Please note: the substantive content of the 2026 NRI Roadmap Survey begins at Question 20 (with prior questions dealing with administrative and other information).

As such all submissions that are published include the responses submitted from Question 20 onwards only.

Q20.

Part 2: Research themes

2.1 NRI comprises the assets, facilities and associated expertise to support leading-edge research and innovation in Australia and is accessible to publicly and privately funded users across Australia and internationally. We are seeking your input on possible directions for future national-level investment - i.e., where the requirements are of such scale and importance that national-level collaboration and coordination are essential.

The 2021 Roadmap used a challenge framework to support NRI planning and investment. With this in mind, consider likely future research trends in the next 5 - 10 years, and with respect to one or more of the 8 challenge areas identified in the 2021 Roadmap as listed below:

- describe emerging research directions and the associated critical research infrastructure requirements that are either not currently available at all, or not at sufficient scale and
- describe current national infrastructure requirements that you anticipate will no longer fit the definition of NRI in 5-10 years.

Do not limit your commentary to NCRIS funded capabilities.

Q21.

Resources Technology and Critical Minerals Processing

While there are many flow phenomena that required specialist facilities to study with regard to resources technology, here we focus on two: the decarbonisation of iron and steel making, and the generation and use of green hydrogen as a fuel for energy generation. Iron production is a carbon-intensive industry for two reasons: the fuel consumed to heat the typical Blast Oxygen Furnace; the use of coke, produced from metallurgical coal, as a reduction agent. The primary product of both combustion (using coal or natural gas) and iron reduction with coke, is carbon dioxide. Hydrogen has the capacity to replace both carbon sources. It can be used as a fuel to raise the temperature for smelting as well as a reducing agent. In both cases, rather than carbon dioxide, the primary product is water. In the long term, this has the capacity to almost eliminate carbon dioxide production from iron making. Research is required into how these processes can be delivered at scale, i.e., how to design burners to operate efficiently and safely using hydrogen, and how to design furnaces to use gaseous hydrogen as their reducing agent. Both involve a number of fluid mechanics processes: from the generation of aerosol of fuel, the control and routing of exhaust, the control of flame and chemical reaction fronts are just some. Shorter term, the capture and storage or re-use of carbon dioxide will need to play a role in the decarbonisation of steel making and heavy industry. The improvement of “scrubbing” of flue gas, and separation, capture, processing and storage of carbon dioxide need specialist measurement capabilities for research into solutions that can be successfully applied at industrial scale. Existing gas turbines cannot be simply switched over to hydrogen (or derivatives such as ammonia) due to hydrogen’s much lower molecular weight and energy density, the challenges of hydrogen storage at cryogenic temperatures, and its volatile combustion properties. Gas turbines (and similarly, jet engines) operate at extreme temperatures and consist of a complicated set of very rapidly rotating internal blades and fins. Specialist facilities are required to attempt to experiment with, and measure, such complicated flows. Another route to study such systems is via computer simulation – however, the complicated physics and large scale of turbines makes this an “extreme scale” computational task, with existing simulation techniques using models of the order of petabytes in size. Computational facilities dedicated to fluid mechanics are required for this with should include • dedicated hardware that can handle the extreme scale computation required • dedicated software for the simulation of fluid flows with complex physics • software engineers for the development of this software, and technical staff for the maintenance and operation of the facility • a mechanism by which the facility can be accessed by all Australian fluids researchers and industry.

Q22.
Food and Beverage

The facilities for research into the measurement and manipulation of fluid flows that are relevant to the food and beverage industry are covered in our responses to other sections of this survey. We highlight the fundamental importance of fluid mechanics in this area from primary production, to transport, the safe and efficient processing and packaging.

Q23.
Medical Products

The understanding and control of flows of biological fluids will underpin the development of medical technology in the next 5-10 years. Biological and biomedical flows are typically small scale. For example, the human airway has vessels ranging from 1-2cm across, down to micron. A similar range is seen in the vasculature. Further, the geometries that these flows occur in are necessarily complex and tortuous. Measurement and modelling that can capture this is essential if medical products that improve on existing treatments are to be developed. The range of fluid flows that dictate the design of medical products include respiration, blood flow, lymphatic pumping, the digestive tract and the transport of neurotransmitters. Measurement capacity that can deal with the complex geometries and potentially complex fluids, either in models or in vivo need to be in place to drive innovation in this area. X-rays and micro-CT for flow measurement would be of immediate benefit to the medical products R&D industry. We note existing facilities that would interact with those dedicated to flow measurement: the ANFF, Microscopy Australia, and the National Imaging Facility. A dedicated fluids research facility would interface with these, quickly boosting the effectiveness of this existing infrastructure. As suggested in other responses, computational facilities that can simulate these flows are important. However a major, almost immediate use of computing would be the processing of large data sets generated by imaging such as MRI, CT and x-ray that can be employed for flow measurement and characterization and therefore R&D into medical products. A measurement and computational facility that can be accesses by all Australian fluids researchers can also ensure the rapid uptake of techniques from other areas to the development of “medtech” and the translation of fundamental fluid mechanics and fluid physics into this domain.

Q24.
Defence

Australia needs to be in a position to manage its own defence. Our global isolation, and associated large coastline, means air and sea defence is crucial. The development, construction and maintenance of our air defence requires testing facilities across a range of flow speeds and device sizes ranging from “low and small” (i.e, drones, micro air vehicles and unmanned air vehicles) to “extremely high and large” (i.e., jets and rockets at super- and hyper-sonic speeds – there is a clear cross-over here with the development required for Space, to which we respond in the relevant section). An excellent example of the kind of Australian innovation possible is the development of the MQ-28A Ghost Bat (Loyal Wingman) unmanned autonomous aircraft. The acceleration of innovation in air defence requires • existing wind tunnel facilities to be coordinated and supported with ongoing technical staff and flow measurement capacity that can be accessed by Australian researchers and the defence industry • new facilities to ensure the breadth of scales present in the fluid phenomena of air defence applications – from “low and small” to “extremely high and large” – can all be modelled, measured and analysed. We note the existing specialist facilities that exist in Australia, including the supersonic capacity of tunnels at UNSW Canberra, the University of Sydney, and DST, and the super- and hyper-sonic capacity of the shock tubes at University of Queensland and facilities at the University of Southern Queensland. Upgrading and supporting these facilities with cutting edge flow measurement and diagnostic equipment and expertise should be a focus for an almost-immediate boost to our National Research Infrastructure capacity. Maritime defence requires facilities that can test equipment at a range of flow speeds, wave conditions and depths. An immediate example application is research into underwater detection, or seen from the other side, vessel masking. The presence of acoustic signatures, formation of bubbles, and even the generation of gravity waves that occur in stratified fluids (such as salt water) need to be measured, calculated and assessed. Again we note existing facilities for maritime research including those of DST, UWA, the Australian Maritime College and the Australian Submarine Agency. These need to be coordinated, and provisioned with the latest measurement equipment. New facilities are required for deep water testing to allow stratified flows and underwater acoustics to be studied.

Q25.

Recycling and Clean Energy

Clean energy in Australia will be based on the use of renewable sources. Here we comment on current technology that needs infrastructure to boost, and emerging technologies that need research investment to move to scale. The most immediate sources that are already deployed at scale are PV solar and wind turbines. Offshore wind turbine development will need to play a large role due to Australia’s energy generation, due to a population concentrated near coastlines and the capacity to access uninterrupted winds on the ocean and less restrictions on the size of turbines compared to those onshore. There are multiple fluid mechanics challenges with the installation of these turbines. The obvious challenge is the aerodynamics – how to design turbines that extract the most energy from a given wind for the least cost. There are multiple “sub challenges” in this: blade design for optimum power; robust design to ensure operation if blade shape is not optimal due to damage (from sources as varied as direct impact to lightning strikes); control of flow-induced vibrations of blade and tower; and wind farm optimisation (i.e., how to position turbines relative to each other to maximise power capture). On top of this there are hydrodynamic challenges: seabed mounted turbine pylons face: wave loading; forces from vortex-induced vibration; scour and removal of the seabed due to induced currents; even the control of the noise generated during their installation. Floating turbines have to be stabilise ever-increasing-height turbines in dynamic currents and wave conditions. Emerging technology that can add significant baseload is ocean wave power which the National Marine Energy Atlas produced by CSIRO indicates could foreseeably provide 11% of Australia’s total power by 2050. Wave energy machines are typically large (10-100m) to operate successfully in long swell waves, and facilities are required to develop prototypes at close to full scale to drive this industry. We do not currently have wind tunnels in Australia even approaching the scale required to study turbine-turbine interaction, or the deep-water testing facilities required to properly investigate many of the hydrodynamic problems associated with pylons and ocean wave power. There are a number of wind tunnel facilities in Australia – notable facilities are those of the DST, University of Melbourne, UNSW RMIT and Adelaide University. Existing hydro facilities include those at the Australian Maritime College at UTAS, the Water Research Laboratory at UNSW and facilities at UWA. However, larger facilities – particularly very large scale wave basins to study arrays or farms of ocean wave power machines - and a nationally coordinated effort to make existing and new facilities accessible to all of Australia’s R&D community (including industry) are required. As highlighted in other sections: computing resources to simulate these phenomena, and to process the extremely large data sets generated, are required

Q26.

Space

Much of the infrastructure required for research and development of space technology is similar to that which we have already highlighted for defence. However, we highlight the need for coordinated infrastructure around supersonic and hypersonic research, both in terms of physical facilities and computational capacity. This spans launch (rockets) and re-entry vehicles, as well as space vehicle control in open space and in thin-atmosphere environments such as Mars.

Q27.

Environment and Climate

Weather and climate modelling is inherently based in fluid mechanics, with models predicting the motion of air and water in the oceans. With respect to research infrastructure, the dedicated fluid mechanics computing facilities outlined in our other responses would certainly benefit Australia's meteorological research. While we have current excellent expertise, a large portion of our climate and ocean modelling relies on capacity from overseas, including the MET in the UK. Dedicated facilities with ongoing technical staff could move this model development onshore. A further benefit from common facilities accessible to a range of fluids researchers would be the cross-over between disciplines. Meteorology has a long tradition of developing and applying data science techniques such as data assimilation (using experimental or field measurements to improve computer models), machine learning and large-scale data decomposition, and methods of modelling complex systems. Australia's fluid mechanics and thermal sciences communities are also applying these data-driven techniques in a range of flow situations. Aligning these communities could see the progress made in both fields brought together to innovate both.

Q28.

Frontier Technologies and Modern Manufacturing

We have commented in "Resources Technology and Critical Minerals Processing" on the importance and requirement for coordinated flow measurement capacity in the production of iron and steel. We note here that other manufacturing requires this measurement capacity. Additive manufacturing requires fluid flows regardless of the technique employed. These are often at small scale (the formation of liquid or molten material in droplets, filaments or beads) and their configuration has a direct outcome on the quality of the final part. The manufacture of microelectronics, especially those which are flexible (wearable tech, embedded sensors, etc) is completely reliant of microfluidics for precision placement of their components. Having measurement equipment that can capture this (high-speed video, laser diagnostics, x-ray based techniques including CT) is required. Carbon fibre and other composite material manufacture will underpin almost all of the research challenges outlined here. Resin injection, permeation of fibre, a curing in large autoclaves and ovens are fluid-flow processes that are still poorly understood due to the small scale and complex geometry of the flows of resin involved – and their control dictates the quality of the eventual formed part. Having dedicated experimental facilities where these flows can be measured and improved, ad computational facilities and expertise that can be used to model them should be prioritized.

Q29.

2.2 The 2024 statement of National Science and Research Priorities (NSRPs) includes outcomes linked to each priority to assist in identifying critical research needed in the next 5 to 10 years.

Consider the priority statements and, with respect to one or more of the 5 priority areas as listed below:

- describe emerging research directions and the associated critical research infrastructure requirements that are either not currently available at all, or
- not at sufficient scale and describe current national infrastructure requirements that you anticipate will no longer fit the definition of NRI in 5-10 years.

Do not limit your commentary to NCRIS funded capabilities, and where relevant, refer to the underpinning outcomes and research identified in the NSRPs document.

Q30.

Transitioning to a net zero future

We have covered a number of points relevant here in our response to the "Recycling and Clean Energy" challenge section. To reiterate our main points: • Large-scale aerodynamic facilities are required to boost Australia's capacity to use wind energy • Large-scale hydrodynamic facilities are required to boost capacity of existing offshore wind power, and emerging technologies in ocean wave power • Facilities for advanced flow measurement in complex reacting and combusting flows is required for the development of energy production from cleaner fuels such as hydrogen and its derivatives. • Dedicated computational facilities are required for the simulation of these systems, as well as the processing of the extreme data sets generated during measurement of fluid flows in large scale energy systems.

Q31.

Supporting healthy and thriving communities

We have commented in the "Medical Products" response on the importance of dedicated flow measurement capacity that can deal with complex geometries and complex fluids. To reiterate our main points: • Dedicated measurement facilities are required that can interface with micro and nano-fabrication facilities, microscopy, and medical imaging to be able to analyse biological and biomedical flows that need to be manipulated for medical products to improve patient treatment • Dedicated computational facilities are required for the simulation of these systems, as well as the processing of the extreme data sets generated during measurement of fluid flows in biomedical and biological systems.

Q32.

Elevating Aboriginal and Torres Strait Islanders knowledge systems

While the AFMS is not suggesting the addition of infrastructure of facilities directly targeting Aboriginal and Torres Strait Islanders knowledge system, we acknowledge the extremely long history of fluid mechanics practice by Australia's first people. The fish traps at Brewarrina constructed by the Ngemba Wayilwan people on the Barwon river are attested to be the oldest human construction in the world. The Budj Bim eel traps around lake Condah, constructed by the Gunditjmara people by cutting channels through the solid rock formed by the lava flow from a previous eruption of Budj Bim volcano, have been dated to be at least 6000 years old. Both constructions show a history of sophisticated water management and hydrological engineering. The seafaring capacity of Torres Strait Islanders, and the coastal Aboriginal nations, is an obvious manipulation of fluid mechanics (of both air and water when sailing). Sophisticated smoke signalling also features prominently, with experienced practitioners able to produce different colours and densities of smoke, as well as being able to manipulate the flow generated to produce swirling, or vortex-dominated, flows rotating in different directions. This manipulation provides a large range of symbols that can be built up to convey information, and requires an intuitive grasp of aerodynamics. Infrastructure for research into fluid flows can certainly contribute to an understanding, appreciation and incorporation of Aboriginal and Torres Strait Islander knowledge systems in Australian society discourse.

Q33.

Protecting and restoring Australia's environment

The facilities that we have proposed throughout this response would benefit Australia's environment by • Having dedicated computational facilities and ongoing staff with relevant expertise such that more weather and climate models can be developed onshore. • Facilitating knowledge transfer across the fluid mechanics R&D communities, ensuring innovation propagates • Accelerating research into and the development of clean energy technologies through access to dedicated experimental and computational facilities that can model systems at a scale that is applicable in the field, and to process the data generated by measurement of these systems.

Q34.

Building a secure and resilient nation

We have addressed a number of points in our response to the "Defence" challenge above. To reiterate: • Coordination of existing aerodynamic testing facilities is required, as is the addition of new facilities, to ensure Australia has the sovereign capacity for R&D into air defence systems spanning "slow and small" (e.g., drones, micro and unmanned air vehicles) to "extremely fast and large" (e.g., super- and hyper-sonic flight). • Similar coordination of hydrodynamic facilities including those in deep water for R&D into underwater detection via acoustic signature, bubble formation, wave generation, etc. • Dedicated computational facilities for the simulation and data processing of measurements of these systems. Regarding a resilient nation: the facilities we have proposed are required will boost national capacity in a number of critical areas making Australia less reliant on international trade. They will increase sovereign capacity and de-risk many of our supply chains.

Q35.

2.3 The case for a new NRI capability, or enhancements to existing capabilities, typically emerges through advocacy from research communities clustering around rigorously identified needs and goals. Such a concept could respond to a requirement for novel or expanded capacity within a domain, or across domains, and must be such that it could only be made available with national-level investment.
If you have identified such a requirement, briefly describe the need, the proposed infrastructure capability, the medium-term goals, impacted research communities, and the timeframe over which you advocate its establishment. Your response can include links to relevant existing reports.

Fluid mechanics – the science and engineering of fluids in motion or at rest, whether they are gases, liquids, slurries, granules or mixtures of these – is crucial to address all major challenges faced by society in the 21st century. The energy transition via an intensification of wind, solar, pumped hydro and wave resources, and the production, storage and use of alternative liquid/gaseous fuels like hydrogen, will only be possible with a large and coordinated national research effort. Bio- and med-tech advances, Australia's vast coastal and marine natural resources, prediction and modelling of weather and climate change and its mitigation, our air- and sea-based defence, and the development of a self-sufficient space industry, all rely on the understanding and manipulation of fluid flows. The Australasian Fluid Mechanics Society (AFMS), representing the fluid and thermal science research and practitioner community in Australia (and New Zealand) commissioned and published a report "Riding the Wave: the value of Fluid Mechanics to Australasia" in Dec 2024 (see: https://www.afms.org.au/docs/AFMS_Riding_the_Wave.pdf). It outlines the importance to the current economy of fluid mechanics to Australasia, providing an estimate of a contribution of $34B/year to the economy. Much of this current contribution comes from major drivers of Australia's current economy – oil and gas (28.3%), and resource engineering (15.4%). Oil and gas may reduce as a proportion of fuel use in the future, but the importance of petrochemicals will certainly remain crucial, and the efficiency of oil and gas extraction and processing with be paramount. Mineral resources will continue to be a pillar of the Australian economy, and this industry needs rapid and coordinated research on fluid flow phenomena (extraction, transport, separation, etc.) to decarbonise at the rate required for Australia to meet its net zero by 2050 ambition. We propose this research must be done in Australia, with the joint support of Australian government and industry. This joint effort must be underpinned by large-scale and dedicated facilities in aero- and hydro-dynamics. While smaller, two other industries stand out as areas where fluid mechanics is already making a significant economic contribution in the AFMS report – life science and pharmaceutical diagnostics (4.2%) and renewable power (6.8%). These two industries are at the forefront of critical challenges facing Australia in the coming 5-10 years. New, dedicated facilities including fluid flow measurement and diagnostic equipment is required to boost both of these burgeoning areas domestically. We propose that Australia desperately needs • (1 – 2 years) A consortium or similar, bringing together the various aero- and hydro-dynamics facilities across the country to drastically boost the capacity of domestic industry to develop and innovate in the fluids space. The primary impacted research communities are those in aerodynamics, aerospace, hydrodynamics, wind engineering, transport, and defence. • (3 – 5 years) The consortium to be supported by the establishment of new, large-scale experimental air and water testing facilities – e.g., wind tunnels, deep water facilities, and wave flumes. • (3 – 5 years) The supplementation of large-scale facilities with cutting-edge measurement and diagnostic equipment that can be deployed at a range of scales, to measure and image flows from atmospheric, to sea- and air-craft, to sub-mm biological flows, to micro- and nano-scale fluidics. The research and development communities impacted by this would be vast; as well as those suggested above, fluids-based research across scales could be boosted and this underpins a huge number of fields which include: aerospace, mechanical and civil engineering; marine and atmospheric science; weather and climate; biomedical, physiological and biological science; advanced manufacturing. • (3 – 5 years) Dedicated high-performance computational facilities for fluid mechanics research incorporating flow simulation, advanced data science for the analysis of the huge spatially- and temporally-varying data sets generated by experimental flow measurement and simulation, and associated data and flow visualisation. These facilities need associated software – with the technical and human resources for software development - and technical staff available on an on-going basis. This would benefit all the research communities previously suggested, as well as those in data science and computational mechanics. The major capabilities that this infrastructure would add are • Physical and computational modelling and measurement of flows at a scale required to study air flows ranging in speeds from almost zero (e.g., urban wind environments) to hypersonic (e.g., space re-entry and defence applications) • The study of water flows of large scale and depth • The measurement, simulation and processing of data from flows in complex geometries and of complex fluids such as those encountered in biomedical and food processing applications. • A knowledge transfer between current fluid researchers across fields via collaboration on dedicated and centrally funded equipment • A rapid development of education and training in advanced measurement and computational techniques to provide the human capital required by Australian industry to boost sovereign capacity. A primary motivation for this infrastructure is to rapidly increase the capacity of Australian industry by • providing the base of world-leading facilities for conducting fluid based research locally • providing ready access to Australia's excellent expertise in fluid mechanics that is not currently adequately leveraged. The aforementioned AFMS report states most fluid mechanics research in Australia is currently funded via public sources such as the ARC; we propose the focussed and dedicated facilities suggested here would instead attract significant industry investment in R&D.

Q36.

Part 3: Industry perspectives

This section is seeking input specifically from industry-based respondents. Other respondents can skip this section.

Recommendation 6 of the [2021 Roadmap] related to improvements in industry engagement with NRI. To complement work on this topic that has occurred since then, we are seeking additional advice on NRI requirements as perceived by current or potential industry-based users.

Q37.

3.1 Have you (or your organisation) interreacted with or used Australia's NRI?

○ Yes

○ No

Q38.

3.2 If so, please briefly outline the NRI capabilities you (or your organisation) have interacted with or used. Do not limit your response to NCRIS capabilities.

This question was not displayed to the respondent.

Q39.

3.3 Please indicate your (one or more) primary reasons for interacting with NRI:

This question was not displayed to the respondent.

Q40.

3.4 If you answered no, please indicate your (one or more) primary reasons:

This question was not displayed to the respondent.

Q41.

Part 4: Other comments

4.1 Please elaborate on any of your above responses or add any other comments relevant to the development of the 2026 Roadmap. Your response can include reference or links to existing reports that you recommend be considered during the 2026 Roadmap development process.

Please consider the report from the Australasian Fluid Mechanics Society, "Riding the wave: the value of fluid mechanics to Australasia" published in December 2024 and available at https://www.afms.org.au/docs/AFMS_Riding_the_Wave.pdf