaging within Standard Formatted Data Units (SFDUs) will be applied, following a recommendation of the Consultative Committee for Space Data Systems (CCSDS). Apart from providing a convenient mechanism for handling the variable length of requested data, this standard will also provide administrative support for description of application data. Both the formatting of data delivered through the DDS and for data delivered on RDMs will apply a similar SFDU packaging scheme.

6.7. TESTING, TRAINING AND SIMULATIONS

The ground system test and validation activities begin around 2 years before launch. Activities will be mostly performed as part of the ESOC ground segment System Operations Validation (SOV) programme, and will include tests involving the payload as delineated in the following sections.

After the launch delay which introduced a 1-year period in which changes had to be introduced both on the spacecraft and on the ground segment, the system test plan was revised to identify tests to be repeated and possibly new tests to be executed to re-validate the ground segment system.

All tests carried out as part of the re-validation activities are identified in this document by additional paragraphs in italics under each of the original sections. Note that wherever the text has been left unchanged it means that the test will not be repeated for the new launch.

6.7.1. Satellite Interface Tests

The purpose of the Satellite Interface Tests (SITs) is to test and validate the external interfaces to the satellite and the basic TM and TC database definition. They are performed with the actual satellite linked to the RMOC via a communications network for TM, TC and voice connections.

The RMOC mission control software will be validated as far as possible early in the programme, with the aid of a dedicated spacecraft software simulator, using telemetry tapes or equivalent generated during satellite check-out tests.

The PIs shall support the satellite interface tests outlined below through preparation of related inputs, review of test plans and procedures, and if required, through actual participation in the tests itself.

6.7.1.1. Mission Sequence Test

To verify the feasibility of selected mission scenarios a Mission Sequence Test (MST) will be performed as part of the Satellite Interface Tests. On the basis of a mission scenario for

Asteroid Fly-by

Near Comet

Lander Delivery and Relay

each covering representative spacecraft and payload operations for a typical mission slice, time-tag command sequences will be defined for the payload and the spacecraft sub-systems, loaded on-board and executed in conjunction with typical ground station pass activities. The MST should be performed as soon as possible in the overall project schedule, as part of the spacecraft/payload functional tests, and/or be conducted during integrated satellite tests in thermal vacuum under the responsibility of the project. The duration of the MST will be approximately one day each).

6.7.1.2. System Validation Tests

A series of System Validation Tests (SVT) will be performed with the satellite, starting at around L-18 months (SVT0), L-10 months (SVT1) and L-4 months (SVT2), with a duration of about two weeks for SVT1 and one week for SVT2. SVT0 will extend over a longer time period and mainly acquire satellite telemetry to verify databases and to perform some basic commanding, SVT1 emphasises 'software' validation activities which include all mission control software facilities and databases. SVT2 is intended for re-validation of outstanding software facilities as well as for exercising and validating FOP sequences with the actual spacecraft.

Following the postponement of the Launch from 2003 to 2004, an SVT-3 will be conducted in 2 parts in September / October 2003, with a duration of 3 days each. The results will be presented at the GSRR2. The purpose of SVT-3 is to revalidate any change in the space-ground interfaces and re-validate procedures which have been modified accordingly.

6.7.2. Network Tests

A network test will be carried out on system level to validate the addressing and routing scheme of the general purpose ground communication network, in order to demonstrate that the required connectivity is provided as required. Furthermore, the network performance will be tested to ensure, that the specified bandwidth requirements are met.

The system network test will be carried out at around L-8 months, and its successful completion is a pre-requisite for the DDS Interface Test and the RSOC test activities to follow prior to launch.

6.7.3. Data Disposition System (DDS) Interface Test

At around L-6 months the Data Disposition System (DDS) interface to the remote PIs will be tested to demonstrate compatibility in terms of physical/logical connectivity and application interfaces (file request/ transfer mechanisms, command request capability). This test may be performed applying an 'operational' scenario with multiple users, and may include measurements of the turn-around times. Note that the DDS interfaces will have to be tested both in the remote configuration and with the payload support systems installed at the OCC in the configuration required for category 1 critical operations (see section 6.4.3 above).

A DDS load test, i.e. with the participation of all PIs simultaneously, will be repeated as part of the re-validation of DDS interfaces after the launch delay.

6.7.4. RMOC/RSOC Interface Test

The objective of the RMOC/RSOC Interface Test is to verify the interface functions and procedures required to cope with the duly provision, incorporation, modification and freezing of a consolidated command request schedule, ready for subsequent up-link to the spacecraft. Furthermore, all operational interfaces defined in the Command Request Interface Document (CRID) and the RMOC/RSOC Implementation Agreement Document will be exercised.

The RMOC/RSOC interface test will be repeated as part of the re-validation exercise after the launch delay.

6.7.5. NASA/DSN Interface Tests

The NASA/DSN Interface test will cover all interfaces and functions required to schedule the DSN support for Rosetta. The NASA/DSN Interface Test will be conducted in the L-8 to L-5 months time frame to verify compatibility of the required formats, communication interfaces (telex, fax, e-mail, file transfer), the physical and functional interface, and the required turn-around times.

Confidence SLE testing will be repeated with DSS-21 and all the relevant DSN stations in preparation for the new launch.

6.7.6. Training and Simulations

Pre-launch operations support will start approximately 6 months before the launch and covers the period from delivery of the spacecraft to the launch site until L-8 hrs in the launch countdown sequence. During this period the Rosetta Mission Operations Centre (RMOC) at ESOC performs its final simulation programme including the validation of the Flight Operations Plan (FOP) and the mission control system. Principal Investigator (PI) or appropriate experiment specialist participation is required for the simulations related to the first experiment switch-on, and other category 1 critical operations (see section 6.4.3 above).

Since most critical mission phases like planet and asteroids fly-bys, comet encounter, Lander delivery will take place as much as ten years following launch, a training and simulation programme will also be set-up and conducted prior to each important post launch mission phase.

A new Simulations Campaign will be carried out as part of the new launch preparation activities.

6.8. RESPONSIBILITIES FOR THE ROSETTA LANDER NAVIGATION

The delivery and relay phase of the Rosetta Lander constitutes a major part of the international Rosetta mission. Analytical efforts are required already well before the launch of the Rosetta spacecraft, in order to establish and demonstrate a feasible separation, descent and landing strategy commensurate with the mission baseline in terms of both on-board and ground resources and constraints. Post launch, i.e. several months before the near comet phase and Lander delivery, the established strategy will be refined based on close comet observations performed by the spacecraft Navigation Camera (NAVCAM), and the Orbiter payload, most notably the OSIRIS camera.

ESA Responsibilities

- Overall mission design and operations implementation throughout all mission phases up to perihelion;
- Perform Mission Analysis / Flight Dynamics studies including, e.g. parametric analysis of Lander delivery scenarios;
- Definition of S/C and ground constraints on the Lander cruise, delivery and relay operations;
- Definition and maintenance of an end-to-end SSP delivery strategy;
- Integration of the ESA System Simulator, comprising a Spacecraft-, Lander - and Cometary environment simulator;
- Conduct Training and Simulations Programme related to Lander delivery;
- Mission operations implementation according to the FOP, based on inputs from Orbiter and Lander User Manuals;
- Provision and maintenance of engineering models of the comet nucleus and its environment for mission implementation purposes;
- Provision of spacecraft telemetry and auxiliary data via the DDS;
- Provision of Cometary images and auxiliary information for landing-site selection.

Lander Team Responsibilities

- Definition of requirements and constraints for the Lander delivery and relay within overall mission baseline;
- Provision of Lander interface design parameters;
- Conductance of independent parametric analysis of Lander delivery scenarios for agreement and incorporation into the overall mission baseline;
- Support of ESA system simulator with manpower and Lander software simulator;
- Definition of the Lander and payload operations through the Science Operations Working Group (SOWG);

- Provision of hardware/software, expertise and authority at ESOC to support critical Lander operations, in particular Lander delivery and relay;
- Lander landing site selection within mission constraints;
- Lander inputs to the final go/no-go for Lander delivery;
- Lander operations through the RMOC/RSOC;

Science Working Team (SWT) Responsibilities

- Definition of overall scientific objectives;
- Definition of Baseline Science Plan(s) for Commissioning, Asteroid Fly-bys, Near comet phase;
- Comet observations (ground based or from space);
- Provision and maintenance of scientific comet models (e.g. nucleus, coma, outgassing rate, etc.);
- Prioritisation of Rosetta payload operations (Orbiter and Lander);

Pre-Launch Implementation: During Phase B, the activities are mainly devoted to the definition of an Lander delivery strategy, whereby an independent checking of Lander delivery scenarios, e.g. by the Lander Team with independent provided tools, expertise and resources, is considered to be essential. This activity has to be concluded by the spacecraft System Design Review (SDR) latest.

Taking into account a frozen spacecraft design, further iteration within the existing mission constraints will be performed in Phase C/D. These iterations will cover Lander system and payload operations, together with appropriate simulators leading to an agreed Flight Operations Plan (FOP).

Post Launch Implementation: After the comet rendez-vous manoeuvre and subsequent comet detection, the separation, descent and landing strategy will be confirmed. Updates of the comet model will become gradually available during the global mapping phase and close observation phase when Cometary parameters are determined within the framework of the near-comet navigation. The global mapping phase will lead to the selection of five potential landing sites. In the subsequent close observation phase Lander check-out activities will be performed and the final landing site will be selected. A few days prior to Lander delivery the detailed orbit manoeuvre implementation will be optimised, the final delivery timeline uplinked and loaded on-board, and the go/no-go decision for the Lander delivery made.

From comet rendez-vous onwards, a joint team lead by ESA will be established at ESOC. It will be staffed with members from ESA and the Lander Team and its mandate will be to agree on the detailed Lander delivery timeline.