Submission 205
Date received: 15/03/2011

MONASH University

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14 March 2011

Chair
House of Representatives Standing Committee on
Infrastructure and Communications
PO Box 6021
Parliament House
CANBERRA ACT 2600
AUSTRALIA

Dear Chair

Re: Inquiry into the role and potential of the National Broadband Network

Please find enclosed Monash University's submission to above inquiry.

The University has responded to the following terms of reference:

b) achieving health outcomes;
c) improving the educational resources and training available to teachers and students,
d) the management of Australia's built and natural resources and environmental sustainability; and
g) interaction with research and development and related innovation investments.

Senior members of the University's management team look forward to discussing our submission with you further on Friday March 18th.

Yours sincerely

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Monash University Submission to the Inquiry into the role and potential of the National Broadband Network

INTRODUCTION

A high speed national data network will assist Australian universities to fully realise their education and research missions in the twenty-first century. This, in turn, will enable many public policy objectives as higher education and research provide the foundations for public, economic and social goods. Collaboration is critical for research impact and transformative education. Information and Communications Technology (ICT) is now absolutely central to the way we work on campus and with the communities we serve. The tools and connectivity provided by ICT are opening up new opportunities every day. Because of this, every aspect of knowledge work seems to have had the prefix 'e' added to it in recent times we all see endless 'eOpportunities'.

Today we work with ever larger digital file sizes due to the continually expanding data sets, tools and content to support collaboration. Bandwidth constraints are limiting Australia's universities in their capacity to collaborate electronically with other sectors of society. Therefore, the progress of research towards breakthroughs, and translation to society, is restricted. These discoveries may result in major new understandings towards curing disease, significant commercialisation opportunities, or social goods that improve the everyday lives of Australians. Bandwidth issues also curtail opportunities for university students to maximise the potential of electronic tools to gain exposure to the world's greatest minds or acquire the necessary graduate attributes for the modern age.

Conversely, this is not the case when it comes to collaborating within the university sector. Australian universities have formed a consortium with government and other interested organisations to provide sufficient bandwidth to enable online collaboration. The following table lays out the connectivity speeds currently experienced in Australian universities compared to the other sectors of society. It also shows the time it would take to transfer a large file under optimal conditions. These conditions include not sharing the link with other data transfer operations and having an equivalent speed remote connection, so it is rarely achieved in practice. File transfers of this size would regularly be needed to enable research or education collaboration. These file sizes might represent a research data set, thirty minutes of DVD quality video or approximately four and half minutes of high definition video.

Universities		Home / Business		Hospitals		Schools	
Typical Data Transfer Speeds (per second)							
Download	**Upload**	**Download**	**Upload**	**Download**	**Upload**	**Download**	**Upload**
10 Gb	10 Gb	20 Mb	1 Mb	10 - 20 Mb (city) 8 Mb (rural)	1 - 4 Mb	2 - 20 Mb	2 Mb
Time Needed to Transfer 1Gigabyte (GB) File Under Optimal Conditions							
1 - 5 sec	1 5 sec	9 min	3 3 ½ hours	9 - 20 min (city) 22 min (rural)	1 ¼ - 3 ½ hours	9 min - 1 ½ hours	1 ½ hours

Monash University's education and research mission is tied to operating in the world. As a result, our submission responds to the terms of reference that deal specifically with education and research as well as those relating to health and the environment. Along with appropriate complementary investments, we wish to highlight the opportunities that a high speed national data network could help to realise. Such a network will help to:

Health

- Provide much needed teaching facilities for students working and studying in rural and regional teaching hospitals.
- Improve collaboration between researchers in health, biotechnology and biomedical engineering.
- Deliver telemedicine services such as the Victorian Stroke Telemedicine project, remote medical imaging and telediagnosis.
- Provide rapid access to patient records and images in emergency situations.
- Provide preventative health care initiatives such as remote diagnosis of breast cancer.
- Deliver vital telemedical services in disaster situations.

Education

- Provide access to rich media educational materials online.
- Replicate the richness of the collaborative on campus environment in many locations.
- Facilitate the development of new pedagogies and teaching methods such as inquiry based learning.
- Evaluate the efficacy of new educational technologies.
- Deliver specialist subjects to regional areas to alleviate the teacher shortage.

Environmental Sustainability

- Reduce the need to travel through providing rich desktop environments and collaborative tools for education and research purposes anywhere, anytime.
- Consolidate inefficient and duplicate data centres into environmentally friendly shared data centres that maximise server virtualisation and shared storage.
- Reduce the travel requirements of support engineers to maintain remote data centres.
- Replace paper based learning materials (and associated impact of distribution) with electronic learning materials and eBooks.

Research

- Facilitate more inclusive and accurate collection of data, particularly in neglected areas such as rural health.
- Facilitate better collaboration between Australian business, industry, manufacturing and universities leading to greater efficiencies, research breakthroughs and translation to society.
- Facilitate a shift in research effort from being university centric to becoming community inclusive.
- Provide greater opportunities for commercialisation and application of research to solving the real world problems of the twenty-first century.

- Enable better immersive visualisation and video environments that promote new research methodologies and resultant discoveries.

APPROACH TO SUBMISSION

This submission commences with background material that provides an introduction to Monash University and the key role ICT plays in our everyday activities in education and research. The subsequent sections lay out how a national high speed data network will assist the efforts of Australia's universities and help to deliver desirable outcomes in health and towards a more sustainable environment.

Why Monash University is interested in increased connectivity

> *Monash University seeks to improve the human condition by advancing knowledge and fostering creativity. It does so through research and education and a commitment to social justice, human rights and a sustainable environment.*
>
> *Monash Directions 2025*

Monash University is an energetic and dynamic university committed to quality education, outstanding research and international engagement. With a population of over 59,000 students and 15,000 staff, Monash is the largest university in Australia. We are also the most internationalised university, drawing students and scholars from many nations to our six Australian campuses, and international campuses in Malaysia, South Africa, and a Centre in Prato, Italy. We teach at thirty-six sites around Victoria, many of them in regional or rural locations. Our Victorian campuses are spread across city, urban fringe and rural locations. Additionally, we have research and education links with universities and other institutions around the globe.

Monash is in the business of creating, enhancing, sharing and disseminating knowledge. We do not do this for its own sake. Rather, we see ourselves as a university in the world that addresses the most important theoretical and practical challenges of our times and inspires graduates to wish to do the same. Realising this vision requires effective partnerships with every other sector of society, from individual students to hospitals, schools, government and non-government organisations, and the service and manufacturing sectors.

Our highest-level strategic document, *Monash Directions 2025,* highlights the vital role that ICT plays in our daily operations. It states that ICT assists us with our work and enables the connections with our students, industry and research partners and our communities. As pervasive as electricity, ICT and the underlying communications infrastructure, underpins every facility, research group and student's learning experience. This is especially true as we enter a truly data and content rich age.

Monash is at the forefront of using ICT to develop new research and education environments and paradigms. Centres for eEducation and eResearch have been established to facilitate and co-ordinate Monash's approaches to using ICT. We recognise that society and knowledge are being fundamentally changed by technology and that our staff and students must master technology to adapt to these changes. This includes mastery of constantly emerging technologies and the capacity to harness incredibly vast quantities of information and data. In light of this, we develop environments to bring staff, students and partners on a voyage of discovery and to create a new generation of technologies, knowledge, and leaders.

This submission responds to the terms of reference related to health, education, sustainability and research. These are four areas in which Monash has a well-established interest and expertise. We have daily interactions with partners in hospitals, schools and other institutions interested in pursuing the most important theoretical and practical challenges we all face.

ICT has fundamentally changed the way we work

Traditional methods of knowledge creation, management and transfer methods are ill-equipped to deal with the growing information demands of the world in which our staff and students live and work. We are all still to catch up with the explosions in demand arising from the increasingly data-driven approach of every industry. More capacity building is needed to take full advantage of emerging technologies. Data storage approaches remain inefficient and student disengagement in the education process remains a challenge despite ever-richer means of communication. Students' preparation for the technological aspects of higher education and work varies greatly depending on their prior access to technology. The full benefits of research findings are often unrealised because old-fashioned dissemination methods preclude further discovery. Technological resource constraints still limit further exploration within and across disciplines. Monash is interested in addressing all these challenges.

The real world issues of today and tomorrow require collaboration for resolution. Collaboration makes the whole greater than the sum of the parts in the knowledge economy. Technology is enabling the collection of incredible quantities of data. Analysis of this data requires the application of many minds. Collaboration too, is a key skill for students to develop to become fully equipped for today's and tomorrow's workplaces.

Universities play a leading role in the development, application and assessment of new technologies. Monash recognises the opportunity and need to have staff, students and partners turning their minds to new ways of working that take full advantage of new technologies in order to unlock the knowledge buried within today's vast data sets. We are creating the classrooms, laboratories and partnerships of the future. This involves facilitating interactions with cutting-edge technologies and encouraging analysis of the efficacy of these technologies. We are continuously finding new ways to use technology to progress teaching and research practices. For example, technology is enhancing our capacity to:

- develop revolutionary, pedagogically exciting teaching methods / disciplines.
- expose students to top minds and research from all over the world.
- engage in collaborative work of all kinds with the communities we serve, including as a regular part of coursework programs, cross-disciplinary work across our international campus network and with partners working together on real world problems.
- invent new methods of research.
- share discoveries.
- find new ways of navigating educational and research resources.
- establish cutting-edge knowledge, information and data management techniques.

Australian universities enjoy high speed connections via the Australian Academic and Research Network (AARNet) and Victorian Education and Research Network (VERNet). As a result, Monash enjoys a 10 gigabit per second (Gbs) fibre network. Monash staff and students therefore experience direct benefits of first class internet connectivity. It is this very connectivity that allows us to push the education and research agendas outlined above.

Investing in greater connectivity between key Australian sectors

Institutions and individuals outside the higher education sector in Australia do not have effective connectivity with universities. This limits their capacity to receive and utilise large scale data and content, which in turn, hinders our opportunities to mine and analyse data or support rich learning environments anytime, anywhere. We experience significant difficulties communicating and connecting with partners in homes, hospitals, schools, business and industry. The aging copper wire communications network is inadequate for the data intensive applications of the twenty-first century.

Universities rely on 10 Gbs download and upload speeds to enable our work. The partner institutions we work with are often restricted to 20 megabit per second (Mbs) download and generally less than 4 Mbs upload speeds. Therefore, the 1 GB file we can upload or download within the university network within five seconds, takes at least **twenty minutes** to download at a city hospital. When colleagues at the hospital have finished with their actions on the file and want to send it back to us, this will take at least **an hour and up to three hours**. By comparison, it would only take around five minutes to transfer that same data file over a 40 Mbs broadband upload link. This obviously limits the collaboration that can occur. In these circumstances, data analysis slows to a crawl. Real time collaboration with colleagues becomes frustrating. It can be more effective to send a colleague hard disk with data in the mail than to wait for that data to transfer over the copper network.

Australian universities cannot fully realise their education and research missions in the twenty-first century without national high speed data connectivity. The potential discoveries that could be uncovered through full online collaboration cannot be imagined and the claims sometimes made in this domain seem outlandish. The ICT research and advisory firm Gartner describes a 'hype cycle' that relates to the introduction of new technologies. Gartner suggests that new technologies travel through a cycle of inflated expectations, subsequent disillusionment, a phase of enlightenment and then a plateau of productivity.[1] For the staff and students of Australian universities trying to work or collaborate with colleagues off the campus network, disillusionment with online collaboration lies in this lack of high speed connectivity.

A national data network that achieves high speed connectivity will address many limitations that we experience today and will open up opportunities that we can only imagine, as well as others that we cannot yet foresee. The potential benefits are enormous yet intangible. The classrooms, laboratories and workplaces of tomorrow will be as fundamentally transformed by high speed connectivity as they have been today by the advent of the internet itself. Monash envisages a future state where collaborating anywhere, anytime will feel like collaborating with a colleague in the next room. We are working on developing and assessing the technologies and approaches that will facilitate this, but doing so is dependent on a national high speed ICT network. Such a network will

[1] Gartner (2011).

provide a backbone for our efforts and open up unimagined 'eOpportunities'. The public, economic and social benefits to be derived are immeasurably positive.

Investing in greater connectivity will address rural and regional disadvantage and reduce carbon footprints

We know that rural and regional Australia experiences severe disadvantages in the knowledge economy due to its lack of effective connectivity. Distance is also an increasing problem in urban environments as individuals and institutions seek to minimise their carbon footprint. A key way to achieve this is through reducing travel. We are yet to achieve the imagined future state in which we can work or learn anywhere, anytime online as though we were in the same room as our colleague or lecturer. National high speed connectivity is likely to get us closer to this state, and therefore, have a significant impact on carbon footprints.

The need for complementary investment

The investment needed in the national data network, regardless of source and regardless of the final technical or project considerations, represents a significant proportion of the nation's future capital investments.

The success gained by Monash in the area of technology intensive research has taught the institution the importance of retaining balance within investment portfolios. In this regard we note a number of important considerations:

- Any user (whether at the individual, corporate or institutional level) will need to make corresponding investments to be able to take advantage of new data network services. A physical network on its own is not sufficient to achieve the many goals to which it aspires.
- 'Investments' in this context relate to financial, technological and human expertise or any combination of these.
- We note particularly the level of complementary investment, in both technology and human expertise, that will be required in the health sector (whether rural or major metropolitan hospitals).
- In the higher education sector, universities will continue to need to make complementary investments which align to their overall research and education missions. Were funding for the physical infrastructure to be made without recognising those needs (alongside other basic funding considerations for Australian universities as a whole), many of the desired outcomes are not likely to be achieved.
- There are many timing issues to take into account, not least the availability of investment funding, human capital and the inevitable changes in underlying technology that will occur during the investment stages in the network. We believe it would be beneficial for there to be a clear set of priorities and a broad understanding of the likely timetable so that all potential user communities can determine their own complementary investment and exploitation agendas.

SUBMISSION TO SPECIFIC TERMS OF REFERENCE

b) Achieving health outcomes

ICT is opening up significant opportunities to achieve health outcomes for all Australians. Current connectivity rates between the university and health sectors severely limit the realisation of this potential. The file sizes created by medical research are growing exponentially. Scientific and medical discovery has already become extremely data and computationally intensive.[2] Everyday, our staff and students who engage with our two hundred partner institutions in the health sector, experience problems communicating electronically for research or education purposes. We work with massive clinical data sets, visualisation and collaboration tools to enable interactions between the institutions. Most hospitals and institutions in Australia still connect to the internet using copper wire technology, limiting data download speeds to a maximum of 20 Mbs. The lack of bandwidth adversely affects research efforts, impedes collaboration and prevents simultaneous delivery of lectures electronically from campus. In order to address immediate issues, Monash has worked with hospitals to upgrade networks. Examples of this include:

- Frankston Hospital located across the road from the Peninsula Campus, where Monash provided a 20 Mbs connection. The hospital previously shared a 10 Mbs internet connection amongst all staff in the 336 bed hospital.
- Bendigo Health where Monash University provided the 1 Gbs data link to allow for telemedicine applications.
- Wonthaggi Base Hospital where Monash University installed an 8 Mbs internet link to give students electronic access to lecture material and video conferencing.
- Mildura Hospital where Monash University upgraded the internet link to 8 Mbs download and 4 Mbs upload (using 4 telephone lines). This was just to provide the 25 students and 15 staff with useable internet and video conferencing facilities but is still inadequate for file and data sharing or collaboration.
- Alfred Hospital, one of Melbourne's major teaching hospitals, to which Monash University provided the 1+ Gbs VERNet link to allow for image, file and data sharing with the researchers at the main Monash campuses.

These connections better facilitate the work of Monash staff and students while they are at the hospital sites and collaboration between colleagues on campus and on the wards. A national high speed data network will alleviate many of the electronic collaboration issues between the university and health sectors, mitigating the need for individual institutions needing to apply connectivity upgrades as the need arises. It will also better prepare the health sector for the significant bandwidth needs that will grow out of new applications and approaches in eHealth.

The application of technology to healthcare has the potential to significantly improve the delivery of health services particularly in rural and regional Australia.[3] Various areas of research examine how

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[2] For example, the size of the 1000 Genomes project data is over 50 TB (or 50,000 GB) with researchers initially spending days transferring the data over the internet between research institutes in the UK and US. Powell (2010).

[3] Bras-Gomes and Patricio (2008) lists the some of the benefits of eHealth as teleradiology (transmission of remote medical images) to establish remote diagnostic centres costs savings from the electronic transmission

technology can be used to deliver health services remotely to address the shortage of highly qualified and specialised medical staff in rural areas. Of course, local doctors will always be needed. A good experience for students on rural clinical placements is more likely to encourage consideration of a career in rural or regional Australia. Incapacity to access the full ICT resources of city-based colleagues is diminishing the rural placement experience of our students today.

eHealth is a term that can be used to describe both greater access to health services, mediated through technology, and the move towards consolidated electronic health records. In the Australian nomenclature, the term eHealth generally refers to the latter. The former is often referred to as telemedicine, telehealth or telediagnonostics. Both aspects of applying technological solutions to improving healthcare will benefit from greater data transmission speeds.[4] It is reasonable to say that the case for telemedicine is well-established, whereas the case for consolidation of personal electronic health records is more emergent. Further research is needed to develop the applications of and clinical methodologies for both telemedicine and eHealth. In telemedicine for example, the next research steps may well concentrate on how to take the paradigms and learnings established in the public hospital system to the places where more patients are located, such as the home, primary and aged care sectors.

Monash University is using telediagnostics in a trial with Bendigo Health to allow Melbourne-based specialist neurologists to remotely treat acute stroke patients living in Bendigo. The Victorian Stroke Telemedicine (VST) project uses a 1Gbs VERNet link to transmit data from brain imaging, video conferencing and high definition camera images to the specialists in Melbourne. The infrastructure also links the Bendigo trauma unit to the Alfred Hospital to obtain specialist trauma care advice. Such collaboration is not possible over the typical 20 Mbs internet connection available in most hospitals.

The future state imagined by those working in telemedicine sees the technologies that are emerging today facilitating a much more patient-centric model of care. Health professionals will be able to provide diagnosis and make treatment decisions collaboratively with greater speed and effectiveness using electronic tools for video-conferencing and large imagine transfer. A single CT study could easily generate 30 or 40 GB in images that require consideration by multiple care-givers. The bandwidth available to local medical practices, specialist suites and even hospitals today cannot support electronic collaboration with the necessary capacity, accessibility and scalability. The future state of telemedicine requires faster upload and download speeds than are currently available. This will enable the high definition video conferencing required to provide a clinical grade collaborative environment. It will also allow for the transfer of large images and for large, multi-person video conferences.

Many of the applications that will become commonplace in telemedicine are available today. However, their only practical application is in locations within five kilometres from an exchange. The

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and distribution of medical images preventative health initiatives such as mobile digital mammography units for breast cancer screening high speed secure access to medical records for emergency rooms and trauma centres. Ziadlou (2008) describes the application of telemedicine in providing acute medical care in disaster situations where it is either impractical or unsafe to deploy specialist medical teams.

[4] Experiments carried out by Ohashi et al (2008), found that 35 Mbs was required to deliver sufficient quality images to allow experienced endoscopists to carry out reliable diagnosis of various conditions.

high definition video conferencing needed to facilitate the human communication that is critical to good healthcare requires highly accessible bandwidth everywhere. As telemedicine becomes more and more common, greater bandwidth will be needed to support healthcare professionals everywhere accessing electronic collaboration and imagine sharing tools concurrently. A national high speed data network will enable this and contribute to greater continuity of care.

Today, the only practical way to reliably transfer diagnostic images is literally in the hands of the patient. The various appointments needed to make diagnostic and management decisions therefore can take months, while the patient's condition potentially worsens. As the population ages, becomes more infirm, and the available health workforce becomes more and more stretched, this model clearly is unsustainable. Urban, regional and rural patients are all disadvantaged by the current model of care. In the future state, diagnosis and effective medical decision making can occur within the hour, by multidisciplinary teams, working together electronically. The concept of the eHospital, which will reduce length of hospital stay, provide better access for the community, and reduce medical errors, will require significant improvements in internet capacity.

Monash is working on the Victorian Regional Cystic Fibrosis Program, which uses video consultations for patient care. This program is modelling and piloting emerging practices in telemedicine. Interaction between electronic healthcare initiatives, such as video-conferencing and electronic health records will be examined in this pilot, which will demonstrate the advantages of a national high-speed data network. Each project in this space will enable greater return on investment for future funding dedicated to eHealth, as the lessons learnt impact on our thinking about methodologies and tools. This will further facilitate work that will have positive impacts for remote Indigenous populations and national screening programs seeking ensure the early diagnosis of disease. Current thinking is shaping the view of the requirements for clinical-grade collaboration tools that support one to many and many to one interactions and the sharing of large images. As with the application of electronic tools to any field of endeavour, effective development requires much research and piloting. In the medical field, this work is absolutely critical to prevent adverse outcomes. Greater bandwidth is needed to move us from the current to the future state.

As the eHealth agenda also moves towards single repositories of digitised patient records, the potential applications in emergency health are very exciting. Doctors in emergency medicine often treat patients with access to only partial information today. In the future state, doctors will be able to access a patient's full medical history when they present in emergency wards. This will allow for much more effective health care. Access to high speed connectivity anywhere, anytime will also enable the Australian Defence Forces' moves into eHealth. Doctors will be able to provide diagnosis and treatment decisions from Australia (regularly in the middle of the night from their homes) to injured or ill troops deployed anywhere in the world. Today, this doctor will probably only have access to 10 Mbs download and 2 Mbs upload speeds. These speeds limit the use of eHealth practices today and the development of these practices for tomorrow.

Using clinical registries to improve the quality and safety of healthcare

The collection of patient information and vital health data has often taken place in an ad hoc manner across the different health providers. Records are stored in variety of systems ranging from paper documents through to individual databases with noticeable differences in the type and quality of information collected.

Centralising and securing patient health records will have a considerable benefit for the provision of health care. Clinical registries consolidate data from across the hospital network on specific medical procedures, devices or drug reactions. Proposals are in place to establish a cardiac procedures registry. Detailed analysis of the data, carried out by specialist medical researchers, hopes to uncover success factors and trends in treatment of these conditions to better improve education and planning.

Likewise, the ability to analyse trends in the adverse drug reaction data set will allow researchers to discover and predict potentially life-threatening drug interactions as well as provide greater understanding of how these drugs work in the general population.

Due to bandwidth constraints between hospitals, emerging medical registries rely heavily on human data entry of paper forms and re-keying of information. This adversely affects the timeliness and accuracy of data as well the cost of maintaining these registries.

Ultimately, the vision is to populate these registries directly from patient data stored in each hospital's computer systems. Achieving this vision relies upon high speed connectivity to all hospitals to allow rapid and reliable transfer of vast quantities of information between hospitals, health providers and researchers.

c) Improving the educational resources and training available for teachers and students

The university classroom of the future

University student life has changed. The university is constituted by students with a broader range of cultural, linguistic and academic formations. Therefore, students come to us with a range of ICT and information literacy. They are studying a wide range of degrees and more of them are going on to undertake postgraduate work. Financial pressures have increased for many students and they need to juggle part time work and other commitments in addition to study. They seek to access resources and collaboration opportunities on campus, at home and at their workplaces.

Many of today's domestic undergraduate students who commence university immediately after completing high school take ICT for granted as a part of everyday life. They have grown up with technology, do not remember a life before computers, and barely remember life before the internet was pervasive. Equipped with mobile computing devices, access to rich media and information anywhere, anytime, they expect their learning to be delivered in a similar way. Engaging with students of the internet generation presents its own challenges and universities need to adapt to this new environment. This includes developing updated teaching pedagogies, moving towards a more inquiry-based learning model and incorporating rich media learning aids. Crucially, immersive environments and simulated digital experiences are as important to education as they are to research. For example, our Law Faculty is finding new ways to expose students to Moot Courts. The combination of bandwidth and Monash's design nous will allow us to produce a flexibly-immersive Moot Court. A single room will one day be the High Court of Australia (while teaching constitutional law); the next day it will morph into the International Court of Human Rights (when teaching Refugee Law or Crimes Against Humanity); the third day it transforms into a Native Title Tribunal in Aurukun (to teach Customary Law). This approach will extend, broaden and deepen our learning and teaching at all levels. It will also facilitate community interaction and education, all in the same physical space in multiple, complementary ways.

Universities are exploring new educational experiences and methodologies that are enabled by technology, such as high definition video, which provides greater access to non-verbal communication than the previous iterations. We also regularly use live classroom software that allows students to hear each other in a virtual classroom environment, share ideas and work together on group projects.

Monash seeks to prepare our graduates for the world. The core attributes we wish to instil include the capacity to be effective global citizens and critical and creative scholars.[5] Sound information and ICT literacy are key to all these attributes. An example of a unit that marries these endeavours is Tropical Terrestrial Biology. In this unit, students from the Malaysia and Clayton campuses collaborate using electronic tools to study the rainforests of Malaysia. They work together electronically on group assignments. Without significant bandwidth, this collaboration environment would not be successful.

The work we do today in education highlights some of the exciting emerging opportunities to change the way we think about education and extend the ways students learn. Examples of this work include:

- using interactive computer models and simulations help students better understand issues of population growth and climate change.
- taking advantage of virtual reality technology to engage in Physics, Chemistry or Molecular Biology experiments that would be too costly or dangerous to carry out in the laboratory.
- using video conferencing to learn a foreign language with a fellow student living in another country.

As students demand a more technologically-rich learning environment, we must continually assess the efficacy of new tools and approaches in order to determine their educational value. Over time, it is this analysis that will ensure we grasp the full benefits of technology-enabled education. In order to best evaluate and develop electronic learning strategies, it is necessary to obtain comprehensive performance data sets from a broad section of students and learning environments.

[5] *Monash Graduate Attributes Policy*, Monash University (2008).

Engineering students collaborating internationally on design projects

Large-scale, team-based, design projects have been an essential part of the student experience in Engineering for many years. As part of these projects, students in the Faculty of Engineering are working in new ways to develop the skills and approaches needed for the workplace. Each year, about seventy Monash students participate in international collaborative automotive design projects run by the Partners for the Advancement of Collaborative Engineering Education (PACE) and the Society of Automotive Engineers (SAE). The projects allow students to form teams and work across the automotive design lifecycle on everything from concept development, through detailed design, simulation and optimisation, to supply chain and product data management. Teams from universities in various countries participate in these collaborative real time projects. Bandwidth is a critical supporting tool for students participating in PACE and SAE projects. Monash students often make use of the University's wind tunnel and expertise in fluid dynamics and specialise in vehicle aerodynamic design. These projects are extremely computationally intensive. Individual results files are in the order of 1 GB. As technology, continues to advance, these file sizes will grow. See http://www.pacepartners.org/index.php and http://www.monashmotorsport.com/.

Contemporary practice in many Aeronautical Engineering firms is to conduct their design work in a 'follow the sun' model. Colleagues work together in virtual teams around the globe on a single design. From 2013, the Faculty will be using the New Horizons facilities, to provide Monash Australia students with design laboratories to work with fellow students at our Malaysia campus and Pennsylvania State University. Students will be exposed to real world design problems and experience the challenges and joys of working in cross-cultural virtual teams. Along with experiences such as those provided by the PACE projects, these formative experiences will help students to develop the team work and communications skills that employers seek. This learning style is enabled by the very best connectivity and collaboration tools as it requires the transfer and storage of very large files. The Faculty is seeking ways to extend this type of experience to all students during the course of their undergraduate degree programs. High speed connectivity will be critical for doing so.

The school classroom of the future

Schools, in particular, do not have access to the bandwidth necessary to create the education approaches of the future.[6] Bandwidth limitations slow down and preclude the realisation of maximum benefit from student and school performance data as well as the assessment of new electronic tools.[7] eLearning platforms are now becoming pervasive, with most Australian schools at least commencing to use these technologies. Due to limitations in bandwidth, each institution runs

[6] During a discussion with Netspace on 14/02/2011, Monash University was informed that Netscape is the sole provider of internet services to Department of Education and Early Childhood Development schools in Victoria. Netspace claimed that the majority of high schools and primary schools in Victoria access to fibre based internet connections that deliver 10 Mbs download and 2 Mbs upload with a shared 2 Gbs filtered connection to the internet.

[7] During a discussion with the Department of Education and Early Childhood Development on 03/03/2011, Monash University was informed that the National Assessment Program – Literacy and Numeracy (NAPLAN) database comprises annual records of performance for over 240,000 students in up to four areas of basic competence. Currently NAPLAN data is collected from each school on paper and manually entered, as it is not possible to transfer student data electronically over the current school network.

its own instances of an eLearning platform. Many schools, for example, are experimenting with the Moodle open source learning platform, but they are unable to share learning environments across the limited connectivity presently available. This leads to a duplication of effort in establishing and maintaining learning environments and prevents robust testing of the benefits across different environments. Limited bandwidth also precludes the effective sharing of electronic teaching resources between schools and with the university sector.

The rich learning environment of the future demands significant upstream and downstream bandwidth to deliver video, interactive learning modules, applications and collaborative tools. Students need access to this bandwidth wherever they choose to learn; whether it is in the home, at the workplace or on the move.

A tale of two curricula - interacting with schools

The partnership between the John Monash Science School (JMSS) and Monash University is a prime example of how ICT can be deployed to dramatically enhance the learning experience. Located on Monash campuses, JMSS and the Nossal High School are the only schools connected to the Monash ICT network. This provides the opportunity for delivering cutting edge curriculum opportunities to students.

Monash academics have been involved in the design of the curriculum structure and of particular innovative subjects that are only available at JMSS, such as Nanotechnology. Much of the collaboration that was needed to jointly do this work was conducted online. It is possible for the school to offer an inquiry-based learning pedagogy as ICT provides the link to vast online research resources and libraries. Students collaborate with University academics to assist with real research projects. As part of their studies, students regularly view high quality video clips to enhance their learning.

The ICT at the school is managed in close collaboration with Monash University to ensure that the provision remains effective and of high standard. Unlike at other schools, there is sufficient bandwidth for all 100 students to conduct research, watch videos, and collaborate with colleagues over the network.

Teachers also benefit from the JMSS experience utilising knowledge gained to further develop curriculum and build capacity in science and mathematics teaching skills.

JMSS connectivity contrasts with that of schools and students located elsewhere. For example, school students and staff can experience connectivity black spots as the current copper wire network infrastructure is stretched beyond capacity when trying to work or study at home. Students and staff often complain that it is very difficult to do anything online in the late afternoon and early evening.

The use of ICT in the development of science education and educators (such as in Chemistry education) is curtailed over the network. It is not possible to concurrently access the electronic video along side the commonly used sophisticated software tools such as those that allow for molecular modelling.

In an on campus setting, these tools work in harmony to engage student teachers in the core questions of Chemistry education. They simply cannot be concurrently delivered to the home or school environment, which limits emerging educators' opportunities to engage in the thinking the combined use of these tools creates.

Teachers also have difficulty accessing the full functionality of ePortfolios of teaching practice and resources. Whilst they can store resources electronically, they cannot share and use them in collaborative online environments that maximise their value.

Ultimately, the lack of bandwidth and connectivity between the University, schools and students stifles innovation in education.

Learning anytime, anywhere

At present in Australia, many students experience connectivity black spots, particularly in the evenings or weekends when the existing data networks are stretched beyond capacity. Websites fail to load, file transfers abort and video playback stutters. This severely hampers further development of rich interactive learning environments which rely on the ability to quickly transfer files and video. This affects all students irrespective of whether they are enrolled at a university, high school or primary school.

Bandwidth black spots are particularly acute in rural and regional areas where even basic connectivity is an issue. Lack of effective connectivity with schools affects any potential learning partnerships within the school sector and between schools and the university sector. Teaching and other educational resources could be vertically integrated via ICT across the school sector to compensate for shortages in science and maths teaching staff.[8] Libraries too, which are of course a great research and educational resource, are now grasping the opportunities presented by new and emerging technologies. The future state sees libraries deliver many more services electronically and being accessible anytime of the day or night. Greater bandwidth will enhance the capacity of libraries to undertake and assess the developments that will see this future state achieved. Bandwidth issues limit our imaginations and slow down the creation of new ways of using ICT to enhance the learning experience.

d) The management of Australia's built and natural resources and environmental sustainability

Moving data rather than people

Monash University, with its significant number of buildings, staff and students, generates a sizeable carbon footprint. Daily mass movement of people attending campus adds to greenhouse gas emissions, road congestion and parking problems. There are also the ancillary impacts of building and associated running costs of air-conditioning and lighting as well as maintaining large car parks.

[8] Harris and Farrell (2007), Williams (2005). In Australia, there is an almost linear relationship between community size and average math score independent of socio economic status. This is in part due to the reluctance of teachers to undertake rural teaching assignments. Hudson and Hudson (2008).

The classroom of the future can be delivered to students on and off campus. This will minimise the need to attend campus and help us to create better understandings of when a physical classroom experience provides the best learning opportunities to students and how this can be enhanced by ICT. The current copper networks to the home do not facilitate this development.

Smarr (2009) conducted energy analysis of various campuses in the United States and determined that the use of intelligent infrastructure would result in an overall reduction of 15% of 'business as usual' carbon emissions. Examples of intelligent infrastructure include using ICT to reduce commuting requirements for students and staff. He recommends universities substitute physical meetings with video conferencing and virtual conferences that maximise collaborative technologies and replace paper based teaching materials with electronic editions.[9]

Monash University is already taking steps in this direction by utilising its high-speed network connectivity with other universities to share data and electronic versions of research materials and journals. Initiatives such as electronic delivery of lectures to students in teaching hospitals or conferences, contribute toward reducing the need for lecturer and student travel. However, these efficiencies are not easily achieved outside AARNet enabled institutions.

Conferences and workshops provide vital opportunities for academic staff to share and build on their knowledge. Many of these conferences are international events, which to a large extent necessitates the need for sizeable groups of people to travel. Australia, because of its remoteness and relative isolation, is not a preferred venue for global conferences. Consequently, Australian academics need to travel regularly to maintain relationships with their colleagues in overseas universities and maintain their level of expertise. Whilst technology will never totally replace the necessity to travel, video conferencing, virtual reality and collaborative tools can markedly reduce travel requirements. The cost savings to universities and reduction in carbon footprint can be significant.

Green IT innovations

Data centres themselves are sizeable contributors to the carbon footprint of a university. To reduce this, Monash University is consolidating much of its ICT to a specialised off campus green data centre and utilising its high speed network to link the data centre to its campuses and some affiliated teaching hospitals.

Where high speed data links are unavailable, such as the Monash University facility at the Mildura Hospital, consolidation is impossible. This has the environmental impact of requiring individual data centres with their own servers, storage, associated cooling, backup power equipment and travel for support personnel.

This lack of connectivity is particularly acute within industry, businesses and the broader community. Schools in particular require their own data centres again with associated backup cooling and backup power equipment contributing to the overall carbon footprint of the educational sector. Readily available, affordable broadband connectivity could allow schools to pool resources utilising

[9] Seetharam et al (2010) modelled the carbon footprint of physically shipping information (on DVDs) compared with streaming the same information over efficient high speed networks. 30 – 65% less energy was required to distribute content electronically compared with shipping physical media.

server virtualisation technology. Regional hubs could also act as backups for other hubs, increasing the resilience of the network and reducing the need for additional backup equipment at each site.

As part of its ICT strategy, Monash University has conducted a pilot migration of 51 servers from one of its faculties to a virtual server farm in its new green data centre. This has a significant positive environmental impact through the decommissioning of 24 physical servers, closure of three separate data centres and reduction of storage from 6.2 TB to 1.2 TB. These migrations are ongoing and Monash University anticipates being able to migrate a further 770 servers during 2011. This will result in even further reductions to our carbon footprint.

g) Interaction with research and development and related innovation investments

ICT has changed the way we research

There has been a dramatic increase in computing power on the desktop over the last decade with many desktop and notebook computers outperforming the university supercomputers of several years ago.[10] The research paradigm is changing from being university-centric to inclusive of the whole community in order to take advantage of this shift. Projects such as SETI@home[11], and the open source software movement are manifestations of this change. Commencing in the 1990s, SETI@home was an early example of what we now call crowd sourcing. The connected world of cloud computing has enabled data processing to place anywhere and to allow everyone to contribute to the capital of human knowledge.

Many of the problems of this century will only be solved through partnerships between academics, researchers, business, industry and the broader community. Monash University hosts world class research facilities including the Monash Centre for Synchrotron Science, Green Chemistry labs, the Multi-modal Australian Sciences Imaging and Visualisation Environment (MASSIVE) high performance computer system and specialised medical and diagnostic equipment at the Department of Medical Imaging & Radiation Sciences. For society to obtain the maximum benefit from these facilities, it is vital that they be utilised by as many researchers as possible both within and beyond university circles.

Whilst these facilities are critical to Australia's research efforts, they do hold some capacity that can be used for education purposes too. Exposing students early to the powerful experience of discovery can make a fundamental difference to their educational experience it can turn the lights on. The Australian Synchrotron currently runs an Educational Virtual Beamline program that allows senior secondary Physics students to run real time experiments and gain new understandings of principles that are core to their studies.[12] Greater bandwidth will allow more of these types of programs to be developed. One day significant numbers of senior secondary students may be able to use the Synchrotron and MASSIVE high performance computer to virtually design and crash test cars. The Australian National Data Service (ANDS) is another important part of the national research infrastructure established in partnership with Monash. ANDS is funded by the federal government

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[10] Brandon (2010).
[11] Participants in the SETI@home program allow Berkeley Institute to utilise the internet to transfer small amounts of data to their home PCs. The PCs process this data in the background or at night giving Berkeley access to a large data processing network at minimal cost. University of California (2011).
[12] Australian Synchrotron (2011).

and seeks to, 'create the infrastructure to enable Australian researchers to easily publish, discover, access and use research data.' [13] It provides a central repository of research data collections so that they can be investigated multiple times as researchers seeking to examine new questions.

The benefits that could be derived from ANDS could grow by an order of magnitude. The data sets could also be made available to other educational sectors. Imagine that Queensland rainfall data was available to schools via ANDS. Students returning to school after a flood event could be led on a discovery process by their teachers examining historical and current rainfall data. A football-mad student could use real sports statistics as a pathway into understanding statistical problems generally. These immersive and real world experiences that allow students to pursue an area of current interest, or a long-held passion, may well be critical to forming their career path. For some of them, this might be the transformative moment that sets them on a career of research and discovery. Making greater bandwidth available to other educational sectors is critical to opening up opportunities of this type.

The amount of data generated by and transferred from these facilities is enormous and is growing dramatically. As of 2010, Monash University stored in excess of 900 TB (or 900,000 GB) of data. The bulk of this data comprises vast datasets generated by the many research projects undertaken at the University. Moving this amount of data around a purpose built fibre data network is challenging, transferring it over a copper line network, designed primarily for voice communications, is impossible.

For effective collaboration to occur between universities and the community, it is vital that partners can communicate and share the large datasets generated by research, manufacturing and industry.

Australian manufacturing needs to become smarter in order to thrive and remain competitive. One of the best ways of doing so is by working closely with universities and researchers to maintain a competitive edge. This may also include diversifying into specialist areas of manufacture, which cannot readily be commoditised. Monash's Clayton campus is surrounded by light industry and small to medium enterprises. There are numerous opportunities for those businesses and the University to engage more closely in research projects with immediate application benefits. Sharing large data files will be critical to doing so.

The new world of eResearch

As in many other disciplines, Scientists are continually finding new ways to use ICT to support their work, using eResearch methodologies. This field is tackling real world problems in ways that would have been hard to imagine just a few short years ago. eResearch is constituted by a number of distinguishing characteristics. It uses high performance computation to deal with massive data sets. It accesses distributed infrastructure, and first class scientific instruments, wherever they are. These characteristics lead to fundamentally different approaches and results than traditional forms of scientific inquiry. Bandwidth is a key enabler for eResearch.

[13] ANDS (2011).

eScience is a term that is used to describe this approach in relation to the sciences. The Monash eScience and Grid Engineering Laboratory is the home of eScience at Monash. Monash's eScience efforts have been applied across a broad range of disciplines including; Chemistry and Physics, Medical and Life Sciences, Engineering and Design, Mathematics and Computer Science, Economics and Finance, Environmental Science, and Earth Sciences and Astronomy. Many of the projects are run in collaboration with colleagues across the globe. This can only be achieved with high speed connectivity. See http://messagelab.monash.edu.au/EScienceApplications.

One current project is examining the optimisation of renewable resources in electricity grids. The project is seeking to model the performance of alternative energy sources as a combinational optimisation problem. Wind turbines, solar photovoltaic, solar thermal, biomass, micro-turbine (gas fired), and geo-thermal will be considered. The generation, capital, maintenance and fixed costs are factored into the calculations as are the uncertainties in relation to decreasing capital costs over time and long-term forecasts for demand growth and fuel costs across the spectrum of fossil and bio fuels. See http://messagelab.monash.edu.au/EScienceApplications/OptimizationOfRenewableResourcesInElectricityGrids.

The Monash eScience and Grid Engineering Laboratory runs an award-winning program to expose students to the very best international research and research minds using high-performance research applications. Monash students participate in seminars with researchers at the University of California San Diego and Oxford University. These interactions prepare students and mentors for an eight week placement program, during which students become members of the relevant research teams. The high definition video conferencing that supports this program has proven to be instrumental in the success of the placements. The technology enabled interaction allows for natural forms of communication, including understanding all the non-verbal signifiers available in any conversation, and a relationship to be established between mentors and students before the placement begins. See http://messagelab.monash.edu.au/MURPA.

Research is a collaborative venture with non-university bodies

The validity and impact of research depends upon participation. This means ensuring that all relevant data is incorporated in the body of research irrespective of the difficulty of obtaining this data. For example, it can be difficult to obtain accurate health data from rural and isolated health services. If this data is ignored it becomes difficult for policy makers and the government to obtain a clear picture of rural health issues.

Research also needs to be more than just an academic exercise. For the nation to obtain the benefit from its investment in research, this research must be used to solve real world problems. This may mean developing solutions to address issues such as climate change or the commercialisation of a technology to provide benefits to society as a whole. Universities cannot do this on their own. It is only by working with partners from business, industry and manufacturing that we can convert research into products or social goods. This flows both ways as business, industry and the community also benefit from the knowledge and research generated by universities.

The problems of the future such as climate change modelling, population distribution and green energy solutions are extremely data centric. The nation needs access to high speed affordable data network to allow the free flow of information and research data between universities, research institutes, business, industry and the community as a whole.

Telling the stories of our history

ICT is creating new ways to tell the story of history. Many of us are familiar with Steven Spielberg's mammoth project to tell the stories of the Holocaust via video recorded visual histories. The Shoah Visual History Foundation is now connected with the College of Letters, Arts & Sciences at the University of Southern California. The Visual History Archive now holds the stories of 52,000 survivors, 2,518 of them recorded in Australia. The Archive will be retained into perpetuity and provides a truly rich insight into the lives of the survivors. Each video is about two hours long, covering life before, during and since the Holocaust. Survivors tell their stories, introduce family members and show photographs or other items of interest. Video recorded oral history can tell the story like no other medium. The shake in the voice, the tear and the other non-verbal aspects of communication are very accessible. It allows for understandings that are not easy to come by if only accessing text. See http://college.usc.edu/vhi/aboutus/.

Academics in the Arts Faculty at Monash are working on a major project examining the history of adoption in Australia. A collection of life stories will inform the central historical account that arises from this project. While the History of Adoption project is using innovative ICT-enabled approaches, it will not be using video oral histories. The electronic tools that could enable a cost-effective visual archive are not accessible due to bandwidth constraints. Given the quality and pervasiveness of webcams, a visual archive could easily be established via people recording their own histories. However, given the sensitive nature of the material, research standards dictate that it would need to be moderated by Monash (eg to remove names of other individuals) and stored by Monash (instead of by a third party such as YouTube). The capacity to upload and transmit files of sufficient size is not accessible. See http://arts.monash.edu.au/historyofadoption/.

Just as the concept of cloud computing is enabled by near-ubiquitous access to the internet, the concept of collaborative research will only take place when it is possible to rapidly and inexpensively transfer vast amounts of data. High speed networks connecting universities have enabled collaboration between researchers to take place on a global scale. In a similar way, high speed networks linking homes, businesses, manufacturers and the community will provide the impetus to carry out research on a community scale.

GLOSSARY

Bits and Bytes[14]

It is important to remember that a bit is a measure of data transmission speed, whereas a byte is a measure of data quantity. Conversion between the two measures can provide an estimate of how long data transfer will take in light of the connectivity speed available. A 1 MB (Megabyte) file is equivalent to 8 Mb (Megabits). If there is an 8 Mb per second (Mbps) connection available, the file will take 1 second to transfer. The measures of bits and bytes used in the submission are listed below.

Gb Gigabit or approximately 125,000,000 bytes

Gbs Gigabit per second

GB Gigabyte or approximately 1,000,000,000 bytes

Mb Megabit or approximately 125,000 bytes

Mbs Megabit per second

MB Megabyte or approximately 1,000,000 bytes

TB Terabyte or approximately 1,000 Gigabytes

[14] Beesky (2011).

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