Australian Academy of Science

Providing the Machinery of Science:

Defining a whole-of-government strategy for securing access to critical research facilities

Discussion Paper

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Dr Mark Matthews
Science Policy Advisor[1]
Australian Academy of Science

Australian Research Infrastructure Project

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Note: this *Discussion Paper* does not necessarily reflect the views of the Australian Academy of Science or the other organisations represented on the project's Steering Group. It has been circulated in order to stimulate debate on policies affecting the provision of research infrastructure in Australia.

[1] mark.matthews@science.org.au tel: +61 (0)2 6247 3966 fax: +61 (0)2 6257 4620

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Abstract

This discussion paper seeks to stimulate a sea change in how the pay-offs to public sector investment in building and securing access to research facilities are judged by policy-makers. This sea change involves emphasising the way in which securing access to leading edge research facilities overseas supplements our own comparatively low level of domestic R&D investment by leveraging *global* R&D investment. Most countries seek to achieve this leverage of global R&D investment because it allows them to benefit from distinctive expertise and facilities available overseas via international research collaboration. However, countries do differ in the policy emphasis on leveraging the global R&D effort and on how effective they actually are in achieving this leverage. Just as in international trade in goods and services, the web of international R&D interactions generates more gains for participants than a 'protectionist' approach – yet there are still strong protectionist pressures.

We should therefore examine the adequacy of our own policies towards leveraging global R&D investment – and recognise that accessing leading-edge research facilities and possessing the best domestic facilities to underpin this international access are key policy issues. This change in policy perspective also involves an increased emphasis on the ways in which leading-edge research facilities can allow a wide range of R&D to be carried out faster and cheaper in the future. There are two reasons for this. First, access to the improved theoretical, analytical and modelling capabilities associated with many lead-edge facilities can reduce the need for costly experimental activities due to more accurate predictions of what may happen in experiments (e.g. less R&D time and cost due to unsuccessful experiments or in analysing data from experiments). Second, the experimental processes themselves are sometimes significantly faster and cheaper due to technological advances in research facilities and equipment (e.g. automatic DNA sequencing machines).

The policy challenge is to achieve these R&D efficiency and effectiveness gains by *both* leveraging global R&D investment (thus avoiding the limitations of our own R&D budgets) and by ensuring that our domestic investment is adequate. Inadequate domestic investment will limit our capacity to access leading-edge facilities & equipment overseas because we will lack the necessary skills and experience in using advanced scientific instruments. Consequently, accessing overseas facilities is not a substitute for adequate domestic investment in research facilities and equipment – these two paths to scientific progress are complementary. Pursuing an approach of this type would however require a major increase in our capacity to coordinate access to, and investment in, research facilities. The required level of coordination could be facilitated by defining the set of critical research facilities (CRFs) that are crucial to meeting Australia's research objectives. CRFs may be located anywhere in the world. Those CRFs located within Australia, and controlled by Australia, should be used to negotiate access to overseas CRFs. The paper therefore concludes by highlighting the need for an integrated set of administrative arrangements and science and innovation budget reporting procedures aimed at ensuring that Australia is able to achieve the level of co-ordination in Commonwealth-State and portfolio-to-portfolio activities necessary to reap these rewards from our investment in R&D.

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[2] mark.matthews@science.org.au tel: (02) 6247 3966 fax: (02) 6257 4620

Executive Summary

i. This Discussion Paper outlines a strategy for securing access to those leading edge research facilities, both within Australia and overseas, that are critical to Australia's future scientific research capability and therefore our future national security, health, prosperity and environmental sustainability. Such research facilities and equipment are referred to here as *'critical research facilities'* (CRFs). CRFs may be located within Australia or overseas. Their importance for Australia is that access to them is a critical means of meeting our national objectives – as exemplified by, but not necessarily restricted to, the set of *National Research Priorities* that will continue be set by the Federal Cabinet.

ii. These leading-edge research facilities are critical to our national interest because obtaining access to their capabilities will significantly affect how quickly and cost-effectively Australia is able to achieve the priorities it has set for itself. Australia only accounts for around 1% of global R&D investment. Consequently there are leading-edge research facilities throughout the world that are useful to us in achieving Australia's research priorities. Ensuring that we can use these facilities makes considerable economic and political sense. *Access to such critical research facilities enhances our capacity to leverage the other 99% of global R&D investment.* It is unlikely that Australia will ever be in a position to provide the wide range of research facilities necessary to achieve our priorities solely through our own public sector R&D investments. It would be foolhardy to base Australia's research priorities too heavily upon the research facilities that we currently have and that we can afford in the future, as this would distort our policy and research goals.

iii. There are compelling economic and national security-related arguments in favour of increasing our emphasis on securing access to leading edge research facilities and investing in a set of domestic research facilities that are *both* useful to us *and* attractive to overseas researchers. Advances in the fundamental theoretical understanding of complex physical, chemical and biological structures and processes, and in the ability to model and predict their behaviour under different conditions, allow new and improved types of research facilities and equipment to be developed and deployed (many requiring highly advanced computational and high bandwidth communication capacities). These technological advances in research facilities and equipment, in turn, enable further advances in this fundamental theoretical understanding to be achieved. In addition, the experimental processes themselves are sometimes significantly faster and cheaper due to technological advances in research facilities and equipment (e.g. automatic DNA sequencing machines).

iv. Australian science and innovation already benefits from this leverage of the global R&D effort by virtue of international research collaboration and the use of overseas research facilities. As a result, our share of global publications is greater than our share of global R&D expenditure. Our strong basic research capabilities allow us to leverage overseas R&D (and the US and Europe in particular). This leverage operates partly via access to leading edge research facilities – access for which Australian scientists do not pay the full cost (which would in most cases be prohibitive).

v. Future improvements in our capacity for R&D commercialisation will not only increase our yield on domestic R&D investment, they will also increase our yield on the leverage of global R&D – greatly multiplying the triple bottom line benefits for Australia.

vi. US policy-makers in particular have persistent concerns over the nature and extent of any 'leakage' of US R&D overseas and the consequent erosion of US scientific and innovative supremacy. However, it is also clear that the US and other leading science powers benefit substantially from leverage of other countries' R&D – not least in providing intelligence on different national science and innovation capabilities and in identifying intellectual property and scientific and technological know-how of commercial interest.

vii. It is essential that our scientists have sufficient capabilities to participate in major international collaborative research programs. Although our strategic relationship with the US and with Europe opens the door to this R&D leverage, our capacity to actually achieve this leverage rests upon having something to offer at the scientific level. This means possessing a mix of research capabilities and carefully selected national research facilities that, *in combination*, give us assets to negotiate with. If we fail to invest in possessing these assets and in coordinating how they are utilised in international negotiations then our relatively low level of R&D investment (in global terms) may lock us out of economies of scale in R&D and will, as a result, mean that spreading our R&D investment thinly across a wide range of research areas *does* become a problem. At present this wide spread is not a problem precisely because we *do* achieve some leverage of the global R&D effort.

viii. There is a clear 'bottom line' in defining policy towards securing access to the machinery of science. If we get our policy wrong, by for example cutting back on the very programs that facilitate our leverage of global R&D investment (i.e. our international research activities and our major national research facilities) then the efficiency and effectiveness of our current public and private sector R&D investment may drop.

ix. One way forward is to identify the research facilities that are indispensable to meeting our policy objectives and to make every effort to ensure that both our stock of domestic CRFs and our access to CRFs overseas is adequate. This paper therefore outlines some inter-linked recommendations aimed at defining a 'whole-of-government' strategy for securing access to these critical research facilities.

x. These recommendations are made in the context of two major consultation exercises that are currently underway: the process of setting national research priorities and the comprehensive review of higher education. The conjunction of these two consultation processes provides an opportunity to define a more coherent and forward-looking approach to providing access to the research facilities and equipment that are critical to performing R&D efficiently and effectively. These recommendations are also being identified during a period in which the Federal government's statements on its science and technology expenditure commitments are in a state of transition. This too provides a timely opportunity to suggest changes pertinent to improving support for investment in, and access to, research facilities & equipment.

xi. The recommendations identified are as follows:

   A. The provision of appropriate support to the office of the Chief Scientist to permit the drawing up and maintaining a list of the research facilities and capabilities that are critical to achieving Australia's research priorities and any other policy objectives that government requires the Chief Scientist to consider. The office of the Chief Scientist would take a 'whole-of-government' approach to ensure that adequate access is being obtained to those CRFs that are located overseas and that adequate funding is available for those CRFs located in Australia. To this end, the office of the Chief Scientist would coordinate all Commonwealth government activities relating to access to CRFs and would also liaise with State and Territory governments over their science and innovation (S&I) investment plans and access provisions. The office of the Chief Scientist would ensure that appropriate influence on obtaining access to overseas CRFs is applied in international negotiations and that facility access, trade and offset agreements take such issues into consideration.

B. Any further changes to the way in which the Federal government reports S&I Budget figures should make plans for investment in research facilities & equipment explicit. This should be part of a move to US-style R&D budgets that also specify how R&D and other aspects of S&I spending breaks down by type of activity: basic and applied research, experimental development (in current cost terms) and research facilities & equipment augmented by a new non-R&D category of *development, commercialisation and deployment*.

C. The office of the Chief Scientist would be in a position to try to broker the adoption of the revised S&I budget framework by all State and Territory governments in order to provide comprehensive information on Australia's public sector S&I budgets. It would also be given the task of seeking to generate greater transparency in the development of S&I budget plans and, if successful, assessing Federal and State S&I spending plans as they evolve (via the shared structural budget framework) and advising on areas of concern with regard to CRFs. Indeed, State government departments may wish to take the lead in producing more structural S&I budget estimates in order to assist in executing their economic development strategies and in building inter-State and State-Commonwealth government cooperation over research infrastructure provision.

D. Finally, the office of the Chief Scientist would be well positioned to alert the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) and State governments to any future structural shortcomings in the funding of CRFs located in Australia - with the option to create a new long-term funding program for domestic CRFs should this prove necessary. Such a situation could arise because existing funding mechanisms are putting Australia's own CRFs at risk. It is not possible to assess the extent of any such shortcomings until the set of CRFs has been defined. However, the final report on this project will provide an indicative 'health check' on the current state of our funding for research facilities and equipment and access to overseas facilities set against underlying investment requirements.

Comments and feedback

The purpose of this document is to:

- highlight the key policy issues relating to public sector investment in R&D facilities and equipment and in ensuring access to overseas facilities and equipment, and to;
- identify possible areas for making policy recommendations;

The intention is to provide an opportunity for policy makers and stakeholders in the public sector R&D effort (such as business and the private non-profit sector) to comment on the 'forward strategy' suggested here and to provide an opportunity for them to put forward their own policy suggestions.

The final report in this project will build upon this policy discussion by providing an empirical account of how Australia's research infrastructure is currently funded and comment on the nature and extent of any mismatch between current funding and underlying infrastructure requirements. The empirical element is intended to provide policy-makers with an indicative road-map for operationalising the R&D leverage-based approach articulated in this discussion paper.

There is no fixed cut-off date for comments on this discussion paper because all feedback received will be used by the Australian Academy of Science in its efforts to inform policy towards research infrastructure funding. However, it will be possible to address any comments received by 13th September in the final report.

Comments should be sent to:

Mark Matthews
Science Policy Advisor
Australian Academy of Science
GPO Box 783
Canberra ACT 2601

mark.matthews@science.org.au

Tel: +61 (0)2 6247 3966

Fax: +61 (0)2 6257 4620

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Contents

Introduction

Advantages of developing a strategy for securing access to research facilities and equipment in Australia

1. The quality of the research facilities & equipment[3] used to carry out R&D and its commercialisation are critical to the success of these activities. In many areas of science the rate of progress of knowledge is determined by the capabilities of the *research instruments* used to make observations and carry out experiments.

2. The rate of technological progress in research instruments is consequently a major contributing factor to the overall rate of advance of scientific knowledge. Newer 'vintages' of instrument and other types of research infrastructure allow experiments to be done faster and allow new experiments and other forms of data collection to take place that were simply not possible before. However, these improvements in research capability come at a price and 'cost escalation' in some types of large research facility can be a major problem.

3. Scientists are often closely involved in, if not leading, efforts to develop and improve instrumentation technologies. This means that the technologies that spin-off from new developments in instrumentation (many of which have had major economic impacts)[4] may not have emerged without the stringent technical demands created by the scientific research involved – often *basic research*. Some countries fund R&D projects explicitly focused on generating technological advances that will allow new generations of research instruments to be built. For example, the US and European R&D aimed at developing terrestrial 'segmented mirror' telescopes that match the capabilities of orbiting telescopes.[5]

4. Public sector investment in facilities & equipment (i.e. collections of research instruments together with the infrastructure that allows them to operate) is consequently an investment *both* in scientific advance *and* in the potential to generate commercial outcomes via spin-offs from technical advances in instrumentation.

5. The same point applies to collections of *specimens* and large complex *data-sets*. In many areas (e.g. entomology and geology) research involves *classification* and *pattern recognition* activities that are essential in order to understand natural phenomena. Without collections of specimens and data this analytical work is not possible and the rate of advance of knowledge in constrained. This point applies as equally to basic research as to applied research that may lead to commercial outcomes.[6]

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[3] Note: the term 'research facilities & equipment' (RF&E) is used in this *Discussion Paper* in addition to 'research infrastructure'. This is in order to avoid confusion over the breadth of the issues being considered – as the concept of research infrastructure can be ambiguous. The focus of this paper is upon investment in research facilities & equipment and in the operating costs that allow these research facilities & equipment to be used.

[4] For example in the growth of high technology companies selling research instruments surrounding major research universities such as Oxford, Cambridge and MIT.

[5] DTI Office of Science and Technology (2001) 'Large Facilities Strategic Road Map', June. Section 3(v).

[6] For example, oil and gas exploration companies would be unable to be nearly as effective in knowing where to look for hydrocarbon resources if large data-sets on geological structures and their likely paths of evolution were not maintained using

6. From a policy perspective therefore, the allocation of funding for research instrumentation and facilities needs to consider the benefits that accrue from the advances in knowledge sought, the R&D productivity gains *and* the potential spin-offs that may take place from invention in scientific instrumentation. Adequate funding for research facilities & equipment is a pre-requisite for efficient and effective science and is also a significant generator of commercialisation options. It follows that the long-term *outcomes* consequent on public sector investment in scientific research facilities should ideally be assessed on this 'triple impact' basis, and these benefits quantified and related to the costs incurred. If this is not done then it can be difficult to demonstrate just how important adequate funding for research facilities is. This is a particularly important issue for major (i.e. expensive) research facilities because funding levels are relatively high and budgetary pressures will therefore tend to limit such funding unless the benefits can be clearly stated.

Purpose of this document

7. The purpose of this document is to:

- highlight the key policy issues relating to public sector investment in R&D facilities & equipment and in ensuring access to overseas facilities & equipment, and to;
- identify possible areas for making policy recommendations.

8. The intention is to provide an opportunity for policy makers and stakeholders in the public sector R&D effort (such as business and the private non-profit sector) to comment on the 'forward strategy' suggested here and to provide an opportunity for them to put forward their own policy suggestions.

The overall project

9. The project with which this Discussion Paper is associated involves collecting, collating and analysing information and data that will allow a set of policy recommendations on research infrastructure funding to be tabled. There is a particular emphasis on mapping out the current role of State governments in funding research infrastructure and on identifying infrastructure investment requirements based on an assessment of recent bids for 'Major National Research Facility' (MNRF) funding – see Annex A for a summary of the project.

10. The final report will build upon this policy discussion by providing an empirical account of how Australia's research infrastructure is currently funded and the nature and extent of any mismatch between current funding and underlying infrastructure requirements. The empirical element is intended to provide policy-makers with an indicative road-map for operationalising the approach articulated in this discussion paper.

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public sector funds. Indeed, the capacity to spot patterns in data on large complex systems is a growing cross-cutting area of scientific research.

Securing access to facilities & equipment in the future: issues for consideration

A budget-neutral starting point

11. This *Discussion Paper* assumes that overall science and innovation budget levels are fixed. It focuses upon the rationales for, and structure of, funding for research facilities & equipment (RF&E) with a view to identifying the areas in which policy improvements could be made. R&D and its commercialisation are areas in which the potential demand for funding from different quarters vastly outstrips the practical realities of Commonwealth and State government budget constraints.

12. It follows that a productive dialogue between government and the research community is best facilitated by recognising these budgetary constraints and by focussing upon what it may be *feasible* to achieve not what it may be *attractiv*e to try to achieve from each group of scientists' perspective. Whilst the long-term returns to investment in public sector R&D are characteristically very high relative to expenditure, these returns are also often diffuse and difficult (in general) to trace back to specific funding allocations and/or funding programs.

13. It consequently makes sense to improve the identification of public sector investment in RF&E and the impact of this investment upon the overall productivity of public sector R&D investment *prior* to seeking additional funding. The case for additional funding, as with any case for re-orienting the mix of current funding, is strongest when the overall impact on the efficiency and effective of the national S&T effort can be assessed (albeit with a very high margin of error).

Differing perspectives towards S&I Budget setting and monitoring public sector R&D investment

14. Policy debates relating to science and innovation in OECD countries tend to focus on the *levels* of the R&D investments being made by different funding sources and in the different sectors in which R&D is performed. The policy dialogue characteristically involves, on the one hand, governments seeking to balance a wide range of pressing budget requirements - many of which have escalating funding requirements (health, aged care, defence etc) – and various interest groups arguing that public sector investment in R&D and its commercialisation should be increased.

15. It is noteworthy that, traditionally, the bulk of the emphasis in policy debates tends to be on levels of R&D investment, and their adequacy, with relatively less emphasis on the *productivity* of that R&D investment. As OECD governments strive to generate better information on the *outcomes* arising from public sector investments in general, and R&D in particular, there is now growing scrutiny of the *R&D productivity* issue. The *efficiency* with which public sector R&D investments are translated into research outputs (publications, patents etc) and with which socio-economic outcomes are generated (wealth, exports, national security capabilities etc), - i.e. R&D *effectiveness,* are relatively new items on policy agendas.

16. A move towards focussing on the *efficiency* and the *effectiveness* of public sector R&D investment requires a significantly different approach to the analysis of R&D investment. Efficiency and effectiveness are concerned not only with the adequacy of *levels* of R&D investment (economies of scale etc), they are also concerned with the *mix* of R&D investments being made. Are we investing in the optimal mix of fixed capital vis-à-vis, labour costs and the multitude of operating cost elements necessary for R&D to take place? These different components of R&D investment are complementary to each other but they can also substitute for each other. Consequently, over-investment in one area (e.g. labour costs) and under-investment in another area (e.g. instrumentation) can in principle affect the efficiency and the effectiveness of public sector R&D investment.

The cumulative benefits of technological advances in research facilities & equipment.

17. One of the main ways in which the wrong mix of R&D investment can cause problems is by constraining the operation of the crucial 'virtuous circle' via which the rate of technological advance in research facilities & equipment generates *both* improvements in the efficiency of overall R&D investment *and* the capacity to advance our scientific knowledge – i.e. the effectiveness of this investment. The greater our scientific knowledge (thanks to previous R&D), the more options we have for increasing the rate of technological advance in research facilities & equipment (for use in future R&D) – provided that the industrial capabilities exist to actually manufacture these research facilities & equipment. Hence, investments in R&D aimed at improving research facilities & equipment, and in providing sufficient capacity to match demand, can have a major 'multiplication' effect on the efficiency and effectiveness of the overall R&D effort.

18. Although this cumulative benefit associated with technological advances in RF&E is not shared by all research fields (notably those like particle physics in which increasingly costly technological advances seem to raise more questions than they answer) it is nevertheless a key dynamic in the discovery process.

19. The experimental development carried out in universities and research agencies is not necessarily all aimed at developing an end product or process (as in the linear model of the R&D sequence).[7] A proportion of it consists of the design and construction of the new and improved research instruments that will be used to carry out new and/or faster and cheaper experiments. However, it is unclear whether this expenditure is reported to the Australian Bureau of Statistics (ABS) as experimental development or whether it is reported as part of the basic or applied research expenditure to which this instrument building relates. In principle expenditure on developing and improving research instruments should be classed as experimental development – but categorisation practices do differ between R&D performing organisations. [8]

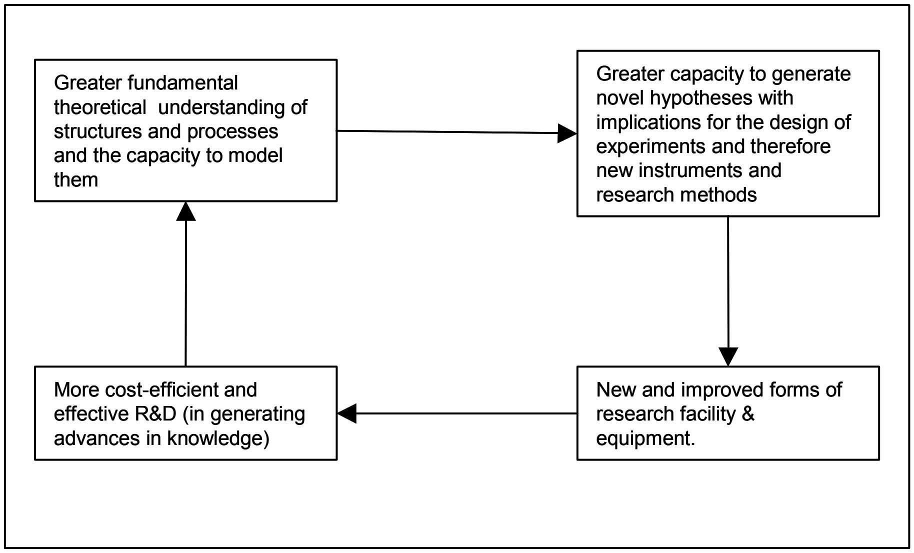
20. This 'inner loop' in scientific activity aimed at developing new and improved research instruments is a key part of the discovery process. Insufficient investment in R&D aimed at improving research facilities & equipment (RF&E) and in providing access to RF&E, will limit the extent to which these cumulative benefits from technological advances in RF&E are

[7] In 2000 7.7% ($213,696) of the R&D performed in Australian universities was classified as experimental development

[8] It is worth noting that expenditure classed as 'other capital expenditure' does broadly correlate with 'experimental development' expenditure in the higher education sector when examined on a field of research basis.

reaped. The following diagram illustrates the 'core' of this cumulative process.

Exhibit 1



21. If the perspective towards R&D neglects this cumulative process then there is a risk that R&D will be less efficient and effective than might otherwise be the case. In practical terms this usually means that too simplistic a policy 'model' of what R&D actually involves is used – this is associated in particular with 'unitary' and top down approaches to setting R&D budgets rather than 'bottom up' analyses of the different types of R&D investments required to achieve given objectives.

22. The cost-escalation found in some types of RF&E tends to offset the potential gains in the efficiency of R&D investment for the simple reason that it is costing so much more to provide the RF&E that enables R&D to be faster and use less resources (particularly human resources). In this sense many of the potential gains in the efficiency of R&D investment are masked, but any significant reduction in the cost-escalation problem would result in major improvements in the efficiency of R&D. It is also the case that the dominant emphasis in improving RF&E is often upon being able to do new experiments and/or collect data this is simply unavailable with the current generation of RF&E.

23. Information and communication technologies can play a key role in reducing this cost-escalation, and this is one reason why adequate investment in ICT-based RF&E is so important. In this respect 'big science' shares many of the concerns of defence R&D and weapon systems procurement agencies – not least because the technologies are closely related. It is possible to provide extremely sophisticated technical capabilities but at dramatically increasing, sometimes prohibitive, cost.[9]

24. This question of 'perspective' is less of an issue in the business sector because companies tend to base their R&D investments on 'bottom up'

[9] In weapons systems this characteristically results in ever decreasing numbers of units deployed relative to the cost of developing and introducing these units. Indeed, the major emphasis placed upon advanced simulation modelling in defence R&D in an attempt to break this cost escalation dynamic (more 'R' allowing less 'D' through better theoretical and simulation capabilities) may generate important cost-escalation breaking spin-off benefits for major research facilities. It is probably fair to say that we understand too little about the underlying causes of cost-escalation in complex R&D plant and that policy formulation would consequently benefit from research on this issue.

project-specific requirements using business planning principles. This means that they address their R&D resource needs by focussing on obtaining the right mix of R&D investments required to meet business objectives. Few companies set an overall 'R&D budget' per se that is independent of supply chain and project specific considerations. Indeed, the very concept of 'R&D' tends to be an issue for accountants in established companies. Corporate scientists and engineers tend to be mainly concerned with *integrating* technology acquired from outside with their internal and contracted R&D activities.[10]

25. In contrast, public sector R&D investment operates through a mix of 'top down' agency and program specific budget allocations (that do not necessarily specify the intended mix of investments) combined with some R&D mix specific funding programs and mechanisms (such as the Major National Research Facilities initiative and other infrastructure support schemes in Australia).

26. Different OECD countries have different levels of information on the composition of R&D investments associated with given budget allocations. For example, the Federal Government in the United States sets its R&D related budgets via a dialogue with the *Office of the Management of the Budget* that involves the *National Science and Technology Council*. Like that in many OECD countries, this process is structured such that agencies provide an indication of why they are spending R&D and how they plan to spend these funds, see exhibit 2. What is more unusual is that this budget setting process allows some indicative estimates, on an agency-by-agency basis, of the breakdown of the Federal budget in terms of basic research, applied research, experimental development, and *facilities & equipment*. It also breaks down Federal Budget allocations by priority area.

27. This more 'structural' approach can be attributed to the United States' long standing concern to enhance both its long-term national security capabilities and economic prosperity. The budget-setting process complements the decentralised priority-setting process by making clear who will be doing what in the non-classified elements of the Federal R&D budget. [11]

[10] R&D based spin-off and start-up companies do however initially adopt an 'R&D' oriented approach, but these too tend to increase the emphasis on 'technology acquisition' as they grow.

[11] This budget information is summarised, to some level of detail, in the 'Analytical Perspectives' budget paper produced by the OMB, see http://www.whitehouse.gov/omb/budget/fy2003/pdf/spec.pdf for the Fiscal Year 2003 edition, pages 159 to 176 for a discussion of the Federal R&D Budget that includes agency by agency and research priority-specific estimates of expenditure on basic research, applied research, experimental development, and *facilities & equipment*.

Exhibit 2: The US Federal Government Approach to R&D Budgets and R&D Expenditure Outturn Data

There are a number of unusual features in the way in which the US federal government reports its R&D budgets and R&D expenditure data. It is necessary to understand these features in order to inform S&I policy using US practices and in order to interpret R&D data.

Reporting R&D budgets

Each relevant federal agency must specify how much it plans to spend on R&D in terms of the thematic area; the type of activity (basic research, applied research, experimental development), and; how much it will spend on facilities and equipment. Scrutiny of the 'analytical perspectives' budget document produced by the Office of the Management of the Budget (OMB) allows the reader to clearly identify how much each agency plans to spend on each type of activity (basic research, applied research, experimental development) and on facilities and equipment. Interagency R&D efforts (such as the National Nanotechnology Initiative) are also clearly itemised in terms of each agency's R&D spending plans.

As regards the pervasive use of the often criticised distinction between basic research and applied research in the US budget papers (first popularised by Vannevar Bush in *Science – The Endless Frontier*) the NSF comments that:

"Bush's model…simplistically depicts innovation as a three-step process….Although it is quite unlikely that either scientific or statistical experts ever really believed that such a model captured the complex relationships between science, technology and innovation, it did (and still does) lend itself to the collection and analysis of data for policymaking purposes…..Bush himself was not particularly concerned about the precision of the definitions used. Rather, he simply wanted to establish a framework that offered the best chance for basic research to receive special protection and, more important, ensured government financial support"[12]

It is more difficult to argue for adequate public sector investment in R&D, and in basic research in particular, if the budget setting process does not make the amounts to be spent on each component of R&D explicit. This is the advantage of the US approach.

Reporting R&D expenditure outturns

The US federal government does not provide 'General University Funds' (GUF) block grants to the higher education (HE) sector in the same way that many other OECD countries do. In line with its 'dirigiste' approach to public sector R&D the federal government prefers to fund R&D in HE via specific objective-focused programs. As a result, the difficulties in estimating the proportion of GUF grants that constitute R&D and the fields of research, socio-economic objectives and other breakdowns of R&D expenditure covered by GUF are avoided – arguably making the current expenditure element of US estimates of HE R&D more accurate than those for other OECD countries. On the other hand, US State governments do provide GUF-type funding for universities and it is not clear how effectively these are captured in R&D data. A major disadvantage in the US R&D expenditure data for HE is that capital expenditure is excluded – and the figures for the US and therefore not compatible with those of other OECD countries.

With regard to R&D fixed capital, whilst most OECD countries report the actual investments in fixed capital in the year in which they were made the US collects data on *depreciation charges* instead of fixed capital investment. This introduces an additional problem in relating R&D budgets and R&D expenditure outturns.

[12] NSF (2002) Science and Engineering Indicators, 4-50.

The key role of computing and communications infrastructure

28. The technical capabilities of the computing and communications infrastructure play a key role in facilitating the effective use of most other types of research facilities & equipment. There are two dimensions to this, firstly in providing the high bandwidth communication links that allow research collaboration and the use of remote or networked research facilities to take place. Secondly, as an integral part of the discovery process itself.

29. With regard to ICT's integral role in the discovery process, the ability to identify patterns in large and/or very complex datasets and to identify changes in previously identified patterns is an extremely important aspect of R&D – not least because this promises to reduce the cost and time of many types of R&D.[13]

30. Much of this research effort stems from concerns with cost-escalation in weapons system procurement. These efforts are, for example, supported by NASA via such research programs as the 'Intelligent Synthesis Environment' (ISE) program. A synthetic environment mirrors a real situation and allows decisions to be made, and their consequences assessed, 'off-line'. Moves to 'dump the D' in R&D are associated with the US Federal Government's efforts to disseminate the advanced simulation techniques developed to simulate complex processes at places like Los Alamos to the US industrial base. This capability to explore options 'off-line' without committing costly resources can dramatically increase the effectiveness of decision-making - particularly in relation to R&D investment and product and process design. The long-term aim of these programs and technology-transfer activities is to transform 'R&D' by dramatically reducing the 'D' element (some 80% of R&D investment in industry and higher in defence).

31. This process may involve a sustained period of increased levels of 'R' and of 'D' investment because of the need to couple theory-based simulation modelling with the experimental development process in order to develop the capability to eventually substitute simulations for actual experimental development. This coupling process involves improving simulation models, and the underlying theory upon which these models are based, via analysis of the correlations between theoretical prediction and actual behaviour. When these correlations are poor, efforts are made to improve the capability of the model in the light of the anomalies and differences revealed via experimental development.

32. The spin-off from this line of R&D for many other types of research is that the advanced simulation modelling and data mining techniques developed for defence and related national security purposes have tremendous potential to increase the effectiveness of investment in basic and applied research. This is because the time and cost associated with monitoring and analysing complex datasets (in the life sciences, physics, earth sciences, space sciences and social sciences) can all be reduced by advances in data mining and simulation modelling. As a result, the

[13] The following paragraphs draw partly upon arguments put forward in Matthews and Johnston (1999) '*International Trends in Public Sector Support for Research and Experimental Development: A Preliminary Analysis'*, DETYA Evaluations and Investigations Program, Report no. 99/8. Matthews and Howard (2000*) 'A Study of Government R&D Expenditure by Sector and Technology'*. Emerging Industries Section, Occasional Paper no. 3, Department of Industry, Science and Technology, Canberra, Australia. Matthews (2000) '*A Global Perspective on Australian R&D and Innovation Effectiveness'*. Paper prepared for the Australian Agri-Food Congress 2000. Melbourne 16-17 August. Published in conference proceedings.

efficiency and effectiveness of basic and applied research investment may increase.

33. Advanced simulation models and data mining are therefore a key pathway to increasing the yield on public sector R&D investment. The computing requirements for handling these calculations are, however, tremendous. The high cost of providing this computing power clearly needs to be placed in the context of the gains in the efficiency and the effectiveness of R&D investment thus generated.

Exhibit 3: the US interagency Knowledge Discovery and Dissemination (KDD) program

The KDD program is used to facilitate research on mining very large datasets that may have a impact on national security. Recent activity involves funding from the Central Intelligence Agency's (CIA) Intelligence Technology Innovation Centre (ITIC) to supplement existing NSF funding aimed at developing improved techniques for identifying underlying patterns in very large and/or highly complex and rapidly changing ('streaming') data-sets. Spin-offs from this national security-related work are expected to appear in areas as diverse as natural disaster response and bio-informatics.

A strategic focus on research infrastructure – 'build it and they will come'

34. In research areas in which facilities & equipment play a critical role in determining the rate of advance of knowledge the policy option always exists to use funding for R&D capital formation as a catalyst for achieving a wide-range of objectives. This is exemplified in the *Canadian Foundation for Innovation* (CFI) – see exhibit 4. By stimulating the establishment of new and upgraded research facilities and equipment governments are able to create 'research foci' or 'magnets' that attract leading scientists from around the world, retain key researchers and facilitate inter-disciplinary and inter-sectoral research collaboration. This approach can be labelled 'build it and they will come' – the priority placed on providing leading edge research facilities and equipment becomes a key enabler of both the domestic research effort and international collaboration.

Exhibit 4: The Canada Foundation for Innovation[14]

The Canada Foundation for Innovation (CFI) was established in 1997 using part of the surplus from the federal budget. Its objective is to fund Canada's research infrastructure at arms length from government. To date Canadian federal funding stands at $3 billion and the CFI will remain operational until 2010.

The CFI contributes 40% of project costs, requiring host institutions to raise the additional 60% of funding. It has turned out that provincial governments have contributed a matching 40% with the remaining 20% coming largely from the private and private non profit sectors (the latter principally in the health and medical area). Bids for funding are required to provide research plans – contributing to a cultural change within Canadian universities. The new facilities help to attract and retain leading researchers and facilitate inter-disciplinary collaboration.

[14] See http://www.science.org.au/proceedings/priorities/strangway.htm for the text of a talk covering key aspects of the CFI by its CEO David Strangway.

Leveraging the global R&D effort

35. Policy-makers tend to be uncomfortable with using Australian tax-payers' money to fund R&D activities carried out overseas. Limitations on funding for overseas research travel, including travel to use overseas research facilities are just part of the issue.

36. The underlying problem seems to be that the benefits of international research collaboration are not currently presented in a manner that appeals to policy-makers (and Ministers in particular). Consequently, it is useful to highlight the economic and national security benefits in addition to the benefits for scientific research.

37. International collaboration allows us to *leverage* the far larger R&D investments made overseas.[15] This leverage reduces the importance of *scale* of investment factors, in effect allowing a broader *scope* of R&D investments to be made without reducing the scale-driven pay-offs to, and other outcomes from, this R&D investment. It is highly plausible that Australia's strong international performance ('punching above its weight') in scientific publications is due to Australia's high level of international collaboration with leading researchers and research groups. Every R&D dollar spent by Australia (though not necessarily *within* Australia) has the potential to leverage the far larger R&D investments being made overseas – particularly in advanced research facilities. *As a result, Australia's relative level and intensity of R&D investment may appear to be low, but this should be viewed partly as an advantage of possessing a strong basic research capability that generates scope for international collaboration rather than as a problem in itself.*

38. Unlike many Asian nations in science and technology 'catch-up mode', Australia already possesses an internationally recognised capability to perform leading-edge basic research. The 'Asian Tigers' face severe (and costly) challenges in building up their basic research capabilities in order to be able to participate in key international collaborative programs. Our basic research capability allows Australian researchers to participate in major international research programs because they have useful inputs to make. On a broader level it provides scope for Australia to negotiate more favourable terms in major collaborative research efforts than would be the case if our basic research capability were weaker.

39. This means that Australia's ability to leverage the global R&D effort is high – driving up our ratio of scientific outputs to R&D expenditure – not necessarily because we are unusually effective in translating R&D investment into R&D outputs (though this may be the case as well) but because our leverage of global R&D investment, in effect, adds a percentage premium to our national R&D investment because our researchers do not pay the full cost of using leading-edge research facilities overseas. For example, in FY 1998-99 one component of the *International Science and Technology Network* (ISTN) program leveraged at least $1,792,920 in host county contributions for an Australian cash outlay of $281,296 (a ratio of 6.4).[16]

40. For this reason, our R&D capability would be put at risk if there were to be a general move towards full cost recovery for using research facilities. Australia stands to lose (in R&D leverage) far more than it would gain from full cost recovery.

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[15] Australia only accounts for around 1% of global (OECD and non-OECD) R&D investment based on 1999 data – see OECD (2001) Main Science and Technology Indicators.

[16] Australian Academy of Science (2001) '*Program of international scientific and technological collaborations, funded as part of DISR's International Science and Technology Networks: A review'*. March. Table 6.2, page 22.

41. Policy problems do exist however because our effective leverage of global R&D investment is not translated into commercial outcomes as effectively as it might due to weaknesses in our industry base. This impediment to innovation should be viewed in the context of our effective leverage of global R&D investment. *If* we were able to reduce the severity of the research commercialisation impediment, our rate of growth the GDP would benefit more from our 'global R&D leverage'.

42. If, however, our R&D policy framework cuts back on aspects of R&D that allow us to leverage the global R&D effort (i.e. those programs that fund the use of overseas research facilities and overseas travel for research purposes) then we restrict our capacity to leverage global R&D. We are likely to be trapped in a vicious circle created by the need to spread our R&D investment thinly across a wide range of research fields without benefiting either from economies of scale in domestic R&D or the leverage of global R&D – thus limiting the efficiency and effectiveness of our public sector R&D investment.

Pursuing national security objectives builds coordination over the exploitation of research assets

43. Whilst there is much scope for using leading-edge facilities & equipment to leverage global R&D via trading access rights this 'value' cannot be exploited if there are no institutional means of asserting influence and co-ordinating these negotiations. Countries with a strong emphasis on national security in their research systems tend to have developed more effective mechanisms for high-level co-ordination and negotiation over access to leading edge research facilities.

44. For example, it is understood that UK Ministers and officials are provided with a classified document for use in a wide-range of international negotiations that details what should and should not be discussed, and negotiated over, as regards research facilities and related matters. This document is believed to contain capability summaries of the key research 'assets' possessed by different countries. The uniqueness and sophistication of the research facility assets, if used as part of foreign policy, can be a useful tool for conducting international relations.

45. To our knowledge, little has been published on how the major science powers control access to leading-edge research facilities by overseas nationals and this issue requires closer investigation. It would be useful to obtain more information on this issue.

46. The United States is particularly adept at using its national security apparatus to pursue joint security and commercial objectives. For example, budget statements highlight the 'dual-use' and spin-off aspects of defence R&D and related mission oriented R&D carried out by organisations like NASA. Defence export controls applied to dual use technologies such as high performance computing (HPC) are a useful tool for pursuing the 'dual objectives' of maintaining national security and maintaining an advantage in commercial technological capabilities. A pervasive national-security orientation in the US science and innovation system assists both in the provision of adequate funding for leading-edge research facilities and in controlling and co-ordinating flows of technological knowledge in and out of the United States. This includes access to leading-edge research facilities, particularly those associated

with the various National Laboratories that have a strong national security remit (Los Alamos etc).[17]

47. Whilst Australia, like many nations, lacks the extraordinarily high defence and defence related R&D investments of the US (see exhibit 5) the benefits of 'mission oriented' R&D and development programs can still be reaped provided that appropriate mechanisms are put in place. This is because mission oriented R&D programs seek to make coordinated investments that drive down the technical risk that a system won't operate effectively. This means that the severity of the 'innovation progression gap' is dramatically reduced and that, consequently, spin-offs can take place at a lower level of risk to potential commercial investors.

Exhibit 5: US Department of Defense and Department of Energy R&D Expenditure in FY 2003

Department of Defense		
Basic research	$1,336m	(2.45%)
Applied research	$3,616m	(6.63%)
Experimental development	$49,570m	(90.88%)
Facilities and equipment	$22m	(0.04%)
Total R&D	**$54,544**	**(100%)**
Department of Energy		
Basic research	$2,517m	(29.58%)
Applied research	$2,866m	(33.68%)
Experimental development	$2,162m	(25.41%)
Facilities and equipment	$965m	(11.34%)
Total R&D	**$8,510m**	**(100%)**

Note: in US budget figures investment in research facilities and equipment is treated separately from the three-part breakdown of the type of R&D activity (basic research, applied research and experimental development). As a result, the breakdown of type of activity only applies to current costs. This is line with original FRASCATI recommendations (possibly based upon the US view), however other OECD countries allocate capital costs to the three part breakdown on the type of R&D.

Source: US Federal Budget, Analytical Perspectives table 8-2 p 170.

48. It is difficult for Australia to deal with 'science power' countries with this strong and pervasive national security emphasis in their R&D activities because the centralised co-ordination mechanisms here are not as strong. The very wide range of technologies over which the US places export controls is salutatory and highlights the pervasive nature of integrated national security priorities and commercial priorities.[18]

[17] It is worth noting that, since the end of the Cold War, the US National Laboratories are under strong pressure from Congress to generate a large increase in the extent to which their capabilities are used to enhance US commercial interests (via, for example, the dissemination of de-classified aspects of the advanced simulation modelling techniques used to design nuclear weapons to commercial design activities).

[18] See http://www.bxa.doc.gov/ for an overview and access to detailed information.

49. Defence R&D in Australia is not as integral to the overall national effort, even in terms of 'dual use' technologies. The mechanisms for co-ordinating control of access to research facilities between the Federal and State governments are not strong and this could become a key issue should State governments take a more prominent role in funding their research facilities. In short, if Australia is to be able to leverage its research facilities as assets in this wider context, arguably the strongest case for any increase in investment in such facilities, then considerable effort would have to go into how to coordinate access to these facilities within the context of a far wider range of foreign policy objectives. Some recommendations are made on this theme at the end of this paper.

50. It is worth stressing that this 'realpolitik' perspective towards research facilities will be an anathema to many scientists. The reality is, however, that the science powers are science powers because public sector R&D has been driven by 'dual priority' national security/national interest and commercial advantage concerns. The technology catch-up strategies pursued first by Japan and more recently by other Asian nations does not always have the same explicit defence dimension, but they do have a very strong 'nationalistic' focus. The community of science is inherently international but it tends to operate in a 'dynamic tension' with strong nationalistic objectives – particularly when major R&D investments are required.

The relevance of the national research priority setting exercise

51. The current discussions on setting scientific *national research priorities* provide an opportunity to explore policy options relating to funding for facilities and equipment within the context of the R&D leverage approach. As research priorities are set by the Federal Cabinet more attention will focus upon how these priorities should be met. This will inevitably involve a consideration of access to the research facilities and equipment necessary to carry out the research targeted in our national research priorities.

52. If a clearer distinction is made between setting *policy* priorities and the *research* priorities that we need to meet these policy priorities then it is easier to incorporate the benefits of leveraging the global R&D effort into the policy framework. In order to meet our policy priorities it makes sense to leverage the global R&D effort rather than attempt to 'go it alone' in R&D terms. Securing access to leading-edge RF&E is a key means of participating in, and therefore leveraging the global R&D effort.

53. The priorities implementation process will consequently need to consider the relevance of the RF&E already in place in Australia, the RF&E available overseas, and any new RF&E investment required within Australia. This, in turn, will (ideally) require the mapping out of the capabilities of our stock of research facilities and equipment and an assessment of the capabilities available overseas.

54. It follows that the scope for influencing both Federal and State government S&I budget planning with respect to RF&E may increase significantly in the next year or so. If this window of opportunity is not exploited by the scientific community then a key chance to improve the coherence of government funding will have been lost.

55. In particular, the very existence of long-term strategic research priorities creates the opportunity to argue for full greater *cycle support* for the facilities and equipment that are critical to achieving these research objectives. This life-cycle support could depend upon the degree of market failure & public good factors involved (limiting long-term private

sector investment in such facilities & equipment). In some areas a high long-term public sector contribution would be required, in others this could be more transient as private sector and international users started to make use of the facility.

56. It would therefore be useful to frame public funding strategies for these priority RF&E in terms of:

- An initial 'start-up' or major upgrade phase of relatively high public funding contributions against total costs;
- A phased reduction in the public funding contribution proportionate to the degree of market failure involved (the proportion of public funding levelling out at a higher percentage for research facilities with limited potential to generate other funding streams);
- An agreed mix of Federal *and* State government funding throughout the public funding commitment;

57. A significant impediment to decision-making over the implementation of Australia's research priorities is that we do not have a comprehensive data-set on the nation's stock of larger RF&E and networks/clusters of RF&E or a set of estimates of the future life-cycle costs of this stock of R&D capital. This makes it difficult to make coordinated decisions over what we have, what we would like to have, and what it will cost to keep it up to date. This contrasts with the information available to US policy-makers, which draws upon surveys of the 'health' of US research facilities and equipment and anticipated new investment requirements.[19]

An efficient division of labour in infrastructure funding involving State governments

58. The State governments are significant funders of the national R&D effort. The R&D expenditure in State government organisations is fairly large in comparison to that performed in Commonwealth government organisations – and is growing rapidly. In 1998-99 R&D performed in the State government sector accounted for 9.93% of national R&D investment compared to 13.48% in the Commonwealth government sector.[20]

59. State government funded R&D is highly focused and concentrates on the agricultural, medical and biological research fields. The two-year time lag before the ABS R&D expenditure figures are published means that the picture provided in the official statistics for 2000 may significantly under-state the current contribution of the States.[21]

[19] This is the 'Survey of Academic Research Instruments and Instrumentation Needs' carried out by the National Science Foundation (NSF). This is a "….congressionally mandated survey that serves as the primary source of information on the need, stock, cost, and utilization of research and development equipment within academia in the United States. It is used by Congress and Federal agencies in planning programs for funding academic instrumentation."
http://www.nsf.gov/sbe/srs/sariin/start.htm

[20] ABS 8112.0 1998-99.

[21] The Institution of Engineers' submission to the national priority setting exercise contains a useful detailed account of the growing role played by State governments in funding R&D.

Exhibit 6: Example of State Government funded investments in research facilities and equipment

The recently announced Victorian research infrastructure grants illustrate the growing level of State government involvement in funding research facilities & equipment. Major recipients of the $59m allocated under round 2 of the Infrastructure Grants Program are:

- Nanotechnology Victoria ($12m)
- Clinical Trials Victoria ($8m)
- Victorian Centre for Advanced Materials Manufacturing ($5m)
- Victorian Institute for Chemical Science ($5m)
- Research Centre for Advanced By-wire Technologies ($4.73m)
- Victorian Centre for Plant Functional Genomics ($4m)
- Centre for pre-Clinical Drug Candidate Optimisation ($4m)
- Collaborative Optical Leading Testbed ($4m)
- Victorian Centre for Oral Health Science ($3.5m)
- Australian Sustainable Industry Research Centre ($2.4m)
- Systems for Sustainable Aquaculture ($2.06m)

60. It is inevitable that State governments will seek to compete in making investments in major RF&E. Provided that wasteful duplication of these investments is avoided by appropriate (limited) co-ordination this will be to the overall benefit of Australian science.

Defining a whole-of-government strategy for securing access to critical research facilities

61. This *Discussion Paper* has highlighted a number of key policy issues concerning our investment in research facilities & equipment. This section identifies one possible way forward.

Identifying 'Critical Research Facilities'

62. Once national research priorities for science have been set, and therefore added to the existing set of Australian research priorities, it would be useful to identify, on a global scale, all the research facilities that are critical to meeting these research objectives. This list of CRFs would be a key resource in the science policy framework.

63. The main purpose of the list of CRFs would be to focus attention on making sure that Australia's research priorities can be delivered by gaining adequate access to these capabilities provided by the CRFs. A global CRF approach would help Australia to leverage the global R&D effort via gaining access to critical research facilities.

64. Those CRFs that are located in Australia (or that have nodes located in Australia if they are networked facilities) would become the logical focus of attention when it comes to considering the adequacy of current and expected future funding. In most cases it would be anticipated that such facilities would overlap with the concept of 'major national research facilities' (MNRFs).

65. The current selection criteria for MNRFs do not explicitly consider the role played by these research assets in helping to facilitate our access to other facilities in different research fields on a global scale. In this sense our selection of MNRFs is not part of a more general *coordinated* R&D leverage *strategy*. In the future, a more strategic selection of MNRFs may be beneficial. This is because our capacity to access leading-edge RF&E overseas requires skills and experience gained though using lower-performance domestic RF&E and via graduate training as part of international collaborative projects using leading-edge RF&E overseas. Obtaining access to leading-edge overseas RF&E is not a substitute for the provision of domestic RF&E – the two approaches have a complementary relationship. In addition, we need the domestic research assets to negotiate with. However, a lack of strategic coordination in these investments may (in principle) result in a set of Australian MNRFs that neither provide us with assets to negotiate with in obtaining access to leading-edge RF&E overseas or provide us with the skills and experience required to use leading-edge facilities overseas.

66. This is not to suggest that our current set of MNRFs do not provide is with these capabilities, but it does highlight a potential problem caused by the lack of a coordination mechanism that treats investment in accessing overseas RF&E and in providing domestic RF&E as complementary options within a single strategic vision. The assessment of MNRF bids on a case-by-case basis without considering these more 'systemic' issues, and the lack of coordination with funding of overseas access of RF&E are less likely to result in the beneficial coordination emphasised in this discussion paper.

Re-engineering the S&I Budget framework in order to implement national research priorities

67. The Australian Academy of Science has already stated that it would like to see a one-line item in the Federal Science and Innovation (S&I) Budget covering investment in major research facilities.[22] There is however a complementary but significantly different approach to this budget issue. This is to highlight the benefits of re-engineering the S&I Budget framework in order to allow the Federal government's *National Research Priorities* and other Australian research priorities to be implemented effectively, and in so doing highlight the importance of making investment plans for 'facilities and equipment' more explicit – thus emulating the approach used in the United States.

68. The argument in favour of re-engineering the S&I Budget framework is that the introduction of a set of national research priorities may bring to a boil simmering concerns about the adequacy of the current S&I Budget framework as a means of informing policy-making and funding allocations. This is not to argue that the current S&I Budget framework is internally flawed in any way. Both the budget setting process and the estimates

[22] Recommendation number 8 in '*Priorities in research and innovation for the next Australian Government*'. Australian Academy of Science. October 2001.

provided in the S&I Budget Statement (collectively referred to here as the S&I budget *framework*) are effective in relation to their current purpose.[23]

69. The point is that this purpose is likely to shift once the national research priorities are implemented. This is because it will become more important to be able to relate budget expenditure plans to actual expenditure outturns, and then to be able to relate the actual expenditure outturns to outputs and outcomes. If these relationships cannot be traced and assessed then it will be difficult to create the necessary feedback loops for assessing whether national research priorities are actually leading to the intended expenditures and what the pay-offs to these expenditures appear to be.

70. Given this new challenge, and the fact that there have already been changes to the way in which S&I budget figures are reported, it is likely that further reporting changes may be being planned.

Implications for the S&I Budget framework of an increased emphasis on the productivity of public sector R&D investments

71. Another point exists in parallel with the implications of setting national research priorities for the S&I Budget Framework. This is that the growing emphasis on measuring and assessing the outcomes and outcomes from public sector R&D (essentially asking questions about the efficiency and the effectiveness of our investments in R&D) will tend to lead to an opening of the 'black box' of R&D expenditure – greater consideration of the types of activity and expenditure taking place than takes place at present. The main reason for this 'unpacking' of the composition of R&D expenditure is that there are very distinct components involved (facilities and equipment, research operating costs, travel, salaries and on-costs etc) that are *complements* and, to some extent, *substitutes*.

72. The effectiveness with which available research time is actually used depends partly upon how adequate the facilities and equipment are (in many cases this means how *new* they are). If they are of an older 'vintage' then it may be necessary to employ more technicians and research assistants than would otherwise be the case. Older vintages of equipment, including computers, are usually slower to perform tasks and more subject to breakdowns etc.

73. In short, it is unrealistic to adopt a greater scrutiny on the productivity of public sector R&D investment without unpacking what these investments consist of, and starting to analyse the set of productivity relationships that link investments in facilities & equipment, buildings, labour costs and other current costs. As with the point made about the implementing national research priorities this too implies that the current design of the S&I Budget Framework may become increasingly out of alignment with the uses to which this information is put.

[23] Indeed, the current S&I Budget Statement is an extremely useful summary of Commonwealth funding plans and how each agencies' and programs priorities and objectives mesh together and all those involved in the preparation of the S&I Budget Statement should be commended for their efforts in this difficult and highly complex area.

The key role played by investment in facilities and equipment in a re-designed S&I budget framework

74. Although these are general points about the S&I Budget framework they do have some very specific implications for how public sector investment in facilities and equipment should be handled.

- Public sector investment plans for R&D facilities and equipment by thematic priority area *and* relative to long-term requirements could become more explicit in the S&I Budget framework.[24]
- Public sector investment plans for other types of facilities and equipment that facilitate the *commercialisation of R&D* could also become more explicit in the S&I Budget Framework. This will require that the OECD's 'FRASCATI' R&D focused expenditure categories are augmented with suitable non-R&D categories.[25] Addressing expenditure classes in this way will have the advantage of helping to map out the growing divergence between the S&I Budget Statement estimates and the R&D-specific expenditure outturns captured, with great accuracy, by the ABS R&D expenditure surveys.
- Public sector investment in leveraging overseas R&D investment should be made explicit – with a particular emphasis placed upon providing access to 'critical research facilities' that are located overseas.

Introducing a more 'structural' element in the S&I Budget Framework along US lines

75. Such changes would, in effect, turn the S&I Budget Framework into a more 'structural' picture of Commonwealth spending plans (see exhibit 7). This would have the effect of aligning the Australian S&I Budget Framework more closely with the US approach – which has a strong structural dimension in the sense that R&D expenditure plans are 'unpacked' in order to identify investment in basic and applied research and experimental development together with facilities & equipment.

76. The US approach to S&I Budgets is notable for its 'nationalistic' emphasis on generating budget estimates that meet Washington's policy objectives and, as a consequence, place less of a priority on complying with OECD guidelines relating to the collection and collation of R&D expenditure data. It is not that the US government breaks the OECD guidelines on the reporting of R&D data, *it avoids being restricted by them* in order to effectively pursue the implementation of policy.

77. US experience also highlights the importance of relating R&D expenditure outturns to budget plans – the two pictures of the public sector R&D effort can be significantly different. This divergence even exists in relation to government department and agencies figures for actual disbursements

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[24] It may be possible to generate a partial set of S&I budget figures that make investment in RF&E explicit simply be using information readily available in the Commonwealth budget papers. The budgets agreed for the R&D performing agencies detail capital appropriations and also provide separate asset valuations for 'land & buildings' and for 'infrastructure, plant & equipment'. It may therefore be possible to estimate both the value of the RF&E capital stock and the projected investments in RF&E using existing sources of budget data.

[25] The OECD's Oslo Manual provides a useful, but not sufficient, basis for augmenting the FRASCATI R&D categories.

and the figures obtained from R&D surveys on actual funding received from these departments and agencies.[26]

Exhibit 7: Outline structure for a revised S&I budget framework

The following method of reporting S&I budgets would retain compliance with the OECD FRASCATI categories whilst augmenting them with key investment categories that lie beyond R&D per se. Indeed, the basic idea behind the suggested changes is to provide 'early warning' of the composition of public sector R&D investments rather than wait until the ABS R&D data are published in order to obtain a detailed breakdown of the type of activity (basic research, applied research, experimental development) and the capital formation component against various thematic priorities. The current time-lag before the ABS data are published limits the utility of these data for policy-making.

If, instead, the ABS data were to be treated as a rigorous and comprehensive assessment of R&D expenditure *outturns* that could be related back to previous statements of *budget intentions* then it would be possible to create a 'feedback loop' between the *ex ante* and *ex post* budget figures. Most importantly, the *process* of setting S&I budgets could draw upon the 'whole-of-government' estimates provided by the use of this new approach – with the iterations in departmental and agency budget scenarios (at both Federal and State/Territory levels) drawing upon this information on the wider picture.

This iterative process could be facilitated by using a standard (secure) web-based *Budget Intention Templates* (BITs). The whole-of-government picture would be provided simply by automatically collating the information, in real time, provided by these BITs using off the shelf spreadsheet packages with links to all BITs. Use of BITs would, in particular, facilitate Federal-State/Territory cooperation – and would be an exemplar of e-government (also raising the possibility of significant time and cost-savings in budget preparation processes).

Budget Intention Templates could cover the following expenditure categories:

- Planned *basic research* expenditure (an amalgamation of pure and strategic basic research);
- Planned *applied research* expenditure;
- Planned *experimental development* expenditure;
- Planned expenditure on *land and buildings* for use in R&D;
- Planned expenditure on *research facilities & equipment and other capital expenditure* for use in R&D;
- Planned current expenditure on *development, deployment & commercialisation* (outside of R&D per se);
- Planned expenditure on *land and buildings* for use in *development, deployment & commercialisation* (outside of R&D per se);
- Planned expenditure on *research facilities & equipment and other capital expenditure* for use in *development, deployment & commercialisation* (outside of R&D per se).

[26] The National Science Board (NSB) has found that this discrepancy reversed direction. In the mid 1980s performer-reported Federal R&D exceeded Federal reports by up to $4 billion (some 10% of the government total). By 1989, the government total exceeded performer reports by $1 billion and the gap was $8 billion in 2002. This problem is OECD wide and relates mainly to defence R&D funding with post-Cold War changes in the composition of R&D activities, and in particular the growing importance of non-traditional forms of R&D being blamed for this funding-trace problem.

If these S&I expenditure categories were set against the key thematic research priorities identified both in existing agency budgets and in the new national research priorities then a comprehensive picture of how we plan to deploy our S&I resources would emerge. Whilst recognising that actual expenditure outturns will differ significantly from these plans, and for good reasons, this 'early warning' information would help to coordinate the national S&I effort. The statements on government S&I spending plans will be far more useful in policy-making. The ABS R&D surveys would become, in effect, the final 'audited' national R&D accounts.

Integrating Federal and State Government Budget Frameworks

78. It would be particularly useful if any move towards a more structural approach in the S&I Budget framework involved an alignment with State government budget plans. Indeed, State government departments may wish to take the lead in producing more structural S&I budget estimates in order to assist in executing their economic development strategies and in building inter-State and State-Commonwealth government cooperation over research infrastructure provision.

79. The OECD's *Government Budget Appropriations or Outlays for R&D* (GBAORD) estimates, which are reported in OECD comparative international R&D statistics, do not usually include State government budget appropriations. As a result, the Federal government department responsible for collating GBAORD estimates (currently DEST) has no incentive to liaise with State and Territory government departments over S&I budget appropriations.

80. If a general S&I budget reporting methodology were agreed with the States and Territories it would then be possible to produce a comprehensive overview of both Federal *and* State government budget plans. There would be some important advantages from doing this:

- Putting together a comprehensive overview of all governments' budget plans would be useful in the context of a move towards setting national research priorities.
- It would be easier to relate actual expenditure outturns and to link eventual outcomes if better information were available on how Federal and State government funding is combined in different research areas.
- The process of trying to agree a shared S&I budget methodology would foster a better understanding of broad policy objectives both between the States and between each State and the Federal government.
- The level of State-Commonwealth co-ordination in the annual process of setting S&I budgets would be improved if iterations in budget plans could easily be collated and areas of overlap/possible duplication identified. This would depend upon a greater degree of transparency in the S&I budget setting process.

A strategic approach to public sector investment in R&D facilities and equipment

81. A move towards a more 'structural' S&I Budget Framework, in which investment in national research priorities and other thematic areas is complemented by closer scrutiny of *how* these priorities will be met, would raise the profile of public sector investment in RF&E.

82. This, in turn, would stimulate a policy debate about the adequacy of this investment – a debate couched both in terms of our capacity to actually deliver on our research priorities in practice and the efficiency and effectiveness with which we advance our scientific and technological knowledge.

83. This would amount to a significant paradigm-shift in the approach to funding RF&E. The current paradigm could be characterised as still being dominated by an 'expenditure' perspective (large amounts of funding are spent and the public and private pay-offs are not clear). In contrast, the 'investment'-based perspective embodied in a re-engineered S&I Budget Framework would help to ensure that our investment in R&D facilities and equipment is adequate in relation to the policy objectives that have been agreed.

84. A more strategic approach could also involve:

- Regular assessments of investment requirements for facilities and equipment (maintenance, performance upgrades and new facilities by thematic research area), linked to;
- Analyses of the role played by different vintages and capability-levels of facilities & equipment in determining the overall efficiency and effectiveness of public R&D investment.
- Placing Australia's resulting R&D capability within a comparative *international context* in order to identify research areas in which we currently possess, or could attain, comparative advantage in research based upon possessing particular configurations of RF&E vis-à-vis areas in which our research can be carried out effectively using RF&E available overseas.

Co-ordinating negotiations over access to leading-edge research facilities as an aspect of foreign policy and trade negotiations

85. This Discussion Paper has argued that Australia would benefit from a more coordinated approach to investing in our own leading-edge research facilities and in securing access to leading-edge facilities overseas. This improved co-ordination would relate to universities, Federal and State government research organisations and to private sector firms engaged in R&D that is either related to Australia's national security interests or to Australia's research priorities.

86. As regards the conduct of international negotiations relating directly or indirectly to access to RF&E some form of central co-ordinating function may well be beneficial. This function would increase in importance in proportion to the extent to which Australia possesses *and controls* unique or otherwise 'high-demand' research facilities – such as would be provided by the '*Square Kilometre Array*' (SKA).

87. One possible approach would be to make sure that appropriate support is provided to the office of the Chief Scientist to ensure that Australian researchers are obtaining sufficient access to critical research facilities (CRFs) both overseas and within Australia. The office of the Chief Scientist could also aim to ensure that decisions over providing access to leading edge Australian research facilities are 'placed on the negotiating table' both with regard to obtaining access to overseas facilities and with regard to any other international negotiation in which Australia seeks to prevail.

88. It would therefore be necessary for the office of the Chief Scientist to liaise closely with a wide range of Commonwealth government departments and agencies (such as DFAT, DoD, ONA, DEST, ARC, NHMRC, IRT, CSIRO, ANSTO, GA, DSTO) together with CCST, the research universities and the State and Territory Governments. The objectives of this effort could be summarised as: '*ensuring that the conduct of all international negotiations takes into account Australia's long term national security, scientific and commercial interests as they relate to access to critical research facilities and that investment in domestic CRFs is sufficient and effective*.'

89. The office of the Chief Scientist could be asked to contribute a tri-annual assessment of the problems faced by, and opportunities presented to, Australia as regards the control of access to leading-edge research facilities. Its remit could cover funding allocation issues relating to critical research facilities as it would be in a position to advise committees such as PMSEIC if it felt that funding policy and agency and program co-ordination problems needed to be raised at that level.

Conclusions

90. This *Discussion Paper* has set out to define a 'forward strategy' for securing access to leading-edge research facilities for Australian science and its commercialisation. This strategy is based upon treating the current national research priority setting exercise as an opportunity to:

- re-focus S&I policy in order to provide a better 'global reach' for Australian science and technology – thus improving our leverage of the other 99% of global R&D investment;
- re-engineer our S&I Budget Framework along US-style structural lines in order to facilitate both the implementation of national research priorities and adequate public sector investment in R&D facilities & equipment;
- improve the co-ordination of international negotiations concerning access to leading edge research facilities.

91. Feedback on this forward strategy from policy makers and other stakeholders would be most welcome.

Annex A: Outline of the Project

This project aims to develop policy recommendations for the funding for Australia's *scientific research infrastructure*, and *major research facilities* in particular. The work is being funded as part of an Australian Research Council (ARC) *Special Projects* grant on Major National Research Facilities (MNRF).[27] This grant was awarded to the Australian Academy of Science (AAS) in 1999.

The project builds upon earlier work carried out by the AAS, including the Forum *'Major Research Facilities: Towards a National Policy Framework*' held in April 2000 and the Academy's response to the CCST 'Major National Facilities Working Group' Discussion Paper on this topic. It also builds upon the 'audit' of major national research facilities in Australia carried out by the consultant in a previous study for the (then) Department of Industry, Science and Resources (ISR) in 1999.

The current phase of the study involves:

- examining *current programs* that support Australia's scientific research infrastructure;
- assessing *areas of need* on the basis of consultations with applicants for funding from last year's MNRF2 bidding round;
- explaining how Australian science benefits from *international collaboration* using research facilities, and;
- examining what can be learned from *policy approaches developed overseas*;
- on the basis of this research, recommending changes to Australia's research infrastructure funding programs.

[27] The current project constitutes the concluding piece of work carried out using these funds.

Terms of Reference

1. Describe existing programs that support research infrastructure for Australian science, in particular:
   - The major National Research Facilities (MNRF) program;
   - Systemic Infrastructure Initiative (SII);
   - ARC's Linkage Infrastructure Equipment & Facilities (LIEF) program;
   - CSIRO, AIMS, ANSTO, Geoscience Australian etc;
   - Institute of Advanced Studies; and
   - State Government initiatives.

2. Examine applications to last year's MNRF program to identify areas of particular need that remain in Australia's research infrastructure.

3. How does Australia benefit from international science and technology collaboration through membership of international projects, such as the Ocean Drilling Program, the Photon Factory, Gemini, International Spillation Fusion Agreement and the International EPSI agreement; and
   - access to major facilities overseas.

4. Recommend changes to Australia's research infrastructure programs that would advantage the development and maintenance of Australia's research infrastructure; and
   i take account of the findings of this study,
   ii take account of examples of good practice from overseas,
   iii give consideration to recent developments in Commonwealth/State relations in Australia.

Membership of the project Steering Group

Professor Michael Barber (Chair)
Secretary (Science Policy), Australian Academy of Science
Pro Vice-Chancellor (Research & Innovation) University of Western Australia

Professor Peter Colman
Head, Structural Biology Division, Walter and Eliza Hall Institute of Medical Research

Professor David Doddrell
Professor of Magnetic Resonance and Director, Centre for Magnetic Resonance, University of Queensland.

Dr Phil McFadden
Chief Scientist, Geoscience Australia

Professor Steve Redman,
Professor, Division of Neuroscience, John Curtin School of Medical Research, Australian National University.

Professor Sue Serjeantson, Executive Secretary, Australian Academy of Science.

Professor Erich Weigold
Director, Research School of Physical Sciences and Engineering, Australian National University.

Professor John White
Professor of Physical and Theoretical Chemistry, Research School of Chemistry, Australian National University.

Dr Martin Gallagher (Observer), Department of Education, Science and Training, Canberra