OFFICE OF THE PRIME MINISTER'S SCIENCE ADVISORY COMMITTEE

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Transit to a better New Zealand – the role of science

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TRANSIT

Eight days ago, a number of us were in Uawa/Tolaga Bay to view the transit of Venus and participate in an event that was the idea of the late Sir Paul Callaghan. For it was at Uawa where the first substantive positive connection between Maori and Pakeha occurred. Science was at the heart of that contact. Indeed the voyage of Cook was firstly a scientific expedition – Joseph Banks was already a Fellow of the Royal Society when he stepped ashore and Cook was to receive the same honour on his return. Paul saw that symbolism in the transit of 2012 as a reason for a forum in which there would be a genuine dialogue between the scientific and broader community about the place of science, scholarship and research in New Zealand's future. When Paul knew that sadly he would not be here to lead this forum he asked me to take his place.

We decided that there was no need to debate the future we want. After all, we can define that in broad terms – we want to be a society with a high standard of living and that means economic growth, we want to be a society that is more cohesive, we want to be a society that takes its custodianship of the environment seriously. Obviously there are different biases in how we get there and the emphases we give to the different dimensions. This is the basis of the political process, but scholarship, research and science are essential to inform the options that a society can choose. There is a strong sense that we have not exploited science sufficiently. This was the focus of discussion and along the way we exposed a few hidden elephants in the room.

CHALLENGES

There are many challenges: how does one balance economic growth and resource use versus resource conservation, what trade-offs are involved, how do we use technologies well and when should we limit their use? We need to consider how do we move from a rather limited understanding of new technologies where there is often accidental or even intentional confusion between science and politics, values and philosophies. In what ways can knowledge have a much stronger role to play in our society?

The simple reality is that everything we do involves tradeoffs. Sustaining 40% more people on the planet, many of whom rightly demand far better standards of living, will involve more energy consumption, more food, more resource use – there is no way around that. How do

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we do that while protecting a planet we have increasingly come to value and see at risk? Indeed I think rich societies are undergoing a fundamental shift in their attitude to the environment, not dissimilar to the shift that happened 200 years ago in relationship to human beings – we abandoned slavery and the beginnings of social welfare appeared.

Too much of the discussion has been trite in imagining that these tradeoffs can be avoided; a much more sophisticated discussion is needed and science and technology will be essential in finding the appropriate solutions.

TRADEOFFS

Parenthetically, one of the surprising things at the forum was the problem of language and the unwillingness of some people to get beyond vision to the hard realities. The tension focused on the word 'tradeoffs'. Some want to talk about balance or equilibrium, some want 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 all were saying the same thing. Paul would have reminded us of the first law of thermodynamics. Unless more resources are added to a system, then tradeoffs are inevitable. That is why they get easier as we get richer.

I suspect some try and avoid the word 'tradeoff' because emotionally it is harder to accept than saying balance or equilibrium. But tradeoffs 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 domestic 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 rises as economies become wealthier.

Tradeoffs are often portrayed as binary – more of this means less of that. Actually it is much more complex, as engineers and evolutionary biologists know. What we are looking for is the optimal solutions to multiple simultaneous demands, where the settings on any one trait affect the settings of many of the 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. Crudely, we tend to think in terms of dollars earned by the state versus state-provided resources for social, environmental and defensive reasons as being where the first level of tradeoffs are made. But we can see it at more detailed levels of policy and in our own lives. For example, as mentioned, no matter how much we value the environment, virtually all of us will give priority in our use of resources to our family and our own lives. And tradeoffs are hard.

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 the public dialogue as we develop a national consensus on how best to manage tradeoffs. It also can have a far better role to play in dealing with many complex policy issues in 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

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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 must require a much more scientifically aware, literate and engaged population. This will be essential if a participatory democracy such as ours is to navigate through the opportunities and threats associated with these challenges and the rapid changes that technology brings. And a constant theme through the forum was that of how do we begin to make a more engaged and literate population, both public and in the policy maker. For the simple point remains that, relative to other small countries, we are three decades behind in making a switch to a knowledge-based economy and society, although we have made some important steps in recent years. Partially as a result we have a relatively high level of dissonance between what we know and what we believe.

WHAT IS SCIENCE?

I have gone a long way through this talk without defining 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 science is about certainty, for in most of science certainty is not possible; 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 are developed to provide protection.

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.

We are in danger of underestimating how much the nature of science has changed over recent decades; it used to be focused on linear questions, those aimed for reductionist precision. But 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, there remain many unknowns, and answers are defined in terms of probabilities and levels of uncertainty. Much of biology and medicine is complex science.

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 aging 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

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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 base on biases, emotions and experience.

SCIENCE AND VALUES

I have spent time on this issue because 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. Science provides some forms of knowledge but societal decisions are properly made on many other grounds with strong value domains: community values, public opinion, fiscal and diplomatic considerations are critical to policy making; similarly, business must take many other domains into account in making its decisions. The role of science and scholarship is to provide the value-free knowledge and options for society to opine on using these other value-laden dimensions.

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 is 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.

CONNECTIONS

But all of this assumes that science, scholarship and intellectualism are well connected to society. Some of the main conclusions of the forum were that they are not well connected either within themselves or with society. The science system per se is highly fragmented by the funding system, inappropriate expectations of immediate impact, and the problems of institutional arrangements which 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. This is a direct 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 the most disadvantaged in both 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, and academia and business. And we have too few public intellectuals – indeed that is one reason we are so vulnerable with Paul's death. And I was struck by a comment in Kim's interview with David Skilling about the tyranny of intellectual isolation. Indeed, being more connected within ourselves and with the world was a major theme that emerged last week.

RESOURCE CONSERVATION AND EXPLOITATION – NOTIONS OF 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 which only unbiased science can provide whereas the weighting of paths and priorities is based on values that the whole community must own.

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But at the interface is a complex interaction that is reflected in part in the concept of risk. This may be the biggest elephant in the room. Risk means different things to different people: scientists may talk in mathematical probabilities, politicians think of risk in an electoral sense, the public generally see risk through 'system one' thinking, to use the decision theorist terms i.e. that which is instinctive and emotional. For most perceptions of risk are biased by who benefits. We have different attitudes 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, yet we are angry when someone else overtakes us at great speed. It is little different when we think about oil wells or sources of power. We forget that there are tradeoffs involved in risk assessment as well. Most of you will think that only 3000 people died in the World Trade Center bombings – in fact it 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 but the reaction in Germany to the Japanese Fukushima disaster has been to switch back to more fossil fuels. And what about fracking? In the USA, the shift to natural gas produced by fracking rather than coal has meant an enormous reduction in CO_2 release into the environment. Do not get me wrong, I am not advocating for any of these technologies; I am merely pointing out that it is not simple and singular – so again we have this problem of how do we weigh-up technologies and risk.

TECHNOLOGY ASSESSMENT

Technologies are developing faster all of the time and they are having far greater impact as they project 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 keeps on emerging. Otherwise some important technologies may wrongly rejected or their harm overstated and yet others may be misused or their potential harm understated. In New Zealand, we have not given much focus to technology assessment and forecasting. We have a further challenge, one we started to address in Gisborne, which is how we integrate the Māori world view into technology assessment. My conclusion from the forum is while it requires serious conversation, the Māori community is highly innovative and keen to be involved.

A key issue is the environment. A major change is underway in the way we think about the environment. We are proud 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 protection. We have a particularly high environmental risk (we are, as Simon Upton said, the "last bus stop on the planet") and there is need for world class defensive biosecurity research. What is the scope of our natural resources – there are apparently a lot offshore, how should we manage and exploit them? The problem of decisions made on the basis of entrenched uninformed views is that it can fix positions in a political process that may not be in our best interests. Risks will always be assessed emotionally but those emotions should be informed by what is or is not known.

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There is one new but now unavoidable and inevitable technology that we take for granted and yet may have many more downsides that other technologies we reject: the internet and the cyberworld. My concerns arise as the very substrate of society moves from the physical to virtual. It may be changing the way our brains develop, it certainly changes the way we interact with each other, which challenges the brain we have carefully evolved over the past 5 million years when we diverged from our last shared ancestor with the chimpanzee. The cyberworld has created the problem of how to discern reliable from less reliable information in a world smothered with information and polemic, leading to increasing confusion and indeed a loss of confidence in science as the key source of knowledge. I shall return to this issue of trust later. Here we have accepted a technology without understanding it because we all benefit from it – had we not gained from it we may have reacted quite differently.

The conflict between the pace of development and of 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.

STRENGTHS AND WEAKNESSES

Before we go further, we should look at some our strengths and weaknesses in relation to the use and role of science.

We are a small nation and one geographically somewhat remote. We are multicultural and both biologically and economically increasingly see ourselves as part of Asia-Pacific, not Europe. We have tendency to be complacent – selling food and tourism has been relatively easy, but sadly, exports as a percentage of our economy are falling. As a nation we have tended to be relatively satisfied with ourselves and not as ambitious as we need to be to thrive over coming decades. It is not realistic to imagine that we can achieve as a small nation the kind of growth we need by looking inwards. We need to be better at looking at ourselves and we need to be better at having the ambition to achieve our potential. We have become too incrementalist. A big bang approach is not realistic but many including myself think we could and should move much faster.

When one looks around the world the most successful advanced countries in economic terms in 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. Should we be partnering more with the other small countries? All said and done, teams are made by marrying different skills and some places such as Singapore have capacities and capabilities we do not have.

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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 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 have its own path to innovation and must build on what they are excellent at – yet nations are good at taking for granted what they are good at rather than using that to build on and create excellence. I suspect we all can feel resonance with this statement – we need to find our own path.

One of the disadvantages is we tend to look at ourselves negatively and introspectively: we need to deal with internal parochialism, we need to become cleverer at self-diagnosis; but intellectuals thinking in isolation will have little impact. There is a need for public intellectualism, and for the discussion to be inclusive.

Serious countries treat ideas seriously. Are we a serious country? Our debates are often superficial and ill-informed – often emotion without knowledge or consideration of the tradeoffs. As a society we do not value ideas much.

Scale is a major issue in innovation. Innovative knowledge appears most at the frontiers of disciplines interacting with other disciplines. Good evidence has emerged that larger cities and clusters are most innovative. Several speakers pointed out the need to build Auckland to scale, to differentiate tertiary institutions more and to enhance connectedness across the country. Our businesses are themselves more individualistic than in many other countries.

A challenge for New Zealand is to maintain its relevance. Our relationship with much of the world is not equal. Our reputation and ability to contribute disproportionately in some areas is important. It is therefore important to understand how others see us. Clean and green serves us well in some quarters. But as Peter Chrisp, head of NZTE, reminded us, we are well off the radar as being innovative and R&D intensive and in Asia that really counts against us. Innovative countries want to associate with other innovative countries. Indeed we have lost our reputation as a test bed of innovation and that has had a price – we have lost the interest of the multinational corporations. An innovation ecosystem needs multinationals, and the lack of them here counts against us. How do we rebuild the reputation as a laboratory of innovation and rebuild that brand and attract those players?

But we have strengths.

New Zealand is increasingly using science as a part of policy development and there has been significant political commitment in recent years to the science and innovation systems.

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

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We are a diverse population, and through that diversity should come more innovation. Our experiences in Auckland with Pasifika and what we saw at Uawa show that we can turn the weaknesses of the long tail of under-achievement into success. We need to be prepared to experiment more to address educational disadvantage.

In general we have a good education system in STEM subjects at secondary school, but we need to think through how to take advantage of new technologies to enhance it and spread it around. There are a number of issues at the secondary-tertiary interface that were identified.

The innovative potential of the Māori community is badly underestimated. Māori themselves understand the need to be part of the innovation society; they understand the need to marry the well-established western tradition of knowledge generation with the strengths of their own cultural identity. There are big challenges in integrating tikanga māori into areas of technology adoption, but with better dialogue we should be able to turn it to a strength.

ROLE OF SCIENCE

So how can science help take us to where we want to go? Public science has 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 decisions. Again we come back to the issue of tradeoffs.
- We need to defend our economy, environment and society through research such as biosecurity, environmental and public health research. How do you value such research – it has immense economic importance but has no direct rate of return.
- We need research to improve the effectiveness of our policy and public expenditure through health research, social science and economic research. What savings might be possible from the public spend if we looked for effectiveness, provided that that 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 for example through biosecurity research.

A notable feature of this list is that as important as these objectives are, I have not yet talked about the most commonly advanced argument for investment in research, namely direct economic benefit.

SCIENCE AND ECONOMICS

In a technological age, multi-factor productivity growth can occur through imitation (that is by knowledge absorption) or by frontier innovation. But as countries become highly

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technological and get closer to the global knowledge frontiers, the latter has the greater impact on growth. 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 even to a country like New Zealand which cannot do everything.

Several clear messages have emerged from the other advanced small nations. Firstly 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. It is generally accepted that assessing the return on R&D is a complicated process with a long lag-time that make such linear models meaningless, even though they are still favoured in some Treasury departments. 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 growth. Annual returns are likely to be in the order of 20–40%. There is also growing evidence that public investment does not displace private investment but fosters it.

While many countries have tried to look at this 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 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."

ECOSYSTEMS

Although the science and innovation ecosystems intersect, they are not the same. Not all innovation comes from science and 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 imaginable. While relevance and impact will be core to research prioritisation, there is a 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 ideas to products.

There are two key questions in the interplay between the science and innovation systems. Firstly what is it that we are doing well now that we could do more of? Second what is it we are not doing much of but where we have a clear competitive advantage? Remember 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 tradeoffs – risks that have to be evaluated and managed. With reference to what is it that we do well that we could do much more of? One simple example suffices to make some points. In theory we could add 15 billion dollars per annum to our bottom line by selling more milk without adding one more cow to our national herd. The genetic improvements in our cows are such that we know that if they could be fed to their potential we would double or triple our milk exports and we know how to sell milk. We could increase the value further, but more slowly, by developing added value products such as foods with proven health advantage. All we have to do is feed and care for the cows differently. And now come the tradeoffs and issues: how do we ensure that the least productive farmers adopt the practices of the most

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productive farmers? 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? Is that acceptable? As part of the solution one possible way to deliver more nutrition to the cow is through changing the forage but that might mean genetic modification of our grass or our soil? What would that mean for the national conversation and national self-image – are we able to separate emotion, science and politics? No we cannot, and nor should we, but we should make our judgements based on what we know and do not know – but as we will face an ever increasing number of new technologies we need to have more mature conversations better informed by science rather than being simply reactive.

And what are we not doing well now where we have a competitive advantage? Paul would have argued that given the quality of our STEM education we have advantages in high value manufacturing in areas such as medical technologies. Another area is clearly advanced foods. But our ecosystem for innovation is not well developed although a lot of change is happening – what do we have to do to develop the capital markets, the partnerships to go to scale? How do we deal with the manifest gaps in managerial and entrepreneurial leadership? Our business does not have a strong culture. How do we learn to value risk takers even when they fail?

But the reality is that many of these points have been made for some time and there has been some progress, but slow compared to our comparators. Why? New Zealand has become risk averse and inward looking when we cannot afford to do so. Again, as David Skilling said to Kim last Saturday, while as individuals New Zealanders like risk in their recreation, as a country we are not adventurous; is it a feature of our political system or of our national identity?

SUMMATION

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 recently, has been diverging for decades. The challenge remains – why? Does it reflect the national psyche and our focus on the short-term versus minimal attention to the long-term? As a nation we seem risk averse, afraid to make mistakes, and rapid to condemn entrepreneurial failure. Why is New Zealand not ready to make the tradeoffs to shift the investment to knowledge and scholarship?

A key challenge is the need for greater science literacy amongst all our citizens and a greater value of intellectual activity in general. Furthermore, the science community needs to understand that it is part of the wider community and communicate better. The media do not make it easy, particularly in dealing with complex issues. Too often they would rather promote controversy than understanding. Without science literacy the understandings necessary to become a knowledge-intensive society will be much harder.

Paul 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 those environmental characteristics alongside those of integrity and our recreational and environmental

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characteristics that will make us attractive. I would suggest that the intellectual and entrepreneurial environment is particularly important for the talent we want to capture. A culture of mentorship and collegiality within the business and entrepreneurial sectors is a strong feature of many international innovation hubs. But individualism is part of New Zealand business too – most of our companies are very small even though aggregation would often make sense.

So where to from here? Connectedness, commitment and conversation remain at the heart of the challenge. Those in the audience need to think how they can contribute in a bottom up way – think that at the moment only one newspaper has extensively covered the *Transit of Venus* event – I do not believe the *New Zealand Herald* even mentioned last week's meeting in Gisborne. 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 about what tradeoffs to make as we try and enhance our economy.

A question that I suspect Kim will ask me if I do not pre-empt her is: was the forum any different to past discussions such as the Knowledge Wave? Even on reflection I would say yes. Firstly it takes place in a different world – one in which it is much clearer that geographical isolation does not protect a country. Secondly it takes place against a growing understanding that science can do so much more. Thirdly it takes place against a better understanding of how the small clever countries have done – and we are not one of those, although we should have been. Fourthly the political rhetoric has changed and science and innovation are now seen by each of the major political parties and some of the minor parties as important if not critical. However, there was some frustration at the forum that while some steps of value have been taken, the lack of an obvious 'burning platform' has meant that we have not had enough sense of urgency. Perhaps we have been too lucky a country and we need to look deeper at ourselves. Paul was trying to help us do that.

Thank you.

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