4. Building Responsive Science and Innovation

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Analysis preceding and developed for Aotearoa New Zealand's Te Ara Paerangi Future Pathways Green Paper Consultation can be combined with a systems perspective to suggest Aotearoa's Research, Science and Innovation (RSI) system does not prioritise or respond as well as it should, and lacks coordinated strategies to address major issues. How can we assess concerns that potentially successful ideas and innovation are being stopped unnecessarily at systemic barriers, which could be removed in the current push for systemic reform?

Ostrom's eight principles for managing common pool resources provide a well-designed framework that can overcome the high level barriers, which may arise from hypercompetition and other dilemmas born out of the institutional structures and funding systems. There are at least three good options for implementing Ostrom's principles in high level institutional and funding structures. These provide enabling conditions for ensuring that efforts to address workforce career issues, funding stability, and improved funding mechanisms lead to a more effective and responsive RSI system. A more compelling basis for enhanced funding levels, trust and self-organising prioritisation can come from: 1) a well-implemented base funding system, 2) implementation of Ostrom's principles and values-driven approaches to rebuild trust, and 3) fellowships support that addresses the stress, connectivity and responsiveness issues currently observed.

Complex systems are path dependent, and vary in their stability and responsiveness as a result of their structure. Normally, stability and responsiveness trade off, yet there are wide concerns that our nation's RSI system is neither stable nor responsive. Under what circumstances can instability and/or poor responsiveness occur, and what solutions can be proposed? Can the solutions be placed in a sequence, so that the complex RSI system evolves beginning with prerequisite steps in favourable directions rather than repeating the same problems?[1,2] Can analysis also overcome limited data availability, and additional problems with evidence-based policy development suggest that alternative complex systems knowledge may also contribute usefully[3], particularly where pathways of transformation are sought?

For RSI systems, recent work strongly suggests a common problem occurs in hypercompetitive systems where bullying becomes a career tool driving mediocre, diversity-depleting outcomes worldwide[4] and within our main research institutions. The root of the problem may have more to do with structures and incentives that drive behaviour and decisions, rather than the natural tendencies of people in social systems. Yet, Universities, Crown Research Institutes and National Science Challenges all operate in ways that are prone to the concerning pattern described. This may occur as a result of conflicts, traps or dilemmas within senior management and/or governance for a number of plausible reasons – many of which may relate to finance or stakeholder relations more than RSI. Many of the situations known to the author are confidential, but common dilemmas and system traps can be described and generalised as Ostrom has shown.

For example, it is apparent from the 1986 Beattie report initiating reform that the detailed knowledge and commitment of experts and technicians could be observed only from middle management downward, while senior management thought and communicated differently. This creates the potential for management to set and defend high level strategy that is poorly understood by researchers, and that is also poor at reviewing the feasibility of proposed research or understanding the consequence of discontinuing established research directions. New and exciting ideas may commonly bump up against the gap between management and researchers, and fail to grow to full potential. The original

solution to this problem was fully contestable research funding. Yet, once longer-term contestable contracts evolved, they may have created another trap or dilemma: a lack of flexibility to accommodate external change, findings and user-led innovation.[5] A non-exhaustive list of examples of system traps and dilemmas is given in the Appendix, enabling a potential solution to be developed that 'diagnoses' the dilemmas or system traps operating within multi-tiered structures, and uses analysis to create a pathway for systems change.[6]

Diagnosis: what is and isn't observable?
The Cabinet Paper initiating Te Paerangi Future Pathways included (at para 44-45):

> The review echoed many of the themes of the RSI Strategy consultation. It found that there is a lack of role clarity for institutions, unproductive competition between institutions, and a lack of integration between our universities, CRIs and other parts of the research system. It repeated the findings from the RSI Strategy about the weak responsiveness of the system to Māori.
> Te Pae Kahurangi also noted difficulties in our system adapting to changing national needs and building capabilities necessary for future resilience and transformation. It found a proliferation of governance, and a large number of competing strategies and priorities which struggle to be given effect.
>
> *I agree with Te Pae Kahurangi's overall assessment, and consider many of the findings apply to the whole of the public research system.*
>
> I agree that overall, our 'public' research system – those parts funded mainly or owned by the Government - is characterised by a significant amount of fragmentation. Individually, our researchers and research organisations continue to produce excellent research. However, the system does not work as well as it should to enable a collective contribution to our long-term challenges.

In short, a problem has been diagnosed, but we need to know why the research system repeatedly returns to a state of fragmentation and does not respond to the nation's "long-term challenges" as well as it should. Investigations from a systems perspective suggest addressable problems at two levels, and possibly a common origin. First, it must be said that taking a systems approach recognises a lack of apparent and usable data to support evidence-based policy.

To overcome the problem of confidentiality preventing transparent disclosure of systemic failures, this system's analysis has been informed by a number of ad hoc conversations over more than four years conducted on behalf of NZAS, or other research efforts to understand science policy and environmental policy needs. These represent the perspectives of 12 individuals, including myself, describing what people consider serious problems in at least eight distinct, large research bodies. In no case are researchers comfortable expressing their experience, concerns and recommendations publicly, though in a minority of cases there would be comfort with Chatham House Rules. Official documents, including redacted Official Information Act releases of National Science Challenge mid-term reviews, provide only limited narratives. From these inputs and wider systems perspectives, the following preliminary assessments or diagnosis can be drawn and used to proceed or generate testable hypotheses.

Trends in institutional structures and funding mechanisms have been away from meaningful control of smaller scale activity, so that important decisions and budgets only exist at relatively large scales, and obscure understanding of detailed activity and its purpose. The Beattie report recorded a different ethos at and below middle management in the mid-1980s[7] – a trend that continues today with the 2020 Briefing to the Incoming Minister of RSI containing only 2 specific science issues and 3 science strategies out of 19 total concerns for the CRIs (see Appendix). In terms of Ostrom's principles this means a lack of access to decisions determining directions and resourcing, accompanied by a lack of low cost dispute resolution. Unfortunately, the lack of low cost dispute resolution makes much of the problem unobservable as evidence: pain has accumulated and researchers feel genuinely unsafe

talking about the best examples. What is observable is a universal pattern of institutions seeking and sometimes developing ideas with no transparent evidence of what prior work they've abandoned unnecessarily, and quite possibly undeservingly. In addition, patterns of funding groups and lines of work that have received ongoing funding are also evident, even when the research does not appear to be delivering the intended outputs and outcomes.

Box 1: Examples of system traps and dilemmas
A preliminary list of dilemmas and system traps (without attempting at this stage to carefully define these two terms' origins in game theory and systems research) includes the following.

- A large research initiative becomes 'too big to fail' because failure endangers its host institution financially or undermines key relationships. It remains active even though it is unlikely to succeed.
- A poorly funded researcher or institution feels they must put in a proposal designed to be assessed positively for funding, even though they know the research will not succeed, can be done more cost effectively another way, or has already been achieved.
- The host institution for a major project or proposal acts in their own interest to concentrate activity within their own walls because it pays high internal overheads rather than in another institution that can contribute better science.
- Unintended consequences can emerge from institutional funding mixed with contestable funding (Savage 2000): hire more people to compete harder. For example, despite the historic high social rate of return of US Federal agricultural block funding to regional universities, some institutions chose to spread funding into new positions who had to compete for external funds to thrive.
- Other typical funding dilemmas associated with hypercompetition or poverty traps include:
    - Very large funding missions may cause the entire national capability to collude on a single proposal, despite each researcher having too little funding to do anything well.
    - Researchers feel forced to accept part funding that doesn't cover full costs of a project, using often the limited funding awarded to chase more funding (resembling a Ponzi scheme).
    - Connecting institutional funding to requirements to bring in commercial/industry funding may lead to the use of institutional funding to subsidise largely or purely commercial consultancy work.
- Rewarding safe low-risk science (when high-risk transformation is needed).
- Not addressing systemic problems by requiring data to support evidence-based decision making when data collection is not feasible or hasn't been prioritised.
- High overheads cause researchers, managers or executives to avoid international funding and get high overhead New Zealand funding in preference to international projects with high-value collaborations.

One last dilemma deserves mention as extraordinarily concerning. An RSI system or team can develop insights, inventions, or new areas of science, greatly improving efficiency or other outcomes. Yet this successful work may bring limited benefits to the finite team, organisation or group conducting the research, whereas failure to solve the problem causes ongoing expenditure that generate research income to a wider sphere of researchers who overlay partial solutions or are simply to be seen to be working on the problem. Both hypercompetitive and non-transparent mission driven funding processes may be prone to this 'mistake'. It is avoidable through transparent processes and trusted social mechanisms that check to ensure work that has social rates of return but low private rates of return[8] is strongly supported. Appropriation of the benefits of contestable research funding provided a primary mechanism for the design of our institutional structure, and concerns arose in the 2010 CRI Task force that the system stood then would put $1 million to an

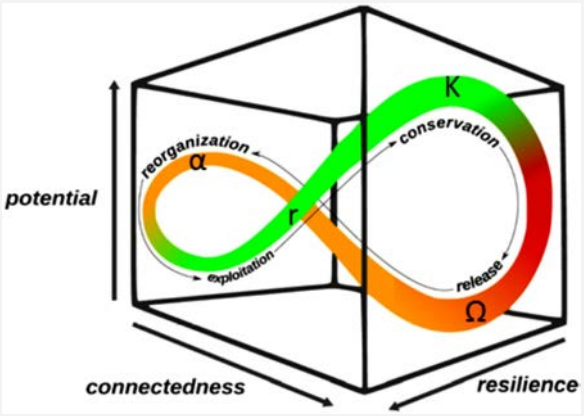
institute's bottom line ahead of $100 million of benefits to the nation.[9] ***What mechanisms does our present system with competing institutions put in place to provide assurance that benefits to all of society are put ahead of the benefits solely contained within our individual research institutions?***

This is a problem when, for example, emerging evidence shows global underinvestment in solutions to climate change. The lack of progress on water quality issues within New Zealand is equally compelling. It is even more of a problem when we need to build a whole system of connected research to deliver solutions. The long-term trend toward defunding integrated, socially embedded research activity needs to be reversed. As an example, American economists reviewed the value and form of regional agriculture research and extension programmes, of the types defunded by New Zealand's circa 1990 reforms, and found social rates of return of 60%.[10] They also raised concerns that their results showed the trend toward competitive funding in agricultural research lowered rates of social return relative to continued institutional funding. One possible explanation is that the research teams were more successful because they were more stable, and better supported to be fully connected to the communities benefiting from the research.

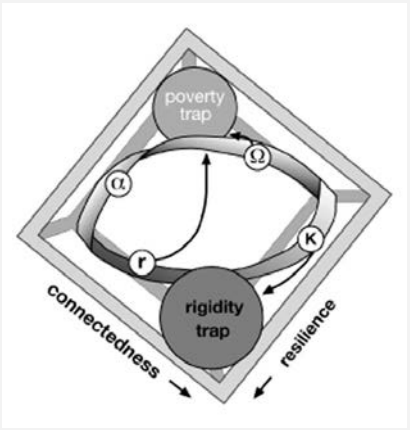
An important, and testable diagnosis emerges. The widely cited model of Holling and Gunderson has recently been demonstrated to be testable with data representing 'potential' (sometimes considered as wealth, capital or capacity) and 'connectivity'. Available data is incomplete yet suggests the system has concluded a period of growth classified as 'exploitation' in complexity models, creating the tensions exacerbated by the pandemic and creating a feeling of urgency in the call for reform. The research workforce appears to be in a state of unrealised potential and poor connectivity associated with a 'poverty trap'; similarly, management and governance structures persist in a 'rigidity trap'.

Box 2: Primer on the Widely-used Systems Model of Holling and Gunderson[11,12]

A



B



Panel A shows the depiction of a panarchy cycle, from a recent analysis[11] measuring the axes including connectivity. The concept is that a wide range of complex systems go through repeated cycles of reorganisation (α), exploitation or exponential growth (r), conservation (K) and release (Ω). The theory can be used to better manage and stabilise a system, or may be most useful to identify that complex systems undergo large repeated cycles due to hidden forcing factors such as an 'automatic steering syndrome.'

Panel B shows a poverty trap and a rigidity trap as typical maladaptive departures from an adaptive cycle in a system. "If an adaptive cycle collapses because the potential and diversity have been eradicated due to misuse or an external force, an impoverished state

can result, with low connectedness, low potential, and low resilience, thus creating a **poverty trap**." Similarly, "A system with high potential, connectedness, and resilience is represented by the **rigidity trap**. It is suggestive of the maladaptive conditions present in hierocracies, such as large bureaucracies."[11]

Our overall analysis suggests that the RSI system has:

- Looped through a panarchy cycle one or more times.
- Recently passed through a stage of attempted growth (r) or 'exploitation' with problematic outcomes.
- The current system is consistent with serious concerns about traps: a poverty trap for the workforce and a rigidity trap for management and governance structures.

Towards a solution?

Ostrom's principles for managing common resources appear to apply,[1] and can in the first instance be applied as tests of what is not working – applied quickly through surveys or the interpretation of consultation feedback. Ostrom also warns us that evidence-based policy may attract evidence for the most measurable or obvious activity in a system, missing higher level structure and barriers operating across tiers and nodes, and leading valuable partial solutions to be enacted as panaceas.[6] Literature on complexity in public policy also emphasises the repeated failure of simplistic solutions that do not recognise the role of intermediaries in large systems with tiers or networks.[13] Finding solutions therefore means making efforts to understand how the structures of management and governance lead to dilemmas and system traps (Box 1) using slower methods such as case studies and faster systems methods.[14] An important consideration is that many individuals will have information on key examples, which may have to be handled at least in part confidentially to understand past barrier-induced failures. This work can guide a process of beginning to put in place structures supporting the overall system. Some options for appropriate multi-tiered or nodal structures include:

- Reforming institutions around common areas of science policy and operation – for example environment and hazards; primary industries; data and technology.
- Forming research councils, such as the proposed environmental research council, after considering boundary issues and whether it is possible given current capabilities.
- Reconsidering the need for a science ethics, policy and oversight body, which possibly could be folded into the Science Commission proposed by Hendy[15].

Ultimately, Ostrom's principles and analysis suggest that large complex systems will require solutions that span or consider different drivers across multiple tiers or layers of nodes. The conditions for incorporating responsiveness and diversity within research excellence are known,[16–18] yet more thought is needed to fully understand how to span structural tiers so to promote success rather than the bullying and mediocrity that leads to poor diversity outcomes.[4] The Kindness in Science (KiS) movement argues strongly that values-driven nodes of activity can be successful, and deserve to expand and become the norm at institutional levels. Ostrom's framework provides the principles, if coupled to requirements of funding and institutions, and enables investigator-driven research nodes to achieve scale and respond to missions of national priority.

Are there sensible concerns that successful values-driven nodes are likely to be limited to dispersed academic success rather than responsive impact in addressing the mission-oriented challenges outlined in the cabinet paper? As noted above, the main barriers appear to be institutional, or put in place by funding structures, many of which presume there must be a distinction between bottom up investigator-driven activity, and top–down mission-oriented programmes. A concern supported by confidential examples supported by some systems level diagnosis is that institutions and large

mission-oriented programmes may preserve business-as-usual activity by encouraging and then limiting the success of small nodes of activity. Therefore, the alternative approach most likely to enable responsive research addressing major challenges, such as climate change issues, is to recognise that missions can serve as magnets for high-performing investigator driven programmes, as NASA now does,[19] in ways that build a future investigator pipeline.[20]

This leads to a simple recommendation: create funding mechanisms and rank proposals in ways that value investigator-driven success and mission-targeting criteria as two complementary axes, or criteria. They are not competing values, and this can mimic the recognition that fundamental and applied research are separate axes[21], or the additive scorings for excellence and impact ratings currently used by the Endeavour Fund. At current hypercompetitive[22] funding rates, more sensible requirements of researcher and stakeholder effort toward proposals can be achieved through pre-proposal systems and other measures.[23] Additionally, care is required to avoid or monitor and manage the unintended interactions of overlapping funding mechanisms,[24] and ensure that benefits to societal well being are properly considered. Beyond that, the likely prerequisites to building better missions are:

1. Base funding[25] to enable collaboration and low-cost development of new ideas, supporting and stabilising the workforce, while allowing for agility and self-organisation in sequencing the most urgent steps that follow;
2. Implement base and competitive funding schemes (with greatly reduced hypercompetition) so that Ostrom's principles[1] operate at institutional and funding body levels, with a focus on smaller investigator-friendly support, efficiency, transparency, clustering into collaborative missions; and
3. Fellowships, primarily for the early career stage, that also target mission criteria, attract and stabilise researchers into the system, and enhance mobility and connectivity between research institutions as well as with policy development[26] and the business sector.

Funding increases and prioritisation will be required as well, but the steps above appear to be sequenced prerequisites along a path to an improved compact between science and society[25] providing for a political economy of funding increases, and prioritising levels of support to research overall and key missions.

Acknowledgements. I thank Priscilla Wehi, Lucy Stewart, and members of the NZAS Council for helpful edits. I thank a number of individuals for valuable discussions, including the careful exploration of narratives where confidentiality has been requested. Richard Walley and Gary Evans provided helpful framing of the 'responsiveness' and 'path dependence problem'. Sneh Patel and Grace Yee provided helpful edits and assistance. TPM provided funding support for this work.

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Appendix 1: Table of notes of concern recorded against each CRI in the Briefing to the Incoming Minister of Research Science and Innovation. Items related to science are boldfaced, and comprise 2 specific science areas and 3 science strategies/plans out of a total of 19 listed concerns.

AgResearch	● Implementation of strategic refresh and **Science Plan** ● Development of Lincoln facility ● Positive early financial tracking following COVID-19.
ESR	● Property programme at Kenepuru ● Implementation of Transformation Programme ● Contributions to COVID-19 Response and Recovery.

GNS Science	• **Response to Whakaari/White Island eruption** • **Implementation of new science plan and science themes** • Developing robust financial systems.
Manaaki Whenua Landcare Research	• Development of an Auckland property strategy • Completion of Lincoln redevelopment.
NIWA	• Development of its property investments (Wellington, Hamilton and Christchurch) • Strategy on how it will respond to changes in its operating environment • Utilisation of and investment in its fleet given current COVID-19 and oil and gas exploration circumstances.
Plant and Food	• Impact on commercial and royalty revenue due to COVID-19 • Impact on long term Capital Plan due to COVID-19.
Scion	• Outcome of MBIE's review of Scion's science • Ability to deliver on its Strategy to 2030 and **transition to a circular bio-economy** • Financial viability.
Source: https://www.beehive.govt.nz/sites/default/files/2020-12/RSI.pdf	