Recommendations of the Microgravity Review Panel

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Summary of Recommendations

We recommend participation in the ESA ELIPS programme at the minimum level to give access to the unique microgravity facilities operated by ESA. We believe that while there is no single scientific area where such an investment would lead to a real breakthrough there are a number of areas where access to this complementary tool would be of value. Such facilities would support the work of many high-quality UK researchers carrying out work of fundamental importance. Importantly we note that without such access, UK researchers will be excluded from European collaborations in many areas of science and will not be able to influence some aspects of future European science policy.

We believe that payment of the subscription constitutes better value for money than uncoordinated funding of individual projects since it, alone, allows full international participation.

Funding would most sensibly come from OST since the benefits would undoubtedly be to pure scientific research and across a wide range of disciplines within the remit of several of the Research Councils. A commitment should be made for seven years to match the ESA subscription cycle, with a review in 2007 (in advance of the following round).

A marginal additional benefit would be gained in attracting students into science and technology and by public engagement in science in an area that is seen as exciting.

The issue

The ability to conduct experiments in a variable gravitational field is a new tool which offers the potential to do new physical and biological experiments. Access to the facilities that comprise this tool is controlled throughout the world by space agencies (and in the case of Europe through the European Space Agency (ESA)). ESA's control is exercised through a quinquennial subscription whose payment allows a member state to access purpose-built facilities, to collaborate in the formulation of research programmes and to participate in projects.

The UK's previous stance with respect to the construction of these facilities and the subscription means that from 2003 the arrangements that have allowed our scientists

to participate in any aspect of ESA's microgravity programmes will cease. We have been asked to address (see Terms of Reference) whether we should now seek to gain continuing formal access to the microgravity facilities by payment of a quinquennial subscription and whether such a subscription would constitute value for money.

To join the ESA programme (ELIPS) at the minimum permitted level, the attached chart (Figure 1) shows that by 2004 we should have to make a further decision to commit to the second period of the programme. That programme continues to 2009. Such a seven-year commitment requires a cumulative subscription of €22M which results in an annual cost of £3.4M (including management and facility usage costs). It should be noted that of this sum 2/3 would be returned to UK industry by virtue of *juste retour* rules.

Methodology adopted by Review Panel

The relatively recent advent of the tool of microgravity means that there is little hard quantitative evidence with respect to its scientific utility through scientific output or applications. The fact that the UK has not been able to participate fully means there is even less UK-based evidence. We have therefore been forced to rely on qualitative input from various sources including UK researchers. In the absence of measures of the quality of UK research using this tool we have used judgements about the quality of the proponents of its use. Other information that we have taken into account included an information paper presented by BNSC, previous reviews in the UK and abroad, interviews with overseas leaders in the field and the research plans of ESA and NASA.

Findings

Our contacts with international colleagues indicate relatively little interest throughout the world from industry in the use of microgravity facilities in the short term. We find ourselves in agreement with this view from the UK perspective. This is not surprising given the fact that the use of microgravity is still in a very early stage and the potential has not been examined or publicised in the UK. We see no widespread use of space facilities for manufacturing operations for the foreseeable future owing to the prohibitive cost.

It follows that we have concentrated our study on the use of the tool in the areas of fundamental scientific research. In this case the chief benefits will lie in the increased understanding of a range of different scientific phenomena where the presence or absence of gravity may be key to their elucidation. As with all high-quality fundamental research, there will be applications of this new knowledge in the longer term. This view is in accord with what we have learned from such organisations as ESA, NASA, and the German and Canadian Space Agencies.

UK scientists account for the fifth largest number of applicants to ESA's international programme in life and physical sciences (after Germany, France, Italy and the USA respectively) despite the lack of formal support. We have noted that of the 56 UK university scientists whose proposals were highly rated by ESA in a recent competition or who are members of ESA's Topical Teams, 41 are rated 5 or above

(23 are 5*) in the most recent RAE. We believe that this indicates that the work being proposed by UK scientists using microgravity is of a high international standard.

We note that the subscription required would amount to a sum of some £60k per year per current researcher. This is a prerequisite to gain access to microgravity facilities and enable them to submit proposals to funding agencies for projects. Only by such participation will UK scientists be able to contribute fully to the development of their field. This takes no account of the penumbra of researchers who would also benefit from such investment by virtue of access to the results. Because the microgravity environment is unique there are no comparators to guide an estimate of value for money.

We have also found considerable public interest in activities in space, particularly those that have human involvement. This has been exploited by several space agencies to enhance the interest of the community in science and its applications, and the UK could do the same. In particular, we noted that of three student groups selected on the basis of scientific excellence from ESA member states for flight of their microgravity experiments on the Russia Foton capsule, two were from the UK, and of 163 participants in a recent European teachers' workshop on the Space Station, 22 were from the UK.

One of the characteristics of a tool such as microgravity is that it finds application across an exceedingly wide range of science. Our investigations have not indicated that any branches of science in the UK would be irreparably damaged by the absence of such a facility, neither is there strong evidence that microgravity would lead to a breakthrough in any single field. However it is clear that one immediate consequence of not participating in the programme is that a group of high-quality UK research leaders will simply be excluded from planning and interpretation of a fraction of the experimental work in their field. The evidence suggests that this new tool can provide information complementary to that provided by other tools.

We believe that there are several areas of scientific research that would benefit especially from the use of microgravity facilities, but our list is not exhaustive nor in order of priority. We are of course unable to take into account those serendipitous discoveries that have historically usually arisen from access to new environments.

- In biology, the ability to conduct experiments with normal gravity and in zero gravity allows the cellular, genetic and molecular basis of signal transduction to be studied since this gives the unique possibility of being able to switch on and off one signal without the interference of side-effects. It seems that cells interact differently in weightless conditions - microgravity will therefore help provide fundamental understanding of inter-cellular signalling.
- Studies of bone growth and loss reveal similar chemical markers in cultures held in microgravity to those found in osteoporotic patients on the ground. The unique environment of microgravity provides a new variable with which to investigate all of these processes.
- Any microgravity facility that allows the possibility of orbital flight is of fundamental importance to astrobiology, a subject in which the UK has a lead.

- In materials science there are many effects that would benefit from weightless research. One area that might be significant is the study of the mechanisms that give rise to various crystal structures in metals, such as dendrites, which are affected by convection in normal gravity conditions.

- In fluid physics, the motion of multiphase materials (containing interfaces) is not completely understood. In normal gravity many aspects of fluid motion are coupled and gravity plays a role. Only when gravity is removed can these effects be decoupled so that understanding of separate phenomena can be achieved.

- Microgravity provides an environment where it should be possible to study a stable Bose-Einstein condensate over a period of time. There are even suggestions that this could help in the study of quantum gravitation.

- Recent work suggests that upon removal of the body force in a microgravity environment it is possible to create simulations of molecular-level systems at much larger scale using dusty plasmas. Such a technique offers the opportunity to investigate detailed behaviour at a molecular level of interfaces using macroscopic tools.

It would be surprising if there were no practical applications from any of these investigations in the long term.

Conclusions

In our opinion there is no overwhelmingly strong case for investment in microgravity access to benefit one field - rather there are a series of marginal arguments across a wide range of fields exemplified by the list above.

- We conclude that access to microgravity facilities will provide an additional tool to aid UK studies of a wide range of scientific topics for at least 50 high-quality UK research leaders and their collaborators. Some of the areas of science they intend to pursue are of fundamental importance.

- Without access to such facilities, UK researchers will be prohibited from prosecuting one aspect of their own research and from collaborating with their European partners. Over time therefore the UK will be excluded from entire areas of scientific endeavour. An example of this exclusion process is to be found in the recent European conference on Spacecraft Structures, Materials and Testing in which there is no UK presence on the coordinating body and only one contributed paper – this is a natural result of an earlier decision by the UK not to be involved in various European space programmes.

- Exclusion from ELIPS may inhibit the UK from influencing the policies in some areas of science which will be developed as a part of the European Research Area and beyond.

- We believe that a contribution of around £3M a year to ESA for access to microgravity facilities is an investment in a unique environment that

constitutes value for money. This implies that membership of the ESA ELIPS programme should be taken up at the minimum level.

- We do not believe that a mechanism of uncoordinated funding of individual experiments would be better, because it would deny the opportunity of the collaborations that are of increasing importance in European science.

- We believe that the UK should contribute the subscription to the ELIPS programme from OST since the benefits will accrue to pure science in the near term. This is because in the initial phase the scientific return from the investment could not be known to an individual Research Council in advance of work conducted under responsive-mode funding.

- In view of the timing of this report in relation to the ESA subscription cycle, it may be necessary to fund the subscription for seven years, but we would recommend a review in 2007 of the continued payment of the subscription (in time to decide on participation in the following round – as indicated in Figure 1, though exact timings will depend on the dates of future ESA Ministerial Council meetings).

- We believe there are also benefits to be gained from the interest generated by such activities in the young and the public. This is important in addressing the need for future students to study science and technology subjects and in engaging the public in scientific issues.

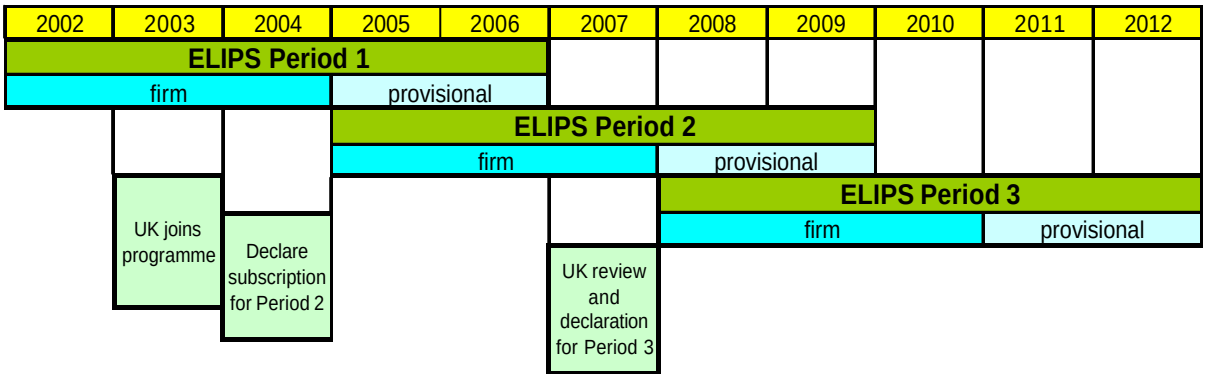

Figure 1: ELIPS programme schedule