

Draft Report from Photon Advisory Panel – 10th Sept 2009

Introduction and General Issues

- Nearly 700 responses were received, the vast majority from individuals. Considering the timing and brief window of opportunity available, the Panel felt this was a large and significant response reflecting a very worried user community.
- Approximately 85% of responses were from users primarily of the synchrotrons, with the majority of these from life science users and a significant share from material scientists. Most of the remaining 15% of responses were primarily laser facility users. The Panel believed that the distribution of responses was a reasonable reflection on the size and funding levels of the various communities using photon-based facilities. However, it was felt that some user groups may have been under-represented – possibly due to variations in awareness, lobbying and outspokenness across the different communities. PAP was concerned that communities currently lacking effective beamlines in the UK (e.g. surface science) may have been disproportionaltely represented.
- Although the timescale to prepare the report was unrealistically short, the workload was distributed in such a way that an attempt was made to consider every response so that they all contributed to the overall conclusions reached later.
- The very clear central message coming through from the responses (from all synchrotron and laser areas) was that, in the current climate, STFC should concentrate funding in existing, successful projects rather than develop new ones, at least for the time being. It was also clear that there is a desire to “keep in touch” with future facility developments.
- UK science, through central facilities, is high value for money in terms of providing highest level facilities. This allows the UK to remain competitive in terms of cutting edge science, maintain a fully integrated skills base essential for developing future large facilities and provides training of PhD students at the highest level.
- It is viewed as essential that in the areas of fully UK-provided facilities, that those producing high level science output and still in their productive prime are maintained while maintaining an ongoing programme of facility development that retains the UK’s high level capabilities. Particularly, those developments already agreed on a science level should be pursued. Budget constraints could be addressed by extending the time-line for a given project.
- PAP is aware of the extreme funding constraints that have arisen for STFC due to an adverse economic climate and the consequent projected budget deficits. We are also aware that ongoing tweaking of current national facility budgets is unlikely to provide a feasible approach to solving the imminent problem. We are concerned that the inflexibility of other STFC commitments means that disproportionate cuts will be imposed on national facilities.

- Facility prioritisation, discussed later in the report, reflects views as expressed by the consultees in response to the specific questions posed. However, we were concerned that the responses may have been restricted by the type of questions included in the consultation and this may have prevented a clear view of appropriate priorities being obtained.
- We note that the level of damage that can be done to science infrastructure with cuts, even over a two to three period in terms of international science funded, is high and can take a generation or more from which to recover. Furthermore, reduction of investment in infrastructure will result in the loss of a generation of new scientists with a catastrophic effect on the future science base and thus the economy of the UK.
- The Panel has a view that this *ad hoc* way of solving recurring financial problems (ie with flexibility over only about 1/3 of the total budget) will eventually kill off much of the best work involving national facility access and eventually will preclude significant access of UK personnel to international facilities. A more radical approach is required.

1. Future opportunities

a) ***Identify the top major scientific challenges to be solved in the future (forward look 10 years)***

The Panel members note that fundamental science and technology underpins all grand challenges. Indeed, many of the large scale facilities that are the subject of this report provide excellent examples of developments arising from fundamental discoveries that have subsequently proven invaluable in their application to a wide range of fields, most of which were never envisaged from the outset. This especially includes the synchrotrons and laser facilities.

Many respondents tended to answer Q1a from the point of view of their own research rather than from a wider perspective. Nevertheless, the Panel has tried to identify some of the broader topics and themes mentioned most often. These can be grouped under themes aligned with typical current Research Council Roadmaps as follows:-

Energy

Energy security and the production of energy from sustainable sources is a major research challenge highlighted by both government and the research councils. This includes the transformation of biomass, utilization of nuclear and safe reprocessing/storage, efficient direct solar energy conversion, energy storage, carbon capture and usage, low and high temperature fuel cell technology using, for example, ethanol. One obvious driver is the conversion of waste materials, for example biomass (lignin and cellulose) to energy (hydrogen and liquid fuels) and to value added products, without affecting food supplies. There is increasing activity in the UK in these areas and although some of the most significant advances have been made elsewhere to date, it is likely in the near future significant UK impact will occur. The following topics are some of the key areas in this regard:-

- Development of new H₂ storage materials: Hydrogen is hailed as a non-polluting synthetic fuel that could replace oil, especially for transport applications. The

- Ethanol / alcohol fuel cells and Lithium battery technology.
- Laser fusion: The progress in controlled fusion technology has put the demonstration of energy gain within reach in the near term (e.g. at the National Ignition Facility in the USA). The demonstration of fusion energy production will doubtlessly energise efforts to turn this highly desirable source of energy into a practical reality. RAL has played a substantial role in the preparation of the high-gain route to fusion energy – Fast Ignition. The proposed HiPER facility on the ESRFI and LFCF roadmaps will provide a key stepping stone to turning the promise of laser-driven fusion energy into a practical reality.
- Optimising bioconversion of waste to fuels through enzyme engineering, with an obvious demand for macromolecular crystallography beam lines at DLS.
- Solar energy : Apart from controlled thermo-nuclear fusion, this is the only energy source that has the capacity to replace fossil fuels. The topic includes conversion to electricity (photovoltaic devices) and conversion to fuels (solar fuels). A recent DOE review stated:- *‘The magnitude of the challenge in energy is so immense that existing energy approaches — even with improvements from advanced engineering and improved technology based on known concepts — will not be enough to secure our energy future. Instead, meeting the challenge will require new technologies for producing, storing and using energy with performance levels far beyond what is now possible. Such technologies spring from scientific breakthroughs in new materials and chemical processes that govern the transfer of energy between light, electricity and chemical fuels. Integrating a major national mobilization of basic energy research — to create needed breakthroughs — with appropriate investments in technology and engineering to accelerate bringing new energy solutions to market will be required to meet our three-fold energy challenge. This report identifies three strategic goals for which transformational scientific breakthroughs are urgently needed: (i) Making fuels from sunlight, (ii) Generating electricity without carbon dioxide emissions and (iii) revolutionizing energy efficiency and use’*. Photon-based facilities can contribute to progress in all these areas.

Health

‘Ageing: lifelong health and wellbeing’ is an identified RCUK priority area. Central to contributing to this challenge area is a requirement for the description and understanding of the cell’s chemistry, the structures and interactions of the proteins and other biomolecules that constitute the living cell and its metabolic pathways. A rigorous understanding of the normal “healthy” state is an essential step to the realisation of molecular medicine – designing and developing novel drugs and therapeutics as a penetrating approach to the treatment of disease. State-of-the art synchrotron facilities are essential for research into the fundamentals of living organisms and to disease processes.

The impact of large-scale facilities towards this theme lies in both the dissection and determination of the molecular processes that underpin both normal and diseased cellular function, and in the applied development of technologies and therapeutics for the diagnosis and treatment of specific pathologies. Synchrotron-based macromolecular crystallographic and spectroscopic techniques have led to dramatic advances in understanding the fundamental biology and chemistry that underpin cellular function

and disease progression. The intensity and automation of beamlines have enabled step-changes in throughput resulting in dramatic increases in the volume of structural analyses that can be performed, which is especially helpful in drug development. Microfocus beamlines have opened up new opportunities for obtaining structural information from previously inaccessible systems, including membrane proteins, large macromolecular complexes and very small crystals. Synchrotron-based macromolecular studies are now invariably an essential component of virtually all drug development programmes.

Understanding the fundamental dynamics of chemical reactions and biomolecular processes, promoted by a wide range of synchrotron and laser facilities, also impacts on drug delivery and medical intervention strategies. Similarly, chemical crystallography contributes to a vast array of chemistry essential for drug synthesis and there is a growing need for structure determination of ever more weakly diffracting samples. This includes samples that are weakly diffracting due to their small size as well as samples of large molecules where there may be disorder within the structure of interest and/or solvent or counter-ions, when diffraction may be very weak, particularly at high angle.

Detector development programmes to increase the resolution and capacity of cell- and molecular-based imaging also form significant contributions to the health theme and offer improved methods of disease diagnosis. The future development of plasma accelerators based on relativistically intense lasers may allow the construction of ultra-compact ‘table-top’ accelerators and photon sources, which have the potential to also impact on the provision of diagnostic and treatment techniques. For example, laser driven proton and ion beams are being considered for the treatment of cancers using hadron therapy. This therapeutic approach has been clinically proven to be highly effective and, in many cases, superior to conventional techniques. To date the widespread application of hadron therapy has been limited by the scale and cost of suitable conventional accelerators (only a few world-wide and none in the UK). The laser driven approach holds the promise of more compact accelerators for such purposes and is being pursued by the RCUK sponsored LIBRA consortium and other groups internationally (e.g. JAEA in Japan and by the MPQ/Siemens in Germany). Similarly, coherent X-rays allow much enhanced imaging of human bodies and hence early stage detection of malignant growths. To date suitable sources are available at synchrotrons, where the basic principle has been demonstrated. However, such large scale facilities are inconvenient for patient treatment and screening, whereas compact laser based sources are more suited to wider application.

Security

Although very few consultation inputs directly identified “Security” related research, the Panel notes that much activity associated with both synchrotron and laser based research will benefit challenges in various areas of national security (including energy, food and personal) - for example through portable spectroscopic techniques and improved detector technologies.

Nanotechnology

Laser and synchrotron facilities both operate within light wavelengths that are compatible with the analysis of nano-scale objects, and hence are highly relevant to the development of materials and constructs within the nanotechnology realm. This is an identified priority area across several of the research councils, and has applications that

range from materials through to living organisms. Laser and synchrotron facilities are primary tools for the analysis of objects on the nanoscale, and could also be instrumental in the generation of such materials.

This theme is also relevant to the emerging field of synthetic biology, in which nano-scale molecular assemblies are being designed to replicate functions of living cells. Many of these studies rely on an intricate understanding and analysis of nanometre scale molecular assemblies, often similar to those provided by protein and nucleic acid complexes. The ability to design and regulate growth and order of such complexes initially requires in-depth analysis of trial-and-error experimental outcomes, leading eventually to controllable systems. Crystalline and non-crystalline diffraction studies, as well as spectroscopic studies (e.g. CD), all as enabled through the range of synchrotron beamlines available at both Diamond and the ESRF, are vital to this emerging field.

A wide range of topic areas are relevant but a partial listing would include photovoltaic devices, electronics/photonics/plasmonics and development of attoscience.

Curiosity-led science vs Application-driven science

Although many RCUK Roadmap Topics in the current portfolio can be classified as “Application-driven” science, we are pleased to note that STFC is keen to also support “Curiosity-led” (or Discovery) science. In addition to research directed at goals with possible spin-offs clearly in mind, it is important to realise the long term benefit of curiosity-led science. A curiosity bottom-up approach is a must in a well balanced science landscape to allow creativity and new ideas to flourish and prepare the ground for new science and applications of science which have not yet been imagined. Lasers provide a shining example for a scientific technique that has led to several new fields of science being developed (and associated Nobel prizes) on the one hand whilst on the other hand impacting on every day life via industry (through measurement, cutting, welding, manufacture etc) and information technology (CDs, DVDs, Chip manufacture). Similarly, fundamental studies of the molecular components of cells and their interactions have also regularly and fortuitously lead to new methods and routes for the development of novel therapeutics. Facilities should therefore be open not only to specific target driven research but also to fundamental, long term, underpinning science driven by the curiosity of scientists.

Current “hot topic” areas include QED tests, single molecular imaging, quantum control and attosecond science. These are areas that could have huge future impact and are major scientific milestones.

b) Highlight the UK involvement in research in these areas including what the UK reputation is in these areas and if it is likely that UK researchers will make these achievements

Due to the short timescale available for producing this report, the panel did not have enough time or resources to data-mine into relevant reports, publications, databases etc to address the question quantitatively. Nevertheless, collectively the Panel has a fairly wide awareness of UK activity and record in the subject areas and believe the statements and observations made below to be useful and to partially reflect the

situation. The panel feels that both the synchrotron and laser facilities provide crucial tools which are key for UK science to contribute and address the challenges highlighted above. These facilities have direct impact on UK ability to contribute to these major challenges - the outcomes of which will have direct impact on quality of life. The following list is illustrative and not intended to be complete, but gives a flavour of the importance of these facilities.

- Synchrotrons are the major tool for structural biology. This is an area that was pioneered in the UK and continues to be one of the most productive and high profile areas of UK research. It has generated multiple Nobel Prizes. The increase in scope of the techniques being developed at present will have ongoing fundamental impact.
- The UK pharmaceutical industry represents 20-30% of UK GDP and has provided written letters (and consultation responses) supporting Diamond and stressing their requirement of this facility in the UK. For example, inputs have been received from AstraZeneca, GSK, Astex Therapeutics Ltd and Evotec Ltd. and samples are shown below:-

“From the perspective of our needs in Drug Discovery it is the continuing availability of world class synchrotron facilities for protein crystallography that has both day to day and strategic impact for our research into new medicines” – Hann, GSK letter.

“Continued investment at DIAMOND to ensure it becomes the synchrotron source of choice for the UK MX community is essential” – Pauptit, AstraZeneca.

“X-ray structures and screening are now central to lead discovery and optimisation in drug discovery. In small companies Astex Therapeutics has pioneered the fragment based approaches, which are also used in Vernalis, Evotec and Heptares, as well as academic centres like Cambridge, Dundee, ICR etc. In large companies GSK, Pfizer, AZ and UCB Celltech have all contributed and depend on central facilities” – Blundell, Cambridge.

- Energy – in terms of catalysis, the UK has the largest independent catalyst company in the world in Johnson Matthey, who have indicated very strong support for DLS and ESRF but with some concerns (see below). There is a strong community in the UK with a very high profile involved in energy research in areas such as H₂ storage, fuel cells and photovoltaics. Energy is a key global concern and as a result UK has developed strong active groups in all the areas above.

“Access to beamtime is a problem - either very expensive or restricted.” – Johnson Matthey

In terms of solar energy, the importance of LSF and the unique capability of the ULTRA facility is given by Prof Pertutz (York):

“Time-resolved spectroscopy is essential to understand charge separation and dynamics of natural and artificial systems for solar energy conversion. Includes timeresolved IR, UV/vis, EXAFS, diffraction etc. Requires lasers (and expertise) currently provided by CLF.”

- The UK high power laser programme has repeatedly been highlighted as innovative and internationally leading in assessments of UK physics. It operates at highest level through the synergy of science driven by UK universities with high performance facilities designed and run by the expert staff at CLF. The strength of this programme is reflected by its dynamism in terms of top-level research output and the very strong support it has received in the recent consultation evaluated by PAP. Currently, the UK effort is not only central to the exploitation and development of cutting edge laser technology, but is also a driver behind the current plans to design and construct the next generation of lasers at the EU level (such as HiPER and ELI).

c) *Identify what facilities will be needed in order for the UK to make significant contributions in these areas*

- Diamond – Phase 3 beamlines and Phase 1 and 2 operating fully. This will cater for:-
 - Energy
 - Health and Pharmaceuticals
 - Fundamental science
 - Engineering
 - Culture
- ESRF including the upgrade. This will cater for studies in areas of :-
 - Health and Pharmaceuticals
 - Fundamental science
 - Energy
 - Engineering
- Current facilities at CLF (eg ULTRA, Octopus, Gemini, Vulcan) maintained for:-
 - Energy: eg solar with ULTRA and fast igniter research on VULCAN.
 - Support for Diamond Users in life Science – eg Octopus imaging capability in Research Complex.
 - New developments at Diamond such as time-resolved X-rays (single crystal and EXAFS) needs both LSF and Diamond specialists.
 - Health
 - Fundamental science such as attosecond and relativistic plasma science
 - Training and skills
- The consultation highlighted the immediate need for the Vulcan 10 PW upgrade for:-
 - Fundamental science
 - Energy
- HiPER and ELI in the future for
 - Fusion for energy
 - Extreme condition science
- NLS/LCLS/X-FEL have roles to play in these areas as well and will provide significant fundamental information on physics of molecular processes. They will potentially provide detailed data on time/spatial resolved structural and spectroscopic materials properties.

- Several users comment that an ability to perform fast time-resolved X-ray crystallographical measurements (single crystal and EXAFS) would be a major development and the panel thought that it should be noted that such developments were facilitated by the location of the LSF in the Research Complex. Cutting edge advances in this area in the UK requires experts in both synchrotrons and lasers working together - i.e. both facilities are required.

d) Does the UK currently provide/have access to the Facilities required? Conversely, are facilities currently being provided/considered that are not necessary to meet the challenges identified in a)?

- At present, most of the basic facilities needed for the majority of medium term science needs are available. However, the Phase III beamlines at Diamond are essential for full coverage of current needs and those in the immediate future. Also, there is a need to combine currently available facilities (ie synchrotrons/lasers and also neutrons, if possible - as many respondents use both photons and neutrons) to provide unique capabilities – via the Research complex. Some of the developments at the Research Complex are not widely known. For example, a few synchrotron researchers commented that improved optical imaging facilities would underpin structural investigations of complex biological systems and seemed unaware that the proposed linking of LSF with Diamond in the moving of the LSF Octopus Cluster to the Research Complex would provide such a facility. This is not unexpected since this move and the launch of the Octopus Cluster has not occurred yet and was as a direct result of the recent Facility Review.
- The selection process and financial pressures have resulted in only the facilities with the strongest scientific cases going forward and has resulted in facilities that are at the highest level when compared to world science. The central facilities are in many fields the key to the UK's continuing competitiveness in the area of science, training of PhDs and students with the highest qualifications. For example, the high level that currently exists in laser facility provision is built on a fragile basis of relatively small numbers of highly trained experts that provide the critical mass of expertise to design and run the facilities. It is essential to maintain a 'critical mass' of personnel to keep the UK competitive and able to execute large scale projects as well as contribute to international efforts. Going forward, the 10PW project has been highlighted in the consultation as being essential in attaining the scientific goals of the high-power laser community.
- Automation techniques on Diamond (particularly for PX, XS and XAFS) and development of combinatorial approaches are essential to maximise efficient usage of the facility. There is a need for increased temperatures, pressures, energy ranges etc for *in situ* sample environments for spatial and temporal resolution plus coupling with secondary spectroscopies. Further advantage can be obtained by provision of an ability to levitate and manipulate samples (with optical tweezers in a combined facility).
- Diamond does not currently have the capacity to do all that we need to do and therefore it is essential to continue on-going involvement with the ESRF, at the very minimum until we have a fully functioning Diamond (22 planned beamlines operating) at which point the UK's future in ESRF might be reviewed. Soft x-ray spectroscopy/microscopy techniques for e.g. surface science are currently lacking in the UK.

- The Panel had concern over the lack of responses in some areas – e.g. the surface science area where there are high quality groups in the UK. Without low energy sources the UK will reduce its competitiveness and this requires some of the phase III beamlines at DLS.
- The Panel is not aware of any facilities in their area, either being provided or being planned, that are not necessary.
- Some lasers are of such a specification that similar systems cannot be accessed elsewhere in the world; e.g. ULTRA laser facility at the LSF and Gemini. The 10PW Vulcan, if built, will also be unique. Such facilities give UK scientists a unique capability to contribute to major global Grand Challenges.

e) Based on b) and d) understand which of a) and/or c) are the top priorities.

Top priorities for scientific challenges

The Panel felt it was not in a position to rank the science based challenges – e.g. it is impossible to rank “energy against health”. The limited representation of bio-medical researchers (synchrotron users) on the panel further complicated this task. This decision is ultimately down to the science proposed and the BIS(DIUS)/RCUK priorities.

Top priorities for facilities

The Panel felt that both the main branches of photon-based research facilities (ie Synchrotrons and Lasers) were very important but at the same time very distinct. It was decided to rank priorities in each area separately, with the understanding that top priorities in each area were to be supported at all costs.

Some of the factors leading to the rankings reached can be summarised:

- In general, responses were very focussed on individual research areas and current facility needs, giving little direction for the panel to talk representatively about new / future facilities.
- Given the community response in the current consultation, the level of support for XFEL and NLS at this stage is limited. However, this is not a judgement on their importance in 5-10 years time – the Panel felt it was insufficiently informed to form a clear view at this stage.
- Withdrawing from EU facilities would destroy the credibility of the UK as a partner in joint ventures and thus jeopardise the UK’s future involvement across the board. We note that, for example, ESRF has also provided excellent value for money. Furthermore, failing to support ESRF would compromise the future of UK Biomolecular Science in Europe.
- If cuts are made to our own national laser/synchrotron facilities, this is likely to impact on the ability of the UK to partake in international facilities in the future; i.e. there will be an increasing lack of expertise both in terms of academics, industry and UK central facility staff. Students will not be trained, the best researchers will leave, UK universities will become uncompetitive, and large Pharma and SMEs will move their interests abroad. This would be disastrous for photon-related sciences, including the life sciences community, throughout the UK. There is an overriding need to continue development of these facilities, as ‘standing still’ is not an option in this rapidly-developing field.

- Fundamental facilities are required to underpin fundamental science. This relates to the training of next generation scientists etc, and may be especially true for new facilities such as X-FEL and NLS.
- LSF is at the ‘heart’ of an inter-linked/related facility arrangement. It operates at relatively small cost but has high impact.
- With regards high power lasers, 10PW is seen as an immediate requirement and strongly supported. The longer term developments at EU level which are envisaged to come on line towards latter part of the next decade are currently a lower priority and consequently HiPER and ELI etc. are deemed to be further down the list of priorities at this stage.
- If the UK withdraws from any current international facility commitments and hence damages its reputation as a major research power within Europe, it is highly unlikely that the UK will be seriously considered for hosting an international facility in the future (e.g. HiPER). We note that hosting such a further large facility is identified as an objective in the latest STFC Roadmap.

Synchrotron facility priorities

Rank	Facility	Comment
1 =	Diamond to completion of Phase 2 (See Note 1 below)	Phase 2 is very important to increase the user base
1 =	ESRF current operations including minimal Phase 1 upgrade	Continued running of ESRF provides greater capacity than Phase 3 Diamond
2 =	Phase 3 of Diamond	Required for surface science/soft x-rays which are currently covered mostly by facilities outside UK. Wellcome Trust have committed to Phase 3 of Diamond.
2 =	ESRF Upgrade Phase 2	
3	X-FEL (See Note 2 below)	Consultation suggested observatory interest at this stage rather than current expected commitment
4	NLS (See Note 3 below)	Requires “drip feed” funding until we are out of current crisis
5	HMFL option at ESRF/ILL	Estimated cost for this option alone is in excess of CLF annual budget and not supported generally in the UK

Note 1 : Both Priority 1 options above are contingent on each other. The Panel sees these as quanta which have to be fully funded and properly. Some supporting quotations from the consultation exercise are listed below.

“Diamond must be the most important. We need reliable, high flux, variable wavelength X-ray photon source. There is considerable need for small angle scattering, circular dichroism, X-ray spectroscopy and EXAFS” – Blundell, Cambridge.

“Cost effective access to reliable, well-run, automated, remotely accessible (or providing mail-in service) synchrotron sources providing MX beamlines with facilities for handling samples requiring biological containment (e.g. virus crystals, category 2) is absolutely essential to the provision of data for the projects that we support! – Pauptit, AstraZeneca.

“(The ESRF) has been the leading European facility and much of the technology that Diamond uses for protein crystallography work has either been developed or seriously tested there” – Hann, GSK.

“(cuts leading to a significant reduction in user access to Diamond) would be a disastrous thing to do just when Diamond is building its reputation” – Hann, GSK.

Note 2 : Lack of expertise in the Panel and lack of input from the consultation responses means that the Panel is unable to evaluate the level of X-FEL need. It is still necessary to establish a user base in the UK with links into potential rather than existing excellence. In terms of priorities, the Panel felt it could not put e.g. a 1% stake in X-FEL above 2 new beamlines at Diamond at this stage. In quotations below, we note GSK (and other) interest and their desire not to be cut out of X-FEL at this stage.

“looking longer term, the possibility of obtaining protein structures by Free Electron Laser coherent X-radiation of very few molecules in solution is of such potential impact that we would like to see the STFC continue funding of basic science in this area” – Hann, GSK.

“We note that the response to the last programmatic review on Synchrotrons and Free Electron Sources emphasized the need to “maintain underpinning technologies, facilities and trained manpower” and the importance of supporting “both existing sources as well as planned facilities” and we would fully endorse this view” – Pauptit, AstraZeneca.

Note 3 : There was a lack of input on NLS from the consultation with the result that no clear recommendation can be provided here. However, there is community interest and the Panel felt it did not wish to see NLS fall off at this stage if it gets good peer review.

Laser facility priorities

Rank	Facility	Comment
1 =	LSF (See Note (a))	This is a very low cost, high priority facility
1 =	CLF HPLs (See Note (b))	e.g. Astra Gemini, Vulcan 1PW, Artemis
2	10 PW Vulcan (See Note (c))	Unanimous support in responses from laser-based community
3 =	HiPER (See Note (d))	Main interest is from perspective of fusion energy
4 =	ELI (See Note (e))	European project on a par with HiPER
5	DiPOLE (See Note (f))	An in-house CLF diode-pump technology programme with links to HPLs and industry. RCUK has it currently linked to 10PW but connection is for possible longterm pump efficiency improvement.

Note (a) : See previous note of being a link between different facilities etc. Links into Research Complex (single-molecule imaging and ultra-fast dynamics).

“Laser technologies as encompassed in the Central Laser Facility are providing dynamic information on enzyme reactions and cellular events and will also be essential. Scientific collaborations are emerging between spectroscopists and structural biologists and will be fostered by the new Research Complex at Harwell.” Professor Dame Louise N. Johnson (Diamond Light Source and University of Oxford).

Note (b) : These facilities currently provide the core of science output from the CLF and are either recently upgraded or completely new.

Note (c) : The consultation clearly highlighted that the 10PW is an immediate requirement for the scientific goals of High Power Laser Science and is strongly supported by the response of the community. The Vulcan 10PW upgrade project has recently been peer reviewed and received an excellent review based on the strength and diversity of the science that can be addressed. It is key to the UK high power laser community, supporting the future development of the community in areas where its current strength lies. Once built, it would be a top priority along with Astra-Gemini for ongoing operations. If considered against NLS the Panel would choose 10PW.

“The Vulcan 10PW upgrade is essential to maintain the pioneering high-intensity high-power experimental output of the UK” R. Kingham, Imperial College

“The planned 10 PW upgrade of VULCAN will be crucial, e.g. for development of ion and electron sources and ultra-high field science” M. Borghesi, Queen’s University Belfast

Note (d) : HiPER is further down the list as it is also a longer term project and depends on what happens in the US at NIF over next couple of years. There are prospects that it could be hosted within the UK.

Note (e) : This is a new design of ultra-short pulse, high energy laser (for Exawatt power levels) under development and current scenarios indicate it is likely to be sited in mainland Europe. Part of ELI is important to the UK community in the longer term.

Note (f) : This is a CLF in-house technology programme without broad community input but if the UK wants to exploit high power laser developments commercially it is an essential stepping stone. It is the type of project that could result in marketable technology in the mid-term if the UK had a strong laser-diode manufacturing base. Overall, it would be good for the UK as it would build on our technological strengths and perhaps reverse a common perception that a weakness of the national science base is that a lot of the technological developments don't take place in the UK. If DiPOLE did not exist as a separate project it would likely result in either (i) a different design for HiPER or (ii) folding of DiPOLE into the HiPER project. The 'value' of doing a different design for HiPER would need to be judged in a few years time depending on the progress with NIF.

2. Matching Current Programme to Roadmap priorities

a) *What are the science drivers for each of the research councils and how does each facility help the UK reach the identified challenge?*

Again, we group areas under main theme headers as:-

Health

- Central to BBSRC Strategic Priorities: (i) Integrative Biology; (ii) The Healthy Organism. Also relevant for Tools and Technologies, and for Synthetic Biology.
- Research themes of MRC: Resilience, repair and replacement, and Living a long and healthy life.
- EPSRC signposting areas: Synthetic Biology, Physics/Life Sciences interface, Nanoscience through engineering to application.
- The Wellcome Trust, although not a RC, is a major funder for research in this area.

Maintenance and development of Diamond is core to all of these.

Energy

- *“Bringing together all facets of energy research and training, including collaboration with the Energy Technologies Institute” [EPSRC]. “Energy is essential in almost every aspect of our lives and for the success of our economy. It is because of issues such as climate change, security of supply and rising fuel costs that it now has such a high profile.” [TSB]* The formation and sponsorship of the Energy Technologies Institute by BP, Caterpillar, EDF energy, Rolls-Royce, E-On, Shell and the public sector (BIS, Dept. for Energy and Climate Change, EPSRC, Technology Strategy Board and Dept. of Transport) demonstrates the importance of this area of research. DLS and ESRF provide the necessary fundamental materials knowledge at relevant spatial and temporal resolutions to understand processes in-situ in for example, catalysis, feedstock storage and release (e.g. H₂ or CO₂), reprocessing of nuclear waste and solar power. Further information will be enabled by the provision of the new facilities. This information provides the basis for new materials and processes with which to tackle the energy issue.

Security

- **EPSRC:** Global Uncertainties - Security for all in a Changing World through imaging and detection techniques, for example.
- **BBSRC – Food Security.** This requires a fundamental (molecular) understanding of the mechanisms of (e.g.) drought resistance in crops. Requires structural biology and synchrotron science.

Pharmaceuticals

- EPSRC signposting areas: Physics/Life Sciences interface, Nanoscience through engineering to application.
- Research themes of MRC: Resilience, repair and replacement, and Living a long and healthy life.
- BBSRC Strategic Priorities: The Healthy Organism, Bioscience for industry.
- The Wellcome Trust, although not a RC, is also a major funder for research in this area.

Both drug design and development are dependent on the structure information derived from synchrotron PX beam lines. The contribution to the understanding of cellular processes that will be contributed by advanced imaging techniques also provides considerable opportunity for industrial exploitation.

Nanotechnology

- EPSRC signposting areas: Physics/Life Sciences interface, Nanoscience through engineering to application.
- “Synthetic Biology” is an emerging field and a spin-off from studies of biological systems and relates to mimicking natural systems in the design and synthesis of “new” biological pathways and artificial cell-like entities that exploit un-natural and synthetic chemical components to form new bio-synthetic machinery [BBSRC]. Relates to structural biology and synchrotron science.

b) *What is the UK expertise for each area of science; eg is the UK world-leading, if not, what specific activities are the UK involved in that will contribute to this?*

- Life sciences: – the UK is clearly, along with the US, the pre-eminent hub for research in this area. Overall the UK structural biology is undoubtedly world-leading and the UK is also in the forefront in several other aspects: protein production facilities (e.g. OPPF), membrane protein crystallisation (e.g. MPL), Diamond & ESRF beamlines. Structural biology clearly provides the biggest impact and return for SFTC investment in facilities. With regard to attoscience, the UK effort is central to this emerging field and will likely underpin improved understanding of the fundamental molecular processes.
- Energy: - Together with collaborators (primarily US, France and Japan) the UK has been at the forefront of the drive to demonstrate high-gain laser fusion. Indeed, the currently favoured ‘Fast Ignitor’ scenario was first proposed and developed in the UK.
- Health: - The UK groups are leading in the drive for compact laser driven accelerators that may impact on next generation health care. Seminal papers in the fields of electron and hadron accelerators were derived from research at the CLF and the university users leading the exploitation and development of this new technology.

c) *What are the technological needs for each activity and what is the UK expertise in such technology (both academia and industry)?*

For the major new facilities in the pipeline (10PW, NLS, XFEL, HiPER, ELI, DiPOLE etc) there is a range of technical issues and problems to be addressed and these are all manageable to the best of our knowledge, but with pan-national contributions. In the current climate, the Panel felt it more immediately useful to highlight technical and development needs for existing and recently provided facilities – ie to reflect consultation advice that we should capitalise more on existing major investments. Some comments received are listed below:-

- Current systems must be maintained and run at an optimum level – low level cutting of personnel and beamtime really reduces efficiency of the facilities and their effectiveness in providing high quality science.
- There is a need for continual detector / sample environment development. In particular, detectors with increased sensitivity are cost effective.
- Projects for small-scale developments are essential. They maximise the facility output for a minimum of additional cost to STFC and should continue to be funded via FRDP.
- There have been many references to the need for automation (ie high throughput) of Diamond beamlines and for Microfocus beamlines. UK expertise in this area is high – many of the development scientists working at the ESRF and elsewhere are UK-trained.
“Multiple beamlines, high throughput, automated service for drug discovery. Good X-ray scattering facilities and accessible on-site biochemistry and other facilities” – Blundell, Cambridge.
- It is essential to have access to high performance computing for analysis of data / data management / interpretation and simulation.
- Some flexibility must be retained to have the capability to take advantage of new developments

d) In a fixed budget, what are the top priorities; eg what facilities really must be provided in order to meet the key challenges?

The Panel was not clear what the term “fixed budget” meant. If the fixed budget was large enough, we would like to see all projects in our area supported and followed through as far as scientifically useful. More likely, the fixed budget will be a limited one and small enough that all current projects, never mind planned projects, will not be guaranteed continued support. In this case, we must expect cuts and closures for facilities and provide advice as to the least damaging course of action. Here, we believe that the users are correct in their almost universal desire to “maintain and exploit” what we already have and what is already in the pipeline but to delay additional expenditure on new and exciting future facilities until the financial constraints are resolved.

Synchrotrons have become established as being fundamental to modern biomedical, chemical and physical sciences. The contribution of macromolecular structure alone has fundamentally changed our understanding of life processes, and provided multiple opportunities for intervention in disease processes. The synchrotrons are an obligatory component of this approach. Reductions in their capability, or even just halting their further development, would radically disrupt the UK health sciences enterprise, including its contribution to the UK economy, and ultimately would slow the development of modern medicines. This would be catastrophic not just for UK science, but for the good of the nation as a whole.

The ultrafast laser programme (both high power and in the CLF) is a key tool for UK science by allowing access to science on the shortest timescale. The UK is one of the drivers of the rapid development in ultrafast lasers, which supports a vast range of fundamental science and applied research, such as ultra-compact particle accelerators and attosecond science. Electronic processes on an attosecond and femtosecond timescale are the fundamental building blocks of atomic and molecular science. The CLF is

central to ensuring that UK science participates in the attosecond revolution and the new Research Centre @ Harwell demonstrates the synergies of having leading photon facilities on the same site. It is essential that the UK maintains its current high profile in such rapidly expanding areas.

Finally, it is also worth pointing out that photon-based facilities can contribute across a very wide research base including studies of physical, chemical, biological and medical systems. They provide spatial dimensions ranging from bulk to micro to nano to molecular to atomic to nuclear and with temporal characteristics measured in timescales ranging from millenia to seconds to picoseconds to attoseconds, and perhaps beyond.

The range of expertise this fosters in a knowledge-based economy should not be underestimated. In a time of hardship and recession a broad range of pursuits should be maintained as in forthcoming better times we do not know what skills/knowledge will be needed to exploit, as yet, unknown directions. In football terms, we could relate this to the well known fact that teams with “strength in depth” or “a strong bench” invariably to best in competition.

In a more general sense, there is widespread belief that in times of recession and economic hardship governments should invest in their science and technology base rather than impose cuts. We would expect STFC to make such observations to government – and to remind them of having made such statements in the past.

CLS Lewis
Chair, PAP
10th Sept 2009