



RESEARCH
COUNCILS UK

Research Councils UK

Large Facilities Roadmap

November 2005



LARGE FACILITIES ROADMAP 2005

EXECUTIVE SUMMARY

The Government's vision is that the UK should be the most attractive location in the world for science and innovation, being a key knowledge hub in the global economy, with a reputation not only for outstanding scientific and technical discovery, but also a world leader at turning that knowledge into new products and services.

Fundamental to achieving this vision is the UK's R&D capacity - excellent skilled people and state of the art facilities and laboratories.

The Science and Innovation Investment Framework 2004-2014, sets out the Government's continuing commitment to ensure that UK researchers have access to world leading scientific facilities, either in the UK or abroad. Increasingly science is an international endeavour both in terms of its scale and the need to address global research challenges, and consequently national research facilities are increasingly being replaced by more advanced and technologically complex international facilities.

In this context, it is important that the UK has a clear strategic view of how best to maintain access to world class facilities. The UK's priorities are set out in this Large Facilities Roadmap. Covering all academic disciplines, the 2005 version of the Large Facilities Roadmap provides a comprehensive picture of the new facilities which are already under construction, and provides details of potential large facility and equipment projects that the Government and the UK's Research Councils would like to see available to researchers over the next 10-15 years.

Scientific research never stands still, nor the research infrastructure needed to support it. This roadmap provides a snapshot of anticipated requirements for access to scientific facilities. As well as articulating the UK's priorities, the Roadmap is used by the Office of Science and Technology and Research Councils UK (RCUK) to take strategic decisions about the best way to provide access to world class facilities and to manage and fund UK investments in priority projects. The Roadmap is expected to be renewed in 2007 to take into account developing needs and emerging discoveries.

Specific information on each of the projects presently under construction is set out in [Section 2](#), and can also be accessed by following the links below.

Project	Lead Council
Diamond Synchrotron	CCLRC (Page 9)
Diamond Synchrotron Phase 2	CCLRC (Page 9)
Research Complex for the Diamond Synchrotron	MRC (Page 9)
ISIS 2nd Target Station	CCLRC (Page 10)
ISIS 2nd Target Station Instrument Suite	CCLRC (Page 10)
Institute for Animal Health - Pirbright Laboratory	BBSRC (Page 10)
Muon Ionising Cooling Experiment (MICE)	PPARC (Page 10)
Halley Research Station, Antarctica	NERC (Page 11)
HECToR – High Performance Computing	EPSRC (Page 11)
Oceanographic Research Ship: Royal Research Ship <i>James Cook</i>	NERC (Page 12)
Redevelopment of the Laboratory for Molecular Biology	MRC (Page 12)
Fourth Generation Light source (4GLS) - exploratory phase	CCLRC (Page 12)

Specific information on each of the new projects is set out in [Section 3](#), and can also be accessed by following the links below.

Project	Nominating Council
Diamond Phase 3	CCLRC (Page 15)
European High Performance Computing Service	EPSRC (Page 16)
Extremely Large Telescope (ELT)	PPARC (Page 17)
Fourth Generation Light source (4GLS)	CCLRC (Page 18)
Fusion Facilities	EPSRC (Page 19)
Gravitational Wave Observatory	PPARC (Page 21)
High Power Lasers	CCLRC (Page 21)
Household Panel Study	ESRC (Page 23)
ISIS Second Target Station Instruments – Phase 2	CCLRC (Page 24)
Linear Collider	PPARC (Page 25)
Megawatt Class Spallation Source for Europe	CCLRC (Page 27)
Mini Fabrication Facility for Nanotechnology	EPSRC (Page 28)
Neutrino Facilities	PPARC (Page 29)
Neutrino Factory	PPARC (Page 31)
Oceanographic Research Ship	NERC (Page 32)
Radioactive Particle Beams Facility	EPSRC (Page 33)
Renewal of the National Institute for Medical Research (NIMR)	MRC (Page 34)
Square Kilometre Array (SKA)	PPARC (Page 35)
Up-grade of the European Synchrotron Radiation Facility (ESRF)	CCLRC (Page 37)
The European XFEL Project (XFEL)	CCLRC (Page 38)

Research Councils UK
November 2005

1. PURPOSE AND USE OF THE LARGE FACILITIES ROADMAP

Introduction

- 1.1 Maintaining access to leading edge experimental facilities is an essential part of keeping UK researchers competitive and at the forefront of their fields of research. This is a critical to delivering the Government's ambition that the UK should be the most attractive location in the world for science and innovation. As well as providing a world class research environment, large facilities also provide wider benefits, for example, by providing opportunities for training skilled people and for stimulating knowledge and technology transfer.
- 1.2 This updated Large Facilities Roadmap has been developed in the context of the Government's "Science and Innovation Investment Framework 2104-2014". This emphasises the Government's commitment to ensuring that UK researchers should continue to have access to world class facilities, either here in the UK or abroad.

Purpose

- 1.3 Investing in leading edge facilities or providing funding to enable access to world class facilities is normally the responsibility of the university or research body where individual researchers are employed. However, as technology has developed, new facilities are increasingly complex and more expensive than those they are replacing. Research too, is being pursued to a greater degree on an international basis, reflecting the nature of global challenges such as climate change and the scale of major endeavours in areas such as particle physics. Many areas which have up until now been dominated by national facilities are in future likely to be replaced by next generation international facilities.
- 1.4 Increasingly therefore, there are a range of facilities that for a number of different reasons fall outside the funding remit or capability of any individual organisation. The types of facility that fall into this class are typically those that are: large and very expensive; have long useful lifetimes i.e. 10-20 years; have multiple users both nationally and internationally; are interdisciplinary; offer unique capabilities within the UK, or more widely; and are potentially jointly funded or suitable subjects for international collaboration.
- 1.5 The UK needs to take a strategic view as to the best way to maintain access for researchers to these large facilities and also to manage the investment of public funds. To help address this need, the first version of Large Facilities Roadmap was published in June 2001, with the second version in June 2003. The Roadmap provides a strategic management tool for Government and Research Councils UK (RCUK), allowing them to take an overview of the largest research facilities in which UK might be involved in the future, across all research disciplines.

1.6 The Roadmap includes national and international projects, within the UK and elsewhere. [Section 2](#) of the Roadmap provides brief details of projects already under construction that have already received. The Roadmap also describes in [Section 3](#) proposals to ensure the continued delivery of support which have been identified as requiring funding within the forthcoming 10-15 years, together with illustrative costings. The types of facilities which may feature on the Roadmap include:

- Small ‘proof of principle’ projects that may then lead to the development of larger, longer-term projects e.g. 4GLS; fusion facilities
- Different development phases of major facilities e.g. Diamond phase III; ISIS Second Target Station Instruments – Phase 2
- Planned replacement or upgrade of existing facilities or equipment e.g. NIMR, upgrade to the European Synchrotron Radiation Facility
- UK contribution to major international projects e.g. European High Performance Computing, Gravitational Wave observatory
- New facilities which will enable the exploitation of new and emerging technology e.g. Neutrino Factory, High Powered Lasers

International Facilities

1.7 Excellent science can only be delivered when working with, and benchmarking against, the best scientists in the world. In many circumstances, the UK’s interests will be well served by participating in a facility overseas, for example through international subscriptions or bilateral arrangements with the host country. In this context, the UK needs to take a view on when and how to participate in major new international facilities, considering the potential for the UK to provide global direction and to disseminate UK excellence, as well as enhancing the international collaborative activities of UK researchers.

1.8 The following projects in this roadmap potentially involve extensive elements international collaboration:

- *European High Performance Computing Service* - The next but one generation of high performance computing systems will be so expensive and resource-intensive that it will not be possible to acquire them on a national basis. The establishment of a European HPC service would ensure that European countries maintain their current ability to carry out world-class research using computer simulation. It should also enable Europe to become a world-leader, along with the USA and Japan.
- *Extremely Large Telescope (ELT)* - At an estimated cost of 1 billion euro, an ELT project will need to be undertaken as a multi-national endeavour. As the partner of choice in most astronomy programmes, the UK is ideally placed to bring together European and US aspirations.

- *Gravitational Wave Observatory* - The future enhancement of VIRGO and upgrade of GEO 600, by a collaboration of UK groups and European colleagues, is essential to allow a European contribution to a world-wide network of advanced detectors. A UK contribution to this will allow access to a wider range of data and also consolidate the UK involvement in the next generation of European detectors.
- *High Power Lasers* - The UK's excellent track record in this field has attracted strong demand for access to the Central Laser Facility, with many academic and industrial users from Europe, the US and Japan. There is now an opportunity for the UK to continue to provide the scientific and technical leadership by taking the initiative to pioneer the next generation of facility.
- *Linear Collider* – A linear collider has been identified by the international particle physics community as its highest priority. R&D on the beam delivery system carried out by UK university groups and CCLRC would be integral to the international design, positioning the UK for future accelerator projects. By concentrating in this area the UK will also be able to take a world lead in this field.
- *Megawatt Class Spallation Source for Europe* - The UK currently has access to the world's most powerful reactor and accelerator based neutron sources, and in the short term the UK intends to build on these opportunities through investment in the ILL's Millennium Programme and the development of a Second Target Station at ISIS. In the longer term the UK will need access to a megawatt-class source to remain competitive and this will require extensive co-operation on neutron policy at a European level.
- *Neutrino Facilities* - The UK is currently positioned to play a leading role in a new field of research within particle physics to understand all the characteristics of neutrinos from both the sun and cosmic rays. There is now a significant amount of activity within the UK focused on studying neutrinos and it has a high strategic importance in the international community.
- *Neutrino Factory* - The CCLRC's Rutherford Appleton Laboratory is a possible location for the international neutrino factory building on ISIS experience. It will take several years to develop the technology and an important first step will be the establishment of a muon ionisation cooling experiment (MICE).
- *Radioactive Particle Beam Facilities* - Europe is extremely well placed to dominate the development of nuclear physics in the coming decades, and has recently published a Long Range Plan (2004) which places construction of the FAIR facility at GSI (Germany) as the top priority for nuclear physics development in Europe. Uniquely, FAIR provides the facilities to carry out international level research in all the areas of UK focus, so it benefits the whole UK community.
- *Up-grade of the European Synchrotron Radiation Facility (ESRF)* - The longer term upgrade programme has the aim of ensuring the ESRF's leading scientific position over the next 10 to 20 years. This will maintain the ESRF's role as Europe's leading provider of high-stability fine-focus hard X-rays.

- *X-ray Free Electron Laser (XFEL)* - The UK now has an opportunity to join the XFEL project. This project aims to enable the powers produced by lasers to be available at X-ray wavelengths. Germany are already funding 60 per cent of the construction and operating costs of the facility, and the UK and other EU members have been invited to join the partnership to make this a European project.
- 1.9 Although many of these facilities are likely to be constructed outside of the UK, there may be strong arguments for the UK bidding to host one or more of these. Hosting international facilities demonstrates scientific leadership and generates inward investment, as well as attracting international research talent. Such facilities also generate secondary industrial benefits, from winning a greater proportion of technology contracts for the facility itself, and the development of business clusters around the site. However, there are also likely to be substantial additional costs to the UK for hosting such facilities.
- 1.10 The Government's Global Science and Innovation Forum is developing an international science and innovation strategy to ensure that the most is made of international opportunities, including looking strategically at the opportunities for the UK to host major international facilities.
- 1.11 Research Councils are planning to develop their strategies in order to contribute European Strategy Forum for Research Infrastructure debate on large facilities and, and UK contributions to discussion for the EU large facilities roadmap.

Mechanisms for funding Large Facilities

- 1.12 The UK currently spends around £230 million of public funds each year on capital expenditure for large facilities projects. It is usual for such projects to be funded from multiple sources including from the Research Councils, international subscriptions, Government departments, charities, international bodies or from the Large Facilities Capital Fund, held centrally by the Office of Science and Technology.
- 1.13 The Large Facilities Capital Fund is used to support large-scale, strategic infrastructure projects in UK universities and Research Council institutes. The Large Facilities Capital Fund budget is approximately £100 million per annum.
- 1.14 Inclusion of a project on the Roadmap does not guarantee funding from either Research Councils or OST via the Large Facilities Capital Fund. Inevitably, there are more potential large facilities projects than available public funding. For this reason, in 2003, OST asked RCUK to undertake an exercise to prioritise which projects on the roadmap might move into a capital construction phase in the next three years, and hence potentially draw upon the Large Facilities Capital Fund and/or require significant investment from Research Council funds. The outcome was published in March 2004 (<http://www.ost.gov.uk/research/funding/lfroadmap/index.htm>).

- 1.15 Following the publication of this Roadmap, the prioritisation exercise will be repeated. The criteria for prioritisation have been agreed between OST and RCUK and include: the excellence of the science; contribution to the international positioning of UK research and fit to the Science and Innovation Investment Framework; timeliness and fit to Research Councils delivery plans; breadth of research base that will benefit; opportunities for knowledge transfer, innovation, and training people; and scope for partnership with others. RCUK will provide advice to OST on the priorities for funding for 2007-2008 to 2009-2010. OST is expected publish the results of this prioritisation exercise early in 2006.

Construction of Large Facilities

- 1.16 The diversity of projects and funding mechanisms means that projects are managed in different ways. For example, some infrastructure projects funded through subscriptions to international organisations are managed by those organisations directly (such as CERN, the European Space Agency and the European Southern Observatory), whereas other projects are managed by Research Councils themselves, by their institutes, by universities or by others whom the relevant Research Council might appoint.
- 1.17 Within this complex framework, it is the intention that all large capital investments will be subject to review at key stages in their lifecycle to confirm the business justification and sources of funding. The process used is designed to be consistent with the Office of Government Commerce's (OGC) guidelines embodied in their Gateway process and is managed by the Research Councils on behalf of the academic community.
- 1.18 Project proposals must first be subject to an independent scientific review. Projects then proceed via the OGC Gateway process to a full business plan review (Gateway 1). Each project has a lead Research Council, and the RCUK Executive Group considers both the science case and business case. Where there is a request to draw upon the Large Facilities Capital Fund, the RCUK Executive Group recommends to OST whether funding should be made available. Approval by DTI Ministers is required in most cases, and if the project is above the DTI's delegated powers, or requires funding from beyond the current three-year Spending Review period, approval is also required from HM Treasury.
- 1.19 A summary of the OGC Gateway Process, and how RCUK is using it in the planning of large facilities, can be found in [Section 4](#).

Adding projects to the Large Facilities Roadmap

- 1.20 Strategically important high priority facilities "projects" are included in the Large Facilities Roadmap if they meet one or more of the following criteria:
- Where the proposed facility has an international dimension and an opportunity exists to share costs and develop relationships to benefit the UK science programme;
 - Where the facility supports the requirements of research communities of more than one Research Council;

- Where the capital investment is greater than the sum of £25 million, and when it represents a significant element of an individual Research Council's budget line.
- 1.21 Additions to the Roadmap are agreed by the RCUK Executive Group, following a recommendation from a lead Research Council. UK researchers or others who wish to nominate specific projects for inclusion in future versions of the Roadmap should contact the relevant UK Research Council in the first instance. A list of UK Research Councils and links to their websites can be found in [Section 6](#).
- 1.22 It should be stressed that the Roadmap does not contain every conceivable project in which UK scientists might wish to be involved, rather it concentrates on those identified by the Research Councils as being of the highest strategic importance. Inclusion in the Roadmap does not guarantee that the UK will participate in a project and it should be stressed that inclusion does not imply a commitment from the UK Government or the Research Councils to fund any particular project. Neither does inclusion on the Roadmap imply possible contributions from any particular source or type of funding. Large-scale facilities are funded via a number of mechanisms in the UK, and that will continue to be the case.
- 1.23 It is intended that the Roadmap will continue be updated and re-published every two years, to reflect the Government's Spending Review Cycle. The next version will be due in the autumn of 2007.

2. PROJECT SUMMARIES FOR FACILITIES CURRENTLY UNDER CONSTRUCTION¹

2.1 The following projects are already under construction following previous recommendation for funding from the Large Facilities Capital Fund.

2.2 Diamond Synchrotron (Lead Council: CCLRC)

2.2.1 Diamond is the largest scientific facility to be built in the UK for the past 30 years. Diamond will provide world leading facilities for research into ground breaking science and new technologies in, amongst others, medicine, nanotechnology and molecular biology.

2.2.2 The Government and the Wellcome Trust are funding the £250 million. Phase 1 of the Diamond Synchrotron is to build the machine and the first suite of seven beamlines.

Estimated date of operation: 2007

More information: <http://www.diamond.ac.uk/default.htm>

2.3 Diamond Synchrotron Phase 2 (Lead Council: CCLRC)

2.3.1 Phase 2 of Diamond will deliver a further 14 scientific beamlines by 2011. These new beamlines will further enhance the capability of Diamond, both by allowing more scientists to use this new facility and also by providing additional instrumentation specifically designed to address some of today's most complex and important areas of science.

2.3.2 Funding for phase II consists of £120 million from Government and £16.8 million funding from the Wellcome Trust

Estimated date of operation: 2011

More information: <http://www.diamond.ac.uk/default.htm>

2.4 Research Complex for the Diamond Synchrotron (Lead Council: MRC)

2.4.1 The Research Complex for Diamond will provide new laboratory preparation facilities for scientists using the Diamond Synchrotron. High quality sample preparation can maximise the scientific benefits of Diamond leading to higher data quality and improved sample measurement time, allowing significantly more scientists to make use of Diamond.

2.4.2 £26 million has been allocated from the Large Facilities Capital Fund for essential infrastructure at RAL and the building of the Research Complex.

Estimated date of operation: 2009

More information: <http://www.diamond.ac.uk/default.htm>

¹ Projects are listed in alphabetical order and do not reflect any element of prioritisation between projects.
<http://www.rcuk.ac.uk/>

2.5 ISIS 2nd Target Station (Lead Council: CCLRC)

- 2.5.1 The Government has committed £100.4 million towards the construction of a second target station for ISIS, the world's highest powered spallation neutron source, located at the Rutherford Appleton Laboratory in Oxfordshire.

Estimated date of operation: 2007-08

More information: <http://www.isis.rl.ac.uk/>

2.6 ISIS 2nd Target Station Instrument Suite (Lead Council: CCLRC)

- 2.6.1 A completely new suite of instruments is being designed and built to use with the source. By building on the unrivalled experience of scientists at the Rutherford Appleton Laboratory these unique instruments will be used by UK scientists in a whole range of diverse scientific fields such as materials science, molecular biology and extreme environments. Six new instruments should be completed at or around the time that the ISIS 2nd Target Station becomes operational in 2007-08.

Estimated date of operation: 2007-08

More information: <http://www.isis.rl.ac.uk/>

2.7 Institute for Animal Health - Pirbright Laboratory (Lead Council: BBSRC)

- 2.7.1 The Institute for Animal Health's Pirbright Laboratory plays a unique national and international role in research on, and surveillance of, highly infectious, mainly viral, exotic diseases of farm animals. It has a world-wide reputation for foot-and-mouth disease, for which it is the world reference centre, and is a major disease reference centre for the OIE, the animal equivalent of the World Health Organisation. Along with the neighbouring Veterinary Laboratory Agency, it carries out the vast majority of UK civil research into highly infectious viral diseases of animals. The future of the laboratory as an international reference centre had been threatened due to the fact that it no longer meets modern standards, but the new building, meeting all requirements, will ensure that the UK continues to be one of the World's leading countries in animal health.

Estimated date of operation: 2010

More information: http://www.iah.bbsrc.ac.uk/publications/annual_reports/2004.pdf

2.8 Muon Ionising Cooling Experiment (MICE) (Lead Council: PPARC)

- 2.8.1 A detailed understanding of the physics of neutrinos will be a big step in furthering our understanding of the new physics beyond the current "Standard Model". In the long term, scientists have proposed development of a "Neutrino Factory" and a first step in developing the technology that will be required for a neutrino factory is the proposed Muon Ionisation Cooling Experiment (MICE) which will be sited at the Rutherford Appleton Laboratory.

- 2.8.2 The first stage in the proposed method of neutrino production is to collide high energy protons with a metal target. The muons that are produced must then undergo “ionisation cooling” which is a subtle and complex technique. The objective of MICE is to demonstrate the feasibility of such a technique.
- 2.8.3 The UK part of the project is being funded by £7.5 million from the Large Facilities Capital Fund, £1.28 million from PPARC and £920,000 from CCLRC.

Estimated date of operation: 2007

More information: <http://www.pparc.ac.uk/Nw/mice.asp>

2.9 Halley Research Station, Antarctica (Lead Council: NERC)

- 2.9.1 The Halley Research Station is owned by the Natural Environment Research Council (NERC) and operated by the British Antarctic Survey, one of its institutes. The Halley station provides a vital platform to conduct globally significant research in space science, atmospheric science, glaciology, snow chemistry, meteorology, geomagnetism, geosciences and human biology. Halley also provides a presence in British Antarctic Territory required by the UK Government. The Halley station is located on the Brunt Ice Shelf in Antarctica. Due to the movement of the ice shelf and snow accumulation, the station has to be periodically dismantled and a replacement built elsewhere, to avoid the station drifting with the ice into the sea. The new station will be the sixth one built since the first was established in 1956.

Estimated date of operation: 2010

More information:

http://www.antarctica.ac.uk/Living_and_Working/Stations/Halley/HalleyVI/index.html

2.10 HECToR – High Performance Computing (Lead Council: EPSRC)

- 2.10.1 The UK needs to be world-class in the use of High End Computing to deliver new scientific knowledge. To achieve this, the UK needs to build on its current investment to provide its engineers and scientists with access to the best possible facilities and to grow a stronger and broader user community. The High End Computing Terascale Resources (HECToR) service, which will be procured by EPSRC in its role as the Managing Agent on behalf of all the Research Councils, is intended to further this ambition. It will include one or more production quality systems, a specific system for Quantum Chromo Dynamics, large capacity data management, visualisation facilities, accommodation, management, computational science and engineering support and training. The initial service capability is for a peak performance of 50 to 100 Tflop/s by the end of 2006, doubling to 100 to 200 Tflop/s after two years, and doubling again to 200 to 400 Tflop/s two years after that.
- 2.10.2 The £102.2 million cost of this facility includes a capital element of £65 million; of which £52 million from the Large Facilities Capital Fund, and the remainder from EPSRC, NERC and BBSRC.

Estimated date of operation: 2007

More information:

<http://www.epsrc.ac.uk/ResearchFunding/FacilitiesAndServices/HighPerformanceComputing/default.htm>

2.11 Oceanographic Research Ship: Royal Research Ship *James Cook* (Lead Council: NERC)

- 2.11.1 The 5,000 tonne ship, the James Cook, will operate worldwide - from the tropics to the edge of the ice sheets - enabling cutting edge scientific research. The ship's design will enable it to work in higher sea-states than the Research Council's other dedicated research vessels. It will be more manoeuvrable, have more scientific berths, and better technical facilities. The James Cook will be one of the most sophisticated research vessels in the world; she will enable UK scientists to continue and expand their leading role in both national and international marine research programmes.
- 2.11.2 NERC have awarded the £36 million contract in July 2004 for the construction of the vessel.

Estimated date of operation: 2006

More information: http://www.nerc.ac.uk/funding/marineplan/jcp_intro.shtml

2.12 Redevelopment of the Laboratory for Molecular Biology (Lead Council: MRC)

- 2.12.1 The Laboratory of Molecular Biology (LMB) in Cambridge, is an institute of the Medical Research Council. The LMB is widely recognised as one of the leading laboratories in the world, with 12 Nobel prizes awarded to staff past and present and with eighteen of its current group leaders elected as Fellows of the Royal Society. It has led to several successful spin-out companies such as Celltech and Cambridge Antibody Technology. LMB is at the forefront of understanding biological processes at the molecular level, improving our understanding of the molecular basis of such diseases as Alzheimer's and Parkinson's. A new LMB building is being constructed to provide up to date world-class facilities. The £155 million modernisation and expansion will enable cutting-edge research to continue, and to capitalise on the enormous opportunities presented by the mass of genomic and functional data now available to the area of neuroscience.

Estimated date of operation: 2010

More information: <http://www2.mrc-lmb.cam.ac.uk/>

2.13 Fourth Generation Light source (4GLS) - exploratory phase (Lead Council: CCLRC)

- 2.13.1 4GLS is a proposed major research facility. If constructed, it would allow researchers to study molecules working in real time, follow chemical reactions as they happen, look at potential drug molecules as they interact with cells and examine the spin of electrons. The research carried out on 4GLS would help develop the next generation of computer memories, pharmaceuticals and catalysts.
- 2.13.2 The exploratory phase of the project involves a three year study to establish the technical know-how needed to build this innovative scientific research facility, including the construction of a prototype test facility. £8 million of funding is through the Large Facilities Capital Fund and £3.5 million through the CCLRC.

Estimated date of operation: 2008

More information: <http://www.4gls.ac.uk/>

3. PROJECT SUMMARIES FOR PROPOSED FACILITIES

3.1.1 The following pages provide a summary about each of the 20 new high priority projects that Research Councils have identified as being of strategic importance to the UK, to maintain access to world class facilities over the next 10-15 years. Projects are listed in alphabetical order:

- Diamond Phase 3
- European High Performance Computing Service
- Extremely Large Telescope (ELT)
- Fourth Generation Light source (4GLS)
- Fusion Facilities
- Gravitational Wave Observatory
- High Power Lasers
- Household Panel Study
- ISIS Second Target Station Instruments – Phase 2
- Linear Collider
- Megawatt Class Spallation Source for Europe
- Mini Fabrication Facility for Nanotechnology
- Neutrino Facilities
- Neutrino Factory
- Oceanographic Research Ship
- Radioactive Particle Beams Facility
- Renewal of the National Institute for Medical Research (NIMR)
- Square Kilometre Array (SKA)
- Up-grade of the European Synchrotron Radiation Facility (ESRF)
- The European XFEL Project (XFEL)

*For each project, costings on all proposals have been provided for **illustrative purposes only** and represent provisional funding scenarios. Timing and expenditure for each project is expected to be modified following due consideration of appropriate funding routes and readiness for construction.*

3.1.2 Table 1 (on page 14) summarises the profile of projected expenditure for these projects.

Table 1 – Proposed Large Facilities Projects

Large Facility	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19	19/20
Supernemo (PPARC)													
Upgrade the Mega Amp Spherical Tokamak (MAST) at Culham (EPSRC)													
Household Panel Study (ESRC)													
New Scientific Opportunities at the European Synchrotron Radiation Facility (CCLRC)													
4GLS (CCLRC)													
UK Participation in the construction of a facility for antiproton and ion research (EPSRC)													
Oceanographic Research Ship (NERC)													
National Institute for Medical Research (NIMR) (MRC)													
ISIS Second Target Station Instruments (CCLRC)													
The European X-Ray Laser Project (CCLRC)													
Linear Collider (PPARC)													
Gravitational Wave Detection Facilities (PPARC)													
A Megawatt Class Spallation Neutron Source for Europe (CCLRC)													
Extremely Large Telescope (ELT) (PPARC)													
European High Performance Computing Service (EPSRC)													
Diamond Phase III (CCLRC)													
Neutrino Factory (PPARC)													
HiPER: High Power Experimental Research facility (CCLRC)													
Mini Fabrication facility for Nanotechnology (EPSRC)													
Square Kilometre Array (PPARC)													

Key:

£0-10m	£10-25m	£25-50m	£50m+
--------	---------	---------	-------

3.2 Diamond Phase III (Lead Council: CCLRC)

- 3.2.1 Synchrotron radiation has enabled pioneering research in the fields of biology, medicine, chemistry, physics, materials science and Earth and environmental science. The combination of high intensity, the ability to focus to less than micron size and the wide photon energy spectrum makes it a preferred tool for the study of the atomic and electronic structure of matter. Diamond is unique as a European national source of synchrotron radiation in terms of its relatively high electron energy (3GeV) and number of cells (24), which provide high brightness and up to 45 locations for beamlines. When it comes into operation, after January 2007, it will be the main source of synchrotron radiation to support the research programmes of a large and growing UK community and the long term plans of the research councils and the Wellcome Trust. Diamond is pursuing a holistic approach to the scientific programmes by melding excellence in synchrotron experimentation with good support laboratories and efficient data handling.
- 3.2.2 Phase III of Diamond provides for the design, procurement, construction and commissioning of 10 beamlines, to be built at two per year to become operational between 2011/12 and 2014/15. They will complement the beamlines that will be completed under Phase I and Phase II, and bring the total to 32, including one test beamline. The proposal also provides for a detector and instrumentation development programme and building works to ensure that the great potential of Diamond is fully realised. This will better exploit the investment in the infrastructure of the facility and allow the breadth of synchrotron science in the UK to flourish.
- 3.2.3 This proposal includes beamlines at the forefront of technology that will exploit the full capability of Diamond and facilitate new research programmes in ultra fast time resolution (sub ps), inelastic scattering and high resolution imaging. These are also areas of great scientific opportunity where the UK community would greatly benefit from a growing activity. Phase III also includes the construction of high-throughput beamlines on bending magnet sources that will produce rapid and reliable data using core techniques (e.g. X-ray powder diffraction) developed to high performance. These beamlines will have automation and provide user-friendly access to the non-specialist. They will extend the user base to new communities in applied areas including archaeology, cultural heritage, industrial processing, engineering materials, forensics, and environmental and medical science.
- 3.2.4 The cost of construction is estimated to be £77 million over eight years. The funding profile is in £ million.

FY 08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16
1.09	9.04	15.75	14.77	14.12	13.68	7.88	0.34

3.3 European High Performance Computing Service (Lead Council: ESPRC)

- 3.3.1 The solution of many of the most challenging and urgent scientific problems requires simulations performed on high performance computing systems. Example research areas are, among others, climate modelling, earth sciences, nanostructure physics, solid-state physics, computational fluid mechanics, astrophysics, quantum chromo dynamics, materials, computational chemistry, molecular dynamics and life sciences. Industries of strategic economic importance to Europe benefit from access to high performance computing systems, including aerospace and transportation, energy, pharmaceutical and biology related chemistry, materials, semiconductors, geophysics and oil exploration. Such systems also benefit European society as a whole, providing, for example, weather forecasting and future services developed under the remit of the Global Monitoring for Environment and Security joint initiative of the European Commission and the European Space Agency (<http://www.gmes.info/>).
- 3.3.2 The next but one generation of high performance computing systems, which will be approaching the petaflop scale, will be so expensive and resource-intensive that it will not be possible to acquire them on a national basis. European countries have so far maintained their position amongst the world leaders in scientific high performance computing applications as well as in computational science and engineering. In the light of the increased investment by the United States and Japan, and increasingly China, this position is now at risk. The establishment of a European HPC service would ensure that European countries maintain their current ability to carry out world-class research dependent upon computer simulation. It should also enable Europe to become a world-leader, along with the USA and Japan, in providing a HPC service to academia and industry.
- 3.3.3 During the timescale of the 7th Framework Programme of the European Commission, France, Germany and the UK propose to establish 3 HPC services, one every two years over a six year period. France, Germany and the UK will each host one of these services, with access being granted to all European countries. A provisional start date for the first service is FY 2008/09, for the second 2010/11 and for the third 2012/13. The UK will negotiate to host one of these services, since this could be used to meet in part the requirements of the next generation national service after HECToR which, assuming a service start of FY 07/08 for HECToR, would be needed in FY 2010/11. Other possible participants are Finland, Italy, the Netherlands and Spain.
- 3.3.4 Each of the HPC centres will have a set of thematic objectives covering the whole range of science and engineering disciplines for which high performance computing is essential. However, it is clear that the climatology research community in Europe has a particular and pressing need for a petascale HPC service for Earth System Modelling. Therefore, one of the services will be focused on meeting the needs of this community, although other research communities will not be excluded from using it.

- 3.3.5 The investment (capital) cost of each of the services is estimated to be 200 million euro (£130 million)². The target for the sharing of this cost is: 15 per cent from industry; 35 per cent from the European Commission; 25 per cent from the host country; and 25 per cent from the other participating countries. There is currently no estimate for the recurrent costs, but these will have to be met by industry and the participating countries. Assuming that the UK hosts the second service and that the only other partners are France and Germany, an estimate for the UK's share of the capital costs in £ million is given below (at a rate of £0.65 to 1.0 euro) (the cost in euro is given in brackets):

FY 08/09	09/10	10/11	11/12	12/13	13/14
8 (12.5)	8 (12.5)	16 (25)	16 (25)	8 (12.5)	8 (12.5)

3.4 Extremely Large Telescope (ELT) (Lead Council: PPARC)

- 3.4.1 ELT is a generic term describing telescopes in the range 20 – 100 metres. The present generation of eight metre ground-based telescopes, complemented by HST and other satellites, have generated a new view of the Universe and have produced a wealth of fascinating questions that only the vast collecting area and high spatial resolution of an ELT will be able to answer. These questions cover all those areas across planetary science, astronomy and cosmology that are the stated priorities in PPARC's strategy for astronomy. They range from long-term modelling of weather patterns in Solar System planets, through direct imaging of Earth-like bodies around other stars, to understanding the complete formation histories of galaxies and probing all the way across the Universe and therefore back in time to image the first objects that ever formed.
- 3.4.2 Cutting-edge telescopes are immensely flexible tools that can be turned to many different projects. For example, we already know that the up-coming generation of space observatories, operating at wavelengths from the far infrared to X-rays, will need the kind of complementary data that only an extremely large optical telescope can provide. Even now, images from HST's Advanced Camera for Surveys reveal objects that are too faint for the largest existing telescopes to obtain spectra. Since spectroscopy remains a key diagnostic tool in astrophysics, we are unlikely to make much progress in understanding the nature of many of these objects without an ELT. The advent of the JWST, scheduled for launch in 2011, will only serve to increase the problem, since this telescope will reveal objects an order of magnitude fainter than can the HST. Unless we acquire facilities that are an order of magnitude larger than the present generation of optical telescope, much of the potential of satellites like JWST will not be fully realised as we will not be able to perform the spectroscopic follow-up required to interpret their discoveries.
- 3.4.3 Thus, even neglecting the new scientific questions that the coming decades will surely raise, there is already a pressing need for an ELT facility. Not only will it allow us to finally address a wide range of already-posed key scientific questions, but it will also provide the complementary data that will unlock the full potential of future satellite missions.

² All costings in euros are given with equivalent £ sterling at a rate of £0.65 to 1.0 euro.

- 3.4.4 In the short-term, the current UK R&D activity comprises three strands. 1) The UK contribution to the EU Framework 6 ELT Design Study, 2) A directed programme of R&D in key areas and 3) An open call for innovative technologies that can make significant impact on scientific output or telescope viability.
- 3.4.5 Recognising that at an estimated cost of 1 billion euro (£650 million), an ELT project will need to be undertaken as a multi-national endeavour, PPARC Council has agreed that the UK should play a proactive role in a global strategy for ELTs, following the Linear Collider model. The UK continues to be the partner of choice in most astronomy programmes and with its current suite of partnerships is ideally placed to bring together European and U.S. aspirations. The UK, pro-rata, share of such a project would be of the order £70 million, with the funding profile for first light 2014 costings (in £ million) given.

FY 08/09	09/10	10/11	11/12
10	10	15	35

3.5. Fourth Generation Light Source (4GLS) (Lead Council: CCLRC)

- 3.5.1 4GLS will be a world-leading photon facility to enable a broad range of outstanding science programmes by the UK and international communities. It will enable the study of real time molecular processes and reactions on femtosecond timescales in short-lived, nanostructured or ultra-dilute systems. The emphasis would be on molecular and device function, rather than the largely ‘static’ structural focus of work on 3rd generation synchrotron radiation sources and X-ray FELs.
- 3.5.2 The 4GLS facility will make unique contributions in a number of areas. These include understanding the function of single biomolecules in living systems and membrane transport; determining catalytic reaction pathways (in areas as diverse as enzyme processes, reactions contributing to atmospheric pollution or occurring in the interstellar medium); studies of electron motion in atoms/molecules and developing ‘coherent control’ of reactions; developing new nanoscale devices through understanding electron charge and spin transport; and development of new dynamic imaging techniques to improve early diagnosis of conditions such as cancer and prion based diseases.
- 3.5.3 The major themes of the science case will be time-resolved measurements in the life sciences and nanoscience. Particular areas of strength are high resolution pump-probe spectroscopy of atoms, molecules and clusters, including high field dynamics, dynamics at surfaces and interfaces, many body problems in condensed matter, and studies of the dynamics of biomolecules in ‘real’ environments.
- 3.5.4 The 4GLS facility will combine energy recovery linac (ERL) and free electron laser (FEL) technologies to deliver a suite of naturally synchronised state-of-the-art sources of synchrotron radiation and FEL radiation covering the terahertz (THz) to soft X-ray regimes. 4GLS is the leading energy recovery proposal in Europe and the most comprehensive in terms of utilisation of combined sources. In terms of multiuser capability, it is currently the most advanced ERL proposal in the world, offering the opportunity to establish an international lead for the UK. 4GLS is complementary to TESLA XFEL, to table-top lasers and to third generation sources available to the UK research community.

- 3.5.5 There will be unique advantages to the 4GLS facility. The facility will utilise a combination of sources with the fully integrated capability to utilise both short pulse SR(ERL) and the FEL sources for pump-probe and two colour experiments. This ensures experimental flexibility and cost effective delivery. 4GLS will have intense, tuneable, variable polarisation FEL sources optimised for spectroscopy and imaging in frequency ranges XUV, VUV and IR-THz. It will make ERL spontaneous light sources available from soft X-ray - THz. This gives short pulse, high repetition rate operation, the capability to ‘pulse tailor’, and low probability of sample damage. 4GLS will be Europe’s most intense broadband source of coherent THz radiation.
- 3.5.6 Key international collaborations have been developed with Jefferson Laboratory (ERL technology), DESY (FEL and linear collider), Forschungszentrum Rossendorf (ERL component development) and Cornell University (superconducting linac and RF technology). 4GLS will underpin the development of key accelerator technologies to support the International Linear Collider Project. 4GLS will be a multi-user facility drawing together the SR and laser communities in new frontier science. The capabilities of 4GLS will ensure that it becomes a major attractor of world class international investigators.
- 3.6.7 The cost of construction is estimated to be £180 million over five years. The funding profile is in £ million .

FY 07/08	08/09	09/10	10/11	11/12
7	35	63	55	20

3.6 Fusion Facilities (*Lead Council: EPSRC*)

- 3.6.1 Fusion holds out the prospect of clean, safe and competitive production of base-load electricity. The Joint European Torus (JET) at Culham, which is currently the world’s leading fusion research facility, has produced 16MW of fusion power, but there are still significant engineering and materials research challenges to be met before a reliable fusion power station can be built. A key next step, is to build the power station sized International Thermonuclear Experimental Reactor (ITER), which should produce 500 MW of fusion power. Rapid realisation of fusion power on the “fast track”, advocated by the UK Government, also requires the construction of the International Fusion Materials Irradiation Facility (IFMIF) in parallel with ITER. IFMIF will test materials at neutron fluences typical of fusion power stations.
- 3.6.2 The UK has a proud tradition in fusion research, through work at UKAEA Culham and hosting JET, which UKAEA operates under a contract with EURATOM for international teams of fusion scientists. A key element of the Culham programme is the world-leading spherical tokamak facility MAST (Mega Amp Spherical Tokamak). Spherical tokamaks, which were pioneered in the UK, can produce the desired plasma pressure (and hence fusion energy) with much lower magnetic fields than conventional tokamaks. They could therefore provide the basis for more compact, non-superconducting (and hence cheaper) power stations.
- 3.6.3 Development of the spherical tokamak is an important part of the integrated European fusion programme, for which the UK takes responsibility. Thus, while MAST is a UK facility, 20 per cent of the operating costs paid by EURATOM, which contributed around one third of the capital and installation costs.

- 3.6.4 MAST's much smaller predecessor START played a key role in establishing the potential of spherical tokamaks, and raised from 13 per cent to 40 per cent the world record for plasma pressure in a tokamak divided by magnetic pressure. MAST was built on a very tight budget, with minimal equipment, the initial goal being to see whether the promise of START is maintained in bigger, hotter plasmas carrying much larger currents. MAST quickly achieved this goal, and has made important contributions to tokamak physics generally. Work at MAST involves PhD students and plays an important role in training young fusion scientists.
- 3.6.5 In order for MAST's full potential to be realised, it now needs major improvements in the capability to produce heat and sustain high pressure plasmas, and allow steady-state operating modes to be thoroughly investigated, which is not possible at present. This should make it possible to produce high performance plasmas, thereby deepening our understanding of tokamak physics generally, and helping to kick start and then support the exploitation of ITER (which will need to be accompanied by smaller, more flexible, experiments). It will determine whether the spherical tokamak concept could provide the basis for a Component Test Facility, which may be required to strengthen and accelerate the fast track approach to fusion by allowing tests of components in neutron fluences typical of a fusion power station. In addition it will determine the spherical tokamak's suitability as a power plant system, so that when commercialisation is reached we know whether it is an option.
- 3.6.6 The only comparable spherical tokamak is NSTX at Princeton, which is currently better powered than MAST, but has a different design and is less flexible and therefore harder to exploit. An upgraded MAST would make important contributions to tokamak physics, and is now needed to establish the full potential of the spherical tokamak concept and to ensure that the UK maintains its world-leading pioneering position in a field that it started.
- 3.6.7 These major contributions to speeding up the development, and ensuring the eventual success, of fusion power, require an investment of £30 million (of which EURATOM should pay one third) in a major upgrade. Operating and maintenance costs (including all manpower, accommodation and overhead costs) would increase by approximately £1.5 million from the present to approximately £7 million per annum (funded 80 per cent by EPSRC and 20 per cent by EURATOM). The upgrade would be completed approximately four years after approval (and for much of that time MAST could still operate). Although the primary purpose is to drive forward the development of fusion power, the upgrade will also involve and enable a wide range of fundamental and applied science, from understanding turbulence and its suppression in magnetised fluids, to development of the instrumentation needed to measure plasma behaviour. Funding profile in £ million.

FY 07/08	08/09	09/10	10/11
4.4	7.3	7.1	0.4

3.7 Gravitational Wave Observatory (Lead Council: PPARC)

- 3.7.1 The first generation of long baseline gravitational wave detectors (LIGO, GEO 600 and TAMA 300) are now undergoing periods of data taking, and will be joined by VIRGO in this activity next year. The upgrade plan for LIGO (Advanced LIGO) in the US is proceeding and the project was approved for funding in October 2004. The UK participates in GEO600 (a joint UK-Germany project) and in Advanced LIGO. Collaborations are being developed with French/Italian groups to upgrade VIRGO so that on a suitable timescale it will be comparable in sensitivity to, and be able to operate in a co-ordinated research program with, Advanced LIGO. World-leading UK technology is already operating on GEO600 that, together with LIGO interferometers in the US, forms the first network of interferometers. Close involvement of the GEO project members in the LIGO Scientific Collaboration has led to the adoption of GEO developed technology in Advanced LIGO. By 2006 GEO600 will be available to be converted to operate as a high frequency detector to extend the bandwidth of the network - targeting neutron star physics in particular, and also as a test-bed of technology for VIRGO.
- 3.7.2 UK groups aim to collaborate with European colleagues to upgrade GEO 600, and enhance the VIRGO detector to make use of the monolithic suspension technology and the advanced interferometry developed for GEO 600. The future enhancement of VIRGO is essential to allow a European contribution to a world-wide network of advanced detectors, with an almost guaranteed detection rate of compact binary coalescence sources, to be operational around the end of this decade. A UK contribution to this will allow access to a wider range of data and also consolidate the UK involvement in the next generation of European detectors.
- 3.7.3 GEO-HF would be a detector having a tunable response targeted at signals in the under-explored 600 Hz to 4 kHz band, triggered by radio, X-ray, gamma-ray and other gravitational wave detector observations. Such signals are thought to be produced by, for example, the ringing of neutron stars resulting from pulsar or magnetar glitches. Signals from low mass X-ray binaries or from the coalescence of compact binary systems are also expected within this band. Observations with this detector would be enhanced by the inclusion of a detector running in narrow band mode in the Advanced LIGO interferometer network, or by VIRGO running with advanced interferometry.
- 3.7.4 The estimated UK contribution to this project is £31 million. The funding profile of this UK contribution is in £ million.

FY 07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
0.5	1.5	3	1	2	3	5	6	6	3

3.8 High Power Lasers (Lead Council: CCLRC)

- 3.8.1 High power lasers enable the physics of matter at extreme densities and temperatures to be studied in the laboratory, with applications ranging from fundamental science (atomic and nuclear physics, relativistic plasmas) to new scientific opportunities (compact particle accelerators and laboratory based astrophysics) and high impact industrial exploitation (inertial fusion energy).

- 3.8.2 The UK has an excellent track record in this field, currently operating the world’s most powerful laser, following a strategy to provide the community with internationally leading facilities. This has attracted strong demand for access to the Central Laser Facility (CLF), invariably more than a factor-2 oversubscribed, with many academic and industrial users from Europe, the US and Japan. Over the next five years, however, a number of competing and higher specification laser systems are due to come online across the world.
- 3.8.3 As a result of recent advances in the field of “fast ignition” fusion energy, there is now an opportunity for the UK to continue to provide the scientific and technical leadership by taking the initiative to pioneer the next generation of facility. This opportunity couples the short pulse laser science being pursued in the UK to the expertise in inertial fusion energy research amongst our academic user community. The solution is to develop a laser fusion facility of sufficient capability that it represents a step-jump from any other emerging system, and with sufficient flexibility to build on the CLF’s leading reputation for enabling a broad range of scientific programmes.
- 3.8.4 Inertial Fusion Energy is an important societal endeavour because it avoids the problems of greenhouse gas emissions and long-lived radioactive products. Traditionally it has been predicted that extremely large-scale systems would be required to achieve ignition and thus energy gain. This philosophy is reflected in the designs of NIF and LMJ. However, recent pioneering work by an Anglo-Japanese team has demonstrated that by combining high energy pulses with Petawatt pulses, much smaller lasers could potentially be employed to achieve the goal of fusion energy gain. Factor-10 reductions in scale are calculated, enabling HiPER to study the unique regime of propagating fusion burn and thus high gain.
- 3.8.5 The proposed design of the HiPER facility is also such that a truly significant leap in peak laser power (two to three orders of magnitude) could be achieved by combining together the beams in an innovative amplification scheme. Beams with powers exceeding 150 Petawatts are calculated, based on existing technology and demonstrated performance. Extension into the Exawatt regime is anticipated based on reasonable developments of current technology. This mode of operation would provide a revolutionary source for particle acceleration research, laboratory astrophysics, atomic physics in extreme thermodynamic and electromagnetic states, transient nuclear physics, neutron scattering science and relativistic plasma physics. It would also enable studies into fundamental High Energy Particle physics previously thought inaccessible.
- 3.8.6 HiPER will be a flagship facility for Europe, representing a critical step in the pursuit of fusion energy, with the ability to deliver a laser power at least two orders of magnitude greater than any other planned system. A facility such as this is required to ensure the UK maintains its international position in this field, which impacts across a very broad range of scientific disciplines. It would ensure that our facilities continue to reflect the long-standing strength and depth of our community.
- 3.8.7 The UK contribution to the construction of the HiPER facility is estimated to be £160 million, 30 per cent of the £500 million total cost. The funding profile of the UK contribution is in £ million.

FY 10/11	11/12	12/13	13/14	14/15
15	50	50	30	15

3.9 Household Panel Study (Lead Council: ESRC)

- 3.9.1 The increasingly complex, dynamic and diverse society in which we live means that the social science community and government policy makers are being faced with ever more searching research questions. To answer these questions there is a huge demand for high quality, large scale datasets that are essential to the social science community and fundamentally underpin the policy making process.
- 3.9.2 This is a particularly timely moment to invest in world leading research infrastructure. There is a unique opportunity to secure our place in the top two of world science, to add to the momentum of previous Spending Review (SR) investments, address outstanding scientific opportunities and to contribute to policy development to tackle many of the most critical challenges facing the UK. Conversely to not take this opportunity would risk the UK position in global scientific leadership, fail to realise the benefits of past SR investments, leave researchers unable to fully address many key scientific questions and leave policy makers bereft of crucial data for evidence based policy making.
- 3.9.3 Developments in technology, particularly e-social science, are creating path breaking new opportunities to link, model and mine large-scale datasets. Yet just at the point when both the demand for major datasets, and the capacity to analyse them, is gathering momentum, there is a very real danger that the UK data infrastructure will lack the depth and breadth to meet the research and policy challenges of the future. This is because many of the UK's existing datasets were never designed to deal with complexities of twenty first century society. They lack the level of granularity which is now essential to address some of the most pressing scientific and policy challenges faced by the UK's ever more diverse population. This in turn threatens to undermine the UK's position amongst the global leaders of social scientific research.
- 3.9.4 To address the problem, this is a proposal for the creation of the biggest single household panel dataset in the world. There are a number of key features to the data set. It will consist of some 40,000 UK households, the members of which will be interviewed on an annual basis to capture short and longer term change in society. The dataset will, for the first time ever, integrate a wide range of social and economic variables with bio-medical data (e.g. DNA, blood and tissue samples). These data will be linked to newly available administrative data sources (e.g. school and hospital records) and to text, voice and video information. This feature will create a unique dataset, with over three times as many households and four times as many data points (around three billion) as any comparable study. The dataset will truly revolutionise the capacity to study our society, in such key areas as household and demographic change, poverty, migration, labour market dynamics, crime and ageing. It will provide groundbreaking opportunities to test new scientific hypotheses and give momentum to the development of new methodological tools and techniques. The dataset will open up major new opportunities for more in depth and informed policy national and regional analysis on such key topics as the provision of public services, tax and pensions, crime, health and education;

- 3.9.5 Funding a new panel study will help to ensure that the UK commands the most advanced social science data infrastructure in the world and sustains its top two international ranking in social scientific research. It will strengthen the UK position as a global leader in such areas as e-social science, building on previous CSR investments. It will provide an unrivalled evidence base to meet the national and regional demands of the wide range of policy makers and will attract world leading researchers to work in the UK.
- 3.9.6 The study will cost £40 million over the next five years, based on Full Economic Costs and is likely to lever in a further £10 million from co-funding. The capital cost of the data collection is estimated to be £24 million over a five-year period. The funding profile is in £ million.

FY 06/07	07/08	08/09	09/10	10/11
6	6	6	6	6

3.10 ISIS Second Target Station Instruments – Phase 2 (Lead Council: CCLRC)

- 3.10.1 Neutron scattering is a key technique for the study of the structure and dynamics of condensed matter. It is an area in which the UK is a world leader. ISIS is the world's leading pulsed neutron source and the construction of the second target station together with a suite of world-class instruments to exploit the unique source performance will maintain its current pre-eminent position.
- 3.10.2 The ISIS Second Target Station (TS-2) has so far received funding for the construction of the core project with the capacity for 18 new beams, which will become fully operational in 2007/08. The phase one instrument suite (seven state-of-the-art instruments) has been funded from a combination of sources, Large Facilities Fund, the EU FP-6 programme and from European partners.
- 3.10.3 The Second Target Station is qualitatively different to the current facility. It is optimised for the study of soft condensed matter, bio-materials, advanced materials and nano-technology. These are all areas of emerging and increasing importance, and encompass many of the new technological areas that are being targeted for future wealth creation. The new capabilities of TS-2 will attract new users, international partners and substantially broaden the user base.
- 3.10.4 This proposal is seeking funding for the second phase of instrumentation for TS-2, at a level of approximately two instruments per year over the period 2007 to 2014. These instruments will create new opportunities for studies of meso-scale structures to longer length scales, perform direct imaging, probe slower dynamics (relevant to soft matter and bio-materials) using spin echo techniques, broaden the diffraction capability to higher resolution single crystal studies and to larger molecular unit cells, and to study the impact of extreme environments (pressure, temperature, and magnetic field).
- 3.10.5 Although there is considerable interest from a number of overseas partners, significant funding from the Large Facilities Fund is essential to maintain and reinforce the UK influence on strategic priorities. Any delay in developing the second wave of instruments for TS-2 will jeopardise the investment offers from European partners.

3.10.6 The primary beneficiaries of these new instruments will be the 450-plus UK academic principal investigators who currently use ISIS and the new researchers who will be attracted to the enhanced facilities. The stimulation of interacting at the facility with world-leading researchers who are attracted to ISIS from overseas compounds this benefit.

3.10.7 Working at central facilities develops a wide range of key skills including teamwork, organisation and planning, and self-reliance, in addition to those required to operate state-of-the-art experimental equipment. Activities at ISIS therefore impact significantly on the training of the 1,200 researchers, the majority aged 30 or younger, who come to the facility each year.

3.10.8 The estimated cost of the construction of this facility is estimated to be £90 million over a six year period. The funding profile is in £ million.

FY 07/08	08/09	09/10	10/11	11/12	12/13	13/14
12.8	12.8	12.8	12.9	12.9	12.9	12.9

3.11 Linear collider (Lead Council: PPARC)

3.11.1 A linear collider (LC) operating at 0.5 to 1TeV has been identified by the international particle physics community as its highest priority. The aim, as agreed unanimously by the international funding agencies, is to produce a fully costed engineering design by 2008 for funding approval, to review the status of the project in the light of LHC results in 2010 and if they are as expected, to proceed with construction for operation by 2015. Commissioning of a LC in 2015 would provide a significant period of concurrent running with the LHC, which is desirable due to the need for a linear collider to make precision measurements of whatever phenomena may be discovered by LHC. Concurrent running of the Linear Collider and the LHC is needed to extract the maximum scientific return from both machines. This timetable is consistent with the OECD Ministerial announcement of 29 – 30 January 2004.

3.11.2 The physics case for the linear collider has been set out by detailed studies in all three main regions: Asia, Europe and North America. All regions agree that it is essential to complement the LHC, which has a large energy reach but cannot be tuned to a precise energy and which suffers from large backgrounds, with the linear collider, which can be tuned to a precise energy and whose clean experimental conditions and precision also lead to unique discovery potential.

- 3.11.3 The scope and parameters for the performance of such a linear collider have been defined by the physics community's International Linear Collider Steering Committee (ILCSC), and against this scope, its International Technology Review Panel (ITRP) recommended that a design should be developed based on superconducting rf (cold) technology. This recommendation was unanimously accepted by the International Committee on Future Accelerators (ICFA) and the particle physics community in August 2004. The regional linear collider consortiums have stood down to be replaced by a single international consortium that met for the first time in Japan in November 2004. At this first meeting the consortium began to define the work that will be required in each of the subsystems to reach a final design. The US and Japanese groups, who have to date worked primarily on the warm technology, have already substantially redirected their efforts to the chosen technology in collaboration with Europe and there will be a period when responsibilities are redefined. The machine will be 30 - 40 km in total length, and there are potential sites in the US, Germany and Japan close to existing accelerator laboratories.
- 3.11.4 UK university groups and CCLRC have developed internationally recognised expertise directed towards the simulation and design of the beam delivery system (BDS) and in technologies such as alignment and feedback, which are applicable elsewhere in the collider. Each of the two planned BDS will be 1.5 km long on either side of the interaction regions and will take the high-energy beams from the main linacs down to nm size at the interaction point. The BDS, housing critical diagnostic instruments, is at the interface of machine and detector and of central importance as stable collisions of these beams are required to carry out the high-luminosity physics programme. It is an area close to the expertise of the UK particle physics community and will position the UK for future accelerator projects. The PPARC-funded programme in association with CCLRC will encompass R&D on the BDS and related areas and will be integrated into the international design. By concentrating in this area the UK will be able to take a world lead in this field. It is expected that the international project will move from the current level of R&D funded in a loosely coordinated manner by the various funding agencies, to a more structured approach with each region taking on specific and agreed responsibilities. This change in approach is already taking place and will be completed during the engineering design phase from 2006 to 2009. During this period the effort and spend will begin to ramp up towards the beginning of construction, with a construction decision planned by 2010.
- 3.11.5 A new technology is needed to reach energies much beyond about 1.5 TeV, and a novel two-beam accelerator design with a much higher accelerating gradient is being developed at CERN, which might be installed as an upgrade to any of the present designs after several years of operation. There is already significant collaboration between the major accelerator laboratories in Europe, the US and Japan, and national laboratories in France and Italy, on the development of the technology.
- 3.11.6 Preliminary costs based on the selected technology have given an overall cost of £3 billion. A leading construction role in the BDS project would require a UK planning provision of around £200 million in 2010 prices. The total UK contribution to the linear collider detectors is likely to be of a similar order to that of the LHC detectors, approx £140 million in 2010 prices.

FY 06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15
7	10	12.5	15	40	60	7	80	65

3.12 Megawatt Class Spallation Source for Europe (Lead Council: CCLRC)

- 3.12.1 Neutrons are an effective, and for many applications a unique, tool for probing the structure of matter. The UK has access to the world's most powerful reactor and accelerator based neutron sources in the form of the Institut Laue-Langevin (ILL) in Grenoble and ISIS at CCLRC's Rutherford Appleton Laboratory. In the short term the UK intends to build on these two opportunities through investment in the ILL's Millennium Programme and the development of a Second Target Station at ISIS. However in the longer term the UK will need access to a megawatt-class source to remain competitive.
- 3.12.2 In the USA, the 1.4 MW Spallation Neutron Source (SNS) is being built at Oak Ridge National Laboratory. Initial scientific operations are scheduled for start in 2007 with the instrument suite being established incrementally over a number of years. In Japan, a new facility (J-PARC) is being built at Tokai. This will incorporate a 1 MW neutron scattering centre as part of a multi-purpose facility for nuclear physics, research on nuclear waste transmutation, and high energy physics, and will become operational towards the end of the decade.
- 3.12.3 In common with other European countries contributing to the European Strategy Forum on Research Infrastructure (ESFRI), the UK recognised that although the baseline option of developing ILL and ISIS will support scientific activities in Europe in the medium term, a next-generation neutron source will be required, and continuing work is necessary to underpin future developments in this and related areas. Therefore, in the medium term, the UK will pursue work on accelerator-based spallation neutron sources in collaboration with European partners and with the MW facilities under construction in the USA and Japan.
- 3.12.4 Options for the realisation of a next-generation accelerator-based neutron source for Europe will be defined by the scientific and technological progress at the two MW-class sources being developed in the USA and Japan. Such options include a MW upgrade to the ISIS facility, developments based on either the SNS or J-PARC technologies at the 1–2 MW level, and the 5 + 5 MW short and long pulse source identified in the ESS study. These and other scenarios will involve extensive cooperation on neutron policy at a European level.
- 3.12.5 As part of its strategic role the CCLRC will continue pursuing these options, working with the community in refining the scientific case for neutrons and in evaluating solutions for technical problems. It will take a lead in developing accelerator and target technologies which have relevance for neutron sources, neutrino factories and other uses of high power proton accelerators while maintaining close cooperation with developments world-wide.
- 3.12.6 The UK contribution to this facility is estimated to be £300 million excluding the site premium, the total cost of the project estimated to be £500 million. The funding profile extends until 2019/20, but is given here until 2015/16 and is in £ million.

FY 07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16
3	10	30	30	30	30	30	30	30

3.13 Mini Fabrication Facility for Nanotechnology (Lead Council : EPSRC)

- 3.13.1 Silicon Enabled Nanoelectronics is a strategic priority, consistent with DTI recommendations in the report of the Electronics Innovation and Growth Team (EIGT), if the UK is to become a world leading knowledge-based society. The global electronics market in 2004 was worth \$1100 billion with the silicon component being \$200 billion. However, the levels of investment needed to build and run industrial fabrication plants to exploit new technologies also runs into billions and companies are unwilling to invest in new or upgrades to existing capital facilities unless there is a realistic chance of pay back. To enable researchers to explore the opportunities to the full, and provide underpinning confidence to industry, a pilot scale fabrication facility (mini-fab) is a requirement, since the ability to fabricate at the nanometre scale will be necessary to master nanoelectronics systems. Nanotube and nanowire markets are predicted to start becoming significant worldwide in 2009, but will be expected to increase rapidly thereafter with an estimated total market (including nanoparticles, nanocells, molecular chips and organic transistors) of some £8 billion by 2014.
- 3.13.2 On a 20-30 year timescale, no other electronic materials technology has the potential to replace silicon, given its robust physical properties, for outstanding performance. As silicon based devices become ever more ubiquitous, the silicon value in products increases both in terms of hardware and software. The era of silicon microelectronics has achieved so much, but the new era of silicon nanoelectronics promises much more. An example might be the “doctor-in-your-pocket”, comprising a laboratory-on-chip for sensing (nanotechnology sensors) and real-time diagnostics (nanoelectronics logic) for a range of medical conditions. Moore’s Law will continue to address the intelligence issue by doubling the computing power that can be put on silicon chips every two years, but what will be needed to implement interactivity will be something considerably ‘More than Moore’. A multitude of heterogeneous technologies for integrating mechanics, fluidics, optics, acoustics, and eventually a direct interface to the human body will be needed to add the full complement of awareness and responsiveness capabilities required for ambient intelligence and research into architectural solutions needed when developing systems on chip. These nanoelectronic subsystems will form the eyes, ears, arms and legs of ambient intelligence, complementing the brains provided by microprocessor and memory subsystems. Possible implementations include those for personal well-being and health (e.g. an implanted thermo-electric cooler to suppress epilepsy), integrated robotic systems, solid state lighting, integrated area map and compass modules, or systems to monitor environmental conditions.

- 3.13.3 A mini-fab, based around a set of 6-8 cluster tools, will enable highly flexible state-of-the-art single wafer processing and integration with other nanotechnologies and existing research infrastructure around the UK. The facility must be able to accommodate the state-of-the-art fabrication of logic circuits, albeit quite slowly by manufacturing standards but acceptable for one-offs or low volume inherent in leading edge research. Strategic partnerships with industry will be sought where this is appropriate and necessary to ensure compatibility with user needs and potential markets. This allows maximum flexibility while avoiding the crippling costs associated with CMOS manufacturing, encouraging new spin-outs and further inward investment. Facility users will comprise a broad community of scientists studying the fundamental nano-scale processes that can be revealed and engineers exploiting the power of intelligent nanotechnology in fields as diverse as communications, medicine, transport and information processing. Such a facility will be intrinsic part of the infrastructure that must be in place if the UK is to well placed to be able to generate wealth from the nanotechnology revolution.
- 3.13.4 The proposed new facility would need a capital investment of circa £50 million with an annual operational budget of circa £5 million. This will provide the infrastructure needed to become internationally competitive in the many interdisciplinary fields that intersect nanotechnology as well as nanoelectronics itself. Global alliances are forming; hence UK participation requires an early start on 1-2 year construction of the mini-fab (i.e by 2010). Funding profile in £ million.

FY 09/10	10/11	11/12	12/13	13/14
10	10	10	10	10

3.14 Neutrino facilities (Lead Council: PPARC)

- 3.14.1 One of the most exciting particle physics results in the last 20 years has been that neutrinos have been shown to have a very small but non zero mass in experiments studying neutrinos from both the sun and cosmic rays. This new discovery has opened up a new field of research within particle physics to understand all the characteristics of these particles, which had formerly thought to be completely understood. The UK is currently positioned to play a leading role in several projects studying the nature and properties of neutrinos.
- 3.14.2 The new results give an indication of the difference in mass between the three quantum mechanical states which combine to make the three flavours of neutrino. The current experiments cannot determine the absolute mass of any one of the mass states, nor determine whether neutrinos have distinct antiparticles, normally assumed but by no means guaranteed. The only way to resolve these issues is to search for a very rare process known as double beta decay that usually happens with the emission of two neutrinos. In the case that neutrinos were Majorana particles (i.e. have no distinct anti-particle), this decay process would also proceed without any neutrinos present, and the signal, although incredibly rare, would be striking in its energy distribution.

- 3.14.3 There is now a significant amount of activity within the UK focused on studying neutrinos and it has a high strategic importance in the international community. UK groups are involved with the NEMO experiment which is taking data in the Frejus tunnel, one of only two such experiments presently running. This experiment is not sufficient to reach the levels of sensitivity needed to observe neutrinoless double beta decay: a more advanced experiment is needed and is in the process of being planned by the NEMO international collaboration. The UK is expecting to play a major role in this new Super-NEMO project and a design study has been proposed by groups in the UK, ideally to position themselves for a major role in the subsequent construction and physics exploitation.
- 3.14.4 SuperNEMO is a next generation double beta decay project being developed by French, UK, Russian, Japanese, Czech and US groups. Based on existing technology from the NEMO projects developed over the last 18 years, this will become the most important double beta decay experiment in the next ten years. It will uniquely address key outstanding questions in particle physics on the nature and properties of neutrinos. The SuperNEMO experiment will have the capability of studying different isotopes so that it remains flexible to future nuclear matrix element calculations that may identify the most promising isotope. As this next generation detector relies heavily on the very well known technology developed for NEMO the amount of R&D needed is expected to be minimal. However, it is essential that such a project have an improved energy resolution. In the initial design study phase, the UK plans to optimise the SuperNEMO modular geometry, calorimeter and tracking parameters to finalise the design of one of the SuperNEMO modules, identify the optimal location for SuperNEMO and the optimal layout of the modules in the likely underground locations.
- 3.14.5 A very large and deep underground facility is needed as the success of the experiment relies on there being only a low background from such sources as natural radioactivity and cosmic rays. The eventual site has not yet been determined however the UK could potentially host the experiment at the Boulby mine.
- 3.1.4.6 The Design study is planned to take two years with a decision to construct the full experiment planned for 2007/8. SuperNEMO would be constructed at an approximate cost of £30 million over two years, including the laboratory infrastructure, and would then operate for at least five years to extract the maximum physics return. The funding profile is given in £ million.

FY 07/08	08/09
15	15

3.15 Neutrino factory (Lead Council: PPARC)

- 3.15.1 The technology needed to design and build the next linear electron-positron collider is generally considered to be mature (at least for energies up to 1 TeV), however, the technology for a muon collider has still to be developed. The technological challenges are formidable (the idea was first explored in the 1960s, but has only been seriously studied in the past five or six years). Recently a three-stage scenario has emerged. The first stage is the design and construction of a muon storage ring to create a 'neutrino factory', with the intense neutrino beams from muon decay in storage ring directed hundreds or thousands of kilometres through the earth to the detectors. This would also demonstrate the production, creation, capture, cooling and acceleration of muons in sufficient numbers to make the muon collider feasible. The second stage would be a 'Higgs factory' - a muon collider operating from the Higgs mass (assumed to be between 100 and 200 GeV) to somewhat above the top quark mass (175 GeV). The third stage would be a multi-TeV muon collider. A multi-TeV muon collider is a much smaller machine (comparable to the SPS or Tevatron) than either a multi-TeV Linear Collider or a Very Large Hadron Collider.
- 3.15.2 The scientific case for the neutrino factory is very strong. The main evidence for neutrino oscillations comes from observations on atmospheric and solar neutrinos. Controlled experiments use neutrinos from a variety of sources. Low energy electron neutrinos come from nuclear reactors. Intermediate energy electron and muon neutrinos can be obtained from the decay of slow muons, for example, the KARMEN experiment at ISIS. Beams from high-energy accelerators are mostly muon neutrinos from pion decay, with a small electron neutrino contamination. The neutrino beam from a muon storage ring contains approximately equal numbers of muon neutrinos and electron antineutrinos (or muon antineutrinos and electron neutrinos) with a similar energy. This allows in principle a complete measurement of the two mass differences and the four parameters describing the neutrino-mixing matrix - only the absolute mass remains to be determined in an independent experiment. The preferred location for the neutrino factory and the detectors depend upon the mixing parameters.
- 3.15.3 High power proton accelerators can be used as drivers for neutron spallation sources, tritium production, hybrid power reactors and nuclear waste incineration, the production of intense muon and neutrino beams, radioactive beam and for materials irradiation. Technical discussions on high power accelerators are taking place in European and International forums.

3.1.5.4 The CCLRC’s Rutherford Appleton Laboratory is a possible location for the neutrino factory building on ISIS experience. This would give potential baselines of 330 km (Boulby), 1,520 km (Gran Sasso), 5,890 km (Soudan) or 8,600 km (Kamiokande). Alternative sites include CERN, Brookhaven, Fermilab and KEK/JAERI. It will take several years to develop the technology and an important first step will be the establishment of a muon ionisation cooling experiment (MICE). Phase 1 of the MICE project has received approval and will be constructed at RAL by March 2007. The results of the next generation of neutrino experiments are needed to complete the machine specification, so that construction could not begin before 2008, and would take at least seven years to complete. There has been no detailed cost estimate of a neutrino factory, but it is likely to be at least £2 billion. If the UK were to host the facility we would expect to be asked to contribute some 50 per cent of the costs i.e. £1 billion. If the UK were not to host the facility the cost would be in the order of £200 million for construction commencing in 2010. The funding profile for the latter is given in £ million.

FY 08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16
5	10	20	30	35	35	35	20

3.16 Oceanographic Research Ship (Lead Council: NERC)

3.16.1 The oceans play a pivotal role in the functioning of the Earth system, for example the possible rapid collapse of the Atlantic Ocean’s thermohaline circulation would lead to severe and rapid climate change in north west Europe. Seagoing science is an essential element of Earth-system science. To maintain the UK’s strong international leadership in producing high quality research in this area, NERC must retain the capability to field internationally competitive scientific programmes at sea using state-of-the-art research ships. NERC has two dedicated research ships for multidisciplinary ocean science cruises – the Discovery and the Charles Darwin (to be replaced by the James Cook in 2006) – and continued investment in these facilities is required to ensure that the UK remains in the first division of seagoing science nations.

3.16.2 The Discovery will be at the end of its scientifically useful life by 2011, by which time the ship will have been in service for 49-years. The replacement of Discovery with a ship that is capable of supporting large multidisciplinary science cruises is required to avoid driving detrimental large-scale changes to UK marine science research, to deliver NERC’s strategy of Earth-system science, and to ensure that the UK’s ocean sciences overall ranking as second to the USA in research excellence is maintained. It will ensure that the UK continues to provide strong international leadership and partnership within International programmes, and that the UK can continue to be involved in large-scale international collaborations. Failure to invest in the timely replacement of Discovery would risk the delivery of NERC strategic priorities and the UK’s strong international reputation with its collaborative science and barter partners – as the ship may have to be withdrawn from service at short notice in the event of a major systems failure.

3.16.3 The UK is heavily involved with the bartering of marine facilities with its partners in the United States, Germany, France, the Netherlands and Norway – with *ca.*200 barter days a year exchanged by NERC. These arrangements ensure that research ships are used far more efficiently and cost-effectively, and they allow the UK scientific communities access to a wider range of marine facilities (including 32-research ships) and geographical areas than would have otherwise been possible. Continued access for the UK research community to barter facilities is contingent on the UK having state-of-the-art facilities to barter with, and so the replacement of Discovery will ensure that the UK's barter arrangements remain strong and that the UK science community can continue to conduct research on a worldwide basis.

3.16.4 The total cost of the replacement of Discovery with the required specification will be £55 million, and NERC has earmarked 30 per cent of the required funding (i.e. £16.5 million) for this project. The indicative funding profile for the build of a ship to be delivered in 2011 is outlined below in £ million.

FY 06/07	07/08	08/09	09/10	10/11	11/12
0.1	1	14	18	18	3.9

3.17 Radioactive Particle Beams Facility (Lead Council: EPSRC)

3.17.1 The many-body aspects of nuclei forge a deep link to other many-body systems, ranging from the super-large (e.g. galactic clusters), through the biological and nano-scale, to nuclei, and to the sub-femto (hadronic structure). In addition, the role of nuclei and nuclear reactions in stars embeds nuclear structure directly into the cosmos. Nuclear structure studies thus span length scales from the femtolevel to universal dimensions, and energy scales from sub-eV to GeV

3.17.2 Over the last half century, much progress has been made in unravelling the nuclear many-body problem, based on data from the 300 nuclei accessible with stable beams and targets. However, the full reach of bound nuclei spans some 6,000-7,000 species with a much larger range of nucleon numbers, where entirely new phenomena come into play, new facets of nucleonic interactions become dominant, new phases of nuclear matter, new topologies and new excitation modes appear. One of the ultimate goals of nuclear physics is to understand the structure of nuclei based on the interactions between quarks as described by the theory of the strong interaction, QCD. With radioactive beams, the straightjacket that had curtailed the development of the subject has been removed and the whole range of the nuclear landscape opened for study. Worldwide this is reflected by the construction of a new generation of accelerator facilities and in the UK by the growth of nuclear physics appointments.

3.17.3 Europe is extremely well placed to dominate the development of nuclear physics in the coming decades, with the opening of major new radioactive beam facilities anticipated at GSI (Germany), GANIL (France), Legnaro (Italy), Munich (Germany) and CERN (Switzerland). NuPECC (Nuclear Physics European Collaboration Committee) has recently published a Long Range Plan (2004) which places construction of the FAIR facility at GSI as the top priority for nuclear physics development in Europe. Similar scale (\$1 billion) projects are underway in Japan (construction started) and the USA (passed CD0 stage).

- 3.17.4 The international FAIR project (Facility for Anti-proton and Ion Research) being built at the GSI Laboratory in Germany will become one of Europe's major laboratories for the physical sciences. Although the main focus will be on nuclear physics, it will also allow a range of studies in atomic physics, inertial confinement and astrophysics. In nuclear physics it will enable us to address the main frontiers of the subject, hadron physics, the phase diagram of nuclear matter and the structure of exotic nuclei. Some of the fundamental questions that will be addressed are: What are the limits of nuclear existence? Can we create stable superheavy nuclei? What would their chemistry be? Can we manipulate nuclear decay rates by controlling the atomic environment? What new chemical elements are created when a supernovae explodes? Can we understand the dilute neutron matter that forms around the surface of loosely bound nuclei at the extremes of stability? Can this tell us anything about neutron stars? Why does the mass of the nucleon not add up? Why do quarks carry only 25 per cent of its spin? How do hadrons change in the nuclear environment? Are there new forms of strongly interacting matter such as pentaquarks and glueballs? Do nuclei at extreme temperature and density melt? Do they undergo a phase transitions to an entirely new form of matter – a quark-gluon plasma?
- 3.17.5 FAIR will be the foremost facility in the world until 2020 and beyond. The international recognition of the UK nuclear physics community is due to concentration of its resources in a few areas of research to achieve critical mass. Uniquely, FAIR provides the facilities to carry out international level research in all the areas of UK focus, so it benefits the whole UK community.
- 3.17.6 For the last two years, international participation in the project has been by Memoranda of Understanding, with Professor Wood, CEO of CCLRC having signed on behalf of the UK. By the summer of 2006, the arrangements for participation will be formalised, with participants joining the project as formal members. The instrument will be as a limited liability company under German law. Decisions on joining must therefore be taken soon. Equally importantly, the science direction of the facility and the major items of experimental equipment are being discussed now, and we need to make a commitment now in order to continue to influence these decisions and set the science agenda in a way that reflects UK interests.
- 3.17.7 The capital costs of the project are currently undergoing a full scale audit, which will be available later this year. The upper limit for facility construction costs has been established as £650 million including instrumentation costs of around £78 million. The first estimate for running costs is in the region of 110 million euro (£71.5 million) per year. The UK contribution is estimated to be £16.8 million over a five year period. The funding profile is given in £ million.

FY 07/08	08/09	09/10	10/11	11/12
3.36	3.36	3.36	3.36	3.36

3.18 Renewal of the National Institute for Medical Research (NIMR) (Lead Council: MRC)

- 3.18.1 The bringing together of NIMR and University College London (UCL) presents an unique opportunity to create what would arguably be the most powerful biomedical research environment in the UK, if not Europe, and will enable the Institute to deliver the vision that MRC has for it as a multidisciplinary biomedical research facility focused on basic and translational research.

- 3.18.2 Co-location with UCL and the physical proximity to the major facilities of UCL Hospital are vital to achieve the cultural shift required for NIMR to deliver the translational aspects of the vision. The partnership also provides the multi-disciplinarity and critical mass required by the vision through providing access to the widest possible range of disciplines, including physics, chemistry and mathematics, available at UCL.
- 3.18.3 NIMR is recognised as one of the UK’s foremost basic research Institutes with a strong scientific track record and a reputation derived from its interdisciplinary collaborations and overall cohesiveness.
- 3.18.4 The partnership between NIMR and UCL will provide a strong platform from which NIMR will be able to develop further its interactions and collaborations, nationally and internationally. NIMR will further benefit from close association with the research activities of the UCL Hospital and the other major hospitals associated with UCL including the Royal Free, Whittington, National Hospital for Nervous Diseases, Great Ormond Street, Moorfields and the Eastman Dental hospital, whilst offering UCL access to the research strengths of NIMR.
- 3.18.5 Close collaboration between MRC Technology and UCL BioMedica, and investment in both chemical biology and medicinal chemistry will increase exploitation of this exceptional research into commercial developments for the public good and economic benefit.
- 3.18.6 The establishment of a joint scientific advisory structure to aid the planning of joint strategies for research, training and commercial exploitation will ensure that our planning draws in wider London and national partners and stakeholders.
- 3.18.7 The location for the new Institute is on the former National Temperance Hospital site (NTH) in Hampstead Road, adjacent to the main UCL campus and its specialist institutes and many other relevant research strengths in the Bloomsbury area. The new building will house 1,000 staff from NIMR and UCL side by side in a modern building providing state of the art facilities, a fitting showcase for the high calibre research carried out by the National Institute.
- 3.18.8 The projected capital cost of the re-location to UCL amounts to £240 million, after the contribution of £45 million from UCL. MRC Council will consider the level of contribution it can make from its own funds. The Business Plan assumes a formal project start date of January 2007 with building commencing in January 2009. The funding profile is in £ million.

FY 07/08	08/09	09/10	10/11	11/12	12/13
9.67	6.62	6.11	30.04	61.60	25.96

3.19 Square Kilometre Array (SKA) (Lead Council: PPARC)

- 3.19.1 The international radio astronomy community has come together and agreed that the next major step in our observational capability at deci- and centimetric wavelengths should be the SKA. The (SKA) represents the future of world radio astronomy and is being planned on a fully global basis with Europe playing a leading role and completion envisaged for 2020. The SKA will be a distributed interferometer array of approximately 100 collecting “stations”, each of area in the order of 10,000 m², and spread out over hundreds of km.

- 3.19.2 When completed, in the second half of the next decade, the SKA will be able to map the sky with a sensitivity approximately 100 times greater than is currently possible and will be able to scan the sky greater than 105 times faster than now. The SKA's power will lead to a transformation of our knowledge of the overall structure of the universe, of many of its fundamental constituents and of its evolution. The SKA may find the key to unlock the secret of Dark Energy, may test one of the bed-rock theories of physics, General Relativity, to destruction and will explore fundamental conditions for the emergence of galaxies, planets and life. It may detect signals from other intelligent civilisations. It is almost certain to produce many new and unexpected discoveries allowing radio astronomers in the 21st Century to add to the long list of fundamental discoveries made by their predecessors in the last century.
- 3.19.3 Over the past five years there has been extensive consideration of new ideas for collector elements and for the exploitation of industrial developments in the areas of signal processing and data transport. A R&D phase is about to start to determine the most cost-effective means by which to construct the telescope. Within Europe we have developed a radically new concept for the SKA, in which the entire collector is composed of large areas of low-cost, low-noise phased-arrays with the beam formation carried out electronically. In this vision the SKA will essentially be a giant IT facility completely unlike any other astronomical instrument. This concept offers major advantages in terms of the efficiency of data-collection, in particular it offers the potential of very large fields-of-view and access for multiple simultaneous users. Such an "all-electronic" telescope will therefore have unprecedented capability and flexibility of operation. The upgrade potential will be based on the ability to process more data in real-time as computing power increases. In the SKA Design Study (SKADS) eight EU nations (led by the UK and the Netherlands) are cooperating to carry out a detailed investigation of the cost-effectiveness of this new concept and to develop necessary "breakthrough" technologies. Its exciting potential has also attracted research institutes from four non-EU countries to join in. The European SKADS team has agreed on those aspects of the programme where the UK has the specific knowledge and skills to take on leadership roles.
- 3.19.4 The development of the SKA is an enormously complex task and it is beyond the capabilities of individual university groups to make a major impact. The UK radio astronomy community has, therefore, come together within a national SKA Consortium (consisting of the Universities of Manchester, Oxford, Cambridge, Cardiff, Leeds and Glasgow) and the Consortium is also forging strong links with industrial partners.
- 3.19.5 The aim is for the UK to take a leadership role in the SKADS R&D phase, and by forging links with UK industry, to ensure that UK PLC will be in the best possible position to play a leading roles in the design and construction of both the international science pathfinder (post 2010) and the full SKA (completion 2020).
- 3.19.6 The cost of the globally-funded project is likely to be of order 1 billion euro (£650 million) with a contribution from Europe of possibly 40 per cent, a comparable amount from the USA, and the remainder from the rest of the world. The UK pro rata share would be of order £70 million.

FY 11/12	12/13	13/14	14/15	2015/16	16/17	17/18	18/19
5	8	12	12	12	8	8	5

3.20 Up-grade of the European Synchrotron Radiation Facility (ESRF) (Lead Council: CCLRC)

- 3.20.1 The 6 GeV storage-ring light source built at the European Synchrotron Radiation Facility in the early nineties was the first insertion-device-based ("third generation") synchrotron radiation source. The ESRF has been extremely successful, both in terms of technical innovation and also where the very large volume of new and exciting science is concerned. With some 5500 scientific User visits each year, resulting in more than 1,100 refereed publications, the ESRF is recognised as one of the world's most innovative and productive synchrotron light source.
- 3.20.2 Advances in fields such as X-ray optics, detectors and accelerator physics, many of which originated at the ESRF, now allow an ambitious renewal programme covering all aspects of the ESRF's activities. Performance would be enhanced by several orders of magnitude. New scientific areas would be addressed with new highly specialised nanofocus beamlines, with even brighter "hard" X-ray beams, and by renewing beamline components such as detectors, optics, sample environments and sample positioning. Special attention would be paid to the development of advanced imaging techniques.
- 3.20.3 As an essential part of future financial planning the ESRF has developed a Medium Term Scientific Programme (MTSP), a scientific road-map covering five years which is updated annually. The longer term upgrade programme would build on the MTSP with the aim of ensuring the ESRF's leading scientific position over the next 10-20 years. New and refurbished beamlines would be built to answer new scientific needs, underpinned by a longer-term programme to maintain and refurbish the accelerator complex at the heart of the ESRF's activities. The overall aim is to maintain the ESRF's role as Europe's leading provider of high-stability fine-focus hard X-rays, allowing innovation in science and technique.
- 3.20.4 The much improved scientific capabilities of the ESRF would be exploited in five broad scientific areas: nanoscience and nanotechnology, pump-probe experiments, science at extreme conditions, structural and functional biology and soft matter, and X-ray imaging. An ambitious programme of instrumentation development (e.g. optics, sample positioning and environment, detectors) would underpin this advanced research.
- 3.20.5 This upgrade programme for the ESRF has been developed over two years and has involved extensive discussion at the ESRF Science Advisory Committee (SAC) and Council, with essential input from the ESRF's scientific User community, directly and via the annual User Meetings. Thus the upgrade programme is a response to future scientific needs as expressed by the very many scientists who use the ESRF's very intense X-ray beams in their research.
- 3.20.6 The UK contribution to this facility is estimated to be 14 per cent of the total at £22 million over a period of five years. The funding profile is given in £ million.

FY 07/08	08/09	09/10	10/11	11/12
3	6	6	4	3

3.21 The European XFEL Project (Lead Council: CCLRC)

- 3.21.1 X rays have become an indispensable tool for research and discovery across a wide range of disciplines in science and technology. Many of the basic questions of science involve a profound knowledge of the intimate details of the structure of the matter, from the understanding of the physical world to the biological molecules that support life.
- 3.21.2 Over the past 25 years extremely bright X-radiation has been produced by synchrotrons, in which electrons are accelerated in an approximately circular path. However, the power available from synchrotron sources remains relatively small compared to that produced in the visible and infrared regions of the spectrum by high power lasers and a long-standing objective of source developers has been to enable the powers produced by lasers to be available at X-ray wavelengths. The European XFEL project aims to make this a reality.
- 3.21.3 In 2003 the German Government gave approval for the construction of an X-ray free electron laser at the DESY research centre near Hamburg. 60 per cent of the construction cost will be borne by Germany and the UK and other EU members have been invited to join a partnership in funding, constructing and operating the facility as a European project.
- 3.21.4 The European XFEL Project will generate short pulse pulses of X-rays with durations of less than 100fs and wavelengths that can be tuned from 6 to 0.085 nm, corresponding to electron energies of 10 to 20 GeV. The short pulse duration will allow ultra-fast processes in molecules and other systems to be studied. The short wavelength limit is less than the characteristic separation of atoms in molecules and atomic structures may be observed directly. However, one of the most dramatic features is the peak brilliance of the radiation that is designed to be approximately *nine* orders of magnitude greater than that available from the best 3rd generation synchrotrons. This increase in power will enable completely new areas of science to be addressed and is certain to create new opportunities across a wide range of disciplines. These include the detailed study of extremely fast processes such as the chemical reactions (femtochemistry), structural biology in which it may be possible to measure the structure of a single complex biological molecule without recourse to crystallisation (thereby increasing dramatically the number of molecules to be studied), condensed matter physics, materials science and plasma physics with applications in astrophysics.
- 3.21.5 Construction will commence in 2006 and will be completed in 2011. The capital cost of the project is approximately 1 billion euro (£650 million), of which the UK contribution is estimated to be £30 million over seven years. The funding profile is in £ million.

FY 07/08	08/09	09/10	10/11	11/12	12/13	13/14
2	2	5	5	5	5	5

4. OGC GATEWAY PROCESS AND HOW IT IS USED IN LARGE SCIENCE FACILITIES

- 4.1 The OST and the UK Research Councils use the Office of Government Commerce's (OGC's) Gateway process to help procure large scale scientific facilities. All new procurement projects in civil Central Government – including NDPBs - are subject to the Gateway process, which examines a project at critical stages in its lifecycle to provide assurance that it can progress successfully to the next stage. The process has a series of Gateway Reviews, as follows:
1. To confirm the business justification;
 2. To confirm the procurement method and sources of supply;
 3. To confirm the investment decision - before letting any contracts;
 4. To confirm “readiness for service”;
 5. To confirm “in service benefits”.
- 4.2 Each project has a Senior Responsible Owner (SRO), a Project Manager (PM), and possibly a Project Owner (PO). One of these assesses the overall level of risk of the project (high, medium or low) using a standard Project Profile Model. For the highest risk projects the Gateway reviews are led by a leader appointed by the OGC, and all members of the team are independent of the procuring Department. For medium risk projects, OGC appoint an independent team leader and the remainder of the team are independent departmental staff. For low risk projects, departments can appoint their own team leader and team members, who are independent of the project. The reviews give each a project a red, amber or green status, depending upon the readiness of the project at that point.
- 4.3 Details of the Gateway process can be found on OGC's website: <http://www.ogc.gov.uk>
- 4.4 In addition, the OST requires all projects prioritised for funding from the OST Large Facilities Capital Fund (LFCF) to pass through a pre-Gateway Review and seek subsequent endorsement from the RCUK Executive Group. All such projects must also seek RCUK Executive Group endorsement following Gateway Review 1 (exceptionally a later Gateway) and subsequent Ministerial and, in some cases, Treasury approval before the funding is formally committed and may be released. Although the overall Gateway process is a requirement of procurement, the emphasis within Gateway is flexibility, with Departments adopting the framework in a way which meets their own needs, according to the nature and complexity of the projects. The OST, as part of the DTI, and the Research Councils as NDPBs, are adopting the Gateway process as set out in the following paragraphs.

- 4.5 Each project will have a lead Research Council. The Chief Executive, as Accounting Officer, will either take on the role of SRO for that project themselves, or will delegate it to one of their senior staff. The SRO will appoint a PM – who might be a staff member of the Research Council or one of its institutes, or located in a university or elsewhere. The pre-Gateway Review for large-scale science projects is a review of a *Science Case*. The PM must ensure that an independent assessment of the scientific value of the project has been made. In practice this will be some form of peer review, which needs to cover the following criteria:
- Importance (depth) of science knowledge to be delivered by project;
 - Breadth of science knowledge that will benefit from investment;
 - Match with international positioning of UK science;
 - Strength of opportunity for training (links to number of users);
 - Contribution to/from UK technology/industry base;
 - Opportunity for spin/off and exploitation.
- 4.6 In addition, the science case should cover the timing (for the facility to be in service, and therefore for key decisions to be made), other possible options, total budgetary estimate and any costs of feasibility studies required before the business case can be completed. The Science Case should also indicate whether sources of funding are in place, or whether the project would require funding from other sources. Other funding sources include other Government Departments, other countries, UK universities and industry. It also includes the LFCF, a capital fund held and managed by the OST to help fund large facilities.
- 4.7 For the largest projects, and any which may want to draw some funding from the LFCF, the SRO will present the Science Case to the RCUK Executive Group for endorsement. The Executive Group acts as the top level review and advisory board for all projects, for the Large Facilities Roadmap and for the LFCF. Assuming that they are satisfied the science case is robust the RCUK Executive Group will authorise the project to move on to Gateway Review 1, the *Business Case*. If funding is sought for a project from the LFCF, the Executive Group will also provide early advice on the relative priority of the project in comparison to other possible calls on the Fund.
- 4.8 Gateway Review 1 will confirm the justification and robustness of the business case. In particular it needs to include:
- A more detailed requirement that reflects user requirements – possibly an outline specification;
 - Confirmation of technical feasibility of the project;
 - Identification of success criteria against which options for delivery of capability from the investment can be judged;
 - Analysis of main options (e.g. UK only, collaboration etc) and cost effectiveness & risk;
 - Analysis of “opportunity cost” of undertaking this project versus other competing for funds in same time-scale;
 - Assessment of affordability;

- 4.9 The SRO will present the results of Gateway 1 to the RCUK Executive Group. The business case should confirm that funding for the project is in place. However, for projects which are seeking some funding from the LFCF, the RCUK Executive Group will only recommend to OST that such funding is made available once they have seen the results of the Gateway 1 Review. If the project is recommended for approval by the RCUK Executive Group, that approval will need to be confirmed by OST. Approval by DTI Ministers is required in all cases, and if the project is above the DTI's delegated powers, or requires funding from beyond the current three-year Spending Review period, approval is also required from HM Treasury.
- 4.10 The Gateway Review 2 will assess the *procurement strategy*. By the time of this review, all funding should be in place, including any necessary in-principle approvals from Ministers and HM Treasury. This review is undertaken before sending out Invitations to Tender (ITTs) and before any major capital expenditure has been undertaken. The procurement strategy will need to:
- Confirm that project is under control (on plan, to budget so far)
 - Confirm that project as planned will deliver expected benefits, or success criteria
 - Review value for money of procurement strategy proposed
 - Confirm that costs are within current budget line
 - Confirm that issues of whole lifecycle funding have been addressed (e.g. where do future running costs come from and commitment in principle)
 - Identify risks and confirm that appropriate risk management plans in place.
 - Ensure that specifications (ITTs if appropriate) reflect project output requirements
 - Ensure that adequate and realistic project plan and management structure in place for the remainder of the project
- 4.11 In general the Gateway 2 Review, and further Gateway Reviews, would go to the SRO and/or a Project Board rather than to the RCUK Executive Group, except for those projects where the procurement strategy has major implications across the Research Councils (e.g. where the location of an international facility might have an impact on other possible facilities). From this point on, the RCUK Executive Group will want to assess progress on all current projects every six-months, on a "by exception" basis.
- 4.12 Progress through the remaining Gateway Reviews will be related to the procurement strategy. For projects being completed under the direct control of one of the Research Councils, the Gateway process should be followed fairly closely. Where, for example, the project is multinational and has developed its own project review procedures, the SRO may use these to assure themselves that an equivalent level of project control information is being provided. Research Councils will in all cases incorporate the Gateway process into their own normal strategic, financial, and administrative procedures.

5. GLOSSARY OF ACRONYMS

4GLS	4 th Generation Light Source
ALMA	Atacama Large mm/sub.mm Array
APS	Advanced Photon Source, Argonne USA
AWE	Atomic Weapons Establishment
BBSRC	Biotechnology and Biological Sciences Research Council
CCLRC	Council for the Central Laboratory of the Research Councils
CERN	Conseil Européen pour la Recherche Nucleaire
CLF	Central Laser Facility
CSAR	Computer Services for Academic Research
CTF	Component Test Facility
DEFRA	Department for Environment, Food and Rural Affairs
DESY	Deutsches Elektronensynchrotron, Hamburg Germany
DTI	Department of Trade and Industry
ELT	Extremely Large Telescope
EPSRC	Engineering and Physical Sciences Research Council
ERL	Energy Recovery Linac
ESA	European Space Agency
ESFRI	European Strategy Forum for Research Infrastructure
ESO	European Southern Observatory
ESRF	European Synchrotron Radiation Facility
EU	European Union
EURATOM	European Atomic Energy Community
FAIR	Facility for Anti-proton and Ion Research
FEL	Free Electron Laser
FIREX	Fast Ignition Realisation Experiment, Japan
FRM-11	Reactor based neutron source being constructed near Munich, Germany
GANIL	Grand Accelérateur National d'Ions Lourds
GSI	Gesellschaft für Schwerionenforschung (Heavy Ion Research Association Darmstadt, Germany)
HEPL	High Energy Petawatt Laser
HPC	High Performance Computing

HPCx	High Performance Computing facility in UK
IAH	Institute of Animal Health
ICFA	International Committee for Future Accelerators
IFE	Inertial Fusion Energy
IFMIF	International Fusion Materials Irradiation Facility
ILL	Institute Laue Langevin
IR	Infra-Red
ISIS	Neutron Spallation Source at CCLRC's Rutherford Appleton Laboratory
ITER	International Tokamak Experimental Reactor
ITT	Invitation to Tender
JAERI	Japanese Atomic Energy Research Institute
JET	Joint European Torus
J-PARC	Japan Proton Accelerator Research Complex
JWST	James Webb Space Telescope
KARMEN	Muon decay experiment on ISIS
KEK	Koh -Ene - Ken : National Laboratory for High Energy Physics, Japan
LCLS	Linac Coherent Light Source at SLAC, USA
LFCF	Large Facilities Capital Fund
LHC	Large Hadron Collider
LISA	Laser Interferometer Space Antenna
LMB	Laboratory of Molecular Biology
LULI	Laboratoire pour l'Utilisation des Lasers Intenses, Paris
MAFF	Munich Accelerator for Fission Fragments
MAST	Mega Amp Spherical Tokamak
MICE	Muon Ionisation Cooling Experiment
MOSAIC	Micro Satellite Applications in Collaboration
MRC	Medical Research Council
NDPB	Non-Departmental Public Body
NERC	Natural Environment Research Council
Newton XMM	X-ray Multi-mirror space mission, ESA
NIF	National Ignition Facility, USA
NIMR	National Institute for Medical Research
OECD	Organisation for Economic Co-operation and Development
OGC	Office of Government Commerce

OIE	Office International des Epizooties
OST	Office of Science and Technology
PO	Project Owner
PPARC	Particle Physics and Astronomy Research Council
RCUK	Research Councils UK
RAL	Rutherford Appleton Laboratory
RRS	Royal Research Ship
SCUBA-2	Submillimetre Common User Bolometer Array - 2
SKA	Square Kilometre Array
SLAC	Stanford Linear Accelerator, USA
SNS	Spallation Neutron Source, Oak Ridge USA
SPIRAL	Radioactive ion beam facility at GANIL
SR	Synchrotron radiation
SRO	Senior Responsible Officer
SRS	Synchrotron Radiation Source at CCLRC's Daresbury Laboratory
TESLA	Proposed linear accelerator and FEL, DESY German
UKAEA	UK Atomic Energy Authority
UoP	University of Plymouth
VLBI	Very Long Baseline Initiative
VLT	Very Large Telescope, ESO
VUV	Very Ultra-Violet
WHO	World Health Organisation
XEUS	X-Ray Evolving Universe Spectroscopy
XFEL	X-ray Free Electron Laser
XUV	Extreme Ultra-Violet

6.0 CONTACTS

General enquiries about the Large Facilities Roadmap should be directed to the RCUK Secretariat.

Research Councils UK

<http://www.rcuk.ac.uk>

Anyone wishing to discuss individual projects on the Roadmap, or who wish to see other projects added to the Large Facilities Roadmap, should contact the most relevant UK Research Council. Contact details can be found on their respective websites:

Arts and Humanities Research Council

<http://www.ahrc.ac.uk>

Biotechnology and Biological Sciences Research Council

<http://www.bbsrc.ac.uk>

Council for the Central Laboratory of the Research Councils

<http://www.cclrc.ac.uk>

Economic and Social Research Council

<http://www.esrc.ac.uk>

Engineering and Physical Sciences Research Council

<http://www.epsrc.ac.uk>

Medical Research Council

<http://www.mrc.ac.uk>

Natural Environment Research Council

<http://www.nerc.ac.uk>

Particle Physics and Astronomy Research Council

<http://www.pparc.ac.uk>