New Zealand e-Science Infrastructure

Training and Capability Development Gap Analysis

Summary Report

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Executive Summary

A gap analysis of HPC and eResearch training and capability development for New Zealand is presented. The gap analysis consists of international and national scans, a future scenario and the development of recommendations.

The International Environment provides a wide diversity of approaches to training and capability development. Much of the training offered is in the form of physical workshops with limited use of online delivery methods. Training is predominantly offered to those already making use of services but it is also used to upskill potential users so that they can make effective use of the services offered.

Within New Zealand all three research e-infrastructure providers, NeSI, NZGL and REANNZ provide training and capability development offerings primarily through workshops. The universities have a wide diversity of activities including courses as part of qualifications, student organised activities and unconference activities.

A future scenario has been developed to help focus the analysis of potential actions on outcomes that could be achieved. The future scenario presents situations in many ways similar to the present one, but with more users engaged across the spectrum. Significant changes are the levels of engagement, particularly from the postgraduate and post-doctoral researchers. As capability develops within the academic community a flow down effect into undergraduate teaching is expected to occur.

The International scan, National scan and Future Scenario have been analysed to develop recommendations for capability development and training. Three sets of recommendations are presented. The first set are recommendations for New Zealand, the second and third are recommendations for NeSI, split across Long Term and Short Term timescales.

- That the activities of eResearch & HPC providers in the areas of outreach, capability development and training be coordinated to best serve the needs of the market.
- That Universities are encouraged to offer postgraduate training that covers the research process and includes information on eResearch and High Performance Computing and external providers of research related services and support.
- That Universities are encouraged to include eResearch and HPC in their undergraduate curricula as appropriate.
- That capability development is seen as a core activity of the organisation and the responsibility of all team members.
- That planning of and for capability development and training activities be coordinated with planning of outreach activities and other NeSI events.
- That development and delivery of outreach, capability development and training activities be aligned with the requirements of the 'sales' process and are part of managing and maintaining ongoing client relationships.

- Training and Capability Development delivered to PhD students and Post Doctoral researchers has the longest term impact and may also deliver the quickest change in research behaviour.
- Training and Capability Development for senior researchers about the possibilities and potential of NeSI will also aid in uptake.
- That community or market building activities be facilitated and promoted by NeSI but delivered by the community. As an example Software Carpentry could be delivered by PhD students and Post-doctoral researchers with coordination and support (and potentially some funding) provided by NeSI or NeSI in partnership with other providers.

As an adjunct to the recommendation: That NeSI consider becoming the New Zealand Coordinator for Software Carpentry (and potentially Data Carpentry) in a similar manner to the Software Sustainability Institute in the UK.

- That regular analysis of the projects using NeSI is conducted and that this analysis is used to inform the development and delivery of training and capability development.
- That projects that the Computational Science Team work on are examined to understand what is generalisable from the project and what training would have enabled the researchers to have achieved the research outcomes they required without Computational Science Team support. Training can then be developed to upskill researchers in these areas.
- A polished "Getting started with NeSI" workshop is developed including processes for registration & creation of NeSI accounts for users. The workshop should include hands-on content that researchers can use to get started from their own desk. This workshop should be able to be run as part of larger events and also as a stand-alone event.
- A small number of broad appeal workshops should be developed/refined and delivered in multiple locations across the country.
- Needs Analysis/Requirements gathering should be performed at the events run to help frame the further development of content.
- The NeSI Educational and Training group be reformed as the NeSI Capability Development Co-ordination Team and the composition of the team be updated to reflect organisational structures in NeSI.2

The short term recommendations are designed to be easily and quickly implemented with the longer term and national recommendations requiring longer to develop and implement. Fuller details regarding the recommendations can be found at the end of the gap analysis.

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Current State

International

The international eResearch and HPC training and capability development situation varies from country to country. We outline below a high level scan of the types of offerings available in countries and regions with developed e-Research programmes.

XSEDE

The US XSEDE Project is a follow on project to the TerraGrid project and aims to provide an advanced virtual environment to support researchers. Service provided include access to High Performance Computing and Visualisation.

XSEDE has a number of outreach, education and training initiatives, these include:

- Education and Outreach Blog
- Curriculum and Educators Programme
- Campus Bridging
- Campus Champions
- Training
- XSEDE Scholars Programme
- Student Engagement
- Speakers Bureau
- Educational Resource
- Conferences and Events

Further details on the XSEDE programmes can be found at: <u>https://www.xsede.org/education-and-outreach</u>

Selected parts of the programme are expanded on below.

Campus Champions

The stated aim of the campus champions programme is to empower campus researchers, educators, and students to advance scientific discovery. This is achieved by appointing Campus Champions at campuses as a local source of knowledge about XSEDE services. The campus champions programme is a two way agreement between the champions and XSEDE with clear expectations of each being set out.

Campus Bridging

The aim of Campus Bridging is to "to lower the barriers to utilization of XSEDE resources by researchers and to disseminate the best practices of XSEDE resources to campus IT staff".

This is achieved by trying to make national resources appear as if they were proximal to on campus users.

Speakers Bureau

The speakers bureau has a stated goal to "...attend and exhibit at national professional conferences throughout the year. Emphasis will be placed on conferences with the potential for recruiting new communities of users."

PRACE-RI

The Partnership for Advanced Computing in Europe Research Infrastructure is a non-profit association providing high performance computing for scientists and researchers in Europe.

A number of training and capability development initiatives are provided by PRACE including

- PRACE Advanced Training Centres (PATCs)
- Summer of HPC
- Best Practice Guides
- White Papers & User Documentation

Information on PRACE activities can be found at: <u>http://www.prace-ri.eu/</u>

Selected initiatives are expanded on below.

PRACE Advanced Training Centres

PATCs are centres in PRACE member countries that provide advanced courses on the use of HPC to PRACE member researchers.

Summer of HPC

The PRACE Summer of HPC selects 10 students from across Europe to work on PRACE research projects and produce a video or visualisation of their work. The programme runs for 2 months (July-August) and is fully funded for the students. Students are either late stage undergraduate students or early stage postgraduate students.

RIKEN Advanced Institute for Computational Science

The RIKEN Advanced Institute for Computational Science (AICS) in Japan operate the "K Computer" for Japenese researchers.

Their main Outreach, Education and Training activity is the AICS Cafe which is a twice monthly cafe for researchers to discuss research and collaborate outside their own discipline.

VIRTUAL INSTITUTE - HIGH PRODUCTIVITY SUPERCOMPUTING

The Virtual Institute - High Productivity Supercomputing comprises twelve european and american member institutions who each have a long history of HPC expertise.

The VI-HPS provides a number of training activities outlined at <u>http://www.vi-hps.org/training/</u> these activites focus on the use of particular tools and applications. The major training activity of VI-HPS though is a series of tuning workshops aimed at capability development to aid researchers to improve the performance of their MPI and MPI+OpenMP codes.

HPC University

The HPC University is a virtual organisation to share and persist education and training materials for all HPC environments from desktop computing to HPC centre resources.

The site <u>www.hpcuniversity.org</u> provides access to resources that have been submitted by eResearch and HPC organisations worldwide.

Shodor

Shodor is a US national resource for computational science education. They work with middle school through to undergraduate students. They provide and develop activities for an online library of educational resources and run workshops to help educators incorporate computational science into the programmes they run.

INTERSECT

INTERSECT is an Australian eResearch and HPC provider in New South Wales, Australia providing a variety of services to member organisations. Their training and capability development activities centre around a variety of "Learning and Development" courses that are offered, details can be found at http://www.intersect.org.au/content/learning-development

National Computational Science Institute

The National Computational Science Institute (NCSI) is a US organisation providing workshops for educators of all levels and curriculum materials to help them incorporate Computational Science in their classrooms. Details can be found on the NCSI website at http://www.computationalscience.org

Software Sustainability Institute

The UK Software Sustainability Institute helps researchers enhance the software researchers use and to introduce new software. They aim to cultivate world-class research through software. As part of their work the SSI provides a number of training activities for researchers, these include:

- Software Carpentry Workshops. The SSI is the UK co-ordinator for Software Carpentry
- Hands On Workshops
- Guided Discussions
- Surgeries
- Online guides and tips
- Advice of self-guided training

Summer and Winter Schools

A number of organisations offer intensive Summer or Winter schools. These are typically one or two weeks in length and focus on a particular area of interest.

http://gridka-school.scc.kit.edu/2014/ http://www.summerschoolsineurope.eu/course/405/swiss-grid-school http://www.isgtw.org/event/summer-school-grid-and-cloud-workflows-and-gateways

These allow attendees (typically postgraduate students) to immerse themselves in the technology and develop skills required for their research.

Software Carpentry

Software Carpentry (<u>http://software-carpentry.org/</u>) is a volunteer organisation whose goal is to make scientists more productive, their work more reliable, by teaching them basic computing skills.

Software Carpentry runs instructor led workshops - typically over two days - often for no cost and certainly low cost (\$20-40). The curriculum at workshops is flexible with a core that must to taught and optional additional topics. A pre-workshop survey is often used to tailor content to the audience.

Software Carpentry is a mature global initiative that has evolved over the last 10 - 15 years, with instructors certified by undertaking a training course covering educational psychology and pedagogy alongside skills training, and then instructing alongside a certified instructor at a Software Carpentry workshop.

Data Carpentry

Data Carpentry (<u>http://datacarpentry.org/</u>) is a new and very formative riff on Software Carpentry aspiring to teach basic concepts, skills and tools for working more effectively with data.

Data Carpentry is a very recent initiative with the first workshop run in May 2014. They focus on the following areas:

- How to use spreadsheet programs (such as Excel) more effectively, and the limitations of such programs.
- Getting data out of spreadsheets and into more powerful tools --- using R or Python.
- Using databases, including managing and querying data in SQL.
- Workflows and automating repetitive tasks, in particular using the command line shell and shell scripts.

New Zealand

The current state of eResearch and HPC Training and Capability Development in New Zealand consists of a number of organisations undertaking some activity - but that these activities are not coordinated in any way between the organisations.

REANNZ

Research and Education Advanced Network New Zealand Ltd (REANNZ) own and operate an advanced network for the research and education sector.

REANNZ have offered workshops as part of the eResearch NZ Symposium for the research community and a large variety of events from conferences, seminars, hui, and on site training for the network community, both academic and technical.

NZGL

New Zealand Genomics Ltd. (NZGL) provide an end-to-end genomics service within New Zealand primarily to the research and education sector.

NZGL run a number of workshops these are structured into introductory and advanced to cater to different needs. Whilst the workshops have pre-defined topics covered a pre-workshop survey is used to tailor the workshop to the needs of attendees.

NeSI

At a national level NeSI have run a number events and initiatives that include training and capability development, and have promoted and sponsored Software Carpentry to the research community nationally.

Computational Science Team

The Computational Science Team brings together staff across NeSI sites into a national team. This team supports researchers to achieve research outcomes by working closely with

an individual researcher or research team to improve and optimise their computation and workflow to get the best advantage from the use of HPC.

Engagement Team

NeSI has an engagement team which includes representatives from each NeSI site. The Engagement team have undertaken a number of outreach activities including, Roadshows which showcase the capabilities of NeSI and the research being enabled by NeSI.

Training and Capability Development

NeSI have offered a variety of workshop targeted at different levels of researchers. These include introductory workshops to help researchers "get started" with NeSI through to advanced workshops covering topics such as GPU Programming, MPI and OpenMP programming.

The full range of workshops offered can be seen at https://www.nesi.org.nz/services/computational-science-team/workshops

A number of workshops are offered as part of the eResearch NZ conference. These workshops often allow a focus on specialised aspects of the NeSI infrastructure

Summer of eResearch

The summer of eResearch was supported by NeSI and it's predecessor BeSTGRID, with teams of senior undergraduate students working alongside active researchers to develop shared software and tools to aid their research. The scheme has run for a number of years and has involved research institutions across New Zealand and included some international linkages.

NZ eResearch conference

The NZ eResearch conference has provided a venue for a number of national NeSI initiatives

These have included the NZ HPC Applications Workshop to allow those developing and using HPC applications to share their experiences with the community and for discussion and debate to be had about user experiences.

Universities

Each of the New Zealand Universities offer courses in topics related to Computational Research, eResearch and/or High Performance Computing. These are typically at the senior undergraduate or postgraduate level.

A brief summary of offerings at each institution is provided, note this information is sourced from both web searches and personal communication, not all courses may be offered currently.

The University of Waikato

The University of Waikato offers papers in Computational Finance, Computational Mathematics, Bioinformatics, Computational Chemistry, Information Visualisation and Programming for Research

The university has a compute cluster - Symphony - that is available for researchers at the university to use. The cluster also has a display wall connected to it for large scale visualisation. Details of the cluster can be found at http://wiki.symphony.waikato.ac.nz/index.html

The Weka group have offered data science training workshops.

University of Otago

The University of Otago offers papers in Computational Physics, Computational Mathematics, Computing for BioInformatics and recently started offering a Master of Business Data Science.

University of Otago are a NeSI member and members of the Computational Science Team are based in Dunedin at the university.

Victoria University of Wellington

Victoria University of Wellington (VUW) offers papers in Distributed Computing in Grids and Clouds and Computational Statistics.

VUW employs a dedicated e-Science Consultant and has a number of compute resources available for researchers on campus including a HPC facility and cycle-scavenging grids. VUW is able to provide one-on-one support for researchers using on-campus and off-campus resources through the e-Science Consultant.

Massey University

Massey University offers papers in Programming for the Computational Sciences, Advanced Computational Methods and Computational Biology.

Massey University is part of NZGL.

Lincoln University

Lincoln University offers papers in Bioinformatics and Visual Data Analysis.

University of Canterbury

The University of Canterbury offers papers in Computational Statistics, Distributed Computing Visualisation, BioInformatics, Parallel Computing Architectures, Parallel Programming using the Message Passing Interface and Structured Programming for Scientific Computing.

The BlueFern Supercomputer Centre at University of Canterbury (BlueFern) has a strong programme of seminars and workshops along with staff contributing to postgraduate level qualifications in High Performance Computing as with CeR this builds on a prior history of serving users within the home organisation and the community more widely.

Full details of the workshops, and seminars can be found on the BlueFern website http://www.bluefern.canterbury.ac.nz/ along with details of the postgraduate qualifications.

The seminars and workshops have typically focussed on a specific application or programming environment/language (OpenFOAM, Octave, Python) and are targeted at domain scientists.

The postgraduate qualifications¹ have been focussed on Parallel Computing and Programming and are aimed at those who want to learn more about developing software that can run on high performance computing architectures.

BlueFern have also run an introductory workshop, however this was a one off rather than a regular occurrence and provide one on one support to users to help them get started.

Auckland University of Technology

Auckland University of Technology (AUT) offers papers in Bioinformatics and Next Generation Networking.

AUT is heavily involved in the Square Kilometre Array Project and the associated computing requirements for the project. AUT have recently established a High Performance Computing Research Laboratory to conduct research into the technologies and software required to meet the challenges of the the SKA Project.

University of Auckland

The University of Auckland offers papers in Parallel and Distributed Computing, Computational Science, Bioinformatics, Structural and Computational Chemistry and High Performance Computing, and is the birthplace of several computational software codes, including R and Beast. A variety of skills training iniatives are running across the University

¹ These courses are no longer offered for academic credit

of Auckland campus; these include postgraduate statistics training and the short courses run by the NZ Social Statistics Network (http://www.nzssn.org.nz/).

CeR have run one off workshops focussed on technical aspects of the HPC environment, and have included such topics as Loadleveler and Intel Phi or systems administrators, HPC researchers and those who wish to fully understand the technical detail of systems their code is running on.

Other Events

THATCamp

In 2014 the University of Canterbury Digital Humanities programme organised a THATCamp. THATCamp stands for The Humanities and Technology Camp and is an unconference format event. The event brought together a number of researchers, students and industry people with an interest in Technology and the Humanities. Various sessions including Introductory Programming, Software Engineering, RaspberryPi, Policy, Data Standards were organised and run around the interests of attendees.

R for Biology & Ecology

A group of PhD and Postdoctoral Students from Lincoln University and University of Canterbury organsied and ran a series of seminars and hands on workshops for researchers in the Biology and Ecology areas in using R. Details can be seen at: <u>http://www.biol.canterbury.ac.nz/R/</u>

This provides a good example of a community of interest coming together to provide training and capability development to each other.

Future State

To propose a future state for New Zealand eResearch and HPC Training and Capability a number of activities were untaken. These included an analysis of users using NeSI for research and job types currently being run on NeSI. Researchers were contacted for their views on Training and Capability Development in the future. The NeSI Education and Training Group were consulted on potential "Future Perfect" scenarios and the interviews reported on the eResearch2020 website were examined.

The results of these have been distilled to produce a description of a desirable future state for New Zealand eResearch Training and Capability Development. This future state should be further validated through discussion with researchers, educators and infrastructure providers.

From this future state directions for training and capability development are identified and synthesised into recommendations.

This Future State is focused on a 10-15 year horizon with some components achievable in shorter timeframes and certainly within 5 years.

Research is increasingly conducted by teams made of researchers from a variety of disciplines, the questions they are asking are more complex and many cannot be answered without research being conducted "in silico". The quantities of data that these research teams consume and generate are growing and the academy and governments have placed increasing emphasis on reproducibility of research, data re-use and data repurposing. This has generated an increased demand for workflow & data publishing services and collaboration infrastructure.

What was seen as eResearch in 2014 has become mainstream in many research disciplines, this is particularly true of High Performance Computing (HPC). Research teams routinely make use of HPC for computation, using standard discipline packages & research codes and in some cases writing their own software. Much of the HPC work is done by PhD students and PostDoc researchers who honed their skills whilst coming up through the student ranks.

These junior researchers are part of a highly networked vibrant self-supporting community that with the support of research infrastructure providers, institutions and the research disciplines provide education, training and support for the common tasks that infrastructure is used for. This may include institutional postgraduate research training, self-run training courses using national and international curricula and resources, learning as an undergraduate, senior student mentoring.

Some research disciplines are still developing their use of eResearch and HPC, in these communities the uptake is variable and patchy. Pioneer researchers are making good use of the resources available and see the contribution to their research area that applying computational techniques can make. They are however worried about others in their

research discipline who show no interest in the area and are concerned that each year the gap between those who can and do use HPC/eResearch and those who don't is increasing. Students of the pioneer researchers make use of eResearch and HPC and link in with the community of researchers already making use of such techniques.

The areas of eResearch and HPC have continued to develop and push the boundaries in terms of research and technology. Advanced researchers in some disciplines are taking advantage of this leading edge to accelerate their research. They have built skills in the technologies they are using through their own self-study, other academics and also training and direct help and support from experts at the research infrastructure providers.

It is part of the usual research process to interact with research infrastructure providers to access resources that are needed for your research. No one university or research institute can provide all the resources that all researchers need. When developing research project proposals it is common to think about the external input that will be needed and what the cost of accessing these provisions will be. These are incorporated into budgets as valid research costs. The home institution has a good relationship with the providers and can provide the information that is needed and can facilitate a relationship being built with the research team.

Recommendations

For New Zealand

NZ1	That the activities of eResearch & HPC providers in the areas of outreach, capability development and training be coordinated to best serve the needs of the market.
	Coordination allows for duplication to be avoided and for researchers to understand the various options available to them. Coordination also helps reduce confusion around the various research infrastructure providers.

NZ2	That Universities are encouraged to offer postgraduate training that covers the research process and includes information on eResearch and High Performance Computing and external providers of research related services and support.
	Postgraduate students are often the researchers working at the cutting edge of their field, by ensuring that they are informed about the options available to them to support their research they are more likely to make use of them. Early awareness allows the students to plan and budget more effectively to make use of research infrastructure.

NZ3	That Universities are encouraged to include eResearch and HPC in their undergraduate curricula as appropriate.
	Universities are charged with delivering research led teaching. As the research processes develops and changes to include the use of eResearch and High Performance Computing it is important that this flows down to undergraduate students. Early familiarisation with this areas will also assist those students going on to further research and more advanced study.

For NeSI

Long Term

NLT1	That capability development is seen as a core activity of the organisation and the responsibility of all team members.
	The researchers using NeSI benefit if each interaction leaves them more self- sufficient. Through a shared vision that capability development is a responsibility that each NeSI team member has, this encourages each interaction with NeSI researchers to be an opportunity for developing that researcher.

NLT2	That planning of and for capability development and training activities be coordinated with planning of outreach activities and other NeSI events.
	Whilst training and capability development activities can be developed in isolation from other NeSI events the co-ordination of events and creating a coherent progression for researchers and building communities of interest through linked events strengthens the community for greater self-sufficiency.

NLT3	That development and delivery of outreach, capability development and training activities be aligned with the requirements of the 'sales' process and are part of managing and maintaining ongoing client relationships.
	By linking the gathering of training requirements with granting access to NeSI platforms (either to individual researchers or to institutions) it ensures that training and capability development are seen as core to the NeSI package. Training & Capability Development delivery can then be aligned to the identified needs of researchers for maximum impact.

NLT4	Training and Capability Development delivered to PhD students and Post Doctoral researchers has the longest term impact and may also deliver the quickest change in research behaviour.
	PhD students and PostDoc researchers, particularly in university settings, spend the most time on research projects, they also have the longest research careers ahead of them and are typically the most open to new research approaches.

NLT5	Training and Capability Development for senior researchers about the possibilities and potential of NeSI will also aid in uptake.
	Senior researchers have a mentoring role for junior researchers and are also most likely to be principal investigators on research projects. Increasing their awareness of the possibilities and potential of NeSI ensures that they are more open and receptive to approaches that make use of NeSI.

NLT6 That community or market building activities be facilitated and promoted by NeSI but delivered by the community. As an example Software Carpentry could be delivered by PhD students and Post-doctoral researchers with coordination and support (and potentially some funding) provided by NeSI or NeSI in partnership with other providers. As an adjunct to the recommendation: That NeSI consider becoming the New Zealand Co-ordinator for Software Carpentry (and potentially Data Carpentry) in a similar manner to the Software Sustainability Institute in the UK.
NeSI has insufficient resources to run large scale community building activities, but could act as a facilitator for the community. NeSI being a national body is well placed to act in a coordination role. By involving the community in the delivery of these activities the community is enriched, developed and grows which should have a flow on effect to the use of NeSI Compute resources.

NLT7	That regular analysis of the projects using NeSI is conducted and that this analysis is used to inform the development and delivery of training and capability development.
	Usage of NeSI will change over time as the existing researchers mature and develop more advanced uses of the infrastructure. New researchers begin to use the infrastructure and as the community of researchers expands, the diversity of uses may increase. Analysis of how NeSI resource are being used allows training and capability development to be focused both on meeting the needs of the current uses and also deliver training that will allow researchers to progress to more advanced uses of the infrastructure.

NLT8That projects that the Computational Science Team work on are examined to
understand what is generalisable from the project and what training would have
enabled the researchers to have achieved the research outcomes they required
without Computational Science Team support. Training can then be developed to
upskill researchers in these areas.Many projects that the Computational Science Team work on will be at the bleeding
edge for a discipline, by leveraging the results of the project and delivering training
and capability development activities to that community, NeSI can encourage
diffusion of innovation through a research community accelerating research progress.

Short Term Actions

NST1	A polished "Getting started with NeSI" workshop is developed included processes for registration & creation of NeSI accounts for users. The workshop should include hands-on content that researchers can use to get started from their own desk. This workshop should be able to be run as part as larger events and also as a stand-alone event.
	Making the transition from a desktop environment to a shared infrastructure service can be extremely daunting for some users. Good first impressions and an "easy on ramp" make the transition less so. A smooth process for user registration and the ability for users to create a personal account that they can then use for further training and computational allocations means they feel they are "part of NeSI" from their first interaction

NST2	A small number of broad appeal workshops should be developed/refined and delivered in multiple locations across the country.
	Creating new workshop materials can be resource intensive. To enable broad delivery of training across the country to meet researcher needs, a small number of workshops that can be developed and refined and used for multiple deliveries should be the initial target. These workshops could also provide an opportunity for Computational Science Team members to cross-train each other and to increase the number of Computational Science Team members able to deliver each workshop.

NST3	Needs Analysis/Requirements gathering should be performed at the events run to help frame the further development of content.
	Researchers gathered for a training event provides an ideal opportunity to engage with them and have an in-depth discussion about the gaps they have in knowledge or capability and therefore what training and capability development activities would be appropriate to develop to meet these needs.

NST4	The NeSI Educational and Training group be reformed as the NeSI Capability Development Co-ordination Team and the composition of the team be updated to reflect organisational structures in NeSI.2
	The change of name reflects the change in terminology and focus used by NeSI.2. NeSI.2 also has a different organisational structure with service lines. It is suggested that the Engagement Service Line has responsibility for the Capability Development

Co-ordination Team and the team includes representation from people with the following responsibilities.
Computational Support
User Support
Outreach
Client Relationship Management
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Glossary

Computational Science Team: See <u>https://www.nesi.org.nz/services/computational-science-team</u> work directly with researchers who have research allocations on the NeSI HPC platforms to advance their science.

eResearch: "research enhanced by the (advanced) use of (advanced) ICT"

e-Science: eResearch applied in the sciences.

HPC: High Performance Computer a computer with many processors (usually 100's-1000's) and a large amount of memory. Often consisting of a large number of nodes connected by high performance networks e.g. Infiniband.