ACIL ALLEN CONSULTING

REPORT TO
VLSCI

4 SEPTEMBER 2015

VICTORIAN LIFE SCIENCES COMPUTATION INITIATIVE

FIVE YEAR REVIEW

LAPSING PROGRAM REPORT

ACIL ALLEN CONSULTING PTY LTD
ABN 68 102 652 148

61 WAKEFIELD STREET
ADELAIDE SA 5000
AUSTRALIA
T +61 (0)412 089 043

LEVEL FIFTEEN
127 CREEK STREET
BRISBANE QLD 4000
AUSTRALIA
T+61 7 3009 8700
F+61 7 3009 8799

LEVEL TWO
33 AINSLIE PLACE
CANBERRA ACT 2600
AUSTRALIA
T+61 2 6103 8200
F+61 2 6103 8233

LEVEL NINE
60 COLLINS STREET
MELBOURNE VIC 3000
AUSTRALIA
T+61 3 8650 6000
F+61 3 9654 6363

LEVEL ONE
50 PITT STREET
SYDNEY NSW 2000
AUSTRALIA
T+61 2 8272 5100
F+61 2 9247 2455

LEVEL TWELVE, BGC CENTRE
28 THE ESPLANADE
PERTH WA 6000
AUSTRALIA
T+61 8 9449 9600
F+61 8 9322 3955

ACILALLEN.COM.AU

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ACIL ALLEN CONSULTING, VLSCI FIVE YEAR REVIEW LAPSING PROGRAM REPORT, SEPTEMBER 2015.

EXECUTIVE SUMMARY

The Victorian Life Sciences Computation Initiative (VLSCI) is a research infrastructure funding initiative that provides supercomputing facilities and resources to support and strengthen life sciences research in Victoria. ACIL Allen Consulting was commissioned to prepare a report on the Initiative's benefits, the operations, mechanisms and processes used to deliver those benefits, and to assess the Initiative's value for money for the Victorian Government, industry and the research community. The report was developed in accordance with the Victorian Government's guidelines for the evaluation of lapsing programs.

The key findings from our evaluation are listed below.

The role of information technology in life science research is strong and growing

The convergence of information technology and rapid advances in life sciences has been the subject of a detailed analysis by the Massachusetts Institute of Technology (MIT). MIT refers to this convergence as a 'cross pollination' of different conceptual approaches. The convergence is in part driven by the enormous volumes of data being generated by life sciences researchers as they strive to collect medical, physiological and genomic data from growing numbers of people, with the aim of identifying common patterns across individuals and ultimately improving health care.

The field of genomics is reportedly the fastest-growing generator of data in the world today. The quantity of genetic data being produced daily is doubling approximately every seven months. The rate of growth is so rapid that the amount of data collected is rapidly outstripping our capacity to analyse it. Without access to high performance computers to analyse data the ability to conduct leading edge research in Victoria will decline over time.

The Victorian Government's decision to invest in the VLSCI was sound

Given the strength of Victoria's life and medical sciences research sector, the Victorian Government's investment in the VLSCI should be regarded as a far-sighted move. In the absence of that support, it is unlikely that any other party or parties would have been in a position to fund the facility.

The Victorian Government's investment in VLSCI has contributed to Victoria improving its global reputation as a world-leading centre for life sciences research. Significant economic and social benefits have flowed to Victoria from hosting this research infrastructure.

The initial $50 million invested by the Victorian Government has led to cash and in-kind contributions of approximately $80 million from Victorian universities between 2008 and 2014. User subscriptions and indirect NCRIS funding totalling around $5 million was also leveraged by that initial investment. In addition, researchers using VLSCI have been successful in winning competitive national and international grants for their research, indicating that keeping pace with these new technologies has delivered results for them.

It is difficult to know if those researchers would have gaining these grants in the absence of VLSCI. However, we note that some two thirds of the researchers ranked the role of VLSCI as either important or extremely important in obtaining their grants. ACIL Allen estimates that the initial Victorian Government's $50 million investment in the VLSCI has generated increased spending on life sciences research of between three and five times that amount. Therefore, it is safe to say that the Victorian Government's initial investment has attracted substantial additional cash and in-kind spending on life sciences research for the State.

VLSCI's facilities have also helped to attract and retain leading edge life science researchers within Victoria. The grants that researchers using VLSCI have won have provided employment opportunities for undergraduate, postgraduate and postdoctoral researchers. They have also helped to train researchers, particularly in bioinformatics, a discipline that is in increasing demand not just in Australia, but around the world.

While some computing time is available to life sciences researchers from Victoria on other supercomputers in Australia, it is insufficient to meet all their research needs. There are also some fields of life sciences research that other supercomputer facilities in Australia are not well suited to support. For example, dynamic molecular modelling work, which has been one of VLSCI's major areas of success.

VLSCI has met or exceeded the objectives set for it

VLSCI has met or exceeded all the key performance indicators set for it, and in a number of cases has done so well ahead of target dates.

Research outcomes have been excellent. For example, the number of papers and presentations by researchers using VLSCI's facilities has grown strongly. The journal impact factors of the publications in which the results of VLSCI-supported research have been published are high and the average impact factor has increased over time, providing a good indication that the research is high quality.

Access to world leading research infrastructure has helped Victorian researchers win grants and form significant research collaborations, including an impressive list of international collaborators. VLSCI has also strongly supported the development of skills that are critical to Victoria's future as a world leader in life sciences.

VLSCI has improved its sustainability

In recent years, the LSCC has been very successful in moving towards a subscription-based model to help fund its operations. By 2014, subscriptions totalled around $2 million. VLSCI has also been successful in attracting increasing amounts of indirect funding from NCRIS over this time. In 2013 indirect NCRIS funding to VLSCI was around $342,000. This more than doubled to $735,000 in 2014 and is expected to almost double again to $1,244,000 in 2015.

Subscriptions and indirect funding from national sources of funding for research infrastructure can make a significant contribution towards meeting ongoing operational costs. However, globally there are no examples of computing facilities that have raised the funds required for the capital investment to upgrade or replace their computing hardware in this way. It is extremely unlikely that VLSCI could do any better in this regard.

Some stakeholders saw VLSCI's governance arrangements between 2008 and 2014 as relatively complex and cumbersome. These arrangements were reflective of the initial funding agreement with the Victorian Government and the financial contributions of partner organisations. However, following the new funding agreement in 2015, these arrangements have been rationalised and simplified.

There is a good case for government to support VLSCI in the future

Victoria has a world class reputation for life sciences research. The Scientific American's sixth Annual Worldview Scorecard of the Biotechnology sector in 2014 ranked the performance of 54 countries. Australia was the fourth ranked country (up from a ranking of seventh in 2013). This ranking has effectively delivered on the vision in the Victorian Government's Biotechnology Strategic Development Plan, namely that Victoria should be *recognised as one to the world's top five biotechnology locations*.

Maintaining or improving this ranking and Victoria's reputation for research excellence in this field is however likely to require further support from governments. That support could be a mixture of Commonwealth and Victorian funding and there are precedents that suggest that Commonwealth funding will be easier to obtain if there is also a contribution from the Victorian Government.

The case for further Victorian Government funding for VLSCI is a strong one. The recognition that Victoria is now a global hub for life sciences research was mentioned above. Other benefits such as research funding attracted to the State, are already considerable. The training and skills development provided by VLSCI is also substantial (it is important to recognise that the skills being developed are also increasingly being sought by firms outside the life sciences sector). The employment opportunities generated are another benefit. Finally, future benefits from the commercialisation of life sciences research are also likely to flow to Victoria, although this will take longer to realise.

To increase the chance that the Victorian Government will provide additional funding VLSCI needs to build a strong case that demonstrates the benefits to Victoria of such funding. This information will also be useful for supporting any requests for funding from national programs.

The VLSCI already provides some access to users from outside Victoria. However, expanding that access will be necessary if the facility is to attract Commonwealth funding.

VLSCI faces some serious risks to its future operations

The Victorian Government has stated its intention to not provide any further funding support for VLSCI following the completion of the current Funding Agreement in 2016. At a minimum, this would force VLSCI to significantly reduce the LSCC's service offering and scale back its outreach functions. At a maximum VLSCI could be forced to cease its operations, including closing the HPC facilities. If the facility was to close then Victoria would most likely experience a permanent loss of a world class research capability, in an important research field where access to expertise in life sciences computing and to HPC facilities is crucial.

A number of strategies and initiatives necessary to mitigate the future risks facing VLSCI have already been developed and reported on. The VLSCI's *Sustainability Plan* (2013-14) demonstrates VLSCI's ability to identify, examine and report on business risks. However, mitigation of these risks (especially those relating to VLSCI's ongoing funding) have been challenging for the initiative in the absence of access to federal government funding schemes such as NCRIS.

Future plans, strategies and priorities should continue to support VLSCI's endeavours to become a sustainable entity over the longer term.

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C O N T E N T S

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1 INTRODUCTION

About VLSCI

The Victorian Life Sciences Computation Initiative (VLSCI) is a $50 million research infrastructure funding initiative by the Victorian Government that provides supercomputing facilities and resources to support and strengthen research in the field of life sciences. The VLSCI has three main elements:

— The Peak Computing Facility (PCF). As planned, by the completion of Stage 2 in July 2012, the PCF reached a ranking of 31 in the Top500 of high performance facilities, and achieved a reputation as the most powerful supercomputer dedicated to life sciences research in the world. VLSCI staff offer specialist technical expertise and services to help users to efficiently access computing resources that are appropriate to their life sciences related research.

— The Life Sciences Computation Centre (LSCC). The LSCC has built specialist teams to support researchers and drive capacity-building activities using a collaborative model. These expert teams are located in a number of research institutions where they work to accelerate life sciences computing.

— The Outreach and Skills Development Program. This program delivers a range of diverse events and activities designed to engage researchers, students, stakeholders, experts and the public in life sciences computing.

Since it was established the infrastructure and expertise offered by VLSCI has become essential to many life science research disciplines, particularly those that involve the use of large amounts of data such as bioinformatics, computational biology, computational imaging, advanced modelling and bioengineering.

1.1.1 Context

The VLSCI is an important part of Victoria's life science research infrastructure and capability in the field of biotechnology that the government's Biotechnology Plan is intended to help maintain. The Grant Agreement between the University of Melbourne and the Victorian Government to establish the VLSCI was signed on 10 June 2008. The Agreement specified three key targets:

— the cumulative value of the contributions to the VLSCI to reach $100 million by 30 June 2013

— the peak computing facility (PCF) to rank in the top 5 facilities for life sciences research precincts internationally, with the target to be the top life sciences PCF by 30 June 2013

— the effective annual full-time equivalent staff resources supported by the VLSCI to reach 30 full-time equivalents by 30 June 2013.

ACIL Allen's November 2013 study (the 2013 study) examined the benefits realised by the VLSCI up to that point and found that all three of these targets had been either met or exceeded.[1]

[1] *Evaluating the VLSCI: A benefits realisation analysis*, ACIL Allen, November 2013

Following a delay in getting started, the Initiative officially commenced in 2009 and later, due to these delays, the five-year program was extended to the end of 2014. The Victorian Government has since approved the continuation of its funding for a further period from 2015 through to end 2016, in partnership with the University of Melbourne and other stakeholder institutions. However, under the terms of the original Funding Agreement the Initiative is required to undergo a 'lapsing program' evaluation. The evaluation report needs to cover the period from 2010 to 2014 inclusive.

1.1.2 Terms of reference

The scope of the services ACIL Allen was required to deliver for this project are shown in Box 1.1.

The evaluation was also required to meet the expectations of the Victorian Government, as outlined in the Department of Treasury and Finance's document *Evaluation policy and standards for lapsing programs*. That document requires the evaluation to assess:

- The evidence of a continued need for the program and role for government in delivering the program. (*Justification/Problem*)
- Whether the program has delivered on its stated objectives and expected outcomes including alignment between the program and departmental objectives and government priorities. (*Effectiveness*)
- Whether the program has delivered in terms of scope, budget and timelines with appropriate governance and risk management practices. (*Funding/Delivery*)
- If the program was delivered efficiently (i.e. maximised output for a given set of inputs) and with economy (i.e. the timely use of inputs at an agreed quality and quantity while ensuring inputs are kept at lowest cost. (*Efficiency/Economy*)

The evaluation is also required to address what the impact would be of ceasing the program (for example, service impact, community, jobs in both the public sector and the wider community) and what strategies have been identified to minimise negative impacts? What alternative approaches or strategies could provide a fall-back position? (*Risk*)

BOX 1.1 – **SCOPE OF EVALUATION**

VLSCI requires:

1. The preparation of a report that will cover the entire Grant Period and be in a form to enable it to be used for public information and dissemination purposes, on the operation, mechanisms and processes utilised by the University to achieve the Project objectives. The report should address, but not be limited to, the following:
   a) Based on the fully audited financial accounts of the Project which include contributions from other States, and other stakeholders (to be provided by the Business Manager) offering an assessment of the project's delivery as value for money for the Victorian Government, industry and the research community,
   b) A summary of the key high-end computing infrastructure built (the systems, applications and ancillary facilities) and how these have and are performing
   c) The key learnings from the design and delivery of the Project
   d) The capacity for the Project to continue or be modified to improve its strategic alignment, effectiveness and administrative efficiency. This should also explore the feasibility/impact of discontinuation of the Project; and
   e) The benefits to the University and the State as a result of the Project
2. An examination and assessment of its qualitative processes, resourcing, governance arrangements within the context of the provision of life sciences computation within Victoria.
3. The possible implications of its current strategy and positioning to be able to respond with agility in an emerging national landscape.

SOURCE: RFQ DOCUMENT, PAGES 2-3

Victorian leadership in life sciences and research

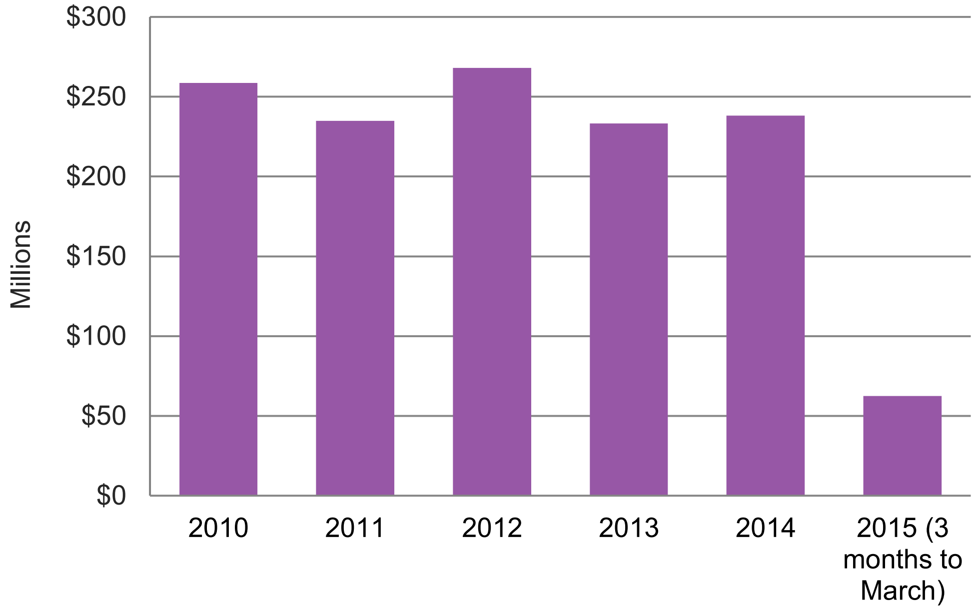
Victoria is regarded as being among the global leaders in biotechnology research. *Victoria's Technology Plan for the Future - Biotechnology* published in 2011 sought to ensure that leadership, and position the sector for future growth and ensure that it remains competitive in a challenging global environment. The Plan confirmed the State's goal to be a leader in life sciences research. It noted that:

> *Biotechnology is a vitally important Victorian industry and an area of competitive advantage for the State, with the potential to make a major contribution to future economic growth and increased productivity. Biotechnology is an enabling technology that is already generating substantial benefits in many areas. They include new treatments for diseases and injuries, more sustainable and productive industrial and agricultural processes, and better environmental management practices.*[2]

Victoria's importance to Australian medical and health research

The value of NHMRC grants being won by Victorian researchers is shown in Figure 1.1. We see that Victorian researchers have won NHMRC grants worth between $225 million and $250 million a year since the establishment of the VLSCI. Note that these figures are for all medical and health research projects in Victoria, not just projects involving VLSCI.

FIGURE 1.1 – **VALUE OF NHMRC GRANTS WON BY VICTORIAN RESEARCHERS**



Notes: 1. The results for only one round of grants in 2015 had been announced at the time this report was prepared. 2. These are NHMRC grants won by Victorian researchers, not just those using VLSCI's facilities.

SOURCE: HTTPS://WWW.NHMRC.GOV.AU/GRANTS-FUNDING/OUTCOMES-FUNDING-ROUNDS , ACCESSED 9 JULY 2015

While the flow of NHMRC funds to Victoria in absolute terms is certainly significant, it is the share of research funding flowing to Victoria that really illustrates that jurisdiction's importance in the field of health and medical research. Figure 1.2 shows that Victorian researchers have consistently received the biggest share of NHMRC grant funding. The jurisdiction receiving the next largest share of grant funding from the NHMRC is NSW. However, the annual share of NHMRC funding flowing to NSW researchers is between 7 and 13 percent less than that for Victorian researchers.

[2] *Victoria's Technology Plan for the Future – Biotechnology*, Department of Business and Innovation, 2011.

FIGURE 1.2 – **SHARE OF NHMRC FUNDING RECEIVED BY DIFFERENT JURISDICTIONS**

Notes: 1. The results for only one round of grants in 2015 had been announced at the time this report was prepared. 2. These are for all NHMRC grants won by Victorian researchers, not just those using VLSCI's facilities.

SOURCE: HTTPS://WWW.NHMRC.GOV.AU/GRANTS-FUNDING/OUTCOMES-FUNDING-ROUNDS , ACCESSED 9 JULY

1.2.2 The Parkville Precinct

One of the reasons that Victoria has such a good record of consistently obtaining a large share of the available NHMRC grant funding is the outstanding concentration of biomedical groups that it has assembled in the Melbourne Biomedical Precinct. The precinct is located in Parkville on the edge of Melbourne's CBD. It has established itself as a leading global research and teaching powerhouse and is reported to be one of the top five biomedical precincts in the world.

Twenty-five organisations (see Box 1.2), located within easy reach of each other, are engaged in breakthrough research, education and the delivery of clinical care and health services. This dense concentration of hospitals, research facilities and academic campuses gives extraordinarily talented individuals from a range of disciplines an unparalleled opportunity to work together in world-leading collaborations.

BOX 1.2 – **PARTICIPANTS IN THE MELBOURNE BIOMEDICAL PRECINCT**

The Melbourne Biomedical Precinct Partners

- The University of Melbourne
- Walter and Eliza Hall Institute
- The Royal Melbourne Hospital and Melbourne Health
- The Royal Women's Hospital (the Women's)
- The Royal Children's Hospital (RCH)
- The Murdoch Children's Research Institute
- Future home of Peter MacCallum Cancer Centre
- The Florey Institute of Neuroscience and Mental Health
- CSIRO

Major Melbourne Biomedical Precinct Collaborations

- The Victorian Comprehensive Cancer Centre Project
- The Melbourne Brain Centre
- The Doherty Institute
- The Victorian Life Sciences Computation Initiative (VLSCI)
- Biomedical Research Victoria

Nearby Major Health & Biomedical Research Organisations Which Collaborate With Precinct Partners

- The Bio21 Molecular Science and Biotechnology Institute
- CSL Ltd (Poplar Road and Bio21 Institute campuses)
- St Vincent's Hospital Melbourne
- St. Vincent's Institute (SVI)
- Dental Health Services Victoria (DHSV)
- Orygen
- The National Ageing Research Institute (NARI)
- Centre for Eye Research Australia (CERA)
- Bionics Institute
- Monash Institute of Pharmaceutical Science, Monash University (Parkville campus)
- BioGrid Australia

SOURCE: HTTP://WWW.MH.ORG.AU/MELBOURNE-BIOMEDICAL-PRECINCT/W1/I1012322/ ACCESSED 13 JULY 2015

The Strategic Plan for the Parkville Precinct developed a vision for the Precinct, namely that it should be:

> *A Precinct that integrates world-class healthcare, research and education to rapidly translate research discoveries into clinical practice, nurture life sciences and biotechnology development and drive economic growth in Victoria.*[3]

This vision has been endorsed by the Government. Key elements identified as important for achieving this vision include:

1. Further investment in world-class facilities for research, education and clinical care.
2. Enhancement of integration and coordination.
3. Realisation of the opportunity currently afforded by the proximity of key institutions to facilitate a focus on cancer.
4. Attraction and retention of the best talent in biomedical research, education and healthcare delivery.
5. Fostering adaptability and innovation, and centres of creativity and excellence.

A number of the investments in research infrastructure and developments in the Parkville Precinct are aimed at strengthening and facilitating the translation of new discoveries from 'bench to bedside' to

[3] Parkville Precinct Strategic Plan – Summary and Strategic Response, Victorian Government, 2006.

improve health outcomes, attract the best and brightest researchers and clinicians, and generate further international investment and research collaborations in Melbourne.[4] These include:

— The new 357 bed Royal Children's Hospital, which opened in November 2011. Campus partners for the hospital include Murdoch Children's Research Institute and University of Melbourne Department of Paediatrics.
— The Royal Women's Hospital, Australia's largest specialist hospital dedicated to improving the health of all women and newborn babies, moved into a new, custom-built hospital in the Precinct in 2008.
— The Bio21 Molecular Science and Biotechnology Institute, which opened in 2005, is a flagship multidisciplinary research centre specialising in medical, agricultural and environmental biotechnology with 500 researchers, students and industry partners ranging from large biopharmaceutical research and development, to small emerging biotech companies.
— The new $225 million Melbourne Brain Centre which opened in October 2011. The Centre, which is a collaboration between the University of Melbourne, the Mental Health Research Institute, the Florey Neurosciences Institutes, Austin Health and Melbourne Health, is the largest brain research centre in the southern hemisphere. It houses over 700 employees, across two campuses, at The University of Melbourne in Parkville and the Austin Hospital in Heidelberg.
— The $210 million Peter Doherty Institute for Infection and Immunity (PDI) will integrate the teaching, training, research and public health activities of the University of Melbourne and the Royal Melbourne Hospital to create a world-class capability in infectious diseases.
— The $150 million expansion of the Walter and Eliza Hall Institute of Medical Research (WEHI) will strengthen its research capabilities through an increase in 400 employees.
— The new Victorian Comprehensive Cancer Centre (VCCC) facility which is currently under construction in Parkville. The building partners for this $1 billion project are the Peter MacCallum Cancer Centre (PeterMac), Melbourne Health and The University of Melbourne. The project will provide a brand new home for the PeterMac and new cancer research and clinical services for Melbourne Health (including the Royal Melbourne Hospital), new cancer research facilities for The University of Melbourne and new education facilities for all the building partners.

1.2.3 Australia's global position in biotechnology

The Scientific American's 6th Annual Worldview Scorecard of the Biotechnology sector ranked the performance of 54 countries in seven categories: Productivity, Intellectual Property Protection, Intensity, Enterprise Support, Education/Workforce, Foundations, and Policy and Stability. Below we discuss the findings for each category.

Productivity

The score card assessed productivity using two metrics: "public company revenues" and the "number of public companies". United States was first in this category. Australia came second in the scorecard. The report found that Australia managed to distance itself from the rest of the pack.

Intellectual Property Protection

Historically, the scorecard used a single metric called 'IP Strength' which consists of the unweighted sum of five measurements: patentable inventions, membership in international treaties, duration of protection, enforcement mechanisms and restrictions (e.g., compulsory licensing). In 2014 a second component was added, namely 'perceived IP protection'. This index was produced by asking a global group of business leaders about their perceptions of domestic IP protection. Again, the United States leads this category by a large margin, followed by Australia, the United Kingdom and Canada.

Intensity

Intensity represents a relative measurement of a country's activity in the biotechnology sector. The metric was calculated using data on:

- public biotechnology company employees per capita
- public biotechnology company revenues per GDP

[4] http://www.vcccproject.vic.gov.au/ThePrecinct Accessed 13 July 2015.

- biotech patents per total patents
- business expenditures on biotechnology R&D
- value added of knowledge and technology-intensive industries.

The top three countries are Denmark (with a ranking of 7.59), the United States (6.2) and Australia (5.3) and Singapore (4.38) is in fourth position.

Enterprise support

To cultivate a strong industry of any sort, including biotechnology, one must support businesses. In large part, that means making sure that enough capital exists to fund innovation. Likewise, countries with the most appealing business environments will attract the most biotechnology companies. The metric consists of the average of four elements:

- a business friendly environment
- biotechnology venture capital
- venture capital availability
- capital availability.

Hong Kong is in first place (with a ranking of 9.78), followed by the United States (9.48) and Singapore (9.29). Australia (6.11) was ranked 20th.

Education/ workforce

This category of the Scorecard is based on five components:

- post-secondary science graduates per capita
- PhD graduates in the life sciences per capita
- R&D personnel per thousand employment
- talent retention
- brain gain.

Luxembourg (with a ranking of 9.86), Saudi Arabia (7.64) and New Zealand (6.46) took the top three spots on the rankings. Australia (5.18) took 7th place in the rankings.

Foundations

This category of the Scorecard is based on four components:

- R&D business expenditures per GDP
- Government support of R&D per GDP
- infrastructure quality
- innovation and entrepreneurship opportunity.

Finland was the highest ranked country, followed by Switzerland and South Korea. Australia was ranked around 20th.

Policy and Stability

To assess the policy and stability of each country, the scorecard used the following measurements from the World Bank's 2013 World Governance Indicators: political stability and absence of violence/terrorism; government effectiveness; regulatory quality; and rule of law. Finland, Singapore and Sweden took the top three rankings. Australia ranked approximately 10^{th}.

For the overall ranking across all the categories discussed above, the US was the highest ranked country with a score of 39.6. Singapore received a score of 31.7 and was the second ranked country. Denmark scored 29.7 and was ranked third. Australia with a score of 28.3 ranked fourth (up from seventh in 2013).

This ranking aligns well with the vision in the Government's Biotechnology Strategic Development Plan, namely that:

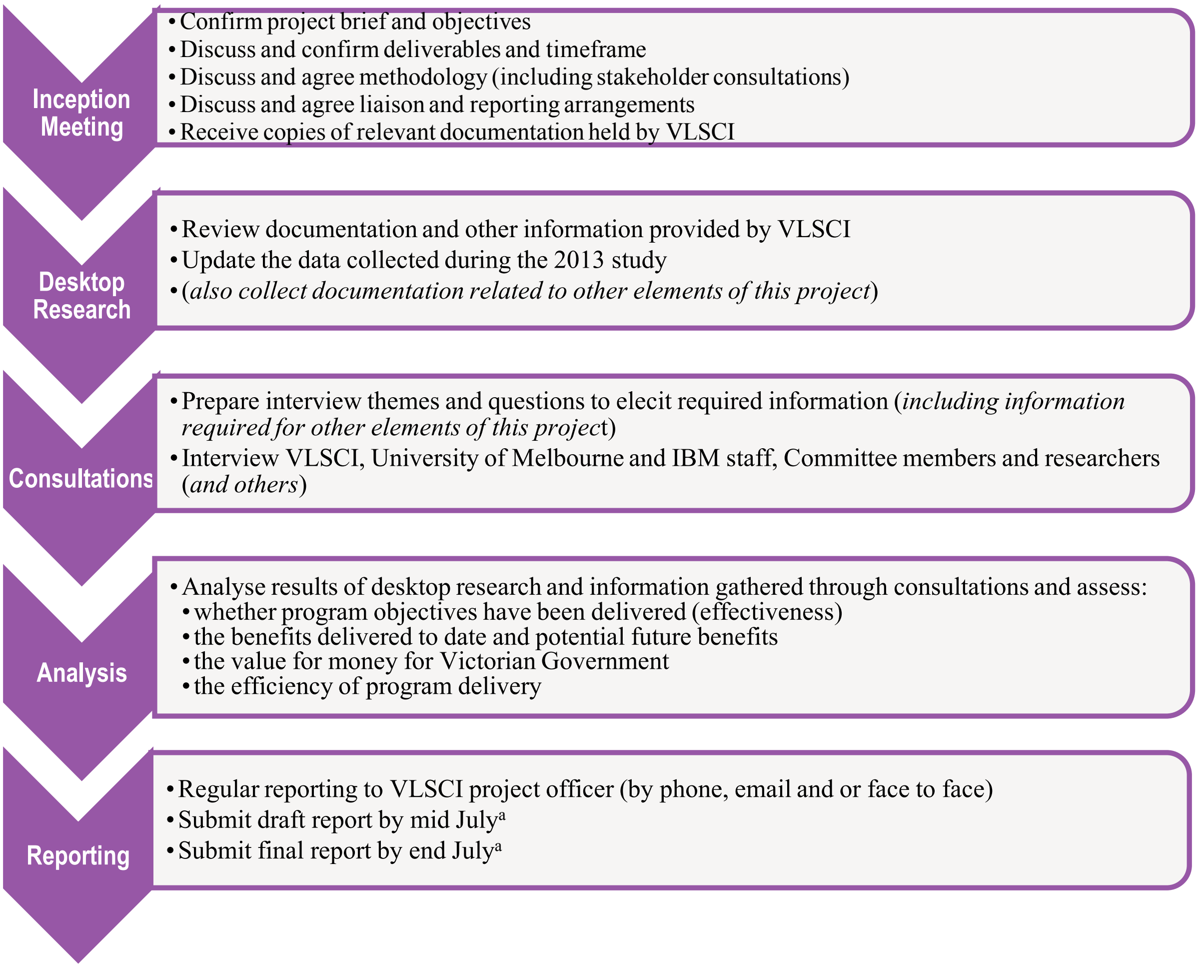
> *By 2010 Victoria is recognised as one of the world's top five biotechnology locations for the vibrancy of its industry and quality of its research.*

Approach to the review

1.3.1 Methodology

The methodology adopted by ACIL Allen to conduct the evaluation is illustrated in Figure 1.3. Each element of the approach is briefly discussed below.

FIGURE 1.3 – **LAPSING PROGRAM EVALUATION OF VLSCI - METHODOLOGY**



[a] Various delays in the execution of the project, in particular in being able to speak to all the stakeholders led to a delay of around a month in the original completion date of end June.

SOURCE: ACIL ALLEN

Inception meeting

The inception meeting provided an opportunity for the ACIL Allen team and the VLSCI to discuss and clarify any issues relating to the project and ensure that there was a common understanding of project objectives, the proposed approach, data sources and timelines for deliverables.

Desktop research

ACIL Allen reviewed the documentation provided by VLSCI (Annual Reports, Business Plans, KPI reports, Financial accounts, etc.), including the data collected through the periodic surveys of researchers (such as publications, grants won, presentations given and students trained). This information was used to update the data collected during the 2013 study.

Consultations

Table 1.1 lists the stakeholders that were consulted as part of this evaluation. ACIL Allen and VLSCI jointly developed the list of stakeholders. All consultations involved a senior member of the project team to ensure the consultations could be thoroughly explored, captured and used to inform the project's analysis.

Prior to the commencement of consultation ACIL Allen prepared a short issues document with a series of themes and questions to help guide the consultations and ensure that the approach used by interviewers was consistent. The document was developed and agreed with VLSCI prior to interviews commencing.

Analysis

ACIL Allen has analysed the results of our review of documents and information provided by VLSCI and other stakeholders (including the results of VLSCI's user satisfaction surveys), our desktop research and the results of the stakeholder consultations. Our objective was to update the information presented in the 2013 study. The additional information available since the 2013 study enabled us to track performance and identify trends and changes over time.

ACIL Allen distilled all information collected and analysed into a draft final report that was provided to the VLSCI. Following the receipt of feedback from the VLSCI the final report was prepared.

1.3.2 Data sources

The VLSCI provided a wide range of documentation to help inform the evaluation, including:

- Annual Reports for 2011, 2012, 2013 and 2014
- Financial Supplements to the Annual Reports for 2011, 2012, 2013 and 2014
- Detailed user reports from 2011, 2012, 2013 and 2014
- An internal evaluation conducted into the LSCC's activities in 2012
- Complete annual reporting files from users for 2011, 2012, 2013 and 2014
- Sustainability planning documents
- Business planning documents
- Press releases and other publicity material
- Other Committee documents upon request.

All of the stakeholders consulted provided information and documents to assist the evaluation.

TABLE 1.1 – **STAKEHOLDERS CONSULTED FOR EVALUATION**

Name	Affiliation
Prof. Tony Bacic	Member, Scientific Advisory Committee (incoming Chairman), VLSCI Member, Steering Committee, VLSCI Director, Bio21 Molecular Science and Biotechnology Institute
Prof. David Bowtell	Head, Cancer Genomics and Genetics Program, Principal Investigator, Australian Ovarian Cancer Study, Peter MacCallum Cancer Centre
Dr Michael Lynch	Senior Program/Policy Officer, Innovation and Technology Research, ¦, Department of Economic Development, Jobs, Transport and Resources, Level 35, 121 Exhibition Street, Melbourne 3000
Dr Gary Egan	Professor & Director Monash Biomedical Imaging Monash University
Prof. Tiffany Walsh	Deakin University
Mr Andrew Gilbert	Bioplatforms Australia
Dr Kathryn Holt	Research Fellow Department of Biochemistry & Molecular Biology Bio21 Institute University of Melbourne
Prof. Liz Sonenberg	Pro Vice Chancellor (Research Collaboration and Infrastructure) University of Melbourne
Prof. Matthew Perugini	ARC Future Fellow and VLSCI user Department of Biochemistry La Trobe University
A/Prof. Toby Allen	Associate Professor and VC Senior Research Fellow, School of Applied Science & Health Innovations Research Institute, RMIT University
A/Prof. Andrew Lonie	Head LSCC
Prof. Robin Stanton	Deputy Chair, ex Steering Committee National Computation Infrastructure NCI, ANU
Prof. Justin Zobel	Head, Computing and Information Systems, University of Melbourne Acting Director VLSCI
Dr John Wagner	Manager and Research Staff Member IBM Collaboratory
Prof. Peter R. Taylor	Former Director, VLSCI
Prof. Michael Parker	Deputy Director, St Vincent's Institute
Prof. David Grayden	Department of Electrical and Electronic Engineering at The University of Melbourne
Prof. Robin Gasser	Faculty of Veterinary Science, University of Melbourne
A/Prof. Torsten Seeman	Ex Victorian Bioinformatics Consortium, Monash University, now LSCC
Dr Clare Sloggett	Bioinformatician, LSCC & Academic, University of Melbourne

SOURCE: ACIL ALLEN CONSULTING

Report structure

The remaining chapters of this report address the key evaluation themes and questions as outlined in the Department of Treasury and Finance's Guidelines for evaluation Lapsing Programs.

Chapter 2 – Justification / problem. This chapter considers the policy and economic rationale for VLSCI and the rationale for government's ongoing support of the initiative.

Chapter 3 – Effectiveness. This chapter considers the extent to which the VLSCI has met the targets and objectives set for it by Victorian Government.

Chapter 4 – Funding, delivery and efficiency (including future potential efficiencies). This chapter considers how the VLSCI has delivered its services and the scope to do so more efficiently in the future.

Chapter 5 – Risk. This chapter considers the impact of the VLSCI ceasing its operations and examines the strategies that have been identified to minimise negative impacts.

Chapter 6 – Conclusions. This chapter presents the conclusions of the review and presents some of the lessons learned as a result of the VLSCI project.

Appendix A – Case studies. This appendix provides additional information relating to the case studies developed for the review.

2 PROBLEM / JUSTIFICATION

This chapter considers the following question: What is the evidence of a continued need for VLSCI and role for government in delivering VLSCI?

Why was VLSCI established?

2.1.1 Policy rationale

The Victorian Government decided in 2008 to establish the VLSCI as part of its plan to create a world class infrastructure base to ensure that Victoria maintains its position as a world leader in the biosciences. Government documents from this time confirm that the creation of the VLSCI was, alongside the construction of the Australian Synchrotron, aimed at providing critical research infrastructure in the State. Both facilities were integral components of the Victorian Government's biotechnology strategies of that period. As Victoria's Technology Plan for the Future stated:

> *Victoria's Technology Plan for the Future will consolidate our leadership in biotechnology, while positioning the sector for the next stage of growth and ensuring that it remains competitive in a challenging global environment.*[5]

Both the Synchrotron and VLSCI have an important feature in common – they are shared facilities, accessible to researchers on a merit basis. This type of research infrastructure has long been considered a cost-effective investment. Funding of research infrastructure is quite different to funding research projects. In the latter case, merit based competition for access to the infrastructure helps to ensure the selection of the best projects. With state-of-the art shared research infrastructure, such as that provided through the VLSCI, there are strong opportunities for research collaboration, with cross fertilisation of ideas. There are also opportunities to undertake projects that are leading edge and take advantage of the capability of the facilities to tackle research challenges that have not been previously possible. The provision of such facilities also helps to attract leading researchers.

World class research requires the provision of leading edge research infrastructure. When access to such infrastructure is combined with incentives to collaborate (such as users do with the VLSCI staff) a 2010 literature review found strong evidence of superior research outcomes.[6] This is because there are large knowledge 'spillovers' associated with collaboration.

Efficiency gains through the provision of shared research infrastructure are also an important consideration. Individual institutions could not afford or justify an investment such as the VLSCI, nor could they use such facilities to their maximum available capacity. The provision of support personnel

[5] *Victoria's Technology Plan for the Future: Biotechnology*, 2011
[6] Allen Consulting Group 2010, *Evaluation of the National Collaborative Research Infrastructure Strategy: Economic Analysis*, Final Report to the Australian Government Department of Innovation, Industry, Science and Research, January 2010.

for major items of research equipment has been recognised as a significant factor in achieving the most efficient use of the equipment. The VLSCI has taken this provision a step further by providing expert advice to researchers to ensure that their use of the VLSCI facilities will provide optimal research outcomes.

Commonwealth Government reports have indicated that Australia has:

> *…been constrained by underinvestment in strategic research infrastructure.* [7]

The Victorian Government's decision to fund the VLSCI filled a major gap in research infrastructure supporting the life sciences.

The convergence of information technology and rapid advances in life sciences has been the subject of a detailed analysis by the Massachusetts Institute of Technology.[8] MIT refers to this convergence as a 'cross pollination' of different conceptual approaches. Given the strength of Victoria's life and medical sciences research sector, the investment in the VLSCI was a far-sighted move.

It is unlikely that, in the absence of Victoria investing in the VLSCI, any other parties would have singly or collectively been able to fund such a facility. While the National Collaborative Research Infrastructure Strategy (NCRIS) has supported a number of different research facilities, it has not made the bridge between the life sciences and supercomputing that has been realised through the creation of the VLSCI. Thus, Victoria's investment in VLSCI has addressed a market failure.

2.1.2 The VLSCI Peak Computing Facility (PCF)

The PCF is a world class petascale facility with four systems built on two architectures (BlueGene/Q and x86). Each system offers varying memory and data-handling capacities to suit the large memory computational resources required for doing genomics analysis to high capacity processing of computational imaging data. Table 2.1 summarises VLSCI's current computing hardware.

[7] *Powering ideas: an innovation agenda for the 21st century*, p 38, DIISR, 2009.
[8] *The Third Revolution: Convergence of the life sciences, physical sciences and engineering,* MIT, 2011.

TABLE 2.1 – **PCF HARDWARE**

Hardware	Specifications
IBM Blue Gene/Q - Avoca	— Peak performance of 838.86 teraflops. — 65,536 PowerPC based 1.6GHz cores. — A total of 64TB RAM. — Interconnect between compute nodes forms a five-dimensional torus providing excellent nearest neighbour and bisection bandwidth. — Suitable for large-scale parallel processing. — Compute nodes run a custom lightweight operating system called Compute — Node Kernel (CNK) that is similar to Linux and mostly POSIX compliant. — The head node runs the RHEL 6 operating system, a variety of Linux.
IBM iDataplex x86 system – Merri	— Peak performance of 7.3 teraflops. — 688 Intel Nehalem compute cores running at 2.66GHz. — 36 nodes with 96GB RAM and 8 cores per node. — 44 nodes with 48GB RAM and 8 cores per node. — 3 nodes with 1024GB RAM and 16 cores per node. — Connected to a high speed, low latency QDR Voltair InfiniBand switch for inter-process communications. — The system runs the RHEL 6 operating system, a variety of Linux.
IBM iDataplex x86 system - Barcoo	— Peak performance - compute nodes currently performing at 20 teraflops — 1120 Intel Sandybridge computer cores running at 2.7GHz. — 67 nodes with 256GB RAM and 16 cores per node. — 3 nodes with 512GB RAM and 16 cores per node. — 20 Xeon Phi 5110P cards installed across 10 nodes. — Connected to a high speed, low latency Mellanox FDR14 InfiniBand switch for inter-process communications. — The system runs the RHEL 6 operating system, a variety of Linux.

SOURCE: VLSCI 2014 ANNUAL REPORT

The hardware listed in Table 2.1 has associated storage capacity of:

— 700TB GPFS Parallel Data Store (shared by Barcoo, Merri and Avoca)

— 1PB HSM tape system, made available through GPFS (shared by Barcoo, Merri and Avoca).

2.1.3 Funding model

The VLSCI's funding model has involved the Victoria Government making an up-front investment, with contributions from major research institutions in the State. The University of Melbourne made significant financial and in kind contributions and Monash University and Latrobe University provided in kind contributions.[9] Researchers from these institutions have benefitted from access to VLSCI.

In addition, major users of VLSCI have been asked to contribute as 'subscribers' to VLSCI's running costs. In some cases, researchers have been able to make these payments from Commonwealth grant funds. While such funds can help cover costs, they do not provide the sustainable basis for future operations. This is partly because Australian grant schemes are reluctant to pay significant usage charges. It is also because, for many users, the VLSCI has offered the possibility of new pioneering research, the success of which has not been certain.[10] This has an impact on the willingness of researchers to contribute scarce research funds.

One of the challenges facing the owners of supercomputers (especially peak computing facilities) is that they become obsolete fairly quickly. This is in contrast to the Australia Synchrotron, where experience suggests that it will take a much longer period before it needs to be replaced. Thus in the

[9] See also discussion in Section 4.1.

[10] It is worth noting that VLSCI users are generally reluctant to change the compute architectures they use unless there is a strong incentive to do so. Consequently, changing architecture, whilst inevitable, is best minimised for ease of access and use by researchers.

case of the VLSCI the capital cost has to be amortised over a relatively short period. For its part, the VLSCI has worked its equipment efficiently. However, obtaining the capital to purchase a replacement for the IBM Blue Gene/Q (BG/Q) at some point in the not too distant future is going to be a challenge.

NCRIS facilities have received some funding from state governments. For example, the Pawsey Centre supercomputer facility, discussed later in this Chapter, has received significant funding from the West Australian Government. In the event that further Commonwealth funds become available under NCRIS (or its successor) the Victorian Government could consider providing sufficient support to ensure that VLSCI attracts NCRIS support. While this would likely require increasing the share of the compute time provided to users across Australia on a competitive basis, maintaining the VLSCI in Victoria would ensure that Victorian researchers have ready access and would help to ensure that VLSCI's contribution to the world class reputation of Victorian life sciences research is maintained.

Does the need still exist?

2.2.1 Increasing demands of life sciences research

The life sciences continue to be very important to the Australian economy. They underpin our agriculture and medical services. Australia's ageing population also benefits from advances in life sciences. The demand for various disciplines within life sciences have seen rapid growth in recent years and this looks set to continue. For example, demand for experienced bioinformaticians is exceeding supply around the world (training bioinformaticians is a real strength of VLSCI). Genomics continues to grow in importance for analysing diseases and helping to optimise treatment. At the same time, modelling of viruses using high performance computing facilities (including those at VLSCI) is making it possible to better understand how viruses interact with the body, which in turn helps to improve the design and delivery new pharmaceuticals and treatment strategies.

In agriculture, the need to increase food production is widely recognised and life sciences research is playing a critical role in achieving this objective. Plant and insect genomics are expected to be even more important in the future. For example, one of the case studies in the 2013 study examined the work by scientists from the University of Melbourne sequencing the genome of the common roundworm, which infects pigs.[11] The hope is that this can lead to the development of treatments for both animals (especially sheep and cattle) and humans.

The convergence of data analytics and life sciences is a trend that is expected to continue to develop in importance. The amount of data being collected as a part of life sciences research is growing dramatically. A recent study by researchers at the Cold Spring Harbor Laboratory in the US says that the field of genomics is the fastest-growing data generator in the world today, with the quantity of genetic data being produced daily currently doubling every seven months.[12] The study suggests that by 2025, genome scientists will generate quantities of data well in excess of the current reigning data kings in science: astronomy and physics. In 10 years' time, genetics researchers could be producing between 2 and 40 exabytes of data every year, depending on the rate of doubling over time.[13]

The Cold Spring Harbour study argues that an important driver of the rapid growth in data generation will be genome sequencing of a significant proportion of the world's human population. The authors estimate that between 100 million and 2 billion human genomes could be sequenced by 2025, representing four to five orders of magnitude growth in ten years. This would far exceed the growth for other big data domains. Indeed, the amount of genome data could be even larger, especially since new single-cell genome sequencing technologies are starting to reveal previously unimagined levels of variation, especially in cancers, necessitating sequencing the genomes of thousands of separate cells in a single tumour. However, just having the genome will not be sufficient: for each individual, it will need to be coupled with other relevant 'omics data sets, some collected periodically and from different tissues, to compare healthy and diseased states. The study concludes that:

[11] *Evaluating the VLSCI: A benefits realisation analysis*, ACIL Allen, November 2013

[12] Zachary D. Stephens, Skylar Y. Lee, Faraz Faghri, Roy H. Campbell, Chengxiang Zhai, Miles J. Efron, Ravishankar Iyer, Michael C. Schatz, Saurabh Sinha, Gene E. Robinson, *Big Data: Astronomical or Genomical?* PLOS Biology, 7 July 2015.

[13] An exabyte is 1,000 petabytes.

Computational challenges will increase because of dramatic increases in the total volume of genomic data per person, as will the complexities of integrating these diverse data sources to improve health and cure diseases.[14]

In a recent letter in Nature News & Comment, Jeffrey Chang, co-director of the Bioinformatics Service Center and assistant professor of integrative biology and pharmacology at the University of Texas Health Science Center in Houston, referred to the US Precision Medicine Initiative, announced in January 2015. This US$215 million initiative relies heavily on bioinformatics. The project involves collecting medical, physiological and genomic data from more than one million people in the United States, and aims to find patterns across individuals. The growth in the clinical use of computation in order to provide improved health care through increasingly personalised medicine and treatment options is likely to continue.

The challenge facing the US initiative is that biological data is accumulating faster than people's capacity to analyse it. One reason for this is that biologists are increasingly finding that questions that are initially based on a single protein or gene quickly expand to require large-scale experiments. Chang refers to Sendurai Mani, a pioneer in cancer metastasis and genomics at the University of Texas, who laments that he is constantly searching for bioinformaticians to analyse such data. He goes on to argue the explanation for the shortage is obvious: there are not enough bioinformaticians.[15]

This conclusion was supported by the views expressed by a number of the stakeholders consulted during the preparation of this report. One of them noted that:

There is plenty of data being generated, the problem is that there are not enough bioinformaticians to analyse that data. The supply (of data) is outpacing capability (to analyse it) at present. All science is now data driven, if you can't manipulate data your ability to do leading edge research will slide.

Another noted that:

You can't do life sciences research without some sort of computational capability.

The computational platforms needed to analyse the volumes of data available are often no longer practical to maintain by individuals or wet-lab teams. The huge growth in the available data and its increasing importance to research has also driven a shift in the stage at which computational questions and expertise become important to the conduct of the research. In the past, data analysis was largely done towards the end of the project, whereas now it is becoming more important to consider these issues as part of the project design stage at the beginning of the project.

At the same time, the expertise needed for the computational component has become more diverse, and more specialised and individual researchers are increasingly unlikely to possess the necessary bioinformatics skills. Hence, there is increasing demand for persons with bioinformatics skills.

Chang notes that in order to support life science researchers, dozens of institutions have set up centralised bioinformatics facilities, most of them in the past decade.[16] When it was first established, the Bioinformatics Service Center in Houston set out to develop a series of standardized services for researchers. However, they found that most researchers came to them seeking customized analysis, not a standardized package. This experience was repeated at the Bioinformatics Core at the University of California, Davis. As Ian Korf, the interim director of the Core noted:

There are no one size fits all analyses.[17] [18]

[14] http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002195#pbio.1002195.ref049 accessed 12 July 2015
[15] Jeffrey Chang, *Core services: Reward bioinformaticians,* Nature News & Comment, 8 April 2015
[16] Ibid.
[17] Ibid.
[18] Indeed, it is the LSCC's approach to this issue, namely by having its experts both work as collaborators on projects and work to build capacity amongst the research teams, which has underpinned the success of the Centre.

The VLSCI is part of this trend, and demand for the services provided by the VLSCI is expected to continue to grow. It is worth noting that applications to use the VLSCI supercomputer increased quickly from its opening and the facility was already oversubscribed by 2010.[19]

Given the strong level of interest in using the VLSCI's facilities, it is not surprising that a number of stakeholders consulted as part of this project expressed concern over the prospect of the possible closure of the VLSCI. Comments made by stakeholders included:

> *There are some life sciences applications that the VLSCI's facilities are uniquely suited to (e.g. dynamic molecular modelling). These applications cannot be readily transferred to other high performance computers in Australia.*
>
> *Without VLSCI there would be a serious loss of scale and capacity. VLSCI provides the essential concentrated expertise needed for multidisciplinary teams. Without VLSCI these benefits to Victoria would be lost. The quality of science would be diminished. Opportunities would be foregone.*

ACIL Allen's consultations for this project suggest that, if leading Victorian researchers who need high performance computing facilities such as those provided by the VLSCI are not able to continue to access those sorts of facilities, they will regard their ability to conduct research as compromised to the extent that a number are likely to leave Victoria and quite probably Australia. Stakeholder comments included:

> *VLSCI was instrumental in encouraging my return to Melbourne from the US. (In the absence of VLSCI I) would leave Australia within a year.*
>
> *In the absence of a suitable replacement for the BG/Q researchers will move interstate or overseas.*

Education and training

The discussion above strongly supports the argument that the importance of computational analysis for life sciences research has grown rapidly in the last few years and will continue to do so into the future as 'big data' biology becomes increasingly important. Consequently, there is a growing demand for persons with the skills needed to do such analysis. Teaching institutions are responding by establishing courses in what is often referred to as quantitative biology (see Box 2.1 for a discussion of this topic by Schatz from the Cold Spring Harbor Laboratory in the US).[20]

Schatz argues that the growth of 'big data biology' requires combinations of skills across many fields which have not been a part of a traditional biology education.[21] For example, while many disease studies might begin with traditional molecular skills to prepare and sequence samples, the analysis can then become computational and quantitative in order to detect the variations, and recognize functionally important mutations from the backdrop of normal human variation. Schatz goes on to say that given the vast opportunities in analysing high-throughput sequences, networks and other -omics data, it is certain that the role of quantitative analysis in biology will only grow in the future and that today's students need to be trained to properly use and understand these instruments of modern biology.

[19] *2010 Annual Report*, VLSCI, 2011
[20] http://www.genomebiology.com/2012/13/11/177 accessed 12 July 2015
[21] Schatz, M.C., *Computational thinking in the era of big data biology*, Genome Biology, 2012. 13(11): 177.

BOX 2.1 – **QUANTITATIVE BIOLOGY**

Quantitative biology does not refer to a particular organism or disease or cellular process, but rather the style of analysis that is applied biological data. It draws on techniques from mathematics, statistics, computer science, physics and other quantitative fields to develop methodologies and answer biological questions about human genetics and plant biology. For example, within human genetics researchers might study the origins and dynamics of human diseases such as cancer, and within plant biology they might assemble the genomes and transcriptomes of important species and then quantitatively model the molecular basis of their development. Answering these biological questions requires access to sophisticated computational and quantitative systems, especially in order to transform or model the raw data in order to develop an understanding of how the underlying biology operates.

The use of quantitative techniques is of course not new. In the mid-1800s they formed the basis for Mendel to derive the fundamental laws of heredity by analysing the transmission of traits among his pea plants, and in the mid-1900s for Luria and Delbruck to solidify the role of selection in evolution by mathematically modelling the emergence of bacteriophage resistance in Escherichia coli. However, recently, quantitative biology has grown in importance because of the explosion in the amount of biological data available brought on by the dramatic improvements to biotechnology and biological sensors. The emergence of these technologies has radically changed the types of questions that it is possible to ask. Just a few years ago it would have been challenging (both from a cost and a complexity point of view) to propose to sequence the genomes of many hundreds or thousands of people to find out what is unique in the genomes of children with a particular medical condition compared with their siblings, but today, thanks to huge improvements in the cost and throughput of DNA sequencing, it is possible to answer this kind of question on a regular basis.

SOURCE: SCHATZ, M.C., COMPUTATIONAL THINKING IN THE ERA OF BIG DATA BIOLOGY. GENOME BIOLOGY, 2012. 13(11): 177.

A number of stakeholders consulted during this project commented on the growing demand for bioinformaticians and the role that VLSCI had played in addressing this need. Interestingly, there was also recognition that people with these sorts of skills were sought after by sectors of the economy other than the life sciences. Comments made included:

> *Prior to VLSCI Victorian bioinformatics was about a decade behind the world leaders. Now it is right up there. … training has been excellent.*
>
> *VLSCI has provided a diverse group of (bioinformatics) practitioners who can help researchers address a wide array of challenges (ranging from genome assembly to statistical analysis)*
>
> *There is a growing demand for bioinformaticians, partly because these are able people (who are) being recruited into other sectors such as finance.*
>
> *(If VLSCI were to cease operations) it would create a diaspora of informatics expertise (mainly outside Victoria).*

It is worth noting that a July 2010 report by the Allen Consulting Group found that skills shortages were of concern to many Victorian biotechnology companies, with over 60 percent of respondents to a survey expressing the view that difficulties recruiting people with appropriate skills had a negative impact on their business. The same companies expected an increase in demand for all occupations and skills associated with the sector over the following three years.[22]

2.2.2 Other Australian computational infrastructure

National Computational Infrastructure

The National Computational Infrastructure (NCI) facility, based in Canberra, is a national research infrastructure provider that provides high-end computing services to Australia's researchers. Its

[22] *Victorian biotechnology industry skills review*, Allen Consulting Group report for the Victorian Department of Innovation, Industry and Regional Development, July 2010.

primary objectives are “to raise the ambition, impact, and outcomes of Australian research through access to advanced, computational and data-intensive methods, support, and high-performance infrastructure”.[23]

NCI is supported by the Australian Government’s National Collaborative Research Infrastructure Strategy (NCRIS). It operates as a formal collaboration between the ANU, CSIRO, the Bureau of Meteorology (BoM) and Geoscience Australia — together with partnerships with a number of research-intensive universities. In 2013 partner organisations contributed $10.4 million to the NCI budget.

NCI offers comprehensive and integrated high-performance services for computationally based research, but with a particular focus on the environment, the climate and earth system science. NCI infrastructure includes a 1.2 petaflop high performance computing system, a 3,200 core high-performance compute cloud, persistent disk storage of more than 49 petabytes, and a purpose-built data centre at the Australian National University (ANU).

NCI is fully engaged with research communities and research organisations, and contributes to the collaborative development of research environments/digital laboratories to enhance research ambition and outcomes in areas of international significance and national benefit.

There are a number of mechanisms for users to get access to NCI services, including:

— Shares of computational time that is allocated to the co-investing partner organisations (ANU, CSIRO, BoM, Geoscience Australia, Intersect Australia, Queensland Cyber Infrastructure Foundation QCIF), ACE CRC, and a consortium of universities including ANU, Monash University, the University of Adelaide, the University of NSW, the University of Queensland, the University of Sydney, RMIT University, and Deakin University)
— The National Computational Merit Allocation Scheme (NCMAS), for researchers at publicly funded research agencies and Australian higher education institutions that are eligible to receive funding from the Australian Research Council. Allocation is based on research merit and computational suitability
— The NCI Flagship Scheme is designed to allocate time to projects that have been identified by the NCI Board as being of high-impact or national strategic importance
— The Commercial and Industry Access Scheme. Under this scheme computing time can either be provided as a Commercial/Industry Partner of NCI (i.e. under contract), or on a Fee-for-Service basis

In 2014, requests for compute time on NCI’s facilities exceeded availability by nearly threefold. Four percent of compute time was allocated to the biological sciences.[24] One stakeholder noted that:

> *The Canberra facility (NCI) is largely used by climate modellers, who provide a major proportion of the funds (for the NCI).*

Pawsey Supercomputing Centre

The Pawsey Supercomputing Centre (Pawsey), in Perth, supports research using supercomputing, large scale data storage and visualisation. The Centre is a joint venture between CSIRO, Curtin University, Edith Cowan University, Murdoch University and The University of Western Australia. It is supported by the Western Australian Government and the Commonwealth Government contributes $90 million in funding under NCRIS and related programs. The Government of Western Australia has committed approximately $20 million over five years to enable Pawsey to operate its facilities and assist the user community to use the facility.

Pawsey provides facilities and expertise to researchers, universities and industry. Key application areas include mining and petroleum and radio astronomy. Other areas supported include nanotechnology, high energy physics, medical research, architecture and construction, multimedia, and urban planning.

Pawsey staff work in facilities in each of its partner organisations, with supercomputing infrastructure hosted at two locations in Perth:

[23] http://nci.org.au/about-nci/our-role/ Accessed on 14 July 2015.
[24] Annual Report 2013/14 accessed on 14 July 2015 at http://nci.org.au/about-nci/annual-reports/

— Pawsey at the Australian Resources Research Centre in Technology Park, Kensington houses a Cray supercomputer for general use, a second Cray real-time supercomputer for operational radio astronomy, an SGI hierarchical data storage system, and SGI remote visualisation and virtual machines capability including a 6Tera Byte shared memory UV2000. Pawsey is also the Western Australian node of NeCTAR Research Cloud, and the Western Australian node of the Research Data Storage Infrastructure (RDSI) Project.
— The Fornax supercomputer at The University of Western Australia, Crawley.

Access to Pawsey's supercomputing resources is by application to one of a number of different allocation schemes, which are targeted at different research communities, fields and levels of supercomputing experience. Pawsey allocates compute time to researchers through project awards. Proposals for projects may be submitted in a number of ways, including:

— NCMAS – Pawsey allocates 15 percent of the compute time available is allocated through this scheme. The scheme operates annual allocation calls, which are open to the entire Australian research community.
— The Pawsey Geosciences Merit Allocation Scheme – 25 percent of the compute time available at Pawsey is allocated through this scheme to the Australian geoscience research community.
— The Astronomy Supercomputing Time Allocation Committee – between five and 25 percent of the compute time available at Pawsey is allocated to the Australian astronomy research community.
— The Pawsey Partner Merit Allocation Scheme – 30 percent of the compute time is available to researchers in Pawsey partner institutions (CSIRO, Curtin University, Edith Cowan University, Murdoch University and The University of Western Australia).
— The Pawsey Director's Allocation Scheme – five percent of the compute time available at Pawsey may be allocated (at the Director's discretion) to short-term projects requiring modest amounts of compute time. The scheme is open to all Australian researchers.

In 2014 Pawsey resources were utilised as follows:

— 25 percent for each of radioastronomy and geosciences
— 30 percent for partner organisations
— 15 percent was allocated through the NCMAS.[25]

Other computational infrastructure

Other high performance computing facilities in Australia are more modest in scope and capacity. Six of the most significant next tier computational facilities are listed below.

The V3 Alliance hosts and operates high performance computing (HPC) facilities on behalf of La Trobe and RMIT universities, the largest of which delivers 45.9 teraflops of performance. The system offers a wide range of software, including applications for computational chemistry, geophysics, engineering, climate modelling and earth systems, bioinformatics, mathematics libraries, statistics and mathematics environments. V3 assists researchers within member universities, research organisations and industry to integrate advanced computing into their current operations. This may involve services ranging from a full requirements analysis to an examination of current in-house processes around the management and use of computer servers.

The Queensland Cyber Infrastructure Foundation provides its members (the University of Queensland, Queensland University of Technology, Griffith University, James Cook University, Central Queensland University, and the University of Southern Queensland) and associate member (the University of the Sunshine Coast) with HPC services, infrastructure and support services. QCIF is funded through its members, triennial grants from the Queensland Government and project-based funding from the Commonwealth Government.

The *Multi-modal Australian ScienceS Imaging and Visualisation Environment* (MASSIVE), is a HPC facility specialising in Imaging and Visualisation. This facility supports research in biomedical science, materials research, engineering, and geoscience and provides an extensive program of user support and training on all aspects of HPC. MASSIVE operates two separate facilities with computer systems

[25] *Empowering cutting edge research for Australia's future*, Pawsey supercomputing centre, 2015.

linked by a high-bandwidth communications link: one located at the Australian Synchrotron and a second at the Monash University campus in Clayton. These two interconnected computers operate at over five and 30 teraflops respectively, using traditional central processing unit (CPU) processing, and accelerated to over 50 and 120 teraflops respectively, using graphical processing unit (GPU) co-processors.

In relation to MASSIVE, stakeholders commented that:

> *MASSIVE has been customised for imaging research and is used by the MRIs (Medical Research Institutes) and synchrotron users.*
>
> *MASSIVE is useful for image processing, but not suitable for life sciences research as special software has to be written to use it for life sciences (research).*

The *National eResearch Collaboration Tools and Resources project* (NeCTAR) is a $47 million Commonwealth Government, Super Science project, financed by the Education Investment Fund. The University of Melbourne is the lead agent appointed by the Commonwealth Government. The Australian research sector has committed $54 million as co-investment to the NeCTAR project. NeCTAR provides information and communication technology infrastructure that creates new information centric research capabilities, significantly simplifies the combining of instruments, data, computing, and analysis applications, and enables the development of research workflows based on access to multiple resources.

In relation to NeCTAR, one stakeholder noted that:

> *…while the compute power (of NeCTAR) is OK, disk storage is the limiting factor.*

The *Swinburne Centre for Astrophysics and Supercomputing* operates a fully integrated suite of Dell PowerEdge servers housing 64-bit quad-core Clovertown technology. The supercomputer comprises over 1000 processors (a theoretical 10 teraflop machine). This processing power is connected with a networking infrastructure built on gigabit ethernet and a large collection of high speed disk arrays.

VLSCI was funded by NeCTAR to build a 'virtual machine' that can be used for genomics analysis on the NeCTAR cloud. This is called the *Genomics Virtual Lab* (GVL). The GVL provides an opportunity for research institutes across Australia to participate in a community of accessible infrastructure, expertise and advocacy that connects genome researchers with massive datasets, sophisticated analysis tools, and large-scale computational infrastructure so that they can undertake high-value globally competitive research. More information on the GVL is provided in Box 2.2.

The GVL has various 'add ons' or 'capabilities' which can be used to tweak the machine to be more specific in what it does. One of the GVL 'capabilities' created was for microbial genomics.

In the UK a big grant was given to the CLIMB project (CLoud Infrastructure for Microbiology). This is the equivalent of Australia's NeCTAR and RDSI. The same UK group has another grant to sequence and analyse bacterial genomes (ngMicrobes). The intention is to use CLIMB to do the analysis. VLSCI argued that CLIMB and ngMicrobes didn't have the software layer to do what was required, but that GVL does. During a visit to the UK, a VLSCI staff member was able to get the GVL working on their system. The UK now intend to roll it out to all bacterial researchers in the UK

In addition, Public Health England (PHE) who sequence and analyse all the bacterial samples in UK, have seen GVL and will be using it internally and for their training courses. Efforts are also underway to show American researchers how the GVL could assist them.

BOX 2.2 – **THE GENOMICS VIRTUAL LABORATORY**

The GVL is broadly targeted at the "sequence-oriented" genome-related molecular biosciences – including epigenomics, transcriptomics, and meta- and eco-genomics. The GVL:

– provides infrastructure tailored to the data-intensive demands of genomics
– provides a forum to collaborate and share data and workflows
– provides resources that advanced research groups can control and customise in the national research cloud
– promotes the use of genome informatics through end-user support, training courses and outreach programs
– builds informatics platforms on national infrastructure in a way that can be extended to other -omics and biosciences in the future.

The GVL provides researchers with access to national-scale projects including the NeCTAR Research Cloud, the Research Data Storage Infrastructure (RDSI), the National Computational Infrastructure (NCI), Bioplatforms Australia (BPA), Australian National Data Service (ANDS), and the European Molecular Biology Laboratory (EMBL) Australia mirror of EMBL-European Bioinformatics Institute (EMBL-EBI). The project is also supported by the Australian Bioinformatics Network and the Australian Genome Research Facility (AGRF).

In Queensland GVL development has been led by the VLSCI in collaboration with the Research Computing Centre (RCC) at the University of Queensland (UQ)which is developing GVL infrastructure on the QLD Research Cloud with Queensland Cyber Infrastructure Foundation (QCIF), and developing researcher resources with QFAB Bioinformatics.

In Victoria the VLSCI is developing GVL infrastructure on the Melbourne Research Cloud with University of Melbourne ITS, and developing researcher resources with the PeterMac and Baker IDI Heart and Diabetes Institute (Baker IDI). The Victorian eResearch Strategic Initiative (VeRSI, now V3)) is also providing support.

In NSW the Garvan Institute of Medical Research is developing and operating Galaxy in house, and is contributing expertise and researcher resources. The Victor Chang Cardiac Research Institute is supporting this effort.

CSIRO is developing and operating Galaxy in house, and is contributing know how and expertise as well as developing researcher resources. CSIRO and Bioplatforms Australia are integrating framework datasets into the GVL. Several other Universities are planning to develop the GVL as further Research Cloud nodes come on line, including Monash University, the University of Sydney and the University of Western Australia.

SOURCE: HTTPS://WWW.GENOME.EDU.AU/ABOUT ACCESSED ON 14 JULY 2015

2.2.3 Australian National Research Infrastructure Review

The Review of National Research Infrastructure recently submitted its report to the Australian Government. One of the members of the Review Panel gave a presentation at the Australian eResearch Organisations' (AeRO) National Forum held in Canberra on 22 July 2015. That presentation outlined the findings of the Review. These included:

— There is a strong case for investing in (vs funding) research infrastructure. Excellent research is only possible with excellent research infrastructure.
— Considerable concern regarding long term projects being managed on short term funding cycles.
— The importance of e-Infrastructure is obvious – radically changing how research is conducted.
— Infrastructure is and should be used collaboratively.
— Government must lead investment. Industry will not do this on its own.
— Human capital must be included in the planning, for operations and skills-base.[26]

The presentation also outlined the key principles that flowed from these findings and which were used to develop the Review's recommendations. Those principles included:

— Excellent research requires excellent infrastructure.
— Research infrastructure includes physical infrastructure as well as human capital.

[26] http://aero.edu.au/forum-2015/ accessed 26 August 2015.

- Need to move from ad hoc to sustained funding.
- Research funding should be matched to additional funding for research infrastructure to support it.
- There should be a focus on collaboration, as per NCRIS.
- e-Research Infrastructure is a fundamental capability.[27]

The Review's recommendations included:

- Government must prioritise and structure investment in research infrastructure through a National Research Infrastructure Fund.
- There should be a seven year funding cycle for facilities, reviewed after each 4 years, with a 20 year horizon. This should be ring-fenced from the annual government budget cycle.
- E-Infrastructure should be recognised as fundamental to all research.
- There should be merit-based access to research infrastructure, including for industry if their research aligns and is not for commercial benefit only.[28]

The Government's response to the recommendations in the Research Infrastructure Review's report has not yet been announced. The above recommendations, if accepted, would appear to strengthen VLSCI's case for national funding. However, the financial resources allocated to support research infrastructure are likely to remain under pressure and the VLSCI would need to develop a strong and competitive case if any future request for national funding was to be successful.

Is VLSCI still the best model for supporting life sciences computing for research?

2.3.1 Victorian vs national focus

The last five years of operation of the VLSCI has demonstrated that there is strong demand for HPC facilities in Victoria to support leading edge research in the life sciences. However, there is clear recognition among most stakeholders that the Victorian Government, on its own, is unlikely to be able to provide the funding for a replacement for the BG/Q when it reaches the end of its useful life.[29] They also recognise that other sources of funding will depend upon the VLSCI's ability to become more accessible to researchers outside Victoria – in effect to become a national facility rather than retaining its current focus on supporting Victorian researchers. Comments by stakeholders include:

> *The current funding model is not sustainable in the long term.*
>
> *VLSCI's business model needs to be improved. It needs to be a national contributor to get national investment.*
>
> *VLSCI needs to nail down its funding model going forward and pitch as a national centre. It needs to position itself for NCRIS funding either via Bioplatforms Australia or directly.*
>
> *Computing (capability) needs to be sustained with reasonable capital expenditure (by Victoria) in partnership with the federal government in order to provide facilities that are nationally accessible to meet the needs of the gene sequencing community.*

The VLSCI already provides some access to users from outside Victoria, through a 15 percent allocation available through NCMAS. Ensuring that non-Victorian researchers are on an equal footing with Victorian researchers in applying to use the VLSCI facilities will be a necessary condition if the facility is to attract Commonwealth funding. Of course, given the existing dominance of Victoria in terms of health and medical research funding, it is possible that researchers from that state will continue to be the major users of VLSCI.

[27] Ibid.
[28] Ibid.
[29] There are differing views on when the Blue Gene Q (BG/Q) will need to be replaced, some say 2016, others argue that it could continue to operate for another year or so beyond that date. The maker of the BG/Q (IBM) has decided to no longer build supercomputers. It should be possible to obtain a service contract from the firm that has taken over from them (Lenovo). However, such maintenance contracts become prohibitively expensive as the age of the computer increases.

Future arrangements for life sciences computational support comprise two elements:

- access to, if not HPC (and storage), then significant high-throughput computing
- access to expert advice such as that provided by the LSCC.

Stakeholders consider that both these elements are required to ensure that Victoria maintains its position as a world leading centre for life sciences research (including biological and medical sciences). A number of key stakeholders strongly support the proposition that a significant life sciences computation facility needs to be retained in Melbourne. Stakeholders are also of the view that, while it may be possible to meet some of the operating costs through a subscription model (or research user charges), meeting the considerable capital cost for machine upgrades or renewal would require funding from governments.

It would appear to be in the Victorian Government's interest to support bids for Commonwealth funding for each of these two elements by providing a significant state funding contribution. Various studies have shown the extent to which the life sciences contribute to the Victoria economy. One stakeholder noted that:

> *…with some 50 percent of medical research funding coming to Victoria, the Victorian government should be willing to make a significant contribution.*

Key findings

The key findings from the discussion in this chapter are that:

- There has been a growing convergence between life sciences and information technology. The creation of the VLSCI was very timely in positioning Victorian life sciences researchers to be among the first users of HPC at an early point in this convergence.
- The Victorian Government's investment in the VLSCI was soundly based. It recognised the world leading status of life sciences in Victoria, the need to maintain that status, and the economic and social benefits that flow to Victoria from this strength.
- VLSCI has attracted leading edge researchers to Victoria and their work using the VLSCI's facilities is receiving international recognition.
- VLSCI has contributed to the training of life sciences researchers in areas that are of growing importance, particularly in bioinformatics. This includes by VLSCI hosting a Bioinformatics Resource Hub. The hub will be funded by $500,000 in NCRIS funding provided by Bioplatforms Australia. The resource hub, known as the EMBL Australia Bioinformatics Resource (BRAEMBL), will provide a significant opportunity to advance bioinformatics expertise and to support broader biological sciences research across a network of Australian Universities and Research Institutes.
- VLSCI has also made a significant contribution to the establishment of the GVL, which is assisting life sciences research across Australia and beyond.
- In the absence of investment by the Victorian Government in the VLSCI, the review considers that it is most unlikely that such facilities, with the same degree of access for Victorian researchers, would have been funded by other means.
- While there are other supercomputers in Australia, they are fully utilised and, in the absence of the VLSCI, the compute time available to life sciences researchers from Victoria would be insufficient to meet all their research needs.
- Other supercomputer facilities in Australia are not suited to dynamic molecular modelling work which has been one of VLSCI's major successes.
- There is a possibility of obtaining Commonwealth Government funding for VLSCI, but to achieve this, VLSCI will need to form appropriate alliances and be willing to make the facility more broadly available to users across Australia. VLSCI has allocated 15 percent of the available time on BG/Q to users through NCMAS for the past three years. However, VLSCI could strengthen any future bid for national funds if it was able to partner with other States that also had strong Life Science research communities.

– It is worth noting that while such an approach would reduce the call on funding from the Victorian Government it would not remove it. ACIL Allen believes a strong case could be made for such support based on the benefits that have flowed to Victoria in the past and those that might flow in the future.

3

EFFECTIVENESS

This chapter considers the following question: What is the evidence of VLSCI's progress towards its stated objectives and expected outcomes, including alignment between the program, its output (as outlined in Budget Paper No. 3), departmental objectives and any stated government objectives?

Performance against targets and KPIs

3.1.1 Previous analysis by ACIL Allen (2010-2013)

In 2013, ACIL Allen was commissioned to undertake an interim evaluation of the VLSCI. In this evaluation ACIL Allen considered, in detail, VLSCI's progress against the targets outlined in the Funding Agreement and the Key Performance Indicators (KPIs) outlined in its 2010-2013 Business Plan. The analysis examined VLSCI's performance against:

- Three key targets specified in the Funding Agreement, namely the:
  - cumulative value of the contributions made to the VLSCI
  - ranking achieved by the PCF
  - effective annual FTE supported by VLSCI.
- There were also five KPIs set for the PCF. These were the:
  - achievements of the PCF – which incorporated indicators for measuring the achievements of researchers who use the facility, and the developments in computational systems and services delivered by the facility
  - capability of the PCF – which incorporated indicators for measuring the availability and performance of PCF systems and support services
  - demand for and accessibility of the PCF – which incorporated indicators for measuring the level of demand for the PCF and the allocations provided to researchers for projects
  - contributions received by PCF from partner organisations
  - level of satisfaction reported by researchers who use the PCF and participate in PCF-dedicated training courses and workshops.
- Four KPIs were set for the LSCC. They were the:
  - achievements of the LSCC – which included indicators for measuring key research achievements and significant developments facilitated by the LSCC
  - participation in LSCC – which included indicators for measuring the profile of projects supported by LSCC and participation and contribution of organisations in the LSCC
  - capability of the LSCC – which included indicators for measuring the number of specialists in the core LSCC pool, the extent and profile of skills in the core pool and the kinds of services delivered by the LSCC
  - level of satisfaction reported by researchers who access LSCC support and services.

— Finally there were three KPIs set for the outreach program. They were the:
  - achievements of the outreach program – which incorporated indicators for measuring the number and types of outreach activities undertaken by VLSCI
  - participation in the outreach function – which incorporated indicators for measuring number, organisation and location of participants of the outreach program, as well as the extent and profile of people accessing the VLSCI and its website news service
  - contributions of participants, stakeholders and sponsors provided to the outreach program and the level of attendee satisfaction in the program's activities.

The high level results of this analysis were distilled into key findings for the 2013 study. These key findings are summarised below.

VLSCI is the world's top life sciences research supercomputer

In 2013, it was ranked as the 39th fastest supercomputer in the world and the second fastest in Australia. At the time it was the world's fastest supercomputer that is dedicated to supporting life sciences research. It was ahead of its closest competitor by a considerable margin.

VLSCI is a powerful mechanism for supporting life sciences research

The combination of access to the world's best life sciences dedicated supercomputer and the support services provided by staff at the Peak Computing Facility (PCF) and the Life Sciences Computation Centre (LSCC) makes the VLSCI a unique facility in terms of its ability to add value to the research projects being supported by the facility. That added value is delivered through a number of mechanisms, including the advice that the highly skilled PCF and LSCC staff can provide on the design and operation of research projects, including what software is most appropriate.

VLSCI enables world class research by Victorian life sciences researchers

The number of publications resulting from the research carried out using the VLSCI infrastructure is increasing over time. Importantly, the majority of the publications are in journals that have been assessed as having Journal Impact Factors (JIF) judged as being in the top 25 percent of journals in their category, demonstrating that VLSCI supported research is highly regarded globally.

VLSCI supports Victoria's strong reputation in life sciences

The VLSCI is helping to build Victoria's excellent reputation for life sciences research and a growing life sciences industry sector. The fact that researchers involved with the VLSCI are increasingly recognised through the awarding of research grants for life sciences research and the granting of various national and international awards also supports the view that the facility is increasing the reputation of Victoria as a world-class centre for life sciences research.

VLSCI is highly effective at increasing collaboration.

The VLSCI is proving to be highly effective in creating and supporting collaborations. Much of the research being supported by VLSCI is by its very nature collaborative, involving the need for team members with differing skill sets such as informatics, chemistry, biology and statistics. In addition, many of the structures established at the PCF and the LSCC are strongly supportive of increased collaboration. VLSCI researchers are also strongly engaged in international research.

In addition, the VLSCI's outreach activities also encourage life science researchers to engage with each other and help build collaborations across research groups.

3.1.2 Analysis of VLSCI's performance against targets and KPIs set for 2014

Using the same approach adopted in 2013, ACIL Allen considered VLSCI's performance against targets and KPIs set for 2014. Analysis of VLSCI's Annual Report and Financial Supplement for 2014 shows that the Initiative has met the targets outlined in the Funding Agreement with the Government. In particular, VLSCI has achieved its targeted:

- *Ranking for the PCF.* The VLSCI maintains it status as a significant supercomputer installation devoted to Life Sciences research
- *Level of staffing and cumulative target for external contributions.* The cumulative value of the contributions to the VLSCI reached the target of $100 million by 30 June 2013, and contributions continued at a high level throughout 2014. Refer to pages 101-104 of the Annual Report for summary financial position and to the attached VLSCI Financial Supplement to the Annual Report for detailed documentation of all contributions for 2014.

ACIL Allen's review of the documentation provided by VLSCI also indicates that VLSCI has achieved (or demonstrated progress towards meeting) the KPIs set for the PCF in 2014. A summary of the findings is provided in Table 3.1.

TABLE 3.1 – **PROGRESS AGAINST THE PCF'S KPIS (2014)**

Category / KPI	Was the KPI achieved?	Evidence of achievement
Achievements		
Key research achievements obtained by users of the PCF	Yes	Details of Case Studies provided in the Annual Report showcase the research achievements of PCF users
Developments in the computational systems and services available in the PCF	Yes	Details provided in the Annual Report – however, information is only provided at a high level
Capability		
Availability and performance of the PCF systems indicated by system units, used system units, efficiency of operation and extent of parallel computation	Yes	Details of available software outlined in section 3 of the Annual Report
Range of software and computational tools on the PCF systems	Yes	Details of available software outlined in section 3 of the Annual Report
Capability of other systems that are integrated with the PCF systems and available to the VLSCI user community	Unclear	Other systems are identified in the Annual Report (section 3), however, details of their integration are not published
Profile of the user and systems support services available to PCF users	Yes	Information provided at a summary level in the Annual Report
Number of staff in the PCF	Yes	Details of staff at the PCF provided in the Annual Report
Demand and accessibility		
Extent of demand for the PCF (e.g. number requesting resource grants, organisations, research discipline, requested and granted resource allocations)	Yes	Details of requests provided in the Annual Report
Extent of use of the PCF indicated by the number of organisations represented by users, projects, users and use of resource allocations	Yes	Details provided in the Annual Report
Profile of grants (number, size of grants)	Yes	Details provided in the Annual Report
Contributions		
Extent of the in-kind contribution from users of the PCF	Yes	Data relating to the extent of in-kind contribution captured and tracked for the Annual Reporting process
Extent to which these contributions are new	Yes	New contributions are reported in the Financial Supplement to the Annual Report

Category / KPI	Was the KPI achieved?	Evidence of achievement
Customer service		
Summary of surveys of users of the PCF showing their level of satisfaction	Yes	User satisfaction survey data published in the Annual Report. User satisfaction data provided for: system support services; user help system activity; reporting; software; job queuing time
Number of users participating in training courses and workshops on the use of the PCF	Yes	Details of workshops and training seminars are published in the Annual Report. Details include the focus of each event, the number of attendees at events, the timing of events and the location of events

SOURCE: VLSCI 2014 ANNUAL REPORT (INCLUDING THE FINANCIAL SUPPLEMENT TO THE REPORT)

ACIL Allen's review of the documentation for 2014, also shows that the VLSCI has achieved (or demonstrated sufficient progress towards) the KPIs set for the LSCC. A summary of the findings is provided in Table 3.2.

TABLE 3.2 – **PROGRESS AGAINST LSCC'S KPIS (2014)**

Category / KPI	Was the KPI achieved?	Evidence of achievement
Achievements		
Key research achievements obtained by LSCC	Yes	Details of key achievements published in the Annual Report. Achievements of two research projects are showcased: Finding ways to diagnose lethal metastatic prostate cancer Streamlining virus modelling processes at the Victorian Infectious Disease Reference Laboratory
Significant developments facilitated by the LSCC	Yes	Details of collaborations outlined in the Annual Report. Collaborations reported with Victorian, Australian, international and industry partner institutions. A total of 88 organisations reported as collaborators
Participation		
Profile projects supported by the LSCC	Yes	Profiles outlined in the Annual Report
Participation and contribution of organisations in the LSCC	Yes	Details of Martin Krzywinski's (Genome Sciences Centre, Vancouver) tour and his engagement with LSCC was published in the Annual Report
Capability		
Number of specialists and their host organisations in the LSCC core pool	Yes	The specialists and their host organisations outlined in the Annual Report
Extent and profile of skills in the LSCC core pool	Yes	Skills are documented on VLSCI's website
Kinds and capability of services delivered by the LSCC	Yes	Capability and services summarised in the Annual Report
Research satisfaction		
Summary of surveys of researchers in the LSCC showing their level of satisfaction	Yes	User satisfaction survey data published in the Annual Report. User satisfaction data provided for: system support services; user help system activity; reporting; software; job queuing time

SOURCE: VLSCI 2014 ANNUAL REPORT (INCLUDING THE FINANCIAL SUPPLEMENT TO THE REPORT)

Category / KPI	Was the KPI achieved?	Evidence of achievement
Achievements		
Key research achievements obtained by LSCC	Yes	Details of key achievements published in the Annual Report. Achievements of two research projects are showcased: Finding ways to diagnose lethal metastatic prostate cancer Streamlining virus modelling processes at the Victorian Infectious Disease Reference Laboratory
Significant developments facilitated by the LSCC	Yes	Details of collaborations outlined in the Annual Report. Collaborations reported with Victorian, Australian, international and industry partner institutions. A total of 88 organisations reported as collaborators
Participation		
Profile projects supported by the LSCC	Yes	Profiles outlined in the Annual Report
Participation and contribution of organisations in the LSCC	Yes	Details of Martin Krzywinski's (Genome Sciences Centre, Vancouver) tour and his engagement with LSCC was published in the Annual Report
Capability		
Number of specialists and their host organisations in the LSCC core pool	Yes	The specialists and their host organisations outlined in the Annual Report
Extent and profile of skills in the LSCC core pool	Yes	Skills are documented on VLSCI's website
Kinds and capability of services delivered by the LSCC	Yes	Capability and services summarised in the Annual Report
Research satisfaction		
Summary of surveys of researchers in the LSCC showing their level of satisfaction	Yes	User satisfaction survey data published in the Annual Report. User satisfaction data provided for: system support services; user help system activity; reporting; software; job queuing time

Finally, ACIL Allen's review of the documentation provided by VLSCI for 2014 indicates that VLSCI has achieved (or demonstrated significant progress towards) the KPIs set for the outreach program. A summary of the findings is provided in Table 3.3.

TABLE 3.3 – **PROGRESS AGAINST KPIS FOR THE OUTREACH PROGRAM**

Category / KPI	Was the KPI achieved?	Evidence of achievement
Achievements		
Major achievements in the outreach program and each of its components; awareness, skills development, education, collaboration and industry uptake	Yes	Details of achievements published in the Annual Report
Activities		
Number and types of outreach activities conducted in each component	Yes	Information collected and tracked for the annual reporting process. Summary information published in the Annual Report
Participation		

Category / KPI	Was the KPI achieved?	Evidence of achievement
Participation of people (number, organisation, location) in the outreach activities	Yes	Information collected and tracked for the annual reporting process. Summary information published in the Annual Report
Participation of organisations in the program and their profile and contributions	Yes	List of participants published in the Annual Report
Extent and profile of people accessing the VLSCI website and its news service	Yes	Detailed information about VLSCI website visitors and the news service are provided in section 7 of the Annual Report. This information includes: – a breakdown of website visitors by country, individual webpages, unique visitors – a breakdown of twitter account activity, access, participation – a summary of VLSCI's coverage by the media
Contributions and satisfaction		
Extent of the contributions from participants, stakeholders and sponsors	Yes	Information collected and tracked for the annual reporting process. However extent of contribution is not clearly identified in the Annual Report
Qualitative response from attendees to the activities	Yes	Information is collected as part of preparing the Annual Report, but is not always published in the report.

SOURCE: VLSCI 2014 ANNUAL REPORT (INCLUDING THE FINANCIAL SUPPLEMENT TO THE REPORT)

The information provided in Table 3.1, Table 3.2, and Table 3.3 clearly shows that VLSCI is meeting the KPIs and other targets set for the Initiative. Moreover, when this assessment is considered alongside the 2013 study, which drew upon 2012 data, it demonstrates that VLSCI has an excellent long-term track record of meeting the KPIs and targets that have been set for it.

Benefits of VLSCI

The benefits generated by stakeholders provide a good indication of a program's effectiveness. Below we discuss some of the benefits that are currently being realised as a result of life science researchers having access to the VLSCI. We discuss benefits in the following areas:

- Publications by researchers
- Presentations by researchers
- The leveraged research funding that VLSCI researchers have managed to attract to Victoria
- Employment opportunities for researchers
- Capacity development.

It builds on the 2013 study. To allow the reader to make a comparison over time those results are presented in this report.

3.2.1 Research outputs

The results of scientific research are normally presented at conferences and or published in peer reviewed academic journals.

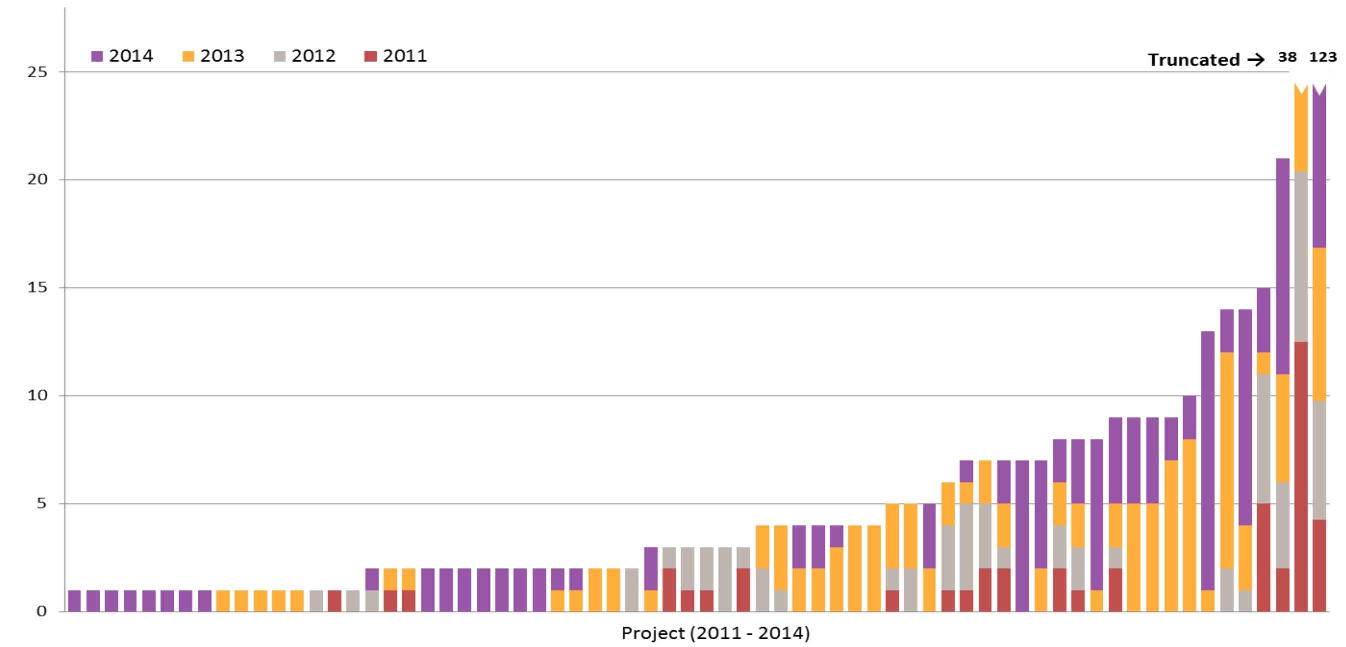
Publications

In 2011, the 42 respondents to a VLSCI questionnaire reported that they collectively had published 66 journal articles reporting on the results of their projects involving the VLSCI. In 2012, 51 questionnaire respondents reported that they had collectively published 88 journal articles as a result of research done with the support of VLSCI facilities.

VLSCI users were asked to complete similar questionnaires in 2013 and 2014. The 94 and 101 respondents in 2013 and 2014 respectively reported that they collectively had published 145 and 155 journal articles in those years.

The information on publications by VLSCI projects is illustrated Figure 3.1.

FIGURE 3.1 – **NUMBER OF PUBLICATIONS BY YEAR (BY PROJECT)**



Note: Each column represents one project. Projects are not ordered by project number.

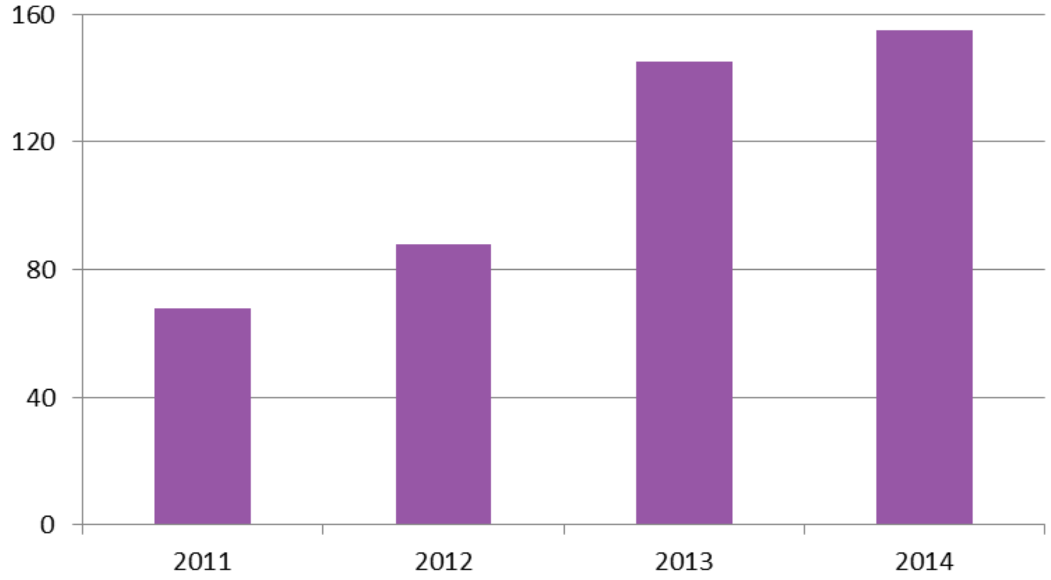
SOURCE: ANNUAL REPORT SUMMARIES FOR 2011 TO 2014.

The number of publications by VLSCI researchers has increased steadily over the period from 2011 to 2014. The observed increase in the number of publications is in part a result of the increasing number of projects using the VLSCI's facilities. ACIL Allen notes that over two thirds of the projects that published their results in 2012 also published in 2014 (20 out of 29). This is a positive sign as it suggests that the results that researchers are obtaining are encouraging them to continue to pursue their particular areas of research. The project with the most publications had produced 123 publications by 2014.

The number of projects using VLSCI almost doubled between 2012 and 2013, however the number of projects now appears to have plateaued with only seven new projects using VLSCI between 2013 and 2014. ACIL Allen would expect the number of projects to plateau in this way as the capacity of the VLSCI to service research projects is finite and once the facilities are fully utilised there is limited scope to provide computational support to more projects unless other projects cease to use the facilities.

Similarly, ACIL Allen would expect that the number publications by VLSCI users would also tend to plateau as the number of projects able to access the VLSCI facilities is limited by the finite capacity of the facilities. Of course, there will be year on year variations as individual projects can potentially have large numbers of publications in various years. The total number of publications by VLSCI supported research projects by year is shown in Figure 3.2.

FIGURE 3.2 – **NUMBER OF PUBLICATIONS BY YEAR (AGGREGATED ACROSS ALL PROJECTS)**



Note: This chart is a summary of the chart above – aggregating all the publications by projects by year.

SOURCE: ANNUAL REPORT SUMMARIES FOR 2011 TO 2014.

The above discussion of publication numbers between 2011 and 2014 illustrates that the existence of VLSCI has had a significant positive impact on increasing Victorian (and others) research output as measured by academic publications, especially since 2013. The increase in publications also contributes to promoting the role of Victoria as an Australian and international centre for life sciences research.

Of course, some care needs to be taken in interpreting the significance of number of publications on its own as the absolute number does not necessarily relate to the quality of the research being done. This issue is discussed further in the section below which examines the journal impact factors of the publications by VLSCI researchers.

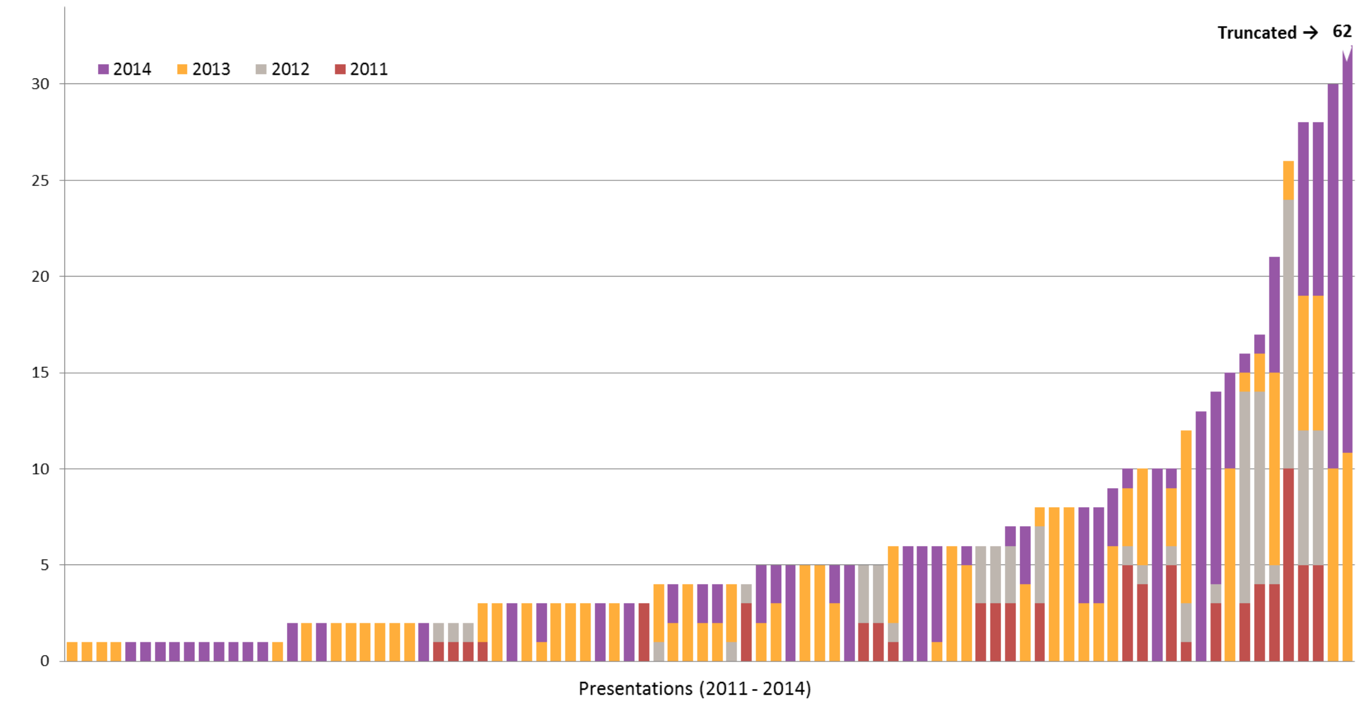
Presentations

In 2011, the 42 respondents to the VLSCI's questionnaire reported that they collectively had given 79 presentations as a result of their projects involving the VLSCI. In 2012, 51 questionnaire respondents reported that they had collectively given 82 presentations.

The 94 and 101 respondents to the VLSCI surveys in 2013 and 2014 reported that they collectively had given 213 and 212 presentations respectively as a result of their projects involving the VLSCI.

Figure 3.3 presents the information on presentations by VLSCI users over the period 2011 to 2014.

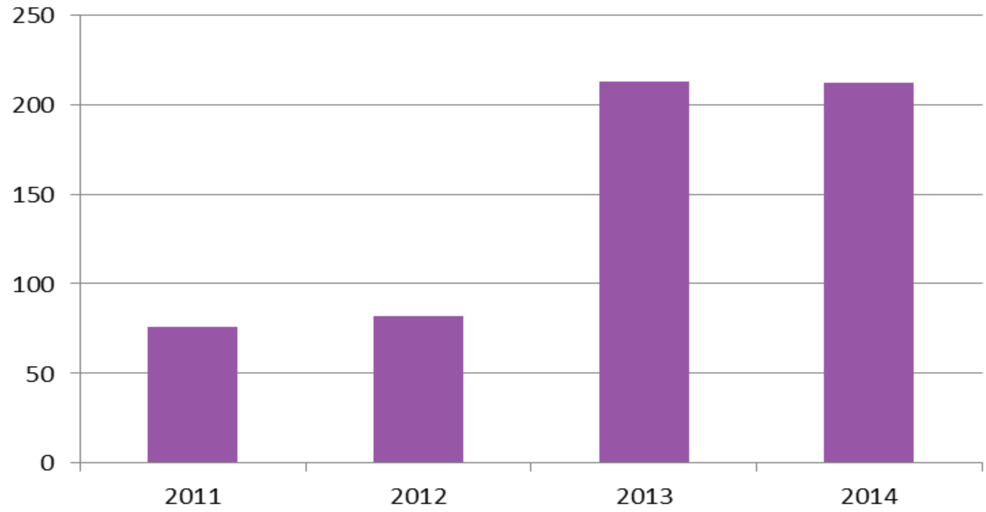
FIGURE 3.3 – **NUMBER OF PRESENTATIONS BY YEAR (BY PROJECT)**



Note: Each column represents one project. Projects are not ordered by project number.

SOURCE: ANNUAL REPORT SUMMARIES FOR 2011 TO 2014.

FIGURE 3.4 – **NUMBER OF PRESENTATIONS BY YEAR (AGGREGATED ACROSS ALL PROJECTS)**



Note: This chart is a summary of the chart above – aggregating all the projects by year.

SOURCE: ANNUAL REPORT SUMMARIES FOR 2011 TO 2014.

The total number of presentations by year is shown in FIGURE 3.4. As with publications, the number of presentations showed a strong increase between 2011 and 2013 before plateauing in 2014. The explanation for the increase in presentations over time largely mirrors that for publications. Although, the number of presentations will be additionally limited by the physical amount of time that researchers will need to set aside from their actual research to physically attend and give presentations.

Again, the above discussion of the number of presentations between 2011 and 2014 illustrates the importance of VLSCI in increasing research output as measured by the number of presentations that VLSCI supported researchers are invited to give. It demonstrates the role of VLSCI in promoting life sciences research and the reputation of its associated institutions (through the increased awareness created by these presentations). These presentations will of course also contribute to promoting the role of Victoria as an Australian and international centre for life sciences research.

Journal impact factor

While the number of publications provides a measure of the level of research activity in the life sciences field being supported by access to VLSCI's facilities, it does not tell us anything about the quality of the research being done. The relative quality of a particular research project is something that often only emerges over time.[30]

However, a useful indicator of research quality can be obtained by considering the standing of the journal that the work is published in. Journal Impact Factors (JIFs) are often used to compare one journal's relative standing against others in the same field.

Since 1975, Thomson Reuters has published the *Journal Citation Report* which has provided quantitative tools for ranking, evaluating, categorising and comparing journals. The JIF is one of these tools; it is a ratio between the number of citations and recent citable items published. It is determined as follows:

> ***A*** *= total cites in Year X*
>
> ***B*** *= Year X cites to articles published in Year X-1 (this is a subset of A)*
>
> ***C*** *= number of articles published in Year X-1*
>
> ***D*** *= B/C = Year X impact factor.*[31]

According to Thomson Reuters:

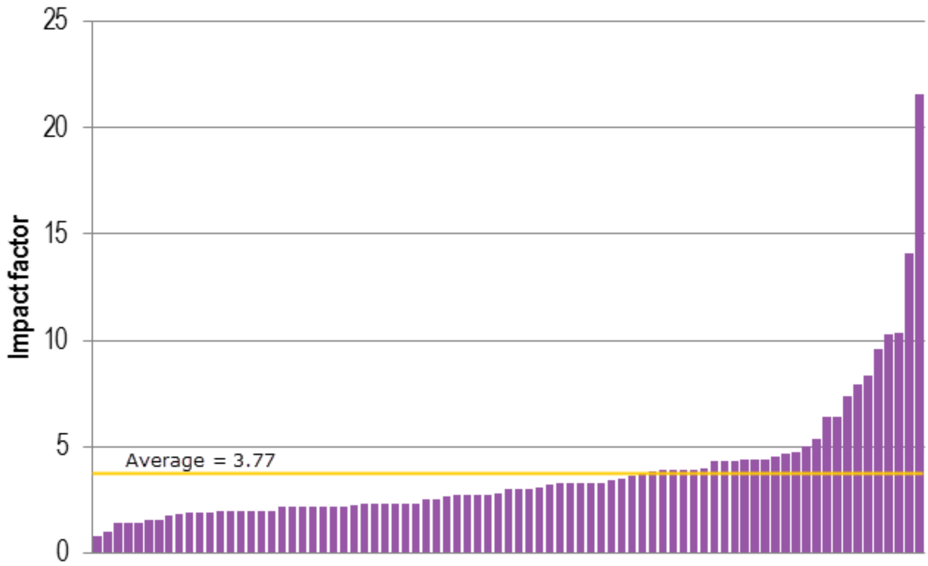
> *The impact factor can be used to provide a gross approximation of the prestige of journals in which individuals have been published. This is best done in conjunction with other considerations such as peer review, productivity, and subject specialty citation rates… The impact factor should not be used without careful attention to the many phenomena that influence citation rates, as for example the average number of references cited in the average article. The impact factor should be used with informed peer review.*

The JIF attempts to remove some of the bias linked to large journals, more frequently issued journals and newer journals. It is not straight forward to define what a 'good' impact factor is. For example, a JIF of 0.99 for a journal in one discipline can indicate a leading journal in that discipline, while a JIF of 11.5 in another discipline can indicate a 'lower ranked' journal in that discipline. For this reason, JIFs do not provide an 'absolute' ranking of a journal. Generally speaking, most JIFs are below five and very few are above 20 (the very highly respected (and ranked) journal *Nature* has an impact factor of over 38).

It is also important to understand that JIFs are not a measure of the impact of individual articles. For this study we are using JIFs to gain an overall assessment of the quality of the body of research facilitated by VLSCI. For the 2013 study the JIF of the journals in which articles generated by VLSCI projects over 2012 ranged between 0.818 and 21.543. The average impact factor was 3.77 (see Figure 3.5).

[30] An illustration of this is provided by considering the Nobel Prize winners. Often the prizes are awarded decades after the research was originally published. For example, the 2013 Nobel Prize for chemistry was awarded for pioneering work on computer programs that simulate complex chemical processes. Those programs were first developed in the 1970s.
[31] *The Thomson Reuters Impact Factor*, Retrieved September 3, 2013, from Web of Knowledge: http://wokinfo.com/essays/impact-factor/

FIGURE 3.5 – **DISTRIBUTION OF IMPACT FACTORS FOR REPORTING PROJECTS IN 2012**



Notes: 1. Distribution of 81 publications only. 2. The average impact factor is for all publications, which means that the same journal may be counted more than once in the average. 3. The number of publications shown in this figure does not necessarily equal the number of publications quoted in the quartile analysis chart later in the chapter. This is because not all of journals in which VLSCI researchers published their results had a Journal Impact Factor.

SOURCE: 2012 ANNUAL REPORT SUMMARIES, RELEVANT JOURNAL WEBSITES.

The publications in which VLSCI projects published the results of their research over the period 2013 and 2014 ranged in impact factor from 1.045 to 42.351.[32] The average impact factor was 5.58 (see Figure 3.6). The increase in the average journal impact factor of publications by VLSCI supported projects from 3.77 as reported in the 2013 study, to 5.58 now provides strong support for the argument that not only has the amount of life sciences research being done (and reported) by projects using the VLSCI facilities increased over time, but that the quality of that research has also increased.

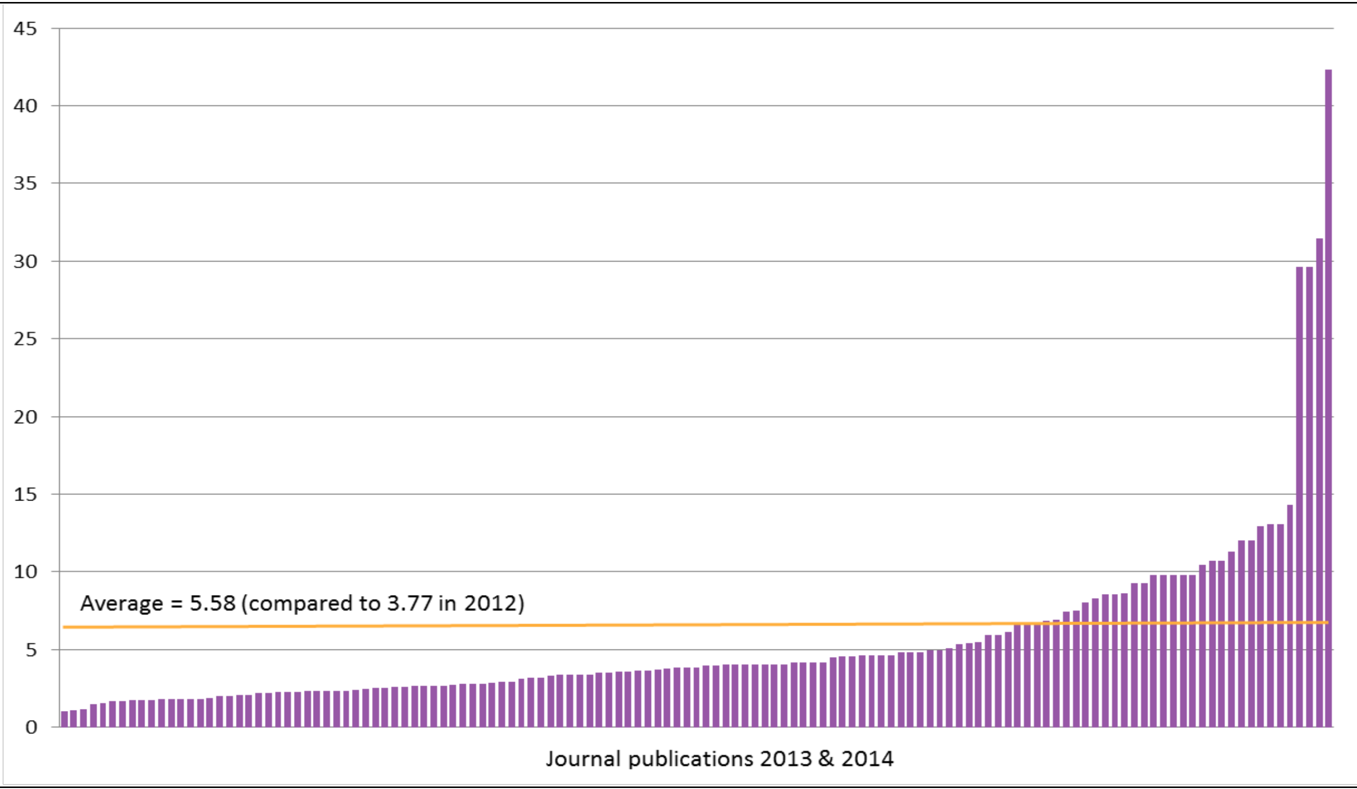
Thomson Reuters ranks journals (based on their JIFs) in quartiles based on journal disciplines; a journal in the first quartile (Q1) is ranked in the top 25 percent of its category. A publication in a journal ranked in the first quartile provides a strong indication that the research that has given rise to that publication is more highly regarded globally.

Analysis of the journals that VLSCI projects were published in during 2013 and 2014 reveals that almost two thirds (65.4 percent) of those journals were ranked in the first quartile, i.e. in the top 25 percent of journals in their category (see Figure 3.7).

Between 2012 and 2014, there was an eight percent increase in the proportion of first quartile publications together with 18 percent reduction in last quartile (quartile four) publications. These changes demonstrate that there was a significant increase in the impact of the journals in which VLSCI researchers published their results. This provides further reassurance of the important role that VLSCI is playing in promoting both high quality research, the reputation of its associated institutions and Victoria as a centre for life sciences research.

[32] Note that some journals are not ranked. For example, a very highly specialised journal which might be the only journal that is published on a particular research topic is unlikely to be ranked as there is nothing to rank it against.

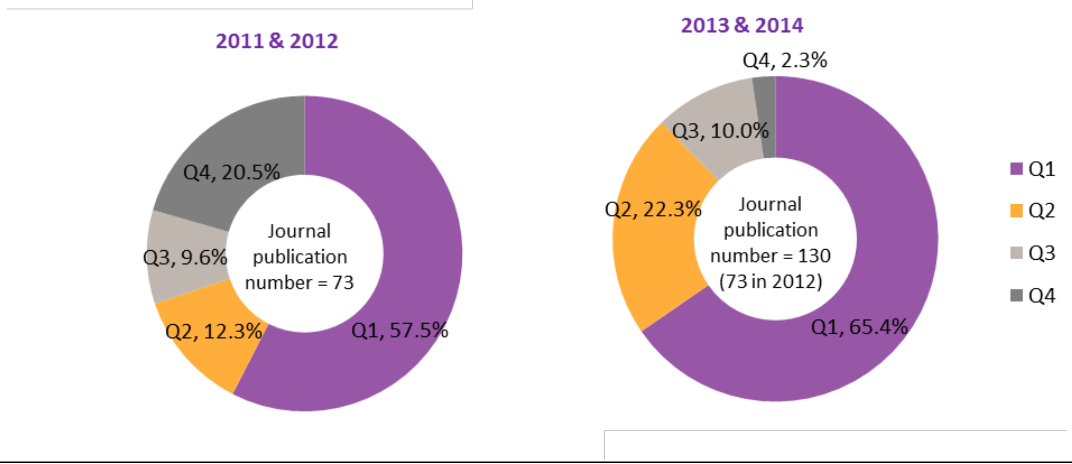
FIGURE 3.6 – **DISTRIBUTION OF IMPACT FACTORS FOR REPORTING PROJECTS IN 2013 & 2014**



Notes: 1. Distribution of 130 publications only. 2. The average impact factor is for all publications, which means that the same journal may be counted more than once in the average. 3. The number of publications shown in this figure does not necessarily equal the number of publications quoted in the quartile analysis chart later in the chapter. This is because not all of journals in which VLSCI researchers published their results had a Journal Impact Factor.

SOURCE: 2014 ANNUAL REPORT SUMMARIES, RELEVANT JOURNAL WEBSITES.

FIGURE 3.7 – **QUARTILE ALLOCATION OF JOURNALS PUBLISHING VLSCI MATERIAL (2012 & 2014)**



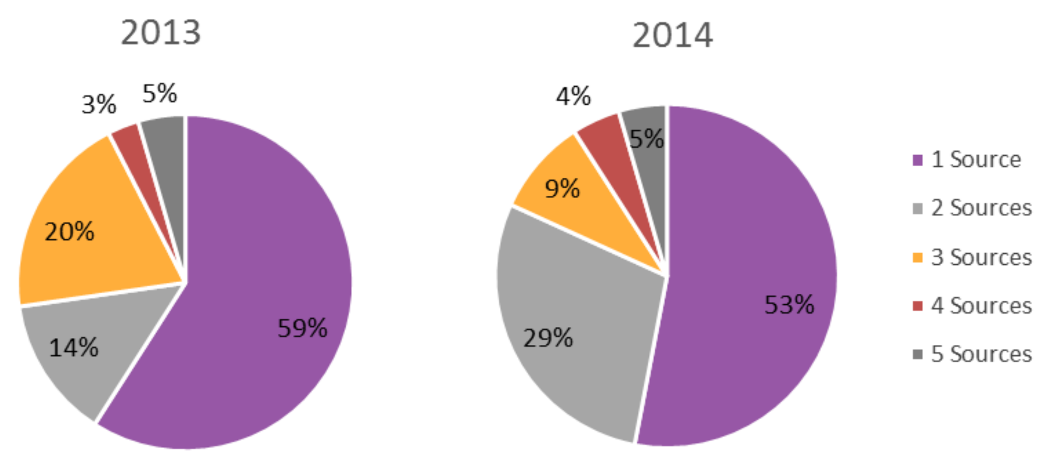
Notes: 1. Thomson Reuters does not provide a journal impact factor for some journals. This is can be because it is a highly specialised journal reporting on research covered by few (or no) other journals and hence the relative quality of the journal is difficult to establish. ACIL Allen has grouped such journals together with the journals in quartile 4. 2. The number of publications shown in this figure does not necessarily equal the number of publications quoted in the quartile analysis chart later in the chapter. This is because not all of journals in which VLSCI researchers published their results had a Journal Impact Factor

SOURCES: THOMSON REUTERS AND ACIL ALLEN CONSULTING.

3.2.2 Leveraged research funding

Researchers accessing VLSCI make use a variety of sources of funding to support their projects. Figure 3.8 compares the sources of funding used by VLSCI users in 2013 versus 2014. While the majority of users only access one source of funds, the proportion of VLSCI users that did so fell from 59 percent in 2013 to 53 percent in 2014. At the same time there was a 15 percent increase in users who accessed two sources of funding.

FIGURE 3.8 – **NUMBER OF FUNDING SOURCES USED BY VLSCI USERS**



SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES.

It is difficult to be definitive about the extent to which the existence of VLSCI has helped researchers to broaden their sources of funding. However, in our interviews with stakeholders there was a consistent view that references to the intention to use the VLSCI's facilities in grant applications generally led to more positive and supportive comments from peer reviewers of those applications. Certainly Figure 3.8 shows that the number of VLSCI researchers accessing more than one source of funding increased by 6 percent between 2013 and 2014.

ACIL Allen believes that to the extent that the existence of VLSCI has increased users' ability to access more research funding options, this will provide greater potential for increased total funding for VLSCI projects. It will also provide greater funding security as it enables researchers to mitigate the risk that a particular source of funding may have less funds available for distribution to successful grant applicants.

Figure 3.9 shows the total value of grants from various funding sources used to access VLSCI between 2011 and 2020. Some responses provided information on the range of time covered by their grants. That information was used to allocate funding awarded to specific years (shown as 'Specified grant period' in the chart). For grants where the starting year was not stated it was assumed the grant started the year after the annual report (shown as 'AAC allocation' in the chart).[33]

Note that the AAC allocation figures include grants for large amounts of funding to a number of Centres of Excellence.

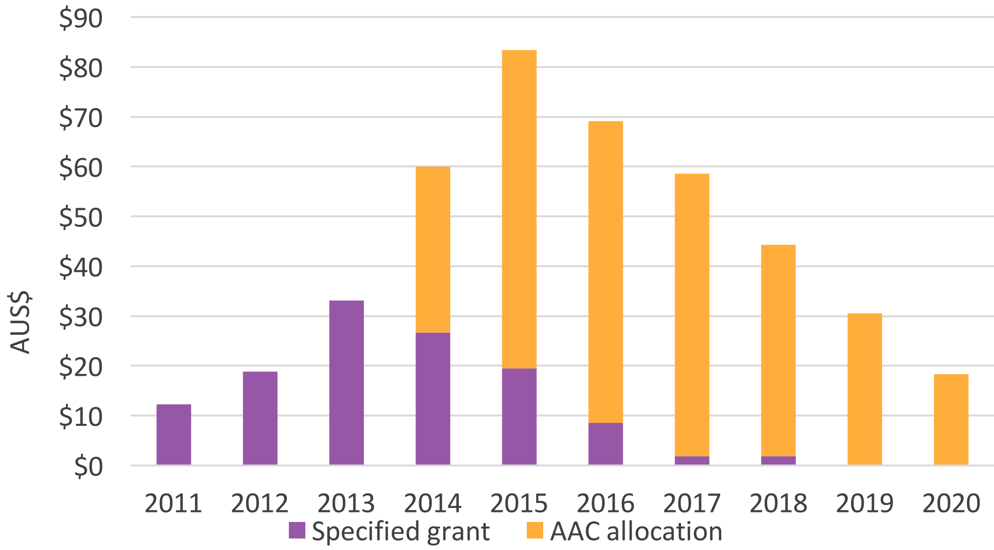
Combining the two flows of funding provides an estimate of the annual flows of research funds into Victoria each year as a result of VLSCI. In 2014, approximately $60 million in research funds flowed into Victoria. This increased to an estimated total of over $80 million in 2015.[34]

The cumulative flow of funds into Victoria over the period 2011- 2016 is around $277 million based on the grants shown in Figure 3.9. ACIL Allen believes there are a number of reasons why the reported value of grants received has increased so significantly for 2013 and 2014. One is that the structure of the questionnaire in previous years allowed users to simply report that they received a grant but did not make it compulsory to specify the amount they received. Another is that the response rate to the survey has improved. Finally, the number of projects using the VLSCI's facilities has increased.

33 The term "AAC Allocation" refers to the allocation being done by ACIL Allen Consulting

34 This figure is likely to be an underestimate since at the time this report was prepared, only one round of successful 2015 NHMRC grants had been announced.

FIGURE 3.9 – **VALUE OF GRANTS USED TO ACCESS VLSCI**

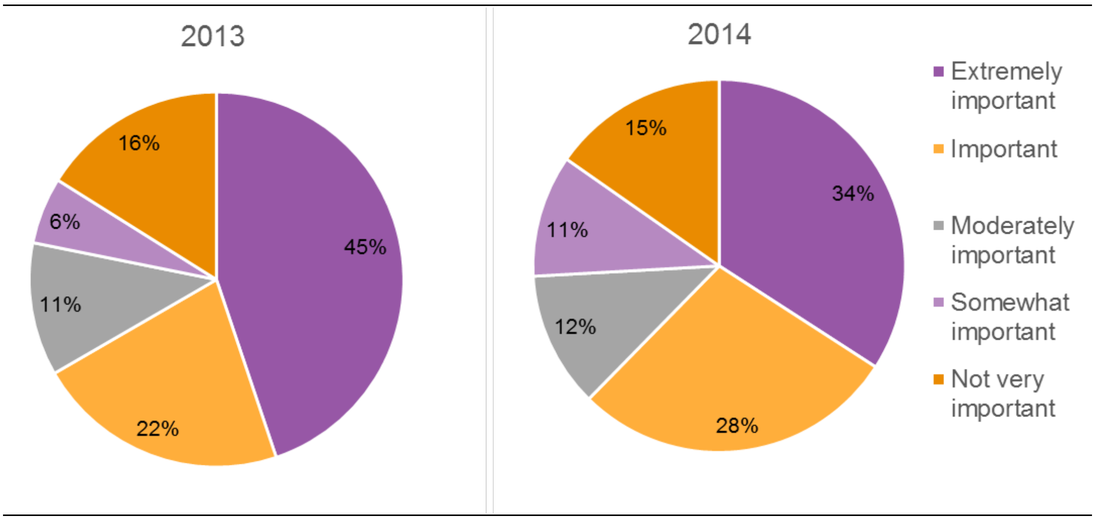


SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES

The projected decline in grants flows from 2014 onwards should not be interpreted as a negative signal. The analysis assumes that no new research grants are awarded to researchers using VLSCI facilities which ACIL Allen would regard as a highly unlikely outcome. However, ACIL Allen would note that one stakeholder (who is a major user of VLSCI for their research) reported that he had received a comment from a peer reviewer of his grant application that expressed some concern that the period covered by the grant application went beyond the date when the current funding agreement for VLSCI expires.

In 2013 and 2014, VLSCI asked its users to report how important access to VLSCI was to the success of their funding applications. The majority of users (over 60 percent in both years) said VLSCI was important or extremely important for the winning of grants. Whereas only around 15 percent said access to the VLSCI was not very important for the winning of grants (see Figure 3.10).

FIGURE 3.10 – **IMPORTANCE OF VLSCI TO WINNING OF GRANTS**



SOURCE: VLSCI ANNUAL REPORT SUMMARIES 2013 AND 2014.

Several stakeholders interviewed as part of this evaluation indicated that their ability to access VLSCI facilities and expertise increased their ability to gain access to funding. For example, comments provided by stakeholders included:

> *… access to VLSCI has helped to me to get $2 million grant from the US Department of Defence.*
>
> *Working with the IBM Collaboratory helped to get a Centre of Excellence grant.*

Another stakeholder down played the importance of access to VLSCI but went on to note that:

> *…data analysis tends to be taken for granted. However VLSCI has changed the awareness of the need for sophisticated analysis.*

Table 3.4 summarises the number, type and value of grants awarded to VLSCI projects between 2011 and 2014.

TABLE 3.4 – **GRANTS AWARDED TO VLSCI PROJECTS IN PERIOD 2011-2014**

Total grants					Type of grants		
Year	Projects reporting grants	Australian grants	International grants	Value of grants (A$m)	ARC	NHMRC	Other
2011	15	18	4	$12.04	5	8	9
2012	19	32	2	$13.40	13	15	6
2013	94	97	9	$249.3	45	23	38
2014	101	74	5	$230.1	28	25	26

Note: The total grant value is the total grant amount identified in particular survey year (2010 – 2014), but may spread across a number of years before (e.g., grant already in place) and after (e.g., continuing of grant) the survey year.

SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES.

In 2013 and 2014, VLSCI users were awarded 106 and 79 grants respectively, totalling $249.3 million and $230.1 million respectively. [35] ARC and NHMRC grants dominate the grants, accounting for an average of 65 percent of the total grant value in 2013 and 2014.

Between 2011 and 2014 both the number and value of grants increased significantly. The increase is seen across all funding categories/bodies, including Australian and international grants, ARC, NHMRC and other grants.

The application process for research grants is a highly competitive process with only a relatively small proportion of applications being successful. As part of the decision process for grants, all applications are peer reviewed. The fact that researchers seeking funding for research projects using VLSCI facilities report favourable peer reviews of their applications that specifically refer to the VLSCI supports the view that the work that those researchers are doing (and VLSCI's role in the research) is highly regarded by their peers.

3.2.3 Use of other computing facilities

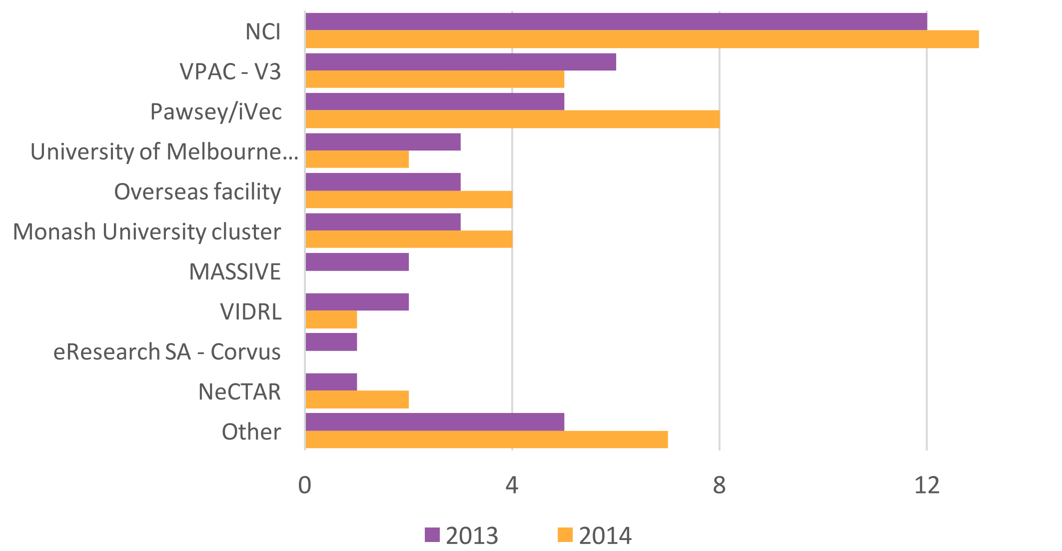
Since 2013, VLSCI has asked their users whether they used any other computing facilities. In 2013, 31 out of 94 respondents (33 percent) reported using at least one other facility, with three using two other facilities and four using three other facilities. In 2014, 29 out of 101 respondents (29 percent)

[35] This value is the total grant amount identified in the 2013 survey, but may spread across a number of years before (e.g., grant already in place before 2013) and after 2013 (e.g., continuing of grant).

reported using at least one other facility, with eight using two other facilities and five using three other facilities.

Figure 3.11 shows which other facilities users of VLSCI accessed in 2013 and 2014:

FIGURE 3.11 – **USE OF OTHER COMPUTING FACILITIES, 2013-14**



Note: 'Other' includes users who specified NCMAS as a facility without further detail as well as some unnamed local clusters. 'Monash University cluster' includes the Monash Campus Cluster, Monash Sun Grid and Orchard.
SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES.

The most frequently accessed other facility is the NCI, with most users using Raijin within that facility. The facilities at VPAC – V3 and Pawsey/iVEC were the two next most-used facilities. Overseas facilities accessed by users include resources at the Max Planck Institute in Germany, Gordon (SDSC) XSEDE in the US and NIC in Germany.

Stakeholders also were asked about their use of other facilities. Some questioned the ability of other facilities to meet VLSCI users' needs. Comments included:

> *Blue Gene Q users will not be able to transition to NCI because NCI does not have the capacity and is not necessarily suited to some needs (of researchers).*

> *…might be able to use NCI but don't know much about how to do so. …depend on the experts at VLSCI and feel that face to face access to local expertise and training is very important.*

3.2.4 The impact of VLSCI on employment

Table 3.5 presents the impact of VLSCI on employment opportunities based on the responses to VLSCI's user surveys.

TABLE 3.5 – **EFFECTS ON EMPLOYMENT FROM VLSCI PROJECTS**

Year	Undergraduate	Postgraduate	Postdoctoral	Other	Total
2011	1	3	5	27	36
2012	0	2	9	19	30
2013	37	48	27	4	116
2014	22	36	15	4	77

Notes: This table presents fewer roles compared to the 2013 study. This is because the 2013 and 2014 surveys simplified the survey questions to focus on a smaller number of key roles (reflected in the table) and omitted some that were included in the 2012 survey (e.g., interns).

SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES

An average of 40 percent of survey respondents in 2013 and 2014 believed that VLSCI had a positive impact on employment opportunities within their research group or with collaborators. In 2013, 116 additional positions were reported (by the survey respondents) to have been created due to VLSCI. A majority of these positions were at the postgraduate level or above. In 2014, the survey respondents reported creating 77 positions.

The large increase in the number of positions created due to VLSCI reported in 2013 reflects the similarly large increase in users of the VLSCI. The large jump in the value of research funding grants won by VLSCI users is also likely to be a significant contributor to the increase in employment as these research grants often include funding to employ postgraduate students and/or postdoctoral researchers.

3.2.5 Skills development and support services

The VLSCI has a significant skills development and outreach program. The program includes a diverse range of events and activities to inform, and train researchers, students, stakeholders, experts and the public about life sciences computing.

Activities designed to support skills development include:

— PhD top-ups – these provide support to exceptional students through annual stipends (28 and 22 students received PhD top-ups in 2013 and 2014 respectively).

— MSc (Bioinformatics) – these provide student bursaries to high achieving students (6 and 5 students received bursaries in 2013 and 2014 respectively). It is worth noting that while some students received bursaries there were many others who did not. However, all the bioinformatics students have learnt valuable skills that are highly sought after by many sectors of the economy.

— Internships – these offer employment to talented postgraduates over their summer recess (4 and 11 postgraduates received internships in 2013 and 2014 respectively).

— Undergraduate Research Opportunities Program (UROP) - these provide direct stipend support to computational biology projects for Victorian undergraduates (16 and 20 students received UROP support in 2013 and 2014 respectively).

— Sponsorship of conferences and meetings (VLSCI sponsored 17 and 15 meetings and conferences in 2013 and 2014 respectively)

— Travel and conference grants for career development (15 and 17 such grants were provided in 2013 and 2014 respectively)

— An extensive training workshop program and through VLSCI staff teaching in University appointments (23 and 37 training workshops were held in 2013 and 2014 respectively and 9 and 6 courses were offered by VLSCI staff at University of Melbourne, Monash and La Trobe in 2013 and 2014 respectively).

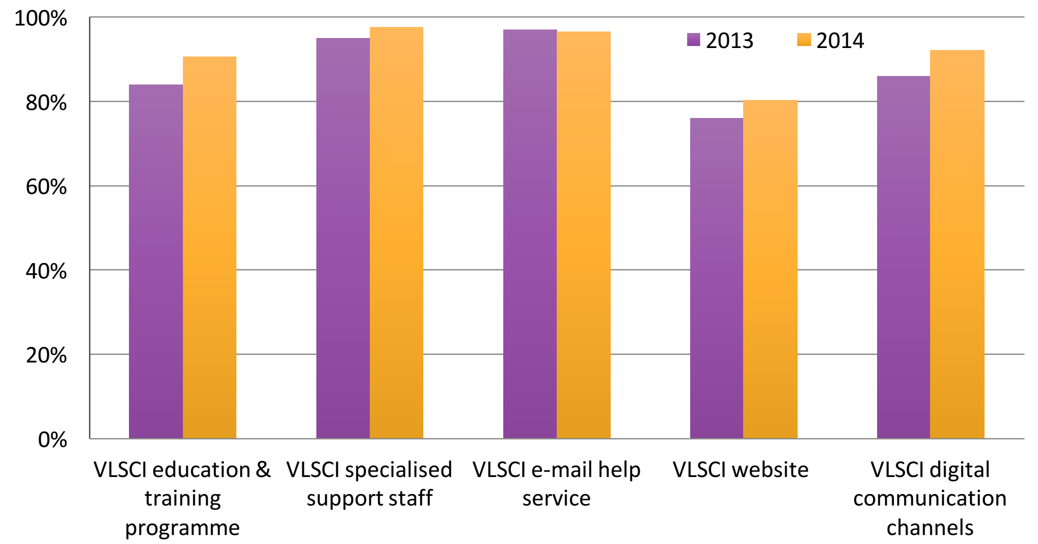
VLSCI has an extensive outreach program. The main avenues for that outreach include:

— the VLSCI web site (there were almost 283,600 webpage views between 1 October and end December 2014

— Twitter (there are now some 400 followers of the VLSCI Twitter account (up from 120 in 2012 and 240 in 2013)
— eNews (some 2600 subscribers by December 2014)
— conventional media (the conservatively estimated media value of coverage of VLSCI on TV, radio and in print was almost $370,000 in 2014).

Figure 3.12 shows the results of surveys of user satisfaction with various key VLSCI training and support services.

FIGURE 3.12 – **USER SATISFACTION WITH VLSCI SERVICES (PERCENTAGE RATED AS VERY GOOD OR GOOD BY USERS) IN 2013 AND 2014**



SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES.

Of those that responded to the relevant questions in the 2013 survey, 84 percent rated the VLSCI education and training programmes as a very good or good, 14 percent rate them as adequate, and two percent as poor.[36] User satisfaction levels were even higher with VLSCI specialised staff support and email support with 95 and 97 percent respectively ranking these services as very good or good. Around 80 percent of respondents ranked the VLSCI website and other digital communication channels (e.g., e-News and Twitter) as good or very good.

The percentage of survey respondents rating VLSCI training services as very good and good increased by an average of 4 percent in 2014 (on 2013) across all service categories. VLSCI staff support had the highest satisfaction among all service categories and reached a satisfaction rate (very good or good) of 98 percent in 2014 (compared to 85 percent in 2013).

Clearly, users consider the education and training and outreach services provided by VLSCI to generally be of high quality and to meet their needs.

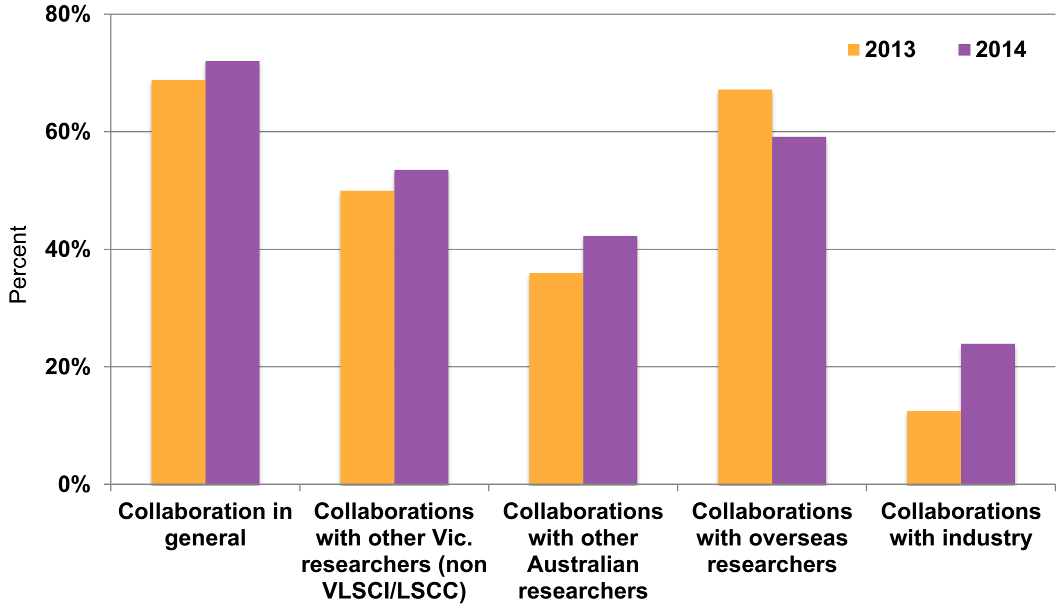
3.2.6 Collaboration

One of VLSCI's objectives is to facilitate greater research collaboration within Victoria, nationally and internationally. One of the key mechanisms for encouraging collaboration is through the activities of LSCC. That group has fortnightly meetings of members to discuss research developments and address any challenges that have arisen. In addition, through their outreach activities they also encourage collaboration between the LSCC and other research groups.

[36] A small proportion of the 94 survey respondents did not respond to this question.

Figure 3.13 shows the percentage of survey respondents that believe VLSCI has improved collaboration in general, collaboration with other Victorian researchers (besides VLSCI staff), other Australian researchers, overseas researchers and collaboration with the industry.

FIGURE 3.13 – **PERCENTAGE OF SURVEY RESPONDENTS STATING VLSCI HAS PROMOTED COLLABORATION (BY COLLABORATION TYPE) 2013-14**



SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES.

Over 70 percent of survey respondents believed VLSCI has improved collaboration in general in 2014. VLSCI is also considered to be effective by the respondents in promoting collaboration with overseas researchers. Efforts to encourage collaboration with industry are seen as less effective than efforts to encourage other types of collaboration. However, it is worth noting that the percentage of researchers saying that VLSCI promotes industry collaboration almost doubled in 2014, increasing from 13 percent in 2013 to 24 percent in 2014.

Users judged VLSCI's efforts to encourage collaboration as having improved in 2014 across most categories. The exception being encouraging collaboration with overseas researchers, although this was still regarded as the second most successful areas for promoting collaboration.

The top five collaborators of VLSCI in 2014 (by collaborator type) are listed in Table 3.6:

TABLE 3.6 – **TOP FIVE VLSCI COLLABORATORS (BY COLLABORATOR TYPE) IN 2014**

Victorian institutions	Australian institutions	International institutions	Industry collaborators
- Alfred Hospital - Baker IDI - Bio21 Institute - Burnet Institute - Deakin University	- ARC Plant Cell Wall Centre of Excellence - Australian National University - Bureau of Meteorology - CSIRO - Curtin University	- Aix-Marseille Université, France - Allan Herbarium Landcare, New Zealand - Alzheimer's Disease Center, NIH-funded, National Institute on Aging, USA - Autonomous University, Barcelona, Spain - Barcelona Supercomputing Center, Spain	- Joint Telstra/Swinburne University-funded Brain and Psychological Sciences Research Centre, Radiofrequency Dosimetry Laboratory, Australia - BlueScope Steel, Australia - Capsugel, France - CSL Limited, Australia - Ioragenex, Inc., Portland, USA

SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES

Importantly, VLSCI has encouraged collaboration not only in relation to the VLSCI project the user was involved in (current projects), but also collaborations in new projects that arose as a result of the VLSCI project (projects arising from a current project). Table 3.7 provides the percentage of VLSCI users that responded 'yes' to the survey questions:

a) For 'current projects':

"Were there any collaborators on this project" AND *"What kinds of collaborations were they- Collaborations with other Victorian researchers (other than VLSCI or LSCC staff)"*

b) For 'projects arising from a current project':

"Have any collaborations resulted from work on this project" AND *"What kinds of collaborations have resulted- Collaborations with other Victorian researchers (other than VLSCI or LSCC staff)"*

The Table provides an indication of the extent to which 'current projects' and 'projects arising from a current project' encourage collaboration between VLSCI users and other researchers within Victoria or researchers in other jurisdictions (other Australian states and overseas).

TABLE 3.7 – **COLLABORATION WITH VICTORIAN AND NON-VICTORIAN RESEARCHERS BY VLSCI USERS (2013 & 2014)**

Year	Project type	Collaboration with Victorian researchers (%)	Collaboration with researchers from jurisdictions other than Victoria (%)
2013	Current project	50%	50%
2013	Project arising from a current project	43%	58%
2014	Current project	57%	43%
2014	Project arising from a current project	33%	67%

Note: Jurisdictions other than Victoria include both Australian states other than Victoria as well as overseas countries.
SOURCE: 2013 AND 2014 ANNUAL REPORT SUMMARIES

Collaboration with Victorian researchers account for a larger share of the collaboration for 'current projects', while collaboration with researchers from other jurisdictions tend to dominate the collaboration in 'projects arising from a current project'.

In addition, while there are only two years of data available, the figures suggest that there is a growing trend for VLSCI projects to lead to collaborative projects with researchers from outside Victoria. It is not possible to say what other factors might have influenced the start of a new collaborative project and whether it might have happened even in the absence of the original VLSCI project. However, there are good grounds for speculating that this increase in collaboration is at least in part due to the growing need for complex genomics research to involve sharing of data across many collections worldwide – an observed and growing trend.

3.2.7 Enhanced reputation

VLSCI has enhanced Victoria's reputation as a world leader in life sciences through the publications and conference presentations of researchers that have used VLSCI facilities to produce leading edge research outcomes. The citation rates reported in this review are already starting to reflect this outcome and, as more publications appear from research undertaken in recent years, Victoria's reputation will continue to grow.

The finding in the Scientific American's 6th Annual Worldview Scorecard of the Biotechnology sector that Australia was ranked fourth in the world behind the US, Singapore and Denmark (see Section 1.2.3). This was up from a ranking of seventh in 2013. It is highly likely that VLSCI has contributed to that increase in ranking.

The QS World University Rankings by Subject highlights the world's top universities in a range of popular subject areas. Published annually since 2011, the rankings are based on academic reputation, employer reputation and research impact. In 2015 the rankings covering 36 subjects, including:

— *Life sciences* – The University of Melbourne was ranked 24th, the highest ranked Australian university.
— *Computer science and information systems* – The University of Melbourne was ranked 13th. The Australian National University (ANU) was ranked 26th and the University of NSW was ranked 35th.
— *Medicine* - The University of Melbourne was ranked 18th just behind the University of Sydney at 17th and ahead of Monash University which was ranked 36th.
— *Pharmacy and pharmacology* – Monash University was ranked 21st. The next highest ranked Australian university was the University of Sydney at 39th.
— *Statistics & operational research* – The University of Melbourne was the highest ranked Australian university at 23rd, ahead of the ANU at 48th.[37]

The above rankings support the argument that Victoria's reputation for leading edge computational health research is a very strong one. It would be difficult to argue that the VLSCI had not played a significant part in growing that reputation.

Potential future benefits

This section summarises the results of the case studies developed specifically for this evaluation (see Appendix A).

3.3.1 Improved health outcomes

The research made possible by the VLSCI can be confidently expected to provide strong future health outcomes. There are several reasons for this optimism. VLSCI has:

— involved medical and clinical researchers in its processes for allocating resources, ensuring that a significant proportion of VLSCI effort is committed to health-related topics
— undertaken an outreach program to help researchers in health-related areas understand how VLSCI facilities can help them.

Most of the research assisted by VLSCI is longer term in nature and it will therefore be some time before the outcomes are translated into health benefits. However, as the Case Studies show, good progress is being made towards such outcomes.

3.3.2 Commercialisation prospects

It normally takes some time for commercial outcomes from public sector research to be realised. This is particularly the case with health and medical related research, where the transition time from research output to a commercial product which delivers a health impact is usually measured in decades. On such time scales, the VLSCI has been operating for a relatively short period and some research outcomes with commercial potential are only just starting to emerge. The Case Studies include examples where vaccines, drugs and diagnostic tests are expected outcomes.

[37] http://www.topuniversities.com/university-rankings/university-subject-rankings/2015/statistics-operational-research accessed 2 September 2015.

Alignment between objectives

3.4.1 Objectives

The Department's objectives

ACIL Allen assumes that the Victorian Government's objectives in funding VLSCI are reflected in the three key requirements that were placed on the VLSCI under the Funding Agreement, namely that:

— the cumulative value of the contributions to the VLSCI should reach $100m in 2013

— the PCF rank in the top five facilities for Life Sciences research precincts internationally, with the target to be the top Life Sciences PCF by 2013

— the effective annual full-time equivalent staff resources supported by the VLSCI reach 30 full-time equivalents by 2013.

The Government's objectives and priorities

Some insights into the government's objectives in the field of biotechnology can be provided by documents such as:

— The Victorian Government's Biotechnology Strategic Development Plan

— The Government's response to the 2005 Parkville Precinct Strategic Plan

— Victoria's Technology Plan for the Future – Biotechnology.

In 2001, the Victorian Government set an ambitious goal for the state, namely that:

> *By 2010 Victoria is recognised as one of the world's top five biotechnology locations for the vibrancy of its industry and quality of its research.*

The Government has worked towards achieving this goal through a series of three-year *Biotechnology Strategic Development Plans*. The *2007 Biotechnology Strategic Development Plan* (the most recent of three) endorsed the following vision for the sector:

> *By 2010, we will aim to ensure that Victoria has mature, sustainable and flourishing biotechnology companies characterised by commercial success, a commitment to skills development, a willingness and capacity to reinvest in the sector and strong public support.*[38]

To realise this vision, the Plan set out four areas for action:

– *Creating a competitive business environment*
– *Building a bioeconomy*
– *Making Victoria a preferred place to live, work and learn*
– *Delivering access to high-quality infrastructure.*

The Government's response to the 2005 *Parkville Precinct Strategic Plan* endorsed the proposed vision for the precinct, namely for it to be:

> *A Precinct that integrates world-class healthcare, research and education to rapidly translate research discoveries into clinical practice, nurture life sciences and biotechnology development and drive economic growth in Victoria.*

Finally, *Victoria's Technology Plan for the Future - Biotechnology* was published in 2011. It sought to ensure Victoria's leadership in the field of biotechnology, and position the sector for future growth and ensure that it remains competitive in a challenging global environment. The Plan confirmed the State's goal to be a leader in life sciences research. It noted that:

[38] *2007 Biotechnology Strategic Development Plan – Year One Progress Report*, Victorian Government, 2009

> *Biotechnology is a vitally important Victorian industry and an area of competitive advantage for the State, with the potential to make a major contribution to future economic growth and increased productivity. Biotechnology is an enabling technology that is already generating substantial benefits in many areas. They include new treatments for diseases and injuries, more sustainable and productive industrial and agricultural processes, and better environmental management practices.*[39]

The VLSCI's objectives

VLSCI's 2011-2013 Business Plan stated that the aims of the VLSCI were to:

- *provide a world-class computational service that will support the transformation of Life Sciences research in Victoria*
- *provide a leading computing facility with the capability to address much larger Life Sciences research problems than currently being addressed in Australia*
- *facilitate greater research collaboration within the state, nationwide and internationally*
- *develop skills in computational biology, bioinformatics, advanced simulation and modelling, data management and more generally the application of advanced computing in Life Sciences*
- *support industry development in Victoria, through the uptake of computational research in Life Sciences.*[40]

The same document listed the planned outcomes of the VLSCI's activities as being:

- *significant research achievements in medical, health, biological and related sciences*
- *new computational initiatives and investments arising from VLSCI activity*
- *new research directions and collaborations with national and international consortia*
- *a sustained national computing capability for Life Sciences research*
- *attraction and retention of world class researchers and students*
- *an increase in skills in computational science and engineering to undertake computationally-based Life Sciences research*
- *an increased capability to educate and train the next generation of bioscience researchers and computational experts.*

By 2014 the Business Plan had evolved to reflect the changed funding circumstances facing VLSCI. The organisation's focus is now on what needed to be done to ensure the ongoing sustainability of the organisation. The VLSCI's 2014 Business Plan listed the organisation's strategic objectives as being:

- *a revised governance model to accommodate existing and new stakeholders*
- *a stakeholder engagement campaign*
- *allocation of funds to maintain and retain high - end facility status whilst transitioning to federal funding cycle*
- *positioning VLSCI as an existing, experienced platform from which to launch any new initiatives in computational biology*
- *staff growth and development and community capacity building.*[41]

3.4.2 Level of alignment

There is a very high degree of alignment between the goals, objectives and priorities of Victorian Governments going back over the last decade with VLSCI's objectives and the outcomes that have been achieved. This is partly because of the broad applicability of VLSCI resources and facilities to the life sciences and biotechnologies that Victorian Governments have sought to promote. It is also a reflection of VLSCI's efforts to generate outcomes that support the Victorian Government's policy objectives.

[39] *Victoria's Technology Plan for the Future – Biotechnology*, Department of Business and Innovation, 2011.
[40] Business Plan 2011-2013, VLSCI, 28th February 2011
[41] Business Plan 2014 (incorporating strategies to sustain VLSCI beyond 2014), VLSCI, 4 April 2014.

Key findings

This Chapter has demonstrated that the VLSCI has:

- performed very strongly against its targets and KPIs. VLSCI has met or exceeded the goals set for it, and in a number of cases has achieved these outcomes well ahead of target dates.
- enabled stakeholders to achieve excellent research outcomes. The numbers of papers and presentations by researchers using VLSCI's facilities has grown strongly. The impact factors of the journals in which VLSCI-supported papers have been published are high and increasing over time, indicating the high quality and novelty of the research.
- through the provision of world leading research infrastructure, helped researchers using these facilities to obtain grants and to form significant research collaborations, including an impressive list of international collaborators.
- strongly supported the development of skills which are critical to Victoria's future as a world leader in the life sciences and other sectors of the economy.
- helped Victorian Governments to meet their objectives and goals in relation to life sciences and biotechnology.

4 FUNDING, DELIVERY AND EFFICIENCY

This chapter considers the following questions: a) Has VLSCI been delivered within its scope, budget, expected timeframe, and in line with appropriate governance and risk management practices? b) Has VLSCI demonstrated efficiency and economy in relation to its delivery? c) If ongoing funding was provided, what level of efficiencies could be provided?

Funding

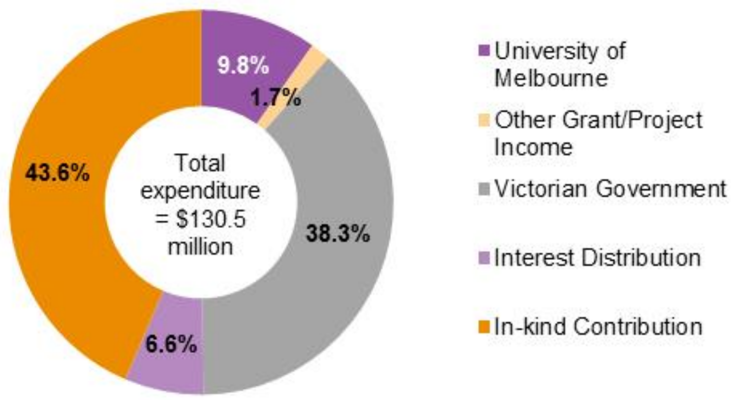
The total amount of funding attracted by VLSCI during the period 2008 to 2014 from all sources amounted to approximately $130.5 million, exceeding the $100 million target. The key sources of support for VLSCI include:

- VLSCI's initial grant funding of $50 million from the Victorian Government
- in-kind support of $56.9 million
- cash support of $12.8 million by the University of Melbourne
- other grants and project income of $2.2 million
- interest distribution of $8.7 million.

The targets set by VLSCI for different categories of contributions (cash and in-kind) components were all met.[42] The share of contributions from different sources is shown in Figure 4.1.

[42] The term contributions includes both cash and in-kind support for VLSCI.

FIGURE 4.1 – **SHARE OF CONTRIBUTIONS BY SOURCE, 2008 - 2014 (PERCENTAGE)**

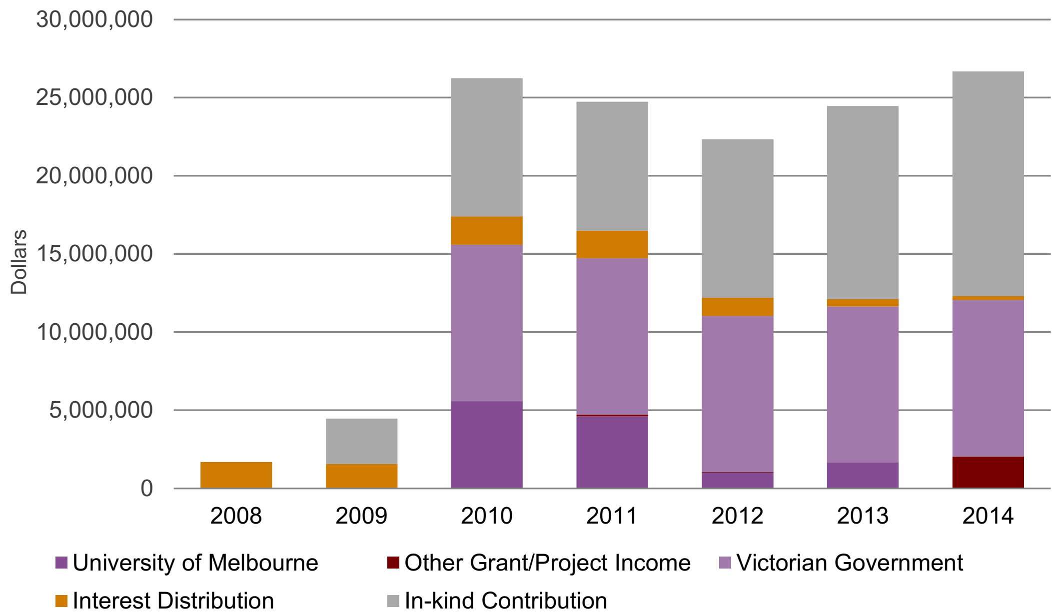


SOURCE: 2012 – 2014 VLSCI ANNUAL REPORT, 2008 – 2014 VLSCI FINANCIAL ACCOUNT, AND ACIL ALLEN CONSULTING, 2015.

Cash was the largest component of contributions over the period 2008 to 2014 (56.4 percent of total contributions). In-kind support accounted for the remainder (43.5 percent).

A breakdown of contributions by source over the period 2008 to 2014 is shown in Figure 4.2.

FIGURE 4.2 – **VLSCI CONTRIBUTIONS BY SOURCE AND YEAR (2008 – 2014)**



Notes: (1) The $50 million funding from the Victorian Government was approved in 2008 but was not formally drawn down until 2010. Therefore, this analysis treats the $50 million as a cash income from 2010 instead of from 2008. The funding is allocated evenly ($10 million per year) across the five years until 2014 (last year of reporting this particular grant under the grant agreement).

(2) VLSCI was established in 2008 and thus the income in its inception year (2008) and 2009 were lower.

(3) Cash contributions are shown based on the year in which they were received. However, those contributions were often intended to be used across a number years. For example, VLSCI received its 2014 cash contribution from the University of Melbourne in 2013.

SOURCE: 2012 – 2014 VLSCI ANNUAL REPORT, 2008 – 2014 VLSCI FINANCIAL ACCOUNT, AND ACIL ALLEN CONSULTING, 2015.

The $50 million in funding by the Victorian Government was approved in 2008 but was not formally drawn down until 2010. Therefore, this analysis treats the $50 million as an income from 2010 instead of from 2008. It is allocated evenly ($10 million per year) across the five years until 2014 (last year of reporting for this particular grant under the Grant Agreement).

VLSCI was established in 2008. The lower income in 2008 and 2009 was expected as VLSCI was still establishing itself and therefore less likely to generate as much income.

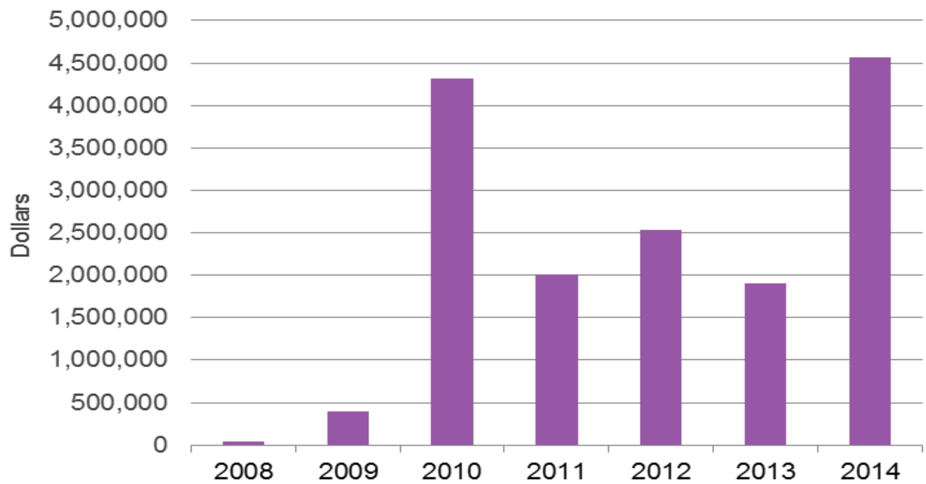
VLSCI attracted its highest level of contributions in 2014. This was largely due to an increase in in-kind support received by VLSCI and an increase in project based income, which was at its highest level during 2014. This shows that VLSCI has had success in attracting funding from its users and is on a path to greater sustainability. Income from interest (earned on banked cash from the Victorian Government) decreased over time as planned expenditure reduced the balance available to generate interest.

The other grants and projects income includes funding from the key projects; such as, NeCTAR and the Australian National Data Service (ANDS), in partnership with the University of Queensland (UQ), for the successful development and roll-out of the Genomics Virtual Laboratory (GVL). New funding was awarded through both NeCTAR and ANDS for two major infrastructure projects to roll out in 2015 in collaboration with the Research Computing Centre at UQ, with a total value of $350,000.

VLSCI sets its target for income each year for tracking financial performance. The target and the income variance (actual funding attracted minus targeted income revenue) are reported in the Financial Supplement of the VLSCI Annual Report every year. Positive/higher variance indicates out-performance.

The contributions variance of VLSCI between 2008 and 2014 is shown in Figure 4.3.

FIGURE 4.3 – **VARIANCE OF CONTRIBUTIONS (ACTUAL TARGET), 2008 – 2014**



Note: The low variance in 2008 and 2009 (inception years of VLSCI) was due to the absence of in-kind contribution target (although targets for other income sources were available), which was not introduced until 2010. Thus, income variance for in-kind contribution was zero for 2008 and 2009.

SOURCE: 2012 – 2014 VLSCI ANNUAL REPORT, 2008 – 2014 VLSCI FINANCIAL ACCOUNT, AND ACIL ALLEN CONSULTING, 2015.

The low level of variance between 2008 and 2009 (inception years of VLSCI) was due to the absence of an in-kind contribution target (although targets for other income sources were available), which was not introduced until 2010. Thus, income variance for in-kind contribution was zero for 2008 and 2009.

The 2014 cash income and in-kind contributions to VLSCI exceeded its target by $4.6 million and led to the highest positive variance since the establishment of VLSCI. In-kind contributions dominate the positive variance across all years (partly due to their large share of the total contributions).

4.1.1 Subscriptions

Subscription fees paid to VLSCI by external organisations are an important source of revenue for the Initiative. For these subscription fees, organisations receive access to LSCC's expert bioinformaticians and direct access to HPC systems. Data provided to ACIL Allen by VLSCI shows that the value of subscription fees grew steadily in recent years, with approximately $2 million of subscription income earned by the LSCC by 2014 (compared to $645,000 in 2013). The subscribers for the year 2014 are listed in Box 4.1 below.

BOX 4.1 – **ORGANISATIONS WHO HELD SUBSCRIPTIONS WITH VLSCI DURING 2014**

— Australian National University and Murdoch Children's Research Institute
— Cancer Council Victoria and Department of Pathology, University of Melbourne (2 projects)
— Eastern Hill Precinct (St Vincent's Institute, St Vincent's Hospital, CERA)
— Melbourne Genomics Health Alliance
— Monash Institute of Medical Research
— Monash University, Central Clinical School
— Monash University, Department of Anatomy and Developmental Biology
— Monash University, Department of Psychology
— Monash University, School of Biomedical Sciences: Biochemistry
— NeCTAR Endocrine Virtual Laboratory
— NeCTAR Genomics Virtual Laboratory (3 projects)
— Royal Melbourne Hospital, Department of Surgery
— University of Melbourne, Dental School
— University of Melbourne, Department of Microbiology and Immunology
— University of Melbourne, Microbiological Diagnostics Unit
— University of Melbourne, School of Population Health: MEGA
— Walter and Eliza Hall Institute, Stem Cells and Cancer Division

SOURCE: VLSCI INTERNAL DOCUMENTS

4.1.2 In-kind contribution

Figure 4.4 illustrates the level of in-kind contribution and its share of total income since 2009. In-kind contributions did not commence until 2009, and therefore 2008 figures are not reported here.

FIGURE 4.4 – **IN-KIND CONTRIBUTION LEVEL AND SHARE OF TOTAL INCOME, 2009 – 2014**

Note: There was no in-kind contribution in 2008 when VLSCI was just established and therefore, year 2008 is not reported here.

SOURCE: 2012 – 2014 VLSCI ANNUAL REPORT, 2008 – 2014 VLSCI FINANCIAL ACCOUNT, AND ACIL ALLEN CONSULTING, 2015.

In-kind contributions have increased over time both level and an as a share of total income. In-kind contributions from University of Melbourne ($6.6 million in 2014), Parkville Precinct ($2.4 million in 2014) and Other Victorian Organisations ($3.2 million in 2014) have been the key sources of support since 2009. In-kind contributions from non-Victorian institutions was $775,613 in 2013 and $2 million in 2014.

In-kind contributions have consistently exceeded VLSCI's targets 2009. In 2014 they were 34 percent over the target set by VLSCI.

4.1.3 NCRIS funding

The VLSCI has already had some success in obtaining funds from national programs such as NCRIS. In May 2015, it was announced that the VLSCI would host BRAEMBL. This follows an agreement between the University of Melbourne and EMBL Australia.[43] Under the agreement, VLSCI will have access to $500,000 in NCRIS funding through Bioplatforms Australia.

BRAEMBL will provide a significant opportunity to advance bioinformatics expertise and to support broader biological sciences research across a network of Australian Universities and Research Institutes.

The choice of VLSCI to host BRAEMBL is an acknowledgement of the expertise and infrastructure dedicated to life sciences computing in Victoria. In another demonstration of the level of expertise that has been built up in Victoria, A/Prof. Andrew Lonie, Head of the LSCC, has been appointed as the Director of BRAEMBL.

This new agreement involves a network of service providers at nodes in Queensland (QCIF), New South Wales, (The University of Sydney Schools of Biological Sciences and Medicine), Western Australia (Centre of Excellence in Plant Biology), Adelaide, (University of Adelaide, Flinders University and SAHMRI) and Tasmania (Menzies Research Institute). Each node will provide local training and researcher support, plus bioinformatics tools and platform access, modelled on the successful services delivered by VLSCI over the past five years.

NCRIS funding support has also been indirectly provided to VLSCI for its role in the Research Data Storage Infrastructure (RDSI), the Australian National Data Service (ANDS) and the Genomics Virtual Laboratory (GVL) projects. The amount of indirect funding from NCRIS has increased over time. In 2013 indirect NCRIS funding was around $342,000. This more than doubled to $735,000 in 2014 and is expected to almost double again to $1,244,000 in 2015.

Delivery costs

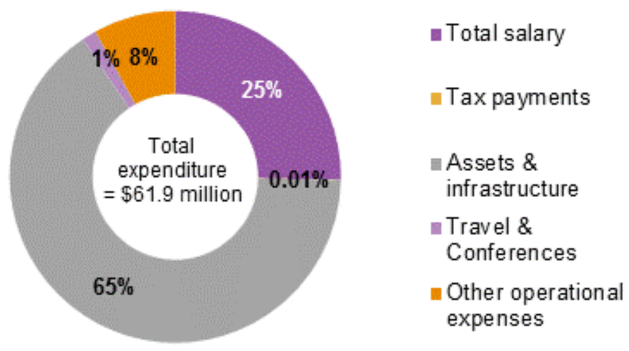
4.2.1 Expenditure by category

Total delivery costs of VLSCI were $61.9 million from 2008 to 2014. The key categories of funding include:

— asset and infrastructure spending of $40.4 million
— salary cost of $15.7 million
— travel and conference spending of $874,592
— tax payments of $6,618
— other operational expenses (services and supplies expense such as student support, utilities and advertising) of $5.0 million. The share of each expense categories are shown in Figure 4.5.

[43] The European Molecular Biology Laboratory (EMBL) is Europe's flagship laboratory for the life sciences. It is at the forefront of innovation in life sciences research, technology development and transfer. It also provides training and services to its scientific community members.

FIGURE 4.5 – **SHARE OF EXPENDITURE BY CATEGORY, 2008 – 2014 (PERCENTAGE)**



Note: Other operational expenses includes services and supplies and student support, utilities and advertising.

SOURCE: 2012 – 2014 VLSCI ANNUAL REPORT, 2008 – 2014 VLSCI FINANCIAL ACCOUNT, AND ACIL ALLEN CONSULTING, 2015.

Spending on assets and infrastructure account for the highest portion of the expenditure, followed by staff salary expenses. This is a reflection of the labour intensive nature of VLSCI's work and its highly valued scientific and computation equipment.

4.2.2 Changes in costs

Figure 4.6 presents the expenditure of VLSCI by cost category between 2008 and 2014. The figure demonstrates that:

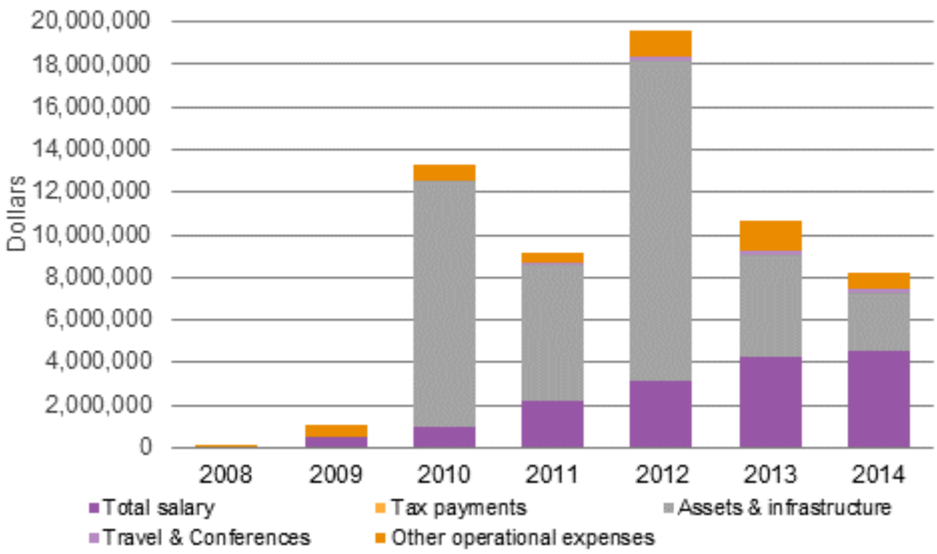
— VLSCI's lowest spending was during 2008-2009. This reflects the gradual development of the Initiative and its acquittal of staffing and physical infrastructure over this early period.

— VLSCI achieved its highest level of operational efficiency in 2014. By operational efficiency we mean the relationship between the contributions made to VLSCI's and expenditure was highest in 2014.

— Salary cost (both in value and as a proportion of total cost) has been following an increasing trend. In contrast, asset/infrastructure costs have been decreasing. This reflects the increased demand for LSCC staff of expert bioinformaticians, which in turn, drives increased demand for professional support from VLSCI's staff using already established infrastructure stock (established over time in earlier years).

— The high asset/infrastructure expenditure in 2012 is due to the $13.6 million PCF expenditure on the fit-out for the BG/Q (as specified in the contract with IBM).

FIGURE 4.6 – **VLSCI EXPENDITURE BY COST CATEGORY, 2008 – 2014 (DOLLARS)**



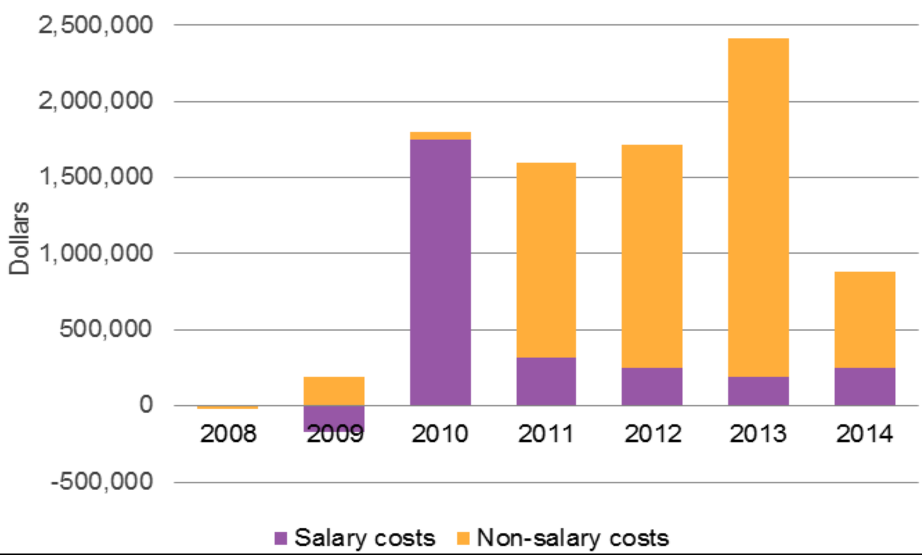
Note: (1) Other operation expense includes services and supplies expense such as student support, utilities and advertising.
(2) VLSCI was established in 2008 and therefore, its expenditure was low in 2008 and 2009 as it was still in the initial stage of developing its staff and capital capacity (thus incurred less cost).

SOURCE: 2012 – 2014 VLSCI ANNUAL REPORT, 2008 – 2014 VLSCI FINANCIAL ACCOUNT, AND ACIL ALLEN CONSULTING, 2015.

As part of this analysis, ACIL Allen also examined the level of variation in VLSCI's costs over the period (broken down by salary and non-salary costs). This variance was compared to the financial targets set for VLSCI between the years 2008 and 2014. We have calculated cost variance as the target minus the actual. This is in contrast to how we have calculated VLSCI's income – i.e. the actual minus the target. The variances were calculated in this way to be consistent with definitions used by VLSCI in its annual reports. In both case of income and costs, positive variance indicates out-performance.

The results of this analysis are shown in Figure 4.7.

FIGURE 4.7 – **VARIANCE OF COSTS (TARGET MINUS ACTUAL), 2008 – 2014 (DOLLARS)**



Note: (1) Note that the costs variance is calculated as the target minus the actual. In contrast, the income variance discussed above was the other way round - the actual minus the target. The variances were deliberately reported this way here to be consistent with the definition in VLSCI's Annual Report. In both case of income and costs, positive variance indicates out-performance.
(2) The negative variance in 2008 and 2009 is a result of the absence of target set for these years at the early stage of VLSCI's life.

SOURCE: 2012 – 2014 VLSCI ANNUAL REPORT, 2008 – 2014 VLSCI FINANCIAL ACCOUNT, AND ACIL ALLEN CONSULTING, 2015.

The analysis of cost variance shows:

- Negative variance between 2008 and 2009. This was largely due to funding not being received by the University of Melbourne for the first two years of VLSCI's operations.
- Positive variance between 2011 and 2014. There are a number of possible reasons for this. For example, that during this period VLSCI incurred lower costs than it budgeted for, that VLSCI set very conservative budgets or that they achieved savings.

Delivery arrangements

4.3.1 Governance arrangements (2008-2014)

The 2008 Funding Agreement between the Victorian Government and the University of Melbourne identifies how the parties will work together to facilitate the installation of the 'most powerful peak computing facility dedicated to life sciences research in the work and a centre of expertise to support users of the facility'. [44] The Agreement sets the high level framework of rules and practices which ensured VLSCI was accountable to its stakeholders and the broader research community.

Under the Agreement, the prime responsibility for VLSCI rested with the University of Melbourne, through its Delegate, the Deputy Vice Chancellor (Research) (DVC(R)). Through the Delegate the University of Melbourne was required to develop a Business Plan which outlined the Initiative's governance and operational arrangements. The Business Plan was to be approved by the Department (and revised annually) before funds could be committed by the Initiative.

> *The University shall ensure that it submits to the Department… the Business Plan for the Project which shall contain, but not be limited to…*
>
> - *The milestones, key performance indicators and associated targets and dates by which the progress of the Project is to be measured*
> - *Cash flow projections and anticipated withdrawals of the Grant from the Trust Account for all stages of the Project*
> - *The proposed allocation of funds to the activities in the Project in the financial year*
> - *The reports to be submitted*
> - *Accessibility to the PCF by third parties*
> - *Risk management plan*
> - *Evaluation plan*
> - *Project governance arrangements*
> - *Any other proposed investors or partners*
> - *Procurement approach and asset management plan*
> - *Sustainability plan for the Project beyond the Grant period*
> - *Any other matters that the Department may reasonably require to be included.*
>
> *(Section 6.1)*

The Business Plan provided detailed information about the elements of VLSCI's governance and operational framework as outlined in Figure 4.8 below. The Business Plan was developed and revised during the period of the Funding Agreement using the University of Melbourne's internal practices and policies.

VLSCI's committees (2008-2014)

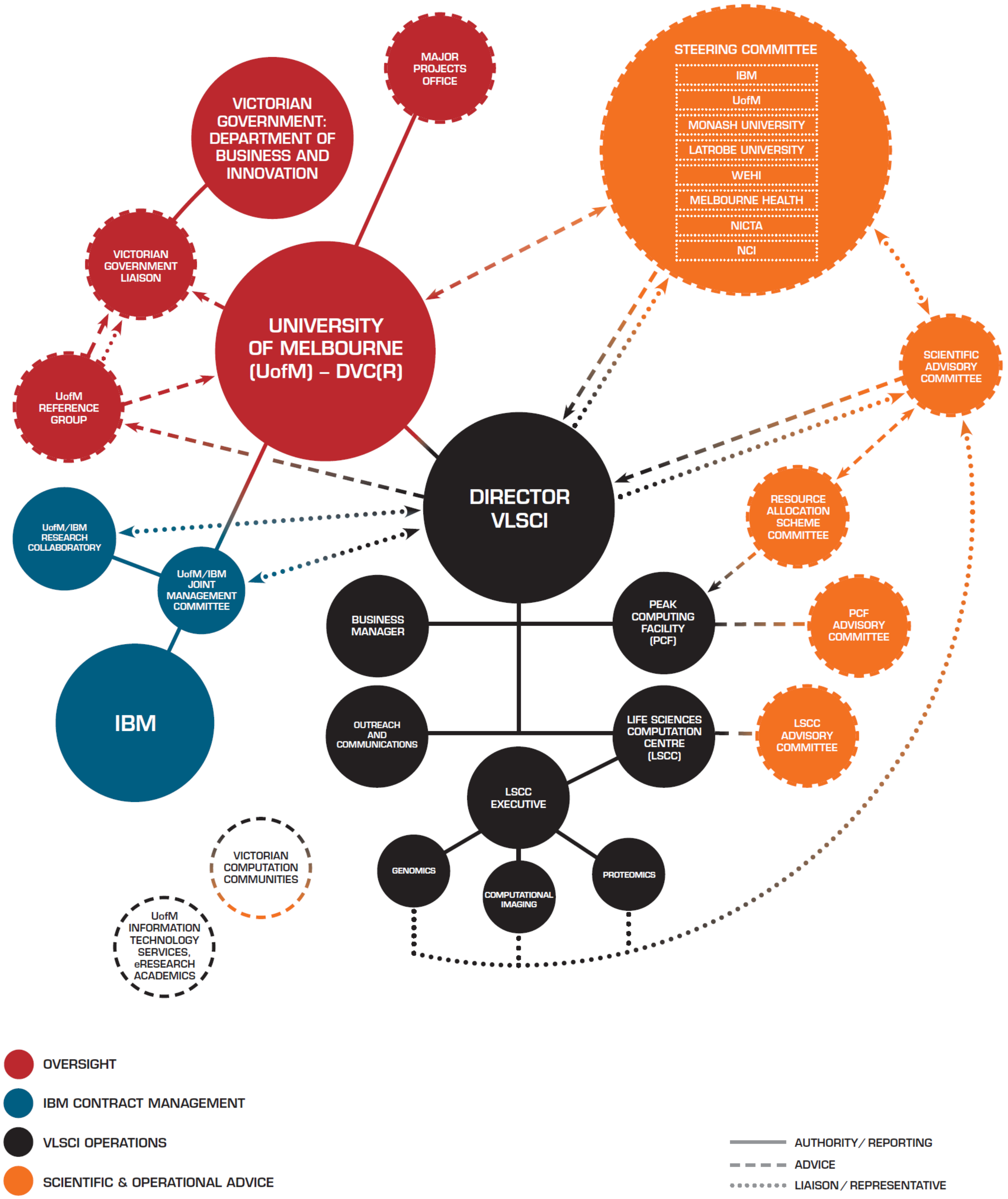
Between 2008 and 2014 a number of governance, advisory and operational committees provided strategic and operational advice to VLSCI. The main committees were:

- *VLSCI Steering Committee.* The Committee provided advice on the overall Initiative especially with its strategies, policies and performance of VLSCI. It reports directly to the DVC(R).
- *VLSCI Resource Allocation Committee.* The Committee's role was to review applications and make recommendations for grant funding.

[44] VLSCI Funding Agreement (2008), C – Background/recitals.

— *VLSCI Scientific Advisory Committee.* The Committee's role was responsible for responsible for making recommendations to the VLSCI Steering Committee and the VLSCI Director on matters of science and computing technology.
— *LSCC Advisory Committee*. The Committee was responsible for making decisions and recommendations to the parties in relation to LSCC resource allocation.
— *PCF Advisory Committee*. The Committee comprised active users on the machines in the PCF who provided feedback about the user experience and advice to the PCF Manager on the operations and performance of the PCF.
— *Sustainability Subgroup.* The Subgroup comprised nominated representatives of the VLSCI Steering Committee. The Committee is convened at the request of the Steering Committee to consider specific matters that may require further examination or consideration.

FIGURE 4.8 – **VLSCI'S GOVERNANCE AND OPERATIONAL FRAMEWORK (2008-2014)**



SOURCE: INTERNAL DOCUMENTS PROVIDED BY VLSCI, AS AT INCEPTION OF VLSCI

A key feature of the committee structure is the level of representation given to a broad range of stakeholders. Additional information about the membership (and responsibilities) of each committee is provided in Table 4.1.

TABLE 4.1 –**VLSCI ADVISORY COMMITTEES 2008-2014**

Committee	Membership	General responsibilities	Specific responsibilities
VLSCI Steering Committee	University of Melbourne (2 nominees) Parkville Precinct Organisations (2 nominees) Monash University (2 nominees) La Trobe University NCRIS National Computational Infrastructure Committee Chair – appointed by University of Melbourne VLSCI Director UoM (2 nominees)	Responsible for making recommendations and providing strategic advice to the University of Melbourne in relation to implementation of the Initiative. Endeavoured to apply and achieve the highest possible standards of corporate governance The authority devolved to the VLSCI Steering Committee by the parties lies with the VLSCI Steering Committee itself, and not with any individual VLSCI Steering Committee member	Responsible for reviewing and advising UoM through the DVC(R) on: – policies and processes for organisations to participate with University of Melbourne in the Initiative – the contributions and resources from University of Melbourne and other parties to the Initiative; – the Annual Business Plan, including the financial plan; – the overall activities and performance of the Initiative – the Reports required by Government and other parties – key policies, procedures and arrangements for researchers to access the Initiative facilities – the continuation of the Initiative after the end of its initial five year term
VLSCI Resource Allocation Committee	Chair – Australian National University Monash University (2 representatives) Department of Primary Industries, Victoria, UoM (2 representatives) Florey Neuroscience Institutes Walter & Eliza Hall Institute LaTrobe University Deakin University RMIT University Bureau of Meteorology University of Qld (2)	Reviewed applications and determines grants using criteria following those used by the Merit Allocation Scheme of the NCI National Facility	Met by December each year to consider the applications and determine the grants for the following year. It also met mid-year in response to a mid-year calls for applications

Committee	Membership	General responsibilities	Specific responsibilities
VLSCI Scientific Advisory Committee	Dean of Science or their nominee – Chair Members will serve for three years. Following the establishment of the initial membership, subsequent members will be chosen by the Chair in consultation with the VLSCI Steering Committee, the DVC(R) and the VLSCI Director E.g., 16 members from 13 different national and international research organisations were members in 2010	The SAC was an advisory body responsible for making recommendations to the VLSCI Steering Committee and the VLSCI Director on matters of science and computing technology	– Reviewed and commented on the Initiative's LSCC proposed cardinal projects and activities, thereby assisting the LSCC – Decided which projects should be supported – Advised on national and international engagement – Commented on the viability of the science either currently underway, or possibly under consideration by the RAS Committee – Assisted with the strategic positioning of VLSCI in relation to the National frameworks
LSCC Advisory Committee	LSCC Head the VLSCI Director each Theme Leader one member of the VLSCI Steering Committee as selected by the VLSCI Director one member of the VLSCI Scientific Advisory Committee	Responsible for making decisions and recommendations to the parties in relation to LSCC resource allocation The Committee endeavoured to apply and achieve the highest possible standards of corporate governance. The LSCC Advisory Committee should act in a manner based on transparency, accountability and responsibility The authority devolved to the LSCC Advisory Committee by the parties lies with the LSCC Advisory Committee itself, and not with any individual LSCC Advisory Committee member	The parties agree that the LSCC Advisory Committee is responsible for resource allocation through: – selection of LSCC Approved Activities, including Project selection and approval of Project Plans – varying Projects – making decisions regarding any matters that the parties refer to the LSCC Advisory Committee
PCF Advisory Committee	PCF Manager (Chair) + 6 representatives from research schools, institute etc.	The Committee comprised active users on the machines in the PCF who provide feedback about the user experience and advice to the PCF Manager on the operations and performance of the PCF	Not applicable
Sustainability Subgroup	Chair, VLSCI Steering Committee + 5 other members	To consider the longer term sustainability of VLSCI	Not applicable

SOURCE: ADAPTED FROM VARIOUS INTERNAL DOCUMENTS PROVIDED BY VLSCI FOR THIS REPORT

4.3.2 Governance arrangements (2015 – onwards)

During 2015, VLSCI's governance arrangements were revised to reflect the new Funding Agreement signed between University of Melbourne and the Victorian Government in 2014. Information about each committee is shown in Table 4.2.

TABLE 4.2 – **VLSCI'S COMMITTEE STRUCTURE FROM 2015 ONWARDS**

Committee	Membership	Role
University Life Sciences Steering Group	– DVC(R) or nominee – Deans from the facilities of: Medicine, Science and Engineering or nominees – Representative of University of Melbourne's ICT capabilities – Representative of VLSCI	– To provide strategic oversight of HPC investments and requirements for the University of Melbourne – To ensure coordination and integration of VLSCI with other HPC initiatives at University of Melbourne
VLSCI Advisory Council (Committee had not convened at the time of writing this report)	– Chair – independent – University of Melbourne representative/s – La Trobe University representative – RMIT University representative – Deakin University representative – Victorian Government representative	– To provide non-executive advice VLSCI about the strategic direction of the initiative – To provide representation for the financial contributors of VLSCI
RAS Committee	– As per Table 4.1	– Role remains unchanged (as per Table 4.1)

SOURCE: INFORMATION PROVIDED BY VLSCI

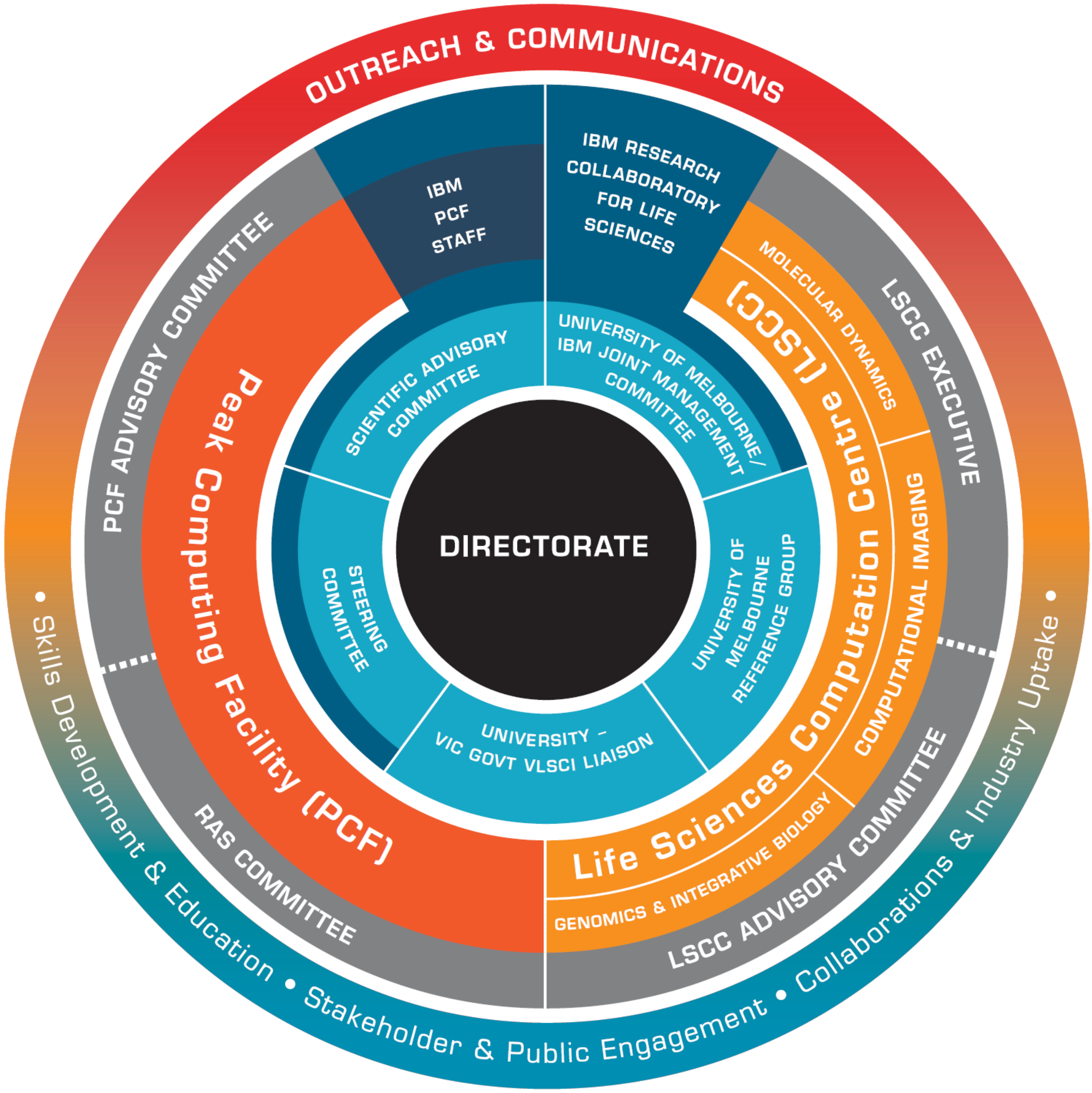
4.3.3 Operational structure

VLSCI's operational structure at the end of 2014 is provided in the Figure 4.9 below. The Initiative's day-to-day operations are overseen by the VLSCI Director who has responsibility for ensuring progress against the Business Plan and the Funding Agreement. The VLSCI Director is supported by a number of managers (or leaders) responsible for the operations of:

— PCF
— LSCC
— VLSCI Communications, Outreach & Skills Development

Staff drawn from across University of Melbourne, IBM and other Victorian Universities support these managers and the VLSCI Director to manage the operational roll out of VLSCI.

FIGURE 4.9 – **VLSCI'S ORGANISATIONAL STRUCTURE (AS AT END 2014)**



Note: This figure provides the organisation structure as at 2014. ACIL Allen acknowledges that there have been some changes to this structure since then.

SOURCE: INFORMATION PROVIDED BY VLSCI

4.3.4 Operational and maintenance processes

Resource allocation processes

The allocation of resources to individual researchers and research projects is a critical activity of VLSCI. The process allocates time on the PCF to applicants using the principles of merit and peer review commonly found in other competitive research funding/resourcing programs.

While these processes have evolved over time, the core of the RAS Committee has remained relatively stable since VLSCI's establishment. As at 2014, the RAS Committee processes include:

— A call for applications to the scheme. This usually occurs through the submission of an application to the scheme by a Chief Investigator. Applications to the Resource Allocation Scheme must be for academic projects and not commercial contracts. This means that the project cannot be work done on behalf of a commercial organisation. Projects that have commercial sponsors, where the computational results are interpreted and value-added for these sponsors, are acceptable. Projects that are for commercial contracts will be considered separately and inquiries need to be made in writing to the PCF Manager. It also means that projects with members outside of Victoria must demonstrate that the main benefits of the project lie within Victoria.
— The evaluation of the applications by the RAS Committee against the evaluation criteria (as outlined below). This process occurs six-monthly and may involve the committee consulting national and international referees on the scientific merit of the application.
— The offer of resource grants on the VLSCI systems under terms and conditions.
— The acceptance of the grants and the terms and conditions of access by Chief Investigators and the host organisation.
— Once a grant is approved for a research project, members are granted logon accounts to access the Peak Computing Facility (PCF).[45]

Evaluation criteria used by the RAS Committee

The following criteria as used by the RAS Committee to evaluate applications for the PCF.

1. Research quality.
   a) Research merit including the potential of the work to generate new knowledge in an important area, the comparative scientific merit of the work within its discipline, originality and international competitiveness.
   b) National benefit and research priorities.
   c) Experience and demonstrated research capacity of the applicant and the project team.
2. Appropriateness of the VLSCI computational resources.
   a) The need for such resources to conduct the research.
   b) Suitability of the system (hardware and software) and its operational environment to support the project.
   c) Evidence or experience to demonstrate that the project will use the facilities efficiently.
3. Reasonableness of the level of resources requested.
   a) Relative to the total amount available.
   b) Needed to make adequate progress in the proposed research program.
4. Track record of the applicant in using the VLSCI facilities where relevant.
   a) In the case of proposals to continue a project, the record of achievement and efficient use of previous allocations.[46]

Maintenance of the PCF

Maintenance of the PCF is a significant activity of VLSCI. Maintenance is managed through a formal maintenance agreement between the University of Melbourne and IBM and overseen (between 2008 and 2014) by the University of Melbourne – IBM Joint Management Committee. These maintenance activities include software and hardware maintenance to ensure the capability is available to users on an ongoing basis. Reported down time for the PCF is provided in some annual reports. The reports shows that there are low levels of down time (especially for maintenance) and high response rates to customer queries and problems with the PCF's hardware.

The maker of the BG/Q (IBM) is no longer building supercomputers. The current maintenance contract with IBM expires at the end of 2016. It should be possible to obtain a service contract from the firm that has taken over from them (Lenovo). However, as any supercomputer, like the BG/Q, ages it becomes increasingly expensive to maintain. Hence maintenance contracts may become too expensive over time.

[45] https://www.vlsci.org.au/ras-process
[46] https://www.vlsci.org.au/ras-process

Effectiveness of delivery arrangements

4.4.1 Governance and operational structures

The governance and operational structures used by VLSCI between 2008 and 2014 reflected the represented nature of VLSCI and the structure of the Funding Agreement. Some stakeholders consulted for this project raised concerns that the governance and operation committee structure in operation during this period was overly complex and required simplification. For example, one former long running and senior VLSCI committee member noted:

> *The VLSCI committee structure, in my opinion, was cumbersome. There were too many levels of committee, and too many decision makers involved in the Initiative.*

In ACIL Allen's view the revised governance arrangements established in 2015 to support the new Funding Agreement address the concerns of stakeholders about the complexity of VLSCI's governance arrangements. These revised arrangements provide a streamlined set of governance arrangements that support the future needs of VLSCI.

4.4.2 Operational practices and processes

The University of Melbourne's policies, practices and procedures guide the day-to-day operations of VLSCI. It is ACIL Allen's view that this this is the most efficient, effective and appropriate approach for VLSCI to have adopted. It is also our view that the use of University of Melbourne processes and procedures has prevented considerable duplication of effort in the design (and ongoing refinement) of practices and processes by the Initiative.

4.4.3 RAS processes and outcomes

A number of senior research leaders were consulted for this project. Each of these research leaders had considerable experience in applying for VLSCI allocations through the RAS Committee. A common feature of these consultations was the high degree of satisfaction with the current processes used to allocate resources for individual projects. All of these stakeholders reported that RAS Committee processes (and the criteria used to determine allocations) were generally appropriate for VLSCI and meets the needs of most applicants consulted for this project. For example, one stakeholder commented:

> *Time allocation has worked well for the researchers who use VLSCI. This is because it [time allocation] has been managed by a committee with expert representatives who have the knowledge to manage resources appropriately. I think the inclusion of representatives from outside the University of Melbourne, in particular, has been an important way of ensuring projects are allocated on a merit basis.*

One possible area for improvement that was identified by a small selection of users involves the application of criteria to highly experienced (and well-known) applicants. These applicants identified a strong preference to implement 'light touch' application processes, which acknowledge the track record of a small selection of highly established researchers seeking to continue existing research projects. For example, one stakeholder noted during consultations, that the:

> *Current allocation processes are fine and meet the needs of most users. However, I do feel there is a case for streamlining the allocation process for existing users with significant track records of delivering research through VLSCI allocations. It seems pointless to use researcher and VLSCI resources to submit/assess applications that have a high degree or merit and will support world class research.*

This approach would reduce the application burden on highly productive/successful researchers during the application phase, and more accurately reflect the likely outcomes from the application process for these researchers.

4.4.4 Implementation milestones

The milestones achieved by VLSCI are provided in Table 4.3. Analysis of these milestones provide a means of demonstrating VLSCI's overall effectiveness and ability to deliver against its formal plans/agreements and the documented priorities of the Initiative.

Table 4.3 shows the large majority of these milestones were delivered in accordance with VLSCI's Business Plan and Funding Agreement – which are the key strategic and operational documents underpinning the Initiative. This is important for demonstrating the high level of connectivity between the milestone achievements of VLSCI and the formal plans and documented priorities of the Initiative.

TABLE 4.3 – **IMPLEMENTATION MILESTONES**

Timing	Milestone reached (as published on the website)	Delivered in accordance with the Business Plan or Funding Agreement
2008		
June	Victorian Premier John Brumby announces the $100 million Victorian Life Sciences Computation Initiative, including $50 million in State funding for peak computing infrastructure at the BIO2008 conference in California on 17 June 2008	N/A
September	Key Victorian Universities and research institutions across Victoria briefed about the project	N/A
2009		
	Business Plan developed in consultation with potential partners such as Monash and La Trobe Universities, the Victorian Partnership for Advanced Computing (VPAC), the Victorian eResearch Strategic Initiative (VeRSI), Ludwig Institute for Cancer Research, Howard Florey Institute, Peter MacCallum Cancer Centre, and St Vincent's Institute	Yes – developed in accordance with the Funding Agreement, however the plan not approved by Government until 2010
November	Call made for a Key Partner to help deliver the Life Sciences Computation Centre (LSCC) and Peak Computing Facility (PCF)	Yes – outlined in the Business Plan
November	Twenty early-stage projects were selected from researchers at The University of Melbourne, Monash University, VPAC, VeRSI, NICTA and WEHI	Yes – referred to in the Business Plan
November	Six postgraduate students sponsored to attend Supercomputing Conference (SC09)	Not mentioned
December	First call for Resource Allocation Grant Scheme	Yes – timeframes outlined in accordance with the Business Plan
December	Announcement of postgraduate intern program developed in association with Australian Mathematical Sciences Institute	Not mentioned
2010		
February	IBM becomes the Key Partner and included in the agreement is the establishment of the first IBM Research Collaboratory for Life Sciences at VLSCI along with the provision of an IBM Blue Gene/P (BG/P) supercomputer and an IBM iDataplex x86 system. SGI were awarded a contract to provide an SGI Altix x86 system for the PCF also	Yes – identified in the Business Plan
March	SGI Altix x86 goes live. Professor Peter Taylor appointed as Director. Professor Justin Zobel appointed as Interim Director until Professor Taylor's arrival in September	Yes – identified in the Business Plan
April	Key IBM technical staff start work at VLSCI, joining growing staff in PCF	
May	Second call for Resource Allocation Scheme, with accompanying information sessions run at major Universities	Yes – timeframes outlined in accordance with the Business Plan
July	Undergraduate Research Opportunities Program UROP) Conference Day, includes presentations by eight VLSCI-supported students working in a biomedical research laboratory on current bioinformatics projects	Not mentioned

Timing	Milestone reached (as published on the website)	Delivered in accordance with the Business Plan or Funding Agreement
August	BG/P goes live. Launch event held on August 10 featured the Victorian Premier, John Brumby, Minister for Innovation, Gavin Jennings, UOM Vice Chancellor Glyn Davis and Senior US and Australian IBM personnel	Yes – outlined in the Business Plan
August	IBM host a workshop: High performance computing: Thinking big! From desktop to supercomputer: Enabling scientific computing	Not mentioned
September	IBM Dataplex x86 goes live. Stage 1 completed	Yes – timeframes outlined in accordance with the Business Plan
November	Six postgraduate students sponsored to attend Supercomputing Conference (SC10)	Yes – outlined in the Business Plan
November	Data storage facilities fully implemented	Yes – outlined in the Business Plan
December	A/Prof. Andrew Lonie appointed as Head, LSCC	Yes – outlined in the Business Plan
2011		
March	LSCC officially opens for business	Yes – outlined in the Business Plan
March	Annual Report notes in-kind contributions far in excess of budget	Yes – exceeds information stipulated in the Business Plan
May	VLSCI announces three-year sponsorship of Bio21 Cluster's UROP program	Yes – in accordance with the Business Plan
June	Launch of VLSCI Exhibition and video – Things Change When You've Got the Power	Not mentioned
July	New bioinformaticians start arriving at LSCC	Not mentioned
October	Resource Allocation Scheme oversubscribed for 2012	Yes
November	VLSCI announces Ph.D. top-ups, travel and conference grants and releases new story on cancer research in the Science Stories series. November – new video released, High Performance Computing Reveals New Drug Targets. Six students supported to attend SC11 in Seattle	Yes – in accordance with the Business Plan
December	5 LSCC and 3 IBM summer interns arrive	Yes – identified in the Business Plan
2012		
February	Announcement of decision to proceed to Stage 2 and purchase IBM BG/Q supercomputer	N/A
March	LSCC Expressions of Interest attract projects from across the Victorian research community	N/A
May-July	Over May/July, PCF installs four racks of BG/Q supercomputer as part of the Stage 2 upgrade, delivering petascale computing for Life Science researchers in Victoria. The upgrade also included other add-ons to existing systems	Yes – identified in the Business Plan
July	VLSCI is the biggest supercomputer facility in Australia, the largest in the world devoted to life sciences research and the BG/Q ranks as the greenest supercomputer in the world	Yes – identified in the Business Plan
2013 - onwards		
2013-15	VLSCI achieved all the objectives set out for its first five years of operation. The initial grant was formally completed on 31 December 2014. The IBM Research Collaboratory for Life Sciences also formally ended with staff from that team moving across to IBM Research Australia. In October 2014 VLSCI secured further funding for 2015/16 to continue to provide resources and support for Victorian research. From 2015 work will be focussed on extending service offerings across Australia and beyond in a range of projects and collaborations	Yes – all primary objectives met by VLSCI

SOURCE: BASED ON INFORMATION PUBLISHED ON THE VLSCI WEBSITE

Efficiency of operations

4.5.1 VLSCI

As part of this evaluation, ACIL Allen considered the level of operational efficiency achieved by VLSCI over the review period. Using indicators of financial performance, ACIL Allen compared the total expenses to total income (using all categories of income and expense discussed above) to identify operating surpluses over the period 2008 to 2014. The results of this analysis show that VLSCI has exceeded its financial targets over the period.

Based on this, ACIL Allen believes VLSCI has operated efficiently and achieved the financial targets set for the initiative.

4.5.2 Overhead costs

The staff overhead costs for VLSCI are met by the University of Melbourne as part of their contribution. These costs are determined in the standard way by the university. Hence, ACIL Allen has not conducted any analysis of these costs as they have no impact on the use of resources under the funding agreement.

4.5.3 Opportunities to generate efficiencies in the future

This chapter has considered the operational efficiency of VLSCI since its establishment. It suggests that VLSCI has demonstrated a trend towards improved operational efficiency over time, even though many of the overhead and running costs are absorbed by the University of Melbourne as part of its contribution to VLSCI, and these costs are not a significant burden on the Initiative.

While operational efficiency is not considered to be a significant issue for VLSCI, one area of future improvement will rest with its governance and operational committee structure. We note that the committee structure (as outlined in Table 4.2) that has been proposed for 2015 is a more streamlined set of arrangements that should generate operational efficiencies over time. It is ACIL Allen's view that these arrangements will be less resource intensive than the previous committee structure, and require less staff time to manage in the future.

Key findings

This chapter has considered aspects relating to the funding, delivery and efficiency of VLSCI. Our analysis has shown that:

— Between 2008 and 2014 VLSCI received approximately $130 million in funding and in-kind contributions from the Victorian Government, the University of Melbourne, other Victorian Universities and other grant/project income. Cash was the largest component of contributions over the period 2008 to 2014 (56.4 percent of total contributions). In-kind support accounted for the remainder (43.5 percent).

— During this period from 2008 to 2014, subscriptions paid to the LSCC rose to $2 million. The VLSCI has also been successful in attracting indirect funding from NCRIS over this time. In 2013 indirect NCRIS funding was around $342,000. This more than doubled to $735,000 in 2014 and is expected to almost double again to $1,244,000 in 2015.

— Between 2008 and 2014 approximately 90 percent of VLSCI's expenditure was on assets/infrastructure and salaries. This expenditure is consistent with their Business Plan as agreed by the Government.

— VLSCI's governance arrangements reflected the range of institutions who had an interest in the Initiative. Between 2008 and 2014, VLSCI had in place a committee system that some stakeholders consulted during this project identified as being overly complex. The committee system established during 2015 should address many of these concerns.

This chapter has identified stakeholder support for the practices and processes underpinning VLSCI's operations, and identified the improvements made to its operating efficiency since 2008.

5

RISK

This chapter considers the following question: What would be the impact of ceasing the VLSCI and what strategies have been identified to minimise negative impacts?

Possible future scenarios

During the course of this evaluation, ACIL Allen has identified three high level funding and operational scenarios, as shown in Table 5.1. The scenarios are provided at minimal, medium and maximal levels and consider the likelihood that each scenario might eventuate over the next five years.

The scenarios are based on the outcomes from stakeholder consultations. It is important to note that the scenarios have not been tested with stakeholders.

The details of each scenario are outlined in Table 5.1. One future scenario for VLSCI will be one which in which VLSCI attracts little or no Victorian Government funding.

Potential future risks

Based on the scenarios outlined in section 5.1 the potential risks facing VLSCI are assessed in this section of the report. The risks were identified following a review of internal documentation and the consultations undertaken for this project. The risks were assessed against the criteria found in VLSCI's risk plans and sustainability reports.

5.2.1 Assessment Framework

The risks are categorised as:

- Financial risks – which encompass the financial viability and cost-based risks to the Initiative.
- Reputational risks – which encompass the user uptake, user satisfaction and project implementation risks to the Initiative
- Workforce risks – which encompass staffing and skills development risks associated with the Initiative.

The likelihood and consequences of these risks were assessed (qualitatively) using a standard classification system of:

- Likelihood:
  - Almost certain – Expected to occur in most cases
  - Likely – Probably occur in some cases
  - Possible – Might occur at some time

  - Unlikely – Could occur, but infrequently
  - Rare – Only likely to occur in exceptional circumstances
- Consequences:
  - Insignificant – Little or no impact on VLSCI
  - Minor – Minimal impact on VLSCI
  - Moderate – Some potential impact on VLSCI
  - Major – Serious potential impact on VLSCI
  - Catastrophic – Real risk of failure.

TABLE 5.1 – **SELECTED SCENARIOS FOR VLSCI'S FUTURE**

Scenario	Details	Likelihood of occurring
Ongoing Victorian Government Funding provided to VLSCI	Under this scenario, VLSCI would continue to receive Government funding for PCF infrastructure (including any necessary upgrades to ensure the operational relevance of hardware is operationally relevant) until 2020. This funding would also include an allocation for salaries and wages however, this support would be lower than provided under previous funding arrangements, in recognition that VLSCI's non-government contributions are growing. Under this scenario, VLSCI would improve access to non-Victorian researchers/institutions in order to attract other funding revenues. However, the level of accessibility would be limited to reflect the Victorian Government's financial contribution and the desire to support Victorian-based research activity	Low: Victorian Government has already articulated the need for VLSCI to seek increased levels of non-Government funding following the completion of the current Funding Agreement in 2016
A mix of Victorian Government and external funding for VLSCI	Under this scenario VLSCI would receive a reduced level of funding (to support hardware and infrastructure upgrades) from the Victorian Government, but would not receive any other funding for salaries, outreach etc. Under this scenario VLSCI would be required to secure an increased level of non-Government funding to support any funding shortfalls (for either infrastructure or salaries) experienced. Support could come from the Federal Government, other universities, private sector or international partners. This would also make VLSCI completely accessible to non-Victorian researchers/institutions who meet the funding or merit criteria	Medium: Victorian Government has already articulated the need for VLSCI to seek increased levels of non-Government funding following the completion of the current Funding Agreement in 2016. VLSCI has commenced planning for this scenario through the Sustainability Subgroup
No Victorian Government funding for VLSCI	Under this scenario all of VLSCI's funding would be derived from non-Victorian Government sources. VLSCI would be free to pursue any strategic funding opportunities that are identified by the University of Melbourne. Under this scenario the University of Melbourne would assume full responsibility for VLSCI's governance and operations – subject to agreement by major funding partners – and introduce any funding/subscription models which supported the needs of partners. Under this scenario the VLSCI's offering is likely to be scaled back to an LSCC-style support and advisory service; it would not be responsible for directly providing hardware and physical supercomputing infrastructure	High: Victorian Government has indicated that funding could be withdrawn permanently

SOURCE: ACIL ALLEN

Using this classification system, risks are given a magnitude rating as shown in Figure 5.1.

FIGURE 5.1 **MAGNITUDE OF RISKS**

	Consequence				
Likelihood	***Catastrophic***	***Major***	***Moderate***	***Minor***	***Insignificant***
Almost Certain	Extreme	Extreme	Extreme	High	High
Likely	Extreme	Extreme	High	High	Medium
Possible	Extreme	Extreme	High	Medium	Low
Unlikely	Extreme	High	Medium	Low	Low
Rare	High	High	Medium	Low	Low

Extreme	Immediate action required
High	Senior management attention needed
Medium	management responsibility must be specified
Low	manage by routine procedures

SOURCE: ACIL ALLEN

5.2.2 Assessment of risks (by scenario)

The results of a high level risk analysis using the classification system outlined above are provided in Table 5.2. It is important to note that these are indicative risks. They do not necessarily represent the full range of risks facing VLSCI, as this would require a dedicated risk assessment and planning exercise to be undertaken for the project.

TABLE 5.2 – **POTENTIAL RISKS ASSOCIATED WITH EACH SCENARIO**

Risk	Area of impact	Likelihood	Impact	Risk rating
Ongoing Victorian Government Funding provided to VLSCI				
Funding provided by the Victorian Government is insufficient to support capital investment in infrastructure and the ongoing operation and management of VLSCI	Financial	Almost certain	Catastrophic	Extreme
The conditions of any Victorian Government funding provided continue to exclude non-Victorian based organisations for accessing VLSCI	Financial	Likely	Major	Extreme
Victorian Government funding crowds out / provides a disincentive for VLSCI to find external revenue sources to support its longer term sustainability	Financial & reputational	Unlikely	Catastrophic	Extreme
Users choose to use other (perhaps more relevant) HPCs or platforms to undertake research – i.e. the platform's functionality and utility becomes outdated – and the benefits of Government's additional investment are not fully realised	Reputational	Unlikely	Minor	Low
A mix of Victorian Government and external funding for VLSCI				
Funding provided by the Victorian Government is insufficient to support infrastructure and ongoing operation and management of VLSCI	Financial	Likely	Moderate	High
Stakeholder contributions do not reach expected levels to support capital investment in	Financial	Likely	Moderate	High

Risk	Area of impact	Likelihood	Impact	Risk rating
infrastructure and ongoing operation and management of VLSCI				
Financial viability of the Initiative highly uncertain discouraging researcher demand for PCF and LSCC – i.e. researchers do not commit to significant projects due to uncertainty	Reputational	Possible	Minor	Medium
VLSCI supports research based on the financial contributions of partner organisations and not the merits of the research project/application	Reputational	Possible	Minor	Medium
Key staff and skills leave VLSCI and built up expertise no longer available to users/financial contributors	Reputational & workforce	Likely	Major	High
Users choose to use other (perhaps more relevant) HPCs or platforms to undertake research – i.e. the platform's functionality and utility becomes outdated – and the benefits of Government's additional investment are not fully realised	Reputational	Unlikely	Minor	Low
No Victorian Government funding for VLSCI				
Stakeholder contributions do not reach expected levels to support capital investment in infrastructure and ongoing operation and management of VLSCI	Financial & workforce	Likely	Catastrophic	Extreme
Key staff and skills leave VLSCI and built up expertise no longer available to users/financial contributors – i.e. researchers require access to the hardware and support/expertise in order to see benefit in VLSCI	Reputational & workforce	Likely	Major	High
Cut down or smaller scale version of VLSCI not considered useful by researchers	Reputational	Likely	Major	Extreme
VLSCI ceases operations and capability is lost for Victoria	Reputational	Possible	Major	Extreme

SOURCE: ACIL ALLEN

The analysis in Table 5.2 shows that there are significant future risks facing the VLSCI – under each of the scenarios. It shows that the nature and scale of support from the Victorian Government will be critical to VLSCI's sustainability. However, the Victorian Government has indicated that it is highly unlikely to provide the funding required to support VLSCI's current functions or investment needed to upgrade its hardware to deliver next-generation HPC capabilities.

The table also highlights the risks associated with relying on contribution and subscription models. A number of stakeholders consulted during this project identified the difficulties faced by other HPCs in securing subscription fees at the levels that are sufficient to support a world-class HPC capability.

From the analysis in Table 5.1 it is clear that scenario number two (a mix of Victorian Government and external funding for VLSCI) offers the lowest potential risks for VLSCI in the future out of the three scenarios identified here. In most cases we would recommend that VLSCI pursues the strategies which reduce the risks associated with this scenario. However, given the indications from Victorian Government regarding the likelihood of any future funding for VLSCI, the risks associated with scenario three (no Victorian Government funding for VLSCI) should also be considered in more detail.

Strategies for mitigating risks

It will be important for VLSCI to pursue strategies which mitigate the risks associated with the future scenarios discussed above. A review of VLSCI's internal risk management documentation and sustainability plans demonstrates that significant amounts of relevant analysis have already been undertaken by the Initiative.

In April 2013, VLSCI submitted a *Final Sustainability Plan* which identified ten key strategic initiatives aimed at delivering sustainability beyond the 2008-2014 Funding Agreement. Most of the initiatives identified in this Plan are highly relevant to the strategies that are necessary to mitigate VLSCI's future risks under scenarios two and three. The initiatives identified in VLSCI's Sustainability Plan are shown in Box 5.1

BOX 5.1 – **STRATEGIES FOR MITIGATING FUTURE RISKS OUTLINED IN VLSCI'S 2013-14 SUSTAINABILITY PLAN**

Initiative 1: Determine ongoing operational funding requirements - The determination of accurate funding requirements will result in improvements to efficiency and transparency in VLSCI's ongoing operations. By identifying where operational efficiency gains and optimisation can be made, the overall cost base will be reduced using a 'Zero Budget' approach and by clearly articulating the ongoing operational funding requirements.

Initiative 2. Reposition the service offering - Repositioning of the service offering to broaden the target market provides access to a wider pool of funding and attracts more researchers to the facility, thus increasing funding. The implications of taking a broader definition of 'Life Sciences' will inform the establishment of a clear target market in terms of the breadth (where we can service) and depth (what research we can service) that aligns with VLSCI's capabilities. New services and/or existing services will be identified that align with the new operational model.

Initiative 3. Revise the approach to customer satisfaction - Consistent and relevant metrics that measure performance and success of the facility will improve service delivery. Management and stakeholders will be informed of the impact of service delivery and potential areas to improve service delivery by a range of activities.

Initiative 4. Develop a more detailed plan of engagement with potential funding sources - The identification of key funding stakeholders, based upon the preferred services access model, will inform the development of an engagement strategy to demonstrate value and secure funding.

Initiative 5. Develop business case to secure transition funding - This project will develop a business case to secure additional funding from Victorian Government to transition the VLSCI to a new sustainable model. Securing short term funding to meet operational expenditure during the transition to a long term sustainable model will rely on the development of a compelling business case for additional funds.

Initiative 6. Prepare the case for additional capital investment - A business plan will be developed to secure new funding from Federal and Victorian Governments and Partner(s) to upgrade the facilities to meet additional demand. Attracting infrastructure funding to upgrade the computational facilities as required ensures the facility remains current and internationally competitive, and additional capabilities provide further room for growth.

Initiative 7. Finalise governance structure under new operational model - A new service access model and new funding requires the development of a governance model that provides transparency and accountability for stakeholders. Strengthening the decision making process and realigning governance to meet the new operational approach will provide improved decision making timelines, clear lines of accountability and improved transparency for stakeholders.

Initiative 8. Implement refined communications plan on service offering - Customer engagement will demonstrate the value proposition of the VLSCI to existing and potential customers, and introduce and clarify the new model of operation. An important part of the new communication plan is to assist researchers to secure grant funding under the new funding model. Preparing VLSCI's existing customers for the change in operational model will result in a smoother transition, and winning new customers ensures new users are secured for the facility.

Initiative 9. Implement the revised governance structure - Transitioning to the new governance structure to align with new funding sources and a new model of operation will result in operational efficiency and improved decision making capability, allowing VLSCI to demonstrate value add to new funding sources.

Initiative 10. Conduct business development activities - In order to ensure ongoing operational expenditure is met and grow VLSCI's customer base, this initiative describes activities to secure further funding. Engaging with lobbyists and State and Federal Government to secure further core funding, and potential partner organisations to secure funding contributions will be complemented by a brand awareness campaign and roadshow to inform stakeholders of facility capabilities to become a national resource.

SOURCE: FINAL SUSTAINABILITY PLAN (2013-2014)

The initiatives outlined in Box 5.1 are built on various sub-plans, strategies and business cases that address the financial and reputational risks facing VLSCI in the future. The initiatives also include a set of well-articulated strategies that seek to simplify the VLSCI's operations, while providing more targeted and meaningful services to researchers.

In ACIL Allen's view the initiatives outlined in the *Sustainability Plan* (with the exception of Initiative 5 – Develop business case to secure transition funding – which relates to the expiration of the First Funding Agreement) provide a sound basis for pursuing risk mitigation. The initiatives should be integrated into any future strategies developed by VLSCI.

During the course of this evaluation, stakeholders have identified a range of mitigation strategies that can support VLSCI's transition to a national facility with an international profile. These strategies include:

- Identify and then secure a strategic funding partner (i.e. another State Government or non-Victorian universities)
- Become a NCRIS funded facility – i.e. national facility
- Attract overseas funding / support, Asia-Pacific, Europe, North America
- Move to a 'fee for service' type model
- Adjust or reduce the scope of service delivery, the capability of the infrastructure, the level of support provided to users, and or education & training and outreach activities.

There is a high degree of overlap between the initiatives identified by stakeholders consulted during the course of this project and those initiatives outlined in the VLSCI's *Sustainability Plan*. This leads us to believe that the key issue confronting VLSCI is probably not whether VLSCI can identify and assess its risks, but whether VLSCI can mitigate those risks given the opportunities available to it. Without access to national funding sources (e.g. NCRIS) VLSCI will struggle to continue to deliver world class HPC capabilities at historical levels. In such a situation, VLSCI will need to rationalise its service offering to better align with the funding that can be secured from subscribers and potential partners.

Key findings

This chapter has considered some of the future risks facing VLSCI. In particular, it has examined the dimensions of these risks relevant to the question: *What would be the impact of ceasing the VLSCI and what strategies have been identified to minimise negative impacts?*

The key findings from the chapter are summarised below:

- A likely future scenario will be one in which VLSCI attracts little or no Victorian Government funding. The Victorian Government has clearly articulated its intention to not provide further funding support for VLSCI following the completion of the current Funding Agreement in 2016.
- The future risks facing VLSCI under a scenario where no Victorian Government funding is provided are significant. At a minimum, the loss of Victorian Government funding would require the VLSCI to significantly reduce the LSCC's service offering and scale back its outreach function. At a maximum, VLSCI could be forced to cease its current operations and close the HPC facilities. Cessation of VLSCI is a distinct possibility if sufficient funding cannot be secured by VLSCI before the end of its current funding agreement. If the facility was to close Victoria would most likely experience a permanent loss of a world class research capability, in a growing research field which requires access to HPC facilities.

A number of strategies and initiatives necessary to mitigate the future risks facing VLSCI have already been developed and reported on. Through its *Sustainability Plan* (2013-14) VLSCI has demonstrated an ability to identify and examine business risks and to report on them. VLSCI will need to continue to work hard at addressing all risks facing the initiative and to put in place both the institutional arrangements and strategies that support its ongoing sustainability.

6 CONCLUSIONS

Overall conclusions

This evaluation has found that the Victorian Government's decision to invest in establishing the VLSCI was a sound one. That decision enabled Victorian life science researchers to be at the forefront of an emerging trend towards the use of high powered computing in life sciences research. Many would agree that this was a far sighted decision and that is likely to have been instrumental in Australia increasing its ranking to fourth in the Scientific American's sixth Annual Worldview Scorecard of the Biotechnology sector in 2014.

The facility has been remarkably successful in delivering against all the key performance indicators set for it, in a number of cases well ahead of the specified target dates. It has delivered the vision in the Victorian Government's Biotechnology Strategic Development Plan, namely that Victoria should be "*recognised as one to the world's top five biotechnology locations*".

The research benefits associated with the VLSCI are significant. The number of publications and presentations has risen over the life of the initiative. The average journal impact factor of the publications in which the results of VLSCI-supported research have been published has increased over time, providing a strong indication that the research is both high quality and novel. The amount of funding flowing to Victorian researchers using VLSCI's facilities has also increased significantly over time and the facility's outreach and training program has helped to build the skills and expertise of Victorians in fields that are crucial to life sciences research.

The $50 million invested by the Victorian Government has leveraged about $80 million in additional funding and in-kind contributions from the University of Melbourne and other Victorian universities between 2008 and 2014. The LSCC has been very successful in moving towards a subscription-based model to help fund its operations. By 2014, subscriptions to LSCC totalled around $2 million. The VLSCI has also been successful in attracting indirect funding from NCRIS. The amount of such funding increased from around $342,000 in 2013, to $735,000 in 2014 and it is expected to reach $1,244,000 in 2015.

Subscriptions and indirect funding from national sources of funding for research infrastructure can certainly make a significant contribution towards meeting ongoing operational costs. However, globally there are no examples of computing facilities that have raised the funds required for the significant capital investments needed to upgrade or replace their computing hardware in this way. It would be extremely challenging for VLSCI to do any better in this regard.

The Victorian Government has stated its intention to not provide any further funding support for VLSCI following the completion of the current Funding Agreement in 2016. If this were to occur then it would at best force VLSCI to scale back its activities and at worst, force it to cease its operations. If VLSCI was to shut down then this would represent the loss of world class research support infrastructure, in a research field which is crucial to Australia's future.

The VLSCI's *Sustainability Plan* (2013-14) identifies a number of strategies and initiatives to mitigate future risks such as the lack of funding support. VLSCI will need to continue to work hard at addressing all the risks facing the initiative and to put in place both the institutional and strategies that support ongoing sustainability.

Some key lessons from the project

There are a number of lessons that can be drawn from this project. We discuss a number of these below.

Collaboration between researchers and the private sector

One lesson relates to the benefits that flowed from the collaboration between researchers and the IBM Collaboratory. For example, one stakeholder noted that:

> *Working with the IBM Collaboratory helped to get a Centre of Excellence grant.*

It also instructive to note that two of the case studies discussed in the appendix to this report involved collaboration with the IBM Collaboratory. The establishment of VLSCI reinforces the message that significant benefits can flow from collaborative arrangements between industry and the research sector.

The importance of having access to the right skills

Another lesson was the importance of ensuring that researchers have access to the skills required to make best use of the research infrastructure. In the case of VLSCI, the LSCC played a major part in ensuring that researchers were able to maximise the benefits of using the VLSCI's facilities to conduct their research. The LSCC built specialist teams to support researchers, to build capacity and increase collaboration. LSCC staff provided important advice on the design and operation of research projects, including what software would be most appropriate. The importance of the LSCC's role in the research is demonstrated by the fact that LSCC staff are listed among the authors of many published research papers.

For example, the Peter MacCallum Cancer Centre is assembling a comprehensive catalogue of all the genetic mutations in human cancers (see Case Study 1 in the Appendix). The LSCC's bioinformatics expertise was seen as essential to the successful outcome of this research. The LSCC's experts were involved in all phases of the research process.

According to the Head of the Cancer Genomics and Genetics Program at the Peter MacCallum Cancer Centre, Professor Bowtell:

> *Having such equipment and skills locally makes a huge difference. It means you have some control over processes which are critical to a whole lot of research programs—and do not become a hostage to the priorities of others. Also you become a magnet to draw good people to you. In Melbourne we can now say that we have all the pieces of the puzzle together and we are ready to go.*

Other stakeholder comments included:

> *Prior to VLSCI Victorian bioinformatics was about a decade behind the world leaders. Now it is right up there. … training has been excellent.*
>
> *VLSCI has provided a diverse group of (bioinformatics) practitioners who can help researchers address a wide array of challenges (ranging from genome assembly to statistical analysis)*

The importance of computational analysis for life sciences research has grown rapidly in the last few years and will continue to do so into the future as 'big data' biology becomes increasingly important.

Consequently, there is a growing demand for persons with the skills (particularly bioinformatics) needed to do such analysis. One stakeholder commented that:

> *There is a growing demand for bioinformaticians, partly because these are able people (who are) being recruited into other sectors such as finance.*

The LSCC's approach to this issue, namely to have its experts both work as collaborators on projects and at the same time build capacity within research teams has been one of the factors that has underpinned the success of the LSCC.

The result is that the pool of highly skilled bioinformaticians has increased considerably. Not only are these skills crucial to life sciences research, but they are also keenly sought after in the private sector as they strive to convert the vast and growing amounts of data being collected into information and knowledge that help them to grow their businesses.

The role of government in supporting computational infrastructure

As noted above, government support is vital to establishing a research focused HPC. While it may be possible to raise the funds required for the operation of facilities such as VLSCI's, this review did not identify any HPC centres who had been able raise the funds required for the capital investment needed to undertake life sciences computational research.

This report has found that such investments in research infrastructure can generate significant benefits.

The importance of national founding sources to the long-term sustainability of state-based research infrastructure

An initiative such as VLSCI requires funding from a range of sources to ensure its long-term sustainability. This stakeholders consulted during the preparation of this report identified the importance of being able to access national funding sources are particularly important to the viability of leading edge research infrastructure such as that provided by VLSCI. Stakeholder comments included:

> *The current funding model is not sustainable in the long term.*
>
> *VLSCI's business model needs to be improved. It needs to be a national contributor to get national investment.*
>
> *VLSCI needs to nail down its funding model going forward and pitch as a national centre. It needs to position itself for NCRIS funding either via Bioplatforms Australia or directly.*
>
> *Computing (capability) needs to be sustained with reasonable capital expenditure (by Victoria) in partnership with the federal government in order to provide facilities that are nationally accessible to meet the needs of the gene sequencing community.*

However, for historical reasons VLSCI's ability to access important national funding programs (such as NCRIS) that would support its long-term sustainability has been restricted. A key lesson for any state government is that it is highly desirable for all future research infrastructure funded by them to be designed to be fully compliant with the funding conditions attached to national research infrastructure programs. This may include allowing researchers from outside the state greater opportunities to apply to use the research facilities.

APPENDIX

A

CASE STUDIES

In Chapters 3 and 4 of this report we have discussed some of the benefits that access to the VLSCI has already brought to Victoria and to Victorian researchers. However, there are also benefits that are only likely to be realised in the longer term. While some of these benefits are likely to be substantial, their timing is much more uncertain as the translation from science discovery to drug or treatment delivery is normally measured in decades.

This Appendix discusses a number of case studies which we believe demonstrate the potential positive impact that research supported by access to VLSCI infrastructure and supporting expertise may bring.

The case studies demonstrate how access to leading edge supercomputing facilities can assist researchers to address significant health and economic challenges facing the State of Victoria, Australia, and indeed the rest of the world. They were selected following consultation with a broad range of stakeholders including, researchers, government officials and leaders within VLSCI.

A.1 Case study 1: Advancing the treatment of ovarian cancer

A.1.1 The research problem

Ovarian cancer is the eighth most common cancer and the sixth most common cause of cancer death affecting women in Australia. In 2009, over 1,300 new cases of ovarian cancer were diagnosed in Australia. In the same year 848 deaths were recorded as being caused by this form of cancer.

In 2013 the Cancer Council of Australia published a report that suggested that women have a 1 in 75 risk of being diagnosed with ovarian cancer before the age of 85.

There are currently no proven screening tests for ovarian cancer. However, ultrasounds and blood tests are being investigated by medical researchers as potential screening tests for this cancer.

Also there is no proven method for preventing ovarian cancer. Oophorectomy (the removal of ovaries) in women with a strong family history of this disease is currently the preferred method of prevention. However, removal of the ovaries does not completely eliminate the risk of getting this form of cancer.

The treatment of ovarian cancer depends on the extent of the cancer within a patient.

A.1.2 The research and VLSCI

Working with clinicians, Professor David Bowtell and his research team at the Peter MacCallum Cancer Centre (Peter Mac) have demonstrated that one type of ovarian cancer, notoriously resistant to conventional ovarian cancer therapy, is responsive to treatment with a drug normally prescribed for renal cancer.

The research has the potential to allow the classification of cancer according to gene activity and identify where key "markers" related to specific biochemical pathways cause cancer. Once the cancer has been effectively identified it allows for the appropriate treatment response.

The Peter Mac team is also involved in the International Cancer Genome Consortium, which is assembling a comprehensive catalogue of all the genetic mutations in human cancers. This large analytical exercise involves sequencing 500 samples of the most common cancers.

The VLSCI's supercomputing facilities and the expertise of the LSCC's bioinformatician supporting the work are viewed as essential to the successful outcome of this research. The LSCC bioinformatician plays a vital role taking gigabytes of sequencing data, correcting for errors, aligning it into the three-billion base pair DNA sequence of the human genome, and then comparing that with the published reference sequence to pick up variations or mutations. The LSCC bioinformatics experts provide a central point for assistance which can be embedded into all phases of the research process.

According to Professor Bowtell:

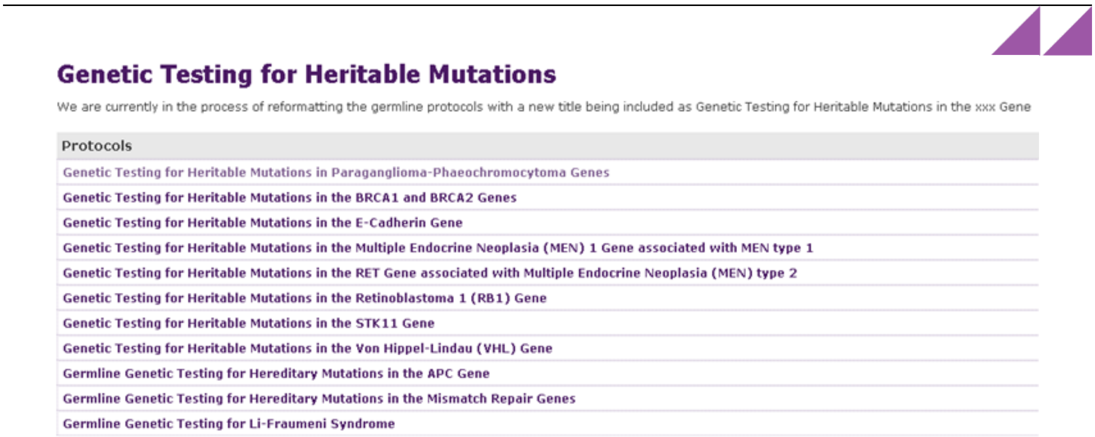
> *Having such equipment and skills locally makes a huge difference. It means you have some control over processes which are critical to a whole lot of research programs—and do not become a hostage to the priorities of others. Also you become a magnet to draw good people to you. In Melbourne we can now say that we have all the pieces of the puzzle together and we are ready to go.*

A.1.3 Impact of the research

Consultation with a senior research leader at the Institute has identified the direct impact of Peter Mac's research on current medical practice. It has identified that research findings have been integrated into the NSW Cancer Institute's protocols/guidelines for genetic testing and referrals – these protocols and guidelines can be accessed through the eviQ Cancer Treatments Online portal (https://www.eviq.org.au/).[47]

Figure A1 provides a screen shot of the types of protocols provided on the eviQ Cancer Treatments Online portal, and the types of protocols that are being developed following the publication of VLSCI-supported research.

FIGURE A1 **CASE STUDY 1 – EXAMPLE OF VLSCI SUPPORTED RESEARCH USED IN CLINICAL PRACTICE**



Genetic Testing for Heritable Mutations

We are currently in the process of reformatting the germline protocols with a new title being included as Genetic Testing for Heritable Mutations in the xxx Gene

Protocols
Genetic Testing for Heritable Mutations in Paraganglioma-Phaeochromocytoma Genes
Genetic Testing for Heritable Mutations in the BRCA1 and BRCA2 Genes
Genetic Testing for Heritable Mutations in the E-Cadherin Gene
Genetic Testing for Heritable Mutations in the Multiple Endocrine Neoplasia (MEN) 1 Gene associated with MEN type 1
Genetic Testing for Heritable Mutations in the RET Gene associated with Multiple Endocrine Neoplasia (MEN) type 2
Genetic Testing for Heritable Mutations in the Retinoblastoma 1 (RB1) Gene
Genetic Testing for Heritable Mutations in the STK11 Gene
Genetic Testing for Heritable Mutations in the Von Hippel-Lindau (VHL) Gene
Germline Genetic Testing for Hereditary Mutations in the APC Gene
Germline Genetic Testing for Hereditary Mutations in the Mismatch Repair Genes
Germline Genetic Testing for Li-Fraumeni Syndrome

SOURCE: EVIQ 2013, https://www.eviq.org.au/category/tabid/65/categoryid/440/default.aspx

[47] eviQ Cancer Treatments Online is a point of care clinical information resource that provides health professionals with current evidence based, peer reviewed, best practice cancer treatment protocols and information. eviQ allows rural, remote and metropolitan health professionals, patients, carers and their families access to the same standard evidence based information. eviQ can be accessed free 24 hours a day. eviQ was launched in October 2009. By February 2013 eviQ had over 25 000 registered users from around Australia and internationally.

The results of VLSCI-supported research have also been used to inform the referral practices for patients with Ovarian Cancer. There is also considerable potential for this kind of research to inform the approaches used with other types of cancer, such as gastric and renal cancer.

While consultations for this project did not extend to the practitioners who use these protocols/guidelines, consultation with a senior research leader at the Institute did indicate that the protocols/guidelines are having a positive influence on the testing and referral of cancer patients. It is anticipated that this influence will grow as additional research is disseminated amongst practitioners across Australia and overseas, and further integrated into protocols/guidelines.

Potential value of research

Improved protocols for testing patients for cancer and referring them for treatment is expected to lead to improved patient outcomes. Improved patient outcomes will, over time, help to reduce the cost (or burden) of cancer on the Victorian economy.

The economic burden of uterine, ovarian and cervical cancer has been estimated for other jurisdictions seeking to understand the total life time costs of cancer to state economies.[48] In 2005, Access Economics estimated that the total life time cost of uterine, ovarian and cervical cancer in NSW to be $1.195 billion (or 0.04 percent of Gross State Product).[49]

Using this estimate, ACIL Allen has calculated the equivalent cost of cancer for Victoria. When adjustments are made for differences between Victoria's and NSW's population (in 2013) and adjustments are made for CPI inflation between 2005 and 2013, ACIL Allen estimates that the potential total economic cost of uterine, ovarian and cervical cancer to the Victoria could be up to $1.15 billion in 2013.[50]

If we assume that through the research supported by VLSCI better detection techniques could be identified and implemented, and if these improvements in detection lead to a direct reduction in the total economic cost of uterine, ovarian and cervical cancer by 10 percent per year, our high level estimates suggest that VLSCI supported research could deliver a total economic benefit of $150 million to the State of Victoria. Additional economic modelling and analysis would be necessary to ensure this benefit is accurately calculated for Victoria.

A.2 Case study 2: 'Worm genome unlocks disease clues'

A.2.1 The research problem

Roundworm infections affect more than one billion people around the world. The worms are (accidently) ingested from contaminated food and water and hatch inside the host's intestine causing malnutrition. This in turn leads to long term physical and cognitive problems especially in children.

The parasite (known as *Ascaris lumbricoides*) causes a disease called ascarisis, which kills around 135,000 people (mainly children) in developing regions of South East Asia, China, South America and Africa.

The World Health Organisation has estimated that up to 1 billion people could experience the burden of parasitic disease in developing tropical nations (WHO 2013). According to researchers,

> *the cost of harbouring parasites in terms of human misery and economic loss is incalculable.*[51]

A.2.2 The research and VLSCI

An international team of scientists, from the University of Melbourne, have sequenced the genome of the common roundworm, which infects pigs, called *Ascaris suum*. The team has developed a 273

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[48] Total lifetime economic costs are defined as the costs of people diagnosed with cancer in 2005, plus any future costs associated with those people.
[49] Access Economics 2005, *Cost of Cancer in NSW*, Report to the Cancer Council of NSW.
[50] Based on ABS population figures and official government inflation data.
[51] Northrop-Clewes, C. and C. Shaw 2000, *Parasites*, British Medical Bulletin, 56 (No 1) 193-208.

million base genome sequence of the worm in the hope that it can lead to the development of treatments for both animals (especially sheep and cattle) and humans.[52]

The pig based parasite is a very close relative of the parasite that affects humans, and the researchers are hopeful that the sequencing of the *Ascaris suum* genome will result in the development of new, urgently required interventions for humans – including vaccines, drugs and diagnostic tests. It is hoped that sequencing will reveal important insights as to how immune systems respond to the presence of parasites that can be applied to other disease factors such as cancer and HIV/AIDS.

In an interview with ABC Radio, research leader, Dr Aaron Jex, was quoted as saying:

> *Although developing a vaccine against these types of parasites is extremely difficult to do, the hope is the more you understand about that interaction between the parasite and the host at the immune level, the more likely it is that you could try to develop vaccines.*
>
> *At least with this information you are one step closer.*
>
> *With only one drug currently used to treat humans and three for animals it is critical that new treatments are developed. There haven't been huge advances in developing drugs for these things for quite some time. If the parasites become resistant to the existing drugs we don't have an alternative.*
>
> *By sequencing the genome we can probably develop new drugs.*

A significant allocation of VLSCI resources in 2011 was "absolutely pivotal" to the success of the research and its publication in one of the world's premier journals (*Nature*). Access to the VLSCI facility aided the group of over 12 researchers (from around the world) to collaborate with some of the world's largest genome-sequencing facilities. These include:

— BGI-Shenzhen in China
— the Natural History Museum in Britain
— George and Washington University in the USA.

A.2.3 Impact of the research

The pursuit of this research has a number of potential benefits to health of industries and communities. For example, Meat and Livestock Australia have estimated that the national economic impact of internal parasites to the sheep industry was over $38 million of lost income and over $83 million worth of increased expenses to producers.[53] The costs of parasites are the highest annual animal health costs faced by Australia's sheep industry.[54] While the same modelling has estimated that the economic cost of intestinal parasites to beef cattle was over $38 million of lost income to the industry. A significant proportion of these losses are likely to occur in Victoria.[55]

The ABS has estimated that Victoria has over 32,000 farms, 14.4 million head of sheep and lambs, 2 million head of beef cattle, 500,000 pigs.[56] Clearly there are many Victorian farmers who could potentially benefit from the development of effective drug treatments against parasites.

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[52] ABC 2011, 'ABC Science News Radio: Worm Genome Unlocks Disease Clues', http://www.abc.net.au/science/articles/2011/10/27/3349715.htm

[53] *Assessing the Economic Cost of Endemic Disease on the Profitability of Australian Beef Cattle and Sheep Producers*, MLA (Meat Livestock Australia) 2006, http://www.mla.com.au/CustomControls/PaymentGateway/ViewFile.aspx?mFDUp1AYI9VUf+h/ZH4CYhopVLs5O3WvlD8Tvjx4WwqIhJCS8/UdRwc9AKswn/HN3EYMKKAfsht7d1Tnt3BqiA==

[54] *The Cost of Round Worms*, Wormboss 2013, http://www.wormboss.com.au/worms/roundworms/the-cost-of-roundworms.php

[55] The report considered that worms were only a risk in southern herds, with those at high risk within this region in areas with average annual rainfall of greater than 600mm. 'Bureau of Meteorology data were used to determine the boundaries and although these were as precise as possible, some provision had to be made as to the exact allocation of these areas. The statistical divisions not included within the analysis are North Western, Far West, 30 percent of Central West, 50 percent of Murrumbidgee and 70 percent of Murray in New South Wales; Wimmera, Mallee, Loddon and Goulbourn in Victoria; Yorke and Lower North, Murray Lands, South East and Eyre in South Australia; and Upper Great Southern and 40 percent of Midlands in Western Australia' (MLA 2006).

[56] *Agricultural Commodities, 2011-12*, ABS (Australian Bureau of Statistics) 2011-12 http://www.abs.gov.au/websitedbs/c311215.nsf/web/Agriculture+-+Summary+Map+-+Agricultural+Commodities

A.3 Case study 3: 'First 3D image of the common cold virus'

A.3.1 The research problem

In an increasingly interconnected world where information, goods, services and people flow between geographic regions, with unprecedented speed and volume, the spread of human viruses can have significant social and economic impacts. Unlocking the mechanisms of these viruses is of growing importance for both 'human wellbeing and our global connectivity'.[57]

The Human Rhinovirus (HRV) is the most frequent cause of common colds in people. HRV infection is a major cause of hospitalisation for patients with underlying respiratory conditions, such as asthma, chronic obstructive pulmonary disease and cystic fibrosis, where HRV can aggravate the underlying existing disease.[58]

Estimates suggest that HRV is linked to about 70 percent of all asthma exacerbations and more than 50 percent of the hospitalised cases. HRV can be a serious problem for infants and the frail elderly. For example, in the USA, 75 percent of common colds in children under five years old are medically attended and HRV has been linked with roughly one third of children with middle ear infections.[59]

HRV is the second most frequent infection associated with pneumonia and bronchiolitis in infants. There is also growing evidence for HRV as the causative agent for severe lower respiratory tract illness in older adults.[60]

There is currently no effective treatment of HRV in Australia or overseas.

A.3.2 The research and VLSCI

In collaboration with researchers at the IBM Collaboratory, scientists from St Vincent's Institute of Medical Research and the University of Melbourne have used VLSCI systems to model the common cold at the molecular level and VLSCI specialist programmers are assisting researchers in building a 'fully atomistic, three-dimensional simulation of HRV. The simulation includes the more than three million atoms of the HRV, as well as the packet of genetic information necessary for the virus to replicate and spread.[61]

The inclusion of the genome in simulations is especially critical to the research, as it affects the HRV interaction with potential drugs. These simulations allow researchers to gain a more precise picture of how drugs attack HRV at the molecular level.

The collaboration used a significant allocation of time on the BG/Q supercomputer to undertake the research. Access to VLSCI's BG/Q supercomputer is seen as vital in providing the processing power necessary to simulate viruses at the molecular level.[62]

A.3.3 Impact of the research

The first 3D image of HRV, responsible for 40 percent of all colds, has been used by the research team to better understand how a new drug, developed by a (then) Victorian company, Biota Pharmaceuticals, works.

[57] Wagner, J*, Nothing to sneeze at: IBM Supercomputer takes on the common cold*, Building a Smarter Planet Blog, 17 July 2012.
[58] *HRV Phase IIb Study Achieves Primary Endpoint*, Biota, Press Release, 2012, http://www.biotapharma.com/uploaded/154/1021819_20hrvphaseiibstudyachieve.pdf
[59] *Human Rhinoviruses: Coming in from the Cold*, NCBI (National Centre for Biotechnology Information) 2012, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2684665/
[60] *HRV Phase IIb Study Achieves Primary Endpoint*, Biota 2012, Press Release, http://www.biotapharma.com/uploaded/154/1021819_20hrvphaseiibstudyachieve.pdf
[61] Wagner, J.*, Nothing to sneeze at: IBM Supercomputer takes on the common cold*, Building a Smarter Planet Blog, 17 July 2012.
[62] 2010 Annual Report, VLSCI

The drug is aimed at stopping the HRV from spreading. It is targeted as a treatment for people with chronic lung diseases like asthma, chronic pulmonary disease and cystic fibrosis, for whom a common cold can be fatal.

The significance of this research extends well beyond HRV. St Vincent's Institute of Medical Research Deputy Director, Professor Michael Parker, who led the research, explained that:

> *…. understanding how the Rhinovirus responded to the drug had implications for a wider range of illnesses. An increase in understanding how existing drugs work with one virus will pave the way for the development of new anti-viral medications for related viruses [such as polio and meningitis] and hopefully save lives around the world* [63]

IBM has estimated that there are approximately 45 million occurrences of the common cold annually in Australia. These cost employers 1.5 million workdays, or approximately $600 million in lost productivity per year.[64] These estimates also suggest that Australian's spend more than $250 million per year cold and cough remedies that are not proven to be effective treatments of the virus. Ongoing research, which contributes to our understanding of the common cold, assists in the development of drugs and preventative methods that would help to minimise the cost to the economy and the community from this virus. For example, even just a 10 percent reduction in the number of lost work days would lead to a $60 million benefit to the economy.

The development of a successful treatment of the common cold could also be very profitable for the firm that developed it. For example, research into the structure of the neuraminidase protein during the 1980s, is credited for helping to develop anti-influenza drugs that now have an estimated annual worldwide sales value of more than $3 billion.[65] According to CSIRO's website:

> *The determination of the three dimensional structure of the neuraminidase protein by Peter Colman and his colleagues at CSIRO in the 1980s, and its use in the development of the anti-influenza drug zanamavir (Relenza®) is a landmark medical discovery. Relenza® and the closely related oseltamivir (Tamiflu™) subsequently developed by the US-based company Gilead Sciences in collaboration with Roche, were both designed on the CSIRO neuraminidase structure and both drugs work against all strains of influenza virus including bird flu and swine flu.*
>
> *These drugs, called neuraminidase inhibitors, represent a new class of anti-viral agent and have world-wide annual sales in excess of $3 billion. They target the enzyme, neuraminidase, which is found on the surface of all strains of the influenza virus. Neuraminidase plays an important role in releasing new virus particles from the surface of infected cells, enabling the virus to spread.*[66]

A.4 Case study 4: Developing a bionic eye

A.4.1 The research problem

It is estimated that there are about 300,000 people who are blind or vision impaired living in Australia. The impact of vision impairment depends on the type, extent and timing of vision loss. Some people gradually lose vision over a number of years; others are blind from birth. However, most people who are legally blind have some vision and may be light-sensitive, have low or limited vision, or have limited peripheral vision. With some vision impairments, sight fluctuates and people may experience some days when vision or light tolerance is much better than others.

The total costs of vision impairment (in Australia) are significant. Work commissioned by The Centre for Eye Research Australia (in 2004) showed that the total real financial cost (direct and indirect) of vision disorders was $5.0 billion (equivalent to 0.6 percent of GDP at that time). The net cost of

[63] *First Image of 3D Common Cold Virus could lead to New Drug Treatments*, Herald Sun, 16 July 2012.
[64] *IBM takes a Really Close Look at the Common Cold*, IBM 2012, http://asmarterplanet.com/files/2012/07/IBM-Common-Cold-Infog_1.pdf
[65] The company that owns and sells Relenza, GlaxoSmithKline, currently has a market capitalisation of $123.62 billion, approximately 99,500 staff worldwide, and revenue of $46.42 billion (October 2013) (http://finance.yahoo.com/q/co?s=GSK+Competitors).
[66] http://www.csiropedia.csiro.au/pages/viewpage.action?pageId=426541

suffering and premature death due to vision loss, over and above its financial costs, was estimated to be a further $4.8 billion in 2004.

A.4.2 The research and VLSCI

The VLSCI is playing a key role in bionic eye research. Bionic Vision Australia (BVA) is developing prosthetic retinal devices to restore a sense of vision to people with retinitis pigmentosa and age-related macular degeneration.[67] VLSCI is giving researchers from BVA access to facilities that allow them to study how the retina can be stimulated. The retina (a very thin tissue that acts like the film in a camera to convert what we see into messages that the brain can interpret) is located at the back of the eye and translates the light that falls on it into nerve signals that travel via the optic nerve to the brain. Damage to the retina, such as in the diseases Retinitis Pigmentosa and Age-related Macular Degeneration (AMD), causes vision loss.[68]

The bionic eye uses an electronic implant placed on or behind the retina, which is connected to a video camera built into a pair of sunglasses. The camera converts images into electrical impulses that activate the remaining cells in a diseased retina. The cells then send visual information along the optic nerve to the brain, where the image is interpreted. In this way the bionic eye mimics the function of the retina and helps to restore some basic sight.

Researchers from BVA have been working with the supercomputing facility since 2011, on a range of projects contributing to the promise of bionic vision. BVA is developing prosthetic retinal devices to restore a sense of vision to people with retinitis pigmentosa and age-related macular degeneration.[69]

For example, since 2011 Professor Anthony Burkitt from the University of Melbourne, has led an investigation of the different ways to stimulate the eye with the aim of developing the bionic eye. Staff from the VLSCI's PCF and the IBM Research Collaboratory for Life Sciences-Melbourne have worked closely with Professor Burkitt's team. They have investigated the retina's neural structure in a way that would not be possible on a conventional computer system. Postdoctoral researchers, postgraduate and undergraduate students associated with the project have benefitted from formal and hands-on training.

Indirectly, the access to HPC facilities and the expertise of VLSCI staff has facilitated national and international interactions with other research groups who do not have the benefit of such powerful HPC facilities or expertise to solve their computationally-demanding problems. It has allowed these groups to undertake modelling of retinal neurons that delivers a more detailed understanding of the impacts of the neuronal structure within the retina on electric current flow than has previously been available.[70]

According to one of the researchers, Dr Tahayori from the University of Melbourne:

> *Doing this kind of work requires a huge number of simulations, and huge amount of computer power to do them.*
>
> *Without a doubt this project wouldn't have been possible without the VLSCI. We could run multiple simulations in parallel, something that is not possible without a computing facility like VLSCI.*[71]

According to a PhD student with BVA based at the University of Melbourne:

> *Using VLSCI has been enormously beneficial because it enabled us to do a total of 75,000 hours' worth of simulations, a feat that would have impossible in the time frame to do on a normal computer. At times we were running 100 or 150 simulations at the same time.*

[67] Centre for Eye Research Australia 2013, *Bionic Eye*, http://www.cera.org.au/our-research/key-projects/bionic-eye
[68] Bionic Vision Australia 2012, *Bionic eye researchers working with the Victorian Life Sciences Computation Initiative*, http://bionicvision.org.au/news/story/bionic_eye_researchers_working_with_victorian_life_sciences_computation_initiative
[69] Centre for Eye Research Australia 2013, *Bionic Eye*, http://www.cera.org.au/our-research/key-projects/bionic-eye
[70] 2011 Annual Report, VLSCI.
[71] *Bionic eye researchers working with the Victorian Life Sciences Computation Initiative*, Bionic Vision Australia 2012, http://bionicvision.org.au/news/story/bionic_eye_researchers_working_with_victorian_life_sciences_computation_initiative

A.4.3 Impact of the research

In August 2013, the researchers working on the bionic eye reached a major milestone in becoming the first group to achieve a successful bionic eye implant. The recipient of the transplant, Ms Dianne Ashworth, has profound vision loss due to retinitis pigmentosa, and the implant allowed her to perceive 'shapes' and 'flashes of light' for the first time.

The consortium behind the research team, Bionic Vision Australia, said that while the implant is still an early prototype the results had given the team confidence. In an interview reported in *The Australian* newspaper on 30 August 2013, Bionic Vision Australia's Chairman, Professor David Penington was quoted as saying:

> *Much still needs to be done in using the current implant to build images for Ms Ashworth. The next big step will be when we commence implants of the full devices.*

Estimates by Invest Victoria place the potential value of the bionic eye at more than $70 million to the state's economy over the four-year period 2010-2014. Invest Victoria has also estimated that the prototype of the bionic eye will generate more than 90 new jobs for the State's biotechnology industry.[72]

The development of the cochlear implant (Bionic Ear) for certain types of deafness shows the potential benefits of supporting the development of high quality technology medical prostheses over many decades. In the 1970s and 1980s, Cochlear Ltd received significant public funding to undertake and commercialise research into hearing implants and by 1983 had delivered the world's first 22-channel implant.[73]

Cochlear Ltd Australia has enterprises in the USA, Japan, Switzerland and Australia delivering implant systems to people in 50 countries. In October 2013, Cochlear Ltd reported to the Australian Stock Exchange a market capitalisation of approximately $3.31 billion, sales revenue of $715 million, an expected profit for 2013-14 of more than $132 million and directly employed approximately 2,700 workers across 25 countries.[74]

Today, the Cochlear Ltd Bionic Ear stands as the world's most widely used cochlear implant systems, with more than 219,000 people worldwide having received cochlear implants since the 1980s.[75] Cochlear Ltd also stands as a significant example of the value that can be generated from public investment in biomedical research and one that it is hoped will be emulated in the future by initiatives such as the bionic eye research program.

A.5 Case study 5: Understanding how bacteria attack cells

A.5.1 The research problem

Bacteria are the source of many common infectious diseases; for example streptococcal sore throat, pneumonia, rheumatic fever, scarlet fever and also potentially life-threatening conditions such as toxic shock syndrome and diphtheria.

Bacterial pathogen proteins produce toxins that attack cells by punching pores in cell membranes. Paradoxically, pore-forming immune defense proteins produced by vertebrates can also damage bacterial membranes. Even though these proteins have opposite functions, they appear to follow the same pore-forming mechanism and their structures suggest an evolutionary relationship.

[72] *Victorian Vision for the Future Worth $70 million*, Invest Victoria Press Release, 2010 http://www.invest.vic.gov.au/200410Victorianvisionforthefutureworth70million
[73] *Cochlear's History of Innovation*, Cochlear, 2013, http://www.cochlear.com/wps/wcm/connect/intl/about/company-information/history-of-innovation/cochlears-history-of-innovation
[74] *Cochlear Annual Report to Shareholders*, cochlear, 2013, http://www.asx.com.au/asxpdf/20130913/pdf/42jbn3fb8gfy9z.pdf
[75] 2010, *Research*, NIDCD (National Institute on Deafness and other Communication Disorders)http://www.nidcd.nih.gov/Pages/default.aspx

Understanding how these hole-punching toxins work can inform the design of new drugs to combat bacterial diseases.

A.5.2 The research and VLSCI

Professor Michael Parker from St. Vincent's Institute of Medical Research and the University of Melbourne, working with Dr Michael Kuiper from the VLSCI and other colleagues have studied a family of hole-punching toxins released from certain bacteria. These toxins recognise cholesterol found in cell membranes, which causes them to assemble into donut-shaped structures. These donuts act as a molecular machine, changing shape and punching a hole through the cell membrane. This cell puncturing can cause cellular death, often increasing the severity of a bacterial infection.

The action of proteins is dictated by their precise three-dimensional molecular structures. So by determining protein structures, it is possible to identify which parts interact with cells, and how they do so. Through this process, researchers can work out how diseases proceed at the atomic level. Such studies also provide the basis for the design of drugs that could thwart the process of punching holes in cells.

Professor Parker, Dr Kuiper and colleagues have shown that the hole punching process involves the assembly of a "pre-pore" on the surface of human cells. Once this happens, an intermolecular electrostatic interaction is established that drives the formation of the pore. This mechanism is likely to be used by other pore-forming proteins that span the biological domains of life.

One of Dr Parker's current projects is looking at a gangrene-causing bacterium. Working with Dr Kuiper and the VLSCI research team has resulted in the construction of colourful computer simulations of the three dimensional donut-shaped protein pre-pore clustering on cell surfaces. VLSCI's BG/Q was essential for this work because of the vast number of atoms involved in the simulations.

As Professor Parker told The Age:[76]

> *These computer simulations are really useful as they can show you surprising new perspectives that inspire experiments both on computer and in the laboratory. Not only could we design drugs to stop the donuts of death forming but we could also make protein donuts to use as biosensors that could measure the flow of chemicals inside and outside cells.*

A.5.3 Impact of the research

Understanding the processes by which bacteria invade cells creates the opportunity to custom design drugs that will block these infections. In The Age article, Professor Parker said that:

> *Understanding 3D protein structures has enabled researchers to design 'smart drugs', where chemists can custom-design drugs to interact with proteins that cause disease.*
>
> *This has the potential to shave years and millions of dollars off traditional drug-design approaches. Bacterial toxins are exciting work. A hole-punching toxin called lectinolysin from a bacterium found in the mouth and throat recognises sugars on the surface of cancer cells.*
>
> *Imagine if we could engineer this protein toxin to punch a hole in these cancer cells but leave normal cells alone – a so-called 'magic bullet'. Protein structures not only allow us to 'see' biological processes but also imagine new useful ones.*

Michael Parker is an honorary Professor of Biochemistry and Molecular Biology at the University of Melbourne's Bio 21 Institute, and Deputy Director of St Vincent's Institute of Medical Research. He is a world leader in the field of protein-cell membrane interactions.

[76] The Age 2015, 'Proteins that pack a punch', 6 March 2015 accessed on 14 July 2015 at http://www.theage.com.au/national/education/voice/proteins-that-pack-a-punch-20150306-3rl18.html

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