MODULUS – Ptolemy

Ptolemy Experiment Flight Operation Plan for Cruise

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CHANGE RECORD

DATE	CHANGE DETAILS	ISSUE
14 July 2004	Document created	1.0
16 July 2004	Document modified following QM tests	1.1
22 April 2005	Update document after successful completion of commissioning; includes revision of plans for Passive and Active checkouts, and outline plans for post-hibernation operations	2.0
29 April 2005	Addition of missing TC – Begin extended AFT	2.1

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1 Introduction

1.1 Purpose

This document defines inputs for operation of the Lander instrument MODULUS-Ptolemy during cruise phases. This document describes qualitatively the operation modes and the general timeline, i.e. the sequence of activities during the commissioning phase of the ROSETTA mission. In addition, the requirements concerning common or sequential operations with respect to other Lander subsystems and/or experiments, are outlined.
The detailed calculation of the resource requirements (power) and the delivered data volume is given along with a comprehensive list of telecommands (where applicable) or the list of parameters that will enable the determination of the telecommands to be used during this phase of operations.
In addition, because Cruise phase operations are naturally a precursor to later mission operations, an outline of post-hibernation phase operations is provided in section 2.4 for contextual reasons.

1.2 References

	Reference	*Title*	*Issue*	*Date*
RD1	RO-LPT-OU-PL-3101	Ptolemy Operations Plan	2.4	06/04/2001
RD2	RO-LPT-RAL-TN-3403	Ptolemy Telecommand and Telemetry Definitions	5.1	26/02/2001
RD3	RO-LPT-OU-DP-3205	Ptolemy FM ADP	1.0	01/12/2000
RD4	RO-EST-RS-3001/EID A	Rosetta EID A	2.0	01/06/1999
RD5	RO-LPT-OU-PL-3108	Ptolemy Operations Plan Mode Description: Cruise Phase Mode	1.0	04/09/2002
RD6	RO-LPT-OU-PL-3112	Ptolemy Operations Plan: Initialisation sequences	1.0	13/07/2004
RD7	RO-LPT-OU-PL-3113	Ptolemy Operations Plan Mode Description: Extended AFT (Limited Cruise Phase)	1.0	05/07/2004
RD8	RO-LPT-OU-PL-3105	Ptolemy Operations Plan for Commissioning and Cruise	2.2	30/09/2002

1.3 Abbrev.

Abbrev.	Abbreviations
Ack	Acknowledgement
CDMS	(Lander) Command and Data Management System
CRC	Cyclic Redundancy Check
LS	Least Significant
MS	Most Significant
PUS	Packet Utilisation Standard
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand

2 Overview of Cruise Phase Operations

The Rosetta spacecraft was successfully launched on 2nd March 2004 at which point the mission event timeline became well defined. The precision in which the Rosetta spacecraft was placed on its interplanetary orbit has resulted in sufficient reserve fuel for it to be targeted for two asteroid flybys (Steins and Lutetia) on its 10 year journey to comet 67P Churyumov-Gerasimenko.

The commissioning phase started soon after launch and consisted of four separate blocks. During this phase Ptolemy modes were performed to check that the instrument had survived the rigours of launch and perform interactive tests with SD2 (the sample carousel), ÇIVA (microscope cameras) and COSAC (GC-MS).

The Rosetta Cruise Phase lasts for six years and consists of a checkout (passive or active) at approximately six month intervals. During this period there are also planet swingbys and two asteroid flybys. The mission timeline for the cruise phase is shown in the table below.

Event	Duration		Date
Earth Swingby #1	----	----	04-Mar-05
P/L Checkout 0	5d	Passive	27-Mar to 31-Mar-05
P/L Checkout 1	5d	Passive	03-Oct to 07-Oct-05
P/L Checkout 2	5d	Passive	06-Mar to 10-Mar-06
P/L Checkout 3	5d	Passive	28-Aug to 01-Sep-06
P/L Checkout 4	25d	Active	27-Nov to 21-Dec-06
Mars Swing-by	----	----	25-Feb-07
P/L Checkout 5	5d	Passive	21-May to 25-May-07
P/L Checkout 6	15d	Active	17-Sep to 01-Oct-07
Earth Swing-by #2	----	----	13-Nov-07
P/L Checkout 7	5d	Passive	07-Jan to 11-Jan-08
P/L Checkout 8	25d	Active	07-Jul to 31-Jul-08
Steins Flyby	----	----	05-Sep-08
P/L Checkout 9	5d	Passive	02-Feb to 06-Feb-09
P/L Checkout 10	15d	Active	21-Sep to 05-Oct-09
Earth Swing-by #3	----	----	13-Nov-09
P/L Checkout 11	5d	Passive	07-Dec to 11-Dec-09
P/L Checkout 12	25d	Active	10-May to 03-Jun-10
Lutetia Flyby	----	----	10-Jul-10
P/L Checkout 13	5d	Passive	6-Dec to 10-Dec-10

During passive checkouts there is no (or very limited) interaction between the spacecraft and ground control. Sequences are controlled by mission timeline events and the data returned at the completion of the checkout which can be several days later. Active checkouts are similar to the commissioning phase in which TCs can be sent from ground control and decision points acted upon during the checkout.

2.1 Passive Checkout Operations

Passive checkouts are performed offline; there is no interaction between ground control and the instruments during the checkout.

The operation sequence for Ptolemy during passive checkouts has the following constraints:

i) The time available for each instrument is 10-20 minutes
ii) There can be no decision points

2.1.1 Payload Checkout #0 (Passive)

During P/L checkout 0 (Passive), Ptolemy performed the following actions:

i) Ptolemy Extended AFT
ii) Check memory TCs
iii) Ptolemy Cruise phase mode (to check a sequence modification).

A constraint with the check memory TCs is that the results are returned within Ptolemy House Keeping (HK) packets where each Ptolemy HK can contain a maximum of three check memory TC results. During normal operation the CDMS collects one Ptolemy HK packet every four minutes. Therefore during payload Checkout #0 (Passive), after the Check Memory TCs, whilst waiting for the check memory results, the opportunity was taken to run Cruise phase mode in order to check a sequence modification.

2.1.2 Default sequence for Passive Payload Checkouts

The realisation that CDMS can be requested to collect 2 HK packets immediately means that the default sequence for Ptolemy during Passive checkouts can be optimised, by first performing the memory checks, then commanding CDMS to request the results, then running the Ptolemy Extended AFT.

The Ptolemy requirements for P/L checkout 1 (and hopefully all future P/L checkouts) are:

i) Check memory TCs
ii) CDMS to request 2 Ptolemy HK packets 5 times.
iii) Ptolemy Extended AFT

Note that two of the check memory TCs have been updated since issue 1.1 of this current document.

The TC timing sequence is shown in the table below.

TC	**Time (s)**	**Duration (s)**	**TM rate (bit/s)**		**Ave. power (W)**	***Task name* / Comments**
			Science	HK		
Switch on Ptolemy	TS1	15	0	8	4.0	*Switch on Ptolemy*
Copy memory PID	TS1+ 15	15	0	8	4.0	*Initialisation 1 Sequence*
Check memory PID	TS1 + 30	15	0	8	4.0	
Start Standby (Initialisation)	TS1 + 45	15	0	8	4.0	
Update Parameter - Flexible	TS1 + 60	15	0	8	4.0	
Safe mode	TS1 +75	15	0	8	4.0	
Check memory Post Launch Mode	TS1 + 90	15	0	8	4.0	*Check memory TCs*
Check memory Cruise Mode	TS1 + 105	15	0	8	4.0	
Check memory Instrument Check-out	TS1 + 120	15	0	8	4.0	
Check memory HTO Conditioning	TS1 + 135	15	0	8	4.0	
Check memory MTO Conditioning	TS1 + 150	15	0	8	4.0	
Check memory CASE Conditioning	TS1 + 165	15	0	8	4.0	
Check memory Survival Evaluation	TS1 + 180	15	0	8	4.0	
Check memory He Tank Rupture	TS1 + 195	15	0	8	4.0	
Check memory Dynamic Pre-operations	TS1 + 210	15	0	8	4.0	
Check memory Calibration	TS1 + 225	15	0	8	4.0	
Check memory Ice Core Anal. (HTO)	TS1 + 240	15	0	8	4.0	
Check memory Atmosphere Analysis	TS1 + 255	15	0	8	4.0	
Check memory Silicate Analysis	TS1 + 270	15	0	8	4.0	
Check memory Ice Core Anal.(MTO)	TS1 + 285	15	0	8	4.0	
Check memory Additional Science	TS1 + 300	15	0	8	4.0	
Check memory Op Limits (1)	TS1 + 315	15	0	8	4.0	
Check memory Ion Trap tables	TS1 + 330	15	0	8	4.0	
Check memory Extended AFT	TS1 + 345	15	0	8	4.0	
Check memory Patch3	TS1 + 360	15	0	8	4.0	
CDMS to request 2 Ptolemy Fast HK packets x5	TS1 + 375	60	0	8	4.0	*Wait to acquire HK packets*
Start Standby (Cruise Phase)	TS1 + 435	15	0	8	4.0	*Prepare for Cruise Phase Mode*
Update Parameter – Extended AFT	TS1 + 450	15	0	8	4.0	
Hazard Enable Cruise Phase	TS1 + 465	15	0	8	4.0	
Begin Extended AFT	TS1 + 480	360	60	8	6.2	*Extended AFT* 8 Science packets generated
Safe mode	TS1 + 840	15	0	8	4.0	*Safe mode*
Switch off Ptolemy	TS1 + 855					

2.2 Active Checkout Operations

There are a total of five active checkouts before the beginning of the Rosetta hibernation phase. The availability of decision points during an active checkout enables a complete checkout of the instrument including the mass spectrometer.

The overall aim is to be able to operate the Ptolemy Mass Spectrometer Checkout mode during the final active checkout before hibernation (P/L checkout 12). However, detailed sequence for this mode is still being tested on the Ptolemy Qualification model. The main concern is determining the optimum operation of the mass spectrometer electron source to preserve its operational lifetime. In order to allow contingency it is preferable to first perform the mass spectrometer checkout mode during an early Active checkout. This would allow time for software modification and a repeat test during the intervening active checkouts if necessary. A provisional schedule is shown below.

Event	Duration	Mode	Date	Proposed Ptolemy activity	Notes
P/L Checkout 4	25d	Active AC1	27.11. – 21.12.2006	Check Memory Cruise Phase Mode Mass Spectrometer Checkout	Plus support COSAC/SD2 test? (TBC)
P/L Checkout 6	15d	Active AC2	17.09. – 01.10.2007	Check Memory Cruise Phase Mode Post Launch mode	i.e. trapped gas test, plus contingency for Ptolemy Mass Spectrometer test
P/L Checkout 8	25d	Active AC3	07.07. – 31.07.2008	Check Memory Cruise Phase Mode Sequences upload	Contingency for Ptolemy Mass Spectrometer test
P/L Checkout 10	15d	Active AC4	21.09. – 05.10.2009	Check Memory Cruise Phase Mode Mass Spectrometer Checkout	
P/L Checkout 12	25d	Active AC5	10.05. – 03.06.2010	Check Memory Cruise Phase Mode Mass Spectrometer Checkout	Final MS run-through, with no decision points

The actions for Ptolemy active checkouts will be:

i) If necessary, load any software patches and mode sequence tables
ii) Memory check TCs
iii) Ptolemy Cruise phase mode
iv) Other operational modes (to be defined)

It is envisaged that as a default, the memory check TCs and Cruise phase mode will always be performed. The TC sequence for this is shown below. As it is likely that each active checkout will be different, a separate document will be produced for each active checkout as required.

Ptolemy active checkout default TC sequence

TC	**Time (s)**	**Duration (s)**	**TM rate (bit/s)**		**Ave. power (W)**	***Task name* / Comments**
			Science	HK		
Switch on Ptolemy	TS1	15	0	8	4.0	*Switch on Ptolemy*
Copy memory PID	TS1+ 15	15	0	8	4.0	*Initialisation 1 Sequence*
Check memory PID	TS1 + 30	15	0	8	4.0	
Start Standby (Initialisation)	TS1 + 45	15	0	8	4.0	
Update Parameter - Flexible	TS1 + 60	15	0	8	4.0	
Safe mode	TS1 +75	15	0	8	4.0	
Check memory Post Launch Mode	TS1 + 90	15	0	8	4.0	*Check memory TCs*
Check memory Cruise Mode	TS1 + 105	15	0	8	4.0	
Check memory Instrument Check-out	TS1 + 120	15	0	8	4.0	
Check memory HTO Conditioning	TS1 + 135	15	0	8	4.0	
Check memory MTO Conditioning	TS1 + 150	15	0	8	4.0	
Check memory CASE Conditioning	TS1 + 165	15	0	8	4.0	
Check memory Survival Evaluation	TS1 + 180	15	0	8	4.0	
Check memory He Tank Rupture	TS1 + 195	15	0	8	4.0	
Check memory Dynamic Pre-operations	TS1 + 210	15	0	8	4.0	
Check memory Calibration	TS1 + 225	15	0	8	4.0	
Check memory Ice Core Anal. (HTO)	TS1 + 240	15	0	8	4.0	
Check memory Atmosphere Analysis	TS1 + 255	15	0	8	4.0	
Check memory Silicate Analysis	TS1 + 270	15	0	8	4.0	
Check memory Ice Core Anal.(MTO)	TS1 + 285	15	0	8	4.0	
Check memory Additional Science	TS1 + 300	15	0	8	4.0	
Check memory Op Limits (1)	TS1 + 315	15	0	8	4.0	
Check memory Ion Trap tables	TS1 + 330	15	0	8	4.0	
Check memory Extended AFT	TS1 + 345	15	0	8	4.0	
Check memory Patch3	TS1 + 360	15	0	8	4.0	
CDMS to request 2 Ptolemy Fast HK packets x5	TS1 + 375	60	0	8	4.0	*Wait to acquire HK packets*
Start Standby (Cruise Phase)	TS1 + 435	15	0	8	4.0	*Prepare for Cruise Phase Mode*
Update Parameter – RF word	TS1 + 450	15	0	8	4.0	
Hazard Enable Cruise Phase	TS1 + 465	15	0	8	4.0	
Begin Cruise Phase Mode	TS1 + 480	840	20	8	10.3	*Cruise Phase Mode* *8 Science packets generated*
Safe mode	TS1 + 1320	520	0	8	4.0	*Safe mode*
Switch off Ptolemy	TS1 + 1840	0	0	0		*Wait for 2HK packets before switching off.*

The following sequence is used to load new sequences and patches onto Ptolemy EEPROM

Load New Sequence

TC	**Time (s)**	**Duration (s)**	**TM rate (bit/s)**		**Ave. power (W)**	***Task name* / Comments**
			Science	HK		
Switch on Ptolemy	TS3	15	0	8	4.0	*Switch on Ptolemy*
Load memory TC (1)	TS3 + 15	15	0	8	4.0	*Load n memory TC's*
Load memory TC (2)	TS3 + 30	15	0	8	4.0	
:	:	:	0	8	4.0	
:	:	:	0	8	4.0	
:	:	:	0	8	4.0	

Load memory TC (n)	TS3 + n*15	15	0	8	4.0	
Check memory of new sequence	Tx	512	0	8		*Check memory loaded* Wait for check memory results
Switch off Ptolemy	Tx + 512	0				

Tx = TS3 + n*15 + 15, where n is the number of load memory TC's.

2.3 Swing-bys and Flybys

2.3.1 Swing-bys

The Rosetta spacecraft uses Swing-by events to gain momentum and achieve course changes on its journey towards the comet. During the Swing-by events the overriding priority is achieve the desired manoeuvres so that the spacecraft remains on course. However there are opportunities for instruments to perform scientific experiments, calibration sequences and/or upload software.

As Ptolemy requires gas samples there are no scientific experiments planned during the Swing-by events. The Earth Flyby events are a good opportunity to upload new mode sequences and any software patches. In which case these should be followed by the TC memory checks and Extended AFT (see 2.1 Passive Cruise Operations).

2.3.2 Flybys

There are two asteroid flybys, Lutetia and Steins, during the ten year cruise to the comet; this is a part of the Rosetta scientific objective. Ptolemy has no remote sensing capabilities at asteroids so its only mission requirement is for safe passage past the asteroids.

Ptolemy could use the asteroid flyby events to upload mode sequences and any software patches and further instrument characterisation provided this does not interfere with other instrument scientific constraints. If Ptolemy is switched on then it should be followed by the TC memory checks and Extended AFT (see 2.1 Passive Cruise Operations).

2.4 Post-hibernation operations

Operations to be undertaken after the spacecraft awakes from hibernation are still TBC. However we outline here the Ptolemy operations that are necessary before touchdown on the comet surface, and we raise the possibility of recovering some of the lost Berenice science through the use of the Ptolemy CASE (Comet Atmosphere Sampling Experiment).

2.4.1 Health checks and dynamic pre-operations

After hibernation, and prior to Lander separation, it is necessary to run a full Ptolemy health check (including Cruise Phase Mode, Post-launch mode, Mass Spectrometer checkout) and also to run Dynamic pre-operations (open gas tank).

2.4.2 Comet Atmosphere Sampling Experiment (CASE)

The CASE study involves analysing volatiles evolved from the comet by trapping them onto a material contained in a Ptolemy oven.

In detail, the oven would first be heated to clean it, then a "blank" experiment would be performed – i.e. we would run the CASE sequence without any comet gas trapped on the oven. At the end of the "blank" run the oven would be clean, and it would be left to collect comet atmosphere for some time (weeks or months). Then we would repeat the CASE experiment run would be repeated to analyse the gases trapped on the adsorbent material.

We wish to explore (with the Lander, orbiter…) the possibility of running the CASE experiment at an appropriate point (perhaps during the Global Mapping phase?). As a pre-requisite to the CASE experiment, dynamic pre-operations must have been performed and its success verified.

2.5 Summary of proposed Ptolemy operations in Cruise and Post-hibernation phases

Proposed Ptolemy operations are summarised in the table below. Note that post-hibernation operations are still very much TBC.

Event	Duration	Mode	Date	Proposed Ptolemy activity	Notes
Earth Swing-by #1	-----	-----	04.03.2005	None	
P/L Checkout 0	5d	Passive PC1	27.03. – 31.03.2005	Extended AFT Cruise Phase mode Check Memory	(Extended AFT is also known as Limited Cruise Mode)
P/L Checkout 1	5d	Passive PC2	03.10. – 07.10.2005	Check Memory EAFT	Proposed default operations for Passive Checkout
P/L Checkout 2	5d	Passive PC3	06.03. – 10.03.2006	Check Memory EAFT	
P/L Checkout 3	5d	Passive PC4	28.08. – 01.09.2006	Check Memory EAFT	
P/L Checkout 4	25d	Active AC1	27.11. – 21.12.2006	Check Memory Cruise Phase Mode Mass Spectrometer Checkout	Plus support COSAC/SD2 test? (TBC)
Mars Swing-by	-----	-----	25.02.2007	None	
P/L Checkout 5	5d	Passive PC5	21.05. – 25.05.2007	Check Memory EAFT	
P/L Checkout 6	15d	Active AC2	17.09. – 01.10.2007	Check Memory Cruise Phase Mode Post Launch mode	i.e. trapped gas test, plus contingency for Ptolemy Mass Spectrometer test
Earth Swing-by #2	-----	-----	13.11.2007	TBC	Opportunity to upload sequences / patches
P/L Checkout 7	5d	Passive PC6	07.01. – 11.01.2008	Check Memory EAFT	
P/L Checkout 8	25d	Active AC3	07.07. – 31.07.2008	Check Memory Cruise Phase Mode Sequences upload	Contingency for Ptolemy Mass Spectrometer test
Steins Flyby	-----	-----	05.09.2008	TBC (TBC)	Opportunity to upload sequences / patches
P/L Checkout 9	5d	Passive PC7	02.02. – 06.02.2009	Check Memory EAFT	
P/L Checkout 10	15d	Active AC4	21.09. – 05.10.2009	Check Memory Cruise Phase Mode Mass Spectrometer Checkout	
Earth Swing-by #3	-----	-----	13.11.2009	None (TBC)	Opportunity to upload sequences / patches
P/L Checkout 11	5d	Passive PC8	07.12. – 11.12.2009	Check Memory EAFT	
P/L Checkout 12	25d	Active AC5	10.05. – 03.06.2010	Check Memory Cruise Phase Mode Mass Spectrometer Checkout	Final MS run-through, with no decision points
Lutetia Flyby	-----	-----	10.07.2010	None (TBC)	
P/L Checkout 13	5d	Passive PC9	06.12. – 10.12.2010	Check Memory EAFT	
RVM #1	-----	-----	23.01.2011	None	
Deep Space Hibernation			14.07.2011 22.01.2014	None	
Comet Approach			Jan-May 2014	TBC	Ideally, full instrument checkout: Cruise Phase Mode, Post-launch mode, Mass Spectrometer checkout

					Dynamic pre-operations (open gas tank)
RVM #2			May 2014	None	
Global Mapping / Pre-separation phase			Aug-Sep 2014	TBC	Dynamic pre-operations Ptolemy CASE blank run Ptolemy CASE experiment
Lander Delivery			Nov 2014	Primary Science; Extended mission	
Perihelion Passage			Aug 2015		

Items highlighted are still very much TBC

3 TC List

This section lists all of the TCs described in this document..

Begin Cruise Phase Mode

1F3C E203 0005 10C1 0300 3975

Begin Extended AFT

1F3C E205 0005 10C1 0300 9850

Check Memory PID

1F3C F001 0013 1006 0900 9802 0008 2364
0084 0008 246C 0090 0E64

Check Memory Post Launch Mode

1F3C F100 0025 1006 0900 9705 0005 1000
0100 0005 1200 0100 0005 1400 0100 0005
1600 0100 0005 1800 0020 C087

Check Memory Cruise Mode

1F3C F200 0025 1006 0900 9705 0005 2000
0060 0005 20C0 0060 0005 2180 0060 0005
2240 0060 0005 2300 004C 3848

Check Memory Instrument Checkout

1F3C F300 0025 1006 0900 9705 0005 3000
0100 0005 3200 0100 0005 3400 0100 0005
3600 0100 0005 3800 0100 EA43

Check Memory HTO Conditioning

1F3C F400 0025 1006 0900 9705 0005 4000
0100 0005 4200 0100 0005 4400 0100 0005
4600 0100 0005 4800 0100 3A21

Check Memory MTO Conditioning

1F3C F500 0025 1006 0900 9705 0005 5000
0100 0005 5200 0100 0005 5400 0100 0005
5600 0100 0005 5800 0100 ACFA

Check Memory CASE Conditioning

1F3C F600 0025 1006 0900 9705 0005 6000
0100 0005 6200 0100 0005 6400 0100 0005
6600 0100 0005 6800 0100 07B6

Check Memory Survival Evaluation

1F3C F700 0025 1006 0900 9705 0005 7000
0100 0005 7200 0100 0005 7400 0100 0005
7600 0100 0005 7800 0100 916D

Check Memory Helium Tank Rupture

1F3C	**F800**	**0025**	**1006**	**0900**	**9705**	**0005**	**8000**
0100	**0005**	**8200**	**0100**	**0005**	**8400**	**0100**	**0005**
8600	**0100**	**0005**	**8800**	**0100**	**B753**		

Check Memory Dynamic Pre-operations

1F3C	**F900**	**0025**	**1006**	**0900**	**9705**	**0005**	**9000**
0100	**0005**	**9200**	**0100**	**0005**	**9400**	**0100**	**0005**
9600	**0100**	**0005**	**9800**	**0100**	**2188**		

Check Memory Calibration

1F3C	**FA00**	**0025**	**1006**	**0900**	**9705**	**0005**	**A000**
0100	**0005**	**A200**	**0100**	**0005**	**A400**	**0100**	**0005**
A600	**0100**	**0005**	**A800**	**0100**	**8AC4**		

Check Memory Ice Core Analysis(HTO)

1F3C	**FB00**	**0025**	**1006**	**0900**	**9705**	**0005**	**B000**
0100	**0005**	**B200**	**0100**	**0005**	**B400**	**0100**	**0005**
B600	**0100**	**0005**	**B800**	**0100**	**1C1F**		

Check Memory Atmosphere Analysis
(NB this TC has changed since issue 1.1)

1F3C	**FC00**	**0025**	**1006**	**0900**	**9705**	**0005**	**C000**
0100	**0005**	**C200**	**0100**	**0005**	**C400**	**0100**	**0005**
C600	**0100**	**0005**	**C800**	**0100**	**CC7D**		

Check Memory Silicate Analysis

1F3C	**FD00**	**0025**	**1006**	**0900**	**9705**	**0005**	**D000**
0100	**0005**	**D200**	**0100**	**0005**	**D400**	**0100**	**0005**
D600	**0100**	**0005**	**D800**	**0100**	**5AA6**		

Check Memory Ice Core Analysis(MTO)

1F3C	**FE00**	**0025**	**1006**	**0900**	**9705**	**0005**	**E000**
0100	**0005**	**E200**	**0100**	**0005**	**E400**	**0100**	**0005**
E600	**0100**	**0005**	**E800**	**0100**	**F1EA**		

Check Memory Additional Science
(NB this TC has changed since issue 1.1)

1F3C	**FF00**	**0025**	**1006**	**0900**	**9705**	**0005**	**F000**
0100	**0005**	**F200**	**0100**	**0005**	**F400**	**0100**	**0005**
F600	**0100**	**0005**	**F800**	**0100**	**6731**		

Check Memory Ion Trap Tables
(NB this TC has changed since RD8)

1F3C	**F005**	**0025**	**1006**	**0900**	**9705**	**0004**	**0200**
0400	**0004**	**1200**	**0400**	**0004**	**2200**	**0400**	**0004**
3200	**0400**	**0004**	**4200**	**0400**	**9115**		

Check Memory Op Limits (1)

1F3C	**F006**	**0025**	**1006**	**0900**	**9705**	**0004**	**0000**
0048	**0004**	**1000**	**0048**	**0004**	**2000**	**0048**	**0004**
3000	**0048**	**0004**	**4000**	**0048**	**8741**		

Check Memory Op Limits (2)
(NB this TC has changed since RD8)

1F3C	**F007**	**0025**	**1006**	**0900**	**9705**	**0004**	**5000**
0048	**0004**	**6000**	**0048**	**0004**	**7000**	**0048**	**0004**
8000	**0048**	**0004**	**9000**	**0048**	**30FF**		

Check Memory Op Limits (3)
(NB this TC has changed since RD8)

1F3C	**F008**	**0025**	**1006**	**0900**	**9705**	**0004**	**A000**
0048	**0004**	**B000**	**0048**	**0004**	**C000**	**0048**	**0004**
D000	**0048**	**0004**	**E000**	**0048**	**889B**		

Check Memory Op Limits (4)

1F3C	**F009**	**000D**	**1006**	**0900**	**9701**	**0004**	**F000**
0048	**F07E**						

Check Memory Extended AFT

1F3C	**F201**	**001F**	**1006**	**0900**	**9704**	**0005**	**2400**
0080	**0005**	**2500**	**0080**	**0005**	**2600**	**0080**	**0005**
2700	**0034**	**8E94**					

Check Memory Patch3

1F3C	**F011**	**0019**	**1006**	**0900**	**9703**	**0007**	**0240**
0100	**0007**	**0440**	**0100**	**0007**	**0640**	**007B**	**04D6**

Copy Memory PID

1F3C	**F000**	**001B**	**10C0**	**0100**	**0002**	**0007**	**0000**
0008	**2364**	**0084**	**0007**	**0108**	**0008**	**246C**	**0084**
4CCD							

Hazard Enable (Cruise Phase)

1F3C	**E202**	**000B**	**10C2**	**0100**	**7FFF**	**FBFF**	**0000**
7945							

Parameter Update – Extended AFT

1F3C	**E204**	**000D**	**10C3**	**0100**	**1FEA**	**0002**	**0005**
2400	**856D**						

Parameter Update – Flexible Mode

1F3C	**F003**	**000B**	**10C3**	**0100**	**85DC**	**0001**	**0000**
6FE9							

Parameter Update – RF Word

1F3C E201 000B 10C3 0100 284E 0001 0900 A2E0

Safe Mode
1F3C F004 0005 10C1 FF00 C48F

Start Standby (Cruise Phase)
1F3C E200 000B 10C1 0000 0001 0000 0000 A744

Start Standby (Initialisation)
1F3C F002 000B 10C1 0000 0001 0000 0000 1DB7

4 Check Memory results

The expected results of the check memory TCs are shown below:

TC Name	Memory Address		Number of words (hex)	Expected Memory Checksum
	Page	Offset		
Check Memory PID	0008	2364	0084	0000
	0008	246C	0090	090F
Check Memory Post Launch	0005	1000	0100	0E00
	0005	1200	0100	BD7B
	0005	1400	0100	28CE
	0005	1600	0100	0200
	0005	1800	0020	5CED
Check Memory Cruise Phase	0005	2000	0060	AA93
	0005	20C0	0060	7A96
	0005	2180	0060	DD92
	0005	2240	0060	93FB
	0005	2300	004C	5A55
Check Memory Instrument Check-out	0005	3000	0100	03B2
	0005	3200	0100	0000
	0005	3400	0100	0000
	0005	3600	0100	0000
	0005	3800	0100	0000
Check Memory HTO Conditioning	0005	4000	0100	0000
	0005	4200	0100	0000
	0005	4400	0100	0000
	0005	4600	0100	0000
	0005	4800	0100	0000
Check Memory MTO Conditioning	0005	5000	0100	0000
	0005	5200	0100	0000
	0005	5400	0100	0000
	0005	5600	0100	0000
	0005	5800	0100	0000
Check Memory CASE Conditioning	0005	6000	0100	0000
	0005	6200	0100	0000
	0005	6400	0100	0000
	0005	6600	0100	0000
	0005	6800	0100	0000
Check Memory Survival Evaluation	0005	7000	0100	0000
	0005	7200	0100	0000
	0005	7400	0100	0000
	0005	7600	0100	0000
	0005	7800	0100	0000
Check Memory Helium Tank Rupture	0005	8000	0100	32FD
	0005	8200	0100	0000
	0005	8400	0100	0000
	0005	8600	0100	0000
	0005	8800	0100	0000
Check Memory Dynamic Pre-operations	0005	9000	0100	1792
	0005	9200	0100	0000
	0005	9400	0100	0000
	0005	9600	0100	0000
	0005	9800	0100	0000
Check Memory Calibration	0005	A000	0100	1262
	0005	A200	0100	0000
	0005	A400	0100	0000
	0005	A600	0100	0000

	0005	A800	0100	0000
Check Memory Ice Core Analysis (HTO)	0005	B000	0100	F047
	0005	B200	0100	0000
	0005	B400	0100	0000
	0005	B600	0100	0000
	0005	B800	0100	0000
Check Memory Atmosphere Analysis	0005	C000	0100	60E0
	0005	C200	0100	0000
	0005	C400	0100	0000
	0005	C600	0100	0000
	0005	C800	0100	0000
Check Memory Silicate Analysis	0005	D000	0100	0000
	0005	D200	0100	0000
	0005	D400	0100	0000
	0005	D600	0100	0000
	0005	D800	0100	0000
Check Memory Ice Core Analysis (MTO)	0005	E000	0100	0000
	0005	E200	0100	0000
	0005	E400	0100	0000
	0005	E600	0100	0000
	0005	E800	0100	0000
Check Memory Additional Science	0005	F000	0100	0000
	0005	F200	0100	0000
	0005	F400	0100	0000
	0005	F600	0100	0000
	0005	F800	0100	0000
Check Memory Ion Trap Tables	0004	0200	0400	C849
	0004	1200	0400	C849
	0004	2200	0400	C849
	0004	3200	0400	C849
	0004	4200	0400	C849
Check Memory Op Limits (1)	0004	0000	0048	5941
	0004	1000	0048	2AED
	0004	2000	0048	0B45
	0004	3000	0048	B8DB
	0004	4000	0048	1562
Check Memory Op Limits (2)	0004	5000	0048	DDB0 or C2E9?
	0004	6000	0048	DDB0 or C2E9?
	0004	7000	0048	DDB0 or C2E9?
	0004	8000	0048	DDB0 or C2E9?
	0004	9000	0048	DDB0 or C2E9?
Check Memory Op Limits (3)	0004	A000	0048	DDB0 or C2E9?
	0004	B000	0048	DDB0 or C2E9?
	0004	C000	0048	DDB0 or C2E9?
	0004	D000	0048	DDB0 or C2E9?
	0004	E000	0048	DDB0 or C2E9?
Check Memory Op Limits (4)	0004	F000	0048	DDB0 or C2E9?
Check memory Extended AFT	0005	2400	0080	2D1B
	0005	2500	0080	AC12
	0005	2600	0080	23C6
	0005	2700	0034	9895
Check Memory Patch 3	0007	0240	0100	46E2
	0007	0440	0100	0D42
	0007	0640	007B	E9A8

5 Operational modes description

5.1 Overview of Ptolemy Operational Modes

The Ptolemy instrument is designed to operate by selection of modes initiated by telecommand from the lander CDMS and then function autonomously.

Whenever power to Ptolemy is turned on, Ptolemy will enter **Safe Mode** and await further commands from the lander CDMS. Ptolemy has two methods of receiving telecommands:

1) by receiving a direct TC from the CDMS. These are stored by the CDMS and are transmitted at a definite time after the start of a CDMS Application Mode Descriptor Table
2) by requesting the next TC from the CDMS stored TC table

From **Safe Mode**, the only mode that can be entered (by command from the lander CDMS) is **Standby Mode**. With Ptolemy in **Standby Mode**, the lander CDMS can command Ptolemy to enable any hazardous commands that are required for the intended subsequent **Science mode**, then the CDMS can send the start **Science Mode** command.

At the end of a **Science Mode** sequence, Ptolemy will autonomously return to **Standby Mode**, where all hazardous commands are automatically disabled. If Ptolemy has been set-up to request TC's then Ptolemy will request the next TC from the CDMS, otherwise Ptolemy will remain in **Standby Mode** until the next TC is sent by the CDMS or it is switched off.

An overview of Ptolemy Modes, and permitted Mode transitions, is shown in Figure 1. There are 4 general types of mode:

- Ptolemy Off
- Safe Mode
- Standby Mode
- Science Modes – of which there are 15 sub-types. Only 1 sub-types will is considered in the present document, this being:
  - Cruise Phase Mode

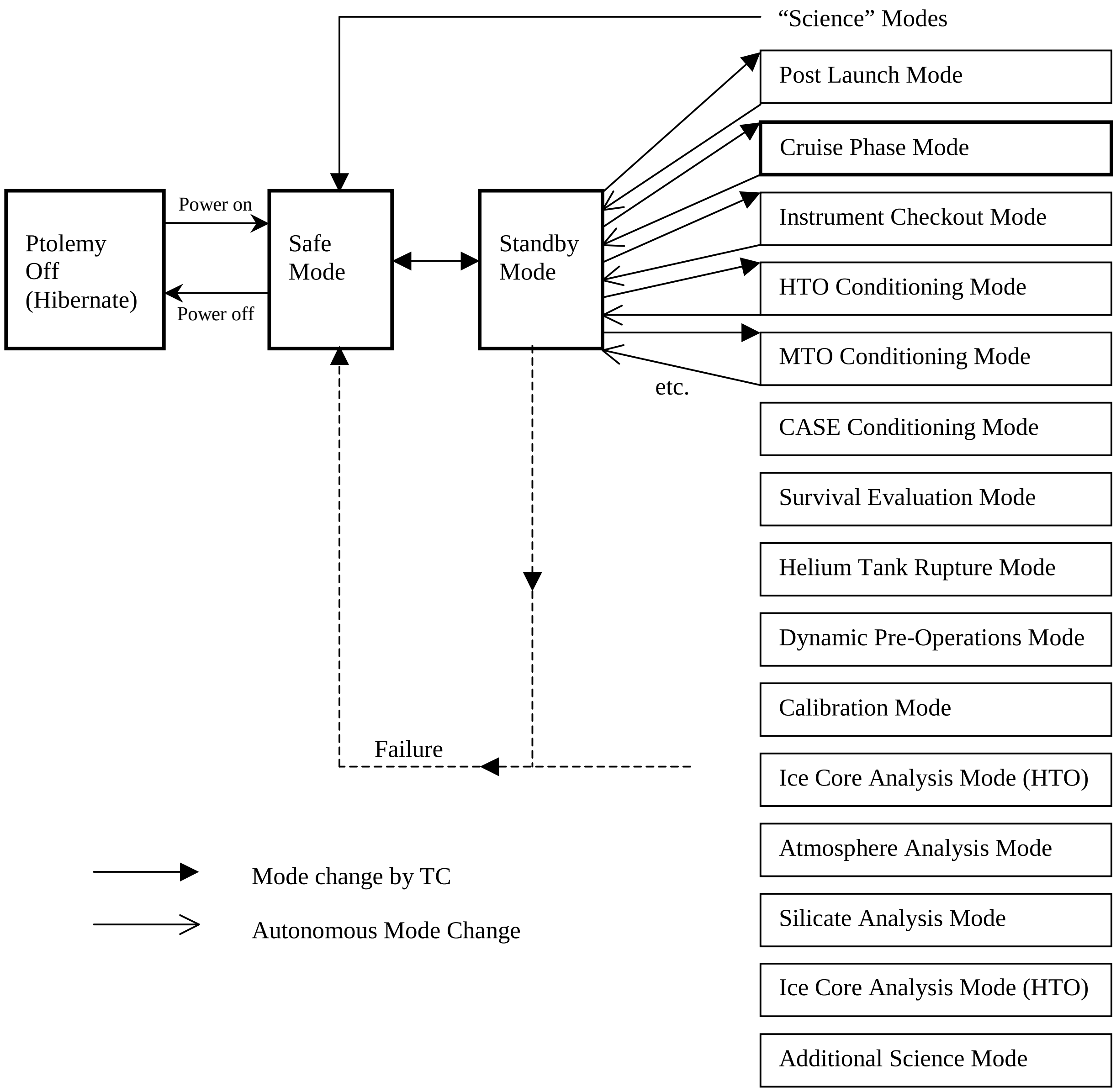

Figure 1. Schematic of the Ptolemy operational modes and permitted mode transitions.

When powered up Ptolemy enters Safe Mode, in which all chemistry components are off and all hazardous commands are disabled. Ptolemy can be moved between Safe Mode and Standby Mode by TC from the lander CDMS. In Standby Mode, hazardous commands can be enabled and parameters can be updated. From Standby Mode, Ptolemy can be commanded to run any Science Mode, in which a sequence of science commands is autonomously executed. On completion of the science mode, Ptolemy reverts to Standby Mode.

5.2 Mode Descriptions

5.2.1 Ptolemy Off / Hibernate Mode

The default Mode for Ptolemy is Off.

5.2.2 Safe Mode

Whenever power to Ptolemy is turned on, Ptolemy will enter **Safe Mode.** All hazardous commands are disabled and all chemistry components are switched off. Ptolemy then awaits further commands from the lander CDMS. In **Safe Mode**, the Ptolemy command store can be modified. From **Safe Mode**, the only mode that can be entered (by command from the lander CDMS) is **Standby Mode**. The TC will also specify the start address for the science software.

5.2.3 Standby Mode

With Ptolemy in **Standby Mode**, the lander CDMS can command Ptolemy to enable any hazardous commands that are required for the intended subsequent mode, and can update any parameters in Ptolemy RAM. From **Standby Mode**, Ptolemy can then be commanded to run any of the **Science Modes**.

5.2.4 Science Modes

There are a total of 15 different science modes. When Ptolemy enters a Science Mode, it performs a series of actions described in a science command sequence, which is stored in a look-up table in EEPROM. The exact duration and power requirement of a mode will depend on local conditions. If Ptolemy encounters an invalid science command, or if Ptolemy detects that any of the science components are operating beyond their safe limits, then Ptolemy will autonomously return to **Safe Mode**. Whilst Ptolemy is running a science mode, it can be commanded at any time by the lander CDMS to return to **Safe Mode**. All other TCs are rejected by Ptolemy whilst running a science mode. At the end of a Science Mode sequence, Ptolemy will autonomously return to **Standby Mode**.

Only 2 Science Modes are used during Commissioning and Cruise Phases. These are Cruise Phase mode and Extended AFT (Limited Cruise Phase mode)

Note:

The Cruise Test Mode checkout can be run at most points during cruise, and provides useful data on instrument status.

Ptolemy has no specific mission requirements for asteroid or planet flybys, and may be left in hibernation (Off) mode.

6 Telecommands

6.1 Telecommand description

Ptolemy receives TC messages from the lander CDMS as a serial data stream containing an integral number of 16 bit words up to a maximum of 32 words.
The Ptolemy TC messages have a format that complies with the PUS standards for Orbiter instruments as described in RD4 Section 2.7.2.2. However, these messages are not treated as packets by the Orbiter DMS or the Lander CDMS but as data fields private to Ptolemy, to be passed on without checks or processing.
The first 5 words of a Ptolemy TC message (0 to 4) contain header information and identify the command type and subtype. The last word holds a CRC over the words in the packet which is calculated in the same way as for the PUS packets for Rosetta. The remaining words (5 to n-2 where the message is n words long) may be allocated to command parameters. A command may have from 0 to 26 parameters.

Command	**Type**	**Sub-type No.**	**params**	**remarks**
Load Memory	6	2	5-56	1-6 load memory blocks
Check Memory	6	9	4-25	1-8 memory check blocks
Copy Memory	192	1	6-26	1-5 copy memory blocks
Standby	193	0	3	page:offset:stored TC enb/dis
Cruise Phase	193	3	0	
Safe Mode	193	255	0	
Hazardous function	194	1	6	Hazard enable masks
Parameter update	195	1	4-26	Offset, length, parameters

See also RD2.

6.1.1 Load_memory – Patch one or more blocks of memory

This TC allows patching of RAM or EEPROM

Summary	Hex	Decimal
Command type	**06**	**6**
Command subtype	**02**	**2**
Number of parameters	**05-19**	**5-26**

Word	Description	Contents	Comment
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**N*2-7**	Total length in bytes-7
03	Administration (MS byte) Type (LS byte)	**1X06H**	X=1 -> acknowledgement; X=0 -> no ack, 06 – Ptolemy Mode Selection
04	Subtype (MS byte) Pad byte (LS byte)	**0200H**	02 Load Memory 00 Not used
05	Memory ID (MS byte) Block count (LS byte)	**NNMMH**	NN Memory ID 96H – PROM 97H – EEPROM 98H – RAM MM Block count (1-6)
06	Memory Page	**0004H – 000FH**	Physical page for 1st patch (EEPROM/RAM only)
07	Patch offset	**0000H –FFFEH**	Offset into 1st page for patch
08	Patch length	**0000H – 0016H**	Number of words in 1st patch
09	Patch data	**0000H – FFFFH**	0: Exec. Stored TCs disabled 1: Exec. Stored TCs enabled
10-n-2	Stored TC enbl/disbl	**0000H – 0001H**	Data of 1st patch may continue. Further blocks also allowed to max of 6.
n-1	Checksum	**CRC over 0 – (n-2)**	Checksum for TC as used in PUS for Rosetta

6.1.2 Check_memory – Perform checksum over one or more blocks of memory

This TC performs a simple checksum (sum of words in block, discarding carrys) over the specified blocks of memory

Summary	**Hex**	**Decimal**
Command type	**06**	**6**
Command subtype	**09**	**9**
Number of parameters	**04-19**	**4-26**

Word	**Description**	**Contents**	**Comment**
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**N*2-7**	Total length in bytes-7
03	Administration (MS byte) Type (LS byte)	**1X06H**	X=1 -> acknowledgement; X=0 -> no ack, 06 – Ptolemy Mode Selection
04	Subtype (MS byte) Pad byte (LS byte)	**0900H**	09 Check Memory 00 Not used
05	Memory ID (MS byte) Block count (LS byte)	**NNMMH**	NN Memory ID 96H – PROM 97H – EEPROM 98H – RAM MM Block count (1-6)
06	Memory Page	**0000H – 0001H** **0004H – 000FH**	Physical page for 1st block (excludes I/O pages)
07	Patch offset	**0000H –FFFEH**	Offset into 1st page for block
08	Block length	**0000H – xxxxH**	Number of words in 1st block
09 – n-2	May specify further blocks in format as for words 06 to 08	**As words 06 to 08**	Total block length may not exceed 1 page (8000H words)
n-1	Checksum	**CRC over 0 – (n-2)**	Checksum for TC as used in PUS for Rosetta

Following a check memory TC, Ptolemy will return a check memory report consisting of 32 words starting at word 32, 64 or 96 within the next housekeeping packet The format for a check memory report is

0F37 Csss 0039 tttt tttt tttt 4006 0A00
nnmm pppp oooo wwww xxxx

where Csss is the sequence control,
tttt is the onboard Lander time,
nn is the memory ID (96 = PROM, 97 = EEPROM and 98 = RAM)
mm is the number of check memory blocks,
pppp is the first check memory page
oooo is the first check memory offset
wwww is the number of words in the first check memory and
xxxx is the result of the check memory sum.

Words pppp, oooo, wwww and xxxx will be repeated for the following mm number of memoryu blocks (up to 5). Any unused words will be 0000.

6.1.3 Copy_memory – Copy memory from one block to another

This TC performs a copy memory from one memory block (page, offset) to another.

Summary	**Hex**	**Decimal**
Command type	**C0**	**192**
Command subtype	**01**	**1**
Number of parameters	**06-1A**	**6-26**

Word	**Description**	**Contents**	**Comment**
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**N*2-7**	Total length in bytes-7
03	Administration (MS byte) Type (LS byte)	**1XC0H**	X=1 -> ack; X=0 -> no ack, C0 – Ptolemy Mode Selection
04	Subtype (MS byte) Pad byte (LS byte)	**0100H**	01 Copy Memory 00 Not used
05	Block count	**0001H – 0005H**	Number of memory blocks to expect
06	Source Page	**0000H – 0001H** **0004H – 000FH**	Source page number for 1st block (excludes I/O pages)
07	Source offset	**0000H –FFFEH**	Offset into page of source for 1st block
08	Destination page	**0000H** **0001H** **0004H – 000FH**	Destination page for 1st block is data page selected at start-up. Destination page for 1st block is program page selected at start-up. Destination page number for 1st block (in EEPROM or RAM)
09	Destination offset	**0000H –FFFEH**	Offset into page of destination for 1st block
10	Block length	**0000H –00xxH**	Number of words to copy in 1st block
11 – (n-2)	May have further records as words 06 - 10		Total block length may not exceed 1 page (8000H) words
n-1	Checksum	CRC over 0 – (n-2)	Checksum for TC as used in PUS for Rosetta

6.1.4 Start_standby – Select Instrument mode – Start standby from safe mode

This TC is sent to effect transition from safe (ROM) mode to science mode which is entered in Standby mode.

Summary	Hex	Decimal
Command type	**C1**	**193**
Command subtype	**00**	**0**
Number of parameters	**03**	**3**

Word	Description	Contents	Comment
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**0BH**	Total length in bytes-7(=11 decimal)
03	Administration (MS byte) Type (LS byte)	**1XC1H**	X=1 -> ack; X=0 -> no ack, C1 – Ptolemy Mode Selection
04	Subtype (MS byte) Pad byte (LS byte)	**0000H**	00 Standby
05	Science mode code page	**0000H** **0001H** **0008H-000FH**	Page for science s/w entry point is code page in RAM as selected at start-up Page for science s/w entry is 1 (execute in PROM) Code page (in RAM) of entry point for science mode S/W
06	Science mode entry point	**0000H-FFFEH**	Offset of entry point on code page (even address)
07	Stored TC enbl/disbl	**0000H-0001H**	0: Exec. stored TCs disabled 1: Exec. stored TCs enabled
08	Checksum	**CRC over 0 – 7**	Checksum for TC as used in PUS for Rosetta

6.1.5 Select_Post_Launch – Select Instrument mode – Post Launch

This TC is sent to effect transition from Standby mode to Post Launch mode

Summary	Hex	Decimal
Command type	**C1**	**193**
Command subtype	**02**	**2**
Number of parameters	**00**	**0**

Word	Description	Contents	Comment
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**0BH**	Total length in bytes-7
03	Administration (MS byte) Type (LS byte)	**1XC1H**	X=1 -> ack; X=0 -> no ack C1 – Ptolemy Mode Selection
04	Subtype (MS byte) Pad byte (LS byte)	**0200H**	02 – Post Launch
05	Checksum	**CRC over 0 – 4**	Checksum for TC as used in PUS for Rosetta

6.1.6 Select_Cruise_Phase – Select Instrument mode – Cruise Phase

This TC is sent to effect transition from Standby mode to Cruise Phase mode

Summary	Hex	Decimal
Command type	**C1**	**193**
Command subtype	**03**	**3**
Number of parameters	**00**	**0**

Word	Description	Contents	Comment
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**05H**	Total length in bytes-7
03	Administration (MS byte) Type (LS byte)	**1XC1H**	X=1 -> ack; X=0 -> no ack C1 – Ptolemy Mode Selection
04	Subtype (MS byte) Pad byte (LS byte)	**0300H**	03 – Cruise Phase
05	Checksum	**CRC over 0 – 5**	Checksum for TC as used in PUS for Rosetta

6.1.7 Select_Safe_Mode – Select Instrument mode – Return to safe Mode

This TC is sent to effect transition to Safe (ROM) mode

Summary	**Hex**	**Decimal**
Command type	**C1**	**193**
Command subtype	**FF**	**255**
Number of parameters	**00**	**0**

Word	**Description**	**Contents**	**Comment**
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**05H**	Total length in bytes-7
03	Administration (MS byte) Type (LS byte)	**1XC1H**	X=1 -> ack; X=0 -> no ack C1 – Ptolemy Mode Selection
04	Subtype (MS byte) Pad byte (LS byte)	**FF00H**	FF – Start Safe Mode
05	Checksum	**CRC over 0 – 4**	Checksum for TC as used in PUS for Rosetta

6.1.8 Hazardous_Function_Enable – Enable/disable hazardous functions

This TC loads 16 bit masks of enable/disable bits for hazardous functions. These masks are copied into hardware registers where they electrically enable and disable the switching on of hazardous controls. The flight software never autonomously enables any of these lines.

Summary	**Hex**	**Decimal**
Command type	**C2**	**194**
Command subtype	**01**	**1**
Number of parameters	**03**	**3**

Word	**Description**	**Contents**	**Comment**
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**0BH**	Total length in bytes-7
03	Administration (MS byte) Type (LS byte)	**1XC2H**	X=1 -> ack; X=0 -> no ack C2 – Ptolemy Mode Selection
04	Subtype (MS byte) Pad byte (LS byte)	**0100H**	01 – Enable/Disable
05	PWM enbl/disbl mask	**XXXXH**	Enable/disable mask for software PWM
06	Valve enbl/disbl mask	**XXXXH**	Enable/disable mask for valve (on/off) outputs
07	Critical function enbl/disbl mask	**XXXXH**	Enable/disable mask for the critical functions outputs
08	Checksum	**CRC over 0 – 7**	Checksum for TC as used in PUS for Rosetta

6.1.9 Parameter_Update – Update Software Parameters

This TC allows updating of entries in a table of software parameters (sometimes called "variable constants").

Summary	Hex	Decimal
Command type	**C3**	**195**
Command subtype	**01**	**1**
Number of parameters	**04-1A**	**4-26**

Word	Description	Contents	Comment
00	Packet ID	**1F3CH**	
01	Packet sequence control	**C000H to C7FFH**	Top 5 bits always 11000B
02	Packet length	**N * 2 – 7**	Total length in bytes-7
03	Administration (MS byte) Type (LS byte)	**1XC3H**	X=1 -> ack; X=0 -> no ack C3 – Parameter update
04	Subtype (MS byte) Pad byte (LS byte)	**0100H**	01 – Parameter Update
05	Offset into table	**0 – Range-1**	Range shall be determined at compile time <FFFEH
06	Number of parameters	**0001H – 0018H**	Number of consecutive parameters to update; 1 – 24
07	First parameter value	**0000H – FFFFH**	New value for 1st parameter (at Table + offset)
08 – (n-2)	[Possible further parameters]	**[0000H – FFFFH]**	Up to 23 further parameters
(n-1)	Checksum	**CRC over 0 – (n-2)**	Checksum for TC as used in PUS for Rosetta