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1. INTRODUCTION

Synchrotron radiation plays a central role in the panoply of photon based probes essential to the global competitiveness of the UK research community. This was recognised in the mid 80s when the SRS first came on line, it remains true today as the Diamond project prepares to replace the SRS, and it will be true for many years to come.

Though synchrotron radiation sources uniquely span wavelengths from the far infrared to ultra-hard X-rays a single facility cannot provide world-leading capability across the whole wavelength range. An appreciation of this underpins the Woolfson Report on Synchrotron Radiation which recommended, in 1993, a ‘three source scenario’ of SR provision for the UK. Hard X-ray radiation would be provided by the UK’s share in the high energy European Synchrotron Radiation Facility (ESRF), the bulk of X-rays for the UK would be provided by a home-based medium energy source (Diamond), and VUV radiation would be provided by a home-based low energy source. The first two recommendations of this report have now been funded, but the provision of *low energy* radiation has not so far been addressed.

The need for world-class optimised UV-XUV radiation sources delivering the long-term scientific needs of the UK and international research communities is well established. The OECD Fine Analysis of Matter Report also acknowledges the requirement for 4^{th} generation light sources and recommends the establishment of an EU initiative for the construction and usage of linac driven FELs.

The vision for 4GLS is to create the world’s leading low energy light source in order to carry out internationally outstanding science. 4GLS is a uniquely flexible source of ultra-high brightness continuous and pulsed radiation covering the IR to XUV parts of the spectrum. It is the first light source in the world that is planned from the outset to be a multi-user, multi-source facility combining ERL (energy recovery linac) and FEL (free electron laser) technology. It will place both UK accelerator science, and science applications of UK accelerators at the forefront of world developments.

The 4GLS Science Case has undergone rigorous scientific peer review (17 referees, of whom 5 are international). The comments of the referees were presented to an assessment panel coordinated by EPSRC (acting for OST) in February 2002. A panel report was subsequently produced, which was presented at the inaugural meeting of RCUK in April 2002. As a result, in May 2002, the proposers were invited by OST to progress to the next stage of the Gateway Process, preparation of a business case.

The following document forms the business case for 4GLS and seeks to:

- obtain the release of funds for the design stage of the project;
- establish the location of the future 4GLS facility to enable completion of the design study; and
- confirm that the project management, resources, and future funding to deliver a successful outcome are clearly identified.

The following document begins by providing a summary overview of the Business Case in Section 2. In Section 3, the science need, the 4GLS source that was proposed to meet the need, the alignment to Research Council priorities, and the outcome of appraisal of alternative ways of meeting the science need are outlined. Section 4 covers management, resource requirements and funding arrangements for the preferred option, 4GLS at Daresbury Laboratory. In Section 5 the strategic impact of 4GLS is described. Readiness for the next phase is Section 6 and the document concludes with recommendations in Section 7. Detailed evaluations are either presented in the appendices or are stand-alone documents that are referenced where appropriate.

2. 4GLS SUMMARY OVERVIEW

This business case proposal examines the need for 4GLS, where it should best be located and how this project will need to be managed and funded to deliver the world class vision.

The proposal arises from the science need for UK and international scientists to understand the *dynamic* behaviour of matter, often in very small (nm) units, on very fast (fs) timescales. This has been discussed and evaluated in the Science Case, which identified the need for an ultra-high brightness *low energy* facility that allows the use of pulsed sources in combination. We proposed to meet this need by constructing 4GLS, a uniquely flexible source of ultra-high brightness continuous and pulsed radiation covering the IR to XUV parts of the spectrum. The proposed 4GLS source is a multi-source machine, combining ERL and FEL technology in a facility that will be accessed by multiple users.

2.1 Ways of meeting the need: option appraisal

This proposal has examined in detail the options needed to respond to the science requirement, namely:

- do the minimum, *i.e*. utilise existing and planned laser and storage ring facilities;
- build only a suite of FELs alongside an upgraded SRS;
- build only a suite of FELs alongside Diamond; and
- build 4GLS – in a variety of settings.

The choice of options for assessment was shaped using feedback from assessment of the Science Case (from the referees' comments, from the panel feedback and from RCUK and OST). Full appraisal of the benefits of these options has been carried out, and the leading options have been taken forward to full cost-benefit and risk analysis. The first stage of this analysis indicated that the 'do minimum' option satisifies only a small fraction of the science need, and has a very poor fit to the UK's strategic aims in FEL and more generic accelerator technology. The option to build a suite of FELs was found to satisfy the science need only in part and to be very expensive given the rather small community that could be served by such a facility. The option appraisal exercise thus strongly endorsed 4GLS as the best way of meeting the science need.

2.2 Project Location

Once it had been determined that the case for 4GLS was supported the team examined the possibilities for the best location of this facility and carried out a detailed cost benefit analysis supported by independent consultants. Factors that would lead to fast implementation of each option were weighted highly. *This is because it is crucial to success that the internationally leading profile of the project is maintained through rapid implementation.* It was also recognised that timely execution of the project is important for cost-effective delivery, as delay impacts substantially on project costs. Thus factors such as the ready availability of land with suitable geology and of staff with the correct expertise were regarded as important.

The outcome of this process was a clear indication that construction of the 4GLS facility at Daresbury Laboratory was the option with the greatest probability of successful delivery of a cost effective solution giving the best value for money. It also was the solution that represented the least risk and the least probability of disruption to other major funded projects.

The following critical success factors further support the outcome:

- The NWDA has agreed in principle to provide financial support for the project in two specific areas; a) a contribution of 5% of the capital costs of the project (up to £4.5 M) and b) the provision of the 4GLS building (likely to be *via* an arrangement whereby the NWDA would construct the building and lease it back to CCLRC).

- By using the existing infrastructure at Daresbury Laboratory many of the initial costs can be saved and operating costs can be shared with the other activities on the site. The only new building required for 4GLS will be that required for the facility. New buildings for offices and workshops will not be required since Daresbury Laboratory already has the capacity for the existing staff of approximately 500, of which about half support the SRS.

- Daresbury Laboratory is well placed for the 4GLS design staff to develop their expertise and exchange ideas in rapidly developing areas through participating in and organising international workshops and through collaborating on related development projects – as emphasised by the leading role given to it by the European Strategy Forum for Research Infrastructures in co-ordinating European R&D technical activity on FELs.

- The project will require high levels of specific expertise in accelerator physics, RF power systems, cryogenics engineering (including superconducting systems) and optical instrumentation. These are skills found in CCLRC but, for the most part, not in industry or academia. Daresbury Laboratory has a considerable pool of expertise in all these areas, in ASTeC (Accelerator Science and Technology Centre), Synchrotron Radiation Department and the Engineering Department.

- Daresbury Laboratory, in collaboration with the University of Edinburgh and IBM, has recently won the contract to host the UK's next supercomputer (HPCx). The location of this facility in close proximity to 4GLS offers unique capabilities in experimental data anaysis, modelling and remote access that are unavailable to industry or academia anywhere other than the Daresbury site. This will enhance the potential of the Daresbury Science Park and stimulate inward investment.

- The Computational Science and Engineering Department (CSED) at Daresbury Laboratory has a long tradition of developing and supporting codes for the analysis and interpretation of experiments performed on facilities. This is both through its own efforts and through a number of internationally recognised networks that are coordinated by the department (*e.g.* the Collaborative Computational Projects (CCPs) and the Synchrotron Radiation Research Theory Network (SRRTNet)).

- The strong e-Science group at Daresbury Laboratory is ideally placed to enable the utilisation of new methodologies produced by CSED coupled with the power of the HPCx facility to enable state-of-the-art simulations and analysis of experimental data produced by the facility. The e-Science group will also play a key role in grid-enabling 4GLS to provide a world leading remote access capability.

- The model of a mixed-economy campus where university researchers and industry work in close proximity to a facility such as 4GLS has already proved very successful at the Jefferson Laboratory in the USA. It is envisaged that the Daresbury Laboratory site will host a vibrant mixture of world leading academic and applied research accompanied by significant industrial growth around the nucleus of the 4GLS facility.

- The NWDA has recently committed to develop the Daresbury Incubator and Science Park alongside the Daresbury Laboratory. Construction of the science park is due to commence towards the end of 2002 and will be well established by the time 4GLS becomes operational. The presence of an international facility such as 4GLS will attract inward investment of high technology companies to the region.

4GLS has the full support of the NWDA in providing a focus for internationally outstanding science in the region.

For these reasons, and for the continuing commitment of all stakeholders involved in this project - vital to its success - this proposal seeks not only the release of funds for the next stages of development but also an endorsement of Daresbury as the future location for the facility.

Figure 1 The Rt Hon. Patricia hewitt MP, the Secretary of State for Trade and Industry at Daresbury Laboratory, February 2002.

2.3 Management

The key findings of Stage Two of the CCLRC Quinquennial Review make it clear that the 4GLS project falls naturally within the management remit of CCLRC. In line with best practice at other leading facilities, we plan an independent Science Advisory Committee (SAC) and a complementary Technical Advisory Committee (TAC) will be formed. A Project Board will also be established, this will provide managerial, technical and scientific advice to CCLRC on all aspects of the project during design, construction and commissioning. The Project Board will also represent the interests of the major stakeholders in the project. An overview of the project programme is shown in Figure 2.

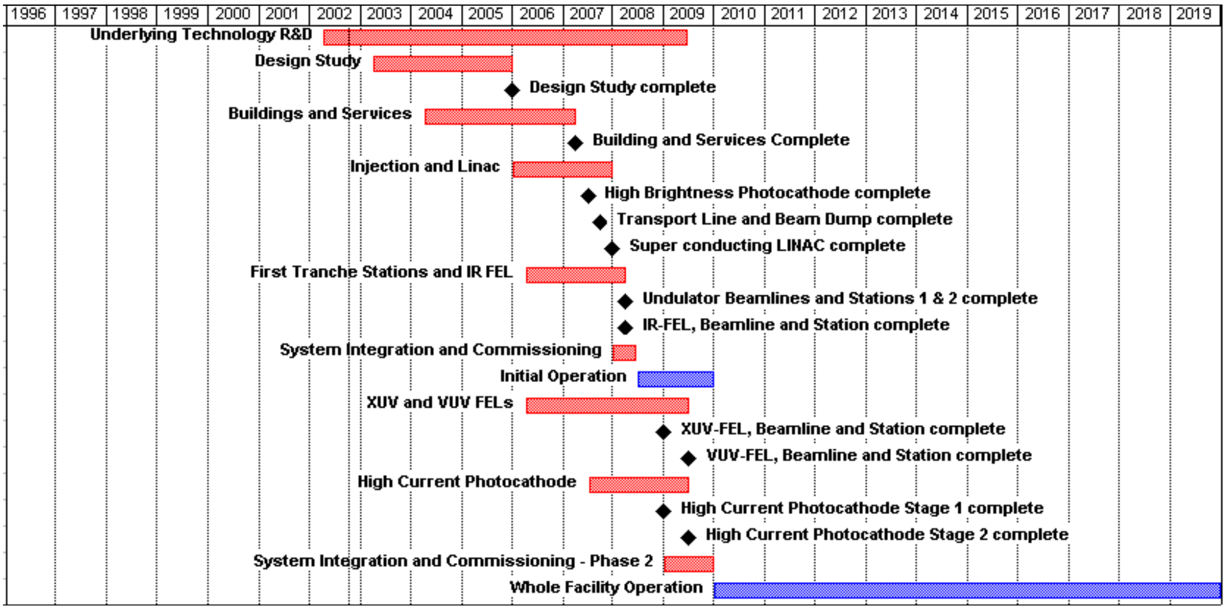

Figure 2 4GLS project timetable and milestones.

The 4GLS project will be managed within the guidelines laid down in the CCLRC Corporate Project Management Handbook (CPMH) to provide a quality management strategy. The CPMH is based on the Body of Knowledge of the Association for Project Management (APM) and BS6079: 1996. It is also compatible with ISO 9001. The 4GLS project will be subject to the CPMH project life cycle model, which necessitates the project not only passing successfully through the Gateway process but also the project life cycle phases of Conception, Feasibility and Implementation. In addition, throughout its life cycle, the 4GLS project will be subject to regular reviews of progress covering time, resource, cost and risk management.

The technical specification and delivery of the project will be guided by the 4GLS Project Board. In addition, the Project Board will provide appropriate managerial, technical and scientific advice to the Project Sponsor during the design, build and commissioning phases of the 4GLS project.

All risks associated with the 4GLS project have been assessed as either medium or low level. Risk reduction strategies have been introduced for medium risks and their status is continually under review. The implemented risk mitigation strategies should lead to a downgrading of medium category risks as the project progresses.

Safety is a critically important issue. The facility will require comprehensive safety management arrangements from the earliest stages to ensure that the highest standards of safety are achieved at all stages of the project including operations. This will include fully compliant radiation protection procedures.

2.4 Stakeholders

The major stakeholders of the 4GLS project are; the UK scientific community, the DTI and the OST, the NWDA, the Research Councils and CCLRC. Other stakeholders are documented in the 4GLS Stakeholder Plan.

The key issues for the high impact stakeholders are:

- Users (both academic and industrial) – active involvement essential in shaping the 4GLS project;
- Government Bodies – to ensure that public funds are used on world leading projects that are good value for money;
- Research Councils (including CCLRC) – to ensure that research on 4GLS is aligned with strategic aims and is cost effective;
- CCLRC – to ensure that 4GLS enables it to fulfil its strategic roles concerning large scale facilities;
- The NWDA – to ensure that the facility, its scientific use and its exploitation are for the benefit of the region and the economy at large;
- Diamond Light Source – to ensure project complementarities and proactive resource management;
- Local Residents and Organisations – to ensure economic benefits to the NW region through high profile projects like 4GLS and future development of Daresbury Laboratory.

2.5 Resources

The Design Study for 4GLS is estimated to cost £5M. The build and commissioning cost of 4GLS is £113M. Lifetime costs, including approximately 2 years initial operation, 20 years operation of the facility (assuming five stations) and decommissioning are £173M. The overall lifetime cost estimate for the facility is thus £291M.

The operating costs for the facility are £8M *p.a.* at 2002/03 price levels. This is made up of staff costs of £4.6M (for 102 staff-years) and non-staff costs of £3.4M. This would provide for 5000-6000 hours of operation per year (24hrs, 7 days per week during operating periods), with five fully staffed and supported experimental stations.

The above figures are before account is taken of the offers from the NWDA. The effect of these offers are detailed in Section 4.4.2.

The costs presented above include VAT and provision is made for the costs of Gateway Reviews. The cost estimates have been refined since the presentation of the Science Case and greater allowance is now made for the costs of the control and personnel safety systems, cryogenics and commissioning. They have been updated to 2002/03 price levels.

4GLS comprises an advanced facility with a number of novel features. It also exploits recent technological advances to an extent that necessitates R&D programmes to be pursued to guarantee optimium performance. These will be independently funded CCLRC activities

The outcome of the Design Study will be to establish the technical parameters and produce more accurate and reliable cost estimates to enable the project to proceed to the procurement phase.

The project will be primarily funded by public funds and consequently it must deliver value for money throughout all phases of its existence. There are a number of criteria against which the project must be judged relating to the efficiency of the project management process. These include costs, time, performance, availability and the size of the prospective user base.

2.6 Funding

As a UK-based world leading scientific facility, the main source of funding for the design, construction and commissioning of 4GLS is expected to be the DTI (OST) and bids have been/will be made in CSRs 2002, 2004 and 2006. Every effort will continue to be made to seek additional contributions to the cost of the project. The other actual and potential contributors include:

- The NWDA. 4GLS has the full support of NWDA in providing a focus for internationally outstanding science in the region. NWDA has agreed in principle to provide financial support by a contribution of 5% of the capital costs of the project (up to £4.5 M) and the provision of the 4GLS building.

- The Research Councils. Following the QQR2 of CCLRC, it is clear that responsibility for the running costs of 4GLS will reside with CCLRC.

- The EU. It is anticipated that the 4GLS project will be eligible for EU funding under Framework Programme 6 (FP6) and its successors.

- Other European partners. The 4GLS project team is mindful that the facility must be used for the maximum benefit of users around the EU. It is the intention during the design study phase of the project to explore the possibility that the source could be built with input from other European partners.

2.7 Impact of 4GLS

4GLS is a flagship project that has been given high profile at international meetings and is recognised by scientists from leading international laboratories concerned with synchrotron radiation provision as having the potential to lead developments in this field.

In addition to satisfying the UK need for a dedicated low energy source the 4GLS proposal greatly extends current technological capabilities and has the potential to give the UK a world leading capability. The realisation of this potential is underpinned by the acknowledged strengths of the full range of Daresbury scientists which, together with other capabilities on the Daresbury site, will be considerably enhanced by 4GLS. This will ensure that the UK community will be welome partners in accelerator based international collaborations, not only for radiation sources but also in other areas such as particle physics applications.

4GLS will present exciting challenges to accelerator physicists and is likely to enhance the status of this profession in the UK and increase its ability to attract new recruits. Such stimulation is essential if the UK is to play a long-term role in other accelerator based scientific challenges.

The development of 4GLS is complementary to the facilities currently managed by CCLRC and will expand its portfolio to provide what is likely to be the most comprehensive and competitive suite of national facilities in the world.

As a national facility, 4GLS offers considerable opportunity for commercial exploitation by UK based companies and will make a major contribution to economic development in the NW.

2.8 Conclusion

This proposal presents a compelling business case for building 4GLS at Daresbury. We seek endorsement of the location of the facility in order to enable completion of the design study. The business case demonstrates a sound project management framework within which the facility can be delivered in a timely and cost effective way and proposes the release of funds for the next stage.

3. THE BUSINESS NEED

3.1 The Science Need

There is a fundamental requirement for UK and international scientists to understand the *dynamic* behaviour of matter, often in very small (nm) units, on very fast (fs) timescales.

This requirement is in turn driven by the small lengths and fast timescales governing many 21st century technologies. For example, semiconductor device structures based on silicon are set to become so small that they will operate normally in a non-equilibrium regime which makes *dynamic* carrier distribution measurements essential for their further exploitation. The development of spintronic memories will require nanoscale characterisation of electron spin distributions of magnetic clusters. Dynamic measurements of protein folding in realistic solutions on fast timescales are necessary to complement the finally folded structure information provided by protein crystallography. The ability to manipulate molecules in high fields is essential for exploitation of the coherent control of reactions, while the ability to follow reaction pathways and pinpoint reaction intermediates is necessary to improve our understanding of all types of industrial catalysis, particularly asymmetric synthesis.

In essence, the UK and international scientific community recognises a need not just to determine *structure* with high precision but to understand *how these structures function*.

The extraction of this dynamic information is far from trivial; it will necessitate cutting edge experiments using multiple pulsed and synchronised sources of ultra-high brightness light. The pulse lengths need to be short enough to study bond breaking and bond making while the energy of the pulses must be low enough to allow very high resolution spectroscopy of the vibrational and electronic motions of these bonds, and to limit damage, *e.g.* to biological material.

The need here is for an ultra-high brightness *low energy* facility that allows the use of pulsed sources in combination. In turn, this requires full exploitation of the expertise of UK accelerator physicists, the UK 'low energy SR' community and the UK laser community.

Rapid developments in accelerator technology over the last ten years have produced a 'technology pull' that exactly complements the 'science push' described above. This enables us to realise scientific goals that far surpass the original expectations for a low energy source as outlined by Woolfson[1]. Detailed consultation with potential users of low energy photons led to the identification of the following key targets for the UK low energy SR and FEL communities:

- optimised "continuous" radiation in the IR to XUV region of the spectrum;
- optimised pulsed sources of radiation in the IR, VUV and XUV regions of the spectrum;
- multiple, synchronised sources to enable pump-probe and two colour experiments;
- both ultra-high brightness and ultra-high flux to enable the study of very dilute or nanoscale samples, and to allow the development of new nanoimaging techniques; and
- pulse lengths that are variable from the ps to the fs regime, with variable pulse spacing for investigation of dynamic processes.

3.2 The Concept

The vision for 4GLS is to create the world's leading low energy light source in order to carry out internationally outstanding science. 4GLS is a uniquely flexible source of ultra-high brightness continuous and pulsed radiation covering the IR to XUV parts of the spectrum. It is the first light source in the world that is planned from the outset to be a multi-user, multi-source facility combining ERL (energy recovery linac) and FEL (free electron laser) technology, Fig. 2. As such, it will place UK accelerator science at the forefront of world developments. ERL technology provides high quality, very high brightness radiation, which vastly surpasses that provided by conventional storage ring technology. It also provides easily tailored pulse characteristics, leading to a high level of experimental flexibility. It is widely regarded by the international community as the technology on which future advances in synchrotron radiation science will be based. FEL technology provides the opportunity to complement this with pulses of very short duration and ultra-high brightness from IR-, VUV- and XUV-FELs *which are themselves individually world class*. The use of locked laser photoinjectors and superconducting technology throughout confers high stability and allows the different parts of the facility to be brought together in a unified whole, and in particular to be used in combination, with the pulses from one source matched and synchronised with those from another. The ERL technology lends itself to clearly identifiable upgrade paths. This is a source that will not become rapidly outdated but will provide the UK with a world leading facility for many years after its construction.

[1] The Woolfson report on Synchrotron Radiation, 1993.

Figure 3 Schematic diagram of the 4GLS concept.

The outstanding properties of 4GLS will enable a paradigm shift in scientific research using low energy photons. The high brightness of the source will lead to step advances in research aimed at exploiting and manipulating the novel properties of systems with dimensions reduced below 10 nm. Indeed, the brightness of the radiation from the new source is so high that *single* nanoscale objects can be studied, for example the distribution of electron spins in single nanoclusters of magnetic material may be determined for the first time. The high brightness also enables the development of a number of imaging techniques, for example the use of the huge brightness of the IR-FEL to develop near-field functional imaging on truly sub-cellular (30 nm) dimensions. The short pulse lengths provided by the source will allow access to the dynamics or kinetics of processes previously inaccessible, for example studies of real-time protein folding, molecular conformational changes and chemical reactions on timescales down to tens of fs. The flexibility and ease with which photon sources may be combined will allow unparalleled opportunities for the development of 'pump-probe' experiments. Of particular importance here are those using the VUV- and XUV-FEL sources, which allow, for example, the creation of transient, short-lived species (such as those created in the upper atmosphere or in interstellar dust clouds) and their subsequent study using continuous radiation. The brightness of these sources, particularly the XUV-FEL leads science into a new regime of high field physics where non-linear processes will be exploited, for example in the development of coherent photon scissors and related tools.

3.3 Source Description

The synchrotron radiation sources may be divided into two main categories, the spontaneous radiation sources and the stimulated radiation sources.

Spontaneous radiation sources

Two sources of spontaneous synchrotron radiation will be available:

- **Undulators** – these will generate optimal high flux, high brightness spontaneous radiation, of variable polarisation, over the photon energy range 3-100 eV. However, they will also generate high intensity radiation in the higher harmonics up to around 800 eV.

- **Bending magnets** – the bending magnet radii can be flexibly varied around the ERL return path arcs and output will range from the far infrared to over 1 keV.

Stimulated radiation sources

Three free electron laser sources operating in the far infrared, vacuum ultraviolet and extreme ultraviolet regions of the spectrum are envisaged. The FELs will be used to generate short pulses of radiation that are widely tunable and more than a million times more intense than the equivalent spontaneous undulator radiation. They will operate in regimes where they offer considerable advantages over table-top laser sources.

The IR-FEL will cover the far-IR region and will generate sub-picosecond laser pulses in the range 3 to 75 μm (0.4 – 0.017 eV).

The VUV-FEL has the potential to generate sub-picosecond, VUV laser pulses in the range visible – 10 eV (extreme UV) with broad tunability. The output of the VUV-FEL will be 5-6 *orders of magnitude* more intense than the spontaneous VUV radiation from undulators on third generation sources.

The XUV-FEL has the potential to generate *ca.* 100 fs pulses and will operate in the extreme UV from 5 - 100 eV in the fundamental though it will be optimised for 10 eV and above. The output of the XUV-FEL will be 8-9 orders of magnitude more intense than the spontaneous XUV radiation from undulators on third generation sources.

These FEL sources should be available for use individually, in combination with undulator radiation or other FEL radiation, or together with table-top IR or visible/UV laser sources. Possible modes of operation are discussed in "Preliminary Thoughts on Possible Operating Modes in 4GLS", Appendix 1.

3.4 Context

A detailed comparison of 4GLS with other national and international advanced radiation sources and with available and anticipated tabletop laser sources is given in Section 9 of the Science Case and "4GLS The International Context", Appendix 2. The relative roles of 4GLS and Diamond were considered explicitly in the Report of the 4GLS and Diamond Working Party, chaired by Prof D.P. Woodruff in August 2001, and included as Appendix VI of the Science Case. A summary of the important conclusions from these documents is given here.

1. **None of the current European 3rd generation sources offers optimised radiation below 100 eV.**

2. **4GLS is highly complementary to Diamond in its SR provision.**

3. **4GLS is the first international proposal for a facility based on combined ERL and FEL technology that will provide multiple photon sources, and which will be able to service multiple users.** It is thus unique in the world in its capacity to carry out a wide range of experiments that combine photon sources, in particular pump-probe experiments.

4. **4GLS will surpass the performance of existing European IR FELs** in a number of ways, including shorter pulses, better energy stability and higher average power.

5. **The 4GLS VUV-FEL has a number of advantages over existing storage ring FELs** arising from the superior electron beam properties possible with ERL technology. The provision of deep to extreme-UV radiation from the 4GLS *cavity* FEL is thus of high significance in a European context.

6. **The XUV-FEL of 4GLS is complementary in energy coverage to planned European XFEL provision**, where the emphasis is on the production of hard X-rays largely for structural investigations. There are however many overlapping aspects where the growing collaborative effort between CCLRC and European Laboratories will be of great mutual benefit.

CCLRC has joined the TESLA project and has an MoU with DESY covering a range of technical activities associated with FEL and collider technology. This should lead to the synergistic development of the 4GLS XUV-FEL and the TESLA XFEL for the benefit of European Users. CCLRC is also embarking on a series of collaborations with other active FEL development groups at *inter alia* Jefferson Laboratory, SLAC, Brookhaven National Laboratory, ELETTRA and BESSY.

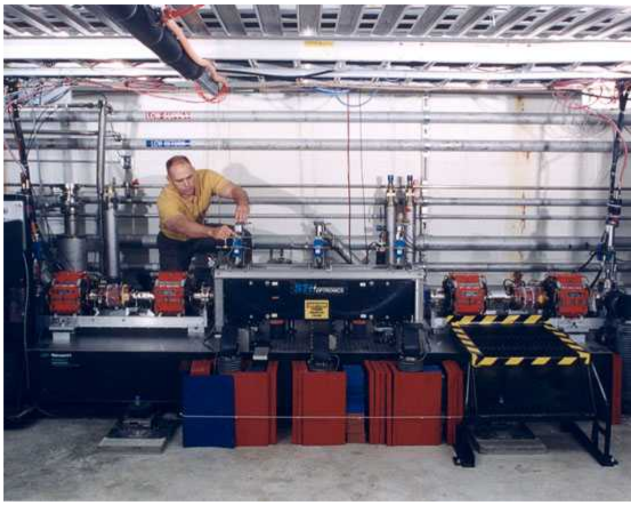

Figure 4 Left: Dr Hywel Price, Director Daresbury Laboratory, some members of the 4GLS team and Dr George Neil of Jefferson Laboratory with the MoU between the two Laboratories. Right: The Jefferson Laboratory Wiggler before dismantling prior to shipping to Daresbury Laboratory.

3.5 Alignment to the Strategic Priorities of the UK Research Councils

The fit of 4GLS to the published strategic priorities of the relevant Research Councils has been considered in detail and is reported elsewhere[2]. A summary of the important conclusions is given here:

- The CCLRC is currently developing its strategic plan and it is already clear that accelerator science and technology, both design and operation, will be core to the corporate mission, objectives and strategic implementation plan of the Council. 4GLS is entirely complementary with the existing facilities managed by CCLRC and with its custodianship of the UK's involvement in international facilities.

- The 4GLS Science Case is well-matched to the strategic aims of PPARC[3]. It will maintain a core competency in accelerator physics in the UK and lead to the development of advanced accelerator technologies to support future major international accelerator projects such as the Linear Collider project. 4GLS will also enable fundamental spectroscopic measurements of relevance to astrophysics.

- The 4GLS Science Case is largely concerned with nanoscience, nanoimaging and dynamics, and there are thus many areas that map directly onto EPSRC priority areas. Key EPSRC strategic priorities are nanotechnology (Materials), nanointerface biology (Life Sciences Initiative) and support of internationally recognised centres of excellence that are able to link effectively with the chemicals and pharmaceuticals industries (Chemistry). A key target in Physics in 2001/2002 was to undertake a forward look into research opportunities in atomic and molecular physics and its interfaces[4].

- 4GLS matches closely to the BBSRC key goals[5] to promote the development of new tools to characterise 'working molecules' i.e. molecules carrying out their biological function and to broaden and strengthen the interdisciplinary research base supporting the development of biological nanotechnology.

- Climate change and sustainable economies are key priority areas for NERC[6]. 4GLS will facilitate entirely new research into the reaction pathways of short-lived gaseous species, such as those contributing to atmospheric pollution. It will contribute to the development of a number of clean technologies and renewables and will improve our understanding of the effectiveness of bacteria in land remediation and bio-attenuation of toxic plumes.

3.6 Meeting the Business Need

The feedback from assessment of the Science Case (from the referees' comments, from the panel report and from RCUK and OST) provides guidance on ways in which the 4GLS

[2] Ancillary paper STRAT07
[3] Ancillary paper SCI04
[4] Ancillary paper STRAT03
[5] Ancillary paper STRAT06
[6] Ancillary paper STRAT05

proposal might be enhanced. The main issues, and their effect on the business case have been considered in detail[7]. In particular, this feedback has been used to inform and influence the range of options to be considered as possible ways of addressing the 'science need'. These options were assessed in a series of workshops facilitated by Gleeds Management Consultants. They ranged from 'do the minimum' to 'build 4GLS', *viz*:

- do the minimum, *i.e.* utilise existing and planned laser and synchrotron radiation facilities;
- build only a suite of FELs alongside an upgraded SRS;
- build only a suite of FELs alongside Diamond; and
- build 4GLS – in a variety of settings.

The full details of this option assessment are available in paper OPT01. These documents examine firstly the possible alternative ways of meeting the 'science need', and in particular whether a FEL, or combination of FELs addresses this in a cost effective way. The broad conclusions are that a suite of several synchronised FELs is required in order to be able to carry out any significant proportion of the science case. When costed, this option is expensive given that its capacity would be very limited compared with a full ERL/FEL facility. The 'do minimum' option was clearly rejected as it would allow only a fraction of the science identified in the Science Case to be carried out. In addition, its fit to the UK's strategic aims is very poor as it would not allow the UK to compete on the world stage in FEL or ERL technology, and would lead to the loss of the UK accelerator physics base. Thus the conclusion from the first stage of option appraisal is that 4GLS represents the best way of meeting the need identified in the Science Case.

The second stage of option appraisal considers the optimum location for the facility. Green field sites and university sites are rejected on both economic and management grounds. In considering possible CCLRC sites (DL and RAL), factors that would lead to *rapid implementation* of the project were given a high weighting. This is because it is crucial to project success that the internationally leading profile of the project is maintained through rapid implementation. It was also recognised that timely execution of the project is important for cost-effective delivery, as delay impacts substantially on project costs. Thus, factors such as the ready availability of land with suitable geology and of staff with the correct expertise were regarded as important. The outcome of this process was a clear indication that construction of the 4GLS facility at Daresbury Laboratory was the option with the greatest probability of successful delivery of a cost effective solution giving the best value for money. It was also the solution that represented the least risk and the least probability of disruption to other major projects (such as Diamond and the ISIS 2nd target station).

[7] Ancillary paper SCI06

4. BUSINESS CASE FOR 4GLS AT DARESBURY LABORATORY

4.1 Management of the 4GLS Project

The CCLRC has recently undergone a Quinquennial Review of its operation. For the 4GLS Project, the key statements of relevance from Stage 2 of this review[8] are that:

- *The science and engineering programmes of the CCLRC are a vital part of the UK science and engineering base.* The CCLRC is a world-leading scientific research organisation bringing together scientists both from the UK and world-wide to participate in research in a multi-disciplinary environment*, by providing access to leading edge, large-scale facilities*[9] and an extensive pool of scientific and technological expertise, skills and innovation.
- Technology programmes at the *CCLRC include, among others, accelerator-based technologies, information technologies, instrumentation and e-Science*. It is the proximity of a critical mass of capabilities - across a broad set of disciplines - that marks out the strength of the CCLRC. *These scientific, technical, educational and organisational capabilities, together with the large-scale facilities and their specialist supporting infrastructure, constitute an integral part of the UK science and engineering base.*
- The CCLRC should act, on behalf of the RCUK and the other Research Councils, as the *national focus for large-scale facilities* for neutron scattering, synchrotron radiation and high power lasers.

Based on these recommendations it is clear that the 4GLS project falls naturally within the remit of CCLRC and should be managed by CCLRC.

In line with best practice at other leading facilities it is suggested that an independent Science Advisory Committee (SAC) and Technical Advisory Committee (TAC) are formed. The SAC should have a membership drawn from the UK scientific community that will use the facility together with international members associated with other world leading facilities. The SAC will provide advice to CCLRC on issues of its management of 4GLS that affect the quality of the scientific output of the facility. The TAC would be made up of technical experts drawn from the UK and abroad. It will provide advice to CCLRC on the design, construction and operation of 4GLS.

4.1.1 Project Management Structure

The proposed 4GLS Project management structure is illustrated in Fig. 5. The executive authority for any project resides with the Senior Responsible Owner (SRO). Given the importance of the current project to UK Science Strategy and to CCLRC, the SRO of the project is the CEO of CCLRC, currently Prof John Wood.

The project sponsor acts as an interface between the end customer(s) of the project and the project manager. The 4GLS project sponsor is currently Dr Hywel Price, Director of CCLRC

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[8] The findings of the QQR2 report were announced by Lord Sainsbury on 30th April 2002 and are available at http://www.qqr.cclrc.ac.uk

[9] This is a reaffirmation of Article 1 of the Royal Charter (available at http://www-internal.clrc.ac.uk/staff/old_human_resources/employee_handbook/missioncclrc.html) that defines the purpose of CCLRC. This Article states that the role of CCLRC is 'to promote high quality scientific and engineering research by providing facilities and technical expertise in support of basic, strategic and applied research programmes funded by persons established in this Our United Kingdom and elsewhere'

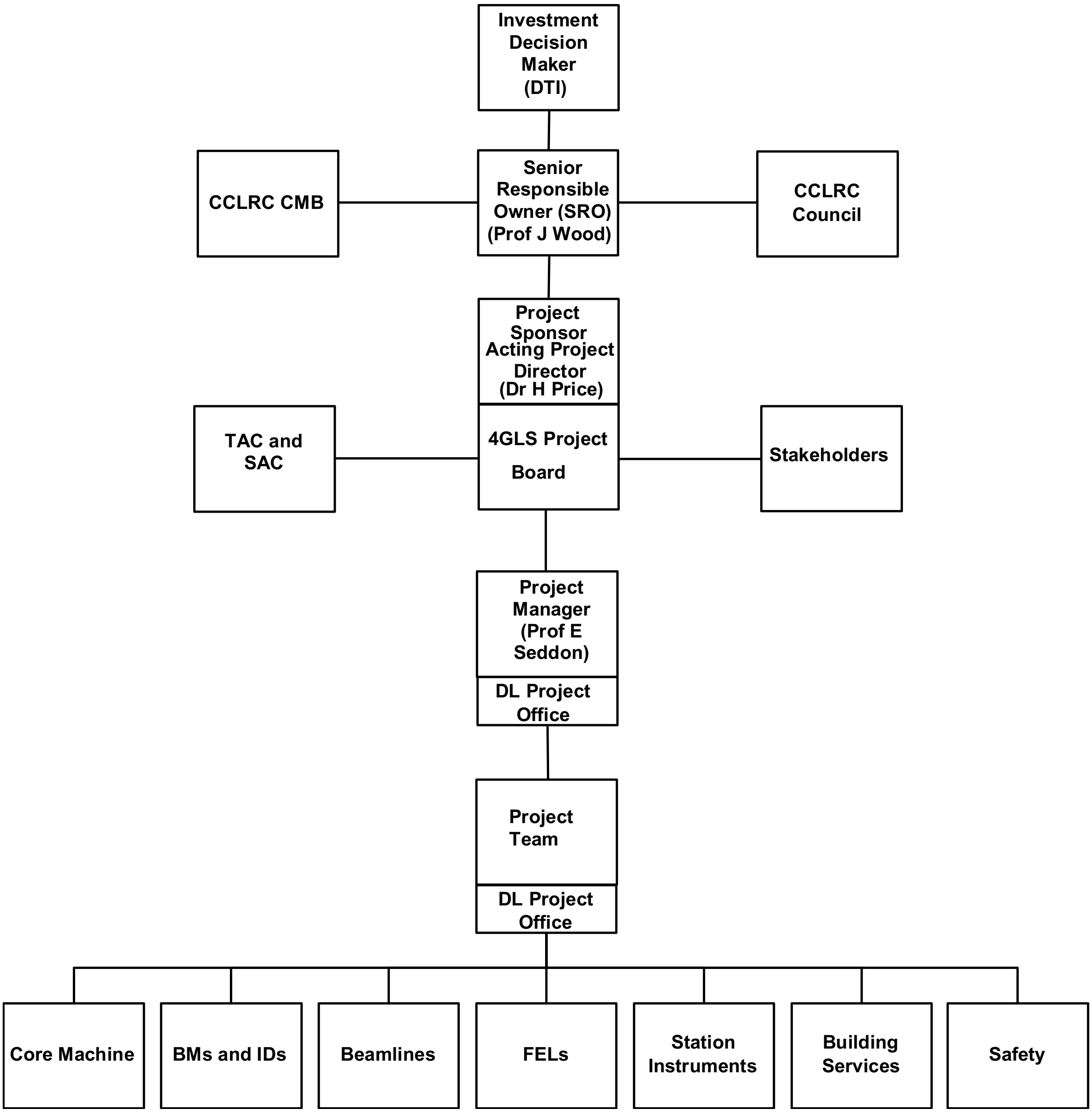

Figure 5 Proposed management structure of the 4GLS project.

Daresbury Laboratory. Currently, he also serves as the Acting Project Director. However, it is recognised that most major facility projects (*e.g*. Diamond) do not combine these roles, and it is anticipated that the 4GLS project will appoint a separate Project Director in due course. The Project Director will then assume the role of liaison between the project, the stakeholders and the scientific and technical advisory boards. This interaction is facilitated by his role as Chair of the 4GLS project board. Such a position would demand the full time services of an internationally established scientist in the field of FELs and/or synchrotron radiation.

A 4GLS Project Board will provide appropriate managerial, technical and scientific advice to the Project Sponsor during the design, build and commissioning phases of the 4GLS project.

Scientific and Technical Advisory Committees will provide advice and international level quality checks on the direction of the project, with the chairs of these committees also serving as Project Board members. UK scientific stakeholders and the funding agencies will also be fully involved in the project and have representation on the 4GLS Project Board.

The suggested membership of the Project Board is:

- the Project Sponsor (Chair) – Dr Hywel Price, Director of CCLRC Daresbury Laboratory;
- the Project Director - role currently filled by Project Sponsor;
- the Head of ASTeC;
- the Chair of the SAC - to be appointed;
- the Chair of the TAC - to be appointed;
- a representative of the funding agencies (*e.g.* DTI and NWDA) - to be appointed;
- a representative of the user community - to be appointed; and
- the Project Manager – Prof Elaine Seddon, CCLRC Daresbury Laboratory

The key role in successful delivery of any project is the Project Manager. The Project Manager's primary responsibility will be to deliver the project to specification, in time, and on budget within the constraints of the critical success criteria in the project specification, strategy and management plan.

Given the complex nature of the project, it is proposed that the project is broken down into seven constituent sub-projects defined in Figure 5. Each sub-project will be managed by a Sub-Project Manager and will be determined by a Sub-Project Specification formally agreed between the Project Manager and the Sub-Project Manager.

Full details of the roles and responsibilities of all managerial positions within the 4GLS project structure are detailed in "Roles and Responsibilities", Appendix 3**.**

Assessment of a wide range of alternative options for management of the 4GLS project is recorded elsewhere[10].

4.2 Stakeholders and Stakeholder Consultation

The major stakeholders of the 4GLS project are: the UK scientific community, the DTI and the OST, the NWDA, the Research Councils and the CCLRC. A detailed Stakeholder Plan can be found in Appendix 5.

Initial stakeholder consultation concentrated on potential users of low energy photons within the UK academic community (Section 11.1 and Appendix III of the Science Case). This was extensive, and focussed on identifying their specific requirements for world leading science. The output from this process was the 4GLS Science Case.

Subsequent work has concentrated on ensuring continued engagement of the research community with the 4GLS project and on broad dissemination of information about the project. A list of such activity is attached at Appendix 4 "4GLS Presentations and Meetings". In addition, we have sought to identify the detailed requirements of other stakeholders in the

[10] PM05

4GLS project and to instigate appropriate mechanisms to manage their interactions with the project.

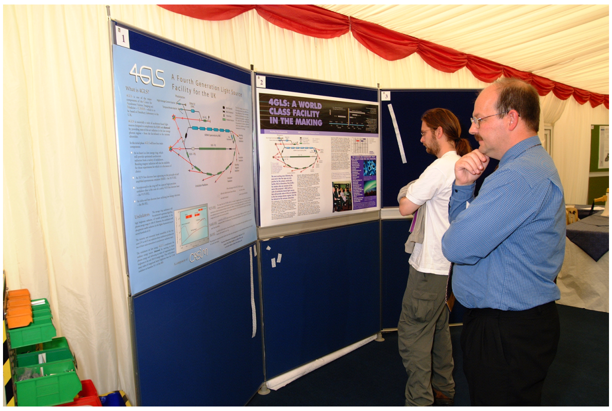

Figure 6 4GLS information at the 2002 Synchrotron Radiation User Meeting.

The key stakeholder management processes detailed within the Stakeholder Plan range from large-scale workshops, formation of focus groups through to one-to-one discussions and briefings between members of the project team and key individuals who have an interest in the project. In addition, it is recognised that the press (scientific, local and national media) will have an important role in disseminating information about the project and in shaping its image. The full range of proposed mechanisms for managing interactions with stakeholder is documented in the Stakeholder Plan.

The key issues for the high impact stakeholders are:

Users – active involvement essential in shaping the 4GLS project: Seek to expand the number of potential users through pro-active measures including continuing the workshop programme, publication of articles concerning the project in the popular scientific media and continuing the series of presentations at major national and international conferences. In addition the project will actively promote the organisational changes occurring within CCLRC as a result of the QQR2 and IiP. As the project progresses, a 4GLS newsletter will be established. The 4GLS website will be maintained and regularly updated. DARTS (Daresbury Analytical Research and Technology Service) will approach potential industrial users *via* targeted presentations. Users of the 4GLS facility have been central to the development of the project – for example the Science Case was submitted by the User Community. This close collaboration has continued, with both the 4GLS Strategy Group and the 4GLS Steering Group currently chaired by users. Following Gateway 1, potential 4GLS users will be represented on the 4GLS Project Board, and it is our intention that the facility will be designed, constructed and operated in continued close collaboration with the Scientific Community.

Government Bodies – to ensure that public funds are used on world leading projects that provide good value for money: The briefings of key government agencies and departments, in particular OST, by the Director of Daresbury Laboratory and the Chief Executive of CCLRC, will continue.

Research Councils – to ensure that research on 4GLS is aligned with strategic aims and is cost effective: Briefings to RCUK on the status and progress of the project by the Chief Executive of CCLRC will continue. EPSRC and other Research Councils currently supporting SR in the UK will receive briefing reports at each meeting of the UK SR Forum, which meets biennially, and at the annual SRS Users Meeting.

CCLRC – to ensure that 4GLS enables it to fulfil its strategic roles concerning large scale facilities. Regular reports from the Project Sponsor/SRO to the Corporate Management Board and to the CCLRC Council.

The NWDA – to ensure that the facility, its scientific use and its exploitation are for the benefit of the region and the economy at large. Best achieved through the synergistic development of 4GLS, the Daresbury Laboratory site and the Daresbury Science Park. Following Gateway 1, NWDA will be represented on the 4GLS project board.

Diamond Light Source – to ensure project complementarity and proactive resource management: Currently the 4GLS project interactions with Diamond have been managed *via* meetings between the 4GLS project manager and the CEO of the Diamond Light Source company. This system has proved successful and will continue. At a more formal level, progress reports on both facilities are requested at each meeting of the UK SR Forum, which meets biennially and cross-representation has been arranged between the 4GLS Steering Group, the 4GLS International Advisory Group, and the Diamond SAC. We anticipate that this will be maintained between the 4GLS and Diamond SACs in future.

Local Residents and Organisations - To ensure economic benefits to the NW region through high profile projects like 4GLS and future development of Daresbury Laboratory: In addition to ensuring that building works during the construction phase have as low an impact as possible on local residents. Regular consultation with local parish councils and residents groups during the construction phase of 4GLS is planned.

Details of action plans for groups whose impact on the project is rated as medium to low are contained within the 4GLS Stakeholder Plan, Appendix 5.

4.3 Timetable and Milestones

An overview of the project programme is shown in Figure 7.

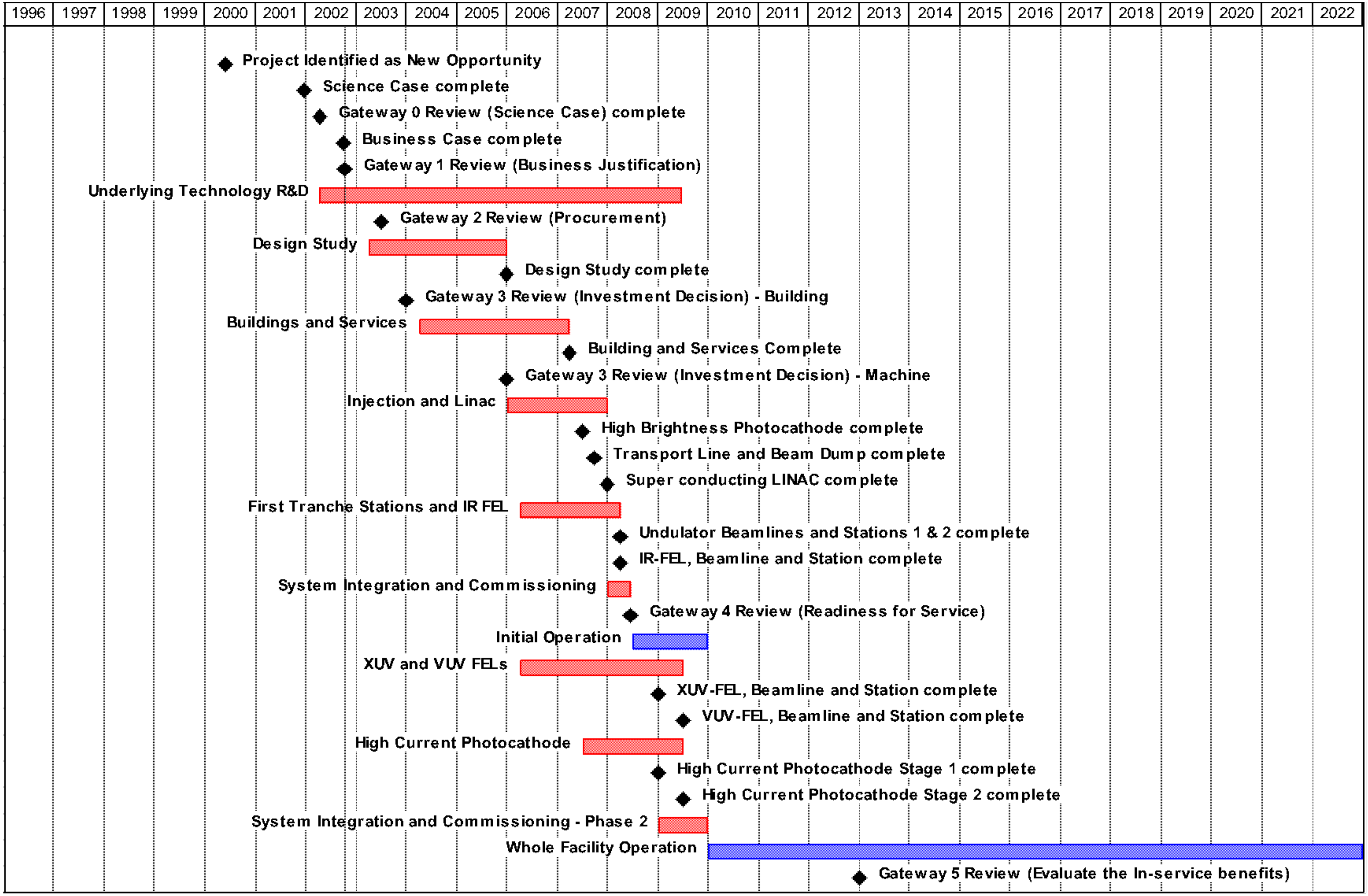

Figure 7 Timetable and milestones for the 4GLS project.

The programme shows the overall span of the project from the start of the Design Study in 2003 to the final Gateway Review (5, Evaluation of the in-service benefits) around July 2010, 6 months from the start of operation of the whole facility. Other possible Gateway Review dates are indicated in the programme. Initial operation of 4GLS using the IR-FEL and undulator-based stations is programmed for mid-2008. Allowance in the operating schedule will be needed for the installation and commissioning of the remaining components of the proposed project: XUV- and VUV-FELs and the high current photocathode.

The construction of the major sub-systems of 4GLS will need to be preceded by a formal Design Study to address the wide range of issues from accelerator physics through to production of procurement specifications for all equipment. Building work will overlap with the later stages of the Design Study in order for the building to be ready for installation of the first machine components. For this reason, two Gateway 3 Reviews (Investment Decision) are shown, one for the procurement of the building and the second for the procurement of the machine components.

There is also a need for R&D programmes (separately funded within CCLRC) in relevant superconducting RF systems, photocathode electron guns, beamline optics, cavity FEL optics and FEL seeding issues. These have already begun.

Completion of two undulators, together with their beamlines and associated stations, will allow an early start to be made on the scientific programme.

It is planned to build the IR-FEL first. This will provide a valuable stepping stone in the development of the facilities and skills needed for the other FELs and will meet the needs of a large component of the science case. Many near field imaging opportunities will be realisable with the IR-FEL. Pump-probe experiments aimed at investigation of real time processes in bio-systems and materials will also be possible.

The high brightness photoinjector will be supplemented by the incorporation of a second photoinjector, starting the programme for delivery of high average currents. In Stage 1 of its development, this would provide currents of tens of milliamps.

Fuller exploitation of 4GLS will be possible following incorporation of the XUV-FEL as this will allow a start on the high field and non-linear physics programmes. It has been brought forward before the VUV-FEL in the project plan in response to the priority given to the science this will deliver by the Science Case reviewers.

In parallel, the high current photoinjector will move into Stage 2 of its development to deliver beams of 100 mA or higher. High average current operation of 4GLS is crucial for those whose science utilises the spontaneous output of the undulators and bending magnets.

The envisaged complement of FELs will be completed with the VUV-FEL, on which a large element of the science case and science output will depend.

At this stage 4GLS will meet its initial design specification. It will be a multi-user facility delivering both FEL radiation, from the infrared to the extreme ultraviolet and high brightness beams of SR to users on bending magnets and undulators. It is expected that 4GLS will develop further from this point with additional beamlines and stations being developed and funded in response to community demand. One of the advantages of 4GLS is the relative ease of further upgrades and changes to the machine configuration for example following increased demand from users or revisions in scientific priorities.

A list of milestones is provided in Appendix 6.

4.4 Resource Requirements

4.4.1 Staffing

The estimates and profiles for the work-years required for the R&D, the Design Study, the construction and the operation of 4GLS are summarised in Fig. 8 and Table 1.

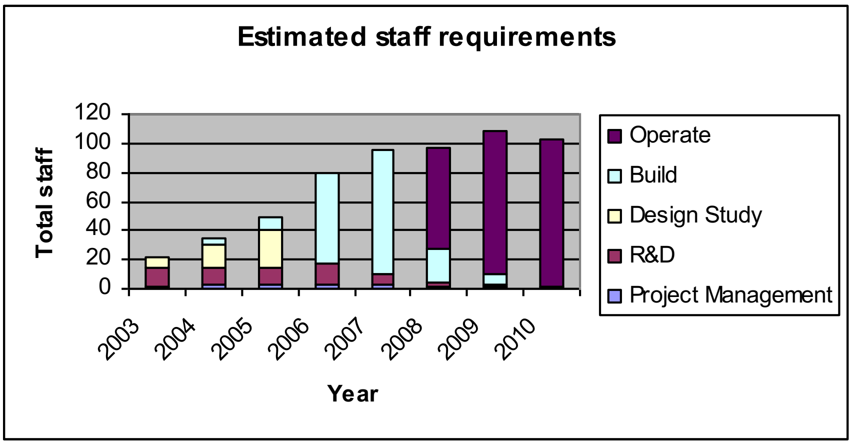

Figure 8 Estimated staff requirements for 4GLS.

Table 1 Staff profile in staff years.

	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11
R&D	12	12	12	14	7	3	2	
Project Management	2	3	3	3	3	2	1	1
Design Study	7	16	25					
Build and commission		3	8.5	62	85	23	6.5	
Operate						69	99	102
Overall Totals	**21**	**34**	**48.5**	**79**	**95**	**97**	**108.5**	**103**

Further details are available in other sections of the Business Case (Design Study, Section 4.4.3) and in ancillary documents (RES01).

Availability of Staff Resources

The project will require high levels of expertise in accelerator physics, RF power systems, cryogenics engineering (including superconducting systems), laser photoinjector systems, high power optics, advanced diagnostics instrumentation, advanced beamline design, experimental systems design and detectors. CCLRC has pools of expertise (mainly based at Daresbury Laboratory) in all these areas spread across ASTeC (Accelerator Science and Technology Centre), the Synchrotron Radiation Department, the Engineering Department and the Central Laser Facility and the Instrumentation Department. Staff in all these departments have been engaged in the development of the conceptual design of the facility.

Some recruitment will be necessary to build on the existing skill base. The forecasted availability of current ASTeC staff in the required period is sufficiently high to give confidence that the level of recruitment required into the Centre is readily achievable. The nucleus of instrumentation scientists and engineers with the required skills for the development of beamline optics and experimental stations will be expected to migrate from the Synchrotron Radiation Department as a phased transition is made from the SRS to Diamond and 4GLS. Some recruitment into Instrumentation Department for advanced detector systems development is also envisaged. It is anticipated that the 4GLS building design-and-procurement will be supervised by a small core of CCLRC and NWDA staff supported by specialist consultants and building contractors.

For operation of 4GLS, the phasing of the build up of staff on 4GLS complements a projected run-down in staff on SRS operations. The proposed schedule plans initial operation in 2008/09, coinciding with the end of the currently envisaged 'bright period' of overlap between the SRS and Diamond.

Staff Development

The novel technologies on which the 4GLS design concept is based are either recently implemented or in the early stages of development and are being actively pursued in a number of locations worldwide. CCLRC has already established links with a number of these and has collaborative agreements, for example with JLAB, SLAC and DESY. It also has several years of experience from its collaborations on FEL projects such as FELIX and EUFELE at ELETTRA.

It will be important for all 4GLS design staff to continue to develop their expertise and exchange ideas in these fast-moving areas through participating in, and organising, international workshops and collaborating on related development projects. Daresbury Laboratory is well placed for this, for instance through the leading role given it by the European Strategy Forum for Research Infrastructures in the organisation of a workshop to co-ordinate technical R&D activity in FELs. There will also be great benefit to be obtained from encouraging short term Visiting Scientist appointments at Daresbury in a number of the key skill areas, to boost progress where appropriate but also to provide rapid training to project staff. A number of potential visitors have already expressed strong interest.

4.4.2 Financial

The lifetime cost summary together with cost estimates for each phase of the project are shown in Table 2.

Table 2 Lifetime cost summary (including VAT).

	£M
a) Design Study	5
b) Build and commission 4GLS	113
c) Additional lifetime costs, including approx. 2 years initial operation + 20 years operation of the whole facility, and decommissioning	173
d) Overall lifetime costs [a) + b) + c)]	291

This assumes that the facility operates with only the initial five stations. The full complement of stations is dependent on the results of the Design Study; it is expected to be around fifteen stations.

The estimates have been refined since the presentation of the Science Case and greater allowance is now made for the costs of the control and personnel safety systems, cryogenics and commissioning. They have been updated to 2002/03 price levels.

R&D is also essential to the project but they have wider roles in the general development of Accelerator Science in the UK and have separate funding, therefore these costs are not included within the project capital costs. However, provision is made for the costs of Gateway Reviews, the last of which might fall in 2013.

No account of sources of funding has been taken in Table 2, which shows total project costs.

The NWDA propose to make major contributions to the 4GLS project (Appendix 7). In particular, they have:

- made a commitment to contribute 5% of the capital costs of the project up to a maximum of £4.5M; and
- they propose to pay for the 4GLS building (estimated at £22.2M + VAT) and lease it back to CCLRC.

The major impact of the NWDA commitment to the project will be to transfer the large capital cost of the 4GLS building to a recurrent, yearly lease-back cost spread over 20 years.

4.4.2.1 Capital Costs

Use has been made where possible of estimates for the Diamond project, which were revised in some detail in September 2001. In several areas of the 4GLS estimate, for example the building, the Diamond figures have been used for guidance. However, they are necessarily approximate at this stage. The machine will be a novel design and the Design Study will be required before more accurate estimates can be made. Overall, the estimates are considered to be good to ± 20%.

The consequences of the NWDA input to the project in terms of capital cost profile (*i.e.* not including operating costs) are shown graphically in Fig. 9 and tabulated in Table 3. The rental costs are included under Running Costs (Section 4.4.2.2).

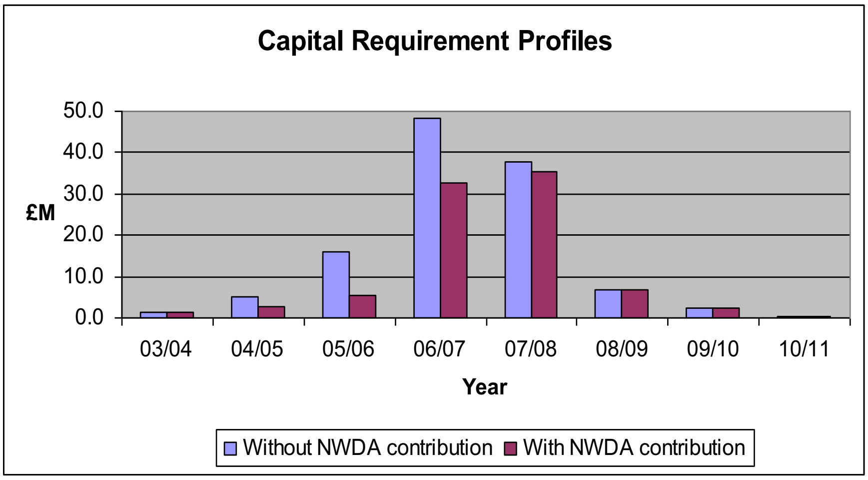

Figure 9 Capital requirement profiles with and without provision of the building by the NWDA and arbitrarily assuming that the NWDA capital contribution is made in years 2006/7 and 2007/8.

Table 3 Spend profile for the project components (£M). Figures in brackets indicate the situation *without* the NWDA contribution.

03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11
Design Study							
0.8	1.7	2.4					
Build and commission							
0.5 (0.5)	1.1 (3.3)	2.9 (13.5)	32.6 (48.3)	35.5(37.8)	6.9 (6.9)	2.4 (2.4)	0.4 (0.4)
Totals							
1.3 (1.3)	2.8 (5.0)	5.3 (15.9)	32.6 (48.3)	35.5(37.8)	6.9 (6.9)	2.4 (2.4)	0.4 (0.4)

Contingency

A contingency fund will be needed for the project to address unforeseen and unavoidable cost increases. The level of this will need to be assessed in parallel with the development of more accurate estimates emerging from the Design Study, based on a detailed analysis of the likely cost variations for component parts of the project. For present purposes, 10% might be an appropriate level, this is well within the 20% variation associated with the present estimates and it is therefore not explicitly included in the estimates.

Decommissioning

With the possible exception of the beam dump, the levels of induced radioactivity in components of 4GLS will be generally very low. The disposal of radioactive components from 4GLS can therefore be expected to be a minor cost. The large main building, which will have excellent infrastructure and stability, could be used for new applications after the predicted life of 4GLS (~20 years from start of operations). The principal cost of decommissioning is likely to reduce to the clearing of equipment (offset by scrap value or sale/reuse elsewhere), for which less than £0.5M at 2002/03 prices would be required. This is insignificant in terms of these estimates.

4.4.2.2 Running Costs

Without any assumptions about funding, the operating costs for the complete facility are £8M *p.a.* at 2002/3 prices (see Table 4). With the NWDA contributions the operating costs for the complete facility would increase to allow for rental (offset by maintenance savings) on the building and are estimated at approximately £9.1M *p.a.* at 2002/03 price levels. This is made up of staff costs of £4.6M (for 102 staff-years) and non-staff costs of £4.5M (including VAT). This would provide for 5000-6000 hours of operation per year (24hrs, 7 days per week during operating periods), with five fully staffed and supported experimental stations.

The costs of renting the main building from the NWDA are included from 2007/08 onwards. These are sensitive to the rental figure that may be agreed and for the purposes of these estimates a value (approx. £1.4M *p.a.*) has been assumed. This would make the overall lifetime costs neutral with respect to purchase, without consideration for the costs of capital, residual value and ownership of the building at the end of the project life.

Alternative modes of operation and support are possible, which could result in lower direct operating costs. For example, it might be decided not to provide 24-hour operator cover, and/or to operate for a smaller number of hours. User groups and consortia might provide some of the 'front-line' support for experimental stations, thus minimising facility-provided staff support. Such options would be considered by the 4GLS Board with input from the User Representation Group in the period leading up to first operations.

The estimate above applies to the operation of the full facility with 3 FELs and 5 stations and both (high brightness and high average current) photocathodes. On the current milestone plan, this would be in 2010/11. First operation would be in 2008/09 with 2 stations on undulators and one on the IR FEL. A cost profile (£M, inc. VAT) based on this plan is shown in Table 4.

Table 4 Cost profile (in £M) including VAT. Figures in brackets indicate the situation *without* the NWDA offer.

	2007/08	2008/09	2009/10	2010/11
non-Staff	1.4 (0)	4.2 (3.1)	4.3 (3.1)	4.5 (3.4)
Staff		3.1	4.5	4.6
Total	1.4 (0)	7.3 (6.2)	8.8 (7.6)	9.1 (8.0)

4.4.2.3 Cost savings

A scientific facility such as 4GLS requires an extensive support infrastructure including office accommodation, user support laboratories, engineering workshops and so on. These would be expensive to provide on a 'green field' site. By using the existing infrastructure at Daresbury Laboratory, many of these initial costs can be saved and operating costs can be shared with the other activities of the site. Specific areas of anticipated savings are described below.

Cost savings from shared support staff

A number of opportunities arise for sharing staff with other facilities at Daresbury Laboratory:

- facility operations teams;
- science teams for accelerator physics and facility exploitation;
- engineering support;
- IT and computing services;
- technical services (vacuum, mechanical, health and safety, electrical and electronic, instrumentation development);
- facility administration & management services.

Cost savings from existing buildings and infrastructural facilities

The only new building required will be that for the 4GLS facility (including its beamlines and stations and any support laboratories that are both essential for its full exploitation and require close proximity). New buildings for offices will not be required since Daresbury Laboratory already has the capacity for the existing staff of approximately 550, of which about half support the SRS. The SRS will have closed or be operated by a very reduced staff by the time 4GLS enters full operation. Any temporary peak in site staffing for an overlap period could be met by the use of temporary buildings.

Daresbury has a number of support laboratories for sample preparation and off-line characterisation that can be shared as required (together with their equipment and staff) by 4GLS. These include laboratories for the support of material science, surface science, structural biology and biological spectroscopy.

Daresbury is also well equipped with laboratories and workshops for vacuum component processing, mechanical, electrical and electronic engineering, and detector and optics development. They can form a firm base for the development and exploitation of 4GLS and need not be constructed, equipped and staffed *ab initio*.

4.4.3 4GLS Design Study

4GLS comprises an advanced facility with a number of novel features. It also exploits recent technological advances to an extent that necessitates R&D programmes to be undertaken to ensure delivery of fully optimised performance. This R&D activity will be independent of the Design Study but will have strong links with it.

The outcome of the Design Study will be a refined set of 4GLS technical parameters, resolution of technical uncertainties and more accurate and reliable cost estimates. These are essential prerequisits for the next stage of the project.

4.4.3.1 Work Programme

A Design Study of this type incorporates a very wide range of scientific and technical skills. In estimating the required resources it has been possible to utilise data from the ongoing Diamond design studies that are of a very similar scale.

Following in-depth assessment of the fundamental, science-driven, 4GLS output specifications and characteristics provided by the 4GLS User Representation Group. ASTeC will provide the accelerator physics expertise that will establish the basic technical parameters for all elements of the facility. Specialist input from other CCLRC departments will be sought as appropriate.

As the 4GLS User Representation Group will encompass the interests of the whole range of potential users of 4GLS there will be close liaison with this group throughout the Design Phase in order to ensure the best science driven final specification. The final Design Study Report will be an important element in successful passage of the project through the Gateway process.

The design project can be subdivided into a number of major components: the high brightness guns; the superconducting linac and its associated cryogenics systems; the complex beam transport lines, including the pulse compressors; the insertion devices and their beam lines and the free electron lasers (FELs). Each component must have basic feasibility confirmed, performance optimised and equipment procurement specifications established, together with reliable cost estimates. These will be undertaken in a well-controlled active project management environment.

In addition to the core accelerator physics there will be contributions in all of the basic technical areas of such a facility; electromagnets, power supplies, radio-frequency systems, diagnostics, cryogenics, vacuum systems, radiation protection and shielding, controls, insertion devices and beam line optics. There will also need to be appropriate levels of support for detailed engineering solutions to be established. Finally the building and associated services infrastructure must be defined.

The Design Study will occupy a period of around thirty months, commencing in FY 03/04. The building specification elements will be completed in time for construction to begin by the end of 2004. This will ensure that the building is completed in time for the installation of the first components of the machine.

Further development of key collaborations, hosting significant numbers of workshops and undertaking overseas visits are essential associated activities that will help support the Design Study.

4.4.3.2 Resources required for the 4GLS Design Study

Table 5 shows a break down of the staff effort required for the 4GLS Design Study. The recurrent and total annual spend are given in Tables 6 and 7. Staff costs include full overheads and (compared to the CSR2002 bid) the staff years in 2004/05 are shown as 16 instead of 14 following an analysis of the tasks that will need attention at this stage.

Table 5 Staff resources in staff-years.

Design Study	**2003/4**	**2004/5**	**2005/6**	**Total**
Layout optimisation	0.5	1.0	2.0	
Electron guns	0.5	1.0	2.0	
50 MeV linac and transport lines	0.0	1.0	2.0	
600 MeV system				
lattice	1.0	2.0	2.0	
S/C RF	0.5	1.0	2.0	
Injection/extraction	0.0	0.5	0.5	
Switch magnets	0.0	0.5	0.5	
Timing system	0.5	0.5	0.5	
IR-FEL	0.5	1.0	1.0	
VUV-FEL	0.5	1.0	1.0	
XUV-FEL	0.5	1.0	2.0	
Undulators	0.5	1.0	2.0	
Beamlines	1.0	2.0	3.0	
Shielding and beam dump	0.0	0.5	0.5	
Cryogenic system	0.5	1.0	2.0	
Building	0.5	1.0	2.0	
Design Study Total sy	**7**	**16**	**25**	**48**

Table 6 Recurrent spend in £k.

	2003/4	**2004/5**	**2005/6**	
Staff Costs	530	1220	1900	3650
Consumables	200	400	400	1000
Meetings etc	100	100	100	300
Annual Totals	830	1720	2400	
			Total	**4950**

Table 7 Total annual spend in £M.

	2003/4	2004/5	2005/6	Total
Annual Spend	0.8	1.7	2.4	**4.9**

4.5 Funding

4.5.1 Funding from OST

As a UK-based world leading scientific facility, the main source of funding for the design, building and commissioning of 4GLS is expected to be OST, and bids have been made in CSR 2002 and will be made in CSRs 2004 and 2006. Every effort is being made to seek additional contributions to the cost of the project. These are described below.

4.5.2 Funding from NWDA

4GLS has the full support of the NWDA in providing a focus for internationally outstanding science in the region. The NWDA has agreed in principle to provide financial support for the project, and discussions are currently underway around the NWDA support in two specific areas:

- a contribution of 5% of the capital costs of the project (up to £4.5 M); and
- the provision of the 4GLS building, which is likely to be *via* an arrangement whereby the NWDA would construct the building and lease it back to CCLRC. (The capital cost of the building is estimated at £22.2M, excluding VAT and at 2002/3 prices).

A detailed statement of this commitment by NWDA is included in Appendix 7.

4.5.3 Funding from the Research Councils

Following QQR2, it is clear that responsibility for the running costs of 4GLS following construction and commissioning will reside with CCLRC. A statement of CCLRC support for the project is attached at Appendix 7. The implications of QQR2 are not yet fully worked through and will evolve further during the construction of 4GLS. However, if current arrangements remain in place, potential users of the facility from HEIs will apply to CCLRC for beamtime, but other resources associated with their research projects (staff, equipment and consumables for work at the home HEI) will be requested through responsive mode grants from the relevant Research Council. Those most closely involved are likely to be EPSRC, PPARC, BBSRC and NERC.

4.5.4 Funding from the EU

It is anticipated that the 4GLS project will be eligible for EU funding under Framework Programme 6 (FP6). The exact mechanisms under which infrastructure will be funded within this Framework have not yet been finalised but indications of the type and level of support for which the project may be eligible are contained in the working document, Support for

Research Infrastructures in the FP6 Specific Programme on "Structuring the European Research Area", May 2002[11]. Three types of funding can be sought by the project:

Design Study - Design study funding from the EU will be available under FP6 for feasibility and technical preparation work. To be eligible, the project must have a clear EU interest. In the case of 4GLS this is provided by its world leading cabilities that will provide a unique facility within Europe. The indicative funding levels for design studies are that up to 50% of the funding may be provided by the EU with typical amounts being 1-10 million Euros. Further information will become available during the next few months, but the EU has already indicated (at a meeting of an ESFRI working group in Rome, September 2002) that 4GLS is particularly well-placed to exploit this funding.

Construction - Under FP6 funding at the 10% level will also be available for infrastructure construction. Indicative funding levels are in the 5-15 million Euro range. The decision to support a facility in this manner will be taken by the EU following announcement of the decision to build a facility by the relevant National Government. The 10% funding will be additional to the 100% funding received by the project from its own National Government. In effect, the project will be allocated 110% funding but the additional 10% EU contribution is specifically for added value activities that provide a European dimension to the project. The aim of the 4GLS project will be to utilise this funding to provide e-science capabilities within the facility, thus enabling remote access from European users *via* the grid. The project is ideally positioned to exploit this technology as CCLRC's e-Science centre is actively involved in the development of grid applications. This vision also provides the European dimension to the project required in order to obtain design study support.

Operations Under EU Framework 5[12] the mechanism for funding operations was the transnational access scheme operated as part of 'The Access to Large Scale Facilities Programme' which provided funding for typically 5-10% of a facilities beam time (maximum 20%) provided that the facility met the following criteria:

- provides a world class service essential to carry out top quality research;
- is rare in Europe;
- has operational costs that are relatively high in relation to costs in its particular field; and
- provides adequate scientific, technical and logistic support to external, particularly first time, users.

Clearly, 4GLS would meet these requirements. The transnational access scheme[13] will continue under FP6, but more importance will be given to the potential of a facility to accommodate new users and to the provision of remote services. Again, 4GLS is ideally placed to utilise this funding stream. All users of the facility will be new users and their training and integration into the facility will form an essential part of the commissioning and operation of the facility. In addition, the DARTS service already provides scientific services to industry,

[11] http://europa.eu.int/comm/research/nfp/infrastructures.html

[12] The mechanisms for Transnational Access are available at http://www.cordis.lu/improving/infrastructure/home.htm

[13] The outline of infrastructure access under Framework 6 is detailed in 'A European Research Area for Infrastrcuture' at ftp://ftp.cordis.lu/pub/improving/docs/infrastructures_sec_2001_356.pdf

and its extension into an academic service would be straightforward. The indicative funding levels for access are in the 0.3-0.5 million Euros per annum range.

4.5.5 Funding from other European partners

The 4GLS project team are mindful that the facility must be used for the maximum benefit of users around the EU. It is our intention to explore the possibility that the source could be built with input from other European partners, during the design study phase of the project. The impact of 4GLS on the EU stage has already been considerable and as the design parameters of the source are finalised, we will be well-placed to explore EU participation in the project with our European.

4.6 Risk

4.6.1 Risk Management

The 4GLS Risk Management Plan (Appendix 8) presents the process for implementing proactive risk management as part of the overall management strategy of the 4GLS project. Risk management is a project management tool to assess and mitigate events that might adversely impact the project thereby increasing the likelihood of project success. The risk management plan describes methods for identifying, analysing, prioritising, and tracking risk drivers. It also deals with methods for developing risk-handling plans and planning for adequate resources to handle risk. The basic risk management strategy is intended to identify critical areas and risk events, both technical and non-technical, and to enable necessary action to be taken to handle them before they can become problems, causing serious cost, schedule, or performance impacts. The 4GLS risk management plan is fully consistent with CCLRC's Corporate Risk Management Plan[14].

During all phases of the project to date, detailed risk analysis has been performed in line with the Risk Management Plan. The risk register is continually under review, and all persons associated with the project can enter risks into the risk register at any time. Formal risk workshops were held during the preparation of the business case that reviewed the whole of the risk register including the current status of each risk. These workshops included input from a professional independent risk assessor provided by Gleeds. Following completion of the option appraisal[15] the risk register was updated. Consequently it currently contains only risks associated with 4GLS at Daresbury Laboratory.

For convenience, the 4GLS Risk Register[16] is divided into the following sub-categories; Cultural and Communication, Process, Economic and Schedule, Staff, Political, Legal, Environmental, Competition and Technical risks. It details all currently identified risks associated with the project together with their assessment and where necessary the associated risk reduction strategies. A number of the risks in the 4GLS risk register are also recognised as corporate risks within CCLRC and the strategy for risk reduction in those cases is in line with CCLRC policy.

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[14] Ancillary paper RISK03
[15] Ancillary paper OPT01
[16] Ancillary paper RISK01

4.6.2 Project Risks

All risks associated with the 4GLS project have been assessed as medium or low category risks. Risk reduction strategies have been introduced for medium category risks and their status is continually under review. The implemented risk mitigation strategies should lead to a downgrading of medium category risks to low status as the project progresses.

The first medium risk category is the technical risk associated with the project. This will be reduced by completion of the Design Study. In addition, many of the individual components that comprise the complete 4GLS facility are already either operational or under development as stand-alone elements at other laboratories around the world. Key collaborations and Memoranda of Understanding have been established with relevant centres enabling the project to draw on a vast body of accumulated expertise and best practice as a risk reduction strategy. The unique combination of elements that comprise the 4GLS facility introduces additional technical risks associated with source synchronisation that can only be addressed by completion of the Design Study.

Other medium category risks include inadequate quality control and inadequate financial control. Quality management is detailed in Section 4.9. Inadequate financial control risks will be reduced by the use of a recognised project management control package. CCLRC is currently assessing various possible control packages. Utilisation of such a package will ensure that correct financial monitoring and control are in place throughout the lifetime of the project. Financial control and monitoring will also be a key element within all project review meetings further reducing the level of risk associated with this element of the project.

Inadequate staffing levels, primarily within ASTeC were also assessed as medium risk. Currently CCLRC is actively recruiting staff to work on 4GLS within ASTeC. Adequate staff should therefore be available for the design work associated with the project. The world leading nature of the proposed facility is seen as a key strength of the project that serves to attract and retain staff within the project team. Consequently, schedule risks that may lead to a slippage in completion of the facility and an associated loss of its world leading position are strongly coupled to staff risks.

Inadequate or incorrect specification was originally detailed as a high risk to the project primarily due to its high impact on the reputation of the 4GLS project and of CCLRC. To mitigate this risk, the advisory committees (SAC and TAC) and the user groups must be fully engaged with the project throughout the design phase and mechanisms for ensuring a two way dialogue with these groups are detailed in the Stakeholder Plan (Appendix 5). In addition, the completed detailed Design Study and the resultant final technical specification for the project will be presented to both the user groups and advisory committees. The project will only proceed once both bodies have formally accepted and signed off on the design and specifications. This risk mitigation strategy currently in place has led to a downgrading of these risks to low. Monitoring of this issue will continue to ensure that the low categorisation is maintained.

Health and safety issues were also originally assessed as high risk primarily because of the high impact of a health and safety violation event. This issue has been addressed and recommendations are presented in the 4GLS Safety and Safety Management document (Appendix 9). This document also details the control measures that will be implemented to address environmental risks associated with the project. These risks will be monitored to ensure the continued success of the risk mitigation strategy.

The risk-register and risk management plan detail the current status of the risks associated with the project. However, risk management is an on ongoing process. Risk information will be included in all project reviews (including Gateway reviews), and as new information becomes available, the 4GLS Project Manager and Project Team will conduct additional reviews to ascertain if new risks exist. The status of all category risks is continually under review, and the effectiveness of the proposed risk reduction strategies in reducing the level of risk will be continually monitored. The goal of the 4GLS risk management strategy is to be continuously looking to the future for new areas that may severely impact the project and introducing control and reduction mechanisms as required.

Development programmes in superconducting RF systems, advanced electron guns, FEL optics and seeding issues are needed to reduce and control the 4GLS project technical risks and to ensure that the UK has the capability to make rapid and efficient progress on the project. In addition to in-house activities, both national and international collaborations have been intitated or extended in order to generate robust technical solutions and prevent time wasting due to “re-inventing the wheel”.

Design studies on 4GLS will not be undertaken in isolation but within a dynamic and emerging world community with overlapping interests. Staff exchanges, visits and workshops will all be used to develop 4GLS concepts further. Exposure of the 4GLS project to continual *international* scrutiny will ultimately ensure the robustness of the solutions adopted for the project.

The 4GLS Project Manager will be responsible for ensuring that all the risks are identified, defined and understood. These risks will be managed in accordance with the 4GLS Risk Management Plan.

4.7 Success Criteria

Ultimately, the aim of the 4GLS project is to provide a world class facility that enables world class science to be performed by UK academic groups. Consequently, the major success criterion against which the project will be judged is the quality of its scientific output. This can be assessed by monitoring the number of publications in high impact International Scientific Journals.

However, the project will be primarily funded by public funds and consequently the project must deliver value for money throughout the design, construction, commissioning and operational phases of its existence. Therefore, there are a number of other criteria against which the project must be judged relating to the efficiency of the project management process. These include costs, time, performance, availability and the size of the prospective user base. The full list of identified critical success criteria together with the minimum acceptable standard, the target standard and the metric that will be used to measure the performance of the facility are given in Table 8.

The success of 4GLS in terms of performance and of scientific and technological output will be monitored annually once it becomes operational. The ultimate success of the facility will, of course, only be assessable after its full twenty-year operational lifetime. However, it is anticipated that an initial judgement on the success of 4GLS will be made after three years of operational life. Assessing the quality of the facility on an annual basis as detailed in Table 8, both before and after the three-year review will enable the progress of the project to be monitored and corrective managerial action to be taken if necessary. This will be an on-going

Table 8 Minimum and target success level criteria.

Factor	Minimum Success Level	Target Success Level	Measurement
Cost	The overall cost is within 10% of the budget.	The overall cost of the project is within the planned budget.	Review costs against budget at each Project Management meeting.
Timing	The project is delivered and available for users by TBD. The minimum success level timing will be decided by the 4GLS Board following completion of the design study.	The project is delivered and available for users by TBD. The target timing will be decided by the 4GLS Board following completion of the design study.	Review progress against time line and project plan at each project management meeting.
Technical Specification	Individual elements of the project deliver a performance within 10% of the target technical specification. The current technical specification is detailed in document TECH01.	Each element of the project delivers a performance in line with the technical specification. The current technical specification is detailed in document TECH01.	Measured by evaluation of performance against the technical specifications on completion of the commissioning phase. The performance of the facility will also be benchmarked annually throughout the lifetime of the facility.
Competitiveness of facility	4GLS delivers an output which is world leading in the majority of its provision.	4GLS delivers world leading low energy performance across all of its component sources.	Comparison of technical capability and science output (the later measured by number of publications in high impact International Journals) with other facilities three years after commencement of operations.

Table 8 continued

Research Output	The facility enables the UK academic community to perform world class science.	The facility enables the UK academic community to perform world leading science.	Analysis of scientific output from the facility. Measured by reviewing number of publications in high impact International Journals. Review will be carried out on an annual basis throughout the lifetime of the project.
Availability of facility	The facility provides TBD days of user beam time per annum. The proposed number will be decided by the 4GLS Board following completion of the design study.	The facility provides TBD days of user beam time per annum. This number will be greater than the minimum target level and will be determined by the project board following completion of the design study.	Measurement of operational time and down time for the facility once it becomes operational. Review to be carried out on an annual basis.
Size of User Base	The facility attracts a large enough user base to ensure full utilisation.	The facility attracts a large enough user base to ensure at least 10% oversubscription.	Evaluation of the number of requests for beam time received by the facility measured against facility operational time. This will be monitored on an annual basis.

process throughout the entire twenty-year lifetime of the facility and is essential to ensure maximum benefit to the UK.

4.8 CCLRC Management of Business Change

The detailed design of 4GLS will be undertaken within ASTeC. The creation of ASTeC within CCLRC reflects a recognition of the key contribution that accelerator science and technology plays in underpinning the provision of such large scale research facilities and it represents an important commitment to future developments. ASTeC will also provide suitable, audited project management skills and a structured learning and development environment for its staff.

Within CCLRC other significant changes have occurred to encourage a stronger internal scientific culture. Cross-departmental science centres have been established and in January 2002, a new Director of SR Science was appointed. This director initiated a reorganisation of the Synchrotron Radiation Department along the lines of Science Colleges that are informed by a Scientific Advisory Committee. It is envisaged that the new structure will enhance the scientific culture of the Laboratory, thus promoting more productive collaborations with external research bodies and resulting in clearer alignment with Research Council funding streams and scientific priorities.

CCLRC recently attainmed the Investors in People (IiP) accreditation. As an outcome of this, and in-line with a policy to develop further large-scale facilities management competence, CCLRC has developed a Corporate Standard for Management Excellence and has embarked on a significant staff training programme.

The change programmes ongoing within CCLRC (at both the strategic and operational levels) will result in a 4GLS workforce that is highly skilled in technical, scientific and managerial disciplines. Thus, it will be well positioned to embrace the challenges that the 4GLS project will undoubtedly present.

4.8.1 Impact upon Daresbury Laboratory Activities

The construction of a major world class facility within CCLRC will obviously impact on other key aspects of CCLRC's core business. However, the 4GLS project plan has been developed in order to minimise, and where possible eliminate, all adverse impacts of the project on other core activities without compromising the project's success criteria. For example, the a controlled build up of staff effort for the design, construction and commissioning stages of the project has been adopted to ensure that there is no conflict between 4GLS and Diamond for the resources of ASTeC. In addition, the planned build up to operations in 2008 will occur in parallel with the anticipated run down of the SRS. This will ensure maximum availability of key scientific staff that will be able to transfer between the two facilities.

The 4GLS project can be subdivided into four phases:

1. Overall Facility Design
2. Facility Construction and Station Design
3. Commissioning
4. Operations

The impact of the 4GLS project on CCLRC and more particularly on Daresbury Laboratory activities is dependent upon the phase of the project and the degree to which the Laboratory's activities are influenced by Daresbury Science Park activities. As the Science Park activities are unknown at present these are not included explicitly at this stage.

Overall Facility Design: At this stage the principal impact of the 4GLS project will be in terms of staff resources. Most of the technical and design activities will be in ASTeC with support from the Central Laser Facility (CLF), the Synchrotron Radiation Department (SRD) and the Engineering Department (PED). The Project is well aware of potential resource conflicts (*e.g.* with Diamond, collider commitments *etc.*) and is actively managing these. Detailed project planning will be an essential component of the minimisation of conflicts.

Facility Construction and Station Design: During the construction phase of 4GLS there will potentially be an impact on some or all of the following - the Laboratory generally, the SRS, MEIS, HPCx, RUSTI and SuperSTEM. This may be via:

- vibration during construction;
- restricted site access;
- loss of car parking;
- general disruption to site activities from building works;
- transfer of scientific effort to 4GLS; and
- a focus of technical effort on 4GLS.

Careful planning will be essential to ensure that the construction phase does not adversely impact key deliverables of the Laboratory.

Commissioning: During the commissioning phase of 4GLS there may be an impact on Laboratory operations because:

- technical effort is focussed on 4GLS problem solving; and
- e-science, IT and theoretical support will need to be developed.

However, the commissioning phase of 4GLS is scheduled to occur in parallel with the run down of the SRS and consequently we anticipate that there will be minimal disruption to services at this stage. The required build up of staff effort will occur naturally, as technical and theoretical support staff will transfer between the two facilities.

Operations: During the operating phase of 4GLS there may be an impact on Laboratory operations because:

- the number of users place increasing demand for accommodation, car parking, meals and other local infrastructure including administrative support.

It is anticipated that this phase will have a minimal impact on the function of the Laboratory as the build up of demand for infrastructure resources by users of 4GLS will occur in parallel with the drop in demand associated with the run down and eventual closure of the SRS.

Overall, no net increase in site infrastructure requirements will arise from 4GLS alone since it will be smaller in terms of staff and the number of simultaneous users than the SRS.

The 4GLS project will impact on CCLRC's core business activities. However, careful phasing and planning of the project will ensure that the adverse impacts of the facility will be minimised while the timing of commissioning and operation will mitigate the potential impact of the run down and closure of the SRS.

4.9 Project Control

4.9.1 Quality

The 4GLS project will be managed within the guidelines laid down in the CCLRC Corporate Project Management Handbook (CPMH)[17] to provide a quality management strategy. The CPMH is based on the Body of Knowledge of the Association for Project Management (APM) and BS6079: 1996. It is also compatible with ISO 9001. The proposed management structure is also based on best practice defined by the Office of Government Commerce's 'Successful Delivery Toolkit'[18].

Throughout the project life cycle, there will be regular project progress reviews covering time, resource, cost and risk management to ensure that quality is maintained. The project management methodology and reporting formats can be found elsewhere.[19]

4.9.1.1 Elements of the Quality System

4GLS Quality Management is aimed at achieving user satisfaction by pre-empting the problems which could impact on the success of the project. It has three key principles:

- meeting the 4GLS project's success criteria and requirements;
- comprehensive forward planning enabling maximum use of routine procedures; and
- continuous and proactive risk management.

To achieve quality aims and principles requires that the following enablers are in place:

- Agreement by stakeholders on the project success criteria and acceptance criteria. Note that these may change during the life of the project and will require regular validation.
- A clear understanding with all members of the project team, subcontractors and suppliers as to who is responsible for achieving what and providing maximum delegated authority to enable this.
- A formal methodology for project control: structured planning of the whole project, measuring project progress against the plan, conducting trend analysis and revising the plan as necessary.
- Well defined business processes reducing the potential for costly errors, providing traceability and allowing management by exception.
- Frequent reassessment of the project risks with all parties and either qualitative or quantitative analysis as appropriate. Continual management of the top risks, based upon detailed planning, including secondary risk assessment.

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[17] Available at http://www-internal.clrc.ac.uk/staff/project_management/CPMHv1-0.pdf
[18] Available at http://www.ogc.gov.uk/sdtoolkit/
[19] PM03, PM04

- Continual open dialogue and exchange of information between everyone involved in a "no surprises" environment.
- Early agreement on a clearly defined acceptance methodology together with agreed acceptance criteria for all elements of the project.

The adoption of the above approach will provide the following benefits to the 4GLS project:

- formal systems to agree the project specification, agree changes and report progress will ensure that both the stakeholders and project team will have a complete and consistent understanding of the project at all times;
- regular reviews will minimise technical errors and reduce waste;
- the project management system will make use of the existing experience at Daresbury Laboratory and provide a training tool for new staff;
- consistent internal and external interfaces;
- disciplined budgetary controls to help ensure that responsibilities are clear and regular reviews take place of how resources are allocated; and
- effective and efficient way of managing change and risk.

4.9.1.2 Internal Quality Reviews

The 4GLS Project Manager will be responsible for achieving the success criteria for the 4GLS Project and for ensuring that all the requirements of the specification are met on time and to budget. The 4GLS Project Manager will also have ultimate responsibility for the risk management of the project. In order to maintain the focus of the project team on the key project milestones the project manager will hold monthly progress meetings with all the key team members. These meetings are designed to:

- obtain feedback and monitor progress;
- define interface problems;
- highlight information required for the completion of an activity;
- resolve problems;
- action individuals within the team to achieve milestones;
- update team; and
- progress risks.

In addition, at monthly intervals the 4GLS project manager will prepare a written report to be submitted to CCLRC senior management.

4.9.1.3 Subcontract Quality

The 4GLS Project Manager will also take overall responsibility for all aspects of any necessary subcontractor work, with support from other areas as appropriate. The Project Manager will be the focal point for all instructions between the 4GLS Project and the subcontractor. He/she will ensure that all relevant information flows to the subcontractor in a timely and controlled manner. Where applicable, all information exchanged will be subject to configuration management and change control procedures.

A detailed scope of supply will be established for each subcontractor. The scope of supply will define the specification based on the requirements and will define interface requirements. The level of detail required for subcontractor documentation will be specified to allow adequate visibility and control. All subcontract documents will be reviewed to ensure compliance with the project requirements.

Review meetings with the subcontractor will be held as necessary and Acceptance Test Specifications, against which acceptance tests to be validated, will be produced. The Project Manager will co-ordinate with the subcontractor to establish a subcontract programme. This will enable the subcontractor to plan activities accurately. The subcontractor's progress against this plan will be measured monthly.

Milestones will be determined within the subcontractor's programme, which will link as necessary to the Daresbury Laboratory Project Office programme. This will ensure that the subcontractor's programme is assessed against the 4GLS Project Plan and will highlight any areas of criticality to the Project Manager. Each subcontractor will provide a monthly progress report that will, as a minimum, detail the following:

- planned activities for the reporting period;
- Actual achievements for the reporting period;
- subcontractor's requirements for the next period; and
- summary of current problem and risk areas.

Meetings with the subcontractor will be chaired by the Project Manager to review the progress report and to monitor progress.

4.9.2 Safety and Safety Management

4GLS is a state of the art accelerator development project that will in time move into a user operational phase. Its components will include a very large cryogenic plant and many superconducting devices operating in a confined space, large numbers of high power DC and pulsed electrical power supplies, equipment for the production of intense RF power, very high field magnetic arrays and extended UHV assemblies with their associated equipment. The facility is designed to produce extremely intense beams of electromagnetic radiation from the infra red to X-Ray by accelerating electrons to high energy. Radiation safety will therefore be critically important. In summary, the facility will require comprehensive safety management arrangements from the earliest stages to ensure that the highest standards of safety are achieved at all stages of the project including operations.

CLRC is uniquely well placed to provide the safety management for this project based on extensive experience in the operation of existing accelerator based facilities in a user environment.

<u>Guiding Principles</u>

It is assumed throughout that 4GLS safety management will be in accordance with best modern practice as set out principally in:

Health and Safety at Work etc Act 1974

Management of Health and Safety at Work Regulations (plus ACOP) 1999

Occupational Health & Safety Management Systems – Specification. OHSAS 18001 was published in 1999 and fits closely with the BS EN ISO 14001 standard for Environmental Management Systems

"Successful Health and Safety Management": HSG65 2000: HSE guidance document

Ionising Radiation Regulations (plus ACOP): IRR99

The Construction (Design and Management) Regulations 1994

The model described in OHSAS 18001 and HSG65 contains guidance on six separate safety management elements: Policy, Organising, Planning & Implementation, Measuring Performance and Auditing (Checking and Corrective action) and the Management Review of performance to ensure continual improvement. It is widely and successfully used in industry and satisfies the Management of Health & Safety at Work Regulations (Reg. 5) which essentially require that a systematic management approach is adopted.

Policy

The 4GLS project will follow the Safety, Health & Environmental policy for CCLRC. The Health & Safety policy will be contained within the CCLRC Safety Health and Environmental Management System (SHEMS) which will act as a top level, stand alone document. The SHEMS for CCLRC contains a series of standard operating controls which include a "New Build, Processes and Activities" procedure. This procedure will provide direction for the proposed project. In addition, the design and construction of the facility will be based on a Health & Safety Plan. The SHEMS will follow all of the key elements in publications issued by the British Standards Institution and the Health & Safety Executive.

Further details can be found in "4GLS Safety and Safety Management", Appendix 9.

5. THE STRATEGIC IMPORTANCE OF 4GLS

4GLS is a large scale facility designed to satisfy the needs of the national and international community of research scientists who make use of low energy photons. The technology and novel combination of photon sources has been recognised as internationally leading, a factor that serves to confirm the UK's reputation as a major player in accelerator technology and design. 4GLS will impact on the Daresbury site, on CCLRC, on the region and finally, and most importantly, on national and international science.

The potential scientific impact of the 4GLS project has been covered in detail in the 4GLS Science Case. The technological and broader impacts of the project are described in this Section.

5.1 Impact on Daresbury Laboratory

The first dedicated synchrotron radiation source was designed and constructed at the Daresbury Laboratory and the Laboratory has an international reputation for research using high quality photon beams. The construction and operation of 4GLS at Daresbury will bring international credibility to the project and enhance the reputation of the laboratory.

The siting of 4GLS at Daresbury will be a great boost to the morale of the existing laboratory staff at all levels and will enhance the recruitment and retention of key staff in the future. It will be a significant addition to the high quality facilities and capabilities located on the site which have been enhanced by a number of other recent achievements briefly described below.

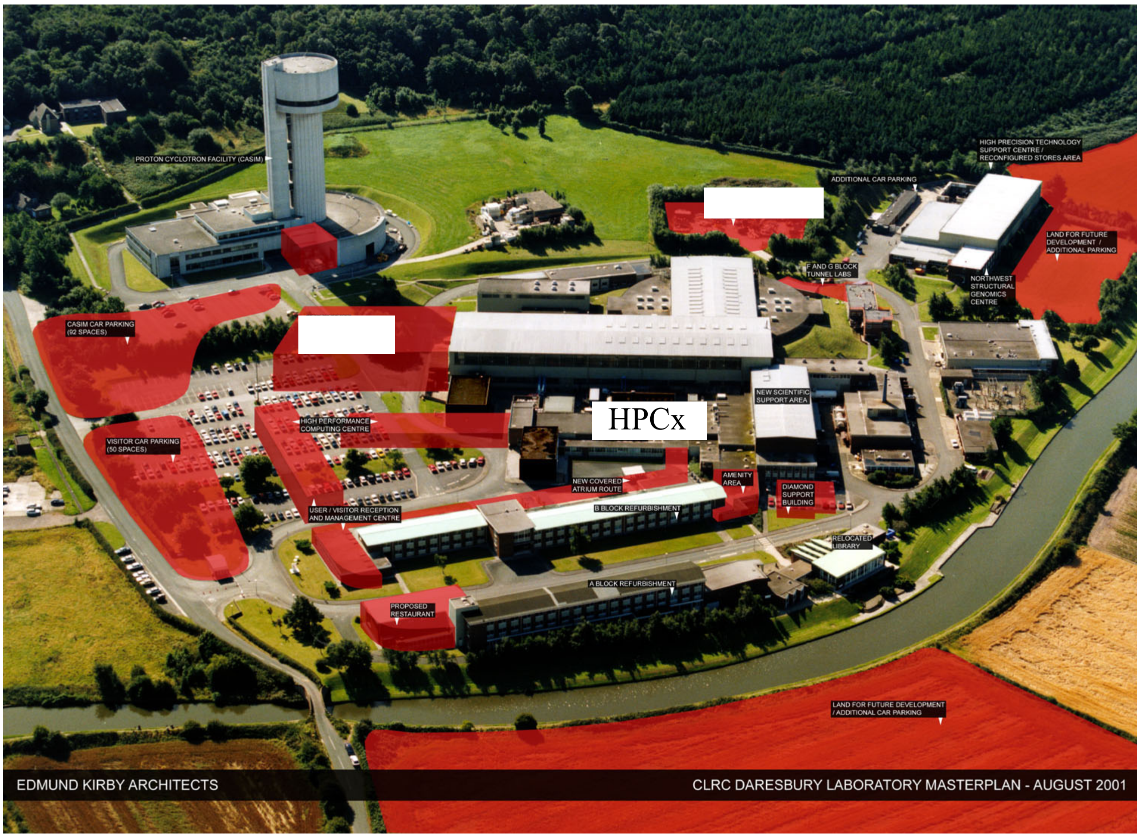

Figure 10 Schematic showing 4GLS in the context of anticpated developments on the Daresbury site.

Daresbury Laboratory, in collaboration with the University of Edinburgh and IBM, has recently won the contract to host the UK's next supercomputer (HPCx). The capability of this instrument located in close proximity to 4GLS offers unique capabilities in experimental data anaysis, modelling and remote access that are unavailable to industry anywhere else. This will enhance the potential of the Daresbury Science Park and stimulate inward investment.

The world leading SuperSTEM electron microscope is now nearing completion on the Daresbury site. This instrument will become the focus of activity for the UK community of electron microscopists and their international collaborators. This will bring state of the art specimen characterisation capabilities to Daresbury that will be a valuable complement to the information on specimen properties that can be obtained using 4GLS. Together, these facilities provide Daresbury Laboratory with world-leading facilities in nanoscience and nanoimaging.

Daresbury Analytical Research and Technology Service (DARTS), the commercial service at the SRS, is demonstrating significant business growth. The skills and marketing expertise of the DARTS team will be a distinct advantage to 4GLS as it will bring an existing customer base to the project. 4GLS also offers DARTS an opportunity to extend its technique portfolio and gain competitive edge. Business development units at overseas facilities (CLS, APS and Australian Light Source) have already registered interest in accessing 4GLS for commercial exploitation *via* DARTS.

The model of a mixed-economy campus where university researchers and industry work in close proximity to a facility such as 4GLS has already proved very successful at the Jefferson Laboratory in the USA. It is envisaged that the Daresbury Laboratory site will become a vibrant mixture of world leading academic and applied research accompanied by significant industrial growth around the nucleus of the 4GLS facility.

5.2 Impact on CCLRC

4GLS is entirely complementary with the existing facilities managed by CCLRC and with its custodianship of the UK's involvement in international facilities. The development of 4GLS will expand CCLRC's facility portfolio to provide what is likely to be the most comprehensive and competitive suite of national facilities worldwide. CCLRC recognises the importance of 4GLS for the UK and is fully supportive of its development at Daresbury.

The alignment and integration of CCLRC strategies from the organisational level through to the international level is compelling and summarised diagramatically in Fig. 11.

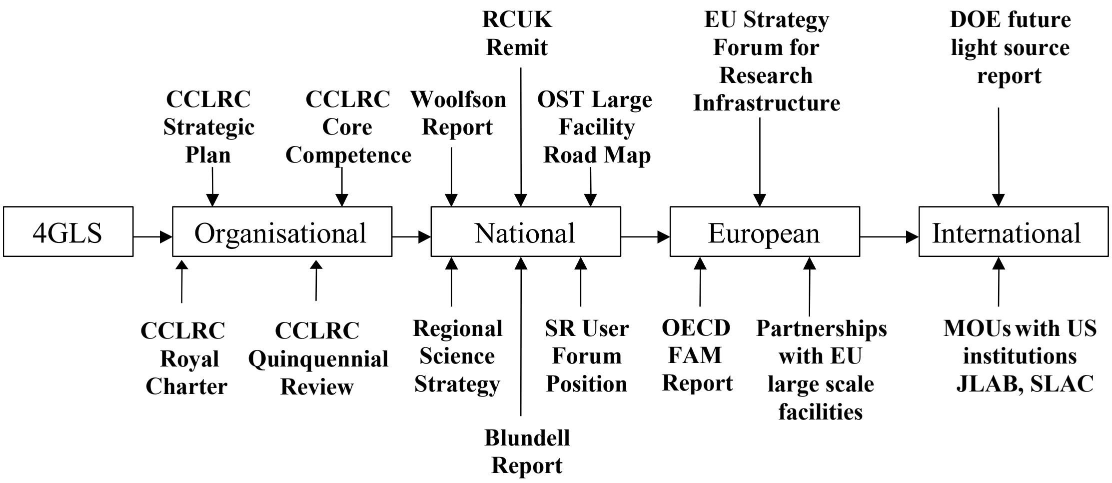

Figure 11 Alignment and integration of 4GLS at the CCLRC organisational level through to the international level.

The CCLRC is currently developing its strategic plan and it is already clear that accelerator science and technology, both design and operation, will be core to the corporate mission, objectives and strategic implementation plan of the Council. Delivery of the 4GLS project will rely heavily on the exploitation of core competences in CCLRC departments and centres such as SRD, CLF and the Accelerator Science and Technology Centre (ASTeC). Alongside major accelerator design and development projects such as Diamond, TESLA, LHC and the partnership with Strathclyde University to develop FEL technologies (joint Basic Technology Fund award), the 4GLS project will serve to enhance and strengthen this distinctive capability within the organisation.

The recently established wholly-owned subsidiary of CCLRC (CLIK) will be mature and experienced at managing CCLRC intellectual property portfolio by the time 4GLS comes on-line. CCLRC will have a professional well managed approach to commercialisation of its IP base and the 4GLS project will benefit from this. The equity realised from the start-up companies or licensing agreements will be reinvested in CCLRC core facilities such as 4GLS for the benefit of the academic community.

5.3 Impact on the Region

The NW Science Council (NWSC) has recently published a NW Science Strategy[20] in which the scientific excellence of the 4GLS project is recognised as an important factor in the delivery of its aims. The siting of 4GLS at CCLRC Daresbury site is fully supported by the NW Universities Association (NWUA), the members of which have played a major role in the genesis of the project, and by the NW Development Agency (NWDA). In recognition of the importance of 4GLS to the economic development of the region the NWDA has commited substantial resources to the project and also entered into partnership with CCLRC to develop an incubator and Science Park alongside the Laboratory. All these regional bodies are represented on the provisonal 4GLS Steering Group and are supporting the project enthusiastically.

The exploitation of the scientific advances achieved with 4GLS will be facilitated by its location close to a number of research led Universities and manufacturing concerns with world players in the aerospace, chemicals, healthcare, nuclear, materials and pharmaceutical industrial sectors. This will have direct benefits on the performance of these elements of the regional economy.

Indirect benefits to the regional economy will arise from the significant addition that 4GLS will make to the critical mass of scientific initiatives and capabilities on the Daresbury site detailed above. This is expected to lead to an increase in small and medium sized enterprises attracted to the area and specialising in the high technology capabilities necessary to the realisation of 4GLS. Such enterprises will both feed into and facilitate sustained scientific and technological activity.

The economy of the region will also benefit indirectly from the increase in skill levels generated by the training activities necessary to sustain 4GLS. This should be a particularly effective contribution to the development of a region where economic activity is not limited by a general shortage of labour.

5.4 Impact on National Science & Technology

4GLS will have a major impact on scientific research in the UK firstly by satisfying the acknowledged need for a dedicated source of low energy photons and secondly by providing world leading capabilities for experiments which combine a range of high performance photon sources.

[20] NWSC Science Strategy, June 2002 (www.northwestscience.co.uk/strategy.asp)

Currently 4GLS features, as a component of CASIM, in the OST Large Facilities Strategic Road Map[21] and will be considered in the context of strategic plans from all Research Councils by the recently formed Research Council UK (RCUK).

The optimum way of meeting the long term need of UK scientists for photon sources has been discussed for more than a decade and several independent reports have been commissioned to evaluate this need[22,23,24,25]. In the context of this business case, the most notable of these studies are the Woolfson Report and its predecessor the Blundell Report. Both reports reviewed synchrotron radiation science in the UK and recommended a 3-source scenario to satisfy anticipated future needs. Of the three sources that were proposed the UK's stake in the European Synchrotron Radiation Facility in Grenoble satisfies the need for a high energy source and the decision to build the Diamond synchrotron will satisfy the need for a medium energy source.

Recently the feasibility of satisfying the needs of the UK low energy community by developing beamlines on the Diamond synchrotron have been considered in various Diamond reports and in a report[26] commissioned by the SR User Forum. These reports show that the UK low energy community will be compromised if it is limited to the use of Diamond and confirm the conclusions of the Blundell and Wolfson reports that a dedicated optimised facility is required for the low energy community. The 4GLS proposal satisfies the UK's need for a dedicated low energy source. More importantly the proposal goes considerably beyond the capabilities that were envisaged to be technologically possible when the earlier reports were commissioned and as a result it has the potential to give the UK a world leading capability in this field.

4GLS is a flagship project that will generate high publicity and widespread interest. It will present exciting challenges to the accelerator profession and is likely both to enhance the status of this profession nationally and to attract new recruits to it, especially from HEIs. Such stimulation is essential if the UK is to play a long term role not only in 4GLS but in many other major scientific challenges.

As a national facility, 4GLS offers considerable opportunity for commercial exploitation by UK based companies - a view that was endorsed by the many letters of support for the science case. Important technological growth areas were identified, examples of which include: bioassay characterisation via high throughput screening, development and characterisation of nanodevices and nanomaterials, development of high performance materials and semiconductor technology development. Use of 4GLS for experimental research and characterisation is only one aspect of commercial benefit. The novel technologies underpinning the facility and detector developments required to record data from it, will require state-of-the-art instrumentation development that will undoubtedly have wider exploitation avenues beyond the large scale facility market.

[21] Large Facilities Strategic Road Map, June 2001
[22] Scientific Requirements for Synchrotron Radiation in the UK, Blundell Report, June 1986.
[23] Review of Synchrotron Radiation Science, Woolfson Report, April 1993
[24] EPSRC, Research in Atomic and Molecular Physics, April 1995, ISBN 1 899371257
[25] CCLRC commissioned Review of XUV Spectroscopy, February 2001
[26] Report of 4GLS and Diamond Working Party, 2001.

5.5 Impact on International Science & Technology

The 4GLS proposal has been recognised by scientists from the leading international laboratories concerned with the provision of photon sources as having the potential to lead developments in this field. This potential stems from the plan to combine ERL and FEL technologies in a multiuser facility with the capability to perform experiments which require a wide range of multiple and synchronised photon sources. The realisation of this potential is underpinned by the acknowledged strengths of Daresbury scientists.

Within Europe a number of stand-alone general user FEL facilities already exist such as FELIX (Utrecht) and CLIO (LURE) though none have the cutting-edge capability that 4GLS will deliver. 4GLS is complementary to planned European sources, such as the TESLA XFEL facility and CCLRC has formally joined the TESLA project and signed a Memorandum of Understanding with DESY Laboratory to conduct accelerator physics based studies into collider and FEL related developments. The Daresbury accelerator team and Daresbury scientists have been central to the development of the EUFELE cavity FEL project at ELETTRA (Trieste). Members of the 4GLS team are playing key roles in the coordination of FEL scientific and technical activity across Europe which is being facilitated by the European Strategy Forum for Research Infrastructure (ESFRI). ESFRI will organise a workshop in the Spring of 2003 and money for FEL development projects is likely to be made available *via* FP6. The 4GLS project will ensure that the UK will have a central role in the sharing of scientific and technological expertise across Europe. The 4GLS Project Board will be well placed to explore further internationalisation of the project and facilitate the participation of European partners in 4GLS as the design study progresses.

The strength and timeliness of the 4GLS proposal has been recognised by a number of leading US establishments (Jefferson Laboratory (JLAB), SLAC, Brookhaven, Duke, Cornell and Vanderbilt). Memoranda of Understanding have been signed between CCLRC and JLAB, DESY and SLAC to develop common accelerator technologies required for the development of 4th generation light sources; other such agreements are also being examined.

Much of the thrust of modern international accelerator studies is towards two principal topics: high brightness and high intensity particle beams. In the case of 4GLS there is a unique opportunity to exploit both themes simultaneously since the project relies on extrapolation of world state-of-art system delivery in both areas. The Energy Recovery Linac (ERL) generates both enormously high electron beam intensity and brightness, and the Free Electron Lasers (FELs) convert this to similar challenging performance levels for the radiation output.

The ERL itself is an exciting accelerator development that has outstanding future potential. It might eventually be the way forward to the next generation of X-ray light sources beyond the generation represented by the ESRF and Diamond. 4GLS will be an important demonstrator of this new technology and expertise in this area is certain to have a major international impact.

The XUV-FEL at the heart of 4GLS is similar to several others planned world-wide. One close example is the TTF FEL at DESY, Hamburg, a precursor for a much more ambitious x-ray successor associated with the higher energy TESLA collider project. Such X-ray SASE FELs require major accelerator development and 4GLS work in this science/technology area would place the UK on the forefront of world activities preparing the way for the *much more* challenging higher energy devices at the appropriate time.

Beyond 4GLS the UK will be faced with determining its role in future major particle physics projects. The proposed electron linear collider is a probable candidate and it is important to recognise the synergy of this with the 4GLS development programme. The collider also needs exceptional beam brightness and exploits similar science (*e.g.* beam dynamics) and technologies (*e.g.* photo-cathode guns) to those on 4GLS. The Daresbury team has already initiated collider associated studies but it would be of great benefit if this could be further assisted by the expertise and experience that would result from a stimulating 4GLS R&D programme. The UK would ultimately benefit by having in place the skill base necessary to make a major direct contribution to any collider project, wherever it might be located.

4GLS incorporates a number of frontier challenges as described above. Embarking on this route and succeeding in delivery of the project will guarantee the UK a world-leading role in accelerator science and technology into the next decade and beyond. This ensures that the UK will be in a position to exploit accelerator based national facilities during this period and be a welcome partner in any major international collaboration.

6. READINESS FOR THE NEXT PHASE

The current OGC guidelines require that at every stage of the Gateway Review Process, a project should address the key criteria for readiness for the next phase of the overall process. Gateway 1 deals with the high level business justification of the project and should also identify key areas necessary to enable the project to progress to Gateway 2 Review which deals with Procurement Strategy.

6.1 Procurement Strategy

Currently, it is impossible to develop a full procurement strategy for the 4GLS project. Completion of the Design Study (Section 4.4.3) is necessary to define fully the key components that will need to be addressed by the procurement phase. Consequently, at this stage we can only present a basic outline of the procurement strategy that the project plans to utilise.

The project has considered a ‘design and build’ option, but the highly specialised nature of the project limits the feasibility of this approach. Indeed, it is clear from the business case that CCLRC staff associated with ASTeC are the best available design team for the facility. Therefore, the project will proceed with a procurement strategy that involves maximum outsourcing to external industrial resources, using internal CCLRC staff as experts for the design phase and as ‘intelligent customers’ of external companies.

Manufacture of all equipment will be performed by industry using existing CCLRC rules and procedures. Large contracts will be placed by competitive tender, conforming to EC requirements. Competitive tender will be used for all major installation contracts, either as part of a manufacture and install process or as part of a separate installation exercise. The SRO of the project will set approval limits for all tender exercises and contracts. Major contracts will be considered by the Project Board who will advise the SRO on their suitability and value for money. The Project Manager and project staff will be set delegated expenditure limits by the SRO.

In essence, the procurement strategy currently envisaged is that CCLRC will be the prime contractor for the technical components of the project and the design, with private industry managing major sub-contracts for the building and manufacture and installation of components.

6.2 Processes Leading to the Development of the Full Procurement Strategy

The next stage in the 4GLS project is the detailed design study. A key output from this phase of the project will be an exact specification of the building required to house the facility. The key parameters that will enable the design of the building are:

- the lattice design of the facility;
- the amount of shielding required by the facility; and
- the amount of energy that the facility will dissipate.

These factors will accurately define the overall size of the facility as well as the building's requirements for air conditioning *etc*.

At this point it is anticipated that a tender exercise for the design of the building by external Architects will be initiated. Following acceptance of the architectural design the Project will apply for full planning permission (current indications are that the outline planning permission granted for Diamond on the Daresbury Laboratory site will cover 4GLS on the site) and define the exact procurement requirements for the building phase. This will be the first major procurement exercise within the project. The unique partnership between CCLRC and the NWDA with regard to the provision of the building for the facility is a key strength of the current business case. The procurement strategy for the building will be finalised as part of the on going negotiations between the Project and the NWDA.

In addition, the design study will define the technical specification of the facility. Following acceptance of the technical specification by the User Representation Group and the Project Board, this study will form the basis of a second major procurement phase by defining the equipment requirements of the project. At this stage, the principal components needed by the project will be fully defined and a detailed procurement strategy will have been established.

6.3 Critical Success Factors for the Next Stage

The critical factor leading to the success of the procurement exercise is completion of the detailed Design Study. This stage will be completed by formal sign-off of the 4GLS Design and resultant technical specifications by the 4GLS Board and the User Representation Group.

The skills within ASTeC, together with the development of close collaborations and MoUs with key international laboratories, are essential in order for this stage to be successful. The principal assumption at this stage is that ASTeC can provide sufficient effort to perform the design study without negatively impacting other key work on facilities such as Diamond. Given its critical importance to the project this has been registered at risk within the 4GLS risk register (risk 4.1). However, as discussed in Section 4.4.1, the recruitment strategies currently being employed by CCLRC in this area are successful, and hence the risk is currently rated as only a medium risk to the project.

Funding for the Design Study has been included in CSR2002 and one of the key aims of this business case is the release of those funds. Detailed development of the 4GLS procurement strategy will be a key element within the portfolio of Design Study work. Throughout the 4GLS project phased release of funds is essential for the project's success. This has therefore been entered as at risk on the 4GLS risk register (risk 3.1) and assessed as a medium risk to the project.

7. RECOMMENDATIONS

The recommendations of this document are

- 4GLS should be constructed since it is the best way of meeting the science need identified in the Science Case. Following feedback from review of the Science Case, options that involve the construction of a FEL suite, rather than the full 4GLS facility, have been examined and have been found not to be cost-effective.
- The 4GLS facility should be located at the Daresbury Laboratory.
- The facility should be managed by CCLRC, consistent with current UK science policy for large scale facilities.
- The Design Study should be fully funded with immediate effect.

The recommendations should be rapidly implemented in order to maintain the internationally leading profile of the 4GLS project and its cost effective delivery.

8. APPENDICES

Appendix 1: Preliminary Thoughts on Possible Operating Modes in 4GLS

Appendix 2: 4GLS International Context

Appendix 3: Roles and Responsibilities Within the 4GLS Project

Appendix 4: 4GLS Presentations and Meetings

Appendix 5: 4GLS Stakeholder Plan

Appendix 6: 4GLS Milestones List

Appendix 7: Letters

Appendix 8: 4GLS Project Risk Management Plan

Appendix 9: 4GLS Safety and Safety Management