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Science and Technology Committee

Government support for Beagle 2

Twelfth Report of Session 2003–04

Report, together with formal minutes, oral and written evidence

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Summary

This inquiry focussed upon the way in which the UK Government supported the Beagle 2 consortium in the development of a lander for the European Space Agency's (ESA) Mars Express mission and the implications of the project for future Government space policy.

We found that the Government was admirably enthusiastic about this exciting but high risk project. However, it was unable to respond to its relatively sudden emergence to find the guaranteed financial backing that was needed to support the development of a lander against extremely tight time and mass constraints. As a result of this, and the failure of sponsorship income to materialise, the project could not proceed to its development and testing phases as early as it should, with a consequent detrimental impact on its chances of success. We have called for improvements in the Government's capacity to respond to major financial commitments at short notice.

The decision for the lander to be developed separately from the orbiter has been acknowledged to be wrong. It reduced the scope for flexible and co-ordinated management of the mission. It also contributed to tensions in the relationship between the Beagle 2 consortium, ESA and other contractors, which increased as technical difficulties with the lander created doubts in some quarters at ESA about the viability of the lander. The decision was in line with existing ESA policy. It was also reinforced by a desire on the UK side for the lander to be distinctively British and a reluctance by ESA Member States to take any financial responsibility for a UK-led project. These concerns must be overcome in future, ESA-managed, missions.

We found that oversight of the Beagle 2 project, both by ESA and the UK Government, was lacking. When the project ran into difficulties, both sides belatedly intervened to introduce more certainty to the financial and management arrangements, but failed to ensure that the most important weaknesses in the mission were adequately addressed.

The Beagle 2 project had wider goals than the search for life on Mars. Technologies developed by UK teams have potential uses in other fields, such as medicine. We welcome the emphasis the Government has given to the science in society and educational objectives behind its support for the project, which helped justify the financial commitment made. The Beagle 2 project also placed the UK in a strong position to contribute to future ESA space exploration missions. These benefits should not be wasted. In this context, we welcome the Particle Physics and Astronomy Research Council's (PPARC) decision to fund early UK participation in ESA's Aurora space exploration programme. Long term participation will be expensive however. In view of the benefits accruing to the wider scientific community and UK science more generally, we have recommended that the Government does not leave it to PPARC alone to fund future UK involvement.

1 Introduction

1. On Christmas Day 2003 the Beagle 2 Mars lander was scheduled to touch down on the surface of the planet and begin its work of looking for any signs of life. It had been launched six days earlier from the Mars Express orbiter as one component of the European Space Agency's (ESA) mission to Mars. The lander failed to make contact with Earth following its scheduled landing and, in the absence of any evidence of its whereabouts, it was subsequently declared lost. The Beagle 2 lander was a British-led project, supported by a large number of primarily UK-based companies, individuals and organisations, including the Government. In total, the costs to public funds of the UK Government's support for the project amounted to some £25 million, over half of the overall declared project costs.

2. In February 2004, ESA and the UK Government established a Commission of Inquiry to investigate the circumstances and possible reasons that led to the failure of the Beagle 2 mission. This inquiry was completed in May 2004. Its full report has not been released; instead, a list of 19 recommendations for the handling of future missions was published. In August 2004 the Beagle 2 consortium published its own report on the project, making available for future missions its assessment of the possible causes of failure, the lessons that had been learnt, and an indication of the scope for technical and project management improvements.

3. We announced our inquiry on 26 May 2004, just after the partial publication of the ESA/UK Report. We have not sought to examine the possible technical reasons for failure. Instead, we have focussed on the environment in which the project developed; the availability and provision of funding; project management and oversight; and the relationship between the UK Government agencies involved and ESA. We have also looked at how the UK Government should use the Beagle 2 experience in developing its space policy. This Report follows previous Parliamentary scrutiny of UK space policy as a whole, by the Trade and Industry Select Committee, which reported in July 2000, and by the National Audit Office in March 2004. Ours is the only Parliamentary inquiry to focus specifically on the Beagle 2 project.

4. In response to our call for written evidence we received nine submissions, including responses from all the key individuals involved in the project. We also asked for, and received in confidence, copies of the ESA/UK Commission of Inquiry's full Report. Regrettably, we have not been able to reveal details of that Inquiry in this Report, but we have used it to develop our questions to witnesses and to inform our conclusions. We held two oral evidence sessions in July 2004, at which we took evidence from the Beagle 2 project team, led by Professor Colin Pillinger from the Open University (OU); from Professor David Southwood, Director of Science Programmes at ESA; and from the principal Government agencies involved in funding the project, the Minister for Science and Innovation, Lord Sainsbury, the Chief Executive of the Particle Physics and Astronomy Research Council (PPARC), Professor Ian Halliday, and the Deputy Director General of the British National Space Centre (BNSC), Dr David Leadbeater. We subsequently received answers to further written questions to witnesses. We publish all this evidence with this Report. We are most grateful to all those who submitted written and oral evidence in the course of this inquiry.

2 Background

UK Space policy

5. The Minister for Science and Innovation takes overall responsibility for civil space policy in the UK but interest in the use of space goes far wider than the Department of Trade and Industry (DTI) and the industries that it helps support. A number of academic scientific disciplines in the environmental sciences, physics and astronomy rely upon the use of space-based exploration and research to support their work. The Department for Transport, Foreign and Commonwealth Office and Department for Environment, Food and Rural Affairs all have reason to consider space during policy formulation. In consequence, the UK's space policy, as outlined in *UK Space Strategy 2003–2006 and Beyond*, is an agreement between all those Departments and Research Councils with interests in civil space. It sets out the vision for UK space policy as follows: "The UK will be the most developed user of space-based systems in Europe for science, enterprise and environment. UK Citizens will provide and exploit the advanced space-based systems and services which will stimulate innovation in the knowledge-driven society". It describes three core long-term objectives:

- enhancing the UK's standing in astronomy, planetary and environmental sciences;
- stimulating increased productivity by promoting the use of space in government, science and commerce; and
- developing innovative space systems, to deliver sustainable improvement in the quality of life.[1]

6. Support of the Beagle 2 project could be said to fall within the ambit of at least the first two of these objectives. An analysis of the degree to which the Beagle 2 mission met the Government's goals in supporting the project is contained in chapter 5 of this Report. The mission was also in line with the Government's long-standing policy of supporting robotic rather than manned space exploration.

British National Space Centre

7. The British National Space Centre (BNSC) is the forum in which UK space policy is discussed and developed and through which funding flows. It was formed in 1985 as an *ad hoc* interdepartmental working arrangement in order to develop a UK space policy which, up to then, had not been fully developed and articulated. Its aim is to "exploit synergies to ensure the maximum collective benefit, in line with the *UK Space Strategy 2003–2006 and Beyond*". BNSC operates within the DTI, its "host partner", and reports to the Minister for Science and Innovation. It is staffed by career civil servants rather than by science specialists. It has no significant budget of its own or project management capability, a reflection of its role of co-ordinating, rather than governing, civil space expenditure. BNSC is essentially a partnership formed from ten Government Departments and Research Councils, whose joint expenditure on civil space amounted to around £188 million in

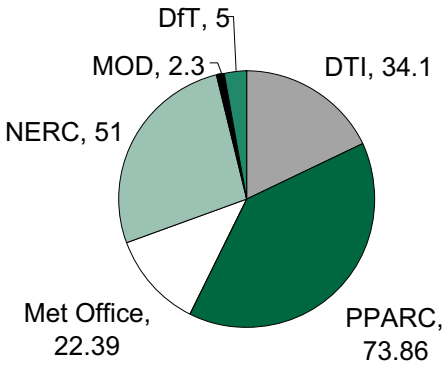
1 BNSC, *UK Space Strategy 2003–2006 and Beyond*, p 11

2003–04. Around 56% of the total of UK space funding goes to ESA in support of its various programmes.[2] Expenditure co-ordinated by BNSC is broken down by contributing partners in figure 1 below.

8. The Trade and Industry Committee's inquiry into UK Space Policy in 2000 concluded that while BNSC had played a useful role in co-ordinating the activities of the various bodies with an interest in space, it had suffered from not having its own funds. That Committee recommended a review of the role, status and organisation of BNSC, to include consideration of giving BNSC its own budget in order to ensure that the UK space programme reflected the long term public policy interests of the UK. The Government did carry out such a review, although this led to no major changes along the lines that the Committee had envisaged. The adequacy of existing funding mechanisms for space science is discussed in paragraphs 27–33 of this Report.

Figure 1

Civil Space Expenditure Co-ordinated through BNSC (£m)



Source: BNSC Annual report, 2004, p 38

PPARC

9. The Particle Physics and Astronomy Research Council (PPARC) is the Research Council responsible for awarding grants for astronomy and planetary exploration. Since 2003–04, it has shared with the Natural Environment Research Council (NERC) the responsibility for paying the UK subscription to ESA.[3] PPARC's total income for 2003–04 was some £300 million. Of this, £47 million went directly to ESA as part of the UK's subscription. In total, around half of PPARC's overall budget goes in subscriptions to various international programmes and facilities, leaving a little over £100 million per year for research grants and training awards in Higher Education Institutions. Grant awards are made for three years in the case of standard research grants and at least four years for rolling grants and revisable grants for the development, construction or maintenance of major equipment. Current grant awards for planetary science amount to some £35 million. Awards are made in responsive and managed modes across scientific disciplines, solely on the basis of

2 BNSC, *UK Space Activities 2004*, p 38

3 NERC paid £46 million to ESA in 2003–04.

scientific merit, as judged by an established system of peer review. In common with other Research Councils, PPARC uses a medium term strategy as a basis for its policies in allocating funding and is required to make bids for funding every two years as part of the Spending Review cycle. The latest PPARC ten year strategy includes as one of its nine "Big Science Challenges" of the decade, "Does life exist elsewhere?". PPARC's contribution to ESA's space exploration programme is discussed in paragraphs 102–109.

European Space Agency

10. ESA comprises 15 Member States, the majority but not all of which are EU Members.[4] It aims to co-ordinate the activities and resources of its members in order to develop a space capability for Europe. ESA's aims in formulating a space programme are to discover more about the Earth and the solar system, to develop satellite-based technologies and to promote European industries. It shares close links with the EU and is currently taking forward a joint European space strategy, as articulated in the European Commission's November 2003 White paper on European Space Policy. ESA also co-operates with other international space organisations such as NASA to share the benefits of space exploration. In 2003 ESA's budget was €2,700 million, which is spent on a *juste retour* principle.[5] At present, the UK contributes about 16 per cent of ESA's total budget. Decisions are made by the ESA Council, which consists of a representative of each Member State, who each have one vote. The Mars Express mission was managed by ESA's Science Directorate and Science Programme Committee (SPC).

Previous missions to Mars

11. The history of missions from Earth to Mars gives some indication of the high risks associated with interplanetary exploration. The repeated efforts of the Soviet Union in the early 1960s to send a probe close to Mars met with almost total failure. The first close–up photographs of Mars were obtained by the American Mariner 4 mission in 1964. The Soviet Mars 2 and Mars 3 orbiters were also successful in capturing many images of the Red Planet but descent craft from both orbiters failed to survive their landings. The first successful Mars landing took place in 1976, when the American Viking 1 and Viking 2 landers took weather readings and tested soil samples on the surface. There were further failures of both orbiter and lander missions launched by the USSR and the US in the years following, including the Russian Mars 96 mission, which carried some European–made scientific instruments. Later that year, the American Pathfinder mission successfully deployed a rover on the surface of Mars, which continued to transmit data back to Earth beyond the 30 day planned life of the mission. In 1999 the American Mars Polar Lander with its two microprobes failed to deploy correctly and no information from the planet surface was received. The US launched a further mission to Mars shortly after Mars Express in June 2003. After a successful landing in January 2004 NASA's twin exploration rovers began their task of studying the history of water on the planet. Overall, the success rate of Mars lander missions is not high: two out of three have ended in failure.

4 ESA membership is as follows: Austria, Germany, Belgium, Denmark, Spain, Greece, France, Ireland, Italy, Norway, Netherlands, Portugal, UK and Switzerland.

5 Each Member State expects to receive, over time, contracts to the equivalent value of its contributions, minus ESA overheads.

3 Brief history of project

Genesis of Mars Express

12. It was the catastrophic failure of the Russian Mars 96 mission—it disintegrated leaving the Earth's atmosphere—that led to the emergence of ESA's Mars Express mission in 1997. It aimed to use or adapt the largely Western European instrumentation lost on the Russian mission. Due to the movements of the planets, Mars missions are only feasible around every two years. The year 2003 represented the best opportunity for some time for a mission to Mars, as its relatively close proximity to Earth would offer the maximum opportunity in terms of the scientific payload on the spacecraft.[6] The aim of the ESA mission was to explore the mineral composition of the planet and its atmospheric conditions. It would image the surface of the planet in far more detail than any previous mission. In addition to the lander, the instruments it carried in order to fulfil this mission were:

- **Energetic Neutral Atoms Analyser (ASPERA)** to study the interaction between solar winds and the Martian atmosphere;
- **High/Super Resolution Stereo Colour Imager (HRSC)** to provide detailed photographs of the Martian surface for use in geological mapping;
- **Radio Science Experiment (MaRS)** to provide pressure and temperature profiles of the Martian atmosphere;
- **Sub-Surface Sounding Radar/Altimeter (MARSIS)** to map the distribution of water and ice below the Martian surface;
- **Mineralogical Mapping Spectrometer (OMEGA)** to examine the mineral content of the Martian surface and the molecular composition of the atmosphere;
- **Planetary Fourier Spectrometer (PFS)** to measure the distribution of chemicals in the atmosphere more accurately than previous missions; and
- **UC and IR Atmospheric Spectrometer (SPICAM)** to measure the composition of the Martian atmosphere over smaller volumes than the PFS spectrometer.

These instruments were provided by space science institutes and university departments in France, Sweden, Italy and Germany.[7]

13. The Science Programme Committee at ESA approved the plan for Mars Express in November 1997 and a target budget of €150 million was agreed between ESA and Member States. This made Mars Express the cheapest ever mission to Mars, according to ESA.[8] A lander was not considered as part of the mission originally conceived but was included

6 Ev 36, 29

7 www.sci.esa.int/science-e/www/object/index.cfm?fobjectid=31033

8 Ev 36

after ESA was persuaded that the science case for a lander was strong and was within the aims of the mission.

14. Box 1 provides a timeline of the major developments in the funding and management of the project.

Box 1: Timeline of Events

April 1997	ESA meeting to discuss possibility of Mars Express.
November 1997	ESA approves plan for Mars Express.
December 1997	ESA Announcement of Opportunity for Mars lander.
February 1998	Beagle 2 team submit bid for lander to ESA.
July 1998	Beagle 2 team resubmit bid to meet revised mass limit of 60kg.
August 1998	ESA indicates Beagle 2 is the preferred lander.
November 1998	Mars Express mission confirmed by ESA.
December 1998	Beagle 2 team approaches PPARC for funding for scientific instruments on the lander and submits bid to Joint Infrastructure Fund (JIF).
January 1999	PPARC agrees a £2.77m funding award for academic elements (announced in August).
May 1999	BNSC approached: Beagle 2 team sought £8.4m in funding and declared the total project cost to be £28.4m (with an estimated £10m being sourced from sponsorship). JIF bid declared unsuccessful.
August 1999	Astrium approaches BNSC for funding and is awarded £5m over the three years to 2001–02.
November 1999	ESA Science Programme Committee approves Beagle 2.
July 2000	BNSC provides £5m and the OU and Astrium agree to underwrite the project by a further £7m against future sponsorship revenues.
September 2000	Casani review of Beagle 2 reports and recommends changes.
November 2000	ESA Science Programme Committee (SPC) approves support to Beagle 2 of €24.2m (approx £16m), €16m (approx £10m) of which was paid directly to Astrium (which would need to be recompensed by a future UK contribution). Remaining €8m split between a communications system and other technical support.
June 2001	Cost at completion now put at £42.5m.
July 2001	Heads of Agreement agreed between participating partners. BNSC and OST commit a further £8.3m based on an agreed and fixed cost of completion of £42.5m.
April 2002	PPARC award £2.05m (against an application for £2.54m) for flight operations funding, with funds split between the OU, University of Leicester and MSSL, together with a £1m contribution by the National Space Centre (obtained from the Millennium Commission).
July 2002	DTI approves £1.5m for parachute development in addition to the agreed £42.5m cost at completion.
February 2003	Delivery of Beagle 2 to Mars Express.
June 2003	Launch of Mars Express.
December 2003	Beagle 2 ejected from Mars Express but fails to respond to attempts to communicate.

The genesis of Beagle 2

15. The Beagle 2 project was first conceived in April 1997, before the formal announcement of the Mars Express mission. Professor Pillinger, the driving force behind

Beagle 2, was given the authority to pursue the project by the Open University, which remained a supporter throughout the project. Since the Viking missions of the 1970s, which found no evidence of life on Mars, further studies had led to the development of the theory that fossil traces found in martian meteorites that had hit Earth denoted the presence of organic matter on Mars. This theory had been given fresh support by a NASA report in 1996 that built upon work at the OU on specific rock samples. Professor Pillinger reasoned that the only way to test this theory and to avoid the threat of terrestrial contamination was to carry out the necessary tests on Mars itself. This was one of the key original aims of the Beagle 2 mission.[9] The lander also carried the equipment to enable it to examine the composition of the ground around the landing site, to study the weather and climate, and to search for any other evidence of life, past or present.

16. The first meeting of the Beagle 2 project team was held on 20 May 1997, comprising Astrium UK, University of Leicester, Mullard Space Science Laboratory (MSSL) and the Rutherford Appleton Laboratory. The other key participant, Martin Baker Aircraft (MBA), did not join the project until a few weeks after this initial meeting. The science package proposed to be included on the lander was decided by October that year.[10] Box 2 below sets out the key stakeholders in the Beagle 2 project and a summary of their roles.

9 Ev 56

10 Ev 57

Box 2: Key stakeholders in the Beagle 2 project

Organisation	Summary of role
European Space Agency (ESA)	Oversight for the Mars Express mission and for approval of the science and instrument payload
British National Space Centre (BNSC)	Provided Government (DTI) funding for the project, as part of its role of a central coordinating office for UK space activities
Particle Physics and Astronomy Research Council (PPARC)	Provided funding for instrumentation, as part of a wider responsibility for space science
Beagle 2 Project Team	Consortium made up of Astrium, the Open University, University of Leicester and MBA, led by Professor Colin Pillinger
Astrium, Stevenage *(referred to as 'Astrium' throughout the Report)*	Project management for the development and testing phases. From June 2001, the entire project was managed by Astrium
Astrium, Toulouse	Prime contractor for the Mars Express mission, overseeing the schedule for each instrument and managing the interfaces between the spacecraft and payload
Martin Baker Aircraft (MBA)	Responsible for the Entry Descent and Landing System (EDLS) until their withdrawal in June 2001
M & C Saatchi	Commissioned by Beagle 2 team to sell sponsorship rights
Mullard Space Science Laboratory (MSSL)	Part of University College London and jointly responsible for Beagle 2 instruments with the Open University and University of Leicester

Development of the lander

17. An Announcement of Opportunity invitation was made to European groups to propose prospective landers for Mars Express in December 1997. The Beagle 2 bid was submitted in February 1998 along with other bids from France/Finland and from Russia/Germany. The bids were assessed in August 1998 and Beagle 2 was judged as the best proposal on scientific and schedule/cost grounds by the ESA Science Peer Review Panel.[11] ESA worked on the general principle that Member State contributions paid for spacecrafts, while individual countries or consortiums paid for and developed the instruments selected to be on board. ESA classed the Beagle 2 lander as a "scientific instrument", implying that it should be funded by national agencies or consortiums.[12]

18. Following its selection as the preferred option, the Beagle 2 consortium approached PPARC for funding. PPARC's appropriate peer review panel examined the proposal and reported in January 1999 that the science in the instrumentation package was of the highest

11 Ev 29

12 Ev 33, 40. This decision is discussed in detail in chapter 4.

quality. It rescheduled its budgets in order to provide a contribution of £2.77 million for the instrumentation on board the lander. At the same time the project team submitted a bid for £6 million to the DTI's Joint Infrastructure Fund.[13] This was unsuccessful. In May 1999 the project team approached BNSC to seek funding of £8.4 million towards the industrially-led parts of the lander, out of what was then an estimated overall cost of £28.4 million.[14] After a full formal appraisal of the project, the DTI agreed to fund the placing of a contract for £5 million with the lead industrial contractor, Astrium, in August 1999.[15]

Financial and management concerns

19. During its early stages the project was managed by a steering group composed of the senior academics and industrialists involved. By April 2000 this had been replaced by a Board of Management on which PPARC, OST, BNSC and, from January 2001, ESA were represented. This was chaired by the OU Finance Director. Professor Pillinger was the lead scientist and consortium leader, although project management was the responsibility of the academics and contractors participating, as discussed in greater detail in chapter 4 of this Report. During the course of 1999 and 2000 the UK Government and ESA became aware of financial problems being experienced by the project as anticipated sponsorship income failed to materialise. Before further money was committed, ESA instigated an independent review of the progress of the project, conducted in August 2000 by John Casani of NASA's Jet Propulsion Laboratory. In response to the concerns raised in this review, and with the support of ESA and the UK Government, full control of the management of the project was given to industry, under the direction of Astrium. In November 2000, ESA approved the award of €24.2 million (around £16 million) funding for the Beagle 2 project. Some £10 million of this was to be repaid to ESA by the UK in some form. A condition placed upon this funding was that there would be greater access for European scientists to the scientific data from the lander.

20. In June 2001 Martin Baker Aircraft (MBA), who were designing the Entry Descent and Landing System (EDLS), withdrew from the consortium. The option of ESA taking over responsibility for the EDLS was discussed but not pursued.[16] Instead, Astrium took the lead on its development, while still having access to MBA staff, facilities and sub-contractors.

21. Concerns at ESA and on the UK side about the progress and rising costs of the project persisted and further pressure was exerted on the Beagle 2 team to formalise the existing informal management arrangements. In July 2001, a "Heads of Agreement" was signed, confirming the relationships between all parties involved in the project and fixing the cost at completion at £42.5 million, under a fixed price contract between BNSC and Astrium. As a result of this agreement, a revised management structure was put in place, with Astrium taking full cost and schedule responsibilities and the Government committed a further £8.3 million.

13 The Joint Infrastructure Fund (JIF) is provided by OST, HEFCE and the Wellcome Trust to support investment in higher education science infrastructure facilities.

14 Ev 30

15 The agreement reached was in fact made by Astrium's predecessor company, Matra Marconi Space.

16 See paragraph 67 for discussion of this issue.

22. BNSC, OST and ESA carried out a joint review of the project in March 2002 due to ongoing concerns with technical problems in the spacecraft development. Although the review highlighted that the consortium was progressing well, there were worries surrounding the airbag development programme. In spring 2002, following a failure of the airbags on the EDLS during a test, Astrium sought to redesign the parachute system using a bigger parachute, whilst remaining within the existing mass restriction for the lander. It received further funding of £1.5 million from BNSC/DTI for this purpose. As this was a significant change to the design of the EDLS, it was deemed to be outside the agreed cost at completion of £42.5 million and so eligible for further funding. Astrium bore some of the increased costs itself and managed to complete this redesign by autumn 2002. A further £2.05 million was awarded by PPARC (slightly less than the £2.54 million applied for) in order to fund Beagle 2 flight operations, which had not been included in the original cost estimates.[17]

Completion of project

23. Construction of the Beagle 2 lander was completed in February 2003 and it was delivered to the Mars Express launch site in Kazahkstan. Delivery was delayed from the previously agreed dates of November 2002 and subsequently January 2003, but ahead of the ESA "need" date of mid March 2003. Mars Express was launched on 2 June 2003 and the Beagle lander was ejected from the orbiter on 19 December that year. Although a number of reasons have been put forward to explain the failure of efforts to contact the lander, neither the ESA/UK Commission of Inquiry nor the Beagle 2 team's investigation could establish with any certainty the cause of failure.

17 Ev 43

4 Funding and management of the project: key issues arising

Political background to Mars Express and Beagle 2

24. The short time scale from mission conception to the launch date in May 2003 presented some stiff challenges for groups providing instrumentation for the mission, not least for the management of the proposed Beagle 2 lander.[18] The very name of the mission, Mars Express, gives an indication of the speed with which it needed to be developed. Although ambitious, this accelerated timescale was very much in tune with the prevailing philosophy for space missions of "cheaper, faster, better". This was a NASA phrase which indicated a belief that it was possible to obtain the benefits of space travel without the long lead time and huge expense of traditional missions. ESA reports that "there was immense pressure on ESA from its Members States to demonstrate similar principles".[19] The Government confirms that BNSC was pressing ESA to adopt a "more efficient, less conservative approach to management of the ESA Science programme" in line with the NASA approach.[20] (Since the failure in 1999 of two NASA missions using this approach, the Mars Climate Orbiter and the Mars Polar Lander, NASA has moved back towards a more conventional approach. For the UK Government, "faster, better, cheaper" remains "an attractive goal" if applied in a more "pragmatic and balanced way".[21])

25. One consequence of ESA's adoption of the Mars Express mission was the deferring of its Planck cosmology mission to study the faint radiation left over from the creation of the Universe. There was insufficient funding to do both. According to the UK representative on the ESA Space Programmes Committee at the time, Dr Paul Murdin, the UK Government supported the switch in priorities in order to force ESA to improve its procurement policies to meet the tight deadlines imposed by the Mars Express schedule "even though from a scientific point of view we were with the majority in preferring Planck".[22] Indeed, Dr Murdin indicates that the downgrading of Planck to accommodate the Mars Express caused some ill-feeling towards it amongst some sections of the space research community.[23]

26. After the failure of the Mars 96 mission, ESA was in need of a success. The Mars Express mission was relatively safe in that it built upon well developed technologies and instruments used in 1996. By accepting the lander, ESA was adding a high profile and high quality scientific package to its mission, albeit one with a higher element of risk. The addition of the lander made the Mars Express mission more attractive to the UK Government in terms of its scientific merit but the wider efficiency agenda was still a

18 See paragraphs 71– 88 below.

19 Ev 36–37

20 Ev 29

21 Ev 64

22 Ev 33

23 Ev 33

factor. For both ESA and the UK Government therefore, the success of this mission was of considerable political as well as scientific importance.

UK Government's ability to respond to sudden demand

27. The initial response from PPARC to the Beagle 2 consortium's proposal in 1998, repeated by the Science Minister, was that "there is no money".[24] This was to be expected, given that funding from the Research Council is committed in accordance with established grant application rounds and the priorities identified in its 5 year strategy and on the OST's Large Facilities Road Map. Because of the rather sudden emergence of the possibility of a UK-led Mars lander and the fact that Mars exploration did not form part of an agreed priority, PPARC found that it had little room for manoeuvre.[25] The Trade and Industry Select Committee confirmed that PPARC did not have sufficient funds to approve the original bid from the Beagle 2 team due to existing commitments to other scientific programmes.[26] The original estimated cost of the Beagle 2 project was £25 million.[27] Given that PPARC had, at the time, only around £100 million per year in unallocated funds to spend across all its disciplines, it was plainly unrealistic for PPARC to fund a substantial proportion of the cost of the scientific instruments on the lander. Professor Pillinger was well aware of the position: he did not try to ask for the total costs of the project at once because he knew that "we would have been told 'no'".[28]

28. The aims of the Beagle 2 project also fell within the remit of other Government agencies within the BNSC partnership but existing funding mechanisms made it difficult for those agencies to offer direct financial support to the project. OST allocates its money for specific projects via the Research Councils and has no mechanism itself for peer reviewing sudden proposals which might cross disciplinary boundaries. A further obstacle was that DTI's industrial policies include no specific objective of supporting UK space exploration. None of the existing DTI schemes supporting business/university collaboration were suitable for a project of this size, complexity, cost and aims. Although the Beagle 2 consortium would have preferred "one big cheque written at the start of the day",[29] in reality it was well understood that there was no prospect of DTI providing the funding for the project up front, as ESA did for Mars Express. The consortium leadership therefore had little option but to try to amass the necessary funding from a number of different sources, each with their differing objectives. Professor Pillinger told us "We tried to put it together bit by bit, like a jigsaw puzzle …".[30]

29. Lord Sainsbury explained that he did not have the money to underwrite the whole Beagle 2 project. The £5 million provided through BNSC in 1999 was "just about something I could lay my hands on within the budgets. There was no way at that point I

24 Ev 59

25 Ev 30

26 Trade and Industry Committee, Tenth Report of Session 1999–2000, *UK Space Policy*, HC 335

27 Ev 70

28 Q 5

29 Q 8

30 Q 7

could have found 20 or 25 million to underwrite the whole budget".[31] This was the order of the public funding eventually provided for the project, spread over four years, garnered from existing DTI budgets earmarked for industrial support. There was no re-allocation of funding within DTI to support the project. [32]

30. It was clear from the outset that the normal pattern of a scientific project could not be followed in the case of the proposed lander. Instead of developing a proposal, applying for funding and then working within the budget awarded, the Beagle 2 team were working within an undefined budget and seeking to obtain funding at the same time as managing the project of building the lander and instruments. In the early stages they were reliant on goodwill and in-kind contributions, and some underwriting, on the part of participating partners, not to mention a good degree of optimism as to the likelihood of further funding.

31. It should not require an inquiry to establish that these were funding arrangements which should not be repeated. The UK Government has accepted the findings of the Commission of Inquiry regarding the need for reliable funding at the outset of the project. The Inquiry recommended that: "Sponsoring Agencies of nationally-funded contributions to ESA projects should ensure that the required financing is committed at the outset to meet the estimated Cost at Completion and require that a structured development programme is established".[33] We welcome the Government's acceptance of this recommendation, with which we agree, but believe that it will be difficult for the UK to implement within the confines of its current arrangements. The mix of industrial and scientific objectives in such space related projects and the absence of a well-financed single UK space agency make for a complicated situation. According to Dr Murdin, this has the result that "when new scientific demands come along, that are out of the ordinary and of national importance, but do not fit into some pre-determined policy to which a budget line is allocated, there isn't money for them".[34] We are all too familiar with this analysis, which could be readily applied to Government policy on renewable energy and nanotechnology, to mention just two examples that we have investigated recently.

32. In our scrutiny Reports on each of the Research Councils, we have criticised the financial restrictions imposed by the Treasury which severely circumscribe their ability to set aside money for future heavy commitments and to respond to sudden demands.[35] There have been some improvements in recent years: Research Councils are now able to carry over ten per cent of their funding from one financial year to the next without fear of having to hand it back to the Treasury and it is widely accepted that resource accounting has helped financial planning. In the 2004 Spending Review, it was announced that the DGRC would be allocated £35 million for each of the years 2006–07 and 2007–08 to spend on emerging priorities. This would "enable Research Councils to respond more quickly and effectively to emerging priorities and opportunities".[36] The Government could provide

31 Q 150

32 See Box 3

33 ESA/UK Commission of Inquiry Report, *Beagle 2*, Recommendation 3

34 Ev 35

35 See, for example, Science and Technology Committee, First Report of Session 2002-03, *The Work of the Particle Physics and Astronomy Research Council,* HC 161, and the Fifth Report of Session 2002-03, *The Work of the Natural Environment Research Council,* HC 674

36 Ev 63

few further details about the potential uses for this funding, other than that it can be allocated to bodies aside from Research Councils; it can be carried forward if unspent; and that there will be "considerable flexibility" in its application.[37] We hope that the Government soon develops a clear indication of the criteria the DGRC will use in considering applications to this strategic fund. For example, it is not clear whether it will be available to be spent solely on major capital projects or facilities that are not included in the OST's Large Facilities Road Map, nor whether Research Councils will be able to borrow against its future provision. We remain to be convinced that this fund is the answer to the questions about strategic funding capacity raised by the Beagle 2 project.

33. The unusually rapid emergence of a project of such scientific value, national importance and considerable expense clearly exposed the weaknesses in the UK's methods of funding large scientific projects. The DTI presides over a system which gives precious little room for manoeuvre when important opportunities arise rapidly. Consequently, the UK risks losing out on the scientific and commercial benefits that such emerging opportunities can provide. **We welcome the establishment in the 2004 Spending Review of a strategic fund to be allocated by the DGRC but are not persuaded that it will rectify the serious weaknesses which the Beagle 2 project highlighted in the Government's capacity to respond to sudden demand. In the absence of other funding streams to cater for such demand, we recommend that the Government considers earmarking this fund primarily for major projects and facilities.**

Support from UK Government and ESA

Introduction

34. Whilst adequate funding of a project such as Beagle 2 cannot guarantee success, it is certainly required in order to give a reasonable chance of meeting the project's objectives. Notwithstanding the constraints imposed by the funding process discussed above, there was still a considerable amount the Government could have done to support the project. Apart from the additional financial help and underwriting that was to be provided, the UK Government was in position to exercise influence through PPARC's representative on ESA's Science Programme Committee, which was responsible for providing advice on the Mars Express mission.

35. From ESA's point of view, having selected Beagle 2 as the preferred lander, it was then the responsibility of the UK consortium to deliver the lander to the required specifications at the required time. The €150 million ceiling for the Mars Express within which ESA was operating represented an important limitation. On a practical level, the interface between lander and orbiter was such that close co-operation between ESA, the consortium leaders and the principal contractors was required throughout the latter stages of the project.

Early response from UK Government and ESA

36. The first response that Professor Pillinger encountered when he suggested the project was partly dictated by the financial constraints faced by PPARC discussed above. There

37 Ev 64

were also some doubts about its merit. The initial view of the project at PPARC was, according to Dr Murdin, "one of scepticism, partly because of reaction against the promotion of Mars Express over Planck in the Agency's programme, partly because the initial understanding of the mission was based on press reports about its relevance to life on Mars rather than a scientific proposal".[38] Professor Pillinger states that "When we began this, there was a perception that we were off on a PR stunt. In fact, PPARC at the beginning did not take things too seriously".[39] He said that only the Chairman and one other member of the Science Committee at PPARC had supported the proposal of an initial £1 million grant to the project.[40] Government witnesses were not prepared in evidence to acknowledge any initial scepticism, but emphasised the quality of the proposal that emerged and its importance.[41] Lord Sainsbury told us that "I personally was rather excited about it".[42]

37. It should be noted that at this early stage the Government did not see itself as a major player in the project. Lord Sainsbury told us that this was seen as a project which would be funded by a combination of academic and industrial money, together with sponsorship income: "Government would play a fairly subsidiary role".[43] It was also expected that ESA would provide some of the funding, in spite of the funding constraints under which it was operating and in spite of the fact that, by treating the lander as an instrument, it seemed to have left to the bidders to come up with the necessary finance. This was apparently not absolutely clear to the UK side at the time. Dr Leadbeater from BNSC told us that the expectation at the start was that Member States would pay for the lander from the overall Mars Express budget and it was only after Beagle 2 emerged as the favourite that it became clear that ESA would not be paying.[44] Despite this, there was still hope from the backers of Beagle 2, including the Government, that ESA would, in the end, make a contribution. Dr Leadbeater told us that "we hoped that ESA's intransigence, if one looks at it in that way, in terms of no money, would change over time, as it did".[45] The view from ESA on financial responsibility was very different: "By accepting to build the lander the British team appeared to the ESA Executive and the SPC (and thereby the other ESA Member States) to have accepted responsibility to manage its provision".[46] ESA was working under the assumption that the UK Government accepted this responsibility.[47] The apparent initial uncertainty over responsibility for funding contributed to the financial difficulties from which the project was to suffer, as discussed in paragraphs 41–59. **BNSC was ill-advised to rely upon ESA to bail out the project if it ran out of money rather than seeking to establish with ESA and others firmer financial arrangements at the outset.**

38 Ev 34

39 Q 39

40 Ev 57

41 Qq 130–132

42 Q 129

43 Q 134

44 Q 152

45 Q 138

46 Ev 37

47 Ev 37

38. Notwithstanding the initial reservations and lack of clarity over funding, Professor Pillinger said that the Government supported the Beagle 2 project very well, once it had been persuaded of the science case for the mission.[48] Dr Mark Sims, the Mission Manager, noted that "it took some time to convince people" that the project deserved this support.[49] Mr Mike Rickett, the Astrium Beagle 2 project manager at the time, told us that "I believe that we had Government on side, and it was very positive and constructive in its support to us".[50] His successor, Mr Barrie Kirk, agreed that "BNSC with their limited technical resources were 100% constructive throughout …".[51] Professor Pillinger confirmed that, by May 1999, Lord Sainsbury and BNSC were strong supporters of Beagle 2.[52] We are aware that the Minister took a strong personal interest in the project and was a keen supporter. This support is reflected in the financial support provided by BNSC as the project progressed, as discussed in paragraphs 41–45 below.

39. One accusation that has been levelled against the Beagle 2 project was that the risks of the mission were underestimated at the outset. Professor Pillinger and other members of the team deny this: participants were under no illusions about the nature and extent of the risks. Lord Sainsbury was reluctant to characterise it as a risky project, but referred instead to an appreciation that it would be a "difficult" project.[53] The National Audit Office (NAO) Report on the UK's Civil Space Activities criticized the failure of BNSC to set out the residual risks of the Beagle 2 project in the appraisal for funding, although these risks had been mitigated as far as possible by March 2003. It said "In the written submissions appraising the case for supporting the project, BNSC did not discuss the material risks alongside the costs and the benefits. The costs and risks, and steps taken to mitigate those risks, which had been fully considered, should have been covered in formal appraisal submissions".[54] The Government accepted this criticism and those of the Commission of Inquiry in a somewhat convoluted manner. Its evidence states that: "We note that those Recommendations of the Commission of Inquiry which cover the same topics that have been examined by the National Audit Office are broadly in line. We accept for that common ground the conclusions on Beagle 2 from both sources".[55] These conclusions serve to confirm that the high risk nature of the project was downplayed in Whitehall at the outset. No doubt this approach made it easier to secure money from Ministers seeking to justify expenditure but a greater emphasis on the risks might have led to a more realistic assessment of the funding required in order to mitigate these risks at an early stage. Notwithstanding the acknowledged failings in risk assessment, **we commend the Government, and in particular the Minister for Science and Innovation, for being enthusiastic about the Beagle 2 project. It was an exciting scientific opportunity with the potential to put the UK at the forefront of space exploration. The Government should not be shy about taking risks in science if the potential benefits are there. In our**

48 Q 2

49 Q 10

50 Q 9

51 Ev 46

52 Ev 59

53 Q 132

54 National Audit Office, *The United Kingdom's Civil Space Activities*, HC 359 of Session 2003–04, p 27

55 Ev 29

view, this was a risk worth taking. Having taken this decision, it was then up to the Government to fund it properly.

40. The initial reaction from ESA to the proposed lander was also one of scepticism. Professor Pillinger reports that the first response from ESA about the involvement of the UK science community was one "little short of incredulity", with doubts expressed about both the funding and technology. Nonetheless, he reports that in the months following his initial suggestion, ESA "seemed to be coming around to the idea" and, in 1998, Beagle 2 succeeded in winning the competition for a lander for the Mars Express against bids from two other joint national bids. Professor Halliday characterised the initial attitude at ESA as "maybe there is not enough money, but let us be helpful".[56] ESA's attitude to the project as it developed is discussed further at paragraphs 46–50 below. It is right that ambitious proposals such as the Mars lander put forward by the Beagle 2 team are greeted with healthy questioning before any public funds are committed. The fact that Beagle 2 was, in the face of some scepticism, endorsed by the peer review system of both ESA and PPARC is a reflection of the quality of the science offered by the project as well as the integrity of the respective peer review systems.

Financial support from the UK Government

41. The UK Government ended up contributing over half of the overall declared costs of the project, as can be seen from Box 3 below.

Box 3 Government funding of Beagle 2

Date	Funding amount	Cumulative funding	Per cent of total cost at completion [a]
January 1999	PPARC award £2.77m	£2.77m	10.3 (10.3)
August 1999	BNSC award £5m	£7.77m	27.3 (28.8)
May 2000	BNSC award further £5m	£12.77m	44.8 (47.3)
July 2001	BNSC and OST provide £8.3m	£21.07m	49.6 (78.0)
April 2002	PPARC award £2.05m	£23.12m	- [b]
July 2002	DTI provide £1.5m	£24.62m	- [c]

[a] *Calculated using NAO cost at completion figures. Figures relate to the estimated cost at completion at the time. Percentage of original cost at completion (£27m) in brackets*

[b] *Funding awarded for flight operations (flight operations is not included in any of the cost at completion figures)*

[c] *Additional funding for parachute development (deemed to be outside of the agreed £42.5m cost at completion)*

42. ESA had asked the Beagle 2 team for a guarantee that the necessary funding for the lander would be in place by October 1998. No guaranteed funding was in place by this date. The UK Government was keen to provide sufficient support to keep the lander on board Mars Express but could not provide the financial guarantees sought by ESA in order to do so. Instead, ESA was informed that a number of funding sources would be sought,

56 Q 141

including commercial sponsorship.[57] Dr Murdin described being placed in the difficult position during this period of providing guarantees as to delivery when the financing of the project was far from clear. He says "the words 'economical with the verité' more than once crossed my mind, as I wondered what these episodes were costing me in credibility".[58] Dr Murdin must have done a good job at reassuring ESA, as Lord Sainsbury told us that the UK Government did not come "under any great pressure" from ESA to guarantee that the whole project was funded.[59]

43. Even when the Government agreed to help, its financial support was slow to materialise. The initial announcement of Government funding was made in August 1999. Astrium received the first tranche of Government money in October 1999 but the PPARC award was not received until June 2000. Other requests for public funding were turned down. PPARC refused a request by the consortium to set aside £5 million in the future projects budget for Beagle 2 science instruments and did not make provision for Beagle in either the 1998 or 2000 Spending Reviews.

44. The Beagle 2 team approached the Government in April 2000 for further funding, when the failure of efforts to attract commercial sponsorship led to cash flow problems.[60] The Government came under Parliamentary pressure to provide further assistance. The Trade and Industry Select Committee concluded that the project was entitled to expect further Government support to fill the funding gap. The Government replied to this Report positively, noting that BNSC had already "successfully worked with the Beagle 2 consortium to ensure that the finances of the project are put onto a more sound footing".[61] In July 2000 it was agreed that the OST and DTI would jointly provide a further £5 million, subject to additional investment by the OU and Astrium. The underwriting parties were to recoup part of this money from any surplus sponsorship income.[62] At the same time, PPARC worked to persuade ESA to become more involved and to provide greater financial investment.[63] DTI, having started out seeing itself as a fairly minor player in the project, found its role increasing in importance. This was not a comfortable position for the department, particularly as the estimated cost at completion escalated. Dr Murdin indicates that the Government sought to limit its exposure by encouraging the quest for other sources of funding.[64] The escalating costs of the project are discussed in paragraphs 84–87.

45. Further money was provided in July 2001 following the successful negotiation of the Heads of Agreement. DTI agreed to underwrite the project with a further £8.3 million, subject to the agreement of a maximum cost at completion of £42.5 million and the implementation of a number of other conditions. It was also agreed that BNSC would act

57 Ev 37

58 Ev 34

59 Q 152

60 See paragraphs 55–59.

61 Trade and Industry Committee, Twelfth Special Report of Session 1999–2000, *Government Observations on the Tenth Report from the Trade and Industry Committee* (Session 1999–2000) on UK Space Policy, HC 908

62 Ev 30

63 Ev 31

64 Ev 34

as the lead public customer, thereby finally establishing a normal customer-supplier relationship in the project. **The UK Government gave the Beagle 2 project moral support but initially took on as little financial responsibility as it could to ensure that the lander was not thrown off the Mars Express mission. The absence of a commitment from the Government at the outset to provide the necessary funding to support the project in full made it less credible in the eyes of ESA and its Member States, not to mention potential backers of the project, the UK scientific community and the public.**

Support from ESA

46. The support ESA was able to provide to Beagle was subject to both financial and political constraints. The €150 million allocated to the Mars Express mission—without a lander—at the outset was one major constraint, although not a totally inflexible one. Any request for additional funding for the lander would require a two thirds majority on the Science Programme Committee (SPC). This was a significant hurdle, as support for the Beagle 2 mission amongst ESA Member States was not unanimous. The UK representative on the SPC, Dr Murdin, acknowledged that "The political support that I was able to muster in the SPC among our partners had its limits".[65] The decision of the SPC in November 2000 to provide €24 million for Beagle 2 was taken by a vote of 10 to 3, with one abstention.[66] Although this was money provided by ESA Member States, there was an apparent understanding that, in the absence of any direct reimbursement, €16 million of it would be reimbursed by the UK in contributions to future SPC programmes. This was, at the time, an unusual step for ESA to contribute in this manner to a national project and there still appears to be some dissatisfaction with the way in which this money will be reimbursed by the UK.[67] It was the strength of opposition to this payment that persuaded the Director of Science at ESA, Professor Southwood, that he should not seek to obtain more funding from ESA Member States when the Beagle consortium reported in May 2001 that a further £15.25 million might be needed. Professor Southwood told the team that he would not ask the SPC for more money as "to lose such a vote would have been very prejudicial to Beagle 2's interest".[68] Instead, he was able to ensure that ESA contributed a further sum, in excess of €4 million, to costs primarily associated with the lander.[69] These costs were directly beneficial to the lander but were absorbed by the overall Mars Express budget.

47. We are surprised that Professor Southwood did not think it worth seeking to obtain further funding from ESA Member States. It may have been possible to persuade Member States of the case for helping the lander: the SPC itself had been convinced of the project's scientific merit and its cancellation would have been a major blow to the Mars Express mission. We accept that there was opposition among Member States, for a variety of reasons. Escalating costs are dealt with at paragraphs 84–87 below. There is evidence to suggest that one factor was submission of the Beagle 2 lander to ESA as an entirely British proposal. Other Member States may not have been willing to provide further funding for

65 Ev 35

66 Ev 65

67 *Nature*, 30 September 2004, p 497

68 Ev 65

69 Ev 65

what could be considered as the very public showcasing of British scientific expertise and endeavour, which could overshadow the existing, decidedly European, Mars Express mission. Beagle 2 did not have a European flag on it. Dr Leadbeater told us that "There was some potential concern, even a little envy I think, about the extent to which the Beagle programme commanded the attention of the media to a degree at the expense of Mars Express".[70] Some potential participants would have lost out due to the alteration in mass specifications when Beagle was accepted, belatedly, as part of the mission. As a result, there was no longer room for instruments proposed by other countries, an outcome which, according to Dr Murdin, "did not win friends".[71]

48. Professor Southwood confirmed that there was some opposition to Beagle but on commercial grounds. The French Space Agency was concerned that there would not be a sufficient transfer of intellectual property rights to enable their own Mars lander programme to take advantage of the technical and scientific advances made by Beagle 2.[72] France nonetheless was convinced enough of the merit of the UK project to vote in favour of financial support for the lander in November 2000.[73]

49. The mixed political support for the lander also had an impact at a practical level. It is clear that there were considerable tensions between ESA and the Beagle 2 team, in spite of the efforts of ESA management to be accommodating. The ESA evidence states that: "Instructions were given to the Mars Express team to do everything possible to facilitate the delivery of Beagle 2 and to accommodate its requirements into the larger Mars Express schedule".[74] But it seems that this message did not necessarily get through. According to the Chief Engineer of Beagle 2, Dr Clemmet, "The technical assistance received from ESA was quite restricted".[75] The Astrium project manager for Beagle 2, Mr Kirk, said that whilst those at ESA with whom he dealt were helpful and enthusiastic, "senior managers with one exception were always reticent. Their life would have been much easier if Beagle 2 had disappeared from MEx [Mars Express] much earlier than it did".[76] In spite of close contacts between ESA and the UK backers of Beagle 2, neither BNSC nor PPARC was convinced that ESA was fully supportive of the lander. Professor Halliday told us that "There was a feeling of struggle, that is clear. On the other hand, ESA did clearly want this [the lander] to happen".[77] There were also doubts about the level of commitment at ESA to the lander, stemming from a lack of confidence in its viability.[78] Dr Clemmet had the perception that "ESA senior management had decided that the Beagle 2 project would fail to complete in time".[79] On the other hand, and further away from operations, Lord Sainsbury detected no lack of enthusiasm from the ESA Director of Science. Indeed, Professor Southwood told us

70 Q 176

71 Ev 35

72 Q 88

73 Ev 65

74 Ev 38

75 Ev 53

76 Ev 46

77 Q 141

78 Different perceptions of risk are discussed further in paragraphs 89 – 91.

79 Ev 53

that he had considered whether ESA could have done anything more to give technical or managerial support to Beagle 2 but "I cannot see what it could have been".[80]

50. There was clearly a gap between the expectations of the project team in terms of the help that they might receive and the obligation felt by ESA to provide assistance to the development of this particular "instrument". Relations between ESA and the Beagle 2 team were affected by the failure at the outset to establish clearly what assistance would be provided by ESA. They were also affected by the perception in the consortium that there were elements within ESA that were less than wholly committed to the success of the project. For this, the ESA leadership must accept some responsibility. Part of this perception stemmed from the doubts about the viability of the project that emerged as it ran into technical difficulties. This is discussed further in paragraphs 89–91 below. **The ESA leadership responded positively and flexibly in 2000 to the financial difficulties in which the Beagle 2 team found itself and helped to keep the project alive. However, there appears to have been a latent resistance among Member States to the British-led lander, no doubt in part due to a perception that this was an exercise in promoting UK national scientific interests. This made it difficult for the ESA secretariat to push for more funds when the project met further difficulties, although we are not persuaded that every effort was made on this front.**

Impact of piecemeal funding on project

51. As a result of the lack of guaranteed funding at the outset, the Beagle 2 project team worked towards their goal with no clear indication that the necessary funding would be forthcoming, from Government, ESA, industry or sponsors. Professor Pillinger did not seem to regard the lack of funding as a major constraint. He told us that "the finance is secondary. We never had any difficulty working without any money because we were all so committed to the idea of going to Mars to look for life".[81] He remained steadfastly optimistic that the necessary funds would somehow materialise, which, to a large extent, they did. Professor Pillinger was perhaps alone in not worrying about the lack of early funding. Even limitless supplies of inventiveness, optimism and commitment need to be supplemented by solid finance from time to time, a point that was perhaps better appreciated by those at Astrium, who contrasted the Mars Express and Beagle 2 programmes: "We had a very clear situation with Mars Express […] On the other side, you had Beagle, which was relatively high risk, relatively high technology development, without a clear statement on funding".[82] Companies involved were understandably reluctant to commit funds to a project which lacked the funding to be completed successfully. Dr Healy is unequivocal: "the source of most of the major problems on Beagle 2 was the lack of funding in the early phase of the programme. This prevented a timely and smooth build-up of the industrial team. It also meant that technical risks were not retired until late in the programme".[83] Dr Southwood concurred: "For me, money is pretty basic […] when you have got money in your hand, the manager can manage much better".[84] Dr Sims explained

80 Q118

81 Q 32

82 Q 33

83 Ev 48

84 Q 89

that "The relatively late funding of mission operations, only 14 months prior to launch, placed large schedule and development pressures on the operations team".[85] The lack of early stage funding also necessitated changes in designs and contributed to further escalation in costs.[86] We understand that it was only in June 2001 that Astrium began technical work on the project in earnest. This left over 80 per cent of the work to be done in 20 months.[87] This was an extremely challenging deadline.

Mitigating risks and testing

52. We asked Professor Pillinger what would have been done differently had the money been forthcoming earlier. He told us that "we would have retired risks earlier if we had early money. That is what space missions are all about".[88] Dr Sims emphasised the importance of early testing. He admitted that "In hindsight, we were under-estimating the amount of testing and the amount of development we needed to do. At the time we started the project back in 1997, we thought a lot of this technology would be off the shelf from American missions, and in reality it was not".[89] Mr Kirk defended the project team's position in evidence. He acknowledged that the initial funding constraints led to an "extremely compressed schedule" but affirmed that "we did not cut corners or lose engineering discipline as recently stated by ESA".[90] Of course, in all projects of this nature there are constraints on the number of tests that can be carried out within the time frame and with the finances available. It is a matter of judgment as to whether the tests carried out provide sufficient evidence for a successful mission.

53. Professor Pillinger did not believe that the tight time scale for testing affected the project at all. He said that the parachute system on the EDLS was tested in every conceivable way "except the prohibitively expensive high altitude balloon deployment".[91] He did not believe that the absence of this test was a mistake, pointing out that previous NASA missions had not, to his knowledge, conducted such tests.[92] This view conflicts with the verdict of his own team's Lessons Learned Report, which states that: "The Beagle 2 team fully agree that more testing would have been valuable and would be keen to carry out such a future test programme with appropriate hardware to eliminate uncertainties in developing future lander systems".[93] It also acknowledges that key tests planned by the team had to be omitted because priority was given to completion of other parts of the programme and, in particular, the decision not to undertake a highly expensive high altitude parachute drop test was driven by cost factors.[94] The Government recognised the

85 Ev 43

86 Dr M R Simms, *Beagle 2:Lessons Learned and Management and Programmatics,* http://www.src.le.ac.uk/projects/beagle2/report/Beagle-2-Lessons-Learned-inners.pdf (hereafter referred to as *Lessons Learned Report*), p 6; see paragraphs 84–87.

87 *Lessons Learned Report*

88 Q 40

89 Q 48

90 Ev 45

91 Ev 58

92 Q 50

93 *Lessons Learned Report*, p6

94 *Lessons Learned Report*, p 6

adverse impact of the testing difficulties, stating that: "a combination of lack of mass margin and schedule and cost constraints associated with adapting US airbag technology for use on Beagle 2 almost certainly increased the relative risk of failure".[95]

54. This verdict is also reflected in the UK/ESA Commission of Inquiry. Its recommendations suggest that the technology used by Beagle 2 was either unsuitable or insufficiently tested: "Adequate competences in air-bag and parachute technology must be available for future European planetary missions, making best use of existing expertise, eg, in USA and Russia".[96] In the absence of any clear cause of the failure of Beagle 2 it is likely that we will never know whether or not the lack of a high altitude balloon test was significant or not. Nonetheless, **the failure of the project's backers to provide the necessary funding for full testing had a major impact on the ability of the project team to mitigate risks, delaying development and testing until less than two years before the final launch date. It added significantly to the risks already associated with the project.**

Sponsorship

55. The absence of full funding from conventional sources led the Beagle 2 team to seek financial backing from other sources. In May 1999, when the team approached BNSC for funding, it envisaged that up to £10 million (36 per cent) of the estimated total costs of £28 million would come from sponsorship.[97] The target set by the consortium was £12 million.[98] The DTI was content for Professor Pillinger to try to raise funding from other sources, partly in order to limit its own potential exposure to meeting the costs.[99] This was also in line with its own policy of encouraging public-private partnerships to undertake national projects.[100]

56. In April 2000 Professor Pillinger engaged M&C Saatchi to work up a strategy for attracting finance. This was viewed at the time as a major success. Professor Pillinger records that "everyone breathed a sigh of relief since the sponsorship problem was now in professional hands".[101] The engagement of such a reputable company helped to convince the main contributing partners to underwrite the project, to a total of some £12 million in May 2000.[102] The cost of engaging M&C Saatchi was £8,000 per month and total costs over a two and a half years from January 2000 amounted to £187,000.[103] A further £45,000 was paid to another agency, SP Active. Some of the work carried out by these two agencies was on a commission basis, with initial fees being deducted from the commission earned from sponsorship deals. In the event, no money from sponsorship was forthcoming.

95 Ev 28

96 ESA/UK Commission of Inquiry Report, *Beagle 2,* Recommendation 19

97 Ev 30

98 Ev 69

99 Ev 34

100 Ev 34

101 Ev 58

102 Ev 58

103 Q 38

57. The reluctance of sponsors to support the project was not surprising. There was no overall backer of the project with the necessary financial commitment to guarantee that it would actually happen. Professor Pillinger did not see this as a significant problem. He stated that "The absence of Government guarantees was not a disincentive".[104] Instead he views ESA as the main culprit. He cited the reluctance of ESA to declare in public that Beagle 2 would be part of the mission as a greater disincentive: "there was never a defining moment when we could say we were a part of the overall mission. This definitely affected the search for sponsors to reimburse money loaned to the project".[105] He also stated that "ESA did nothing to refute or confirm rumours" that Beagle might not be part of the mission.[106] The search for sponsors was also affected by the downturn in market conditions which occurred around the time that funding commitments were most needed.[107] This Report has not focussed on the way the responsibilities for raising private finance were structured or carried out. It is, however, perhaps reflective of the unorthodox, amateur nature of the "gentleman's agreement" underlying Beagle 2 at the start which allowed £232,000 in all to be paid over with no sponsorship returns whatsoever.

58. The consortium's search for sponsorship income clearly unsettled some at ESA, where there was a keen awareness of the need not to make too much of the risk of failure in public. Professor Southwood refers to the "adverse effect" of Beagle's search for sponsorship: "We were constrained in expressing disquiet in order not to disturb the ongoing quest for external sponsors in Britain".[108] He notes that this was the first time a mission had sought commercial sponsors and refers to this as "a flaw in the approach".[109] He told us bluntly that "there was enormous pressure not to let the British people know how high risk it was and that was for a very simple reason and it was very straightforward. They were still looking for commercial sponsorship".[110] There were also concerns within ESA Member States about the "innovative" approach to funding adopted by the Beagle 2 team. Dr Murdin refers to the French distaste for a project involving private enterprise, believing that "it was inappropriate for ESA to launch a 'Formula 1 car' covered with advertisements".[111] France is not the only European country which does not have the same tradition of public-private partnerships for major capital projects. Another adverse consequence Dr Murdin cites of the quest for sponsorship was the branding by Professor Pillinger of the project as "the British-led Beagle Lander". He states that this national labelling "did not help in getting support within ESA from other countries".[112] The "Britishness" of the project was an important element for its principal supporters, not least the UK Government, and not just for PR purposes.[113]

104 Ev 70

105 Ev 59

106 Ev 70

107 Ev 70

108 Ev 38

109 Ev 39

110 Q 133

111 Ev 35

112 Ev 35

113 Ev 70

59. Professor Pillinger was extremely active in raising the public profile of the mission and in seeking supporters. Concerns have been expressed about the extent to which the quest for sponsorship affected the team's ability to focus on the project. Dr Murdin, the PPARC representative on the ESA Science Programme Committee, thought that this activity "had the effect to slow down progress on the Lander, already proceeding at a slower pace than it would have been if Pillinger had been free from the burden of fundraising".[114] The Astrium project manager, Mr Kirk, denied that "we took our eye off the ball chasing sponsorship".[115] Dr Sims pointed out that sponsorship-seeking activities were carried out by Professor Pillinger alone and were kept "entirely separate" from the technical and scientific mission.[116] Nonetheless, the quest for funding was, at the very least, a significant burden on the project leadership and added to the concerns at ESA about the viability of the project. The UK Government accepts that projects of such complexity should not be "exposed to the uncertainty of funding from sponsorship during their development", without ruling out completely the involvement of a fully committed sponsor at the outset.[117] **We conclude that the pursuit of sponsorship income was an innovative and necessary attempt to meet the funding gaps which were evident in the programme from an early stage. But it did nothing to encourage a realistic assessment of the risks of the project or an open dialogue between participants. It also affected the credibility of the project, which had an impact on the degree of support for it in some quarters. Whilst in the right circumstances there may be a place for commercial sponsorship in such missions, we believe that in this case the DTI should have been focussing its efforts on finding sufficient funding for the project rather than relying upon the securing of commercial sponsorship. We recommend that in future the DTI is extremely cautious about part-funding projects which are reliant to a significant degree on the future attraction of commercial sponsorship. At the very least, DTI needs to satisfy itself of the availability of sufficient funding in the event that commercial avenues prove unproductive.**

Treatment of lander as an instrument

60. "You cannot have two captains on the ship".[118] That is what Professor Southwood told us was his firm management principle. Yet two captains is exactly what the decision to treat the lander as an instrument (not made by him) ensured. The reasons why the lander was treated as an instrument relate partly to ESA practice and partly to financial considerations. Dr Murdin, the UK representative to ESA at the time, sought to discover the reasons for the decision to designate Beagle as an instrument but "without coming to a clear understanding of it". He suggests that ESA may not have had the requisite skills to handle the project and that it could have been a "ploy by ESA to get more voluntary contributed resources from the Member States for the ESA science programme".[119] It is common practice at ESA for the platforms to be paid for from the subscriptions of

114 Ev 34

115 Ev 45

116 Ev 41

117 Ev 28

118 Q 80

119 Ev 34

Member States and the instruments to be provided, and paid for, by individual countries or collaborative projects.[120] Professor Southwood explained that "there is a principle […] that we like the sharp end of our missions to be run from inside our Member States, with the scientists themselves taking over as much responsibility as possible".[121] Professor Southwood also acknowledged the financial motivations behind the decision. There was no provision made for a lander in the original ESA budget for Mars Express. If ESA was to take on new responsibilities he said that "we do not come near to staying in budget".[122]

61. The decision by ESA to treat the lander as an "instrument" on board the orbiter has been acknowledged by most of those involved as a mistake. The Commission of Inquiry Report was quite unequivocal. Its first recommendation was:

> "Future lander missions should be under the responsibility of an Agency with appropriate capability and resources to manage it. The lander/orbiter mission should be managed as an integrated whole. Nationally-funded science instruments should be included in the lander on the same basis as on the orbiter."[123]

This recommendation bears out the view of the Beagle 2 project team that the lander was a platform rather than an instrument—a spacecraft in which a number of scientific instruments were carried. The view of Mr Kirk that "The lander needs to be classified as a spacecraft" was shared by others on the project team who submitted evidence. [124] This was also the view of PPARC at the time. One of the reasons why PPARC was prepared to fund the scientific instruments on Beagle 2 was that the costs of spacecrafts and landers should be borne by ESA rather than the smaller national funds for instrumentation.[125] The UK Government accepts the Commission of Inquiry's conclusion on this point.[126] Lord Sainsbury acknowledged that this was "one of the misjudgements that was made in all this".[127] ESA has been less forthcoming in accepting this as a mistake. Whilst ESA has said that in future the recommendations of the Commission of Inquiry Report will be followed, Professor Southwood defended the decision, pointing out that several 'instruments' developed by others were more expensive and complex than Beagle 2 and more critical to the success of the mission".[128] ESA would only have taken on the lander as its responsibility if it could have financed it from within its own budget and if "the Principal Investigator would accept ESA management authority".[129] There must be doubt as to whether either of these two conditions could have been fulfilled, but ESA had little reason to pursue them and showed no desire to do so.

120 Ev 66

121 Q 76

122 Q 76

123 ESA/UK Commission of Inquiry Report, *Beagle2*, Recommendation 1

124 Ev 45

125 Ev 30

126 Ev 27

127 Q 137

128 Ev 66

129 Ev 66

Impact of the decision

Priority

62. It is not only with hindsight that the decision to regard the lander as an instrument was regarded by most as a mistake. Its impact during the project was profound. Professor Pillinger regarded this decision as the main constraint on the Beagle 2 project, as it meant that the lander did not have the priority in the Mars Express mission that he believed it deserved.[130] The team's Lessons Learned Report complains that "Beagle 2 programmatic planning was consistently forced to meet the needs of Mars Express at the expense of its own requirements".[131] The Government shares the team's view of the issue, stating: "It now appears clear that treatment as an 'instrument' reduced the level of ESA management attention given to implementation of the advice from Casani. Attention on the ESA side was initially more focused on the success of Mars Express, leaving responsibility for remedial solution on the lander programme to the Beagle 2 team, which did not have access to enough resources fully to mitigate the risks during development".[132] For ESA the primary responsibility was to deliver the Mars Express successfully and to ensure that any instruments did not have a negative impact on the rest of the project.[133] It is understandable that financial considerations were uppermost in the thinking of ESA management, but Beagle 2's high risk nature and uncertain viability were other factors. ESA had already seen some of its scientific instruments disappear with the Russian mission in 1996. Professor Pillinger notes that ESA was "rather concerned that it not be lost again, and therefore the instruments on the orbiter were the priority".[134] Another failure would certainly have been difficult to bear, particularly if the cause of the failure was the malfunctioning of the lander. Allowing the UK to bear the cost and the risk was a safer option, both politically and technically, even if it added to the complications of managing the Mars Express mission.

63. The completely separate development of the lander and the orbiter also complicated links between the main contractors. Despite the fact that the main industrial contractors for each spacecraft were two different arms of the same company, relations between Astrium Toulouse and Astrium UK were strained. Dr Sims could not explain why relations between two parts of the same company were so uncomfortable but ventured that there was "a difference of priority. UK Astrium was concerned with the lander and Astrium France was concerned with the orbiter".[135] The difficulties over developing, and paying for, the interface between the lander and orbiter were not eased by this arrangement. Dr Clemmet cites the treatment of the lander as an instrument as the reason for "inadequate management" of this interface, which was not given a detailed specification.[136] Dr Healey, from Astrium UK, referred to the tensions with the Mars Express contactors caused by the uncertainty over the funding and management arrangements prior to July 2001. For

130 Q 47

131 *Lessons Learned Report*, p 5

132 Ev 28

133 Ev 37

134 Q 14

135 Q 18

136 Ev 53

example, Dr Sims alleges that Astrium Toulouse was inflexible in its handling of the interface with Beagle 2, sticking rigidly to the requirements agreed in 1999.[137]

Mass constraints

64. In addition to the financial ceiling placed upon the whole Mars Express mission, ESA also had to determine the mass to be allocated to any lander. Professor Pillinger indicates that the original intention had been to allocate over 200kg to the lander. (The total mass of the Mars Express was 1,223kg, 866kg of which was the fuel and weight of the orbiter itself.) The teams were briefed accordingly on the mass before they responded to the December 1997 Announcement of Opportunity. According to the UK Government, the 120kg allocated to lander modules in October 1997 was reduced to 60kg in the 1998 Announcement of Opportunity due to a revision of the launch costs of Mars Express.[138] The Beagle 2 team resubmitted its bid to conform to the new mass restrictions in July 1998 and this was the limitation it worked towards. The Casani review in September 2000 highlighted the tight mass restriction and recommended an increase. This did not happen. The consortium complained that "the fundamental difficulty associated with the mass and volume constraints remained with no relief being provided by Mars Express".[139] The Government reports that the "lack of access to significant mass margin significantly hindered normal risk management practice during the development of Beagle 2".[140] With a number of other instruments all being manufactured to precise requirements and an inflexible overall mass budget, the room for manoeuvre was very limited. Professor Southwood told us that he considered that there was no other instrument that could have been sacrificed to enable the mass to be increased, for instance, when a larger parachute proved necessary.[141]

65. In June 2001 a request was made by the Beagle 2 consortium to increase the mass limit to 71kg. Professor Pillinger claims that no direct response from ESA was made to this request. Instead, mass was reviewed by all parties during the negotiation of the Heads of Agreement in July 2001 and a revised mass of 70.9kg was agreed.[142] Thereafter, the issue remained subject to continuing negotiation, to the evident dissatisfaction of both sides. ESA report that the Beagle 2 team revised their mass waiver request many times during the ensuing months due to various complex technical issues.[143] Professor Pillinger reports that the prime contractor on Mars Express, Astrium Toulouse, accepted a waiver request in January 2002 which was overturned the following month by the Mars Express project manager. The final mass of the Beagle 2 lander was 68.9kg. The continuing negotiations between the different parties over mass restrictions serve to underline the problems created by the dual management structure. A mass budget needed to be specified in the first instance but a flexible approach was needed as the project developed and encountered technical difficulties. As a result of not knowing the true extent of room for manoeuvre on

137 Ev 43

138 Ev 28

139 *Lessons Learned Report*, p 7

140 Ev 28

141 Q 106

142 Ev 66; 4.5kg of this was residual mass on the orbiter, 1kg was for margin.

143 Ev 66

the mass margin, Professor Pillinger was reluctant to ask for more, believing that "if we put another ounce on the spacecraft, we would get bounced off".[144] ESA was eventually able to offer some flexibility, but an integrated lander and orbiter would have made such decisions less convoluted and subject to misunderstanding. It is the view of the Beagle 2 team that a lander with a similarly small mass is feasible, and no doubt any future lander would benefit from the lessons of Beagle 2. But in this case it was a question of priorities. **Had a Mars lander been part of the original mission, and managed by ESA, we suspect that it would have been given a priority commensurate with its potential scientific output, with mass levels tailored accordingly to give it a greater chance of success.**

Management responsibilities

66. Another consequence of the dual approach was that ESA sought to take no role in the management of the Beagle 2 project. It took the view that, by accepting to build the lander, the British team appeared to accept responsibility to manage its provision. Professor Southwood explained that, without any initial financial contribution, ESA had no legitimate authority in 1998 to ask for management insight into the building of the lander.[145] This situation was to change as ESA became more involved in the project. In September 2000 ESA was asked by BNSC to act as technical customer on its behalf, a role which involved the provision of a technical audit of the Beagle 2 design.[146] Once ESA had made a financial contribution, in November 2000, it was invited to join the Board of Management and from then on ESA was also represented at the fortnightly Beagle management meetings. **Given the importance of the interface between lander and orbiter and the importance of the former to the mission as a whole, it was remiss of ESA not to ensure that it had the role of at least a close observer from the outset of the Beagle 2 project.**

67. If there was some reluctance at ESA to take on the management of the lander, this was matched by the reticence of the Beagle 2 project team to cede any management responsibility to ESA. Professor Pillinger told us that he had made no effort to persuade ESA to take on the management role of the project, largely because he did not believe that this would have improved the chances of success: "I do not see any difference between Astrium managing a lander if the Open University is the customer, or Astrium managing a lander if the European Space Agency is the customer".[147] He did offer ESA the chance to manage the Entry Descent and Landing System (EDLS), which was causing ESA some concern. Professor Southwood thought that this would have been a good idea.[148] This did not happen as agreement could not be reached, evidently because ESA did not have the technical competence to advise on parachutes.[149]

144 Q 60

145 Ev 37

146 *Lessons Learned Report*, p 5

147 Qq 12–14

148 Q 91

149 Q 169

68. It was put to us by a member of the Beagle 2 team that "To suggest that simply putting ESA in control would achieve that result [success] would be a complete illusion".[150] Of course, no management structure could guarantee success, but in our view the chances would have been improved markedly if the two contractors had been working directly for the same agency. Significantly, Dr Healy points out that "No overall optimization of the orbiter/lander combination was attempted".[151] Such issues would have been better addressed by a single manager with a remit to ensure that both lander and orbiter succeeded. This would have changed the basis of the relationship between the Beagle 2 project team and ESA. Instead of having to prove to ESA that the lander was technically and financially feasible and not a danger to the orbiter, the project team would have relied upon ESA to a greater extent to provide what help was necessary in order to make the joint project succeed.

69. There were cogent reasons why it was in the interests of each side for the lander to be treated as an instrument. For ESA, the lander represented a significant financial and political commitment, which Member States were reluctant to make, as well as what it viewed as a substantial risk of another failure.[152] For the Beagle 2 project team, there was the challenge and the kudos of managing the lander as an exciting, high profile, British-led project. For the Government, there was no desire to manage the project directly, nor any capacity within BNSC, so a UK-led consortium was very attractive. A success for British science and engineering was more appetizing than an equivalent European success. Thus, the option of ESA management of the lander was not pursued, in spite of the overwhelming advantages of a fully integrated mission. These considerations resulted in the parties involved working within an uneasy management framework, with its increased risks of failure and consequent loss to all sides and, more importantly, to the wider scientific community. **It is extremely disappointing that ESA, the UK Government and the project team were unable to co-operate in such a manner as to give the lander the maximum possible chance of success. We believe that both the Beagle 2 project team and the UK Government should have done more to persuade ESA to take greater responsibility for managing the lander project, if necessary, at the expense of some UK ownership. For its part, ESA should not have been influenced so much by the apparent attraction of getting a lander for free, albeit at the expense of European ownership. It should now recognise that this was a mistake and ensure that it takes full management responsibility for similar future missions.**

Communication

70. One technical constraint has, with hindsight, proved to be of some significance. One of the conclusions of the unsuccessful US Mars Climate Orbiter mission in 1998 was that the absence of any communication between the mother ship and the lander was a major weakness and should not be repeated. The Russian Mars 96 mission had also suffered from the same gap. Yet on Mars Express, the mistake was repeated and there was a similar lack of communication. A decision was taken in 1998 that the orbiter would not be able to

150 Ev 45–46

151 Ev 48

152 See paragraphs 89 – 91 for discussion of risk perception.

communicate with the lander during its descent nor for ten days after landing.[153] The orbiter was scheduled to continue on its orbit and would have been on the other side of the planet during this period. Professor Pillinger states that "the lander in a fully integrated project would never be put at such a risk".[154] The prototype communication system built by the Beagle 2 team was dropped when ESA advised that no ground or space based asset could be made available to receive any signals.[155] The Chief Engineer of the project, Dr Clemmet, believes that ESA could have provided a communication link for telemetry during the descent of the lander to Mars.[156] This is called for in future missions by the ESA/UK Commission of Inquiry, which also recommends more robust communication, to enable the lander to be activated in the event of catastrophic failure. **Had ESA implemented the lesson of earlier failed missions on the importance of communication between lander and orbiter, it would have secured a vast amount of information which could have been used to help establish what happened to the lander and therefore to reduce the risk of future failures. It is a pity that this lesson had not been learned from two previous missions.**

Management of Beagle 2 project

The Beagle 2 team

71. In its initial stages, prior to 1999, the Beagle 2 project was led by Professor Pillinger as Principal Investigator, with representatives from the University of Leicester and from industry partners. At this point, the participants were no more than a loose coalition of the willing. Professor Pillinger explains that "as the project had no official funding a contract between the partners would have been impossible to negotiate".[157] Before 2001, there was no customer and supplier relationship, a situation Professor Pillinger defended: "It is very difficult to define a management structure when you do not have any money to be a customer to place an order with someone".[158] Instead the parties involved had an informal arrangement. Professor Pillinger explained that "We set off on Beagle 2 under a very clear gentleman's agreement".[159] The success or otherwise of this gentlemen's agreement is discussed in paragraphs 76–79.

Management Effectiveness

72. The unusual combination of circumstances which led to the development of the Beagle lander ensured that, at one level, the project was unique. Professor Pillinger acknowledges that "no other space project has been conducted like Beagle 2".[160] However, the consortium is keen to maintain that, within these unusual circumstances, the actual management of the

153 Ev 59

154 Ev 59

155 Ev 59 ; *Lessons Learned Report,* p6

156 Ev 53

157 Ev 71

158 Q 20

159 Q 20

160 Ev 71

project was relatively conventional and thoroughly effective. The Lessons Learned Report produced by the Beagle 2 team concludes that the project was "internally managed to high professional standards under severe schedule and financing constraints".[161] Professor Pillinger describes the real management of the project as "totally conventional and carried out in an exemplary manner".[162] The Lessons Learned Report says that the Beagle system was "not very different" from the approach adopted by NASA of delegating missions to academic-led consortia with NASA oversight.[163] Professor Pillinger states that "The [management] structure was similar to what would have been required had Astrium been an ESA spacecraft contractor". The arrangements were, he said "a very typical management structure for a project like this".[164] He cited, in his defence, the Casani review, which concluded that "Your way of doing things is nuts, but it seems to work!".[165] In fact, the Casani review suggested that the management arrangements were far from conventional, and suggested a number of improvements.[166]

Box 4: Management of Beagle 2 consortium

1997–99	Consortium headed by Professor Pillinger as lead scientist. Dr Mark Sims from Leicester University is Manager of the proposal.
April 1999	Astrium takes over management of development and testing phases. Dr Sims to be mission manager in operational phase (post-launch) and to have responsibility for delivery of instruments other than the OU's Gas Analysis Package (GAP). Martin-Baker Aircraft (MBA) responsible for EDLS.
July 1999	OU, Leicester Univsersity, Astrium, MBA begin regular management meetings
April 2000	Beagle 2 Board constituted. BNSC/PPARC represented
July 2000	OST represented at Board meetings
September 2000	BNSC asks ESA to act as technical customer on its behalf
January 2001	ESA represented at Beagle 2 Board and fortnightly management meetings
June 2001	Withdrawal of MBA from consortium
July 2001	Astrium assumes full responsibility as prime contractor for project management following Heads of Agreement

73. The picture of management normality presented by the Beagle 2 team contrasts sharply with the views of both ESA and the UK Government. ESA was particularly critical. It claims that the management structures were demonstrably not working. In May 2001, it states that "Beagle 2 was way behind schedule with unclear lines of responsibility, many unclear contractual arrangements, with disaffected partners, and a CaC [Cost at Completion] that was stated to be adrift by over £15M".[167] In evidence to us, Professor Southwood was highly critical of the management, which he described variously as "highly

161 *Lessons Learned Report*, p 10

162 Ev 71

163 *Lessons Learned Report*, p 4

164 Q 20

165 Ev 58

166 See paragraphs 78 – 79.

167 Ev 67

original", "deeply flawed" and "a mess".[168] He clearly questioned the abilities of Professor Pillinger as a manager, although not as a scientist.[169] It is interesting to note here that Professor Pillinger, unlike ESA, did not regard himself to be the *manager* of the project, only its leader. Professor Southwood certainly did not believe the management arrangements were typical. He stated that "To our knowledge no spacecraft had been built by a 'coalition of the willing' between industry and scientists such as was in place until spring 2001".[170] He did, however, acknowledge that in the "faster, cheaper, better" era the approach was "radical but it matched other new approaches of the time".[171] It is true that the overall approach of a Principal Investigator managing a spacecraft was similar to recent NASA missions. The main difference with the NASA approach is that NASA would grant the Principal Investigator the money to get on with the project, rather than leave it to him or her to try to secure the necessary funding.

74. The UK Government was also far from convinced that the initial arrangements were going to work. The UK Government, in the shape of the PPARC representative on the ESA SPC, was instrumental in putting pressure on the consortium to improve management. The UK Government made the establishment in 2001 of a Heads of Agreement to formalise management arrangements a condition of the provision of further funding.[172]

75. As Professor Southwood summarised "The way this started was with a gentleman's agreement, it can work as long as the gentlemen remain gentlemen".[173] In this case, the gentlemen could not stick together. The weakness of the informal arrangements was illustrated by the withdrawal of Martin-Baker Aircraft (MBA) from the consortium half way through the project. We understand that there are still some unresolved disagreements between some of the participants.[174] The extent to which MBA's withdrawal affected the project is disputed: the consortium thought it made far less of a difference than the Commission of Inquiry. We have not taken a view on this, but we found it extraordinary that a principal contractor—charged with responsibility for the crucial landing systems—could simply withdraw halfway through such a major project, and without financial penalty. We appreciate that ESA had used MBA before for its Huygens probe (the success of whose own lander will only been known after Christmas 2004), and MBA continued to make its facilities available to Beagle, but the US firm's withdrawal certainly served to highlight the inadequacies of the gentleman's agreement. The project was hugely complex, involving universities and companies throughout Europe working separately on instruments and systems which had to be integrated on the lander within extremely strict mass and time limits. **The project went well beyond the normal scope of the work of a Principal Investigator. The consortium leadership was understandably keen to maintain control over what was very much the team's own initiative, which was pursued with admirable determination and considerable success. The team was perhaps unduly reluctant to accept that the project as a whole may have benefited from**

168 Qq 87 and 108

169 Qq 92–93

170 Ev 67

171 Ev 37

172 Ev 71

173 Q 89

174 See paragraphs 111–113.

greater involvement from ESA, which could have provided it with the necessary financial resources. It was the absence of the guaranteed funding that made a formal agreement between participating parties difficult to achieve. This in turn was a fundamental weakness in the project management.

Oversight of management

76. It was in the interests of both ESA, as Mars Express sponsor, and the UK Government, a principal funder of Beagle 2, to monitor the progress of this high risk project very closely. When PPARC agreed to award its first funding to the project in January 1999 it ensured that it became a member of the management board, with permission to attend any meeting concerning Beagle 2. Another condition was that PPARC be kept informed of developments on the project.[175] Payments were also staged to meet certain agreed milestones in project development. From early 2001, ESA was represented on the Beagle 2 Board and represented at management meetings.[176]

77. Concerns about the project's progress surfaced relatively early, largely as a result of the failure of the anticipated funding to materialise. The UK Government was concerned about the funding, but also the management. The Government requested that "a full appraisal of progress and risks" was made by the Beagle 2 team when the consortium asked for more money in April 2000.[177] It was only following this review that Ministers agreed to provide a further tranche of £5 million to accompany the £7 million underwrite from the OU and Astrium.[178] It was but a few months later, in September 2000, that the Casani review drew attention to weaknesses in the management structure and the potential for problems in future unless realistic mass margins and access to testing facilities could be provided.[179] We have not seen copies of these reviews, but we note that the Government was prepared to provide further funding to a project which, only months later, was the subject of a review that called for some major changes in key aspects of the project, including its management structure. It is difficult to believe that the Government's appraisal of the project prior to July 2000 was sufficiently rigorous, bearing in mind its acceptance of the criticisms made in the subsequent Casani review.

Implementation of Casani Review

78. ESA was not initially involved in the management of the Beagle 2 project but became increasingly so as its own financial involvement in and concerns over the project intensified. Although ESA was aware by mid-1999 of serious financial problems in the Beagle 2 project team it was not until ESA awarded £10 million to the project following the Casani review that it became more involved in the management. [180] It was ESA's concern over the financial health of the project that prompted it to commission this independent review, in September 2000, headed by a senior American engineer at NASA, John Casani.

175 Ev 61

176 Ev 71

177 Ev 30

178 Ev 61

179 Ev 28

180 Ev 37

The Casani review reported that there were risks associated with the consensual management structure, which was complex and fragile, and the inadequate schedule contingency. It said that the EDLS was not robust and that "classical risk management was non-existent because, in the absence of margins, there was no effective means to mitigate risk". The report also highlighted a number of potential risks associated with the adaptation of airbag technology, as well as expressing concern at the tight mass margins. It concluded that the project was "challenging but doable" if the deficiencies highlighted were addressed.[181]

79. Both ESA and the UK Government accepted the findings of the review but not all of its conclusions were addressed. The Beagle 2 Lessons Learned Report states that the project team "responded positively to all those recommendations within its remit".[182] It was not until the following summer that Astrium took over full management control of the project, a change that Lord Sainsbury had already pressed for, and the Heads of Agreement provided a formal framework for the participating partners to work within. Professor Southwood said that the Casani report was "largely implemented". One omission in implementation stemmed from the failure of ESA and Astrium to agree a contract due to a dispute over access to intellectual property rights.[183] The oversight of the management of the project was complicated by the US International Traffic in Arms Regulations (ITAR) and by Intellectual Property Rights (IPR) issues. The airbags being developed used specialist, ITAR–restricted technologies which meant that ESA, the Open University and Astrium were unable to have full visibility of testing. Dr Sims states that the academic input into critical areas of the EDLS was circumscribed and greatly limited his management oversight.[184] It made it more difficult for both BNSC and ESA to gain a clear view of how this aspect of the project was progressing. The ability of the team to develop new airbags was constrained by the tight mass margins, which ESA was not willing to alter. The Government reports that it was the reluctance of ESA to allocate additional mass margin that "fettered the full implementation of advice from that review".[185] The Commission of Inquiry clearly did not find that it was adequately implemented. It recommended that:

> "When an independent review of a nationally–funded project, such as the Casani review of Beagle 2, is commissioned, it is essential that ESA and the Sponsoring Agency ensure that its recommendations are properly dispositioned and those which are agreed are actioned and followed up through a formal process."[186]

We understand that some parts of the review, such as those relating to IPR issues, were beyond the control of ESA and the UK Government. Other issues, more crucial to the mission's success, such as mass margins and funding for testing, were not. **The establishment of the Casani review was a useful means of gaining an independent**

181 Ev 31

182 *Lessons Learned Report* p 5

183 Ev 68

184 Ev 42

185 Ev 28

186 ESA/UK Commission of Inquiry Report, *Beagle 2*, Recommendation 5

assessment of the project. Having commissioned it, ESA should have taken greater responsibility for implementing the most important of its recommendations in full.

Heads of Agreement

80. In June 2001 Astrium approached BNSC, reporting both the withdrawal of MBA and a shortfall in funding which threatened the completion of the project within the schedule. These factors persuaded the UK Government that a more formal management structure was needed to accompany a new injection of funds. In July 2001 a Heads of Agreement was negotiated which, although not a legal instrument, set out the commitments of the parties concerned on a formal basis. This involved Astrium accepting a firm fixed price contract for the completion of the lander and a commitment of a further £8.3 million from DTI and further contributions from the OU and ESA to match the cost of a new Planetary Protection Facility at the OU, which was required for the lander to be assembled in a completely sterile environment.[187]

81. The Heads of Agreement provided the Government with a limit to its financial exposure and instead passed the burden of risk to Astrium by committing the company to pay for any cost overruns. Dr Healy of Astrium said that, in agreeing to this, "we probably took on more risks commercially than in the cold light of day we might have done", a point acknowledged by the Government.[188] In the event, Astrium overspent and had to bear an extra £1.5 million of costs.[189] After the signing of the Heads of Agreement, regular management meetings of the Beagle 2 team became fortnightly. Due to continuing concerns about the test programme for the airbags a further review was insisted upon by BNSC, OST and ESA in March 2002. This reported good progress in some respects but highlighted critical problems in the airbag development programme. These worsened when an airbag exploded during a test in the US, requiring a substantial redesign of the airbags for the EDLS.

82. The ESA/UK Commission of Inquiry was critical of the assessments of the Beagle 2 project that were carried out during its life: "In addition to the ESA–led reviews of interfaces, formal Project Reviews of nationally–funded contributions to ESA missions should be undertaken by the sponsoring Agency to a standard agreed with ESA and should cover the entire project".[190] Another recommendation reads:

> "For future science payloads which are critical to overall mission success or have a very high public profile, the ESA Executive should make a formal, comprehensive assessment of all the aspects of proposals including technical, management and finance, and advise SPC accordingly before acceptance. If the assessment is not positive, ESA should advise the SPC not to accept the proposal."[191]

187 Ev 31–33

188 Q 42; Ev 31–33

189 Q 43

190 ESA/UK Commission of Inquiry Report, *Beagle 2*, Recommendation 4

191 As above, Recommendation 2

83. Had the recommendations of the Commission of Inquiry been in place at the time, the Beagle 2 lander would not have made it on board the orbiter. ESA relaxed its own policies and practices on project management and kept the door open despite the failure of the UK side to provide the requested guarantees regarding its finances and management. We recognise that ESA stretched its own rules in order to ensure that the lander flew, which was in its interests as well as those of the Beagle 2 team and the wider scientific community. We believe that once ESA realised the difficulties the lander was experiencing, it should have tried to persuade Member States to provide the support necessary to ensure that the project was kept on track.

Escalating costs

84. The costs of the project increased from an initial estimate of around £25 million to the eventual cost at completion of £45 million. On top of this, much of the work was carried out for free by the Open University, the University of Leicester and by companies involved looking to showcase their skills. The participating partners estimate that they invested £6.1 million from their own resources prior to the receipt of any funding.[192] Although consortium members have made public few details of further contributions these are substantial. For example, the OU made no charge for any of the indirect costs associated with the project. Both the University of Leicester and the OU met all staff costs involved. Astrium told us that they lost £1.5 million on the project. The real economic costs of the lander and instrumentation it carried are therefore difficult to estimate but are significantly in excess of £45 million.

85. Costs increased due to changes in design in key parts of the lander, such as the probe, which in turn affected the interface with other systems, some of which were already experiencing development difficulties. The short and fairly inflexible time scale added to the costs: companies were required to work round the clock at times, engaging high levels of manpower.[193] Some costs were insufficiently defined and allocated at the outset: Dr Leadbeater said that "there was ambiguity about who would pay for what, associated with a lander".[194] There was also no agreement at the outset on who would bear the cost of the lander's operations once on Mars.[195] For example, Professor Pillinger took an encouraging comment from PPARC to mean that they would bear the costs of operations.[196] It was only in July 2001 that the funding of the Beagle 2 operations centre was determined between ESA and the consortium. Similarly, there were problems in integrating the systems on the lander with those of the orbiter, partly due to late changes in design.[197] Technical difficulties in the EDLS, eventually necessitating redesign, added substantially to the costs. Lord Sainsbury probably summed up the overall position accurately when he said "Right at that early stage we should have understood more clearly perhaps how tight the margin was

192 Ev 68

193 Ev 42

194 Q 149

195 Ev 41

196 Ev 70

197 Ev 42

but I think people were carried way by how exciting this project was and we said 'Let us try and do it'".[198]

86. Were the initial cost estimates realistic? It is inevitable in a project of this complexity and difficulty that there will be some unforeseen costs but the margins built in to cope with these were nowhere near sufficient. The Government has accepted the verdict of the NAO that there were "weaknesses in the original cost estimation".[199] We sought to establish how the estimates could be so far out. Dr Sims admitted that "It is fair to say that we all had great difficulty estimating the initial costs. As time went on we hit development problems and it was only natural that those costs would rise".[200] The parties involved in the project acknowledge that the margins were too tight, both in terms of finance and mass.[201] Lord Sainsbury commented "Maybe we were all a bit greedy in thinking that we would try and get some more scientific benefits and not leave ourselves enough margin in terms of mass and so on to do that".[202]

87. Even allowing for the unique difficulties in costing such a complex mission, an increase of costs of around 57 per cent suggests a substantial underestimate in the first instance. At the very least, the estimates were based on the optimistic premise that partners would provide their services in kind. There was no doubt a strong determination to keep estimated costs to a minimum. Professor Pillinger was aware that he had little enough chance of getting Government funding for a project estimated to cost £25 million. An initial price tag of £45 million may well have seemed completely unrealistic to potential investors. We have no reason to suspect that the costs were consciously underplayed in the first instance in order to get the project up and running but it is clear that this underestimate contributed significantly to the subsequent management and other difficulties faced by the project. The continuing requests for further funding also put the Government and PPARC in the difficult position of reallocating resources in order to meet unplanned demand. Professor Pillinger describes the funding as being "drip–fed".[203] This was true, although the Government was responding to successive demands and was not asked for all the money up front. Had the original estimate been more realistic and had efforts to secure commercial sponsorship been as successful as envisaged, the Government and PPARC would not have had to keep providing extra funds.

Conclusions

88. The UK Government and ESA were sufficiently closely involved in the project to have known about the difficulties it was facing. They should both have exerted pressure to ensure that a Heads of Agreement was signed well before July 2001. The late agreement left a huge amount of work to be done in a very short space of time, a fact which contributed to the costs and to the limiting of the scope for thorough testing of the lander, particularly the reconfigured EDLS. **For far too long the Government failed to ensure that the nature**

198 Q 195

199 Ev 29

200 Q 48

201 Qq 141 and 194

202 Q 141

203 Q 31

and extent of the risks were identified accurately so that the funding necessary to help mitigate those risks as far as possible could be provided. The failure by all parties to establish at the outset some quite basic elements of cost attribution accentuated funding difficulties. Once they became financially committed, both the Government and ESA took steps to monitor the project, but neither was willing or able to ensure that the recommendations of their various reviews were fully implemented.

Different perceptions of risk

89. The dual management structure for the lander might work in situations where both sides are confident of success and the project runs smoothly. The Beagle 2 project illustrates the added tensions that the dual management structure can produce when this is not the case. It was clear from our evidence sessions that there was a substantial difference in the perceived chances of success of Beagle 2 between the UK side and ESA during the latter stages of the project. Professor Halliday, Chief Executive of PPARC, told us that "we believed that there was a perfectly reasonable chance – hard to quantify – that this mission would work".[204] Professor Southwood told us that he considered the project to be "extremely high risk".[205] Risk assessment is not exact science. It is reasonable for there to be different estimates of the chances of success in this type of mission. What surprised us was that the UK side were apparently unaware of this difference in perception, despite working closely with ESA over many months and years. Professor Southwood did not put a figure on the chance of success as he saw it, but the language that he used in evidence to us clearly surprised the witnesses from the UK side. To Professor Halliday, "high risk" meant something like a chance of one in a hundred.[206] He told us that "if David Southwood really believed that there was a one per cent chance or a 0.1 per cent chance, which is the kind of number hiding behind his rhetoric, if that was really true he damn well should have told us".[207] Dr Leadbeater added that the only time Professor Southwood expressed concern was not in the critical May–July 2001 period, but much later, in 2002, when a new design of parachute was found to be required.[208]

90. For his part, Professor Southwood acknowledged a difference in perceived risk, but argued that the UK side was well aware of his doubts. He told us that "The British usually appeared more optimistic about Beagle 2's chances of success than ESA. ESA avoided public comment but the ESA reporting to the Member States through SPC was unavoidable and at times so honest about risk and Beagle 2 that it caused written complaints from the British authorities".[209] He said that everyone knew his private view of the project: "Of course I made clear, and I think everybody knew, I thought it was extremely high risk but, I ask you, what would you have done with it in the spring of 2003?".[210] He insisted that "I will tell you that privately I do not think anyone could have

204 Q 163

205 Q 80

206 Q 169

207 Q 163

208 Q 169

209 Ev 67

210 Q 80

doubted my position".[211] Lord Sainsbury took issue with this comment. He referred to the regular reviews and meetings at which "people are required to say what they think" and "In none of the papers where they were asked for a decision was there a view which said the Director of Science at ESA believes that this project should stop". Dr Leadbeater considered that Professor Southwood, in expressing his doubts about Beagle's viability, was "overstating the position of an organisation which, two minutes earlier, had signed up to a major agreement for the final push".[212]

91. Although he worked to help the lander succeed, Professor Southwood's support for Beagle was tempered by his view of its chances. He appeared to take the view that if the British wanted to try to land Beagle 2 on Mars with very little chance of success, that was their concern, as long as it did not jeopardise the orbiter. In our view, his responsibilities extended beyond the orbiter, to include the instruments it carried. We agree with Professor Halliday that he had a responsibility to give his best advice to the Beagle 2 team, formally in meetings, not just privately or behind the scenes. If ESA made it clear that it thought the chances of success so low that it was not worth pursuing, the UK side would have had to respond to this. Lord Sainsbury acknowledged that any such view would have been taken "very seriously indeed".[213] **Relations between ESA and the UK side were strained by different attitudes towards the lander. Professor Southwood clearly had very strong doubts about the lander's chances of success. He should have made these reservations clear – formally – in order that they could be addressed.**

Who was in charge?

92. The separate management of the orbiter and lander and consequent complex lines of responsibility made it difficult to establish who was actually able to take a decision on whether Beagle 2 should be part of the mission. Professor Pillinger and his team could have taken a decision if they did not think that there was a realistic chance of the project working. But Professor Pillinger never had any doubts. Lord Sainsbury also had a say, as the principal financial supporter of the project on behalf of Government. Had he not agreed to provide more funds when needed, it would have been extremely difficult for the project to proceed. In fact, Lord Sainsbury told us that there were two occasions when there was a possibility that the project would be stopped. The first was in 1999 after the first evaluation when he took the view that, in spite of tight time, mass and budgetary constraints, the project was "doable and it was sufficiently exciting to get a decision to go ahead".[214] The second occasion was in July 2001 when, after a succession of overruns, the estimated final cost had increased to £42.5 million. The Minister took the view that, in the light of the money already committed, it was right to provide the funding necessary to save the project, but with a firm Heads of Agreement in place. He told us that: "It could have been a decision where I should have said, 'No, this it too tight, we are going to take too many risks in the end and you should cut it off at this point'".[215]

211 Q 113

212 Q 149

213 Q 172

214 Q 162

215 Q 162

93. The third party was ESA. Professor Southwood explained that the UK was responsible for ensuring that the performance of the lander was sufficient for it to be included in the Mars Express mission. He felt that he only had the authority to refuse flight if there was proof of detrimental effects to Mars Express or its launcher.[216] We were surprised to hear that he, as mission manager, did not think it was possible for him to stop the lander joining the mission, whatever his feelings on its chances of success. He said that it was not his decision to cancel and that he had no authority to do so: "I had to cede responsibilities to the British, who were managing it".[217] This may have been the formal position, but it was clear that in practice he had a considerable influence on its chances of making the mission. When he became Director of Science Programmes at ESA on 1 May 2001 he was apparently surprised to find that the project had made it so far. He told us that "I came in and within 15 days I had decided that this thing—it was very frustrating because I wanted it to be successful—was not going to work; I thought it would be a failure then".[218] He believed that ESA should show itself willing to stop the project and he sought to produce convincing evidence that Beagle 2 should not be continued unless there were major managerial changes.[219] He states that "I could not prove incontrovertibly that the lander would fail before the fact—nor did I believe it would".[220] There seems to be some confusion here as to whether or not, in mid–2001, he thought the lander would fail. Nonetheless, Professsor Southwood was successful, along with the UK Government, in forcing change in the shape of the Heads of Agreement. Had the UK Government not agreed to provide additional funding and had the management structure not been improved, he said that he would have taken the option of proposing cancellation.

94. Any recommendation not to accept the lander would have been extremely controversial, given the amount of money already committed and the design of the orbiter to accommodate a lander. Professor Southwood took the view that after the Heads of Agreement had been signed, "it was not possible to cancel Beagle 2 but […] its delivery was going to be problematic".[221] We agree that any decision to cancel Beagle after 2001 for any reason other than overwhelming evidence that it could not succeed would have been politically extremely difficult. There was no such evidence. The lander was certainly high risk but there was no suggestion that it did not have a chance of success. **By failing to subject the lander to sufficiently rigorous scrutiny in its early stages and to provide the necessary support, ESA and the UK Government left themselves with few options when the project ran into serious problems. The decision to allow the lander to proceed in 2001 was the right one. It was also the only one realistically available.**

Collective responsibility

95. Those who take decisions have a responsibility to stand by them. As Lord Sainsbury put it, candidly and perhaps rather pointedly, "if it had been successful we would have all claimed credit for it, and given that it was not successful we should all collectively share

216 Ev 67

217 Q 80

218 Q 94

219 Ev 38

220 Ev 67

221 Ev 38

in what I think were some of the misjudgements made".[222] Professor Southwood took responsibility on behalf of ESA for the project only in May 2001 and may not therefore feel personally responsible for some of the earlier decisions on Beagle with which he may have disagreed. This change in personnel does not alter the role of ESA. **ESA was not a disinterested carrier of a foreign enterprise. ESA had called for proposals for Mars landers in 1997 and selected Beagle 2, in preference to two other bids, in 1998. It had allowed the project to proceed when it failed to meet key milestones and had stepped in to provide funding when the project was in trouble. It was part of the project. It cannot dissociate itself from the fate of the lander after the event. We commend Professor Pillinger and his team for the enthusiasm with which they conceived and pursued the project. For the sake of future space programmes, however, they should also learn the management lessons laid bare by Beagle 2.**

222 Q 143

5 Impact of Beagle 2

Aims of Government support

96. In assessing the performance of Government agencies in supporting the Beagle 2 project it is important to recall the rationale underlying the decisions to support it, as they went considerably beyond the pure science case. The Government lists its reasons for supporting the project as follows:

- its intrinsic scientific value, confirmed by peer review in PPARC and at ESA;
- its industrial significance to the space sector;
- its wider potential in promoting interest and understanding of science and engineering to the general public.

The full value of the industrial and scientific benefits stemming from Beagle 2 can only be realised in the context of the UK's participation in future lander missions and projects. Participation in ESA's Aurora programme is discussed in paragraphs 102–109 below. There are also other benefits arising from the Beagle project, regardless of further UK involvement.

Scientific spin-offs

97. Because of the severe mass constraints on the lander, the Beagle 2 team were required to miniaturise the instruments it carried to a degree not previously seen. Some of the instrumentation developed also has important uses outside the space sector. The Gas Analysis Package (GAP) was developed as a sample processing system feeding a miniature mass spectrometer weighing only 1.62 kg.[223] This has huge potential for use in the medical sector. The Open University and the Wellcome Trust are working to adapt the GAP carried on Beagle 2 for clinical applications. Also, the X-Ray instrument developed by the University of Leicester is being trialled for use as a portable geological survey device for use in developing countries.[224] A specialised clean room was required to ensure that the construction of the lander was free from terrestrial contamination because none of the participating partners had facilities to meet the requirements of international planetary protection regulations.[225] This world class facility, built in rapid time at the Open University, is now available for the scientific community at large. The scientific outputs of the programme are not confined to the PPARC academic community. The earth sciences and life sciences stand to gain substantially from the exploration of Mars whilst the robotic–related technologies and lab-on-a-chip instruments used in the project have wider applications on Earth.

223 Professor Pillinger, *The Guide to Beagle* 2, December 2003, p 133

224 Ev 27

225 Ev 58

Public understanding of science

98. Perhaps the most striking achievement of the Beagle 2 mission was the way in which this science story captured the attention of the public and sparked huge interest in space exploration more generally. The mission was the subject of television documentaries, countless newspaper and journal articles—not only in the scientific press—and news coverage. Much of the credit for this must go to Professor Pillinger for his persistence and innovative approach to attracting interest in, and financial support for, the project. The timing of the landing for Christmas Day, when the news agenda is generally light, was also a potential advantage. The overall impact of the project on public attitudes to science and space exploration is difficult to judge. There is evidence from opinion surveys that suggests public interest in space is growing, particularly among the young, and that there is strong support for robotic missions in general, and, specifically, for another attempt at a Mars landing. The British public thought that it was worth attempting.[226] Each of the Research Councils spends a small proportion of its funds—usually no more than £2 million per annum (less than 1 per cent)—in promoting public understanding and engagement with science. We have consistently called for such activities to be enhanced and better co-ordinated. We have also emphasised the wider benefits to the UK that can stem from participation in high profile scientific projects and the hosting of international facilities in this country. **We welcome the fact that the Government recognised the wider benefits of Beagle 2 in citing public understanding of science goals as one of the factors contributing to its support for the project.**

99. Measuring the value of such activities is always difficult. OST is currently implementing a programme of actions stemming from its public consultation on the British Association for the Advancement of Science's (BA) *Science in Society* report. An evaluation of the wider impact of UK involvement in space programmes could be included in these actions to provide the Government with a yardstick by which to judge success and to inform future decisions on support for involvement in similar projects. Our view is that the high public profile and ambitious nature of the Beagle 2 project is likely to have generated an interest in science that countless Research Council programmes could never match. **We recommend that in future decisions on support for collaborative and UK-led projects the Government sets out the weight it assigns to the wider public benefits as well as the economic analysis.**

Education

100. The OU has developed foundation course material and published books relating to the Beagle 2 project. BNSC worked with teachers and industry to develop a set of lesson plans suitable for use in the school curriculum. This has led to "substantial" follow-on interest in existing space programmes and will be a model for future lesson plans.[227] Astrium sponsored a competition in schools targeted at children yet to select their GCSE subjects.[228] According to Dr Murdin, "Educational development was one of the undoubted

226 Ev 49; Demos, *Masters of the Universe Report*, www.demos.co,.uk.media.pressreleases/pressereleases2004/mastersoftheuniverse2/

227 Ev 27

228 Ev 55

successes of Beagle 2" and the Government reports that the education objective was successfully met.[229] In previous inquires we have called for the teaching of science to be more closely related to topical issues and for it to be taught in a more inspiring way.[230] The Beagle 2 mission provided an excellent opportunity for schools to demonstrate an imaginative approach to the teaching of science. Although we are not aware of any survey of use, it is clear that many schools responded positively. Children up and down the country will have been inspired both by the attempted landing and by the spectacular pictures of Mars provided by Mars Express and by the NASA mission. There may also be an impact on higher education, with astronomy and other physical sciences being seen as more attractive to greater numbers of students. **We commend the efforts of the Government and others to use the Beagle 2 project as a tool for science education. We recommend that the use made of the lessons devised is monitored and that, if successful, similar approaches are adopted with other high profile science missions.**

Future participation in ESA programmes

UK's standing in planetary exploration

101. One of the three objectives of the UK's space strategy is "enhancing the UK's standing in astronomy, planetary and environmental sciences".[231] Dr Murdin's evidence suggests that the Beagle 2 project did little to enhance the popularity of UK planetary science amongst certain European counterparts. He says "The criticism of the Beagle project is worrying to members of the UK space community, who fear that Pillinger's unorthodox methods and the high-profile Beagle failure will damage space science in this country. On the other hand the Beagle attempt is also respected".[232] We have already referred to the tensions created with national partners over the promotion of the lander as a specifically British rather than European project but the fact that the UK proposal won the competition for the lander underlines the strength of the UK in planetary exploration.[233] These issues are likely to have to be considered in the context of future UK participation in European space programmes.

The Aurora Programme

102. The ESA's Aurora Programme for solar exploration was conceived in 2000, following a mandate by European Ministers to prepare for the next steps in human exploration. The UK contributed £1 million to the progamme in 2001 to participate in its project definition phase. The Aurora Programme has two main objectives:

- a primary objective to create, and then implement, a European long-term plan for the robotic and human exploration of the solar system, with Mars, the Moon, and the asteroids as the most likely targets; and

229 Ev 27, 34

230 Science and Technology Committee, Third Report of Session 2001–02, *Science Education from 14 to 19*, HC 508–I, para 40

231 BNSC, *UK Space Strategy, 2003–2006 and Beyond*, p 12

232 Ev 36

233 See paragraph 47.

- a secondary objective to search for life beyond earth, using sophisticated and newly developed scientific instruments to investigate this possibility.

The initial programme will consist of:

- a lander demonstrator (EDLS demonstrator);
- Exo-Mars: a rover and laboratory to search for signs of life; and
- Mars Sample Return: a mission to take samples and return them to Earth for further analysis.

103. The dates for these missions are not yet set in stone but ESA's current plans are to send a rover to Mars in 2009. If successful, it is possible that the sample return mission could be launched as early as 2011. The aim is for the programme to culminate in a human expedition to Mars by 2033. The Programme will adopt a "step-by-step" approach, with Member States committing themselves only to successive five year periods of the programme, with the option to change the level of participation—or indeed pull out completely—at the end of each period.

104. All ideas for exploratory missions and scientific research will be assessed for feasibility and sent to Aurora's Exploration Programme Advisory Committee for further review. Once exploration missions, and associated technologies, have been approved, industry will be invited to tender for the work required, with the Aurora Programme Committee following each stage of each project to ensure that everything is proceeding to plan.

105. The procedure for participating in the Aurora programme means that there is no prospect of ESA simply repackaging and refining the technologies developed by the Beagle 2 team for use on future missions. The consortium would have resubmit its proposals for instrumentation. The Beagle 2 consortium partners are in a strong position to succeed in future competitions and indeed are already involved. PPARC has allowed the team to use some residual funding to allow it to prepare for any future bids.[234] Astrium report that the Beagle 2 experience has enabled UK industry to take the lead in three and to participate in three other studies awarded by ESA for planned Aurora missions.[235] Dr Clemmet believes that UK industry is "now in the leading position in Europe" for future planetary surface exploration.[236] Despite the lander's failure to communicate since launch, the consortium partners were successful in developing instruments and systems which could be used in future missions. These include miniaturised integrated electronics, robotic arms, time-critical software and parachute design.[237] The UK is acknowledged to be strong in many of the science areas included by the Aurora programme, and world leading in some. The partners in the Beagle consortium are keen to build upon their work in constructing the instruments and the lander, although the Aurora programme is not the only option. One member of the consortium reports that organisations in the US and Canada have "courted" the Beagle 2 team.[238] Dr Healy told us that it would be "a complete waste of all the money,

234 Q 73

235 Ev 49

236 Ev 55

237 Ev 46

238 Ev 55

time and energy that has been put into Beagle if that were the end of it, if we do not go into Aurora or something like that".[239] We share this view.

106. The Government agrees that UK scientists are now in "a strong position" for future collaborative projects and that the reputation of UK scientists and engineers has been enhanced.[240] It concludes that "the initial industrial objectives have been met. UK firms have been positioned to take roles in ESA's next generation exploration programme Aurora and to contribute to international opportunities, eg. NetLander, the US exploration initiative".[241]

107. The acceptance of the recommendations of the ESA/UK Commission of Inquiry indicate that there will be no repeat of a national lander riding on an ESA mission. Although there is much negotiating to be done on the development of the Aurora programme, we understand that ESA will take responsibility for the management of future landers and rovers once the successful bid has been accepted. There will be no UK-led Beagle 3. Professor Southwood confirmed "You would have to call Beagle 2 European if it were done by me".[242] Given the experiences of Beagle 2, it is highly unlikely that the Government would fund any lander managed separately from the main mission, but the provision of the support necessary for the UK to play a prominent part in the design and build of future landers and rovers is a realistic option. In the light of its experience, the Beagle 2 consortium would no doubt be in a strong position to make any future bid very competitive in terms of the science offered. **We hope that the uneasy relationship the Beagle 2 consortium had with ESA does not colour ESA's view of the desirability of future collaboration.**

108. The Government has not yet taken firm decisions on levels of UK participation in the different aspects of the Aurora programme. The Government told us that it plans to participate in the preparatory phase of the Aurora programme in order to help UK academic and industrial interests to shape the programme to meet UK priorities.[243] ESA required €25 million to continue the preparatory phase until decisions can be taken at the next Ministerial Council meeting, planned for June 2005. The deadline for contributions to this sum from Member States was 30 September 2004. The following day, PPARC announced that it had committed £3.5 million towards the European Preparatory Space Exploration Programme, with a further £1.5 million put aside for either UK preparatory activities or as additional contributions to ESA.[244] It is not clear yet how this compares to contributions from other partners but Lord Sainsbury expects that this sum will put the UK among the leading contributors.[245] This funding will ensure that the UK is fully engaged in the design of the early missions and their scientific payload. Firm financial requirements will depend upon the missions and programmes agreed at the ESA Ministerial Council.[246] At present, it is estimated that the full cost of participation in the

239 Q 73

240 Ev 27

241 Ev 27

242 Q 117

243 Ev 64

244 PPARC Press release, 1 October 2004

245 PPARC press conference on Aurora, 1 October 2004

246 Ev 64

Aurora programme proper is likely to be in the region of £25 million per annum over the first five years at least.[247] This is around double the £10–13 million per annum over the 2003–08 period that PPARC has earmarked for projects related to the search for life elsewhere. It would also represent just over eight per cent of PPARC's budget for 2004. This would be in addition to the £47 million subscription to ESA for this year. It is therefore unlikely that PPARC alone would be able to fund full participation in the Aurora programme without further additional funding from the 2004 Spending Review, which we understand is being sought. Decisions on the allocations by OST to each of the Research Councils following the 2004 Spending Review are not expected until the early part of 2005, somewhat later than the usual November announcement.

109. Important decisions need to be made in the near future about UK participation in the future of European space exploration. One key consideration will be the extent to which the objectives of the Aurora programme match those of UK space policy. Lord Sainsbury has sounded cautiously optimistic on this score. At the 2004 Farnborough Air Show he said, "I have great hopes that it [Aurora] will develop into a proposal that will offer the UK an opportunity to meet our objectives, with a strong focus on robotic exploration".[248] Although the Science Minister has not ruled out the possibility of UK involvement in the long term Aurora goal of human exploration, the additional costs are not thought at present to add sufficiently to the scientific benefits that can be achieved by robotic exploration. This goal is still some way off and there is much in the early part of the programme which matches up with the Government's current policy on space exploration. PPARC has consulted widely on participation in the programme and concluded that there is a high scientific value in involvement at least up to the point of a Mars sample return mission.[249] PPARC has to make its decisions on funding in the light of its other funding priorities and the Spending Review allocations for 2004 and future years. Its remit requires it to focus on scientific rather than industrial goals, although interaction with industry is now becoming more intensive. We have frequently referred to the long history of cutting edge British science failing to attract the support necessary to stay in front and failing to transfer scientific knowledge into commercial success. We would not like to see interplanetary exploration added to the list. The scientific advantages in relevant technologies gained by the Beagle 2 mission should not be wasted. In this context, **we welcome the UK's full participation in the preparatory phase of ESA's Aurora space exploration programme. We hope that this engagement at the outset will help the UK shape the content of the programme and gain substantially from it in terms of industrial and academic participation. In view of wider considerations relating to the educational, industrial and science in society agenda, we believe that Government, not just PPARC, should ensure that UK plc is in a position to build on the scientific base established by the Beagle team and to support participation in future planetary exploration missions, on a well defined multinational basis. OST and DTI should examine the case for UK participation from the point of view of their different objectives and provide the appropriate support, to add to that of PPARC, in a co-ordinated way.**

247 Ev 50–51

248 www.esa.int/export/SPECIALS/Aurora/SEMXYZ274OD_2.html

249 PPARC, *Aurora The UK's Decision*, 1 October 2004

6 Publication of Commission of Inquiry Report

110. The Commission of Inquiry was jointly established by Lord Sainsbury and the Director General of ESA in February 2004 to investigate the circumstances and possible reasons that led to the loss of the Beagle 2 mission. It looked at the possible programmatic and technical shortcomings and sought to provide recommendations for the future rather than to "assign individual responsibilities".[250] The Report was compiled by the ESA Inspectorate and the nine strong inquiry team comprised ESA members and outside consultants, including John Casani. It conducted a series of interviews with the project team for six days over a three month period.[251] None of the project team has seen a copy of the report, although they have been briefed on its findings.

111. The Government evidence describes the decision to publish only the recommendations of the report, as follows:

> "Having considered the relevant factors, it has been decided to withhold the full report under the following exemptions in Part II of the Code of Practice on Access to Government Information:
>
> Exemption1—Defence, security and international relations.
> The full report contains confidential matters involving other member states and material which has been provided in confidence by the European Space Agency (although, without disclosing the full report, they have agreed to the release of recommendations from it which are now in the public domain).
>
> Exemption 4—Law enforcement and legal proceedings.
> There are potential, if not actual, ongoing legal disputes and disclosure of the full report could have a possible impact in that context.
>
> Exemption 13—Third party's commercial confidences.
> The circumstances arising from the Beagle 2 events will relate to commercially confidential matters between UK firms and other interested parties."[252]

The Report itself states that: "The work of the Commission of Inquiry will remain confidential until an official release of the findings authorised by both the UK Minister for Science and Innovation and the Director General of ESA. All members will sign a non-disclosure agreement".[253] Professor Southwood told the Committee that he had no personal objection to the report being published but indicated that it was ESA policy not to publish internal inquiry reports.[254]

250 ESA/UK Commission of Inquiry Report, *Beagle 2*, p 3

251 Q 68

252 Ev 28

253 ESA/UK Commission of Inquiry Report, *Beagle 2*

254 Qq 122–127

112. In our view the Government's arguments for not publishing the report are weak. To take the first reason first, we cannot see anything in the report which could be said to adversely affect international relations. Whilst some of the negotiations and reviews during the project may have taken place in private meetings, there is nothing in the report which seems to require confidentiality on this score. There are strong reasons in favour of publication: ESA receives significant public funding from its Member States. Taxpayers, and in particular the space research communities, in those countries are entitled to know how it is being spent. From a UK perspective, the public accountability argument carries even more force, given the amount of public money that DTI eventually contributed. The UK side was, quite reasonably, very keen to tell everyone about the Beagle 2 project when it was seeking publicity for it prior to launch. It should not be shy about saying what went wrong. Lord Sainsbury has made some effort to do so, from his point of view, but is not in a position to evaluate the technical aspects of the mission.

113. With regard to the legal reasons for non-publication, we understand that no such proceedings have begun. If there were such proceedings active, there would be a case for non-publication of those parts of the report which would be relevant, but it is an absurd and unsustainable principle to use the potential for future legal action as a justification for non-publication.

114. The commercial confidentiality argument is also thin, especially in the light of the publication of the Lessons Learned Report by the Beagle 2 project team. This contains very detailed information on the technologies and tools developed, their testing, operation and cost. This information, some of which is no doubt of commercial value, was volunteered by the parties involved in order to benefit future missions. No company objected to the publication of any part of this report.[255]

115. The decision not to publish the report was only taken on 21 April 2004. If it was one of ESA's routine internal inquiries, which do not get published, there would have been no need for such a decision to be taken. The difference in this case was that this was both an ESA and UK mission, and that the UK Government commissioned the review in conjunction with ESA. The normal procedures therefore did not apply. It would have been possible to seek the permission of participants to publish the report in full.

116. The published recommendations of the Report are sensible and helpful, and should, if they are followed closely, provide a better chance of success for future missions. But they do not give the full picture of how the mission got into such difficulties and reveals little about the relationship between ESA and other parties. If there was a genuine desire to publish the findings of the report, but concern over commercial confidentiality, an edited version could be published, with sensitive parts removed. Lord Sainsbury suggested that this would in fact be difficult, given the nature of the report.[256] We disagree. We are not persuaded that the reasons presented by the UK Government give the whole story, We suspect that there were strong political reasons for the report to be kept internal. Whilst it avoids direct personal criticism, it nonetheless does not present a picture of mission management that ESA would necessarily be content to advertise. A decision not to publish limits any embarrassment. The avoidance of political discomfort is not, under the

255 Ev 68

256 Q 197

Government's Code of Practice on Access to Government Information, sufficient reason for not disclosing information. **The decision not to publish the Commission of Inquiry's report in full was based on the sensitivities of the parties involved rather than any convincing legal or commercial considerations. This is an affront to accountability. We recommend that the full report be published without delay.**

7 Conclusion

117. The complex story of Beagle 2 can be summarised fairly simply. Professor Pillinger saw an opportunity for an exciting scientific project and he and his colleagues pursued it with great enthusiasm, energy, and considerable success, beating competition from other proposed landers. ESA saw the lander as a means of enlivening an otherwise unambitious mission to Mars but was not prepared to adjust the mission to give the lander the high priority that its science and profile might have merited, had it been part of an ESA mission from the start. The UK Government provided moral and financial support to the project, but not quickly enough. It also tried to convince ESA to contribute more and then was left to bail out the project when it was faced with financial difficulties. There were management failings and unrealistic cost estimates during the project, for which all parties involved must shoulder some responsibility. Some of them have already done so. In spite of the reservations in ESA that have subsequently been aired, it would be wrong to give the impression that the project was doomed to failure. The short time scale and funding difficulties may have increased the risks of an already risky project, but there was still, as far as we know, a realistic chance of success when the Mars Express was launched. After two technical inquiries no faults or systems errors that could have caused its failure have been found, although the lack of a communications capability during the lander's descent means that information is limited. On another day, the lander might have made it. Many have their theories, but the likelihood is that we will never know why it failed to land as planned and communicate with Earth. There are nonetheless considerable benefits emerging from the project, in terms of the development of the technologies used for other purposes and in the stimulating effect the project had on UK space science and the promotion of careers in science to a young audience.

118. It would be easy with the benefit of hindsight to criticise the Government for supporting a project which, in the eyes of the watching public at least, was a spectacular failure. We believe that, once committed, the Government was right not to withdraw funding, but instead to try to find ways of improving the chances of success. The costs of withdrawing in 2001 would have been high, not only in purely financial terms but in terms of the reputation of UK science within ESA and beyond. The Government would no doubt have attracted considerable criticism from the scientific community and indeed from this Committee. Our criticisms are based on the failure of the Government to provide an adequate guarantee of support early enough to give it the maximum chance of success and its failure to engage, with ESA, in sufficiently close monitoring of the progress of the project in its early stages.

119. Was the £25 million well spent? Both Lord Sainsbury and Professor Southwood thought so.[257] We are prepared to agree, provided that the opportunities presented by the Beagle 2 mission are not wasted. The early signs are encouraging. The failure of the mission has not blunted the enthusiasm of the Beagle 2 consortium to try again and PPARC has given a financial commitment to continue to support UK engagement in ESA's space exploration programme. We hope that the UK Government as a whole will be similarly positive about UK participation in another Mars mission and believe that it should provide the necessary long term financial commitment to ESA's Aurora space exploration

257 Q 82

programme to enable the UK to reap the full benefits that the Beagle 2 mission undoubtedly sowed.

Conclusions and recommendations

1. We welcome the establishment in the 2004 Spending Review of a strategic fund to be allocated by the DGRC but are not persuaded that it will rectify the serious weaknesses which the Beagle 2 project highlighted in the Government's capacity to respond to sudden demand. In the absence of other funding streams to cater for such demand, we recommend that the Government considers earmarking this fund primarily for major projects and facilities. (Paragraph 33)

2. BNSC was ill-advised to rely upon ESA to bail out the project if it ran out of money rather than seeking to establish with ESA and others firmer financial arrangements at the outset. (Paragraph 37)

3. We commend the Government, and in particular the Minister for Science and Innovation, for being enthusiastic about the Beagle 2 project. It was an exciting scientific opportunity with the potential to put the UK at the forefront of space exploration. The Government should not be shy about taking risks in science if the potential benefits are there. In our view, this was a risk worth taking. Having taken this decision, it was then up to the Government to fund it properly. (Paragraph 39)

4. The UK Government gave the Beagle 2 project moral support but initially took on as little financial responsibility as it could to ensure that the lander was not thrown off the Mars Express mission. The absence of a commitment from the Government at the outset to provide the necessary funding to support the project in full made it less credible in the eyes of ESA and its Member States, not to mention potential backers of the project, the UK scientific community and the public. (Paragraph 45)

5. The ESA leadership responded positively and flexibly in 2000 to the financial difficulties in which the Beagle 2 team found itself and helped to keep the project alive. However, there appears to have been a latent resistance among Member States to the British-led lander, no doubt in part due to a perception that this was an exercise in promoting UK national scientific interests. This made it difficult for the ESA secretariat to push for more funds when the project met further difficulties, although we are not persuaded that every effort was made on this front. (Paragraph 50)

6. The failure of the project's backers to provide the necessary funding for full testing had a major impact on the ability of the project team to mitigate risks, delaying development and testing until less than two years before the final launch date. It added significantly to the risks already associated with the project. (Paragraph 54)

7. We conclude that the pursuit of sponsorship income was an innovative and necessary attempt to meet the funding gaps which were evident in the programme from an early stage. But it did nothing to encourage a realistic assessment of the risks of the project or an open dialogue between participants. It also affected the credibility of the project, which had an impact on the degree of support for it in some quarters. Whilst in the right circumstances there may be a place for commercial sponsorship in such missions, we believe that in this case the DTI should have been focussing its

efforts on finding sufficient funding for the project rather than relying upon the securing of commercial sponsorship. We recommend that in future the DTI is extremely cautious about part-funding projects which are reliant to a significant degree on the future attraction of commercial sponsorship. At the very least, DTI needs to satisfy itself of the availability of sufficient funding in the event that commercial avenues prove unproductive. (Paragraph 59)

8. Had a Mars lander been part of the original mission, and managed by ESA, we suspect that it would have been given a priority commensurate with its potential scientific output, with mass levels tailored accordingly to give it a greater chance of success. (Paragraph 65)

9. Given the importance of the interface between lander and orbiter and the importance of the former to the mission as a whole, it was remiss of ESA not to ensure that it had the role of at least a close observer from the outset of the Beagle 2 project. (Paragraph 66)

10. It is extremely disappointing that ESA, the UK Government and the project team were unable to co-operate in such a manner as to give the lander the maximum possible chance of success. We believe that both the Beagle 2 project team and the UK Government should have done more to persuade ESA to take greater responsibility for managing the lander project, if necessary, at the expense of some UK ownership. For its part, ESA should not have been influenced so much by the apparent attraction of getting a lander for free, albeit at the expense of European ownership. It should now recognise that this was a mistake and ensure that it takes full management responsibility for similar future missions. (Paragraph 69)

11. Had ESA implemented the lesson of earlier failed missions on the importance of communication between lander and orbiter, it would have secured a vast amount of information which could have been used to help establish what happened to the lander and therefore to reduce the risk of future failures. It is a pity that this lesson had not been learned from two previous missions. (Paragraph 70)

12. The project went well beyond the normal scope of the work of a Principal Investigator. The consortium leadership was understandably keen to maintain control over what was very much the team's own initiative, which was pursued with admirable determination and considerable success. The team was perhaps unduly reluctant to accept that the project as a whole may have benefited from greater involvement from ESA, which could have provided it with the necessary financial resources. It was the absence of the guaranteed funding that made a formal agreement between participating parties difficult to achieve. This in turn was a fundamental weakness in the project management. (Paragraph 75)

13. The establishment of the Casani review was a useful means of gaining an independent assessment of the project. Having commissioned it, ESA should have taken greater responsibility for implementing the most important of its recommendations in full. (Paragraph 79)

14. For far too long the Government failed to ensure that the nature and extent of the risks were identified accurately so that the funding necessary to help mitigate those

risks as far as possible could be provided. The failure by all parties to establish at the outset some quite basic elements of cost attribution accentuated funding difficulties. Once they became financially committed, both the Government and ESA took steps to monitor the project, but neither was willing or able to ensure that the recommendations of their various reviews were fully implemented. (Paragraph 88)

15. Relations between ESA and the UK side were strained by different attitudes towards the lander. Professor Southwood clearly had very strong doubts about the lander's chances of success. He should have made these reservations clear – formally – in order that they could be addressed. (Paragraph 91)

16. By failing to subject the lander to sufficiently rigorous scrutiny in its early stages and to provide the necessary support, ESA and the UK Government left themselves with few options when the project ran into serious problems. The decision to allow the lander to proceed in 2001 was the right one. It was also the only one realistically available. (Paragraph 94)

17. ESA was not a disinterested carrier of a foreign enterprise. ESA had called for proposals for Mars landers in 1997 and selected Beagle 2, in preference to two other bids, in 1998. It had allowed the project to proceed when it failed to meet key milestones and had stepped in to provide funding when the project was in trouble. It was part of the project. It cannot dissociate itself from the fate of the lander after the event. We commend Professor Pillinger and his team for the enthusiasm with which they conceived and pursued the project. For the sake of future space programmes, however, they should also learn the management lessons laid bare by Beagle 2. (Paragraph 95)

18. We welcome the fact that the Government recognised the wider benefits of Beagle 2 in citing public understanding of science goals as one of the factors contributing to its support for the project. (Paragraph 98)

19. We recommend that in future decisions on support for collaborative and UK-led projects the Government sets out the weight it assigns to the wider public benefits as well as the economic analysis. (Paragraph 99)

20. We commend the efforts of the Government and others to use the Beagle 2 project as a tool for science education. We recommend that the use made of the lessons devised is monitored and that, if successful, similar approaches are adopted with other high profile science missions. (Paragraph 100)

21. We hope that the uneasy relationship the Beagle 2 consortium had with ESA does not colour ESA's view of the desirability of future collaboration. (Paragraph 107)

22. We welcome the UK's full participation in the preparatory phase of ESA's Aurora space exploration programme. We hope that this engagement at the outset will help the UK shape the content of the programme and gain substantially from it in terms of industrial and academic participation. In view of wider considerations relating to the educational, industrial and science in society agenda, we believe that Government, not just PPARC, should ensure that UK plc is in a position to build on the scientific base established by the Beagle team and to support participation in

future planetary exploration missions, on a well defined multinational basis. OST and DTI should examine the case for UK participation from the point of view of their different objectives and provide the appropriate support, to add to that of PPARC, in a co-ordinated way. (Paragraph 109)

23. The decision not to publish Commission of Inquiry's report in full was based on the sensitivities of the parties involved rather than any convincing legal or commercial considerations. This is an affront to accountability. We recommend that the full report be published without delay. (Paragraph 116)

Formal minutes

Wednesday 13 October 2004

Members Present

Dr Ian Gibson, in the Chair

Paul Farrelly	Mr Tony McWalter
Dr Evan Harris	Geraldine Smith
Dr Brian Iddon	Bob Spink
Mr Robert Key	Dr Desmond Turner

The Committee deliberated.

Draft Report (Government support for Beagle 2), proposed by the Chairman, brought up and read.

Ordered, That the draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 119 read and agreed to.

Ordered, That the provisions of Standing Order No. 134 (Select committee (reports)) be applied to the report.

Resolved, That the Report be the Twelfth Report of the Committee to the House.

Ordered, That the Chairman do make the Report to the House.

Ordered, That the Appendices to the Minutes of Evidence taken before the Committee be reported to the House.

[Adjourned till Thursday 14 October at half past Nine O'clock.

Witnesses

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Fourth Report	Office of Science and Technology: Scrutiny Report 2003 *(Reply HC 588)*	HC 316
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Ninth Report	The Work of the Engineering and Physical Sciences Research Council. *(Reply HC 169, 2003-04)*	HC 936

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Second Report	The Research Assessment Exercise *(Reply HC 995)*	HC 507
Third Report	Science Education from 14 to 19 *(Reply HC 1204)*	HC 508
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Fifth Report	Government Funding of the Scientific Learned Societies *(Reply HC 53)*	HC 774
Sixth Report	National Endowment for Science, Technology and the Arts: A Follow-Up *(Reply HC 276)*	HC 1064
Seventh Report	The Office of Science and Technology: Scrutiny Report 2002 *(Reply HC 293)*	HC 860
Eighth Report	Short-Term Research Contracts in Science and Engineering *(Reply HC 442)*	HC 1046

Oral evidence

Taken before the Science and Technology Committee

on Monday 5 July 2004

Members present:

Dr Ian Gibson, in the Chair

Paul Farrelly	Mr Tony McWalter
Dr Brian Iddon	Bob Spink
Mr Robert Key	Dr Desmond Turner

Witnesses: **Professor Colin Pillinger,** Planetary & Space Sciences Research Institute, **Dr Mike Healy,** Director, Earth Observation, Navigation & Science, EADS Astrium Limited, **Mr Mike Rickett,** former Director, Earth Observation and Science Division, Astrium Limited, and **Dr Mark Sims,** Space Research Centre, University of Leicester, examined.

Q1 Chairman: Thank you very, very much for coming along. Beagle has fascinated us all for some time and we are very interested in asking you a few questions about the project and the future and so on. Thank you all for coming, because I know you have all played a major part in the project. It is not our remit, although some Ministers might like it, to go out to Mars as a committee and look for the thing; we are not trying to find Beagle or anything like that or exactly why it failed really. We have seen the report of the commission of inquiry and looked at the issue through that. We understand the restrictions that are placed on parts of that. We are really interested, as guardians of the public money, as a select committee, to know how it was used in support of the project, looking at how any similar missions might be supported by the government in the future, the lessons to learn, the research community in future that would be involved in it, and what we have found out. We know of course that Beagle 3 is being talked about, so that will also be part of our inquiry and our questioning. Thank you very, very much for coming. We will try to keep our questions short, so that it gives you all a chance to give short answers. Do you agree with the former UK representative at ESA, Paul Murdin, when he said that the Government did all the right things for Beagle? Colin, would you like to take that?
Professor Pillinger: I think the Government supported us very well after we managed to persuade them it was worth supporting us.

Q2 Chairman: How did you persuade them, and why?
Professor Pillinger: I was absolutely convinced that the science was world-class, and of course I had 20 years of background on which I had built it. It would have been very easy to accept a Government "sorry, there are not any funds available for this" in 1997, when I first went to them. Many other projects have been told that there are no funds in the budget, and that is true because these missions are put together years in advance—so they did need persuading.

Q3 Chairman: The money dribbled out, did it not; it did not come in one big cheque or one big hand-out? Do you think that made a difference to the success of the project?
Professor Pillinger: It would have been nice to have had the money all at the beginning.

Q4 Chairman: Did you ask for it?
Professor Pillinger: No, we never asked for all the money at once.

Q5 Chairman: Why not? I would have.
Professor Pillinger: Because we believed that if we asked for a large sum of money all in one tranche, we would have been told "no". We did try to convince them a little bit at a time; and of course there was a difficulty in that nobody ever believed that they carried the entire budget for a project like this. The industrial partners would never be funded by PPARC, in the same way as the scientists would never be funded by the DTI; so we tried to put this thing together in bits, ourselves at the OU, then to Astrium—MMS as it was.

Q6 Chairman: So if I said you were cobbling it all together, would that be a fair description?
Professor Pillinger: I would not use the word "cobbled", but—

Q7 Chairman: What would you say?
Professor Pillinger: We did try to put it together bit by bit, like a jigsaw puzzle, including the sponsorship.

Q8 Chairman: Would any other panellist like to add to that in any way, as to how they saw the contribution by the Government to the project? How would you describe it in your lighter moments?
Dr Healy: The approach to the funding overall was probably more innovative than the project team would have liked. We would have liked a much simpler structure, where there was one big cheque written at the start of the day, and we could have got on with the programme. That is the way that future programmes need to go down. There was an awful

lot of goodwill to try to make the programme happen, despite the relative lack of budgets that were in place at the time.

Q9 Chairman: Mike? I know that you are a former director but you were there at the time.
Mr Rickett: I would say that it would have been probably quite difficult for us to have formulated on day one a clear picture of exactly the way the programme was going, and therefore the full extent of the funding that was ultimately required to do the job. There was an element of chicken-and-egg about it; we had to spend at least some time during the early parts of the programme working out within the partnership just how we would mount this mission and how we would go forward with it. In all of that time, I believe that we had government on side, and it was very positive and constructive in its support to us.

Q10 Chairman: In your darkest moments, you did not worry that it might not all go right, in terms of the money coming forward, and as partners in it you had thought, "this is a risk"?
Mr Rickett: Absolutely. It was always a big risk, but we were certainly convinced as a team that we had something special here, and that ultimately we would win through in terms of funding.
Dr Sims: Beagle was a unique opportunity and that is why we agree with the comments of the two Mikes before me: we believed in the end goal, and it took some time to convince people that the funding should be there. The problem of course is that Mars Express happened on a very rapid timescale outside the normal timescales of projects of five to 10 years.

Q11 Mr Key: Why were the lander and orbiter missions not managed as one project?
Professor Pillinger: It is traditional that national contributions are made in terms of instruments. This is the way in which ESA has always operated, and ESA has learnt that this is a mistake. The team always believed that we were making a spacecraft and not an instrument. It was far more complicated than an instrument.

Q12 Mr Key: What efforts did you make to try and persuade ESA to take on the management and oversight of the lander or of parts of the Beagle 2 project?
Professor Pillinger: I do not think we ever tried to have them take on the entire management. I did offer them the chance to manage the entry descent and landing system because that was causing a considerable amount of concern within ESA.

Q13 Mr Key: Do you think they have the management expertise to manage such a project?
Professor Pillinger: They do have the management expertise. I do not see any difference between Astrium managing a lander if the Open University is the customer, or Astrium managing a lander if the European Space Agency is the customer.

Q14 Mr Key: Do you think the chances of success would have been improved if ESA had been managing the project?
Professor Pillinger: No, I do not. I think the chances of success would have been improved had we been treated at the same level as all the other instruments on Mars Express, but we always knew from day one that Beagle was considered as an add-on to the project. It was described as "the cherry on the cake" on a number of occasions. One has to remember that the instruments that were aboard Mars Express had already been lost once, so the European Space Agency were rather concerned that they not be lost again, and therefore the instruments on the orbiter were the priority, as opposed to the lander, which was considered as an add-on.

Q15 Mr Key: Would anyone like to add to that?
Mr Rickett: I guess the question infers that ESA were not involved with the programme to some extent. It certainly was the case that they were not remote from it. They had residents within our team, who worked very closely alongside us, and we worked very closely with John Credland, who was the then head of the science programmes. He was part of the steering group that met on a regular basis to oversee the way in which the programme was running. They were certainly involved with it and were not remote from it.

Q16 Mr Key: Dr Sims, why were relations with Astrium Toulouse different?
Dr Sims: This comes back to the fact that the Mars Express was originally conceived as an orbiter-only mission. It relates to some of the comments that have just been made in that ESA's priority was to recover the science and the instruments that had been lost on Mars 96. Therefore the lander was there as an option, and, I believe, in the initial invitation to tender to industry it was described as an option. Astrium Toulouse had the job of delivering the orbiter. I would have to consult my Astrium colleagues to know whether it was a fixed price contract or whatever, but their job was to deliver the orbiter to the specification. Consequently, they took the route of defining the interfaces on Beagle very early in the programme because they had to, in order to progress their orbiter. That gave us a distinct problem in that in the January 1999 kick-off meeting we were still in a phase of deciding what the envelope of Beagle 2 was. We already knew the mass had to be 60 kilos, and there was some uncertainty at that stage in our design; and we also knew the volume constraints because Beagle had to be designed so that it would not interfere with any of the Mars Express instruments if for any reason we did not eject. I think it was a management decision by Astrium Toulouse to force us to keep to our interfaces.

Q17 Mr Key: Dr Sims, why was the interface between the two parts of Astrium so poor?

Dr Sims: I really do not know, is the honest answer.

Q18 Mr Key: Would you agree that they were poor?
Dr Sims: I would not say they were very poor; I would say there was a difference in priority. UK Astrium was concerned with the lander and Astrium France was concerned with the orbiter.

Q19 Paul Farrelly: Professor Pillinger, you referred to concerns when you spoke about the entry of landing systems. Can you say what those concerns were, and be precise as to who held those concerns?
Professor Pillinger: The concerns over the entry descent and landing system emerged when ESA, together with NASA—it was a panel chaired by a man called John Casani—looked at the whole project in September 2000. Only the USA had managed to land successfully on Mars, and they had a similar system on Pathfinder. We were actually using the same company that had supplied to Pathfinder; nevertheless, the NASA reviewers, who had intimate inside knowledge—remember everything in this area is covered by ITAR, International Restrictions on Arms—had detailed information inside and they felt that we did not have an adequate testing programme. They voiced this concern at the review report, which said the project was eminently do-able, but that we should have help with the mass money and the entry descent and landing system testing.

Q20 Dr Iddon: Professor Pillinger, did you plan a management structure from the start of the project, or did it evolve as you went along; and in either case did you base the management of the project on any known examples that had gone before?
Professor Pillinger: It is very difficult to define a management structure when you do not have any money to be a customer to place an order with someone. We set off in Beagle 2 under a very clear gentleman's agreement. The obvious way forward was to get the project selected by ESA so that we could then move on to get the funding from government. The management in the initial stages, therefore, was clearly me as the PI, with Mark Sims acting as project manager to get a proposal through the system. However, we were supported by Astrium and indeed everybody else in the consortium right from the first meeting that we held at the Royal Society in May 1997. Astrium had up until this time been MMS and still were MMS, and they were transferring from Bristol to Stevenage. Once the proposal was accepted, Mike Rickett gave us a very senior engineer to be the spacecraft engineer, and very shortly thereafterwards gave us a project manager. Of course, we now had what appeared to be two project managers, so it was designated that John Thatcher, who was the Astrium industrial project manager, would be called the programme manager, and Mark Sims would become the mission manager in charge of the science and the operations when we got to Mars. That was, as far as I was concerned, a very typical management structure for a project like this. The industrial role is to deliver the spacecraft, and thereafter the scientists who expected to get the data out of it would run the project.

Q21 Dr Iddon: Is it right for me to assume, therefore, that the lack of knowledge about the total finance that might be available as the project progressed was a factor in determining the management model, and perhaps a factor in the failure, in that you did not know how much finance you were going to have or even need ultimately?
Professor Pillinger: I think everybody knew where we were. We were all aware of the constraints under which we were operating. We had several goes at estimating the costs. It was quite clear that the costs at the beginning of 2000 were probably just under 30 million. Later on, when there was a restructuring of the programme because of the departure of Martin Baker, those costs were clearly going to escalate because we were behind on testing, behind on schedule, and Astrium was going to take on additional risks. Certainly, if they were going to take additional risks under the form of the fixed price contract, then it would be prudent to make sure that there was contingency funding. Finally, there was another change in the cost, when we found that we had to design a completely new parachute; and that was coped with by the Government giving a small increment in funding to Astrium for a specific parachute study, and by the OU and Astrium coming to an accommodation over the way in which funds would be reimbursed if we got anything back from sponsorship.

Q22 Dr Iddon: In the end, who had overall control of the project? Where did the buck stop, or who did the buck stop with?
Professor Pillinger: Ultimately, if anybody was going to say "this project stops", they would have had to persuade me that I was to stop trying to make the project happen. However, the man who was managing the project who controlled the budgets was John Thatcher of Astrium—although he did not control any budgets for the science instruments, which were all controlled by the individual suppliers of the instruments, which included the OU, Leicester and a number of other universities.

Q23 Chairman: Was there ever a moment when you discussed that possibility, of abandoning the whole thing? Did you ever worry? Did you have a sleepness night?
Professor Pillinger: Me?

Q24 Chairman: Lots of sleepness nights, I guess.
Professor Pillinger: No, I never had any sleepness nights. I always thought we had a very just cause and that the science that we were intending to do would carry us through; and I always thought that the technology—in fact, in a room very much like this it was admitted that the science and the technology were world-class.

Q25 Dr Iddon: Were the working relationships between all the parties involved in this, which after all must have been a complex project, made clear at the outset, or were they clarified at the heads of agreement meeting and finalised in June 2001?
Professor Pillinger: There was never a time when the people working on this project did not know what the management structure was. It was absolutely clear the rules under which we were working. The rules between Martin Baker and Astrium were absolutely well known. We had to formalise arrangements in order to qualify for funding, as and when these were stipulated; but when you have money you can sign contracts. If you do not have money, there is absolutely no point in signing any contract.

Q26 Dr Iddon: So we are back to the finance again. This keeps bobbing up.
Professor Pillinger: Ultimately, contracts can only be signed when somebody has a cheque to offer to somebody else.

Q27 Dr Iddon: There had been a previous project of course, the Rosetta Mission, which—
Professor Pillinger: Which I was involved in.

Q28 Dr Iddon: Yes. That had failings in management and technical leadership, so I gather. Was anything learned from that project to apply to this project?
Professor Pillinger: Can I comment on that? I was involved in Rosetta, and I will absolutely say to you that the management of the Rosetta lander was a shambles because it was a project that was very, very loose, and it constantly had changing oscillation between French and German PIs. Every time the six months moved on, so that it was somebody else's turn, everything got changed.

Q29 Chairman: How much did that cost the nation, then, Colin?
Professor Pillinger: It did not cost us anything. We had an instrument on board the lander which did not come into the management province. When I set up Beagle, I resolved that we would not have anything like the bickering that ever occurred in Rosetta. In fact, there was never an occasion in Beagle when there was any quarrel over who was managing what.

Q30 Dr Iddon: The Casani review was rather critical of the management structure of Beagle 2. Did you see a copy of that, where the project management was described as "fragile"?
Professor Pillinger: Yes, I have seen a copy of the Casani report. I also was there when John Casani gave a verbal report. It was about 2 am on a Saturday morning at the end of the project, and Casani's words were actually—I think I quoted in my written presentation—"your way of doing things is nuts but it seems to work".

Q31 Dr Iddon: We have gone through Rosetta and we have gone through Beagle, and we hope there is a future project, obviously; that is what this Committee would like to think. Can you tell us after all those questions on management what you would do different in future to make a project more successful?
Professor Pillinger: The two things that I would like to make the project more successful is a very early decision, with priority, if you are building a lander, to say this is a lander project. I would not turn down the opportunity to hitchhike again, but by the same token I would expect, if I was a hitchhiker, to have equal rights in terms of priority. I have already explained that we knew what we were letting ourselves in for. We knew Mars Express was going to give the orbiter priority, but if I was doing it in future that would be my first priority, to say this is a lander project. If you want to have a lander successful, then the sensible way to do it would to be sent two landers because you are never going to get a 100% risk-free project. Thereafter, put the money in place early; do not have people trying to be drip-fed with money.

Q32 Dr Iddon: So we have two conclusions to my round of questions. First, the finance has got to be clear from the start—as you are saying loud and clear—and, secondly, do not piggyback on somebody else's project but do a lander project on your own.
Professor Pillinger: The finance is secondary. We never had any difficulty working without any money because we were all so committed to the idea of going to Mars to look for life. I personally believe that that is still a very valid goal; in fact it is even more valid now than it was in 1997.

Q33 Dr Iddon: The primary conclusion is, "do not piggyback". Is that what you are saying?
Dr Healy: With regard to this hitchhiking business, the lander has to be an intimate part of the mission. The problem with Beagle is that it was an optional extra. It was a very nice optional extra to have, but you had a mission that was perfectly valid without it. Some of the earlier questions were about differences between Toulouse and the UK on how things were being managed, but you had a Mars Express programme that was relatively low risk, with instruments and a spacecraft that was a deviation to Rosetta; so it was very close to something that had already happened. It was under contracts from about 1999. We had a very clear situation with Mars Express. The only area that was not clear was whether Beagle was going to be there or not. On the other side, you had Beagle, which was relatively high risk, relatively high technology development, without a clear statement on funding. It was not until July 2001, when the funding was in place, that the management structure could then be formalised, rather than relying on a gentleman's agreement, and at that point it then ran pretty much as a normal project would have run. However, just getting that funding sorted out that late in the day caused some tension with Mars Express and created a position where we were always under pressure when it came to delivering Beagle.

Q34 Dr Iddon: Are you saying the opposite to what Professor Pillinger is saying; that the financing was a primary factor and not a secondary factor as Professor Pillinger said?
Dr Healy: I do not think there is a big difference between the two of us on this one. It has to be an intimate part of the mission. Colin might say it has to be the number one priority—I just think it has to be part of the mission right from the word "go", and you need the funding in place. You need those two things.
Professor Pillinger: I do not think we disagree, but Mike came along very late in the project and has seen it as a very clear industrial contract. Mike Rickett was around at the beginning, when I was the Pied Piper and leading everybody the dance.
Mr Rickett: If you are looking for lessons for the future, then I would have to say that you have to get the financing in place. As far as Beagle was concerned, I am not sure that that had so much of an impact. As Colin says, there was so much enthusiasm within the team to make it successful that we did not really need the binding that maybe future projects will need. When Casani talked about fragility, I think he was referring to the fact that there was not really a legal contract binding these guys together, and in the event, if things went wrong then partners might walk away.

Q35 Dr Turner: It seems very strange to have a project which has lots of elements, but which only gets drawn together after seven years, but seems to have started out without all the costs worked out. It has all the appearance of being a bit amateurish. Would you agree?
Professor Pillinger: No, this was never an amateur project, and we knew from the beginning that the costs were going to be something of the order of 25 million plus. The project was reasonably carefully costed within the bounds that we had. If the project actually did escalate in price, then it was inevitable it was going to escalate in price because we would find ourselves playing catch-up because we did not have all the money in place at the beginning. This project was never amateur. It might have been an image that was worth portraying because it was a media-friendly image of some boffins going to Mars, but—

Q36 Chairman: Did Saatchi not pay you anything?
Professor Pillinger: Saatchi never paid us anything. We paid Saatchi. The deal we had with Saatchi was that we paid them some money up front. If they had attracted sponsorship, that money would have been returned out of the first—

Q37 Chairman: But that never happened.
Professor Pillinger: Because it never happened. We never—

Q38 Chairman: How much was it with Saatchi—can you tell us?
Professor Pillinger: We were paying them on a retainer, which was a monthly sum of money, which was £8,000 a month.

Q39 Mr McWalter: Why are you worried about saying it was amateur, because the original Beagle was amateur, and the costs were unknown, and what was going to be found was unknown? It was only as a result of the Beagle that Darwin himself became a professional and it was the making of him. I do not see why it is a bad thing to accept that. This mission is a bit of a make-or-break thing: if it made it, you would not be amateur, and if it did not, then you might be!
Professor Pillinger: The connotation that it was amateur would not do the reputation of my industrial partners much good. When we began this, there was a perception that we were off on a PR stunt. In fact, PPARC at the beginning did not take things too seriously; but Paul Murdin said at one of these inquiries "we were surprised when we saw the science". There was no reason for them to ask for a science case because they had no money to give us; but when they saw the science case and realised just how strong the science case was, they began to get the message that the science case had been rather well conveyed to the industrial partners, because the industrial partners were prepared to back the science with their own resources. This is why I am keen to get over that this was done by people who were at the very top of their field in terms of the science and the engineering. I think Mike Rickett gave us the best people he could find for this project; he really scoured the country and found the best people.

Q40 Dr Turner: What effect do you think it might have had on the technical development work that went into the project, and therefore the potential for success of the project if the funding had not been on such a "catch as catch can" basis? If you had a clearer idea of where your funding was coming from at an earlier stage, would the development of the project have been very different?
Professor Pillinger: I think we would have retired risks earlier if we had had early money. That is what space missions are all about. You can design on a piece of paper and work out what will work theoretically, but the way in which you can demonstrate it will work will be to do a test; and tests do not always have to work to be valuable. Tests that do not work can be just as valuable as those that do because they give you the limitations of your technology. It was particularly important in Beagle that we had a few tests that failed, because we were always capped in terms of mass, and if we found ourselves having to revise one part of the system without a mass margin somewhere else, we have to know where we could take mass away from, because we would be staying within the bounds of our tests.

Q41 Dr Turner: How much did it affect the consortium when Martin Baker withdrew?
Professor Pillinger: It certainly affected the consortium in the sense that Astrium had to take on an area in which they were lacking in experience, but nevertheless they were so committed to this project that they were prepared to learn this technology and learn it fast. It is a tribute to Astrium that they did take this on. They were so dedicated to us.

Mr Rickett: I was actively involved with that decision, and I would say that it did not have a material impact on the programme; in fact if anything it was a positive impact at the end of the day. The so-called withdrawal was not a withdrawal at all; it was just that the two brothers, John and Jim, who run Martin Baker, made it very clear to me in a number of personal meetings that they saw space as a peripheral business. Their business is ejection seats, and they were not in the business to invest in this programme. They did not see a future in it. But, on the other hand, they did not wish ill of it and they were very clear that they would allow us to use their people and their expertise beyond their fundamental withdrawal in terms of their personal support. We actually used the Martin Baker expertise. We put a manager in and used exactly the same building; and we also used the expertise of their suppliers because a lot of the IPR and entry and descent landing system was really in their suppliers, as opposed to Martin Baker himself.

Q42 Dr Turner: This is a fixed price contract. Did that not expose you to a lot of risks? What were the economic costs of the work that you did?
Mr Rickett: I do not think I can comment on the specific amounts we are talking about, but certainly we did take on risk. As with all programmes where you take on fixed price, you look at the risks and list and monitor them and put in place mitigating actions to reduce the impacts of those risks, should they materialise.
Dr Healy: It is true to say in this contract though that when we took on the firm fixed price contract there were constraints on how we would manage that risk, in terms of the mass and volume constraints that we were given. That did mean that we probably took on more risks commercially than in the cold light of day we might have done. In the end, we finished up over budget—it cost us more to do than we envisaged at that time. From a purely commercial point of view, this probably was not a great contract for us.

Q43 Chairman: How much?
Dr Healy: We overspent by about £1.5 million, compared to the fixed price contract we had; so that was no profit; that was just pure overspend.

Q44 Paul Farrelly: I just wanted to go back to the entry descent and lander systems because we have heard the concerns that are being expressed through the NASA review. We have just heard that you have got involved with a company that then made it clear that "it is not actually part of our business". NASA and other agencies must have people they deal with all the time. I am somewhat confused as to why you got yourself into this situation.
Dr Healy: The simple fact is that we were using sub-contractors on NASA programmes, so we novated the contracts, the ones that Martin Baker had; and we took those over. So they are with two suppliers in the US that supply into NASA programmes. In fact we were using the NASA expertise that had been developed for landing on Mars to reduce that risk.
Professor Pillinger: Perhaps I can clarify something here. Martin Baker were the holders of the contract from ESA to build the entry systems for the Huyens probe, which is on its way to Saturn. We will not know whether that works until just after Christmas. We brought Martin Baker in after they volunteered to join the Beagle project because they thought that they were going to expand into the space business. It transpires that half-way through the project they had a change of heart. As Mike Rickett mentioned, there were two twins that ran this company, but they had very different views on space, and one wants to and the other one does not.

Q45 Paul Farrelly: So you did take on a company for which space was a curiosity value.
Professor Pillinger: No, we took on a company that was tying to break into this business. They did a very high-profile job with the European Space Agency, giving them credibility; so they were absolutely right for us, and they had all the sub-contractors in the US that we wanted to use.
Dr Healy: When we took on the Martin Baker contract and we looked back at our systems design with the information that we then had directly from the suppliers, there were fundamental flaws in that design which we had to resolve. That was part of the risk that we did not really completely expect when we took the firm fixed price contract on, which led to the re-design of the parachute that Colin mentioned.

Q46 Bob Spink: It is our job, as a committee, as you understand, to ask tough and provocative questions, but I, certainly, and many of the members of this Committee, recognise your enthusiasm, creativity and resourcefulness in pursuing this very exciting project. You would have to have no heart and no curiosity not to want such projects to go ahead and succeed. That is what we are really about. I tell you that so I can get your goodwill right at the start, because I need it because I have got two or three minutes and I want to tackle some of the engineering and science issues. If we can get short, snappy answers, I have a whole list of things I want to try and get through. What further tests should have been performed on the lander before it was deployed? What additional tests should have been made?
Dr Healy: There were no additional tests that we thought necessary. I think if you ask any engineer whether they would like to do more testing, the answer is always "yes".

Q47 Bob Spink: What were the main constraints—money, time, facilities or engineering and science expertise?
Professor Pillinger: I think that the main constraint was that we did not have the priority that we would have liked in this mission.

Q48 Bob Spink: Was it a mistake not to programme at the start of the project the full costs and time required for all the various testing that needed to be done?

Dr Sims: When we started the project, I should say we did it on a formal work breakdown structure, I am trying to get round the perception of it being amateurish; it was always done on a full work breakdown structure. It is fair to say that we all had great difficulty estimating the initial costs. As time went on, we hit development problems and it was only natural that those costs would rise. In hindsight, we were under-estimating the amount of testing and the amount of development we needed to do. At the time we started the project back in 1997, we thought a lot of this technology would be off the shelf from American missions, and in reality it was not. It all had to be designed for Beagle 2 specifically, and the constraints then, which were mass and volume.

Q49 Bob Spink: Did you use CPA techniques, modelling, at the beginning—critical path analysis and—
Dr Sims: Oh, yes. There was always a formal schedule, which was revised throughout the programme.

Q50 Bob Spink: Was the lack of high altitude balloon test a serious mistake?
Professor Pillinger: No. NASA did not do high altitude balloon tests with MER-A or with Pathfinder as far as I know.

Q51 Bob Spink: Do you think that the EDL systems were robust enough?
Dr Healy: We would have loved to have done end-to-end testing, but it is a bit difficult to simulate the Martian environment, so you are always going to make compromises. But at the end of the day the Commission spent three months going through in detail, and as far as I am aware they could not find any design flaw that we had. So even though a number of decisions were made under quite a lot of time pressure, when we have looked back at that, we still think the decisions were the right ones.
Professor Pillinger: No-one could find something that could not or should not have worked.

Q52 Bob Spink: What additional facilities would you have liked there to have been on Beagle 2?
Dr Healy: The trouble is, you need mass, then you need volume, and you need things for communication telemetry whilst going through the lander sequence. That would have been very helpful to have, but we would have needed 5 kilogrammes more mass and a completely differently planned mission, because you need to communicate to something that was not there.

Q53 Bob Spink: What is your hunch on what went wrong? What do you think happened in a nutshell? It is guesswork, but—
Professor Pillinger: I prefer to believe that the atmosphere was thinner than we anticipated and it was outside the models that we used.

Q54 Bob Spink: So it went faster and hit the ground harder.
Professor Pillinger: It went faster than it should have done. That is the only thing for which we have any evidence.

Q55 Bob Spink: Would a communication system, back to Mars Express—
Professor Pillinger: It would have told us whether that was true.

Q56 Bob Spink: Do you think that the single biggest mistake was not to have that communication system in, with the mass on one side?
Professor Pillinger: No, because what was the point of spending 5 kilogrammes for something that could not communicate?
Dr Sims: The problem was there was no asset to receive that signal either.
Professor Pillinger: That would have been 5 kilogrammes totally wasted.
Dr Healy: You would have had to have changed the complete Mars Express mission in order to communicate with Mars Express, because Mars Express was the wrong side of the planet when Beagle was landing.
Professor Pillinger: Mars Express could not turn to look at us anyway.

Q57 Bob Spink: What part did ESA play in the lack of a communication system?
Professor Pillinger: The decision regarding the Mars Express entry was taken in 1998 so it was well known long before we ever got to Mars that Mars Express could not listen to us for ten days.
Bob Spink: Thank you. I am finished now, Chairman. Good luck with the next project.

Q58 Chairman: Was the 60-kilogramme limit a real problem to make it successful?
Dr Healy: Yes.

Q59 Chairman: That was a terrible decision. You were handicapped by that.
Professor Pillinger: It was not just the 60-kilogramme—

Q60 Chairman: Was it a major factor?
Professor Pillinger: When we actually asked for that to be upped to 68, after the Casani review, we did not get a decision on that request, and so we were for ever after that point—this was where it was worse—believing that if we put another ounce on this spacecraft, we would get bounced off; and so we did not feel as though we could ask for anything else.

Q61 Chairman: But it was a handicap.
Professor Pillinger: It is always a handicap. Mass is the only thing you have got to—

Q62 Chairman: You will know there has been a restricted report by a committee of inquiry. I do not know what you know about it or what you think about it. Can you tell me? We have been given the privilege of seeing it but under stringent conditions.

Professor Pillinger: We have been briefed on the recommendations and background to how the recommendations were arrived at. On this side of the House we participated and co-operated with the review 100%. We allowed total insight into the project.

Q63 Chairman: So why is it not being published, in your view, and should it be published?
Professor Pillinger: You should ask the people who—

Q64 Chairman: I am asking you, Colin.
Professor Pillinger: I do not know why it is not being published. My view would have been to be totally open. I come from an organisation that has a name that is synonymous with openness.

Q65 Chairman: We know the people to ask, is what you are saying—"do it". You would be happy to see it.
Professor Pillinger: I am quite happy to see anything. If it criticises me, I am quite happy to answer it. What the team really wanted—never mind about whether it is published or not—was to sit down with this committee and discuss how they reached their recommendations.

Q66 Chairman: That is why I asked you if you were happy with the committee of inquiry report.
Professor Pillinger: No, the team on this side would really like to sit down and discuss how those conclusions were reached, so that we could say, "we did not do that; we agree we did not do that, but we did this."

Q67 Chairman: Why do you think they are hiding it up, then?
Professor Pillinger: You have to ask the people who—

Q68 Chairman: Okay.
Dr Healy: There are two things to say on the report. Even though we engaged 100%, that was in total six days of the commission talking to the team at various different points over a three-month period, so there is not a great deal of interaction there—six days over three months. We did not get the opportunity to understand what is in the report, other than the recommendations that have come out in it. If they have done some other work, if they have come up with some good reasons, we just do not know what they are and—

Q69 Chairman: Let me put it to you that if it caused embarrassment to the ESA if it had been published—would you surmise on that?
Professor Pillinger: If it caused embarrassment to somebody and I felt it was unjustified, I would defend them in the same way as I would defend anybody in this team, because I think most people working on this project did their very best to get this spacecraft to Mars.

Q70 Mr McWalter: When you say that potentially it looks like the thinness of the Martian atmosphere that was obviously, as it were, against you, is your conclusion that the lander was destroyed on impact, or did it bounce; and would you like to give us a probability on both those two options?
Professor Pillinger: I am not going to give you any probabilities. We searched for the wreckage of Beagle. If we could have found it on the surface of Mars, we would have known how far it got, irrespective of if we got a picture and irrespective if we got a signal. Malin Space Science Systems of NASA were extremely helpful in looking. I was disappointed that ESA did not also help us look for Beagle on the surface of Mars.

Q71 Mr McWalter: Does that suggest you thought it was destroyed on impact?
Professor Pillinger: If we could have seen the wreckage on the surface of Mars it would have been helpful to us because we would have known how far we got.

Q72 Mr McWalter: Obviously, you are looking to promote another mission in 2007. Can you tell us who has expressed an interest and what the response has been from the Government?
Professor Pillinger: Interestingly enough, Lord Sainsbury, two days after Beagle did not call in, said that we must resist the temptation to only do low-risk projects. This side of the House here—I think we always wanted to fly Beagle again, but we were very spurred by the inquiry, to the point where we all got around the table quite recently, and—I am afraid you are not going to like this, but we all decided to spend our own resources on researching how we think we might fly Beagle again. That is probably another gentleman's agreement that you do not want to know about.

Q73 Mr McWalter: Have you been so far promised any funding for another mission?
Professor Pillinger: PPARC were very generous in that they allowed us to use the residual money from the operations to keep the teams alive so that if a chance arose to fly the Beagle science package again, we would be ready.
Dr Healy: It is worth saying, though, that it would be a complete waste of all the money, time and energy that has been put into Beagle if that were the end of it, if we do not go into Aurora or something like that. That would be the biggest waste of money possible. We have actually established a scientific and industrial lead within this activity in space, and that is not something that you can often say.

Q74 Chairman: Thank you very much. Despite all the questioning, we are very proud that we were part of that enterprise because many good people in this country have been inspired by it, and young people inspired by science is what it is all about.

Professor Pillinger: Chairman, you can either shed tears because it has gone or you can smile about it, and I am glad you are taking the latter route.

Chairman: We know that all experiments and all ventures do not work in the scientific world, but we go on, so thank you very much indeed for coming today and helping us in this inquiry.

Witness: **Professor David Southwood,** Director, Science Programmes, European Space Agency, examined.

Q75 Chairman: Thank you, Professor Southwood for coming along. I believe you were present in the first session and heard the nature of our questioning and the issues that arose. Can I start off by saying thank you very much for coming today. You heard my final remarks; we are all pro science, and we want to make sure that science advances, and in this area particularly. My first question would be why the Mars Express only started the project in 1997, leaving only six years to the launch date, because there was an opportunity, was there not, in 2003 to get something going to Mars? Why did it take so long to move it along?

Professor Southwood: I think Europe sometimes finds it hard to get its act together. In fact, Western European nations had started trying to go to Mars with the Russians in the closing phase of the Soviet Union, with the two missions to Phobos, both of which failed—partial failures in one case. Then subsequently the Russians, I think wanting to open up to the West at that particular time in the late eighties, introduced a mission originally called Mars 92, which, due to the chaos in the Soviet Union, did not get launched until 1996, and so it changed its name to Mars 96 and was a complete loss. The spacecraft upper stage engine failed and the spacecraft failed to leave earth orbit. Much of the instrumentation on that spacecraft was from Western Europe, and indeed the existence of that programme had, I am sure, de-prioritised the need for ESA to have a Martian programme. Scientists are not terrifically sensitive about flag, and Russia had a long history of Martian exploration, or attempts at Martian exploration. So in 1996 there was a failure. It was a fairly catastrophic failure for the Russian space programme in fact. It was very clear that Russia was not going to suddenly re-institute a new programme overnight. So the nations that had up to that time been most interested in Martian exploration, which did not include the United Kingdom but Germany, France and Italy, were then interested in whether something could be saved from the wreckage, and could come Phoenix-like out of the ashes, and Mars Express was that answer. At the same time, we like to kill multiple birds with one stone, and we were under enormous pressure for the faster, cheaper, better approach to be shown to be possible in the European context. Mars Express was taken on as a new way of working. In Mars Express itself we did it faster than we had ever done things before, and moreover had industry and scientists working together in ways that we would never have trusted them to in the past. We empowered the scientists and industry to talk together, because it is a dangerous thing to do, because the scientists put up the demands on the industrial side and the price rises as well, and we have to pay the industries; so we were very nervous about this. In fact, we designed a system that worked, and Mars Express was delivered successfully. The idea of putting a lander on—there was no lander on Mars 1996; it was an orbiter whose primary purpose was to fly a high-resolution stereo camera, which we have now flown, and I hope those results you have seen. That was, so to speak, properly where we began.

Q76 Chairman: Professor Pillinger described the lander as an add-on; they did not have the same status as some of the other instruments.

Professor Southwood: It was late. It was only when we had scoped the mission that it was clear that there could be a lander because there was the capability to launch some extra kilogrammes. You start a mission by identifying roughly the resources and technical requirements, and then you refine them in a series of totally well-defined phases. They are called sometimes pre-phase A, phase A, phase B. They all have totally well-defined activities associated with them, and you home in on the resources on the management structure and so on. During the early phases, it was clear that we had mass margin and it could be used if somebody would give us a lander—and also if somebody would build us a lander, because the issue is not simply mass and not simply money, it is also management. We were trying to do a mission to a very tight budget—cheaper, faster, better—and you do not suddenly take on new management responsibilities without consideration—clearly, we do not stay in budget if we do that, or we do not come near staying in budget. Furthermore, there is a principle—I do not know that it has a name but I think it is a little like subsidiarity—that we like the sharp end of our missions to be run from inside our Member States, with the scientists themselves taking over as much responsibility as possible.

Q77 Chairman: The question is about the lander and the status of the project.

Professor Southwood: We received an offer of a lander from the United Kingdom, and we realised it was going to be done in an even more creative way. That is very clear in the documents.

Q78 Chairman: We are going to have to have sharper answers if we are to get through all the questions. Was the lander treated in a different perspective and more seriously than in the other instances?

Professor Southwood: Yes, because it started off being seen as an isolated element under British management. In fact, the management was, as you

heard yourself, very unusual. By two years or so into the project, it was clear that was not working. We then had to impose a much more traditional approach to delivery. I am afraid that is just the way it was.

Q79 Chairman: Did you think the lander would fail or crash?
Professor Southwood: You have got to ask me at what point did I realise it was very unlikely to succeed. Continually during the programme, your view of how the programme is evolving changes. That is engineering for you. Say you miss more and more tests and more and more time for tests, so you adjust your risk—my private risk assessment. By the time it was launched, I thought the likelihood of failure was very high. I could not have told you a numerical value. I am not a betting man, so I would not have given you odds, but I would have said by the end of the programme I was fairly clear.

Q80 Chairman: So why did you not pull it at some stage?
Professor Southwood: It is not my responsibility to pull it. I made it clear what my position was. I made it clear I required it to be safe and not to harm the rest of the spacecraft, but there is a managerial division you make. I had to cede responsibilities to the British, who were managing it. As long as they were willing to deliver it, and they delivered it eventually, we bent over backwards to get it up into space. We took it months late. I had a special aeroplane to make sure it got to Kazakhstan. We did everything we could to make sure our side of the bargain was kept but, you see, you cannot have two captains on the ship. That is a management principle on which I am very firm. There was a division of responsibility. If it had been my responsibility from the start, of course I would have dealt with it differently and if necessary been able to cancel it, but it was not my final decision to cancel. Of course I made clear, and I think everybody knew, I thought it was extremely high risk but, I ask you, what would you have done with it in the spring of 2003? Did you know it was not going to work? I did not know it was not going to work. I just thought it had a high risk of not working. There was nothing else to do with it. The next time we could have flown Mars Express would have been in 2009 because 2003 was a very special year.

Q81 Chairman: Really for the major project, it was expendable. If it did not work, what the heck; it was the British anyway that were involved?
Professor Southwood: I think you have to ask the British what they thought. My responsibility was to make sure that it was delivered.

Chairman: You have made it very clear from your point of view what your responsibilities were.

Q82 Paul Farrelly: I appreciate from this that you might not want to take a hitchhiker on board again in the future.

Professor Southwood: No, I think we were happy to do it. I certainly think it was a wonderful mission and I actually still think it was money well spent. I strongly resonate with what one of the earlier witnesses said about the fact that the investment was in the skills that had been developed.

Q83 Paul Farrelly: That was the preamble and not a question. We heard from Professor Pillinger that it would have been, in his word, "nice" if they could have looked for the wreckage of the lander if indeed there was wreckage but the Express, the Orbiter, was the other way round the planet and looking in the wrong direction. I do not know how accurate that picture is but was there any sense or attempt in trying actually to co-ordinate the two vehicles as you went along with the project or were you just being a piggy-back operation?
Professor Southwood: No, you work in the appropriate engineering environment. I think you have got the wrong picture. Of course, what you are talking about is: where was Mars Express when Beagle landed? In fact it went around behind the planet because it was in the process of being inserted into orbit. There was no point in looking for it at that stage. We had no instruments working. We were going through the most critical phase of our part of the mission, which was to make sure we got into Mars' orbit. That was quite as important as making sure that Beagle had earlier got on to an orbit that landed it. We had to make sure that Mars Express got on to an orbit that did not land it but put it into orbit around Mars. Of course later we looked, when we had the cameras working et cetera, but we then had to go through a massive number of manoeuvres to move from the equatorial orbit we used to deliver Beagle to put us into the polar orbit we used to survey Mars. I can tell you that was an enormous amount of effort, very nail-biting, and it took us several weeks. If that was not showing we bent over backwards for Beagle, I do not know what was.

Q84 Chairman: Was that a high risk manoeuvre, too?
Professor Southwood: Yes, of course.

Q85 Chairman: You put yourself in that position, with a high-risk strategy of re-manoeuvring yourself?
Professor Southwood: Absolutely clear, yes.

Q86 Chairman: That was even though Beagle caused that to happen? Is that what you are saying?
Professor Southwood: I think you are making an antagonism that I do not have towards Beagle. I wanted to do my best for Beagle. Equally well, I wanted to observe the managerial niceties and indeed it is a matter of discipline. It is just a distinction. I cannot throw my weight around on issues I have not paid for.

Q87 Mr McWalter: I am happy to probe that antagonism a little, if I may. If the Government said, "We are now going to put £35 million into a mission

in 2007 under Professor Pullinger's leadership", would you jump for joy or would you be absolutely dismayed?
Professor Southwood: I would jump for joy that the Government wanted to do that science. Personally, I think it is terrific science. I think it is also galvanising for the public. If you tried to do it with the same managerial structure that was introduced in 1998, I would give the strongest advice against doing it, but that is not to say anything against Colin Pillinger. I am not criticising Colin Pillinger as a scientist. The managerial structure of Beagle was highly original and I think deeply flawed, but you do not find out that it is deeply flawed until afterwards. If you had never tried it, you would still be being pressed—not you collectively but I would still be being pressed—to try such things.

Q88 Mr Key: Professor, it has been suggested that some other European countries, notably France, were not impressed that the project was called the British-led Beagle lander project. Do you think it is true that deep down some Member States were viscerally opposed to this?
Professor Southwood: There were issues. I do not think "viscerally" is quite correct. There are too many scientists in France who were enthusiastic about the science and scientists do not get viscerally upset on nationalistic grounds. Certainly there were problems because of course you probably know that France at the same time was trying to undertake a multiple lander programme called Mars NetLander. I think the French Space Agency were concerned that there was not sufficient IPR transfer to France to allow them to ride on the developments being done by the Beagle team in Britain. I think you can regard that as perhaps having commercial interests. I do not think the word "visceral" really applies there either. I think perhaps "commercial" might be a better word.

Q89 Mr Key: Was it all a question of money really, given that there was no guaranteed state funding for Beagle?
Professor Southwood: For me money is pretty basic. We have introduced new requirements, with a lot of help from the British, let me say, to make sure money is available and clear up-front and it is also clear who is responsible up-front. I think when you have got money in your hand, the manager can manage much better. I am a manager and I would like the people I work with to be managers. Money is fundamental but managerial structure is also fundamental. You have to know who has the final say on things, who takes decisions, and there has to be a hierarchical arrangement so that you know ultimately who carries the can. The way this started with a gentlemen's agreement, it can work as long as the gentlemen remain gentlemen. I think one of the problems was that when the money is coming from diverse sources, when you get into trouble it becomes difficult; when it is fair sailing, nobody worries.

Q90 Mr Key: Professor, why was the Casani Review not implemented?
Professor Southwood: It was largely implemented. I think you have to be cautious about saying "it was not implemented". Parts of it were difficult to implement.

Q91 Mr Key: Why?
Professor Southwood: In particular, we tried a very simple solution which was to put in a new management structure, which eventually we put in. That was that the United Kingdom Government gave Astrium UK a managerial role with a contract and made it clear they were in charge. That took much longer than was needed in the circumstances. Also I think there was the issue of IPR. The entry-descent landing system was at the core of the success or failure of the mission. That is self-evident. For me, it would have been very good for ESA to take over that clearly as a well-defined element that could then be managerially separated from the rest of the lander. If you separate bits and pieces, you do not separate the management. Then there is no line of command. For me, the problem we then had of course was that there were many sub-contracts and also certain companies had spent their own money. If I were running a company and I had spent money, I would not want to give it away, or I would be reluctant. We were working against the clock. This was in the autumn of 2000. I think that the best compromise was met, given the fact that the clock was ticking and given the fact that we had managerial complications.

Q92 Paul Farrelly: We have gone back round in circles here about the management, in your words, being deeply flawed. Are you saying that Colin Pillinger, who was the inspiration and the driving force behind the project, is a good scientist but is not necessarily a good manager?
Professor Southwood: I always think in terms of things like sport. Colin Pillinger may be the David Beckham but it is the manager—

Q93 Paul Farrelly: He is not the Alex Ferguson?
Professor Southwood: It was not Alex Ferguson I was thinking of but our Swedish manager but there you go! Yes, Alex Ferguson will do. There are two different roles here: there is the inspiration; there is the creativity, the imagination. Colin Pillinger has it in spades. He has the public appeal. He can persuade people, and he is right to do so. That does not make him necessarily a good manager. There is a different skill involved in management. I do not know whether David Beckham would be a good manager. I have no idea.

Q94 Dr Iddon: Can I ask you, Professor Southwood, whether you knew what the management structure of Beagle 2 was from the outset and, if it changed, when it changed? How closely were you monitoring it?
Professor Southwood: I came in in 2001. You will understand that I actually knew I was going to take the job in late 2000. Because I wanted it a clean issue and I did not want my nationality to become controversial, because of issues associated with

other countries, I actually remained very out of it until I became the manager, until I became Director, and that was on 1 May. I came in and within 15 days I had decided that this thing—it was very frustrating because I wanted it to be successful—was not going to work; I thought it would be a failure then. I then dug my heels in and Astrium realised that I was not just going to shell out money or anything like that without a price; that is, without what I felt was a clean managerial arrangement to convince me that it made engineering sense. We spent a very difficult summer and I would not have minded betting in June or July of that year that Beagle would be abandoned. The problem was that we had already spent a lot of money—"we", the team had spent a lot of money, and that becomes very difficult.

Q95 Dr Iddon: Who are you directing your criticisms at? I have written some down here: it was a highly original management structure; it was deeply flawed; you cannot have two captains on the ship. You have been very critical of the management but were you directing your management criticism at anyone on the Beagle 2 project and, if so, who?
Professor Southwood: Actually, my primary target is not the Beagle 2 team; it is the fact that they were in a system where they were trying something completely new, which was not working. Then you have to do something about it. If I sound critical, it is just because I do not want it to happen again.

Q96 Mr McWalter: Did you try and get those changes? You say it was fantastic science and really interesting and, lo and behold, 15 days after you have got your new job, you are basically pulling the rug really. You had a very negative attitude to the thing. I was involved in some of that. Given that that was going on, why did you not insist that there would be changes, say in the landing system, which would then have made you happy?
Professor Southwood: Because I did not have the authority. I was not in charge.

Q97 Mr McWalter: You would have dumped payload on your mission?
Professor Southwood: Yes, and I would do the same with other countries. I have done the same with other instruments in other countries.

Q98 Chairman: Who were you firing the bullets at? Is it OST, the DTI or who?
Professor Southwood: In the UK?

Q99 Chairman: Yes?
Professor Southwood: I think I am not really firing the bullets. I am just saying the system failed.

Q100 Chairman: You could have fooled me. You have criticised on a broad front. We are trying to nail you.
Professor Southwood: I think, if you want me to say, and I think this will happen in the future, and it has been put together by BNSC, they will never start anything and they will not put anything to ESA without having a clearly defined agreement at the starting point as to where the money is coming from, who is responsible and a managerial structure in place. That is what we are doing already with new programmes; for instance, the mid-infrared instrument for the James Webb telescope.

Q101 Mr McWalter: Nothing risky would ever happen?
Professor Southwood: Come on, everything is risky in space. It is a highly risky business. That is why you do everything you can to mitigate risk. One clear way to mitigate risk that we all are in charge of is to get the money in place and get the management in place. The risks come because you cannot go up there and fix it because you are doing things 100 million kilometres from home. That is where the risks lie.

Q102 Bob Spink: Could I just re-direct very briefly? You said that you took a view early on that the project would fail. Did that view influence you in not allowing sufficient mass?
Professor Southwood: Not at all. It seemed to me on the mass that we went from 60 kilograms at the beginning to I think finally 72 kilograms, so we went up by 20% anyhow. How is that done? If you had declared that 12 kilograms that eventually were going to appear at the beginning, they would have gone immediately. I am afraid you manage things by keeping margin and you give out the margin as you see that the pressure you are exerting is failing to deliver. Management is done by creative tension.

Q103 Bob Spink: Professor, you have heard the previous witnesses say that they asked if they could increase mass from 60 to 68 kilograms and they did not get a response from you, from the ESA. Can you explain why that was the case, if it was indeed the case?
Professor Southwood: I do not know what the date was. Do you have the date? Early on you fix the boundary. They know you have got margin, but equally well we did not know the margin we had until we were sure of the performance of the launcher and we were sure of the delivery mass on all the other instruments. Remember, we were launching much more than 60 kilograms. This was a small element. Our ability to be generous also is a function of time.

Q104 Bob Spink: Do you accept that this lack of mass increased the risk?
Professor Southwood: Of course.

Q105 Bob Spink: Were there any instruments at all in Mars Express that could have been left out to create more mass for the lander that could have been a trade-off, looking back and in fairness?
Professor Southwood: Look at the results we have got already. Would you not have wanted to see those three-dimensional pictures which are high resolution and utterly unique; the discovery of methane—unique; the discovery of the ice and separation of the water ice from dry ice—unique? Come on, I think we have done pretty well.

Q106 Bob Spink: I am just asking the question.
Professor Southwood: The short answer is "no".

Q107 Bob Spink: I think you have already answered this. Do you think that we should go ahead and follow through with more projects?
Professor Southwood: I would love you to do that. I would simply say: take the advice of the inquiry board and look at those recommendations before you let the money go. Make sure that those are obeyed.

Q108 Dr Turner: Professor Southwood, you keep telling us that at quite an early stage you got a very strong view that Beagle was likely to fail. Could you tell us why you thought it had a very high risk of failing and, secondly, did you have a strategy in your mind that could have been applied to reduce its risk?
Professor Southwood: Yes to both. The short answer is certainly that I had a strategy, which was to sharpen up the management. I came in and found it, frankly, a mess. There was no structure of sub-contracts; there was no clear hierarchy. I like the management hierarchy to match the way the money flows. I could not find it. I am afraid, although I am an academic, I am a manager also, and I have always enjoyed managing, and it was not sound.

Q109 Dr Turner: The failure was obviously a technical one. Could you relate the perceived flaws in cash flows and the structure that you detected to actual technical difficulties which would have led to its failure?
Professor Southwood: Yes. This becomes a little bit of a personal perspective, but clearly if we had had in place a clear managerial arrangement for the procurement of the entry to the descent landing system, I think we could have shortened the schedule of delivery on that substantially; we could have done far more testing; and we would have found some of the shortcomings that emerged much earlier in the game. Equally well, we could even have modified the Mars Express programme to meet Beagle's requirements much more easily. One of our problems was that Beagle was so behind. We had frozen Mars Express because you have to bolt it together; you have to close things down; you have to take decisions. Some of the lack of flexibility we had was simply that Beagle was so late. If we had had a clearer situation in 2000, and certainly in 2001—and I came in in September—when we finally put together the agreement that I think worked remarkably well, all things considered, I was told there were six days margin in the schedule. The agreement was not signed for another month or so, at which time I said, "Do we cancel it?" Of course the answer was "no".

Q110 Paul Farrelly: That was September 2001?
Professor Southwood: Yes.

Q111 Paul Farrelly: I was just looking at the time lag for government contributions to Beagle 2 going from your May date when you said you came in very quickly. You said this was likely to fail in your own mind. In July 2001, the British Government provided £8.3 million, which was the biggest single chunk of funding.
Professor Southwood: But then we had to tie that to the management structure, which was the heads of agreement. We did not want that money given away without getting a price of it, which was management structure.

Q112 Paul Farrelly: I wanted to ask you a question. On that time lag, after you came in and made your assessment, the Government provided £12 million, half the amount of funding. Do you think to have done that, the Government was actually appraised properly of the risks of failure, and do you think that that money, in your view and given your assessment at the time, could possibly have been used better within the European Space Agency for other space projects?
Professor Southwood: It was such a golden opportunity. It is very easy to be wise after the event. I do not think I ever hid from anyone that this was a high-risk strategy but, on the other hand, once in a while you have to take a high risk. I firmly was going to get a price for that money, which was much clearer management. I think Astrium stepped in and started sorting the problems out, but they had their own problems. The company was in trouble.

Q113 Paul Farrelly: Do you think the Beagle team was giving an accurate assessment to the British Government funders of the risks involved and the problems it was facing, particularly with the landing difficulties?
Professor Southwood: It depends who you mean by the British Government. I think that there was an enormous pressure not to let the British people know how high risk it was and that was for a very simple reason and it was very straightforward. They were still looking for commercial sponsorship. There still was the hope of getting sponsorship and getting money back. I know I was put under pressure, and I find it quite reasonable in the circumstances, not to say publicly, not to broadcast the fact, that I thought it was very high risk. I will tell you that privately I do not think anyone could have doubted my position. On the other hand, do not get me wrong. Once I had made the commitment in the autumn of 2001 that we were going to launch, the instructions I gave to my project manager who is sitting right behind me were: we do everything we can to deliver. But probably he did not tell the Beagle 2 team everything because project managers need to have margin to negotiate. That is just good management.

Q114 Dr Iddon: Could I ask a final question on that? I am an observer on this scene. What I am listening to is a representative of the European Space Agency, critical of a part of a mission which obviously you are responsible for, the Orbiter, and yet I am hearing a gap in management style here. Is there not something wrong with the European Space Agency if it cannot be completely open and critical of a

mission which is being attached from another European country, if you follow the drift of what I am trying to say?
Professor Southwood: I know what you mean. It depends and in a way, I think Europe is at that particular stage where there is a gradual ceding of power from national capabilities to European capabilities. Personally, I am very happy to keep the strengths in the national side as best I can.

Q115 Mr McWalter: So ESA has major managerial weaknesses itself?
Professor Southwood: No, that is not what I am saying.

Q116 Dr Iddon: What are you saying? We need to get to the bottom of this.
Professor Southwood: What I am saying is that there are perfectly good reasons for doing things the way we do; that is, leaving certain capabilities if they exist best on the national level with national entities.
Dr Iddon: Even though they may fail?

Q117 Paul Farrelly: As long as it does not blow up your craft?
Professor Southwood: You are British. If you want me to take responsibility, by all means I will. Equally well, we were working in a system where the British had taken responsibility. Good for them. I was happy to call Beagle 2 British. You would have to call Beagle 2 European if it were done by me. You cannot have both.

Q118 Bob Spink: Do you think that ESA could have given more managerial and technical support to the Beagle 2 project?
Professor Southwood: That is a question I ask myself. I cannot see what it could have been. I put somebody permanently in Astrium, and he worked up a very good relationship with the team. I have given clear instructions to my project manager, sitting behind me here. On the other hand, you have to give people responsibility, and there was a responsibility vested in Astrium UK.

Q119 Bob Spink: Are you pleased in a way, since it failed, that Astrium is a British failure and not a European Space Agency failure?
Professor Southwood: Come on, I am British. I was very, very upset. I really wanted it to work. I can tell that you my life would have been more difficult had it worked.

Q120 Bob Spink: But had it worked—
Professor Southwood: I think what you are trying to get at, and I am not afraid to say it: had it worked, then I am sure I would have been sitting here trying to defend why all missions were not done this way, and that would have made my life even more interesting than it is now. Of course, I wanted it work.

Q121 Chairman: As a last question: why do you not publish it?
Professor Southwood: It is not for me to publish it. It is an independent inquiry report. There are two parties to that: the British Government and the European Space Agency.

Q122 Chairman: Are you keen on it being published?
Professor Southwood: I do not mind. Let me just state that I am not speaking *ex cathedra*. As a private position I do not mind. From a public position, I have to say ESA and the United Kingdom, and this is now speaking *ex cathedra*, made an agreement not to publish for reasons that I think are explained to you. One was because it involves inter-governmental agreements and the second was that there are issues concerning, say, the commercial relationships between several companies.

Q123 Chairman: Those little sentences could be blanked out and the majority of that report could be published? A lot of what you have said is in there.
Professor Southwood: I deliberately did not bring the report with me so you would get what I thought and what my colleagues thought. I also deliberately tried to avoid the sensitive areas.

Q124 Chairman: You have done that and we have done it too.
Professor Southwood: I think that is a very good idea.

Q125 Chairman: Is it not time to open it up now and put it out there? People are asking for it.
Professor Southwood: I think this is a matter of policy. I am not a lawyer and I am only recently a civil servant. I do not feel capable of answering that question.

Q126 Chairman: Has ESA got an official position on this document?
Professor Southwood: The ESA position is that they do not normally publish. They did not publish, for instance, the much more expensive failure, the inquiry board report on the Ariane 157. That was far more serious for Europe than the loss of Beagle 2.

Q127 Chairman: Do you think the British are the inhibitory force here?
Professor Southwood: It was a joint agreement, so I do not think you can blame it on one side. I do not have anyone from the UK Government sitting beside me.

Q128 Chairman: I am not going to get you to say it, am I?
Professor Southwood: No.
Chairman: Thank you very much, Professor Southwood. It has been very interesting.

Monday 12 July 2004

Members present:

Dr Ian Gibson, in the Chair

Paul Farrelly
Dr Brian Iddon
Mr Robert Key
Mr Tony McWalter
Dr Desmond Turner

Witnesses: **Lord Sainsbury of Turville,** a Member of the House of Lords, Parliamentary Under-Secretary of State, Science and Innovation, Department of Trade and Industry, **Professor Ian Halliday,** Chief Executive, Particle Physics and Astronomy Research Council and **Dr David Leadbeater,** Deputy Director General, British National Space Centre, examined.

Q129 Chairman: Thank very much for coming to help us. I apologise for the late start; some of our Members were listening to the good news for British science, which is emanating from the lips of the Chancellor at the minute, and I think we will be hearing more detail of that through Lord Sainsbury and others later in the week. We will hear just what it means, but it sounds like it is really, really good news, so it is congratulations all round to the science community. The Beagle Inquiry, you have probably followed our session last week and the questions we asked, so I will fire ahead, if I may, Lord Sainsbury? What was your initial response to the Beagle 2 Project when you were first confronted with it and it was put in front of you? Were you excited, it must happen, or were you sceptical?
Lord Sainsbury of Turville: It seemed to me then that it was actually a rather exciting project in terms of something which would capture people's imagination. I personally was rather excited about it, and I guess the first question I had was: is this good science? Will this really deliver world-class science, or is it just something which is an exciting thing to do? I think the first important issues it was that it had been chosen by ESA as a result of an Announcement of Opportunity. The science case then went to the PPARC Astronomy Committee, who gave it a top rating as being important scientifically. I have always taken the view that the space budget has really three things to do: one is world- class science, the second commercial things, and the third Earth Observation. This very firmly came into something that I wanted very much to.

Q130 Chairman: So there were no sceptical voices around any of the tables that you attended in those early days?
Lord Sainsbury of Turville: Not at all in terms of the quality of what was being proposed, or its importance.

Q131 Chairman: In terms of what might there have been some scepticism?
Lord Sainsbury of Turville: I think everyone was always aware from the very beginning that this was, certainly from a time point of view, if nothing else, going to be a difficult project.

Q132 Chairman: Risky? Risk attached to it?
Lord Sainsbury of Turville: I do not think we saw it particularly in those terms; it was, "Could you deliver this? Could you deliver Mars Express and Beagle 2 in the time frame?" I think one has to always remember that the reason this project came into being was that there was the failed Russian 1996 mission; in other words, there had been a lot of work done on design and so on, which was sitting there, and there was this moment of alignment between Mars and Earth in 2003, which would be a good time to do it. I think that people felt that this was a real opportunity which we should seize. Clearly, the reason it was called Mars Express was that it was going to be done very quickly.

Q133 Chairman: There were no sceptical voices in terms of the project team and its role in it at all? We heard somebody last week who was quite sceptical about the management and so on?
Lord Sainsbury of Turville: No, I do not think anyone said, "These are not people who can do this." They were people who, as a whole, were rated very highly and I think were felt perfectly able to do it.

Q134 Chairman: The initial thinking on who would be ultimately responsible for funding this, how did you see your input into it, representing the British financial wing?
Lord Sainsbury of Turville: I guess by the time I first got involved it was on the basis that the lander was going to be a UK project because it was deemed to be an instrument, and therefore it would be paid for on a national basis. There was a plan, which was put forward at that stage, that it was going to be funded, by a combination of academic money, industrial money and sponsorship, with Government playing a fairly subsidiary role.

Q135 Chairman: The interaction between PPARC and the DTI, how would you describe it in those early days? The discussions about funding and the project, and so on? Did you leave it to PPARC to make their hard decisions?
Lord Sainsbury of Turville: I think the other point that it is very important to be clear about here is the other reason why it was very difficult. It presented difficult decisions was that because it came so late in terms of its timing in our planning cycle. It was not in the same category as other science projects which

we had known about for a good while, that is to say that we have these proposals and the question is which are the best projects to fit into this budget?

Q136 Chairman: Who was going to pick up the tab for it? Who picked up the tab? How was that discussed and decided?
Lord Sainsbury of Turville: The point I was going to make was that because it came late most of the PPARC funds, which would be the normal place for this to come from, had already been allocated to projects. PPARC found some money to do this, and we then took a decision that it was sufficiently important that we would find other funds from within the DTI and BNSC.

Q137 Mr Key: Do you think the decision to treat Beagle 2 as an instrument rather than an integral part of the mission was a mistake?
Lord Sainsbury of Turville: Yes, I think it was one of the misjudgements that was made in all this. Of course, up to that point, it was the norm to treat science payloads as instruments—that was the way it was done. I think, looking back, we should all have seen that in a sense the world had changed in two ways: one is that the lander is very sophisticated, almost as sophisticated as the spacecraft itself; two, that the lander was involving a lot of companies. It was not just a small group of academics in a university doing this. By this time we were talking about a project which involved a lot of businesses. I think at the very end of the day something like 50 businesses were involved together with a large number of universities. To treat this as an instrument was, in retrospect a mistake, even though that was the way ESA selected payloads at the time.

Q138 Mr Key: Would you like to add to that, Dr Leadbeater?
Dr Leadbeater: I can add some detail. The background in part was the tightness of budgets seen from both sides of the Channel. It was difficult for the European Space Agency because there was a capped budget, associated with the Mars Express Programme, so they had a difficulty. They had scientists that wanted the lander because it offered very, very high priority Science. They had a budget of 150 MEuros—excuse the European numbers—for the whole Programme, and to start with they were unclear whether there could be a lander; so they used an Announcement of Opportunity process which, on the one hand inferred that the UK would pay, but on the other hand did not at the start identify where the money would come from. From the UK view it was seen to be a very high benefit Programme. We could see ways of giving some money and we hoped that ESA's intransigence, if one looks at it in that way, would change over time, as it did. So a difficult Programme, but it was seen to be of high benefit both industrially and scientifically and it was thought possible to close the financial gap, even if it was not easy.

Q139 Mr Key: It is clear, Dr Leadbeater, from your recently published *UK Space Activities 2004* that BNSC thought a lot of this Programme, and you said that, "Although the loss of Beagle 2 is disappointing the instrumentation of technologies developed on this project have placed UK academics and industry in a strong position to take a leading role in ESA's future plans to investigate life in the universe." The problem is, is ESA risk averse when it comes to this sort of project? Was that part of the problem, rather than just the French not liking the Brits getting in on it, which is what we were told last week?
Dr Leadbeater: I think there has to be a balance between accepting a Programme like this that is quite high risk and at the same time putting it into a framework where you can manage it with a good degree of confidence that you will successful, i.e. that over time you will reduce the risk. I think it is fairly reflected in the Commission's Report that, had we started with the lander classified as a spacecraft and not as an instrument, things could have been done over time, which would have helped us to manage the risks in a positive way. I would not infer that in that ESA was risk averse. It was a difficult Programme and there were definitely things that could have been done had it been a planned mission within the ESA Programme from day one. This was an unplanned lander, which people both in the UK and in the European Space Agency tried hard to get into the Programme.

Q140 Mr Key: Did either you or Professor Halliday meet ESA senior management to discuss this at any stage?
Dr Leadbeater: BNSC met with ESA senior management quite often, especially during the periods in 2000 and 2001, where additional resources were brought to the Programme.
Professor Halliday: I have had various meetings at a reasonably high level, with my second in command, Paul Murdin, who was one of the conduits between PPARC management and ESA management. So we had, we believe, a pretty good view of what was going on and the catalogue of risks and so on, which in our business are not unknown.

Q141 Mr Key: Did you feel from the start that it was a struggle to persuade ESA, or did there become a moment when it was clear that things were not going well?
Professor Halliday: There was a feeling of struggle, that is clear. On the other hand, ESA did clearly want this to happen. The question is then resource, mass, all sorts of parameters. So at a level of science delivery, as seen from my perspective and reflecting the views of others, this was seen as an additional thing to Mars Express, that if it worked it would completely change the perception of Mars Express from really solid science to something rather exciting. This led a certain dynamics of maybe there is not enough money, but let us be helpful.
Lord Sainsbury of Turville: I do not know if this is quite the right way of putting it, but I think we were all scientifically a bit greedy, given the resource that

one had, which was only 150 MEuros. I think both ESA and ourselves were excited about the prospect of the lander. After all, they issued the Announcement of Opportunity. The question, I think, was that, given that you had only 150 MEuros, should you have tried to do so much with that? Maybe we were all a bit greedy in thinking that we would try and get some more scientific benefits while not leaving ourselves enough margin.

Q142 Mr McWalter: I do not know about David Southwood, who is the Director of Science Programmes of the European Space Agency, who came into the process a bit late, because he made it very clear to us last week that he was not excited at all; he thought that the project was going pretty much nowhere, and he had very strong doubts about it. Was any pressure put on him or did you end up with a rather reluctant Director of Science Programmes at ESA still being in charge of the delivery mechanism for the lander? What pressure was put on him? What arguments were put to him to get him to change his mind about his view?
Lord Sainsbury of Turville: He came into this quite late in the process. As I remember, at the time there was no lack of enthusiasm, particularly from him as regards it being a good scientific project. I do not think there was a question about that. There were many opportunities when he could have said that this is not going anywhere, this is not the right thing to be doing. He did not say that, but I do not think he showed any particular lack of support or enthusiasm for it.

Q143 Mr McWalter: He was deeply critical of the management of the project and more or less indicated that he thought because it was so poorly managed it would not succeed, but he kept these thoughts to himself at the time, did he?
Lord Sainsbury of Turville: I think if it had been successful we would have all claimed credit for it, and given that it was not successful we should all collectively share in what I think were some of the misjudgements made in that.

Q144 Mr McWalter: He told us more or less that he thought the project should have been pulled, but that it was not his responsibility to pull it. Whose was it, or did you yourselves consider pulling it in 2001?
Lord Sainsbury of Turville: At each of the stages where we put new money in we obviously looked at one of the option, which was whether to stop the process. Of course, the nature of these things is that as you approach a hard decision and if analysis tends to reinforce one's gut feeling, which is that once you get to a certain point if you stop it you can be certain to lose all the money, while if you put the extra bit of money in then at least you have a chance, you should go ahead. If you are at a 50-50 chance almost certainly the correct thing to do is to go ahead with it. So I think Professor Southwood may have been aware of that position, but he certainly did not, so far as I am concerned, at any point say—"This is not going to work, you should stop it." He did have at that stage, of course, a considerable amount of ESA money in it, so he cannot say that it was no responsibility of his.

Q145 Mr McWalter: That is very interesting. In a wider front in terms of funding, do PPARC and the DTI, have the flexibility to respond to these relatively immediate requests for funding where opportunities of national significance arise? Are you of the view that where things like this occur that you do have sufficient scope for making the case to be flexible, to get additional funding factored in?
Lord Sainsbury of Turville: In this particular case we clearly did not. If we had had more spare capacity it would have been enormously helpful, but we did not have that. Again, as I say, these science projects are sensibly and reasonably planned a long time ahead, and in this case it came after most of the funds had been allocated.
Professor Halliday: If you go back to the 1997–98 period, when this was all being discussed, the PPARC budget had been decreasing in real terms for many, many years.

Q146 Mr McWalter: I remember us talking about this.
Professor Halliday: The stress and strain on that budget was really pretty big and this kind of freedom really did not exist. There are a number of things going on at the moment in space in big instruments of one kind of another where, thanks to the generosity of the Government, the UK is taking a leading role and I think that if this opportunity came along now, perhaps today particularly, I am sure we would react to that in a very different way. On the other hand, if you are planning 20, 30, 40, 50 million pounds expenditure, then the expectation is that there is a run-up when people think seriously about technicalities and so on. So if somebody appeared now and said to spend 50 million in the next three or four years, we would still have problems fitting that into the budget. It is hard to get that total flexibility.

Q147 Mr McWalter: So you are saying that if this happened now we might be all right because there is a better structure in place, but when it happened then it did not go quite so well. Do you think that funding uncertainty was a contributory factor in the end to the failure of the mission?
Lord Sainsbury of Turville: I think there were three things which increased the risk and they interacted. One is the point we have already discussed, which was treating Beagle 2 as an instrument; the second was the small mass margin; and the third was the tightness of finances, both in terms of the lander but also of the total project. As I said, it was only 150 MEuros, which for this sort of operation is not a lot. If you compare it with the Rosetta Mission, which hit very similar problems, that was rescued by the fact that they were able to transfer funding from a much more generous budget for the total Rosetta project to DLR, the German Agency, to deal with the problems that arose with its lander. So I think it was the tightness both on the lander budget and on

the overall Mars Express budget, which was indeed very tight. It is those three things that separately and together probably increased the risk.

Q148 Dr Turner: I pointed the figure at the piecemeal nature of the funding and I suggested that that in itself greatly increased the risks involved. So clearly Professor Pillinger felt that had he asked for a greatly increased sum of money in the beginning he would not have got anything. Was he right in that or could he have somehow found the money if he had come up with a realistic total sum at the very beginning, instead of going in for a bit and trying to get things by stealth?

Professor Halliday: Could I make a couple of comments about the risk calculation and what underlies this in terms of finance? It is clear that with more money you can do more work and retire risks at some kind of level. In reading the transcript of what David Southwood said to you a week ago, I was a bit taken aback in the sense he uses language like "very risky; we should have cancelled it". My belief, which you cannot calculate and I cannot calculate, is that these things about the finance, about some of the problems of management, definitely increased the risk of failure, but it went from, let us say, a 40% chance of success to a 30% chance of success; it did not go from a 40% chance of success to a part in 100, which is what the "very risky" kind of language tends to get into your head. So not enough money, not enough time, all just surreptitiously increases the risk of failure, and I do not think anybody in this room behind me would dispute that. It is when you get into a language, which is partly hindsight driven, that since it failed it was absolutely bound to fail, I think that is a wrong impression, which was certainly left by David Southwood's testimony to me. As the Minister said, many times we have looked at funding, continuation in the light of all the knowledge that we then had, and the decision was to continue. That is a language of risk management and so on, which seems to me the right kind of language to use.

Q149 Dr Turner: When you were first approached by Professor Pillinger, did you feel that his figures were realistic? The initial charge for funding was only 10% of the final cost of the project. Did you think that it stacked up at the time?

Professor Halliday: I would have to look back at the papers. The first number that effectively I have in my head, which I would have to look at the papers, some number like £24 million or £25 million for the total project.

Dr Leadbeater: Can I respond to that? The initial number that BNSC and PPARC looked at was £28.5 million and over the period the increase—it is in the National Audit Office Report—went up by about 50%. When you look at that amount there are some issues where there are additions that relate to the need for facilities, for example the Planetary Protection Facility, or in other words, the Sterilisation Facility. There was an assumption in the original proposals from Professor Pillinger that such items would be paid for by ESA, or that they would be paid for through some form of investment infrastructure budget. Over time that proved not to be possible, but when you look at the Programme hard, the cost completion including these items went from £28.5 million to £42.5 million. There was quite a lot of escalation in there but there were also factors which did not relate to the Beagle lander costing more. I would argue that that was again a consequence of treating Beagle as an instrument, because normally the infrastructure associated with an instrument is paid for by ESA. This was a case where, because it was a spacecraft which had a mix of instruments and was a mini-platform in its own right, there was ambiguity about who would pay for what, associated with a lander, and the mission itself, Mars Express had low contingency; so it was not able to deal with some of those platform and infrastructure issues. Things like the Planetary Protection Facility were totally unique; ESA had never had a requirement for such a facility, so it did not exist. So you have to look very carefully at that. Chairman, it may be helpful to refer to the previous question about the evidence from Professor Southwood. I think it is very important that the Committee look at the evidence that the Government provided because it includes the clauses from the Heads of Agreement that was negotiated. That document was not decided upon until the middle of 2001, but it does define the role of ESA, what the relationships had to be between the partners; it defined who was going to pay for the Planetary Protection Facility and other things; and it actually confirms what ESA agreed to sign up to: ESA was a positive contributor to the negotiation of that agreement, in July 2001, and it went on to provide the BNSC with advice about the milestones and other things that had to be defined in the contract, that was let on Astrium in September 2001. So David Southwood is reflecting his concerns that there were difficulties with the airbags, for example, but is perhaps overstating the position of an organisation which, two minutes earlier, had signed up to a major agreement for the final push on the Programme.

Q150 Dr Turner: Hindsight is a wonderful thing of course, and with hindsight it would have been very helpful to the Programme if all those involved had known that the Government was going to underwrite it at the time, but of course they did not. Lord Sainsbury, can you tell us why the Government did not underwrite it? If you were faced with a similar set of circumstances again, would you consider underwriting it so that the Programme had a guarantee to it and the essential work to reduce risk could be done at an earlier stage?

Lord Sainsbury of Turville: Yes, if I had the money to do so. At that point the original ROAME statement, which was approved, in July 1999, for five million, was just about providing something I could lay my hands on within the existing budgets. There was no way at that point I could have found 20 or 25 million to underwrite the whole budget.

Q151 Dr Turner: Would you agree that had you had that capacity then things might have turned out differently, it would have at least notionally enabled the risks to be reduced?
Lord Sainsbury of Turville: Yes, absolutely. Going back to the three points: the treatment of it as a lander, the small mass margin and the tightness of the finances on the Mars Express project, and the lander itself were the three things that ultimately increased the level of risk.

Q152 Dr Turner: Do you think that ESA were placed in a difficult position because they were being asked to accept the project of Mars Express which, at the outset, was not completely funded? Did you get pressure back from ESA to guarantee the funding of the project?
Lord Sainsbury of Turville: I do not think we had a great deal of pressure at that point. I think we saw the pressure being on ourselves to find the money to do this. We thought that the proposal which, again in retrospect, looks rather optimistic, was do-able. I do not think we came under great pressure from ESA at the start to say that the whole lander is totally funded.
Dr Leadbeater: I think the situation at the start, as I have said, was that the Agency was uncertain about how much mass it could allow for a lander—and indeed that changed. It was reduced. The expectation to start with, when the competition, the Announcement of Opportunity, was issued was that Member States would pay. But once the Science Reviews and the competition were decided upon and Beagle came out, head and shoulders above the others, the UK said fairly that it would make efforts to identify how funding could be provided. It did not say to ESA, "We have all the money and here we go," it said we would attempt to do so. I am sure that if you have read the Commission of Inquiry Report, you will see that it identified that there was a period where the United Kingdom and ESA officials were working together to try and identify how that could be done. Professor Pillinger made some innovative suggestions about where money could be brought to the table, through PPARC, through the DTI, through sponsorship, and, indeed, through the provision of support from ESA itself. So that progressed over a period of 18 months. I think it is important to identify that at the first phase, where the DTI provided five million, the project was in a feasibility phase: the project had not started off for real. At the second time of asking the Programme was moving into an ESA-CD development phase, so there was a need for a steep increase in funding. So the Inquiry recommendations are saying that the funding should be available at the start of each phase. It does not necessarily mean that all the money has to be available on day one at the start of the feasibility study.

Q153 Dr Turner: That is fine. How dependent were you on the materialisation of sponsorship, which of course did not, and where did the Government find the money to plug that gap?
Lord Sainsbury of Turville: Clearly the funding from sponsorship was a key part of the original plan. Of course, the change in the economic situation made that very unlikely and we then had to go to a whole series of different pockets of money to find the money to do it.

Q154 Dr Turner: Do you think that PPARC and the DTI have enough flexibility to deal with these requests for funding in the future, when the odd project of national significance like this materialises? Do you need to have some kind of arrangement to accommodate this in future, so that if a future project is to fail it is not going to fail because of administrative or funding reasons, but purely because the technology, despite everything being done for it, did not work?
Lord Sainsbury of Turville: I am hopeful that gradually we are getting into a position where, with the science budget, we do leave ourselves—this is more generally rather than the space budget—some money, particularly with the Director General of the Research Councils, so that all the money is not allocated, so that we can deal with particular opportunities or things that come up. Of course we have not had, and still do not have, a very significant space budget to make this very easy. The problem here was that it did come very late in the day and I think it is going to be a long, long time before we say, if something comes up at a later date, that we have 20 million sitting around which has not been allocated, because we tend to make these judgements very carefully and use every bit of money we can. I agree in principle it would be nice, and we are putting aside some money now so that we can deal with some problems that arise on big facilities, or other surprise events.

Q155 Dr Turner: So you will keep something in the back pocket in the future?
Lord Sainsbury of Turville: Yes.
Professor Halliday: Can I just make a technical remark about that? Up until the introduction of resource accounting, basically we were not allowed to keep money in the back pocket, i.e. unspent. With resource accounting we can now put money in the bank, either for flexibility or for forward planning, and this year we are under spending quite seriously in PPARC, very deliberately, because next year we know there will be some big bills in. So resource accounting changes the mindset as to how you think about these things, and certainly we are struggling with them. As the Minister said, if you do not spend money and suddenly have to spend it you can spend it extremely badly. So there is always a tension between planning forward and therefore cutting down your flexibility. How much flexibility you keep is a difficult judgement that we struggle with essentially all the time.

Q156 Dr Iddon: If I can go back to management, Lord Sainsbury, in this batch of questions, please? We have had quite frank views on the management of this project, and all that this Committee is concerned about is that we learn from the mistakes

of this project and the previous Rosetta Project, so that for the next one we get things right. We thank people for being extremely frank, but the problem is that we have had conflicting views about the management and what might have gone wrong and what did go wrong on Beagle 2. Might we seek your views too, please?

Lord Sainsbury of Turville: I think there are two parts to this. One is the overall management of it, because the decision to make it an instrument meant that there was this divorce from the management of the lander and the total project, and if there is one lesson we absolutely have to learn it is that you have to run these as integrated projects—that is absolutely essential to it. So there was a failing there and I think we need to learn from that.

Chairman: I will suspend the hearing for 10 minutes.

The Committee suspended from 5.04 pm to 5.11 pm for a division in the House

Q157 Chairman: I interrupted your answer, Lord Sainsbury.

Lord Sainsbury of Turville: I was saying that it seemed to me that there were two issues. One was the integrated management for the whole project, the lander and the spacecraft; the second was the question of the management of the lander itself and the putting together of that. What we did was to approach it in the same way as we would have approached other instruments, and again maybe there is a lesson that one should not treat this kind of thing, from a management point of view, as an instrument. It should really have been treated in the same way as the kind of management of the total spacecraft. I think there is another point to make, that, given the pressures of time and so on, it was extremely difficult to manage in the way one would have liked to have seen. That is no criticism of the people who did it; it was the fact that there was a tremendous pressure from a time point of view to do that.

Q158 Dr Iddon: Of course the Casani Review was implemented.

Lord Sainsbury of Turville: Yes.

Q159 Dr Iddon: I presume the ESA was the main driving force in that, although you might like to correct that assumption if it is wrong. Did you feel that following the Casani Review most of the recommendations of it were implemented, or were you disappointed about the outcome of the Casani Review?

Lord Sainsbury of Turville: Can I make a general comment? I think there were specific actions which came from particular actions which he suggested in his Review. I do not think it is right to say that there was not a follow-up. But of course quite a lot of that was to do with things like the amount of mass and so on, and, given those restrictions, it was very difficult to follow it through completely, but perhaps David can elaborate on that?

Dr Leadbeater: I think the Minister has made the main point, that having treated the lander as an instrument, it had a somewhat detached position from the Mars Express Project. By the time that Casani looked at the Programme, which was in September 2000, the situation in terms of the management of the Programme, which was broadly a gentlemen's agreement with some subsidiary contracts. That was developed during the feasibility study that had been running, and under the contracts which were let as a result of the second injection of funding by Government. The Programme was in transition. John Casani's Review broadly said that the status of the Programme was satisfactory at that point in time, but it highlighted some problem areas. It identified some issues in management really for the future, not for the past; it identified some issues that related to margins, and in particular the issue of the transfer of the technology related to the Entry Descent and Landing System, which had been taken from a US Programme, and it identified that the test requirements for that were, in the opinion of the experts, a significant challenge for the future. He said that more work needed to be done on the airbags and on the test programme associated with them.

Q160 Dr Iddon: That is what we heard in the previous evidence taking session, that more time was necessary to test, particularly the parachute system concerning the weight of the lander and so on. Whose responsibility would it have been overall to pull this project if it was going drastically wrong? We have not really had an answer to this question yet.

Q161 Chairman: Where did the buck stop?

Dr Leadbeater: If I can try to answer that first? I think at the time that Casani looked at the Programme the buck, in terms of the lander, because of its treatment as an instrument, was certainly considered by ESA to be with the Beagle 2 Programme and therefore with the United Kingdom. I think the view that BNSC took in the light of the Casani Report was that John Casani's team had said that a lot of reliance was being placed on a very competent sub-contractor. In other words, Casani was saying, "We think that these technologies associated with the landing system are difficult but you have a very competent player in charge of that." Various people have various views about that statement, but John Casani was not raising a red flag at that time and saying that it is all bad, he was highlighting an issue that would require more effort. I think in hindsight one could say that through the eyes of that sub-contractor, and certainly through mine, there was not an appreciation of how big a problem that would become over time because of the issue of margins, and that it would be relatively late in the Programme, before it became apparent that improving those airbags could not be done within the margins that were allowed. If I may, Chairman, refer back to the Heads of Agreement—

Q162 Dr Iddon: I wonder if you could answer the question though? We keep asking this question: where does the buck stop? Who made the decision?

Lord Sainsbury of Turville: Let me answer it because it is quite clear that in the end it was my responsibility because I got the advice from officials and other people as to the action which should be taken, and there was always the option of stopping the project. There were two occasions when I think that was a possibility and on each occasion I decided we should go ahead. The two occasions I think were very early in the project when the first ROAME was produced, and it is a question of whether one made the right judgement, and one perhaps should at that point have said that here is a project which is extremely exciting but, in the nature of these things, you should start out with a great deal more margin in terms of mass or finance or time. I have to say I thought that it was do-able and it was sufficiently exciting to get a decision to go ahead. The second moment was towards July 2001 when it was clear that we were not talking about the previous figure for cost completion which we had was £36 million. It had gone up to £42.5 million. We at that point had a succession of overruns, and that was a point where one could have said no, we have gone too far on this, it is not under control. I took the position that, at that point in time we were pretty committed financially and that the right thing to do was to go for the fixed price contract, to insist on a Heads of Agreement with everyone quite clear about who had responsibility, and in that way we could still be able to do it. It would have been a decision where I should have said, "No, this is too tight, we are going to take too many risks in the end and you should cut it off at this point."

Dr Iddon: Thank you for that added touch of frankness and we might well have reached the same decisions ourselves, but it is good to know.

Q163 Paul Farrelly: Lord Sainsbury, on that second point you have talked about cost overruns and that second point in July 2001, very shortly after David Southwood came in at the European Space Agency. I want to return to his evidence because his evidence and yours, given your previous remarks, are completely at odds. He said—and I am paraphrasing, and I do not think I am being unfair in putting it in this way—that when he came in he quickly realised that the management was a shambles; that the project would very probably fail but it was too far gone and there was nothing really pragmatically he could do about it, bar let people hitch a ride as long as they did not blow up the spaceship. I think that is a fair summary, but in fact I will read you what he said to us in evidence. "I came in and within 15 days I had decided that this thing was not going to work; I thought it would be a failure then. I then dug my heels in." So my question to all three of you is, was it the case of management at that critical time that did not share his view, or that you did not know that that was his view even though he said he was quite clear in giving his evidence to us?

Professor Halliday: Seen from my perspective, and there was £2.7 million of PPARC money riding on this for the instrumentation, we believed that there was a perfectly reasonable chance—hard to quantify—that this mission would work, that it was interesting science and there was a bunch of very dedicated people working their socks off. Given that, if David Southwood really believed that there was a 1% chance or a 0.1% chance, which is the kind of number hiding behind his rhetoric, if that was really true he damn well should have told us.

Q164 Paul Farrelly: You are saying that he did not tell you?

Professor Halliday: Not at that level. The rhetoric was that the risks were increasing. The management, we are all agreed, was not perfect, the time was tight—there were all sorts of things increasing the risk. There is a very different kind of statement between the chance of failure has gone up by 10%, 15%, 20% and it has become catastrophically obvious that this thing is destined to fail, and I think some kind of distinction really does need to be drawn here.

Q165 Paul Farrelly: Is that view shared by everyone?

Dr Leadbeater: I would like to repeat what I said before, and that was that at the time he came in he was a party to the negotiation to the Heads of the Agreement, which indeed he signed, and there are various things in the Heads of Agreement, like agreeing to an increase in the mass margin, agreeing that ESA would become the technical adviser to the British National Space Centre. ESA placed staff at Stevenage within Astrium as a permanent presence in the Programme from that point onwards. Those are the actions of an organisation which is still taking a strong part in the Programme, that is my interpretation.

Q166 Chairman: There is a political aspect to this too? Union Jacks were flying; the Queen had been supplanted on Christmas Day. Did that feature in anybody's thinking at any meeting you were at, that they were too far down the line down; they had a prime spot on Christmas Day, on Radio 4 *The Nation Awaits*. We had to go ahead with it; you must suspect that some people do think that?

Lord Sainsbury of Turville: As I say, July 2001 was the point of decision. This was a decision point at which one could have pulled the plug on the whole project, and that was realistically one of the options. There was not on the table at that point anything from David Southwood saying that we should not go ahead. As far as I know there was no communication of that sort.

Q167 Chairman: That was in 2001?

Lord Sainsbury of Turville: Yes, July 2001.

Q168 Paul Farrelly: Chair, if I could just follow with my line of questions? I also asked Professor Southwood whether he thought the Beagle team itself was giving all of you an accurate assessment of the risks involved, and I will quote to you what he said to us again: "It depends who you mean by the British Government. I think that there was enormous pressure not to let the British people know how high risk it was." Then he went on to say, "I will

tell you that privately I do not think anyone could have doubted my position." Is that again an instance of Professor Southwood being in a position of people saying, well, he would say that now, would he not?

Professor Halliday: The problem here is the language. What do you mean by all these numbers? To be really black and white, is he saying that there is only one chance in 100 this will work or—

Q169 Mr McWalter: A high risk.

Professor Halliday: A high risk to me sounds like a chance of one in 100. The average success rate in going to a Mars is something like 40%, it is not huge, and even with NASA type budgets it is not a 99% success rate, so this is a high risk business. The question is how many of the risks you can mitigate, and that is where the budget, the time and the mass come in, and you can reduce the risks of failure, et cetera.

Dr Leadbeater: Can I make a further comment? There are some magic words in the Commission of Inquiry Report where it is talking about the issue of risk and at one point it uses the words, "but did not say so". I suggest that you look at those words, where it is talking about the issue of risk. I would also make the point that it was in March 2002 that Professor Southwood, the Head of the Research Councils and my DG at BNSC took part in a further review of the Programme and they broadly found that good progress was being made, that the Programme was healthy, with the one exception of the airbags, which had still not completed a full test cycle. Professor Southwood was a party to that exercise; he was a member of the three-man senior team. The only point in my experience where Professor Southwood expressed concern was much later in 2002 when the issue of the need to design a new parachute came, where ESA, in fairness, said that it did not have parachute experts because it was not a competence that the Agency had, and they held up their hand and said, "You need advice from somewhere else." That was really the only time at which public expression of those concerns occurred. I should also say quickly that a Beagle 2 Management board, or essentially a financial and Programme review board, met regularly. The ESA team was a party to that and certainly after the prime contract was let on Astrium there were regular presentations to that board on the status of the Programme. Those were fulsome and, as far as I am concerned, frank. I think the evidence that you heard last week from Michael Rickett, who was the Astrium Programme Manager at that time, reflects that opinion.

Q170 Paul Farrelly: Professor Southwood uses the language "it is not going to work". Lord Sainsbury, before the Heads of Agreement, when £12 million of public money had gone into the budget, what steps did the Department take to make sure that those conduits of money had taken the appropriate steps themselves to ensure that there was a proper management structure in place? How did you concern yourselves with the management structure before public money was handed over?

Lord Sainsbury of Turville: This is in July 2001?

Q171 Paul Farrelly: This is before July 2001.

Lord Sainsbury of Turville: From fairly early on we had people sitting in on the Management board of Beagle 2. I cannot remember the exact dates when we started having that but it was fairly early on that we actually had involvement. In fact, after we had produced the initial grant of £5 million in 1999 the BNSC, PPARC and DTI became members of the Beagle Team and management board, which regularly reviewed the finances of the project, with the University of Leicester, which was looking after the instruments for Beagle 2, and Astrium, which was looking after lander. They made regular and detailed reports to the Beagle 2 board. Following the agreement between ESA and its Science Policy Committee in November 2000 to commit £10 million to the Beagle 2 project, ESA then joined the Beagle 2 board and had a full contractual relationship with ESA.

Q172 Paul Farrelly: Did any of your beagles on the board, as it were, emit any signals that something was wrong?

Lord Sainsbury of Turville: No. Just going back to your previous question, there were no reports from any of those people, including David Southwood, which said "No, this is not doable, you should stop putting money in." These are serious matters. This is not about everyone should have known what my view was. These are regular reviews, board meetings, at which people are required to say what they think. In none of the papers where they were asked for a decision was there a view which said the Director of Science at ESA believes that this project should stop. Of course if it had been, that would have been something that one would have taken very seriously indeed.

Professor Halliday: Just to add to that. That does not imply that it was all sweetness and light and everything was easy. This was a hugely demanding project, problems would appear and be faced up to, retired, solved, next. That is the environment in which this kind of science gets done. There are tensions and pressures and so on. It is not that you would expect the board to see no trouble and sail through life without any sweat; such boards are designed to see these pressures and tensions. It is almost routine business for PPARC in these kinds of big projects to face up to these problems and resolve them and so on. You have to be aware of these kinds of tensions.

Q173 Mr McWalter: I would like to pursue that but I have been asked to ask easier questions. I do not know why that has happened to me today but that is the way it goes. One of the aspects of Beagle 2, although I called it a failure earlier, was that it did not achieve its primary objective but it is widely agreed that there have been many additional benefits that have come out of the project: the spectrometer;

the capacity for environmental monitoring; terrestrial environmental monitoring; a whole lot of other issues that arise there. In view of the spin-offs of the project for industry and also the public understanding of science, the engagement that was characteristic of the project, do you believe that the financial support provided by the Government was money well spent?

Lord Sainsbury of Turville: I think there are different aspects of this. I think the most important benefit is that it positions us for the future in this area of robotic exploration, which I feel to be what the future is going to be about. It is very interesting how if you look at the Aurora Programme, out of the nine major studies which are being done we are leading on three of them in the UK and are involved in three others. I think that is partly due to the work which was done by the Beagle 2 team. I think it has positioned us well for robotic exploration. Clearly there are some spin-offs and you have mentioned the two obvious ones which are the gas analysis package and also the x-ray instrument. The gas analysis package could be very important and Wellcome is now investing in that. The third thing it did was in an extraordinary way it inspired the British people to see that there was an exciting issue here. I would have liked to have said that we found out what we wanted to find out, because that was what it was about, but, as Ian has said, it was a high risk project—these projects are high risk—and we did get some quite substantial benefits.

Q174 Mr McWalter: Your answer to the question, "Was it money well spent", is yes?

Lord Sainsbury of Turville: I think it was because at the end of the day it moved us forward in this area and positioned us well for the future.

Q175 Mr McWalter: I think I have got the answer. How many of the Government's original objectives in backing the project were met, do you think? Most?

Dr Leadbeater: If I could answer that. I think the answer is most. The original ROAME identified clearly the science objective but we were looking to work with the subcontractors and the supply chain exposing the technology to the industry which means bringing together a whole host of players who did not normally work together. McLaren, for example, the Formula 1 team, designed part of the aero shell. Those supply chain issues were important. There were targets in terms of education during the cruise phase to Mars, a whole set of education material was produced, on the one hand by the Open University but also by the British National Space Centre. Teachers were involved in that and, indeed, they developed lesson plans. A whole host of things were done in that area. We have positioned the scientists and the engineers for the Aurora Programme. On those scores, the positioning and the benefits, it is clear that our objectives were achieved. Clearly it would have been better had it worked.

Q176 Mr McWalter: That is enough of these positive questions, I want to ask a rather more negative question. What has been the impact of the Beagle project on the standing of UK planetary science in Europe? I am bearing in mind here the remarks made by Paul Murdin, and you have just mentioned Formula 1. He says that the French said: "It is inappropriate at ESA to launch a Formula 1 car covered with advertisements", that is their rather negative way of looking at our attempts to get sponsorship. We have had other evidence that the quest for sponsorship distorted the management effort in quite major ways. Murdin goes on: "In general, our attempt to carry out projects as a matter of national pride without being able to pay our way cost the UK political credit in the European space community". Would you agree with those comments? He is saying the impact has been quite strongly negative on our standing.

Dr Leadbeater: I do not entirely agree with that. Paul is absolutely right that at the start of the programme there was intense competition with the other Member States. The payload fraction of Mars Express that allowed us to fly the lander meant that instruments from other Member States could not be flown on the platform, so there was scientific competition at that point. At the point that we were trying to negotiate an investment by ESA in the programme, again there was concern about the mix of funding for the programme, so there was then Member State competition. Clearly it would have been better had the UK been in a position with larger contingencies and flexibilities to have stepped forward quickly but I think there was recognition in the international community that the science around the lander was of absolutely first rate, ie at the leading edge. There was some potential concern, even a little envy I think, about the extent to which the Beagle Programme commanded the attention of the media to a degree at the expense of Mars Express. Again, that was an element of scientific competition and that is healthy, that is creative tension.

Q177 Chairman: Let us have some Scottish passion, Ian.

Professor Halliday: I think if we can put, let us say, the ideas and inspiration of Colin together with the budget increases the Government is putting on the table we can have a seriously important role in the European space community.

Q178 Chairman: I was going to ask you about that in a minute.

Lord Sainsbury of Turville: I think the fact that on the Aurora Programme we are leading on three of the nine projects and are involved in three others says that there is an understanding across Europe that we have built up some real expertise in this area.

Mr McWalter: Touché.

Q179 Paul Farrelly: One of my concerns is that when Beagle was on mission with Colin Pillinger enthusiastically singing its praises it was a really exciting project, but the more this inquiry has gone

on and the more evidence we have taken it has left a lingering impression that it is another tale of British amateurism which gives full vent to our self-deprecating humour. I noticed on one comedy programme that it has been relegated from being a dustbin lid or a barbecue to being a cheese grater surrounded by skinny little Martians puzzling over what it is. What are you going to do to try to dispel that impression and to communicate the benefits that you have just been talking about in answer to Tony McWalter's question?
Professor Halliday: Hopefully it will land on PPARC's desk. I think the correct riposte is that there is an Aurora Programme that I believe is currently being tailored very close to Colin's and the British design. It is probably later rather than earlier, but that is life. It is up to us to add just a touch of professionalism and control over all machinery so that the next machine that goes to Mars takes Colin's instruments with it and we deliver all the science. I think that is the only true riposte to this. Can we put a Union Jack on it in the way that we did with Beagle—

Q180 Chairman: Or will it be a French flag?
Professor Halliday: Certainly it will have a European Union flag on it at some level. Whether we can distinguish it and put a Union Jack on some part of it is a challenge that we always face in these kinds of situations.

Q181 Chairman: So there will be a European approach to the problem this time, much better co-operation?
Professor Halliday: I am sure both sides have learned from this.

Q182 Chairman: Will there be interaction and collaboration to an extent that we have never seen before on a project like this?
Professor Halliday: I am not sure than we have ever seen before. We are engaged with other instruments with ESA right now where the UK has a major role in the James Webb space telescope where new management structures have been put in place, agreed by both sides, PPARC and ESA,—

Q183 Chairman: Is there going to be a lander on the Aurora then?
Professor Halliday: Yes.

Q184 Chairman: Did you say that loudly enough?
Professor Halliday: Yes.

Q185 Chairman: Come on, let us hear it.
Professor Halliday: It still will not be a 99% probability of success. No matter how hard we work, this is a difficult area.

Q186 Chairman: Have you set aside a funding stream for this?
Professor Halliday: We are putting money aside for Aurora. There is an initial study stream where we have contributed money and there will be an iteration of that for a ministerial meeting at which the major decision will be taken.

Q187 Chairman: You had better change your PPARC Five Year Strategy because it is not in there. Do you take the point?
Professor Halliday: I take the point.

Q188 Chairman: We are suspicious. You really must get it in there.
Professor Halliday: We wrote a bid to the Spending Review—

Q189 Chairman: Where is this funding stream?
Professor Halliday: It comes under a variety of disguises. We had a bid—

Q190 Paul Farrelly: It was done secretly!
Professor Halliday: Not at all. We had to go to the current Spending Review which, as you know, is not entirely resolved. The science budget is not and the PPARC budget is not. We have a bid in there jointly with NERC to look for origins of life and so on of a substantial nature and whether we will get it I do not know. Part of that debate is will we put a third of that money in, let us say, from our current budget. That is the plan that we are working on.

Q191 Chairman: When can we look forward to that decision?
Professor Halliday: We will hear the PPARC allocations in, let us say, September/October is my guess. On a timescale of Christmas through Easter we would then expect to write the plan for PPARC spend in all the areas, including this area, up until 2008. On that kind of timescale we would expect to make decisions: have we put serious money aside for Aurora, for ministerial sign-up for Aurora, on that kind of timescale during the next six months.

Q192 Chairman: We will be meeting the Minister for Science around that time so I am sure it is on our agenda. Lord Sainsbury, what lessons do you think the Government has learned about this in terms of this joint project in the work that is going on now for Aurora? What is the major lesson that you are imposing on the Aurora Programme?
Lord Sainsbury of Turville: I think the lessons to be learned really follow from the two main things I mentioned at the beginning. One, which is recommendation one of the report, is you must manage a lander/orbiter like this as an integrated whole. That is the first lesson, you cannot do this and say that one is an instrument where we just leave it to the people to design the instrument and then put it on board. The second thing is you must have enough time and mass and financial resources at the start of the project so that you have much more flexibility to deal with problems that inevitably will come.

Q193 Mr McWalter: Is the third one not to trust American technology on the lander?

Lord Sainsbury of Turville: There is an issue about trusting someone who says that they have access to technology through the relationship with another country. I have to say, I put that in the category of things that will go wrong and that is where you need the margin to be able to deal with it. I do not think you will ever go through one of these things without there being problems and issues arising, the question is you must have enough mass and time and financial resources to be able to deal with those effectively.

Q194 Chairman: Does it not seem very obvious that from a management point of view you must have the money right up-front so that people know it is going to be there. Something may go wrong but if you have enough money there it is less likely that something will go wrong because they will know within what confines they can design and so on.
Lord Sainsbury of Turville: Yes. I think the question is how much margin that should be. In this, as in everything else, we thought there was a margin, we thought there was a reasonable budget and so on but it subsequently turned out that it was very tight.

Q195 Chairman: So it was a bad judgment?
Lord Sainsbury of Turville: I think there was a collective bad judgment on those two issues. One was it was being treated as an instrument and no-one at any point said "This is the wrong way to treat it". Right at that early stage we should have understood more clearly perhaps how tight the margin was but I think people were carried away by how exciting this project was and we said, "Let us try and do it".

Q196 Chairman: David Southwood was not.
Lord Sainsbury of Turville: I do not think he was there at that particular point. I think the other part of it is in a sense we did the same thing with Mars Express itself. Mars Express was a very tight project, it was tight on time and finances. In that particular case it has been a huge success and is producing wonderful science so it was right to take some risks, because there was a risk involved in that also.

Q197 Dr Iddon: Finally, can I refer to the Commission of Inquiry report that you set up along with the Director General of the European Space Agency. Can I ask you who is responsible for the decision not to publish that report, at least a full version in part with the sensitive issues which we know about removed?
Lord Sainsbury of Turville: That was a joint decision of myself and the Director General of ESA. It was a joint decision that we should not do this. As I think we made clear, there are some real problems about producing it in terms of confidentiality, legal reasons and so on. I think it would be very difficult just to excise parts of it, as you will know if you read it, because there are considerable chunks which go into particular areas and it would be difficult to take those out. You have read the report and you can see that it does not say there was gross incompetence or recklessness of any individual and, therefore, it seemed to me the central issue was to publish the bits of it which are important, which are the bits of the recommendations that we need to learn from. Also, it is quite important to realise that this was an internal inquiry, it was not a public inquiry with all the safeguards and the ability for people to be represented and, therefore, going public with this as opposed to using it as an internal inquiry does present some quite serious difficulties to me because if it was a public inquiry people should have had much more rights of representation and so on. It was an internal inquiry to learn the lessons and it seemed to me the right thing was to put the recommendations into the public arena so that people could see that we were learning the lessons from it and not spending the time trying to pin blame on individuals, which seemed to me totally inappropriate because, as I have said and if you read the report, it is clear that in decisions which were made if there were misjudgments, they were misjudgments about those fundamental issues of the instrument and the mass. Those were pretty much collective decisions and I think there is no point in saying, "It was this person or that person", we all made them and if it had been a great success we would have all claimed credit for it—I certainly would—and, therefore, I think you have to put your hand up and say, "I was responsible, with other people, for making those judgments".
Dr Iddon: That is clear, we are not going to see this report ever in the public arena. Thank you very much.

Q198 Chairman: Our final question would be do you not think that the whole business of space research and so on would gain credibility if we had a UK Space Agency? You could all answer that one. Would you welcome that? It would give it credibility. It would give it focus. It would signal the right things to Europe and move things forward. Do you not think so?
Professor Halliday: I have some serious problems and those are reflected in some studies that NASA has been doing. At the moment I have on my desk the resonsibility to look after British astronomy and, therefore, I and my colleagues have decisions about is it best to do this astronomy in space or is it best to do this astronomy on the ground, how much in space, how much on the ground, etcetera, etcetera. I think that is the right set of things to have on the table, ie the driver is the science and you make these relative decisions. I think that is a piece of true honesty. The American inquiry, which they did not act on, was whether ground-based astronomy, which is dealt with in the National Science Foundation, should somehow or other be put together with the space astronomy, which is dealt with in the States in NASA. They have a different split. They went round and round. There was clearly a lot of unease that astronomy was not being dealt with in one place where rational decisions were being taken. Eventually they said in this context of the States that the balance of keeping space astronomy in the space age outweighs putting it together, but I still believe it is a fine call and we happen to have gone one way rather than the other.

Q199 Chairman: Lord Sainsbury, do you have a view on that?

Lord Sainsbury of Turville: I would go along with Ian on this. The real issue is how you treat the budget and the money. We have taken a view which is that space should not be seen as the end and it should always be measured against the uses. As Ian was saying, the question is not that we have a space budget and you tell people "You have got to spend that on space", what we are saying to NERC or PPARC is, "You have challenges which are scientific challenges and all the time you have got to balance do you want to achieve those scientific challenges through space or some other way". That is why we have given the money to the research councils for that and, indeed, for the other parts of it, only keeping some technology issues in a central budget. I think there are some real benefits from this which are that you really do relate what you do to very clear objectives and those objectives are about world class science or about commercial issues or about earth observation and not just about national prestige in space. I think there are some merits in this issue in the way that we organise it. As always it has some disadvantages as well but I would not be arguing for a National Space Agency particularly.

Q200 Chairman: Dr Leadbeater, you are a centre, not an agency, what do you feel? Do you think you need to have your role increased?

Dr Leadbeater: If I can comment quickly. The National Audit Office looked at the BNSC partnership model in detail last year and they thought on balance that it was a good way to work. A consequence of it is that in the UK the balance of knowledge in terms of management, organisation and running projects actually rests in the industry and in conjunction with universities. That is a strength. In France, there is a tension between what industry wants to do and what in-house the French agency CNES wants to do with its 2,000 people. I think, as we have discussed here, many in the UK would like to see more flexibility in the budget, an ability to do perhaps a little more, but I think, again, we would like to see that being done through universities and through the industry, not through the creation of a stand-alone agency which runs many things itself and needs a very large budget to do so. I would enjoy the greater flexibility of a slightly larger budget. As the Minister is not kicking me under the table, I can say that, but it is sought within the current model for the reasons that Professor Halliday has indicated.

Chairman: That has brought us to the end of this inquiry into Beagle. Thank you very, very much indeed for helping clear the air. We may never know where Beagle is but it sounds like we will be carrying on the project with Aurora. Thank you very much indeed. We look forward to meeting you again, Lord Sainsbury, at Minister's Question Time later this week. I doubt that there will be questions about Beagle so you can relax. Thank you.

Written evidence

APPENDIX 1

Memorandum from the Government

INTRODUCTION

1. The Government welcomes the Committee's interest in the funding and management of the Beagle 2 mission, following on from the Commission of Inquiry's report. This report was called for jointly by the UK's Minister for Science and Innovation and the Director General of the European Space Agency (ESA). We were pleased to provide the Committee with confidential copies of the Commission's report and look forward to appearing before the Committee in due course.

RESPONSIBILITIES OF UK GOVERNMENT BODIES FOR CIVIL SPACE

2. Government's responsibility for civil space rests with the Minister for Innovation and Science in the DTI. The Office of Science and Technology (OST)—a part of DTI—has overall responsibility for the Research Councils. Responsibility for Space Science— in particular in exploration to Mars—rests with the Particle Physics and Astronomy Research Council (PPARC), which is a partner in the British National Space Centre (BNSC). DTI is the host partner and has taken the lead in consideration of requests for support from industry for Beagle 2.

OUTCOMES OF THE BEAGLE PROJECT

3. DTI's initial decision to invest in the Beagle project rested on scientific and industrial objectives, and wider benefits in education and to society as a whole.

4. The initial industrial objectives have been met. UK firms have been positioned to take roles in ESA's next generation exploration programme Aurora and to contribute to international opportunities, eg NetLander, the US Exploration initiative. About 100 SMEs were involved in the Beagle 2 supply chain partnership.

5. Technology has been developed and transferred as planned. The parachute development is but one example.

6. Instrumentation developed for Beagle 2 is available for exploitation in domains outside of the space sector. For example, the Wellcome Trust has invested at the Open University (OU) to exploit the Gas Analysis Package in hospitals and laboratories. The X-Ray instrument developed by University of Leicester is being trialled for use as a portable geological survey device for use in developing countries. Many more success stories can be identified.

7. Our involvement in Mars Express links the UK to an ongoing success story. Mars Express has already confirmed the presence of ice in the subsoil of Mars. UK scientists are recognised as having proposed and implemented a world-class scientific instrumentation capability for Beagle 2 that is internationally admired; they are now in strong positions for future collaborative projects. Likewise the UK's engineers are recognised for having developed world-class solutions at modest cost (relative to the traditional cost of space missions).

8. The objective in education has also been successfully met. The OU has been able to develop foundation course material, publish books and contribute to countless press and TV events. BNSC has facilitated a web based set of lesson plans suitable for use in the school curriculum. These were developed during the 6-month journey to Mars and have led to substantial follow-on interest in Mars Express and the NASA rovers. The lesson plans were developed with teachers and industry and we will use this formula in developing future lesson plans.

9. Space has become front-page news.

RESPONSE TO THE RECOMMENDATIONS OF THE COMMISSION OF INQUIRY

10. The Government has accepted the Recommendations of the Inquiry. There are, however, a few points of interpretation which may help the Committee with its Inquiry.

11. ESA's initial decision to canvass proposals for prospective landers for Mars Express through an Announcement of Opportunity (AO) followed normal practice at that time to select nationally funded "instruments" for flight on ESA funded spacecraft. The rapid development concept of Mars Express and the uncertainty about whether any Lander(s) would be flown added further doubt about the resources and

management effort need to develop Beagle 2. We agree fully with the Commission that in future complex landers which need tight integration with the overall management of the space craft should not be treated in this way.

12. The mass allocated for landers in the initial AO (120kg) was reduced significantly at the time of a second AO (90kg, split 60kg for an exobiology lander (Beagle) and 30kg for a network camera). This was precipitated by reconsideration of the launch cost of Mars Express. The Beagle 2 lander was fully compliant with the original AO, but was at the 60kg limit with no mass margin after the second. Treatment of Beagle as an instrument and lack of access to significant mass margin significantly hindered normal risk management practice during the development of Beagle 2.

13. An independent review in September 2000 confirmed the viability of the Beagle 2 project but highlighted difficulties ahead in development and test of the airbags, unless action was taken to improve access to testing facilities and provision of realistic mass margins. Initial reliance on the expertise of the US sub-contractor of Martin Baker Aircraft which was based on their successful experience in a US Jet Propulsion Laboratory programme, and failure to allocate significant additional margin fettered the full implementation of advice from that review. It now appears clear that treatment as an "instrument" reduced the level of ESA management attention given to implementation of the advice from Casani. Attention on the ESA side was initially more focused on the success of Mars Express, leaving responsibility for remedial solution on the lander programme to the Beagle 2 team, which did not have access to enough resources fully to mitigate the risks during development.

14. With no physical evidence of the reason for the failure of Beagle 2, the Commission has had to concentrate on process issues which might have affected the development programme and hence the performance of the entry decent and landing system. We accept that a combination of lack of mass margin and schedule and cost constraints associated with adapting US airbag technology for use on Beagle 2 almost certainly increased the relative risk of failure. We support the need for a further meeting of experts so that experience gained during the development of Beagle and that known to Russian and US experts is more fully exposed to mutual benefit.

15. We agree that firm fixed price contracts are best used where there is a mutual and balanced understanding of the risk being transferred to the contractor and the premium to be paid by the customer for the contractor's acceptance of that risk. Likewise, we accept that projects of the complexity of Beagle 2 should not be exposed to the uncertainty of funding from sponsorship during their development. However, that should not rule out the involvement of a sponsor who makes a commitment at the start of full development.

16. It is acknowledged that Astrium took a significant risk when taking responsibility under the firm fixed priced contract for US subcontractors of Martin Baker Aircraft that were working under cost plus contracts, as is the norm in the US space industry.

17. The time history of Government involvement in ESA's Mars Express project and its Lander Beagle 2 is provided at Annex A. That chronology provides evidence of Government's role to help facilitate the selection of Beagle 2, to provide funds for a previously unplanned spacecraft, to increase the role of ESA, to negotiate a vital Heads of Agreement at a time of financial crisis, to participate in international and ESA led reviews and to promote opportunities for the scientific and industrial communities

Decision not to Publish the Commission of Inquiry Report

18. Having considered the relevant factors, it has been decided to withhold the full report under the following exemptions in Part II of the Code of Practice on Access to Government Information:

> Exemption 1—Defence, security and international relations.
>
> The full report contains confidential matters involving other member states and material which has been provided in confidence by the European Space Agency (although, without disclosing the full report, they have agreed to the release of recommendations from it which are now in the public domain).
>
> Exemption 4—Law enforcement and legal proceedings.
>
> There are potential, if not actual, ongoing legal disputes and disclosure of the full report could have a possible impact in that context.
>
> Exemption 13—Third party's commercial confidences.
>
> The circumstances arising from the Beagle 2 events will relate to commercially confidential matters between UK firms and other interested parties.

THE NATIONAL AUDIT OFFICE REPORT ON UK CIVIL SPACE ACTIVITIES

19. The NAO carried out its examination of UK civil space activities during the period April 2003 to February 2004. Its report, which was published on 16 March 2004, includes a three-page consideration of the Beagle 2 project. It concludes:

20. "Beagle 2 represented a high risk high reward project. Although it failed in its prime task it has produced a number of benefits for the United Kingdom's space industry and scientific community The prospects for the valuable science were assessed and confirmed under the usual arrangements for rating the value of potential projects. And the technical risks surrounding the project were sensibly approached and mitigated.

21. In the written submissions appraising the case for supporting the project, BNSC did not discuss the material risks alongside the costs and the benefits. The costs and risks, and steps taken to mitigate those risks, which had been fully considered, should have been covered in formal appraisal submissions.

22. Before mid-2001, ie before BNSC was in a position to take a lead in the contractual arrangements and verify the cost estimates, project costs rose by 57% more than those originally estimated by the Beagle 2 project consortium which reflected weaknesses in the original cost estimation. The use of cost plus contracts in the early part of development exposed the project to cost growth risks which were not adequately dealt with by contingency. Later contracts were let on a fixed price basis. ESA and its member states should ensure that the national space organisations are strongly involved in the formation and management of consortia established for the provision of instruments from the outset of the projects.

23. Additional consideration needs to be given in these areas if high risk, but high benefit, projects are to be fairly appraised and tightly managed".

24. We note that those Recommendations of the Commission of Inquiry which cover the same topics that have been examined by the National Audit Office are broadly in line. We accept for that common ground the conclusions on Beagle 2 from both sources.

June 2004

Annex A

FUNDING AND MANAGEMENT OF THE BEAGLE 2 PROJECT

Competitive selection of Beagle as the Lander for Mars Express

1. A majority of UK investment in Space Science at mission level is conducted through the European Space Agency. Nevertheless, in the mid 1990s there was substantial European involvement in the Russian Mars 96 mission, alongside preparatory discussions about European participation in US led missions and a future ESA Mission. Although Mars 96 was unsuccessful, UK and other European groups had developed relevant instrumentation and had developed initial concepts for a Mars Mission through ESA funded studies.

2. BNSC (under the joint sponsorship of PPARC and DTI) was at the same time pressing ESA to adopt a more efficient, less conservative approach to management of the ESA Science programme, in line with NASA's policy of "faster, better, cheaper". Mission feasibility studies were being focused on a previously unplanned mission, Mars Express, taking advantage of available instrumentation and the prospect of an optimum point of closest approach in 2003 between Earth and Mars. A target budget ceiling of 150mecu was agreed with ESA member states. The science community was already convinced that a lander or network of two or more would substantially increase the science return from the mission. It was realised however that the sensitivity of launch cost to the overall mass of the Mars Express would constrain the mass of its payload and that of any lander(s).

3. ESA's Science Programme Committee (SPC) approved a Science Management plan for Mars Express in November 1997 which anticipated an Announcement of Opportunity (AO) invitation to European groups to propose prospective Landers. The AO was issued in December 1997. The Beagle 2 consortia led by Professor Pillinger of the Open University (OU) submitted a substantial proposal in February 1998 in parallel with competitive bids from France/Finland and Russia/Germany.

4. The bids were assessed in August 1998, when Beagle 2 emerged as the best proposal on scientific and schedule/cost grounds.

5. Mars Express was not confirmed as an approved ESA mission until November 1998. At that stage, Beagle 2 was acknowledged as the preferred Lander, but ESA sought confirmation that Beagle 2 could be realised within available allocations of mass (approx 60kg) and that funding from outside Mars Express budgets was assured.

Initial Request for Support during Project Definition (1999)

6. In pursuit of this highly innovative opportunity, the Beagle 2 team approached PPARC for financial support for the science instrumentation package and made a bid into the OST Joint Infrastructure Fund (JIF). PPARC evaluated the science case for Beagle 2, reporting in January 1999 that the science was of the highest quality (alpha-plus). PPARC responded quickly to the request to support the cost of instrumentation for the lander and agreed to contribute £2.77 million, and rescheduled budgets accordingly. Given its prior commitments, PPARC was unable to contribute to the cost of the lander itself and was in any case concerned that the cost of platforms (spacecraft or landers) should be procured as normal through the ESA programme and not through the much smaller national funds for instrumentation.

7. The bid for a JIF award did not succeed.

8. The Beagle 2 team approached the Director General of BNSC in May 1999, seeking a contribution from government of up to £8.4 million towards the industrially led parts of the Lander. This was part of an overall declared cost of £28.4 million. Of the remaining cost, the Beagle 2 consortium estimated that up to £10 million would come from sponsorship. The request was appraised by BNSC in consultation with PPARC.

9. The rationale for Government support was as follows:

— its intrinsic scientific value, confirmed by peer review in PPARC and at ESA;

— its industrial significance to the space sector;

— its wider potential in promoting interest and understanding of science and engineering to the general public.

10. The industrial case emphasised:

— the innovative partnership arrangement between Open University (OU)/University of Leicester (UoL) and Martin Baker Aircraft (MBA) and Astrium;

— the potentially large supply chain of small firms in the UK (approx 100);

— ability to position UK firms for future international collaborative lander opportunities;

— technology transfer opportunities resulting from exposure to US developed entry descent and landing system equipments.

11. The case for wider scientific, economic, educational and quality of life benefits included:

— exploit the high public interest in planetary exploration evidenced by 500 million internet hits when US Sojourner (Mars Pathfinder lander) transmitted for the first time in 1997;

— opportunity to develop education materials for schools and adults, in conjunction with the launch, coast, landing and science exploration parts of the mission.

12. Following preparation of a formal Research, Options, Appraisal, Monitoring, and Evaluation (ROAME) submission and approval by Ministers, BNSC/DTI placed a contract for £5 million with Astrium in September 1999.

Advice from the Trade and Industry Committee (July 2000)

13. During March/April 2000, the House of Commons Trade and Industry Committee examined the role of BNSC, its programmes and support to industry. In particular it received evidence and interviewed witnesses from academe, PPARC and BNSC. In respect of Beagle 2, the Committee's report concluded "It would be a sad comment on the seriousness of the UK contribution to space science if the necessary funding could not be found. The project is entitled to expect Government support in finding ways to fill the funding gap which we understand has yet to be filled".

A Second Request for Government Support

14. It remained a working assumption during late 1999 and early 2000 that sponsorship income would be secured by the OU, who had contracted Saatchi's to secure sponsorship opportunities. Though remaining very positive about signing major sponsors before launch, the OU realised in early 2000 that sponsorship money would come later rather than sooner. This precipitated a probable cash flow crisis in April 2000 when the Beagle 2 team again approached Government, indicating that the project was likely to collapse without interim support. The cost to completion remained at £28.4 million.

15. This second approach was considered together by PPARC, BNSC and DTI including OST. The possibility of support was only considered after a full appraisal of progress and risks had been presented by the Beagle 2 consortium to a Beagle Management Board on the request of BNSC, DTI and PPARC. After preparation of a further submission and approval by Ministers, it was agreed in July 2000 that OST and DTI would contribute a further £5 million (shared 50:50) subject to additional co-funded investment by OU and Astrium. An underwriting agreement was negotiated whereby the four underwriters would recoup part of their investment from any surplus sponsorship income.

An Independent International Review (Casani)

16. In addition, PPARC worked to secure a greater involvement and financial investment by ESA in Autumn 2000. As part of its consideration of greater investment, ESA commissioned an independent review led by Dr John Casani, Jet Propulsion Laboratory (JPL) of NASA. His review group, which included acknowledged experts from the US and Europe including UK, carried out a thorough examination of the status of the lander and its instrumentation. Casani declared the Beagle 2 project as "eminently doable" but did highlight major risk issues associated with adaptation of airbag technology, access to testing facilities in the US and potential fragility of the consensual management arrangements within the Beagle 2 Consortium.

17. In the light of advice from Casani, ESA's Science Programme Committee (SPC) agreed in November 2000 to a package of support measures. These included compensation to Mars Express for integration costs and orbit analysis, agreement to invest £10 million in work packages at Astrium and MBA and agreement to make available the science data to scientists throughout Europe.

Rising Cost to Completion (Autumn 2000 to Spring 2001)

18. The project entered a critical period between November 2000 and May 2001. ESA sought to implement the increased management oversight sought by SPC, issuing a management plan on November 22. ESA also sought to agree a set of work packages with Astrium and MBA. This took longer than BNSC anticipated. It became clear to BNSC in Spring 2001 that MBA wished to withdraw from the Beagle 2 consortium. Astrium and MBA were in negotiation about hand over of responsibility for the Entry Descent and Landing System (EDLS) to Astrium, while retaining access to some MBA design staff.

19. Greater awareness of the cost and schedule implications of resolving development problems with the EDLS led to greater confidence in the cost to completion, which as a partial consequence had risen to £42.5 million. A downturn in the world economy led to a significant reduction in advertising budgets and growing awareness that sponsorship income was likely to come later on and with less assurance.

Negotiation of a Heads of Agreement (HoA) between all parties to Beagle 2

20. Astrium approached BNSC once again in June 2001 highlighting the increase in cost, the decision of MBA to depart and a shortfall in available funds to ensure completion within schedule and available budgets. In negotiation with BNSC, Astrium expressed a willingness to accept a firm fixed price contract (FFPC) for the completed lander including the EDLS, if HMG could accept the fully itemised cost to completion.

21. At this stage, BNSC, OST and the Minister for Science considered whether the risks were so high that Government support should be withdrawn. It was concluded however on the basis of good progress made with a majority of work items and on advice from ESA that the project should continue.

22. BNSC and OST then started to negotiate a HoA which confirmed the relationships between all parties, confirmed the availability of funding to meet the cost to completion, Astrium's willingness to accept a FFPC, ESA's position as advisor to BNSC and right of management access to all aspects of the programme. The HoA was agreed in July 2001 (see Annex B). Subsequently a FFPC was placed on Astrium for completion of the Lander. Under the HoA, BNSC and OST committed a further £8.3 million alongside further contributions from OU and ESA to cover the cost of the Planetary Protection Facility.

23. The decision to sign a Heads of Agreement and to proceed with a firm fixed price contract was again subject to formal submission and approval by HMT and DTI Ministers

Final development under a Firm Fixed Price Contract (FFPC)

24. It is acknowledged by Government that Astrium took on significant risk when accepting responsibility for the former contractors of MBA in the US which were working on cost plus contracts. This followed close examination of options and risks by the company in conjunction with the Beagle 2 consortium, with the full participation of the Beagle 2 Management Board.

25. Due to the ongoing concern about the development and test programme for the airbags, BNSC/OST/ESA also insisted that a further review be held in 2002 once initial drop test of the airbags had been conducted.

26. That Review, held in March 2002, confirmed the good progress being achieved by the Beagle 2 consortium, but highlighted the criticality of the ongoing airbag development programme.

27. Failure of the airbags during a drop test in Spring 2002 led Astrium to redirect tests towards characterisation of a safe working envelope for the airbags. Astrium then sought design changes to reduce the speed of the lander on final descent by modifications elsewhere in the EDLS, in particular by proposing a larger parachute, within the same folded volume and mass. As this represented a significant change from the inherited design of the EDLS, BNSC/DTI agreed to provide a further £1.5 million to conduct a risk reduction programme to examine an innovative new design of a high drag non gliding parachute and

transfer the relevant technologies into the UK. This co-funded action was successful, such that Astrium went on at its own cost to develop and test a new parachute. All of this was completed in a three-month period in Autumn 2002.

28. In parallel, the set of innovative instruments, for example the Gas Analysis Package, that had been supported by PPARC were completed to time cost and specification.

29. The Beagle 2 Lander was subsequently completed and accepted for flight on Mars Express after a thorough Flight Acceptance Review conducted by ESA.

30. Beagle was subsequently launched successfully in June 2003 and completed check out tests during the 6-month coast phase to Mars. It was released precisely to plan on 19 December for an intended touch down on Christmas morning.

Annex B

EXTRACT FROM "BASIS OF AGREEMENT ON SUBSEQUENT FUNDING, PROCUREMENT AND MANAGEMENT OF BEAGLE"

This agreement between the Open University (OU), Astrium, BNSC, University of Leicester and ESA (the parties) defines:

1. how they will enter into a process to determine a fixed price for the completion of the Beagle 2 Lander, consistent with the launch of ESA's Mars Express mission and available resources;
2. how they propose to contribute additional resources and determine whether those are sufficient to justify placing a fixed price contract on Astrium;
3. how they will implement organisational, management and monitoring changes, which are necessary to a successful outcome.

The parties have, by signing this agreement, confirmed their acceptance of these conditions in principle, and committed their respective organisations' best efforts to match available resources to a negotiated fixed price and revised schedule for the completion of Beagle 2. Although this agreement does not constitute a legal instrument, the parties agree to enter immediate negotiations aiming at signing a formal Letter of Agreement on the basis of the accepted principles, when it has been decided that a fixed price contract can be let within available resources. This agreement will enable the project to continue in the immediate term and maintain its delivery schedule.

The DTI is prepared to consider an agreement to underwrite the costs for completion of Beagle 2 to an additional value of £7.5 million under the conditions that follow.

(a) The agreed maximum cost at completion is £42.5 million, as defined on 29 June 2001. Within two weeks of this agreement being signed by all parties, ESA will assist BNSC in negotiating a fixed price contract with Astrium, taking full account of the benefits of a revised schedule, agreed descoping and of fully costed work packages. Escalation beyond that agreed price would be borne by Astrium. Any savings in the cost at completion resulting from pre-contract negotiations that result in the increased underwriting exceeding the residual shortfall—at the point of agreement on the fixed price—would be shared equally by Astrium and the Government, and would go to reducing the total underwriting commitment of each towards the project.

(b) A revised management structure will be agreed on the supply side, with Astrium taking full responsibility for delivery of the Beagle project to cost and schedule. It is recognised that the instruments are funded separately and will be issued free to Astrium. BNSC will act as the lead public customer; acting on behalf of all Departmental and institutional interests, procuring the placement of a contract with Astrium under the conditions of this agreement. Consideration will be given to modifying the existing contract between the OU and Astrium for Beagle 2, providing that there is no conflict with BNSC's lead role, the agreed fixed price and the one-on-one management arrangements proposed in this agreement. Other partners will have appropriate contracts with Astrium.

(c) To reach the agreed cost at completion, the parties will negotiate a work package plan based on necessary descoping of the lander, its descent system and the instruments. That plan will be agreed between Astrium and BNSC, advised by ESA, the OU and the University of Leicester in respect of the lander and its descent system and by the parties in respect of the instruments. ESA will also be a partner to the agreement in its capacity as manager of the Mars Express programme (including elements dedicated to Beagle 2).

(d) ESA will assist BNSC in determining a fixed price contract with Astrium, and, thereafter, in monitoring the schedule and technical progress. ESA will provide BNSC with advice on progress and technical milestones thereby allowing BNSC to release staged payments. The monitoring should include monthly reporting of progress and technical status. Accordingly, Astrium will make available to ESA the relevant progress against the work plan and technical data necessary to carry out the above tasks.

(e) ESA will support drop tests in the USA from US Fiscal Year 2002, as part of existing ESA/NASA agreements. ESA confirms that a formal waiver has been issued accepting the 71 kg mass allocation requested by Beagle 2, and that upon agreement of a firm price it will issue the revised schedule agreed with the Mars Express project.

(f) The OU will supply the GAP and PAW electronics for no additional funding (estimated as an in-kind contribution of £0.8 million). The OU and University of Leicester will additionally agree whether an exchange of funds is required between them to cover the cost of PAW electronics, which is included within the £0.8 million.

(g) ESA agree to fund establishment of the Beagle 2 operations centre as part of the Mars Express Science Operations Centre. ESA will not support the scientific activities required to carry out the experiments and process the data.

APPENDIX 2

Memorandum from Professor Paul Murdin

BEAGLE 2—WHAT WENT RIGHT AND WHAT WENT WRONG?

1. From 1994, until I retired in 2002, I was the Director of Science at the British National Space Centre (BNSC), under the supervision of the Director General, at first Mr Derek Davis and the Dr Colin Hicks, and the Head of Astronomy at PPARC, the Particle Physics and Astronomy Research Council (which paid my salary and on whose behalf I worked, under the supervision of Dr Ian Corbett and Prof Ian Halliday). I represented the UK at the European Space Agency (ESA) on the Science Programme Committee (SPC). I witnessed the birth of the Mars Express project and took part in many of ESA's key decisions about it. I encouraged Beagle 2 and I helped persuade BNSC to finance it. I was very sad at Beagle's loss. It is with this background that I offer a perspective on Beagle to the parliamentary enquiry into its loss.

2. Mars Express was a reaction by ESA to the failure of a Russian Mars mission in which many European scientists had participated. The notion was to create a Mars mission that would build on the proven technology and design of the instruments on the failed mission, and of a previously used ESA spacecraft, in order to exploit the work that had been done in preparation. Also there had been a competition for an ESA mission opportunity in which a Mars mission had been proposed. Although a mission on cosmology, Planck, had been selected, there had been, during the Mars mission study, a considerable build up in Europe of relevant expertise in planetary missions. The launch date was decided by a late discovery that the Mars opposition of 2003–04 was particularly favourable for the transfer of a spacecraft from Earth to Mars—with a given and affordable rocket you could take the greatest possible mass to Mars, and do the most science possible. This launch date was not far away at the time the decision to go for Mars Express.

3. At the outset therefore, and as the name indicated, Mars Express was intended to be a standard mission, quickly procured. It was, consequentially, cheap. Even so it required a certain amount of painful adjustment for the ESA budget in order to fit the expenditure into the Agency's funding profile, and the launch of Planck was postponed. From a UK political perspective this pressure was welcome, because we were pressing ESA to change to be more efficient. It was clear that ESA would have to implement more efficient procurement procedures to carry out Mars Express in time within the budget available, and would learn from the experience. The UK was thus politically in support of what was done, even though from a scientific point of view we were with the majority in preferring Planck. Some UK scientists were of the opinion that Mars Express was originally lacklustre. The cosmologists interested in Planck made sour comments about it being necessary to come second in an ESA competition to get your mission launched. It is unrealistic to expect these people to have ever been happy about Mars Express and Beagle.

4. The proposal by Prof Pillinger to add a completely new aspect to Mars Express, namely the examination *in situ* of the martian surface, was thus a welcome improvement in the scientific potential of the mission. As Pillinger documents in his book on Beagle, although I could not interfere in the management processes of ESA and invite him to the crucial meeting at which the instrumentation content of Mars Express was to be decided, I pointed out that I could not forbid him to go, either. My view was that even if his proposal was not chosen, it would put this issue on ESA's scientific agenda for the future. He went.

5. In fact, Pillinger carried the argument in ESA and, in spite of the conservative spirit in which Mars Express had begun, a completely novel developmental aspect was added to the mission—the Lander. (This is actually typical: in general, there is no such thing as a non-developmental space science project—the technological and scientific environment is always changing.) However, for the UK there was a sting in the tail of this positive decision. ESA had taken up a rather doctrinaire view that, like the scientific instruments carried on the orbiting spacecraft, planetary Landers were the responsibility of the proposers and had to be managed and voluntarily funded by the member states, not by ESA. The precedent was the Lander for the Rosetta mission (for which Prof Pillinger had earlier made an instrument). I had probed the reasons for this decision (taken before my time) but without coming to a clear understanding of it. I believe that in part it

was an acknowledgement of the skill limitations in ESA (although ESA by definition has more space skills than any individual member state), but I believe mostly that the decision had been a ploy by ESA to get more voluntarily contributed resources from the member states for the ESA science programme.

6. The resources required for a Mars Lander were completely beyond routine sources in the UK. Space scientists are used to this situation and have almost boundless optimism, which I admire. Pillinger set out to put together the required package of resources. He did so, raising the public profile of Beagle with consummate political skill, aided by brilliant performances in front of parliamentarians and this Committee, which provided immediate and strong UK political support. The actual money came in a longer drawn out process and a thinner stream.

7. As is well known, PPARC has the responsibility in the UK to fund instrumentation for the ESA space science programme. PPARC's initial reaction to Beagle was one of scepticism, partly because of reaction against the promotion of Mars Express over Planck in the Agency's programme, partly because the initial understanding of the mission was based on press reports about its relevance to life on Mars rather than a scientific proposal. Once the proper proposal had been evaluated by peer review, PPARC was clear that the science was excellent. This decision was a validation of the decision-making process in the Research Councils.

8. My own evaluation was that, in its unique way and with Pillinger's isotopic compositional analysis, Beagle would undoubtedly identify the chemical processes that had gone into forming the surface of Mars and was important science, if for this reason alone. If some processes were biological that would be a big bonus, as an important step along the road to the discovery of extraterrestrial life. I regard this as the astronomical discovery of greatest potential significance that is possible in the 21st century. Extraterrestrial life will have evolved differently from our own. It will be in some ways similar to and in some ways different from our own kind of life. To have a sample to compare and contrast will open up our understanding of biology and biochemistry in ways that we can only suspect. Extra-terrestrial biological material discovered will not only be interesting. The way it will change our knowledge is potentially mind blowing. Thus, I supported the Beagle project scientifically and administratively, as I support the scientific exploration of the planets in general, as a scientific "tall poppy" that stands out above others. It is this that justifies the undoubtedly large costs that are involved.

9. Pillinger, the parliamentary community, ESA, BNSC and the British public, including me, were convinced of the value of Beagle and all wanted the project to succeed. With the public support, we officials drove it on, within our limitations. In PPARC we shifted money in the budget to respond to the delay of Planck and agreed to fund the main instrument on Beagle from the space created. Given the scale of the PPARC budget and its commitments, money for the Lander itself was out of the question, as Pillinger knew and accepted. The mantra "there is no money" became one that I and everyone in PPARC repeated and he learnt to expect. Pillinger therefore set out to seek private sponsorship. This was supported by BNSC because of the DTI commitment to the creation of public-private partnerships for carrying out national projects. Pillinger had also, because of his Open University (OU) background, seen the educational and therefore sponsorship-attractive potential of the mission. Educational development was one of the undoubted successes of Beagle 2.

10. Pillinger persuaded the space industry to provide in-kind services to the design work and was given excellent support by the OU, his university. But the support of industry and the university was limited, too, by their ability to pay. At least one important consortium member dropped out and the rest increasingly turned to Government to support the project in the usual way. Other private sponsors did not come forward with anything like the amount needed. At first it was thought that they would appear at about launch time, when publicity opportunities would be more overt, and the issue became one of cash flow, or finding a "bank" to loan money that would be repaid when sponsorship happened. There was no conventional route for this and seeking it had the effect to slow down progress on the Lander, already proceeding at a slower pace than it would have been if Pillinger had been free from the burden of fundraising.

11. I was repeatedly consulted by DTI on the standing of the project, because DTI progressively got drawn into it financially as well as politically. It tried to do so in a way that both limited its exposure and kept pressure on the OU to continue efforts to raise the money. DTI (and ESA) also insisted on strengthening the project management, through the experienced space groups at the University of Leicester and Astrium. Of course, they had to manage under difficult funding conditions.

12. In first taking the Beagle project to ESA for the approval of the SPC, I had been asked to undertake that the Agency would not be held liable for the costs of the Lander and that we, the UK, could deliver it. The finances were not clear, and I had to do what was asked in such a way that was both honest but left room for manoeuvre. The words "economical with the *verité*" more than once crossed my mind, as I wondered what these episodes were costing me in credibility.

13. As the project developed, its potential for a positive benefit for the Agency (both in terms of scientific outcome and publicity as the Agency tried to raise its profile in Europe) became even clearer to ESA than when it had been selected. Many individual people in ESA gave Beagle support. Twice they helped me make formal representations to the Agency for considerable ESA resources to be allocated to Beagle. These included augmentations of the Mars Express project to make it possible for it to carry and manoeuvre Beagle. They included sterilisation facilities to permit ESA under international obligations to land a

spacecraft on another planet. It is a significant indication of the worry in the Agency about the deliverability of the project that they also included the preparation of a ballast which could be fitted in place of Beagle if it failed to be delivered. (You can't just leave a bit off a spacecraft, which has to be balanced in mass, thermal and electrical properties, so the ballast is technological and making it costs resources.)

14. The political support that I was able to muster in the SPC among our partners had its limits. The result of one such vote in SPC was that the resources were to be regarded as a loan to be paid back by a UK contribution to ESA in the future (some sort of technological development, for example, that we would want to do anyway and would target to ESA objectives). This commitment, about which of course I consulted by phone overnight during the relevant meeting, created an angry reaction among those whom I hadn't consulted when I returned from ESA's Paris headquarters to the UK. The second time we carried the decision in SPC for the sterilisation facilities and some other costs by a single vote (the facilities were to be part of a general capability for such lander projects in the future, in the Aurora programme for example). With the second vote, it was clear that we were not going to be allowed to get more from ESA for Beagle. One difficulty was that the severe mass constraint on Mars Express meant that instruments proposed from other countries had been thrown out when Pillinger pushed Beagle to the front of the queue. This did not win friends. Another difficulty was that in order to raise the potential for sponsorship, including the parliamentary backing, Pillinger had (for these good reasons) branded Beagle as "the British-led Beagle Lander project", and this national labelling did not help in getting support within ESA from other countries. The French in particular were resentful about this and what they generally saw as lack of European finesse. In any case they had distaste for the involvement of private enterprise in the project, saying that it was inappropriate for ESA to launch a "Formula 1 car" covered with advertisements. In general our attempt to carry out the project as a matter of national pride without being able to pay our way cost the UK political credit in the European space community, like a Scot in a London bar who waits for someone else to stand the round and then asks for malt whisky because of its quality and origins. On the other hand our scientific determination and imagination was admired.

15. As is well known, the DTI did provide finance for Beagle through the BNSC, with ministerial support, willingly but carefully given by Lord Sainsbury. The DTI takes care of its public money and the procedures to allocate resources take time. BNSC carried through the procedures diligently and amazingly quickly in the circumstances. But, given the launch deadline, any time spent without cash slowed down progress on the Lander. Of course, DTI had to be assured that the project was of scientific importance—PPARC had spoken on this point—but had to find reasons within its own industrial policies to support Beagle. The Office of Science and Technology, OST, is part of DTI, but rightly takes an arm's length approach to scientific research, delegating decisions like this to the Research Councils and not interfering in scientific decisions. The result is that when new scientific demands come along, that are out of the ordinary and of national importance, but do not fit into some pre-determined policy to which a budget line is allocated, there isn't money for them. In this respect Beagle 2 is like (but rather more positive than) Cold Fusion, Cluster, vCJD, and Foot and Mouth Disease (examples I deliberately choose because of the differences of approach, requirement, importance and outcome). If we have a consistent policy in such cases, I don't know what it is.

16. DTI financed Beagle on the basis of its desire to open up projects like this to private participation (mixed success in the case of Beagle), to encourage technological development in space capability (big success), to encourage public interest in technology and in industry (another big success), and to make progress in changing the way in which a massive European organisation, ESA, was working (at least a partial success).

17. Although Pillinger had made some rather negative public comments about NASA's Landers, which had proved extremely irritating to NASA officials, Beagle was much admired by progressive staff in NASA, although no doubt this admiration is now tempered by the failure. NASA was supportative in sharing intellectual knowledge about the Lander's landing system. Nevertheless some technology development proved to be necessary under the stringent mass constraints. This caused further congestion in the completion of the project and at one stage, when all of us in ESA and BNSC were going wobbly and thinking of pulling the plug, we arranged for the Beagle project to be reviewed by John Casani from the Jet Propulsion Laboratory, NASA's project manager for the Galileo project to Jupiter. He gave a positive, although qualified, recommendation to continue, with the words "it was do-able".

18. The bottom line was that the project was done, successfully and on time. But it didn't work. ("The operation was a success, but the patient died.") Since we don't know why, it is hard to form a more global conclusion than the list of relatively detailed recommendations published by the ESA enquiry. I think the most likely thing is that there was a technical failure, but there is no indication one way or the other whether more time or more money would have enabled it to have been discovered before launch. If there is a Beagle 3, say as part of the ESA Aurora programme, it won't be done to the same extreme scheduling pressure, and it must be set up financially from the start, leaving the scientists and technologists more opportunity responsibly to concentrate on delivering the project. During the Beagle 2 experience, we found no viable alternative to the Government as by far the major source of money. I think we in Government did get away with contributing the smallest sum of money possible from public purses. There were, of course, collateral costs, to which I have referred at various stages in this account. There were also collateral benefits, which I have also mentioned.

19. The tough competitive route that I have described in this account is an example of what lies behind the UK's boast that we produce the highest impact science at the lowest cost. The Beagle failure is one of the prices we pay for this general success. Of course, all science is a venture into the unknown and risky. The risks for a successful landing on Mars have historically been around 50-50. All Landers are technologically difficult, and all Lander projects are fraught—from personal knowledge I could cite the Rosetta Lander as a similar but more generously funded German-French project (and of course we don't know yet whether it will be successful). In my view we did all the right things for Beagle. The potential outcome justified the money spent and the risks taken, even if, in the event, it did not pay off. In any project, you have developmental risk, financial risk, and scheduling risk. If you are under an obligation to mitigate one or two, you can, but it is hard to mitigate all three at once, as Beagle 2 was attempting. But the alternative for Beagle was not to try—I thought and still think it could have been successful. Inaction grows no poppies at all, and certainly not tall ones.

20. The criticism of the Beagle project is worrying to members of the UK space community, who fear that Pillinger's unorthodox methods and the high-profile Beagle failure will damage space science in this country. On the other hand the Beagle attempt is also respected. In a conversation with me at the ESA SPC, one of the older, pioneer space scientists in Europe admired Beagle 2 as a return of the buccaneering spirit to British science. This is something that I hope the UK Parliamentary Committee on Science & Technology will encourage, in supporting Beagle 3 and the UK's participation in ESA's Aurora programme. If we do participate, however, we should do so more conventionally than with Beagle 2.

June 2004

APPENDIX 3

Memorandum from the European Space Agency

Abstract

The reasons that led to the failure of the lander after its release towards Mars are associated with institutional failure rather than any lack of technical competence on the part of the scientific and engineering team. The evolution of the project, from the perspective of the ESA Executive, is analysed with the aim of clarifying why the radical management approach adopted for provision of a British-led lander to the ESA Mars Express mission, which though matching the *zeitgeist* of the times when it started, should not be repeated. The ESA Executive has fully accepted the recommendations of the Joint UK–ESA Inquiry Board and the effect of these recommendations are elucidated. Among the major lessons to be learned are that:

- Resources must be identified at the beginning of projects.
- There needs to be a clear internal management responsibility and authority and clear interfaces between partners throughout.
- Managerial or financial arrangements that lead to less than open transfer of information should be avoided or at least minimised.

1. I respond on behalf of the European Space Agency (ESA) and its Director General, M Jean-Jacques Dordain, to the request made by the clerk of the House of Commons Select Committee on Science and Technology for written evidence concerning the British Government support to the Beagle 2 project.

2. I am the Director of Science at ESA and have held the post since 1 May 2001, when I succeeded Dr Roger Bonnet. The Science Programme of ESA, which I direct, is under the authority of the Science Programme Committee (SPC), made up of representatives of each Member State and responsible for determining the Science Programme content. Proposing the scientific content is the task of the scientific community, through a continually renewed and respected advisory structure, whose highest body is the Space Science Advisory Committee (SSAC).

3. I preface comments with a personal statement the fact that I believe that delivering the Beagle 2 lander involved extraordinary efforts by some extraordinary individuals. Although the scientific community carries no responsibility in what follows, it is clear that its enthusiasm to see Mars Express with a lander implemented was contagious, right up to the SPC, which also includes members who are scientists. Moreover, one needs to remember that the unique skills and techniques developed are not lost; they reside in the scientists and engineers in academia and industry who were involved. I think that the public world-wide has largely understood this; I hear regret from all sides on the "fall at the last hurdle" but in tones of sympathy not scorn.

4. Mars Express itself was ESA's response occasioned by the ready availability of refurbishable or adaptable models of Western European instrumentation lost in the Russian Mars 96 mission failure. Mars Express is the cheapest Mars mission; the Mars Express orbiter has been very successful.

5. The Mars Express programme started in 1998. The zeitgeist of that time is worth recalling. Many felt that space in general should be cheaper and that new approaches could yield new breakthroughs. The slogan of the NASA Administrator, Dan Goldin, "cheaper, better, faster" was repeated everywhere in Europe and

there was immense pressure on ESA from its Member States to demonstrate similar principles; Mars Express was to be done in new ways. The spectacular (total) failures of the both the NASA Mars missions of 1999 had yet to happen.

6. Beagle 2 was to be built in an even more different way, by a consortium of industry and academics brought together to work to the common goal but with a consensus management. The funding was to be raised by a mixture of direct contribution (from industry and academia wishing to showcase skills), commercial sponsorship and scientific sponsorship (ie research grants). The approach was radical but it matched other new approaches of the time; industry and academia were to work together and both public and private finance was sought. However, had either Recommendation 3. or Recommendation 9. of the joint UK–ESA Beagle 2 Inquiry Board been in place, the open-ended nature of the funding would have led to rejection at this point.

7. During spring 1998, it was accepted by ESA's technical staff and enthusiastically endorsed by the science advisory structure that there could be a lander element on Mars Express. Nonetheless, whereas the orbiter payload heritage was clear, from the start it was clear that any lander was to be a tough call.

8. The Beagle 2 plan emerged from the UK in the same spring and had enormous appeal to planetary scientists focusing as it did on "astrobiology". The science of the lander enhanced the orbiter science.

9. Nearly all ESA science missions are built co-operatively between ESA and its Member States, a principle (a bit like "subsidiarity" in the context of the EU) pertains which leaves scientists in the community across to do what they can do best. This means that the noblest parts of missions often are built under the responsibility of the Member States (normally, but not exclusively, scientific instruments).

10. In a space project, clear lines of management are essential. In a co-operative project (with funds controlled by different sources) defining clear boundaries of responsibility is essential. Lines of managerial responsibility have to follow lines of resource provision. Moreover, to avoid conflicting lines of responsibility or gaps in responsibility, partners must have clear demarcation of interfaces.

11. By accepting to build a lander the British team appeared to the ESA Executive and the SPC (and thereby the other ESA Member States) to have accepted responsibility to manage its provision. The primary responsibility of ESA was to deliver it successfully, provide facilities for it to operate effectively but also to ensure that it did not have any negative impact on the rest of the project. This was far from an unprecedented approach; the Rosetta cometary mission, then being built, had a German lander.

12. Early correspondence indicates that the British ESA delegation were aware of their responsibility to assure funding; an early letter (28 April 1998) from Dr Paul Murdin, BNSC/PPARC to Dr Bonnet, then ESA Director of Science, quotes an estimate of £40 million cost and, while acknowledging the difficulty of the task, indicates the intention to seek various sources of funding, including the notion of seeking sponsorship from commercial sources. Had Recommendation 2. of the joint UK–ESA Beagle 2 Inquiry Board been in place, the open-ended nature of the management should have led to rejection at this point.

13. Dr Bonnet's reply (20 May 1998) indicates that the positive scientific assessment had been made without judgement on financial credibility, but also brought the news that a 120kg lander (as proposed by the Beagle 2 team) was no longer technically feasible. Within days, a letter had been received from Prof. Pillinger indicating that a 60kg lander was feasible which retained the core science capability.

14. The lander (60 or 120 kg) was a clearly defined item with "clean" managerial and technical interfaces. Because the programme started without a direct ESA financial contribution, ESA's authority in 1998 to ask for management insight on the building of the lander could only extend to agreeing schedule as well as technical interfaces and requirements and asking for assurances that the work would be managed in an effective manner. It seems likely that had Recommendation 4. been in place at this time, Beagle 2 would not have proceeded.

15. Despite the division of managerial responsibility (see paragraph 9, above), ESA project managers have to keep in touch with progress on mission elements under the management of other partners. By mid-1999, it was clear to ESA that there were serious financial problems in the Beagle 2 project team. Serious doubts on the viability of the project led to the implementation of an independent review led by a senior American engineer, John Casani, of the Jet Propulsion Laboratory (JPL), Pasadena, California. The report indicated that the management arrangement was fragile. The project lacked adequate schedule and mass margins and therefore was very high risk. The entry descent and landing system (EDLS) development plan was not robust. Nonetheless, if all deficiencies could be addressed, the project was do-able. Had either Recommendations 5. or 10. of the joint UK-ESA Beagle 2 Inquiry Board been in place, the project should have been considered for cancellation at this point.

16. One outcome of the Casani report was that additional funding was sought from the ESA Science Programme Committee. The SPC was asked to provide immediate funding for a package where specifically it was envisaged that ESA might play a role in overseeing developing the EDLS.

17. It remained both the British view and the ESA Executive view that the final responsibility for Beagle 2 funding was with Britain, as was borne out in November 2000 by a letter from Dr Ian Corbett, Deputy

Chief Executive of the Particle Physics and Astronomy Research Council (PPARC) to Dr Bonnet, then ESA Director of Science, expressing his commitment to do his utmost to recompense the ESA Science Programme in support of his Minister's wish.

18. In fact it never proved possible to reach an agreement on a simple takeover of the EDLS by ESA. Nonetheless, the support agreed by SPC was provided to the Beagle 2 team.

19. By late 2000, the management approach to Beagle 2 was becoming a concern both in ESA and at senior levels in Britain. In the autumn of 2000, the British made the first suggestion of bringing the programme under a single prime contractor, Astrium, UK. This was eventually done in the following year.

20. In May 2001, I became Director of Science. I found myself immediately faced with two crises resulting from shortcomings in Member State capability to manage their side of projects, the provision of payload for Herschel-Planck and a continuing Beagle 2 crisis. The Herschel-Planck crisis was much larger financially and more complex in that it involved problems in many Member States. I discussed matters not only with my staff but also with my predecessor, Dr Bonnet, with whom I routinely still meet. However decisions were mine. Cancellation of Herschel-Planck seemed unthinkable. Nonetheless, its crisis helped my resolve that, despite the money already spent, ESA should show itself willing to stop Beagle 2 at this time.

21. A series of critical actions and reviews took place in the summer of 2001. In initiating these and at times being involved personally, my aim was to bring things to a head and produce convincing evidence that unless there were major managerial changes Beagle 2 should not be continued.

22. In passing, one can note that in so far as some of the conditions of the Casani report had not been met, one can say at this point that had Recommendation 5. of the Inquiry Board been in place at this time, the programme would have been halted. However it is my belief that no single edict would have stopped a project on which such a lot had already been spent.

23. By the autumn, there was in place a "Heads of Agreement" between the parties, which established ESA as technical advisor to BNSC, and Astrium as the Prime Contractor with a firm-fixed-price contract through the Open University. The Heads of Agreement resolved many of the immediate management and funding issues, but did not implement full ESA management. The estimated cost had risen to £42.5 million.

24. Beagle 2 had started as a tough call, but by autumn 2001, just over a year from delivery due date to ESA, it was indubitably high risk from any engineering standpoint. Enormous amounts of time had been lost through piecemeal funding and in negotiating the resolution of the management and immediate funding arrangements. From this point onwards, I realized that it was not possible to cancel Beagle 2 but that its delivery was going to be problematic.

25. Actually building equipment for space is only a small part of the work, testing and verifying individual element performance and robustness to the hostile environments the equipment will face is a very major effort. The testing and verification process has to be continually repeated as one integrates the parts into the whole system that is going to be launched and function in space. Ultimately in this programme, the whole system meant Beagle 2 taken together with its "mothership", Mars Express.

26. There is no simple break-point where one decides a space development is no longer do-able. Rather, as the schedule is foreshortened one systematically eats away at the safeguards implicit in the testing and verification programme. An attenuated testing programme to meet the cost and schedule constraints inevitably increases technical risk.

27. During the 2001 crisis, the Mars Express team first became aware of one adverse effect of Beagle 2's seeking commercial sponsorship. Sponsors are risk-averse. We were constrained in expressing disquiet in order not to disturb the ongoing quest for external sponsors in Britain. It follows that, in the Agency's view, following Recommendation 8. of the Inquiry Board would make commercial sponsorship of missions impractical.

28. Nonetheless, one could not hide the risk internally. Within the Executive, there was no doubt of the high risk of the project. Furthermore, reports to the SPC had to describe the problems encountered and the high risks of the project. However, as regards external communications, staff members were constrained not to make public statements but to refer all enquiries to the Director. In addition, from summer 2001 onwards, the ESA Science Directorate continuously maintained in reserve statements and crisis plans for the contingency of Beagle 2 cancellation or, after launch, "failure".

29. After Autumn 2001, no further direct financial contribution to Beagle 2 was made by ESA. However, the accommodations made on the Mars Express side of the now clear interface (schedule flexibility, manpower support, etc) increased the Mars Express cost.

30. Instructions were given to the Mars Express team to do everything possible to facilitate the delivery of Beagle 2 and to accommodate its requirements into the larger Mars Express schedule. Naturally a manager in charge of a complex project does not want every card in their hand seen; the Beagle 2 team would

not have known in advance how much bending of the schedule there could be in order to achieve delivery.

31. Once Astrium were in charge of the project, the contracts for subsystems could be organised. Certain single source suppliers (mainly in the USA) insisted upon cost-plus contracts; the Astrium team, constrained by a firm-fixed-price contract, found themselves with open-ended risk. During a time of serious downturn in the world market, this increased the difficulty of bringing the development work together, underpinning the Inquiry Board's Recommendation 7.

32. A variety of technical crises followed in the succeeding months, many documented, often very openly, in the 2-hour television documentary broadcast by the BBC in December 2003. Such crises are inevitably part of doing things that have never been done before; what was unusual was the interest of ordinary people and the team's willingness to share the experience with them.

33. There is little doubt that the American rules for allowing transfer of information to foreigners [the ITAR (International Traffic in Arms Regulations) rules] that apply to all space equipment (air bags, in this case) hampered free exchange of information at critical points in the implementation of the landing system. Anyone who has seen the documentary will understand Recommendation 19. of the Inquiry Board that adequate competencies in air-bag and parachute technology must be available in Europe for future European planetary missions, making best use of existing expertise, eg in USA and Russia.

34. In 2001, delivery of Beagle 2 to the Mars Express team in Toulouse was agreed for mid-December 2002. In the event, Beagle 2 was accepted in late February 2003. Nevertheless, there is no shame in this; the work of the team in making that delivery was extraordinary.

35. Once in space, Beagle 2 checked out successfully. Unsurprisingly, in light of the nature of the project, a fair amount of onboard software had to be uploaded and tested during the cruise to Mars. This was accommodated very efficiently between the Beagle 2 team and the Mars Express operations team.

36. On 19 December 2003, Beagle 2 was successfully deployed. The trajectory was as accurate as anyone on Earth could attain, being achieved by using not just ESA's world-wide facilities but also those of NASA's Deep Space Network.

37. No signal was due from Beagle 2 until it had landed. None was subsequently received.

38. The inclusion of a transmission/commanding capability on Beagle 2 and relying less on autonomy during descent could have removed uncertainty on technical reasons for failure and certainly would have reduced it. Had Recommendations 10. and 11. of the Joint Inquiry Board (echoing similar policies introduced by NASA following the 1999 failures) been in place in 1998 when mass allowance was reduced to 60kg, it seems likely that Beagle 2 would not have been seen as build-able.

39. The Agency should limit what it says regarding what went wrong on the British side. It is clear that some more concrete help coming earlier might have reduced risks. The search for commercial sponsors, here attempted for the first time, was a flaw in the approach. Moreover the initial "consensus" management approach led to basic deficiencies in information (for understandable commercial reasons) and major gaps in documentation of the overall system requirements of Beagle 2. Recommendation 9. addresses this deficit.

40. As far as the ESA Executive is concerned, similar activities will not be recommended to start without appropriate guarantees. As an example of how things might be done in the future, without removing the critical involvement of scientists at the "sharp end" of space missions, PPARC and BNSC have worked closely with the ESA Executive to set up a new kind of partnership between ESA and Member States for the provision of the Mid-Infrared Instrument as a European contribution to the American James Webb Space Telescope.

41. Mars Express itself has been in operational orbit about Mars since early January providing unprecedented stereoscopic images of the planet. Already, by the end of January, long before commissioning was complete, the identification of water in various ways had been announced. Subsequently the intriguing detection of methane (from an active volcano or evidence of life?) has caught public attention. Overall the mission is building up a large store of new scientific data about our neighbour to be mined for years to come.

42. I would like to close by stressing what went right on the British side: the gallant taking up of a challenge, the unprecedented attempt to gather the scarce available means and to manage an unmanageable situation, the incredible communications skill displayed by the Principal Investigator, the admirable response from the British public. Everybody faced with a new situation did their best. Risks were taken, and the report of the Inquiry Board indicates how to reduce them in the future. However there is no way to remove risk completely in space activities. Should we refuse to repeat this adventure, because it will be risky? We would as well refuse to live—because that is risky too.

June 2004

APPENDIX 4

Memorandum from Dr Mark R Sims

ROLES IN BEAGLE 2 PROJECT:

Study, Proposal, and Project Manager July 1997 to October 2000
Beagle 2 Mission Manager (Responsibilities instruments, science oversight of project, flight operations) October 2000 to date

EXECUTIVE SUMMARY

Beagle 2 represented at its conception a unique opportunity for the UK to explore Mars. Funding, development problems and interface constraints caused many stresses on the program. Design, development and schedule problems caused industrial costs to rise during the programme. There was no opportunity to retire risks early in the programme because of a lack of early funding. Despite these problems Beagle 2 was designed, built and flown successfully to Mars and its subsequent failure following or during landing may in fact by due to bad luck compounded by the highly constrained mission requirements placed on it.

SUBMISSION TO SELECT COMMITTEE

Background

1. When, in 1997, ESA announced Mars Express, a unique opportunity occurred. Beagle 2 was the UK-led response, with its proposal to design and build a small probe to be carried to Mars (on Mars Express), which would then separate, and descend on to the Martian surface to search for evidence of life using highly innovative scientific instruments.

2. Mars Express was designed as an Orbiter with a limited capability to carry a lander as a "hitchhiker". It was evident from the start that the ESA priorities were to maximise the chances of success for the Mars Express mission not taking Beagle 2 into account and to be satisfied that Beagle 2 did not hazard Mars Express, either technically or in terms of the cost and schedule. These factors and the standard mission approach, see 3., led to a mindset within ESA of an "instrument" role for Beagle 2. It should be noted that from 2000 ESA was tasked by BNSC to act as a technical customer on their behalf.

3. The norm for ESA space science programmes is for the Agency to provide and fund the main mission assets-launcher, spacecraft, operations-and for national agencies to provide and fund the scientific instruments, generally through academic space research groups, often working with industrial partners. The Beagle 2 project was constrained to follow a similar approach in line with this practice, although the Beagle 2 team from project start recognised the probe as a complex, innovative spacecraft and adopted what we believe was an appropriate management and development strategy. It was also acknowledged that the mission was "high risk" and that development problems and solutions might increase the risk, however all efforts were made to minimise risk firstly by rigorous analysis, and secondly testing where possible.

4. The Beagle 2 project was conceived in 1997 before ESA's formal Announcement of Opportunity for Mars Express. Industry expertise was used from the project start to ensure a viable technical design and management approach and to draw on relevant previous experience in UK industry. Project management was led, initially, from the University sector (see 6,7), during feasibility studies, proposal and definition studies 1997–99. Management for the probe was then transferred to industry for the subsequent development and hardware manufacture and testing phases, whilst management of the scientific payload was retained within the University groups, following practices that are in common use in the UK for other ESA space science missions.

5. Beagle 2 was required to fit within a very constrained mass (60kg) and volume limit. Consequently only very limited margins were possible, forcing Beagle 2 to adopt innovative engineering solutions to try and ensure a robust design.

Management Arrangements

6. In the early stages of the project, project management was exercised by a management team led by the consortium leader, Professor Colin Pillinger, with representatives from the University of Leicester and the industry main partners. My role was that of co-ordinating the various inputs, assigning actions and producing integrated schedules and cost summaries.

7. Following provisional proposal acceptance in December 1998 and initial kick off meetings, in April 1999 a full time industrial project manager John Thatcher (of Astrium) was appointed and tasked with development of the probe and all industrial aspects of the project including associated funding issues. The academic groups were responsible for provision of the instruments, science oversight of the design, planetary protection and PR (communications), and following launch, management of the operations. John Thatcher and I worked in close co-operation with the Chief Engineer Dr Jim Clemmet (then at Astrium) to ensure continued development of the probe.

8. Once the project had been approved by ESA to proceed as a hardware development, in late 1999, a Beagle 2 Board, consisting of high level representatives from the various consortium member organisations, was formed at the request of BNSC to monitor technical progress, schedule and cost. All key mission-critical cost and technical issues were referred to the Board. ESA and OST were represented on the Board, along with the Open University, University of Leicester, Astrium and BNSC. I was not a member of the board but attended when requested to present reports on status, schedule and technical progress.

9. ESA set up an independent review (25–29 September 2000) of Beagle 2 under the chairmanship of John Casani from NASA, JPL. On the recommendation of this review, industry was tasked with the management of the whole probe procurement under the control of the Astrium industrial project manager. This was further formalised via "prime contractor" contract placed with Astrium following the cost review in June 2001, see 21. Following implementation of the recommendations, I moved into the role of Mission Manager with prime responsibilities of instrument development and preparation for, and implementation of flight operations.

10. The Beagle 2 project team responded to all the Casani review recommendations within its remit. These recommendations were translated into agreed actions and tracked, with their status regularly reported to ESA and discussed at the project management meetings attended by ESA (six issues of the response summary document were produced, provided and reviewed). Much was gained by implementing many of the Casani review's recommendations and the design and schedule became more robust as a result. However the fundamental difficulty associated with the mass and volume constraints on Mars Express remained.

Cost Factors

11. Management and Costings of the project were based, throughout, on a formal Work Breakdown Structure and a schedule. Both of which were updated as required throughout the project history.

12. An initial costing based on estimated industrial and academic costs conducted in March 1998, at the time of the initial proposal submission, indicated a cost of £38.3 million, £25.9 million UK, £8.2 million German contribution and £4.2 million Italian contribution. At this point Beagle 2 included a rover to be provided by DLR Germany and Italian contributions to the on-board electronics and sample handling. The mass of Beagle 2 at this point was 110kg. Italy subsequently withdrew from the project. Initial industrial costs were based on written rough order of magnitude (ROM) estimates. The entry descent and landing system was estimated at £9 million (Martin Baker Aircraft Company) and the lander support systems (Matra-Marconi Space Systems now EADS-Astrium) at £3.7 million, assembly and test £3.4 million, payload £5 million, management and systems engineering at £4.8 million. Given the novel nature of Beagle 2 it is fair to say that all parties had great difficulty estimating accurate costs.

13. In July 1998, following descoping of Beagle 2 to fit within the revised Mars Express mass constraint of 60kg, the total cost was re-estimated at £33.1 million (including foreign contributions of £3.7 million on a no exchange of funds basis). The entry, descent and landing costs had risen to £10.2 million and lander costs to £7.2 million (having taken on some of the previous foreign contributions and having become more detailed). Assembly and test costs were £2.8 million with payload costs at £5.7 million and management and systems engineering at £3.5 million. By December 1998 the lander costs had been revised upwards to £8.7 million.

14. Operations costs were not included in the July 1998 and the July 2000 estimates, these costs being considered in full detail for the first time in mid 2000. Funding for operations planning did not become available until 2002, see 31.

15. On 26 August 1999 PPARC awarded a total of £2.7 million (out of a funding application of £3.2 million) for support of the Beagle 2 instruments (following a review 28 July 1999). The proposal to PPARC included a management plan, cost justification and risk assessment for the whole project. Grants were awarded to the Open University, the University of Leicester and University College London (Mullard Space Science Laboratory (MSSL)). The shortfall in instrumentation funding was made up by contributions from the institutions, unpaid overtime and various companies/organisations donating or providing items either at reduced cost or in some cases at no cost.

16. On 9 September 1999 BNSC confirmed an offer of sponsorship of £5 million to cover initial industrial development costs following Lord Sainsbury's announcement of 3 August 1999.

17. *Arrangements seeking funding for Beagle 2 via sponsorship were the responsibility of the Open University. These activities were kept entirely separate from the technical and scientific development of the mission.*

18. In July 2000 total cost excluding operations and science data analysis was £33 million: £10.1 million for the entry descent and landing system; £13.4 million for the lander support systems (now including integration and testing, management and systems engineering); £6.7 million for instruments and a foreign contribution (Germany, Switzerland) of £2.8 million.

19. ESA SPC approved total funding of 24.2Meuro towards Beagle 2 following its 92nd meeting on 11–12 October 2000. This consisting of 2.2Meuro for contributions in kind to be funded by the Agency, 3.8Meuro

for the Melacom telecommunications package, 2.2Meuro for agency resources to manage both industrial and science procurement and 16Meuro for Beagle 2 for which the UK would need to compensate the ESA science programme.

20. After October 2000 Beagle 2 I ceased to have a role in cost summaries and discussions (except 21 below) as they became the full responsibility of the industrial project manager. I retained responsibility for the Leicester instrument programme and the Beagle 2 operations costs.

21. An industrial cost review was called for by BNSC in June 2001 and I was requested to undertake the review having been assured that I would be given full access to all industrial costs, however no access was given to historic costs. A total industrial cost to completion of £42.5 million, not including instrument or operations, was identified comprising probe industrial costs of £35 million, a risk contingency of £4.8 million, £1.9 million for planetary protection and £0.8 million for the interface electronics to the Open Universities GAP experiment. During the financial review it was noted that only a limited number of sub-contracts were firm fixed price. In particular many of the larger subcontracts, especially many of those related to "high risk" items for the entry descent and landing system, were on a cost plus basis as most of the US suppliers were unwilling to enter into Fixed Price Contracts.

The following reasons for cost increases were cited during the course of this review:

- a compressed schedule requiring large amounts of industrial manpower to achieve;
- a compressed schedule resulting from a stretched design phase due to excessive environmental loads imposed by Mars Express, and redesign of the probe leading to delays in freezing the design of Beagle 2, along with interface and development problems on critical Beagle 2 systems;
- commercial requirements and pressures within various sub-contractors;
- unplanned costs for example extended access to the Plumbrook Vacuum test facility for airbag tests; and
- a lack of definition of some requirements and late changes to interfaces as a result of test or design changes.

22. Industrial costs increased further when a new parachute was required because of problems with the airbag design set a new requirement for a lower landing speed. ESA, DTI via BNSC and the Open University funded the cost increases and the project continued through to delivery and flight operations. Astrium were placed on a firm fixed price contract despite some US companies continuing to work on cost plus contracts.

Technical and Scientific Management Issues

23. Beagle 2, led by industry with inputs from the academic team, established a structured development plan in order to control its design, development, build and test. ESA complimented Beagle 2 on its Design, Development and Verification Plan. Changes to the plan deemed necessary due to cash flow constraints and increases in cost (largely related to airbags, parachute redesign and assembly, planetary protection, integration and verification issues) caused the development plan to be revised on several occasions. This is not unusual in a dynamic fast moving project. Updated plans were consistently reviewed and agreed with all members of the consortium and ESA prior to implementation. ESA attended Beagle 2 project management and review meetings whenever possible and Beagle 2 gave ESA full technical visibility of the project at both system and instrument level. Some key tests originally planned by the Beagle 2 team had to be deleted. Priority was given to mission critical developments (main parachute, airbags, electronics, software), and to the completion of the assembly and test programme.

24. USA suppliers for critical components were selected by Beagle 2 by Martin-Baker (in particular for the entry, descent and landing system components) and Astrium to provide maximum use of existing world-wide expertise and to minimise as much as possible development risks and the schedule.

25. USA International Traffic in Arms Regulations (ITAR) and Intellectual Property Rights (IPR) issues prevented complete oversight of the probe design by the academic members of the team, in particular on issues relating to the Entry Descent and Landing System, the airbags, and their gassing system, the pilot parachute and its deployment device. This limited any input from the academic side into a number of critical areas. The University of Leicester was not named on any USA Technical Assistance Agreements (TAAs), which greatly limited my oversight of these systems. The rationale given was that naming of academic groups would hinder the progress though the USA State Department and many technologies were proprietary to companies. The Open University was named at a latter date on TAAs and export licenses to support final assembly operations at the Aseptic (sterile) Assembly Facility (AAF) at the Open University.

26. Instrument development proceeded through to delivery with some problems and some impacts on the overall schedule. Problems were of a technical and developmental nature.

27. There was no opportunity to retire risks early in the Beagle 2 programme because of a lack of early funding.

28. The identification of Beagle 2 as a "hitchhiker" and instrument on Mars Express led to an uncomfortable working relationship with the Mars Express prime contractor Astrium Toulouse France. They stuck rigidly to this philosophy and insisted throughout on Beagle 2 adhering to outline interface requirements set at kickoff meeting in January 1999 and made only minimal allowances in terms of interface definition or re-analysis of mission requirements to ease development or schedule of the lander.

OPERATIONS

29. Under my leadership as Beagle 2 Mission Manager the Beagle 2 team has conducted a full analysis of the possible technical reasons for failure and documented the flight operations and search conducted for the probe following its successful flight on board and its ejection from Mars Express (19 December 2003). We have also compiled a "lessons learned" list. It is the project's intention that both should be published and made freely available.

30. Flight Operations was funded by grants from PPARC together with a contribution from the National Space Centre (£1 million) through its status as a Millennium Commission Landmark Project. By setting up the Beagle 2 Lander Operations Control Centre (including its required hardware and software) in a major science visitor centre widespread public access was provided to a live space mission as it unfolded. Considerable public interest was generated in Beagle 2, in part through this innovative approach to mission operations.

31. Following a review on 23 April 2002 PPARC awarded £2.05 million (against an application of £2.54 million) for Beagle 2 operations, with funds again split between the three academic institutes Open University, University of Leicester and MSSL. Mission operations and data analysis plans were revised to fit within the available cost envelopes. PPARC funding included sub-contracts for industrial support during the mission and funds for data analysis following landing. Unspent balances on these grants have now been re-assigned by PPARC for further scientific developments drawing on the experience gained from Beagle 2.

32. The relatively late funding of mission operations, only 14 months prior to launch placed large schedule and development pressures on the operations team. However mission operations preparation and flight operations were accomplished and Beagle 2 was successfully operated from launch 2nd June 2003 through to ejection from Mars Express on 19 December 2003. Beagle 2 was operated on 10 occasions during the cruise to Mars and was nominal at ejection.

COMMENT ON THE ESA COMMISSION OF ENQUIRY

33. Analysis of possible failure scenarios was provided to the Commission for their consideration. My face to face interview with the Commission lasted on 25–30 minutes. No direct interviews were held with the Beagle 2 Chief Engineer Dr Jim Clemmet. There was no feedback session(s) given to the Beagle 2 team prior to finalisation of the Commission's recommendations.

CONCLUSIONS

34. Exploring Mars is hazardous and approximately two out of three of all space missions sent to Mars have not succeeded. It has been said by NASA and others that the difference between success and failure on a Mars mission is very small. We cannot rule out the possibility that Beagle 2 may simply have been unlucky either through encountering unexpected atmospheric conditions or something as simple as landing on a pointed rock on its first impact with the surface. Therefore it cannot be said without question that the failure of the mission was due to design or management flaws.

35. My contention is that Beagle 2 was designed to be as robust as possible within its interface, schedule and funding constraints and engineered and constructed in a professional manner. However, I fully agree with the ESA Commission of Enquiry that an orbiter and lander such as Mars Express and Beagle 2 should be developed as a single integrated project and, had that been the case, some of Beagle 2's technical management problems may have been solved more easily.

June 2004

APPENDIX 5

Memorandum from Eur Ing Barrie Kirk

EXECUTIVE SUMMARY

A fair and balanced view of the Beagle 2 project has yet to emerge. As the EADS Astrium Project Manager during the latter stages of the project, I hope that I can assist the committee in correcting this situation with a personal input to your inquiry which is distinct from that of my former company.

The funding and organisation of the project developed in unusual circumstances and led to an extremely demanding final 24 months to launch for the project team. However we managed the tasks pragmatically and delivered the spacecraft in time after proper and comprehensive design, development, manufacture, assembly and test phases and after a series of rigorous external reviews.

The engineering challenge posed by the mission phase from separation from Mars Express though to first transmission from the Martian surface must be put into its proper perspective. I consider it at least an order of magnitude more difficult than taking a spacecraft from Earth into Martian orbit. This is not to say the project team was less than totally committed to success. Only that we also fully understood the difficulty of what we were attempting. To suggest that management and organisation difficulties and indeed loss of engineering discipline were contributory factors to the disappointing outcome is quite untrue.

Beagle 2's achievements were substantial. The early mission phases were successful. A wide range of new and advanced technologies with both space and potentially terrestrial applications have been developed. The project stimulated UK public interest in science and technology particularly with the young. All of these are investments for the future. The cost of the spacecraft to the UK taxpayer has been significantly exceeded by the return to UK companies. In the fullness of time I do not doubt that Beagle 2 will be justly valued as a major step forward in answering questions about life beyond Earth.

1. Introduction

1.1 Much of what has been reported or implied about Beagle 2 since February 2004 has been based on speculation and misrepresentation. In particular some of the comments from ESA have been distorted and an unbalanced picture has emerged.

1.2 As EADS Project Manager between July 2001 and my retirement in October 2003 I was responsible for the management of the spacecraft, leading the industrial participation and coordinating with other parties involved in the programme including the Universities, the Mars Express (MEx) project and the various agencies. I participated in all of the major events, reviews and meetings during that period. These are my own personal views as distinct from those of EADS Astrium on some of the main issues together with some key facts.

2. The Technical Challenge

2.1 You wish to focus on the funding and management aspects of the project. However the reason you are investigating at all is that Beagle 2 failed to communicate from the Mars surface. So first the engineering challenge of achieving this objective must be placed into a proper perspective.

2.2 Having worked in space for 30 years on telecommunications, earth observation and science missions I know that space is an unforgiving environment. Even in the mature telecommunications sector, insurance premiums are still significant. MEx was the first ESA planetary mission and their operations staff were performing critical operations at a great distance from Earth so there were risks. However from the engineering viewpoint the challenge of orbiting Mars is not so great. Most of the technology is derived from developments with 20–30 years of heritage.

2.3 The technology for getting an ultra compact, complex spacecraft travelling at 21,000 kph down onto the surface and safely transmitting is quite different from that on MEx and is much more demanding. Beagle 2 had to separate itself from MEx with many millions of kilometres still to travel. Many functions were required to happen autonomously in sequence in less than nine minutes after entering the atmosphere and many more within the next hour in order to ready the lander for first transmission. Moreover the conditions in the atmosphere and on the ground were far from certain. Retro propulsion as used on the US landers was not feasible because of mass limitations. Thus Beagle 2 was dependent on the very thin Martian atmosphere to dissipate well over 99.99% of the spacecraft's kinetic energy. By any standards a tough challenge and in my view at least an order of magnitude greater than getting a spacecraft from Earth into Martian orbit.

2.4 This is not to say that the project team did not believe the mission could succeed. Indeed the commitment of the project team to success was total. It was just we were also realistic about the level of risk particularly during this phase of the mission. Some seem now to believe that the risks were played down. I don't know by whom as I always heard it correctly referred to as a high risk but high science return mission.

3. Funding

3.1 The financing for the spacecraft excluding instruments was only completed by BNSC/OST, the Open University, ESA and EADS Astrium in June 2001 after a costing hiatus earlier in that year. The cost at completion including ESA supplied hardware was around M 44 GBP to which the UK taxpayer contributed around 50%. The return to UK companies to develop the necessary technology, expertise and facilities was somewhat higher at 75% representing a significant positive cash flow into the UK economy. EADS Astrium contracted under firm fixed price conditions and an overspend included in the above figure was absorbed by the company in addition to their original underwriting commitment.

3.2 The overall funding profile was by June 2001 very rear loaded. Only 18% had been spent over the three prior years because of funding uncertainties. That this was an inadequate percentage to mitigate technological risks became clearer with time. The remaining 82 % of the funds were spent mostly within the 18 months up to delivery.

3.3 Development of the airbag and its gassing system were performed under cost plus conditions by the leading US companies with Pathfinder experience. These used specialist ITAR constrained technology and eventually consumed a seemingly disproportionately high percentage of the total spacecraft budget (around 18%). Amongst other things this demonstrates the considerable development and testing performed in moving from Pathfinder technology to Beagle 2.

4. Programmatics

4.1 The initial funding constraints led to an extremely compressed schedule with development model testing slipping in parallel with the flight model. The overall test programme had to be adjusted with tests being switched to different models. However we did not cut corners were nor lose engineering discipline as recently stated by ESA.

4.2 The need to perform final spacecraft integration in extreme biologically clean facilities was new for Europe. This put additional strain on the latter stages of the schedule with activities taking about three times longer than in a typical spacecraft integration environment.

4.3 Airbag developments were successfully completed by July 2002 and flight proving tests of airbags and gassing system by January 2003 in parallel with spacecraft final integration.

4.4 All of these factors were far from ideal and the schedule margins were always tight but we did succeed in delivering a performant and verified spacecraft to MEx one week ahead of their need date in February 2003. ESA convened a Flight Qualification and Acceptance Review and approved the spacecraft for launch some five weeks later.

5. Organisation/Management

5.1 Although Professor Colin Pillinger was leading the project and its Principal Investigator he was not responsible for managing activities. The project management set-up although complex on paper was made to work by the pragmatism of the various individuals involved. I chaired fortnightly meetings throughout this period with 10 managers and senior personnel from the Open University, Leicester University, ESA, BNSC and EADS Astrium regularly attending. This was successful in coordinating activities, identifying problems and keeping all parties up to date particularly regarding the tight schedule.

5.2 I am sure nobody involved would want to repeat of that tight programme. However at all times the highest professional disciplines were maintained. The main risk that we were running was a failure to deliver the spacecraft to MEx on time. In the event this was achieved and there are many positives to be learnt from the experience.

5.3 ESA have suggested that we took our eye off the ball in chasing sponsorship. They were not one of the three underwriters and were not party to the facts. Colin Pillinger was the public face of the Beagle 2 and was indeed active in this area. However the project management, engineering and scientific activities continued without disruption. I was the only person from the hundreds in the industrial team involved in any sponsorship meetings between July 2001 to April 2003 and my involvement was limited to one half day meeting in July 2002. Project resources were so focussed that this issue was handled offline. This may well have reduced the chances of achieving sponsorship. I am personally of the opinion that it was more to do with the risk of negative publicity for the sponsors such as this inquiry. This may severely limit but should not entirely preclude such funding possibilities in the future.

6. Causes and Lessons

6.1 Lack of hard evidence to date prevents a "most likely" cause for the failure of Beagle 2 to communicate from being identified. Surface imaging may yet alter this view. Based on recent data, there is at least *prima facie* evidence that the atmosphere could have been much thinner than we were expecting. As Beagle 2 was so dependent on the already very thin atmosphere this could have been a key factor. A single point type failure within the spacecraft cannot be ruled out with such a complex series of mechanical and electrical functions having to occur within a very short period.

6.2 At EADS Astrium we completed a lessons learnt exercise soon after launch. The failure of Beagle 2 to communicate does not much change those conclusions. A streamlined organisation and up front funded programme are certainly necessary. The lander needs to be classified as a spacecraft and as such an essential part of the total mission and not as an optional instrument. The development status of technology need to be correctly assessed and mitigated early which requires advance funds. I would advocate building a second flight (qualification) model of the spacecraft and sending it through an end-to-end simulation sequence from separation to first transmission rather than performing the tests separately as we did on Beagle 2. Very much much easier said than done within the limitations of testing on Earth. For instance there is the difficulty of simulating high velocity atmospheric entry and our type of airbags only perform in near vacuum. These factors may influence the design of future spacecraft which could also benefit from a reduction in the number of potential single point failures. All of these these are valid lessons but none will guarantee success. To

suggest that simply putting ESA in control would achieve that result would be a complete illusion. Landing on Mars will remain a high risk venture for the foreseeable future whatever actions and improvements are taken.

7. What has Been Achieved

7.1 In some quarters a binary view of the projects has been presented with MEx a 100% success and Beagle 2 a 100% failure. This is a totally simplistic and neither is true. Most of the MEx's technology already existed and needed no development. For example the spacecraft's power subsystem, AOCS, TTC, structure, thermal control and deployable solar arrays were all derived from technology from communications spacecraft in the late 1970s. The bi propellant propulsion and high gain antenna technology date from in the 1980s. This was a correct policy for that particular mission but it does mean the technological as opposed to science return is quite modest.

7.2 Beagle 2 was not finally successful in obtaining science data from the surface of Mars. However many key milestones had been achieved successfully. Spacecraft equipment such as the spin up and ejection mechanism, miniaturised integrated electronics, robotic instrument arm, high strength impact resistant composite structure, wide beam patch antenna, miniaturised transceiver, advanced main parachute, radar altimeter trigger, motorised solar array and time critical software were all developed by UK companies and flown for the first time on Beagle 2. In addition we can already foresee some terrestrial applications. We developed an expertise and facilities for sterilising, assembling and testing the flight spacecraft in biologically clean conditions for the first time within Europe.

7.3 On the wider front the project has raised public interest in science, technology and space exploration to unprecedented levels within the UK particularly amongst the young. All of these are investments in the bank for future use.

8. Support from the Parties

8.1 I considered that BNSC with their limited technical resources were 100% constructive throughout my involvement in the programme. In particular they assisted with the new main parachute. They put their head above the parapet and should not be criticised for so doing.

8.2 The academic/ industry interface worked well with close dialogue between EADS Astrium, the Open University and Leicester University and we could not have designed and built such a complex and compact spacecraft without it. Other unexpected entities such as the radio telescope community emerged to help during the programme and there are many opportunities for closer cooperation in the future.

8.3 EADS Astrium certainly underestimated the risks in committing to a firm fixed price contract. However they transferred significant resources to Beagle 2 to ensure the work was completed professionally and on time and swallowed the overspend. Not once was it suggested to me that corners be cut to save costs or maintain schedule nor were they. Around 95% of the industrial companies and suppliers approached were delighted to become involved. Many of the smaller participants are immensely proud of their participation in a leading edge project and rightly so.

8.4 The people we dealt with at ESA on a day-to-day basis were always enthusiastic and helpful, they recognised Beagle 2's challenges and wanting the mission to succeed. However senior managers with one exception were always reticent. Their life would have been much easier if Beagle 2 had disappeared from MEx much earlier than it did. Certainly not a big picture view especially considering the funds allocated to them for Beagle 2. Their reluctance to release mass, withdrawal from the new parachute development and recently lack of provision of any surface imaging to assist in the search typifies the problem.

8.5 In contrast NASA/JPL although not directly involved have been very helpful particularly in searching for signals (from Mars Odyssey) and providing images (from Mars Global Surveyor) whilst progressing their own intensive missions on the surface.

9. Conclusions

9.1 Beagle 2 should be viewed as substantial but not complete success. I am quite sure that within time it will be rightfully considered as a major step forward in answering fundamental questions concerning life beyond Earth. Meanwhile a wide range of technologies have been developed for future missions. Public perception of space science and engineering within the UK has been substantially and positively altered. Within the UK, close and effective working relationships have been formed between BNSC, the Universities and industry with more than 40 subcontractors and suppliers many contributing to a space programme for the first time. These are no mean feats.

9.2 My first experience on a space project was OTS 1 the first European geostationary communications test satellite. This spacecraft was lost during launch. The response from ESA and industry was immediate. There was no talk of giving up or the task being too risky and difficult. A second satellite OTS 2 was assembled and launched within eight months and has subsequently proved to be one of the cornerstones of successful worldwide telecommunications. That is the type of response that we now need. It was sad to see

that a lander was recently removed from the possible Bepi Colombo mission to Mercury in favour of two orbiters. This may have scientific justification but it does suggest that we allow ESA to set our sights too low. Beagle 2 has shown what can be achieved by adopting a completely different mindset.

9.3 I was delighted to become involved in such a challenging project and my view has not changed. The whole project team did an amazing job. A former British Prime Minister is quoted as saying "The men who try to do something and fail are infinitely better than those who try to do nothing and succeed". Colin Pillinger is certainly not in the second category and the rest of us should not allow ourselves to be so categorised.

June 2004

APPENDIX 6

Memorandum from EADS Astrium Limited

EXECUTIVE SUMMARY

1. This submission addresses the management issues surrounding Beagle 2 in the context of UK Space Policy. We place the origins of Beagle 2 in the context of its difficult birth; we discuss the BNSC/ESA Commission of Inquiry, identify the positive impact that Beagle 2 has produced, and draw lessons for UK space policy in the future. We submit that the most urgent issues relate to the necessity to build on the positive aspects of Beagle 2 by re-inforcing the UK national space programme and earmarking new funding of £30M per annum for the UK to play a leading role in the long term planetary exploration programme of ESA ("Aurora").

CONTEXT—1997

2. In our view, it is impossible to divorce the origins of Beagle 2 from the context of international space policy in the late 1990s.

3. In the US, NASA is responsible for space science including space telescopes such as Hubble and planetary exploration. During the 1980s the number and frequency of launch of NASA scientific satellites diminished as the unit cost grew to the billion-dollar level. Where these missions were successful (Hubble, the Galileo Jupiter mission, the Magellan Venus Mapper) the scientific returns were great, but all suffered financial difficulties along the way. Then, in 1992, one of these billion dollar missions, Mars Observer, exploded on arrival at the Red Planet. The reaction of NASA was to make a sharp turn in policy towards something that became known as "smaller, faster, cheaper". NASA's focus turned towards more frequent and modest missions. Each one would answer highly focused scientific questions but taken together would contribute towards a coherent long-term programme.

4. "Smaller, faster, cheaper" implied relaxing some of the traditional aspects of spacecraft project management and streamlining documentation and testing procedures. More advanced technology was employed as it was felt that an increased risk on a lower cost, single mission was acceptable.

5. The mantra found ready acceptance in the space community worldwide. To scientists, it offered the chance of securing more data, more quickly. To policy makers, it seemed a short cut to controlling budgets and delivering better "value for money" to taxpayers.

6. This approach had some early successes, most notably the DoD/NASA Clementine Moon mission of 1994 and the Mars Pathfinder mission of 1996. Pathfinder returned NASA to the surface of Mars for the first time since 1974. The daily movements of Pathfinder's rover, Sojourner, were followed by hundreds of millions of people via the new phenomenon of the World Wide Web.

7. "Smaller, faster cheaper" ultimately proved to be a dead-end for NASA following a series of mission failures and cost over-runs, most notably the unrelated losses in 1999 of the Mars Climate Orbiter and then Mars Polar Lander. The failure reports of these and similar missions make interesting reading and have resonance with the recommendations of the Beagle 2 report. The net effect has been for NASA to take a more cautious approach, exemplified by the dual launch of the Mars Exploration Rovers in 2003, carrying a total price tag of over $800M.

ORIGINS OF BEAGLE 2

8. For science missions, ESA is responsible for building, launching and operating the spacecraft. However, the individual national agencies are responsible for providing the scientific instruments carried by those spacecraft and for exploiting the science generated. In the UK, PPARC has this funding responsibility.

9. "Smaller, faster, cheaper" had a significant impact on UK thinking. Faced with slowly diminishing overall science budgets in the 1990s, PPARC was an initially lonely voice in the ESA community demanding efficiency improvements in the long running ESA space science programme.

10. Ironically, ESA's first lower cost mission was Mars Express. This came about as a quick response to the loss of a Russian mission ("Mars 96") that was carrying instruments from various European countries. Faced with its budget limitations, PPARC was unable to support any instrumentation. (Mars Express, the "mothership" of Beagle 2, went into orbit on 25 December 2003 and has generated scientific data both of extraordinary quality and quantity.)

11. However, in the original Mars Express Announcement of Opportunity, there was the possibility of carrying one or more landers. An international peer group selected Beagle 2 as scientifically the most interesting of the proposals.

12. A lander was regarded by ESA as an "instrument" even though its cost and complexity place it far closer to a spacecraft. Therefore—as with the lander "Philae" aboard Rosetta—which later suffered technical and budget difficulties—a national agency (or agencies) was expected to pay for it.

13. However, a lander (costing tens of millions) is far more than a scientific instrument (usually costing less than £10M). It involves entry, descent and landing systems, power and computer support, radio telemetry and ground infrastructure completely out of the experience of the laboratories and universities who normally build instruments for PPARC. PPARC never had and still does not have the budget, resources or technical management capability to manage such a project. In fact, Beagle 2 was in some ways more complex than Mars Express, and certainly required much innovative technology, especially due to the constraints of mass and volume.

14. BNSC, as a central coordinating office for space activities, also does not have a project management capability. This situation may be contrasted with France, Germany and Italy, which have significant national programmes and the associated management infrastructure. This is not to diminish the enormous personal commitment and efforts of all those at BNSC and PPARC who laboured long and hard to make a success of Beagle.

15. However, the indominatable Colin Pillinger was not put off. In the absence of a single organization to weld the scientific, technological, educational and visionary aspects of Beagle 2 into a single act of funded policy, he developed a kind of "boot-strapping" approach. This involved a jigsaw of PPARC funding for instrumentation; some DTI pump-priming funding; contributions in kind from industry (especially at the start) plus hoped for commercial sponsorship (underwritten by academic, industrial and Government bodies).

The ESA/BNSC Commission of Inquiry

16. We were desperately disappointed at the failure to communicate with Beagle 2 after its landing last Christmas. We were keen to support the Commission of Inquiry (CoI) to learn as much from this experience as possible given the absence of information since its ejection from Mars Express.

17. We provided many documents and hosted two separate days of review at Astrium in Stevenage with the CoI. The initial day was more of a general introduction and was wide ranging. The second day, three weeks later, was focused on several technical areas. The discussions were positive and constructive. The CoI members were highly complimentary concerning the attitude and commitment of Astrium and its subcontractors. From that time, there was no contact with the CoI. Informal feedback from BNSC and members of the CoI was provided to Mike Healy regarding the recommendations contained within the confidential report. No one at Astrium has seen this report.

18. We believe the process followed by the CoI was flawed, even if the resulting recommendations are generally sensible. We are particularly uncomfortable to be in a position where technical conclusions have been drawn, based apparently on new analysis and opinion, without having the opportunity to examine these claims or study the new analysis that has been produced. We feel that an essential step was omitted in the review, whereby new analysis is shared with the project team to offer the opportunity not only to understand and appreciate how certain conclusions have been reached but also to modify these conclusions where appropriate.

19. On the key recommendations:

- We very much agree that the source of most of the major problems on Beagle 2 was the lack of funding in the early phase of the programme. This prevented a timely and smooth build-up of the industrial team. It also meant that technical risks were not retired until late in the programme.
- We agree that the non-classical "partnership" that developed between Government, industry and scientists, as a consequence of complex funding mechanisms, was not a sufficiently robust approach compared with classical project structure where there is a clear management chain.
- It is very clear to us that the mass and volume restrictions placed on the lander added risk to the project. Beagle 2 suffered from being treated as simply an instrument on-board Mars Express. No overall optimization of the orbiter/lander combination was attempted. Such optimization could have greatly improved the chances of success and the understanding of any problems encountered during the entry, decent and landing sequence.

— The recommendations also highlight the lack of key European technologies. In fact, we had to make use of US expertise and technologies to implement Beagle 2. Perhaps one of the major steps forward that Beagle achieved was to drive a very rapid acceleration through the learning curve for planetary landers. It is vital to continue the investment into these skills and capabilities so that the UK can lead Europe in developing a stronger capability in this key area for future space exploration.

20. Nonetheless, and despite the Inquiry's recommendations on some technical points, we do not believe a convincing explanation has been revealed for the loss of Beagle 2. Thus we strongly believe that a technological investigation including further testing of some elements of Beagle 2 should be urgently undertaken. Funding for this should be a rational precursor to future UK involvement in planetary exploration.

Impact and Benefits of Beagle 2

21. Beagle 2 galvanised both the UK space community and the general public. There were substantial contributions from many companies: EADS Astrium contributed £5 million alone. Why? Several reasons emerge:

— Robotic planetary landers will be an essential part of the World's space programme over the next few decades and UK industry aimed—and still aims—to participate in this area ahead of European competition.

— Beagle 2 genuinely drove the technical state-of-the-art in areas of miniaturized instrumentation, electronics, structures and operational infrastructure.

— The UK space industry wanted to have a flagship to connect its successful but low visibility activities with the general public, not least to address in a practical way the key skill shortages from which it suffers.

22. Evidence that Beagle 2 succeeded in all these areas is not hard to find:

— ESA has been planning for three years its "Aurora" Mars exploration programme. Out of nine major studies awarded in competition by ESA for planned Aurora missions, UK industry is leading three and is involved in three others, significantly assisted by Beagle 2 experience.

— The Beagle 2 team members have proposed scientific instrumentation for the first Aurora mission that has been selected after international review.

— The Gas Analysis Package (GAP) specifically developed by the Open University for Beagle 2 has been successfully applied to medical applications.

— According to a MORI poll of the general public, 72% believe Beagle 2 was worth attempting, and 66% believe it is worth trying again. 70% believe that involvement in space encourages young people to become scientists and engineers.

23. Our impression is that the British public has a mature attitude towards space exploration. They know it is hard, but they want the UK to stick with it. They expect us to learn the lessons and move on.

Policy Lessons of Beagle 2

24. It is important to realize that—in financial terms—Beagle 2 was a small project. UK industry has successfully delivered far larger projects such as the 500M€ Envisat environmental monitoring satellite; civil and military telecoms projects, as well as large pieces of ESA science spacecraft. At present, EADS Astrium Ltd is building Earth observation, Space Science, civil and military telecommunication spacecraft worth more than 1B€.

25. Thus, it would be a false conclusion that the UK lacks the technical or management capability to undertake a project such as Beagle 2. Rather, the combination of the ESA/national funding principles in force at that time; the lack of a UK space agency of the classical type (with its own budget) and extreme mass and schedule constraints all conspired to raise the risk level of the project.

26. However, we believe the fact that Beagle 2 was a risky project was fully understood by everyone involved: the raw statistics show that two in three Mars missions fail. In the prevailing context of "smaller, faster, cheaper" the risk of failure was thought acceptable given the high scientific return. It should not be overlooked that Europe has succeeded on its first attempt at a Mars mission with Mars Express, and that this is a remarkable achievement.

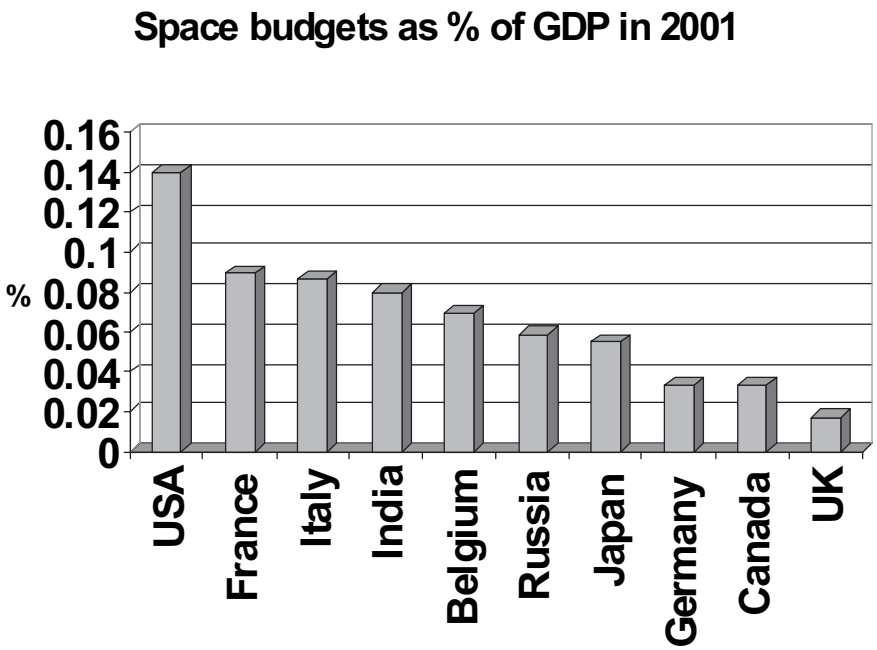
27. From the perspective of the UK space community, Beagle 2 came as a breath of fresh air. UK civil space policy is resolutely utilitarian. Its success is largely judged on the development of applications that lead to downstream benefits (direct broadcast television, local based services, weather forecasting, etc), making space technology quite invisible to the end-user.

28. Yet this approach denies the most striking aspect of space; it is exciting and risky, meaning that it appeals to the heart as well as the mind. To the general public it is one of the most positive and high visibility aspects of scientific endeavour. In fact, among young people, "science" and "space" are two different things. The first is "boring" and the second is "cool".

29. In most countries, cultural aspects are an accepted part of space policy. Acceptable objectives include: expressing national identity; inspiring young people to follow careers in technology; and generating a positive image for science. This applies not just to the US. In France, the hugely successful Ariane launcher programme is regarded as contributing to foreign policy as an emblem of French technological prowess. In Belgium, Spain and the Netherlands, their astronauts are national heroes. India has a far larger and more ambitious space programme than the UK, and China is now also a major player.

30. On the point of education and training, there is documentary evidence showing the dramatic correlation between the NASA budget during the 1960s and 1970s and the numbers of PhD students in mathematics, physics and engineering. The peak around 1970 corresponds to the "Bill Gates" generation that created the US high-tech boom of the 1980s.

31. This leads to the most fundamental message of Beagle 2: UK space needs an increase in funding to allow a reasoned but striking investment in those projects whose benefits are more than purely utilitarian. How much? First, consider UK space expenditure with those of a range of other countries (published data from Euroconsult, Paris).



32. To put these expenditures into more tangible terms: the UK spends about £3 per annum per head of population on civil space; Belgium spends about £10, France £15 and the US £30. Are all these countries wrong in their assessment of the importance of space and only the UK is correct? Not surprisingly, we think not. But in 2004, the Demos "think tank" reviewed UK space policy with an independent eye and concluded that the UK should have a target to increase its civil space spending up to the European average (ie a three fold increase) to once again become a strong player on the European stage.

33. What are the priorities? For most major countries, a strong national programme provides a foundation upon which their scientific and industrial communities are able to position for leading roles in the ESA programme. The lack of sufficient financial means to implement a national strategy covering scientific and industrial priorities has long been a weakness of the UK. Recent changes in the DTI have made this situation more difficult, as the small national technology programme has been eliminated. Evidence that all is not well can be seen by the fact that UK industry is now under-returned against our subscriptions to both the ESA space science and Earth science programmes.

34. It is ironic that Beagle 2 was a "UK national programme"—albeit one that required significant private sector and European investment. It occurred despite the system and clearly the system was poorly adapted to manage it. In the future, any national programme needs to be supported by an appropriate management infrastructure. If a national management agency is not available, the resources of ESA could be used. This is an approach followed by, for example, Belgium for its PROBA small satellite programme.

35. Given that both the US and Europe are planning a long-term commitment to planetary exploration and recognizing the demonstrable benefits of Beagle 2, the UK should strongly re-affirm its commitment to this area of space activity by immediately earmarking new funding for the ESA Aurora programme. This

new funding of about £30 million per annum over the next five years would allow the UK to take a leading role. Such an amount would raise the current UK civil space spend of £3 per year per head of population up to £3.50, so cannot be regarded as a wild or ill-judged increase.

36. Within a robust European programmatic and management context, this programme will deliver good science, create new technology in relevant fields such as fault tolerant software and autonomous robotics and inspire a new generation to train in science and technology, to the greater benefit of the economy.

CONCLUSION

37. History reveals many examples across British science and technology where an early investment has been wasted by a loss of nerve when problems arise. It would be tragic if Beagle 2 becomes no more than a footnote in the history of space exploration, while the rest of Europe forges onward in a partnership with the USA. This really would be the one way to waste all the investment (private as well as public) that has been made in Beagle. The UK should re-state its intention to be a significant player on the European stage by assigning additional funds to (i) strengthen the national programme and (ii) participate in the ESA's Aurora programme.

June 2004

APPENDIX 7

Memorandum from Professor Richard Holdaway, Rutherford Appleton Laboratory

1. As Director of Space Science and Technology at the CCLRC Rutherford Appleton Laboratory, I am pleased to have the opportunity to provide input to the Select Committee.

2. For reference, my department is the largest R&D space department in Europe, and probably has more experience of space science and technology, space system development and space project management than any other group in the UK, so we are well acquainted with the issues and problems of space project management.

3. From the outset, we appreciated the vision of Beagle 2 and many of the novel approaches being taken. It captured public imagination as never before, and was in any ways a flagship for innovation.

4. However, we had misgivings from the start, some of which are identified in the joint BNSC/ESA review recommendations.

5. In essence, our considered view and advice focuses on three issues:

5.1 The programme did not have a clear funding lead body. Funds were obtained from BNSC/DTI, PPARC and ESA, but no single body took overall responsibility. It is essential that all future programmes should be led by single body with clear overall responsibility and authority.

5.2 There was significant scientific and technical ability on the team, but questionable experience and professionalism in the overall management and technical leadership. There is a parallel here with what we saw in the early days of the Rosetta mission, where the same lesson was learned very late on and then not applied to Beagle 2.

5.3 Whatever funds were needed for the programme, they were not clearly identified at the start of the mission. It is not even clear that the project was peer reviewed scientifically before funds were committed. Future projects must identify clearly and unambiguously the level and source of funds required at the time of project approval, as is the norm for Research Council led projects, and those funds must be deliverable.

June 2004

APPENDIX 8

Memorandum from Dr Jim Clemmet, formally Chief Engineer for Beagle 2, Astrium Ltd

1. INTRODUCTION

Firstly, I should present to you the extent of my involvement with the Beagle 2 project. At the request of Mike Rickett, then the Director for Earth Observation and Science Division at Astrium Ltd, Stevenage, I joined the Beagle 2 project late 1998 as Engineering Manager for those areas of the project that Astrium were expecting to be responsible, ie prior to the start of the implementation and before its selection by the European Space Agency (ESA). As the responsibilities of Astrium evolved throughout the duration of the

programme, so did my responsibilities increase. My final role was that of Chief Engineer for Beagle 2. I left Astrium in September 2003 but have retained an involvement through a personal arrangement with the University of Leicester.

2. Summary

- Funding limitations, particularly early in the programme, threatened mission success.
- Beagle 2 should have been assigned an increase in its allowable mass early in the programme.
- Beagle 2 should have been classified by ESA as a Spacecraft, not an instrument, removing the need to seek private funding through sponsorship.
- Having supported the selection of Beagle 2 for the Mars Express mission, BNSC should have take an early role in resolving the financial difficulties of the project.
- ESA should have provided more positive technical support to Beagle 2.
- ESA should have promoted a more positive attitude towards Beagle 2.
- The project was subjected to an extensive series of reviews with ESA and BNSC participation.
- Although Beagle 2 did not reach its final scientific goal, the programme achieved many successes .
- UK industry is now in a strong position to lead European planetary surface exploration.
- Beagle 2 motivated interest in science amongst the British public, creating an opportunity to encourage our students towards science, engineering and technology.
- Several recommendations are made, building upon the momentum created by Beagle 2.

3. The Key Restraints

As is well known, the project commenced only with the goodwill of those organisations directly participating.

Lack of initial funding and uncertainty continuing through to mid 2001 made it difficult to maintain progress against a planned development programme. This uncertainty then became a threat to mission success in that delivery to the launch site, to the schedule dictated by Mars Express, meant that not all planned activities could be completed. Beagle 2 was not a firm part of the mission until less than two years before launch.

The Beagle 2 probe was initially required to be delivered in November 2002, some six months before launch. It was subsequently agreed with ESA that a delivery mid-March 2003 would be acceptable but this was later revised to January 2003. In the event, Beagle 2 was transported to the launch site with the Mars Express orbiting spacecraft in February 2003. Lack of realism in the schedule requirements given to Beagle 2 and lack of appreciation of the needs of the Beagle 2 project introduced risks into the development programme.

From a technical perspective, Beagle 2 was required to fit within tightly constrained mass and volume limits. Consequently only very limited margins within the project were possible. Beagle 2 was initially assigned a mass budget of 63kg by ESA; a formal request was submitted for an increase but this was rejected by ESA Mars Express project management with an instruction to resubmit once the mass of the flight hardware had been measured! The Beagle 2 design team were therefore continually battling to control mass, not knowing whether the design would be accepted for launch. Volume was restricted to avoid obstruction of the field of view instruments on board Mars Express should the ejection of Beagle 2 fail and both spacecraft proceed together into orbit around Mars.

It would be interesting to know what Mars Express mass margin was remaining at launch.

4. Project Management

4.1 *BNSC role*

The BNSC is essentially an enabler and, in contrast to other national space agencies, has only very limited technical capability and no laboratories of its own. Indeed it is staffed by appointees from governmental ministries and research departments. The support from BNSC was therefore political and financial. My personal experience of BNSC with regard to Beagle 2 is one of a sympathetic and supportive organisation.

Beagle 2 would not have been selected to fly on Mars Express without the early support from BNSC. But having provided this support, presumably based upon a UK strategic view, it should have ensured that the funding difficulties did not prevail.

The difficulty faced by BNSC in finding funds for Beagle 2 was that Beagle 2 was not a planned or targeted mission. Funding presumably could only be found by cutting back or delaying other programmes or using contingency reserves. It is interesting to note now that the UK is under-returned on its contributions to the ESA Science programme.

4.2 *ESA's role*

It is ESA's role to approve the science for the mission and to select the payload instruments. Normal practise with ESA Science missions is that the instrument Principal Investigators (PIs) are required to find their own funding. Prior to Mars Express, the ESA role has historically included overseeing the schedule for each instrument and managing the interfaces between the payload and the spacecraft platform. In the case of Mars Express these responsibilities were passed to the industrial prime contractor for the orbiter, Astrium SAS, France. Astrium SAS had submitted a competitive proposal for Mars Express and had stated compliance with the option for a lander, although the interfaces for a lander were clearly not present. ESA's classification of Beagle 2 as a payload instrument rather than a spacecraft resulted in inadequate management of the interface between the two spacecraft. At no time was a specification specific to this interface generated by ESA or its prime contractor. Beagle 2 shared the same Payload Interface Definition specification as the instruments that remain on Mars Express in orbit around Mars.

Having included an option for a lander in the Invitation To Tender for Mars Express and then selecting Beagle 2, ESA then stepped back from taking responsibility for the implementation of this option.

ESA was tasked by BNSC to act as technical customer on their behalf. In this role, ESA's responsibility was to provide a technical audit of the complete Beagle 2 design and was not confined to simply ensuring that the probe did not jeopardise the success of ESA's own Mars Express orbiter mission.

The journal "SCIENCE", volume 304, 28 May 2004, reports that Professor Southwood, ESA's Director of Science, has said that ESA's role was essentially ensuring that it was safe to launch and would not compromise Mars Express or contaminate the surface of Mars. This is what many in the Beagle 2 team perceived during the course of the development programme. It is probable that many at ESA expected the Beagle 2 project to fail well before delivery.

The technical assistance received from ESA was quite restricted, being limited to targeting the landing site, the Spin Up and Ejection Mechanism (the SUEM) and co-ordinating the communication system between Beagle 2 and Mars orbiters (ESA's Mars Express and NASA's Odyssey). This might have included the provision of a communication link for telemetry during entry and descent. Beagle 2 was advised that no such facility would be available. It is not known by Beagle 2 to what extent if at all ESA negotiated with NASA for such a capability or whether any offer was made.

4.3 *Industrial team*

With such a short time frame to design and develop a unique product, care was taken to maintain professional engineering discipline and management. Standard tools for programme management were employed, typical of those used by Astrium for all its successful spacecraft prime contracts. Members of the project core team individually had extensive experience in the space industry.

The project team believe that the withdrawal of the Martin Baker Aircraft Company (MBA), from the project in June 2001, although perhaps unfortunate, was not a critical loss. The MBA Beagle 2 team were retained by Astrium as consultants throughout the rest of the development, assembly, integration and verification programme to ensure transfer of the technology. The MBA EDLS team leader availability was restricted by MBA to the end of 2001. MBA management were excluded from this arrangement by MBA. Astrium appointed its own EDLS manager following the withdrawal of MBA. The appointee has exceptional experience of the space industry and having an aerothermodynamics background. Information flow between the EDLS and System level was much improved.

5. Reviews and Information Flow

Beagle 2 provided BNSC and ESA representatives full visibility of the project through fortnightly management and system engineering meetings and project reviews.

Key system design reviews were held at a number of critical stages through the development programme, eg prior to release of finance from BNSC, the withdrawal of Martin Baker Aircraft Co., the introduction of the new parachute. These were instigated with the purpose of validating the viability of the Beagle 2 design and the programme planning. At each of these ESA fielded their team of experts. One of these, known as the Casani Review, in September 2000, involved a team of highly experienced engineers from the Jet Propulsion Laboratory (JPL, USA). Beagle 2 passed each of these milestones.

Beagle 2 acted upon all recommendations from the Casani review, regularly reporting progress to ESA. The recommendation that ESA should relieve the mass constraints received no response.

Beagle 2 conducted reviews of equipments throughout the programme but one specific review to note was the Critical Design Review of the new main parachute. ESA were invited to this review but declined to send any representative, claiming no expertise! I have the perception that ESA senior management had decided that the Beagle 2 project would fail to complete in time, that the airbag problems would not be resolved and that the challenge of developing a new parachute was too much to overcome.

Finally, reviews were implemented at key points during the assembly of the lander, eg closure of lander lid, closure of aeroshell prior to shipment to acceptance vibration test and shipment to Mars Express at the launch site. The final two reviews were for Flight Acceptance and Planetary Protection—both were successful, with no significant outstanding actions. All these reviews were attended by BNSC and ESA representatives.

6. ESA Commission of Inquiry

Despite the statement in the media invitation, issued by the British National Space Agency (BNSC), for the release of the findings of the ESA Commission of Inquiry that "The Commission of Inquiry . . . interviewed the key players -directors, managers, scientists, and engineers—involved in the development of Beagle 2", as I have previously reported to BNSC, I was not interviewed by the Commission of Inquiry.

It is not possible to make any comment on the report prepared by the Commission of Inquiry since this of course has not been made available to either the Beagle 2 project or to the public. But with regard to the 19 published recommendations, Beagle 2 was given the opportunity to comment on the factuality of the statements made. This feedback was generally disregarded by the Inquiry team.

It is unfortunate that the Commission of Inquiry was not conducted by a truly independent team.

It is ironic to note that ESA is conducting an internal study for the possible next European mission to Mars and is seeking support and consultation from the Beagle 2 team.

7. Beagle 2 Internal Inquiry: Possible Causes of Mission Loss

The Beagle 2 project team has been conducting its own investigation into the loss of the mission since 25 December 2003. Our initial efforts were focussed on recovery strategies primarily relating to communication modes. However we immediately began collating information on other possible causes of failure.

The Beagle 2 report into the mission loss includes:

- an appraisal of the management of the project;
- mission achievements;
- an extensive listing of all identified failure modes;
- a lessons learnt database;
- a report on the communications search primarily using NASA's Odyssey orbiting spacecraft but also the Jodrell Bank radio telescope and to a limited extent Mars Express (Mars Express was not in an orbital position to communicate with Beagle 2 until two weeks after the scheduled landing);
- a report on the surface imaging campaign conducted with excellent collaboration from the USA team operating the MOC camera onboard NASA's orbiting Mars Global Surveyor (MGS) spacecraft. There have been no images of sufficient resolution from the Mars Express High Resolution Stereo Camera;
- an analysis of the more likely failure scenarios.

The last of these includes an assessment of the effect of the Martian Atmosphere recorded at sometime after the time of entry. It should be noted that a dust storm was prevalent as Beagle 2 and Mars Express approached Mars. In information to which the Beagle 2 team has been given access, JPL state that the effect of the dust storm was at its peak on the 23 December 2003, just two days before Beagle 2's scheduled landing. Beagle 2 has also been provided measured data on the density of the atmosphere, mid-January 2004 by the Principal Investigator for the SPICAM camera on Mars Express (obtained directly from the PI, with no involvement of ESA). This density profile compares favourably with that reconstructed by JPL for the Mars Exploration Rover SPIRIT lander derived from telemetry data recorded during its descent to the surface early January 2004. Beagle 2 acquired knowledge of the existence of the SPICAM data and gained visibility of the MER data indirectly. Other than during the period to establish radio contact with Beagle 2, ESA has not assisted the Beagle 2 team in its investigation into the loss of the mission.

Both SPIRIT and OPPORTUNITY experienced significant delay in the deployment of their parachutes due to late triggering caused by the unusual atmosphere. Should Beagle 2 have experienced a similar delay, as would seem likely, then there is a good possibility that there would not have been sufficient time to inflate the airbags before impact.

The Beagle 2 team cannot claim that this is the probable cause for mission loss, we have insufficient data. Other scenarios are also credible. But in my personal view this is the most likely.

8. Return on Investment

8.1 *Industrial Opportunities*

From an industrial viewpoint, the UK is now in the leading position in Europe for future planetary surface exploration. ESA is currently reviewing its plans for the exploration of Mars, ie the Aurora programme. Aurora had a single objective: to enable ESA to negotiate with NASA as a credible partner in a combined programme of exploration of Mars, culminating in "Man on Mars by 2030". Many of course have a problem with manned spaceflight in general and the ethics of placing a human on another planet, particularly one with the potential of having its own life forms. Regardless of the end goal, a new programme will emerge and the first mission, or missions, will be a technology demonstrator, building upon the lessons and technologies of Beagle 2. If it is agreed that the UK wishes to participate in this programme, then UK industry is in a strong position to become prime contractor for this next European mission to Mars and to provide key technologies. But the industrial opportunities are not confined to Europe; for example, the Beagle 2 team has been courted by organisations in the USA and Canada.

8.2 *Education*

The motivation behind Beagle 2 was not just the science return but also to encourage youngsters to follow education and careers in sciences, engineering and technology. Industry shared this with academia. For many years now it has been difficult to find young engineers and of course there is a shortage in teachers of sciences and mathematics.

There has been a tremendous public interest in Beagle 2, aided by positive media coverage and extra-curricular activities of many members of the Beagle 2 team. Many talks have been given and continue to be given in schools and at public events. BNSC has introduced a schools education initiative based upon Beagle 2. Astrium sponsored a schools competition targeted at students who have not yet selected their GCSE subjects.

Whether Beagle 2 will have succeeded in its objective of engendering an interest in the sciences and encouraging our students to follow careers in engineering and technology, we will only be able to judge in the future.

It is important now to continue with a positive message to the public and build upon these achievements and not to promote the message of failure as has the ESA Commission of Inquiry.

8.3 *Spin off*

The Open University's GAP experiment (miniaturised mass spectrometer) has potential in medical, social and security applications. The University of Leicester's XRS instrument (X-ray spectrometer) has potential, I understand, in the medical field. We should ensure that these potentials, and possible several others, are realised to the full.

9. Recommendations

- The UK should capitalise upon the successes of Beagle 2 with the government positively supporting UK industry as it seeks to maintain its leading role in planetary exploration.
- The government should build upon the educational initiatives created by Beagle 2 to encourage young people to follow careers in science and technology.
- The BNSC should be assigned a space budget comparable in terms of proportion of GDP to other leading nations in Europe, thus enabling a serious space plan with room for flexibility as new unforeseen opportunities arise.
- The UK should have a true Space Agency that is more than a policy making body; it should have a strong body of core engineering experience within its own organisation to ensure good return on its investments rather than depend upon ESA where there may be conflicts of interest.

10. Closing Statement

The UK still has the opportunity to be the first to directly discover whether there is extinct or extant life on Mars. This is a unique opportunity and if the political will is present a re-flight of the Beagle 2 science package could be possible as early as 2007 using an evolutionary design derived from the Beagle 2 lander.

I would of course welcome the opportunity to discuss this submission with the Science and Technology Committee.

June 2004

APPENDIX 9

Memorandum from Professor Colin Pillinger, Planetary and Space Science Research Institute, the Open University

1. As Consortium leader, and lead scientist, for the Beagle 2 project I am pleased to have the opportunity to provide evidence to the Parliamentary Science and Technology Committee's Enquiry into the fate of the British Mars lander of ESA's Mars Express (MEx). A previous Parliamentary Enquiry, by the DTI, concerning UK Space Policy (April 2000) drew attention to Beagle 2 and was helpful in gaining Government support for the mission. In the debate which followed publication of that Committee's report, the statement was made that "the trouble was [with UK Space Policy] that there was not enough projects like Beagle 2". Against such a background, and with the possibility of new Government investment in world class science, it is important that it is appreciated the Beagle 2 team did everything possible, within the constraints it was under, to give the best chance of success to the Mars lander. As it currently stands there is enormous danger that after one perceived failure, the UK Government's attitude to space exploration will revert to the sorry state which existed pre-Beagle 2.

2. It must be understood from the outset that the failure rate for Mars missions is 66%; since 1997, when Beagle 2 was conceived, it is slightly better at 50%. Many more prospective projects fall by the wayside before getting anywhere near the launch pad. We never said it would be easy landing on Mars; to get to the surface of the red planet requires everything in the mission to be perfect. Beagle 2 was the hitchhiker on MEx, priority was always assigned to the orbiter. ESA often stated that Beagle 2 was the "cherry on the cake". The lander team recognised the risks but as this was the only opportunity they were ever likely to get to go to Mars, and particularly as the science that Beagle 2 might achieve was potentially history-making, the rewards were considered to far outweigh the risks. The team never gave less than total commitment.

3. By keeping its report on Beagle 2 confidential, and publishing only its recommendations, ESA and BNSC have given some sections of the media a misleading impression that the British project management team might be culpable. It is therefore valuable to contribute to an open discussion of the project's history. The Beagle 2 team have carried out their own technical assessment of the project which will be provided to the Committee and subsequently published and from it created a working list of lessons learnt.

4. The seeds of the Beagle 2 idea were sown long before the advent of MEx. As a new PhD graduate I was lucky enough to be involved in the Apollo programme, strange as it may now seem as a member of one of sixteen groups intent on evaluating an ages-old idea that the Moon's *Mare* might be dried up seas containing evidence of an ancient microscopic life. The investigation was short-lived, and my attention, as that of others, turned to Mars and meteorites to seek evidence that life on Earth might not be unique, and find the first stepping stones to establishing that the human race are not alone in the Universe. The Viking missions, the USA's Mars landing programme of the mid-1970s, were inconclusive. With perfect hindsight the wrong experiments were done by scientists with the best intentions; the absence of evidence of life was taken as evidence of absence. A few dedicated individuals however seized on an inspired post-Viking idea that the mission had provided just a suspicion that, on Earth, we already had rocks from Mars, meteorites blasted off the planet by asteriodal-sized impacts. It took more than a decade to demonstrate that this controversial hypothesis was probably correct. Along the way, evidence was gradually accumulated that the Viking conclusions were premature and that conditions appropriate for life to prosper existed on Mars. Tantalisingly the meteorite studies have gone much further. There is a hint that the remains of past life have actually been found on Mars. If correct, this is probably one of the most incredible pieces of scientific detective work ever; members of my group, and other UK scientists with whom I have worked, were first to unearth many of the clues in this investigation. The whole picture was brought dramatically to world attention in 1996 by a report, from the NASA Johnson Spacecraft Center, that tiny fossils and mineralogical evidence had been found in a particular martian meteorite, attention to that rock having been drawn by the work of the Open University (OU).

5. Although many things about martian meteorites can be demonstrated unequivocally by isotopic measurements, at the present time, two things cannot—the fossils, if that is what they are, and organic matter discovered by the OU to exist in the samples, cannot be shown to be indigenous. There is circumstantial evidence that the organic matter was acquired on Mars however, the only way to prove it would be to go to Mars and make the measurements in situ so avoiding the ever-present threat of terrestrial contamination. The simplest experiment, which needs to be done, to provide the required data, is to measure the difference in carbon isotopic composition between any co-occurring organic matter and aqueously-deposited carbonate minerals. On Earth a large difference, in a particular direction, is taken as the best evidence that life has been present throughout the four billion years of the geologic record.

6. Because of the thirty years of experience within my group in building mass spectrometers (including one for ESA's Rosetta mission) we believed we could provide the equipment to conduct the necessary experiment on Mars. From work concerning global warming on Earth, we suggested the instrument we would build could be used to detect, in the martian atmosphere, the metabolic waste products (eg methane) of living organisms. However, to interpret all the results, visual, chemical, minerological and environmental parameters were also needed, so a minimum (in fact optimum) science package of about 11 kg was

conceived. Contributions came from a number of sources, not just the UK, but other European countries and the USA. The cost of this package is not identifiable because the instrument providers were prepared to supply (and often did so) without any visible means of support (I invented the term "Marslighting"). The science package that Beagle 2 wanted to take to Mars was decided on 6–7 August 1997, only the "mole" as a subsurface sampling device, was added at a later time (October 1997). In other words the science case was ready to review and development could have begun at a very early stage of Beagle 2.

7. Following the revelations about fossil organisms, it became clear that ESA were interested in the possibility of life on Mars. The interest came, however, not from the Space Science Directorate but from the Microgravity Division, the part of the Agency responsible for the manned space programme (and incidentally the part of ESA now advocating the strategy called AURORA). I was asked to serve on a committee evaluating whether life was possible elsewhere in the solar system. It was then that I heard that the Space Science Directorate were considering a Mars mission for 2003, the year when Mars would make its closest approach for millennia. The urgency with which the ESA project was being put together led to it being named Mars Express. The purpose of this mission was to recover science lost when a Russian launch to the red planet (Mars '96) disintegrated as it attempted to leave Earth's gravity on 17 November 1996. It is perhaps worth recording that this was not an ESA mission but was heavily loaded with European experiments (alas only a minor contribution from UK) yet ESA were discussing its resurrection within a few months of the loss. After overcoming some reluctance, I managed to take part in these discussions, other groups having aspirations to land on Mars for the purpose of making geophysical measurements, were already present. My suggestion that any lander sent should address the possibilities of life on Mars, and that the UK science community would want to be involved, was met by a response which was little short of incredulity. "You don't have the technology. Who will pay? Certainly not the UK!" were some of the comments which greeted the proposal. The thought that if we wanted to discover life on Mars we might have to go it alone to build a lander first entered my head in this meeting; the name of the putative spacecraft, Beagle 2 honouring Darwin's ship, was dreamed up by my wife only an hour after the meeting ended.

8. In the 10 months following, ESA seemed to be coming around to the idea, not just a lander but landers. The mass allocated to lander construction rose steadily until over 200 kg was said to be available for a geophysical network, one component of which would be a larger craft concentrating on life detection. This was the situation when teams were briefed on how to respond to the Announcement of Opportunity to bid to be a part of the MEx mission (December 1997). Quite why and when that climate of optimism evaporated is unclear, within a month of the briefing, with all the proposals in, the story suddenly became different. The maximum allowed for a lander(s) would be 60 kilograms, since no lander of this size had been bid there would be no lander. The change of circumstances, however, did not deter the Beagle 2 team, we worked out that by shedding the parts of our payload which were needed for collaboration with the network, and some clever lateral thinking in respect of mobility, we could make a lander of 60 kilograms (just) without sacrificing any of our original science goals. Our thanks for this piece of innovation was that ESA decided to stage a new competition, one which consumed another six months at a time when real design work could have been going on. Beagle 2 eventually won the new competition in December 1998, with a proviso that we had a year to come up with a viable design, and funding.

9. Early in 1999 MMS (now Astrium) appointed a Project Manager (we already had a Chief Engineer from them). Monthly, all-up, project management and regular systems team meetings were constituted. The structure was similar to what would have been required had Astrium been an ESA spacecraft contractor. Throughout the year, whilst I tried to raise funds for Beagle 2, the project team, unsupported save for their own internal resources, continued with the detailed design. I had approached PPARC and received the expected response "no budget had been set aside for Mars". Pressing further, it was anticipated that £1 million might be available but only the Chairman and one other member of the Committee supported the suggestion. A proposal for ca £6 million to the Joint Infrastructure Fund was unsuccessful (possibly deemed inadmissible) and Beagle 2 was considered to be not of sufficient priority as a £25 million bid to the Comprehensive Spending Review of the time. A science proposal, but no costings, was reviewed in January 1999. Mid-year, with the MEx project being confirmed by the ESA Council of Ministers, we were given an indication that some funding from the DTI might become available. A cost review of the UK Science onboard Beagle 2 was hastily convened (July 1999) and we were asked to justify a contribution of around £2.5 million. On August 3rd, Lord Sainsbury announced he had found £5 million for industry and PPARC were providing £2.7 million for the academic community. In reality none of these monies reached the project until after the next ESA Science Programme Committee (SPC) gave Beagle 2 another one year stay of execution in November 1999. But we had a project so a Board of Management for Beagle 2 was set up to oversee all top level decisions. At the start of 2000 we were allowed to spend £1.5 million in the first instance; all the industry money was committed by the time we received it.

10. The amounts of money available were far short of what we knew would be needed to complete the project. I had been pursuing the possibility of raising the shortfall through sponsorship. My PR campaign was increasing the profile of our activities and I interviewed six agencies who had expressed an interest in being commissioned to sell the sponsorship rights. Eventually I chose M & C Saatchi as having easily the highest standing in the advertising world and being one of the most reasonable in respect of terms. A strategy

outlined by the CEO of Saatchi's sponsorship arm (and a crate of media coverage) convinced the Board, the primary partners in Beagle 2, the OU, Astrium and BNSC (DTI/OST) to underwrite the project to the tune of £12 million; the University of Leicester agreed to meet its own costs and prevail on the Millennium Commission, via the National Space Centre, to contribute to the cost of spacecraft operations; Martin-Baker Aircraft (M-BA), who were at the time leading the development of Beagle 2's landing system, declined to join the underwrite. Everyone breathed a sigh of relief since the sponsorship problem was now in professional hands.

11. At the end of the summer of 2000, the European Space Agency convened an independent review of the Beagle 2 project by a team predominantly comprised of NASA engineers and chaired by John Casani of the Jet Propulsion Lab. The impression within the Beagle 2 team was that this review was expected to condemn the project. Quoting from Casani's verbal report to the Beagle 2 team, in the presence of MEx project management, he said "Your way of doing things is nuts, but it seems to work!" This has been interpreted as meaning the management structure was frail. He recommended that Beagle 2 was eminently doable but help should be given with money and mass. Beagle 2 met all the recommendations made by Casani. Thereafter, ESA's SPC agreed to a contribution to Beagle 2 after we had demonstrated European involvement (we identified the "Marslighters" amongst the 13 countries clandestinely working on the project). Not all the sums of money advanced by ESA to Beagle 2, against promises of future commitments from PPARC to other ESA missions, however, were spent directly by the project. Some were used to provide things which should have previously been in the MEx budget but which had been neglected because of the doubts as to whether they would be needed for Beagle 2. ESA became members of the Board of Management and the systems team.

12. The review focused a great deal of attention on the lander's entry descent and landing system (EDLS). During the negotiations concerning what ESA's financial contribution might be, I made the offer that they could put their resources directly into the EDLS, manage it, and thus have complete oversight and a share of the technology, IPR etc. Initially they thought this was an attractive proposition but they later turned it down.

13. During 2001, whilst design and testing of the lander and instruments was progressing, it became obvious that the project did not have a viable EDLS design. Whereas ESA had been reluctant to take over responsibility for this aspect of the work, in order to save the project, Astrium agreed to become sole prime contractor. Inevitably this was going to lead to a cost rise because unknown risks were being added to their portfolio. Items which were known about by everybody involved, but not in the original budget, would also need to be paid for. For example no money had been set aside by PPARC for the post-landing operations phase. Additionally, none of the establishments now involved in Beagle 2, ESA included, had a facility to assemble the lander to the sterility/cleanliness standards required for the project and to meet international Planetary Protection regulations. New financial arrangements, with the OU, the Government and ESA contributing to the additional costs, were agreed.

14. Tests of the Beagle 2's gasbag design could only be carried out within a US controlled facility. As these began, the worst fears concerning the gasbags were realised when a set of bags, being inflated to the required pressure, burst. The project was faced with some stark alternatives: re-engineer the gasbags to a different design or a much higher specification, or take a different course of action that could work without changing the gasbag design. The first option was going to require considerably more mass; additionally information flow was restricted because of IPR and ITAR (International Traffic in Arms Regulations) issues (a US company was involved), indeterminant costs (the contractor would only work on a costs plus profit basis) could accrue, and unknown delays due to new manufacturing procedures and a greater/unspecified access to US test facilities might be involved. Mass increases were considered to be a show-stopper, we had already requested the allowance for Beagle 2 to be increased to 68 kg without receiving a decision from ESA. Gasbag mass, and far too many other issues, were totally outside the control of the project in the first option. Therefore we opted to keep the gasbags as they were, test and operate at a much lower specification and reduce the requirements for landing by re-designing the main parachute together with adding a radar altimeter trigger (RAT) to inflate airbags. ESA were fully aware of this management decision, absolutely correct in my opinion, which meant the project could source new items, conduct new tests and manufacture within the UK; as a consequence we were in control of our own destiny. Some additional costs in respect of parachute development were met by BNSC/DTI and Astrium were compensated by the OU by a rewriting of the underwriter's repayment arrangements.

15. By 21 May 2002 a successful gasbag test had been held; by the end of June a series of tests covering all aspects of the required procedures (proof leak testing, inflation, gas-generation, separation, drops on slopes and sample rocks) had been completed. The parachute/RAT programme could go ahead, some small amounts of mass needed had been garnered by a complete assessment of the mass budget; a contribution of 275 g was made by the instrument package, mainly from a modification of the pumping system. The parachute was tested in every conceivable way except in a prohibitively expensive high altitude balloon deployment.

16. In the summer of 2002, the project was ready to begin assembling the spacecraft. The empty Aseptic Assembly Facility (AAF) was operating at class 1 (1 particle/cubic metre) the first spacecraft hardware (the heatshield/front cover) was delivered in July. Actual construction started in late October when Beagle 2's sterilised electronics module arrived. The lander lid closed for the last time at the end of January and the

completed Beagle 2 probe was sealed in its nitrogen-filled transport container on 7 February. It was returned to the AAF, for a checkout, after it was accidentally over pressurised; a review decided that the only potential damage was one non-critical component in the environmental sensor science package. Beagle 2 passed its flight readiness review and was installed on MEx on 1 April, two months ahead of the required launch date. It met international planetary protection regulations with almost a factor of 10 margin and Beagle 2 was indeed fit for purpose.

17. It might be of value to have some information about various organisations and their commitment to the project. The idea of sending Beagle 2 to Mars occurred on 18 April 1997, the OU's then Vice-Chancellor Sir John Daniel gave me the go-ahead to pursue this goal on 25 April. Thereafter, at every juncture where finance or other commitments were necessary, the OU were always the first to offer additional support or suggest a solution to problems. My first meeting with Paul Murdin, representing BNSC/PPARC, occurred on 30 April. His words were "I can't tell you to go ahead but then I can't tell you not to." I first met Lord Sainsbury, as the new Science Minister, at the Farnborough Air Show in 1998 when he responded with the then party line on Beagle 2 "It's a PPARC issue and they say there's no money." By May 1999, Lord Sainsbury was a strong supporter of Beagle 2; BNSC and, in particular Dave Hall and David Leadbeater were champions on our behalf, especially in dealings with ESA.

18. The first meeting of the Beagle 2 project was held on 20 May 1997. All the contributors who were to play a major part in the mission, the University of Leicester, Astrium, MSSL (University College London), Rutherford Appleton Laboratory were there, only M-BA, who joined a few weeks later, were absent. Many other companies made commitments by December 1997. The European Space Agency understandably, as we were always aware it would, gave its priority to MEx. Despite dealing with a variety of British born representatives, I doubt whether ESA, as an organisation, ever understood the level of commitment we had in the UK to Beagle 2; there was always a feeling within the team that ESA expected us to fail a review, run out of funds, lose the support of our backers or give up for some other reason, so that they did not have to go to the trouble of cancelling the project although the threat was constantly there. There was never any public declaration to the effect that Beagle 2 had been selected by ESA for Mars Express. As a consequence there was never a defining moment when we could say we were a part of the overall mission. This definitely affected the search for sponsors to reimburse money loaned to the project.

19. The ESA expectation that we would not be onboard when MEx took off manifested itself in a variety of ways. For example, we learned in September 1998 of an Agency decision that the orbiter would not be able to communicate with Beagle 2 for 10 days after it arrived at Mars; the lander in a fully integrated project would never be put at such a risk. Subsequently a deal was negotiated with NASA to fill the gap partially. We had to fight to have Beagle 2 spun off at six days out from Mars; MEx wanted 10. In addition to the mass restriction, Beagle 2's heatshield could only be a certain size, so that MEx instruments could see past the lander in the event the spin mechanism did not function. The spin-up mechanism had to be tested over 50 times to satisfy MEx. With respect to the vexed question of communication with Beagle 2 during entry and descent, Beagle 2 built a prototype comms package but dropped it when it was recognised that nothing was available to listen to us. It was rumoured that NASA offered the Deep Space Network; if so that message never reached the project. Provision for communication on MEx (this was never a Beagle 2 responsibility) only materialised when ESA made a financial contribution in 2000. We also discovered that the MEx bus had not been designed to accommodate Beagle 2; work to the structure to support the lander had to be done by Astrium, Stevenage. Had Beagle 2 been a fully integrated and accepted part of the project as a free-standing spacecraft, none of these problems should have arisen. The main lesson to be learned is that a future landing attempt should be given an absolute priority, or at least not be considered as of secondary importance.

20. The Committee will no doubt be concerned with whether the Government's share of the costs of Beagle 2 have been wasted. In my opinion they have not. The technology to land a small integrated package on Mars is close to being demonstrated. None of the many technical suggestions offered for Beagle 2's failure to respond to communications may be applicable. Nobody has identified anything which could not and should not have worked; something incredibly simple could be the cause. Many of the risks can be mitigated by using technology now available and additional tests but mostly through being fully in control of the project.

21. One thing which is certain is that if the scientific reasons for sending Beagle 2 were valid in 1997 then they are even more so in 2004. Recent space missions and ground-based studies suggest that the tentative conclusions drawn from meteorite studies are worthy of in situ investigation on Mars, as are new tentative reports of methane in the martian atmosphere. No lander proposed by NASA (or any other Agency) other than Beagle 2 has the capability to conduct the necessary experiments before 2009.

22. The open media campaign we conducted for Beagle 2, showing real live action in a space project, engaged the public at a time when there is a desperate need to encourage young people into science, engineering and technology areas. To abandon Beagle 2 now would be a huge mistake. The money spent would indeed then be forfeit. The Beagle 2 team felt totally a part of the project and it showed in their

commitment; indeed so did a large cross section of the public. A fully integrated joint UK/ESA project could undoubtedly be motivated in the same way and could have a better chance of succeeding with greater ESA resources. All that is needed is an early firm decision to make landing the priority and commitment to a cost envelope so that risks can be mitigated. Since no risk can ever completely be retired, it would be prudent to build two spacecraft and use the information feedback from the first to give the second a better chance. The Beagle 2 team achieved a 2003 launch from a start which was essentially autumn 2000; it is not too late now to try again in 2007.

June 2004

APPENDIX 10

Supplementary evidence from Dr Mark R Sims

1. Schedule

Critical path analysis was used on Beagle 2 and schedules were integrated, analysed and maintained using Microsoft Project. The Entry and Descent system being high risk and requiring extensive development was close to or on the critical path most of the time. However at other points in the program the structure, lander electronics, probe software, spin up and eject mechanism and instruments were the critical path. Given the required development time no one item was ever a large distance away from being on the critical path.

The schedule was a prime discussion point at all system and management team meetings. The ESA Lander manager attended these meetings unless he was supporting Mars Express meetings or tests. Schedule problems were discussed and conflicts were resolved and priorities agreed at these meetings. The Beagle 2 Board was informed of all major schedule problems.

It was obvious by mid 2000 and in particular by the Casani review in September 2000 that the schedule was critical particularly as no major construction or test work had occurred due to the lack of early funding. Following suggestions by the Casani review team the programme test model philosophy was restructured to generate margin within the overall schedule. Development and test problems required near continuous replanning to retain any margin, however Beagle 2 was delivered in time for launch. Astrium assigned a specific individual to construct and monitor the schedule taking inputs from all the team members.

2. Relationship to Astrium Toulouse

As stated in my written and oral evidence the relationship was difficult due to the different priorities of the two parts of Astrium. The Toulouse team wishing to any minimise changes to Mars Express, retain design margins and (I assume) contain their own costs treated Beagle 2 as any other instrument. A special visit was made by John Thatcher (then the Astrium project manager), myself and Dr Jim Clemmet (the chief engineer) to discuss interfaces, and the Beagle 2 schedule directly with Astrium Toulouse. However it was made clear by Astrium Toulouse at that visit that the lander interfaces and schedule had to remain within the values agreed at the initial kickoff meeting in January 1999. This again reflects on the problem of the lander not being treated as a spacecraft and integral part of the mission from the outset, noting that the lander was not finally approved as part of the mission until the end of 2000.

July 2004

APPENDIX 11

Supplementary memorandum from the Government

Question 1

What conditions were attached to each tranche of funding to the Beagle 2 project awarded by PPARC, BNSC and the DTI?

1. The answer to this question covers all of the funding from Government and ESA required to complete the Lander, its instruments and its specific ground support operations. Some additional funding was required within ESA, first so that the Mars Express orbiter could prepare for and integrate and launch Beagle 2 onto its final approach to Mars, and second for management of collaborative actions with NASA. A distinction as regards sources of funding is drawn between OST—a part of DTI with responsibility for the Research Councils—and DTI with its responsibility for support to industry and innovation.

2. PPARC provided the funds needed to aid development of instrumentation for Beagle 2 and for post-launch support that would have supported dissemination of data from Beagle 2 to scientists in the UK during the planned operational phase on the surface of Mars. DTI and OST provided Government's contribution to development in industry of the lander. Funding was provided in 7 tranches:

Tranche 1: PPARC Grant for Instrumentation

3. PPARC awarded in July 1999 a grant totalling £2.7 million to the Open University, Leicester University, and the Mullard Space Science Laboratory, University College London to build the instrumentation payload on Beagle 2.

4. The grant was awarded under the following conditions:

— the Principal Investigator must provide PPARC with a list of all external funding sources together with full details of the support, financial or otherwise, to be provided in each case. In the event of a funding source withdrawing their support, either in full, or in part, PPARC must be informed immediately;

— PPARC will be a member of the top level Management Board and will, where appropriate and necessary, appoint a representative to attend any meeting concerning Beagle 2. It will be the responsibility of the Principal Investigator to inform PPARC of all meetings associated with the Beagle 2 project; and

— if PPARC for whatever reasons, deems the Beagle 2 project is no longer viable this grant will terminate with one months notice. PPARC recognising that staff are recruited to and employed on the Beagle 2 project may enjoy a period in excess of one month, will, where necessary and appropriate, meet the additional costs incurred by the institution honouring these employment commitments. The Institution will be required to action the period of notice immediately on receipt of the formal notification of premature termination. The Institution should not enter any commitment on any other costs once the period of notice has been notified to the institution. PPARC will not be liable for any expenditure, other than the additional salary costs as specified above, incurred beyond the revised termination date.

Tranche 2: Grant towards support of Industrial activities during Feasibility

5. A grant of £5 million was approved by DTI and applied through a direct contract from BNSC to Astrium as the lead partner and other industrial companies. Approval by Ministers on 23 July was in response to a ROAME proposal WP 99/12 June 1999. A contract was placed on 28 September 1999. There were no clawback conditions. There were however two significant milestones (MS) for payment:

MS1: Successful completion of Beagle 2 Interface project design review, which was conducted by the ESA Mars Express project. (October 1999)

MS2: Technical progress review, plus evidence of progress against commercial sponsorship plan and agreement on a programme of public outreach activities. (April 2000)

6. Payments were made after agreement on completion of agreed work and confirmation at Beagle 2 Management Board meetings at which BNSC/PPARC/DTI were represented.

Tranche 3: Pre-financing of the Beagle 2 project in advance of sponsorship income

7. Additional funding was sought by the Beagle 2 consortium in June 2000. Government was prepared in principle to offer further support subject to an underwriting agreement which was agreed by DTI/OST/OU/Astrium in July 2000. Under the terms of that agreement, the Open University was required to place a further contract on Astrium and the underwriters agreed how any excess sponsorship income would be returned to them, proportionate to their investment.

8. It was subsequently proposed to Ministers that DTI and OST—in accord with that underwriting agreement—should jointly invest £5 million alongside a further £7 million from the Open University and Astrium. Ministers agreed to the proposal on 8 August 2000.

9. The subsequent contract placed with Astrium required that the industrial team complete a series of technical milestones to the satisfaction of a BNSC appointed project manager, acting jointly on behalf of OST and DTI. Payments were only to be approved after formal agreement by the project manager and after financial and programme oversight by the Beagle 2 Management Board. The milestones were proposed by ESA, agreed by BNSC and accepted under the contract by Astrium.

Tranche 4: A contribution from the ESA Science programme

10. The ESA Science Programme Committee (SPC) agreed to a proposal from the ESA Executive to contribute £10 million (16 million euros) to the Beagle 2 project in November 2000, subject to the conditions that ESA would become strongly involved in the management of the Beagle 2 project and that European Scientists would gain greater access to scientific data from the Lander.

11. In accord with SPC conditions, ESA placed a contract on Astrium in December 2000, covering a set of agreed work packages that included parts of the Entry Descent and Landing System (EDLS), and the subsequent Assembly Integration and Test (AIT) of the Lander and its instruments. In addition, ESA gained full visibility of the entire lander programme through membership of the Beagle 2 Management Board.

12. The ESA elements of the programme were managed in accord with agreed milestones, and with the overall project schedule and development cost plan maintained by the consortium's project manger.

Tranche 5: Extension of the Underwriting (pre-financing project) in accord with a formal Heads of Agreement signed by all major parties to the programme

13. After a thorough consideration of options, including termination, Lord Sainsbury accepted in August 2001 recommendations from DTI/OST to make a further contribution of £8.3 million: 4.3 DTI/4.0 OST); subject to the strict terms of a Heads of Agreement concerning the roles of all parties, and proportionate changes to the underwriting agreement.

14. The Heads of Agreement (HoA), whose extensive terms were included in Annex A of the Government's Evidence to the Committee, required the prime contractor, Astrium, to accept a firm fixed price contract; and ESA to agree to an increase in the mass margin for the Lander and to act as technical advisor to BNSC.

15. Under the firm fixed price contract agreed on 31 August 2001, Astrium was required to develop, test, integrate and deliver the Lander to ESA. Payments were made in accord with a milestone schedule that was once again proposed by ESA, agreed by BNSC, accepted by Astrium and managed by BNSC's project manager on behalf of OST and BNSC.

Tranche 6: Risk Reduction and Technology Transfer for a new Parachute

16. Following failure of an airbag and other problems during development, Astrium declared in June 2002 that it would need to significantly reduce the specification for the airbags and as a consequence design a completely new parachute in order to achieve a lower impact velocity on landing. Astrium sought additional support for this major redesign which it argued fell outside the firm fixed price contract. Astrium advised that without such additional support it would need to terminate development under the terms of the contract.

17. Ministers agreed to a £1.5 million cofunding alongside new investment by Astrium, split into two phases (£750/750k), to develop and test a non gliding ring-sail parachute, using a material completely new to space. Government applied further conditions, namely that the technology should be transferred into the UK and that the manufacture of the flight parachutes should remain—as before—the responsibility of Astrium under the firm fixed price contract, which was in all other respects to remain valid. Astrium agreed.

18. As a result, Astrium terminated its cost plus sub-contract with Pioneer (US) and transferred the technology to a team led by Analyticon comprising design and manufacturing expertise from Irwin (UK) and Lindstrand.

19. Outcome: The lander was subsequently delivered as planned to ESA in Baikonur in March 2003 ready for the launch in June 2003.

Tranche 7: PPARC grant for post launch support (distribution and analysis of scientific data)

20. PPARC awarded in April 2002 a grant of £2.1 million for post-launch operations support.

21. The grant was awarded on the following conditions:

— This award is contingent on the project raising £2 million from the National Space Centre and the Millennium Commission, as stated in the proposal. PPARC therefore reserves the right to terminate this grant if these funds are not forthcoming;

— Should the Beagle 2 mission not proceed or the (specific instrument name) cease to function, PPARC will terminate the research grant three months from the date of cancellation or failure, unless otherwise stated; and

22. Following the loss of Beagle 2 PPARC invoked the termination clause but invited the universities groups to submit proposals on the need for continued funding to evaluate the lessons learned in relation to the instrumentation package and to carry out additional preparatory studies for Aurora. PPARC has approved the funding of these proposals.

QUESTION 2

At what points during the course of the Beagle 2 project were bids for funds to DTI and PPARC turned down and what was the value of such bids?

23. In December 1998 the Open University made a bid for £5.959 million to the Joint Infrastructure Fund (JIF) for an entry, descent and landing system for Beagle 2. The proposal was assessed as being of alpha quality in terms of the science and strategic importance. It was not funded by the OST's JIF Executive Committee on the grounds that there were proposals of even higher quality. Bids for JIF funding were from across the UK research base and were judged strictly on competitive basis. The scheme was highly oversubscribed.

24. As referred to in the government's evidence, paragraph 15, PPARC together with the BNSC and DTI was asked to consider underwriting the project in the first half of 2000 to enable the Open University to manage a cash flow crisis. PPARC was specifically asked to contribute £4 million. It declined on the grounds that it was more appropriate for government ie DTI and OST to consider such a request. This was done and DTI and OST provided funding (Tranche 3 under Question 1.)

QUESTION 3

Which other funds within BNSC and DTI were used to provide funding for the project (Question 136)?

25. All sources of funding are covered by the answer to Question 1.

QUESTION 4

At what points during the course of the project were you made (aware) that changes had been made to the cost at completion figure?

26. The Cost at Completion (CaC) was declared by the Beagle 2 team to be £28.5 million in July 1999, when Ministers agreed to the first £5 million grant from DTI. There had been no further change when ESA contributed to the programme in November 2000. The Beagle 2 consortium declared an increase to £36.1 million at a Beagle 2 Management Board meeting in May 2001. When all parties agreed to sign the Heads of Agreement in July 2001, the CaC had risen to £42.5 million.

QUESTION 5

What steps are being taken to set aside money in order to deal with problems that arise on large facilities or similar major projects (Question 154)?

27. There are two separate issues here.

28. The first issue is how the risks of increased costs are dealt with during the life of a major approved project. The answer is that the OST and PPARC have instituted tighter project management and cost controls. In the course of project definition and approval, each project is allocated a contingency depending on factors such as the overall level of risk and the complexity associated with the project. The level of contingency allocated is reviewed and agreed with the project programme board, which recommends the release of this contingency to the funding agency. Consequently, the overall funding allocated to a project includes contingency and the risk of cost overrun is held by the project.

29. The second issue relates to how the Government, through the OST and PPARC, is ensuring that there is some degree of financial flexibility to respond to new emerging opportunities. In the 2004 Spending Review the government announced a central fund of £35 million per annum "to enable Research Councils to respond more quickly and effectively to emerging priorities and opportunities". PPARC has developed a planning process which enables it to identify new and emerging opportunities and to prioritise these against existing planned programmes within the uncommitted element of its budget. The extent to which PPARC can realistically accommodate new large scale projects or facilities, for example Aurora or a Linear Collider, is limited, and it will look to additional funding from government through Spending Reviews to support some of the highest priority opportunities.

QUESTION 6

The 2004 Spending Review announced a central fund of £35 million in 2006–07 and 2007–08 "to enable Research Councils to respond more quickly and effectively to emerging priorities and opportunities." By what process will this money be allocated and by whom? Will it be able to be carried over, if unspent? Would it be available to fund projects in a specific discipline which arise at short notice? Will there be any caps of the size of individual awards?

30. The £35 million per annum strategic funding provided in the Spending Review, from 2006–07 onwards, will be held centrally by the Office of Science and Technology for flexible deployment by the Director General of the Research Councils against emerging priorities. It will be available for the DG Research Councils to allocate both to Research Councils and other delivery agents. The stated purpose of

this funding stream implies that there will be considerable flexibility in its application. The normal Treasury rules on end-year flexibility rules will apply to this funding stream, such that money unspent on one year will generally be carried forward for spend in future years.

QUESTION 7

How much funding is PPARC setting aside for the Aurora programme, over what period of time (Question 186)? What consideration has been given to including the Aurora programme on the large facilities road map?

31. In its Strategic Plan 2003–08 PPARC identified "Does Life exist elsewhere?" as one of the nine big science challenges for the next decade, and the need for a concerted programme of planetary exploration as well as the discovery of earth-sized planets beyond our solar system as priorities.

32. Within its current 10-year plan (based on a flat cash budget) PPARC is planning to spend £10–13 million per annum on projects in this area. How much of this planned funding will be spent on the Aurora programme cannot yet be decided as the Aurora programme is still being defined. ESA has recently invited member states to participate in a second Preparatory European Space Exploration programme. This programme will shape the Aurora programme in terms of specific missions, timescales and the overall level of investment required. PPARC participated in the first preparatory phase at the level of £300k per annum. It intends to participate in this second phase with the objective of positioning UK universities groups in collaboration with UK companies to shape the programme to meet the UK's priorities. The level of PPARC's investment to deliver this objective will be a matter for negotiation over the next month. The Aurora programme itself and the overall level of resources required is likely to be decided at the ESA Ministerial Council currently planned for June 2005. PPARC is seeking additional funding from the 2004 Spending Review settlement to enable the UK to play a leadership role in the programme.

33. The Aurora programme has already been placed on the large facilities road-map.

QUESTION 8

What is the Government's current view of NASA's "faster, better, cheaper" approach to space missions?

34. This approach was last reviewed by PPARC in 1999, when the impact of the "faster, better, cheaper" philosophy on the successful outcome of NASA missions was examined. The NASA policy had resulted in a marked increase in the number of missions since 1992, reversing the downward trend of earlier years. Although these faster cheaper missions involved increased risk, the policy had not led to a diminution of the science return for the programme overall. There had been failures, but on the other hand large expensive missions (eg Mars Observer) had also failed. It was found that the number of missions had doubled since 1992 and the failure rate was probably about the same, but the numbers were too small to be statistically significant. It was concluded at that time that the risks to the ESA programme of moving to the same philosophy were controllable.

35. NASA has taken a more cautious approach since 1999, in response to further failures, notably the separate losses of a Mars orbiter and a Mars lander, as well as a Comet rendezvous mission.

36. The number of missions launched in Europe at comparable cost had not approached the uncomfortably low number faced by NASA in the early 1990s. Less reliance on cost plus contracting and a relatively competitive market for institutional missions had helped to contain costs.

37. Parallel faster and cost effective initiatives in Europe have met with success, but have emphasised greater re-use of platforms and core instrumentation, (Integral/XMM), dual launch (Herschel/Planck) and more attention to risk mitigation and matched levels of contingency. While there is still room for improvement, Space imposes a very hostile environment in which to conduct science. Therefore, a rigorous approach to quality and reliability is paramount.

38. The emergence of small satellite technologies and the advance in information and communications technologies has aided a more evolutionary approach for the underpinning bus technologies, helping to balance the necessary cost of bigger steps needed to support advanced instrumentation techniques for challenging world class science missions. More attention is being given to the use of a class of applications where clusters of satellites and small constellations can offer an alternative cost effective means to meet user requirements.

39. In summary, we can confirm that the "faster, better, cheaper" philosophy coined by NASA remains an attractive goal for the UK, but is and must be applied in a pragmatic and balanced way, which properly takes account of the risks and the benefits.

QUESTION 9

When was the decision taken not to publish the Report of the Commission of Inquiry? Which organisations have objected to its publication?

40. The decision not to publish was taken jointly by the Government and the European Space Agency at a meeting between Lord Sainsbury and Jean Jacques Dordain (DG/ESA) in London on 21 April 2004. The reasons for this decision were set out in Lord Sainsbury's response to Question 197 on 12 July and in paragraph 18 of the Government's statement of evidence to the Committee. As it had never been the intention of government or ESA to publish the report, anyone with concerns about publication would have felt no need to object to publication. The Government did not therefore receive any such objections.

September 2004

APPENDIX 12

Supplementary memorandum from the European Space Agency

1. (a) *What approaches were made by the Beagle 2 project team for funding from ESA were made during the project?* (b) *What funds were awarded to the project, on what dates?*

(a) Approaches for funding for Beagle 2 were made to ESA in Autumn 2000, May 2001, June 2003.

(b1) November 2000: The ESA Science Programme Committee approved expenditure of up to 24.2 million € (equivalent to £17.5 million) on Beagle 2 was in with 10 votes in favour, three against (Italy, Belgium, Spain), and one abstention (Switzerland). [En passant, the vote demonstrates that, contrary to common opinion, France supported Beagle 2].

(b2) £10 million (16 million €) of the 24.2 million € was paid directly for Beagle 2 development. It was paid to Astrium UK on achievement of a set of defined milestones between 2001 and 2003.

(b3) The residual 8.2 million € was to be used by ESA to procure and manage a communications system for Beagle to communicate with either Mars Express or the NASA Odyssey spacecraft [4 million € (£2.5 million)]. It further agreed technical support plus in-kind contributions (test facilities, etc.) to a similar value [This in kind support in fact rose to £5 million over the project lifetime.]

(b4) May 2001: At the Beagle 2 Steering Committee on 23 May 2001, it was suggested that a further £15.25 million might be needed. The situation was confused as Martin Baker was in process of withdrawing from the consortium and progress was well behind schedule and management was confused. The vote in 2000 indicated that I could not ask SPC for more money and be sure of the 2/3 majority needed—to lose such a vote would have been very prejudicial to Beagle 2's interest. I made it clear that I would not ask for money from SPC.

(b5) Equally well matters could not continue as they were and so I set about a series of actions that would lead either to cancellation or more UK support. In the ensuing month, there was an intensive review of costs including development of a risk register (containing 125 items) and a risk attribution of £4.8 million. A series of reviews, collocations and other meetings led to the Heads of Agreement and the injection of UK money in August 2001.

(b6) August 2001: A compromise was reached between the Beagle 2 team and the British whereby they would make available an additional £8.3 million. In obtaining the compromise, I made concessions. It was agreed that certain costs that were directly beneficial to Beagle 2 were absorbed by the Mars Express budget (these were in excess of 4 million €) but much was in-kind. Major items ESA took responsibility for were: access to the NASA Plumbrook test facility (valued at £0.6 million, building an aseptic facility at OU (£1.9 million), and elements of the ground system associated with the Mars Express SOC.

(b7) A firm fixed price contract was negotiated with Astrium so that they would have a clear prime contractor responsibility. The Minister had requested strengthened management (something strongly endorsed by me) and that ESA guarantee that there would be no further requests for funds. ESA could not really guarantee to do the latter as it was not given sufficient insight (see later) to do so.

(b8) After September 2001, I made it clear that my staff support all possible efforts that could be made by all parties to accommodate Beagle 2, whilst not jeopardising the overall need to meet the launch date. Beagle 2 was eventually delivered in late February and Mars Express project (ie ESA) absorbed all resultant costs associated with the efforts made on the part of the project.

(b9) There was no further approach to ESA before launch. In spring 2002, associated with the need for a new parachute system, the Beagle 2 team returned to the UK authorities for more money and/or for reorganisation of priorities in reimbursement of sponsorship. ESA was excluded from discussions on the arrangements for this. ESA understood that the confidentiality was because sponsorship was still seen as a possible means of recouping the investment.

(b10) Astrium approached me in June 2003 about the possibility of ESA paying fees for the use of the name Beagle. I responded by indicating that we would henceforth refer to the lander as the Mars Express lander. The issue was dropped.

2. (a) *At what point during the course of the project were you aware that changes had been made to the cost at completion figure?* (b) *What assurances were requested by ESA as to the sources of funding and likely final cost of the project?*

(a) ESA received the information, formally, on 23 May 2001 at the Beagle 2 Steering Committee.

(b) Second question is not appropriate for ESA to answer; final responsibility lay with the UK authorities. We worked with the UK authorities and Astrium towards getting a clearer and stronger management structure. Throughout it was made clear that the ESA Executive would not ask SPC to provide additional funds.

3. *When was a request for the mass limit on Beagle 2 to be increased to 68kg received by ESA and what response was made (Questions 60 and 103)?*

During the July 2001 review a significant mass increase of Beagle was also discovered and a new budget was developed with the agreement of all participants. This gave total mass allocation to Beagle of 70.9 kg:

— 65.4 kg for Probe ejected mass;

— 4.5 kg for residual mass on the Mars Express spacecraft; and

— 1.0 kg of margin.

This budget was agreed by ESA and after a review (26 July 2001), ESA sent written confirmation to the BNSC Astrium and the Beagle consortium that when the request for waiver was formally submitted via the Mars Express prime contractor it would be signed by the agency.

The waiver request was subsequently revised many times by the Beagle 2 team over the following 18 months as mass estimates changed mainly due to:

— problems with the airbags;

— inability to predict the need for balance mass on the Probe; and

— doubt over the ability of the Beagle 2 entry system to support the higher mass during entry.

The final revision of the waiver was raised by Beagle 2 on 19 March 2003 and was signed by ESA on 26 March. The final values were 68.9 kg ejected mass of the Probe and 4.9 kg residual mass on Mars Express. The issue is not simple. Beagle 2 mass increase was associated with a decreased entry corridor that automatically tightened the requirements on the accuracy of the Beagle 2 injection by Mars Express. We had to study very carefully in conjunction with the Prime contractor that the spacecraft could achieve what Beagle 2 would need. This was not a minor task.

4. (a) *For what reason was it ESA policy to treat landers as scientific instruments?* (b) *Would ESA have been prepared to manage the Beagle 2 project from the outset, if asked?* (c) *In your view, how would the management of Beagle 2 by ESA have affected its chances of success?*

(a) Member States often take responsibility for specific elements of programmes, usually the noble work and often instruments, (hence the phrase: "treated as an instrument"). Several "instruments" were/are more expensive and complex than Beagle 2 and many were more mission-critical: Mars Express could fly without Beagle 2, but, for example, Integral could not have flown without either IBIS (built by the Italian Space Agency) or SPI (built by CNES). In this case, there was no funding available for a lander within the ESA budget as set by Member States. It was natural to see if a Member State wanted to build a lander.

(b) ESA would have been prepared to manage a lander only if it could have ensured adequate resource at the outset provided for within its own budget and—of course—if the Principal Investigator would accept ESA management authority.

(c) ESA tries to be flexible; however policies and practices are based on "success-orientated" engineering principles and European agreed standards (ECSS).

5. (a) *What evidence did you have that the management structure of the Beagle 2 project "was not working" (Questions 78 and 108)?* (b) *Are you aware of examples of similar projects being successfully managed in the same way as the Beagle 2 project was originally (Question 20)?*

(a) In May 2001, the Mars Express spacecraft was going through CDR and entering integration. Beagle 2 was way behind schedule with unclear lines of responsibility, many unclear contractual arrangements, with disaffected partners, and a CaC that was stated to be adrift by over £15 million. More specific statements are quoted in the Beagle 2 Inquiry Board report, to which the Select Committee Members have been given access.

(b) Nothing had been managed in this way before.

— Commercial sponsorship was untried for any such mission.

— To our knowledge no spacecraft had been built by a "coalition of the willing" between industry and scientists such as was in place until spring 2001 (and whose possible fragility had already been remarked by Casani).

6. (a) *Who was responsible for taking a decision on whether the lander should form part of the Mars Express mission after October 2000 (Question 80)?* (b) *On what grounds could such a decision be taken?* (c) *What criteria were used to assess whether the chances of success were sufficient to warrant the lander's inclusion on the mission?*

(a) The responsibility would have depended on the nature of the reasons for non-flight. Cancellation came closest in during the period May–July 2001, where I prepared the ground with the ESA DG and DG BNSC for the possibility of proposing cancellation.

(b1) As described above, in May 2001, I felt that the likelihood of success was very low. Note that I did not immediately feel I alone could cancel Beagle 2, nor did I feel it was my duty to do so. My course of action was to set about producing a clear picture which would allow the British authorities either:

(i) to see to what I could see and to accept cancellation,

or

(ii) to get them to put in a system and resources adequate to get the lander built.

(b2) I quote from the paragraph (b5) in the answer to question 1 above, ". . . and so I set about a series of actions that would lead either to cancellation or more UK support. In the ensuing month, there was an intensive review of costs including development of a risk register (containing 125 items) and a risk attribution of £4.8 million. A series of reviews, collocations and meetings led to the Heads of Agreement and the injection of UK money in August 2001."

(b3) By September 2001, new resources had been secured and a new management system could be organised. Reassured, I instructed my staff to do everything they could to enable delivery of Beagle 2.

(b4) Thus Beagle 2 would have been cancelled in 2001 if the UK had relinquished responsibility and not come up with additional funds and improved management (Heads of Agreement). Throughout, the UK authorities, as the largest stakeholder, would have had the final say in its non-flight if the issue were performance. Only if there had been proof of detrimental effects to Mars Express or its launcher, would I, acting on behalf of my DG and the Agency, have had the authority to refuse flight. Then I would have acted in my capacity as being responsible for Mars Express as a whole and my responsibility to the launch authorities.

(c) It should be remembered that risk assessment involves an element of personal conviction. I could not prove incontrovertibly that the lander would fail before the fact—nor did I believe it would. Had Beagle 2 been refused flight by ESA simply on grounds that it had a high (say, 50–50) chance of failure, I would probably now face inquiries from UK into why the risk had not been taken. Hence, once the SPC had accepted the provision of a British-led lander, the British had to have the final say in this question. The British usually appeared more optimistic about Beagle 2's chances of success than ESA. ESA avoided public comment but the ESA reporting to the Member States through SPC was unavoidable and at times so honest about risk and Beagle 2 that it caused written complaints from the British authorities.

7. *Did ESA break its own policies and practices in maintaining support for Beagle 2 in spite of apparent early difficulties, and if so, why?*

As is made clear in the Inquiry Board report and in its public recommendations, policies and practices were not followed in order to get Beagle 2 built and delivered against a launch date that could not be changed. ESA tries to be flexible but 'success-orientated'. Policies and practice are not "laws"; professional engineering judgment and procedures are invoked before waiving any policy or practice.

8. *Which parts of the Casani Review were "difficult to implement" and for what reasons (Question 90)?*

ESA was unable to conclude a contract with Astrium, which gave ESA full insight into overseeing the EDLS as had been intended.

9. (a) *Do you agree with the assertion of the Beagle 2 project team that they met all the recommendations of the Casani review within their remit?* (b) *What steps did ESA ensure that all its recommendations were implemented?*

(a) Astrium and ESA tracked the Casani review implementation with a spread sheet system to track all recommendations from the Casani review. Progress meetings took place on a monthly basis.

(b) ESA was unable to implement the review fully as Astrium would not accept ESA contract conditions, as they would not release Intellectual Property Rights. This precluded ESA taking full responsibility either regarding the EDLS or elements of it.

10. *Was NASA approached at any stage in order to use the Deep Space Network to try to communicate with the Lander?*

NASA made approximately 40 attempts to communicate with the Beagle via its Odyssey spacecraft and DSN between 25th December 2003 and 4th January 2004. ESA also organised for a "listen in" for Beagle transmissions by the JPL dish at Stanford University in California. From 4 January 2004, Mars Express attempted communications with Beagle in nominal mode and then in a super sensitive "Canister Mode". Both Mars Express and Odyssey made last attempts on 3 February 2004. It can also be recalled that the capability for Beagle 2 to respond to such communications had been provided by ESA.

11. (a) *When was the decision taken not to publish the Report of the Commission of Inquiry?* (b) *Which organisations have objected to its publication?*

(a) The British Minister, Lord Sainsbury and the ESA DG, M Jean-Jacques Dordain jointly took the decision at a meeting in London on 21 April 2004.

(b) As far as is known to ESA, no organisations have had access to the report. None was asked for their opinion whether they had any objections to a full publication. Other than the Inquiry Board and the Select Committee a limited number of British officials and senior ESA staff have had access as yet to the full report.

12. *How does ESA plan to manage a future Mars lander mission as part of the Aurora programme?*

Lessons should be learnt from Beagle 2. As stated by the British Minister and the ESA DG, the (19) recommendations of the joint UK-ESA Inquiry Board will be followed.

August 2004

APPENDIX 13

Supplementary memorandum from Professor Colin Pillinger, Planetary and Space Science Research Institute, the Open University

Q1. *Funding awarded*

Details of the funds received by the project are attached as a spread sheet—Annex 1. Although the announcement that Beagle 2 was to receive Government support was made on 4 August 1999 by Lord Sainsbury (communicated to me by Paul Murdin 20 May 1999) Astrium only received the first tranche of funding in October and the Open University's contribution from PPARC was not released (June 2000) until after the Beagle 2 Board was constituted.

Non attributable costs

Prior to receipt of any awards the project team (mainly the OU, Astrium, Leicester and Martin-Baker Aircraft, M-BA, but including others) estimated they had invested £6.1 million from their own resources in Beagle 2. This number is included in the £45.2 million costs to completion, generally accepted as the cost of Beagle 2. Since 2000, no contractor has divulged details of their own investment on top of the funding received. However, I can say the following contributions were made available:

(i) The Open University contributed substantially in kind to the project in a great many ways: it paid agency fees to M&C Saatchi, legal fees relating to contracts, made available a major building for Beagle 2 assembly, met the running costs and installed some specialist equipment associated with that building. OU general and Science Faculty budgets contributed to building the GAP mass spectrometer prior to the receipt of Wellcome funding and paid for a subcontract for an Astrium project manager and purchased time on Astrium vibration test facilities. In addition no charge has been made by OU for indirect costs arising from non-specific project related staff (secretarial, finance office, purchasing department) for TV documentary production costs, PR events or overheads (heat, light, telephones, copying, printing, security, insurance etc). None of the awards, except that from PPARC, included a payment for overheads.

(ii) The University of Leicester also made contributions in respect of under-funding in a number of staffing areas, management, instrument design, assembly and test, additional operations support and its outreach activities.

(iii) Neither University charged any of its permanent staff to the project all such costs were met from baseline funds.

(iv) Astrium's Mike Healy declared verbally to the Committee that the company had lost £1.5 million on the project over and above taking no profit margin; I have no further details.

Q2. *Unsuccessful applications in addition to the JIF bid*

(i) A verbal presentation made to the PPARC Astronomy Committee requesting a sum of £5 million be set aside in the future projects line for Beagle 2 science involvement.

(ii) Information was provided to PPARC so that a £25 million bid could be made in respect of the 1998 Comprehensive Spending Review.

(iii) The University of Leicester, via the National Space Centre, made a number of bids to the Millennium Commission for Beagle 2 support, the largest of which was for £5.7 million. An award of £1 million was received for operations, and paid to the project to purchase the ground test model of the lander from Astrium.

(iv) Other grant awarding organisations approached without success included NESTA and the Wolfson Foundation.

(v) An enquiry regarding an application to the Gatsby Foundation was made however it was decided that "Beagle 2 was not in the Foundation's sphere of interest". A similar statement was made by the Trustees of the OU's Development Fund.

Q3. *M&C Saatchi's role*

A total of £187.5k was paid to M&C Saatchi over a period of two and a half years, beginning January 2000. Another company SP Active, formed by the Chief Executive of Saatchi sponsorship after he left the company in late 2002, received £45k. Part of the time the Saatchi Agency and SP Active worked on a commission only basis. The arrangement with M&CS was that initial fees would be deducted from the commission due had any successful sponsorship arrangements been completed. No contracts were concluded. Probably greater than 150 companies received information about Beagle 2 with M&CS working proactively (M&CS contacted companies to see if they wished to be involved) and reactively (the B2 opportunity was promoted in response to a company approaching the Agency for a new advertising or brand awareness campaign). M&CS made various estimates of the rate card worth (advertising equivalent) of the Beagle 2 brand with £70–100 million eventually taken as a working figure. It was agreed with the Beagle 2 Board in 2000 that £10 million ought to be a minimum sale value of the Beagle 2 sponsorship package with £12 million being set as a target. In the period 17 December 2003 to 31 January 2004 alone, we estimated that Beagle 2 attracted over £250 million worth of news coverage.

Q4. *Sponsorship conditions*

Beagle 2 would have worked with a single or multiplicity of sponsors. Only minimal conditions regarding sponsorship were imposed:

(i) The science of the mission was of paramount importance and must not be jeopardised.

(ii) Nothing could be added to the Beagle 2 lander to increase the mass or reduce the power budget; minimal mass logos would be permitted.

(iii) The project would not consider any sponsor deemed to be likely to embarrass or bring any of the participants into disrepute; for example tobacco companies or organisations having what might be described as an unethical policy would not be considered. What was or wasn't likely to cause difficulties was to be decided by myself, in consultation with the OU's Vice-Chancellor.

(iv) The project would not change its name to reflect just the name or brand of a sponsor—the "X" lander was not allowed but the "X" Beagle 2 lander would have been. This stipulation was made to avoid confusion; three years work had been invested in raising awareness of Beagle 2. A new name might be thought to be a different project. The project also wished to retain its Britishness, and connection to the voyages of HMS Beagle, Darwin, FitzRoy etc.

The first three conditions were reached in conjunction with ESA who signed a HOA with the OU on PR.

Sponsors were offered alternative deals either (a) everything could be paid upfront, with no account taken of attendant risks, or (b) they could pay according to an incremental scheme whereby payments would fall due as various milestones were reached and the project progressed. In the latter scheme if the mission failed at any point payments would cease. The second scheme was potentially more expensive than the first and included bonuses depending on media coverage obtained.

The absence of Government guarantees was not a disincentive, in fact BNSC greatly assisted in the fund raising campaign by joining the OU and Astrium in the "underwriters" agreement in 2000. The underwriters agreement removed the problem of "Beagle 2 needs sponsors or it won't fly"; it meant M&CS could tell potential sponsors "it will happen so join in". Although the underwriters agreement was intended to remove doubt, it could do nothing about the fact that Beagle 2 was treated by ESA as an add-on and subject to rumours that "it might not fly if ESA was not 100% happy". These tended to undermine sponsorship negotiations and cause decisions by interested organisations to be deferred. ESA did nothing to refute or confirm rumours. The other instruments on Mars Express were not subject to speculation that they would not be accepted by ESA. Ultimately, the sponsorship search was not helped by a serious downturn in the advertising market/economic climate and the collapse of dot.com boom, which coincided with the time when decisions could be put off no longer.

Q5. *Declared costs*

In the early days of Beagle 2 it was decided that approximately £25 million would be required to fund Beagle 2 and this value was used by me in numerous interviews etc. It was first declared officially to PPARC for the purposes of the CSR in 1998. Following the failure of the JIF bid I provided a more detailed estimate of £28.3 million, including some science, in a letter to BNSC. Thereafter £25 million for the spacecraft only was used as the basis for the underwriters agreement. This estimate was increased to £34.9 million after the Casani review when ESA undertook to provide additional support for the project to reduce risk. The size of the ESA contribution direct to the project was 16 million Euros (ca £10 million). ESA also paid other costs to MEx but these were never considered by us to be attributable directly to Beagle 2 because they should have already been a part of the mission as Astrium Toulouse led tender for MEx contract including the Beagle option. A new and much more detailed costing was done in 2001 when Astrium became the sole prime contractor and obtained better visibility of the Entry, Descent and Landing system (EDLS) and the costs of the Aseptic Assembly Facility were recognised. Until that time it was believed that it might be possible to modify/upgrade existing clean rooms. A further £1.5 million was made available to the project in 2002 as an investment in parachute technology when it was realised Beagle 2 had to land at a reduced speed for minimising the risk of gas-bag failures. Operations costs were never included in early cost estimates. The subject of operations was raised by me during the first ever dialogue with PPARC concerning Beagle 2; in response I received the answer "of course PPARC want to be involved in the science return". I took this to mean "get funds for the spacecraft and you can expect operations costs to be found".

Q6. *Astrium involvement*

Astrium (Matra Marconi Space) attended the first official meeting of the Beagle 2 consortium (May 1997). Thereafter they commenced work and were committed to the project, supporting it in all possible ways, obviously, however, financially constrained by their management, as were the OU and Leicester. None of the organisations involved were able to work completely unfettered. Everyone involved felt that we had a good chance of the project attracting the funding which would see it completed. It was always believed that funding would come from a multiplicity of sources: the partners themselves, Government (ie PPARC or other), the Millennium Commission, a non-Governmental trust, a rich individual, advertising, sponsorship or source nobody had yet thought of. With this in mind everyone worked as fast and as hard as they could. The underwriters agreement was an effort to give the group collective security; it was a great pity that M-BA dropped out of the underwriting at the last minute. Negotiations on the underwriting idea began in April 2000 as soon as it appeared that ESA were prepared to accept Beagle 2. However, there was never total security with respect to ESA. All ESA decisions relayed to the project were conditional and caveated including the one made in November 2000. There was never a public announcement or even an official letter accepting Beagle 2 that I am aware of. None ever came to me. Consequently such funding as there was never totally turned on.

Q7. *Formal project management*

In so far as the project had no official funding a contract between the partners would have been impossible to negotiate. As long as everyone was working strictly on a voluntary basis the right to withdraw had to remain open. Whilst no contract existed, the organisation was as formal as we could make it and a steering committee at the level of myself, senior people at Astrium, Leicester and M-BA was organised and met regularly. The request for greater formality came from Dr Paul Murdin. It was not clear whether he was asking on behalf of BNSC of PPARC, what was clear was the OU would not receive the award of funds from PPARC for GAP without a Board of Management; this was established early 2000 and BNSC, PPARC and OST joined the original group of four. As a result of the underwriter's agreement contracts were placed between BNSC the OU and Astrium. When ESA made a financial contribution to the project they were invited to join the Board (from early 2001). Miles Hedges, the OU's Finance Director, was Board Chairman.

Q8. *Precedents*

Obviously no other space project has been conducted like Beagle 2. I suspect, however, there are a number of precedents in British history where the participants believed that it was the right thing to do and would not take no for an answer.

At the working level, however, the management of the project was quite conventional. Whilst I was described as Lead Scientist and Consortium Leader, I never managed the project so any claim that the management was taken out of my hands is false. During the proposal stage of Beagle 2, it was handled as an academic idea, Mark Sims of Leicester acted as the Manager. Astrium managed their involvement as a possible future business opportunity with John Hobbs as their representative. After rejection of the first proposal by ESA, I met senior Astrium Management (Mike Ricketts, Peter Truss) and the decision to continue was taken. When the second proposal was provisionally accepted Astrium appointed a Project Chief Engineer (Jim Clemmett) on 22 January 1999 and a project manager (John Thatcher) on 22 April 1999. Mark Sims took the role of future mission manager (this meant he would again run the project at the operations/science exploitation stage after the spacecraft delivery). He was also responsible for delivery of all the instruments other than the OU's GAP with a deputy to assist him. Individual instruments had their own manager. A number of other work package managers were appointed for the Astrium's spacecraft involvements. A project manager for the GAP mass spectrometer was seconded from Astrium to ensure the interface with this major item of equipment was straightforward. M-BA were considered as co-prime contractor in charge of the EDLS. Co-prime management is not unusual when two major companies jointly bid for a project.

When ESA joined the project at the end of 2000 an ESA Beagle 2 Project Manager, Con McCarthy, was given a desk within the Astrium Factory co-located with Astrium's workforce. When John Thatcher was taken ill (30 August 2001) and M-BA withdrew, Barrie Kirk became project manager (20 September 2001) for the entire spacecraft. Additional work package managers were recruited for the EDLS elements of the system, with some M-BA personnel retained on contract. Whilst most work package managers were internal Astrium appointments the company were not afraid to recruit from outside to obtain the best people. As tasks were finished or changed, eg the move from design to integration to test, managers with relevant skills transferred in and out of the project. The only work package manager outside control of the overall Project Manager was the Planetary Protection Officer (PPO Dr Andy Spry), recruited by the OU (16 January 2001) from the pharmaceutical industry. The PPO's role was to certify independently that the spacecraft met COSPAR requirements. Dr Spry had to report to a Committee set up for the Royal Society chaired by Professor Geoffrey Eglinton, FRS and responsible to the Physical Secretary, to confirm that standards were met. (The Royal Society were the COSPAR signatory). He interfaced directly with ESA.

Throughout the project first a Systems Team, which became the Management Team and then the Operations Team held fortnightly meetings to review progress. ESA and BNSC were represented.

In my view the real management of the project was totally conventional and carried out in an exemplary manner. The PR was handled entirely separately and the engineering team were not distracted by PR activities.

In attached Annex 2 are descriptions of my role and that of the Astrium PM and the mission manager which I prepared in conjunction with ESA at the end of 2000. It should, however, be stated that all Beagle 2 project proposals prior to this had, as required, contained Beagle 2 management plans.

Q9. *Beagle 2 mass*

Although the Casani review of September 2000 recommended that Beagle 2 be given more mass, the project continued to work on within the original constraints of 60 + 3 kg. Some of the mass was consumed when the MEx spacecraft was strengthened to accommodate the lander/probe. On 6 June 2001, Astrium submitted a formal mass waiver request for the mass budget to be increased to 71kg. On 17 July, the Heads of Agreement signed by all parties stated that mass had been increased. On 25 January 2002 the MEx prime contractor (Astrium Toulouse) accepted the waiver but on 11 February 2002, nine months after application it was rejected by the ESA MEx project manager Rudi Schmidt. The Beagle 2 project was still formally

seeking a waiver on 18 March 2003 after delivery of the spacecraft, having raised the issue with the ESA Beagle 2 project manager on many many occasions during project management meetings. Formal project management requires that the formal paperwork is in place. The waiver request was the correct procedure for Astrium to follow.

Q10. *AOB*

I have received a copy of a note to the committee from David Southwood stating that he has identified errors in the Beagle 2 project report and these have been corrected at his request. This report, well known about by all concerned, was provided to the ESA PR department as a courtesy in advance of publication, not for comment. I, therefore, rejected the request for changes on the grounds that the project report is the collective recollections and deliberations of many dedicated people who were considerably closer to the project than Professor Southwood. If the report is incorrect then we were all under the same misapprehensions.

September 2004

Annex 1

BEAGLE 2 FUNDING

Question 1	**Funding awards received**			
Recipients	*Source*	*Invoice Date*	*Sterling Amount*	*Date Received*
Astrium Contract	BNSC	26 Oct 1999	1,500,000	01 Dec 1999
	BNSC	13 Apr 2000	1,750,000	01 May 2000
	BNSC	26 Apr 2000	1,750,000	01 May 2000
			5,000,000	
OU, UoL, MSSL	PPARC	Oct 1999—Jun 2003	2,737,258	Quarterly profile payments
			2,737,258	
OU	BNSC	31 Oct 2000	1,791,667	08 Dec 2000
Payments made	BNSC	31 Jan 2001	708,333	26 Feb 2001
against project	OST	04 Apr 2001	2,500,000	11 Jul 2001
milestones	OST	26 Sep 2001	830,000	26 Oct 2001
	OST	27 Feb 2002	2,170,000	11 Apr 2002
	BNSC	27 Feb 2002	735,000	29 Apr 2002
	BNSC	04 Jul 2002	415,000	16 Jul 2002
	BNSC	01 Oct 2002	415,000	4 Nov 2002
	BNSC	10 Oct 2002	415,000	16 Jan 2003
	BNSC	04 Dec 2002	1,245,000	17 Dec 2002
	BNSC	19 Dec 2002	830,000	22 Jan 2003
	BNSC	17 Mar 2003	245,000	27 Mar 2003
	NSSC Milestone 1	23 May 2003	510,000	12 Jun 2003
	NSSC Milestone 2	23 May 2003	490,000	19 Aug 2003
			13,300,000	
OU & Astrium	OU Underwriting		2,000,000	Committed 2000
	OU Underwriting		1,500,000	Committed 2000
	Astrium Underwriting		3,500,000	Committed 2000
	OU Underwriting		1,900,000	Committed 2001
			8,900,000	
Astrium	ESA	01 Dec 2000	3,415,259	01 Dec 2000
	ESA	01 Dec 2002	975,788	01 May 2003
	ESA	01 Mar 2001	975,788	15 Jun 2001
	ESA	15 May 2002	975,788	01 Sep 2002
	ESA	21 Jan 2003	975,788	01 Mar 2003
		01 Apr 2003	2,439,471	01 May 2003
			9,757,883	
OU & Astrium	ESA	01 Jun 2002	684,078	01 Sep 2002 contribution committed in 2001

Question 1	**Funding awards received**			
Recipients	*Source*	*Invoice Date*	*Sterling Amount*	*Date Received*
	ESA	01 Jun 2002	1,270,430	01 Sep 2002
			1,954,508	
OU, UoL, MMSL	PPARC	Oct 2002—Sept 2004	2,075,185	Quarterly profiled payments extended to May 2005
			2,075,185	
Astrium	??	01 Oct 2002 01 Dec 2002	750,000 750,000	04 Nov 2002 01 Feb 2003
			1,500,000	
Grand Total			**45,224,833**	

Key
OU = Open University
UoL = University of Leicester
MSSL = Mullard Space Sciences Laboratory

A grant of £2.6 million was awarded to the OU by The Wellcome Trust, in respect of the Gas Anaylsis package, although there is some overlap with the Beagle 2 project this was not solely awarded for the lander project.

Annex 2

6.1 Roles and Responsibilities of Key Personnel

6.1.1 *Consortium Leader, Lead Scientist (Prof C T Pillinger, Open University)*

The Consortium Leader, as of right, is entitled to attend all science and engineering meetings and contribute to the decision making process concerning any facet of the Beagle 2 project both internally and externally. He will liaise with the Programme Manager (see below) to secure the efficient and satisfactory direction of the Beagle 2 project. As Lead Scientist he is responsible for delivering the scientific objectives of the Beagle 2 project and to this end he will consult with the Mission Manager (see below) concerning the Beagle 2 project instrumentation package and spacecraft operations and receive recommendations from the Science Group. The Lead Scientist will be the chief representative on the Mars Express Science Working Team. As the public face of Beagle 2, the Consortium Leader controls the communication programme dedicated to achievement of public awareness, understanding and appreciation of the project's scientific and technical achievements. He is authorised to commit the consortium to activities related to sponsorship and to negotiate the financial arrangements in return for exposure provided by the project. In respect of technical and engineering issues related to sponsorship he will consult with the Programme Manager and the Systems Executive. In financial and legal matters arising out of sponsorship he will be supported and advised by the Open University's internal organisations and external consultants (M&C Saatchi). In respect of circumstances where a sponsor's suitability might require endorsement he will consult with the OU's Vice Chancellor. He will liaise with ESA concerning co operation on Beagle 2/Mars Express communication issues.

The Consortium Leader will maintain a list of scientists associated with Beagle 2. The Consortium Leader will interface to the Mars Express Project Scientist.

6.1.2 *Consortium Programme Manager (Mr J. Thatcher, Astrium Ltd)*

The Consortium Programme Manager is responsible for the delivery of the Beagle 2 Spacecraft in accordance with the agreed technical, schedule and cost targets. He is accountable to the Beagle 2 Board. He is authorised to commit the Consortium in all transactions with external organisations within the technical, cost or schedule domains and represents the single point of contact for all formal external communications within these domains. For matters concerning the performance, cost and schedule of the industrial team, the Consortium Programme Manager participates in and reports to the Industrial Management Group. With the concurrence of the Local Project Managers (see below), he is empowered to mobilise and deploy the available resources of the participating organisations to the extend provided in the

budgetary allocations agreed by the participating organisations to the extent provided in the budgetary allocations agreed by the participating organisations. In respect of science issues he will consult as appropriate with the Lead Scientist and the Mission Manager.

The Consortium Programme Manager will be the point of contact for ESA and Astrium Toulouse.

6.1.3 *Mission Manager (Dr Mark Sims, University of Leicester)*

The Mission Manager is responsible for all technical matters relating to delivery of the Beagle 2 Science Payload in accordance with the technical requirements and in accordance with delivery requirements. He leads the Payload and Flight Operations Working Groups and will become the Flight Operations Director during mission operations. Together with the other members of the Systems Executive, he has responsibility for the overall technical performance of the Beagle 2 probe. He reports to the Programme Manager and Consortium Leader and is the ESA and Mars Express point of contact regarding flight operations. He is the interface to the Providers of Instruments and is supported by the Instrument Manager (Dr D Pullan, University of Leicester).

APPENDIX 14

Supplementary memorandum from the European Space Agency

CRITICAL ITEMS DISPUTED BETWEEN ESA AND BEAGLE 2 TEAM IN THE DRAFT REPORT RECEIVED BY ESA

1. Beagle 2 was not approved by SPC (ie ESA) in November 2000 but on 10 November 1999. It had been given preliminary approval one year previously. The date given by the Beagle 2 team is when the SPC approved support from ESA resources of up to 24.2 million € (ESA/SPC(2000)34, rev 1) due to failure up to that point to find resources in UK and was in response to an approach from the UK to ESA.

2. Overall limits on allowable mass were known from 10 July 2001. The ESA DG (Antonio Rodotá) signed the agreement then accepting a Beagle 2 mass up to 71kg. Astrium had provided the figure to BNSC who put it in the agreement. Of course, the Beagle 2 team could not do what they liked within this limit and continual evolution of the Beagle 2 design required continual reassessment by ESA and the MEx prime contractor of the use of that mass to ensure system (MEx + Beagle 2) level engineering coherence.

3. The MEx project manager did not advise the Beagle 2 team that no space or ground-based asset could be made available to receive signals had Beagle 2 transmitted in descent. Amongst other possibilities, ESA had helped refurbish Jodrell Bank against just such potential use.

4. ESA (actually myself) did not decline an opportunity to view film of the air bag tests out of lack of care or interest but to avoid any violation on the part of Astrium or the Beagle 2 team of their US ITAR clearance.

5. Similarly ESA's absence from the parachute system CDR was also for reasons of principle, not lack of care or interest.

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