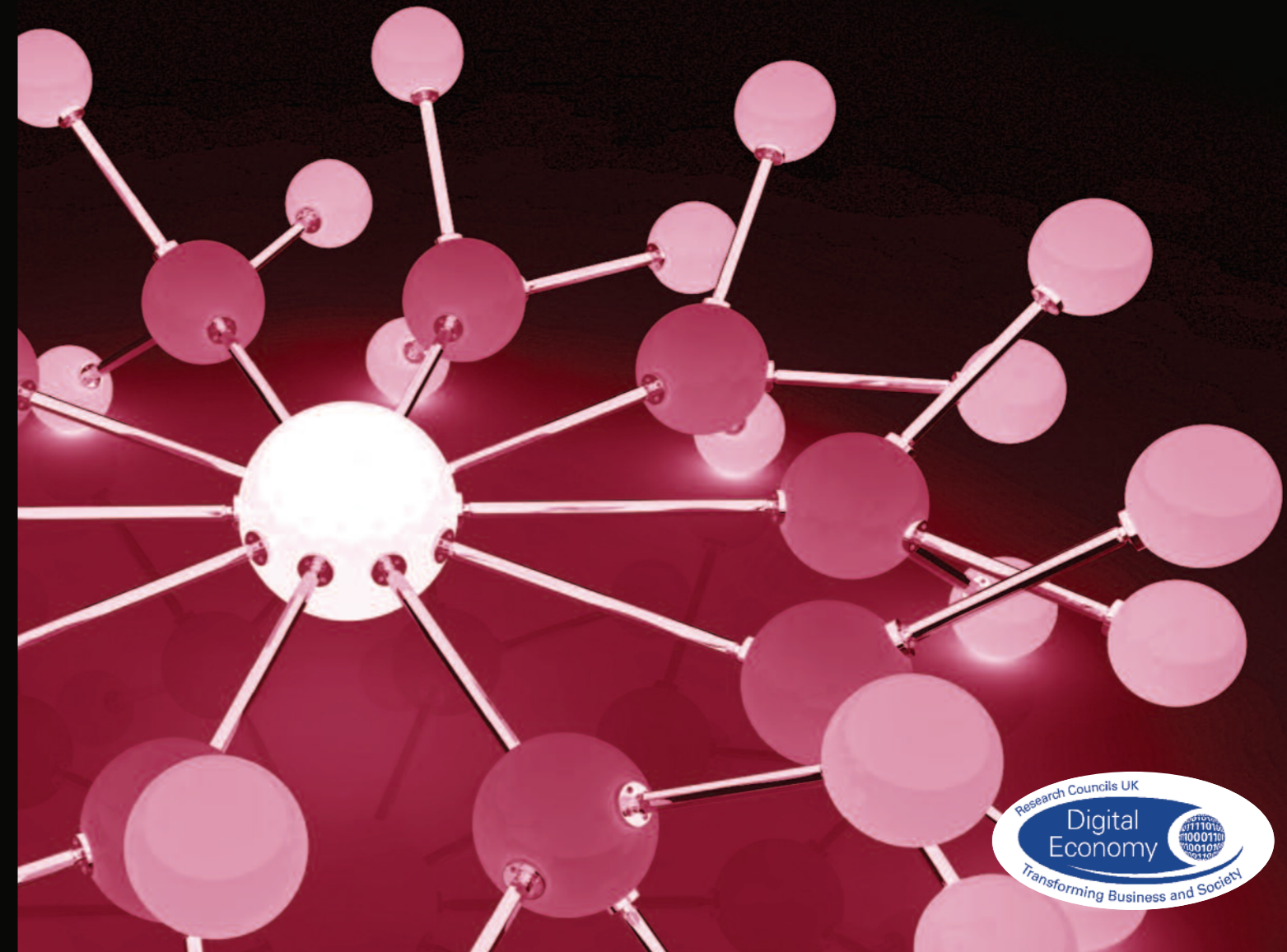**University of Salford**
A Greater Manchester University

Digital and Media Technologies:

A Review of Infrastructure Needs for Leading Edge Research in the United Kingdom

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Executive Summary

As part of the developing Research Councils UK (RCUK) Digital Economy Programme the Arts and Humanities Research Council (AHRC) has collaborated with the Engineering and Physical Sciences Research Council (EPRSC) to commission a study to review the capital needs to support leading edge research using new and related media technologies. The goals of the study are to broadly assess the current situation, identify any gaps in provision and comment on modes of support provision. Specifically, regarding the latter, to consider whether there is a need for the large-scale provision of facilities, infrastructure and equipment for particular communities over existing modes that are tied to individual research projects. The scope of the study is restricted to facilities and activity that are funded by research councils, however, some other facilities and practices are described in order to capture best practice. The study has not attempted to capture a representative picture of commercial or defence infrastructure or activity.

A set of more detailed questions have emerged through consultation:

> Is the national research infrastructure fit for the purpose of supporting the Digital Economy?

> In particular, is it relevant, reachable and usable by all the stakeholders and does it bring them together or keep them apart?

> Does it support the kind of multidisciplinary research and innovation embraced by the Digital Economy or does it trap us in the old ways of fragmented research?

> Is it flexible enough to support research into both social needs driving technology development, and technology development driving social change?

> Specifically if the answer to some of these questions is no, could this be addressed through provision of a national media lab and if so what form would it take?

> Realising the digital economy embraces the full spectrum of technology, people and services, therefore a research infrastructure is required to ensure a multidisciplinary approach can be achieved. The study has found that while infrastructure provision is broad and state of the art, there are hurdles to multidisciplinary collaborative research and multi-stakeholder innovation. People do not necessarily have access to the other people, places and infrastructure that would promote such activity. While this does not stop much good research, it does limit the relevance, impact and scale of research projects.

To give examples of this problem we consider two scenarios of international significance that are relevant to a wide range of digital economy stakeholders but where our current infrastructure may limit the collaboration between them. Social and participative media is of interest to both social scientists and technologists. It has potential to impact positively on the economy, quality of life and the environment, by allowing a wider range of people to interact in more ways without the need to travel. Exchanging views on both the 2012 Olympics and the discussion around climate change could both become a popular pass time, and some would argue that if the later does not, significant consequences will ensue. It is likely that people will discuss both of these across a range of media, such as social networking tools and blogs, and using a variety of devices, such as computers, interactive television and mobile phones.

There is significant research that should be done, for example, around the provision of new services and the study of social change. Consider for example the 2012 London Olympics. This is a global event, being hosted in the UK that will have a significant economic impact and needs to demonstrate a lasting national legacy. The Olympics is also an increasingly significant digital event not only encompassing the distribution of media but also, for example, electronic ticketing and social networking dialogue. New technologies and services will be delivered and deployed in 2012 but these will inevitably have been developed on a distributed and disconnected research infrastructure that will hinder the true potential of what can be achieved and hence, potentially impact the lasting legacy. Had an integrated research infrastructure existed then this would have facilitated a greater level of engagement by the academic and commercial communities that would not only better enable a multidisciplinary approach but would also have better addressed issues of scalability and compatibility. That in turn would have ensured a more efficient transfer of research to commercial reality and potentially produced a higher quality outcome. Countries that excel within the digital economy will be those that are able to bring together technical research with sociology and industrial knowhow to produce solutions that are truly fit for purpose. Time and time again it has been demonstrated that the most technically advanced hardware does not necessarily produce the best commercial products (e.g. VHS versus Betamax) and equally, the most successful services are often never appreciated beforehand (e.g. SMS text messaging). Working within isolated pockets of excellence is not an optimum model for the UK to become globally competitive within the digital economy. While a testbed in one university lab might allow people to interact in numerous ways between say mobile phones and TV's. The psychologists wanting to study how people interact across it may be in a different university. Furthermore, what is found to be true in a university lab often does not translate when deployed to the larger and more complex real world. Had our testbeds been interoperable and capable of pervading not only the nation's laboratories but the nations itself,

the impact of the research would have been far greater. Whilst the scenario of the Olympics may represent an opportunity lost, climate change represents an a challenge that must be met. Climate change will itself be an important driver within the digital economy requiring new digital technologies to be developed, new ways of gathering, processing and presenting data to be realised and new social paradigms to emerge. These can only be achieved with the underpinning of an appropriate national research infrastructure. We need to bring together the people including users, researchers, industrials, and policy makers. An integrated tested infrastructure is needed to develop and evaluate new technologies and ways of processing information that can then be assessed within living labs and tested for scalability. Location is important for different places are impacted by their local environment which could mean that a service that works well in the South East simply does not translate to the North West. Finally, new online tools are required which enable people to better understand their role within the overall climate change debate, for them to engage with that debate and to effect behaviour change in a constructive and willing manner. All of these factors simply cannot be adequately addressed or realised with our current approach.

Recommendations

To address the concerns of fragmentation and access, along with the detailed considerations at the end of this executive summary, our primary recommendation is that:

The Digital Economy research program would benefit from a digital research environment

By digital we mean a metaverse that brings the people of the Digital Economy to the real and electronic places where they can best innovate together, underpinned by the interoperable testbeds and online tools. This would link laboratories, social places and people who may be at these, at home or on the move. Rather than favouring one or a few groups or places while excluding many other others, this could leverage the majority of Digital Economy research across the UK. This would bring together people and places across the country, supporting collaboration across a meta-testbed that hosts online tools across a full range of ubiquitous and specialist devices. People would include researchers, developers, innovators, exploiters, owners and beneficiaries. Places would include large facilities, sites engaged in digital hubs and post doctoral schools, media cities, living labs and specialist labs open to the digital economy community. An evolving set of online tools would include Internet and broadcast based media, for example video, 3D video, 3D CGI, Audio and 3D audio, media tools, for example editing, and social and collaborative environments to support distributed research and collaborative bidding. Test beds would be situated within and across the places, supporting pervasive and ubiquitous networking accessed through a large variety of media devices, from phones to

large screen public displays, allowing them to routinely connect to large scale computation and storage. All orginisations of computing would be supored including cloud, parallel and clouds of parallel groups etc. It is suggested that this could be called the Digital Media Lab of the Digital Economy.

The purpose would be to provide fair, open and routine access to places, people, digital resources and equipment spread across the digital economy. While there are many reasons to have a UK Media Lab to support the digital economy, there is little support for this being in one physical location, and location based facilities suffer problems of participation and sustainability. Indeed, having a media lab which was not digital seems to fly in the face of the Digital Economy, whereas a digital media lab would be a flag for the Digital Economy to fly.

Digital Media Lab UK

People

**Researchers
Users
Innovators
Exploiters**

Places

**Specialist Labs
Digital Hubs
Large Facilities
Living Labs**

Testbeds

**Ubiquitous Devices
Cloud Computation
Pervasive Networks
Storage Farms**

Online tools

**Collaborative
Social
Media
Media Tools**

1. People
> People should be given support and encouraged to use and contribute to Digital Media Lab.

> Even encouragement should be given to all classes of stakeholders: Researchers, developers, exploiters and users.

> People should be given routine and flexible ways of working with other's regardless of being in the same location or not.

> Online tools should be easy to use and training should be offered.

> The choosing / development of these tools should be supported along with their deployment and ongoing support.

> Ubiquitous access that pervades the places the people live, go an work, should be supported through properly supported testbeds.

> Mobility grants and workshops could help define what is needed.

2. Places
> The set of connected places should encourage the full diversity of Digital Economy activity.

> Places must have a tangible and unique contribution to the program.

> Some will support Interdisciplinary and full stakeholder involvement.

> Others will support specialist activities.

> Testbeds should provide ample resources and use to the online tools, and through them access to other people and places, within the physical places.

> Physical places should fit a local niche or unique environment and may contribute to a wider need.

> Widening access to existing and future physical laboratories should be encouraged and supported.

> Facilities should advertise and where appropriate provide services through the Digital Media Lab.

> Facilities must be provided with adequate staffing to become routinely usable by a range of researchers, exploiters and end users.

> Sustainable business models must underpin this.

> Research councils should consider contributing to the initial costs not only of installation but of staffing needed to reach a point of sustainability.

> Cases for ongoing support from the Research Councils would need to be backed up through demonstrable uptake.

3. Testbeds
> Physical network test-beds are beneficial and perhaps necessary in supporting Digital Economy research.

> These will provide the networking, computation, interface devices (including sensors) and data storage upon which the tools to support Digital Economy activity are ubiquitously available to the community.

> A testbed might cover a university lab or campus, or a science park, living lab or media city.

> These must be integrated, interoperable, scalable and funded in such a manner to ensure long term sustainability.

> They should exploit existing national infrastructures.

> The Last Mile access needs to be addressed as part of the test-bed.

> Regulatory issues need to be resolved to provide an open platform in terms of who can access it and what services are allowed to be delivered over it.

> The creation of these test-beds must be carried out within a partnership model that includes academic and industrial participants.

4. Online tools
> The range of collaboration tools should be capable of scaling to include CSCW, Video-conferencing and collaborative virtual environments.

> Social tools should help people build communities. The range should scale to forums, discussion boards, social networking tools, like facebook, and social virtual worlds like secondlife.

> The set of supported media should be able to evolve to include broadcast and internet distributions of audio, video, 3D Video and 3D CGI.

> Media editing tools should be sufficient to support the usual content creation and production tasks for each of the supported media.

Detailed findings

In summary, we found:

> Media needs to be understood as part of what the Department for Culture, Media and Sport (DCMS) defines as the 'cultural industries', which includes advertising, architecture, arts and antiques crafts, design, designer fashion, digital and ICT, music, publishing, radio and television, software, computer games and electronic publishing, video, film and photography, and visual and performing arts. However, though media is undoubtedly an extremely significant part of a wider culture industry, it is also a major and meaningful part of our wider social life.

> It is incredibly difficult to articulate what counts as 'infrastructure'. This is evident in our review of extant facilities and research in the area. Indeed, to further complicate matters, definitions of what should be included under the heading of digital media are also difficult to construct. In this document we use the term research infrastructure to mean the physical, technical and virtual facilities that are available to support publicly funded research.

> In surveying Media and the Humanities it is necessary to recognise that such activity is widespread across the UK. Indeed, if we use the 2008 Research Assessment Exercise (RAE) results as a broad indicator of activity, then the Communication, Cultural and Media Studies Unit of Assessment received 47 geographically dispersed submissions including, for example the universities of Ulster, Cardiff, Sussex and Glasgow. The Library and Information Management (21 submissions) and Computer Science and Informatics (81 submissions) Units of Assessment were similarly geographically dispersed.

> There is a good range of media technology across the UK and the country is generally well provided for in terms of underlying network, computer, production studios, visualisation facilities and video conferencing. Yet, it is notable that our world share of super-compute seems to be falling rapidly. While it is harder to find details of many smaller facilities, most of the universities we looked at had a mix of workstations, media software and cameras. The greatest lack in provision seems to be in supporting a wide range of researchers to access and routinely use specialist facilities and places and to work together.

> It would seem helpful to offer a directory of research and research infrastructure across the UK and the terms under which it is accessible to others within and across Higher Education Institutions (HEIs) and industry. However, an issue with this is the rapidly evolving nature of research and infrastructure and the possibility of keeping such a database up to date.

> Many existing media based laboratories are both under utilised and have the infrastructure capacity that could support a wide range of digital economies research. Many digital economy researchers would benefit from using them and are held back by not having access to such technology. There is a clear potential to better utilise existing and future generic media infrastructure for a wide range of digital economies research.

> For a facility to be used routinely by non-experts, the functionality that they require must work without technical hitch and help in understanding how to use it must be routinely available. Non-expert users will not take up a technology for which much of the required functionality is not working, or fails regularly, or if they cannot get the help to get started or overcome simple problems.

> The majority of university research facilities are supported through part time and ad-hoc input from academics, researchers and postgraduate students. Usually all of these people have full time responsibilities outside of supporting the facility and its uptake. There is a need for joined up thinking between the funding of facilities and the funding of research which uses them. If a case can be made for existing or future media facilities supporting an open door policy to digital economy researchers and there are those that would make use of this, supporting the staffing for this might make more sense than spending yet more money on under utilised equipment.

> In terms of sustainable uptake of infrastructure, while there are examples of good practice in research, there is much to learn from the web and media industries. Shining examples like YouTube and the BBC's 21cc work because they are easy and fun.

> If the UK is to be at the forefront of science then it should be building facilities that define the state-of-the-art. However, this introduces risk into procurement, commissioning and uptake. Most media laboratories that attempt to define state-of-the-art take around two years to fully bed in. From talking to the administrators of five of the countries top visualisation centres and two advanced ubiquitous computer labs, only the simplest had reached a state reasonable functionality and reliability within two years of commissioning.

> Attention needs to be paid to the location of research, whether physical/virtual, formal/informal. A mix of locations is important to the research community. However, it was also recognised the increasing shifting of research from 'controlled" labs to living labs and research in the wild, combined with increased needs for user engagement represent several challenges for infrastructure deployment and usage.

> Leading researchers are not always located alongside the 'best infrastructure'. It does not always follow that leading researchers should be co-located with the 'best infrastructure' though. Benefits could be realised through locating infrastructures in proposed areas of development for example.

> The world is not flat but spiky. There are places of expertise and opportunity spread across the country. There is potential to innovate in places where all the stakeholders go. At the same time there is still need to carry on methodical research in laboratory conditions. There is a need for greater interaction between the spikes and greater mobility of researchers around them.

> There has been a strong trend towards research in the wild, embodied through initiatives such as the living labs. Living labs in particular fit the nature of the digital economy by encouraging multidisciplinary research, exploitation and use in the places where all the stakeholders go. However, even living labs seem to be stalling and the living labs consortium is reportedly looking at integrating their real places into a virtual metaverse to get the ball rolling again. Furthermore, there remains a strong need for constrained laboratory conditions that are arguably best supported in the institutions where they are most regularly needed.

> There is no standard format for successful information communication technology (ICT) Clusters/Media Cities although the most successful ICT Clusters/Media Cities seem to be embedded within their region, in addition to partaking in the global market. They also appear to be focussed on a regional niche.

> There is significant latent capacity in the underlying network that connects the universities. However, there is no standard mechanism for extending this to places outside university. Large scale ventures such as living labs and media cities need prolonged negotiations with network providers and commercial partners.

> The potential need for higher bandwidth saturation across the Janet network brings to a head the issue of quality of service and Quality of experience both issues the Internet television companies and ISPs. The capacity of the bandwidth available is not the only challenging factor to a more flexible high bandwidth research net-work environment, one which will need to integrate Optical switching, DWDM and maybe an MPLS switching structure. New forms of differential switching and rigorous QOS standards would enable not only the bandwidth and capacity for UHDTV but also enable the challenges of 3D feature manipulation and recording in realtime across networks. Which will expand in its research scope over the next few years.

> An interesting conundrum is that the lack of funded articulated infrastructures limits the potential of high bandwidth complex research enterprises. The media and digital research areas use of evolving infrastructures, specifically IT & IP heavy systems, then define as a fundamental tenant the challenges embedded within the design and implementation of infrastructures with enough scope, ability and upgradeability to act as the bedrock to build an academically robust research mechanism in the future.

> Physical network test-beds are essential for supporting the digital economy research but these need to be integrated, scalable and funded in such a manner to ensure long term sustainability. These test-beds should exploit existing national infrastructures, but last mile access needs to be addressed as part of the test-bed, and regulatory issues need to be resolved to provide an open platform in terms of who can access it and what services are allowed to be delivered over it. The creation of these test-beds must be carried out within a partnership model that includes academic and industrial participants.

> The provider of the joint academic network have suggested that they would be happy to look at providing greater connectivity to selected projects in the digital economy, such as supporting or interconnecting hubs or post-doctoral schools, if asked.

> With rapidly changing research and its requirements for infrastructure, coupled with the time it takes to get a facility off the ground and widely used, we need to future-proof major investments in infrastructure. We need to plan to future-proof our research base to ensure that we are able to integrate new interests of society and place us in a position to appropriately respond to new research questions, challenges and opportunities.

> Rapidly changing equipment, technologies and performance is inherent in this domain: labs, funders and commercial partners need to ensure that we carefully consider the merits of buying equipment over 'hardware-as-a-service' approaches (i.e. renting computer clusters, nationally, probably much more cost-effective and resulting in greater utilisation). As such cloud approaches develop, along with 'software as a service', this extends into the software arena too. However, there will remain a strong need to support special equipment, special places and special people that cannot be met solely through standard services. Furthermore, while the e-science GRID has provided routine remote access to super-compute for all researchers, relatively few use it in preference to buying powerful personal computers.

> While physical laboratories are essential to today's research, the approach of carrying out the nation's research solely in physical laboratories is entrenched in problems of location and ownership which, enflamed by difficulties in sustainability, lead to poor levels of access and utilisation.

> Our research and the research community are in agreement regarding the importance of interdisciplinary activity and the challenges that this creates. Many universities have, or are choosing to specialise in specific areas and thus we cannot and should not try to co-locate all research activity solely in large physical labs as this will always exclude. It is also necessary to recognise that expertise and facilities may be located elsewhere in the world. This mitigates against the idea of physical centralised provision. Indeed, the one thing that everyone we have engaged with throughout the study agreed upon is that centralised provision of a physical laboratory is not preferable.

> An approach to widening access to people, places and technology resource, that avoids many of the problems of centralised and physical facilities, while providing flexibility for the future, may be to provide a virtual research environment across the country's infrastructure. If we to have one Digital Media Lab. Let it be truly digital.

Moving Forward

We propose that a network or working group and a Sandpit are organised to allow the digital economy community to take the above recommendations forward.

Introduction to the study

As part of the developing Research Councils UK (RCUK) Digital Economy Programme the Arts and Humanities Research Council (AHRC) has collaborated with the Engineering and Physical Sciences Research Council (EPRSC). This study is primarily concerned with the provision of support for undertaking new research rather than on support for the archiving, preservation or digitisation of the outcomes of previous research.

The aim of the study was:

"to review the capital (equipment, facilities, infrastructure) needs to support leading edge research using new digital and related media technologies and identify any significant gaps or unmet needs which require investment by the Research Councils to supplement current provision and funding sources to enable UK research leadership in the field. As a part of this one option which should be considered is whether there is a case for the Research Councils to provide additional support for the development of 'digital media laboratory'-type research facilities or similar research resource facilities in the UK."

The focus of the study was upon:

"whether there is a need for large scale provision of facilities, infrastructure or equipment as a research resource to support innovative high quality research by relevant research communities rather than on the equipment needs of individual projects which can be met through existing grants provision unless a case is identified for considering that current provision met through project funding could be met more efficiently and effectively through provision of some common facility or provision."

Further, a key focus upon the research needs of the arts and humanities and engineering and physical science research communities was requested with the needs of other research communities and opportunities for inter-disciplinary research being considered as appropriate. Additionally, it was requested that opportunities for collaboration with non-academic organisations be considered where appropriate.

How New is New?

From around the late 1950s and 1960s the idea began to emerge that we were shifting into a new historical period, characterised by new forms of society and culture, based around new information and digital technologies, and the importance of the transfer and ownership of information and knowledge. In particular, the Austrian Economist Fritz Machlup in 1958 suggested that we were witnessing a shift towards a 'new economy', based around 'knowledge industries'. Similarly, in 1968 Peter Drucker noted the shift in employment trends away from 'manual' labour towards 'knowledge work'. From this point on, theories of a new 'information society' began to grow and develop, most notably with the rise of several new technologies in the 1990s, such as the advent of the Internet. However, it is prudent to be cautious of this (so-called) digital or information revolution. The term 'digital' simply refers to information transmitted in binary-code, which is far from new, and dates back to signal beacons (which were either off or on) if not before. Similarly, much of which is hailed as 'new' in the media, such as the Internet, is simply recombinants of 'older' media forms, such as text, images and videos. But what is undoubted, is that new communication and media technologies have increased the power and reach of media and the cultural industries in our everyday lives.

Understanding the Digital Media Context

In recent decades the mass media has undergone a digital revolution. Often a distinction is drawn between so called 'old' media forms, such as television, radio, and print publishing, and 'new' media forms such as the Internet, digital games, mobile telephones. But of course, these 'older' media forms have seen their nature and contents shaped by new digital technologies. Who can ignore such developments as digital television and radio, YouTube, 360 degree programming, the Blogsphere, ebooks and Wikipedia. As the Department for Culture, Media and Sport (DCMS) report Creative Britain argues:

Rapid progress in digital technologies is changing the way information is produced and exchanged in the economy. New and increasingly affordable software formats, innovations in hardware and faster broadband are challenging business practices. Convergence is muddying distinctions between publishing, broadcasting and telecommunications. Some consumers – increasingly able to access content through multiple platforms – are pushing hard at the boundaries between production and consumption of content. These developments have profound implications for the creative industries – most obviously in the advertising, film, television and radio, music, software and games sectors (p.36).

Media thus needs to be understood as part of what the DCMS defines as the 'cultural industries', which includes advertising, architecture, arts and antiques crafts, design, designer fashion, digital and ICT, music, publishing, radio and television, software, computer games and electronic publishing, video, film and photography, and visual and performing arts. However, though media is undoubtedly an extremely significant part of a wider culture industry, it is also a major and meaningful part of our wider social life.

In surveying Media and the Humanities it is also necessary to recognise that such activity is widespread across the UK. Indeed, if we use the 2008 RAE results as a broad indicator of activity, then the Communication, Cultural and Media Studies Unit of Assessment received 47 geographically dispersed submissions including, for example the universities of Ulster, Cardiff, Sussex and Glasgow. The Library and Information Management (21 submissions) and Computer Science and Informatics (81 submissions) Unit of Assessments, also of interest, were similarly geographically dispersed.

Media Fragmentation

The media industry is fragmenting due to current and potential future innovation and this is leading to a demand for a large number of smaller multimedia organisations. The continued digitisation of the multimedia industry has seen the number and types of multimedia programmes increase by an order of magnitude. Furthermore the different types and flexibility of digital transmission of media (e.g. satellite, cable, terrestrial, Internet, WLAN, Cellular and so forth.) has facilitated diversification of multimedia programmes from standard definition TV to high definition TV and mobile definition TV and more. For example today Italy has 1500 TV channels that earn 2.5 billion euros and that can be divided into three categories, on the basis of the six platforms currently available (DTT, IPTV, Sat-TV, Web-TV, Mobile TV on the DVB-H network and on the mobile network): 444 can be received via the TV set (Sofa TV), 812 on the Internet (Desktop TV) and 151 on the mobile phone (Hand TV) (Friday Files, 2007). Many existing multimedia organisations have found it very difficult to keep up with this incredible pace of change and this is resulting in the emergence of a plethora of small and medium sized specialist multimedia organisations. These new organisations specialise in the type of media they create for example educational, entertainment, game, advertising, drama, edutainment, film, 3D and so forth. Smaller specialist companies require multimedia designers who understand the fundamental design processes of all types of multimedia and broadcast media and are able to design with more than one type of the main media genres namely: audio visual, 2D/3D graphics/animation, interaction and interactive applications e.g. games, e-learning etc. The growth of these multimedia design companies means that there will be a growing demand for creatively talented and technically cognisant skilled professionals who have and who have the potential to conceive creative media through the synergy between technology and art.

Adapted from correspondence with Prof John Cosmas, Brunel University

Provision of Media Research Infrastructure in the UK

Methodology

Digital economy research should bring together those that use the technology, those that develop it and those that study its use. A strategy for infrastructure provision that does not consider the balance of these three strands is unlikely to result in wide, effective and sustainable utilisation. Thus, the consultants enrolled on this project represent Art and Design, Computer Science, the Creative Industries, Cultural Studies, Digital Media, Information Systems, Media and Sociology. In order to fulfil the aims of the study, the team developed the following set of research questions to guide the study:

> What do we mean by infrastructure?
> What do we have at present and how well does it work?
> What works/does not work internationally?
> What forms might infrastructure take in the future and how might it be provided?
> What do current non-users of infrastructure have to say about provision – now and for the future?

Whilst data collection was guided by this research framework, and of course the overall aims and focus, our approach was revised through the research process accordingly, in the light of the data obtained and its interpretation. This allowed for corrections in the trajectory of the research to be made in a very agile way leading to high quality output in an efficient fashion. To ensure the quality of the process and content of the work, regular reviews within and beyond the consultancy team have been undertaken. This was undertaken via follow up emails, telephone calls, and interviews. In order to widen participation and undertake the review in a transparent way, a web site, wiki, workshop and email discussion were organised and advertised through the EPSRC's Digital Economy email list.

The study is, as expected by the brief, based primarily upon desk-based research. This involved the review of a variety of UK oriented digital media related reports, RAE 2008 submissions for Unit of Assessment 66 - Communication, Culture and Media Studies, the assessment of media cities around the world and a web based survey that mapped current infrastructure provision to the themes of the digital economy. Details of this pool of data can be found in the references section of this report and on a wiki which was set up for the study – http://octave.salford.ac.uk/DEIwiki The digital economy community were invited to look at and contribute to the wiki through both the scoping study web site:

http://www.digitaleconomyinfrastructure.salford.ac.uk

And a mail-shot from the EPSRC to their digital economy distribution list. We stress that the survey, and its data organised on the wiki, offers a flavour of the mix, distribution and trends rather than a definitive list. The wiki categorises and details and/or links to: 4 Media labs, 21 Living Labs, 15 digital economy doctoral schools, 6 supercomputers, 36 GRID projects, 15 large facilities, 6 large

research centres, 38 distributed High Performance Computers (HPC), 281 Access Grid nodes, 42 modern Virtual Reality (VR) systems, 25 UK institutions and 4 national centres and networks, engaged in arts humanities and media research. To supplement this desk-based research, we held a digital economy community focused workshop in February 2009. The invitation to this event was open and distributed via the EPSRC's Digital Economy email list. The workshop was attended by 26 people. Twelve where stakeholders from academic institutions across the UK; two were from industry; one a planner of regional infrastructure; two from the research councils, one from AHRC and the other EPSRC; two from the MEDIACityUK team; seven our own consultants. From the workshop we were able to develop an interim report which was circulated via the to EPSRC's Digital Economy email list for comment. The report was also sent for review to an independent consultant.

The Structure of the Report

The remainder of the report is divided into five key sections. The first deals with the existing provision of media research infrastructure in the UK. This section begins with highlighting the difficulties in defining, and finding, existing digital and media infrastructures, but suggests that it would appear that across the UK universities do have a variety and varying degree of available resources and facilities. This section highlights and discusses some of these infrastructures under the heading of 'living labs', 'processing', 'network capacity', 'test-beds', and 'video conferencing' as well as commenting on 'underlying consumer trends'. The following section provides an overview of digital and new media and related research at UK-based HEIs. The next section contextualises infrastructure provision in a global perspective, and considers the relative importance of 'New Century City Developments', such as Seoul's Digital Media City Project. The section 'Considerations for Infrastructure Provision' specifically reflects upon the research evidence and opinions that have been garnered in constructing this report, and considers various forms of infrastructure and possible ways forward for continued and new provision. These findings and recommendations are then drawn together and reflected upon in the final section of the report, the conclusion.

Media research infrastructure scales from a mobile phone used to capture and upload video to YouTube, to large multi-modal immersive display and capture facilities. We carried out a web-based search on media-related facilities both in the UK and across the world, but of course, some kinds of infrastructure were easier to find than others. While most (if not all) universities in the UK would have labs of personal computers running media applications and many with a range of cameras, microphones, speakers and screens, these kinds of facilities are often not broadly advertised. In contrast, large visualisation facilities and supercomputers are much easier to find on the web.

In general our survey found that there is a good range of media technology across different labs in the UK and that the country is well provided for in terms of underlying network, computer, production studios and visualisation facilities and video conferencing. It is notable that our world share of supercomputing seems to be falling rapidly. While it is harder to find details of many smaller facilities, most of the universities we looked at had a mix of workstations, media software and cameras. The greatest lack in provision seems to be in supporting access and use of specialist facilities for a wide range of researchers. What follows comprises an overview of the existing provision of media research infrastructure in the UK.

A Cross Section of Media Facilities and Equipment in Higher Education

To support the claim of the UK having a good range of media technology across different labs we now look at a number of examples. While not being a comprehensive list, the following provides a fairly representative set of the mix of facilities used for media/humanities research. Nottingham's Mixed Reality Lab (MRL) is a clear example of good practice in supporting media based work for the digital economy. MRL has received funding for both a digital hub and a postdoctoral school from the Digital Economy program. The lab, which was funded through both rounds of HEFCE SRIF investment, is an excellent example of how technology can pervade into everyday things. Much of the equipment is relatively low cost but is used and incorporated in highly intuitive ways. The lab has more mobile and potentially ubiquitous equipment than large facilities but does have a panorama projection wall. The Dap-lab at Brunel University has a studio environment, equipped with digital software that responds to body movement and sensory processing. University of Bradford has a variety of labs for computer games, graphics programming and video editing. Equipment includes Minidress's Cameras, Minidisk Recorders, digital cameras, mobile phones, PDAs, laptops, data projectors, tripods, a motion capture system, scanners for film, slide and print material, Macintosh workstations with Apple Cinema displays, image processing and industry standard compositing software for photography, video, 2D & 3D animation. Large facilities include production spaces and a photographic studio. Cardiff University Department of Journalism, Media and Cultural Studies is equipped with CoolEditPro for the

broadcasters, QuarkXPress on Apple Macs and InDesign on PCs for print journalists. Large facilities include newsroom and broadcast facilities and radio and television studios. De Montfort University Institute of Creative Technologies has equipment that includes 20 Microsoft Windows and Apple Mac works stations running 3D software such as MAYA, 3DMax, Multimedia software such as Adobe Dreamweaver, Flash, Director and Digital Imaging software such as Photoshop, Premiere and After Effects and specialised facilities in Sound, Video and Holography. Goldsmiths College has creative and production facilities supporting video, sound and photographic editing; video conferencing; digital and 35mm cameras, cassette recorders; and projectors; and digital studios. Newcastle University Culture Lab has an assembly of flexible, re-configurable spaces equipped for uses ranging from real-time interactive technology experiments to live performances, lectures and readings, conferences and seminars. Multimedia Labs facilitate digital video/audio editing, compositing, graphics, motion graphics, animation and sound recording. University of Sheffield Humanities Research Institute has a suite of studios with acoustic treatment housing technology for sonic art and media production and a reportedly extensive range of portable equipment for recording or live performance. University of Wolverhampton Centre for Art, Design, Research and Experimentation has an animation studio equipped with 25 workstations; multi-resource and seminar rooms with data projectors, CD and DVD viewing facilities, and stereophonic sound reproduction; digital printmaking facilities; and studios with Apple Mac workstations. Warwick University has large high definition video screens; spatial sound; video conferencing; broadcast quality recording; and co-located reconfigurable usability and digital gadget labs.

Research spaces

Space is as important as the equipment it houses. Examples of where multi-media rich space has been designed to maximise multidisciplinary collaboration include The University of Lancaster's InfoLab21 and The University of Salford's THINKLab. Furthermore, an example of where a department is organised around a working study layout is at the University of Wolverhampton. Rooms can be reconfigured to mimic home, office, hospital or other specialist environments to support usability studies on digital product and services at the university of Warwick. Both the EPSRC and JISC are currently calling for greater research into research spaces. The SPIRE network of excellence is being set to allow many of the researchers that design and use these spaces to know about each other and have a framework for interaction and collaboration. . SPIRE has come from a recent EPSRC sandpit and is lead by Ruth Aylett of Heriot-Watt University.

Living Labs

The digital economy programme focuses on multidisciplinary research that utilises ICT towards an economic or social benefit. End-user and commercial involvement are thus key. While research in university laboratories allows risks to be managed and accurate

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results to be gained, it is at some point necessary to take the research to the people who will commercialise or use the approaches that come from the results. The sooner this is done the higher the chance of the research becoming applicable. Innovation can be strongly encouraged by bringing university research to the places where it will be seen by the companies that could exploit it. How useful a technology or application is can only really be gauged by watching the end users use it. These concepts are encompassed in the living lab. We take the following definition for living labs from http://www.openlivinglabs.eu:

"A Living Lab is about experimentation and co-creation with real users in real life environments, where users together with researchers, firms and public institutions look together for new solutions, new products, new services or new business models. But also Living Labs are about societal involvement, about promoting innovation in a societal basis, involving academia, Small to medium enterprises (SMEs), public institutions and large companies in an Open Innovation process that because happens in real environments has an immediate impact. This is how Living Labs aim to contribute to a new Innovation System where users and citizens become active actors and not only passive receivers".

We have identified four living labs in the UK that fit the original themes of the digital economy. Essex, Wales, Scotland and in the north of Ireland The Digital Lifestyles Centre is a new interdisciplinary Research Centre at the University of Essex. The centre was originally created to optimize the design and development of pervasive computing technologies in inhabited environments, by combining the expertise of a number of research units at the University. The Digital Lifestyles Centre bridges the gap between the social and technological sciences by focusing on the development of innovative applications and technologies through the use of new people inspired methods and tools. The Scottish Living Lab (SLL) Initiative is an initiative of 6 Scottish Universities and public and private bodies in Scotland supporting innovation and industrial and social development. It aims to strengthen innovation capability in Scotland by bridging gap between technology development and user appropriation, focusing on strengths of Scottish Industry, such as wireless applications, digital design and health. The TRAIL vision is to develop participative methods that identify the unmet health-related needs of ageing, rural dwellers of Northern Ireland and the border counties of Ireland as they age in place. Other UK Living labs include: Manchester's EastServe, Milton Keyne's ConnectMK, and UK Connected Nottingham.

Processing
The digital economy themes present a variety of requirements for processing, but processing capabilities and needs vary greatly. A powerful desktop or laptop computer is capable of downloading and displaying a video stream on demand. Viewing a High Definition video stream, such as available now on BBC iplayer, requires a reasonably powerful computer, ideally with dual core processing.

As Ultra High Definition (UHD) video becomes a commonplace commodity, home computers will become more powerful to support this. 3D content that today is used in computer games but soon will be part of video, can be rendered either on a supercomputer before streaming or locally on the client. Video games have fuelled the need for processing 3D on home computers and graphics cards offer high performance at a very low cost. High Performance Computing (HPC) provides considerably more power than can be found on a home computer. Non-distributed HPC is provided by supercomputers. A supercomputer is a computer that is at the frontline of current processing capacity, particularly speed of calculation.

The academic systems in the top500 list vary over time but current UK members are: Edinburgh, Cardiff, UCL, and Reading.

There is a continual cycling between using centralised and decentralised computing that is likely to continue. The anticipated trend toward centralised data storage, and distributed processing means a shift towards system virtualisation (as with Amazon's commercial 'cloud computer' offerings) or multi-threaded applications on many processor cores for data intensive applications such as GRID applications.

Many Core will be disruptive due to the necessity of software rewrites across the board. Event driven multi-threading will require new hardware and new compilers. This will initially be driven by specialist industrial and research requirements. There is an opportunity to make the key themes leaders in this transition. Example hardware includes NVIDIA Tesla and Cell chip systems, both of which are making inroads into the supercomputing arena and are products which have evolved from the media domain.

Network capacity
One of the few certainties in future infrastructure trends is that the need for bandwidth will continue to grow. An opinion held by many is: 'give people enough bandwidth and all sorts of new ideas will emerge from them playing with it'. Bandwidth determines the quality and speed at which media content can be transferred and is thus of vital importance to media research. It is true that exciting media applications can be supported across low bandwidth. Video taken on a phone can be uploaded to YouTube or photos from many phones at a public event uploaded and processed to reconstruct the event in 3D. The latter was demonstrated at President Obama's inauguration. The growth of the use of ultra high definition video and emerging applications that combine many HD or Ultra HD video and high quality audio streams into free viewpoint 3D AV, require very high bandwidth and current technology demonstrators require significant server side processing. 3D video is rapidly growing in quality, in terms of capture, reconstruction, delivery and display. The BBC are working towards novel online services that integrate AV and 3D content for the London Olympics and Sony plans to release 3D TV's in the coming year. It is foreseeable that many people's TV's will be capable of displaying 3D Ultra high definition within the next

five years. While providing the bandwidth from the place of content capture to the homes is not the responsibility of the Research Councils, researchers do need access to sufficient bandwidth to prototype systems, applications and content and to study how both producers and consumers might use it.

An obvious question is: 'does the UK have sufficient bandwidth capacity between its universities to support the research into Ultra High Definition video and multi-stream UHD?' To answer this question we went to the providers of the service. UK Universities are connected to the Internet through the Joint Academic Network (JANET) provided by the Joint Information Systems Committee (JISC). JANET(UK) manages the operation and development of JANET, the UK's education and research network, on behalf of JISC for the UK Further and Higher Education Funding Councils. Universities are connected to JANET by regional providers, such as Net North West. Consulting with both JISC and Net North West yielded the answer that there is significant latent capacity in the UK's academic network that could be utilised to support such research. JISC representatives report that most universities are not making heavy demands on the bandwidth that they already have. Universities can request to increase their bandwidth allocation but JISC currently receive very few requests that are based on the need for high quality media streaming such as UHD. JISC have already set up a working group to look at UHD video but presently it is looking for people wanting to use it rather than trying to find more bandwidth to support it. The working group suggest that there is plenty of latent bandwidth within the joint academic network JANET, and they are ready for universities to give them justification to unlock it. Supporting single UHD video streaming between universities should not normally be a problem. However, the quality of service might not be particularly high. Latency is likely to be in the order of seconds with potentially hundreds of seconds of fluctuation. This would make it difficult to use UHD to support live interaction between people such as video conferencing. Supporting multi-stream to within latencies required to support natural interaction between people at each end can probably be supported by the underlying network but the universities doing this may need to apply to increase their bandwidth allocation. There are few if any universities in the UK that would need to run additional cabling to the campus to do this. As we have already mentioned, there is an argument that providing more bandwidth than people currently needs encourages the development of new applications. An example of this is the Tele-immersion initiative in the States that grew out of the challenge of what to do with unprecedented, and at the time huge, bandwidth. The cost of giving greater access to all universities regardless of what they are doing may be hard to justify. JISC are open to the digital economy programme suggesting where more bandwidth should be provided. One possible suggestion is to increase the bandwidth between digital hubs and their spokes. Another possibility might be to increase the bandwidth between the digital hubs. However, there may be universities engaged in bandwidth thirsty research as part of the digital economy program that do not have a digital hub while

some of the digital hubs may not have a justifiable need for more bandwidth.

Given the trend towards living labs and their high relevance to the digital economy, it is reasonable to ask: do we have sufficient bandwidth in the places where living labs exist or are likely to arise? Furthermore, do we have sufficient bandwidth between living labs and the universities that use them? JANET provides the backbone from which higher education institutes connect to the Internet. There is no provision to connect JANET to public or commercial places. JISC to some extent can be reluctant to provide network support outside of higher education as doing so exceeds its remit and puts it in competition with commercial providers. Net North West did not see a fundamental problem in connecting JANET to commercial and public places and sighted MediaCity:UK as an example of where it was being done. They have already connected JANET to the following science parks: Manchester Science Park, One Central Park, Westlakes Science Park, Salford's Technology House and Daresbury Science and Innovation Campus; and the following public places: Manchester's Chethams Library, and Liverpool's national museums and foundation of art and creative technology. Net North West did say however, that providing the networking for a living lab would normally involve other providers and the organisation of this could be complex. We asked the question, could a project to build a living lab reasonably expect adequate network provision within a few months? Behind this question was the possibility that a living lab might be funded out of the digital economy program or that a digital economies project might want to add advanced media research to an existing living lab. We sought to find out if sorting out the network provision would seriously cut into the lifetime of the project. The answer was that there was significant risk of prolonged negotiations between providers and with subcontractors before the lengthy installation procedure could be started. Net North West suggested that if specific living labs or a trend towards the funding of living labs were being planned, it would be very useful to be warned of all this by the funding councils. A working group could consider the challenges before such projects are started.

The potential of a living lab can lie more in the bringing together of synergistic researchers, innovators, exploiters and users than in the theme of the research project that created it. Furthermore living labs can be expensive to set up and thus difficult to justify to answer only immediate research questions. There is both a need to encourage participation and sustainability of laboratories that reside where people work and go. For media focussed living labs, a core encouragement is shared access to bandwidth. There thus has to be a business model that encourages the provider to provide access to high quality networking and for businesses, researchers and people to get good value for money from it. An interesting business model has been used for parts of Lambdanet in the States, in which companies rent a room or building on a site with network piped in, paying according to the level of connectivity. It can be seen how this

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might encourage network providers to offer a variety of services within shared public and corporate spaces.

Test-beds

There is a requirement to construct and maintain physical infrastructure test-beds to both evaluate the performance of implementations and also to act as a fertile ground for facilitating the creation of new applications. Whilst there are many test-bed implementations throughout the world that offer examples of good practice, these nevertheless tend to be funded on a short-term basis, often duplicate similar effort and are generally not interconnected. This limits their ability to truly evaluate large-scale scenarios, issues of interoperability and to provide sustainable, long-term support for the research communities. The Internet is a good example of a federated network in which applications have been allowed to be developed in the small scale before being rolled out to the broader world where they have made significant contributions. Test-beds need to also provide such a freedom of development. Equally, test-beds need to be flexible in order to evaluate the richness of modern devices that encompass games consoles, smart phones, net-books and future generation of technologies. Such test-beds as well as providing the support of physical devices and applications are also a rich source of network traffic and data. Such data is invaluable to the research community who are focused on simulation studies of network routing, protocols and security. Providing an underpinning architecture of test-beds should however, not be limited to the academic community but, rather, fully engage with the telecommunications companies and commercial research laboratories. Therefore a true shared environment would allow researchers access to internal network operational parameters such as mobile phone location registers for example and also allow industry to work closely with the researchers thereby facilitating a more rapid prototype to market development cycle.

In one sense, the UK already has a national test-bed infrastructure or, at least, the backbone of one, and that is SuperJanet. However, whilst the core of SuperJanet is well provisioned, the weakness lies at the edges where it joins the local networks of academic institutions. In general, local access or the so-called 'last mile' access remains the main limitation for access to core network bandwidth and services. Therefore any test-bed infrastructure must truly address the end-to-end service delivery and not simply focus on the core. In addition, current regulatory restrictions placed on SuperJanet prevent access to it or the delivery of services that have a commercial dimension. Physical network test-beds are essential for supporting the digital economy research but these need to be integrated, scalable and funded in such a manner to ensure long term sustainability. These test-beds should exploit existing national infrastructures, but last mile access needs to be addressed as part of the test-bed, and regulatory issues need to be resolved to provide an open platform in terms of who can access it and what services are allowed to be delivered over it. The creation of these test-beds must be carried out within a partnership model that includes academic and industrial participants. Finally, aspects of good practice that have been demonstrated within existing test-beds should be extracted and used to move forward.

Video Conferencing

Several people responded to the initial draft of this study to say they would like to see greater infrastructure to support cross institute collaboration. While some of these appeared to be using the word 'infrastructure' in a wider sense than just technology, tools such as video conferencing are very useful in supporting distance collaboration. Skype offers a free and routinely accessible form of video conferencing that is fine for one-to-one interaction. Interaction between groups of people, while supportable from Skype at a cost, is better supported by Access Grid. The UK has above 10% of the worlds Access Grid nodes. These support reasonable quality multi-site and multi-camera video conferencing across the Internet. Both Skype and Access Grid can be run in High Definition provided HD cameras and sufficient computation and bandwidth are available (5Mbps for IOCOM HD codec). The UK is well provisioned for access grid generally with over 30 systems of the approx 300 world wide.

Underlying consumer trends

Underlying consumer trends seem to indicate decentralisation of data and compute. Examples of consumer data decentralisation are some of the photograph storage services such as Flickr. Consumer systems will converge, while data storage and processing will increasing take advantage of pervasive broadband and become one step removed from the user. This will put increasing pressure on communication channels, software protocols, storage system, encryption and transmission systems, display systems, and power systems. Research in these areas will benefit the key themes, but there will be an application gap while the paradigm shifts to the new processing and data distribution paradigms.

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An Overview of Digital/New Media and Media Research

This section of the report provides an overview of digital and new media and related research at UK-based HEIs. The dominant focus of research in most HEIs continues to be 'traditional' media forms, and most notably television and film. In particular, these areas continue to be the focus of research for many well established and leading media research centres such as at Goldsmiths College and Cardiff University. However, research on the culture, politics and uses of 'new media' appear to be significant areas of rapid growth since the last RAE.

There is UK wide reference to video/computer game research. Centres of excellence here include Bath Spa with its National Video game Archive, Brunel with its GameLab and the BITlab, Nottingham Trent's involvement in Nottingham's annual Gamecity festival and academics' work at the University of the West of England (UWE) on gaming and gender, as well as significant work at the universities of Bedfordshire, Bournemouth, Leicester, Salford, Sheffield Hallam, Stirling, Ulster and elsewhere. However, in most cases, even where what appears to be well established centres of excellence much of this research seems based (to a greater or lesser extent) around specific individuals' work and profiles; such as Newman at Bath Spa, Gauntlet at Bournemouth, Krzywinska at Brunel, Kennedy at UWE and Kerr at Ulster.

Another recent key area of development is in relation to new media and journalism. Significantly, interest in new media and journalism appears to have developed most notably around the twin-themes of sport and international relations. For instance, research at UCLan and Derby on new media and journalism addresses their relation to international relations. While the work of Redhead at Brighton, Whannel at Bedfordshire, Hughson at UCLan focuses on new media journalism and sport. Closely connected to this is the research of Miah at West Scotland on sports technology and Crawford at Salford on sports video games.

A significant area of new media focused research is in relation to digital performance and art. RAE submissions such as those for Bradford, Bedfordshire, Cardiff, de Montfort, Royal Holloway, Salford, South Bank, Staffordshire, Sussex, West Scotland and Westminster all include digital performance work, such as digital theatre, story-telling, poetry and art. One example here of particular note, is Pullinger's (at De Montfort University) co-authoring work on the interactive online novel Interactive Alice.

E-democracy, online activism and politics appears a well-established and key research area at many HEIs, including: Oxford, Ulster, Leicester, Swansea, Sussex, Stirling and significantly so at Leeds. Also linked to this is work on the role of new media in processes of globalization and risk, such as that found at Nottingham Trent University.

Also of note here is the work of many institutions in establishing or working in partnership with digital archives, such as Middlesex's Archive of Black History, Bradford's partnership with the National Media Museum, and Leicester University's leading research on new media and museum studies.

Everyday life, the uses and culture of media continues to be a key theme at many instructions, such as Goldsmiths and Cardiff, but other institutions such as the LSE, Oxford and Sussex appear to be leading the field here in relation to new media technologies. In particular, Sussex has a Centre for Material Digital Culture and LSE academics Haddon and Silverstone continue to produce pioneering work in relation to the uses and domestication of new media technologies.

Other notable activities include: the challenges of new media policy, ethics and property rights (e.g. Derby); new media's role in education and/or children (e.g. Bournemouth, Sheffield Hallam, Oxford and LSE); the Relationship between media and gender (e.g. East Anglia, Goldsmiths and Sussex).

In terms of the structuring of infrastructure we found several models:

> Discipline centres – centres housed within a university which are wholly or predominantly populated by a distinct academic group.
> Interdisciplinary centres/institutes – centres housed within a university but which were populated by staff from different disciplines. Such centres often cut across schools and faculties throughout institutions.
> Large scale institutional and inter-institutional research council funded clusters/networks such as the Digital Economy Doctoral Hubs, the National Centre for e-Social Science, Arts-Humanities.net, the Arts and Humanities e- Science Support Centre and the Digital Curation Centre.
> Inter-country networks such as: CESSDA (http://www.cessda.org/), CLARIN (http://www.clarin.eu/), DARIAH (http://www.dariah.eu/) and the ESS (http:// www.europeansocialsurvey.org/).

In the light of changing definitions of media, and media convergence, it is thus unsurprising that our survey has revealed a diverse and ever growing set of digital media oriented research activity across the UK. Indeed, it is important to examine the functions researchers and centres claim to be engaged with, rather than those we might traditionally ascribed to them to get a real sense of what is happening across the UK. This is particularly the case given the multitude of names given to centres operating in the area. These include: centre's for media research, culture labs, digital media research centres, digital labs, Info Lab and IT Innovation Centres. Though this is in no way an exhaustive list, such activity conducted within the area of digital media includes: digital performance, video games, virtual museum/zoo design, creative industry development, digital media and migration, digital music composition, new media policy, digital healthcare and so forth. Of course, as a result, such diversity in research practice revealed a multitude of research infrastructures in place. These are of varying

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Contextualising Infrastructure Provision

sizes, forms, generations and cost. Such infrastructure includes: performance spaces, mobile phones, personal computing equipment, TV/Radio studios, virtual environments, computer aided design, archiving facilities (for text, video, photography and audio), animation, telematics, digital cameras and motion capture. Again, in no way is this list exhaustive.

A further nuance we have found is the orientation of the reviewed centres in terms of their socio-economic impact agenda. Although it is somewhat of an oversimplification to differentiate between 'societal' and 'commercial' impacts, it is notable, yet to be expected, that most centres were explicitly oriented toward the former. However, a lack of an explicit commercial orientation should not suggest this does not exist. Indeed, at most centres we found evidence of members working alongside other organisations, commercial and non-commercial. Further primary research would be required however, to develop a fuller understanding of the nature of such collaborations. Of particular interest here would be the sharing and dependence upon research infrastructures amongst the parties involved. Our study suggests that often, the research infrastructures of Universities are used by outside organisations rather than the opposite.

This section contextualises infrastructure provision in a global perspective. Placing the UK's current provision in an international context. We begin by summarising key relevant reports from around the world. We then look at places across the world that encourage multidisciplinary innovation around media and ICT technology, such as living laboratories and media cities. Where possible, we consider what lessons might be learnt from similar past or current initiatives worldwide.

We start by summarising the findings of the following reports: Digital Britain; AHRC Future Directions Consultation; Large Scientific Facilities; RCUK Large Facilities Road Map; European Roadmap for Research Infrastructure; and Digital Humanities Centres in the US. The joint DCMS/BERR Digital Britain report attempts to put the UK at the forefront of the global economy. The interim report outlines plans for the country's digital transition include specific proposals on: next generation networks; universal access to broadband; the creation of a second public service provider of scale; the modernisation of wireless radio spectrum holdings; a digital future for radio; a new deal for digital content rights; and enhancing the digital delivery of public services. A 22-point action plan outlines a programme of work with commitments to: upgrade and modernise wired, wireless and broadcast infrastructure; secure a dynamic investment climate for UK digital content and service; provide a range of high quality UK made public service content; ensure fairness and access, with universal availability and promotion of skills and media literacy; and develop the infrastructure, skills and take-up to enable widespread online delivery of public services. With regard to Digital Humanities, the questions asked by the AHRC's" Future Directions" consultation are: what it means to be human in the digital world; and how we live in the digital age. Consideration has been given here to the need to embed digital technology in the methods and scope of the arts and humanities. Engagement with broader range of partners in the creative and cultural industries and businesses on global issues – e.g. intellectual property, has also been considered. Significant investment has been made and is planned for large research facilities in the UK. £800M has been invested in ten large research facilities in the UK since the millennium, with a further £250M earmarked for another five facilities (ref. postnote July 2008 Number 313 Large Scientific Facilities). However, few of these have had a strong media technology focus. Over 60 large facilities are summarised in the RCUK large facilities roadmap 2008. We have identified 18 of these as being strongly related to the Digital Economies themes and having a strong focus on media technology. The scale and importance is reflected in the focus that governments are giving to it: Australia is creating a entirely new nation-wide high-speed communications network (Digital Britain Final Report). The Digital Britain report argues that other countries around the Pacific Rim from Japan and Korea to Singapore and New Zealand are all adopting next generation networks. High speed broadband and smart-grid technology formed an important part of the USA administration's recent stimulus programme. Elsewhere in Europe, Germany, Finland and France have all adopted national

broadband or wider digital strategies. The European Roadmap for Research Infrastructures of 2006 brought into question that there will be enough adequately trained young people over the next 5 to 10 years. In particular it pinpointed the sustainability of funding over lifetime and not just capital spending as a key issue. This issue has come up more often than anything else in our research for this digital economies report. Zorich's (2008) study of Digital Humanities centres in the US found two models – resource focussed and centre focussed. The resource focussed models were organised round a primary resource and were virtual in nature – individual and organizational members sustained the resource by providing content and volunteer labour. In contrast, centre focussed models were generally organised around a physical location. Zorich argues that both models bring issues and opportunities. Local centres were found to offer flexibility. Resource focussed models offer collaboration and knowledge building opportunities beyond disciplinary and institutional boundaries, but they can be slow to adapt to change due to a multiplicity of vested interests and their sheer size. Reward systems are needed to encourage collaboration. Shared resources can improve the visibility of projects. Projects often have overlapping agendas. Shared projects minimize redundancy. Certain members may monopolize or damage centralised resources. Policies to regulate centralised resources are required, alongside personal trust between users. Key questions are: how to establish and maintain such mechanisms? How is institutional parochialism overcome? How are benefits of collaboration articulated and enacted? and What training is required for responsible use?

Living Labs
We have identified a strong international trend towards the living lab approach and have identified 21 living labs that fit the themes of the digital economy. Of these four are within the UK.

Media Cities, Media Labs, and New Century City Developments
Media Cities, Media Labs, or as Joroff et al. (2008) recently dubbed them 'New Century City (NCC) developments, ICT clusters of one kind or another have been established in diverse locations around the world. The concept of an ICT cluster as a regional economic development model stems largely from the extraordinary success of California's Silicon Valley. Attempts to emulate the success have multiplied around the world,. Considered in this report are Seoul's Digital Media City, Korea, Leipzig Media City, Germany; The Digital Mile, Zaragoza, Spain; Dubai Media City; Smart City, Malta; and Smart City Kochi, India; Media Production City, 6th October City, Egypt; Yalova Beehive, Turkey; the Dublin Media Lab.

A cluster has been described as "a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities." (Porter 1998) Studies by the OECD and others (Hertog et. al. 2001), however, have underlined that each cluster 'case' is unique, that the regional context has enormous impact, and there are no general

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rules or principles on what makes an ICT cluster a success, like Silicon Valley, or a failure, like the Dublin Media Lab (Kim 2002).

It is clear from the experience of other projects around the world that the Silicon Valley success can be regarded as no more than a 'model' upon which to build, and not something that can be simply replicated elsewhere. Importantly, embedding the project within the local region, and targeting niches in the global production network seems to be the hallmark of the more successful projects, despite the global nature and reach of such ICT cluster projects (Rosenberg, 2002). Relying on the global market alone is a recipe for failure.

Seoul's Digital Media City Project

The stated vision on this project is to "develop a futuristic info-media industrial complex that will serve as a centre of information technology in northeast Asia." It is envisaged that it should "become an incubator for developing social capital."

The Seoul Digital City is located in the Sangam New Millennium town and endeavours "to combine urban and economic development plans of Seoul in a single location… [towards]… nurturing social capital for Korea's future development."

According to the MIT Centre for Real Estate, "A major feature of the project is Digital Media Street, which will host entertainment and retail establishments, technology companies, prestige housing, R&D institutions, and universities. Digital Media Street is an opportunity to develop and test new technologies, and to refine them in a living laboratory environment… A permeable realm that blurs the transitional edge between public and private space will be created by juxtaposing digital information with physical places…… coordinated digital displays will set the mood for events, while portals to sister cities will afford glimpses into different places. Technology will effectively serve and manage, as well as entertain."

The Digital East Asia website announces that "one of the largest buildings in the world is planned for a city sector dubbed "Digital Media City"… The new building is expect to rise by 2015 and will create an estimated 86,000 jobs, not bad in these times".

As a cluster, Seoul's Digital Media City is, according to Kim (2002), the most carefully targeted of Asia's cluster projects, being targeted at the Media and Entertainment industry, and being located in South Korea's capital city. Clusters including the Cyberport in Hong Kong; Singapore Science Park; Taicang Science and Technology Park, China; Hi-Tech Park Shanghai, China; Hong Kong Science Park; Hsinchu Science-based Industrial Park, Taiwan and Nankang, Taiwan, are all focussed mainly on ICT hardware and software production, with some paying additional attention to biotechnology. Seoul is the only one to focus on Media and Entertainment.

This is perhaps in stark contrast to the experience in the Middle-East. The Dubai Media City claims to be the "only global media hub in the region," aiming to provide "a world-class environment for every

kind of media business, which broadly includes media and marketing services, printing and publishing, music, film, new media, leisure and entertainment, broadcasting and information agencies. In this open and flexible environment, you and your company can operate with collective synergy and individual freedom. Being a dedicated media zone, DMC ensures that all media businesses are given the "Freedom to Create" (see http://www.dubaimediacity.com/). Some of the major broadcasters based at Dubai Media City include: APTN, Reuters, CNN, BBC World, Bloomberg L.P., CNBC Arabiya, Voice of America (VoA) and others.

However, since the Dubai Government, on the demand of the military regime of Pakistan lead by General Pervez Musharraf, ordered the shutting down of the Pakistani independent and private channels Geo News TV and ARY One World, based in the Media City, news media have been extremely wary of their location in this cluster. The conditions were removed later but "a marked difference has been observed in the coverage of Geo TV and ARY OneWorld… Years after the opening, international and local media companies are still suffering the consequences of censorship. While Dubai Internet City sells itself as a business-friendly environment with excellent connectivity, the reality is it is heavily censored." **(http://en.wikipedia.org/wiki/Dubai_Media_City)** There are additionally many other contenders in direct competition with the Dubai Media City, including Creative City and RKA Film City, in the United Arab Emirates, the 6th of October City-based Media Production City in Egypt, and Cisco's ongoing projects in the Istanbul satellite town of Yalova, in Turkey.

Europe, similarly, has yet to see a successful localised cluster stand tall above all others in the region. Activities in Denmark, Germany, France, and worst of all in Ireland, have had mixed ambition and mixed success. A notable case, which seems to be thriving is the Digital Mile in Zaragosa, Spain, successful due to its discrete nature and the careful planning of its location. In contrast the most ambitious, in Dublin, the least successful officially closed in 2005. 'Media Lab Europe,' as the Dublin project styled itself, was the European partner of the American MIT Media Lab, and operated for 5 years. The decision to go into solvent liquidation was taken "because its principal stakeholders, the Irish Government and the Massachusetts Institute of Technology (MIT), had not reached agreement on a new funding model for the organization." **(http://medialabeurope.org/).**

The latest European-based NCC is MediaCity:UK, which is currently under development at Salford Quays in Greater Manchester. Set to be the home of a number of BBC departments, HEI buildings and numerous other small, media and large media business and organisations, this venture stalled somewhat with the recent global economic crisis. However, with signs of economic recovery on the horizon, and various quasi-government organizations considering premises at the Quays, it looks likely that other significant media-focused tenants will soon join the BBC and the University of Salford at the Quays.

Computing

The UK's share of supercomputing is indicated in the HPC top500 list. This list is updated regularly and can provide us with indicators. National distribution is given to a great deal of variability with figures for the top six HPC nations (by computer cycles) taken between early 2009 and June 2009 showing a high degree of variability (see Table 1).

Table 1: Distribution of Computer cycles across the six HPC nations

January 2009		June 2009	
India	2.70%	India	2.70%
France	3.20%	France	3.20%
Japan	4.20%	Japan	4.20%
United Kingdom	7.40%	United Kingdom	7.40%
Germany	7.70%	Germany	7.70%
USA	60.00%	USA	60.00%

Application share globally applied to themes internationally:

> Biology 1 system 0.20 % share of top 500 cycles
> Medicine 3 systems 0.60 % share of top 500 cycles
> Digital Media 2 systems 0.40 % share of top 500 cycles
> Media and digital media 1 systems 0.40 % share of top 500 cycles
> Gaming 4 systems 0.80 % share of top 500 cycles

From the above it is unlikely that there is great investment in the UK into supercomputers for the key themes listed above. Nonetheless it can be seen that the UK is well provisioned comparatively: though most of this resourcing is weather forecasting, financial, and data centre based, with some research, and some nuclear/military.

Considerations for Infrastructure Provision

The following section reflects upon the research evidence and opinions that have been garnered in constructing this report, and considers various forms of infrastructure and possible ways forward for continued and new provision.

Problems of defining Infrastructure and Media

As already stated, it is incredibly difficult to articulate what counts as infrastructure. This is evident in our review of extant facilities and research in the area. Indeed, to further complicate matters, definitions of what should be included under the heading of digital media are also difficult to construct. Without a doubt, despite our best intentions we will have excluded someone, or something from this survey as a result. Indeed as one respondent from the research community commented "not quite clear on the criteria for inclusion/exclusion?". For example, UCLIC at the University of Central England (UCL) does a lot of digital/media-related research, though has no definable large facilities. By contrast, the University of Birmingham has a large computer cluster, shortly to be expanded even further, and a key research group there, the Advanced Interaction Group, does a lot of research on future digital media uses and social effects. This is a real practical problem – if it is so difficult to define what the UK has, how can funding be allocated wisely? The answer, it would seem, would be to recognise the complexity of the area and work with that rather than trying to pin down infrastructure in too finer detail.

Infrastructure as a research instrument

It is clear that the context, content and process of media research across the UK, and indeed the world, is diverse. At an abstract level, one might think of the need for infrastructure as a research instrument and as an object one researches. Researchers within media and humanities need access to both. With respect to infrastructure as an instrument, a workshop (Arms and Larsen 2007) held between the US National Science Foundation (NSF) and the UK's Joint Information Systems Committee (JISC), concluded:

"The widespread availability of digital content creates opportunities for new forms of research and scholarship that are qualitatively different from traditional ways of using academic publications and research data" (p.1) and that such availability of digital content: "provides an infrastructure for novel forms of research. To support cyberscholarship, such content must be captured, managed, and preserved in ways that are significantly different from conventional methods". (p.1)

It has been argued that JISC can provide the coordination for this and an agenda is in place to enact this by 2015. An embedded assumption within the report is that coordination is required to facilitate advancement rather than local silo thinking. The problem with this thinking is that it is an assumption. There is an assumption that the 'right' solution that will work for everyone is deterministic. To quote the report: "Cyberscholarship is only possible when most of the content in a field is accessible to computer programs". Clearly, given our

findings, this is a somewhat over simplification of the situation – even if we acknowledge the boundaries of what the report deems cyberscholarship (that concerned with digital content). Indeed, the report later suggests that variety is necessary - a single approach cannot fit all categories of content yet every category of content does not need a completely different approach. The report advocates a small set of approaches to support a wide variety of content. Whilst this flexibility is welcomed, again our survey suggests that it is impossible to be too restrictive regarding the infrastructure to be provided.

Leading Edge Research Infrastructure and Leading Edge Research Conflation

A further area that our survey has revealed is the need to ensure that a conflation of leading edge research infrastructure and leading edge research does not occur. Members of the research community were keen to point this out. Leading researchers are not always located alongside the 'best infrastructure'. The RAE 2008 results provide strong support for this thesis. RAE 2008 clearly demonstrates that different levels of research excellence are present within an institution and, within any given subject area, distributed across institutions.

Centralised vs. Decentralised Provision

Our research and the research community are in agreement regarding the importance of interdisciplinary activity and the challenges that this creates. As one researcher states: "The Department does not maintain a digital media laboratory. However, many of our academic staff and students would welcome collaboration with institutions that support this kind of infrastructure facility. A significant component of our research concerns the design of new digital applications and their impact on the economy and society". Building upon our argument about the conflation of infrastructure and expertise, we cannot assume that the requisite multidisciplinary expertise required to leverage infrastructure will be located at a single location, nor that it could ever be. Indeed, it is clear that many universities have, or are choosing to specialise in specific areas and thus we cannot and should not try to co-locate all research activity in large labs as this will always exclude. As the assessor of the interim report we produced states "While having facilities available is always good, I would like the report (or maybe the follow-up work) to really address what opportunities exist in terms of research and integration between the digital and media technology disciplines, and therefore what support would be most appropriate to enable these opportunities to be fulfilled".

A further related point to this one is that whilst this report focuses upon provision within the UK, we have to realise that expertise and facilities may be located elsewhere in the world. This further mitigates against the idea of centralised provision. As one respondent commented: "surely the success of any digital economy project will, primarily, be how it is able to integrate and support a global economy". The one thing that everyone we have engaged

with throughout the study (it would appear) is in agreement with, is that centralised provision is not preferable. One researcher commented that there is a need to place more emphasis on the concept of international collaboration. The UK should not, if we are to be successful in promoting innovation, limit activity to that which is going on nationally. This is borne out by our section on international perspective which stresses the geo-regional profile of the most successful ICT clusters around the world.

Research Locations

The issue of research location was brought up, time and again within the study. Here we were interested in the idea of 'where' research is carried out. Unsurprisingly, what we established is that a mix of locations is important. For example, whilst one might suggest that the headroom available within JANET would enable higher bandwidths on campus for research, it assumes that research only occurs on campus in 'controlled' conditions. Whilst this is still an important method for large areas of academia, with the democratisation of technology, large areas of important media-related research need to be done in the field, not under controlled conditions. Thus, we had views from members of the community support the idea of 'on' and 'off' campus infrastructure provision – as one researcher comments:

"I agree that bringing together researchers in common shared, non-territorial locations is valuable. I agree that bringing together users in public/known spaces is valuable for evaluation. But for creativity, design, and development, living labs or locations in public-oriented spaces are often less valuable than other spaces".

A further consideration is the requirement for a further nuancing of what we mean by 'place' or 'location'. We agree with many research community members who believe that whilst physical co-location amongst researchers within and across disciplines, and researchers and users, can be important – we need to recognise the need for increased support for virtual collaboration. This point was further picked up in relation to notions of international collaboration. Moreover, increased uptake of digital media in the UK and the decreases in costs associated with it further add to the mix. For example, in the last ten years in the media there has been a rapid levelling of the complexities of technologies used and employed by Broadcasters, and those, which have become available to the public. Broadcast companies traditionally used a level of technology far superior to that available to the user. This is not necessarily the case today. User generated content, mobile production and distribution, high definition video and audio recording, Internet distribution are all technologies and systems available to the user market. Interactive, community based and non-broadcast methods of media production are all enabled and empowered though this technological sea change. It is then imperative that we create a research method and system to enable research in these areas. This research cannot and should not be done on campus; the results may be spurious or skewed as the environmental and social concepts and mechanisms

are as important to the analysis of this digital/new media as the technological.

Community/Enduser Engagement

The rise of user generated content and the pervasiveness and ubiquity of digital media as alluded to in the last section clearly open up the area of community and end user engagement on a number of fronts. Whilst product development requires the input of any defined user community, this has implications for, as we have stated earlier, where development and implementation occurs, and thus where infrastructure resides. An issue here is the need to consider the locations of research (virtual or physical) viz engagement. As Ferneley and Light's (2008) work demonstrates – there are different kinds of user: Primary – those intended to interact with a set of sociotechnical arrangements, Secondary – those who are intended to use the outputs of Primary Users and, critically Bystanders – those not intended to engage with a set of arrangements, but who do so by accident or choice. Whilst all groups are important, the latter probably brings the greatest breadth of challenges, particularly where research infrastructure is provided 'in the wild' as it were. The case in the box below demonstrates the potential issues associated with unexpected engagement. So whilst, research councils and the REF framework would encourage engagement, and we would certainly see this as necessary, deploying infrastructure to facilitate this suggests considerable challenges. This is particularly so given that technology is not static and we cannot predict the effects new developments will have in particular contexts.

Leading researchers are not always located alongside the 'best infrastructure'.

The one thing that everyone we have engaged with throughout the study (it would appear) is in agreement with, is that centralised provision is not preferable.

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This incident occurred in a city centre location. A fire brigade was called to a welder's van where oxyacetylene cylinders, which are highly flammable, had overheated and were in danger of exploding. A 200m exclusion zone around the cylinders was made resulting in the rail and tram networks, a number of arterial roads and a major car park being cordoned off. Professional members of the public who work within the city centre were the car park's main users. Five fire engines were deployed and all fire fighters located close to the cylinders wore protective clothing in case the cylinders exploded. From the general public's perspective there appeared to be nothing happening. A plasma screen was erected, linked to a laptop using an application that allowed them to model alternative traffic flows dependent on which roads they chose to close. Previously such models would have been generated by a Control Office who would then communicate possible closure scenarios to the incident ground who would then decide which closure option to implement. The aim was to give a visible interpretation of the problem to all fire service personnel.

The intended Primary Users were senior fire and police service personnel who could work collaboratively by modelling the exclusion zone and a variety of road closure options to find a mutually agreeable road closure solution.

Senior incident based fire service personnel commented on feelings of empowerment and enhanced professionalism as the use of the technology enabled them to make informed decisions at the incident ground. They further perceived that these decisions, and indeed the rationale for them, had rapidly transferred, via the plasma screen, to operational personnel. However, the presence of the plasma screen attracted the attention of the general public, many of whom were attempting to gain access to the car park that was inside the exclusion zone. Whilst senior management believed the plasma screen gave an appearance of professionalism a number of members of the public regarded the technology with amusement: 'members of the public couldn't work out what the screen was there for. I had two people joke that it was a bloody great big A to Z [road map] and didn't we know where we were?' – officer.Of more concern was the interpretation that several members of the general public made of the data. The traffic flow model displayed on the screen clearly showed the location of the overheated oxyacetylene cylinders which was represented by a large red icon. Several members of the public made a judgement of the location of their cars relative to the cylinders and, despite repeated requests by fire fighters not to enter the exclusion zone, decided to cross into the zone and retrieve their cars. Effectively they moved from a Bystander to Secondary User role and, using the displayed data, made, what they believed to be, an informed decision to 'cross the line'. (Adapted from Ferenely and Light, 2008)

Sustaining and widening the access of facilities
Many existing media based laboratories are both under utilised and have the infrastructure capacity that could support a wide range of digital economies research. Many digital economy researchers would benefit from using them and are held back by not having access to such technology. There is a clear potential to better utilise existing and future generic media infrastructure for a wide range of digital economies research. Such infrastructure is funded from sources such as HEFCE Science Research Investment Fund (SRIF) and Research Capital Investment Fund (RCIF), and for specific research projects by research theme focussed councils such as the EPSRC. While this does not remove the need for future infrastructure spend to support the digital economy it does raise the opportunity for joined up thinking and reduction of expensive redundancy and under utilisation. Most universities will have a range of high quality research of high relevance to the digital economy that differs in the infrastructure it needs to support it. If such under utilised infrastructure exists within the university or another nearby, then it is likely to make more sense to support its shared use than its replication. Such collaboration offers other benefits such as cross-discipline knowledge exchange and promotes future joint bidding. However, there are several barriers that stand in the way of opening up the UK's latent media infrastructure capacity to a broad range of the digital economy researchers who would benefit from it. Firstly, people need to know what is where, how often it is available and who can help them use it. Secondly, the equipment needs be ready for routine use by non-experts, albeit after appropriate short training. Thirdly, there needs to be someone capable of providing this training and helping them to get started. There is little evidence of media-based research facility in the UK that adequately meets all of these prerequisites. However, an example of one that might seems to come close is the visual learning lab at Nottingham. In contrast there are supercomputing facilities that do clearly meet the prerequisites, for example at Oxford where people can receive training and application support to complement access to a range of clusters and shared memory machines.

While the UK has a representative range of media technology, many researchers find it hard to access much of this range. There is not so much a shortage of equipment as insufficient provision to widely utilise it. We temporarily move away from higher education to examine an example of best practice in secondary education, which demonstrates how novice users can be supported to make quick and effective use of a wide range of media technology. The BBC's 21cc Class Room of the future offers high potential for wide access media focussed research infrastructure in higher education institutions. 21cc is embodied by two media focussed teaching resources, one in London and the other in Salford. Both have a wide range of low cost and versatile technology that can be combined in many ways. Equipment includes Mac and PC workstations, and audio recording studio and listen room, various video cameras and microphones, a variety of editing and production software, and low cost projectors and retrofrefelctive curtains that allow blue screen filming against a projected backdrop.

The facilities are staffed by people who can quickly motivate and show children how to use them. Within one day, children not only learn a range of technologies and approaches to creating interesting content but actually design and complete a piece of their own. Integration of the technologies and showing others how to use this in creative ways is something that 21CC do very well while the majority of research labs seem to do badly. In research it is the norm for much more expensive facilities to be inadequately staffed and maintained making it impractical for non experts or occasional users to utilise them. There is also littlededicated funding for researchers to visit facilities in different universities.

Moving back to higher education to look at where some good practice does exist, a good starting point is UCL. When UCL installed its visualisation facility it did not staff it with a computer scientist or ICT technician but with a psychologist who spoke the language of many of the potential users. This facility is now heavily utilised by end users from across the university who are using it for psychological studies within their disciplines. The vast majority of similar facilities across the UK are mostly used by one computer science research group and thus spend much of their time idle. An example of where relatively complex technology can be integrated into a very nice environment in which a range of disciplines can work is the THINKLab at the University of Salford. An example of where experimental media technology can be combined reconfigured in many ways to fit numerous user needs is the Octave at Salford. An example of where numerous media technologies have been integrated into everyday things and used in a variety of creative ways is at MRL at the University of Nottingham. What all of these facilities have in common is staffing to support wider uptake from other disciplines. However in our opinion, 21CC stands out above these and the other research facilities that we know of, by providing adequate staffing to support routine use by non-experts. The equipment in the research laboratories is in general more experimental yet there is nothing like the level of staffing and range of staff skills to help others make use of it. 21CC has spent less on equipment and more on staffing and simply provides a much better balance. We have found no evidence of a research laboratory in the UK or elsewhere having staffing as able to encourage use by others, as evident in the two 21CC facilities. The majority of university research facilities are supported through part time and ad-hoc input from academics, researchers and postgraduate students. Usually all of these have full time responsibilities outside of supporting the facility and its uptake. The result is often woefully under utilisation of expensive equipment while other researchers need such equipment to compete at an international level. There is a need for joined up thinking between the funding of facilities and the funding of other research for using them. If a case can be made for existing or future media facilities supporting an open door policy to digital economy researchers and there are such that would make use of this, supporting the staffing for this might make more sense than spending yet more money on under utilised equipment. The EPSRC strongly encourage the

consideration of sufficient staffing; however other funding streams, such as SRIF and RCIF from HEFCE have and do not.

Infrastructure investment is typically awarded to support excellence in research; however, researchers can move institute. A report into research infrastructure in the United States highlighted the problem of sustainability of research facilities (Zorich 2008). In particular, the report pointed out that the leaders of research that won the original grants often move on and there expertise or enthusiasm for the equipment is often not replaced. It is not uncommon for a leading researcher to take key members of their team with them as they move. This can leave a facility not only leaderless but without the technical expertise to use it. Sometimes the pragmatic solution is for the institute to cut its losses and close the facility or find other researchers who can at try to build up activity around it. Doing the latter is difficult when expertise has been lost.

Operationlising State-of-the-art Facilities
We suspect that most media laboratories that attempt to define state-of-the-art take around two years to fully bed in. From talking to the administrators of five of the countries top visualisation centres and two advanced ubiquitous computer labs, only the simplest had reached the state of full functionality and reasonable reliability within two years of commissioning. One centre told us that from over £2M of investment in immersive projection technology, after two years and the gradual replacement of all but one component, the system was now finally in a state where it could be used. In another, many of the major components still do not interoperate after a year. We know of four where hundreds of thousands of pounds had been spent on graphics super computers which never worked and because there was no staffing to try and get them working and negotiate with the vendors, warranty ran out before the issue was resolved and the computers were scrapped. It is interesting that these computers came from three different blue chip manufactures, suggesting this is not an isolated issue. Given that these problems are embarrassing to the institutes, it is likely that there are many other recent examples that we have not been told about. A large facility or complex media laboratory will realistically take a at least one person year of expert, often research level, technical support to bring it to a point where it can be routinely utilised by non-experts. Facilities that combine many research level technologies will take longer.

Here we look at problems that are often encountered in the procurement and commissioning of research infrastructure that defines the state-of-the-art. These problems manifest themselves down the line when many of the expensive facilities, here and abroad, are out of date before being routinely useable.

Defining the state-of-the-art in research infrastructure — If the country is to be at the forefront of science then it should be building facilities that define the state-of-the-art. However, this introduces risk into procurement, commissioning and uptake. While all of these

can be managed, doing so is often hampered by a funding strategies both within universities and Research Councils that do not appear to adequately take account of risks and the need to resource reducing them. There is a world of difference in the risk of building a widely usable research laboratory for ubiquitous mobile devices or immersive multi-modal display and capture, compared to a teaching lab full of PCs with standard software. Yet resourcing of technical support is typically more carefully considered than that for research. This seems to come from a belief that researchers are clever enough to sort out their own technical problems. This belief does not take into account that researchers are usually fully committed on other work, such as a funded project or teaching.

Procurement — Suppliers need to cover risk and building infrastructure that defines state-of-the-art is high risk. Many suppliers will only enter into contract on an open book basis, where they guarantee an overhead above their costs but not the costs themselves. Many labs require a chain of suppliers to work together to provide interoperability between components. If several of the elements are defining state-of-the-art then the risk one not working or lacking interoperability needs to be managed. Even if a lead supplier is given overall responsibility, they will not be able to enter a contract that guarantees things beyond their control. Thus either the institute needs to become the project manager, or enter an agreement in which outcome can not be guaranteed within a budget. Often the institute is well placed to take on some of the riskier elements of the project as they have already built research prototypes that define the state-of-the-art. However, undertaking this requires expert staffing. In either case, in order to manage the risk, the institute needs to have a project manager/team skilled in specific technical knowledge, complex requirement specification, procurement negotiations and contracts, testing and sign off. Yet infrastructure investment often precludes spending money on staffing. The responsibility for managing procurement is typically left in the hands of an inexperienced academic, researcher, technician or even PhD student. While HEFCE implemented a national procurement process for SRIF infrastructure, it was run to a set of rules better suited for low risk procurement, such as a supercomputer of specific capacity, or a set of PCs and printers.

Commissioning and sign-off — When buying standard pieces of kit, commissioning and sign-off are straight forward. When commissioning a laboratory that defines state-of-the-art, many teething problems will be encountered. The challenge is to resolve all of these before the deadline on the spend. Given that procurement will have been protracted due to managing the risks described above, this can be easier said than done. The institute is often then faced with a choice of signing off before the laboratory is fully commissioned or being unable to pull the money down from the research council. Taking the latter route means that the institute has to resource solving the problems that the contractors were able to solve or to be pulled into legal proceedings for non-payment. While a seemingly bulletproof testing specification should in theory

clarify where problems lie, contractors are not likely to have agreed to one that places them in risky territory. While some vendors will continue to help after sign off, particularly if doing so has been written into a maintenance contract, few seem to iron out all the problems encountered in commissioning.

Routine use — For a facility to be used routinely by non-experts, the functionality that they require must work without technical hitch and help in understanding how to use it must be routinely available. In contrast many advanced media based facilities only have a small subsection of the potential functionality working and the technical support, which often is the research staff or students, are too busy trying to keep things working for their own research to help others. Non-expert users will not take up a technology for which much of the required functionality is not working, or fails regularly, or if they can not get the help to get started or overcome simple problems.

The 'chicken and egg' problem — Should technical support be provided to encourage uptake of a facility or should it be provided once grants for research that use the facilities are bringing money in? It is hard to obtain research grants to get research infrastructure working or even to get grants for projects where this is a substantial part of the work. It can also take several years to gain funding for a new idea. It is thus very hard for a facility that has not been adequately staffed to reach a point of financial sustainability through grant proposals before the equipment goes out of date. Should the limited staffing that many facilities have concentrate on getting everything working or on generating grant income to maintain or increase the staffing? Media-based facilities are of wide relevance to other researchers but these will only want to use a working facility. As a rule of thumb, one could estimate that a full time member of technical support can be funded from four medium sized research projects. If a researcher gets on average one in four of the bids they make and they make four medium sized bids a year, it takes four years for one person to bring in enough money to provide minimal staffing for a facility. By this time the equipment is out of date and the software out of repair and no longer licensed. This new staffing of course should be working only on the research projects; however, many universities rely on a single academic to raise the funds to staff multi-million pound facilities.

Universities have long ago moved the responsibility of managing and maintaining ICT for teaching away from the academics and over to ICT specialist. In contrast, this has not widely happened in research laboratories. While it is of course more challenging to farm out responsibility for maintaining research equipment, it is more challenging to get researchers to help occasional users to use it.

Multidisciplinary research is core to the digital economy programme and we have asked the question, is our existing media infrastructure widely utilised by multidisciplinary research. The UK is not obviously short of media infrastructure to support digital economy research. However, we have found little evidence of wide multidisciplinary

research utilising our best media infrastructure. While there are top researchers making use of much of the UK's media infrastructure, there are many more who have no straightforward way of accessing much of it. Many of the advanced research laboratories are woefully understaffed resulting in poor utilisation and usually almost no uptake from outside the local department. Investment in new infrastructure should not repeat the mistake of overlooking cost of ownership. Furthermore, there is ample opportunity for multidisciplinary digital economy research to utilise much of the equipment already spread across most of our universities, but again the true cost of supporting uptake must be funded. In short, we need to stop buying expensive kit without balancing the investment with staffing that can maximise the utilisation.

Conclusions

There is a great deal of diversity of research content, process and infrastructure related to digital media throughout the UK. This diversity is a strength to be welcomed. The UK's experience in this respect mirrors many other countries position's. Such diversity also permeates extant media lab and media city initiatives around the world too. The one thing that presents itself as making such diverse sets of arrangements work is not focussing upon solely upon a global perspective over engagement at the local level. Infrastructure tailored to the needs and strengths of particular local circumstances came though strongly as a requirement of the research community above that for dedicated generic media lab type facilities. These lessons will be of particular importance if capital expenditure is to be set aside for additional location-based infrastructure, but should also be taken into consideration when funding distributed infrastructural enhancements. A key question should be, "Are the proposed projects embedded within their UK region as well as targeted at global reach?"

The primary initial finding is that places and people are of utmost importance and that the places where multidisciplinary media research has greatest potential impact is where people live or go. There is a strong trend away from watching broadcast media to participating in the creation of "future media" content and experience. This provides the pull for convergence of humanities, technology and social science research. The future media trend is demonstrating the power of the people when it comes to driving content and experience. Is there not a case for similar to happen in research? Applications that embody this scale from YouTube, to international democratic news and tele-presence experience between public places across the world. The infrastructure that underpins such activity is already strong but is not always at its strongest in the places where people live or go.

There is an emerging trend away from single discipline research in university labs and towards multidisciplinary research in the places where it impacts. One example of this is the 27 living labs already established in Europe's cities and the proposals for more submitted in response to the EPSRC's call for digital hubs. While many improvements to widely available media technology are on the horizon, and what will be taken up is under some debate, the only widely agreed certainty is a continued growth in the need for bandwidth. In contrast to the foreseen need to increase the bandwidth to where people live and go, the majority of current and planned provision to support research is between universities and in some cases to major national sensors and computer resource. There is significant latent capacity in the Joint Academic Network and there is an opportunity to release this to the research centres engaged in digital economy media research. For example those digital hubs that sit within a university campus could be interconnected with greater bandwidth for little cost. However, the funding model for JANet only takes the bandwidth to the university campus and not within it and does not take it to public places or spread it across a city. This is connected with the problem that many testbeds reside within a

single laboratory, are relatively small, and interoperable. If multidisciplinary research is to move from the university lab to the places it will be used then there is a need to revisit the model of what constitutes a place of academic research and thus requires bandwidth. If we are to scale to collaborative research and commercialisation that spans the breadth of the digital economy, we need scalable and interoperable testbeds that are adequately connected.

A specific question this study was asked to look at is whether there is a need for a Media Lab like facility in the UK? While there is clear stakeholder support for replicating the positive features of The Media Lab in the UK, there was a reluctance to follow in the unsuccessful footsteps of the Dublin Media Lab. This opened the question of what was meant by a Media Lab facility? Was it a place that brought humanities and technology research together within the focus of media? Should it have a similar funding model to the original Media Lab? Should it be in one place or distributed? Following the above trends, a UK Media lab could be a virtual entity that brings together academic and commercial research in the places that people live and go through media technology.

It is certainly evident from our research that the potential utilisation of the majority of large scale media-based facilities in the UK is held back, firstly by a lack of support for staffing to encourage others to uptake the technology, and secondly, by the lag in bidding for and gaining funding to do research after the infrastructure is put in place. Furthermore, the need for adequate support of advanced technologies in the public and work place will be more pronounced than in the university. Therefore, funding for infrastructure, support and research must go hand-in-hand.

This research has also identified the need to coordinate the efforts of researchers in this area to create a pool of best practice and to leverage existing infrastructure provision. A directory of 'who's who' and 'who has what' could be helpful here, as it is apparent that one of the major obstacles to eradicating a silo approach to academic research, is that many academics do not know, and it is difficult to find out, who else is out there and interested in similar ideas and collaborations to them. Mostly we only discover others' academic work once it has been completed and published, sometime many years later. Even within a solitary academic institution it is often difficult to know what fellow academics are working on, and some intra-university networks, such as the Digital Cluster at the University of Salford (www.digital.salford.ac.uk) have been established to try and overcome these difficulties, but only with limited success.

In terms of technological infrastructures, there are many improvements to widely available media technology are on the horizon, and what will be taken up is under some debate, but the only widely agreed certainty is a continued growth in the need for bandwidth. There already exists significant latent capacity in the Joint Academic Network and there is an opportunity to release this to the

centres engaged in digital economy media research, but it is unclear whether increased bandwidth should be directed towards those who currently appear to need this, or if more widespread and democratic access to increased bandwidth would push innovation forwards in other institutions.

It is clear that there is no one answer to 'the best' form of infrastructure provision. Certainly, centralising provision in major cities or by institution for example, could, and probably would, potentially rule out development and innovation in other geographical areas and institutions. Furthermore, requirements shift over time, depending upon research trends, and thus there is a need to develop an infrastructure provision structure that takes a long term view based upon general ideas, but also with the flexibility to accommodate innovation in response to, and for the purposes of, societal development.

We have not seen a need for significant new spend in physical infrastructure or a need to radically change where this resides. There is a pull towards more research in the wild and this fits the nature of the digital economy program and thus should be supported. There is a stronger need to make what infrastructure we have more open to a broad range of researchers and stakeholders, regardless of who they work for or where they are. These needs, major issues, a recommendation of how these could be addressed, along with a detailed list of considerations, are given in the executive summary. The recommendation is framed within a model that considers people, places, testbeds and online tools.

There is a strong trend away from watching broadcast media to participating in the creation of "future media" content and experience. This provides the pull for convergence of humanities, technology and social science research.

About the Authors

Prof David Roberts is Head of the Virtual Environments and Future Media research Centre at the University of Salford. As well as contributing to his field in research he has designed four and directed the research within three immersive visualisation centres. In the last SRIF round of HEFCE he worked with National Procurement to coordinate 60% of the national spend on visualisation infrastructure. He is involved in a number of initiatives and projects around MediaCITYUK, including leading the design of a microcosm living lab. He has written several reports that have changed the way in which infrastructure is owned, supported and ran within his own university. Roberts primary research is in reproducing the face to face meeting across a distance, for which over the past year he has published ten papers and led a large EPSRC collaborative project. He is Co-General Chair of IEEE/ACM Distributed Simulation and Real Time Applications. Until recently he was also Co-Scientific Director of THINKLab.

Dr Garry Crawford is a Senior Lecturer in Cultural Sociology at the University of Salford. His teaching and research primarily focus upon audiences, fan cultures and the everyday uses of media. Garry Crawford is the Director of the Salford University Digital Cluster (www.digital.salford.ac.uk), which is a centre of excellence for research on digital media, and new and convergent technologies. He is the author of Consuming Sport (Routledge 2004), and the co-author of the second edition of Introducing Cultural Studies (Pearson 2008, with B. Longhurst, G. Smith, G. Bagnall, and M. Osborn), the Sage Dictionary of Leisure Studies (Sage, 2009, with T. Blackshaw), and is currently working on two books on video gaming for Routledge: Gamers: Video Gaming and Everyday Life (with V.K. Gosling) and an edited collection entitled Online Gaming (with V.K. Gosling and B. Light). Garry is an executive trustee of the British Sociological Association (BSA), and review editor for the journal Cultural Sociology.

Dr David Kreps is Director, Centre for Information Systems, Organisations and Society (ISOS), Salford University, a Senior Lecturer in Information Society, is an 'early adopter', pioneering thinker and commentator, with a fascination for technology and its impact upon society. A web developer since 1995, following his career as a Local Authority Arts Centre Director, he did his PhD thesis on Cyborgism, and since completing it in 2003 has become an expert on Web Accessibility, and explorer into the philosophy of Virtuality. David has been Principal Investigator on a European Social Fund eDiscrimination project, and two Environmental Informatics projects studying energy use in domestic (DEHEMS) and public buildings (BEPMS). He is Vice-Chair of the IFIP Working Group 9.5 on Virtuality and Society, and has published widely in Information Systems journals and conferences on eAccessibility and Virtuality. His background in Cultural Studies and Sociology foster a critical approach to his research in IS.

Prof Ben Light - holds a chair in Digital Media in the School of Media, Music and Performance and is a member of the Communication, Cultural and Media Studies research centre. His work is concerned with how people interact with socio-technical arrangements on an every day basis. Starting in the 1990s with a focus on the formal work organisation, he has over the past 5 years moved towards studying arrangements in domestic settings – specifically in the area of internet usage and digital gaming.

Prof Nigel Linge is the head of the Centre for Telecommunication and Network Research Ceantre at the University of Salford. Professor Linge has a research track record in the field of computer networking where he has carried out research into intelligent traffic routing, distributed firewall security for networks, network adaptable applications and a range of projects in the general field of context driven networks and information systems. The work on context driven information system was sponsored by EPSRC within the Distributed Information Management programme (Grant GR/N35823 "Intelligent Optimisation of Information Processing for Context Aware Environments"), and is now being extended to develop lower level protocols required for the exchange of context information within ad-hoc wireless networks and also to define structures for the formatting and organisation of context information within nodes.

Laurence Murphy is Senior Lecturer in Media Technology and programme leader for both the BSc Media Technology and the BSc Mobile and Internet Television. Laurence is Director of Media Technology for Media at the new Salford University complex at Media City UK. He is an active researcher in Mobile and Internet broadcast systems, High Definition & 3D Television and Digital cinema. He is currently engaged in PHD research into changing media technologies and their impact on both the Broadcast industries and the viewer. Laurence began his operational career as a location sound recordist in 1985 whilst studying for his 1st degree. After a move into Camera work he progressed into studio and outside broadcast technical management. He is an active camera and engineering consultant for a number of broadcast companies and manufacturers. He began his association with Salford University in 1992. He designed the four camera studios within the school. His academic career began with a BA in Communication Media in 1986, his second degree MA in Television and Documentary he completed in 1999.

Steering:

Prof Michael Joroff, MIT - director of research and special programme development for Massachusetts Institute of Technology's School of Architecture and Planning. Prof Joroff is a professional researcher whose expertise includes group facilitation, project design and management. He is currently co-leading the New Century Development (NCD), an initiative to undertake research activities and communication forums aimed at understanding and improving the physical real estate development processes in the 21st century – and is strategically supporting the development of the MediaCityUK initiative in Salford Quays, in particular advising on developing effective avenues to link the business community with research base to develop high-end research infrastructure for the digital media sector.

Dr David Good, Cambridge MIT, Cambridge University – is a lecturer in the Department of Social and Developmental Psychology within the Faculty of Social and Political Sciences, Cambridge University; a Fellow of Kings College, Cambridge; a member of the Governing Body of the Royal College of Art and Education Director at the Cambridge-MIT Institute. David's expertise includes the interpersonal and psychological processes underlying human communication, and the social consequences which follow. This involves studying phenomena ranging from interactional breakdown in certainpsychopathologies to the use of new media in the creation of electronic town halls. Recently, his focus has been on the study of information and communication technologies, and the use of ideas from human communication in the design of novel ICT.

Prof Peter Barrett – Is a Professor of Construction and Property Management at the University of Salford. He is the principle investigator of the EPSRC Framework for innovation and Research (FIRM) which brings together three universities and a range of companies and regional networks around MEDIACityUK. Until recently he was Head of Research at the University of Salford, with the role of Pro Vice Chancellor of research. Peter is well established in the field of the Built Environment in which he has lead many projects and published numerous papers.

Dr Bruce Weir, BBC - Bruce Weir has been employed as a Research Engineer at BBC Research & Development since 2000. He has undertaken a wide variety of media research projects, with an emphasis on the future development of broadcast studios integrated with virtual reality systems. His particular interest is the development of new forms of media which extend the technology of Massively Multiplayer Online Games to provide far richer narrative types than are currently possible with existing internet technologies. He is currently undertaking an infrastructure specification project for the new BBC R&D facility based at Media City in Salford, to ensure that it has the necessary technical capabilities to support future media research over the next decade. Before joining the BBC he gained a PhD in Physics at the University of Cambridge.

Prof Terence Fernando - is the Director of the Future Workspaces Research Centre and the Scientific and Technical Director for the Think Lab at the University of Salford. During the last four years, he led a regional research centre on advanced virtual prototyping, involving the Universities of Salford, Manchester and Lancaster. This EPSRC/OST funded (£1.7m) project brought together the key research teams in the region to develop visualisation and simulation technologies for product design. He has a broad background in conducting multi-disciplinary research programmes involving large number of research teams in areas such as distributed virtual engineering, virtual building construction, driving simulations, virtual prototyping, urban simulation, and maintenance simulation.

Prof Elaine Ferneley – is Director of Manchester Business School's MBA programmes. Before joining academia she worked for IBM and ICI developing collaborative virtual environments for various commercial purposes. Since joining academia, she has used her commercial expertise to develop industrially relevant research projects focusing on digital technology adoption, diffusion and innovation. In recent years she has worked on developing digital truth and trust models for electronic health care systems with AT&T Istel, on the EU funded projects including the e-Cognos (£3.2m) and Funsic (£1.3m) projects which explored collaborative virtual environments for the construction industry (industrial partners included Taylor Woodrow, Hochief and YIT), on the EPSRC C-Sand project on formalisation of sustainability knowledge, on the adoption on mobile technologies by the emergency services, on business networking technologies with Co-operatives UK Ltd. and on emerging concepts of digital 'self' within social networking technologies specifically as used by pre-teens.

Mr Matthias Fuchs – is a Programme Leader MA Creative Technology, Programme Leader MSc Creative Games. He has expertise in New Forms of Interaction in 3D Environments, Game Design, Knowledge Spaces, Representation of Knowledge in 3D and Environments, Sonic Art, Semiotics of Games and Sound. Mathias has been conducting research into feasibility of a New Media Centre in Linz (Upper Austria). In 1999 ARCHIMEDIA (Linz) commissioned piece for the Mind Zone at Millenium Dome Greenwich to represent developments in Media Society. In 2001 Sibelius Academy, Helsinki asked him to develop Games related content and infrastructure. In 2004 he developed an MSc Programme in Creative Games in cooperation with industry, Ludic Society and research network Games Studies.

Prof Mike Kagioglou - is the director of the EPSRC funded (£4.98m) IMRC (Salford Centre for Research and Innovation - SCRI) and of the EPSRC funded (£7.3m) IMRC (Health and Care Infrastructures Research and Innovation Centre – HaCIRIC). The Innovative Manufacturing Research Centres (IMRCs) are engaged in innovative research around the issues of organisation, people and digital technologies. HaCIRIC is a multidisciplinary collaborative centre between Salford, Imperial, Loughborough and Reading

Universities with many links to other Universities and institutions. Mike was the Programme Director for the MSc Built Environment for Healthcare, currently on contract with Blackwells for a book on Improving the Performance of Healthcare Infrastructures and is working with many primary care trusts on new models of healthcare delivery, including utilisation of digital technologies, Acute Trusts, the Department of Health and other healthcare infrastructure delivery vehicles such as community health partnerships and strategic health authorities.

Data Gathering, Web and Wiki

Rhianne Jones – is currently a PhD researcher and Graduate Teaching Assistant in the school of English, Politics and Contemporary History at the University of Salford. Prior to this she was a part-time lecturer at Liverpool John Moores University. Her research interests concern people's everyday usages of social networking sites and how they weave these into their lives.

John O'Hare - has 15 years' experience in electronics with a 2:1 BEng(Hons) in Electronic and Electrical Engineering and time in industrial electronics product design, general ICT (courses throughout in windows, CISCO, Linux, programming, and content design), and more specifically VR systems with a MSc in Virtual Environments from The Centre for Virtual Environments. As a content creator and consultant with the VETS group in the more commercially tasked arm of the CVE John spent several years in a client facing role as a consultant, and representing the University nationally and internationally at presentations and trade shows. Latterly John has been employed by ThinkLab, responsible for the new octave system, an advanced VR research platform designed and built by the Centre for Virtual Environments with designinput and technical overview throughout. His ongoing mandate is to secure additional funding, and assist research, while managing and developing the technical facilities onwards into the next generation system mooted Media City.

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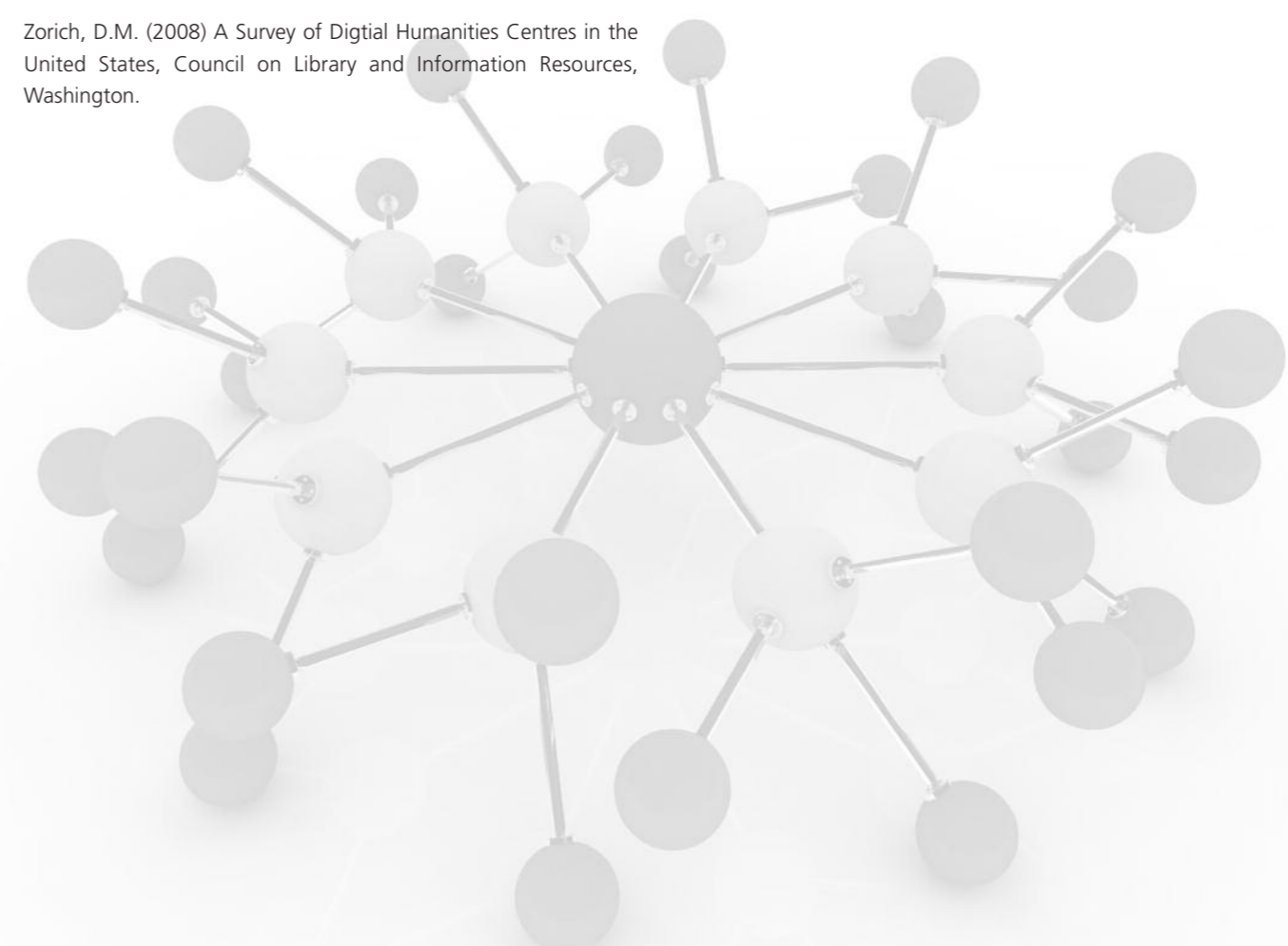
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Notes