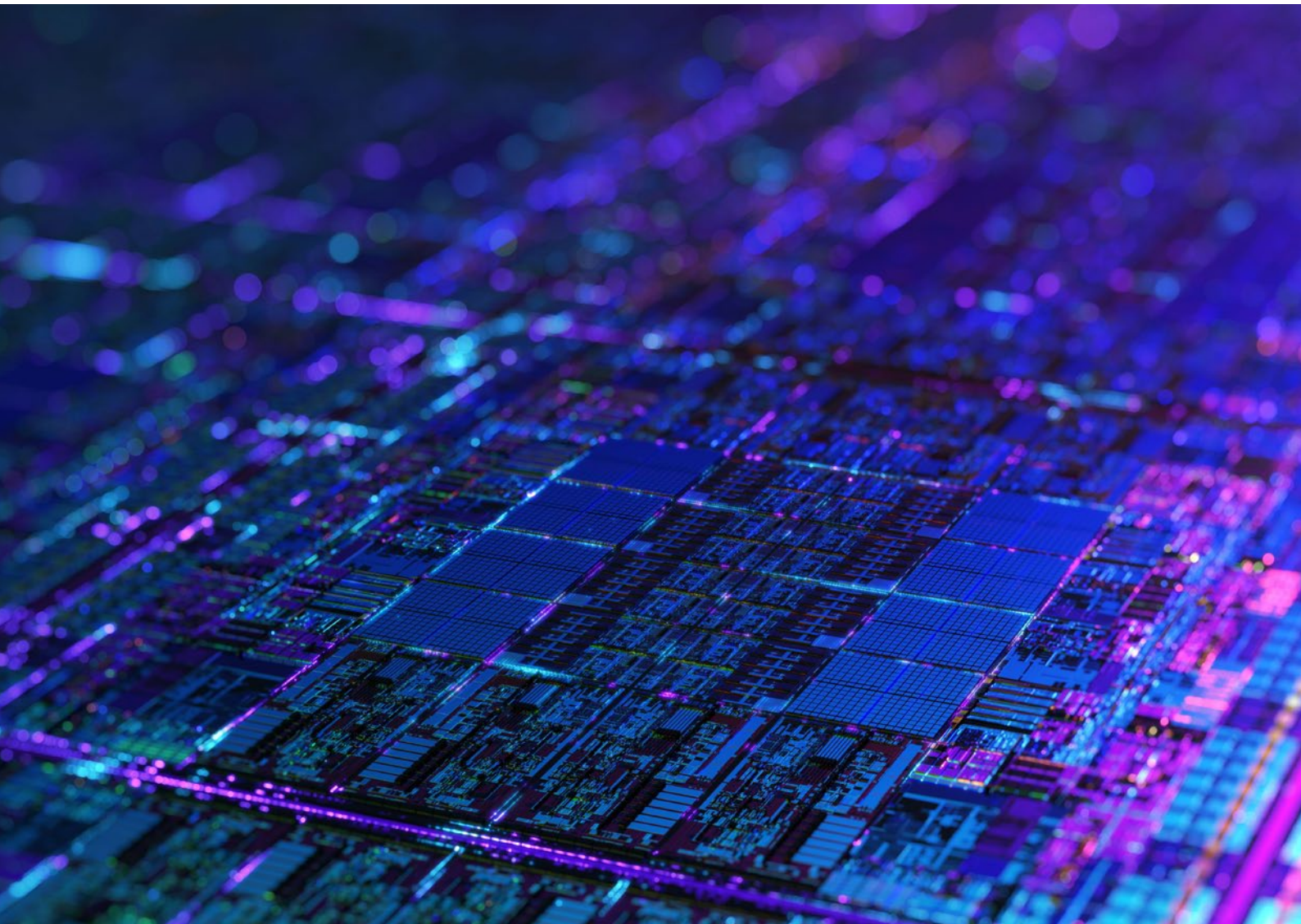
Australia's National
Science Agency

Responsible innovation at CSIRO



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Within CSIRO, we have worked with a broad range of key stakeholders and groups across our organisation. This includes senior leaders, professional staff, the research teams generating new findings, postdoctoral fellows and postgraduate students. We gratefully acknowledge the input provided through consultations with leaders from our Agriculture and Food, Australian Centre for Disease Preparedness, Data61, Energy, Environment, Health and Biosecurity, Mineral Resources, and Manufacturing Business Units, along with many of our Future Science Platforms and Missions.

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CSIRO acknowledges the Traditional Owners of the land, sea, and waters of the area that we live and work on across Australia. We acknowledge their continuing connection to their culture, and we pay our respects to their Elders past and present.

Accessibility

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Important disclaimer

Executive summary

As Australia's national science agency, we solve the greatest challenges through innovative science and technology. Every day, we work at the forefront of emerging research areas. Our collaborative research turns science into solutions for food security and quality; clean energy and resources; health and wellbeing; resilient and valuable environments; innovative industries; and a secure Australia and region.

But transformational research can also produce disruptive technologies. It can precipitate societal change and uncertainty, raising social and ethical challenges for societies – and their decision-makers. Responsible innovation is one pathway to addressing those challenges. It's our way of designing and delivering socially responsible science and technology, for the benefit of all Australians.

To do this well, responsible innovation must be more than a set of principles or guidelines; it must be a rigorous, robust, and repeatable scientific process. That's why, from 2019, we have undertaken a robust program of multidisciplinary research, in the form of our Responsible Innovation Future Science Platform (RI FSP). We have developed two innovative science frontiers: responsible prediction, and social and ethical risk management.

And we have applied them to assess the full spectrum of consequences from cutting-edge innovations. In particular, we bring responsible innovation to our work on emerging digital technologies like AI and quantum, novel genetic technologies in fields like healthcare and manufacturing, and environmental-scale solutions for our changing climate. The RI FSP was born of the need to look ahead and meaningfully examine the social and ethical risks and opportunities of future science and technology. To foster trust and confidence among stakeholders, end-users, and communities. To deliver socially responsible science and technology to create a better future for everyone. This report explains how we go about responsible innovation through:

- DISCOVERY: Validating the concept at all levels of our organisation, by road-testing responsible innovation through applied scientific inquiry.
- DIFFERENTIATION: Building an evidence base around how, where, and why responsible innovation can deliver impact in our organisation and beyond.
- DELIVERY: Identifying ways responsible innovation can be activated and delivered, to provide tangible and meaningful benefits right across society.

Here we've aimed to show what responsible innovation can be, what it can deliver, and how we are operationalising it as a core competency at CSIRO, for the benefit of all Australians.

1

The rationale for responsible innovation

Climate change, pandemics, food and energy insecurity – complex challenges like these demand novel and often disruptive solutions from science and technology.

As pressures on our environmental, social, and economic systems continue to mount, so do expectations of innovative research and development.

It's no longer enough to have great ideas: there must also be a clear and considered pathway to impact. That's where responsible innovation steps into the spotlight.

Future science at CSIRO

CSIRO invests in the cutting-edge science that underpins innovation in Australia. Through initiatives like our Future Science Platforms, established in 2017, we aim to:

- help reinvent and create new industries for Australia,
- grow a new generation of future-ready researchers, and
- attract the best students and experts to work with us on a range of future science challenges.

We bring together talented interdisciplinary teams to develop future science and technology, moving us closer to the breakthroughs needed to tackle our world's greatest challenges. Our focus is on leading-edge innovations with the potential to reinvent industries, create new ones, and improve aspects of our daily lives.

But our ambitions go beyond delivering great science, and developing the next generation of researchers. For our research to have a real and lasting impact, it must deliver outcomes that are meaningful, fit-for-purpose, and needed by Australian society. That's why it's critical for our investment in future science and technology to reflect the values and aspirations that guide Australia's future.

From the food we eat to the healthcare we access; the technologies that shape the way we communicate, and the jobs of the future; the energy systems that power our societies, and the environment we live in – our future science and technology is formulated to shape Australia's future for the better.

> "Responsible innovation reminds us that people are at the heart of any innovation – that is, the people who are driving the innovation, and those who stand to benefit from it."
>
> CSIRO Leader

Looking ahead for Australia

Transformational research in emerging domains has the power to generate widespread benefits for society, industry, and the environment.

But it can also precipitate major disruption, uncertainty, and inequity.

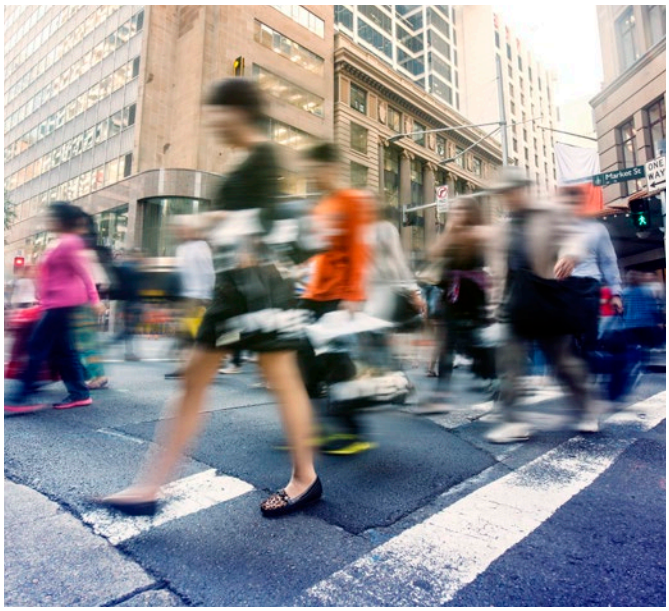
That's why it's critical that we ask ourselves how we go about assessing and understanding the risks and benefits of our highly diverse and growing portfolio of future science and technology research.

As the national science agency, how do we take responsibility for making sure those innovations we are developing are fit-for-purpose and truly needed by Australian society?

And how do we ensure that we are delivering socially responsible science and technology for the benefit of all Australians?

Underpinning the decision to establish CSIRO's Responsible Innovation Future Science Platform (RI FSP), is a clear commitment to developing the skills, knowledge and capabilities that enable us to answer these questions in a systematic and scientific way.

Along the way, this commitment has begun to differentiate the way we approach our science. And responsible innovation has evolved from a single portfolio of projects, through numerous internal and external collaborations and partnerships, into the very DNA of our organisation.



Understanding responsible innovation

Responsible innovation is the idea that through research, we can shape scientific innovation and new technologies to deliver widespread benefits for society. This is even more critical when we think about new and emerging areas of future science and technology that are likely to have far-reaching and potentially disruptive impacts on the world around us.

Responsible innovation isn't our idea. It has been explored by scholars and researchers around the world. Over the last five years, we have connected with and learned from many of our international colleagues. We have also invested in new early career researchers, who are working on responsible innovation within CSIRO and through partnerships with Australian universities. All towards building this new capability across the research and innovation system.

As we progressed, it became clear that responsible innovation is much more than a set of guiding principles for scientific endeavour. It embodied a noticeable shift in mindset among the colleagues we worked with. We discovered its application across disciplines is nuanced and demands specificity, to truly add value to our future science and technology.

Early on in our journey, we had a strong sense that responsible innovation should become a core part of our applied scientific offering. We tested the relevance of responsible innovation across several of our research portfolios. And we benchmarked our approach against our international peers.

Our experience was telling us that this could transform the way we pursue future science and technology at CSIRO. That beyond socially responsible science and technology which mitigates potential harms to society, we might even unlock socially innovative science and technology. Socially innovative science and technology raises the bar even higher. It meets social needs or addresses persistent social challenges in new ways; potentially even strengthening our social systems and civil society.

And as we contemplated how best to unlock these possibilities, this question continued to occupy us. How do we continue finding new scientific frontiers in the field of responsible innovation itself?

> "Responsible innovation is a rigorous approach not only to understanding if we can do something...but if we *should* do it."
>
> CSIRO Leader

Finding the frontiers

Our Responsible Innovation Future Science Platform is a robust program of multidisciplinary research. We are focused on building the foundational capabilities and methodologies needed to understand and anticipate the full spectrum of consequences from our cutting-edge innovations.

In this way, responsible innovation reflects our commitment to systematically and scientifically assessing the risks, benefits and uncertainties of CSIRO's future science and technology. It's our mission to ensure socially responsible science and technology is designed and delivered for the benefit of all Australians.

We know it's not possible to fully predict all the implications of new areas of science and technologies before they are developed and deployed. But with a rigorous scientific approach, we can put an in-depth, meaningful examination of potential social and ethical risks at the forefront of innovation – not as an afterthought.

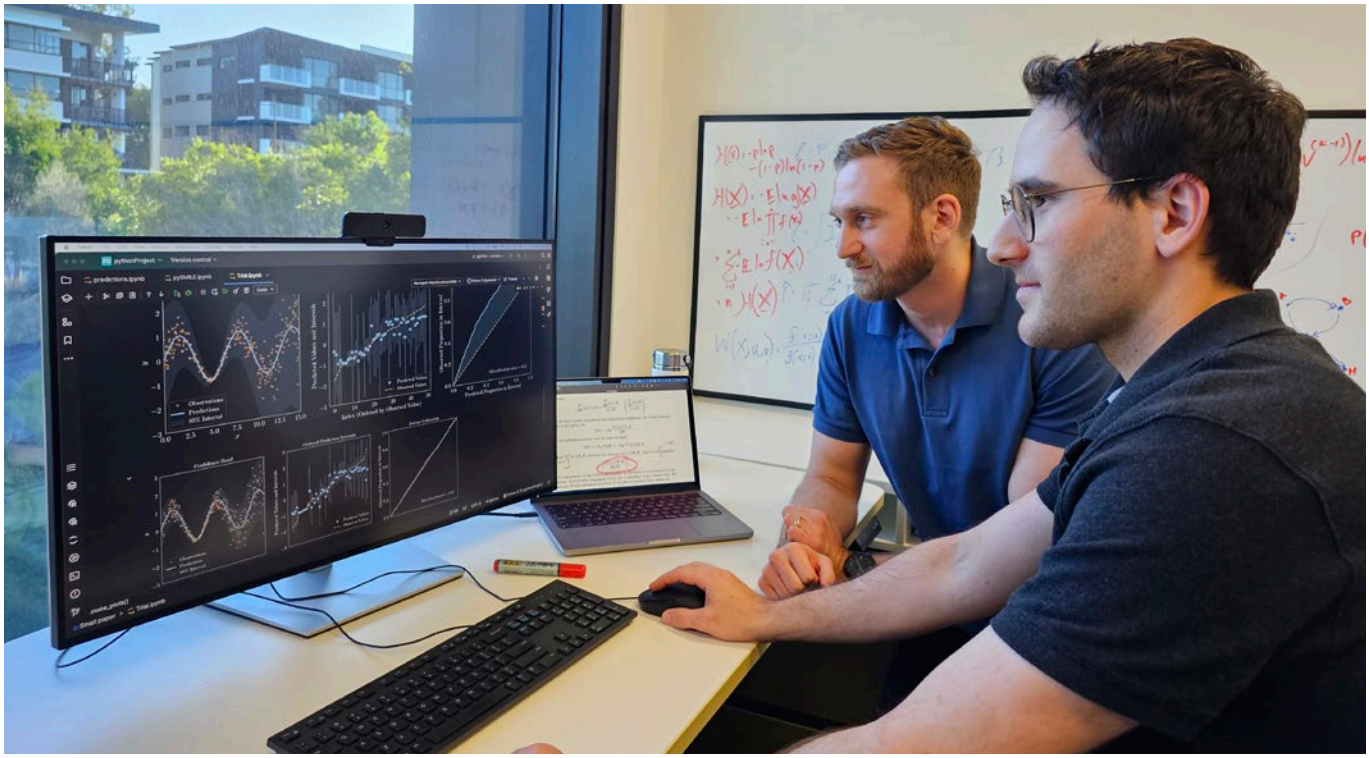
Our approach systematically develops risk tolerance thresholds to help us prioritise:

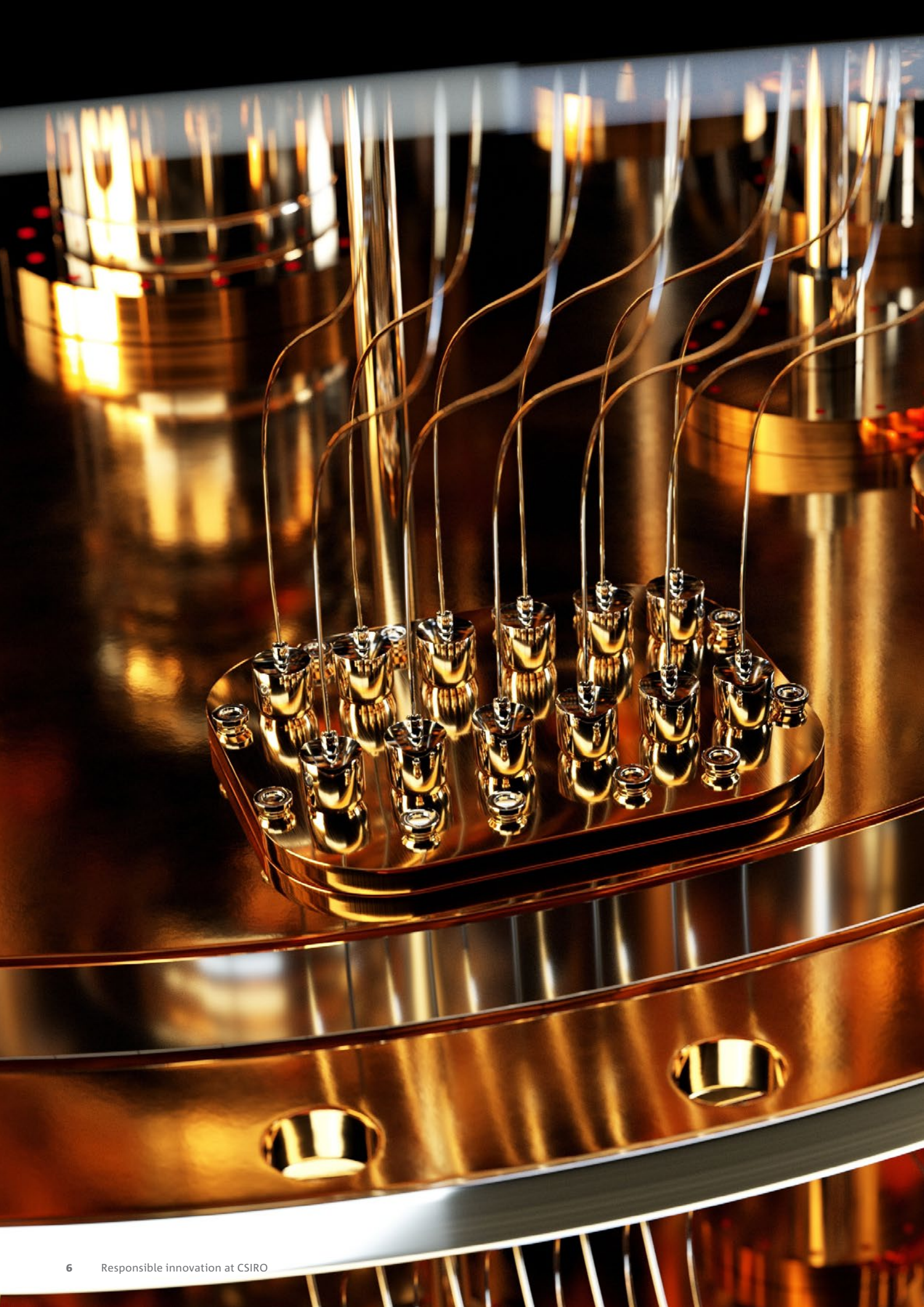
- how technologies will or won't be developed,
- what controls are needed to mitigate and manage potential risks, and
- which outcomes from future science and technology are desirable – and which are unacceptable.

Adopting this approach allows us to consider the social, environmental and economic benefits and costs of pursuing certain innovations (or not). It gives us the insights we need to align research and development on future science and technology with the values and expectations of the Australian community.

In doing this, our responsible innovation research is a way for industries, communities, and end users of future science and technology to understand its impacts on their lives. It gives people a voice to shape scientific innovation for the better – right from the start of the research and development process.

> "The role of responsible innovation is to help us to ask the right questions about our disruptive science and technology...at the right time."
>
> CSIRO Leader





What if we don't prioritise responsible innovation?

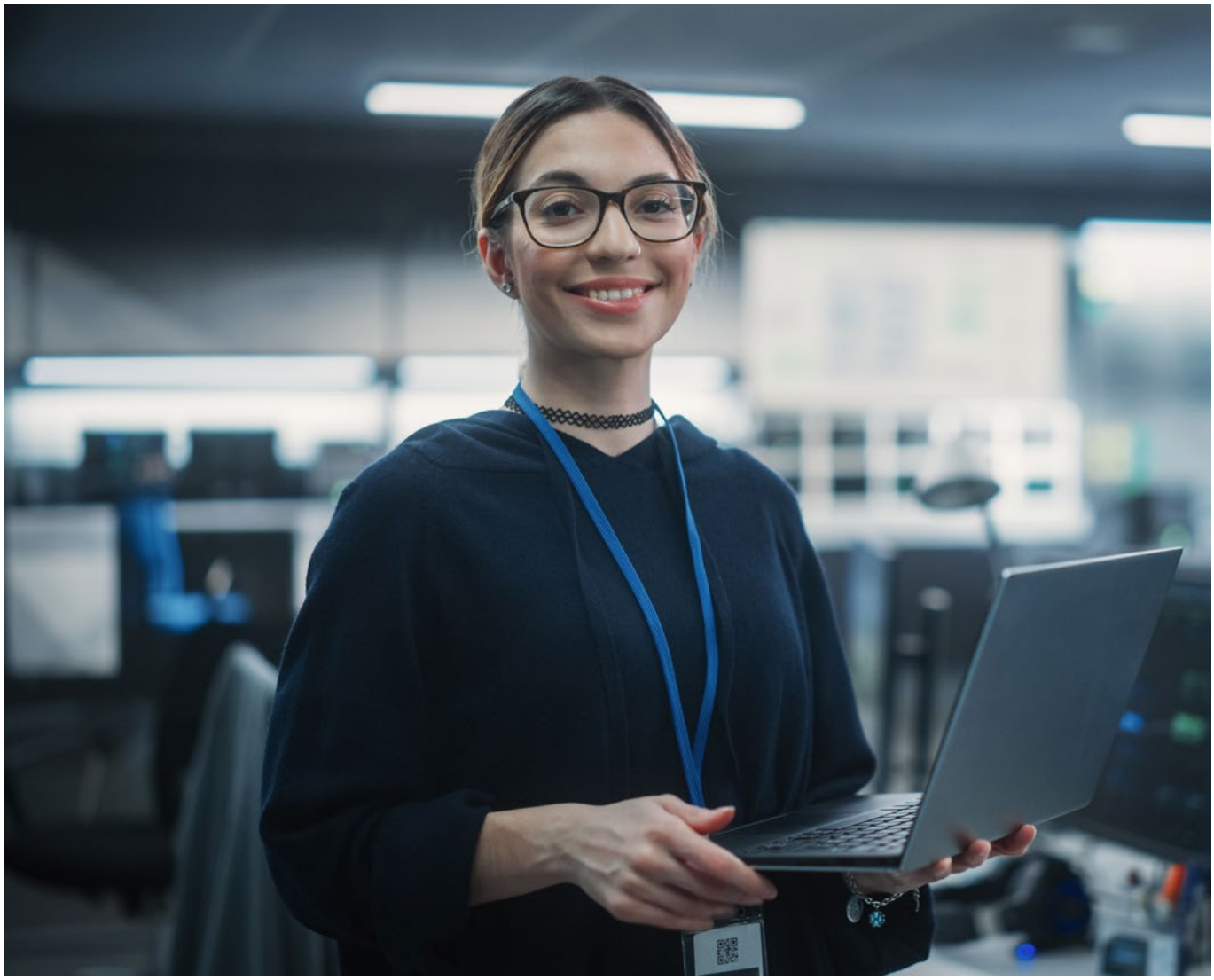
> "For our science and technology to have real impact, people need to have real trust in what we are doing."
>
> CSIRO Leader

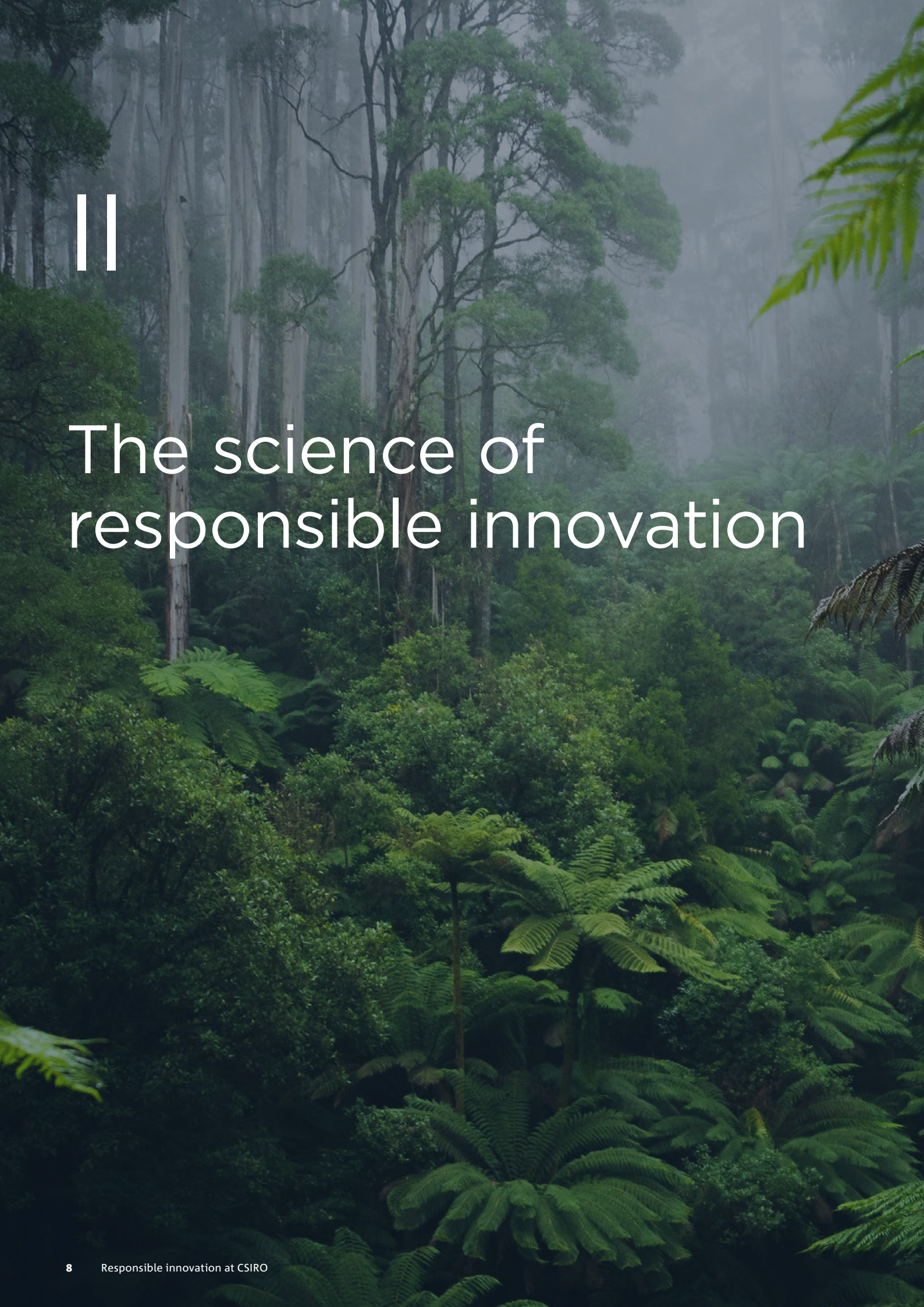
We believe that Australia's national science agency should work to find innovative ways of ensuring that future science and technology is socially responsible. Otherwise, the impacts of our science and technology solutions risk becoming fragmented and inefficient, leading to costly problems down the line, or worsening the equality of outcomes that can be achieved.

If future science and technology is developed outside the guardrails of responsible innovation, the risks are threefold:

- A 'tick box' approach to important social and ethical issues, which fails to proactively capture the diverse needs and values of the Australian people.
- Missed opportunities to realise positive, meaningful outcomes – or worse, the potential to create or exacerbate social inequities.
- A breakdown in public trust, where investment in science does not yield acceptable solutions.

When it comes to doing responsible innovation...we can't afford not to.





II

The science of responsible innovation

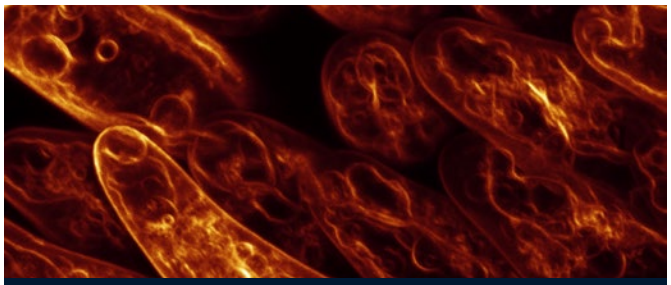
Our priority areas

New science and technologies are emerging at a rapid pace. These leaps forward in knowledge and new technologies can create complexities for our societies and decision-makers.

Transformational research in emerging domains holds enormous potential to generate widespread benefits. But it is, by its nature, disruptive – and that can bring uncertainty.

When we looked across our diverse Future Science Platforms at CSIRO, we identified three areas undergoing that rapid pace of change and where responsible innovation could play a role.

These broad areas also cover almost every sector where CSIRO is developing and applying future science and technology. Their fast pace of development, coupled with their high potential for transforming all areas of society, made them clear priority areas for responsible innovation.

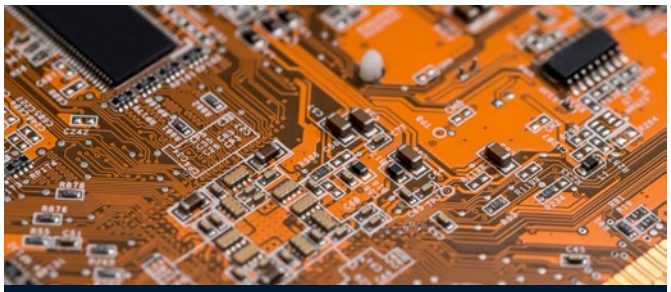


Socially responsive genetic technologies

This includes system-scale changes arising from advances in engineering biology. This area incorporates industry-scale disruption as well as personal uses arising from novel health and food applications, responses to infectious diseases, vaccine development and approaches to biosecurity and anti-microbial resistance – among others. All with a focus on how such applications can be socially responsive.

Managing risk for environmental-scale interventions

This incorporates large-scale energy system change, along with associated infrastructure and new ways of storing energy, negative emissions and permanent carbon locking technologies. This area also takes in applications of future science and technologies seeking to effect change at the landscape, regional or climate scale, with a focus on how this impacts our social systems.



Emerging digital technologies

This includes quantum technologies and their applications, artificial intelligence (AI) and machine learning and cybersecurity applications. It also encompasses broader considerations associated with the use of data and digitalisation. In this area, there's a focus on the social and ethical considerations associated with the design and deployment of these technologies into society.

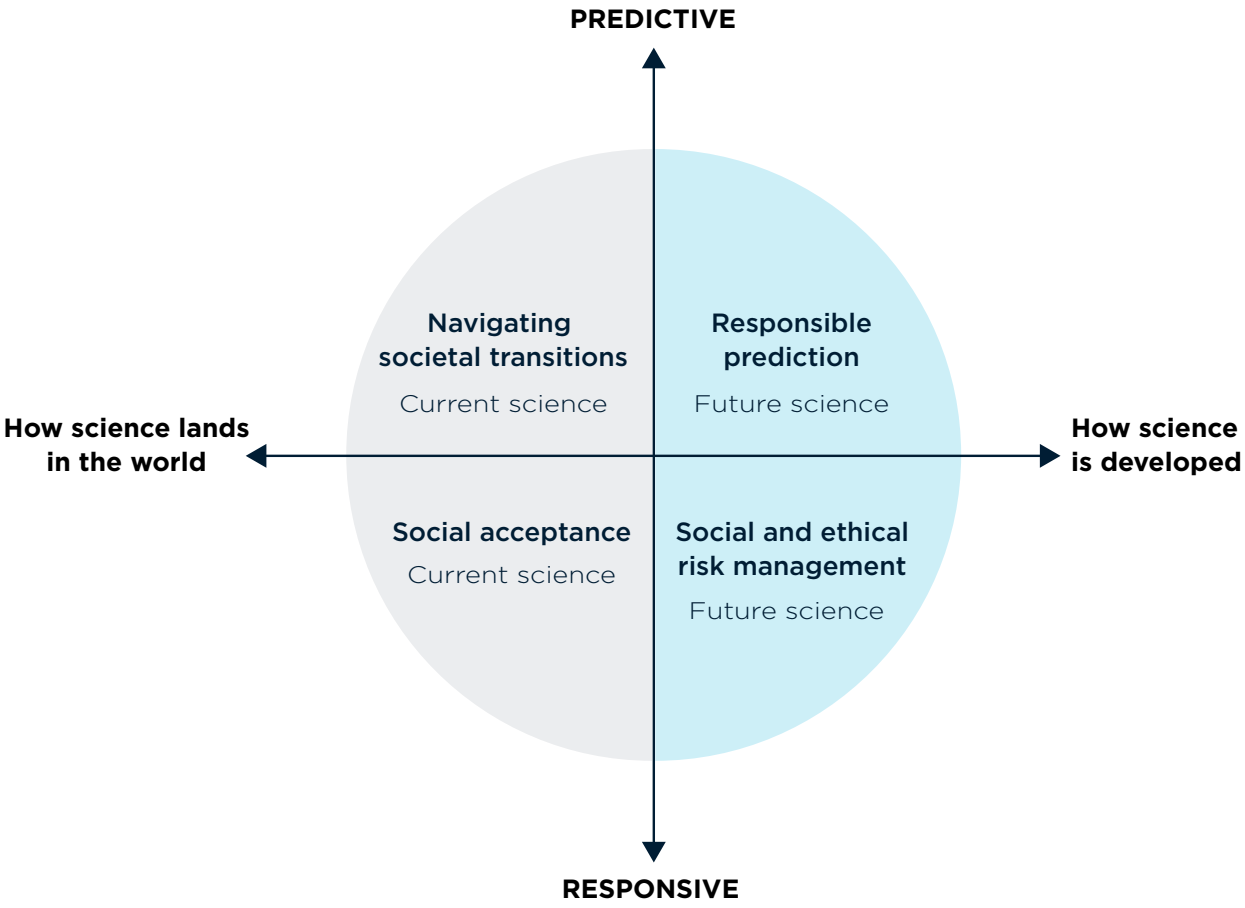
Our science frontiers

Inclusive community and stakeholder engagement techniques are a well-established and core part of our science delivery. They serve to bring diverse values, needs, and expectations into consideration. Likewise, collecting and modelling social data offers a rich understanding of societal aspirations. These techniques help us identify the conditions underpinning aspects of how our social systems operate.

But we are also interested in how new capabilities and methodologies can be developed in the field of responsible innovation. What other tools do we need in our toolbelt to better understand and navigate the interface between future science and technology, and society at large?

Tackling this question is critical to supporting the decisions we're making right now – and those we will be making in 20 or even 50 years' time.

Here at CSIRO, we have sought to identify opportunities to develop responsible innovation as a new applied science. In doing so, we reviewed our existing research projects, along with the skills and capabilities being applied to deliver socially responsible outcomes. This process allowed us to identify and build on our existing strengths. Importantly, it enabled us to scope out where we could build new areas of applied responsible innovation science in our portfolio.

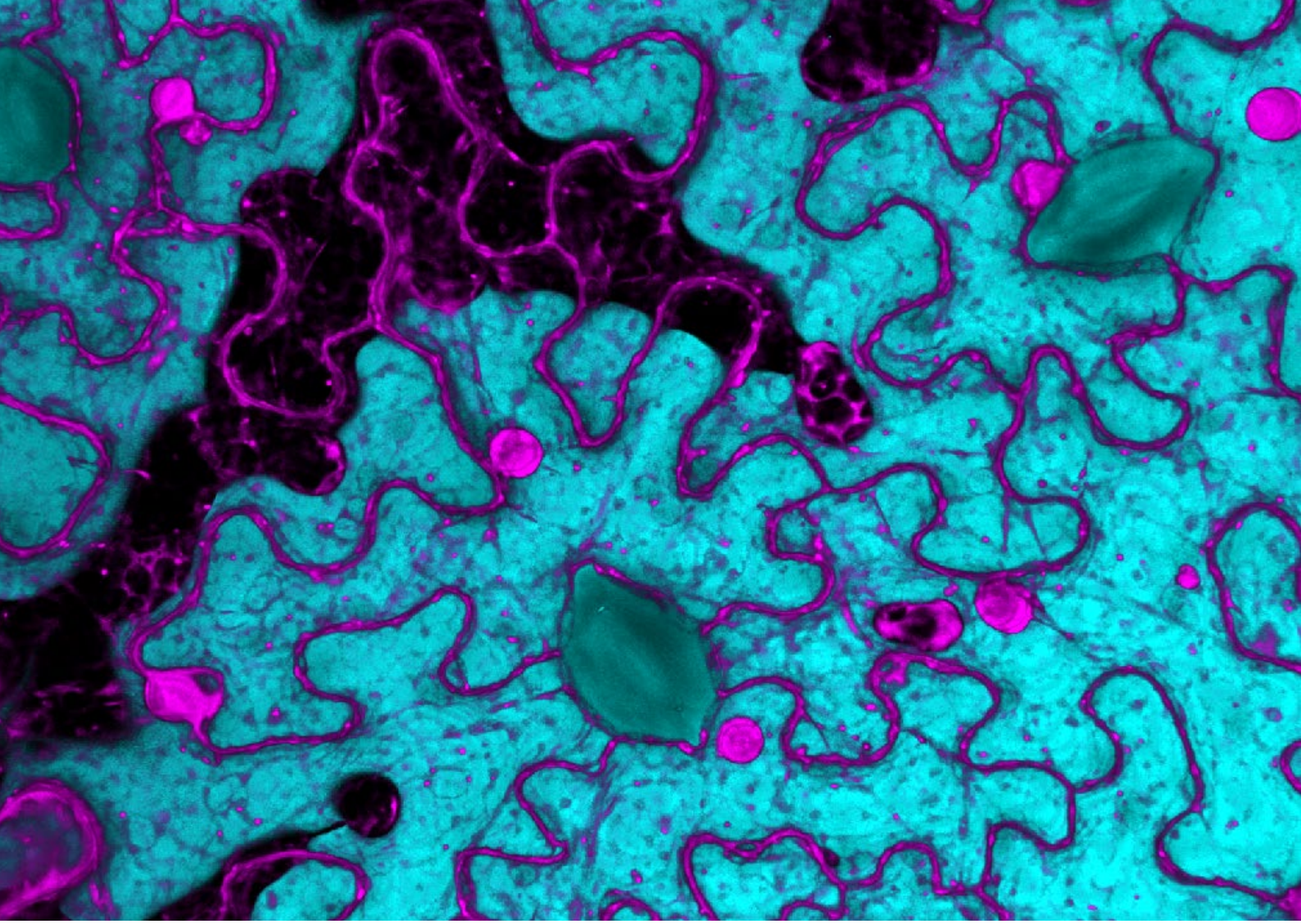


The first axis asks whether our science is responsive or predictive in nature. Responsive research tends to be designed to address identified challenges or problem areas. In other words, we have an idea of what we think we need to do in response to what we are observing or experiencing. Predictive research tends to be more anticipatory in nature. It means we understand there is change taking place in a system, but we might struggle to fully understand its implications, or how to respond. Predictive research is more about how we design research to anticipate and better prepare for those changes.

The second axis asks whether our science is *internally focused* on how researchers go about responsibly developing new and cutting-edge areas of future science and technology alongside who needs to be involved at those early stages. Or, whether the research is *externally focused* on how science and technology lands into the world. This includes evaluating risks, responsibilities, and impacts in the delivery of future science and technology.

Next, we identified the applied science needed to help us operate in those four areas. This process highlighted some of our existing strengths. For example, CSIRO is very good at modelling the drivers of social acceptance in a range of contexts. But how might we build on that expertise and advance the way we collect and use socio-economic data to understand a range of dynamic and changing social conditions? Another area that CSIRO is currently focused on is how to support and navigate societal transitions in a complex and changing world. But where might we build more specific focus on identifying the social and ethical risks that accompany those transitions so that we can better mitigate them?

In building on this analysis and our own applied interdisciplinary science strengths and experiences, we identified two responsible innovation science frontiers.



Our responsible innovation science frontiers

Responsible prediction

Exploring new ways to model and measure social systems and conditions. This area seeks to drive a methodological step-change in social data analysis and is highly experimental in nature. We aim to build on established modelling techniques to more accurately represent feedback loops and dynamics within social systems. It also involves applying new forms of data analysis to help us notice patterns in metadata and generate more nuanced understanding and insights.

Social and ethical risk management

Seeking new methodologies that demonstrate more systematic and applied scientific approaches to identifying and mitigating social and ethical risks. The aim is to move beyond ad hoc case studies, toward approaches that can be scaled and potentially applied across different technology sectors. This area takes us beyond documenting social impact of science and technology, to establishing the criteria that can reliably identify socially responsible science and technology and potentially even socially innovative science and technology.

Our science results

Each of our two science frontiers host a series of projects that cover our three priority areas:

- socially responsive genetic technologies
- managing risk for environmental-scale interventions; and
- emerging digital technologies.

The future science and technology emerging from these priority areas demands an approach that anticipates potential consequences, and engages deeply with societal and ethical considerations.

Within these responsible innovation projects, we are tackling a range of national challenges. We do this by creating highly interdisciplinary teams, and bringing their diverse specialisations and expertise to these challenges. What's more, they also bring a strong focus and commitment to responsible innovation science, in the way they tackle these challenges.

As a result, the findings they generate are collectively building the scientific evidence base for what it means to deliver *responsible prediction* and social and *ethical risk management* across a range of diverse areas.

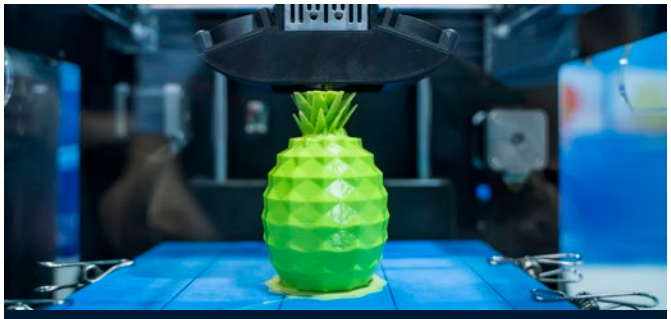
We are still in the early stages, continuing to build these new methodologies and capabilities. But as we do, exciting possibilities are emerging across science endeavours that are critical to Australia's future.

Here are just some of the projects we are working on...

RESPONSIBLE PREDICTION

Our interdisciplinary project teams in responsible prediction are:

- **working with diverse stakeholders and communities to identify new fit-for-purpose and innovative solutions,**
- **anticipating potential harms and finding ways to mitigate them, and**
- **applying novel techniques to collect, generate and analyse social data with a future-facing lens.**



Serving up our future foods

Our researchers are teaming up with consumers, manufacturing firms, food companies and food scientists. Through focus groups and surveys with these stakeholders and end-users, we are co-designing and developing new fit-for-purpose food innovations that meet Australia's changing needs. We've already identified how 3D printed foods can provide aged care residents and those with medical needs with enhanced care and nutritional outcomes.

Supporting communities in Australia's renewable energy transition

Our researchers are creating realistic simulations of evolving stakeholder and community attitudes towards renewable energy solutions. We are using community surveys alongside social and broadcast media, supported by analyses that draw on the latest artificial intelligence techniques. Through these innovative methods, we are anticipating new ways to support more cohesive communities and reduce the likelihood of social conflict.

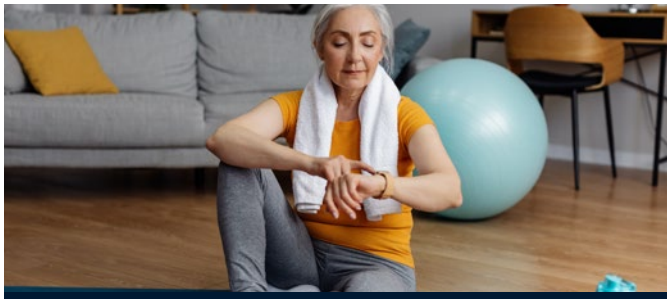
Transforming the future of healthcare

Our researchers are bringing together AI experts, health scientists and clinical practitioners to assess potential uses of AI in Australian healthcare. Our focus is on anticipating the potential benefits, as well as the critical risks. By creating an environment where all stakeholders are able to trust healthcare decisions informed by AI, we can build a safe and reliable healthcare system that delivers improved patient outcomes.

SOCIAL AND ETHICAL RISK MANAGEMENT

Our interdisciplinary project teams in social and ethical risk management are:

- **drawing on the insights of stakeholders and communities to surface the range of social and ethical risks frequently overlooked in formal risk assessments,**
- **applying repeatable methods to identify and document those risks, and**
- **contributing to the development of acceptable strategies to mitigate social and ethical harms.**



Unlocking the possibilities of personalised healthcare

Our researchers are exploring how advances in genomic technologies and computational capabilities are revolutionising the diagnosis and treatment of disease. We are working with diverse stakeholders to identify and mitigate potential social and ethical risks. These include protecting patient privacy, increasing accessibility and equity in healthcare and supporting digital literacy for caregivers and their patients. This work will help safely unlock the possibilities of a personalised healthcare system.

Innovating in a changing climate

Our researchers are working with research institutions, government agencies, civil society organisations, and industry partners to collectively map pathways for developing and deploying novel climate technologies. The aim is to convene participatory processes that support a robust and collective exploration of likely and acceptable risk/benefit profiles for different technologies. Our focus is on how social and ethical risks and opportunities are captured and represented in those processes.

Powering up Australia's quantum economy

Our researchers have identified how quantum technologies are likely to disrupt and transform fifteen major industry sectors in Australia over the coming decade. By working collaboratively with stakeholders across each sector, we are now developing the framework for identifying and mitigating critical risks. This will support greater quantum readiness for each sector, and enhance the potential quantum contribution to Australian society.

Collectively, the science being developed in the projects in our two responsible innovation science frontiers has broader significance as an interdisciplinary effort and capability supported by robust methodological approaches that can be applied across different fields of future science.

Our approach to responsible innovation as an applied science can accommodate the nuances of context. It's responsive to the range of theoretical and methodological differences between the scientific disciplines which are engaged in the delivery of responsible innovation.

Collectively, the evidence generated by these projects contributes to a growing body of knowledge on responsible innovation, and informs the development of a new scientific practice at CSIRO.

Our learnings so far

Some lessons from our responsible innovation journey at CSIRO to this point:

- We took the concept of responsible innovation and committed to exploring its value to our organisation in a serious and robust way. This could not just be 'lip service' to a set of guiding principles. For us that commitment meant playing to our strengths as the national science agency and investing in a Future Science Platform to advance this emergent area of applied science.
- Importantly, this commitment to exploring the possibility of responsible innovation as part of our applied scientific offering was strongly endorsed and supported by our senior leadership.
- Our early experimentation and research are demonstrating for us that responsible innovation is a worthwhile investment in our future science and technology.
- We have now positioned responsible innovation in CSIRO as a distinct applied interdisciplinary scientific approach that prioritises our focus on the societal impacts of our future science and technology.

III

The pathway to responsible innovation

Delivering our vision

At CSIRO, we know our responsible innovation science must be rigorous, robust and repeatable. So we go about delivering outcomes that are meaningful, fit-for-purpose, and needed by Australian society in three key ways:

DISCOVERY:
identifying what makes responsible innovation work

This entails validating the concept at all levels of our organisation, by road-testing responsible innovation through applied scientific inquiry. We do this with interdisciplinary teams, across diverse areas of future science and technology. This is the foundational process of building responsible innovation as science.

DIFFERENTIATION:
demonstrating how responsible innovation makes a difference

This involves building an evidence base that shows us how, where, and why responsible innovation can be operationalised as a core competency in our organisation. As a result, we better understand how to create scientific outcomes that are meaningful, fit-for-purpose, and reflect the needs and values of Australian society. We don't just elevate responsible innovation as an evidence-based offering. We demonstrate how to operationalise and deliver responsible innovation.

DELIVERY:
ensuring the benefits of responsible innovation are shared

We do this by identifying the pathways through which responsible innovation can be activated and delivered. This ensures tangible benefits now and into the future. In doing so, we enable the positive impact of responsible innovation to be experienced and accessed in a range of different ways across society.

DISCOVERY is where **we build and scale the science of responsible innovation**.

We do this by:

- **Establishing** a dedicated research program to prioritise responsible innovation as a long-term investment in future science and technology.
- **Piloting** responsible innovation case studies across diverse future science and technology to document the risks, benefits and opportunities.
- **Scaling** those case studies beyond a single technology or issue to tackle complex challenges facing Australia.
- **Collaborating** with national and international research institutions and government agencies to elevate the value and practice of responsible innovation.
- **Partnering** with industry and communities to design responsible innovation solutions that are fit-for-purpose.

To establish:

- A network of interdisciplinary researchers working to advance the science of responsible innovation.
- A knowledge space where industry and government can explore challenges and opportunities through responsible innovation.
- Better understanding of what responsible innovation means (and doesn't mean) in different contexts and applications.
- Increased awareness of responsible innovation and its role for a broader range of stakeholders, including the Australian public.

DIFFERENTIATION is where we demonstrate **how responsible innovation differentiates and adds value** to our science and technology, including how organisations differentiate their impact when they do this well. We purposely seek to avoid a 'checklist' or 'cookie cutter' approach to responsible innovation. And we deliberately draw on the strength and breadth of theoretical and methodological scientific expertise within CSIRO. All this helps generate outcomes that are fit-for-purpose and responsive to context.

We do this by:

- **Consolidating** and applying the scientific evidence base that enables us to move beyond social impact, and actually validate what constitutes socially responsible – or even socially innovative – science and technology.
- **Working** even more closely with partners and communities to evidence how responsible innovation creates new value or opportunities, and/or reduces risk or harm across a range of contexts.
- **Evaluating** the cultural change within organisations that commit to learning about, practicing and applying responsible innovation.

To establish:

- Clear criteria that can be applied to the evaluation of socially responsible science and technology.
- Greater trust and confidence among stakeholders, ends users and communities in what constitutes socially responsible science and technology – and what that means for them.
- Organisations that are known as social innovators when it comes to designing, delivering, and applying socially responsible science and technology.

DELIVERY is about the range of delivery modes and how **we can share the benefits of responsible innovation** to realise a broader societal benefit from our science and technology.

We do this by:

- **Preparing** the scientists of the future with responsible innovation as part of their core skill sets, and creating new modes of primary, secondary, tertiary and professional education and training in responsible innovation
- **Supporting** government agencies to assess the impacts of future science and technology on Australian society
- **Equipping** industries to transition to more socially responsible practices and be held accountable for their performance
- **Identifying** and delivering alternative and/or new options to create greater access to the benefits of socially responsible science and technology (especially where some parts of the Australian community have been missing out on the benefits of science-based innovations).

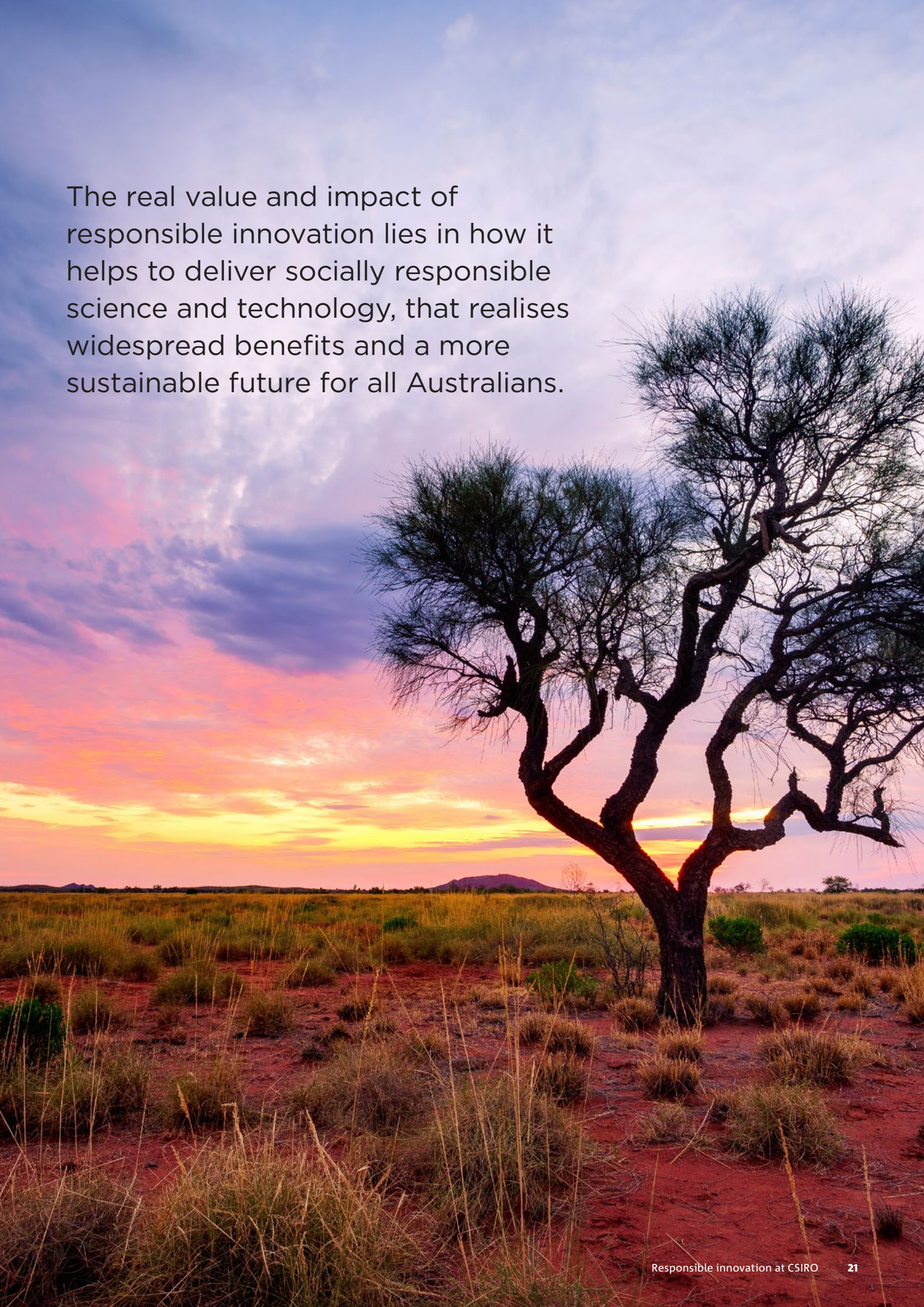
To establish:

- Widescale uptake and practice of responsible innovation as inherent to applied science and technology development, with accompanying breakthroughs in the field as new generations of scientists and engineers engage with it.
- Policies and regulations that lead to greatest possible benefits for Australian communities.
- Organisations empowered and supported to deliver evidence-based socially responsible science and technology in our changing world.
- A workforce equipped to embed and apply responsible innovation in and via science and technology solutions.
- Increased public confidence in science and technology to help address societal needs and opportunities.

Our Responsible Innovation FSP has constructed a distinctive and impactful presence within this bourgeoning field. From the foundations laid by decades of international collaboration and research, we have built a systematic and scientific approach to responsible innovation.

Reinforced by clearly defined priority areas and science frontiers, and cemented with the ever-expanding capabilities of our interdisciplinary research teams, we offer our blueprint for how responsible innovation can shape future science and technology for the better.

The real value and impact of responsible innovation lies in how it helps to deliver socially responsible science and technology, that realises widespread benefits and a more sustainable future for all Australians.



As Australia's national science agency, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Creating a better future for everyone.

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