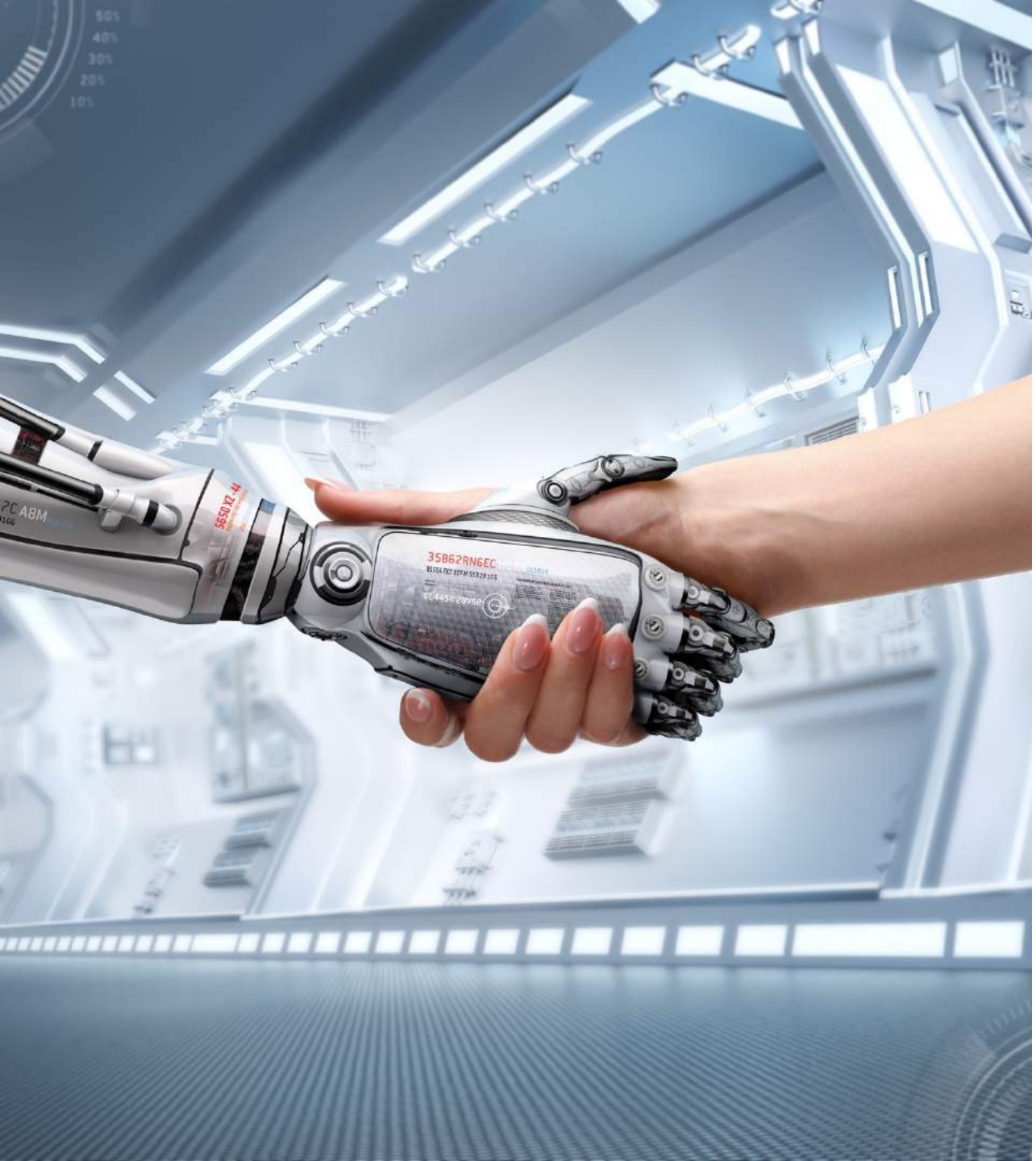


Digital Sciences Initiative

https://dsi.sydney.edu.au/

Faculty Update

8th September 2021

THE UNIVERSITY OF SYDNEY

Digital Sciences Initiative

Embrace the global digital opportunity

Investment

Growth

Precinct

Put digital at the heart of everything we do

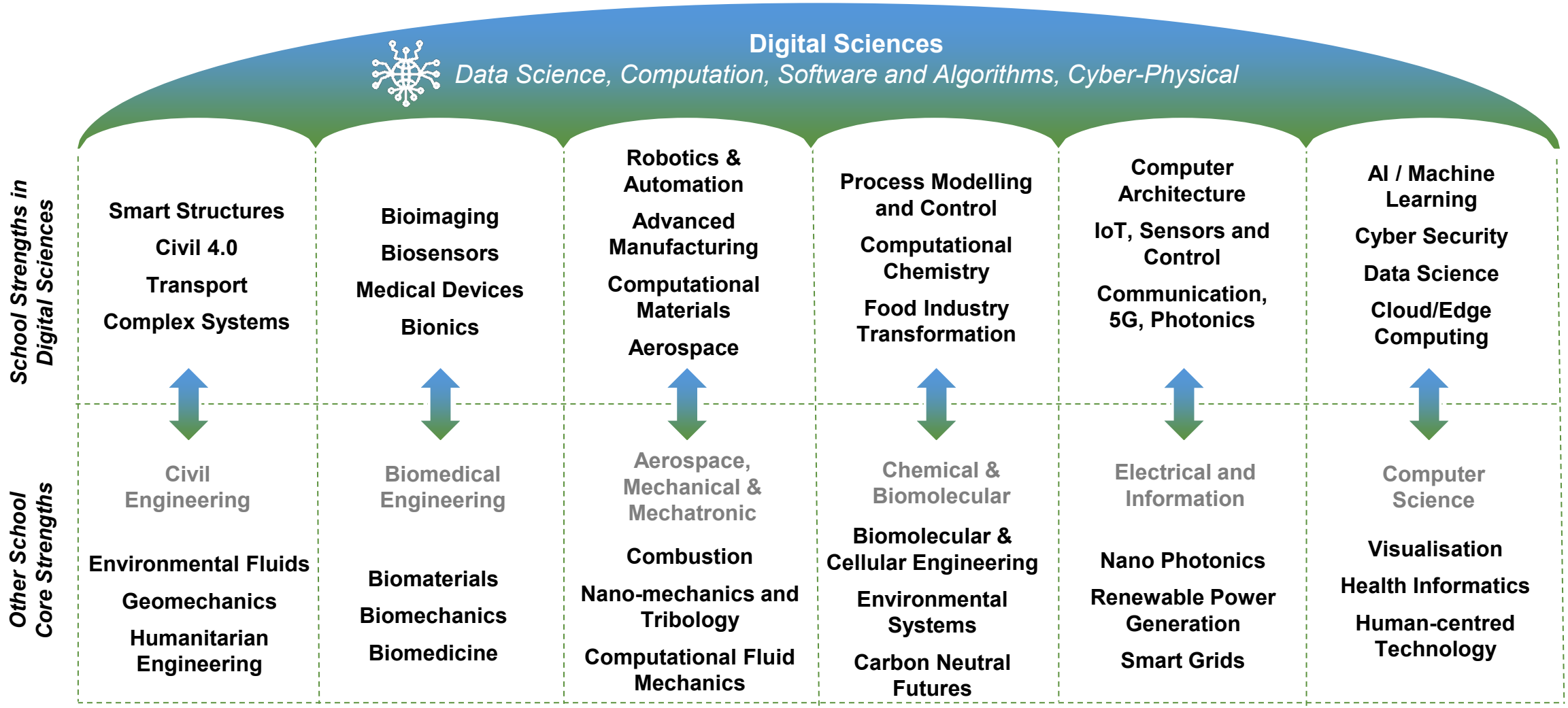
Research

Education

Engagement

For the Faculty:

Digital Science can be a unifying future-focussed strategy encompassing all disciplines across the Faculty



For the University:

The foundation for digital futures across the university community

Medicine and Health

Build current collaborations:

- Biomedical Eng.
- Medical Imaging
- Data Science

Growing new strengths:

- Genomics
- Medical Devices
- Brain and Mind

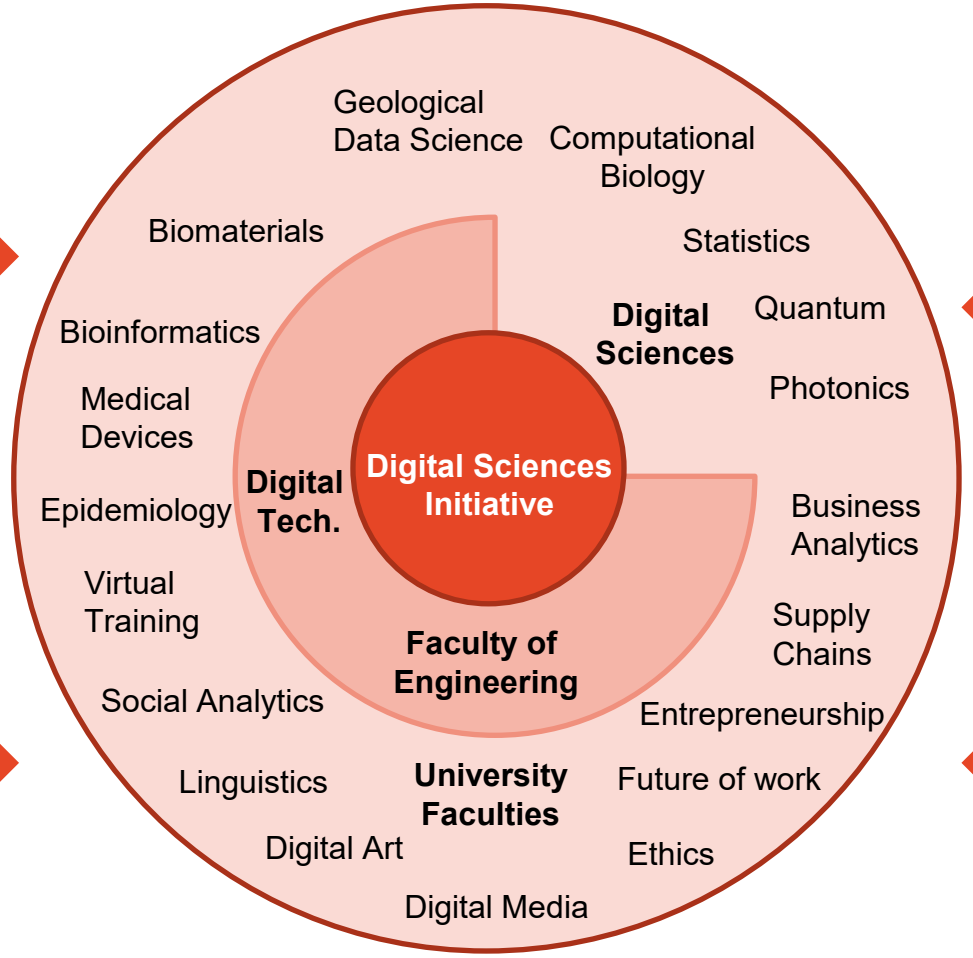
Arts & Humanities

Applied digital tech:

- Language processing
- Digital arts
- Social data analytics

Impacts of digital tech

- Ethics
- Social Media
- Digital Inequality



Science

Digital science collaborations:

- Statistics and Data Science
- Photonic devices
- Microscopy

Building on digital applications

- Geology and mining
- Biology models (CPC)
- Agriculture robotics

Business

Digital technologies:

- Analytics, econometrics
- Marketing
- Supply chain modelling

Digital business

- Digital Ecosystems
- Leadership
- Future of work

The Digital Sciences Institute Future Vision

Digital Sciences Institute

- More than **500 staff** comprising researchers, teachers, technical and support staff
- More than **6000 students**, comprising 800 research students and more than 5000 undergraduates

Research

- **Top in Australia**, top 25 in the world in digital sciences by 2030
- Increase in core digital sciences research funding to over **$40m a year**

Skills and training

- Graduate **1,500** highly trained digital science students per year
- Deliver training to over **300** postgraduate digital science specialists per year

Industry

- Leverage increased industry funding for digital technologies to **$60m a year by 2030**
- Research partner of choice in digital transformation of government and industry

Digital Sciences Initiative: Mission-Oriented Research

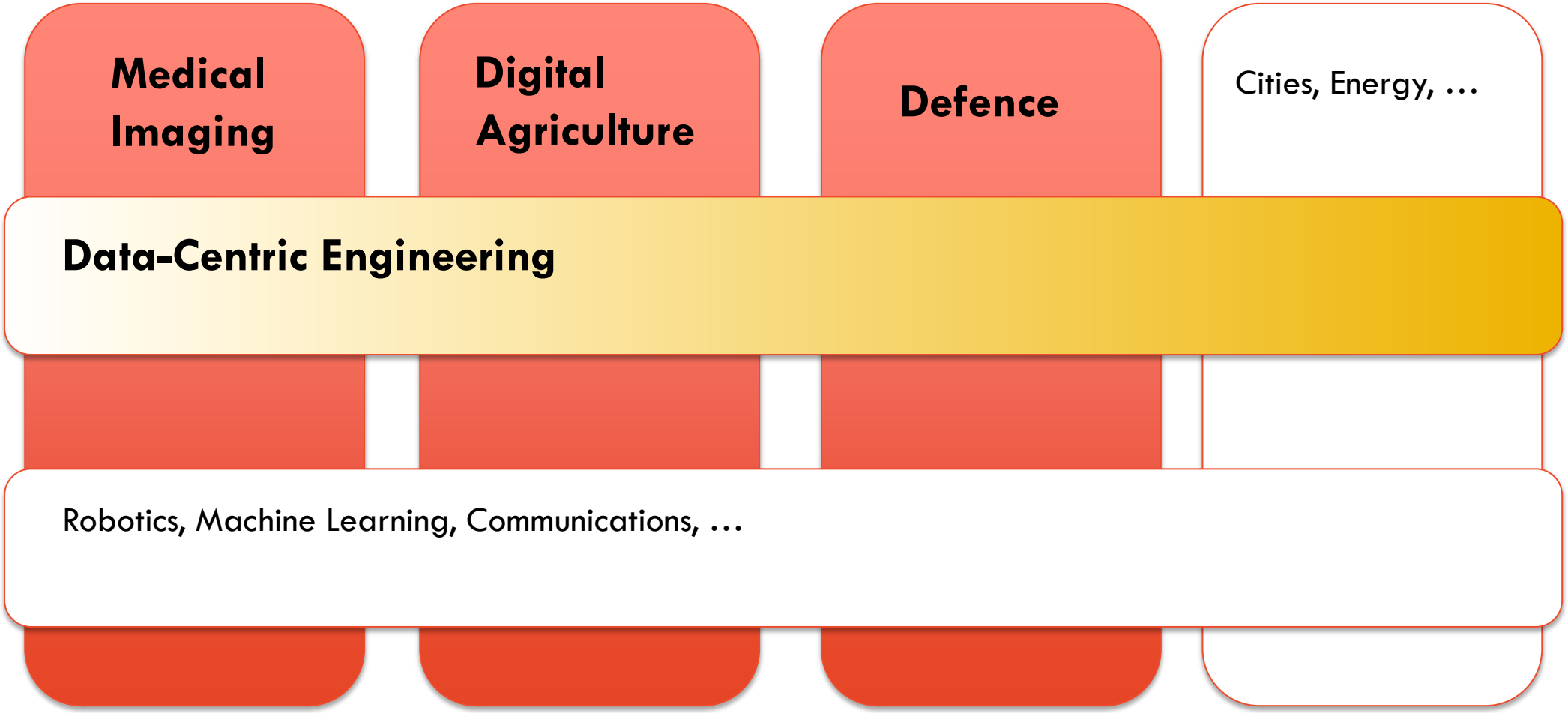
Break down silos

Work on bigger themes/projects

Work better with industry/government

Scale
Excellence
& Impact

Digital Sciences Initiative – Four Initial Research Missions

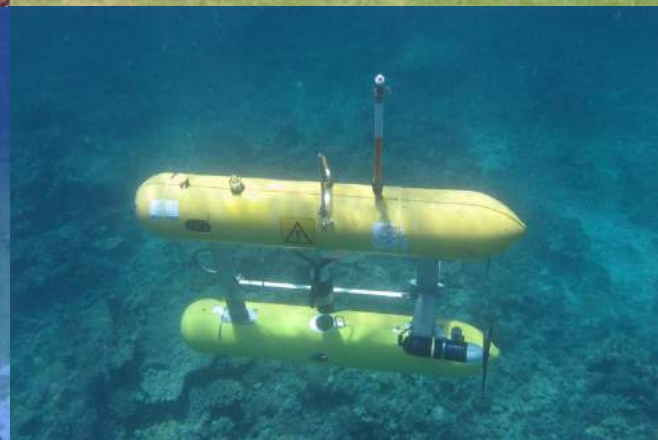


Defence

The University of Sydney
Faculty of Engineering

Engineering and Technology Innovation for Defence

THE UNIVERSITY OF SYDNEY

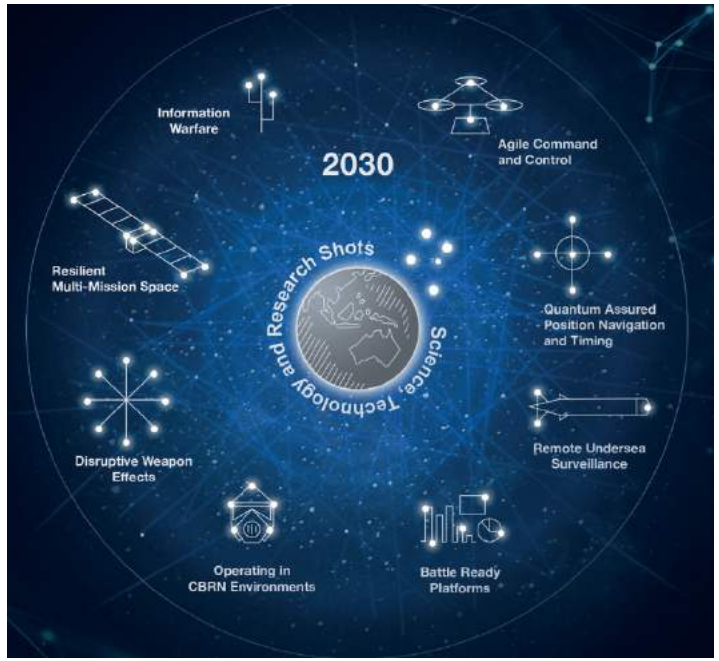


The Defence R&D Landscape

The Federal Government has the priority:

"Supporting business and academia to turn creative ideas into ground-breaking defence capabilities"[1]

Opportunity to contribute to the security of Australia, and leverage funding available to accelerate research programs which may have dual use



[1] Peter Tesch, Deputy Secretary Strategy, Policy and Industry

Our Current Engagement

Current portfolio includes $8.9m of research funding distributed across the Faculty

39 Academics with recent (last five years) funded research by Defence or with capabilities directly aligned with defence needs.

Advanced Sensors and Photonics
X. Yi, C. Jin, G. Brooker

Computer Engineering
P. Leong, D. Boland

Networks, Communications, Cyber
B. Vucetic, Y. Li, S. Seneviratne, K. Thilakarathna, L. Song, J. Davis, B. Scholtz, A. Zomaya

Robotics and Machine Learning
S. Williams, I. Manchester, G. Francis, F. Ramos, S. Cripps, H. Durrant-Whyte, V. Ila.

Computational Design and Engineering
B. Thornber, M.Cleary, D. Verstraete, L. Tong, G. Steven, G. Vio, K.C. Wong, C. Lei

Materials Design and Modelling
J. Cairney, S. Ringer, B. Uy, K. Rasmussen, G. Ranzi, A. Paradowska, A. Hadigheh, X. Liao

Medical Devices and Technology
A. Kyme, A. McEwan, O. Kavehei

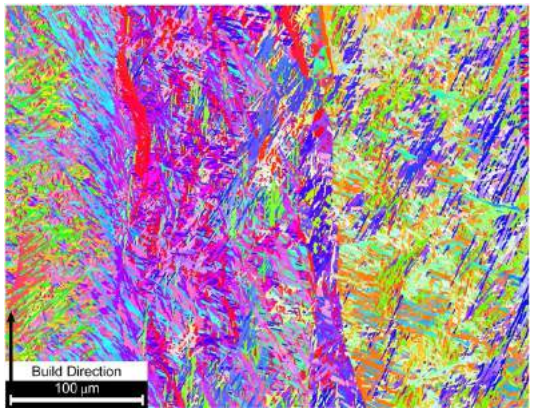
Our Vision for Defence Partnerships

Vision: Translate excellence in engineering research and training into strategic defence advantage for Australia and its allies

Align with the Starshots:

1. Remote Underwater Surveillance
2. Battle Ready Platforms
3. Information Warfare

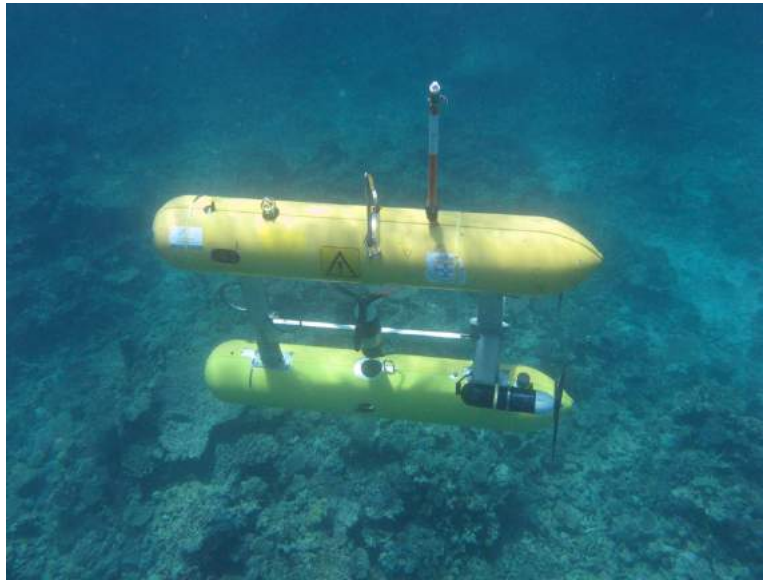
These are the first three focal points – but we are open to new foci



Three Core Mission-Focussed Areas

1. Remote Undersea Surveillance

"Our vision is for a future of pervasive underwater surveillance focused on monitoring and protecting Australia's marine estate. We envisage a network of acoustic receivers complemented by observations collected from remote sensing and in-situ assets, including crewed and un-crewed surface and submerged vessels, that are tightly integrated to provide situational assessment in the marine environment"



Three Core Mission-Focussed Areas

2. Battle Ready Platforms

"Science and technology innovation are needed to improve combat capability of the ADF using technologies which; enable increased scale by approaches such as reducing the number of crew required to deploy and support a system of platforms, and the acquisition and operating costs of platforms; to increase platform effectiveness; to increase ADF responsiveness, and to increase the resilience of platforms and assets in operation."

Three Core Mission-Focussed Areas

3. Information Warfare

"Our vision is to enhance Defence digital and information skills enabling the use of information as a deterrence and effect.

Our mission is to deliver capabilities to identify, predict, and mitigate diffused security risks through a cross-disciplined, multi-tiered approach within all information environments including (i)Physical layer: infrastructure and device-level, (ii) Network layer: communications, and (iii) Application layer: influence warfare at the users and social layer. "

Goals of the Defence Working Group

1. Fostering strategic readiness
2. Co-developing research programs
3. Partnering in government tenders
4. Boosting visibility in key networks
5. Aligning professional staff support

Specific targets for 2022:

- DIH submissions in our core themes
- ITRP *"Centre for Defence Digitisation"*

	Investment Phase	Value Range	Indicative Timeline	Technical Readiness Level
1	**Concept Exploration** *The focus of this phase is to explore your proposed innovation and demonstrate how it will be matured.*	$50k - $1m *Average $250K*	Contract delivery 2-12 months	TRL 1-3
2	**Technology Demonstration** *The focus of this phase is to demonstrate the concept, which may include analytical or laboratory studies and testing.*	$100k - $5m *Average $1.7m*	Contract delivery 1-3 years	TRL3-4
3	**Prototype System** *The focus of this phase is to develop a prototype in a system context with an increased focus on systems engineering principles.*	$300k - $8m *Average $2.8m*	Contract delivery 1-3 years	TRL5-6
4	**Integrated Capability Development** *The focus of this phase is to demonstrate the prototype in an integrated and relevant capability environment (e.g. in an aircraft, ship, network etc)*	$700K - $6m *Average $3.2m*	Contract delivery 1-4 years	TRL 6-8

Australian Government
Australian Research Council

Contact:

We are keen to boost membership of our working group. To get involved, contact A/Prof Ben Thornber:

ben.thornber@sydney.edu.au

THE UNIVERSITY OF SYDNEY

Digital Agriculture

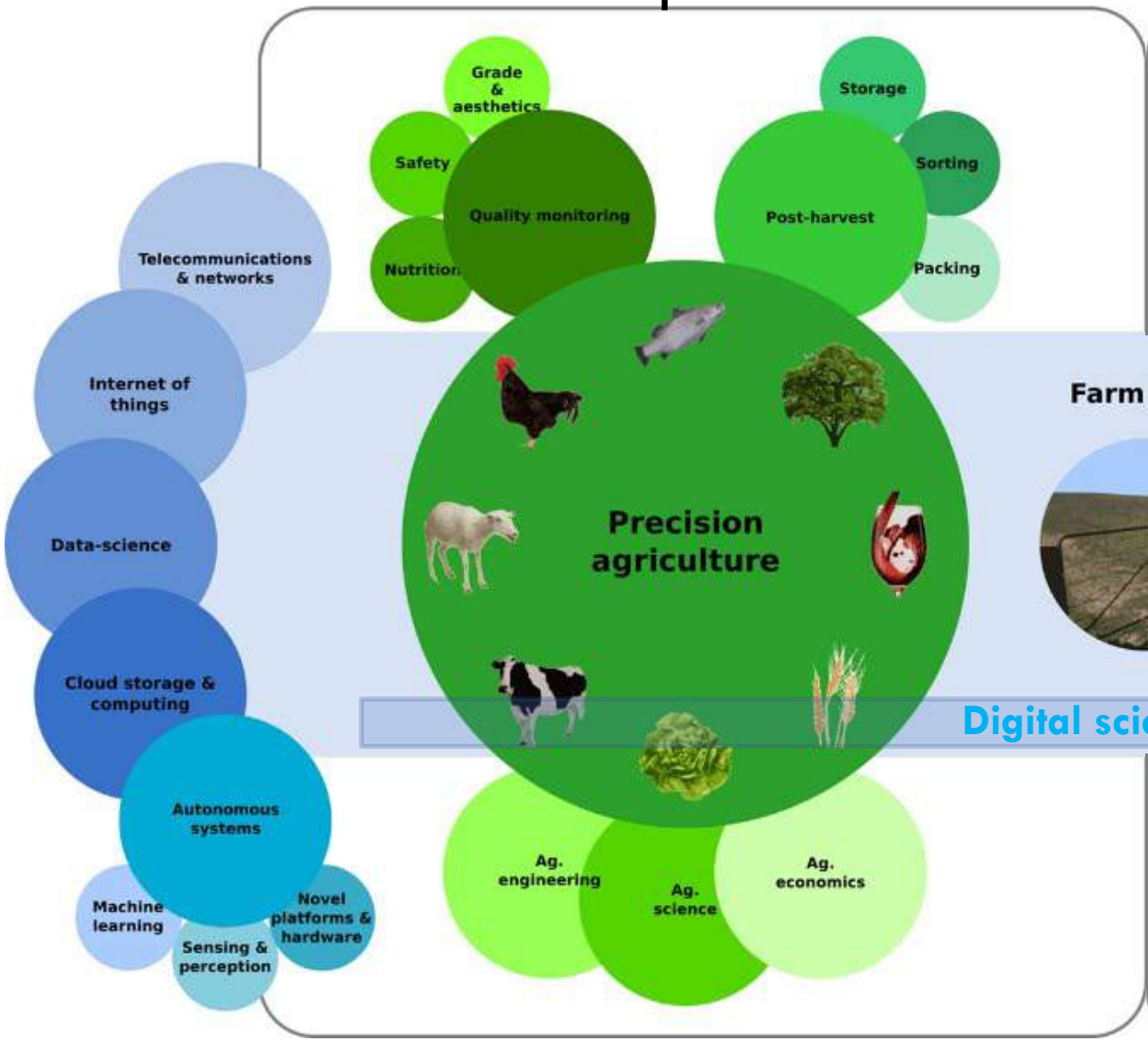
Digital Agriculture Mission

- Australian Centre for Field Robotics
- School of Biomedical Engineering
- School of Chemical and Biomolecular Engineering
- Sydney Institute of Agriculture

Digital Agriculture Mission

On-farm production

Processing, distribution and consumption



Outcomes from digitising

- produce products of high quality with known provenance and traceability that match consumer requirements.

Digital science opportunities across the whole supply chain

- increased profitability for the grower with minimal impact to the environment
- reduced risk and increased efficiency for other enterprises in the supply chain

AGRICULTURAL PRODUCT SUPPLY CHAIN

Digital Agriculture Mission

Current Research Target Areas

1. In-field sensing of soil properties

Employ novel chemical and physical measurement techniques using mechatronics and robotics to achieve field-deployed status.

2. Data fusion and modelling for improved production decisions

Utilise spatial and temporal digital data from diverse sources to improve decision making by exploring machine learning techniques to model and predict changes in important operational issues.

3. Improving supply chain operation and outcomes

Identify points in the supply chains where novel operational or product measurements would improve outcomes and also build processes to enable transmission of provenance and traceability information along the chains.

Digital Agriculture Mission

Soil Nitrogen/Phosphorus/Potassium (NPK) in-field sensing system

The Challenge

- The main nutrients of interest for determining fertiliser requirements are plant-available forms of Nitrogen (N), Phosphorus (P) and Potassium (K).
- Currently, physical sampling a small number of locations and off-farm lab analysis provides average available NPK values for a whole field or area.
- This leads to uniform application rates for fertilisers across a field or area.

Digital Agriculture Mission

Soil Nitrogen/Phosphorus/Potassium (NPK) in-field sensing system

The Challenge

- However, these macronutrients display significant within-field variability (CV=34%) and have a spatial autocorrelation range between 100m and 200m.
- This variability translates to spatial variability in actual fertiliser requirements.
- Observations would need to be at a sampling spacing of less than 100m to accurately describe the spatial variability.

Digital Agriculture Mission

Soil Nitrogen/Phosphorus/Potassium (NPK) in-field sensing system

The Solution

- Provide digital data on the spatial distribution of available NPK in the soil to calculate a spatial distribution in the requirement for synthetic fertiliser.
- This will improve nutrient use efficiency, optimise farm variable costs and profit, and minimise the potential for losses to the environment. (private & public gains)

The Action Plan

Develop a robotic system to locate and sample soil and prepare extractant

+

Develop/test novel methodologies to analyse NPK in extractant onboard robot

=

Autonomous analytical system capable of providing digital soil data at a fine spatial resolution

Digital Agriculture Mission

Soil Nitrogen/Phosphorus/Potassium (NPK) in-field sensing system

The Action Plan

Robotics

Agerris Digital Farm Hand

Potential Analytics

- Optical fibre-based spectroscopy
- UV-vis transmission spectroscopy
- LIBS & ICP-OES combined
- Capillary electrophoresis
- Electrical impedance spectroscopy
- Neutron activated gamma spectroscopy
- X-ray fluorescence spectroscopy

Digital Agriculture Mission

Soil Nitrogen/Phosphorus/Potassium (NPK) in-field sensing system

The Action Plan

Phase	Deliverables	Completion
Phase 0	• Completion of background research • User requirements gathering • Technical specifications presentation and approval	Aug 21

Phase 1	• Sampler Preliminary Design Review
	  • Evaluation of design concepts and preliminary system model in CAD
	  • Selected design with justification
	• First analysis hardware procurement (optical spectroscopy) & results of initial work for integration on DFH robot.
		Late Nov 21

Phase 2	• Sampler Critical Design Review
	  • Final CAD design and,
	  • Manufacturing plan
	• Other NPK analysis hardware procurement initiation
		Early Apr 22

Phase 3	• Procurement, fabrication and manufacturing of sampler hardware. • Integration with DFH robot for adaptive algorithm deployment * • System prototype assembly and testing in the lab • System field trials and final report(s)	Late Jun 22

Digital Agriculture Mission

Data fusion and modelling for improved production decisions

The Opportunities

Digital data from a variety of sources, modalities and volume are available for use in developing models for describing and predicting significant operational pathways and outcomes. Some areas of interest:

- Machine learning for modelling the relationship between crop and animal production metrics, the environment & agricultural inputs.
- Perception models designed to `understand' farm data such as recognising crop/weeds.
- Decision models for controlling soil moisture levels in irrigated farms.
- Probabilistic decision models for site-specific management of inputs (e.g. fertiliser and pesticides) to help optimise profitability and minimise variability in quality.

Digital Agriculture Mission

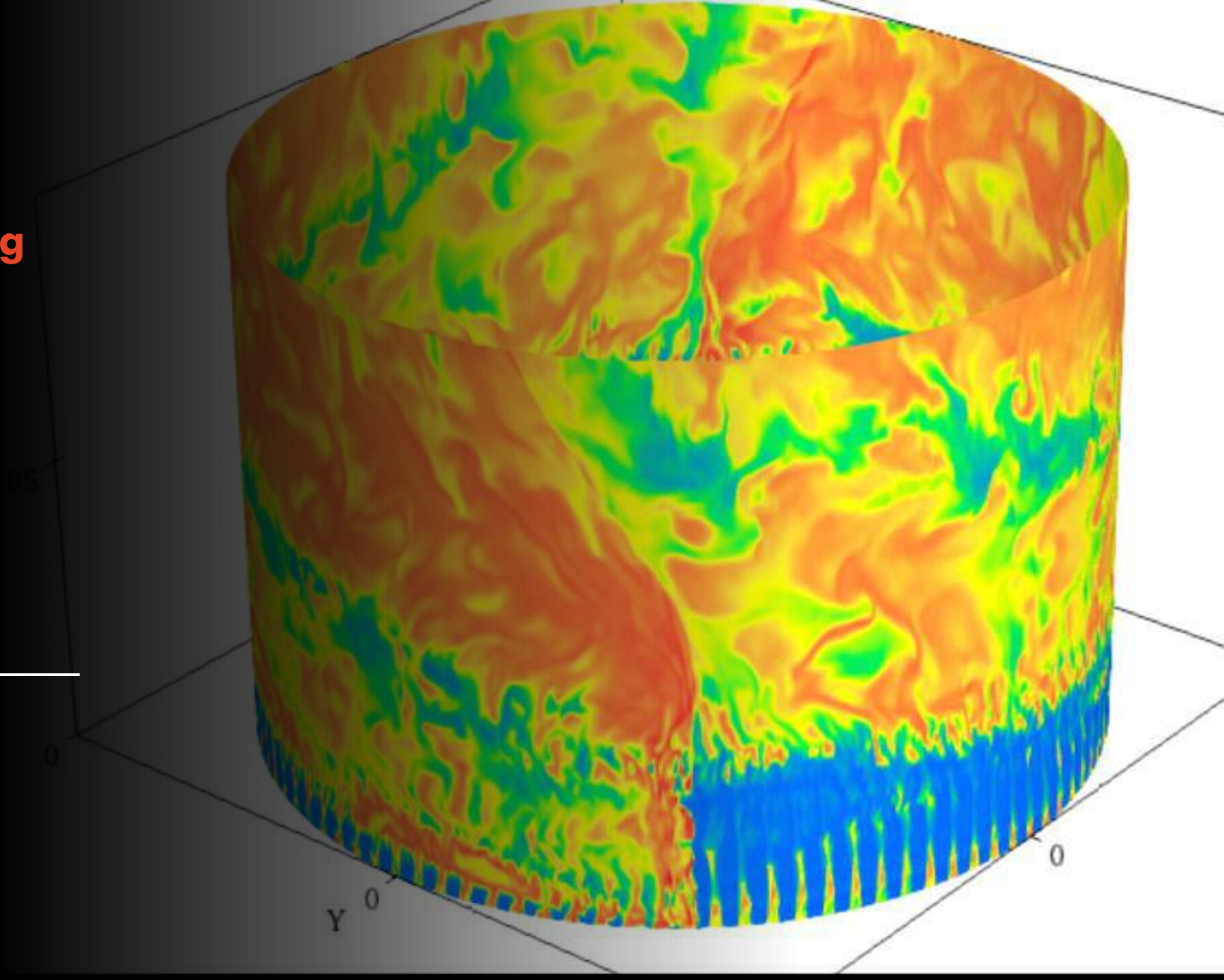
Funding Targets

- Ag machinery manufacturers
- Commodity Research & Development Bodies
- ARC Linkages
- ARC ITTC
- ARC ITRH

Data Centric Engineering

Data-Centric Engineering

Mission Update –
8th September 2021



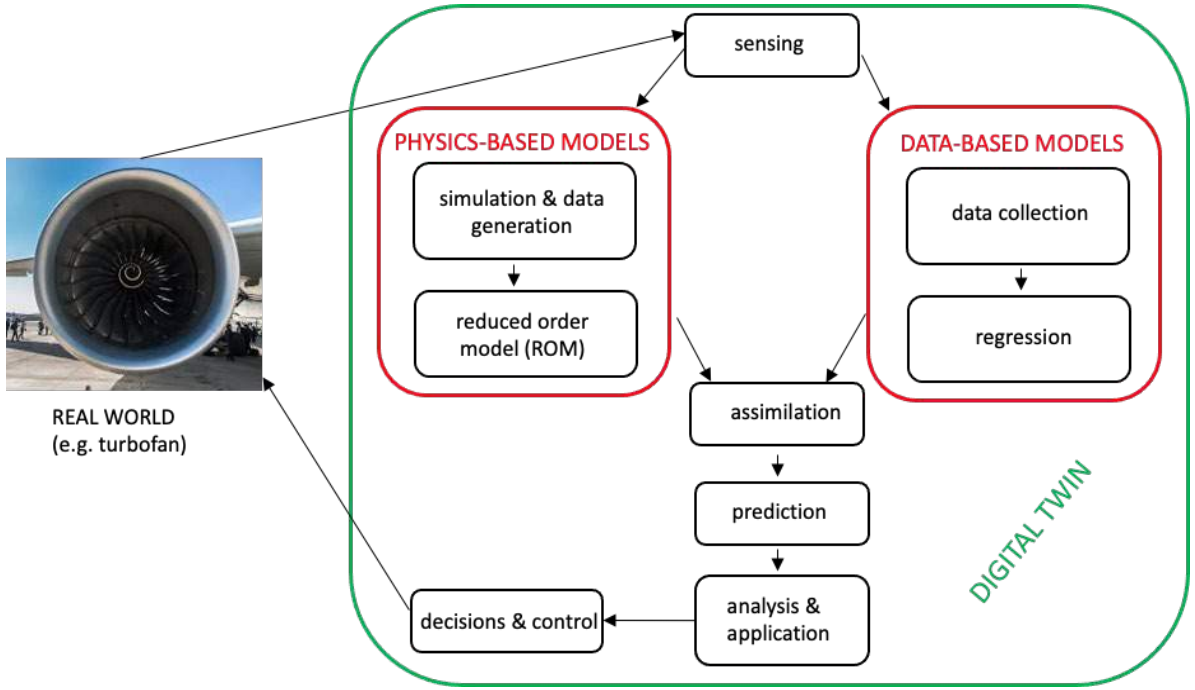
Outline

- What is Data-centric Engineering?
- Our Vision
- The Four Pillars
- Methods
- Website and Activities
- Partnerships
- Funding

What is data-centric engineering?

Data-centric Engineering is the integration of:

- probabilistic physical models
- sensing, data & diagnostics
- control & decision making
- high performance computing



The aim is to ultimately build Digital Twins of real-world systems that are capable of simulation, design, uncertainty prediction and real-time control.

Our Vision

We will develop and exploit the rapidly advancing fields of data-science, to establish deep synergies between physics-based simulation, data analysis, design and operational decision making for the betterment of industry and society

The Four Pillars

FLUIDS

Plumes:
- atmospheric pollutant dispersion
- cloud seeding and marine cloud brightening

Bushfires:
- autonomous aerial suppression

Energy & Propulsion:
- wind-turbines and aerodynamics
- combustion and engines

SOLIDS

Structures:
- steel frame reliability and performance assessment
- fault detection and prevention

Biofabrication:
- patient specific prothesis design for arterial stents, bone fixation plates and dental implants
- surgical planning involving patient-specific prosthesis

Astronomy:
- space telescope thermal, mechanical and optical modelling for planet detection

PARTICLES

Mineral processing:
- crushing and agglomeration processes
- development of a granular pressure sensor
- metallurgical furnaces and sintering

Drug delivery:
- optimised dry powder inhaler designs
- patient specific drug powder dosing

SYSTEMS

Climate:
- Global cirulation and biogeochemical modelling

Energy:
- energy networks
- virtual power plants

Our Methods

PROBABILISTIC PHYSICAL MODELS
(stochastic / deterministic)

SENSING, DATA & DIAGNOSTICS

CONTROL & DECISION MAKING

HIGH PERFORMANCE COMPUTING

Website & Activities

Home / Data-centric engineering

Data-centric engineering

A fusion of advanced physics-based computation with modern statistics and data science

Data-centric engineering integrates computational modelling of physical systems, statistical analysis and the rapidly growing field of data-science to build data-driven models of complex engineering systems, such as those involving fluid flow and combustion, electrical power networks, materials and structures, and chemical processes. It draws upon disparate fundamental streams of engineering and science such as finite element and finite volume methods for computational mechanics, and Bayesian statistics and probability theory to build Digital Twins of real-world systems capable of simulation, design, uncertainty prediction and real-time control.

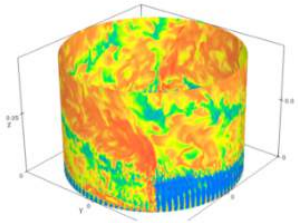


Figure 1: CFD predictions of temperature in a rotating detonation engine

We are a multidisciplinary group of researchers from across the University of Sydney and external organisations with combined experience in advanced materials, structures, electrical power systems, computational fluid dynamics, nuclear physics, statistics, optimisation, control, algorithms and software design. Our objective is to build unique capability – both in research and application – for developing and using data-driven engineering models of complex engineering systems.

- **Our Research** – fundamental developments in new statistical and computational methods that will underpin this field, providing reliable and robust methods that scale to real-world applications.
- **Global Partnerships** – develop strong research and development connections with other world-leading universities in this field.
- **Industry Engagement** – identify and partner with key industries, companies and public institutions for areas like health, infrastructure and defence with interest in data-driven engineering methods.
- **Entrepreneurial Outcomes** – our ambition is to be a world-leader in data-centric engineering, providing our industry, public and academic partners with state-of-the-art software, solutions and services.

Presentation slides

Stochastic probability density function (PDF) models for non-linear mechanics

Heterarchy - a multi-scale journey

Structural analysis and design - What we do, and what we could do

Digital Materials: design, optimisation and structure-function relationship

High speed aerodynamics

DCE meeting - Clément Canonne (Computer Science)

Tropical Climate Physics

Prosumeration of power supply

Phase retrieval and design with automatic differentiation

FSA: Co-designing future high performance systems for efficiency and scalability

Seminar replays

The statistical finite element method (statFEM)

Data-centric engineering programme - Prof Mark Girolami, The Alan Turing Institute

Partnerships

Australia's National Research Priorities

Advanced manufacturing

Environmental change and health

Cyber security

Soil and water

Transport

Food

Energy

Resources

Industry

Cardinal Health

Proveris

Ausgrid

Rio Tinto

DefendTex

Canon

DST

Allegra

Google

AGL

Reposit Power

WaterNSW

DoE

Corin Pty Ltd

Bureau of Meteorology

Great Barrier Reef Foundation

Waterdome Technologies

Energy Australia

University Sydney & Partners

Faculty of Engineering

CSIRO Data61

Faculty of Science

Cambridge Alan Turing Institute

ARC Hub in Intelligent Robotic Systems

ARC ITTC Data Analytics for Resources and Environments

ANSTO

Data-Centric Engineering

Funding

Year 2021

Faculty of Engineering seed funding

- Purpose – to demonstrate collaborations, generate joint publications, write external proposals
- 6 PhD students spread across some horizontal and vertical branches
- Postdoc (0.5FTE) to develop proposals
- Business development manager (0.2FTE) to develop industry links

Data61 Research Training Scheme (late 2021 application)

- Purpose – to establish strong engagement with select companies and demonstrate large scale collaboration
- 12 - 15 PhD students spread across most horizontal and vertical branches

Funding

Year 2022

ARC Industrial Transformation Training Centre / Research Hub

- Purpose – to expand industry engagement, to make the DCE group internationally known
- 20 PhD students spread across all horizontal and vertical branches
- 5 postdocs
- Need to develop collaboration with other universities and industry

Year 2024

ARC Centre of Excellence

- Purpose – Forging a new paradigm for engineering computation and data-driven digital twins.
- Fusion of statistical methods with physical models of fluids, solids, particles and systems.
- Applications including aerospace and structures, chemistry and materials, energy networks and medical devices.

Digital Health Imaging

Digital Health Imaging

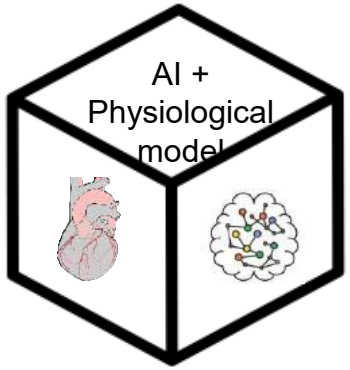
What

- Redefine healthcare through AI advances for medical imaging
- Promote the synergy of our strengths and leadership in AI and medical imaging
- Build strong relationship and trust with industry for truly impactful research

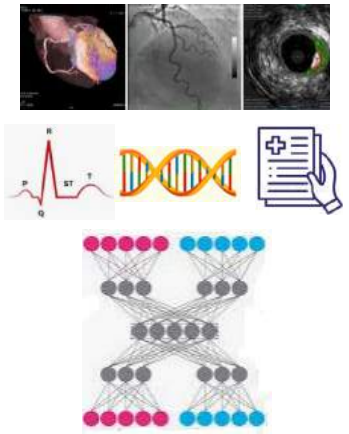
Who

Top-tiered scientists in AI, medical imaging, clinic research, and medical devices:
CS: J. Kim, T. Liu, A. Withana;
EIE: D. Xu, L. Zhou;
BME: F. Calamante, A. McEwan, R. Sullivan, A. Kyme;
BMC: M. Barnett, C. Wang;
Medicine: S. Lewis

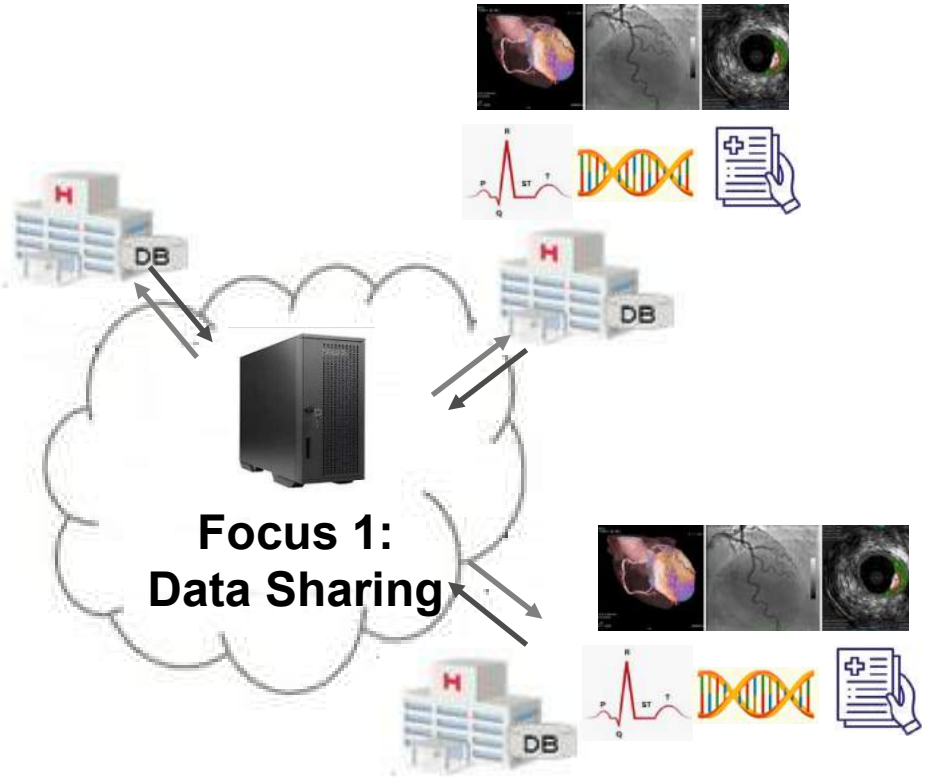
Three Focus Areas



Focus 3: Explanability



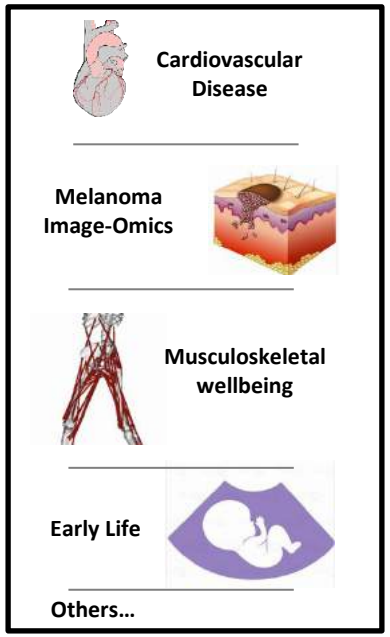
Focus 2: Multimodality



Focus 1: Data Sharing

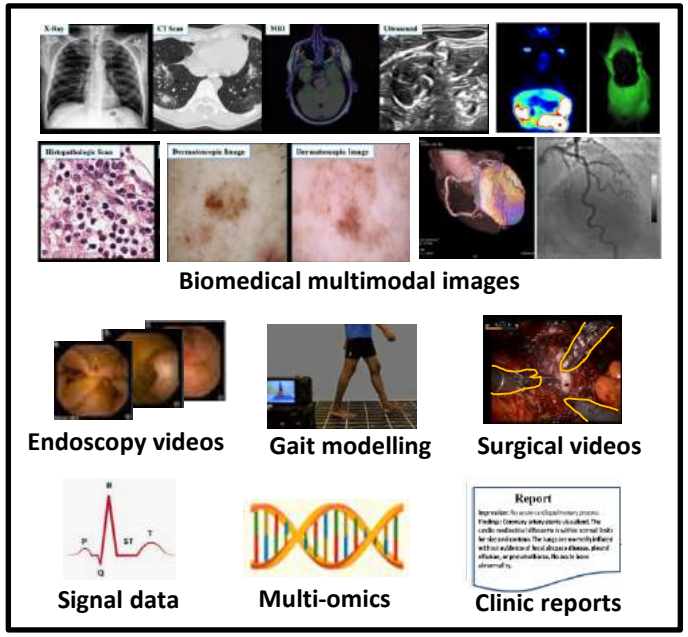
Biomedical Multimodal Learning (BML) for Digital Health Imaging

1 Medical Applications



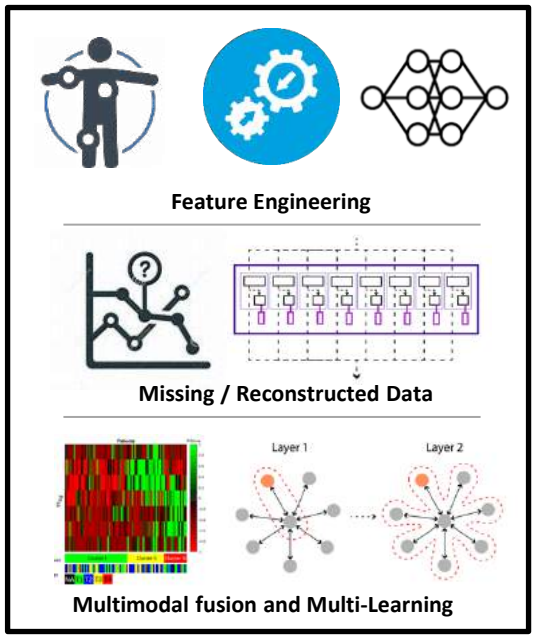
Medical applications that rely on **multimodal data for disease understanding, diagnosis surgery, and treatment**.

2 Multimodal Data



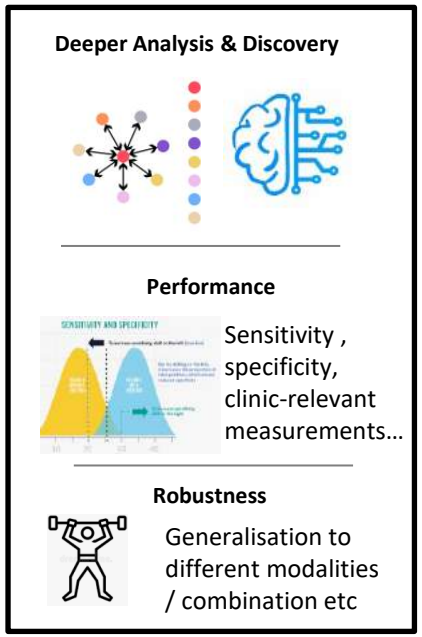
Rich array of complementary biomedical data that are **processed in siloes** and then later **combined / fused.** Imaging as the 'link' to all other data.

3 Biomedical Mutimodal Learning



Advancing **multimodal learning in the biomedical multimodal domain**, which introduces fresh and novel challenges.

4 BML Decision Support



Developing a suite of **Digital Tools for enhanced clinical Decision support.**

Expertise

- Computer Vision
- Multimodal data representation and fusion
- Image visualisation and navigation
- Biosensors and Materials
- Clinical implementation, evaluation & translation

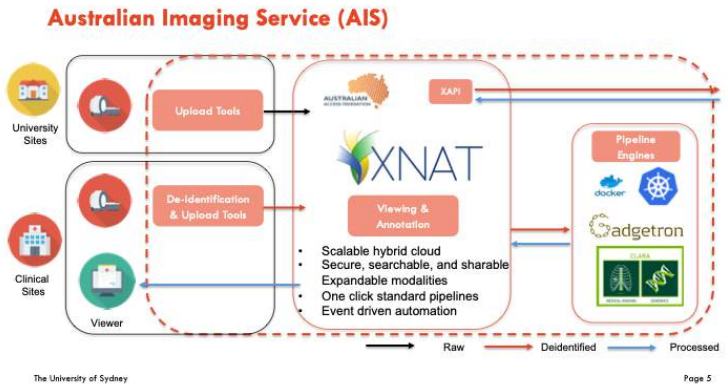
Research Development

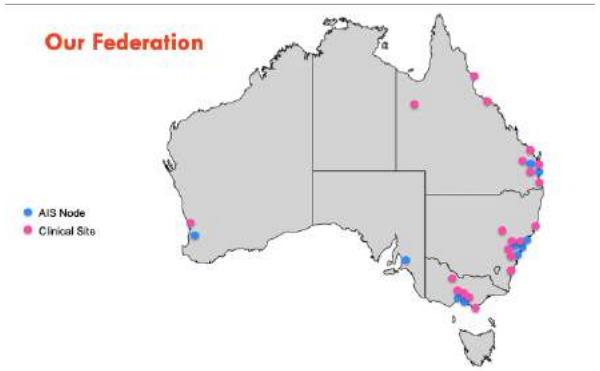
Phase 1 – Establish BML capacity and strength
Phase 2 – Identify partners with novel applications that need BML
Phase 3 – Refine and fine-tune components of the BML with partners
Phase 4 – Apply for funding and other opportunities

Imaging Data Sharing for Digital Health Imaging

Objective: Addressing **Data Privacy, Security, Validity and Logistic** concerns for medical imaging innovat

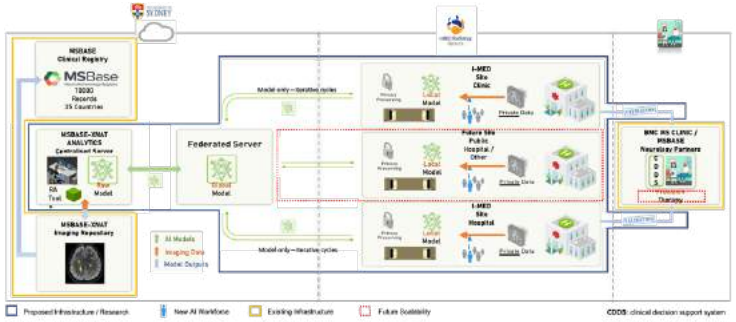
Scope A. Scale up leveraging existing USYD and partner infrastructure with broader applications and areas





Led by USYD, providing a mechanism for **national standardization of the management and analysis of imaging data** across 11+ academic institutions

MRFF- TRANSCEND



NVIDIA SNAC MSBase Neuro-Immunology Registry I-MED Radiology Network

… …

Focused with **federated learning** technologies and aimed for **multicentre clinical applications**.

Noise Labeling
Domain Adaptation/Transfer
…
Incremental Learning
Adaptive Learning

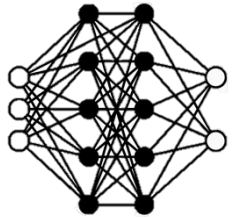
- Federated medical imaging nodes with XNAT repositories and GPU accelerated CLARA for ML.
- Federated Learning for imaging classification and segmentation at scale.
- Seamless clinical PACs/RIS integration CTP or TORANA portal for secure data transfer and query.

Imaging Data Sharing for Digital Health Imaging

Objective: Addressing **Data Privacy, Security, Validity and Logistic** concerns for medical imaging innovat

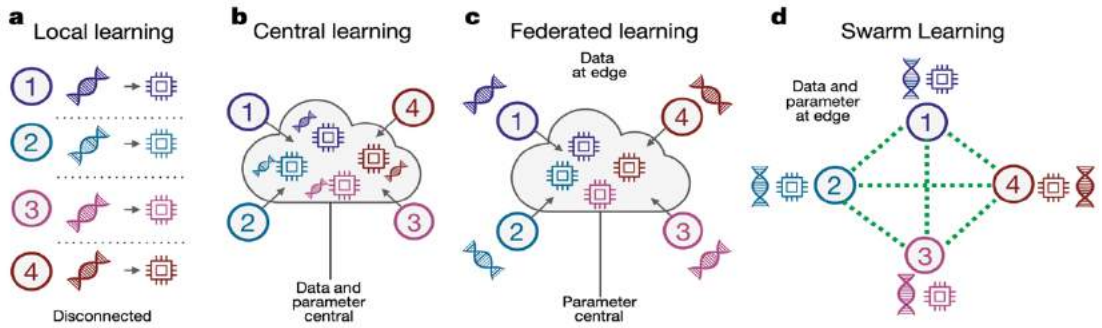
Scope B. Expansion of new research and development areas

- **Medical imaging AI with differential privacy**



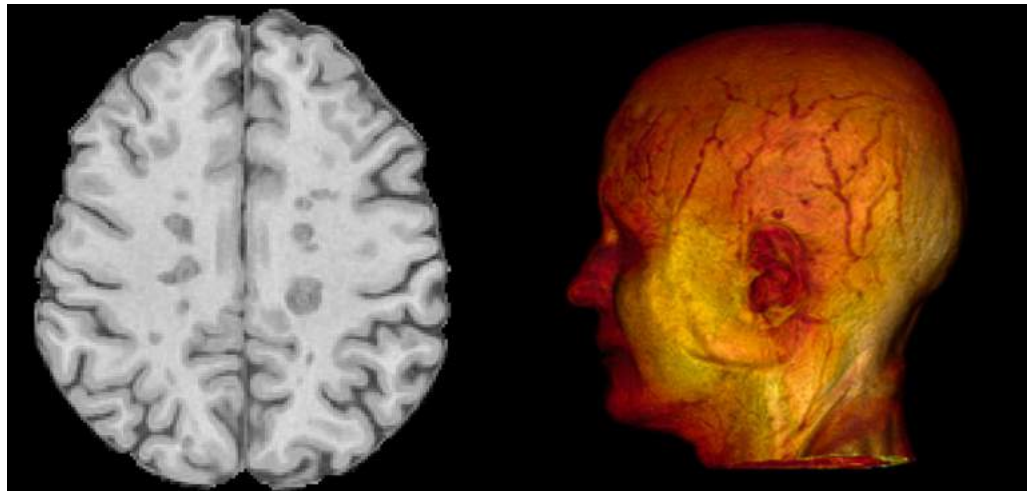
- **Model privacy in federated learning and other inferencing applications**

- **Swarm learning**



… …

- **Data content-based anonymization with deep learning**



Digital Central – Collaboration with UTS

Building Collaborations – Digital Central

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4.1. Data, Statistics and Machine Learning

- database systems
- organisation, storage and retrieval
- data models
- probabilistic algorithms
- statistical decision-making
- machine learning
- image analysis
- AI

4.2. Robotics and Cyber-Physical Systems

- sensing
- data fusion
- intelligent control autonomous systems
- automation
- humanmachine teaming
- Internet of Things
- edge computing photonics
- hardware design

4.3. Smart Cities

- Civil 4.0 and smart structures
- construction
- automation
- autonomous driving and intelligent transport
- smart grids
- enewable power generation and transmission
- electrical machines
- energy optimisation

4.4. Smart Societies

- Social data analytics
- sentiment analysis
- computational social systems
- multimedia
- visualisation
- natural language understanding
- digital media and digital arts
- digital inequality
- privacy and ethics of data and AI

4.5 Smart Defence

- Cybersecurity
- cyber defence
- UAVs
- SUVs for border defence
- data science and AI for foreign interference and trade monitoring
- food security
- information warfare
- quantum technology for defence
- quantum cryptography
- advanced human performance

EoI for Space in Tech Central

Current Working Groups

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