Ptolemy Operations Plan

CHANGE RECORD

DATE	CHANGE DETAILS	ISSUE
14-Sept-99	First draft of Ptolemy Operations Plan	1.0
12-Oct-99	Add mode Standby 0, modify mission timelines	1.1
9-Feb-00	Minor changes following 3rd Rosetta Lander Science meeting	1.2
16-June-00	Major changes. Ptolemy now uses 28V and 5V power rails. Heaters and reactors controlled by PWM. Mode names changed and new modes added. Revision as instrument systems better defined	2.0
8-Febuary-01	Minor changes, some estimates of power & data volume for all modes. Dynamic Pre-operations now occurs before lander ejection	2.1
2-March-01	Modify description of Post Launch mode. Update power for section 4.	2.2
5-April-01	Minor changes to Dynamic Pre-operations	2.3
6-April-01	Updated with measured power for safe mode	2.4
16-October-01	Complete revision	3.0

CONTENTS

1. General

1.1 Scope

Someone needs to write a bit of blurb here.

1.2 Reference documents

RD1	RO-LPT-RAL-TN-3403	Issue 5.1	26/Febuary/01
	Telecommand and Telemetry Definitions		
RD2	RO-LPT-OU-PL-3105	Issue 1	…

1.3 Overview of Ptolemy

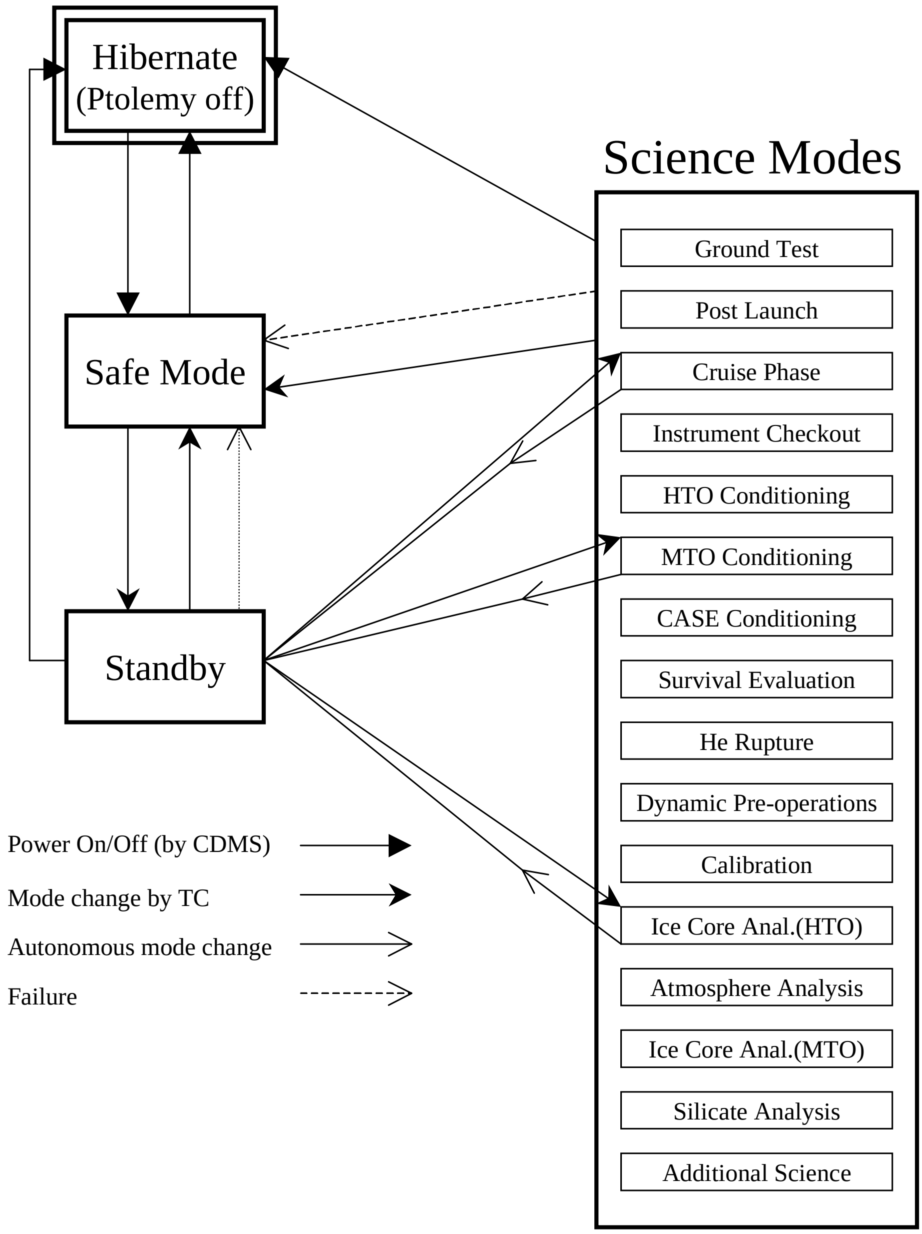
A bit about Rosetta mission, Ptolemy is on the Lander, Ptolemy is a GC-MS etc.
Ptolemy is classed by the lander as an intelligent unit, i.e. most Ptolemy actions are controlled by its own micro-processor without direct control by the lander CDMS. Ptolemy operates in a series of modes.

2. Ptolemy Operation

The Ptolemy instrument is designed to operate by selection of modes initiated by telecommand from the CDMS and then function autonomously. At power on, Ptolemy will enter **Safe Mode** and await further telecommands from the lander CDMS. Ptolemy has two methods of receiving telecommands

i) 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 (AMDT ref???)
ii) Requesting the next TC from the CDMS stored TC table.

Safe mode is used to check and/or modify Ptolemy memory, all science components are switched off. The only TC mode change command that is accepted by Ptolemy in **Safe Mode** is a TC to enter **Standby Mode**. The Safe mode TC will cause Ptolemy to immediately enter **Safe mode**, whatever its current mode. When Ptolemy enters **Safe mode** it immediately attempts to switch off every science component three times, disables all hazard commands and then waits for any TC's from the CDMS.
Standby mode is used to send "Hazard enable" TC's to enable operation of the various science components and send any mode change TC's. Whilst in **Standby mode**, Ptolemy can be set to request TC's from the CDMS TC store. When set to request TC's, Ptolemy will request the next TC from the CDMS store at a rate on one every 15 seconds (TBC) whenever it is in **Standby mode**.
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. The basic instrument modes are described in section 2.2 and Table 2.1. At the end of the science command sequence Ptolemy will return to **Standby mode**. If an invalid science command is encountered then Ptolemy will return to **Safe mode**. A return to **Safe mode** is also initiated if Ptolemy detects that a science component is operating beyond its safe limits.



2.1 Ptolemy Telecommands

A complete list and definitions of the Ptolemy Telecommands is in RD1. A list of commands and in which modes they are accepted by Ptolemy is shown in table 2.1

TC Commands	Current Ptolemy Mode		
	Safe Mode	Standby Mode	Science Modes
Memory Management TC's			
Load Memory	Yes	No	No
Dump Memory	Yes	No	No
Check Memory	Yes	No	No
Copy Memory	Yes	No	No
Mode Selection TC's			
Standby	Yes	No	No
Ground Test	No	Yes	No
Post Launch	No	Yes	No
Cruise Phase	No	Yes	No
Instrument Checkout	No	Yes	No
HTO Conditioning	No	Yes	No
MTO Conditioning	No	Yes	No
CASE Conditioning	No	Yes	No
Survival Evaluation	No	Yes	No
Helium Tank Rupture	No	Yes	No
Dynamic Pre-operations	No	Yes	No
Calibration	No	Yes	No
Ice Core Analysis (HTO)	No	Yes	No
Atmosphere Analysis	No	Yes	No
Silicate Analysis	No	Yes	No
Ice Core Analysis (MTO)	No	Yes	No
Additional Science	No	Yes	No
Safe	Yes	Yes	Yes
Miscellaneous TC's			
Connection Test	Yes	?	?
Hazardous Function	No	Yes	No
Parameter Update	No	Yes	No

2.2 Mode Descriptions

2.2.1 Safe Mode

Ptolemy waiting for CDMS instructions, Ptolemy memory can be modified.

Ptolemy enters **Safe Mode** upon power-up. On entering Safe mode all the science components are switched off and all hazard commands are disabled. The only mode change TC that can be entered from **Safe Mode** is **Standby**. Ptolemy memory can be modified in **Safe mode**. This can be used to modify the Ptolemy software in RAM. Usually the memory modified is the Science mode sequence tables in EEPROM.

2.2.2 Mode: Standby

Ptolemy set-up. Write Ptolemy status to CDMS back-up RAM. Hazard commands may be enabled by CDMS

This is the only mode that can be entered from **Safe Mode**. On entering **Standby**, Ptolemy will update the CDMS back-up RAM. When Ptolemy is in **Standby mode** Hazard Enable TC's will be accepted by Ptolemy, however no science components can be switched controlled.
At the end of any of the science modes, Ptolemy automatically returns to **Standby mode**. Any science components which are still active at the end of the science mode, will remain on until either switched off by a science command in another science mode or Ptolemy commanded to return to **Safe mode**.

2.2.3 Science Modes

Control Ptolemy Science components

There are a total of 15 Science modes which control the various science components that make up the gas control and mass spectrometer system of Ptolemy. The science components consist of heaters, chemical reactors, gas control valves and the mass spectrometer (described in REF). The science components are controlled by science commands stored in Ptolemy EEPROM. When a science mode is started Ptolemy will process each science command in the sequence until it reaches the end of the sequence where upon Ptolemy returns to **Standby** mode. If Ptolemy encounters an unknown command in the sequence then it will immediately return to **Safe mode**. Whilst Ptolemy is in a Science mode it will only accept the the **Safe mode** TC. Any other TC transmitted by the CDMS will not be acted upon and Ptolemy will report that an invalid TC was received in the next HK packet.

2.2.4 Mode: Ground Test

Spare mode to allow ground testing.

This mode can be used for ground test. The mode sequence can be written to Ptolemy EEPROM whilst it is in **Safe Mode**. Ptolemy can then be commanded by the CDMS to perform the test sequence.

2.2.5 Mode: Post Launch

This mode performs any tasks required soon after launch such as heating some of the chemistry components and mass spectrometer to out-gas the system. It will also go through a test sequence to evaluate the status of the instrument.

Check status of helium tanks, evacuate air between tanks and L-valves
Bake-out mass spectrometer

2.2.6 Mode: Cruise phase

Ptolemy will carry out some limited operations to check the instrument, similar to the Limited Functional Test sequence. The mass spectrometer high voltage supplies and nano-tips are not operated.

Sequence overview:

Read Temperatures of all thermocouples.
Read Pressure from all pressure sensors.
Read Baseline power levels.
Operate a sequence of valves to exercise them.
Operate most science components for a few seconds whilst monitoring pressure and temperature sensors.

2.2.7 Mode: Instrument checkout

Complete instrument functional checkout.

This mode performs a complete check of the instrument before the lander is ejected from the orbiter. Any non-hazardous system that can be operated is activated. Evaluation of the instrument is assessed by monitoring pressure, temperature and power levels. Helium is not available.

Sequence overview:

Read Temperatures of all thermocouples.
Read Pressure from all pressure sensors.
Read Baseline power levels.
Turn on manifold heaters
Operate a sequence of valves to evacuate the manifold
Turn off manifold heaters
Heat reactors to test that they work.
Sequence valves to move gas around the system
Operate ion trap to obtain a baseline scan

Mode	Phase/Function	Power requirement	Time (h)
Hibernate	Most of cruise phase Ptolemy is off.	Survival	-
Safe Mode	Ptolemy waiting for CDMS instructions. Command store can be modified	Low	-
Standby	Ptolemy set-up. Write Ptolemy status to CDMS back-up RAM. Hazard commands may be enabled	Low	<0.01
Post Launch	Test sequences during commissioning phase	Medium	0.25 (TBD)
Cruise Phase	Minimal functional tests	Medium	0.25 (TBD)
Instrument Checkout	Complete instrument functional checkout	Medium	1.5
HTO Conditioning	Condition a high temperature oven	Medium	0.1
MTO Conditioning	Condition a medium temperature oven	Medium	0.1
CASE Conditioning	Condition the oven containing the comet gas absorbant phase (Comet Atmosphere Sample Experiment).	Medium	0.1
Survival Evaluation	Instrument functional test and ion trap baseline test	Medium	0.2
He Tank Rupture	Rupture a helium tank	Medium	
Dynamic Pre-operations	Science sub-system thermally conditioned	High	1
Calibration	Reference gas calibration of GC and ion trap	High	1.5
Ice core Anal. (HTO)	Highest Priority Science Isotopic analysis of comet sample using a high temperature oven	High	5
Atmosphere Analysis	2nd Highest Priority Science Analysis of comet atmosphere	High	4
Silicate analysis	Generate fluorine for oxygen isotope analysis of comet silicates	High	4 (TBD)
Ice core Anal. (MTO)	Isotopic analysis of comet sample using medium temperature ovens	High	2 (TBD)
Additional Science	Back-up routines and end of mission phase	TBD	TBD
Ground Test	Spare mode to allow ground testing		

Table 2.1 Description of Ptolemy modes. Survival power is the power from the spacecraft heaters to maintain Ptolemy within non-ops temperature range. During hibernation, Ptolemy is switched off.

2.2.8 Mode: HTO Conditioning
Condition a high temperature oven

Sequence overview:

Heat oven (max temperature 800^{o}C)

2.2.9 Mode: MTO Conditioning
Condition a medium temperature oven

Sequence overview:

Heat oven (max temperature 180^{o}C)

This mode is also used to calibrate the docking station position potentiometer if enabled in standby mode. The docking station motor will be operated for at least 1 minute to determine the docking station maximum and minimum positions. The results are stored on Ptolemy

2.2.10 Mode: CASE Conditioning
Condition the oven containing the comet gas absorbant phase (Comet Atmosphere Sample Experiment).

Sequence overview:

Heat oven (max temperature 250^{o}C)

2.2.11 Mode: Survival Evaluation
Survival evaluation, instrument functional test and ion trap baseline test

This mode performs an instrument check-out as soon as possible after landing. In order to save power, this is a simplified version of mode **Instrument Checkout**. Hazardous commands are not enabled. No helium is available. At the end of these mode Ptolemy will indicate that the mode was completed successfully and that it is OK for the CDMS to continue with the next command to rupture a helium gas tank.

Sequence overview:

Read Temperatures of all thermocouples.
Read Pressure from all pressure sensors.
Read Baseline power levels.
Turn on manifold heaters
Turn off manifold heaters
Operate a sequence of valves
Heat reactors to test that they work.
Operate ion trap to obtain a baseline scan

2.2.12 Mode: He Tank Rupture (Gas Tank)
Rupture a helium tank

If the CDMS indicates that it is OK to continue, then this mode will rupture the helium tank specified by the gas tank parameter.

Sequence overview:

- Check Helium system
- Rupture helium tank
- Open L-valve to helium gas supply and monitor pressure

2.2.13 Mode: Dynamic Pre-operations (Gas Tank)
Science sub system thermally conditioned.

This mode conditions the Ptolemy science system using the helium specified by the Gas Tank parameter. After completion of this mode, Ptolemy needs to be switched off for at least two hours (TBD) before Ptolemy performs any science analysis mode or **Calibration mode**. This time is top allow Ptolemy's GCs to cool down back to ambient temperature. Other instruments can be operating during this window.

Sequence overview:

- Set pressure of plenum chamber to 6 bar
- Set pressure of GC columns to 1 bar
- Obtain Ion trap background
- Heat GC columns to 170^{o}C
- Heat Reactors
- Obtain Ion trap background 15 minutes later

2.2.14 Mode: Calibration (Gas Tank)
Reference gas calibration of GC and ion trap

This mode analyses the reference gas, required for accurate isotopic analysis of the comet. The helium gas tank used is specified by the Gas Tank parameter

Sequence overview:

- Prepare hydrogen source
- Evacuate Manifold
- Start helium
- Obtain reference gas
- Measure background
- Measure reference gas through V13
- Measure reference gas through GC1

Measure reference gas through GC2

2.2.15 Mode: Ice Core Anal. (HTO)
Isotopic analysis of comet sample using a high temperature oven

This mode performs a complete isotopic analysis of a sample from the high temperature oven. It is the highest priority science and follows on directly from **Calibration**. SD2 needs to collect a sample and load it into one of the three high temperature ovens. The sample is heated in steps up to a maximum of 800^{o}C and the gas released at each temperature step is analysed.

Sequence overview:

Heat oven to –50^{o}C
Dry sample, analyse CO, CO_2 and N_2
Heat Oven to + 100^{o}C
Analyse H_2O
Dry sample, analyse CO, CO_2 and N_2
Heat oven to +400^{o}C
Dry sample, analyse GC 4 trace, CO, CO_2 and N_2
Prepare oxygen, heat oven to +400^{o}C
Analyse CO_2
Heat oven to +800^{o}C
Dry sample, analyse GC4 trace, CO, CO_2 and N_2
Prepare oxygen, heat oven to +800^{o}C
Analyse CO_2

2.2.16 Mode: Atmosphere Analysis
Analysis of comet atmosphere

This mode performs a complete isotopic analysis of a sample from the high temperature oven containing the absorbant phase. It is the 2nd highest priority science and follows on directly from **Calibration**.

Sequence overview:

Heat oven to +200^{o}C
N_2 isotope analysis
Water isotope analysis
Dry Sample
Reference gas isotope analysis
GC analysis
Isotope analysis CO, CO_2

2.2.17 Mode: Silicate Analysis
Analysis of cometary silicates.

This mode performs an oxygen isotope analysis of the cometary silicates using a high temperature oven.

2.2.18 Mode: Ice Core Anal. (MTO)
Analysis of comet sample using a medium temperature oven.

This mode performs a complete isotopic analysis of a sample from a medium temperature oven. It follows on directly from **Calibration**. SD2 needs to collect a sample and load it into one of the medium, temperature ovens. The sample is heated in steps up to a maximum of 180^{o}C and the gas released at each temperature step is analysed.

Sequence overview:

Heat oven to –50^{o}C
Dry sample, analyse CO, CO_2 and N_2
Heat Oven to + 100^{o}C
Analyse H_2O
Dry sample, analyse CO, CO_2 and N_2
Heat oven to +180^{o}C
Dry sample, analyse GC 4 trace, CO, CO_2 and N_2
Prepare oxygen, heat oven to +180^{o}C
Analyse CO_2

2.2.19 Mode: Additional Science
Backup routines, end of mission phase

This mode can be used for other experiments as required.

2.3 Science Mode development

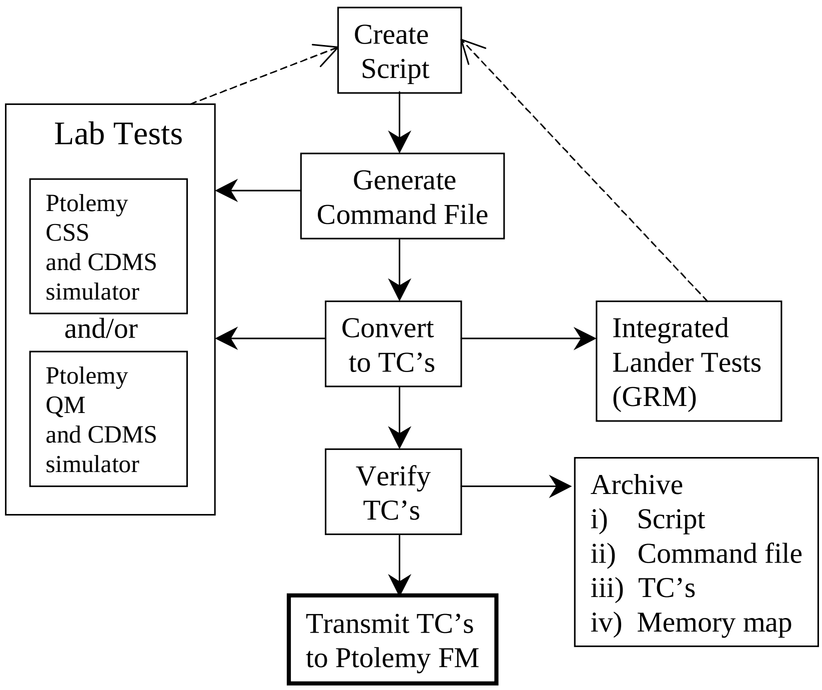
The science modes will have default sequences stored on the Ptolemy EEPROM before launch. The actual sequences will be determined by experiment and characterisation of the QM; as well as the available resources, such as power, time, data rate etc. There are several models of Ptolemy that can be used to aid development of the sequences. These are:

i) Chemistry Set Simulator (CSS). This consists of the Ptolemy electronics and processor with the science components indicated by LEDs or panel displays. Ptolemy TC's can be generated and sent in real time using the Ptolemy EGSE, through the CDMS simulator. This is a useful tool to determine that science components operate in the expected order and can be used to determine the amount and timing of data generated.

ii) Ptolemy Qualification Model (QM). This is a complete flight representative instrument. The QM is controlled by the Ptolemy EGSE in the same manner as the CSS. Operation of a science sequence on the QM will provide better estimates of power and time to run a science sequence, although limited resources (chemical reagents and mass spectrometer life-time) will prevent frequent use of the QM.

iii) Ground reference model (GRM). This consists of the Ptolemy electronics and processor with many components replaced by simulators (e.g. resistors for reactors), integrated with other lander sub-systems and experiments. This instrument will be useful for verifying Ptolemy operation by TC and its interaction with other Lander instruments (notably SD2).

The method of generating a new science sequence is shown below.



2.3.1 Create Script

A script is the list of science commands that the science team would like Ptolemy to operate. The script is generated using the Ptolemy EGSE (ref, document). The EGSE ensures that only valid commands can be entered.

2.3.2 Generate Command file

Once the script has been generated, it is converted into hex code by the Ptolemy EGSE and stored as a command file with date and time of creation. This is the hex code that needs to be loaded onto Ptolemy EEPROM. At this stage the Ptolemy EGSE can transmit the TC's directly to the Ptolemy Chemistry Set Simulator and/or the Ptolemy Qualification Model.

2.3.3 Convert to TC's

The Ptolemy EGSE converts the command file into the sequence of TC's necessary to load the hex code into Ptolemy EEPROM. At this stage the sequence of TC's necessary to operate the science mode can also be generated.

2.3.4 Verify the TC's

The TC's that have been generated can be verified on any of the Ptolemy CSS, QM or GRM, whichever models are most appropriate.

2.3.5 Transmit TC's to Ptolemy FM

Once the Potolemy science team are satisfied that Ptolemy will operate the desired experiment, the TC's can transmitted to Ptolemy FM. Estimates of time sequences and resources required will have been determined.

2.3.6 Archive

Documents of the script, command file and transmitted TC's and Ptolemy memory map will be placed in the data archive.

2.4 Mode resources

Each mode of operation uses some of the limited resources on the lander and Ptolemy instrument. The main resources used are battery energy, time, helium and the sample ovens. Table 2.2 shows the estimated duration and power used for each of the modes. Table 2.3 shows the other resources used by each mode.

Mode	Duration (min)	Power (W)			
		5V		28V	
		Average	Maximum	Average	Maximum
Hibernate	-	0.0	0.0	0.0	0.0
Safe Mode	-	2.0	2.0	2.0	2.0
Standby	-	2.0	2.0	2.0	2.0
Post Launch	60.0*	2.3*	3.8*	7.0*	11.8
Cruise Phase	15.0*	2.3*	4.3*	8.0*	11.8
Instrument Checkout	16.4	2.3	4.3	10.1	11.6
HTO Conditioning	6.0*	2.8*	4.8*	6.0*	11.8
MTO Conditioning	6.0*	2.8*	4.8*	4.0*	11.8
CASE Conditioning	6.0*	2.8*	4.8*	4.0*	11.8
Survival Evaluation	4.6	2.4	3.5	7.1	11.8
He Tank Rupture	21.0*	2.4*	3.8*	2.0	2.0
Dynamic Pre-operations	187.0*	2.8*	5.0*	7.7*	11.8
Calibration	54.8	3.5	5.9	10.3	11.8
Ice core Anal. (HTO)	223.9	4.3	5.9	7.6	11.8
Atmosphere Analysis	220.0*	3.8*	6.8*	8.0*	11.8
Silicate analysis	240.0*	3.8*	6.8*	7.0*	11.8
Ice core Anal. (MTO)	120.0*	3.8*	5.9*	7.0*	11.8
Additional Science	TBD	TBD	TBD	TBD	11.8
Ground Test	TBD	TBD	TBD	TBD	11.8

* To Be Confirmed

Mode	Duration (min)	Helium (ml)	Ovens	Other resources used
			-	
Hibernate	-	0.0	-	-
Safe Mode	-	0.0	-	-
Standby	-	0.0	-	-
Post Launch	15.0*	0.0	-	-
Cruise Phase	15.0*	0.0	-	-
Instrument Checkout	16.4	0.0	-	-
HTO Conditioning	6*	0.0	-	-
MTO Conditioning	6*	0.0	-	-

CASE Conditioning	6*	0.0	-	-
Survival Evaluation	4.6	0.0	-	-
He Tank Rupture	21.0*	30.0*	-	-
Dynamic Pre-operations	187*	347*	-	-
Calibration	54.8	223	-	Ref gas, 6ml H_2
Ice core Anal. (HTO)	223.9	442	1 HTO	R5, 9ml H_2
Atmosphere Analysis	220*	440*	1 HTO[1]	Ref gas
Silicate analysis	240*	400*	1 HTO	R1
Ice core Anal. (MTO)	120*	150*	1 MTO	R5
Additional Science	TBD	TBD	TBD	TBD
Ground Test	TBD	0.0	-	-

* To Be Confirmed

[1] This oven can be re-used for comet atmosphere analysis

The data generated by Ptolemy for the various modes is shown below. The data generated are transferred to the CDMS in packets of 128bytes.

Mode	Duration (min)	Housekeeping (Packets)	Science (Packets)
Hibernate	-	0	0
Safe Mode	-	1 per minute	0
Standby	-	1 per minute	0
Post Launch	15.0*	15*	60*
Cruise Phase	15.0*	15*	12*
Instrument Checkout	16.4	17	12
HTO Conditioning	6.0*	6*	1*
MTO Conditioning	6.0*	6*	1*
CASE Conditioning	6.0*	6*	1*
Survival Evaluation	4.6	5	92
He Tank Rupture	21.0*	21*	20*
Dynamic Pre-operations	187*	187*	251*
Calibration	54.8	55	1421
Ice core Anal. (HTO)	223.9	224	9088
Atmosphere Analysis	220*	220*	9000*
Silicate analysis	240*	240*	9000*
Ice core Anal. (MTO)	120*	120*	5000*
Additional Science	TBD	TBD	TBD
Ground Test	TBD	TBD	TBD

* To Be Confirmed

3. Ptolemy Mission Timelines

These mission timelines are provisional, depending on when certain operations can be performed (such as SD2 sample collection), requirements from other instruments and when lander resources become available (power).

3.1 Post Launch/ Commissioning

This phase of the mission is used to check the operating status of Ptolemy and perform any tasks required soon after launch. TC's are transmitted to Ptolemy to request memory checksums of the various science sequences already storred in memory. A complete health check of Ptolemy can be assessed by setting Ptolemy into Cruise Phase. Once the health check of Ptolemy has been evaluated, then the Post Launch mode can be operated. A complete description of Ptolemy operation during the Post Launch/Commissioning phase is in RD2, RO-LPT-OU-PL-3105.

Mission Phase	Mode	Duration (min)	Energy (Wh)	Science Data (kBytes)
	Post Launch/Commissioning			
T1 start	Switch on Ptolemy	0.25	0.02	0
T1 + 15	Check memory TC's	5	0.3	0
T1 + 315	Set-up cruise test	1	1.0	0
T1 + 375	Cruise test	14	2.4	2
T1 + 1215	Safe mode	84.75	5.7	0
T1 + 6300	Switch off Ptolemy			
T2 start	Switch on Ptolemy	0.25	0.02	0
T2 + 15	Initialise Ptolemy	1	0.1	0
T2 + 75	Post Launch	60	9.3	20
T2 + 3675	Safe mode	5	0.3	0

T2 + 3975	Switch off Ptolemy

The time delay between T1 start and T2 start should be sufficient for the Housekeeping and Science data returned by operating **Cruise** mode to be analysed by the Ptolemy team and confirm that it is OK to continue with the planned operation of **Post Launch** mode. (Allow at least 2 hours for an initial evaluation of the Cruise mode results by the Ptolemy team).

3.2 Cruise Phase

During the cruise phase Ptolemy will be in hibernation (switched off) for most of the time, only requiring survival power. Occasionally Ptolemy will be switched on for updates to the command sequence tables, check the memory of the science sequence tables or to perform the **Cruise Phase mode**, the minimum functional tests. A complete description of Ptolemy operation during the Post Launch/Commissioning phase is in RD2, RO-LPT-OU-PL-3105.

Time (s)	**Task**	**Duration (min)**	**Energy (Wh)**	**Science Data (kBytes)**
	Cruise, check Ptolemy memory			
TS start	Switch on Ptolemy	0.25	0.02	0
TS + 15	Send Check memory TC's	4	0.3	0
TS + 270	Wait for memory results	79.5	5.3	0
TS + 5040	Switch off Ptolemy			
	Cruise, Ptolemy test			
TS2 start	switch Ptolemy	0.25	0.02	0
TS2 +15	Initialise Ptolemy	1.0	0.1	0
TS2 + 75	Start Cruise test	14	2.4	0
TS2 + 915	Wait for cruise test results	24.75	1.7	0
TS2 + 2400	Switch off Ptolemy			

Cruise, Load memory sequence

TS3 start	switch Ptolemy	0.25	0.02	0
TS3 +15	Load n memory TC's	n x 0.25	n x 0.0167	0
TX	Check memory loaded	0.25	0.02	0
TS + 15	Wait for Check memory results	8	0.5	0
TX + 495	Switch off Ptolemy			

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

3.3 Asteroid Flyby

Ptolemy has no mission requirements for asteroid or planet flybys (it will probably be in hibernation mode).

3.4 Pre-ejection phase

Ptolemy requires helium to condition various components before scientific analysis. Ptolemy will perform a complete instrument check-out (**Instrument Checkout**) and the activate one of the helium tanks using the **He Tank Rupture** mode, about four days before lander eject. This will allow enough time to confirm that the **He Tank Rupture** mode was successful and the helium supply is available. In case the **He Tank Rupture** mode is unsuccessful, two further **He Tank Rupture** modes are timelined; the first to attempt to activate the helium tank for a longer time, and the second to activate the second helium tank. These sequences are to be removed once successful activation of a helium tank is confirmed from ground control.
[Note: At this stage SD2 is disabled (to prevent the drill activating and damaging the orbiter), so Ptolemy is only able to condition the high temperature oven containing the adsorbant phase (**CASE Conditioning**)]

Descent Phase

Ptolemy has no mission requirements for the descent phase, apart from the requirement to land on the comet surface safely (it will probably be in hibernation mode). It should be noted that Ptolemy has requested that the high temperature oven filled with adsorbant, is located under the Ptolemy tapping station by default.

First Scientific Sequence (0 to 61.5 hours)

The primary mission objective for Ptolemy is the chemical and isotopic composition of two comet samples, one from the surface and the other at the maximum depth that the drill can achieve. Further objectives are the analysis of a comet sample using a medium temperature oven (for comparison with COSAC and ÇIVA) and analysis of the comet atmosphere using the HTO containing the absorbant material.

The first four samples to be analysed by Ptolemy are two HTO samples (one surface and one at depth), one atmospheric sample and one MTO sample. During the first 61.5 hours, Ptolemy has been assigned two operational windows (Lander fifth iteration). The preferred option is two analyse two HTO samples. Alternatives are to analyse an MTO sample (less energy) or an atmospheric sample (does not require SD2 operation). The timelines below assume that the first two samples will be the HTO samples.

First Operational Window

First, Ptolemy needs to perform modes **Survival**, **Calibration** and **HTO Conditioning**. Ptolemy will then analyses a surface sample **(Ice Core Anal (HTO)**, after SD2 has collected a surface sample and deposited it into HTO1. Once Ptolemy has analysed the sample it will then condition the HTO oven, so that this oven will then begin to absorb any comet atmosphere.

Second Operational Window

Ptolemy will perform **Instrument Check-out** and **HTO Conditioning** then analyse the comet sample collected at depth by SD2 **(Ice Core Anal (HTO)**.

Second Scientific Sequence (61.5 to 100 hours)

Ptolemy will use this sequence to analyses the two samples not analysed during the first 61.5 hours (Comet atmosphere sample and a MTO sample)

Extended Mission Phase

Ptolemy will have three high temperature ovens and four medium temperature ovens to carry out further experiments. The exact experiment will depend on the results/discoveries from the main mission phase. The oven with the absorbant phase will be used to sample the comet atmosphere about once a week. The duration of this phase depends upon the amount of helium usage from the gas tanks.

End of Mission phase

There are many circumstances which will result in Ptolemy not being able to operate (pressure, temperature, available power, helium). We hope that after other instruments have met their objectives, Ptolemy will be able perform oxygen isotope analysis of silicates in the high temperature ovens (**Silicate Analysis**).

Mission Phase	Mode	Duration (min)	Energy (Wh)	Science Data (kBytes)
	Pre-Ejection			
Eject – 4 days	Instrument Check-out	17	3.4	4
	He Tank Rupture	21	1.5	3
Eject – 3 days	Instrument Check-out	17	3.4	4
	He Tank Rupture	22	1.6	3
Eject – 2 days	Instrument Check-out	17	3.4	4
	He Tank Rupture	22	1.6	3
Eject – 1 day	Instrument Check-out	17	3.4	4
	Dynamic Pre-operations	187	32.7	55
	CASE Conditioning	6	0.7	1

Descent Phase

Descent	None	-	-	-

First Scientific Sequence (0 – 61.5 hours)

Mission Phase (Time, minutes)	Mode	Duration (min)	Power (Wh)	Science Data (kBytes)

First Operational Window (0 – 7 hours)

T0 – T30	None	-	-	-
T30	Survival Evaluation	5	0.7	12
T39 – T40	SD2 – Rotate carousel HTO1 to Ptolemy docking station			
T40	Calibration	55	12.6	1421
	HTO Conditioning (HTO1)	6	0.9	1
T105 – T180	SD2 – Collect comet surface sample, deposit in HTO 1 and rotate HTO1 to Ptolemy docking station			
T180	Ice Core Anal (HTO)	230	44.3	9088
T410 – T411	SD2 – Rotate carousel HTO4 to Ptolemy docking station			
T411	CASE Conditioning (HTO4)	6	0.7	1

Ptolemy total 302 minutes, 59.2 Wh

Second Operational Window (T11 to 20 hours)

T660 – T661	SD2 – Rotate carousel HTO2 to Ptolemy docking station			
T661	Instrument Check-out	17	3.4	4
	HTO Conditioning (HTO2)	6	0.9	1
T685 – T940	SD2 – Collect comet sub-surface sample, deposit in HTO 2 and rotate HTO2 to Ptolemy docking station			
T940	Ice Core Anal (HTO)	230	44.3	9088
T1190- T1191	SD2 – Rotate carousel HTO4 to Ptolemy docking station			

Ptolemy total 253 minutes, 48.6 Wh

Second Scientific Sequence (T61.5+ hours)

Mission Phase (Time, minutes)	Mode	Duration (min)	Power (Wh)	Science Data (kBytes)

Sample 3 (Start S = 0 to 5 hours)

S 0	Instrument Check-out	17	3.4	4
	Calibration	55	12.6	1421
	Atmospheric Analysis	220	43.3	9000
	CASE Conditioning (HTO4)	6	0.7	1

Ptolemy total 298 minutes, 59.3 Wh

Sample 4 (Start S = 0 to 3.5 hours)

S 0 – S1	SD2 – Rotate carousel MTO1 to Ptolemy docking station (after analysis by ÇIVA			
S1	Instrument Check-out	17	3.4	4
	Calibration	55	12.6	1421
	Ice Core Anal (MTO)	120	21.6	5000

Ptolemy total 192 minutes, 37.6 Wh

4. Ptolemy Power Profiles

Ptolemy uses the 5V rail and the 28V rail. Power and times for each procedure are best guesses. The maximum power required by each component is listed below.

Component Type	Max 5V power (W)	Max 28V power (W)	Control
Ptolemy On	2.0	2.0	CDMS
Valve	0.4	-	On/Off
Injector Valve	1.2	-	On/Off
L-Valve	1.2	-	DAC
Reactor	-	9.8	PWM
Heater	-	9.8*	PWM
SMA Heater	2.0	-	DAC
Docking Station	2.0	-	DAC
High Temp Oven	0.0	9.8	PWM
Medium Temp Oven	0.0	9.8	PWM
Ion Trap	0.5	-	On/Off
Ion trap scan	3.0	-	DAC

Notes: CDMS is control by the lander. Ptolemy is switched either on or off
On/Off, the itme can be switched either fully on or off
DAC, the amount of power used depends upon a digital to analogue converter controlled be Ptolemy.
PWM, the amount of power used is controlled by Ptolemy's pulse width modulation controller.
* The Ion trap heater requires 11.0W on the 28V rail

Control methods
Each component type is controlled by Ptolemy by one of three methods:

i) On/Off The component can be either switched on and operating at full power or switched off, requiring no power.
ii) DAC The voltage to the component is controlled by an 8bit digital to analogue converter.
iii) PWM The power to the component is switched at a rate of about 4Hz. The duration for which the power is switched on in each cycle controlled by the Ptolemy processor

4.2 Example modes

These modes have been designed using the procedure above. Power estimates

Mode: Instrument Checkout

Operation	Time (s)	Power (W) 5V	Power (W) 28V
Read all sensors	3	2.0	2.0
Turn on manifold heaters	61	2.0	11.6
Operate valves, evacuate manifold	28	2.7	2.0
Heat reactors to test that they work.	137	2.9	9.5
Operate ion trap to obtain a baseline scan	752	2.3	10.5

Total time	981 s	Average power (5V)	2.7 W
Total Energy	12260 J	Average power (28V)	10.1 W

Mode: Survival Evaluation

Operation	Time (s)	Power (W) 5V	Power (W) 28V
Read all sensors	3	2.0	2.0
Turn on manifold heaters	61	2.0	11.3
Operate valves, evacuate manifold	34	2.6	2.0
Heat reactors to test that they work.	137	2.5	8.0
Operate ion trap to obtain a baseline scan	38	2.7	2.0

Total time	273 s	Average power (5V)	2.4 W
Total Energy	2594 J	Average power (28V)	7.1 W

Mode: Rupture Gas Tank

Operation	Time (s)	Power (W)	
		5V	28V
Initialise Ptolemy	300	2.0	2.0
Rupture gas tank	60	3.5	2.0
Admit helium gas to chemistry	600	2.6	2.0
Switch off system	300	2.0	2.0
Heat reactors to test that they work.			
Operate ion trap to obtain a baseline scan			

Total time	1260 s	Average power (5V)	2.4 W
Total Energy	5490J	Average power (28V)	2.0 W

Mode: Dynamic Pre-operations

Operation	Time (s)	Power (W)	
		5V	28V
Prepare helium gas system	2215	2.9	5.9
Condition GC columns	7200	2.8	8.7
Obtain mass scan of helium gas	334	2.9	2.0
Condituin manifold heaters and reactors	1142	2.8	8.0
Test helium operated valves, shut down	328	2.0	2.0

Total time	11219 s	Average power (5V)	2.8 W
Total Energy	117800 J	Average power (28V)	7.7 W

Mode: Calibration

Operation	Time (s)	Power (W)	
		5V	28V
Prepare helium gas system	590	2.7	11.0
Evacuate manifold	1049	3.0	11.4
Prepare hydrogen gas system	266	4.1	5.9
Prepare reference gas	250	4.8	5.9
Measure reference gas (no GC)	68	5.0	5.9
Measure reference gas GC1	879	3.9	11.5
Measure reference gas GC3	188	4.0	9.3

Total time	3290 s	Average power (5V)	3.5 W
Total Energy	45320 J	Average power (28V)	10.3 W

Mode: Ice Core Anal. (HTO)

Operation	Time (s)	Power (W) 5V	Power (W) 28V
Close docking station, prepare helium gas	680	2.8	10.7
Evacuate manifold	809	3.7	10.1
Prepare hydrogen gas	266	4.1	5.7
Sample analysis (pyrolysis) at -50°C	1300	3.6	7.7
Mass spectrum, isotope analysis N_2, CO, CO_2 and CH_4			
Evacuate manifold	209	4.5	7.9
Sample analysis (pyrolysis) at +100°C	2013	3.4	8.2
Mass spectrum, isotope analysis N_2, CO H_2O and CO_2			
Evacuate manifold	209	4.1	7.9
Sample analysis (pyrolysis) at +400°C	1612	3.4	7.0
Mass spectrum, GC analysis and isotope analysis N_2, CO, CO_2 and CH_4			
Evacuate manifold	209	4.5	6.2
Prepare oxygen	485	3.6	11.6
Sample analysis (combustion) at +400°C	2147	4.3	6.4
Mass spectrum, GC analysis and isotope analysis N_2, CO, CO_2			
Evacuate manifold	209	4.1	6.2
Prepare oxygen	485	3.3	11.6
Sample analysis (combustion) at +800°C	2800	4.2	5.8
Mass spectrum, GC analysis and isotope analysis N_2, CO and CO_2			

Total time	13433 s	Average power (5V)	4.3W
Total Energy	159652 J	Average power (28V)	7.6 W

Science 2

Operation	Time (s)	Power (W)
Collect sample	31	5.2
Allow sample to adsorb	300	3.0
Prepare hydrogen gas	608	8.2
Evacuate manifold	888	7.7
Close tapping station	322	8.3

Heat oven to +200°C	300	11.3
Transfer sample	67	5.6
Prepare helium	198	6.6
Nitrogen isotope analysis	221	9.6
Water isotope analysis	211	11.8
	308	6.5
Evacuate manifold	471	9.7
Reference gas carbon isotope analysis	361	9.3
	299	11.2
	309	5.9
Reference gas nitrogen isotope analysis	221	9.6
Reference gas water isotope analysis	211	11.8
	308	4.6
Reference gas oxygen isotope analysis	414	4.6
Prepare second sample	1008	8.2
Carbon isotope analysis	361	9.3
	299	11.2
	309	5.9
Wait for reactors to cool down	300	3.8
Oxygen isotope analysis	414	4.6

Total time	8753 s
Average power	10.6 W
Total Energy	92782 J