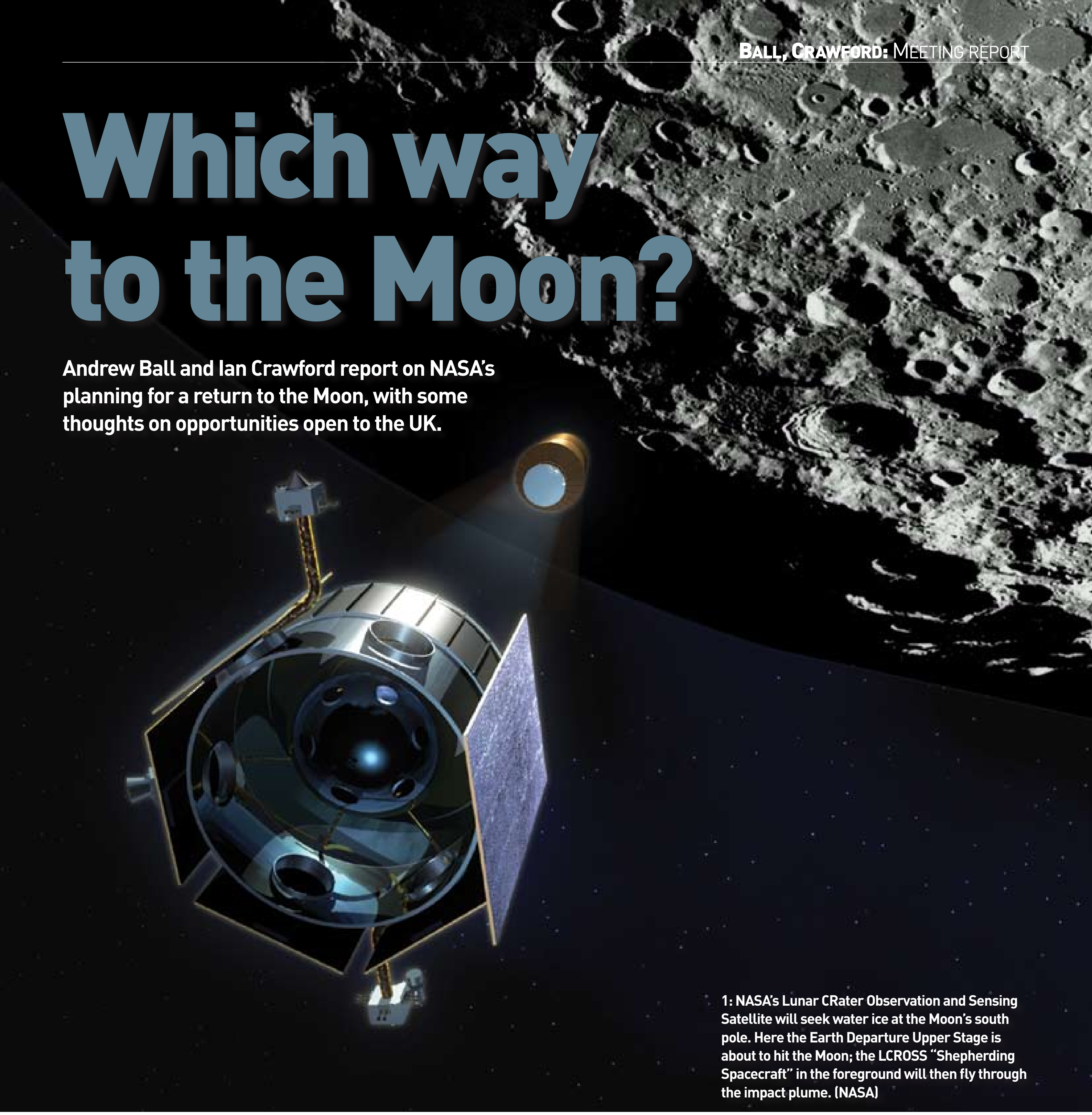
Which way to the Moon?

Andrew Ball and Ian Crawford report on NASA's planning for a return to the Moon, with some thoughts on opportunities open to the UK.



1: NASA's Lunar CRater Observation and Sensing Satellite will seek water ice at the Moon's south pole. Here the Earth Departure Upper Stage is about to hit the Moon; the LCROSS "Shepherding Spacecraft" in the foreground will then fly through the impact plume. (NASA)

Abstract

A PPARC-led delegation comprising David Parker (BNSC/PPARC Director of Science), Prof. Sir Martin Sweeting (Surrey Satellite Technology Ltd), Ian Crawford (Birkbeck College) and Andrew Ball (Open University) attended the NASA Exploration Strategy Workshop in Washington DC, from 25–28 April 2006 (http://www.aiaa.org/events/expwkshp). NASA initiated the workshop as a first step in its activities during 2006 to define a strategy for lunar exploration, building on the "Vision for Space Exploration" announced in 2004 (http://www.nasa.gov/mission_pages/exploration/main/ and http://exploration.nasa.gov/). Given the backdrop of the Vision framework, the goal was to bring together the reasons why we (meaning humanity) are going back to the Moon and what we want to do there. For many, the answers to these questions have been clear, albeit diverse, for a long time, being articulated and updated in various forms over the years (e.g. ESA 1992, 2003; Spudis 1996, 2001; Crawford 2004a,b; Stern 2005). The answers to the "why" and "what" questions reflect a wide variety of scientific, technological, commercial and societal motivations.

The NASA Exploration Strategy Workshop was attended by about 200 invited delegates, mostly from the USA. Some 60 had come from 12 other nations, including ESA and its largest member states, Russia, Canada, Japan, India and China. Only a fraction of the US attendees were NASA employees, the rest being from industry, science, other government agencies and special interest organizations. In parallel, NASA released a call for information to gather input from those not able to attend. Given that this was a NASA event held in Washington DC, we found it much more internationally balanced than we had expected.

The first day featured invited plenary presentations, followed by two days split into seven working groups of about 25 people, and finally a half-day plenary session for feedback and closing remarks. The first day gave an overview of the situation, briefing the attendees for the subsequent working group sessions. There seems little doubt that the USA intends to push ahead with the "Vision for Space Exploration" as outlined in 2004 (http://www.nasa.gov/mission_pages/exploration/main/ and http://exploration.nasa.gov/). The plenary session covered lunar science, the current exploration architecture (robotic and crewed); commerce, and links with Mars exploration. Little was said about current or planned lunar missions from Europe, Japan, India, China, etc, but current international efforts and the results expected will no doubt influence NASA's plans.

The initial "Vision" architecture defines little more than the technical means for a return to the Moon. It includes two new launchers (Cargo Launch Vehicle and Crew Launch Vehicle), two crewed vehicles (a Crew Exploration Vehicle and a Lunar Surface Access Module) and a Robotic Lunar Exploration Programme (RLEP). This starts in October 2008 with the launch of the Lunar Reconnaissance Orbiter (LRO) and LCROSS (Lunar CRater Observation and Sensing Satellite). A robotic lunar landing is then planned. This second launch is currently in the "requirements definition" phase, with the codename RLEP2. It seems, however, that the ensemble of objectives to be addressed on the lunar surface by the initial robotic element cannot be met by a single lander. This is particularly true of the need to first find and characterize any polar volatiles, before related *in situ* resource utilization (ISRU) can be demonstrated. How the missions beyond LRO/LCROSS will be used in the Vision and interact, if at all, with non-US activities is a matter for discussion within and beyond NASA. NASA needed this workshop to give the process greater direction, help broaden the range of stakeholders and to initiate an open discussion with potential international partners. On this last point, nothing seemed to have been ruled in or out at this stage, a situation that marks a window of opportunity for the UK and other countries.

It seems to be a matter of debate whether NASA can actually meet the Vision goals of developing the necessary infrastructure and flying a crew of four to the lunar surface by 2018. There are a number of risks, not least in terms of resources and the degree to which the programme can survive the current US administration. Perhaps the USA is keen for international partners to step forward to share the burden, though whether partners would want, or be permitted, to be on the critical path for the core elements seems to be an open question. NASA is keen to work towards a global exploration strategy, but the framework for co-operation with potential partners remains to be defined. The programme seems likely to survive in some form, the biggest imperative perhaps being that the USA returns a crew to the lunar surface before China does it alone.

The science case

The authors were assigned to the same working group (chaired by **David Beaty** from NASA JPL), one with a slight science bias in its composition. We were fairly successful in getting science objectives included in the group output, as well as those concerning technology (including lunar orbital navigation and communications infrastructure), commerce and society. The scientific objectives included:

- Identification and characterization of palaeoregoliths
- Establishment of a lunar drilling programme (with palaeoregoliths in mind)
- Calibration of the lunar (and thus terrestrial) cratering rate
- Search for ancient Earth meteorites (important for astrobiology)
- Sampling of a representative range of crustal lithologies (including especially the South Pole Aitken Basin and the far-side highlands)
- Establishment of a global network of seismic and heat-flow stations
- Search for, and characterization of, polar ices
- Establishment of a lunar life sciences programme
- Characterization of the lunar surface as a platform for astronomical observations (e.g. optical/IR interferometry and far-side radio observations)
- Assessment of lunar resource potential (including ISRU)
- Assessment of the value of lunar operations as a test bed for future Mars exploration.

There are many reasons why the UK might be motivated to become involved in the next steps of lunar exploration, boiling down to a set of scientific, technological, commercial, educational, societal and political arguments. The scientific case has been well developed and articulated over the years, although it still lacks prominence in the current PPARC strategy and in ESA's planning for the Cosmic Vision and Aurora programmes. However, there does now seem to be an increasing understanding of the scientific potential of these activities, as set out most recently in the *Report of the RAS Commission on the Scientific Case for Human Space Exploration* (Close *et al*. 2005). There are certainly many promising young (i.e. "post-Apollo generation") members of the UK planetary community keen to explore the Moon, even some currently working abroad who might be attracted back to the UK to do so. It is worth noting that the UK already plays a role in lunar research, participating in the Clementine, SMART-1, Chandrayaan-1 and LRO missions, as well as geological studies using remote sensing data and lunar meteorites. In addition, we should be alert to possible synergies with Mars exploration, as emphasized during the workshop's plenary session by **Charles Shearer** (University of New Mexico) in his presentation of a "Moon/Mars science linkage analysis". Given the currently higher priority given by PPARC to martian science, and the prospect of a Mars sample-return mission, the links highlighted could yield an excellent set of strategic criteria for prioritization of the UK's lunar science interests.

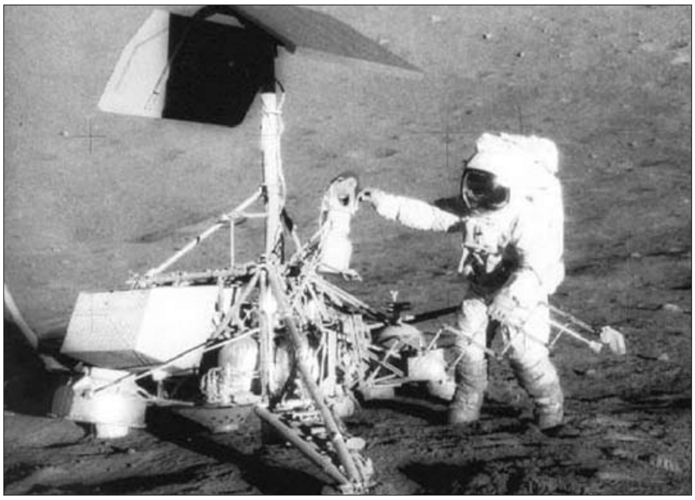
The way forward

If the UK is serious in being involved in future robotic and human lunar exploration, there are several roles that we could play. These include many in which the UK has world-class capability, such as: the provision of space instrumentation for remote sensing and *in situ* measurements, spacecraft platforms and subsystems including microsatellites, communications and navigation systems; elements of surface infrastructure such as landers, penetrators and rovers; ground-based facilities for sample curation and analysis (e.g. UKCAN); and, last but not least, a broad community of scientists and engineers with knowledge and experience in many other fields applicable to lunar exploration. One possibility would be for the UK to make an early bid to provide, in whole or in part, a lunar orbital communications/navigational infrastructure. This would play to UK industrial strengths, and would provide an element that would rapidly become an essential contribution to the more ambitious elements of the Vision later on. We should not underestimate the strength of this potential bargaining chip. However, a communications infrastructure will not, in itself, yield the scientific or educational/inspirational benefits that we should also aim to get from participation. We should have other strings to our bow.

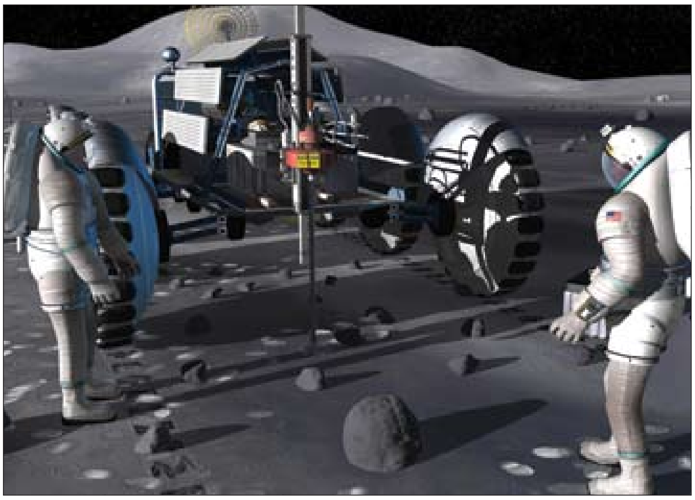
In the short term we should consider participation in robotic surface exploration, building in part on the Beagle 2 legacy. It was clear that the RLEP is overstretched, and this may provide opportunities – either for UK/European participation in RLEP2, a UK-led robotic lander to complement RLEP2, or perhaps UK participation in a Chinese lander such as the proposed Chang'E II mission. Since it seems that RLEP2 will concentrate on Vision-oriented technology development (e.g. ISRU demonstrations), there is in principle a niche for a UK-led robotic lander to concentrate on scientific exploration (e.g. surface geochemistry, a geophysics package, and/or sample-return). This could be scientifically very valuable if sent to key parts of the lunar surface that have not yet been visited. Moreover, technology and experience developed would also help support the UK's priorities in Aurora and other programmes, especially Mars Sample Return.

A UK astronaut programme?

In the longer term, one exciting possibility would be to ask NASA to facilitate the training and flight of a British astronaut (e.g. a lunar field



2: Astronauts achieved great things during the Apollo landings, including visiting Surveyor 3, during the Apollo 12 mission. Could UK astronauts visit the Moon, through NASA's Vision for Space Exploration? (Apollo 12/NASA)



3: NASA's Vision includes plans for a return to the Moon, including sampling and drilling into the surface, as depicted here. UK expertise in, for example, robotics, instrumentation and space medicine could be part of this enterprise.

geologist) in return for our unmanned infrastructure contributions. Actually a minimum of two such astronauts would be required, both to provide a backup, and to provide sufficient "free" astronaut time for educational activities, which we see as one of the major benefits of participation. However, it would be important that this be part of an on-going programme with well-defined goals, not perceived as a one-off "stunt". If we are to maintain public interest and excitement (and thus make the most of the educational benefits) we would probably need a flight before the first non-US astronauts are likely to make it to the Moon (2025?). This would mean starting with an initial Soyuz flight to the ISS, while making it clear that this is part of a programme ultimately leading to the Moon (perhaps by another UK astronaut at the appropriate time). It is in any case very likely that the first batch of lunar astronauts will be selected from those who have already had space experience (certainly this was, very wisely, the case with Apollo), so a prior visit to the ISS could also be seen as part of the essential training of a UK lunar astronaut. This being the case, the initial science beneficiaries would be the life sciences, especially human physiology and medicine. The UK does have a significant interest in this field (e.g. Fong 2004a,b, Rennie and Narici 2004), and the Independent Microgravity Review Panel (Wakeham *et al.* 2003) made it clear that there are scientific benefits to be had from these activities.

Probably the most realistic way to arrange all this in the short term will be bilaterally with the USA, as part of the Vision, the wheels of ESA being rather slow to turn, owing to its existing ISS commitments and other financial and programmatic constraints. However, it is important not to alienate ESA, especially given the UK's leading role in Aurora, and in the long term we believe that working through ESA should be the norm. Indeed, the UK should help formulate a possible lunar strand to Aurora that seems likely to be put before the ministers in 2008. Moreover, if a UK astronaut arrives at the ISS for the purposes of life-science investigations leading to future Moon missions, it would clearly make sense to utilize the facilities offered by the Columbus module (assuming that this will have been launched by then). Of course, the UK hasn't contributed to Columbus, but this difficulty might be avoided if the UK were to sign up to ESA's Programme for Life and Physical Sciences utilizing the ISS (ELIPS) at the modest level recommended by the Microgravity Review Panel (Wakeham *et al.* 2003). This would of course further boost UK space life sciences in readiness for the later opportunities to be provided by lunar operations. That said, we should not lose sight of the fact that the ultimate aim is a British Lunar Field Geology Programme, in return for our provision of lunar infrastructure. Thus, in the longer term, it will be the UK planetary science community that stands to benefit most. This being so, we should also aim to bolster UK lunar science expertise in readiness for the new data and rock samples that will ultimately come our way as a result of participation in the programme. Of course, this also plays to existing UK scientific strengths in geophysics and extraterrestrial sample analysis.

A British Space Agency?

Going forward, it will be important for PPARC (or its successor agency) to keep in touch with the NASA strategy process if the UK is motivated to seek a significant role in international lunar exploration. We believe that the UK should be proactive in its approach, formulating a position and discussing opportunities with potential partners, before those opportunities evaporate or are taken by other nations. The possible scale and multidisciplinary scope of the UK's participation in global space exploration activities raises the question of whether the UK currently has the institutional infrastructure to deal with such an involvement. For example, should the UK have a space agency? This could then have responsibility for UK participation in ESA programmes, Aurora, and any bilateral agreements with the USA (along the lines set out above), and possibly other countries such as China and India. Crucially, a dedicated space agency could ensure that all the multidisciplinary aspects of space exploration (e.g. space science, planetary science [including astrobiology], life sciences [including human physiology and medicine], physical and materials science, and science education) are co-ordinated under one roof rather than, as at present, all-too-often falling between the stools of different research councils. The desirability of such coordination was recognized by the 2004 *Cross-Council Report on Aurora* (Holdaway 2004), and would be even more desirable if the UK were to participate in the US Vision in addition to Aurora. ●

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