Supplementary Material

This document provides a summary of the information, including technical details, presented at the Particle Therapy Innovation Workshop, held at the Westmead Institute Medical Research facility on 28 November 2025.

Section 1 – Program

0900: Session 1: Welcome and opening remarks A/Prof Verity Ahern, Director Radiation Oncology Network, Western Sydney Local Health District, NSW.

0905: A vision for investing in research in NSW – Darren Saunders, NSW Dep. Chief Scientist & Engineer

0915: Addressing the national and regional gap: ANSTO's perspective – Dr Richard Garrett

0930 – 1030: Biological systems and particle physics

- Radiation Biology (clinical translation)
  - Cell death: Prof. Tony Cesare (CMRI)
  - Targeting Glioma with Precision Radiotherapy and Biochemical Dose Amplification: Dr Mitra Safaevi-Naeini (ANSTO), *virtual*
  - Spatially fractionated RT: Dr Leyla Moghaddasi (RNSH, NSW Health)
- Plant Science: Matthew Gillihan (ARC Centre for Excellence in Plants for Space, Adelaide), *virtual*
- Particle Physics: Prof. Kevin Varvell (University Sydney)

Q&A (10 mins)

1030 – 1045: Coffee break

1045 – 1200: Session 2: Space and detectors

Session Chair: Prof. Tom McGoram (ANU), *virtual*

Space

- Radiation Testing of Electronics for Space Missions: (Dr Jafar Shojaii (Macquarie Uni)

Novel detector development

- 30 years of CMRP research activities in particle therapy: Prof. Anatoly Rozenfeld (UOW)
- LETd verification using silicon microdosimeters: Prof. Anatoly Rozenfeld (UoW)

Q&A

1145 - 1235: Session 3: The technical platform

Session Chair: Prof. Annette Haworth (USyd)

Imaging (clinical translation)

- Biologically targeted Radiation Therapy (BiRT): Prof. Annette Haworth (USyd)
- MRI guided proton therapy (10 mins): Dr Brad Oborn (UoW)
- PET imaging in a particle therapy facility: a vision for the future: Chandrima Sengupta (USyd)

Accelerator science

- TURBO: A/Prof Suzie Sheehy (UMelb)

Q&A (10 mins)

1235 – 1315: Lunch

1315 – 1345: Session 4: Education and research

The Australian Nuclear Research and Education Network: Dr Ed Simpson (ANU) *virtual*

Training through research access: Ms Michelle Durante (AINSE)

1345 – 1515: Session 5: Physical requirements for the facility – international experience

Session Chair: Dr Richard Garrett (ANSTO)

- The MedAustron research room: Dr Dale Prokopovich
- Paul Scherrer Institute): Dr Martin Grossmann *virtual (pre-recorded)*
- CNAO: Dr Marco Pullia: *virtual*
- Room design and Facility requirements (40 mins)
    - 3-minute pitch: David Waddington; Mitra Safaevi-Naeini; Ed Simpson, Tony Cesare
    - Discussion

1515 – 1530: Coffee break

1530 – 1615: Session 6: Making the facility a success: access, sustainability and funding

Session Chair: Prof Tomas Kron (Peter MacCallum / UMelb)

Accessing ANSTO's national facilities: Dr Ceri Brenner (presented by Dr Mitra Safaevi-Naeini)

Heavy Ion Accelerators ANU: Prof. Tom McGoram *virtual*

Business models for university supported research infrastructure University of Sydney: Prof. Fernando Calamante

Panel discussion, Q&A

1615: Preparing the White Paper

Section 2 Presentation Details

Radiation Biology

The Translational Radiation Biology Group on the Westmead Precinct was established in 2018 and has become the national leader of research in this field, with international impact [1,2]. A major focus has been investigating (cancer) cell death in response to ablative radiation therapy, with emerging evidence that the repair of DNA double-strand breaks rather than the damage itself frequently drives lethality. Further, the repair pathway that is engaged shapes not only cell fate, but also its immunological consequences. This Group aims to expand their investigation of cell death in response to PBT, carbon ion and other ion therapy leading to a sophisticated understanding and implementation of personalised radiation therapy at a Hybrid Facility.

Neutron capture enhanced particle therapy ("NCEPT") enhances the effectiveness of particle therapy by combining the primary radiation beam (proton or carbon ion) with a neutron capture agent which selectively boosts the radiation dose to cancer cells while sparing damage to healthy tissues[3]. This technique was developed by a multi-disciplinary team at ANSTO, was awarded a A$1.6m grant from the Medical Research Future Fund in 2025 and is attracting international interest.

Spatially fractionated radiation therapy and FLASH (ultra-high dose rate) radiation therapy using proton and carbon ion beams are areas of active research internationally. Whilst Australian researchers have initiated FLASH research to treat brain cancers[4], further research is limited without access to protons which is the focus of international studies.

Biologically guided radiation therapy (BgRT) uses biological information about the tumour to inform how a tumour will respond to radiation – different tumour regions respond differently to radiation[5]. Australia-based research has demonstrated less aggressive parts of a tumour could receive less radiation dose resulting in fewer side effects of radiation, and more aggressive part of a tumour could receive higher doses of radiation to minimise the risk of tumour recurrence. Hypoxic tumours (those with a deficiency of oxygen in tumour cells) are highly resistant to the effects of radiation, requiring 2-3 times more radiation dose to eradicate hypoxic tumour cells than typically delivered in a typical therapeutic x-ray beam. Protons and carbon ions have the potential to safely deliver such high doses in contrast to conventional x-ray-based treatments.

While the Opal reactor at Lucas Heights produces a significant fraction of radionuclides such as Technetium-99M for medical imaging purposes, a Hybrid Facility with dedicated beamline could develop and produce new radioisotopes (such as Actinium^{225}, an alpha emitter) with additional applications in imaging and treatment, or drugs that contain novel isotopes. Translation of this research to routine production would require separate license radiochemistry infrastructure and be pursued through existing facilities and a dedicated business case. Nevertheless, there is an opportunity to build Australian capability in radiochemistry, add synergistic capacity to ANSTO and potentially generate a commercial income stream to support the facility.

Space biology

The ARC Centre of Excellence in Plants for Space (Adelaide) is an international research consortium building novel solutions for long term space habitation and on-Earth sustainability. The areas of research within this consortium and the research partners, illustrating the extensive collaborations that would develop at a Hybrid Facility are shown in Supplementary Appendix 1. The goal of the ARC Centre of Excellence in Plants for Space is to re-imagine plant design and bioresource production, through the lens of space. A particle accelerator generating high-energy proton and heavy-ion beams at a Hybrid Facility would approximate solar particle events and galactic cosmic rays allowing plant scientists to investigate:

- Mutation rates and repair mechanisms in space-like environments – seeds and vegetative tissue
- Plant-based biosensors – transgenics, DNA-damage responsive promoters, 'living dosimeters' inside habitats or greenhouses.
- Shielding, habitat design – material science for long-term protection

- Plant-microbe systems:
  - Impact of radiation on microbial consortia and impact on plant performance
  - Pathogen behaviour under radiation (a biosecurity consideration)

Cancer imaging

Confidence in radiation therapy delivery accuracy relies on image guidance for dose calculation accuracy, dose delivery accuracy and ability to reduce the amount of normal tissue surrounding the tissue that is irradiated. MRI-guided photon radiation is available at four centres in Australia and has only been available for clinical use around the world since 2014. The use of MRI-guided PBT is a compelling vision and remains in the commissioning phase at one research bunker in Dresden, Germany (OncoRay). A portable MRI on air-skates, 0.5 – 1.5 T with functional MRI (fMRI) potential and capable of imaging patients, animals or cells with either a horizontal beamline or pencil beam scanning delivery of PBT, would allow multiple areas of research at a Hybrid Facility. A new frontier would be to have a dedicated / isolated high field MRI where particle beams are directed down the bore of an MRI scanner.

PET imaging can measure physiologic and anatomic changes in a tumour at the time of radiation treatment enabling parts of a tumour that are responding less well to radiation to be targeted with a higher radiation dose. For carbon ion therapy, the PET detectors would detect C^{10} and C^{11} (β emitters). However, there remains much development work to make PET detection of these β emitters feasible for clinical adoption.

MRI and PET imaging are not routinely available in treatment rooms in PBT facilities abroad. Many Australian researchers are internationally recognised for their pioneering work in cancer imaging placing us in a strong position to lead cancer imaging for particle therapy research.

Particle physics

Particle physicists study the basic building blocks of matter and their interactions. The tools include particle colliders. Australia is involved with the Large Hadron Collider (LHC) at CERN in Switzerland via the ATLAS experiment. The LHC beam has a proton energy of 6.8TeV, nearly 13,000 times the energy of the proposed Hybrid Facility. Australians also have access to SuperKEKB at KEK in Japan, an electron-positron collider with a circumference of around 3km, generating 10 times the energy that can be generated from a Hybrid Facility. A Hybrid Facility in Australia with much lower energy beams would provide particle physics researchers with the ability to test novel particle detection systems and radiation hardness testing, as well as allow student training in preparation for work at CERN and SuperKEKB, effectively developing our workforce and maintaining international collaborations.

Radiation testing for space missions

Integrated Circuit Chips are compact electronic devices where thousands to billions of components such as transistors and resistors are built into a single semiconductor substrate to perform complex functions. For example, an ICC 1.4 x 1.6 mm designed at Macquarie University contained 3 million transistors. Cumulative radiation effects on ICCs result in transistor current loss, transistor threshold voltage change and leakage current increase through total ionizing dose effects and displacement damage. Radiation hardening of the ICCs is needed to mitigate these risks and can be achieved by process (development and improvements in ICC manufacturing processes and materials which required billions of dollars of investment) or design (using commercially available manufacturing

processes). While radiation testing (Single Event Effects Testing) can occur at the Centre for Accelerator Science at ANSTO and the Heavy
Ion Accelerator Facility at ANU, higher energy is needed. Only a handful of facilities with the required energy are available internationally with up to a 1-year waiting list, and cost of around A$2,000 per hour; each ICC needs 8 hours of testing.

Microdosimetry

The Centre for Medical Radiation Physics at the University of Wollongong first established a heavy ion particle therapy collaboration with Japanese colleagues in 2000 and began collaborating with colleagues at Massachusetts General in 1998. Since then, silicon microdosimetry (Silicon on insulator (SOI) Microdosimeter) has been invented and developed at CMRP to study the distribution of deposited energy in well-defined microscopic volumes, and to relate the type and amount of radiation to a biological event. Microdosimetry was endorsed for particle therapy application through ICRU Report 98 in 2024 and the SOI microdosimeter has been implemented in 12 particle therapy facilities. Eighteen PhDs have trained in particle therapy and microdosimetry through CMRP and conducted research in particle therapy facilities abroad.

Accelerator science

A synchrotron is an advanced particle accelerator required for multi-ion generation. Using synchronized electric and magnetic field to boost charged particles, treatment times are longer than conventional radiation therapy delivery as the beams take time to switch energy. The TURBO (Technology for Ultra-Rapid Beam Operation) programme at the University of Melbourne is investigating how to improve beam delivery time for particle therapy. A full-scale 'TURBO' beamline in a research hall in a Hybrid Facility could demonstrate an Australian-made technology for ultra-fast beam delivery, particle arc, motion tracking and more. Novel magnetic designs could also be developed and tested, potentially leading to more compact synchrotron designs[6]

Education and Research

A Hybrid Facility is more complex to construct and maintain than a proton only facility from the technical and other perspectives. However, Austria with a smaller population than Australia has been able to achieve this (Supplementary Appendix 2). MedAustron partnered with CERN and PSI for the procurement of accelerator components, construction of the accelerator facility and training of future operation personnel as there was no domain specific know-how in Austria at the time. A small number of Australians do have the knowledge and experience, including in technical, engineering and research scientist fields, to support a Hybrid Facility in a nationally collaborative effort and organisations exist to develop the workforce over time.

The Australian Institute of Nuclear Science and Engineering (AINSE) links ANSTO with 38 universities across Australia and New Zealand to support the research journey of students and early career researchers in nuclear science, engineering and related research fields and is ideally placed to add a HPTC to the national infrastructure that is accessed by university students. AINSE offers scholarships and events to around 500 students per year and 128 PhD students in 2025, as well as travel and accommodation support for researchers provided by ANSTO through merit-based access. The organisation has expertise in moving large numbers of students across Australia and New Zealand to access ANSTO facilities. These students and researchers are important vehicles to international collaborations. There are some similarities to HITRI*plus,* The European Heavy Ion Therapy Research Community funded from the European Union's Horizon 2020 research and innovation programme.

This programme provides 500 hours of transnational access to one of the four heavy ion centres in Europe and the accelerator facility at GSI, Germany.

The Australian Nuclear Research and Education Network (ANREN) is a self-organised group of Australia's limited nuclear academic expertise working together to increase nuclear literacy across the country to build collaborations in research and education, to uplift and meet the need for Australia's growing need for nuclear expertise. ANREN members are based at nine universities and have a diversity of expertise in foundational nuclear science, applied nuclear science, medical radiation science, nuclear engineering and interdisciplinary nuclear research such as mining engineering (Supplementary Appendix 3 2).

RADINNOVATE (Radiation Innovation Training Centre) has been established through funded by the Australian Research Council to train a new generation of researchers and leaders in nuclear science and radiation technology (2024 – 2029). It will run collaborative and co-designed research projects between three university partners and 15 industry partners across the key themes of defence and space, mining, critical minerals and waste, health and medical technology, quantum computing, and regulation.

Physical requirements of the facility

MedAustron, Paul Scherrer Institute (Switzerland, PBT only) and CNAO are three particle therapy facilities with active non-clinical research (NCR) programmes.

The **MedAustron** NCR infrastructure includes 9 laboratories, 3 storage rooms and 16 offices with 35 workstations. The dedicated room is 12 x 8m, dual-isocentric and can deliver research and clinical beams with flexible beam parameters such as high and low flux. The accelerator is able to operate in released non-clinical configurations as well as customised requested settings to maximise flexibility for researchers. The research programme for 2025 – 2028 has four fields, each with work packages, and there have been three previous successful 3-year research programmes starting in 2016Work package leads report to an Executive Committee monthly where shifts are allocated for the NCR, grant applications and publications are reviewed. The Executive Committee meets with an Advisory Board twice a year to recommend the NCR beam time usage applications.

The **Paul Scherrer Institute** PROSCAN is a clinical proton facility which included an experimental room when constructed 30 years ago. The experimental room is flexible for userspecific test arrangements and can automate irradiations.

NCR is one of three goals of **CNAO**, along with clinical and post-graduate education goals. The experimental room is accessible during treatment hours allowing experiments to be set up for many days. It allows multiple configurations and a customised dose delivery system. Scanning magnets and the monitoring system are installed on rails. A biological laboratory is available on site and small animal irradiation is possible due to a nearby animal house facility. A Boron Neutron Capture Therapy room will be available soon, as will He, Li, O and Fe ions. CNAO is undergoing an expansion and are currently designing a carbon ion super-conducting gantry in collaboration with CERN, MedAustron and Instituto Nazionale di Fisica Nucleare (INFN) – the EuorSIG (European Superconducting Ion Gantry) project.

A HPTC needs to support diverse researcher communities covering a broad portfolio that allows alignment with changing research priorities over many years, to constantly demonstrate value. While the core infrastructure may be fixed (the accelerator), more flexibility such as beam species and energies will permit support for more research. Research & development is mandatory to keep a large investment up to date and being able to make the system evolve requires being allowed to change it (subject to certifications).

Some specific requirements for a **non-clinical research hall** identified by workshop attendees are as follows:

- Large room size (at least twice the size of a treatment room) to accommodate:
  - diverse experiments at the same time, including those that require radiation exposures over a period of days, weeks or months,
  - diverse equipment including MRI (including low-field, portable MRI) and PET scan, as well as future proofing; appropriate magnetic shielding; space and access for portable, self-contained imaging systems; flexible positioning around irradiation setups.
  - additional beam lines over time,
  - Separation of sterile areas for cells, and non-sterile areas e.g., plant science where soil and microbiomes may be contaminants,
  - Capability to 'match' a clinical room, including aligned lasers.
- Sufficient radiation shielding of the room to allow researchers to work in the room during clinical hours when the beam is ON in other rooms, for example to set up equipment.
- Small size beam, spot scanning.
- Mechanism to vary oxygen concentration in the room as well as in-air capability for experiments.
- Medical gases (for anaesthesia of animals)
- Multiple tissue culture cabinets / hoods
- PC2 compatible for lentiviral transduction
- 4+ hypoxic tissue culture incubators
- Bench tops for cell harvesting.
- Water cooling / temperature control
- IT and remote access
- Temporary brick walls will allow multiple spaces, if the room is large enough, to create adaptability into the space.
- Crane within room to move equipment around.
- Control room for remote experiment monitoring, analysis
- Horizontal and vertical beams as well as a gantry.

Accelerator requirements to support non-clinical research.

- Accelerator capability
  - Diverse range of beams available over time, not immediately
  - Variable beam energy (not essential)
  - Low(er) energy beamline from a linear accelerator injector (potential to collaborate with ANU)
  - Responsive operation (start/stop beam; energy)
- Feasibility to adapt to accelerator developments
- Strong collaboration with other accelerator facilities

General facility requirements to support non-clinical research.

- Adjacent fully functioning, modern tissue culture laboratory – to avoid the need to move cells between facilities.
- A room capable of receiving cell cultures and animals for radiation, with the necessary infrastructure to hold samples (and equipment) that receive treatment – a 'cool down' room.

- Animal housing. Space for small and large animals to be 'housed' pre- and postirradiation, in transit to dedicated animal house on the Westmead Precinct
- Chairs, refrigeration, centrifuges (micro, tissue culture, cyto), cell counters, low magnification microscopes, basic fluorescence, shakers, heating blocks, pipettes, storage for plastics, consumables etc
- Live imagers – unless other microscopes are available on campus.
- Storage and preparation rooms
- Mechanical workshop
- Electronics laboratory
- Dosimetry laboratory
- Chemical laboratory
- Software laboratory
- Pre-clinical laboratory
- Ability to access out of hours
- Data storage, remote access

Facility governance

Clear lines of responsibility for and control over the accelerator, beamline and other infrastructure (vendor vs facility) are essential. This includes responsibility for operational and regulatory requirements, noting differences in the control systems for medical certification vs research (including live cells and animals) requirements.

The Facility will need access models that support diverse research communities, and users will need to be managed in different ways. Consideration must be given to what researchers and students will be allowed to do in the research room.

Sustainability and funding

The **MedAustron** NCR infrastructure involved significant investment for the construction and ongoing operating costs by Austrian authorities as well as recurrent investment by university collaborators. An NCR programme is organised into four fields, each with work packages. Work package leads report to an Executive Research Committee monthly where shifts are allocated for access to the research room and beamline, grant applications and publications are reviewed. The Executive Committee meets with an Advisory Board biannually to recommend beam time usage applications. **CNAO** was created by the Italian Ministry of Health in 2001 to introduce proton and carbon ion therapy in Italy; it is a not-for-profit private foundation. **The Paul Scherrer Institute** is funded primarily by the Swiss Confederation supplemented by third-party funding from European Union programmes, industry contracts, national grants and user fees. There is a defined allocation of research funding for material sciences, particle physics, nuclear energy and safety, general energy and life sciences.

The Office of the NSW Chief Scientist & Engineer (OCSE) developed a 20-year R&D Roadmap[6] which identifies four technology themes where NSW has international competitive advantages – Digital, Materials / Chemistry, Biotechnology and Energy. A Hybrid Facility would build capacity in many applications across the identified categories of competitive advantage (R&D, Education, Workforce, Industry, Innovation), including Simulation and training, Semiconductors, MedTech, Smart Materials and Nuclear Science. The support of the OSCE through establishment of collaborative research, innovation and commercialisation networks, exemplified by their support to develop the RNA Research & Manufacturing Facility at Macquarie University, is relevant to how the Westmead Precinct HPTC could be supported and established, including through workforce development.

ANSTO manages four major national facilities with thousands of users and experiments, that must stay scientifically competitive and financially defensible over decades. Three facilities are within the National Collaborative Research Infrastructure Strategy (NCRIS), and the Synchrotron has dedicated funding. The NCRIS Roadmap (to 2028) funds ANSTO for access to infrastructure, and step-change funding to uplift the baseline tied to new national capabilities. The Hybrid Facility is a potential new node in Australia's national research infrastructure system, receiving baseline funding (NCRIS) and relying on appropriate funds from government, co-investment and partners' capital. Stable, recurrent public funding will require demonstration and measurement of impact (national research outputs and industrial outcomes) which needs to be built into the establishment of the Facility.

Four access channels exist across ANSTO's infrastructure and are suggested as a model for the Hybrid Facility:
Merit access (60-70%): Proposals are scored 2-3 times per year via independent, competitive peer review on scientific quality, national benefit (the economic, health, environmental or social impact), team track record and the need for the facility. ANSTO acknowledgement is through publications, co-authorship, media. Commercial access (10-15%): This is deliberately capped, used in a disciplined way and priced below true market value. Its role is to provide a clear pathway for industry and clinical partners who need confidentiality or rapid turnaround. For example, the full cost recovery rate of accessing the Synchrotron is $1366 per hour of beamtime and around 10% of available beamtime is notionally reserved for commercial work. As a comparison, access to the Brookhaven National Laboratory, US Department of Energy, New York, costs around US$10,000 / hour.
Discretionary (5-10%) and internal (10-15%) access: Existing ANSTO facilities retain 1-8% discretionary time for urgent or high-impact work such as rapid response to an industry or defence need, long-term ANSTO-led programmes that maintain sovereign capability, multi-year projects where beamtime is pre-committed in grants or national programmes, pilot data to make a compelling grant proposal or critical experiments for a student thesis. Proposals are continuously accepted.

ANSTO recommended that donors (state government, hospital, university or philanthropic donor) of the Hybrid Facility or NCR hall are given a clearly defined share of beamtime for a finite period, whilst maintaining peer review of research and transparency, for example, 30% of available beamtime for 5 -8 years (with preferred access to lock-in co-investment).

ANSTO also advised that there needs to be a core specialised workforce funded as infrastructure to operate the research hall, manage proposals, safety, scheduling and reporting, including medical physicists, accelerator engineers / physicists, dosimetrists, detector engineers, data scientists, radiobiologists, beamline and instrument scientists who support users and run their own research programmes to keep the facility internationally competitive.

Heavy Ion Accelerators (HIA) has three nodes (Heavy Ion Accelerator Facility at ANU, Australian Ion Implantation Laboratory at ANU, and the University of Melbourne Experimental Condensed Matter Physics Accelerator Laboratory. HIA's access policy is consistent with NCRIS principles, viz. wide accessibility to researchers and industry and enhances participation of researchers in, and provides access to, the international research system. HIA is accessible to domestic and international research and industry users based on scientific merit (alignment with national science and research priorities, the NCRIS Roadmap and HIA's business strategy) and feasibility (can the user's proposal reasonably be carried out at HIA facilities? Is there sufficient beamtime +/- support personnel available?). Prices range from $3,000 - $12,000 / 16hour day of beamtime, noting that the actual cost of running a facility is around $50,000 / day. Pricing considers whether access is assisted or unassisted, publicly or privately funded research, small or large enterprise. In-kind support can be provided for new/untested capabilities or high benefit to HIA. Access costs are factored into research grant applications. The facilities operate 24 hours / day and manage around 300 users / year. The access model is for users to be present at the laboratory so hard problems can be solved together, building knowledge and collaborations. The success of the HAI nodes is due to long-term vision and sustained funding by the Australian Commonwealth Department of Education as National Research Infrastructure (NRI) for infrastructure and technical workforce. This funding comes with performance metrics including uniqueness of infrastructure, the volume and variety of users, the impact on research and industry (fundamental science and research translation – commercialisation, support to policy and good public decision-making and governance), and collaboration with other NCRIS infrastructures so that users work between facilities seamlessly. Another factor in sustainability has been the university environment, particularly fundamental physics that drives innovation and evolution of technical capabilities, keeps facilities internationally competitive and builds and strengthens international collaborations. The university provides co-located capabilities such as quantum scientists, laser physicists, earth scientists, and a PhD student community helps build international connections. The technical workforce and mechanical workshops are essential for sustaining and improving the accelerators beyond original design, building unique and world-class instrumentation, and providing flexibility to meet new user requirement. Retaining the technical staff.

Sydney Imaging Facility receives some NCRIS funding as a node of the National Imaging Facility, representing a minor component of funding. Some recommendations for making the Hybrid Facility sustainable were as follows:

- Research sustainability:
  - Open access model for researchers
  - Research infrastructure excellence depends on the equipment, staff and processes. ○ Develop meaningful partnerships, with win-wins ○ Create a model for pilot funding for new research ideas
  - Interdisciplinary partnerships and international collaborations are important
- Funding models.
  - A detailed and realistic business case is imperative. ○ Capital expenses and not operating expenses can be provided by universities and the Australian Research Council Linkage Infrastructure, Equipment and Facilities (ARC LIEF) scheme.
  - Co-investment is important. NCRIS, NSW government, philanthropy and industry can provide both capex and opex.
  - Capitalising service contracts for the first 5-year period (building some opex into the capex) is useful, although planning for ongoing funding when contracts end needs to be built into the business case.
  - Research grant applications, such as MRFF, should include a nominal financial component to access the Facility.

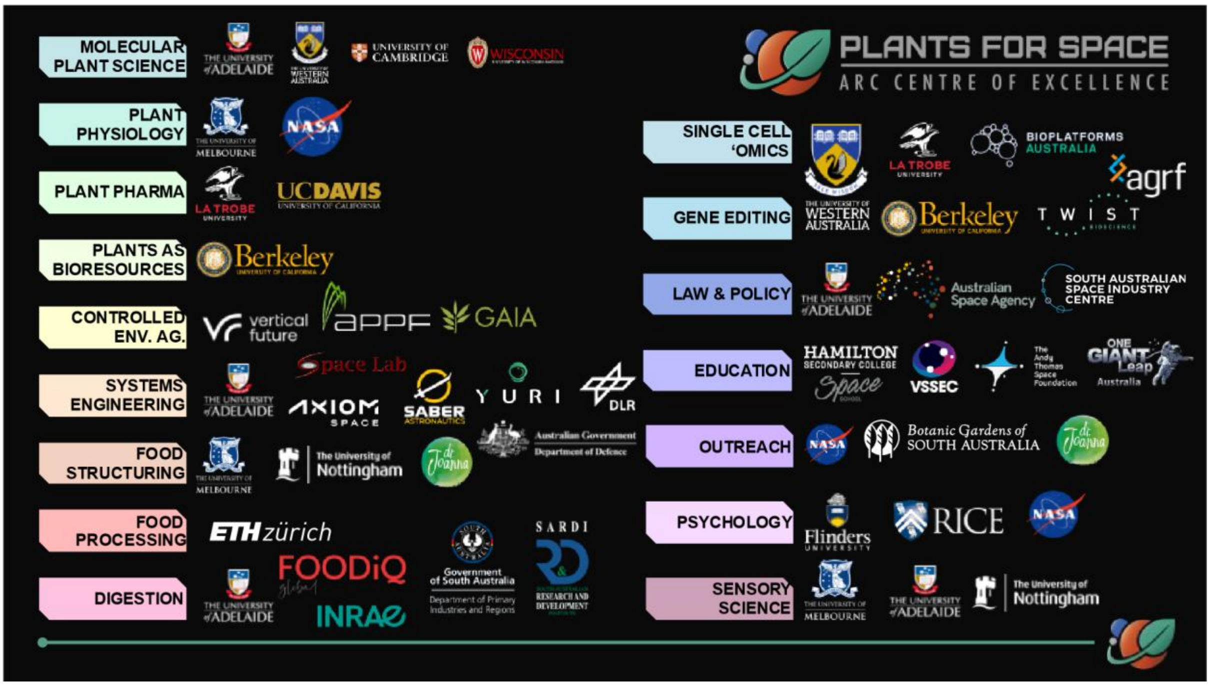
References

1. Homologous recombination promotes non-immunogenic mitotic cell death upon DNA damage. Nat Cell Biol 27,59-72 (2025). https://doi.org/10.1038/s41556-024-01557-x.
2. DNA-repair-driven cell death compels us to rethink cancer therapies. Szmyd R, Gee, H, Cesare A. Nat Rev Mol Cell Biol 26:643-644(2025). https://doi.org/10.1038/s41580-02500879-4.
3. Neutron capture enhanced particle therapy (NCEPT) | ANSTO

4. https://charlieteofoundation.org.au/research-grants/treating-gbm-in-aflash/#:~:text=His%20research%20focuses%20on%20understanding,cellular%20responses%20to%20radiation%20therapy.
5. https://birt.sydney.edu.au
6. Current and future synchrotron designs for carbon ion therapy. AIP Conference Proceedings, March 2021. DOI:10.1063/5.004781

Supplementary Appendix 1.

Partners in the ARC Centre of Excellence in Plants for Space consortium and fields of research.



Supplementary Appendix 2.

Worldwide multi-ion facilities in operation compared to national population.

Facility	Country	Population	Facility / population
MedAustron	Austria	9.1 m	1 / 9.1 m
HIMC, Hyogo, Gunma, SAGAHIMAT, i-ROCK, Osaka, Yamagata	Japan	122.6 m	1 / 17.5 m
Taipei	Taiwan	23.1 m	1 / 23.1 m
Heidelberg, Marburg	Germany	84.7 m	1 / 44.3 m
Yonsei	South Korea	51.8 m	1 / 51.8 m
CNAO	Italy	58.7 m	1 / 58.7 m
Shanghai, WuWei, Lanzhou, Hanghou	China	1.425 b	1 / 475 m

Supplementary Appendix 3.

ANREN members and areas of expertise

Foundational nuclear science	Applied nuclear science	Medical radiation science	Nuclear engineering	Interdisciplinary nuclear research
Nuclear structure	Dosimetry	Radiation biology	Computational materials	Safety critical systems design / AI integration
Nuclear fission	Nuclear medicine	Particle therapy	Nuclear incident modelling	Human and organisational factors
Nuclear reactions	Radiation protection	Theranostic medical physics	Nuclear materials	Social licence
Hadron physics	Radiation transport	Boron neutron capture therapy medical Physics	Nuclear reactor kinetics	Radiation Medicine
Quantum chromodynamics	Radionuclide development	Particle therapy medical physics	Radiation damage	Mining Engineering
Nuclear astrophysics	Single atom detection	Medicinal chemistry	Reactor control systems	
	Radiation detection	Space medicine	Waste management	
		Medical physics	Nuclear fuel cycle	