Institution: The Open University, UK

Unit of Assessment: B7 Earth Systems and Environment Sciences

Title of case study: Space instrumentation: An exemplar of academic-industry partnership

1. Summary of the impact

The Planetary and Space Sciences (PSS) research group at The Open University has designed, built and deployed space flight instrumentation that is at the core of several iconic ESA (European Space Agency) missions. Following on from that work, the OU team has led and supported UK academia-industry consortia tendering to undertake ESA funded projects preparing for future missions. The work undertaken by these consortia has influenced ESA policy and practice, and helped enterprises in the UK Space Sector to attract significant funding, win contracts to supply ESA with goods and services, and move into new areas of business.

2. Underpinning research

The underpinning research associated with this case study relates to knowledge and understanding gained during The Open University's work in both building and operating instrumentation for space missions.

The Planetary and Space Sciences research group at the OU has a strong record of innovation in instrumentation for analytical measurements on extraterrestrial samples (e.g. Romanek et al. 2004, Alexander et al. 1998). The PSS team also led the science on a series of space exploration missions including building instruments to make in situ measurements on Solar System bodies. The PSS group involvement in key European missions has included:

- Leading *Beagle2*, the lander element of ESA's 2003 *Mars Express* mission (Wright et al. 2003) including an innovative gas analysis and stable isotope mass spectrometer package.
- Leading the *Surface Science Package* on the *Huygens* probe (containing nine independent sensor subsystems) that determined the physical nature and condition of Titan's surface at the landing site, on the successful ESA *Cassini-Huygens* mission to Saturn and Titan (Zarnecki et al. 2005).
- Leading the development of a gas analysis and mass spectrometry instrument known as *Ptolemy*, which aims to measure cometary hydrogen, carbon, nitrogen and oxygen, and their isotope ratios as part of the *Rosetta* mission to sample a comet in 2014 (Morse et al. 2009).

Following on from the intensive development phases for these missions, the PSS team worked on research contracts funded by ESA in preparation for future missions, where their experience in science objectives, instrument design, and operation played an important role in the success of the projects.

Specific examples of ESA studies include:

- The L-VRAP Project: this study was an exercise to design a dual mass spectrometer system capable of detection, quantification and characterization of volatiles for future missions to the Moon – based on gas handling and mass spectrometry instruments developed for *Mars Express* (*Beagle2*) and *Rosetta* (Wright et al. 2003; Wright et al 2012). The work made use of strong UK heritage in building such instruments and anticipated renewed ESA interest in lunar missions in the last year.
- The DUSTER Project: This ESA project proposed an alternative to the use of a heavy vibrating mechanical pump to compress Martian atmosphere to blow away dust that has settled on the solar panels and thermal radiators of Mars landers. The Open University proposed an elegant alternative system that makes use of day-night temperature variations to fill and pressurise a container with Martian atmosphere. In the cold of the Martian night the container is opened and atmosphere is chemically trapped in the vessel. In the warmer

daytime, with the container valve shut, gas desorbs (Patent to Sheridan et al. 2010). The now pressurised gas is directed via a moveable nozzle to remove fine dust from solar panels and thermal radiator exchangers thus directly enhancing mission performance and lifetime.

- Mars sample return and storage projects: The Open University team worked on several ESA funded projects aiming to develop understanding and expertise in preventing biological contamination of the target celestial body (either Mars or Earth). The knowhow for this work had been developed in earlier preparation for the *Beagle 2* lander on the Mars Express mission in order to meet Committee on Space Research (COSPAR) rules on contamination.

3. References to the research

Academic outputs

Alexander, C.M.O'D. et al (1998). The origin of chondritic macromolecular organic matter: a carbon and nitrogen isotope study. (Meteoritics and Planetary Science, 33 (4), pp. 603-622.

Morse, A.D., Morgan, G.H., Andrews, D.J., Barber, S.J., Leese, M.R., Sheridan, S., Wright, I.P. and Pillinger, C.T. (2009). Ptolemy – A GCMS to measure the chemical and stable isotopic composition of a comet. In: *Rosetta – ESA's Mission to the Origin of the Solar System*, (eds. R.Schulz, C.Alexander, H.Boehnhardt and K.H.Glassmeier), Springer, ISBN 978-0-387-77517-3.

Romanek, C.S. et al. (1994). Record of fluid-rock interactions on Mars from the meteorite ALH84001. Nature, 372 (6507), pp. 655-657.

Wright, I.P., Sims, M.R., and Pillinger C.T. (2003), Scientific objectives of the Beagle 2 lander, Acta Astronautica, Volume 52, 219-2.

Wright, I. P.; Sheridan, S.; Morse, A. D.; Barber, S. J.; Merrifield, J. A.; Waugh, L. J.; Howe, C. J.; Gibson, E. K. and Pillinger, C. T. (2012). L-VRAP-a lunar volatile resources analysis package for lunar exploration. Planetary and Space Science, 74, pp 254–263.

Zarnecki, J.C. et al. (2005). A soft solid surface on Titan as revealed by the Huygens Surface Science Package. Nature, 438 (7069), pp. 792-795.

Patent

Sheridan, Jarvis and Morgan (2010). Miniature valve for helium flow control. The Open University, PCT/GB2009/002584.

Funding:

2011- 2012: €298,779 awarded by ESA to Professor Colin Pillinger for the project 'L-VRAP: Lunar Volatile (Resources Analysis) Package for Lunar Exploration'. Partners included Astrium Ltd, Fluid Gravity Engineering Ltd, RAL Space.

2013: €182,000 awarded by ESA to Dr Manish Patel (Lead partner Magna Parva Ltd) for the project entitled 'DUSTER: Dust Unseating from Solar panels and Thermal radiators by Exhaling Robot'. Partners included Magna Parva Ltd (Lead) and Fluid Gravity Engineering Ltd.

2006-2009: €134,500 awarded to Dr Simeon Barber by ESA (Lead partner Systems Engineering and Assessment Ltd) for a series of four projects entitled 'Mars Sample Return Planetary Protection'. Partner SEA Ltd.

4. Details of the impact

The work of The Open University Planetary and Space Sciences group has had significant impact through academic-industry partnerships, supporting UK space sector and government agencies. Our research can be very applied in nature, and we "speak the language" of industry and

engineers, meaning we can work well in multidisciplinary and cross-sector teams. Here we use a series of case studies to illustrate The Open University contribution to academic-industry partnerships that have attracted ESA funding, won contracts to supply ESA, and supported enterprises to move into new areas of business, all of which help to safeguard jobs in advanced manufacturing in the UK. Some of the projects we have undertaken have also influenced ESA's ability to develop global partnerships.

The first example, the L-VRAP (Lunar Volatile Resources Analysis Package 2011-2012) project within ESA's Lunar Lander programme, initially attracted €300k to a consortium led by The Open University (including RAL Space, EADS Astrium Ltd, Fluid Gravity Engineering (FGE), and the NASA Astromaterials Research Office, USA). The L-VRAP project allowed EADS Astrium, an established prime contractor in space hardware, to be involved in Lunar Lander design with a view to future opportunities to tender for contracts with ESA in any eventual mission implementation. The L-VRAP study allowed FGE, a UK based scientific consultancy specializing in computational physics, to apply its expertise in a new area of research, Jim Merrifield of Fluid Gravity Engineering commented:

> 'Partnering with The Open University on the L-VRAP project has enabled us to restart our line of activity in in-space plume modelling which has allowed us to make a stronger case for proposing repeat business. Additionally, certain aspects of the plume regolith interaction needed to support L-VRAP have enabled us to participate in contracted work concerned with the sub-sonic liberation of dust from solar panels on Mars. This is a new area of work for us, both in terms of application and flow regime.'

The L-VRAP project has also had significant impact in the European Space Agency because of the recent renewed interest in international partnerships for a lunar lander mission. Berengere Houdou, Head of the ESA Lunar Lander Office commented:

> 'The work of The Open University team led to the design of a package to analyse complex chemistry and potentially valuable resources on the Moon. This has provided us with an important input for discussions with potential international partners, with a view to developing an international lunar exploration programme.'

The second example, the DUSTER project (2012-2013), is led by the UK based space engineering consultancy Magna Parva, with partners FGE and makes use of a key piece of Open University knowhow, chemical pumping. The initial work has attracted over €450k to UK industry and placed them in an excellent position to win the contract to build devices to extend the lifetime of future martian explorers built by ESA. Miles Ashcroft of Magna Parva commented:

> 'The successful contract win with ESA to perform the DUSTER project was heavily influenced by the ability of MPL to be able to partner with Fluid Gravity Engineering and The Open University. In particular the benefit of utilizing existent practical research and a knowledge base in the applicable field. Additionally it is expected that this will provide on-going benefits as the developed technology is pulled through into flight applications.'

In our third example, The Open University partnered with SEA (Systems Engineering and Assessment), in 4 ESA studies (2006-2009) to help implement planetary protection strategies for

Mars missions. The work was led by SEA, and the partnership with the OU allowed them to move into a new area of business, training scientists and engineers in European industry and research organisations in building microbially clean spacecraft. The training materials developed by The Open University were delivered to Thales Alenia Space (Italy – prime contractor for ExoMars) who have delivered training to over 600 people working on ESA space mission programmes in 6 countries across Europe. Subsequently, SEA won contracts from ESA to undertake work on precision cleaning for returned Mars sample curation. This work is of strategic importance to the UK, since it is prioritising sample curation in the post-*ExoMars* programme.

Finally, the impact of the Planetary and Space science group capability extends to several international partners. One such example is CSEM, a Swiss manufacturer of MEMS (microelectromechanical systems) for clocks and watches, for whom a €400k ESA project with The Open University enabled a move into the manufacture of MEMS-based miniature gas chromatograph-mass spectrometry equipment for space missions and other applications.

5. Sources to corroborate the impact

External sources corroborating impact:

1. ESA Report 103345. Lunar Volatiles Package for Lunar Exploration (L-VRAP) (2012) http://esamultimedia.esa.int/docs/gsp/C103345ExS.pdf

2. Lester Waugh, of EADS Astrium reflects on the positive impact of work on Beagle 2 upon the European Space Agency. http://www.independent.co.uk/student/magazines/enginnering-with-esa-mars-attracts-427097.html

3. Systems Engineering and Assessment case study on their planetary protection business highlighting the Open University http://www.sea.co.uk/Docs/aerospace/Aerospace%20Case%20studies%202011/planet%20protect%20cs%20aug%2008.pdf

Beneficiaries who could be contacted to corroborate impact:

4. Head of the Lunar Lander Office, European Space Agency
5. Director, Magna Parva
6. Senior scientist, Fluid Gravity Engineering
7. Senior Engineer, Thales Alenia Space (Italy) – customer for the OU/SEA planetary protection training materials
8. Head of Imaging systems - RAL Space