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IAC-15,A3,4,2,x28653

ROSETTA LANDER – PHILAE ON COMET 67P/CHURYUMOV-GERASIMENKO

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Rosetta is a Cornerstone Mission of the ESA Horizon 2000 programme. In August 2014 it reached comet 67P/Churyumov-Gerasimenko after a 10 year cruise. Both its nucleus and coma have been studied with its orbiter payload of eleven PI instruments, allowing the selection of a landing site for Philae. The landing on the comet nucleus successfully took place on November 12th, 2014.

Philae touched the comet surface seven hours after ejection from the orbiter. After several bounces it came to rest and continued to send scientific data to Earth. All ten instruments of its payload have been operated at least once. Due to the fact that the Lander could not be anchored, the originally planned first scientific sequence had to be modified. Philae went into hibernation on November 15th, after its batteries ran out of energy. Re-activation of the Lander was expected for May/June 2015, when CG would be closer to the sun and, indeed, radio contact with the Lander was re-established on June 13th and for (so far) seven more occasions.

Rosetta is an ESA mission with contributions from its member states and NASA. Rosetta's Philae lander is provided by a consortium led by DLR, MPS, CNES and ASI with additional contributions from Hungary, UK, Finland, Ireland and Austria.

I. INTRODUCTION

Rosetta is a Cornerstone Mission of the ESA Horizon 2000 programme [1]. In August 2014 it did rendezvous with comet 67P/Churyumov-Gerasimenko (CG) after a 10 year cruise. Both its nucleus and coma have been studied in detail. The mission is dramatically improving our understanding of the formation and evolution of the Solar System as well as the origin of life by investigating a comet both from orbit as well as with the Lander, Philae, in-situ, on the surface of the nucleus.

Observations with the instruments aboard the main spacecraft allowed the selection of a landing site for Philae and the preparation of the actual landing sequence [2]. Philae was separated from the Rosetta main spacecraft on November 12th, 2014 and touched the comet surface after seven hours of descent. However, the lander bounced off again and only came to rest after a leap of about 2 hours, approximately one kilometre from the originally targeted site [3]. Philae was operational for almost 64 hours after separation and provided unique information from the surface of the comet. All ten instruments aboard could be operated at least once. First scientific results have been published e.g. in [4].

Philae is operated by the Lander Control Centre (LCC) at the German Aerospace Center, DLR, in Cologne and the Science Operations and Navigation Centre (SONC) at the Centre national d'études spatiales, CNES, in Toulouse via the Rosetta Mission Operations Center, RMOC at the European Spacecraft Operations Centre (ESOC) in Darmstadt. The scientific lead is at the Max Planck Institute for Solar System Science in Göttingen, Germany, and the Institut d'Astrophysique Spatiale in Paris, France.

The Lander system has been provided by an international consortium (with partners in Germany (lead), France, Italy, Hungary, Finland, UK, Ireland and Austria) and supports a scientific payload of ten instruments with an even larger number of sensor elements [5].

II. LANDING PREPARATION

Philae has been designed in a way, it could cope with a wide variety of possible comet thermal environments, shapes or surface properties. For more detailed information see e.g. [5,6]

At arrival at the comet in August 2015 a very stringent plan to coordinate the reception of data obtained from the orbiter, analysis and interpretation of these data, led to a landing site selection process in three steps and to the required preparations for the actual Separation-Landing-Descent (SDL) sequence [2].

The site selected and later named "Agilkia", was considered best, taking into account all technical and scientific aspects [2].

In preparation for the comet landing on November 12th, Philae was switched on already on November 10th to allow for a 24 hours heating phase to warm up the batteries to the required temperatures for operations.

On November 11th, the ADS (Active Descent System) tank was attempted to be opened, but failed.

Despite some uncertainties regarding the status of Philae´s condition (ADS failure, a problem to boot CDMS as well as during the conditioning of the primary battery), a GO decision was given to continue the sequence to deliver the Lander to the comet.

All the following activities in the landing timeline were performed flawlessly; including the activation of instruments like ROMAP, MUPUS, CIVA, SESAME and CONSERT.

III. SDL (SEPARATION – DESCENT - LANDING)

The final Rosetta pre-delivery manoeuvre was performed on November 12th at 06:06 UTC.

Separation from the orbiter, by activation of the MSS (Mechanical Support System) occurred, exactly as planned, at 08:35 UTC.

As foreseen, approximately 2 hours after separation, the communications link between Rosetta and Philae was established and data were acquired for the rest of the descent e.g. confirming the deployment of the landing gear, the ROMAP boom and CONSERT antennas.

Descent to the comet lasted almost exactly 7 hours. A Touch-Down (TD) signal was generated at 15:34 UTC [3] causing the CDMS to change the SW mode from "descent" to "on-surface"; ROLIS to stop taking descent images; set the Landing Gear brake at the Cardanic Joint for 2 sec to full closure; attempt to fire

the ADS thrusters and attempt to fire the anchoring harpoons.

While CDMS, landing gear and ROLIS performed smoothly the planned post-TD operations, this was not the case for ADS and the anchor, as the cold gas system failed to thrust and the harpoons did not fire.

IV. TOUCH-DOWN AND BOUNCING

Philae touched the surface of 67P on November 12th at 15:34:03.98 (± 0.10 s) UTC [3]. The touchdown signal was received and the Lander switched into the on-comet mode, starting the pre-programmed timeline. As neither ADS nor the anchoring harpoons were working, the Lander bounced off again and only came to rest after about 2 hours and three more ground contacts. The landings as well as the re-construction of the trajectory are described in detail by Biele *et al*. in [3].

Some instruments were switched ON during the bounce, as it was planned to operate them immediately after landing. E.g. ROMAP obtained particularly valuable data, while Philae was hopping in low altitude above ground [7]. CONSERT measured the internal properties of the nucleus [8] and COSAC and Ptolemy received excellent mass spectra in "sniffing mode", apparently analysing material excavated during the (first) touchdown [9,10].

Lander HK data indicated not only that the harpoons have not been fired but also the movement and rotation of the Lander (periodic illumination of the solar panels).

For the analysis of the hopping and the determination of the final location of the Lander data from OSIRIS, NAVCAM, ROMAP, ROLIS, CONSERT, MUPUS-TM and Lander HK have been used [3].

III. FIRST SCIENTIFIC SEQUENCE (FSS)

The unexpected bounce at touch down required a major adaptation of the FSS operations, which nevertheless ended in a self-standing suite of in-situ measurements which has never before been performed on a comet surface.

The batteries allowed operations for almost 64 hours after separation. In this time all instruments could be operated at least once. Between Landing and depletion of the batteries on November 15th at 00:05 UTC there were altogether five communications slots when commanding and data retrieval was possible. Details on the FSS are described in [11].

IV. WAKE-UP AND LONG TERM SCIENCE (LTS)

Due to the badly illuminated final landing spot of Philae, Long Term Science (LTS), based on the solar generator output was not possible immediately after FSS. The solar panels were only illuminated for about 1:20 hrs per comet rotation. Consequently, Philae fell into hibernation, and one had to wait for closer heliocentric distances, when enough power would be available to boot the Lander again and operate the communications system.

The first contact with Philae, after this hibernation occurred on June 13th, 2015. The link was short and it was not possible to send any commands. In the following, signals from the Lander were received seven more times, the last slot (so far) being on July 9th.

There is justified hope that in the late-October till December timeframe further contacts with the Lander can be established. For more details on the attempts to command Philae for LTS, see e.g. [11].

V. CONCLUSIONS

Philae performed the historic first landing on a comet in November 2014. Despite bouncing, due to failures of ADS and the anchoring harpoons, the Lander came to rest and performed outstanding science. After a first sequence Philae went into hibernation from which it woke up at closer heliocentric distances and re-established short RF links with the Orbiter after June 13. We are looking forward to the possibility to obtain further scientific data until the end of 2015.

ACKNOWLEDGEMENTS

The authors would like to thank the teams of Rosetta and Philae for realizing the project. We would like to particularly emphasize the contributions of Dr. Helmut Rosenbauer, whose efforts were essential for the realization of the Rosetta Lander.

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