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Ptolemy: Operations to date as part of the Rosetta mission and plans for the comet encounter.

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1. Introduction

Rosetta is the European Space Agency 'Planetary Cornerstone' mission intended to solve many of the unanswered questions surrounding the small bodies of the Solar System. Launched in March 2004 it is now over three-quarters of the way through its decade long cruise, leading up to entering orbit around the nucleus of comet 67P/Churyumov-Gerasimenko in mid-2014. To date, this cruise has included three gravitational assist manoeuvres using Earth and one such manoeuvre using the gravity well of Mars. In addition, targeted flybys of two asteroids have returned a plethora of data to be compared with the comet observations to come. These flybys were of the 5.3 km diameter E-type asteroid 2867 Šteins on September 5th 2008, and a similar 3,162 km flyby of the 100 km diameter asteroid 21 Lutetia on July 10th 2010. Rosetta is currently in hibernation whilst at a heliocentric distance too great to allow Solar-powered operation and will awaken in early 2014 as it once again approaches the inner Solar System [1].

2. Ptolemy overview

Ptolemy is a miniature chemical analysis laboratory aboard the Rosetta lander 'Philae' and is intended to determine the chemical and isotopic composition of cometary material sourced from beneath, on and above the surface of the target comet. Samples are taken from the Sampler, Drill and Distribution system (SD2) and are then processed in a chemical preparation suite before delivery to a three channel gas chromatograph (GC). Elution products from the GC are passed to a quadrupole ion trap mass spectrometer for detection and quantitation [2]. As well as analysing solid samples, Ptolemy can passively adsorb coma material onto Carbosphere^{TM} molecular sieve contained within one of the 26 SD2 sample ovens for later thermal release and analysis. Ptolemy can also make direct 'sniff' detections of the current spacecraft environment, bypassing the sample inlet and GC system, instead directly analysing the inside of the mass spectrometer which is connected to space via a vent pipe.

3. Cruise operations

Ptolemy has to date been operated in space during sixteen checkout and science windows during a commissioning, calibration and science program that has brought the instrument to a state of readiness where Ptolemy is now ready to undertake science operations upon arrival in the vicinity of the target comet. Ptolemy has performed in an active fashion with ground intervention and a passive fashion whilst outside of contact with Earth and has shown itself to be a very dependable and adaptable instrument.

4. Test campaign

The test and science campaign to date necessitated a complex set of laboratory and software testing spread across a number of sites throughout Europe, collaboration between several instrument teams and communication between several teams of scientists and engineers. Experiments were first performed on a number of laboratory instruments at the Open University, Milton Keynes, UK, before testing on the Philae lander Ground Reference Model (GRM) sited within the Deutschen Zentrums für Luft- und Raumfahrt (DLR) campus, Cologne, Germany with subsequent spacecraft operations controlled via the Spacecraft Operations and Navigation Centre (SONC) located at the Centre National d'Etudes Spatiales (CNES), Toulouse, France, the Lander Control Centre (LCC) located again at the DLR campus, Cologne, Germany with final spacecraft control undertaken through the Rosetta Ground Segment located in Darmstadt, Germany [3].

5. Results to date and comet plans

The flight instrument sensitivity was determined to be of the order of one ion count per $1x10^{-11}$ mbar for

a particular mass, which lead on to the combined science operations during the targeted flyby of asteroid 21 Lutetia. Whilst no unambiguous detection of an asteroid exosphere was resolved during these operations, much was discovered concerning the operation of the instrument in space and important lessons were learnt which will feed into operations around the target comet and which will benefit the planning of future exosphere studies [4,5].

Whilst some sections of Ptolemy were not tested in space due to concerns over consumable usage, every section that could be tested in space, has been thus tested. The result of this testing is a comprehensive set of experiments to be operated prior to Lander ejection, shortly after landing, during the primary science phase (the First Science Sequence) and during any extended mission (Long Term Science). Such a complete set of experiments taking place in a variety of locations from comet orbit to comet surface will allow great insight into cometary outgassing, allowing the determination of the chemical and isotopic evolution of cometary material from solid material beneath the surface to daughter species in the lower coma.

This work details the test campaign to date along with the experiments intended to be operated after comet arrival and the rationale for them.

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