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Submission by the Bureau of Meteorology to the

Inquiry into Australia's international research collaboration

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Executive Summary

Key Points

- International research collaboration is an important enabling activity for Australian science.
- The nature of collaboration by the Bureau of Meteorology is multi-faceted and serves a number of purposes.
- International scientific and technical collaboration is essential for the operations of the Bureau of Meteorology.
- The Bureau of Meteorology has realised discernable and tangible benefits from international research collaboration.
- The Bureau recognizes that researchers in its domain of interest do face some barriers to effective collaboration.

Specific points against Terms of Reference

TOR 1: The nature and extent of existing international research collaborations.

The nature and purpose of existing Bureau of Meteorology international research collaboration includes (i) Transfer of knowledge and technology from the International community to Australia and the Bureau, (ii) Exposure to new ideas and innovations, (iii) International involvement and investment in Australian projects, (iv) Mutually supportive scientific activities, particularly with respect to data, (v) Enhancing the skills of Bureau experts, (vi) Training for young and emerging scientists, (vii) The provision of research services to the international community, and (viii) Benchmarking for national research. These collaborations have yielded identifiable and tangible benefits for the Bureau and the nation. Collaboration extends over all functions of the Bureau but is particularly strong in the area of warnings and weather forecasts. The SW Pacific and SE Asia is a major focus of collaboration. In terms of research collaboration with individual countries, the US, China, UK, France and the Republic of Korea are most prominent.

TOR 2: The benefits to Australia from engaging in international research collaborations.

The Bureau of Meteorology recognizes direct benefits of international research collaboration to both its own operations and services as well as to the nation more broadly, in areas such as climate change, water resources, emergency management and national innovation generally. The science of meteorology, hydrology and climate is inherently global and “international”, not respecting international borders or geopolitical boundaries. As a consequence, to meet the requirements of Australia, we must encourage and support international research collaboration in these fields. For fields relevant to the Bureau, there is a well-established intergovernmental framework and the Bureau takes extensive advantage of this in delivering enhanced and more reliable outcomes for Australia. Increasingly, the Bureau is using international research collaboration to support directly capability and capacity development, particularly in complex areas such as modelling. The Bureau recognizes discernable and tangible benefits for Australian scientists, including those in the Bureau, from international research collaboration.

TOR 3: The key drivers of international research collaboration at the government, institutional and researcher levels.

The global scale and ever-increasing complexity of issues such as climate change are driving international collaboration at the Government level. Policy development in key areas such as water and climate are informed through knowledge gleaned from international collaboration as well as knowledge directly generated within Australia. Institutions are developing mechanisms that allow them to address capability (and sometimes capacity) gaps through international

collaboration. Modern communication technology allows an international research partnership to be as effective for institutions as a local one. Significant drive stills comes from the researcher level, in part motivated by the quest to bring the best science to bear on the problems of interest, and in part by the desire to conduct science and be recognized amongst peers.

TOR 4: The impediments faced by Australian researchers when initiating and participating in international research collaborations and practical measures for addressing these.

The remoteness of Australia from the main research hubs in North America and Europe remains a significant impediment, despite the progress with communication. Cost-effective video-conferencing facilities, open to all researchers, would provide one effective measure. World-competitive scientific infrastructure is needed to attract the highest calibre collaboration; in some key areas this is lacking. The fragmentation of Australia's research community through different funding and governance arrangements inhibits nation-to-nation collaboration – often collaboration must be restricted to a particular agency. While agreements with countries like India have boosted the effectiveness of collaboration, such opportunities need to be available more generally.

TOR 5: Principles and strategies for supporting international research engagement.

The products of international research collaborations should be discernable and tangible. A policy framework that provides guidance on appropriate levels and mechanisms and a means for measuring and reporting the impact, including benchmarks would be beneficial. At a fundamental level, the impact of international research collaboration will be measured by the value it returns to national capacity, capability and productivity. The nature of the collaboration may vary, as outlined in the response to Term of Reference 1, but the product of collaborations should be discernable and tangible. Regional science hubs, for example in earth system modelling may enhance the effectiveness.

Bureau of Meteorology's relevance to the Inquiry's Terms of Reference

The Bureau of Meteorology is a scientific and technical operational agency. The nature of its systems and services mandates high levels of international collaboration, including for research.

Introduction

The nature of international research collaboration

International research collaboration delivers advantages and value in a number of ways including:

(i) Transfer of knowledge and technology from the international community to Australia and Australians;
(ii) Exposure to new ideas and innovations;
(iii) Opportunities to attract international involvement and investment in Australian projects;
(iv) Mutually supportive scientific activities, particularly with respect to data;
(v) Enhancing the skills of Australian experts;
(vi) Training for young and emerging Australian scientists;
(vii) The provision of research services to the international community; and
(viii) Benchmarking for national research.

The functions of the Bureau of Meteorology are prescribed by the *Meteorology Act 1955*[1], including

> *6 (1)(g) the promotion of the advancement of meteorological science*, and
> *6 (1)(i) co-operation with the authority administering the meteorological service of any other country*.

Together these functions explicitly recognize that international research collaboration is fundamental to the observation, warning and other national information services provided by the Bureau of Meteorology. These authorities provide the overarching context for this submission.

The scientific basis of meteorology and climate is inherently global in nature and does not recognize geopolitical boundaries. Physical interactions on global scales, and the need for global observations to understand and predict the weather and climate at regional scales mandate that international collaboration is strong and purposeful.

Research underpins four of the five Outcome areas of the Bureau of Meteorology – Observations, Warnings and Weather Forecasts, Climate Information and Water Information. Many of the associated deliverables are explicitly dependent on successful international research collaboration.

For meteorological and related research, much of the international collaboration is coordinated through the World Meteorological Organisation (WMO), sometimes in partnership with other United Nations' agencies such as the UN Educational, Scientific and Cultural Organisation (UNESCO). Non-governmental bodies such as the International Council for Science (ICSU) also play important roles.

International research collaboration within the Bureau of Meteorology is also supported through specific bilateral protocols under Section 6 (1)(g) of the Meteorology Act 1955 and other bilateral (e.g., the Agreement relating to Scientific and Technical Cooperation between the United States of America and the Government of Australia) and multilateral arrangements. In this submission international research collaboration is assumed to include the overall conduct of international science and technology relationships.

Currently, research in the Bureau of Meteorology is undertaken through two alliances with CSIRO, the Centre for Australian Weather and Climate Research (CAWCR) and the Water Information Research and Development Alliance (WIRADA).

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[1] Additional authority is provided by the *Water Act 2007*

Response to the Terms of Reference

1. The nature and extent of existing international research collaborations

Summary: The nature of existing Bureau of Meteorology international research collaboration includes (i) Transfer of knowledge and technology from the International community to Australia and the Bureau, (ii) Exposure to new ideas and innovations, (iii) International involvement and investment in Australian projects, (iv) Mutually supportive scientific activities, particularly with respect to data, (v) Enhancing the skills of Bureau experts, (vi) Training for young and emerging scientists, (vii) The provision of research services to the international community, and (viii) Benchmarking for national research. These collaborations have yielded identifiable and tangible benefits for the Bureau and the nation. Collaboration extends over all functions of the Bureau but is particularly strong in the area of warnings and weather forecasts. The SW Pacific and SE Asia is a major focus of collaboration. In terms of research collaboration with individual countries, the US, China, UK, France and the Republic of Korea are most prominent.

The nature of existing Bureau of Meteorology international research collaboration falls within the eight areas listed under (i) through (viii) above, but with some areas such as data exchange taking on greater importance for the Bureau.

(i) Transfer of knowledge and technology

The Bureau of Meteorology has a long-standing policy of promoting the transfer and uptake of international knowledge and technology, often through research collaborations. Several contemporary examples illustrate the fundamental importance of this policy.

- The Australian Community Climate and Earth System Simulator (ACCESS) is a joint collaboration between the Bureau of Meteorology, CSIRO and Australian Universities to develop a world-leading weather and climate modelling facility for Australia. Underpinning this collaboration was an agreement with the United Kingdom Met Office to incorporate the Met Office Unified (atmospheric) Model into ACCESS and support its development through a two-way collaboration between the ACCESS community and the Met Office. The licence arrangements allow for waiver of the annual fee if the collaboration is judged by the Met Office to be of material benefit; this has been the case through two years of the Agreement. In turn, the Bureau of Meteorology has released an ACCESS-based weather prediction system that is yielding unprecedented skill, approaching that of the global leaders in the field. A world-class climate model is close to complete. Significant collaborations with New Zealand and the Republic of Korea have emerged on the back of the initial ACCESS framework.

- The Bureau of Meteorology Next Generation Forecast and Warning System was supported by the Australian Government in the 2009-10 Budget. At the heart of this system is the US-developed Graphical Forecast Editor Suite, the use of which is covered by an agreement between the US National Oceanic and Atmospheric Administration and the Bureau of Meteorology. A strong and mutually beneficial research collaboration supported the implementation and further development of the system, a system which has already had significant impact through its initial operation in Victoria, including during the Black Saturday event.

- The BLUElink Project is supported by the Bureau of Meteorology, the Royal Australian Navy and CSIRO to deliver ocean forecasts for the Australian region. The modelling has

benefited directly from importation of a leading international model (from the US), and the research is undertaken within an international project known as GODAE OceanView. The importation of scientific knowledge has, and continues to directly benefit the project.

- DART® (Deep-ocean Assessment and Reporting of Tsunamis) real-time monitoring systems were developed by the US NOAA Pacific Marine Environmental Laboratory and play a critical role in tsunami forecasting. The Bureau of Meteorology imported this technology as part of the Australian Government response to the 2004 Boxing Day tsunami and now operates DART® buoys at six sites. While the moorings are purchased at market value, continued international research collaboration is essential for the effective use and further development of this technology.

(ii) Exposure to new ideas and innovations;

All four of the examples cited above owe their existence to initial exposure to the science and technology through regular international collaboration. The Bureau of Meteorology participates in many expert groups and scientific panels, in part to ensure it is exposed to the latest trends in science and any innovations that may be of benefit to the Bureau. While each international research activity undergoes a test for the discernable and tangible benefits it will return to the Bureau, the Bureau of Meteorology is convinced that international collaboration is fundamental to the scientific health and evolution of the Bureau.

(iii) Opportunities to attract international involvement and investment in Australian projects

One of the most complete data sets of tropical convection ever collected resulted from an international collaboration known as the Tropical Warm Pool International Cloud Experiment (TWPICE), conducted in the area around Darwin in late 2005 and early 2006. The experiment was hosted by the Bureau and involved European and US research collaborations. The Cape Grim Baseline Air Pollution Station operated by the Bureau frequently attracts significant international collaboration. Both ACCESS and BLUElink also attract direct international engagement in Australian projects.

(iv) Mutually supportive scientific activities, particularly with respect to data

In terms of priority, the international exchange of data and development of associated scientific standards and protocols ranks for the Bureau as the highest among the benefits retained for Australia and the Bureau. Current agreements under the aegis of the WMO underpin weather and climate warnings and services. International research collaboration provided one of the initial foundations and continues to contribute to its enduring strength. More recently, within the WIRADA agreement, the Bureau has been leading the development of an international water data transfer standard within the Hydrology Domain Working Group of the Open Geospatial Consortium. A further somewhat different example is provided by the Intergovernmental Panel on Climate Change – Bureau experts have participated in each of the first four Assessments and, in turn, the IPCC Assessments have informed Australian science and related policy development.

(v) Enhancing the skills of Australian experts

In addition to the aim of gaining exposure to new ideas and innovations, Bureau of Meteorology experts are also encouraged to forge international relationships to enhance their personal knowledge and skills. As part of the ACCESS development, a number of Australian scientistrs have had extended visits to the UK. The Bureau supports participation in a number of expert groups to improve skills and technical knowledge.

(vi) Training for young and emerging Australian scientists

This is effectively a sub-category of (v) and is particularly important for young scientists and scientists working on newly emerging areas. The Bureau encourages all young scientists to develop international research relationships as part of their career development. Such links have been greatly facilitated by internet technologies.

(vii) The provision of research services to the international community

This is not an explicit objective of the Bureau[2]. However, from time to time, the Bureau is requested to make its scientific and technical expertise available for international projects. Often such projects are led by AusAID. Often capacity development and exchange of scientific and technological know-how are explicit objectives of such projects and these are facilitated by international collaboration. Current examples (both funded through AusAID) include the Southwest Pacific Sea Level Climate Monitoring Project and the Pacific Climate Change Science Project (with CSIRO).

(viii) Benchmarking for national research

Other meteorological services, such as the UK Met Office and the US NOAA National Weather Service are often used as benchmarks for the Bureau of Meteorology. International research collaboration provides a means for continuous benchmarking of Bureau of Meteorology services, systems and technology against international counterparts.

The extent of the collaboration spans all outcome areas and most deliverables of the Bureau. Collaborations with the USA are the most extensive but China has now emerged as the second most important relationship. Within Europe, the most significant partnerships are with the UK and France. The SW Pacific and SE Asian regions are the most important in terms of regional relationships. Interestingly, the Republic of Korea through the Korea Meteorological Administration is now second only to China (and ahead of Japan) in terms of scientific and technical exchanges.

2. The benefits to Australia from engaging in international research collaborations

Summary: The Bureau of Meteorology recognizes direct benefits of international research collaboration to both its own operations and services as well as to the nation more broadly, in areas such as climate change, water resources, emergency management and national innovation generally. The science of meteorology, hydrology and climate is inherently global and "international", not respecting international borders or geopolitical boundaries. As a consequence, to meet the requirements of Australia, we must encourage and support international research collaboration in these fields. For fields relevant to the Bureau, there is a well-established intergovernmental framework and the Bureau takes extensive advantage of this in delivering enhanced and more reliable outcomes for Australia. Increasingly, the Bureau is using international research collaboration to support directly capability and capacity development, particularly in complex areas such as modelling. The Bureau recognizes discernable and tangible benefits for Australian scientists, including those in the Bureau, from international research collaboration.

Australia benefits substantially as a nation from participation in international leading-edge scientific research in the meteorological, hydrological and oceanographic sciences. Clearly, for

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[2] As of the 2009-10 Portfolio Budget Statement, neither research nor international activities are any longer explicit outputs from the Bureau.

the Bureau of Meteorology, these manifest most directly through improvements in and reliability of our warnings and weather forecasts, climate and water information, and observational networks. However, we also recognize other benefits, for example through informing water and climate change policy, aviation, foreign aid and development programs, as well as the general strengthening of the Australian research community.

While Australia is unique as an island continent and has distinctive weather and climate regimes, most of the scientific challenges faced by Australia are shared and effective access to state of the art scientific knowledge, methodologies, technologies, information and data is critical to our national well-being, prosperity and growth. For example, while Australia has a comprehensive observation network, data from other sources such as satellites are critical for our national warning and prediction capabilities. The meteorological community, operating through the World Meteorological Organization, is long-regarded as an outstanding example of successful international cooperation and collaboration, delivering benefits both globally and on the national scale, while sharing the costs of delivering this massive underpinning infrastructure.

As noted above, our relationships are both multi-lateral, such as through the WMO, and bi-lateral, such as with the National Weather Service in the US on development of our Next Generation Forecast and Warning System. Collaborative efforts give economies of scale and deliver national cost effectiveness by enabling leverage with other international partners. The ACCESS modelling system delivers national benefit both through the rationalisation of Australian effort but also through the introduction of additional capability derived from the UK Met Office partnership, at limited cost, a capability that was beyond the Bureau's reach and beyond the capacity of the national ACCESS partnership. Such relationships are long term and strategic in nature, aimed at national benefit, not just the Bureau.

Australia acquires both enhanced capability and capacity through international research collaboration. We are viewed as an important and willing contributor with scientific credibility and prepared to work on developing solutions to global and regional problems in areas such as climate change, the water cycle, high impact weather, and the Antarctic environment. Solutions developed internationally are also more likely to be aligned with national interests and benefits when we are directly involved and shape the agenda. We also enhance our scientific reputation through our commitments to applying our science skills to assisting our neighbours in the Pacific, such as through the Pacific Climate Change Science Program.

Whilst the Bureau of Meteorology and CAWCR scientists are involved in a number of major research collaborations, it is important to recognise that there are also substantial benefits from research carried out in quite small projects. For example, discrete studies such as that with Brazilian researchers on subtropical cyclones, or with the Meteorological Service of Canada on improving lightning probability forecasts, bring benefits to the respective communities and the scientists within both partners, and also encourage knowledge transfer in discrete fields of science.

The Tropical Warm Pool International Cloud Experiment provided an example of national benefit deriving from attracting a large international experiment to Australia. The study was the largest field program to be held in Australia and several years in the planning and involved several aircraft from Europe, USA and Australia, ground-based stations, a research vessel and hundreds of scientific and technical personnel. The resultant data set will be of value to Australia and the international science community for many years.

3. The key drivers of international research collaboration at the government, institutional and researcher levels

Summary: The global scale and ever-increasing complexity of issues such as climate change are driving international collaboration at the Government level. Policy development in key areas such as water and climate are informed through knowledge gleaned from international collaboration as well as knowledge directly generated within Australia. Institutions are developing mechanisms that allow them to address capability (and sometimes capacity) gaps through international collaboration. Modern communication technology allows an international research partnership to be as effective for institutions as a local one. Significant drive stills comes from the researcher level, in part motivated by the quest to bring the best science to bear on the problems of interest, and in part by the desire to conduct science and be recognized amongst peers.

Climate change is the most obvious example of an international and national scientific issue that is only approachable through international collaboration; it is not tractable for a single nation, no matter how mighty. Weather prediction is similarly limited – if Australia was to rely only on the knowledge and data collected within Australia's jurisdiction, predictions a day in advance would be challenging. The advent of satellite technologies has broken many of these barriers but Australia still must rely on international collaboration to access such data.

The increasing complexity of science, particularly in the emerging field of Earth System Science and related modelling, severely tests all nations, let alone a smaller nation with limited resources. International research collaboration is an important strategy for staying abreast of developments and gaining access to the latest science and technology.

Government

The two issues mentioned above present challenges at the Government level. For climate change there are extensive national and international collaborations in all facets of climate change – the scientific basis, impacts, adaptation and mitigation. The Intergovernmental Panel on Climate Change, while principally in place to undertake regular assessments, also indirectly drives international climate change research collaboration on a grand scale.

The Australian Government's Super Science initiatives are in part a response to the challenge of complexity. The policy recognizes the need for national collaboration, on a large scale. In many areas, such as marine and climate science, this collaboration needs to extend globally.

For the Bureau of Meteorology, Government level interests (and drivers) are expressed through the authority of the *Meteorology Act 1955* and the *Water Act 2007*. Particular challenges relate to extremes in weather and climate, such as the fire weather conditions leading to the Black Saturday bushfires, and pressing issues such as water resources and availability.

International and intergovernmental agreements also provide drivers for international research collaboration. Examples include the UN Framework Convention on Climate Change, the WMO Convention and Government commitments to SW Pacific countries through the International Climate Change Adaptation Initiative.

Institutional

The *Meteorology Act 1955* authorises research collaboration between national meteorological and hydrological agencies. As such, it represents the main institutional driver for international research collaboration within the Bureau. The agreement with the UK Met Office provides an example where this institutional arrangement is providing both opportunity and motivation to extend collaborations in a way that has not been done before.

The WIRADA and CAWCR partnerships with CSIRO also drive international collaboration, for example in relation to the development of the Australian Water Resources Information System and the monitoring of air pollution at Cape Grim.

Researcher level

A great deal of international research collaboration is still driven from the bottom up, at the individual researcher or research team level. At this level, gaps in knowledge and/or capability are quickly identified and in many cases an international solution has many appeals.

Science progresses through the dedication and commitment of individual researchers. Scientists get the opportunity to challenge and advance their science by making connections with similar institutions and researchers overseas.

The natural desire to be recognised and rewarded as an individual and as part of an elite group of international experts is also a driver for scientists to commit to collaborative relationships. These overseas collaborations often also enable access to more advanced and sophisticated science and support systems. They can also allow our world-leading scientists to train colleagues in techniques that we have developed within Australia.

4. The impediments faced by Australian researchers when initiating and participating in international research collaborations and practical measures for addressing these

Summary: The remoteness of Australia from the main research hubs in North America and Europe remains a significant impediment, despite the progress with communication. Cost-effective video-conferencing facilities, open to all researchers, would provide one effective measure. World-competitive scientific infrastructure is needed to attract the highest calibre collaboration; in some key areas this is lacking. The fragmentation of Australia's research community through different funding and governance arrangements inhibits nation-to-nation collaboration – often collaboration must be restricted to a particular agency. While agreements with countries like India have boosted the effectiveness of collaboration, such opportunities need to be available more generally.

At a practical level, despite tremendous improvements in communications technologies, Australia still suffers from a tyranny of distance. Collaborations often require at least some face-to-face contact, and email and videoconferencing cannot cover all situations. Travel costs, particularly to the major development centres such as Europe and North America, are high and the time demands are substantial, while the travel can be tiring. For agencies without access to international research communication networks the cost of video-conferencing remains a factor.

International research collaboration is often attracted to world-leading scientific infrastructure and the ability of Australia to develop and sustain relevant competitive scientific infrastructure may be an impediment to beneficial collaboration. International researchers in climate and earth system modelling are now pointing to supercomputing as a limiting factor on scientific progress and have suggested international research collaboration may need to explicitly include such facilities. Australia has strengthened its own supercomputing facilities, including at the Bureau of Meteorology, but more generally is limited in terms of the capacity it can bring to high-end modelling issues and this in turn may inhibit our ability to participate at the leading edge of such research.

While Australia is physically large, the research population is small by international standards, meaning that many areas in science are covered only thinly. The competing time demands can prevent enough individual or team specialisation to achieve international recognition and attract collaborators. The fragmentation of Australia's research community exacerbates these problems of operating within 'silos'. A wider accessibility to research funding opportunities and more flexible institutional arrangements (such as developed by CAWCR and ACCESS) would help ameliorate this.

Language may be an impediment in some cases, as most Australians are fluent only in English, yet many collaborators have good English as a second language. It may be advantageous to encourage learning of other languages by Australian scientists and collaborations of foreign-born scientists with overseas colleagues.

Overseas institutes and agencies may lack the financial resources to host Australian scientists (particularly so for SE Asia and the SW Pacific), and we could assist if we had the capacity to pay part or the total of these expenses in many cases.

Benchmarks for levels of international research collaboration would be useful. While individual agencies like the Bureau of Meteorology have guidelines for international engagement, it is sometimes difficult to set guidelines for research since the benefits are often not direct and accrue over the longer term, making tests of discernable and tangible benefits difficult.

Membership in elite international expert teams builds the status of the individual member organisations and provides enhanced organisational capacity and access to resources that may not be available within Australia, and the increased pool of scientific expertise available encourages cross-fertilisation through attracting the best scientists to either work in Australia or take on long-term visitor arrangements. There is, on the other hand, significant scope for personal capability development of science staff, particularly younger and early career Australian scientists and graduate students where opportunities are facilitated to work and develop their careers overseas, and bring new skills back to Australia later in their careers. An environment of exchange visits and encouragement for career development has the added benefits of rewarding international friendships and enhancing job satisfaction.

5. Principles and strategies for supporting international research engagement

Summary: The products of international research collaborations should be discernable and tangible. A policy framework that provides guidance on appropriate levels and mechanisms and a means for measuring and reporting the impact, including benchmarks would be beneficial. At a fundamental level, the impact of international research collaboration will be measured by the value it returns to national capacity, capability and productivity. The nature of the collaboration may vary, as outlined in the response to Term of Reference 1, but the product of collaborations should be discernable and tangible. Regional science hubs, for example in earth system modelling may enhance the effectiveness.

In the case of the Bureau of Meteorology, there are a number of recent examples where the benefits of international research collaboration have been significant.

Few Government Agencies have international outcomes as part of their high-level objectives. Fewer still would explicitly recognize international research collaboration as a high-level function, though some may recognize it as an enabling function. The benefits of international research

collaboration often manifest indirectly. A policy framework that provides guidance on appropriate levels and mechanisms and a means for measuring and reporting the impact of international research collaboration activities may be beneficial. These should include benchmarks.

The alignment of International Science Linkage type activities with National Research and Super Science initiatives such that significant international research is aligned with major priorities would enhance our collaborative scope.

Policy and funding could be provided to encourage regional international science frameworks. The European COST model is an example that provides significant national and international collaboration with well focussed and leading edge objectives. A Pacific and Asian region science hub could also be a way forward. We could support the development of major science hubs with encouragement for international participation e.g. for a national computing infrastructure, building science directions with significant international alignment and national spin–offs.