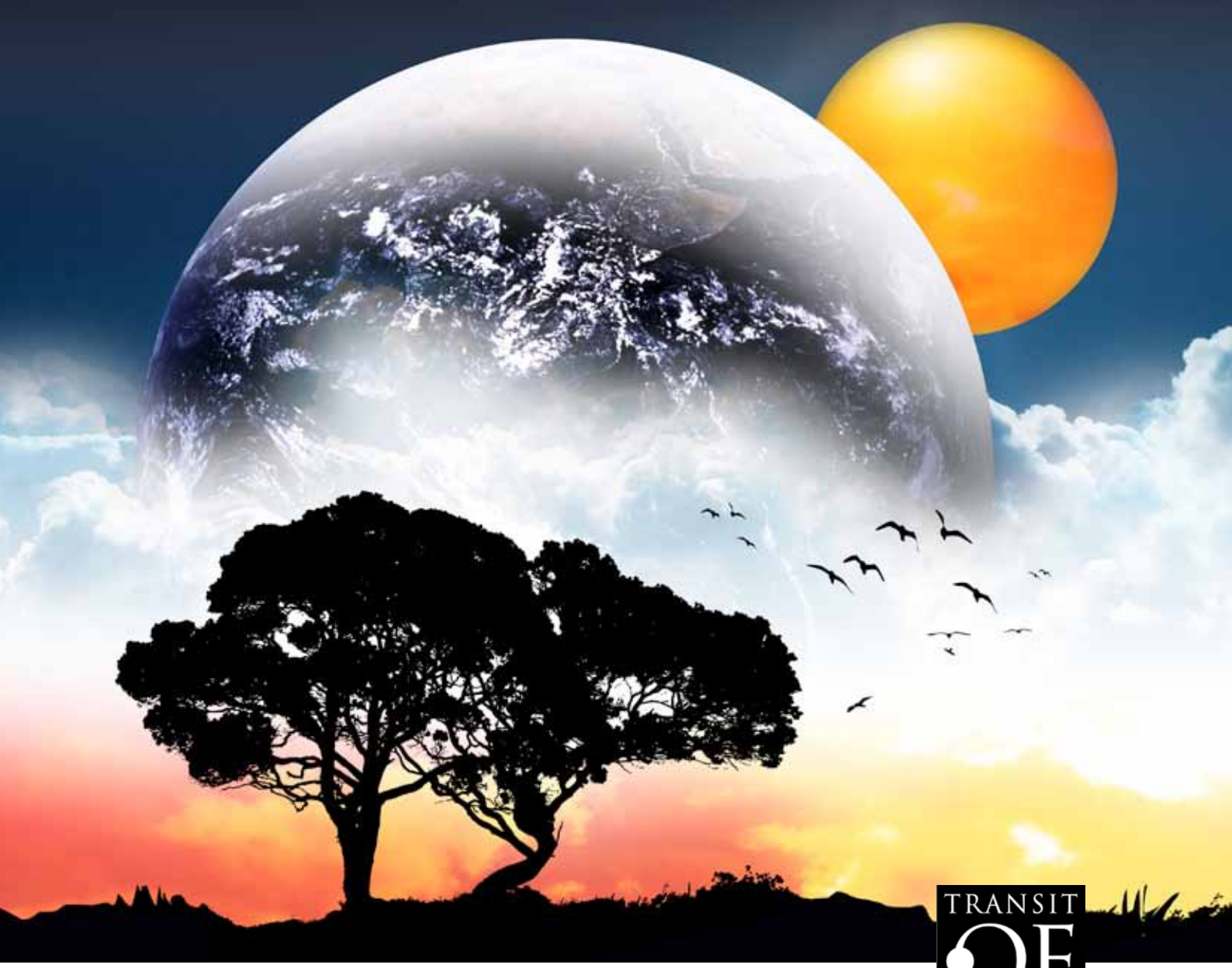

Science and New Zealand's Future: Reflections from the Transit of Venus Forum

A report to the Prime Minister from Sir Peter Gluckman

OFFICE OF THE PRIME MINISTER'S SCIENCE ADVISORY COMMITTEE

Introduction

On June 7 and 8th 2012, over 250 New Zealanders including leaders from government agencies, local bodies, science organisations, academia, business, iwi and NGOs, as well as successful locally and internationally based Kiwi entrepreneurs and many young people, gathered in Gisborne for a Forum to discuss how New Zealand could better use science to advance economically, environmentally and socially.

The Forum was conceived of by the late Sir Paul Callaghan. He saw it as a way to commemorate the many scientific associations underlying James Cook's arrival in New Zealand in 1769.

Because of his terminal illness, Sir Paul asked me to take over the leadership of the Forum. Paul and I made the decision that the focus of the Forum should not be on a discussion of where New Zealand wants to go, as that is generally agreed by most New Zealanders (albeit with different emphases), but rather how science can accelerate us down the collectively acknowledged path. As I stated in my opening remarks …

> *"The question which we came together for, at the inspiration of Paul, was how can science, the power of the mind and scholarship help make this country achieve some generally held goals, economic prosperity, a high standard of living for all, greater social cohesion and achieving that necessary economic growth without harm to our environment."*

Captain James Cook's voyage to the South Pacific had been sponsored by the Royal Society of London as part of an 18th century international scientific collaboration to observe the Transit of Venus. He did this successfully in Tahiti and thereafter under sealed Admiralty instructions sailed south in search of the legendary great southern continent. Following an initial landing in Gisborne that was fraught with misunderstandings, Cook then landed at Uawa (Tolaga Bay) where the first amicable and constructive dialogue between Māori and Pakeha occurred. It was therefore highly appropriate that, on the day prior to the Forum, its participants gathered with many others in Tolaga Bay/Uawa to observe the latest transit of Venus and the last that will be observed for more than a century. The enthusiasm of the people, both young and old, of Te Aitanga-a-Hauiti to engage with the Forum participants was palpable and invigorating.

The nature of the constructive and committed dialogue at the Forum itself was an illustration of the hunger, and indeed passion, many New Zealanders have for New Zealand to be more ambitious in its use of science and scholarship. There was clear recognition that science and scholarship have critical and greater roles to play in advancing New Zealand economically, in moving our society towards greater social cohesion, and in protecting our environment – and yet doing so within a broad range of constraints. And science promotes New Zealand's place in the world.

While it was acknowledged that some significant steps in the right direction had been made in recent years, there was an essentially unanimous view that a more cohesive and aggressive approach was needed if New Zealand is to make best use of its latent capacities in the pursuit of such national but realistic aspirations.

At the same time, it was agreed that difficult issues in moving New Zealand ahead should not be avoided or consigned to being adjudicated on the basis of rhetoric alone, and were therefore canvassed. These matters included the complex subjects of technology assessment, risk management, how trade-offs are to be managed, how the tail of educational disadvantage for many New Zealanders might be remedied, and addressing those structural and operational limitations still occurring both within the science system and within the innovation system (these are not the same).

"New Zealand is at last starting to move beyond its traditionally somewhat hesitant approach to the use of science, scholarship and intellectualism."

The overwhelming sense of the meeting was that New Zealand is at last starting to move beyond its traditionally somewhat hesitant approach to the use of science, scholarship and intellectualism. With this, there is an energy and capacity that can be harnessed to advance New Zealand more rapidly and effectively, particularly in the economic domain, thereby empowering the nation's capacity to improve social conditions and better protect the country's unique environment. Science offers the fundamental capacity to work objectively through some of the complex trade-offs that all countries face when navigating the demand for growth and social expectations on one hand and environmental protection and constraints on the other. A more mature and robust approach to technology and

risk assessment and its application is called for – one based on knowledge rather than simply gut reaction and rhetoric.

The Forum comprised many different voices; it was constructive and highly collegial but at the same time was made up of a series of frank conversations. Naturally there were some diverse views and, at times, advocacy for particular positions. Nevertheless, the desired sense of direction consistently emerged. There was a clear view that within Māori and Pasifika communities there remains a great deal of latent and actual innovative potential to be unleashed.

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The Forum consisted of an opening address by myself[1] followed by six sessions, each with four to six presentations by invited speakers followed by extensive dialogue with the participants. The sessions were on prosperity, resource management, the environment, a Māori perspective on innovation, our people, and New Zealand's place in the world. I then summarised the meeting. In parallel there were several public panel discussions convened by Ms Kim Hill, and there was considerable web-based interaction. It is not my intent to summarise the proceedings session by session, rather I shall identify the major themes and conclusions reached[2].

This report reflects my own personal summary and interpretation of the meeting. It is also inevitably influenced by other recent dialogues I have been part of, including meetings with the Chairs of European Science and Innovation Advisory Councils and other chief scientists, particularly those from other small advanced countries.

Overall impressions

Fundamentally, the Forum was addressing a group of challenges – how does one balance economic growth and resource use versus resource conservation, what trade-offs are involved, how can we use technologies well and when should we limit their use? How should we move from a rather limited understanding of new technologies when there is often accidental or even intentional confusion between science on one hand and politics, values and philosophies on the other? And in what ways can knowledge and scholarship play a much stronger role in our society?

At the Forum there was overwhelming support for the centrality of science and scholarship as a strategy for advancing New Zealand. There was a strong view that New Zealand had failed to adequately grasp the opportunities that science and scholarship offer. It was noted that over some decades most other small advanced nations had invested significantly more in science and had done so in a more holistic way. This higher public investment in R&D in other countries had been paralleled and then exceeded by increased private sector investment. This has seen dividends coming to these countries in terms of their economic development and international standing. The New Zealand situation is complicated by the nature of our business mix, the lack of multinationals and our isolation, but we should expect dividends from greater public and private investment in R&D.

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A number of systematic and organisational limitations for using science optimally in New Zealand were identified by participants, who presented their arguments in a constructive spirit. The view was strongly put and agreed that generally there must be a more complete perspective on how science contributes to New Zealand's development. There has been a strong and very focused belief in the utilitarian role of science in providing the substrate for economic innovation. In itself this is true and should be reinforced, but not at the expense of a broader commitment to the many other ways that science contributes to advancing New Zealand. Indeed, some of these areas have received minimal focus over some decades.

While the tone of the meeting was very positive and enthusiastic and acknowledged that your government had made important steps to address this deficit, it was felt that greater attention to the broader uses of science was desirable if New Zea-

1 Available at www.pmcsa.org.nz.

2 The full proceedings of the Forum are available at http://www.royalsociety.org.nz/events/2012-transit-of-venus-Forum-lifting-our-horizon/Forum-programme/.

land was to fulfil the ambitions that we all have for this country.

Strengths and weaknesses

We are a small and geographically remote nation. We are multicultural and both emotionally and economically we increasingly see ourselves as part of the Asia-Pacific. We tend to be complacent – selling food and tourism has been relatively easy, but worryingly, exports as a percentage of our economy have stagnated over some years. As a nation we have been relatively satisfied with ourselves and not as ambitious as we need to be in order to thrive despite the inevitable challenges, including those of rearrangements of the global economy over the coming decades. It is not realistic to imagine that we can achieve as a small nation the kind of growth we need by looking inwardly. We need to be better at looking at ourselves and at learning from and linking to the changing world.

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When one scans the globe, many of the most successful high-income countries (at least in economic terms) over the past decade have been small countries. Countries like Denmark, Singapore, Korea, Israel and Finland have all managed to withstand the economic storm better than most – and they have done so on the basis of becoming knowledge-intensive economies. Several consistent themes emerge.

It is clear that smallness does indeed drive a culture of doing more with less (although there is a limit to that concept) and that while we might not often think we do it well, technology transfer tends to be more efficient in small countries. Smallness forces small countries (and companies) to focus on thinking globally – they fail if they do not. This raises the question: should we be partnering more with the other small countries? All said and done, good teams are made by marrying different skills, and some places such as Singapore have capacities and capabilities that we do not have.

Parenthetically one of my more interesting conversations recently was with Saul Singer, one of the authors of *Start-Up Nation* – the book that documents and explains Israel's rapid emergence as the hot-house of knowledge-based start-up activity. We discussed how countries look at themselves. As he said so pithily, "Finland has start-up envy, Israel has Nokia-envy". His point was that every country must develop its own path to innovation and must build on what they are excellent at – yet all nations are good at taking for granted what they are best at rather than using that to build on and create excellence. We all can feel resonance with this statement – we need to find our own path.

One of the negatives that was discussed is that we tend to look at ourselves introspectively: we need to deal with our sometimes choking internal parochialism, we need to become cleverer at self-diagnosis, but intellectuals thinking in isolation will have little impact. There is a need for informed and inclusive public discussion. As one of the participants said, "Serious countries treat ideas seriously". Our debates are often superficial and ill-informed – often entirely emotive with neither knowledge nor consideration of the fact that every decision involves implicit or explicit trade-offs.

"Serious countries treat ideas seriously."

Scale is a major issue in innovation. Innovative knowledge appears most often at the frontiers of disciplines interacting with other disciplines. Good evidence has emerged from analysis that larger cities and clusters are the most innovative. Thus, several speakers pointed out the need to build Auckland to scale, the need to encourage greater differentiation among our tertiary institutions and reduce their focus on internal competition and thus a trend to become somewhat homogeneous, and the need to enhance greater connectedness in the science and innovation sectors across the country. It is probably to our disadvantage that our businesses are themselves more individualistic than in many other comparable countries, with our SMEs tending to be smaller.

A challenge for New Zealand will always be to maintain its relevance. Our relationship with much of the world is not equal. Thus our reputation and ability to contribute disproportionately in some areas where we can deliver is important. It is therefore imperative to understand how others see us. 'Clean and green' serves us well in some quarters. But we are well 'off the radar' in terms of being viewed as an innovative and R&D intensive nation, and in Asia that really counts against us. Innovative countries want to associate with other innovative countries. Indeed, we have lost our past

reputation as a test bed of innovation, and that has had costs.

One cost is that we have lost the interest of multinational corporations. An innovation ecosystem needs such corporations and the lack of them here counts against us. How do we rebuild our reputation as a laboratory for innovation and attract those players?

But we have many strengths that must be built upon.

New Zealand is small enough to be nimble and be more inclusive in the use of science as a part of policy development; indeed, there has been significant political commitment in recent years to this strategy.

We are strongly conscious and proud of our environment, and 'clean and green' is a strong brand that sells in consumer-focused markets. But in other markets, New Zealand's reputation as corruption free is the key value proposition. We need to be clear about our strategy market by market – in many markets, the concept of sustainability is gaining value rapidly, but in a world of food, water and energy insecurity, continuity and safety of supply remains the primary concern for many. The challenge will remain of how to balance and indeed integrate these concepts.

In general we have a good education system in the science, technology, engineering and mathematics (STEM) subjects at secondary school, albeit with a long tail of under-achievement. But we need to think through how to take advantage of new technologies to enhance STEM education and science literacy and to disseminate them. There are a number of issues at the secondary-tertiary interface that were identified and need addressing.

We are a diverse population, and through that diversity should come opportunities for more innovation. There is growing experimental evidence, supported by what we saw at Uawa, suggesting

"We need to be prepared to experiment more to address educational disadvantage."

that we can undoubtedly create culturally informed initiatives that turn the weaknesses of the long tail of under-achievement into success. We need to be prepared to experiment more to address educational disadvantage.

The innovative potential of the Māori community is sadly underestimated. Māori themselves understand the need to be part of the innovation society, and they understand the need to marry the well-established western tradition of knowledge generation with the strengths of their own cultural identity, whether drawn from contemporary experience or traditional knowledge. There may be challenges in integrating Tikanga Māori into areas of technology adoption (and vice versa), but with better dialogue we should be able to turn this marriage into a strength.

The nature of science

Science is not just a collection of facts – rather it is a particular way of observing the natural and built world so as to gain a better understanding of it. It is wrong to assume that science is about certainty, for in most of science certainty is not possible; rather, it is largely about reducing uncertainty. But science, both formal and informal, remains the only process we have to gather reliable information about our world on any scale and from any perspective. To reject this is to reject the very basis of logical assessment of the challenges we face.

The one dimension of science that needs to be protected at all costs is the need for the collection and interpretation of data to be value-free. Such freedom from bias is not easy and processes such as peer review have been developed to provide protection and correction. But while this formal face of science is often presented as a western tradition that gained impetus after the Enlightenment, observation and experiment have their presence in every culture. But it is where the boundaries between what is observed and what is believed become blurred that confusion appears and that can lead to real problems.

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We are in danger of underestimating how much the nature of science has changed over recent decades. While it used to be focused on linear questions, those aimed for reductionist precision, much science has undergone radical change particularly as the biological, environmental and human sciences have come to dominate. Science now deals with complex non-linear phenomena where certainty is not possible, where there remain many unknowns

and answers are defined in terms of probabilities and levels of uncertainty.

But much complex science has another dimension. It involves the values dimension. Typical examples include food security, the use of genetic modification, dealing with adolescence or the ageing population and climate change. These are issues of high public concern and political complexity. Such science has been termed 'post-normal science' and can be defined as the application of science to public issues where facts are uncertain, values are in dispute, stakes are high and decisions are urgent. So by their very nature these characteristics mean that science is now intimately linked to and intertwined with the values and concerns of the public and body politic. In turn the related domain of economics also now has post-normal aspects. The old model of economics based on the presumption that humans always act rationally in their decision-making has been replaced by a much more complex understanding of how people make decisions based on biases, emotions and experience.

It is important that we do not put science on a lofty pedestal that it does not deserve to be on.

"... science is part of, not distinct from, society."

Throughout the Forum it was clear that the participants understood that science is part of, not distinct from, society. Science provides some forms of knowledge but societal decisions should be and are properly made on many other grounds with strong (but sometimes inadequately examined) value domains: community values, public opinion, fiscal and diplomatic considerations are critical to policy making. The role of science and scholarship is to provide the value-free knowledge base and options for society to opine on when accommodating the other value-laden dimensions that are properly part of democratic decision making.

Because of this intertwining of values with knowledge, a further complexity arises. Science can become the proxy for a values or political debate which is essentially independent of the science. A current example is the pseudo-debate about anthropogenic climate change. While there are real knowledge gaps, most of that debate is not really about the existence of climate change – rather it being used as a proxy for a values debate about economics and intergenerational equity. As scientists get drawn into such debates, they can turn into advocates and risk loss of public trust.

But this discussion assumes that science, scholarship and intellectualism are well connected to society. In fact some of the main conclusions of the Forum were that in New Zealand science is not well connected, either within itself or with society. The science system per se has become highly fragmented by the mix of sometimes ad hoc funding systems. There have also been at times inappropriate expectations of immediate impact coupled with problematic institutional arrangements that do not allow us to maximally use what capacities and capabilities we have in the public science system. We still see enormous divides between the scientific disciplines themselves and between the sciences and the humanities. Regrettably, this is in no small part a direct and cumulative result of our funding models, both for individuals and for institutions. It is sad that the one area in which we should have real advantage as a small country, interdisciplinary science, is arguably the most disadvantaged in both the science and academic systems.

Scholarship of all forms should be valued. We stand out amongst advanced countries in not having many places for interaction between academia and policy, academia and business – there is essentially no rotation between the sectors. And we have too few public intellectuals. And I was struck by one comment – that we face the tyranny not of distance but of 'intellectual isolation'; it was noteworthy that even those from within the digital world speaking at the Forum saw the need for New Zealand to deliberately invest in an enhanced strategy of engagement with policy makers and thinkers overseas. Indeed, being more connected both within ourselves and with the world was a major theme of the Forum.

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The types of science

One of the consistent ideas throughout the Forum, and which is reflected in other conversations, is that it is essential that we all understand the full range of contributions that science and scholarship should and can make to New Zealand's development. Public science and scholarship, including

the humanities and social sciences, have many purposes and it is important to have much more holistic and informed understanding of these.

- There is an important cultural component in creating a society that values knowledge and supports the development of our people, capabilities and capacities.
- We need research that enhances our national identity, be it to understand our peoples and their history, or our indigenous flora and fauna, or our environment. We need research to understand and best manage our natural resources for both economic and conservation reasons. Conservation science is complex and can lead to important but not necessarily intuitive or emotionally-based decisions. Again, we come back to the issue of trade-offs.

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- We need to defend our economy, environment and society through research in areas such as biosecurity, the environment and public health. But how do you value such research? It has immense economic importance but has no direct rate of return.
- We need to improve the effectiveness of public expenditure through better use of health research, social science research and economic research. And the growing use of evidence in public policy-making was noted. Scientific disciplines can be applied to the evaluation of new and extant programmes. What savings might be possible from the public spend if we looked for effectiveness, assuming that this is the basis on which we choose to fund?
- We need research to support our trading and diplomatic interests – for example through Antarctic research, science to support foreign aid, or to support trade agreements such as through biosecurity research.
- We need science to support innovation that directly feeds through to economic growth. But it is important here to understand that this requires a full range of science domains, from what is often called discovery science to late stage development. Innovative countries, especially the smaller ones, see investment in scientific serendipity and in discovery science as critical and continue to increase their commitment. The international literature makes it abundantly clear that there is a very high rate of return on such research.

Science and economic growth

There was vigorous debate about whether economic growth should be judged by dollar value alone, or whether it should include measures of human, social and natural capital. The limitations of the current formulae are well known. Nevertheless, there was agreement that multi-factor productivity growth can occur through imitation (that is by knowledge absorption) or by frontier innovation. However, as countries become increasingly technological and get closer to the global knowledge frontiers, the latter has by far the greater impact on growth. The evidence suggests that while knowledge transfer and absorption promotes growth in low GDP countries, in high-income countries it is no longer enough to have high absorptive capacity and to be competitive they must also have high frontier innovation. Indeed, this applies to a country like New Zealand, even though it must be selective, and the challenge becomes one of prioritisation.

Several clear messages have emerged from the other advanced small nations. Firstly, it is generally accepted that assessing the return on R&D is a complicated process with long lag-times. Further, the linear model of the relationship between investment in an individual research project and private sector developed innovation is now rejected in favour of a much more holistic approach. While it is difficult to measure the direct effects of public R&D spend on economic growth, there is a consensus about its importance and ability to generate return. In general, estimates of the rate of annual return on public investment in R&D are in the order of 20-40%. There is also growing evidence that public investment does not crowd out private investment but rather actually fosters it. While many countries have tried to look at the issue of impact and the broader issues of social and policy return as well as direct economic return, the reality is that quantitative assessments are difficult and artificial. That does not mean that just because

"... assessing the return on R&D is a complicated process with long lag-times."

we cannot measure it well we should ignore it – in a quote attributed to Einstein, "not everything we can measure is important and not everything that is important can be measured".

A second message that has emerged is that while the science and innovation ecosystems intersect, they are not the same. Not all innovation comes from science and it is clear that not all science is driven by a need to innovate. But without a commitment to and a culture of scholarship and enquiry, innovation of the type that will lead to economic growth at a scale we need is not achievable. While relevance and impact will be core to research prioritisation, there is an ineluctable need to sustain a high corpus of research for ideas generation – that indeed is the primary role of universities in a science and innovation ecosystem. It is business that has the role of filtering those ideas and turning them to products.

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There are two key questions in the interplay between the New Zealand science and innovation systems. Firstly, what is it that we are doing well now that we could do more of? Secondly, what is it we are not doing much of but where we have a clear competitive advantage? We will not get rich from our small internal market, but only by increasing sales to the ever-increasingly inter-dependent world.

The answers are not easily arrived at because whatever we do there are trade-offs – risks that have to be evaluated and managed. One example suffices to make some points. In theory we could add at least $15 billion dollars per annum to our national income by selling more milk – and do so without adding one more cow to our national herd. The genetic improvements we have made to date in our cows mean that if they could be fed to their biological potential we would double or triple our milk production, and we know how to sell milk. We could increase the value further, but more slowly, by developing value-added products such as foods with proven health-enhancing properties. All we have to do is feed and care for the cows differently. But now come the trade-offs and thus the constraints and issues – how do we ensure that the less productive farmers adopt the practices of their most productive counterparts? How do we deal with effluent and what would we feed the cows on? Yes, this is likely to involve more grain, more palm kernel and so forth, and would we need feedlots? And what trade-offs are acceptable? Perhaps technological solutions can be found – a scientific effort in this domain would appear meritorious.

I am not advocating for any particular position; rather I am using this as a good example of where emotion, science and politics interact and yet there may be enormous economic opportunity. In a participatory democracy such as ours, open discussion of such trade-offs is essential. However, this should occur in the context of first being informed by science of what we know and do not know – often such debates in New Zealand have occurred on the background of polemic rather than knowledge. We need to distinguish between rejecting a technology per se and rejecting a particular application of that technology. We will face an ever-increasing number of new technologies where we must have such informed conversations.

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And what are we not doing well now where we have a competitive advantage? Given the quality of our STEM education we have advantages in areas such as high value manufacturing, science based services and the digital economy, and the government has made important commitments in this direction recently. Indeed, this is already a particularly rapidly growing part of our economy.

Trade-offs

The discussion of 'trade-offs' featured frequently in the Forum. The reality was generally accepted that everything we do involves trade-offs. Sustaining 40% more people on the planet, many of whom rightly demand far better living standards, will involve more energy and food consumption and more resource use – there is no way around that. How do we do that while protecting a planet we have increasingly come to value and see at risk? I suspect that rich societies are undergoing a fundamental shift in their attitude to the environment, not dissimilar to the shift that happened in

western societies beginning about 200 years ago in how people considered other human beings – we abandoned slavery and the beginnings of social concern and welfare appeared. In my view, too much of the national conversation has been trite in imagining that these trade-offs can be avoided – a much more sophisticated discussion is needed and science and technology will be essential to finding appropriate solutions.

Indeed, one of the surprising things to me at the Forum was the problem of language and the unwillingness of some to get beyond vision and rhetoric to the hard realities. Some wanted to avoid the use of the word 'trade-offs' and preferred to talk about 'balance' or 'equilibrium'. Others wanted to talk about 'ecosystems' in a very generic way – talking about the health of the New Zealand ecosystem means everything from environment to economy. But I think the discussion allowed most participants to come to understand that these are all actually ways of saying the same thing. All decisions involve a trade-off at some level and unless more resources are added to a system, then more difficult trade-offs become inevitable.

My view is that some at the Forum wished to avoid the word 'trade-off' because emotionally it is harder to accept the realities it implies than saying

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balance or equilibrium. But trade-offs are real at every level from the planetary to the individual. In our own lives we prioritise – nearly all of us will prioritise our family and household economy over the environment no matter how much we value it. While one does not have to be rich to value the environment, it helps, which is why a focus on environmental protection generally rises as economies become wealthier.

Trade-offs are often portrayed as binary – more of this means less of that. Actually it is again much more complex: what we are all looking for are optimal solutions to multiple simultaneous demands, where the settings on any one trait affect the settings of many others in non-linear ways. Optimisation does not mean any one trait is set to a maximum and there may be multiple solutions. It is the identification of and the choice amongst options that is, in effect, the nature of policy formation, and this can be difficult.

Science literacy

There is no challenge that we will face over coming decades that does not depend on science. It will be critical to our economic, our environmental, our social and our cultural development. And this does not just mean science in the laboratory or field setting; science has a critical role to play in public dialogue as we develop a national consensus on how best to manage trade-offs. It also can have a far fuller role to play in dealing with many complex policy areas such as health, education and social welfare. And science can help in finding ways to use resources more efficiently – be it fresh water for irrigation or fuel for transport, heating and energy, it is win/win for both the economy and the environment if we can improve productivity while consuming such resources more efficiently.

All of this requires a much more scientifically aware, literate and engaged population. This will be essential if a participatory democracy such as ours is to find its way through the opportunities and threats associated with existing challenges and

"... how do we begin to make a more scientifically engaged and literate population, both public and policy-maker?"

the rapid changes that technology brings. Thus another constant theme throughout the Forum was that of how do we begin to make a more scientifically engaged and literate population, both public and policy-maker? For the point remains that, relative to other small countries, we are behind in making the switch to a knowledge-based economy and society. As a result, we have a relatively high level of dissonance between what we know and what we believe.

Technology and risk

Ultimately the primary discussion at any level, from global to local, will be about the balance between resource conservation and resource exploitation, using these terms in the broadest sense. A mature conversation will depend on a solid evidential base provided by unbiased science, whereas the weighting of paths and priorities is based on values that the whole community must own.

But at the interface is a complex interaction that is reflected in part in the concept of risk. Risk means different things to different people – some scientists may talk in mathematical probabilities, politi-

cians think of risk in an electoral sense, the public generally sees risk through 'system one' thinking, to use the decision theorist's term, i.e. that which is instinctive and emotional. For most people, perceptions of risk are biased by perceptions of who benefits. We have a different attitude to risk if we think we can benefit than if we think someone else benefits. For example, we are happy to break the speed limit for our advantage and take the risk, but we are likely to be angry when someone else overtakes us at speed. It is little different when we think about oil wells or sources of energy.

We often forget that there are trade-offs involved in risk assessment as well. Most think that only 3000 people died in the World Trade Center bombings – in fact the toll was about twice that, for people responded by avoiding aeroplanes and taking cars and an additional 3000 people died from the increased traffic on the road. It gets complicated – fossil fuel power has killed many more people than nuclear power stations (particularly through coal mine disasters), but the reaction in Germany to the Japanese Fukushima disaster has been to switch back to more fossil fuels. I am not advocating any particular technology – merely pointing out that consideration of risk is not simple and singular. There are problems around how we weigh up technologies and risk.

Technologies are developing faster all of the time and they having far greater impact as they project into the community so much more quickly. The challenge is for society to understand and accommodate these technologies at a pace commensurate with their development. There is an urgent need to give far greater weight to the social sciences if we are to cope with the flood of new technologies that are emerging. Otherwise, some important technologies may be wrongly rejected or their harm overstated and yet others may be misused or their potential harm understated.

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A concern raised at several points during the Forum was the role of the media in discussion of these issues. There are many examples where the mass media has ignored the balance of evidence in favour of creating false debate or the appearance of controversy, or promoted a values-based position without providing the public with an understanding of the facts.

The implications of these issues for society are real. The conflict between the pace of development and understanding can be reflected in the rejection of science – an illogical but understandable response to the pace of change. These issues are real and technological advances must be accompanied by greater scientific literacy for all if a participatory democracy is to use science well.

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Important decisions made on the basis of entrenched but knowledge-uninformed views can fix positions in a political process that may not be in our best long-term interests. Ultimately, risks will always be assessed emotionally but those emotions should be informed by what is known or not.

The environment

A key issue for all New Zealanders is the environment. We are proud as a nation of our environmental consciousness. But we must not confuse bottom-up efforts based on passion with the need to have a scientifically based approach to environmental protection. We have a particularly high environmental risk because of our geography and ecological history and there is need for world-class defensive biosecurity research. What is the scope of our natural resources on and offshore: how should we manage and exploit them? The science of conservation has advanced considerably. I would have liked to see the Forum consider in more detail what this science suggests.

A summary of key points

Key points that emerged in the two days of discussion that in my view merit prominence and highlight the constructive ways in which we could move forward include:

- It was emphasised that while the science and innovation ecosystems overlap they are not the same. Thus there is a need for distinct mapping and planning of the science and innovation ecosystems.
- There was an overwhelming consensus that science should have a significantly greater role

to play in mapping our economic, social and environmental agenda. Science also has a major role to play in informing policy making, in foresighting and in risk assessment. There was a surprisingly widespread concern that science is still perceived in many quarters, including within much business, as a luxury rather than an essential underpinning component of innovation and development across all domains (even though the significant progress made in recent years was acknowledged). Areas where science was identified as being underplayed included in making social spending more efficient, understanding our environment and natural resources, and developing a culture of innovation. The public science system was seen as too transactional and insufficiently strategic. In the policy arena, technology assessment and risk assessment were seen as weak.

- There was a strong feeling that New Zealand has not yet fully embraced a strategy that builds on its latent capacities and capabilities so that the potential to be a small, rich and clever country can be achieved.
- The voice of business at the meeting made several important points that resonated. Firstly, it was clear that successful business understands the importance of greater corporate responsibility to the environment and that this is not just a superficial statement – rather there is a growing understanding that this is core to success. Secondly, it was noted that scale is important in innovation ecosystems. In that sense it is important that Auckland, which is the only city that has the scale to create a potentially competitive full science and innovation ecosystem, is encouraged in its development on behalf of the whole country. Thirdly, we need to use a variety of approaches to better integrate activities across New Zealand and connect them to Auckland. This in turn relates to my earlier points regarding fragmentation and incentives. Fourthly, the very small size of New Zealand businesses was noted – this reflects the individualistic nature of the New Zealand business personality. We need to encourage aggregation and collaboration, both onshore and offshore. A key feature of overseas innovation ecosystems is the culture of mentorship and the Forum identified the general lack of such a culture within New Zealand entrepreneurial business.

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- An issue that was clearly identified was the lack of a critical mass of talent in areas of technology entrepreneurship. This cannot be addressed rapidly from within New Zealand. The country needs a strategy to attract such talent from overseas or alternatively to form strategic alliances that could allow assistance from offshore talent. The relationship to other small innovative countries was seen as important in that regard.

"An issue that was clearly identified was the lack of a critical mass of talent in areas of technology entrepreneurship."

- A major concern was that the science system remains fragmented, largely because of two factors: under-investment in science and structural issues in the public system, including a series of incentives that focus on the individual or the institution rather than the worth of the science. While the PBRF system has considerably enhanced academic attention to outputs, its focus on the individual is antithetical to achieving effective collaborative and interdisciplinary research that is at the mainstay of much science-based innovation. This is exaggerated by a lack of rationalisation in the tertiary sector, which was seen as a major impediment (while acknowledging the difficult issue of parochial politics). As a result, the Forum repeatedly heard that New Zealand science remains silo-ridden with inadequate cross-discipline and cross-institutional activity. The structure of our contestable funding systems aggravates this problem. It also inhibits intellectually high-risk work and therefore the potentially most innovative and impactful research[3]. Thus the funding models are seen to seriously disadvantage interdisciplinary and innovative science.

3 An exception would be the Centres of Research Excellence and some platforms administered through MBIE.

This was seen as a critical issue to address with urgency.

- There was overwhelming agreement that far greater emphasis needs to be given to improving connectivity within the science system itself, between science and business, and between science and policy. The continuing lack of scientists rotating between these sectors was noted and several references were made to practical ways this could be addressed, as it has been in other countries. In turn, these sectors need to be better engaged with their counterparts overseas to ensure that New Zealand can take full advantage of clever thinking, wherever it originates.
- There is an urgent need to lift science literacy and communication. This was discussed in particular reference to getting a more constructive national consensus on issues of risk assessment and understanding the trade-offs that need to be made to move this country ahead. There was sense that this lack of understanding was holding back progress.
- It was considered that there would be value in refining and aligning policy settings across primary, secondary and tertiary science education

"... aligning policy settings across primary, secondary and tertiary science education to ensure that national needs for a scientifically literate population as well as a professionally qualified workforce are met."

to ensure that national needs for a scientifically literate population as well as a professionally qualified workforce are met. Indeed, significant issues were identified at the boundary between secondary and tertiary STEM education. There was extensive and exciting discussion around the use of using modern and novel approaches to develop science education in ways that could be more inclusive of low decile, rural and high Māori and Pasifika populations. Several informal approaches have been developed by innovative New Zealanders and the potential for some of these to be incorporated more formally into science education merits consideration.

- The lack of forecasting and risk assessment based on science was seen as a major deficiency and indeed a risk within the policy process. The role of science at the centre of these activities has been identified in most jurisdictions and formal procedures established. In general, greater use of long-term forecasting is seen as critical in identifying challenges, developing requisite capacities, finding solutions and handling new technologies.

"The lack of forecasting and risk assessment based on science was seen as a major deficiency and indeed a risk within the policy process."

- There was much discussion on the issues of resource management and the environment. Clearly New Zealand greatly values its environment. The importance of high quality research in protecting our human and land-based resources through public health and biosecurity research was emphasised. The need for research of quality to properly map and understand our mineral resources on- and off-shore was noted. Parenthetically, reports from other jurisdictions have pointed out the importance of understanding local geological structure in assessing risk levels associated with activities such as offshore drilling and fracking – rather than treating all such activity as the same. While there was some passionate environmental advocacy, there was a good understanding that science-based analysis is necessary for understanding how best to create a knowledge base against which the complex decisions on the balance between resource extraction versus conservation can be made. A disappointing omission from the Forum discussion was the value of science in achieving conservation and environmental goals.
- The image of New Zealand in terms of marketing was discussed at length. Three valuable marketing images were apparent. The most obvious in some markets, particularly mature markets, is the environmental image of New Zealand – there remains a consensus that this is important to protect. Secondly, the importance of our corruption-free high quality regulatory frameworks was seen as important in many markets, particularly those where food safety is paramount. Thirdly, what is less appreciated is the importance of being seen as innovative and science intensive. It is increasingly clear that countries that see themselves as clever and innovative, particularly those in Asia, want

to be aligned with and partner with countries that they perceive similarly. We were informed that, regrettably, New Zealand is not yet seen to have those qualities in international surveys. This is a point meriting urgent attention.

- International science and science-based diplomacy were seen as major ways for New Zealand to sustain and build its relevance, and indeed your government has already moved in such directions.

"International science and science-based diplomacy were seen as major ways for New Zealand to sustain and build its relevance..."

- There was extensive discussion within the Forum on Māori perspectives. What is clear is that there is already evidence of an increasingly innovative Māori engagement using science and knowledge for their own and thus New Zealand's enhancement. There are potential issues – in particular in ensuring proper dialogue in discussing and evaluating new technologies – but I am reassured and convinced that with proper engagement a true and unique partnership in science-based innovation, environmental and social enhancement will emerge.

Concluding remarks

In Gisborne we heard strong arguments for the many uses of science, yet our combined public and private spend on R&D is about a third of that of our comparator countries and until your government recently took some important steps, has been diverging from theirs for decades. The deficit in private sector investment in R&D is concerning; it should rise as the public science system becomes more robust. The challenge remains – and it has to be asked why have we ended up in this position? Does it reflect the national psyche and our focus on short-term outcomes? In contradistinction to our individual behaviours, as a nation we seem risk averse, afraid to make mistakes, and rapid to condemn entrepreneurial failure.

Connectedness, commitment and conversation remain at the heart of our challenge. Sir Paul Callaghan developed the phrase: *The place where talent wants to live*. There is global competition for the innovator, scientist and entrepreneur. To attract these people one first needs an ambience of intellectual adventurism and valuing knowledge. It is developing those characteristics, alongside those of integrity and our recreational and environmental opportunities, that should make us attractive to talent. Indeed, I would suggest that the intellectual and entrepreneurial environment is the most important component for the kind of talent we want to capture. We need as a country to value intellectualism, entrepreneurship and curiosity more highly. We need to get beyond polemic and have much more informed conversations as we try and enhance our economy.

The Forum sensed that things are changing. The conversation took place in a context that was different to previous discussions. Firstly, it took place in a different world – one in which it is much clearer that geographical isolation does not protect a country from international fiscal crises. Secondly, it took place against a growing understanding that New Zealand has to strive harder to make its place in the world. Thirdly, it is understood that science, scholarship and science-based innovation can do so much more for New Zealand. Fourthly, it took place against a better understanding of how well the small clever countries have done – and we aspire to be one of those. Fifthly, the political rhetoric has changed and science and innovation are now seen as important, even critical. But while some valuable steps have been taken in recent years, the lack of an obvious 'burning platform' has meant that perhaps as a country we have yet to develop a suitable sense of urgency.

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