



# EU / USA Trip Report

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*Prepared by Paul Bonnington (Associate Dean IT, University of Auckland), Warwick Clegg (Director REANNZ), Charles Jarvie (Acting CEO REANZ) and Carol Moffatt (Director, REANNZ).*

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## Introduction

The Ministry of Foreign Affairs and Trade (MFA) sponsored the Research and Education Advanced Network of New Zealand (REANNZ) Company in a visit to the European Commission in Brussels and the United Kingdom to study advanced networks in the European Community and raise the profile of the new advanced network which is to be launched later this year in New Zealand. The visit also looked to improving links for the science and education communities. To take full advantage of this opportunity, the REANNZ Board extended the visit by including meetings in the USA to study their advanced networks and related applications.

Participants were:

Associate Professor Craig Paul  
Bonnington  
The University of Auckland  
Private Bag 92019  
Mathematics/Physics Building  
Princes St, Room 31  
Auckland  
**NEW ZEALAND**

Phone: +64-9-373-7599  
Fax: +64-9-373-7457  
Email: [p.bonnington@auckland.ac.nz](mailto:p.bonnington@auckland.ac.nz)

Charles Jarvie  
Acting Chief Executive Officer, REANNZ  
PO Box 5336  
Level 5, 22 The Terrace  
Wellington  
**NEW ZEALAND**

Phone: +64-4-471-5390  
Fax: +64-4-471-1284  
Mobile: +64-21-628-290  
Email: [charles.jarvie@morst.govt.nz](mailto:charles.jarvie@morst.govt.nz)

Professor Warwick Clegg  
Director, REANNZ  
PO Box 5336  
Level 5, 22 The Terrace  
Wellington  
**NEW ZEALAND**

Phone: +64-4-463-5188  
Fax: +64-4-463-6059  
Mobile: +64-29-463-5188  
Email: [warwick.clegg@vuw.ac.nz](mailto:warwick.clegg@vuw.ac.nz)

Carol Moffatt  
Director, REANNZ  
PO Box 5336  
Level 5, 22 The Terrace  
Wellington  
**NEW ZEALAND**

Phone: +64-3-312-4304  
Fax: +64-3-312-4315  
Mobile: +64-274-389-025  
Email: [carol.moffatt@xtra.co.nz](mailto:carol.moffatt@xtra.co.nz)

The participants and Board of REANNZ are grateful for the opportunity that MFA, supported by the Ministry of Research Science and Technology (MoRST), have provided, and also for those who kindly made the detailed logistical arrangements. We are grateful also to those people we visited, who all gave generously of their time.

The report captures in shorthand form the key observations and conclusions of the delegation. In certain areas it recommends policy review. Some

recommendations may in fact already be elements of existing policy and the delegation may simply be unaware of this position in New Zealand – in which case it is hoped the otherwise redundant reinforcement is seen as earnest support of those policy objectives.





## Executive Summary

In comparing the intended New Zealand developments with those in other countries, considerable comfort has been derived from the understanding that, at the network level, we are progressing on broadly similar pathways. However, as might be expected, compared with more mature instances of advanced networks, the NZ initiative needs further work to provide the extensive member support, promote international network-enabled research collaborations, and initiate essential developments in middleware (the software layer which sits between the physical network and the specific applications) – a significant example of which is federated identity authentication. It will be very important to align middleware developments so that they will be consistent with, and compatible with, similar developments internationally. While standards directions are becoming clear there will be situations where it will be preferable to adopt an existing sector-specific solution to allow early benefits to be enjoyed even if they are not currently aligned with emerging standards. Explicitly accommodating both approaches will be important – the ongoing costs of maintaining multiple standards will ensure steps are taken internationally and nationally to rationalise once the practical issues are better understood.

We were made aware yet again of the speed of development; not just in networks themselves but also in the infrastructures they provide to facilitate communities of interest and collaborations at the regional, national and – crucially – the international level, and also of the generality of a model of network renewal every four to five years. This latter invariably requires the injection of external funding and can be used to drive new innovation in network technologies and services

The importance of taking an integrated view (physical network and the collaborative research structure which it supports) can hardly be over-emphasised and is the reason why Information Society Technologies are the largest priority in the current research programmes of the European Union. It was indicated to us that this integrated infrastructural approach would be vigorously pursued in the new Framework Programme VII that is to be released shortly.

The growth of awareness and use of the advanced network in New Zealand would be greatly facilitated by a co-ordinated programme of visits to New Zealand by overseas experts, and equivalently by New Zealanders to overseas destinations.

Further co-ordination would be advantageous in ensuring a New Zealand presence at a variety of international conferences in subjects relating to advanced networks and their uses. Co-ordination for both these sets of activities will ensure maximum return on the money invested and maximum dissemination of the benefits to the whole community.

National research and education networks (NRENs) elsewhere are themselves increasingly integrated together in such overarching arrangements as TEIN2 (shortly to be upgraded to TEIN3), GEANT2 and GLORIAD. New Zealand's participation in such network integration is highly desirable, but our ability to participate is vitally dependent on the acquisition of increased international capacity – the most expensive feature of our network. It should be noted that benefits here would not just be for our research and education communities, but also for economic development with emerging trading partners for New Zealand. New Zealand institutions and sector end users must be encouraged to see NRENs and associated middleware tools and activities in the same light as their now more experienced EU and USA peers.

The extension of NRENs to link with regional networks to give connectivity to schools is widespread – bringing benefits of shared learning material resources, distance learning programmes, videoconferencing and professional development for teachers. Another feature noted on this set of visits is the frequent aggregation of members' commodity Internet traffic over paths within an advanced network with cost benefits because of the aggregation, and the use of two or more ISPs rather than a single provider. Finally, the effort which the best NRENs put into promoting working groups, communities of interest and communicating with their members by arranging conferences, training courses and producing web-based and hard copy news and information is a pointer to significant work required by REANNZ in this area as soon as possible.



## E-infrastructure

The meetings in Europe, United Kingdom and USA underscored the established policy consequences of focussing on collaborative outcomes derived from the use of ICT in research and education. Whether it was called “e-infrastructure” or “Cyberinfrastructure” there was evidence of multiple project initiatives that were being driven by a requirement to explore and develop the necessary networking and application sharing tools. Information gained:

- Review “e-infrastructure” policy to emphasise a coherent communications and collaboration framework. Both the EU and USA have established strong policy and funding programs dedicated to achieving social and economic outcomes from e-infrastructure. The EU emphasises networks and grids. In the USA NSF currently focuses on its middleware initiatives.
- Make more explicit the policy pursuit of better research and education outcomes through national and international collaboration using and sharing technology platforms e.g. network, computational, storage, and sensor infrastructure.
- Analyse the funding implications of the international dimensions of collaboration given the relatively high costs associated with New Zealand’s connection to the other NRENs. Lack of competing infrastructure serving NZ’s international connectivity requirements presents issues for both the R&E communities as well as the business sector.
- Consider the policy, funding and governance issues relating to regular “refresh” cycles for network infrastructure in research and education
- Consider the policy, funding and governance issues relating to a New Zealand Middleware Initiative (NZMI) to improve the power and accessibility of on-line resources
- Examine where further policy and architectural coordination between Ministry of Research and Technology and Ministry of Education will identify network and lower layer synergies to deliver benefits to schools.
- Consider what inter-Ministry emphasis is required to provide a supportive environment for innovation to flourish in the priority thematic areas that can be facilitated by technology platforms.

## Communications

NRENs put much effort into the process of communicating with users within member institutions. While many have outsourced front line or first level technical network operations (as REANNZ is doing) there is however an additional strong emphasis on providing support to institutional users. The key areas of interaction are:

- Member services
- Training
  - Workshops on design techniques that allow users to utilise important but complex network functionality
- Events
  - Strategic
  - Technical
  - Briefing
- Awareness
  - Liaison with funding agents and policy agencies
  - Education and research sector conferences
- Communication
  - Promotion of services
  - Web based content
  - Leaflets
  - Video clips/DVDs
  - Poster graphics



## Capability building

As the organisations we met with have been driving or using advanced networking techniques for many years the area of capability building was not now explicit in their projects. However discussions with them revealed that a number of opportunities and approaches were possible to assist the NZ situation. These included the following suggestion:

- Adapt policy work which encourages innovation to also embrace the collaborative opportunities offered by sector use of advanced network techniques
  - Recognition that innovation is 95% existing ideas from anywhere, realigned with 5% clever application – not 100% original thinking
- Connect, where appropriate, current opportunities such as:
  - Science exchanges,
  - Short term visits to and from New Zealand
  - Science promotion (MFaT),
  - CRIs capability funding,
  - FoRST fellowships,
  - Harkness fellowships,
  - Royal Society Science Teacher Fellowships to work through the advanced network.
- Scientists be encouraged to use their special interests with overseas scientists working with other NRENS
- Identifying common themes of New Zealand science and research programmes with the European Union (in line with the proposed Science Agreement with the EU)
- An aggressive programme identifying visitors to New Zealand and key New Zealanders for short visits to advanced networks and related programmes overseas
- The coordinating of New Zealand participants at international workshops and conferences related to Advanced Networking topics and making their reports available.





## Technical

### Grids and access

To ensure best use of available funding it is desirable that there is initially some coordination of grid developments with networks and AAA policies:

- Europe (despite some local differences) presents a harmonised development approach through major initiatives such as EGEE
- USA appears to have solid separate initiatives that tend to be sector specific e.g. Teragrid, Virtual Data Toolkit, NEESGrid, Geosciences Network. and Biomedical Informatics Research Network
- Shibboleth is the emerging AAA architecture standard (SAML2 aligned).
- Many important sector specific applications such as NEESGrid and BIRN are not Shibboleth compatible but their apparent high utility to the sector outweighs the support issues
- GLOBUS, the world leading open source software toolkit for Grid computing has been widely adopted and adapted in Europe and in the USA.

### Commodity Internet services

- Many NRENs provide commodity internet services as their members see architectural and economic benefits
- Generally NRENs generate more traffic than they receive from the Internet i.e. they are net exporters
- Commodity Internet traffic makes up almost 80% of total traffic to some smaller NREN backbones. R&E traffic is much peakier but demands better network performance.
- Usually two or more ISPs are providing services
- Networks frequently peer locally to offload traffic at no cost where that makes economic sense

### Network lifecycles

Especially in Europe and the UK networks were regularly upgraded with new technologies even though the increased capacity and technical functionality was not driven by immediate demand. UKERNA, SURFNet, DANTE/GEANT had clear strategies for renewing technology over a 4~5 year period

- Policy agencies should consider implications of refresh cycles of the NZ network in line with other current NREN practices



## Management and monitoring the network

- Strong trend to outsource technical management and trouble ticketing
- NRENs maintain in-house technical design capability.
- Performance testing methodologies vary but all results are available to members
- REANNZ measurement infrastructure design commended

## Middleware

- Focus ICDF and eCDF policies on themes consistent with utilising the new network to achieve current high level policy outcomes
- Prioritise new developments around both local and international directions
- Emphasise policies that encourage international collaboration using the Advanced network

## International

- Develop appropriate policies for multi-national research opportunities that exist through shared network platforms e.g. TEIN2 (EU to Asia), TRANSPAC2 (USA-Asia) etc for international collaboration and ensure that New Zealand researchers are able to both connect and work alongside their counterparts in other developed countries.
- Explore whether practical inter-government (e.g. Australia) cooperation is possible in this area given high costs and similar objectives. Commercial aspects will be most challenging.

## Schools

“There is clear evidence from many sources that the connection of secondary and primary schools to the Internet via NRENs and also the provision of support and application services to schools features high on the agenda in many countries in very recent years<sup>1</sup>”.

This theme was also evident from the visit to Thomas Jefferson High School in Virginia, and discussions with John Silvester and Jim Dolgonas from CENIC in California. Architecturally NRENs do not primarily provide solutions to the last mile access issue that to varying degrees challenges all countries and states

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<sup>1</sup> TERENA Compendium of National Research and Education Networks in Europe, 2005 Edition.

visited or reviewed. However the NREN focal point of research and education enables a natural extension to dealing with schools-related opportunities and providing flexible support arrangements. Frequently the schools are accessed via ISPs or regional broadband or network consortia that then link with the NREN. Achieving commercial flexibility rather a single-source network solution was seen as an important outcome.

Some early areas that may bear fruit are as follows:

- Develop integrated policies including common architectural layers with both MoRST and MOE for schools (and where appropriate libraries, museums). The network access problem will be common even though applications will vary by sector.
- Study the work already undertaken by TERENA to inform local school/network links
- Consider the metrics as described in the TERENA annual compendium for adoption in New Zealand



## **Governance, Funding and Staffing**

### **Funding**

NRENS we met or reviewed were funded in varying ways – some funded directly from the Government, others funded by users (who were generally funded by Government). The percentage of total funding from direct Government and direct user funding varied considerably in the EU and also in the USA.

- UKERNA received 90% of its funding from the Government.
- Internet2 and its network Abilene are funded from University user membership and separate connector charges.
- National Lambda Rail (NLR) is a collaboration of institutions with each contributing network assets and labour towards a shared mission.
- In some countries institutions pay for the access links to the NREN, in others the NREN pays for this
- Regional and metropolitan networks working with NRENS require different funding approaches especially in relation to the connection of schools, museums and libraries.

### **Staffing**

While somewhat related to the size of the country the staffing of EU NRENS ranged from about 3 people (e.g. Cyprus) through to about 100 (e.g. UKERNA and SURFNet). The median EU figure was about 30 staff for activities that were solely or primarily related to NREN activities. Of the total FTEs about two thirds were technical staff.

This was a surprising finding and contrasts with the total staff of 10 FTEs that have been forecast in the REANNZ business plan (excluding the outsourced help desk functions).

The additional roles relating to communication mentioned elsewhere will require new positions to be established and the budget implications worked through.

### **Governance and Legal Form**

The most common model (by a small majority) in the EU was where the NREN was a separate legal entity. The entity is controlled by the research and education community which itself is largely government funded.

NRENs that can operate with a degree of independence from Government may have certain advantages, such as easier decision-making procedures. This model is more common in countries where research networking has developed over many years and is well established.<sup>2</sup>



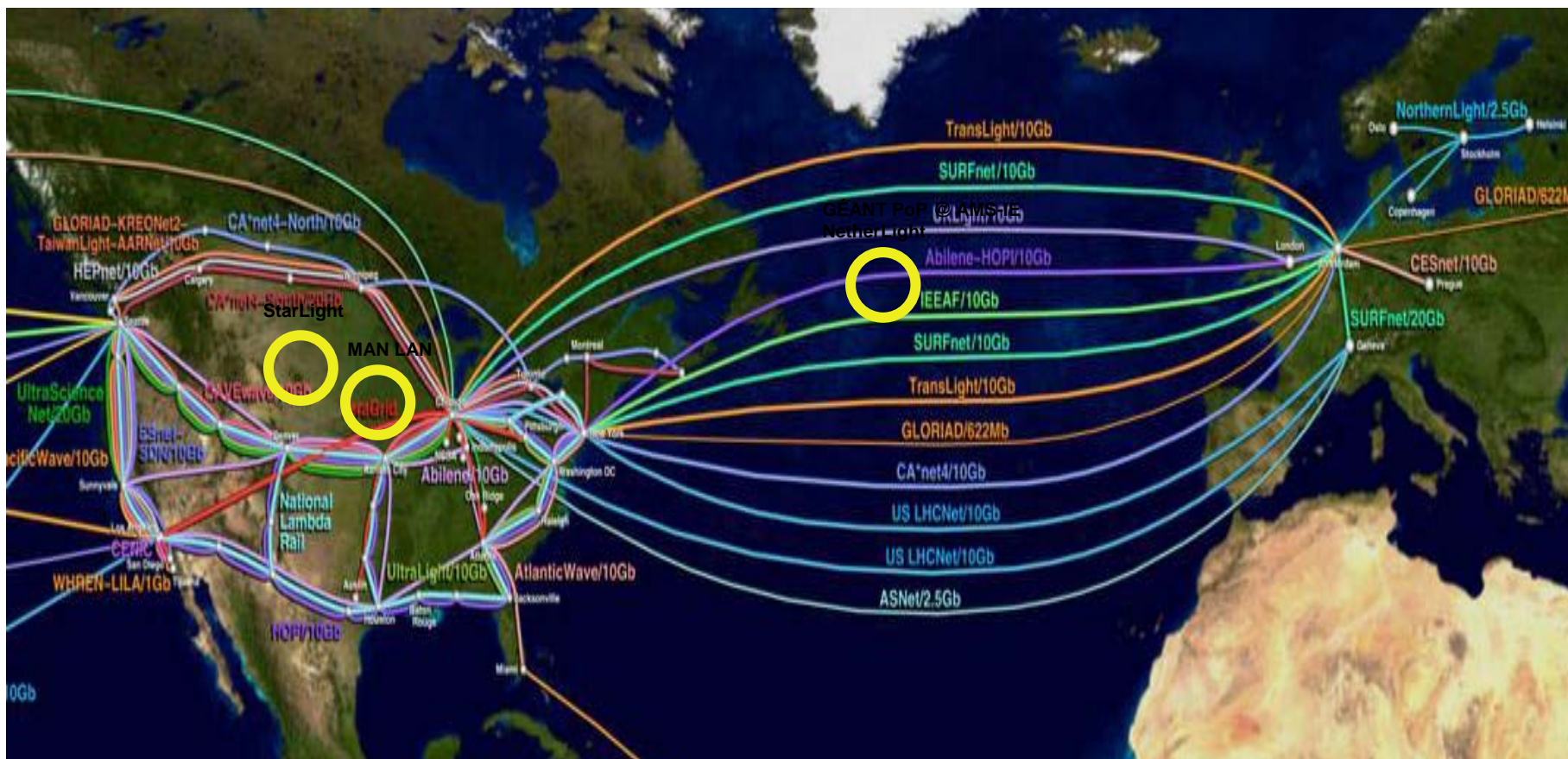
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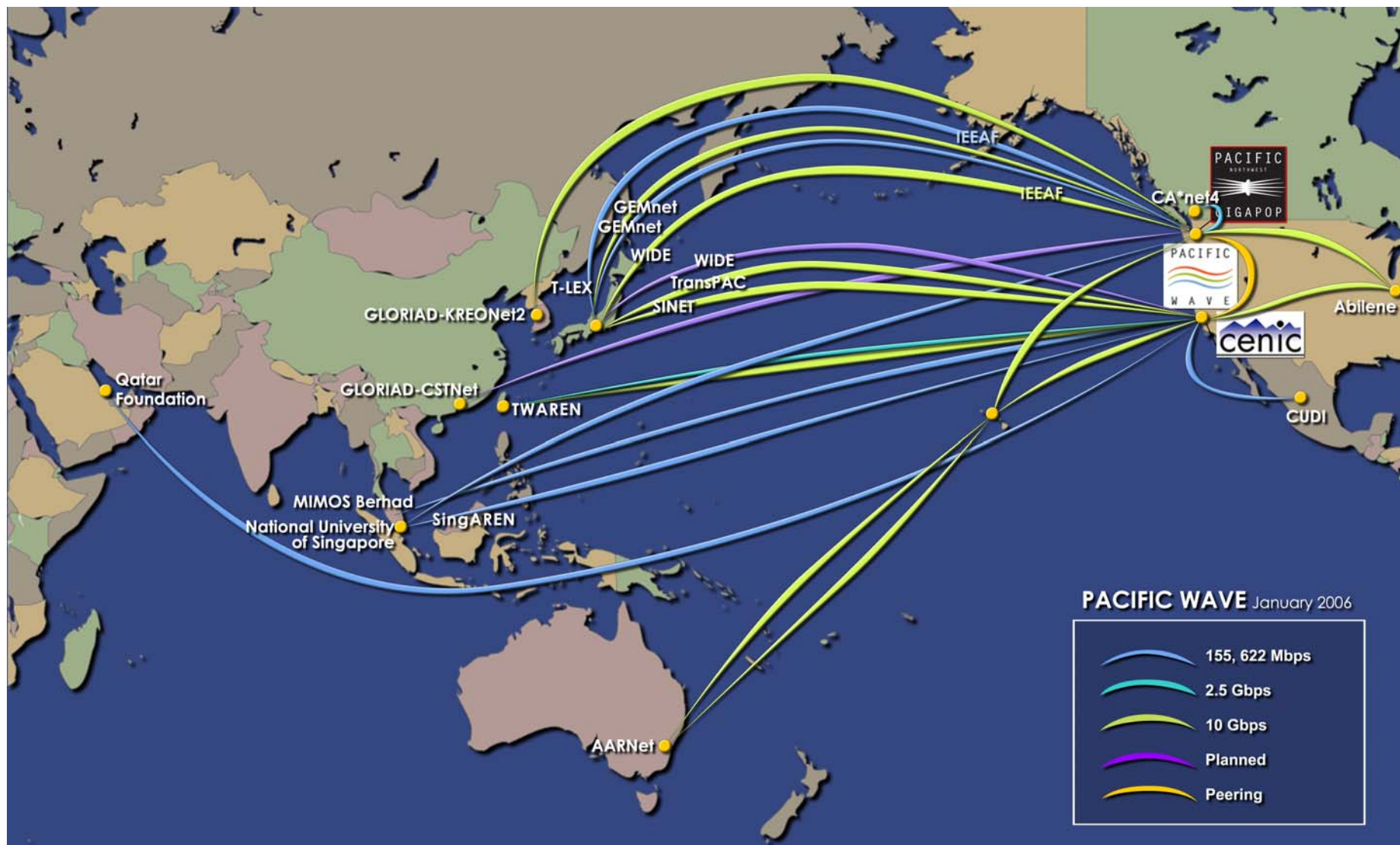
<sup>2</sup> TERENA Compendium, 2005 Edition



## Global Network Collaborations

These two schematics show key NREN international links. The difficult position of New Zealand is evident and underscores the need for focus on this aspect of the collaboration strategies.





## APPENDIX 1 – Meetings and Contacts

### BELGIUM

#### European Commission

- **Mario Campolargo**, Head of Unit, Research Infrastructure, [mario.campolargo@cec.eu.it](mailto:mario.campolargo@cec.eu.it)
- **Bernhard Fabianek**, Research Network Officer, [bernhard.fabianek@cec.eu.int](mailto:bernhard.fabianek@cec.eu.int)
- **Enric Mitjana**, Scientific Officer, [enrich.mitjana@cec.eu.int](mailto:enrich.mitjana@cec.eu.int)

#### Belnet and Begrid

- **Pierre Bruyere**, Director, [pierre.bruyere@belnet.be](mailto:pierre.bruyere@belnet.be)
- **Jan Torreele**, Technical Director, [jan.torreele@belnet.be](mailto:jan.torreele@belnet.be)
- **Rosette Vandenbroucke**, BEGRID, [vandenbroucke@helios.ihe.ac.be](mailto:vandenbroucke@helios.ihe.ac.be)

#### 6NET 6Diss

- **Theo de Jongh**, EC Project Coordinator, Cisco Systems, [tdejongh@cisco.com](mailto:tdejongh@cisco.com)

#### SURFnet

- **Kees Neggers**, Managing Director, [kees.neggers@surfnet.nl](mailto:kees.neggers@surfnet.nl)

### UNITED KINGDOM

#### Joint Information Systems Committee

- **Malcolm Read**, JISC Executive Secretary, [m.read@jisc.ac.uk](mailto:m.read@jisc.ac.uk)

#### DANTE

- **David West**, Project Manager, [david.west@dante.org.uk](mailto:david.west@dante.org.uk)
- **Matthew Scott**, Chief Financial Officer, [matthew.scott@dante.org.uk](mailto:matthew.scott@dante.org.uk)
- **Michael Enrico**, Network Engineering & Planning Manager, [michael.enrico@dante.org.uk](mailto:michael.enrico@dante.org.uk)
- **Boris Mimeur**, Operation Manager, [boris.mimeur@dante.org.uk](mailto:boris.mimeur@dante.org.uk)

### UKERNA

- **Geoff Peters**, Chairman, [chairman@ukerna.ac.uk](mailto:chairman@ukerna.ac.uk)
- **Tim Marshall**, Chief Executive, [t.marshall@ukerrna.ac.uk](mailto:t.marshall@ukerrna.ac.uk)

- **Bob Day**, Chief Technology Officer, [r.day@ukerna.ac.uk](mailto:r.day@ukerna.ac.uk)
- **Shirley Wood**, Customer Support Director, [s.wood@ukerna.ac.uk](mailto:s.wood@ukerna.ac.uk)
- **David Salmon**, Research Support Coordinator, [d.salmon@ukerna.ac.uk](mailto:d.salmon@ukerna.ac.uk)
- **Jeremy Sharp**, Advanced Technologies Officer, [j.sharpe@ukerna.ac.uk](mailto:j.sharpe@ukerna.ac.uk)

## WASHINGTON

### National Science Foundation

- **Kevin L. Thompson**, Program Director, Office of Cyberinfrastructure, [kthomps@nsf.gov](mailto:kthomps@nsf.gov)
- **Douglas Gatchell**, Program Director, Office of Cyberinfrastructure, [dgatchell@nsf.gov](mailto:dgatchell@nsf.gov)

### Internet2

- **Douglas Van Houweling**, President and CEO of Internet2, [dvh@internet2.edu](mailto:dvh@internet2.edu)
- **Heather Boyles**, Director, International Relations, [heather@internet2.edu](mailto:heather@internet2.edu)
- **Russ Hobby**, Chief Technical Architect of the End-To-End Performance Initiative, [rdhobby@internet2.edu](mailto:rdhobby@internet2.edu)
- **Steve Corbató**, Director of Network Initiatives, [corbato@internet2.edu](mailto:corbato@internet2.edu)
- **Laurie Burns**, Executive Director for Member & Partner Relations, [lburns@internet2.edu](mailto:lburns@internet2.edu)
- **Eric L. Boyd**, Performance Engineering Consultant, [eboyd@internet2.edu](mailto:eboyd@internet2.edu)

## CHICAGO

### Argonne National Library

- **Ian Foster**, Head, Distributed Systems Lab Mathematics & Computer Science, [foster@mcs.anl.gov](mailto:foster@mcs.anl.gov)
- **Maxine Brown**, Associate Director, Electronic Visualization Laboratory, [maxine@uic.edu](mailto:maxine@uic.edu)
- **Scott Lathrop**, TeraGRID Director for Education, Outreach and Training, [lathrop@mcs.anl.gov](mailto:lathrop@mcs.anl.gov)

## SAN DIEGO

### University of California San Diego (UCSD)

- **Mark James**, BIRN Coordinating Centre Project Manager, [mjames@ncmir.ucsd.edu](mailto:mjames@ncmir.ucsd.edu)



- **Andrew McCulloch**, Chair, Bioengineering NBCR, [amcculloch@ucsd.edu](mailto:amcculloch@ucsd.edu)
- **John Wooley**, Associate Vice Chancellor, UCSD, [jwooley@ucsd.edu](mailto:jwooley@ucsd.edu)
- **Ramesh Rao**, UCSD Division Director, [rrao@ucsd.edu](mailto:rrao@ucsd.edu)

#### **California Institute for Telecommunications and Information Technology**

- **Tom Defanti**, Senior Research Scientist, [tdefanti@ucsd.edu](mailto:tdefanti@ucsd.edu)
- **Jurgen Schulze**, Postdoctoral Scholar, [jschulze@ucsd.edu](mailto:jschulze@ucsd.edu)

#### **San Diego Supercomputer Center**

- **Phil Andrews**, Director High End Computing Technologies, [andrews@sdsc.edu](mailto:andrews@sdsc.edu)
- **Mark Sheddon**, Associate Director, [sheddon@sdsc.edu](mailto:sheddon@sdsc.edu)

#### **LOS ANGELES**

##### **University of Southern California**

- **John Silvester**, Executive Director, Center for Scholarly Technology; Chair of CENIC; Director Pacific Wave, [silvester@usc.edu](mailto:silvester@usc.edu)
- **Jim Dolgonas**, CENIC President, [jdolgonas@cenic.org](mailto:jdolgonas@cenic.org)



## APPENDIX 2 - Organisation Outlines

Background notes on organisations met during visit (compiled by Jason Darwin, Victoria University).

### DANTE

<http://www.dante.net/>

*Provides management and administration services for the construction of pan-European networks.*

DANTE (Delivery of Advanced Network Technology to Europe) was established in 1993 in Cambridge, UK. It is a limited liability company and a “Not for Profit” organisation. The location of Cambridge was chosen as a result of an international competition, with the tax benefits which the UK government offered constituting a significant factor in determining the choice of location.

DANTE’s purpose is to plan, build and operate pan-European research networks. It was set up, and is owned, by a group of National Research and Education Networks (NRENs). It was established in 1993 and has since played a pivotal role in four consecutive generations of pan-European research network: EuropaNET, TEN-34, TEN-155 and now GÉANT.

The European NRENs need an efficient and cost-effective vehicle to co-ordinate pan-European research networking on their behalf, and to ensure that project results are delivered on time, within budget and with high levels of reliability.

Although based in the UK, DANTE is a truly European company. It has a diverse, multi-lingual staff representing many different nationalities and operates throughout Europe. The company has had a conscious policy of recruiting from across Europe throughout its eleven-year history.

DANTE’s activities typically include:

- Project management
- Data communications infrastructure development
- Project feasibility assessment
- Procurement exercises
- Network technology research
- Network service development and provision
- Information dissemination and customer support



DANTE currently has an annual turnover of approximately 50 million Euros, of which around half comes from European Commission project funding. It has 'Research Association' status in the UK.

Due to their pan-European nature and the essential role they play in enabling and supporting research activities, Europe's research networking backbones have typically been co-funded by the European Commission within the EU's Research & Development Framework Programmes. Within these Programmes, funding is provided to projects, which must involve partners in at least three EU member states. In the case of pan-European research networking projects, the NRENs and DANTE are the project partners, and DANTE acts as the managing partner of the project. It serves as a secretariat, undertaking management and coordination functions on behalf of the other project partners, as well as taking responsibility for building and managing the network itself. This organisational model has proven to be a very successful way of operating research networking on a "continental" level and is beginning to be emulated by other world regions, which are adopting a similar model for their research networking requirements.



## **GÉANT**

<http://www.geant.net/>

*Gigabit-speed pan-European network, now superseded by GÉANT2.*

GÉANT is the name used to refer to both the pan-European research and education network and of the corresponding four-year project that created it. (The project is officially called GN1 but is more commonly called GÉANT.)

### **The GÉANT Project**

The GÉANT (GN1) project was co-funded by the European Commission as part of its Fifth Research & Development Framework Programme. GN1 was a contract between 26 National Research and Education Networks (NRENs), DANTE and the European Commission. It began in November 2000 and ended in May 2005, having been extended from its original planned conclusion of October 2004. DANTE was the co-ordinating partner of the project.

The project's purpose was to improve on the previous TEN-155 pan-European research network by creating a new backbone at gigabit speeds – the GÉANT network.

The project had four main objectives:

- Gigabit speed
- Geographical expansion
- Global connectivity
- Guaranteed quality of service

The signatories to the GN1 contract were eligible to receive co-funding from the European Commission under the rules of the European Union's Fifth R&D Framework Programme. One of the conditions of the contract was that the project partners must sign a Consortium Agreement, which committed them to certain binding principles of cooperation and conduct.

As well as the 26 NREN signatories to the contract with the European Commission, by the end of the project there were:

- 29 NREN Consortium members, directly connected to GÉANT
- 33 countries in Europe connected to GÉANT, either directly or indirectly

Within Europe, GÉANT reached, indirectly, over 3,500 research and education institutions.

It is:

- A multi-gigabit data communications network connecting European national research networks
- Reserved specifically for research and education use



- One of the most advanced and reliable networks in the world

GÉANT had two roles. Firstly, it provides an infrastructure to support researchers, allowing them to:

- Rapidly transfer large quantities of data
- Make use of advanced network applications such as grid computing
- Collaborate on research projects in real-time
- Perform previously unimaginable cutting-edge research

Secondly, it provides a platform for research into networking itself, which is performed by NRENs, by DANTE staff and by other organisations involved in European R&D projects.



## GÉANT2

<http://www.geant2.net>

*Multi gigabit-speed pan-European network, successor to GÉANT.*

The GÉANT2 network will provide the high-performance, state-of-the-art network infrastructure that is fundamental to the European Union's vision of a European Research Area (ERA). The network is the core activity of a coherent set of initiatives that seek to develop all aspects of European research and education networking. The project within which the network is being built and developed also includes an integrated research programme, the development of support services for network users, initiatives to monitor and address disparities in the level of development of research and education networking around Europe, and a comprehensive study into the future of European research and education networking.

The partners in the project are 30 European NRENs, DANTE and TERENA.

The project's overall objectives are:

- To plan, build and operate a multi-gigabit pan-European backbone research network interconnecting Europe's national research and education networks (NRENs), over which a suite of advanced services will be offered to meet the increasingly demanding requirements of Europe's research and education community
- To conduct joint research into the development of networking technologies and services, with the primary aim of developing ideas from concept to production service to directly serve the users of GÉANT2 and its connected NRENs
- To support effectively and directly projects and users who have advanced networking requirements
- To pursue initiatives targeted at closing the 'digital divide', through both in-depth analysis of the picture of research networking in developing areas and the provision of direct support
- To examine the future of research networking, exploring the case for the sustaining of research and education networking beyond the conclusion of the project.



## EGEE

<http://public.eu-egee.org/>

*Project to foster production grid infrastructure for use by academia and industry.*

The Enabling Grids for E-science (EGEE) project began on 1 April 2004. EGEE's objective is to build on recent advances in grid technology to provide a production grid infrastructure, based on production-quality software, which will be available to scientists 24 hours a day. EGEE will provide academic and industry researchers with access to major and reliable computing resources, independent of geographic location – and it will also attract a range of new users to grid computing.

The project will primarily concentrate on three core areas:

- The first area is to build a consistent, robust and secure Grid network that will attract additional computing resources.
- The second area is to continuously improve and maintain the middleware in order to deliver a reliable service to users.
- The third area is to attract new users from industry as well as science and ensure they receive the high standard of training and support they need.

The EGEE project is among the largest of its kind, with funding from the European Commission of more than 30 million euros. It will run for two years, but was conceived as part of a four-year programme. The results of the first two years will provide the basis for assessing subsequent objectives and funding requirements for the latter two years.

EGEE is constructed around 12 partner 'federations', comprising 70 partner institutions. These federations also cover a wide range of both scientific and industrial applications. Two key pilot applications were originally selected for prioritisation in the early stages of the project, High Energy Physics and Bioinformatics:

- **High Energy Physics:** The Large Hadron Collider Computing Grid is designed to handle the petabytes of data that will be generated each year by the Large Hadron Collider at CERN (due to be switched on in 2007). The first phase of this project (known as LCG-1) is operating a series of prototype services. It uses middleware developed mainly by the DataGrid project, allowing physicists to access worldwide distributed computing resources from their desktops as if they were local resources.



- **Bioinformatics:** Biomedical Grids seek to address the needs of several communities, who are facing equally daunting challenges in managing enormous volumes of bioinformatics and healthcare data.

EGEE has since established a broader portfolio of applications across a wide range of sectors, including Earth Sciences, Astroparticle physics and Computational Chemistry.

The grid developed through the EGEE project is being built using the infrastructure of the GÉANT2 network and the European national research and education networks it connects. DANTE manages GÉANT2, and is also a partner in EGEE. The organisation is contributing primarily to the fourth joint research activity (JRA4, entitled 'Network Services Development').



## EGEE objectives

The objectives of the Network Services Development team include:

- Developing interfaces to the network control plane to allow grid middleware to make reservations of network connectivity. These connectivity reservations will be specified in terms of bandwidth, duration and quality of service, and provisioned through the dynamic reconfiguration of the network
- Developing tools to measure network characteristics, thus allowing network performance to act as an input into the way grid middleware organises and allocates resources to perform a grid job. These tools will provide access to standardised network performance data, but also to higher-level services. These will include end-to-end measurements of the network, for the purposes of assessing application performance, identifying and diagnosing faults, allocating resources and monitoring adherence to Service Level Agreements (SLAs)
- Studying the benefits and availability of IPv6 in the context of the EGEE grid.

For the purpose of the EGEE project, the 70 partners have been divided into 12 different federations. The federations for the EGEE project are:

1. CERN
2. Central Europe including Austria, Czech Republic, Hungary, Poland, Slovakia and Slovenia
3. France
4. Germany and Switzerland
5. Ireland and the United Kingdom
6. Italy
7. Northern Europe including Belgium, Denmark, Finland, The Netherlands, Norway and Sweden
8. Russia
9. South-East Europe including Bulgaria, Cyprus, Greece, Israel and Romania
10. South-West Europe including Portugal and Spain
11. NRENS (National Research and Education Networks)
12. United States



## **BELNET**

<http://www.belnet.be/en/>

*Belgian national research network providing high-bandwidth Internet connection to Belgian academic, and government departments. Creator of BEGrid initiative.*

BELNET is the Belgian national research network that provides high-bandwidth Internet connection to Belgian universities, colleges, schools, research centres, and government departments.

An Act of 7 May 1999 charges BELNET with the development and the management of a telematics research network for the benefit of:

1. institutions of higher education, research institutes, and agencies providing scientific services, which depend on or are subsidised by the federal government, the Communities or the Regions;
2. the federal ministries and departments;
3. international organisations with a head office in Belgium that develop research activities.

In addition to carrying out these tasks, BELNET is also charged with the management and housing of the Belgian Internet exchange node BNIX (the Belgian National Internet eXchange) and of FedMAN (Federal Metropolitan Area Network), the network that connects all the federal administrations with one another and with the Internet.

### **Recent history**

#### **2001:**

Connection with Géant, the European research network, at 2.5 Gbit/s.

#### **2002:**

New BELNET GigaNet network becomes operational, with redundant connections of 2.5 Gbit/s to the 15 BELNET Points of Presence (PoPs).

Development and management of the Federal Metropolitan Area Network (FedMAN), commissioned by FEDICT (the federal government agency for information and telecommunications technology), a computer network that connects 16 federal government departments with each other and the internet via the BELNET network.

#### **2003:**

Advances services are more strongly represented on the network, e.g. Native IPv6 and Multicast.

The capacity of the Belgian internet exchange BNIX is expanded to 10 Gbit/s.



**2004:**

Creation of BEgrid, the BELNET grid initiative, that promotes grid computing for the Belgian Research world and offers basic services to enable the startup of a Belgian Research Grid infrastructure.



## Egrid

<http://www.begrid.be/begrid.htm>

*First building block of Belgian computational grid. Connected to EGEE.*

**BEgrid** is the Belgian Research grid computing/data grid infrastructure that results from the BELNET Grid Initiative, which promotes grid computing for the Belgian research world and offers basic services. Computing and Data resources are distributed over several sites and are available to BEgrid participants. The grid middleware is the production grid middleware that is used by the European grid project EGEE.

BEGrid is considered to be the first building block of a Belgian computational Grid. All the institutions in Belgium that are connected to BELNET can become part of BEGrid. Currently, the BELNET backbone runs at 2.5 Gbit/s.

BELNET will also take care of the co-ordinating tasks, including setting up a Certification Authority and Grid management, such as definition and maintenance of Virtual Organisations, and new versions of the middleware.

A range of applications are now running on BEgrid either as tests or as full production: High Energy Physics (CMS, AMANDA), Astrophysics, Hydrology, Medical Imaging, Fluid Dynamics, and Mathematical Calculations (Mathematica and Octave).

Belgium, by means of the VUB and ULB, is a partner in EGEE. Since the beginning of BEgrid it was the intention to connect to other national or international grid infrastructures. EGEE was the most obvious choice to realise the first international connection of BEgrid.

Each infrastructure that wants to connect to EGEE has to go through a series of certification tests conducted by the Regional Operation Centre (ROC) of EGEE. For BEgrid these tests were done by the Dutch ROC. The procedure for BEgrid certification consists in running the tests consecutively on each of the BEgrid clusters. The first EGEE certification for BEgrid has been concluded successfully last summer.

As an example of the advantages of the BEgrid-EGEE integration, the EGEE Virtual Organisation CMS (one of the High Energy Physics experiments) is now also supported on BEgrid and CMS members throughout the world can use BEgrid resources while Belgian CMS users also can use resources of the CMS VO worldwide.



## DISS

<http://www.6diss.org/>

*Project to provide Ipv6 training to research networks in developing countries.*

6DISS is a two-and-a-half-year European project to provide IPv6 training and knowledge transfer to research networks in developing regions. It also aims to establish contacts with networking personnel and organisations in these regions, in order to encourage cooperation and possible future participation in European R&D activities.

The project is targeting eight developing regions: [Asia-Pacific](#), the [Caribbean](#), [Central Asia](#), the [Mediterranean](#), [South & Central America](#), [South-East Europe](#), [Southern Africa](#), and [Sub-Saharan Africa](#). IPv6 training workshops will be organised in each of these regions, with follow-up support being made available. This will also provide an opportunity to evaluate the current state of research networking in each region. In addition, the project will provide specialist training for instructors and engineers at locations in Europe, develop e-learning material for online distribution, and exchange deployment experiences with research networks in China and India.

6DISS builds on the IPv6 deployment experiences of the [6NET](#), [Euro6IX](#) and [GÉANT](#) projects, as well as the liaisons established with the [IPv6 Forum](#), [European IPv6 Task Force](#) and [IETF](#). The aim is to let organisations in developing countries benefit from this experience since they have fewer legacy installations and are therefore able to utilise the new technology in an efficient manner. The documentation produced by the aforementioned projects will be used as the basis of the 6DISS training material, and will be further expanded and improved during the lifetime of the project.

6DISS involves nine partners from the commercial, research and academic sectors and represents a total investment of EUR 1,053,265; 85% of which is funded from the [Information Society Technologies Programme](#) of the [European Union](#). The project started on 1 April 2005 and runs until 30 September 2007.

### Objectives

- Establish information exchange on Internet deployment issues with emerging network operators, universities, commercial organisations governments and regulators in developing regions.
- Enhance overall knowledge by exchanging IPv6 deployment experiences with China and India.



- Exploit skills and knowledge gained by IST projects dealing with deployment and evolution of the Internet.
- Disseminate the documentation on IPv6 deployment and migration produced by IST projects, and improve this in response to feedback from users.
- Improve the opportunities for developing countries to participate in European R&D activities by establishing contacts and knowledge of the available skills and facilities.
- Help develop state-of-the-art infrastructures in the targeted regions.
- Promote European technologies, particularly with respect to IPv6 where Europe has a strong competence.
- Inform workshop participants about latest standards and interoperability issues.



## **SURFnet**

<http://www.surfnet.nl/info/en/home.jsp>

*Netherlands research network, allowing hybrid use of Internet and lightpaths (10Gbps).*

SURFnet operates and innovates the national research network, which connects circa 180 institutions in higher education and research in The Netherlands. SURFnet is an important partner in the GigaPort project, the national project involving the development of the next generation Internet in the Netherlands.

On 23 January 2006 SURFnet launched its new network, SURFnet6, which provides universities, research centres, and universities of applied science with both 'regular' Internet use and lightpaths with speeds up to 10 Gigabits per second. The new network is fully equipped to handle the anticipated growth in Internet traffic over the next years for 750,000 staff, researchers and students of 180 institutions.

SURFnet6 has been established with a contribution from the Dutch Government's BSIK programme, in which natural gas revenues are invested in strengthening the knowledge infrastructure in the Netherlands. The new network offers Dutch research and education an excellent international starting position.

SURFnet6 was developed within the GigaPort-project, a successful public-private collaboration of the Dutch Government, industry and educational and academic institutions. GigaPort aims to reinforce the national knowledge infrastructure. Kees Neggens, director of SURFnet and GigaPort project leader: "SURFnet6 exemplifies the impact for the Netherlands of a fruitful collaboration between higher education and private enterprise."

### **What are lightpaths?**

SURFnet6 is globally recognised as a special network in that it is a hybrid network that offers both full Internet functionality and lightpaths. A lightpath is a direct network path from one computer to another for which a permanent or temporary connection of fibre-optic cables is configured without using routers. Traffic on a lightpath does not encounter any other traffic. It can therefore reach its destination directly without any interruptions. Lightpaths are useful for exchanging large amounts of scientific data and high quality



video in health care. SURFnet6 is the world's first national research network that is set up in this hybrid manner.

### **What new applications does SURFnet6 enable?**

Two examples of applications that are already in use:

- Very Long Baseline Interferometry (VLBI) is a technology that allows astronomers to observe objects in space with an extremely high resolution. Using the SURFnet6 lightpaths, JIVE in Dwingeloo combines the datastreams coming from telescopes in other countries to form a simulated telescope as large as a whole continent, or even the entire earth.
- Avans Hogeschool has locations in Breda, Tilburg and 's Hertogenbosch. These locations have recently been connected over lightpaths, creating a network that allows staff and students to work at any location. Three major advantages are low costs, high performance and security.



## **TEIN2**

<http://www.tein2.net>

*Project to improve research and education IP connectivity between Europe and Asia..*

TEIN2 is a project that began in spring 2004 to improve research and education IP connectivity between Europe and the Asia-Pacific region, and within Asia Pacific for the benefit of developing ASEM countries. The project is to be largely funded by the European Commission, and will be supported by a number of Asian and European partners. It is intended to contribute to the further development of the Trans-Eurasia Information Network (TEIN) initiative.

TEIN2 has three main objectives:

- Increase direct Internet connectivity for research and education between Europe and Asia
- Improve intra-regional connectivity within Asia
- Act as a catalyst for the development of national research networking in the developing countries in the Asia-Pacific region.

The project aims to achieve these objectives by building and operating two key elements in networking between Europe and Asia:

- Asian regional infrastructure connecting TEIN2's Asian partners
- Connectivity between the TEIN2 regional backbone and GÉANT.

As well as encouraging increased research collaboration between Asian NRENs, and between Europe and Asia, TEIN2 will provide the increased capacities required to accommodate that anticipated expansion. The project is divided into two phases.

### **Phase 1**

Phase 1 began in May 2004. It comprised a feasibility study to explore user needs and the connectivity market, and to plan further stages of the project.

### **Phase 2**

Phase 1 was successfully completed and the feasibility study accepted by the European Commission in November 2004. Phase 2 will build and operate the network. This phase of the project is scheduled to run until the end of 2007. During the first part of Phase 2, tendering for the infrastructure and network management services is being carried out. It is expected that the first links will come into service in late 2005.



## **UKERNA**

<http://www.ja.net/about/ukerna/ukerna.html>

*Organisation that manages JANET.*

UKERNA (United Kingdom Education and Research Networking Association) manages the operation and development of JANET on behalf of JISC (Joint Information Systems Committee) for the UK Further and Higher Education Funding Councils. JISC also works in partnership with the Research Councils. UKERNA is government funded, with the primary aim of providing and developing a network infrastructure that meets the needs of the education and research communities.

UKERNA is the trading name for the JNT Association, which since 1994 has had responsibility for the management of the United Kingdom's Higher Education networking programme. It manages the operation and development of the [JANET](#) network, which links the UK's education and research organisations to each other, as well as to the rest of the world through links to the global Internet.

### **History of UKERNA**

The histories of UKERNA and JANET are closely entwined. JANET came first.

### **The Wells Reports**

In the 1970s the UK's Computer Board commissioned two reports from working parties led by Professor Mike Wells into the state of networking between the nation's educational establishments. The reports recommended the setting up of a national research network that would link university computing centres. The second report concluded with a recommendation that the Computer Board and the Research Councils 'set up a small, full-time unit to co-ordinate, guide and rationalise network development involving those bodies receiving their principal funding from the Department of Education and Science.'

### **The Network Unit**

This small, full-time unit became the Network Unit, set up with a two-year remit from 1 November 1976 to 31 October 1978. Its three members spent those two years travelling the length and breadth of the country, visiting every one of the then 50 universities to obtain a comprehensive view of what was happening in data communications and to understand the requirements of users and service providers. The Network Unit also wrote two reports,



concluding with the recommendation that 'all network development should be carried out according to a programme formulated and supervised by a full-time Joint Network Team (JNT). The JNT would be an executive successor to the Network Unit.'

### **The Joint Network Team**

The JNT was set up in 1979, with a small team of six people and a three-year remit. Unlike its predecessor it was able to fund research on networking and get involved, for example in the development of protocols and also hardware. The ultimate aim, as per the Wells reports, was still to create a national education and research network.

This was finally achieved when in 1982 the Science and Engineering Research Council (SERC) agreed to hand its own proprietary network, SERCnet, over to the JNT for development into a full-blown national network connecting all universities and Research Councils. The network was named [JANET](#) and came into operation in 1984.

The JNT continued to manage JANET for another 10 years, but it became clear that this was inadequate. The organisational framework that existed in 1990 was largely improvised, having been created over ten years previously to support the JNT as a relatively small collaborative networking venture between the Computer Board, the SERC and the other Research Councils. It was funded partly by the SERC (approximately 10%) and mainly by the Computer Board (approximately 90%).

Most JNT staff were on the SERC payroll, making the JNT subject to the after-effects of SERC policy, which was not always compatible with its own – for instance, if the SERC had a ceiling on hiring new employees, the JNT couldn't have a recruitment drive. The JNT's size and complexity were also becoming increasingly inappropriate for the current networking programme, and increasingly acting as an inhibitor to progress.

In short, the Computer Board felt that the JNT in its current form would not be sufficient to carry the programme through to the next stage in its development. It therefore agreed to the formation of an autonomous Networking Association that would replace the JNT and take responsibility for the networking programme of the UK academic community. The Network Association would be run as a company.

The Computer Board finally disappeared on 1 April 1991, transforming into the Information Systems Committee (ISC) of the Universities Funding Council. ISC's task was to deal with networking and specialist information services. It



assumed funding responsibility for JANET and oversaw the creation of the new company, the JNT Association.

The ISC transformed further under the newly created Higher Education Funding Councils into the [Joint Information Systems Committee \(JISC\)](#) on 1 April 1993.

### **UKERNA's name**

Even though the JNT Association is a fully independent legal entity, because it is publicly funded [JISC](#) decided it should not be able to own trademarks – including its own name – that could conceivably be sold elsewhere. For this reason it is officially called the JNT Association, *trading as* UKERNA, the United Kingdom Education and Research Network Association.

UKERNA now manages the operation and development of the JANET network under a Service Level Agreement from [JISC](#).

### **The objects of UKERNA**

The objects of UKERNA as stated in the Memorandum of Association included the following main clause:

“to take responsibility for the networking programme of the education, learning and research communities in the United Kingdom; and to research, develop and provide advanced electronic communication facilities for use within these communities, and to facilitate the electronic connectivity of these communities to external third parties.”



## JANET

<http://www.ja.net/>

*UK 2.5Gbps education and research network.*

JANET is the network dedicated to the needs of education and research in the UK. It connects the UK's education and research organisations to each other, as well as to the rest of the world through links to the global Internet. In addition, JANET includes a separate network that is available to the community for experimental activities in network development.

The JANET network connects UK universities, FE Colleges, Research Councils, Specialist Colleges and Adult and Community Learning providers. It also provides connections between the Regional Broadband Consortia to facilitate the DfES initiative for a national schools' network. Over 18 million end-users are currently served by the JANET network.

The range of activities facilitated by JANET allows individuals and organisations to push back the traditional boundaries of teaching, learning and research methods. For example, JANET's videoconferencing and video streaming capabilities are being used to deliver lectures to remote groups of students. For researchers, the high capacity of the JANET backbone allows the linking of large data storage and high performance computing facilities at a national and international level.

JANET developed out of a number of local and research networks dating back to the 1970s. In the early 80s a standardization and interconnect effort started, hosted on an expansion of the pioneering [SERCnet X.25](#) research network. The system first went live in April 1983, hosting about 50 sites with line speeds of 9.6 [kbit/s](#). In the mid-80s the backbone was upgraded to a 2 [Mbit/s](#) backbone with 64 kbit/s access links, and a further upgrade in the early 1990s sped the backbone to 8 Mbit/s and the access links to 2 Mbit/s, making JANET the fastest X.25 network in the world.

In March 2001 **SuperJANET4** was launched. The key challenges for **SuperJANET4** was the need to increase network capacity and to strengthen the design and management of JANET to allow it to meet a similar increase in the size of its userbase.

**SuperJANET4** saw the implementation of a 2.5Gbit/s core backbone from which connections to regional network points of presence were made at speeds ranging between 155Mbit/s to 2.5Gbit/s depending upon the size of the regional network. In 2002 the core **SuperJANET4** backbone was upgraded to 10Gbit/s.



**SuperJANET4** also saw an increase in the userbase of JANET with the inclusion of the Further Education Community and the use of the **SuperJANET4** backbone to interconnect schools networks.

Work is currently (2005) underway to procure [SuperJANET 5](#), the next generation of the backbone which will include the ability to dedicate connections to specific projects using [Wavelength-division multiplexing](#). This is scheduled to be deployed during 2006.

JANET is linked to other European and worldwide [NRENs](#) through [GEANT](#), has a private connection to CERNET in China and peers extensively with other [ISPs](#) at [Internet Exchange Points](#) in the UK.



## Internet2

<http://www.internet2.edu/>

*US university-led consortium aimed at creating research networks, the results of which can be transferred to the broader Internet community.*

Internet2 is a US consortium being led by 207 universities working in partnership with industry and government to develop and deploy advanced network applications and technologies, accelerating the creation of tomorrow's Internet. Internet2 is recreating the partnership among academia, industry and government that fostered today's Internet in its infancy. The primary goals of Internet2 are to:

- Create a leading edge network capability for the national research community
- Enable revolutionary Internet applications
- Ensure the rapid transfer of new network services and applications to the broader Internet community.

### **What is Internet2?**

Internet2<sup>®</sup> is a not-for-profit consortium, led by over 200 US universities, developing and deploying advanced network applications and technology, accelerating the creation of tomorrow's Internet. With participation by over 60 leading companies, Internet2 recreates the partnership of academia, industry and government that helped foster today's Internet in its infancy.

### **Is Internet2 a separate network? Will Internet2 replace the current commercial Internet?**

Internet2 is not a separate physical network and will not replace the Internet. Internet2 brings together institutions and resources from academia, industry and government to develop new technologies and capabilities that can then be deployed in the global Internet. Close collaboration with Internet2 corporate members will ensure that new applications and technologies are rapidly deployed throughout the Internet. Just as email and the World Wide Web are legacies of earlier investments in academic and federal research networks, the legacy of Internet2 will be to expand the possibilities of the broader Internet.

### **How will Internet2 benefit current Internet users?**

Internet2 and its members are developing and testing new technologies, such as IPv6, multicasting and quality of service (QoS) that will enable revolutionary Internet applications. However, these applications require performance not possible on today's Internet. More than a faster Web or



email, these new technologies will enable completely new applications such as digital libraries, virtual laboratories, distance-independent learning and tele-immersion. A primary goal of Internet2 is to ensure the transfer of new network technology and applications to the broader education and networking communities.

### **What kind of technology will be needed to use the advanced Internet applications and technologies?**

We expect the capabilities needed to use new technologies and applications being tested and developed by Internet2 and its members to be built into upcoming generations of commercial products. Internet2 corporate partners are working closely with the Internet2 community to expand the capabilities of their products and services as well as the global Internet. For example, just as most personal computers sold today include the ability to use the Internet, tomorrow's commercial products will include the ability to use advanced networking capabilities.

### **What is the relationship between the Next Generation Internet (NGI) Internet2, and other advanced networking initiatives?**

The university-led Internet2 and the federally-led NGI are parallel and complementary initiatives based in the United States. Internet2 and NGI are already working together in many areas. For example, through participation in a NSF NGI program, over 150 Internet2 universities have received competitively awarded grants to support connections to advanced backbone networks such as Abilene and the very high performance Backbone Network Service (vBNS). Internet2 is also forming partnerships with similar advanced networking initiatives around the world. Working together will help ensure a cohesive and interoperable advanced networking infrastructure for research and education, and the continued interoperability of the global Internet.

### **How much is being invested in Internet2 and where is the money coming from?**

Internet2 members have committed to actively collaborate in the development of advanced networking technologies and applications. For Internet2 universities, this means providing high-performance networking on their campuses—investing to upgrade their campus networks and connecting to a national Internet2 backbone network. For Internet2 corporate partners, this means actively collaborating with Internet2 universities and in Internet2



initiatives. Internet2 universities have committed over \$80 million per year in new investments on their own campuses and corporate members have committed more than \$30 million over the life of the project. In addition, Internet2 member institutions may receive funding in the form of competitively awarded grants from the NSF and other federal agencies participating in the federal Next Generation Internet initiative.

**What about educational institutions that are not Internet2 members?**

Participation in Internet2 is open to any university that commits to providing on-campus facilities that will allow advanced applications development. The investment this requires may be more than many institutions can manage right now. However, Internet2 also supports collaboration by Internet2 universities with non-member institutions. Fifteen years ago, connecting to the Internet could be as expensive as participating in Internet2 today. As the technology dropped in price, the entire academic community benefited from the efforts of the initial research participants. Deployment of Internet2 technology will follow a similar pattern.

**What are some of Internet2's long-term goals?**

A key goal of this effort is to accelerate the diffusion of advanced Internet technology, in particular into the commercial sector. In this way, Internet2 will help to sustain United States leadership in internetworking technology. Internet2 will benefit non-university members of the educational community as well, especially K-12 and public libraries. Internet2 and its members aim to share their expertise with as wide a range of computer users as possible. This approach characterized the first Internet and it can work again today.



## Abilene

<http://abilene.internet2.edu/>

*Internet2 backbone network (10Gbps).*

The Abilene Network is an Internet2 high-performance backbone network that enables the development of advanced Internet applications and the deployment of leading-edge network services to Internet2 universities and research labs across the country. The network has become the most advanced native IP backbone network available to universities participating in Internet2. Abilene enables faculty and staff at Internet2 universities and research labs to develop advanced network services and applications.

The Abilene Network supports the development of applications such as virtual laboratories, digital libraries, distance education and tele-immersion, as well as the advanced networking capabilities that are the focus of Internet2. Abilene complements and peers with other high-performance research networks in the U.S. and internationally.

Created by the Internet2 community, Abilene connects regional network aggregation points—called gigaPoPs—to provide advanced network services to over 220 Internet2 university, corporate, and affiliate member institutions in all 50 states, the District of Columbia, and Puerto Rico. The current network is a primarily OC-192c (10 Gbps) backbone employing optical transport technology and advanced high-performance routers.

The Abilene Network is partnership of Internet2, Qwest Communications, Nortel Networks, Juniper Networks, and Indiana University.

### Abilene Network Goals

The goals of the Abilene Network are to provide an advanced backbone in support of:

- Cutting-edge applications developed by using innovative, experimental techniques and requiring high-performance network services not available on existing commercial networks.
- The deployment and testing of advanced services, including multicast, IPv6, measurement, and security, which are generally not possible on the commodity Internet.
- Connectivity to other research and education networks throughout the world and peering with other federal research networks, thus enabling the international research community to collaborate in new ways.



- Access for researchers to a rich set of network characterization data collected in a high-performance networking environment supporting new and innovated applications.

### **Abilene History**

On April 14, 1998, Vice President Al Gore announced the Abilene network during a ceremony at the White House. Initial operation began in February 1999 and full deployment of a 2.5 gigabits per second backbone was completed by the end of 1999. Abilene underwent an upgrade to 10 gigabits per second and includes native IPv6 capabilities. The upgrade was completed in 2003.

Abilene is named after a railhead established in Abilene, Kansas during the 1860's. In its time the ambitious railhead of the 1800's staked a claim on what was then the frontier of the United States; the Abilene Project establishes a foothold from which to explore and develop pioneering network technology. The links of last century's railway changed the way people worked and lived. The Abilene Network is transforming the work of researchers and educators today.

### **How does Abilene relate to Internet2?**

Abilene is a high-performance backbone network used by the Internet2 community. The Abilene network supports Internet2 by providing an effective interconnect among the regional networking aggregation points, or gigaPoPs, pioneered by Internet2 universities. Abilene's advanced capabilities help Internet2 members develop and deploy new applications more quickly and more broadly. Independent of Abilene, Internet2 working groups are tackling networking development issues such as Quality of Service, multicast, and IPv6. Abilene facilitates this work in support of Internet2 and its mission.

### **Who can connect to the Abilene network?**

Any higher education institution that is an Internet2 member is eligible to use the Abilene backbone network. Abilene is a backbone network interconnecting the gigaPoPs and the Internet2 members. Private and government organizations focused on research and education and collaborating with Internet2 universities also can connect to Abilene with appropriate authorization from Internet2. All of Abilene's expenses are recovered through direct charges to the gigaPoPs and the institutions which it interconnects.



Types of Participants: Primary participants will typically be research and doctoral degree-granting colleges and universities, other non-profit organizations, governmental agencies, or Collaboration Sites of Affiliate and Corporate Members located in the United States. These organizations are able to commit and deploy the substantial resources necessary to implement Internet2 capabilities. In addition to participation by Primary participants, other individual or networked aggregates of educational institutions (including both non-profit and for-profit K-20, technical, and trade schools), or individual museums, art galleries, libraries, hospitals, as well as other non-educational, non-profit, or small for-profit organizations and government agencies that require routine collaboration on instructional, clinical, and/or research projects, services, and content with Primary participants or with other Sponsored participants also may become Sponsored participants.

Corporate members seeking to connect research facilities to Abilene are expected to connect them as Collaboration Sites and Primary participants. Network participants are other research or educational networks, both national and international, with which Internet2 has agreed to peer and which have agreed to conform to the [Abilene Conditions of Use](#). These are networks that have a primary commitment to advanced networking and advanced applications.

### **Does Abilene receive direct federal funding?**

No. Abilene is a project supported through the participation of Internet2 corporate, university and affiliate members.

### **How does Abilene relate to the federal government's Next Generation Internet (NGI) initiative?**

As with Internet2, Abilene supports the [NGI](#), an initiative among federal research agencies. Abilene is a powerful element of the partnership among universities, industry and federal agencies devoted to advanced networking development. For example, Abilene is a key enabler of the university community's effort to collaborate with federal agencies on research and development of advanced network technologies and applications. Further, the Abilene network interconnects with existing federal research networks, such as the Energy Sciences Network (ESnet) and the DARPA Supernet.



### **What is the relationship of Abilene to other high performance networks, such as the National Science Foundation's very high performance Backbone Network Service (vBNS)?**

The vBNS is a network provided under an extension of a cooperative agreement between the National Science Foundation (NSF) and Worldcom to NSF-approved institutions of research and higher learning, and continues to play a key role in the Internet2 project. Abilene provides a complementary alternative to the vBNS and other research networks. Each gigaPoP or connecting institution makes an individual decision about which networks provide the necessary capabilities for advanced application development on its campus. It is intended that any institution connected to one of the networks will be able to access an institution on the other. Abilene and the vBNS maintain limited peerings at multiple points around the country to support the high-performance interconnectivity of Internet2 members on both networks. Together, Abilene and the vBNS provide the means to more effectively test and develop new ideas and technologies currently under development by Internet2 members.

### **What is the relationship between Abilene and the vBNS+?**

The vBNS+ is the commercial follow-on to the vBNS network. Abilene maintains limited peering with the vBNS+ to ensure the high-performance connectivity of Internet2 members connected to these networks.

### **Does the Abilene network replace Internet2 universities' existing commercial Internet connections?**

No. The [Abilene Conditions of Use](#) makes it clear that Abilene is not intended to carry any commercial traffic unrelated to Internet2 goals. Abilene connectors are required to segregate educational traffic from commercial traffic to the extent technically possible. Internet2 universities maintain and continue to experience substantial growth in the use of existing Internet connections, which they obtain from commercial providers. Abilene is a special network service made available by Internet2 to its members for developing advanced research and education applications.

### **How does the Abilene Project fit into Internet2's long-range plans?**

A long-range goal of Internet2 is to ensure that developments and advances made by the project are put to use in the broader global Internet. A core engineering principle of Internet2 is to develop new capabilities that work with



existing technologies and within diverse networks. Working with corporate partners such as Qwest Communications, and Nortel Networks, the Abilene Project will help meet both of these objectives. At the same time, Abilene will allow the entire networking community to benefit from the work now being done by the university community in partnership with industry partners and federal agencies. By acting as a test bed for new designs for networking, and by publishing the interfaces which result from that work, we believe Abilene will lead to broad public benefits resulting from its pioneering work.

**What capabilities does Abilene have beyond those of the commercial Internet?**

Abilene provides the advanced networking capabilities required to develop the applications and network services higher education needs to meet its research and education missions. This includes the testing of new networking technologies such as Quality of Service and multicast. Abilene uses high-speed Sonet facilities and IP-over-Sonet routers. Abilene is operating initially at OC-48c (2.4 gigabits per second) backbone links. In parallel, we are working with our partners to deploy additional links running at 10 gigabits per second.



## National LambdaRail

<http://www.nlr.net/>

*US trans-continental Ethernet network, research-gearred, permitting deeper experimentation than Abilene.*

**National LambdaRail** is a high-speed national [computer network](#) in the [United States](#) that runs over [fiber-optic](#) lines, and is the first [transcontinental Ethernet](#) network. The name is shared by the organization of [research institutions](#) that [developed](#) the network, and, to date, plans to continue developing it. LambdaRail is similar to the [Abilene Network](#), but LambdaRail permits deeper experimentation than Abilene does.

It is primarily oriented to aid terascale computing efforts, but is also not intended to be a service network, but to be used as a network testbed for experimentation with next-generation large-scale networks. National LambdaRail is a university-based and -owned initiative, in contrast with Abilene and [Internet2](#), which are university-[corporate](#) sponsorships. This gives universities more control to use the network for these research projects.

Links in the network use [dense wavelength-division multiplexing](#) (DWDM), which allows up to 32 or 40 individual optical [wavelengths](#) to be used (depending on hardware configuration at each end). At present, individual wavelengths are used to carry a 10-[gigabit](#) Ethernet signal, although other systems such as [SONET](#) may also be used in the future.

### Multiple Networks, Singular Capability

The defining characteristic of the NLR infrastructure is its ability to support many distinct networks for the U.S. research community using the same core infrastructure. Experimental and production networks exist side-by-side but are physically and operationally separate. Production networks support cutting-edge applications by providing users guaranteed levels of reliability, availability, and performance. At the same time, experimental networks enable the deployment and testing of new networking technologies, providing researchers national-scale test beds without the limitations typically associated with production networks.

The contiguousness of the many kinds of networks running over the NLR infrastructure provides researchers convenient and broad-based access to multiple networks, as well as access to real-world production network data. This same feature facilitates the migration of promising technologies into production, and permits research and development to transcend individual networking technologies. By enabling work across and on the potential



interrelationships among traditionally separate network layers—optical networks, switched networks, routed networks, end-to-end transport protocols, as well as middleware and applications—NLR enhances system-level integration of new technologies and enables increasingly critical capabilities such as resource management and security.

NLR's WaveNet, FrameNet, and PacketNet services are already in use by more than a dozen cutting-edge research projects, including the National Science Foundation-supported Extensible Terascale Facility and OptIPuter projects; the U.S. Department of Energy's UltraScience Net project; CENIC and the Pacific Northwest Gigapop's Pacific Wave project; the CAMERA project led by CalIT2, the Venter Institute and UCSD's CEOA; the University of Virginia-led CHEETAH project; as well as Internet2's Hybrid Optical Packet Infrastructure (HOPI) project.

## Goals

The goals of the National LambdaRail project are:

- To bridge the gap between leading-edge [optical](#) network research and state-of-the-art applications research;
- To push beyond the technical and performance limitations of today's [Internet backbones](#);
- To provide the growing set of major computationally-intensive science (often termed [e-Science](#)) projects, initiatives and experiments with the dedicated bandwidth, deterministic performance characteristics, and/or other advanced network capabilities they need; and
- To enable and to rekindle the possibilities for highly creative, out-of-the-box experimentation and innovation that characterized facilities-based network research during the early years of the [Internet](#).

## Participants

The following is a list, from the official LambdaRail web site, of LambdaRail "members and associates". The list is apparently in no particular order.

- [Corporation for Education Network Initiatives in California \[1\]](#) [CENIC](#)
- [Pacific Northwest GigaPop \[2\]](#)
- [Pittsburgh Supercomputing Center \[3\]](#)
- [Duke University](#)
- [Mid-Atlantic Terascale Partnership \[4\]](#) through the [Virginia Tech](#) Foundation



- [Cisco Systems, Inc.](#)
- [Internet2](#)
- [Florida LambdaRail, LLC \[5\]](#)
- [Georgia Institute of Technology](#)
- [Committee on Institutional Cooperation](#)
- [Cornell University](#)
- [Louisiana Board of Regents](#)
- [Oklahoma State Board of Regents](#)
- [Lonestar Education and Research Network](#)
- [University of New Mexico](#)
- [University Corporation for Atmospheric Research](#)
- [Pennsylvania State University](#) (New participant) [Video Presentation](#)



## **Pacific Wave**

<http://www.pacificwave.net/>

*US peering-exchange project designed to enhance efficiency of IP traffic.*

Pacific Wave is a joint project between the Corporation for Education Network Initiatives in California (CENIC) and the Pacific Northwest Gigapop (PNWGP), and is operated in collaboration with the University of Southern California and the University of Washington. Designed to enhance efficiency of IP traffic, Pacific Wave peering services offer excellent opportunities to:

- Pass IP traffic directly with other major national and international networks;
- Reduce costs associated with IP traffic that would otherwise transit multiple circuits;
- Increase efficiency by directing traffic as quickly as possible to the target network/organization, reducing the number of 'hops' required to complete for the data to get to its destination.

### **About Pacific Wave: Today**

Pacific Wave is a state-of-the-art international peering exchange facility designed to serve research & education networks throughout the Pacific Rim and the world. Pacific Wave enhances research and education network capabilities by increasing network efficiency, reducing latency, increasing throughput, and reducing costs. Pacific Wave is a joint project between CENIC, the Corporation for Education Network Initiatives in California, and the Pacific Northwest Gigapop, and is operated in collaboration with the University of Southern California and the University of Washington.

Today, Pacific Wave is available at three U.S. Pacific coast locations: Bay Area (Sunnyvale and Palo Alto), Los Angeles (3 sites), and Seattle. Over 16 major, internationally recognized, research and education networks are among its dozens of participants. The distributed design of Pacific Wave allows participants to engage in bilateral peerings regardless of which node they are physically connected to. This design offers significant flexibility and opportunities for networks utilizing any of a dozen trans-Pacific cables for their circuits as well as for building redundancy and robustness into peering relationships that would otherwise be cost prohibitive and complex to engineer. Current participants represent networks and agencies from throughout the Pacific Rim including Japan, Korea, Australia, Canada, Taiwan, Singapore, Malaysia, Qatar, and the United States.



## **Pacific Wave: Near Future**

Pacific Wave, along with its partner StarLight in Chicago, are the sites where the vast majority of international R&E networks choose to land and interconnect with each other and with other networks in the US. Pacific Wave and StarLight have had for nearly a decade not just a vision, but highly successful implementations of direct, super-high-performance and highly flexible interconnection, exchange and peering among R&E networks and connectors. This is a model which has come to be used by Gigapops and others to connect nearly all of today's R&E networks to each other, and to connect most universities and research sites and resources to R&E networks and other research partners.

This model seeks to recognize, and responsively serve, the diversity of needs of different networks, connectors and users. It is a vision of providing the flexibility and adaptability needed to leverage the rapidly changing technologies, and application and project opportunities that all evolve at the pace of "internet time". It is a vision of enabling network managers and users maximal choice and diversity of approaches, to meet their needs including performance and policy requirements, while at the same time providing carrier-class production-quality super-high-performance very-low latency, low-hop-count, inter-connection, exchange and peering (with top end-to-end performance) among connectors and all significant current and future R&E network fabrics (some of which are already providing customized wavelength level services).

Pacific Wave is now actively engaged in several collaborative efforts (IRNC, GLIF, TransLight, GLORIAD, etc.) to make the vision of adding allocatable, switchable lambda capabilities to our n-way open exchange fabrics a reality. Addition of such services is a natural outgrowth and evolution of our existing inter-connection exchange and switching fabrics and the shift in the telecommunications marketplace and next generation R&E networks towards inexpensive lambdas.

