



New technologies  
that are  
changing/developing  
rapidly that we need  
to be aware of

And do we need to change to  
make the most of this?

Dr Cathy Foley | 30 September 2019

- **Our changing world**
- **Action needed**
- **Way forward**
  - This involves start-ups and SMEs



The world is changing and  
there are lots of challenges



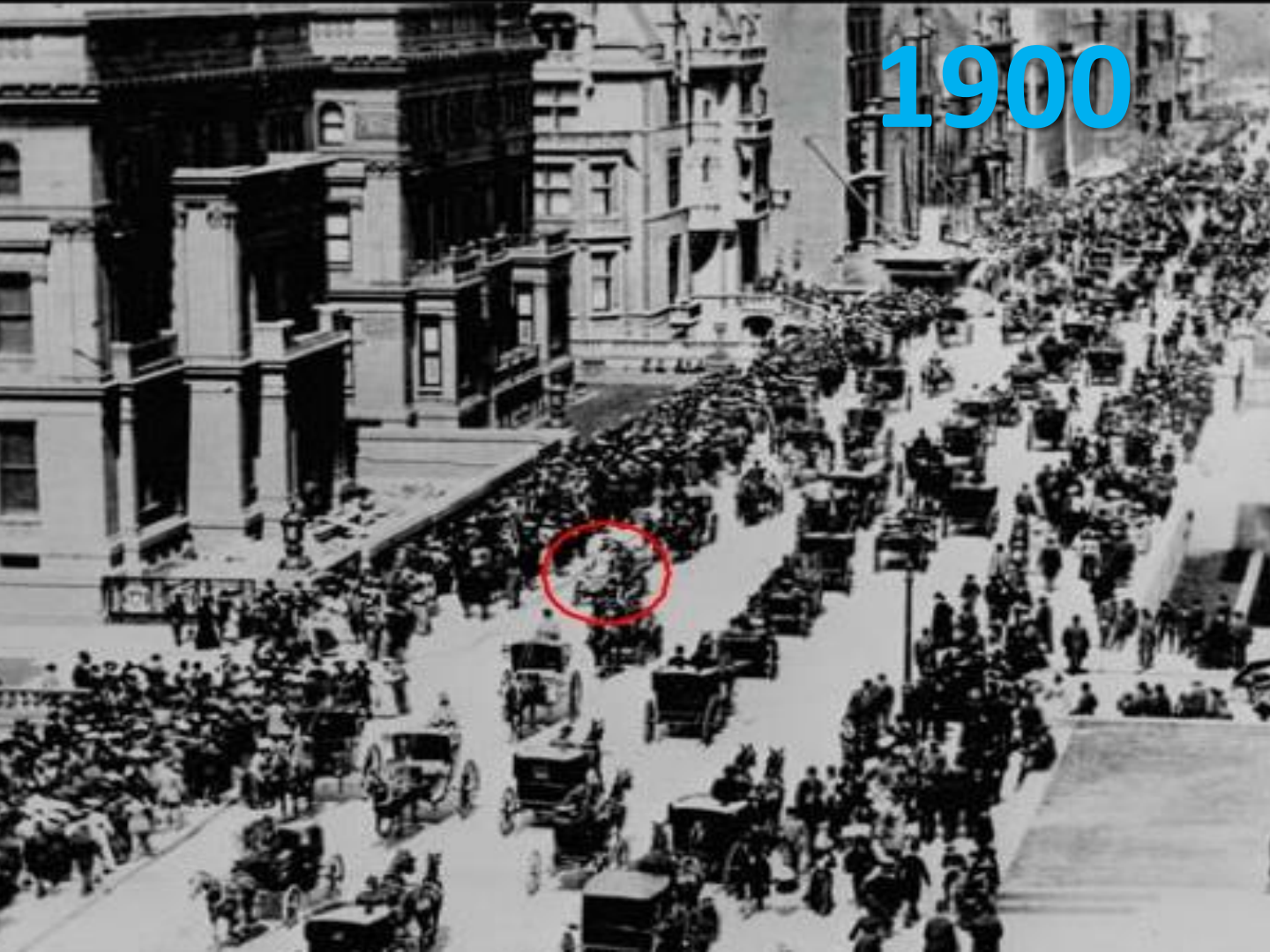
# Technology becoming ubiquitous ..... fast!





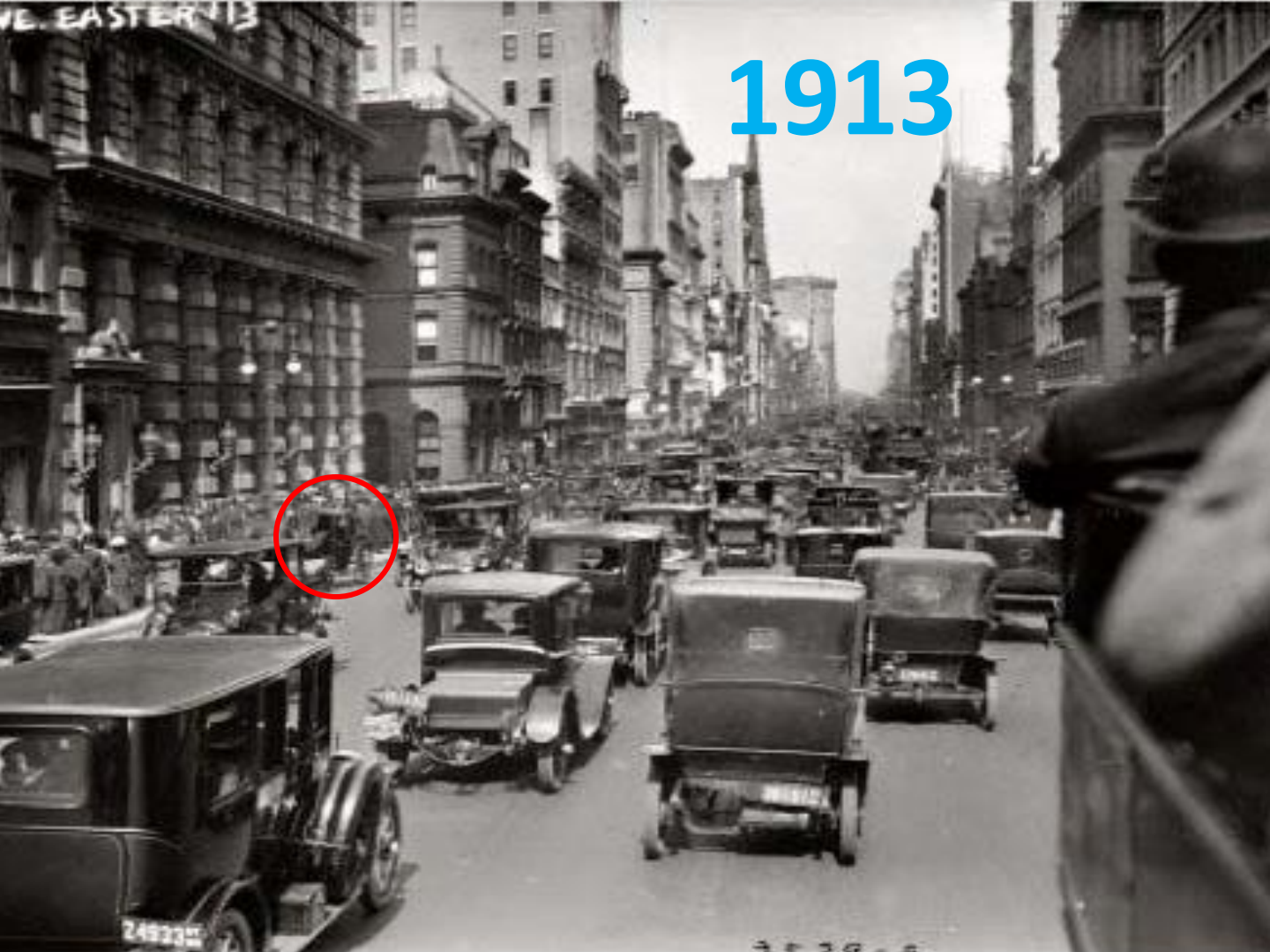
But our world has been  
changing really fast since 1900  
and accelerating

1900

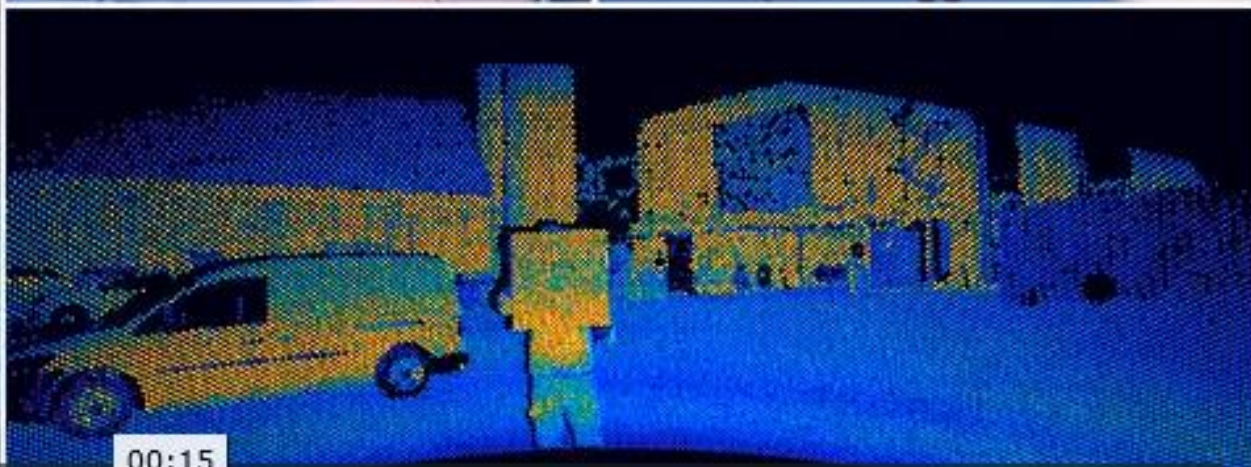


VE. EASTER '13

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# 2019+



## A strong vision for Australia

Informed by the evidence, National Outlook participants explored multiple potential futures and identified two contrasting scenarios for Australia in 2050. **Slow Decline** and the **Outlook Vision**. In **Slow Decline**, Australia fails to adequately address the global and domestic issues, resulting in declining economic, social and environmental outcomes. In the **Outlook Vision**, Australia takes decisive action and a long-term view, achieving much more positive outcomes. Drawing on CSIRO's integrated modelling, this report shows that the difference between these two scenarios is large and worth fighting for.

### Slow Decline

In **Slow Decline**, Australia drifts into the future. Economic growth, investment and education outcomes are all relatively weak. Australia's economy is increasingly vulnerable to external shocks. Real Factor Productivity (RFP) growth remains well below the global frontier and wage growth is consistently low.

Australia's energy system, housing its main export for export in the coal sector is an asset, but also a liability. Australia's energy system is ageing and inefficient. The ageing coal and gas assets are a major concern. The ageing coal and gas assets are a major concern. The ageing coal and gas assets are a major concern. The ageing coal and gas assets are a major concern.



### Outlook Vision

In the **Outlook Vision**, Australia reaches its full potential. Economic growth remains strong and resilient to external shocks. Australia's economy is increasingly competitive and resilient to external shocks. Australia's economy is increasingly competitive and resilient to external shocks.

Australia's energy system, housing its main export for export in the coal sector is an asset, but also a liability. Australia's energy system is ageing and inefficient. The ageing coal and gas assets are a major concern. The ageing coal and gas assets are a major concern.



# Australian National Outlook 2019



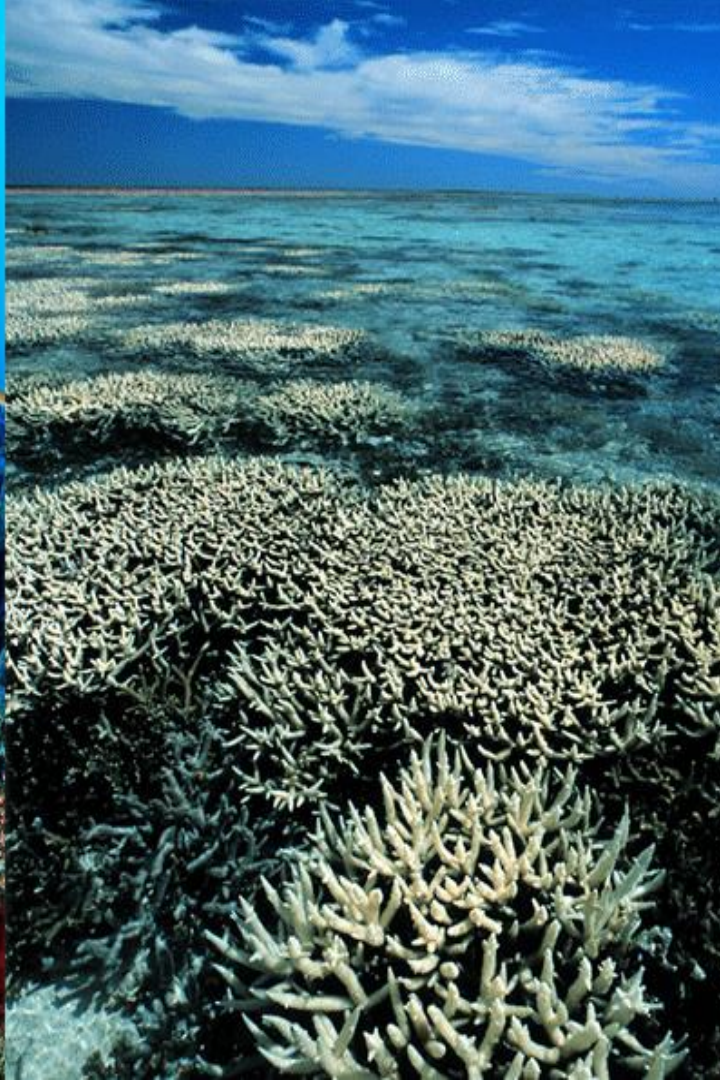


Drought

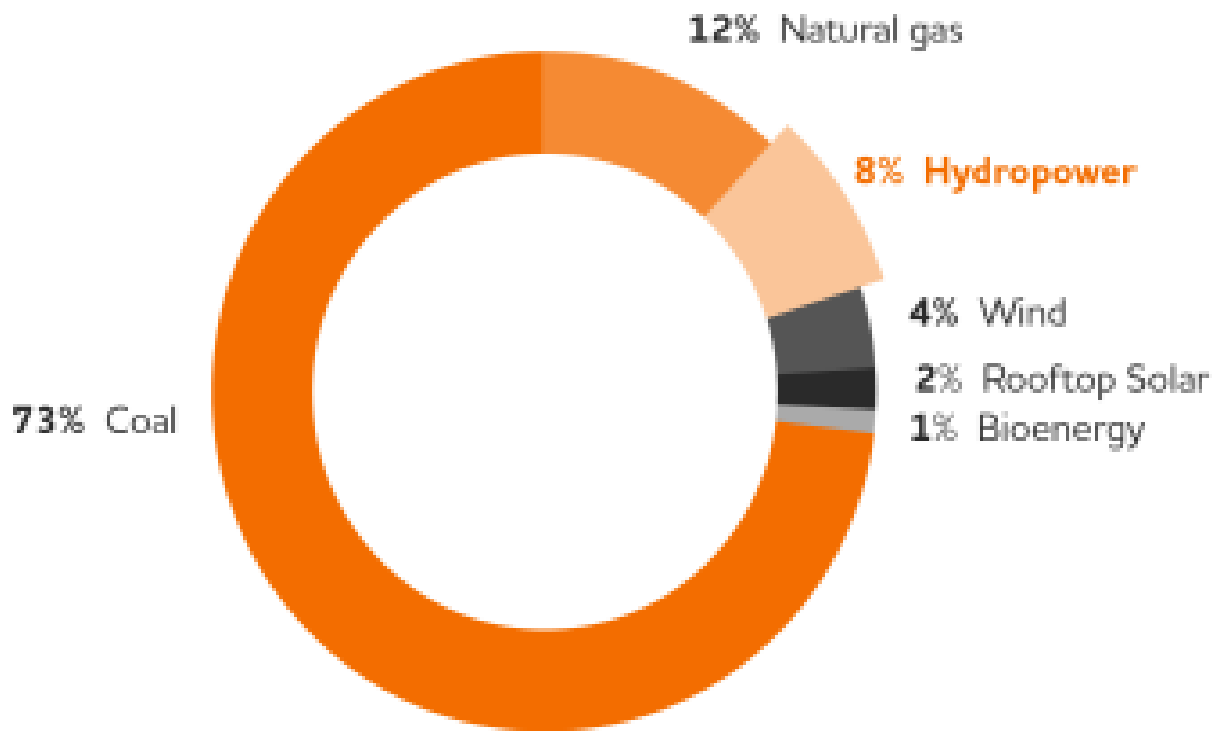


# Murray Darling Basin



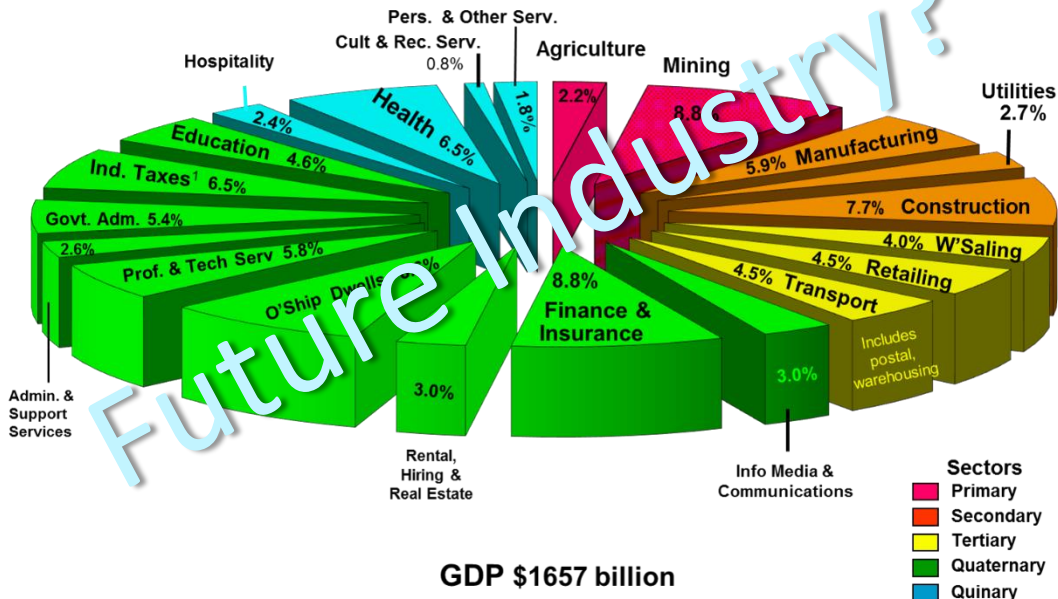


## ELECTRICITY GENERATION IN AUSTRALIA'S NATIONAL ELECTRICITY MARKET



# Australia's Industry Mix

Shares of GDP, in F2014 price terms Year to March 2016



Note <sup>1</sup>: Less subsidies, but includes stat. discrepancy (0.2%)



# Major challenges for Australia

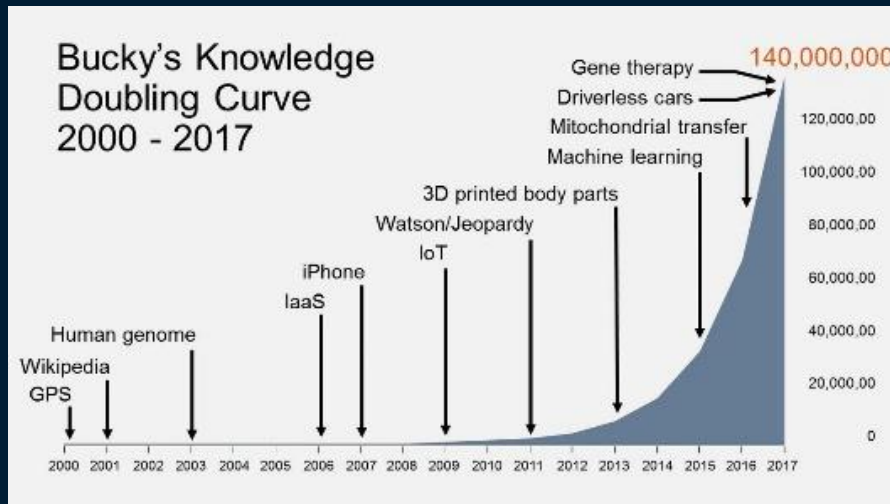




# Australia's Greatest Challenges



# Information is growing at exponential rates....



## Why can't we solve these problems?



**The volume of information  
available is incomprehensible  
i.e., not comprehensible**



#1 Future science will be disrupted by digital

## Digital Capability + Domain Science = Data as the “new oil”



Integration of **massive diverse** data sets – new breakthroughs

**Sensors & automation** - feed real time decisions and **actions**

Dataset access critical & **contested**

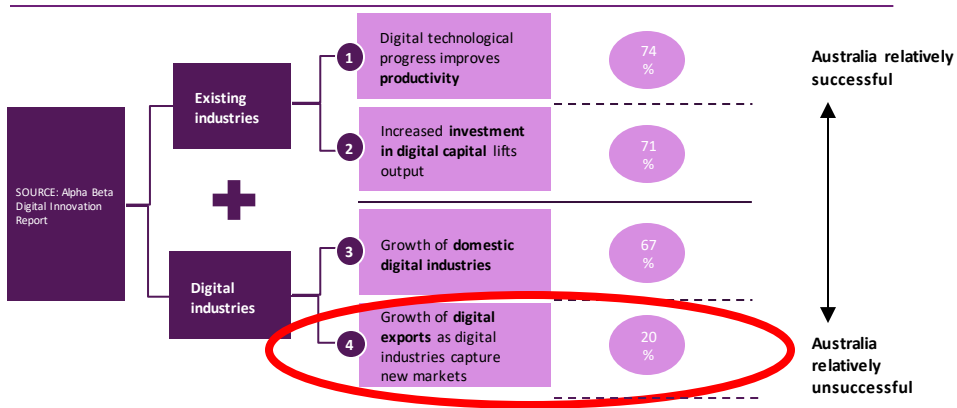
Risk of data **concentration in private monopolies**

Digital ecosystem **co-operatives** emerge

# Australia's \$315B Opportunity

Source of economic value from digital industries

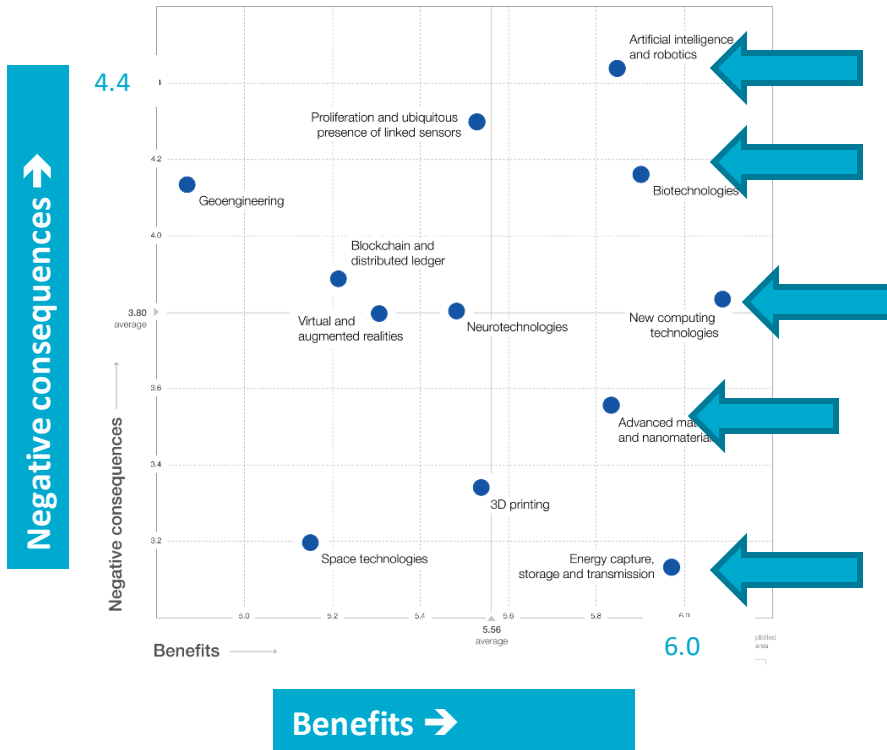
Australia's share of advanced economy average





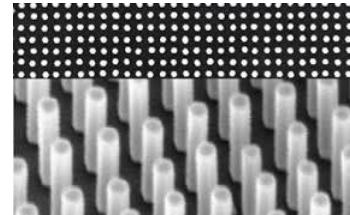
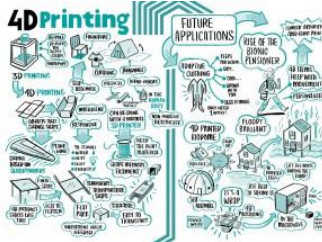
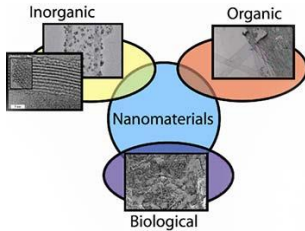
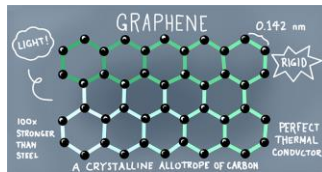
## #2 Breakthrough science and technology is emerging

# Exponential growth and convergence of General Purpose Tech



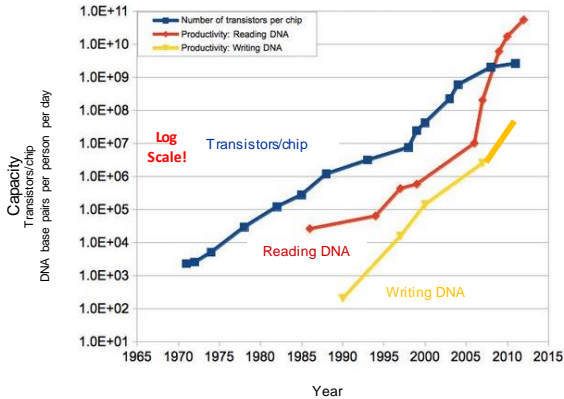


# Advanced Materials and Processes



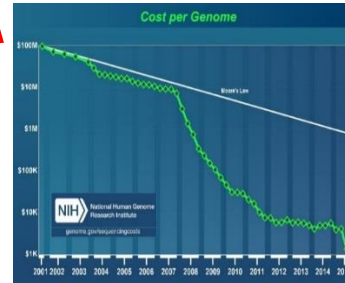


# SYNTHETIC BIOLOGY



2001: Human Genome Project \$100 M USD

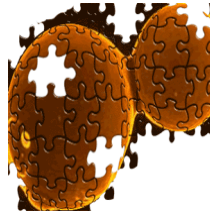
Reading DNA is cheap



Now: \$1000/genome

Writing DNA is getting cheaper

Moore's law: the number of transistors on integrated circuits doubles approximately every two years



Should we synthesise human genomes?

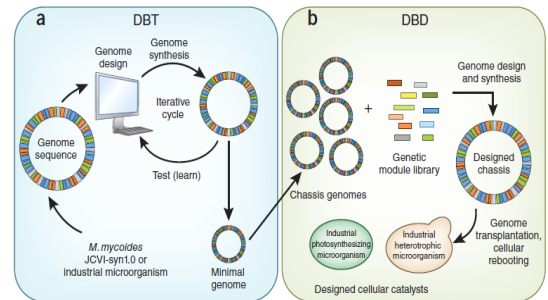
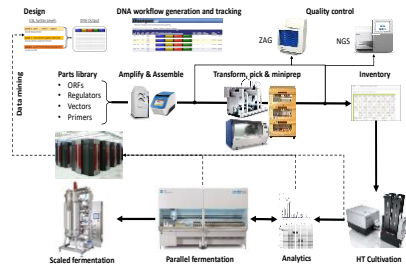
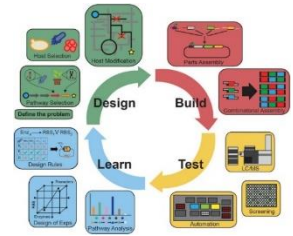






# BioIndustry: Design-Build-Deploy

- Intersection of biotechnology, information technology, manufacturing and automation
- D-B-T engineering
- Modular, plug-and-play DNA parts, truly predictable behaviour
- High-throughput design and construction
- Open frameworks for data and parts sharing
- Disruptive - will drive innovation in many disciplines
- AI will speed this cycle
- Bioelectronic hybrids will provide ultimate connectivity
- Transdisciplinary research and social science are key





# AI increasingly underpinning everything

## DARPA S&T PRIORITIES – SEP 2018

1. **Artificial Intelligence**
2. **Cyber** deter, resilience, attribution, offensive capabilities
3. **Biothreats** sense and mitigate
4. **Weapons of Mass Terror in Cities**  
chemical, biological, radiological or nuclear warfare
5. **Hypersonics** offensive & counter
6. **Space** new architectures/paradigms eg mesh satellite comms
7. **EM Spectrum** control AI, collaboration machine enabled
8. **Robotics** SubT Challenge
9. **Social** modelling societies, behaviour
10. **Fundamental technologies** electronics & leapfrog



**'AI is my #1 priority'**

DARPA Director, Steven Walker, Sep 2018

*AI can enable all of this  
to move at a faster pace*



So what does the future hold for science research?

How will new tools such as big data, automation, artificial intelligence and machine learning impact the everyday scientist?



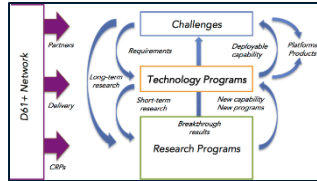
Future labs, field work and infrastructure



# New ecosystems in S&T



**Open Science**  
data sharing and  
co-operation



**Open innovation**  
co-creation & challenge  
models



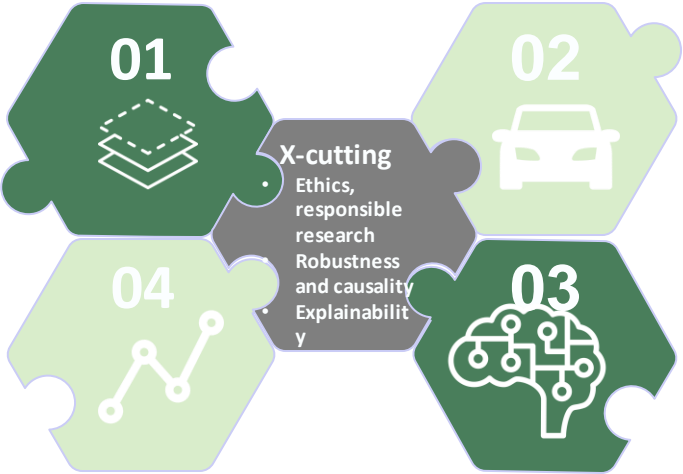
**Tokenisation**  
driving new economy  
in science

**Publications and  
Peer Review**

Open access  
Open source / open data  
Arxiv  
Crowdsourcing reviewing  
Repeatability / Statistical Significance  
Integrity

<https://medium.com/deip/how-tokenization-drives-the-new-economy-for-science-2ac21f62df1b>

# New Capability to assist: Artificial Intelligence / Machine Learning





# Future Science

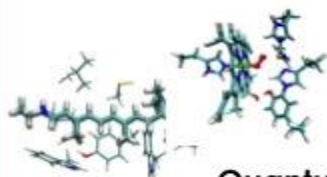
- More data driven science – more data streams and the ability to learn directly from data without process conceptualization.
- Scientists will be augmented – better interfaces (eg speech, gesture, cyberphysical) and intelligence (learning to work with humans). How do we collaborate and communicate with machines?
- More complex tasks will be automated using new techniques such as reinforcement learning – computers learning from computers.
- Explosion in tools to understand and exploit data types such as image/video, speech and text.
- Science publications will use formats understandable by computers so that complex reasoning can occur automatically.

# Multi-scale quantum and classical molecular simulations

System size

**Quantum chemical techniques**

Explore local chemistries



**Correlated quantum chemistry**

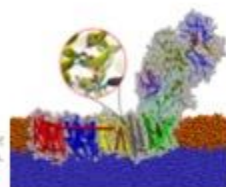
**Quantum Chemical DFT models**



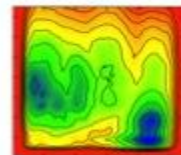
**QM/QM**



**QM/MM  
DFT/MM**



**Classical MD**



**Accelerated sampling**

Explore conformational phase-space



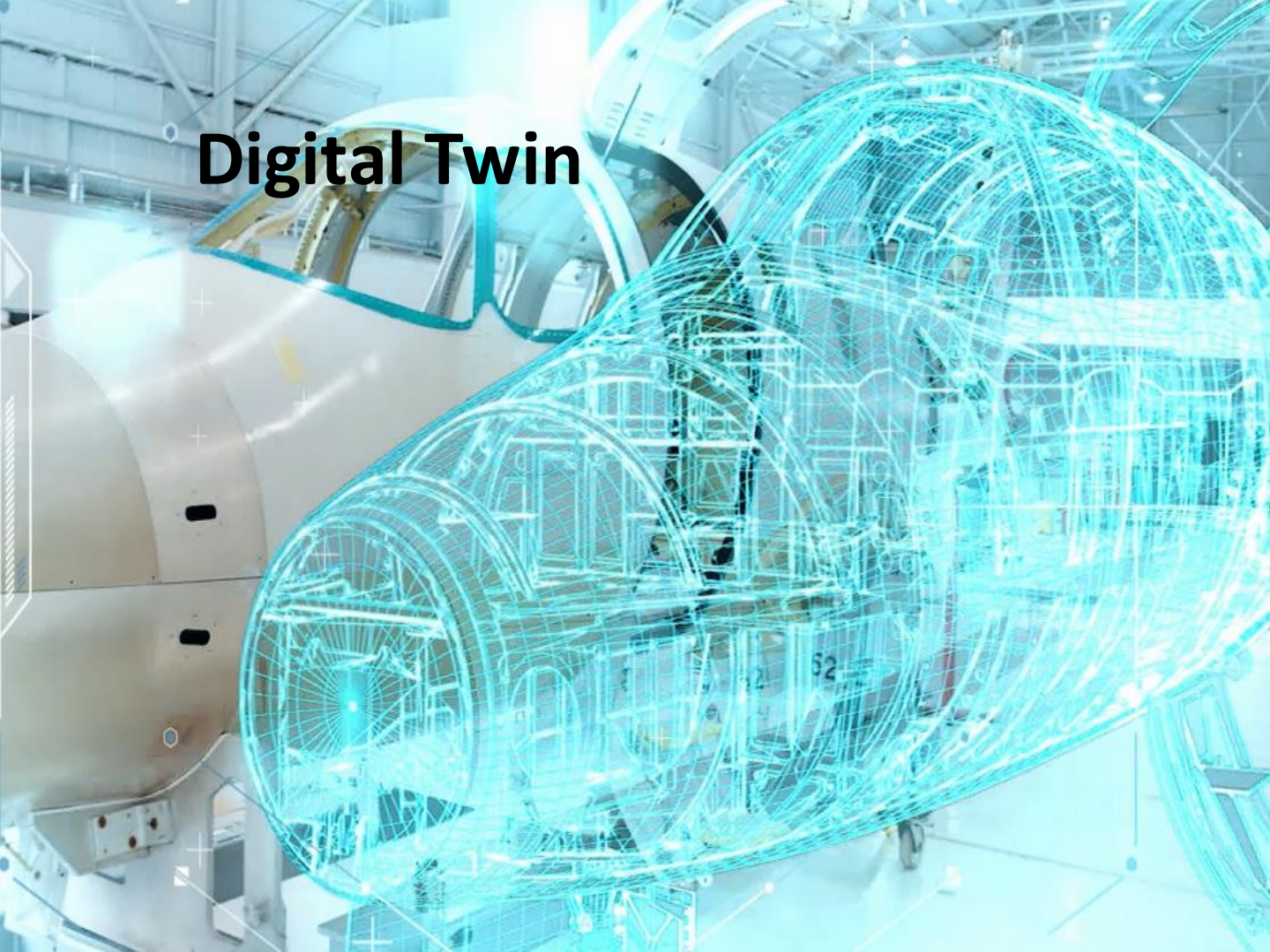
**Continuum calculations**

**Classical molecular simulation techniques**

Time scale



# Digital Twin



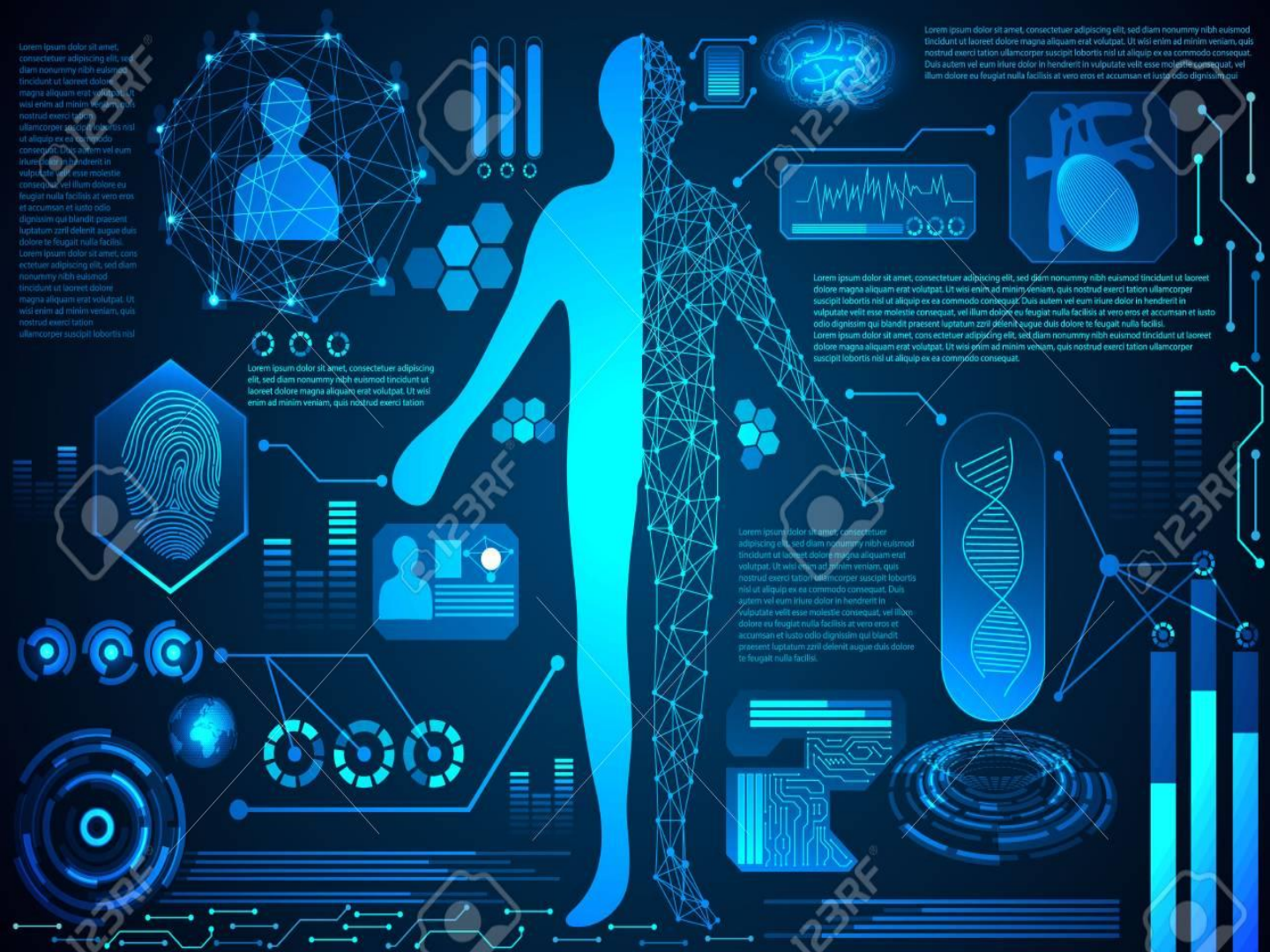
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#3

Where does Australia fit  
in with solving these  
interconnected  
challenges?



# Our place in the global science sector





## AUSTRALIA'S INNOVATION CREDENTIALS



### RANKED 1ST

FOR **TECHNOLOGICAL READINESS**<sup>1</sup>



CSIRO RANKS IN THE

### TOP 1%

OF THE WORLD'S **SCIENTIFIC INSTITUTIONS** IN 14 OF 22 RESEARCH FIELDS<sup>4</sup>



### 3RD HIGHEST

NUMBER OF UNIVERSITIES IN THE **WORLD'S TOP 100**<sup>2</sup>



### ALMOST 49%

OF AUSTRALIAN FIRMS ARE **INNOVATION-ACTIVE**<sup>5</sup>



### RANKED 5TH

FOR **GLOBAL ENTREPRENEURSHIP**<sup>3</sup>



### AROUND 43%

OF AUSTRALIA'S WORKFORCE HAS A **TERTIARY QUALIFICATION**<sup>6</sup>

Sources: 1. Economist Intelligence Unit, 2018 Technological Readiness Ranking, forecast for 2018–2022; 2. Shanghai Ranking Consultancy, Academic Ranking of World Universities 2018; 3. Global Entrepreneurship and Development Institute, Global Entrepreneurship Index 2018, 29 November 2017; 4. CSIRO Annual Report 2017–18; 5. Department of Innovation, Industry and Science, Australian Innovation System Report, November 2017; 6. Australian Bureau of Statistics, Cat. No. 62270DO001\_201805 Education and Work, Australia, May 2018 Table 10 (released 8 November 2018)



But our collaboration  
and translation sucks

Bottom of OECD



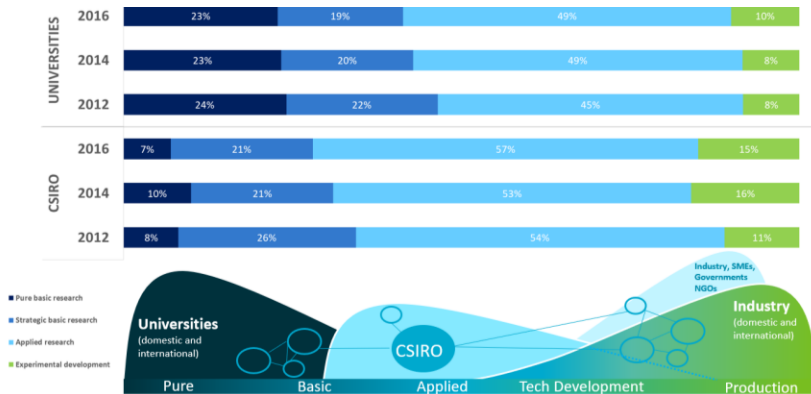
Can we reorganise  
ourselves to do better?



# Our place in the complex innovation system

# Ecosystem

- CSIRO's applied research investment and commercialisation capability is an area of relative strength, although universities have been growing their focus in this area



COMMERCIALISATION PARAMETERS	GO8 UNI'S	AUS. UNI'S (EXCL. GO8)	CSIRO
Avg revenue yielded from active LOA	\$9M	\$0.4M	\$37.5M
Avg research commercialization equity holdings	\$6.3M	\$1.6M	\$13.5M
Average no. of dedicated commercialization staff (FTE)	12	2	93

Sources: ABS Data 2016, CSIRO Annual Report; National Survey of Research Commercialisation

3%

30%





# Ecosystem Model vs Institutional

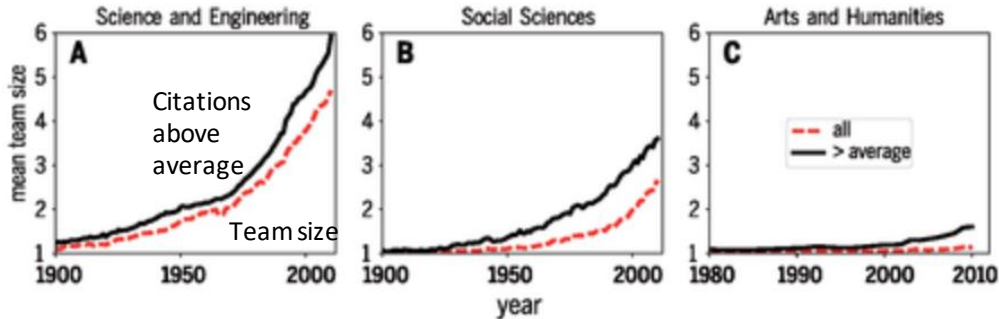
- **‘Valley of death’ services:** incubation, prototyping, development, commercialisation, funding
- **Continual innovation platforms:** open innovation, connecting needs to ideas and solutions
- **Talent platform:** expert connect, accelerated learning, frictionless mobility (students, industry, govts, research)
- **Research platform:** assured, open, cooperative network - tokenisation of research, open science, citizen science
- **Data platform:** connecting research system to exponential data and applications to derive value from it
- **Secure, high performance computing infrastructure**



## ECOSYSTEM MODEL vs Institutional

- Connects the system
- Provides virtual scale
- Lifts productivity
- Enables Data and High Power Computing Access
- **Accelerates innovation**

# Science and impact of teams



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**Disruption comes from small teams**

**Impact comes from big teams**

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# Small Projects to large critical mass sized missions to address these challenges from big to small

Build world's best teams

Inspire the nation

Focus on what is needed

Attract talent

Provide confidence to student choosing careers

Linking the sector for greater impact

Scale and focus

Start-ups SMEs and Multinational to invest here in Australia

**Address challenges**



## Example: “Collaboration R us”





## #4 To deliver on any vision:

Success of addressing  
big challenges needs a  
supply chain of small  
businesses



## Helping start-ups and SMEs via Collaboration Hubs

14  
Companies

152  
Headcount  
(186 incl  
departures)

~1300m<sup>2</sup>  
Lab and office  
space occupied

115  
Maker space  
users

2  
Start-up  
closures

0  
In the boarding  
lounge

4+  
Pipeline of  
inquiries

\$1.5m  
NSW Industry  
4yr support



Baraja Pty Ltd \$0-\$145M in 4 years

Optical device research solution

Assisting high-tech start-up to accelerate and de-risk product development. Co-located at CSIRO Lindfield



# Ability to scale up







POWERED BY



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[CAREERS](#)

[LOCATIONS](#)

[KEY DATES](#)

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# ON: accelerating innovation

# 53+

ON is Australia's national science and technology accelerator, powered by CSIRO.

We unlock the innovation that will fast track change.

If you're working on a big idea and need help taking it to the next level, we can help.

Learn more about us

[Programs](#)

[The Fine Print - how to join us](#)





# Sustainability

- Move to zero carbon products
- Provenance
- Circular economy
- Design for recycling
- Sustainable feedstocks
- Sovereignty especially for defence
- Dual use export
- Potential disrupted exporting
- Platform capability that has dual use



# Success needs:


Technology that is needed

Business model that works

Easy/seamless to adopt

Government regulation



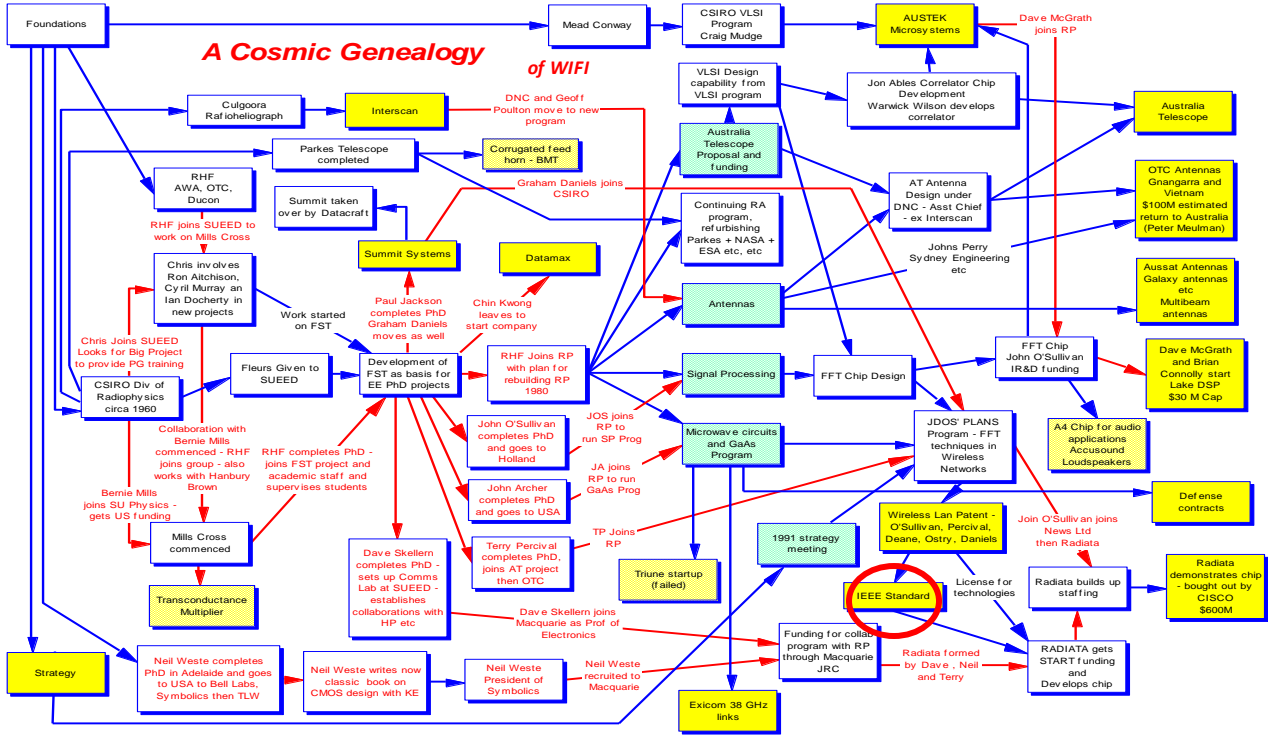
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20 years

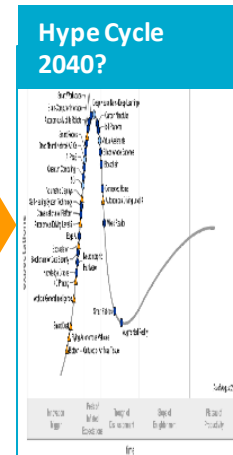
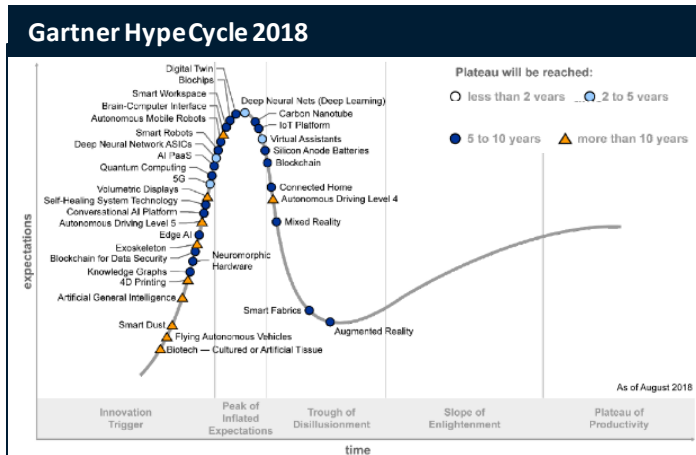




# A Cosmic Genealogy of WIFI



# Accelerating cycles



# A way forward

World is changing

Major challenges ahead

How we do science is changing

Adopt the opportunities of materials, synbio, quantum, ML/AI and data

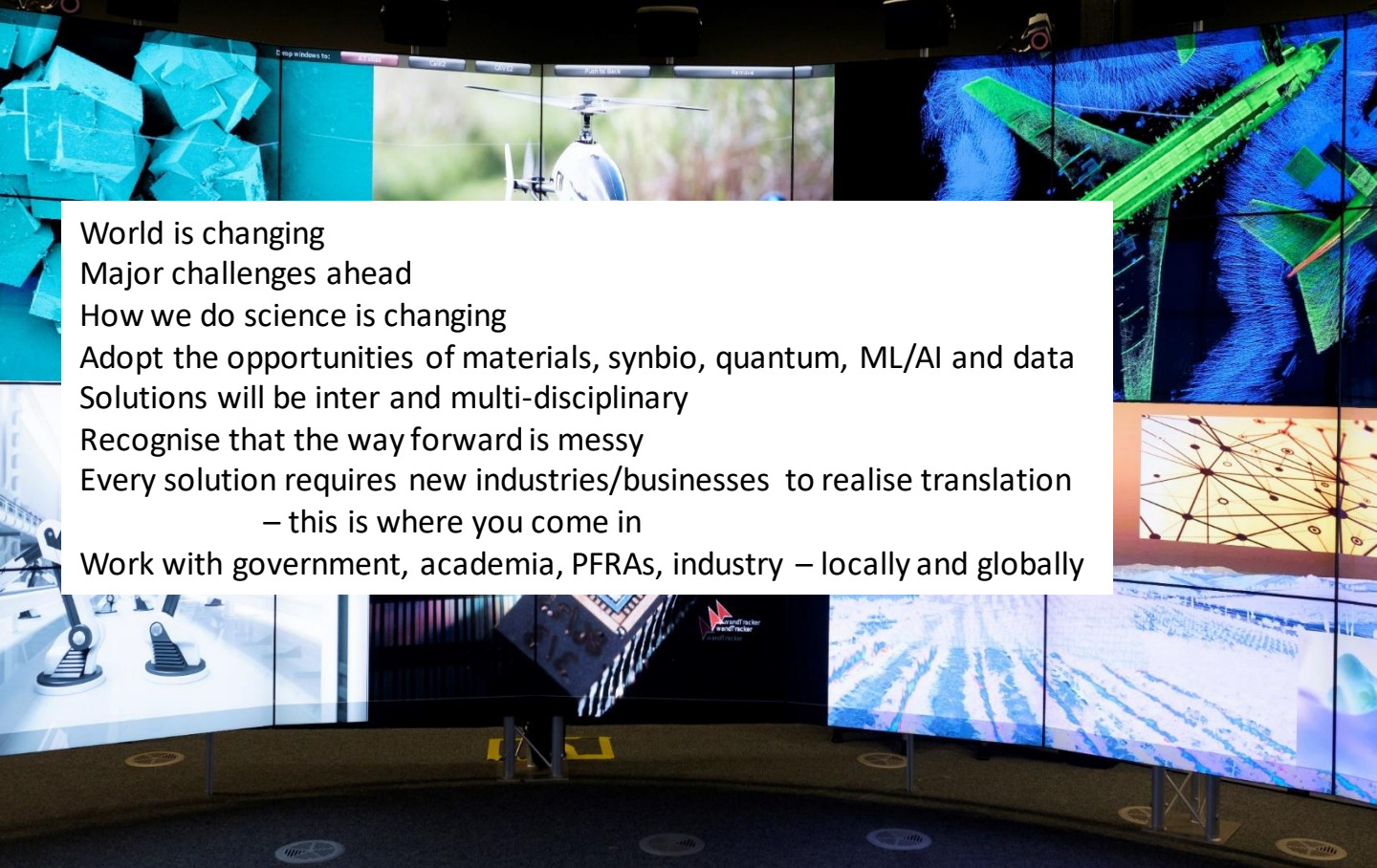
Solutions will be inter and multi-disciplinary

Recognise that the way forward is messy

Every solution requires new industries/businesses to realise translation

– this is where you come in

Work with government, academia, PFRAs, industry – locally and globally





Thank you!