E-SCIENCE LEADERSHIP COUNCIL

ENGINEERING AND MANUFACTURING WORKING GROUP

DEVELOPING E-INFRASTRUCTURE IN THE UK'S ENGINEERING AND MANUFACTURING INDUSTRIES

Report commissioned by the Department for Business, Innovation and Skills

June 2012

Engineering and Manufacturing Working Group

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EXECUTIVE SUMMARY

Key Recommendations

Action in the Short Term (the next 12 months)

Building Awareness: Government funded e-Infrastructure Awareness Teams and Awareness Centres are required now to remove the largest barrier to increased utilisation of the e-infrastructure and the benefits that go with its use.

Support for Specific Case Studies to use as Exemplars: Co-funded studies are required to provide UK and international exemplars in order to encourage and incentivise UK OEMs and particularly SMEs to adopt use of e-infrastructure.

Provision of Software and Application Expertise: Government funded e-Infrastructure Expertise Teams are required to allow businesses in the UK engineering and manufacturing sector access to critical software and applications while the results of training and education pull through in the medium and long terms.

Security: Government investment is required in the protection of UK national core Intellectual Property (IP).

Wider / Deeper Study: Government funding is required to allow a wider, deeper study to be conducted, using international examples in order to inform a systemic approach to strengthening the UK's e-infrastructure and widening use within the engineering and manufacturing sector.

Action in the Medium Term (the next 3 years)

Training: A Government sponsored Training Needs Analysis needs to be conducted and followed up by the establishment of co-funded Training Teams.

Software Usability: A Government approach to Independent Software Vendors (ISV) is required to encourage a collaborative approach to software development alongside UK engineering and manufacturing users.

Software Licensing: A Department for Business, Innovation and Skills (BIS) white paper should be launched to highlight the barrier to economic growth caused by current licensing model and to provide more flexible and affordable models that can be accepted and implemented by UK and European ISVs.

IP Management: A Government sponsored study (working with the Strategic Advisory Board for Intellectual Property (SABIP)) is required into suitable future IP Management Models that can then be implemented across UK industry and academia.

Connectivity: A co-funded study is required in order to determine where targeted co-investment in connectivity will produce the highest return on investment.

Action in the Long Term (the next 10 years)

Education: The Government must work with academic institutions in order to provide incentives to attract under graduate and post graduate UK students that will go on to embed e-infrastructure expertise in the UK engineering and manufacturing sector.

Continued Investment: An on-going Government co-led and co-funded study is required to ensure that co-funded investment continues to be effectively targeted within the UK e-infrastructure over a period of 5 to 10 years including strategic investment and on-going operations maintenance.

Aim

This report has been commissioned by BIS with the aim of assessing the progress that has been made by the UK engineering and manufacturing industries in the adoption, utilisation and exploitation of UK e-infrastructure. The report has highlighted a number of significant barriers to that progress and made recommendations to enable the removal or neutralisation of those barriers.

Compiling the Report

This report has been compiled by the ELC Engineering and Manufacturing Working Group. In order to ensure that the report is a true reflection of the current state of e-infrastructure utilisation in the UK engineering and manufacturing sector a survey was commissioned. The survey asked engineering and manufacturing businesses questions concerning:

- Current e-infrastructure capability available within the business.
- Current e-infrastructure capability available external to the business.
- Current utilisation of both internal and external e-infrastructure capability.
- The level of e-infrastructure skills and knowledge within the business.
- Awareness of publicly funded e-infrastructure.
- Current utilisation of publicly funded e-infrastructure capability.
- Potential future utilisation of publicly funded e-infrastructure capability.
- Current barriers to utilisation of publicly funded e-infrastructure.
- Competitors (national and international) benefit from utilisation of publicly funded e-infrastructure.
- Requirements to improve utilisation of publicly funded e-infrastructure in the short, medium and long term.

- Accessibility and utilisation of industry specific and open source software and applications.
- Priorities for government funding of e-infrastructure.
- Where government funding would most benefit the business in the short, medium and long term.
- Awareness of and engagement with the ELC.

The survey was provided on-line to enable it to be completed and returned as simply and quickly as possible. The survey was distributed via email link by BIS to an address list generated by BIS. The addressees covered a wide range of engineering and manufacturing businesses in terms of size, from industry leading OEMs to relatively small scale SMEs. Addressees also covered all possible sub-sectors within the engineering and manufacturing sector including:

- Aerospace, Marine & Defence
- Automotive
- Chemicals
- Construction
- Electronics
- Manufacturing, Materials & Engineering
- Infrastructure
- Oil & Gas
- Utilities

Despite intervention direct from BIS and an expansion of the address list uptake and responses to the survey remained low. The Engineering and Manufacturing Working Group believes this indicates a failure to engage with e-infrastructure by a broad cross section of the industries within the sector. This failure to engage is undoubtedly caused by a failure to recognise the potential business benefits from adoption, utilisation and exploitation of e-infrastructure brought about by a lack of awareness of the subject in general. The likelihood of this lack of awareness was recognised when the survey was compiled; hence e-infrastructure was described as a number of components that would be more identifiable to the survey addressees rather than describing the holistic ecosystem, which it was judged would fail to engage any response to the survey from the majority of addressees.

The failure to engage with the survey and the lack of awareness it displays is an important outcome in itself. Lack of awareness is judged as one of the main barriers to developing the UK's e-infrastructure and several of the Engineering and Manufacturing Working Group's recommendations are aimed at addressing this in the short term.

However, despite the low response the results of the survey are important and represent the views from a number of OEMs, SMEs and academic institutions. These views have given a clear indication of the current e-infrastructure capability, utilisation and barriers to utilisation. These views have been supplemented by a number of interviews conducted with individuals within the engineering and manufacturing sector with a current interest in e-infrastructure and with e-infrastructure providers. Survey and interview responses have been reinforced by reference to a wide range of previous UK and international reports into e-infrastructure development and by reviewing international examples of successful development, particularly in the USA. Comprehensive survey result appear at Appendix A to the main report.

Report Methodology

Purpose of Report

The context for this report is the UK Government's recognition of the urgent need, in the current economic climate, to drive business growth fuelled by scientific research and innovation. High-performance computing capabilities, and the skills necessary to fully exploit those capabilities, are playing an increasingly important role in supporting scientific research and innovation and are thus critical to driving that growth. To allow full exploitation of these capabilities an effective 'e-infrastructure' is essential, comprising of the compute capability, networks, data repositories, software and skills.

The purpose of this report is to assess the current state of e-infrastructure in the engineering and manufacturing sector, and make recommendations for targeted government intervention that will drive further economic growth, making the best possible use of limited funds, with a view to increasing private sector funding for e-infrastructure over the next 10 years as shown in Figure 1.

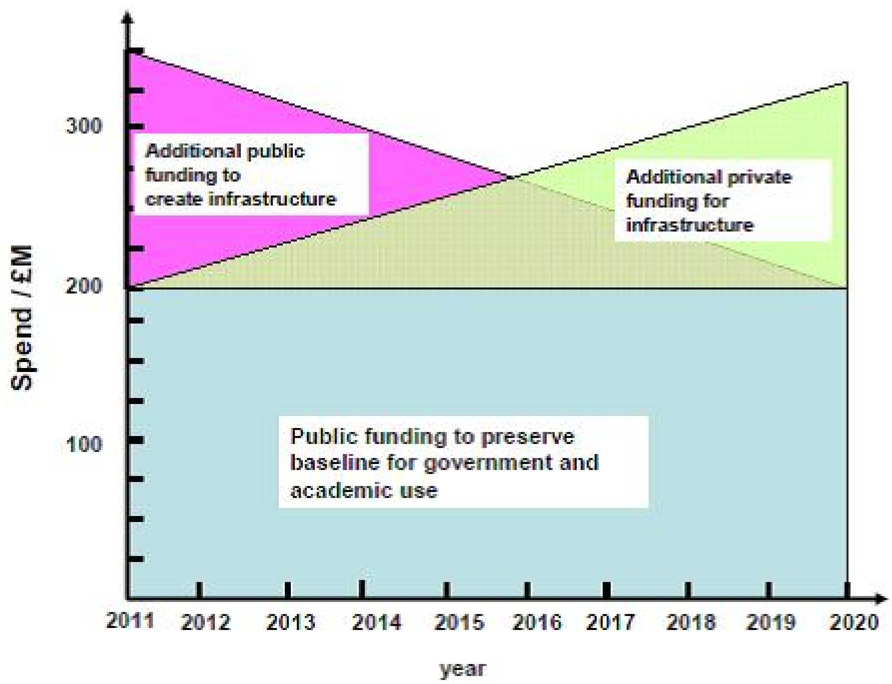

Figure 1 – e-infrastructure funding model to 2020 showing anticipated growth in private involvement and investment (targeted to grow to 30% of the total cost by 2020)

Sources for Report

Three principle sources have been referred to during the compilation of this report:

- The results of an e-survey (hereafter referred to as the survey) commissioned specifically to inform this report and targeted at a broad range of UK businesses,

- A number of targeted interviews and conversations with users, providers and academics operating in the e-infrastructure environment.
- A range of open-source documents relating to UK and European e-infrastructure policy and development. These documents are referenced in the report and listed in Appendix B.

The Scope of E-Infrastructure in the UK Engineering and Manufacturing Sector

What is e-infrastructure?

'e-Infrastructure' is the term used for the distributed computing infrastructure which provides shared access to large data collections, advanced ICT tools for data analysis, large-scale computing resources and high performance visualisation.[1] The UK's e-infrastructure is critical to growing the UK economy.[2]

e-Infrastructure Components

For the purpose of the survey, and this report, e-infrastructure has been broken down into the 6 highly inter-connected components listed below. This is not an ideal approach as it encourages e-infrastructure to be thought about as a series of component capabilities rather than a holistic ecosystem, which is where the true potential benefits lie. However, it was considered that this component approach was required to aid the understanding of the system in current non-e-infrastructure users in the sector. For the purpose of this report the 6 components are:

- High performance computing
- Data-intensive computing and storage
- Software and applications
- Training and skills provision
- Networks
- Security and authentication

e-Infrastructure Processes

These e-infrastructure components are used in combination to support two main processes within the engineering and manufacturing sector:

- Scientific research and innovation
- Operational support

These are explained below.

[1] Joint Information Systems Committee (JISC) Circular 01/07, Appendix E.

[2] -, *Delivering the UK's e-Infrastructure for Research and Innovation*. Research Councils UK on behalf of the Department for Business, Skills and Industry, July 2010.

Scientific research and innovation
The overall process of research and innovation that involves the creation of new knowledge and the development and exploitation of that knowledge into commercial products and services, shown in Figure 2.

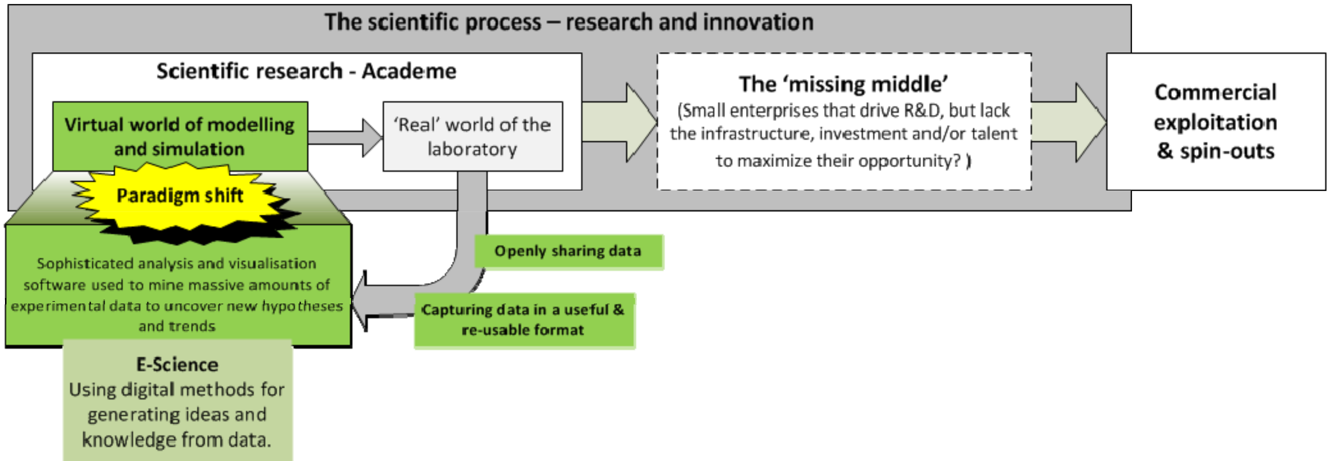

Figure 2 – The research and innovation process

The process involves the progression through three different technology readiness-levels; 'concept', 'lab', and 'production'. Technological readiness at the 'concept' level refers to first ideas of applying a technology in a certain context as well as the start of basic research. Technological readiness at the 'lab' level means that the technology has been applied successfully to an entire system (or its components) in a laboratory environment without external/unknown factors. The final technological readiness level, 'production', indicates that the technology has been thoroughly tested under real world conditions and is ready to be applied in a real production environment.[3]

Within this overall process, a disconnect is sometimes observed between the academic research being undertaken within universities, and the product innovation (research and development) being undertaken within commercial organisations. This is shown as the 'missing middle' in Figure 2.

Even where large OEMs have their own significant HPC capability, they may utilise external HPC providers for research and development purposes, either because their production capacity is fully utilised, or because they need a more flexible or unique architecture within which to perform a particular activity.

Operational Support
e-Infrastructure is also used to support advanced simulations and data analysis as part of the engineering and manufacturing design and delivery processes. This can require large-scale compute capacity and capability and/or large-scale storage. Typically this involves an occasional, temporary requirement for large-scale compute capability and/or large-scale storage, where the main driver is additional capacity. Such simulations are typically becoming more and more comprehensive in terms of the amount of the product that is being simulated simultaneously, thus involving multi-physics problems multi-disciplinary optimisation, design of

[3] _, *ICT for Manufacturing: A Roadmap for Horizon 2020,* Draft version, February 2012.

experiments and robustness requiring increasing compute power and capability. Increased capability may also require the development of existing and new applications.

When considering the exploitation and further development of e-infrastructure within the engineering and manufacturing sector, it is important that this is done so within the context of these overall processes.

Engineering & Manufacturing Sector Scope

For the purpose of this report, the engineering and manufacturing sector is understood to consist of the following categories of business:

- Aerospace, Marine & Defence
- Automotive
- Chemicals
- Construction
- Electronics
- Manufacturing, Materials & Engineering
- Infrastructure
- Oil & Gas
- Utilities

Challenges faced by the manufacturing sector

- Competitiveness.
- Innovation.
- Complexity of processes and supply networks.
- Cost pressures.
- Customer expectations regarding quality, speed, customer products.
- Sector needs to enable better connectivity, mobility and manufacturing intelligence as it moves from product centric to human centric business and operation.[4]
- IP protection.

e-Infrastructure Stakeholders

The effective use of high performance computing (HPC) can be challenging because of the specialised and diverse skills, knowledge and expertise and investment required to build and then to maintain the operational HPC ecosystem. These barriers and complexity have led to slow adoption of the technology by many companies, particularly SMEs, over the past 20 years. The list of stakeholders is shown below:

- End users (both academia and industry)
- HPC service providers
- HPC systems vendors
- Independent Software Vendors (ISVs)
- Research software providers
- Application experts
- HPC consultancies
- Networking and Security providers.
- Data/Enterprise systems providers.

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[4] _, *Factories of the Future 2020 Roadmap Working Document.* European Factories of the Future Research Association, May 2012.

These are further expanded in Appendix C.

Potential Benefits

The benefits to the UK engineering and manufacturing sector of improving the capability and uptake of e-infrastructure are potentially significant; HPC delivers competitive advantage if deployed successfully. 'HPC [and the associated components of e-infrastructure] is a key enabler for making Europe's products innovative and of high quality at competitive prices'.[5] It is difficult to quantify precise benefits in terms of increased GDP or business profit. However, it has been reported that 2% increase in EU GDP could be realised by an e-infrastructure investment of €600m. In individual businesses an ROI between 3:1 and 9:1 has been reported.[6] What is clear is that greater use of the full e-infrastructure will bring tangible benefits to the design, manufacturing, supply chain and life-cycle areas for businesses within the sector as follows:

- Design:
  - Design innovation - quicker identification of materials.
  - Faster solutions to design problems.
  - Faster and less costly new product development.
  - Virtual engineering assessment in systems where the validation of materials performance by system-level testing is expensive, time consuming, or not possible.
  - Virtual engineering assessment of new materials that might be considered risky to assess with physical prototypes.
  - Migration from physical test to virtual based simulation.

- Manufacturing:
  - Better control of the manufacturing process.

- Supply Chain:
  - Optimising external logistics.
  - Processing monitoring of the supply chain.
  - The ability to dynamically reconfigure supply chains.

- Life Cycle:
  - Improved capabilities for predicting engineering system performance or life cycle.
  - Improved product life cycle management for advanced materials.
  - Improved competitiveness due to ability to link customer and after-sales information with R&D to develop personalized and customized end products.
  - Faster time-to-market for new products.

Overall expected benefits relating to e-infrastructure supporting the operation and business processes of manufacturing enterprises of the future include improved competitiveness due to the ability to offer value-added services, improved equipment uptime, reduced cost for servicing, increased service efficiency, higher customer satisfaction and more marketable products by extraction of customer and after-sales information and using this information to develop

[5] Sawyer, M. & Parsons, M (ed), *A Strategy for Research and Innovation through High Performance Computing*. PlanetHPC, University of Edinburgh, 2011, p.9.

[6] Goldbeck Summary, p.8.

personalize and customized end products. All these factors will potentially lead to a competitive technology and market advantage based on improved performance.[7]

Awareness of the ELC (from the survey)

The terms of reference of the ELC engineering and manufacturing working group includes a remit to assess how the sector views, and wishes to engage with, the ELC as a national advisory body. Only 33% of the survey recipients had heard of the ELC or were aware of its objectives. Taking into account all survey respondents are current e-infrastructure users this represents a poor level of awareness. Of those that were aware of the ELC opinions ranged from 'a good start' to a 'wait and see' attitude. It is clear that the ELC needs to engage with the engineering and manufacturing sector with a more focused approach in order to explain the scope and benefits of UK e-infrastructure and to create a collaborative approach to developing e-infrastructure in line with the sector's requirements going forward.

Current infrastructure

Figure 3 shows conceptually the use of current e-infrastructure by OEMs and their suppliers (which include SMEs), highlighting the fact that some elements of the infrastructure are publicly-funded, some elements are privately-funded, and there are certain barriers to accessing both (discussed later in the report).

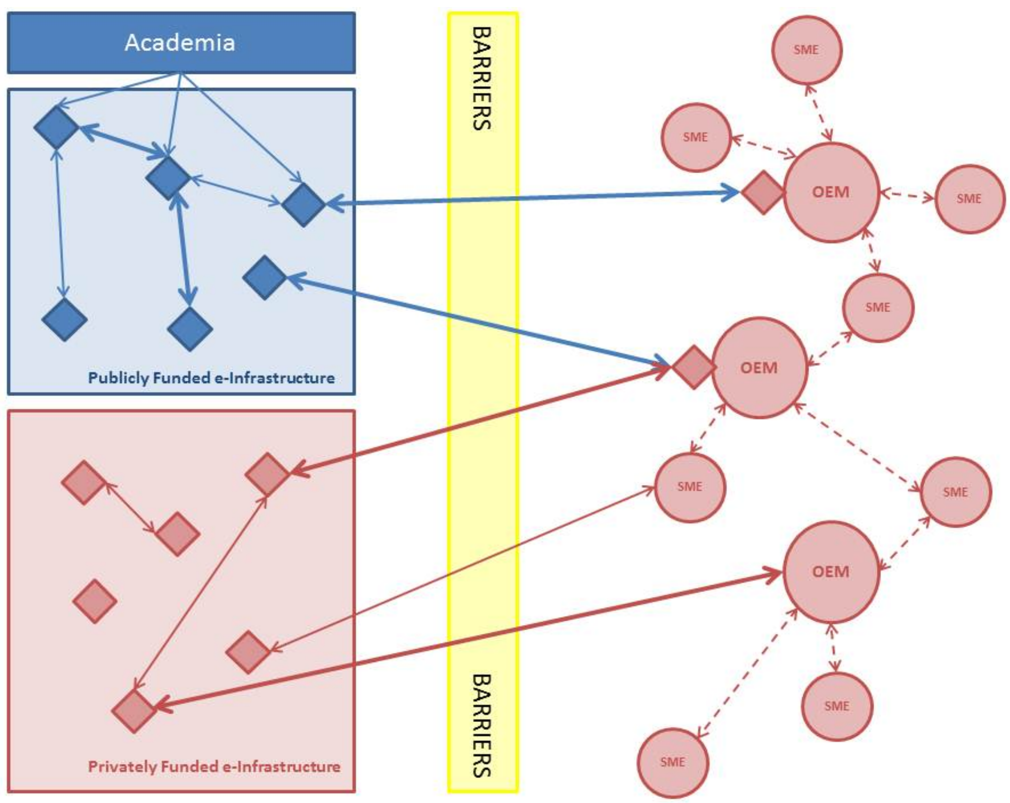

Figure 3 – Current e-infrastructure environment

7 _, *Factories of the Future 2020 Roadmap Working Document.* European Factories of the Future Research Association, May 2012 and Goldbeck Summary, pp.7-8.

High Performance Computing

The commercial use of HPC has been growing rapidly for the past two decades within traditional sectors such as aerospace and automotive and new sectors such as biotechnology and finance. In order to reap the benefits of new or enhanced products and services enabled by HPC requires investment in industrially relevant HPC applications and development of appropriate delivery models to transfer these products and services into business and research.[8]

Publicly-funded

- HECToR – HPC resource for use in academia and industry - based at the University of Edinburgh's Advanced Computing Facility (ACF) / EPCC.
- BlueGene/Q - HPC resource for use in academia and industry - based at the University of Edinburgh's Advanced Computing Facility (ACF) / EPCC.
- DiRAC – Integrated set of four HPC facilities used for theoretical astrophysics and particle physics research, located in Cambridge, Durham, Edinburgh & Leicester.
- Science & Technology Facilities Council (STFC) e-Science Centres - Daresbury Laboratory, Rutherford Appleton Laboratory (RAL).
- nVision Centre - University of Northampton.
- Virtual Engineering Centre (VEC) - University of Liverpool.
- etc

Privately-funded

- Advanced Simulation Research Centre (ASRC).[9]
- In-house company HPC facilities (generally OEMs only - too costly for SMEs).
- Cloud HPC services (e.g. Amazon EC2).
- Overseas services such as CPU 24/7 in Germany, or the NCSA (NATO CIS (Communication and Information Systems) Services Agency) in the USA.

Data-intensive computing and storage

Publicly-funded

- MIMAS – a national data centre based in the University of Manchester. (?)
- EDINA – a national data centre based in the University of Edinburgh. (?)
- Specialist public databases.

Privately-funded

- Privately-provisioned Cloud storage (e.g. Amazon, Google, etc).
- In-house private company storage.
- Private databases.

Software and applications (including software development)

Publicly-funded

- Software and applications funded and developed by academic institutions.
- UK Collaborative Computational Projects http://www.ccp.ac.uk
- NSCCS (EPSRC UK National Service for Computational Chemistry Software) http://www.nsccs.ac.uk/
- CECAM (http://www.cecam.org) (European level)

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[8] Sawyer, M. & Parsons, M (ed), *A Strategy for Research and Innovation through High Performance Computing.* PlanetHPC, University of Edinburgh, 2011.

[9] With public funding assistance on start-up.

Privately-funded

- Open source software.
- Commercial software (COTS).
- In-house developed bespoke software.

Training and skills provision

Publicly-funded

- JISC (Joint Information Systems Committee) Advance – provides information advice and guidance to the sectors and is responsible for seven services and thirteen regional support centres.
- NSCCS (EPSRC UK National Service for Computational Chemistry Software) http://www.nsccs.ac.uk/

Privately-funded

- In-house training courses and CPD programmes.

Networks

Publicly-funded

- JANET (Joint Academic Network) – Network for education & research in the UK - a shared service of JISC.
- GEANT – Pan-European network for education & research.

Privately-funded

- In-house corporate networks.
- Privately-funded national networks.

Security and authentication

Publicly-funded

- Shibboleth - a standards-based, open source software package for web single sign-on across or within organisational boundaries.[10]

Privately-funded

- Various commercial and bespoke security and access control software systems.

Utilisation

The following section describes the use of e-infrastructure within the engineering and manufacturing sector.

Functional Scope

e-Infrastructure is used to perform the following generic tasks in the engineering and manufacturing sector:

Materials Research

Research on the development, characterisation and application of new materials, especially in the area of design for composites. Full characterisation of composite materials, and their behaviour under real world operating conditions is still poorly understood and requires

[10] See http://shibboleth.internet2.edu/project.html (accessed 22/06/2012).

significant compute power to solve. This area also includes research within the chemicals industry and consumer packaged goods such as development of catalysts, etc.

Design Collaboration
In the past few decades, manufacturing has undergone major changes driven primarily by globalisation, specialisation and increasing customer demands. Major challenges facing European manufacturers are the growing complexity of processes and supply networks, increasing cost pressures in the face of competition from BRIC countries especially, and growing customer expectations for quality, speed and custom products. As a result, enterprises increasingly specialise and outsource processes which are not core competences. The optimal orchestration of suppliers and other collaborators into an interoperable, collaborative, agile, and manageable supply network has therefore become a key differentiator,[11] and e-infrastructure is potentially of great benefit in supporting such collaborative integration.

Product and Process Simulation
One of the particular aspects of design, whether collaborative or not, that requires significant compute power is simulation of designs before committing significant funds to physical tools, prototypes and facilities. This applies to simulation of products, processes, in fact anything of significant complexity that benefits from proving in the 'virtual' world. Access to such simulation capabilities through the e-infrastructure is of key importance for the engineering and manufacturing sector.

Analytics for Agile, High Value Manufacturing
Another significant use of compute power is the analysis of large amounts of data to enhance knowledge and provide a predictive capacity. For example, ActionPlanT has highlighted the potential importance of making sense out of stored and streamed production data through modelling, simulation, and analytics.[12] The ActionPlanT Consortium argues that current manufacturing execution systems (MESs) are too static and do not lend themselves to dynamic, agile and evolvable production systems. They argue that the high dynamicity of future manufacturing systems will require the full exploitation of knowledge extracted from production processes to provide constant optimisation of quality and resource usage. A new MES generation is foreseen to deal with this highly dynamic manufacturing environment, including real-time synchronisation with supply chain management systems.[13] In future factories, the demand on computing power and connectivity will also increase due to the following requirements:

- Connectivity and control of machinery, robots, production lines and operators with each other and to back-end systems.

- Production, supply chain, stakeholder, customer, and life cycle data management, collaboration and analytics.

Change in Utilisation
Change in utilisation models from individual analysis to full system design using Multi Discipline Optimisation (MDO), stochastic and robustness studies requiring significant HPC compute resources and highly complex ecosystems.

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[11] _, *ICT for Manufacturing: A Roadmap for Horizon 2020*, Draft version, February 2012, p12.
[12] _, *ICT for Manufacturing: A Roadmap for Horizon 2020*, Draft version, February 2012, p6.
[13] _, *ICT for Manufacturing: A Roadmap for Horizon 2020*, Draft version, February 2012, p20.

Organisational Scope

Organisationally, e-infrastructure is used within the engineering and manufacturing sector by original equipment manufacturers (OEMs), their suppliers (both large and SMEs) and academic researchers in universities.

Conclusions

Looking at the current provision and utilisation of e-infrastructure within the engineering and manufacturing sector, it is clear that significant capability exists, albeit somewhat fragmented in certain areas. It is also clear, however, that the *utilisation* of publicly-funded e-infrastructure is significantly higher in academia than it is in industry. Currently industry is unable to reap the advantages offered by utilisation of e-Infrastructure[14] due to a number of barriers, which are discussed in the next section.

It is also clear that there are a number of different communities of users of e-infrastructure, with different requirements, and that attempting to design generic solutions that suit all of them might prove fruitless. A better approach could be to focus solutions on the holistic requirements of specific user communities, especially in the industrial arena, but undertake to ensure that solutions can sit alongside each other comfortably in the same overall e-infrastructure architectural environment.

Barriers to utilisation of e-infrastructure in the UK Engineering and Manufacturing Sector

Barriers preventing companies from adopting modern ICT technologies are a combination of technological, social and economic. For example, the European Information Technology Observatory (EITO) highlights that European SMEs are poor at applying ICT advances to holistic manufacturing enterprise operations beyond the conventional shop floor. Limited investment in research and development (R&D), a not yet favourable environment for new high-tech entrepreneurship, and indifferent attitudes towards new ICT and innovation are hindering investments in modern ICT systems and delaying organisational changes in business processes for production, supply chains and marketing.[15] This "hindering of investment", especially in SMEs, indicates one of the factors which must be considered when seeking to build on or improve opportunities for private investment in e-infrastructure components.

The research conducted specifically for this report (the survey and interviews) suggests that the current main barriers to the uptake of e-infrastructure in the engineering and manufacturing sector fall into the following categories:

- Lack of **awareness** of what's there or what value can be obtained from it.
- Lack of **skills** and knowledge in making use of what's there.
- **Software usability** (and more general usability of the e-infrastructure).
- Flexibility and affordability of **software licensing models**.
- Antiquated models for dealing with intellectual property (**IP**) **ownership**.
- Concerns over **security**.
- **Connectivity** issues.

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[14] _, *A Strategic Vision for UK e-Infrastructure: A Roadmap for the Development and Use of Advanced Computing, Data and Networks.* E-science Leadership Council, November 2011.

[15] _, *ICT for Manufacturing: A Roadmap for Horizon 2020*, Draft version, February 2012, p.10.

These are each explained below.

Awareness

As already stated the sector's awareness of the ELC and its objectives is poor. Awareness of the availability of publicly funded e-infrastructure is also low. Of the survey respondents 57% claimed that the biggest barrier to them using government funded e-infrastructure was 'I don't know what's out there.' Only 50% were aware of publicly provisioned HPC, including HECToR, the Hartree Centre, the e-Infrastructure South Consortium and other university based facilities. When asked the same question concerning the other elements of e-infrastructure the positive responses were considerably lower. However, the issue is deeper than these responses indicate. Less than 10% of the survey recipients responded and completed all the questions raised. It is a reasonable assumption that a large proportion of the recipients that did not respond did so because they did not believe that the survey applied to them or because they were unable to engage with the questions through a perceived lack of knowledge of the subject. This indicates a wide awareness gap, particularly with SMEs but also prevalent in a number of OEMs, that requires bridging before businesses within the sector will engage with e-infrastructure in a meaningful and positive manner. This was also reflected in a survey conducted for the Advanced Simulation Research Centre (ASRC) in 2011, which found that many companies who could potentially make use of the facility, both OEMs and SMEs, were not aware of what was available to them. For those who were aware of the centre and its product offerings, many people didn't know the value of it to their business or how to make best use of it.[16]

The awareness gap can be attributed in part to a cultural blind spot within businesses in the sector. Overcoming cultural issues has been identified as a key factor contributing to the successful application of e-infrastructure.[17] Traditional engineering and manufacturing businesses that have remained viable without use of the e-infrastructure in their design and production processes are unable to see the purpose of engaging with it. This is more applicable to the SME community. However, as OEMs begin to invest and rely more heavily on e-infrastructure their supply chains will be increasingly constrained by non-users. As a result SMEs who continue to fail to engage with e-infrastructure may find themselves cut off from their OEM consumers.

In order to break down cultural barriers and bridge the awareness gap, the engineering and manufacturing UK sector must be aware of what is available to them within the UK e-infrastructure and then the business benefits of engaging with e-infrastructure have to be demonstrated. The benefits have to be presented in a focussed manner, tailored to match the expectations of individual SMEs and OEMs if necessary. This includes demonstrating that there is an engineering or manufacturing problem that can be overcome by using e-infrastructure and that there are appropriate processes, applications and assistance available to the business in question.

Skills

A recent survey indicated one of the major reasons given for not using more Computer Aided Engineering (CAE) is a lack of expertise and appropriately trained people. It has been identified

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[16] _, *CFMS-ASRC Phase 2 2013-2016 Decision Brief*, January 2012.

[17] Goldbeck, G., *Creating Impact from e-Infrastructures in Chemicals/Materials Industries.* Goldbeck Consulting, June 2012, p.8.

that the hardware and software of the e-infrastructure must be combined with education resources in order to be successful.[18]

The survey also highlights that skills are a significant issue, which could potentially be addressed through training and focused assistance. 100% of survey respondents agreed that more training and skills provision would make government funded e-infrastructure more accessible, more useful and hence increase availability. The requirement for increased provision of skills indicated by the survey took two strands:

- Direct training for business employees in software and application utilisation. While this approach would produce the most visible and measurable benefits it requires a considerable investment in cost and time within businesses.

- Pro-active policies and incentives to encourage new starters and under graduates to pursue courses that will benefit the engineering and manufacturing sector through increased utilisation of e-infrastructure capability and attract UK nationals into high-tech post graduate courses for the same purpose.

The research identified a particular issue in relation to UK nationals. It is important to have a good flow of an expertise from graduates, to post-graduates and then on through industry. However, it was reported[19] that a large proportion of the post-graduate flow is coming from outside the UK, typically only spending about 5 years in UK industry, and then returning to their country of origin, causing a break down in the supply chain of expertise into UK businesses and a shortage of long-term experience within industry. This further illustrates the need to incentivise UK nationals to go through the technical education / career route.

Software Usability

Software represents the critical interface between the user (OEMs and SMEs in the engineering and manufacturing sector) and the other components of the e-infrastructure. Current provision of software presents a number of issues to the user:

- Cost.
- Complexity and usability of specialist software.
- Applicability and supportability of general and open source software.
- Licence models for third party software (see following section).

Highly complex, specialist software can be prohibitively expensive to buy for most SMEs and even a proportion of OEMs. Some specialist software packages are only required during certain phases of the design and manufacture process and therefore a licence for use from a third party HPC provider is often the most economical way to access it. However, licensing software for use, even for a relatively short period of time can also prove prohibitively expensive. This points to indicates issues with the current licensing models that will be discussed in the following section.

Software and applications is the point at which a business will interface with e-infrastructure and the component through which benefit to that business will be realised. The USA ManufacturingHUB provides a working example of software being made available to a wide

[18] Goldbeck, G., *Creating Impact from e-Infrastructures in Chemicals/Materials Industries.* Goldbeck Consulting, June 2012, pp.2-3.
[19] L. Glazier, Rolls Royce, interview 25 June 2012.

range of SMEs over extant networks, bringing simulation tools into the business's normal work environment with no requirement for the business to consider the HPC capability, networks, etc. However, the survey demonstrates that an over emphasis on the importance of HPC, networks and security (see Question 18, Appendix A). This indicates a gap in awareness of the role and value and benefit of interaction with well developed, task specific software.

Complex, specialist software often requires equally specialist skills to operate it and manage the interface. To obtain these skills requires a considerable investment in education and training before a business can access its full capability. This issue has already been highlighted in this report. However, there are other options to improve access to software which could reduce the training burden:

- Simplify the interface of the most commonly used complex software in order to make it more accessible with reduced training. It has been recognised that ISVs must be encouraged to participate in co-design of new applications with end users to ensure that software meets the performance demands of UK engineering and manufacturing.[20]

- Provide software specialists to operate the application on a business's behalf and under its direction where that software is only required for a limited period. Software specialists would work alongside the business's designers, manufacturing and production engineers to ensure the full capability of the application can be realised and put to use.

- Provide community environments on the web that combine education, collaboration and simulation resources, enabling the engineering and manufacturing sector to learn about, try out and collaborate on specific applications that support their business.[21]

A cost effective solution to using complex, specialist software is the use of open source applications. There are very successful open source software and project developments. For example the KNIME project (http://www.knime.org) has developed a platform for data integration, processing, analysis and exploitation that is deployed at major corporations and used in many areas of research from pharmaceuticals to city planning. Other examples include the R-project and software for statistical computing (http://www.r-project.org). However, open source software can be particularly challenging with respect to usability, it seldom meets all the requirements of a business in terms of functionality and capability. 50% of survey respondents felt that open source software was generally inadequate for the needs of their business. There are also issues, if not formally supported, with companies being unwilling to invest critical activities to it due to the lack of control and uncertainty about its future.

Against this background, the impact and role of SME's, both in relation to their utilisation of e-infrastructure and their possible contributions towards the development or extension of existing e-infrastructure, through investment and development of, for example, new software applications, is revealed. The development of software infrastructures over the last decade from monolithic systems to more open systems means that applications can now be developed by SMEs and connect more easily into established platforms. Platform providers (whether in open source such as KNIME or software vendors such as Accerrys, Esteco, Ansys, etc) integrate with a wide range of third-party providers, including small ISVs making the tools more easily

[20] Sawyer, M. & Parsons, M (ed), *A Strategy for Research and Innovation through High Performance Computing*. PlanetHPC, University of Edinburgh, 2011, p26.

[21] McLennan, M. & Kennell, R., *HUBzero: A Platform for Dissemination and Collaboration in Computational Science and Engineering.* Computing in Science & Engineering 12, 2010, pp.12-17.

accessible for industry and end users and more acceptable to corporate IT. Notwithstanding this, there are typically issues or at least a perception of issues, with open software development that still create barriers to its adoption by more SMEs in the engineering and manufacturing sector. One is the usability of software that is often developed on a small budget and for a specific technical need. Another is support for the 'hardening' and commercialisation of the software such that it is reliable enough to be adopted (and if necessary developed) by a larger community than that which originally developed it.[22] Finally, such software often tends to be developed in isolation without consideration of how it could or needs to fit into the wider e-infrastructure ecosystem.

Software Licensing Models

Licensing for the kind of specialist software needed to support advanced simulation and research activities can be expensive, and prove prohibitively so for SMEs. Such software is typically targeted at OEMs, who have the financial scale and level of requirement that is necessary to make such software practical and affordable. Whilst OEMs might require their supply network to have access to the same software applications that fall within their standard architectural stack, this is often not financially feasible for all but the largest suppliers. 33% of survey recipients felt that industry specific software was hard to access, either due to its cost, complexity or to the interface issues identified above.

Inflexible licensing models mean that short term use of an application to support a specific requirement is either not possible, or attracts disproportionately high costs making the application prohibitively expensive. There is evidence that inflexible software licensing models are preventing SMEs from accessing e-infrastructure and therefore restricting their business opportunities and growth.[23] The survey indicates that there is a requirement for innovative, flexible licensing models that are demand led and pay-as-you-go. Such licensing models are critical for the effectiveness of facilities such as the ASRC in Bristol, where companies need to be able to experiment with software in a production environment for short periods of time, making perpetual ownership of a software license unnecessary. Some software vendors are beginning to realise the opportunities afforded by more flexible licensing models, and the ASRC has already proved the effectiveness of such models,[24] but these models are by no means the norm yet in the field of specialist software for engineering and manufacturing.

A cost effective solution also needs to be architected to allow SMEs access to specialised third party applications on a pay-as-you-go, cost effective business model basis across the UK geographical region as this could also lead to companies investing in or relocating to the UK if there exists a competitive business model for e-infrastructure.

IP Ownership

Current IP management models do not reflect the requirements of collaborative innovation, design and production. As businesses work together over the e-infrastructure, whether to enable design innovation or to streamline the supply chain it is inevitable that a degree of information will need to be open source and that IP cannot be retained by a single business. As e-infrastructure use increases and the system becomes more collaborative so the flow of

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[22] This issue is also prevalent within research communities - see _, *E-infrastructure - Taking Forward the Strategy: Synthesis of Interviews with Expert Stakeholders.* Research Information Network, September 2010, p.24.

[23] Martin Aston, CFMS ASRC,interview, 21 June 2012.

[24] _, *CFMS-ASRC Phase 2 2013-2016 Decision Brief*, January 2012.

information and therefore IP will also increase. Current industrial and academic collaborations consistently raise IP management as an issue and it is probable that issues that are as yet 'below the radar' will be raised in the future and block progress and growth until they can be resolved.

Current IP management models require review in order to ensure they are fit for the purposes of UK engineering and manufacturing operating collaboratively within the e-infrastructure in the 21st Century.

Security

The nature and configuration of HPC capability, and the business model wrapper within which it is provided, such as Cloud-based pay-per-use models, is providing increased opportunities for access to HPC facilities and computing resources in general. However, "security is a key issue when moving to a pay-per-use model".[25] The number of governments giving high priority to security of information systems and networks has increased since 2008 in response to the ubiquity of ICTs in OECD economies, high uptake rates among individuals and organisations, and the potential risks of greater reliance on information systems.[26]

Cloud-based HPC capability raises particular issues in relation to security. Cloud Computing provides an infrastructure to utilise and share both computational and data resources whilst allowing a pay-per-use model, useful to cost-effectively manage hardware investment or to maximise its utilisation. Cloud Computing also offers transitory access to scalable amounts of computational resources, something that is particularly important due to the time and financial constraints of many user communities.[27] Unfortunately, security concerns hinder realisation of these potential benefits. This was reflected in a 2011 survey[28] of users, and potential users, of the ASRC facility[29] in Bristol, which found that remote access and confidentiality were indicated by current and prospective customers as the most attractive characteristic of the service offered by the ASRC to their business requirements, and that security was one of the most significant concerns for companies that hadn't yet used an external facility for providing their HPC services.

A number of communities whose emerging information models appear otherwise well suited to Cloud Computing are forced either to avoid the pay-per-use model of service provision or to deploy a private cloud infrastructure. Deploying a private cloud requires an extended time frame and relevant investment in hardware, management, software resources and significant IT skills and knowledge. These limitations also apply to the deployment of a private cloud based on open source software because while licencing costs are eliminated, the bulk of the investment in hardware and support resources is still required.

There remain questions as to just how much of an issue security is with Cloud-based business models. Many potential users very much see it as an issue, whereas service providers quote

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[25] Van der Pyl,T., *Director, Components and Systems*, DG INFSO European Commission, available from: [http://www.planethpc.eu/index.php?option=com_content&view=article&id=43:inteview-with-thierry-van-der-pyl&catid=2:news&Itemid=4] accessed 18/6/2012.

[26] OECD Information Technology Outlook 2010 Highlights http://www.oecd.org/dataoecd/60/21/46444955.pdf accessed18/6/2012.

[27] Wallom, D.,Turilli, M.,Taylor, G., Hargreaves, N., McMorran, A. Martin, A. Raun, A., *MyTrustedCloud: Trusted Cloud Infrastructure for Security-critical Computation and Data Management.* 3rd IEEE International Conference on Cloud Computing Technology and Science, 2011.

[28] _, *CFMS-ASRC Phase 2 2013-2016 Decision Brief*, January 2012.

[29] The CFMS Advanced Simulation Research Centre (ASRC) in Bristol, which began customer operations in April 2011, is designed to provide infrastructure and ICT that allows customers to conduct collaborative research and simulation in a secure environment with HPC support.

defence-grade encryption levels and see security issues as more a question of perception than reality.[30] However, even if it is just a question of perception, security is still an important issue that needs to be addressed.

Connectivity

Although there is universal praise for JANET, and the belief that it offers the UK with a major competitive advantage,[31] there is also recognition that if the growth in the use of e-infrastructure is to succeed, it will put JANET under considerable strain, to the point where it could become a weak link in the system, or even a major barrier to its further use, with Professor Douglas Kell, Chief Executive of BBSRC (Biotechnology and Biological Sciences Research Council), suggesting that JANET might soon 'break' without a step change in capability.[32]

The survey conducted for this report highlighted the importance of access to high speed, cost effective secure networks for the UK engineering and manufacturing community and, although the network wasn't identified as a major barrier at present, increased internet speeds and bandwidth were identified as the most important element that the government could act on right now to improve things for companies.

HPC currently requires an expensive, high bandwidth connection, so increased use of HPC over the e-Infrastructure will only add to the strain on JANET.

Connectivity is a particular issue for SMEs wanting to access external HPC services over the Cloud, who currently either have to pay for a dedicated, high-cost network connection, or have to make do with slow performance. When asked what the UK government could do right now to help businesses with their immediate e-infrastructure requirements the highest response to the survey (80%) was for improved network access including increased speed and bandwidth.

[30] _, *CFMS-ASRC Phase 2 2013-2016 Decision Brief*, January 2012.

[31] HEFCE review of JISC, December 2010.

[32] See http://blogs.bbsrc.ac.uk/index.php/2011/06/e-infrastructure-networks-and-change/ (accessed 22/06/2012).

The Future Requirement for e-infrastructure in the UK Engineering and Manufacturing Sector

Survey recipients were asked what their requirements for government funded e-infrastructure would be over the short (next 12 months), medium (next 3 years) and long term (next 10 years). Their responses are summarised in the following sections. Within each timescale a graphical summary of where requirements were identified appears in Appendix A at Questions 19, 20 and 21.

Short-term Requirements (the next 12 months)

High Performance Computing

In the short-term, companies are looking for a **secure** HPC service provision that they can use either as a 'burst' capability, providing extra capacity when needed or a more flexible HPC environment suitable for experimentation and proving (for those companies that already have their own in-house HPC capability), or as a total capability (for those companies that have no in-house capability).

Software and Applications

A requirement was identified to support universities in the short-term to help them develop leading-edge software, along with a need for tools to enable remote visualisation of data, reducing the need to transmit large files around. A significant requirement identified was an urgent need for a cost-effective, on-demand licensing model for the geographically-independent provision of software applications.

Networks

Short-term network requirements include the provision of secure, high-speed, high-bandwidth national networks as a reliable and cost effective service. There was also a requirement identified for improved project-based communication tools to support collaboration between companies and academic institutions.

Training and Skills

The survey also identified a current shortage of skills in high performance technologies, which could be addressed through providing specific training and development at all levels, along with industry and academia collaboration forums.

Medium-term Requirements (1 - 3 years)

High Performance Computing

In the medium term, no new requirements were identified for HPC, simply continued investment and upgrade, development of next generation HPC cluster technologies (ie GPU and MIC) and increasing access to cores for industry (e.g. c100,000).

Networks

Similarly, medium-term network requirements were for continued performance upgrades and security improvements, with an increased capacity to match the anticipated growth in data-intensive usage.

Security and Authentication

The development of a world class UK PLC security and authentication environment was highlighted in the medium term order to better protect UK IP.

Long-term Requirements (4 - 10 years)

Longer-term, the requirement doesn't change significantly across any of the e-infrastructure categories, with continued efforts being required to improve HPC performance and capability, improve capability in the area of simulation knowledge mining and abstraction, develop next generation best in class software and applications to deliver UK competitive advantage, improve the technical skills and knowledge base and increase opportunities for collaboration.

Perceived Lack of Requirement in Data Intensive Computing

Across this area of the survey data intensive computing consistently ranks as a low requirement. This contradicts the current fact that industry has to cope with manipulating ever increasing data sets. This indicates a wide gap in awareness and lack of recognition of the potential that improvements to data intensive computing could have for a business. The results above are further are backed up by the survey responses to Questions 3, 4, 7 and 18 (see Appendix A). Although awareness is a general problem schemes to combat it must give due weight to the potential for data intensive computing.

Overcoming the Barriers

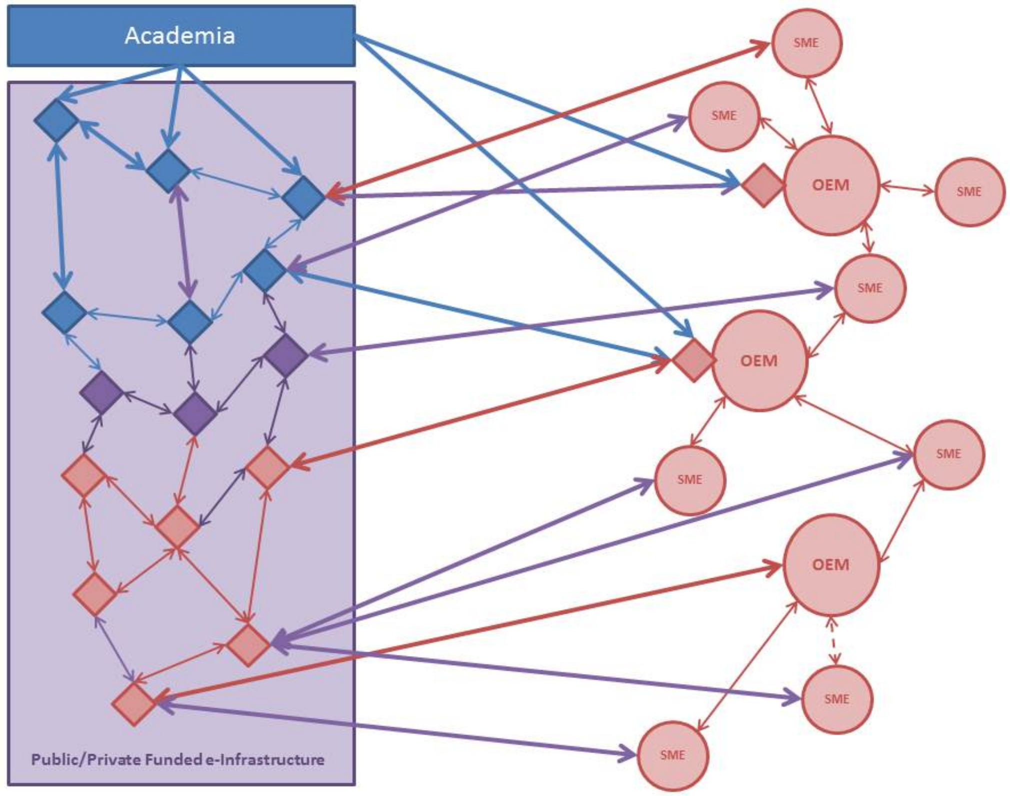

Figure 7 – ‘Ideal’ model of UK e-infrastructure

Figure 7 represents the ‘ideal’ future conceptual model for UK e-infrastructure within the engineering and manufacturing sector, highlighting the more integrated nature of the publicly and privately-funded elements. Many publicly, privately and co-funded HPC nodes are available and seamlessly connected along with the requisite data storage, software network connectivity, applications, licenses and security in place. OEMs and SMEs are also seamlessly connected within their supply chains with fast, reliable access to the HPC hubs. OEM’s internal HPC capacity also forms part of the overall e-infrastructure environment which also allows access to academic institutions and their research activity. However, to allow the current e-infrastructure environment to migrate towards this model first the barriers that exist must be removed or lowered to a point that SMEs can easily cross them. To enable this, the following actions need to happen.

- The **awareness** gap must be crossed and cultural blind spots need to be cleared. This is currently the biggest barrier to SMEs accessing and benefiting from the UK e-infrastructure. This includes allaying concerns on data security. This issue could initially be resolved in the short term but with an ongoing remit to raise awareness within the UK engineering and manufacturing sector.
- **Collaboration** creating an environment that enables knowledge and skill sharing across OEMs, SMEs, UK Government, academia and vendors.

- **Skills and education** need to be addressed and applied to ensure that the UK engineering and manufacturing sector has people that can exploit the e-infrastructure capability now and improving in the future. This issue can be resolved by different actions in the medium and long term.

- **Software usability** needs to be improved through provision of expertise, improvements to software interfaces and increasing skills in the UK engineering and manufacturing sector. This can be achieved by action in the short and medium terms.

- **Software licensing models** need to be reviewed to increase flexibility and improve affordability. This issue requires action in the medium term.

- **IP Ownership** management models need to be reviewed to ensure they are fit for the purposes of the UK engineering and manufacturing sector working collaboratively within the e-infrastructure. This issue requires action in the medium term.

- **Connectivity** between OEMs and SMEs within their supply chains, HPC hubs and academic institutions needs to be enhanced with improvements to reach, speed and bandwidth. This issue requires action in the medium and long term.

e-Infrastructure as an Ecosystem

Getting maximum uptake of, and value from, e-infrastructure is not just a question of dealing with specific issues in isolation. Indeed, Voss et al. (2007)[33] point to the sub-optimal results that can ensue when the problems are tackled in isolation. They describe how solutions that tackle specific parts of the problem, in this case specific components of the e-infrastructure or specific barriers preventing its uptake and use, tend to get "deeply embedded in the socio-technical arrangements of use, creating path dependencies that constrain future development. Often, the choices made to overcome the identified obstacles are not optimal in the long-term but once established they are difficult to change, potentially creating 'lock-in' to suboptimal solutions". The responses to the survey reflect this suboptimal thinking on e-infrastructure. The survey indicates that on current usage and knowledge e-infrastructure is regarded as a combination of HPC and network with the other components ranking far behind (see responses to Question 3 at Appendix A). This implies that the UK engineering and manufacturing sector is some distance from considering e-infrastructure in holistic terms.

This points to the need to address the barriers identified, and e-infrastructure development, in a holistic way, considering the requirements of all stakeholders, and the integration of all necessary components into a systemic whole in support of the wider goal of economic growth. The European Commission call for FP7 ICT WP 2013 also proposes such an approach. Preparation of the call for FP7 ICT WP 2013 is currently in its final preparation stage, with tentative WP publication targeted for July 2012 and calls expected to close in December 2012 or early 2013.[34] Figure 8 illustrates the proposed structure of HPC Cloud-based simulation services for SMEs that the call is intending to support:

[33] Voss, A., Mascord, M., Fraser, M., Jirotka, M., Procter, R., Halfpenny, P., Fergusson, D., Atkinson, M., Dunn, S., Blanke, T., Hughes, L. and Anderson, S., *e-Research Infrastructure Development and Community Engagement*, Conference paper for UK e-Science All Hands Meeting, 2007.
[34] See http://cordis.europa.eu/fp7/ict/computing/presentations/plans-wp2013.pdf (accessed 22/06/2012).

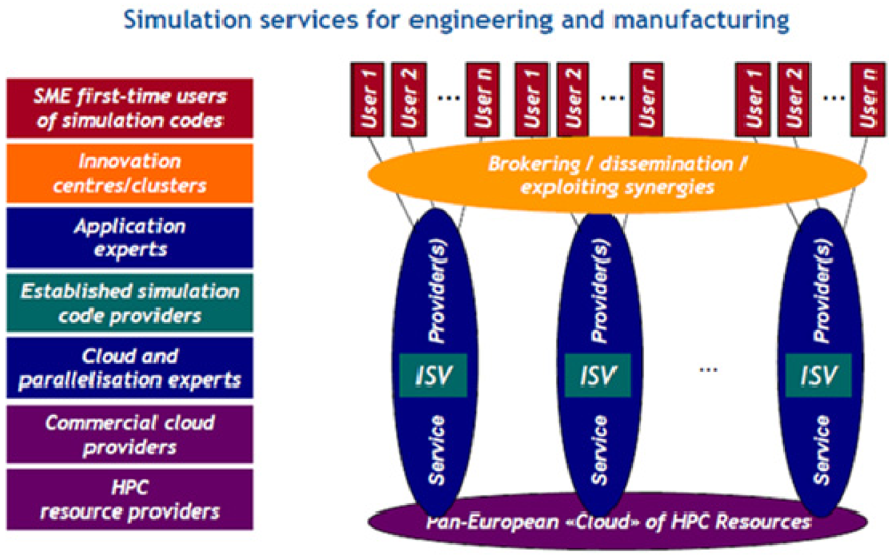

Figure 8 - FP7 ICT WP 2013 - proposed structure of HPC Cloud-based simulation services for SMEs

The key elements of an e-infrastructure for the field of materials and engineering (ICME - Integrated Computational Materials Engineering) consists of libraries of models, experimental data, software tools (including integration tools) and computational hardware.

A successful example of the holistic approach is the virtual aluminium castings (VAC) methodology developed by the Ford Motor Company. It offers one detailed case study for integrating materials, component design and manufacturing. The method was based on a holistic approach to aluminium casting and component design; it modified the traditional design process to allow variation in material properties attributable to the manufacturing process that flowed into the mechanical design assessment. Fully funded by Ford to address specific power train components the VAC methodology was implemented by the company reducing product process and development time by 15-25% and reducing cost by $120 million.[35]

The holistic approach can realise rapid growth in the use of e-infrastructure resources. There are successful examples in the USA, which could provide a template for application in the UK. NanoHUB is an online resource for nanoscience and nanotechnology which offers remote access to a wide range of simulation tools and well as teaching and education resources to allow their use. Online tools can easily be built and adapted to meet the requirements of specific users. 230 such tools are now available on NanoHUB, over which have 30,000 users have run 2 million ‘one click simulations’ to date. NanoHub has 100,000 registered site users. This approach is now being used to provide simulation tools to the SME manufacturing community. Purdue University's ManufacturingHUB is serving SMEs that could use high-performance computing and simulation to innovate new products but are not doing so because of barriers including the cost of commercial software licenses, the cost of powerful computers and the staff to manage them, and the difficulty of learning to use complex simulation tools.[36]

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[35] Allison, J. *ICME: The Next Big Thing in Materials.* Materials Information Luncheon, August 2011. Available from http://materialsinnovation.tms.org/resources/1108-allison.pdf accessed 25 June 2012.

[36] http://nanohub.org/ and http://manufacturinghub.org/

Although not evidenced by the survey, existing publications clearly point to the need to address the barriers for e-infrastructure uptake and further development in a systemic fashion. This will require a wider and deeper study of system-wide requirements of the engineering and manufacturing communities, which couldn't be accomplished within the scope of this short study, especially given the lack of engagement with the survey.

Recommendations for Government Intervention in the further development of the UK's e-infrastructure for the UK Engineering and Manufacturing Sector

Not Hardware

The research indicates that hardware isn't a significant barrier to the uptake and development of the e-infrastructure. HPC hardware is undoubtedly becoming more commonplace and accessible. This provides an opportunity that should be built upon, supported by funding for collaborative projects that will facilitate the **adoption of HPC solutions** on a wider scale. However, wider adoption and use presents significant challenges in terms of increased energy use and sustainability that need to be addressed concurrent to encouraging expansion.

One area where it was felt that awareness needed to be raised was with the provision of generic HPC capability by external service providers. It was suggested[37] that existing providers tend to provide generic solutions focusing on scale and speed, which tended to be suitable for explicit solvers but not implicit ones. It was suggested that increased awareness was needed in the HPC service provider marketplace of the architectural differences needed to support both implicit and explicit solvers, as the massive memory chip architecture needed to support implicit solvers is generally not available currently.

Whatever hardware *is* in place must be accessible and affordable, which is especially important for SMEs. This means access and pricing models that allow short term use and pay-as-you-go terms.

Action in the Short Term (the next 12 months)

Building Awareness

The most urgent requirement is to bridge the awareness gap concerning e-infrastructure, particularly within the SME community. Blanket awareness campaigns are unlikely to be effective as they fail to cross the cultural barriers that exist in the business sector. The survey indicated a very high preference (83%) for businesses to engage with the ELC face-to-face through meetings and workshops. These engagements must be focused to demonstrate the benefits of e-infrastructure to individual businesses or small, homogenous groups of businesses. The benefits should be presented by identifying an existing manufacturing or engineering problem and demonstrating the applications and assistance available within the e-infrastructure that can overcome that problem. This approach has been identified as a key factor in successful e-infrastructure implementation.[38]

There are two approaches to delivering focused awareness engagement:

- Awareness Teams. Small teams or individuals that can reach into businesses to provide focused engagement, discuss the business' requirements and provide information and some demonstration of what is available within the e-infrastructure to help surmount that

[37] L. Glazier, Rolls Royce, interview, 25 June 2012.

[38] Goldbeck, G., *Creating Impact from e-Infrastructures in Chemicals/Materials Industries.* Goldbeck Consulting, June 2012, p.8.

problem. This could be delivered on a face-to-face basis to individual businesses or as roadshows to focussed groups of businesses that are likely to have similar issues.

- Awareness Centres. Regional or industry specific awareness centres that provide expertise and access to the e-infrastructure where businesses can be engaged and the full capability of e-infrastructure can be demonstrated.

A combination of these two approaches will provide the most comprehensive engagement model; awareness centres that have individuals that can reach into businesses and then draw them into the centres so the full e-infrastructure can be demonstrated in a focused manner that relates directly to that business. A BTC in Southwest England is currently being developed along these lines that could provide a model for future expansion.
Part of the process of engagement must include steps to overcome the perception of security issues within the sector. This can be achieved by referencing high security demanding e-infrastructure users, e.g. banking and defence that currently use remote and cloud computing facilities without irrational security fears.

Government funded Awareness Teams and Awareness Centres are required now to remove the largest barrier to increased utilisation of the e-infrastructure and the benefits that go with its use. Although listed as a short term action there will be an ongoing requirement for co-funded awareness activity into the long term until e-infrastructure use within the UK engineering and manufacturing industry becomes second nature.

Support for Specific Case Studies to use as Exemplars

An effective means of raising awareness of, and convincing companies to use, the e-infrastructure resources available to them is through the implementation and communication of successful 'pilots' or case studies that demonstrate the value and impact of using the e-infrastructure. Although not suggested explicitly by respondents to the survey for this report, it is alluded to as an activity that the ELC could help support, and it is an approach that has proved successful in other countries. It was also highlighted in a telephone interview. The perception is that there is significant potential to be gained through the collaboration on high performance computing projects of non-competing companies. This is something that could be explored through one or more focused case studies, to demonstrate the potential of such collaboration and encourage others to follow suit. Supporting such collaborations is one of the main ideas behind the CFMS ASRC centre in Bristol. The government could support this by helping to identify the capabilities that exist in UK companies, help get NDAs (non-disclosure agreements) in place, and facilitate sessions to introduce potential collaborators to each other.

International exemplars also need to be studied and presented so the success of initiatives such as NanoHUB and ManufacturingHUB is fully understood in order to reapply what can be translated to the UK e-infrastructure. Concurrently, if the benefits to manufacturing SME users of ManufacturingHUB can be captured and articulated then these can also be presented as incentives to adopt use of e-infrastructure by SMEs in the UK.

Co-funded studies are required to provide UK and international exemplars in order to encourage and incentivise UK OEMs and particularly SMEs to adopt use of e-infrastructure.

Provision of Software and Application Expertise

To allow immediate use of available software and applications that might otherwise require considerable investment in training in terms of cost and time, software and application experts must be put in place that can be plugged into businesses where most potential benefit is apparent.

Government funded Expertise Teams are required to allow businesses in the UK engineering and manufacturing sector access to critical software and applications while the results of training and education pull through in the medium and long terms. Small teams with expert knowledge and experience in the most commonly applicable software and applications need to be established either regionally or in industry specific groups. Individuals from the teams can be plugged into businesses to work alongside their design and production departments in order to immediately access the benefits of e-infrastructure capability. These Expertise Teams could be combined with the Awareness Teams.

Security

The UK's core IP is potentially at threat. **Government investment is required in the protection of UK national core IP.**

Wider / Deeper Study

A longer-duration (e.g. 6 month) study is needed to address some of the systemic issues and barriers to uptake that have been identified, and to design the next generation of the UK's e-infrastructure as a holistic ecosystem, rather than tackling individual issues and individual components of the infrastructure.

More work is required to focus on SMEs and their relationship to e-infrastructure from these two perspectives: both as e-infrastructure users, and as potential investors in/developers of e-infrastructure. This work would draw on the findings from one of the four ELC working groups (e.g. the 'missing middle' and supporting academics with industry interaction/spin outs led by Kaitlin Thaney and John Bancroft) in order to define and explore the nature of 'missing links' preventing or hindering innovation, which may include commercial and IP considerations and their role within the 'missing middle'. The key factor to consider here is that the 'missing middle' could offer software services within the e-infrastructure across the e-science network to other users such as researchers encountering usability and accessibility issues with existing software.[39] This vision is predicated upon the idea of dynamic collaboration – efficient and secure collaboration between many different stakeholders. It has been suggested that "large companies as well as SMEs stand to gain from collaborative manufacturing" (source: ActionPlanT[40], p.12).

Once again, the USA examples of NanoHUB and ManufacturingHUB should be included in this study. ManufacturingHUB allows SMEs to tackle engineering and manufacturing issues using specific simulation tools (with the training resources to use the tools available on-line), running on remote HPC systems using the extant national connectivity resources. In doing so it has drawn SMEs into e-infrastructure use with its attendant benefits. A study of how this has been

[39] For example, social scientists experiencing difficulties with data analysis software SSPS, see _, *E-infrastructure - Taking Forward the Strategy: Synthesis of Interviews with Expert Stakeholders*. Research Information Network, September 2010, p.23.

[40] _, *ICT for Manufacturing: A Roadmap for Horizon 2020*, Draft version, February 2012.

achieved and the benefits could have direct and positive impact on the way in which the UK e-infrastructure develops in the medium to long term.

Government funding is required to allow a wider, deeper study to be conducted, using international examples in order to inform a systemic approach to strengthening the UK's e-infrastructure and widening use within the engineering and manufacturing sector. The study can combine with the recommendation above to provide domestic and international exemplars of the benefits of e-infrastructure use.

Action in the Medium Term (the next 3 years)

Training

Training Needs Analysis (TNA) needs to be carried out across the UK engineering and industry sector in order to ascertain the training needs of OEMs and particularly SMEs that would allow them realise the benefits of effective access to the e-infrastructure. Once this is complete and the results analysed Training Teams are required to run events and programmes across the UK that can be accessed by SMEs in particular. **A Government sponsored TNA needs to be conducted followed by the establishment of co-funded Training Teams.** Training Teams could be combined with the Awareness and Expertise Teams.

Software Usability

Software usability needs to be improved through advances in software and application interfaces making them more accessible. **A Government approach to ISVs is required to encourage a collaborative approach to software development alongside UK engineering and manufacturing users.**

Software Licensing

Software licensing models need to become more flexible in order to allow SMEs to access software and applications that could benefit their businesses and allow greater access to the full e-infrastructure capability. **A BIS white paper should be launched to highlight the barrier to economic growth caused by current licensing model and to provide more flexible and affordable models that can be accepted and implemented by UK and European ISVs.**

IP Management

IP Management Models require reform in order to ensure they meet the requirements of collaborative innovation over the e-infrastructure in the 21st Century. **A Government sponsored study (working with the Strategic Advisory Board for Intellectual Property SABIP) is required into suitable IP Management Models that can then be implemented across UK industry and academia.**

Connectivity

Connectivity is the issue which current e-infrastructure users see as offering the highest return for an immediate investment. However, improvements in connectivity are more likely to be realised in the medium term. The UK engineering and manufacturing sector will benefit by improving connectivity in terms of reach, speed and bandwidth. **A co-funded study is required in order to determine where targeted co-investment in connectivity will produce the**

highest ROI. Although targeted, co-funded investment in improved connectivity could begin within the medium term it will require commitment stretching into the long term and beyond.

Action in the Long Term (the next 10 years)

Education

School leavers and academic institutions, both HE and FE, need to be incentivised to produce under graduate investment that will benefit the UK engineering and manufacturing sector. Only when graduate level employees with deep knowledge of the e-infrastructure capability as well as their own industry specific subjects exist in SMEs as well as OEMs will e-infrastructure use become second nature and the full capability be exploited. Academic institutions must also attract UK students into appropriate post graduate programmes to ensure that the UK remains a leader in e-infrastructure exploitation in the engineering and manufacturing sector. **The Government must work with academic institutions in order to provide incentives to attract under graduate and post graduate UK students that will go on to embed e-infrastructure expertise in the UK engineering and manufacturing sector.**

Continued Investment

Although many areas of the UK e-infrastructure are currently well provisioned, e.g. HPC availability and capability, long term continued investment will be required to ensure this remains the case. **An on-going Government co-led and co-funded study is required to ensure that co-funded investment continues to effectively targeted within the UK e-infrastructure over a period of 5 to 10 years including strategic investment and on-going operations maintenance.**

Opportunities for private investment

One of the critical aspects of continued government support for e-Infrastructure in the context of a general tightening of public expenditure is the identification of opportunities to increase private investment in e-infrastructure, at increasing levels over the coming years (see Figure 1). The lack of response to the survey for this report indicates the level of challenge that might be experienced in accomplishing this goal without focused attention on this specific issue. Without a more in-depth study it is difficult to identify specific opportunities for private investment; however the recommendations for focused case studies highlight possibilities. For example, if major industry leading OEMs can see significant value in collaborating with key suppliers on exemplar case study projects, they may well be willing to invest funds in certain aspects of e-infrastructure to directly support such projects. Investing in e-infrastructure from the 'bottom-up' in this way is likely to be more effective than expecting private companies to invest in generic aspects of e-infrastructure that they might not see any direct benefit from.

APPENDICES

Appendix A – Edited Survey Results

The survey was completed by the following:

- Jaguar Land Rover - CAE & HPC IT Manager.
- National Nuclear Laboratory - Technical Team Manager.
- Altair Engineering - Director, Product Design.
- University of Warwick - WMG Systems Manager.
- Teer Coatings Limited, Miba Coating Group - R&D Technology Centre Manager.
- Rolls-Royce plc - Chief of World Class Systems.

The following is an extract of the survey results:

Q1: What capability exists internally (within your company) in the following areas? Please indicate those you have, whether you use them or not, and describe the nature of your usage.

High Performance Computing

- Jaguar Land Rover (JLR) utilise a large on premise HPC internal private cloud consisting of dedicated and non-dedicated capability that jobs are scheduled to based on resource scheduling. JLR HPC is utilised for virtual simulation for automotive design and simulating real world physical behaviours such as safety, fluid dynamics, aerodynamics, combustion, climate control, durability, fatigue ride and handling etc.
- Linux cluster (currently ~256 nodes) is used for a wide range of modelling and engineering design needs. Most common users being atomistic modelling, environmental risk assessment, computational fluid dynamics modelling, finite element modelling and nuclear physics.
- Multi-core Linux clusters use for solving large CAE and CFD problems.
- A 3100 core high bandwidth, low latency Linux cluster used for research activities.
- Main HPC capability is a 2880 core IBM iDataplex. The computer is available for use by anyone, for research and development purposes.
- We use a commercial SolidWorks package for engineering modelling. It is not clear if this really counts as "high performance computing" as the capability appears reasonably ubiquitous these days.
- High Performance Computer clusters used for large simulations enabling 'better Engineering'.

Data-intensive computing and storage

- JLR utilise a large, highly per-formant parallel file system storage array that is used to store the Computer Aided Engineering (CAE) input files and the simulation results data that are generated from the HPC simulations.
- Most of this work relates to nuclear physics data.
- Large disc arrays for storing CAE and CFD results and models.
- IGM GPFS 100TB, 55 TB MHD & 45 TB general use.
- Limited data storage because of the research nature of the work. Intention is for people to carry out analysis and then offload results.
- Only on-site servers - i.e. nothing specialised for very large data volumes.

Software and applications

- JLR utilise approximately 83 applications from third party vendors and internal developed applications for CAE and HPC.
- The environmental modelling and risk assessment people use this most often for building environmental safety cases for plant and disposal sites.
- CAE and CFD codes in HyperWorks (RADIOSS, Acusolve, Motionsolve, Optistruct) used for assessment of structural performance (crash simulation, weight optimisation, mechanism simulation etc. and fluid flow (wind turbine, HVAC simulation etc.) Abaqus, LS-DYNA used in addition to Altair Products plus additional software available on Altair's partner programme (nCode, etc.)
- Moab / Torque.
- Software obtained as required by users/customers. Some of users in-house codes used. Software is predominantly associated with engineering analysis.
- SIMION for electrostatic modelling

Training and skills provision

- JLR have onsite training facilities and leverage third party offsite training facilities for standard, bespoke and custom training events. JLR are key members of UK NAFEMS , the National Association for Finite Element Methods and Standards.
- Some work in producing simulators for plant.
- We have comprehensive training courses available for Altair Hyperworks products to train engineers in the use of our CAE and CFD tools. In addition to this our consultancy projects often include elements of technology transfer where we assist our customers in understanding how to solve problems specific to their needs.
- Postgraduate Studies in Scientific Computing.
- None available at present.
- Nothing specific.
- Formal training is via Manchester University MSC in HPC.

Access to External Networks (for Collaborative work)

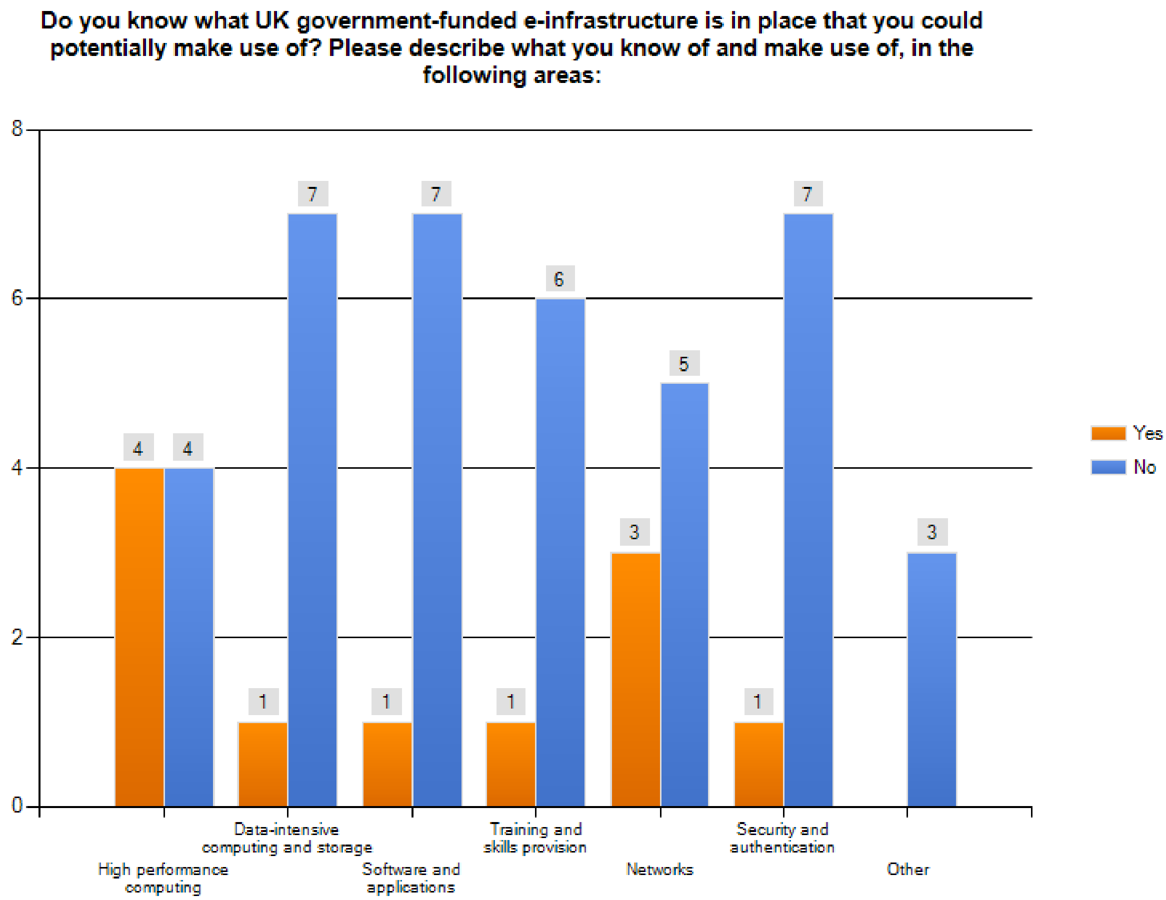
- JLR have a high speed internal Local Area Network (LAN) a high speed inter-site Wide Area Network (WAN) and an external WAN infrastructure to enable connection to external suppliers and cloud providers such as Google and TATA.
- We use leapfrog and FTP to transfer data between us and our customers, but do not have direct access to other companies IT networks.
- Ethernet interconnection to campus network.
- CFMS has numerous relationships with industrial organisations and software vendors.
- Access to the Technology Strategy Board's "_connect" system, plus various "ad hoc" systems used by other parties (e.g. "Net Meeting", WebEx, etc.).
- We have access to CPU 24/7 in Berlin and NCSA in Indiana US. We also have access to ASRC (a RR/Airbus JV in Bristol) and have accessed HECToR.

Security and authentication

- JLR have deployed physical security, access cards, RSA tokens, secure VPN technology, network security protocols with user based authentication and access control.
- OCNS security arrangements for data protection.
- I am not familiar with Altair's security arrangements - would need someone in the IT group to answer this question.
- Security standard appropriate for commercial use. Not used for secret work at present.
- Nothing specific.

- We have state-of-the-art security and authentication capability and also comply with export control regulations.

Q3:



Q4: For each element of UK government funded e-infrastructure that you use, please indicate how is it useful to you (what value do you get from using it)?

High Performance Computing

- Do not currently use but are very interested.
- N/A.
- We have done some code development on HECToR.

Data-intensive computing and storage

- Do not use.
- N/A.
- None.

Software and applications

- Do not use.
- N/A.
- SILOET is providing significant potential.

Training and skills provision
- Do not use.
- Could be useful with future business.
- N/A.
- Useful MSc course.

Networks
- Do not use.
- Useful alerts to funding, competitions, etc.
- None.

Security and authentication
- Do not currently use but are very interested.
- N/A.
- None.

Q5: For each element of UK government funded e-infrastructure that you use, please indicate what would make it more useful?

High Performance Computing
- Ability to load up and test applications on server for less cost and ability to use smaller processes sequentially for performing lots of jobs not needing highest end capacity of capability.
- On demand access to external burst HPC infrastructure (including applications and licences) with a simple and cost effective global consumption business model.
- Awareness and help with data interpretation, etc.
- Bigger clusters available to use +10,000 cpu cores.

Data-intensive computing and storage
- On demand access to software and application licences with a simple and cost effective global consumption business model.
- Awareness and help with data manipulation and transfer.

Software and applications
- Awareness of what is available and help to understand its relevance to our technological and scientific needs.
- More collaboration/sharing amongst non-competing orgs.

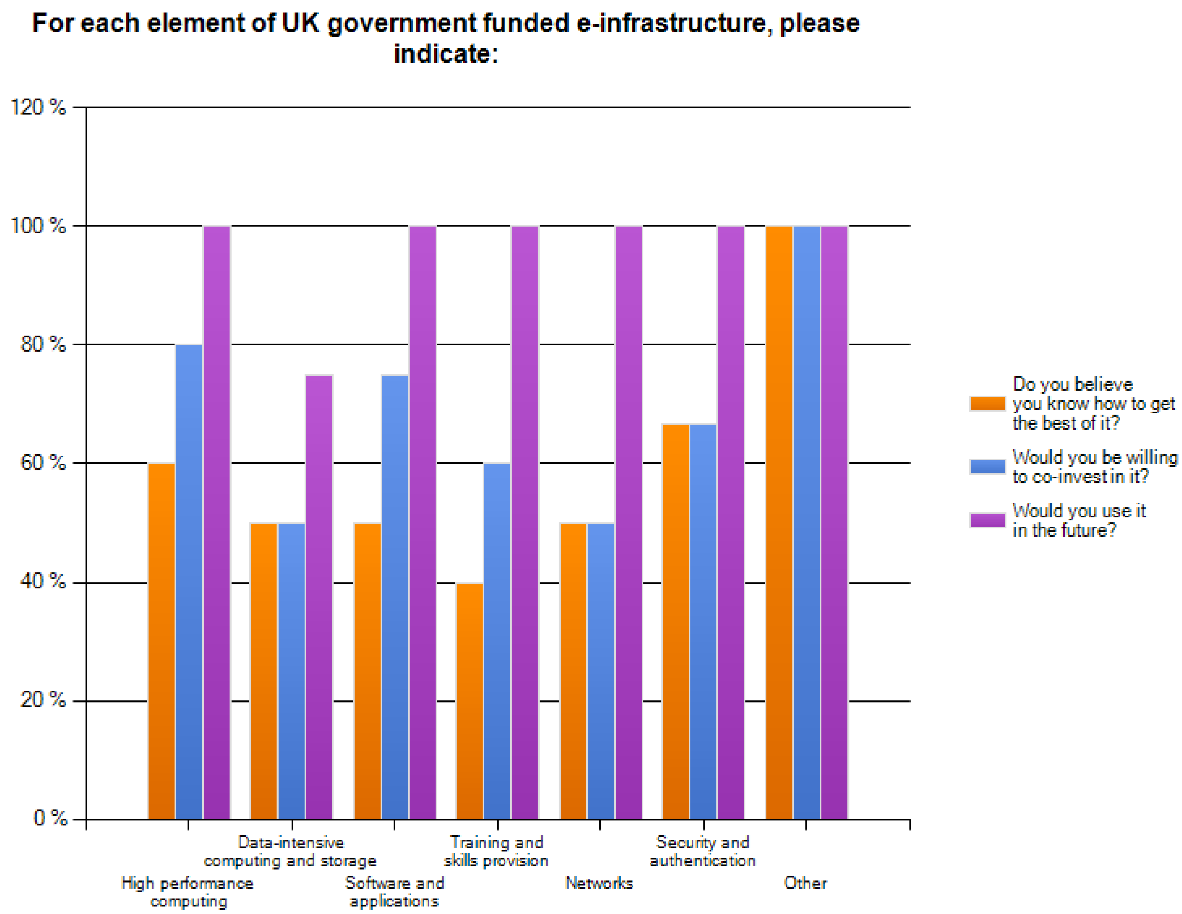
Training and skills provision
- An easier and cheaper way to host training packages that are relevant across industry, so that important training packages can be rolled out at lower cost.
- Awareness of what is available and help in specifying and evaluation training needs.
- More pro-active policies to attract UK nationals into high tech post-grad courses.
- Vital in providing the appropriate skills and training for the new starters and graduates leaving university in preparation for developing UK as a world class technology centre of excellence and innovation.

Networks
- Improved interfaces, higher bandwidth infrastructure, 4G capability?
- Faster 10G links with state of the art security.

- More secure and cost effective.
- Could become a universal tool, especially if it could support international networking.

Security and authentication
- Awareness and help with identifying relevance and need.
- Faster 10G links with state of the art security.
- Vital, this is critical to protect the UK Intellectual Property as the UK trades and manufactures with other geographical countries and regions that do not respect the same views as the UK on IP protection.

Q7:



Q8: Please describe what use you make of other, privately funded, external (to your company) capabilities/services in the following areas:

High Performance Computing
- HPC HW vendors.
- Occasionally have used T-Systems cluster in Germany.
- Trials with software providers (e.g. modelling of electrostatic systems).
- We run big simulations on non-UK HPC clusters.

Data-intensive computing and storage
- Specialised Storage vendors.

Software and applications

- Third party software developers, open source software.
- Use third party CAE tools on a regular basis.
- Trials with relevant software providers, e.g. for modelling.
- We invest in code development.

Training and skills provision

- Third party providers.
- Employees have access to external training courses.
- Training in data acquisition and control software and hardware.
- We use consultants.

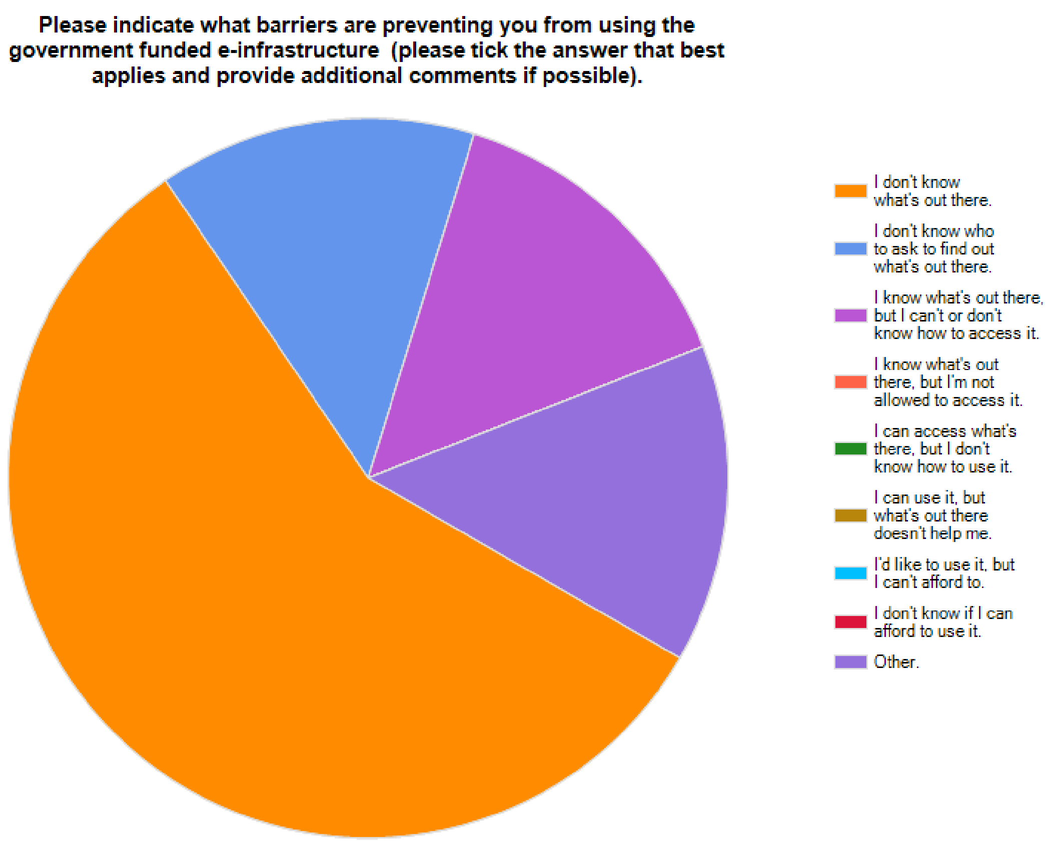
Networks

- Third party providers, cloud based services.
- "_connect"
- We invest in a global network.

Security and authentication

- Consultants.
- Indirectly via ISP provision, etc.
- We invest in state-of-the-art security.

Q9:



Q10: In relation to government-funded e-infrastructure, what do your competitors have access to that you don't?

High Performance Computing

- External Government funded/subsidised HPC capacity for production and research programmes.
- No knowledge of competitor use.
- 200,000 cores at Livermore National Lab HPC.

Data-intensive computing and storage

- External Government funded/subsidised HPC storage architecture capacity for production and research programmes.
- No knowledge of competitor use.
- Not aware.

Software and applications

- External Government funded/subsidised software and application development for production and research programmes.
- No knowledge of competitor use.
- Same.

Training and skills provision

- External Government funded/subsidised training and skills programmes for production and research programmes.
- No knowledge of competitor use.
- Not aware.

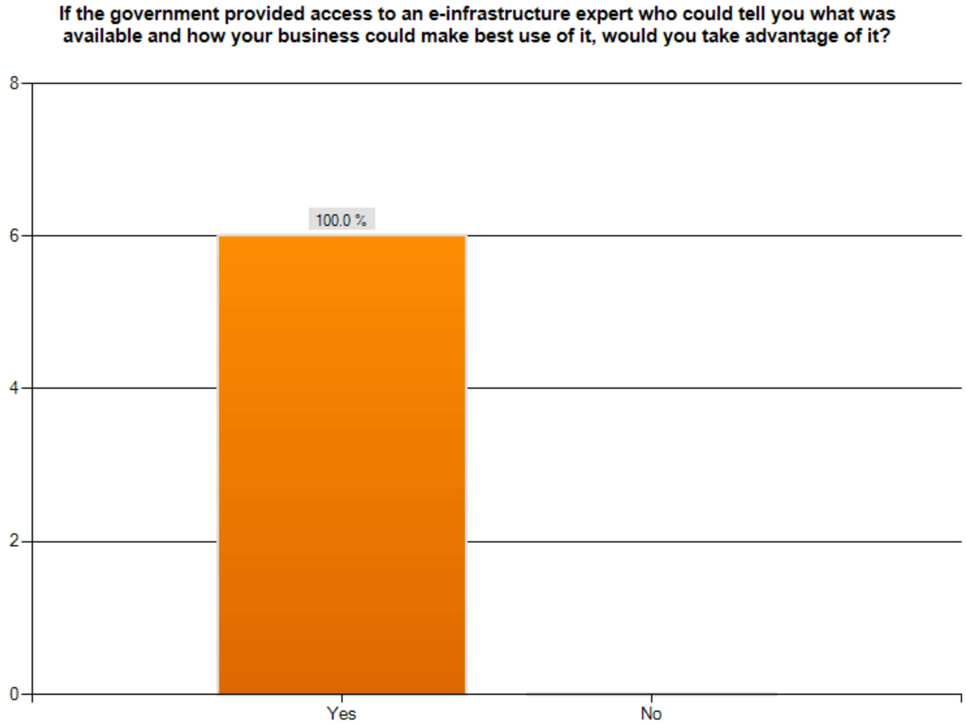
Networks

- External Government funded/subsidised High per-formant network infrastructure for production and research programmes.
- No knowledge of competitor use.
- Not aware.

Security and authentication

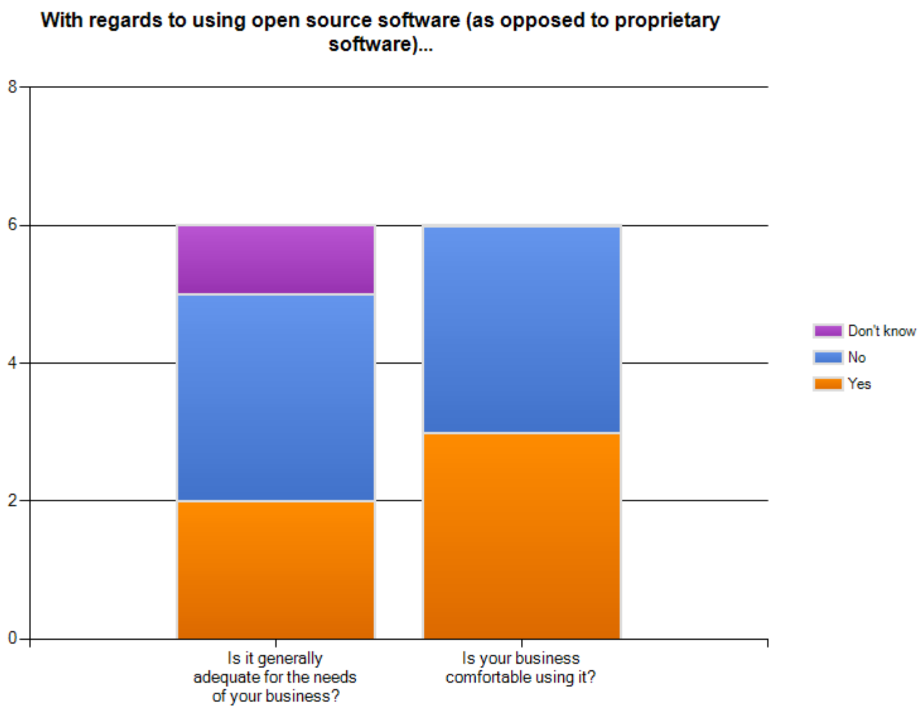
- External Government funded/subsidised security programmes.
- No knowledge of competitor use.
- Not aware.

Q15:



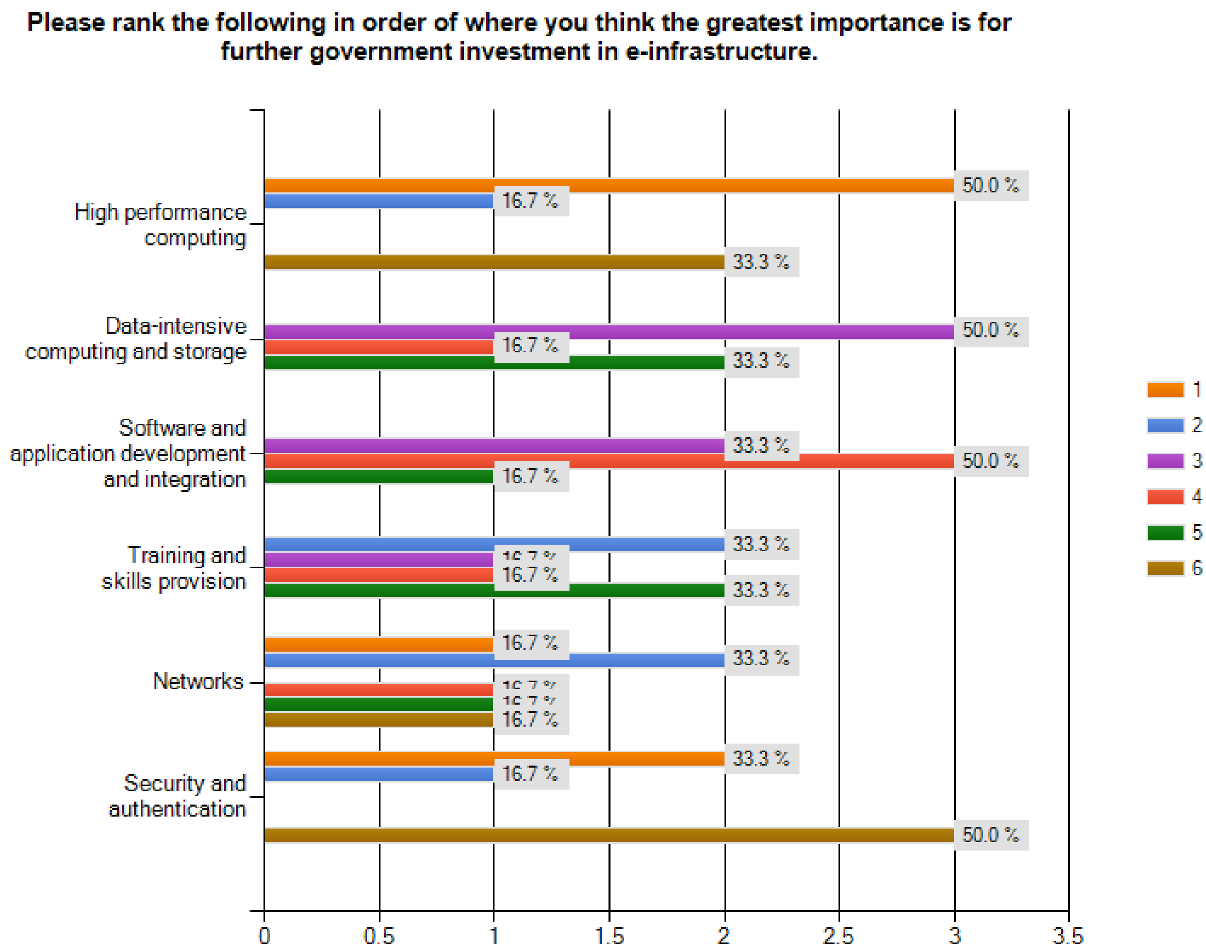
If the government provided access to an e-infrastructure expert who could tell you what was available and how your business could make best use of it, would you take advantage of it?
8
6
4
2
0
100.0 %
Yes
No

Q17:



With regards to using open source software (as opposed to proprietary software)...
8
6
4
2
0
Is it generally adequate for the needs of your business?
Is your business comfortable using it?
Don't know
No
Yes

Q18:



Q19: What can UK government do to help you - what could be provided to you RIGHT NOW to meet your immediate requirements?

High Performance Computing

- Access to cost effective on demand HPC burst capacity.
- Facilitate awareness of what can be achieved.
- Easier access to more.

Data-intensive computing and storage

- Initiate investment into a meta data model for simulation.
- Facilitate awareness of what is available.
- Access to existing experts (GCHQ?).

Software and applications

- Initiate research programmes for software and application development and investigate UK on demand pay as you go licence model for third party applications.
- Provide more resources.
- Facilitate awareness of what is available.

Training and skills provision

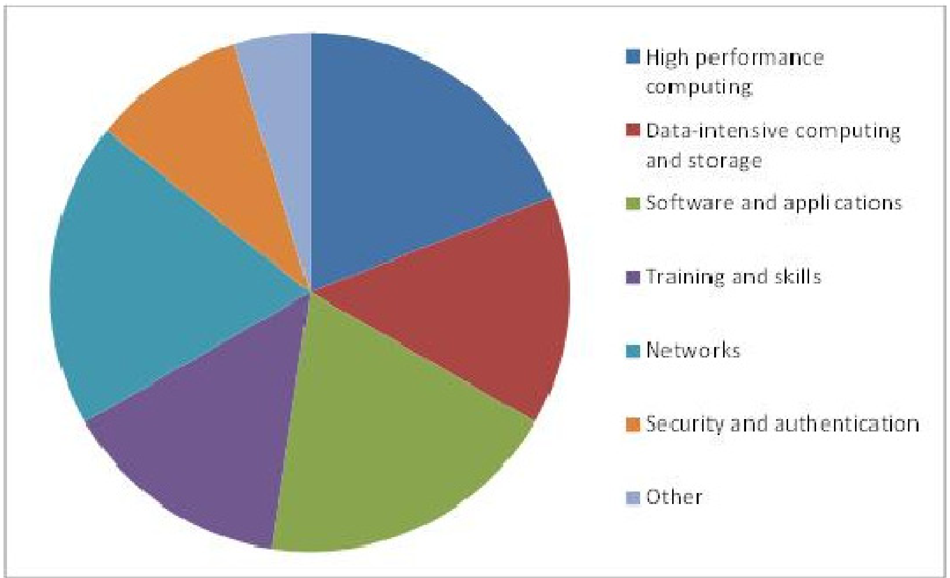
- Promote University courses to assist development of UK Technology PLC.
- Provide more resources.
- Facilitate awareness of training and match to requirements.

Networks

- Access to high speed cost effective networks.
- Increased Internet speeds.
- Provide more resources.
- Support increased bandwidth in the local area.

Security and authentication

- Formulate a security and IP investment programme for UK PLC.
- Provide more resources.
- Facilitate awareness of what is available.



Q20. What can UK government do in the medium term (1 to 3 years) to meet yourrequirements?

High Performance Computing

- Invest in UK HPC research programmes.
- Easy Access to c100,000 cores of high memory architecture.

Data-intensive computing and storage

- Develop strategy for decision support from data mining.
- Advance data mining and information management technologies.

Software and applications

- Initiate research programmes for software and application development and investigate UK on demand pay as you go licence model for third party applications.
- Provide more resources.

Training and skills provision

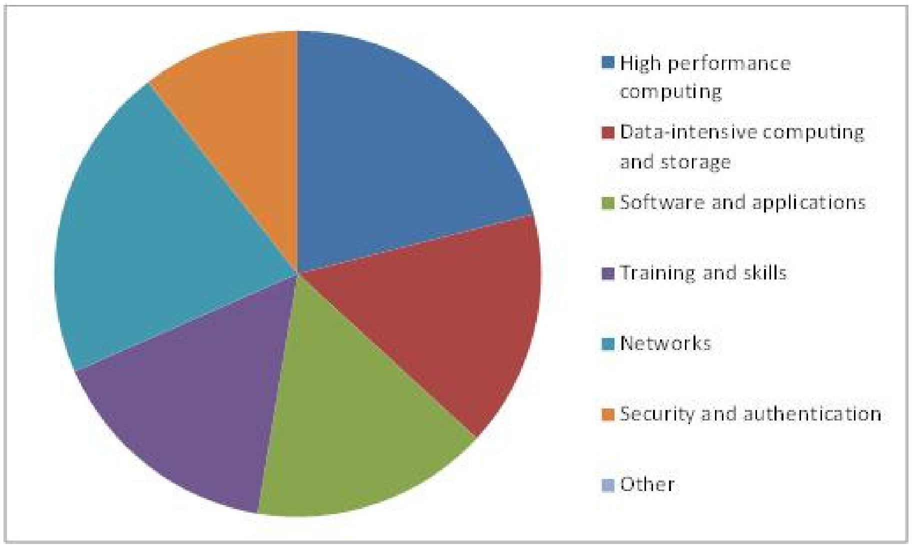
- Promote University courses to assist development of UK Technology PLC.
- Provide more resources.
- A resource pool.

Networks

- Access to high speed cost effective networks.
- Provide more resources.
- National 10G network.

Security and authentication

- Deployment of a security and IP investment programme for UK PLC.
- Provide more resources



Q21. What can UK government do in the long term (4 to 10 years) to meet your requirements?

High Performance Computing

- Invest in UK HPC research programmes.
- 1,000,000 cores?

Data-intensive computing and storage

- Develop strategy for decision support from data mining.

Software and applications

- Initiate research programmes for software and application development and investigate UK on demand pay as you go licence model for third party applications.
- Provide more resources.

Training and skills provision

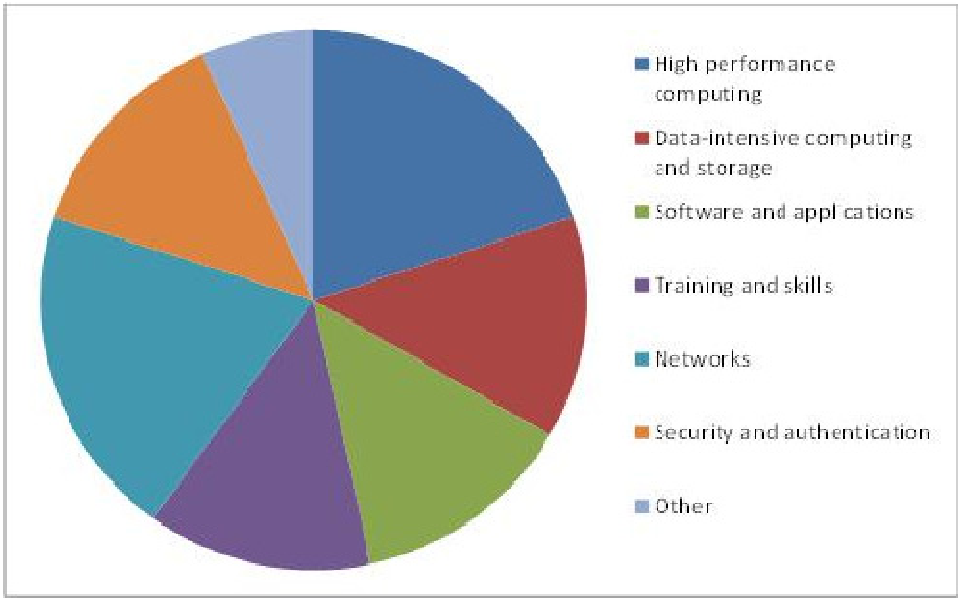
- Promote University courses to assist development of UK Technology PLC.
- Provide more resources.

Networks

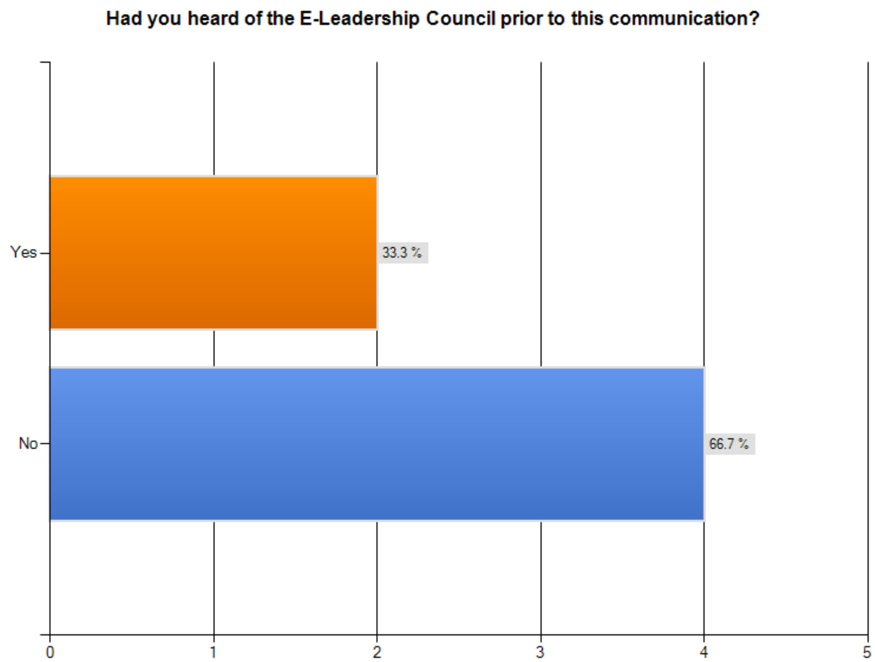
- Access to high speed cost effective netorks.
- Provide more resources

Security and authentication

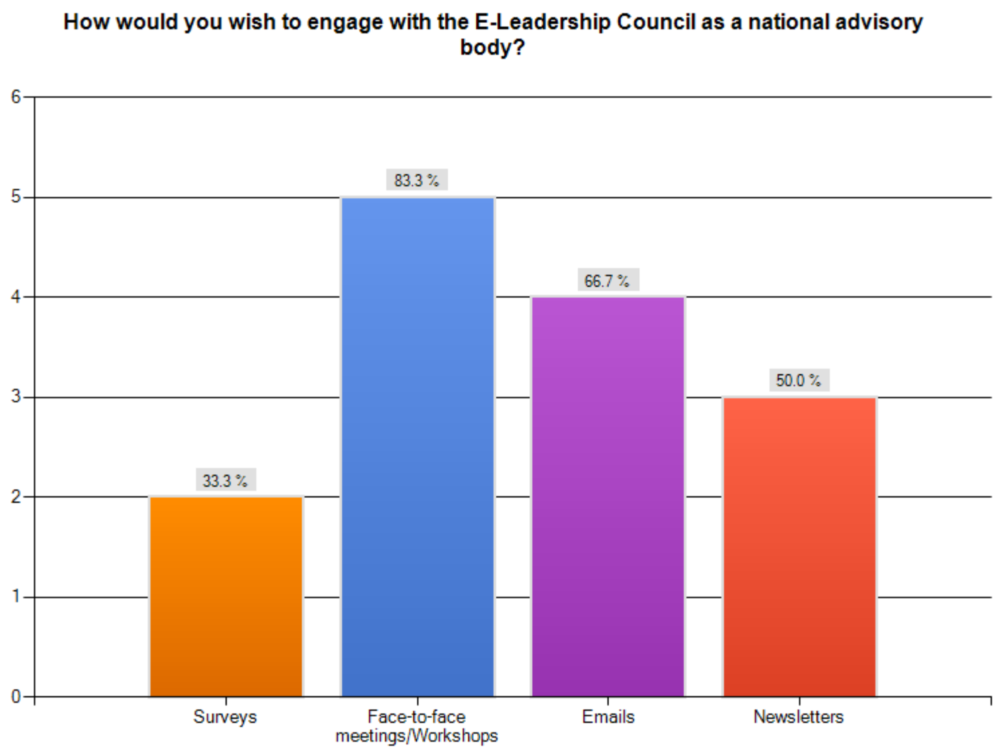
- Deployment of a security and IP investment programme for UK PLC.
- Provide more resources.



Q22:


Had you heard of the E-Leadership Council prior to this communication?
Yes
33.3 %
No
66.7 %
0
1
2
3
4
5

Q23:


How would you wish to engage with the E-Leadership Council as a national advisory body?
6
5
4
3
2
1
0
33.3 %
83.3 %
66.7 %
50.0 %
Surveys
Face-to-face meetings/Workshops
Emails
Newsletters

Q24. Is there anything else you'd like to input to the E-Leadership Council at this stage?

- I believe the ELC Engineering and Manufacturing work group should engage UK PLC with a focused activity to develop and deliver a strategy to assist UK Engineering and Manufacturing. E-infrastructure can deliver competitive business advantage.
- There needs to be an explanation of what exactly constitutes "high performance computing" etc.

Appendix B – Reference Documents

Documents and Reports

_, *A Strategic Vision for UK e-Infrastructure: A Roadmap for the Development and Use of Advanced Computing, Data and Networks.* E-science Leadership Council, November 2011.

_, *CFMS-ASRC Phase 2 2013-2016 Decision Brief,* January 2012.

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_, *E-infrastructure - Taking Forward the Strategy: Synthesis of Interviews with Expert Stakeholders.* Research Information Network, September 2010.

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_, *ICT for Manufacturing: A Roadmap for Horizon 2020*, Draft version, February 2012.

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_, *OECD Information Technology Outlook 2010 - Highlights.* OECD, 2010.

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Wallom, D.,Turilli, M.,Taylor, G., Hargreaves, N., McMorran, A. Martin, A. Raun, A., *MyTrustedCloud: Trusted Cloud Infrastructure for Security-critical Computation and Data Management.* 3rd IEEE International Conference on Cloud Computing Technology and Science, 2011.

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http://manufacturinghub.org/

http://shibboleth.internet2.edu/project.html

http://www.oecd.org/dataoecd/60/21/46444955.pdf

http://www.planethpc.eu/index.php?option=com_content&view=article&id=43:inteview-with-thierry-van-der-pyl&catid=2:news&Itemid=4

http://blogs.bbsrc.ac.uk/index.php/2011/06/e-infrastructure-networks-and-change/

http://cordis.europa.eu/fp7/ict/computing/

http://cordis.europa.eu/fp7/ict/computing/presentations/plans-wp2013.pdf

http://materialsinnovation.tms.org/resources/1108-allison.pdf

Appendix C - Stakeholders

The following list of stakeholders was taken from PlanetHPC:[41]

End users

The problem holders. These companies range from some of Europe's largest companies to some of the smallest SMEs. They are characterised by their need to solve or understand a problem through use of HPC. They may own and develop their own software applications or use applications developed by third parties. Many large companies have a mixture of in-house and third-party applications.

HPC service providers

Public or private providers of HPC system resources. The services provided go well beyond access simply to computing hardware, but include access to storage, development tools, management and accounting systems and take into account security, networking and data transfer considerations. This category includes cloud computing providers who offer HPC-like services.

Independent Software Vendors (ISVs)

Companies that provide HPC software applications to solve specific problems or tools to support HPC development. Access to such applications is controlled through specific licensing terms linking the application to individual systems and/or users. Europe has considerable strength in this area.

Research software providers

Academic and research organisations that provide HPC software applications to solve specific problems or tools to support HPC development. Often such provision is a by-product of the scientific research being undertaken by the organisation. Access to such applications is often through Open Source licensing. Again, Europe has considerable strength in this area. The use of HPC involves many different actors, each of which can benefit through collaboration.

Application experts

Companies and academic organisations that can provide modelling and simulation consultancy support to assist the end users with their HPC use, in particular with regard to instantiating models and interpreting the results. This is often a highly skilled activity where very specific problems are well understood by the organisation's staff.

HPC consultancies

Companies and academic organisations that can provide parallel computing and supercomputing expertise to application owners (end users, ISVs and research software providers) to optimise and port applications between different HPC systems.

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[41] A Strategy for Research and Innovation through High Performance Computing, Sawyer, M. and Parsons. M. , eds. PlanetHPC published by University of Edinburgh 2011, pp.28-29.