Painting courtesy Robert Murray

The scientific case for human space exploration

Ian Crawford and Charles Cockell report on a wide-ranging RAS Discussion Meeting putting the broad scientific case for people in space, at the Linnean Society on 10 December 2004.

Despite the tragedy of the Columbia accident in February 2003, and the resulting hiatus in construction of the International Space Station, the prospects for human space exploration are in many ways brighter than at any time since the Apollo programme in the late 1960s. In January 2004 President Bush announced a new Vision for Space Exploration, which has refocused NASA's objectives towards human missions to the Moon and Mars, and the European Space Agency's Aurora programme has established similar objectives for Europe.

At some stage the UK will have to decide whether, and to what extent, to participate in these exciting endeavours. It is clearly important that the scientific issues are carefully examined, which was the primary motivation for this meeting. In addition, the RAS has decided to establish an independent commission, under the chairmanship of Prof. Frank Close, to examine the scientific arguments for and against human spaceflight (see "Human spaceflight review" p1.7). The members of the review commission were present at the meeting, which may therefore be seen as marking the beginning of the evidence gathering phase of the commission's work.

While the subject of human space exploration is controversial in the UK, with many scientists believing that the resources would be better invested in robotic missions, it can be argued that human beings are uniquely qualified to undertake key scientific investigations in the space environment. These range from life and physical sciences research in microgravity, to geological and biological fieldwork on planetary surfaces. The meeting covered all these areas, providing a valuable interdisciplinary overview of the scientific case for human space exploration. Many of the talks also addressed some of the wider societal issues that arise in the context of human space activities.

Space life sciences

The first talk was given by **Kevin Fong** (lecturer in physiology and Director of the Centre for Aviation, Space and Extreme Environment Medicine, at UCL), who reviewed the UK's position on human spaceflight from a life-sciences perspective. He argued that the study of human physiology in the space environment provides unique insights into whole-body physiology, and in such areas as bone physiology and neurovestibular and cardiovascular function. These areas are important for understanding various terrestrial disease processes (e.g. osteoporosis, muscle atrophy, cardiac impairment, and balance and co-ordination defects). Moreover, research in space physiology provides a stimulus for the development of innovative medical technology, much of which is directly applicable to terrestrial medicine. Unfortunately, present UK government policy with regard to human spaceflight means that the UK space life sciences community is effectively excluded from participating in research in these areas. Dr Fong further argued that human spaceflight is of educational value in inspiring the younger generation to take an interest in science and engineering, and pointed out that the independent Microgravity Review Panel, which reported in 2003, had come to the same conclusion. Indeed, the Microgravity Review Panel had recommended that the UK participate in ESA's Space Station Utilisation Programme (ELIPS), but the government has so far failed to act on this advice.

The second talk was given by **Bernhard Hufenbach** (ESA Directorate of Human Spaceflight, Microgravity and Exploration) who reviewed the past achievements and future opportunities of human spaceflight from a European perspective. Europe started to invest in human spaceflight in the early 1970s with the development of Spacelab, a versatile scientific laboratory launched with the US Space Shuttle. Between 1983 and 1998, 23 Spacelab missions were implemented, with European scientists involved in more than half of them. In 1994–95 there were two European astronaut missions to the Russian Mir Station, lasting 31 and 179 days, respectively. Then in 1998 Europe joined the International Space Station (ISS) Programme and is today a major contributor to the development and user of the ISS infrastructure. While past investments in human spaceflight were largely political driven, clear scientific achievements and benefits can already be identified, particularly in space life sciences (including human physiology and medicine), fluid and materials science, and fundamental physics.

Today, Europe invests about €700 million annually in human spaceflight and related research activities, and is in the process of defining its future contribution to international space exploration in a way that combines the skills and capabilities of automatic and human missions.

Humans vs robots

After the coffee break, **Paul Spudis** (Applied Physics Laboratory, Johns Hopkins University, and Presidential Commission on the Implementation of US Space Exploration Policy) outlined the new US vision for the human exploration of the Moon and Mars. He explained that this differs from earlier – failed – visions in that it is supported politically at the highest levels of the US administration, and that it will adopt an affordable step-by-step approach that does not assume unsustainable increases in NASA's budget. A key aspect of this strategy will be to assess the extent to which extraterrestrial resources, for example lunar polar ice deposits, can be used to support exploration activities, thereby reducing launch costs from Earth. Dr Spudis went on to outline the scientific importance of the Moon as a natural laboratory for planetary science, a site for future astronomical instruments, and as a potential source of energy and raw materials. He argued that human adaptability and versatility, especially as field scientists and engineers, means that a human presence will be required to maximize these benefits. Dr Spudis also argued that learning to live and operate on the Moon will be the best possible proving ground for eventual human and robotic operations further afield.

Dr Spudis was followed by **Jim Garvin** (NASA Chief Scientist) who argued that human-based exploration of the Moon and Mars will greatly accelerate the pace of scientific discovery relative to what can be achieved robotically. Humans bring speed, agility, versatility and intelligence to exploration in a way that robots cannot. Although the Mars Exploration Rovers (MER) Spirit and Opportunity are doing a fantastic job on Mars, there can be no doubt that humans would have achieved far more, and done so much more quickly. For example, Spirit traversed a total distance of 3.9 km in its first 330 days on Mars, which may be compared with the total of 36 km traversed by the Apollo 17 astronauts in just 22 hours of EVA activity on the Moon in 1972. Moreover, many of the scientifically most interesting localities on Mars (such as scarps at the edge of the polar ice deposits, and the floors and walls of outflow channels) are characterized by steep slopes and rugged terrain that robots cannot easily explore. It is at just such locations where the versatility and experience of human explorers will come into their own. Dr Garvin made the further observation that human exploration may actually be less expensive than comparable robotic missions. For example, the MER missions cost approximately $1 bn, whereas a human mission to Mars might cost $100 bn. However, if human exploration can be shown to be more than a hundred times as capable and efficient, then its cost "per discovery" will be less – and some discoveries may be impossible using robots anyway.

The first talk after lunch was by **Charles Cockell** (British Antarctic Survey) who discussed the advantages of human over robotic exploration in searching for evidence of life on Mars. Dr Cockell began with the observation that the "robots versus humans" debate overlooks the fact that there is a sense in which humans are the most complicated and versatile robots to which we will ever have access. Although it is true that humans will face many dangers and obstacles operating on other planets, mostly due to their physiological limitations when compared to robots, the potential scientific returns (resulting from rapid sample acquisition, the ability to integrate widely disparate data and past experience into a coherent picture, and the on-the-spot ability to recognize observations to be of importance even if they relate to phenomena not anticipated in advance) is more than sufficient to justify employing astronauts as field scientists on other planets. Moreover, as stressed by other speakers, the unique ability of human beings to engage with other human beings will greatly enhance the educational and cultural benefits of planetary exploration.

The next talk was by **Bernard Foing** (Chief Scientist of the ESA Science Programme and Director of the International Lunar Exploration Working Group) who presented a rationale and roadmap for Moon–Mars exploration. The key scientific rationales for Moon and Mars exploration include the formation and evolution of rocky planets, accretion and bombardment in the inner solar system, comparative planetology and astrobiology. Planetary exploration will begin with robotic precursors, but lead on to human exploration. Dr Foing identified three top-level imperatives that will drive this process forward: the "cultural imperative" to explore our surroundings, the "scientific imperative" to understand what we find, and the "political imperative" to try to unify humanity through global endeavours of mutual achievement and challenging enterprise. He stressed that, rather than fixing any particular destination, the most important thing is to establish a process of exploration that will "draw us out into the solar system".

The final talk was given by **Ian Crawford** (UCL and Birkbeck College) on an integrated scientific and social case for human space exploration. He argued that an ambitious human spaceflight programme stands to enhance human knowledge across several fields simultaneously. In the case of lunar exploration, he stressed the unique potential of the Moon as an archive of early solar system history, and the probable requirement for human field-geologists in order to access it. However, other disciplines would also benefit from a return to the Moon, and simplistic "cost benefit analyses" from the point of view of any single discipline are meaningless in isolation. This is because the same "costs" (say of establishing a lunar base) may confer simultaneous "benefits" in areas as diverse as lunar geology, observational astronomy, materials science, biology and human physiology, and medicine. Moreover, science is only one thread in the much larger overall case for human spaceflight. Other threads include the economic (e.g. enhanced employment in key industries, and the resulting positive multiplier effect on the wider economy); the industrial (e.g. the development of new skills and technologies likely to have wider applications); the educational (e.g. the inspiration of young people into science and engineering); the political (especially the encouragement of international cooperation); and the cultural (i.e. the general enrichment of our world view from an expansion of human horizons). Any responsibly formulated public space policy must take a holistic view, and weigh all of these factors before deciding whether or not an investment in human space exploration is worthwhile.

Conclusion

There was unanimity among the contributors that human spaceflight has the potential to advance human knowledge on several fronts simultaneously. The space life sciences, and especially human physiology and medicine, require people in space because people form the experimental subjects for this research. At the same time, the fields of planetary geology and astrobiology stand to benefit enormously from the versatility of human beings working as field scientists on the Moon and Mars. Crucially, the latter activities will rely on the former – field geology requires active, healthy people operating on planetary surfaces, which means that the effects of the space environment on human physiology must be fully understood and appropriate countermeasures devised. As Paul Spudis pointed out in his talk, science both enables, and is enabled by, human space exploration. ●

Ian Crawford is in the Department of Earth Sciences at UCL and Birkbeck College. Charles Cockell is at the British Antarctic Survey.

Further information

It is intended that the proceedings of this meeting will be published in a special issue of the journal *Earth, Moon and Planets*. In the meantime, the abstracts of the talks, poster contributions, and the speakers' presentations (as PDFs of the original PowerPoint slides), are available at: http://www.star.ucl.ac.uk/~iac/RAS_space_meeting.html.