WG 2.2 REPORT

Working Group 2.2 National and University Facilities

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EXECUTIVE SUMMARY

To a large and increasing extent, the research ambitions of the Australian astronomical community are outward-focused on large international collaborations at the megascience scale, e.g. through involvement in SKAO, ESO, and LIGO. Such projects offer a critical contribution to keeping our national community competitive on the world stage. Our contributions to these international projects rests upon a long history of excellence at the national level.

The critical expertise developed through and for onshore facilities gives Australia strong leadership at the international level. Moreover there are also scientific, technical and educational needs that cannot be effectively realised by international collaborations alone. Thus it is of vital importance that we maintain the strongest and most impactful parts of our national and university facility landscape in the coming decade, in order to preserve and strengthen Australian leadership in advancing global astronomy, science and technology.

The recommendations of Working Group 2.2 National and University Facilities are based on input collected from the broader community in the following ways: 1) via the surveys conducted by Working Group 3.1 Demographics, Society, and Workforce both individually and institutionally, 2) via community input submitted directly to us, 3) via facility input submitted directly to us, 4) via input raised at the WG 2.2 online town halls, 5) via input raised at the in-person town halls and 6) via WG 2.2 membership contributions. We present these recommendations as well as a summary of the contributions received across these various categories, and we include as appendices the submissions where relevant.

We also include in our report a discussion and reflection on 1) the evolution of community priorities in the context of WG 2.2 as compared with the report from the Decadal Plan 2016-2025 inputs, and 2) a consideration of the large-scale trends that have emerged during this process as relevant and important in the context of WG 2.2.

Overall, we find the projected role of national and university facilities in the coming decade is one that emphasises complementarity, distinctiveness, innovative agility and community development - critical needs of the national astronomy landscape that cannot (and will not) otherwise be met.

KEY RECOMMENDATIONS OF WG 2.2

Recognising that: 1) Allocation of resources to universities and other organisations hosting significant astronomy infrastructure comes from a broad array of sources, and 2) university and national-scale facilities support the community in a very broad range of contexts, from enabling the science priorities to facilitating in-kind access to larger international projects to training, education, and outreach; the recommendations of this working group will necessarily be heterogeneous and some will be general principles.

Recommendations

1. **Prioritisation of resources and funding** towards current and proposed national and university facilities which occupy different parameter space compared to international facilities and contribute to key science priorities for the Australian community. These will play a critical complementary role to the megascience ambitions of the Australian astronomy community, directly and indirectly (e.g., as proof of concept/trial runs/capability demonstrators). Specifically (and of equal priority in terms of being raised here):
    a. Support for the substantial role filled by the suite of Australia Telescope National Facility instruments in delivering high-impact science with capabilities unique in the southern hemisphere, including wide-field survey, large single dish, rapid-response, imaging at centimetre wavelengths, and VLBI.
    b. Allocated funding to enable continued astronomy-led operations of the AAT until the completion of high-priority science surveys by 2030, to allow for an orderly transition from AAT operations to full membership of ESO.
    c. Continued support for the Murchison Widefield Array, as the direct path to Australia's participation in the low-frequency Square Kilometre Array (SKA-Low) telescope under construction in Western Australia, until the SKA is operational. The MWA establishes and supports the low radio frequency community that will transition to the SKA-Low and leverage Australia's massive investment into the SKA project.
    d. Fund the design and development of an Australian gravitational wave pathfinder to lay the foundations to future construction and operation of a full next-generation southern hemisphere gravitational wave detector hosted by Australia.

2. **Improved coordination and collaboration** amongst the broad and diverse suite of national and university facilities across Australia for better visibility of these facilities within the community. This could be, e.g., via the formation of a network under a coordinating body, potentially with considerations of financial coordination and tangible connections to international and space facilities, data/computing facilities and/or instrumentation.

3. **Provide access to unique capabilities** that complement international facilities and support the community's wider needs. Although they provide unprecedented opportunities, mega-scale facilities such as SKA/ESO/LIGO cannot deliver everything required to advance our understanding. National and university facilities that provide complementary and additive capabilities should be prioritised. These facilities will increase Australia's impact and multiply our benefit from participating in international projects.
   a. Examples of such capabilities include: ASKAP's wide field of view and autonomous operations, world-leading surveys being completed by the AAT, frequency range and rapid-response of ATCA, the fully-automated ANU 2.3m telescope, Murriyang for technology development and demonstration in addition to single dish support for future radio interferometric surveys, the MWA as Australia's low-frequency SKA precursor, the Long Baseline Array southern-hemisphere VLBI capability and the University of Tasmania geodetic VLBI network

4. **Preservation of technical capability and agility** within the national and university facility landscape to enable continuation of the rapid and experimental innovation that is inherent to these facilities, achievable through continued and sustainable funding of technology development. It is critical that we maintain these key technical competencies which Australia has leveraged into membership in the major projects at the frontline of the science priorities, which require cash and skills beyond the level of any individual nation. This requires the existence of onshore facilities as stepping stones between the <$1M level and the >$100M level.

5. **Maintenance and extension of time-critical follow-up and multi-messenger capability,** recognising that in rapid response time domain explorations or joint multi-wavelength campaigns, geographic distribution is the critical component. As such, there must always be sufficient Australian capability at multiple wavelengths to follow up quickly on targets initially alerted by major facilities to the east - in particular, facilities located in Chile,

such as the Rubin Observatory. Similarly for multi-wavelength joint campaigns, Australia's longitude in the Southern Hemisphere presents great opportunities for it to operate and host many radio/IR/optical facilities to link with worldwide programs.

6. **Improved data access ecosystem** for current and future facilities that is fundamentally integrated into the facility operational workflow and ensures legacy access to science data products beyond the lifetime of the facility. This includes considering what, if any, long-term archiving of both the data and the software to reduce and analyse said data should occur as part of the shutdown.

7. **Improved opportunities for education and training** of students and early-career researchers via national and university facilities, both in terms of fundamental capabilities and with a future-proofed view to the evolving future of astronomy research.
    a. Coordinated and impact-driven efforts into optimising the form of these education and training opportunities, determining what form they might take, e.g. hands-on training, instrumentation opportunities, technical internships, observing/data reduction schools or other forms.

8. **Improved working conditions** for facility-associated staff who contribute to ongoing facility operations and delivery of science data to the community, e.g. via tenure and better job stability to avoid losing this critical expertise.

9. **Preservation of fundamental research capabilities** within the national and university suite of facilities, alongside exploration of opportunities for alternative funding models and collaborations external to the astronomy community.

10. **Preservation of dark and quiet skies** as part of a broader coordinated global effort, in collaboration with governing bodies such as the International Astronomical Union and the International Telecommunication Union.

11. **Future-proofing of facility operations** to adapt to the cumulative and ongoing evolution of technology (including digital transformation, automation, artificial intelligence, distributed work and mixed reality) climate/environment, university funding, best practice for engagement with Traditional Owners and the need for future capabilities and instrumentation as driven by community science goals

Questions for community consideration

1. Are the current NCRIS and Linkage schemes serving their purpose? Are the funds sufficient in both total amount and the individual amounts to support the needs of Australian astronomy at the national/university level?
2. Once a capability is lost, it becomes incredibly hard to get it back again (both infrastructure and skilled workforce). Can the community achieve its megascience ambitions without diverting so many resources from the broader community that key traits of a healthy research environment are lost?

TIMELINE OF WG 2.2 ACTIVITIES

DATE	DESCRIPTION
29/02/2024	Initial meeting and discussions within WG 2.2 membership
13/05/2024	WG 2.2 meeting to finalise input into the demographics surveys
14/06/2024	WG 2.2 Community Input Form sent to the ASA mailing list
20/06/2024	WG 2.2 Town Hall A held online
21/06/2024	WG 2.2 Town Hall B held online
10/07/2024	WG 2.2 Facility Input Form sent to the ASA mailing list
18/07/2024 to 02/08/2024	WG 2.2 participation in national in-person town hall tour
21/08/2024	WG 2.2 Community Input Form closed to further submissions
21/08/2024	WG 2.2 Facility Input Form closed to further submissions
28/08/2024	WG 2.2 draft report v1.0 sent to the ASA mailing list
02/09/2024	Closing date for community input into WG 2.2 report
03/09/2024	Final version of WG 2.2 report sent to Decadal Plan Editorial Board

FINDINGS: DEMOGRAPHICS SURVEY

Working Group 3.1 on Demographics, Society, and Workforce conducted individual and institutional surveys of the community, circulated via the Astronomical Society of Australia email list and Slack. Complete analysis of both surveys is presented in the report of Working Group 3.1. Here, we synthesise some of the results directly related to the facilities. These results directly inform the recommendations of our working group.

In the institutional survey, CSIRO and 8 out of the 15 universities that filled in the survey report expenditures on at least one significant (>$25k/year budget) facility in 2019-23. The expenditures are dominated by CSIRO and ANU. CSIRO and 4 universities report operating more than 1 facility, while 6 universities reported expenditures totalling less than $50k over the entire five-year retrospective period.

The need for advanced computing linked to all stages of observatory operations came through very strongly in the individual survey responses. While the importance of Data and Computing is addressed via a dedicated Working Group (WG 2.3), the survey results highlight that regardless of observatory scale, location, or technique, computing is deeply embedded into all aspects of facilities at present and this will only become more true over the period of the 2026-2035 Decadal Plan.

The survey responses also highlighted the high degree of interconnectedness between this Working Group and the Instrumentation Working Group (2.4).

Of the 557 individual survey respondents, 307 (55%) responded in the affirmative to the question **"Do you/will you use data from national/university facilities in your research?"**. Among these respondents, the number who answered that the importance of the national/university facilities to their work was highly important or critical (4 or 5 on the 1-5 scale) was 196 (35% of all respondents). The numbers do not significantly change when asked to consider the period of the previous 5 years or the next decade, so there is still a strong and vital role to be played by national and university-scale facilities. Over 30 individual existing and planned facilities were named.

By far the strongest level of support for facilities was across the radio and optical/near-infrared (OIR). Note that each individual could name multiple facilities in their response, so the number of observatories mentioned is far larger than the number of respondents. ASKAP was the most frequently listed facility, followed by AAT and ATCA. The ANU 2.3m telescope, the Murchison Widefield Array and Murriyang, the CSIRO Parkes radio telescope were also each mentioned in more than 60 responses. The Long Baseline Array and Siding Spring Observatory (other telescopes) were also each mentioned around 40 times. Observatories run by other universities tended to see critical use from much smaller groups, highly concentrated at those institutions - but in the aggregate were used by nearly 100 respondents, equivalent to the AAT or ATCA.

Some general capabilities were also mentioned multiple times, most prominently the need for computing infrastructure to deal with data reduction and archiving, and the requirement for local telescopes on which to undertake instrument development. Links to multimessenger astronomy (e.g. dark matter, cosmic rays, neutrinos, gravitational waves) were strongly supported, but by smaller numbers of survey respondents.

66% of survey respondents identifying as PhD candidates use national or university facilities for their research, slightly higher than for the non-PhD cohort (53%). This suggests that access to these resources are critical for training and research development.

The important roles of national/university facilities in order of frequency were to conduct research, access data products, training/education, prototyping/technology demonstration, accessibility and flexibility for innovative experiments, and outreach/communication. There is some degree of overlap between categories, and respondents could choose more than one response, but it is obvious from the data that the national/university facilities continue to play a vital role in Australian astronomy research, and will do so for the foreseeable future.

For the question **"What changes… would you like to see to help with national/university facilities"**, computing once again came to the fore. 119 survey respondents would like more support in processing data, and 91 would like more support in accessing data. For the non-computing changes, 109 respondents would like more visibility/connectivity of facilities (e.g. via a network), 95 would like support to visit key institutions, and 81 would like more support in accessing facilities.

The individual survey also included two free-response questions relevant for WG 2.2.

The first, "**What unique existing capabilities in Australian national or university facilities must be preserved from your perspective, and why?"**. This question received 164 individual responses, many of which fell into a few broad areas both general and specific. Of course, the number of times a specific facility was mentioned in the list of facilities used (see above) and the number of times it featured in the free-response section did not necessarily align. Broadly grouped, the free responses tended to focus on the following:

1. Accessibility of onshore facilities for hands-on student training. There is increasing recognition that while remote observing is essential and enables a high degree of access, there is no substitute for “learning by doing” with hands-on experience. Individual responses made this point for instrument builders as well as observers.
2. Accessibility of onshore facilities for high-quality research projects that do not require megascale international or space facilities, proof of concept observations, technology demonstration and instrument development. These require availability of high-quality facilities capable of prioritising technology development. Such observatories must not be massively oversubscribed and are cheaper to run, so they can take on more experimental/higher risk projects, and may support large blocks of flexibly scheduled time where necessary.
3. The ability to take advantage of Australia’s geographic location to follow up on transients discovered in Chile and elsewhere. Fully exploiting this advantage requires robotic/automated facilities across a range of locations, wavelengths, sensitivities, and techniques (photometry, spectroscopy, interferometry, polarimetry).
4. World-leading strengths in radio frequency instrumentation.
5. Capability of AAT at least through 2030, which is significantly more powerful than the next-largest optical/NIR telescopes available in Australia and has unmatched multiobject spectroscopy capability. If a post-AAT future is contemplated, a transition plan must be considered.
6. Radio capabilities that will not be provided by SKA and cannot be given up: the only southern hemisphere VLBI network, survey and wide-field capability of ASKAP, the frequency range and rapid-response capability of ATCA, and Murriyang, the only large single-dish radio telescope dedicated to scientific research in the southern hemisphere.
7. Links to broader capabilities of national priority beyond pure astronomy research, e.g., position navigation and timing geodetic VLBI observations, space communication, tracking, and situational awareness.

The second free-response question relevant to WG2.2 was **“What capabilities that are not currently supported by Australian national or university facilities are the highest priority for development, and why?”**.

This question received 94 individual responses, which again mostly fell into several broad themes, summarised here and listed approximately ordered by the number of times mentioned:

1. Computing support, broadly defined across areas of data reduction, transfer, storage, and archival access. Data and computing will be discussed in detail in the WG 2.3 report, but it is important to include here as the widely-held view is that computing cannot be cleanly separated from the productive use of facilities. It is recognised that computing support for national facilities is not currently sufficient to cope with the large data volumes expected over the period of the Decadal Plan.
2. A pathfinder to a next-generation gravitational wave facility within Australia, with the goal of future funding/construction of a full GW detector towards the end of the decade to align with the next-generation of international facilities.
3. Full-sky monitoring for radio transients at high time resolution, to open up new parameter spaces for discovery.
4. Millimetre-wave/sub-mm radio development to support participation in large-scale international and multimessenger programs (see WG 2.1 International and Space Facilities).
5. Contributions to space-based astronomy missions in order to maintain the high-level instrumentation workforce (see WG 2.1 International and Space Facilities and WG 2.4 Instrumentation reports).
6. Efficient operation models placing less demands on support staff and budgets (e.g., robotic operations, more reliable systems, better integration and coordination between institutions and facilities).
7. OIR: more spectroscopic capability at telescopes at a range of resolutions and apertures 1+ metre at a diversity of locations.

FINDINGS: WG 2.2 FACILITY INPUT FORM

One of the activities of WG 2.2 was to put a call to the community for submissions related to national and university facilities, which we would then attach to this report as appendices. This was an important aspect for us because we see the role of our WG as providing as much broad information as possible to the Editorial Board for the final formation of the Decadal Plan, and we also wanted to give facilities a chance to represent themselves in their own words (within a set of specified guidelines that were developed within WG 2.2 to maximise consistency in answers).

In addition to these guideline questions, we also requested facilities fill in a spreadsheet about their available capabilities based on a combined version of metadata stemming partly from the previous Decadal Plan and partly from activities within the science-focused Working Groups of this current Decadal Plan - the goal of this spreadsheet is to facilitate matching of science requirements to facility capabilities.

We released our call for input on 10th July 2024 via the ASA mailing list, with an initial deadline of 31st July 2024. This was later extended to the 8th August 2024, and we accepted final submissions ultimately until 21st August 2024. That noted, all submissions received were submitted by 9th August 2024.

In total, we received 12 submissions covering the following facilities:

- Anglo-Australian Telescope (AAT)
- Australian SKA Pathfinder (ASKAP)
- Australia Telescope Compact Array (ATCA)
- Greenhill Observatory: 1.3m, 0.5m telescopes
- Long Baseline Array (LBA)
- Mopra radio telescope
- Mount Pleasant Radio Observatory: 26m, 14m, 12m telescopes
    - Also including: Ceduna SA, Katherine NT, Yarragadee WA
- Mt Kent Observatory: Minerva-Australis, SONG-Australia
- Murchison Widefield Array (MWA)
- Murriyang, the CSIRO Parkes radio telescope
- RSAA: 2.3m telescope, SkyMapper, DREAMS, UKST
- Siding Spring Observatory (SSO)

We additionally received a separate input from the Australia Telescope National Facility (ATNF) which is responsible for managing and operating the suite of CSIRO radio telescopes, outlining their overall vision for the next decade.

We have attached each of these submissions (along with their capabilities spreadsheets) as appendices to this report, and we submit these as part of our WG report with the goal of providing direct information from key national and university facilities to be considered and incorporated as part of the Decadal Plan. As such, we make no further attempt to summarise their submissions, but note that we have ensured that our recommendations reflect the needs and priorities of these facilities where possible.

FINDINGS: WG 2.2 COMMUNITY INPUT FORM

In addition to the facility input form, we also released a community input form that was designed to capture feedback from individuals as opposed to facility representatives. This form was put together based on the input we had initially collected within the WG 2.2 membership to understand the context of our members, as this input had been extremely useful in shaping our early discussions and identifying key topics and priorities for our working group to explore.

We have attached the blank template of the form as an appendix for reference. This form was shared with the community via the ASA mailing list on 14th June 2024, in advance of our dedicated WG 2.2 town halls. We kept the form open for community submissions until 21st August 2024. In total, we received 4 submissions to this form from four community members who chose to identify themselves to the WG. We summarise the feedback and input received below.

Suggested priorities to be considered as part of WG 2.2

Note: these are listed in their order of appearance in community submissions, not in terms of any other assigned priorities.

- Support of facilities to include full consideration of hardware and software to maximise the science extracted from the data
- Large aperture array to be built during the upcoming Decadal Plan period, as a new national opportunity to provide an Australian niche
- Support for an ASKAP upgrade and SKA commissioning
- Personal prioritisation of facilities (based on relevance to the submitter): AAT, ANU 2.3m telescope, ATCA
- Facilitation of science via national and university facilities
- Maintaining Australia’s capability through future novel instrumentation/techniques and training the next generation of astronomers

Impact of the previous Decadal Plan

- All submissions said that the previous Decadal Plan had been positive for their facilities of interest, with the exception of changes affecting AAT/AAO
- A comment was made about mega-surveys and large international teams eroding “open skies” models in favour of “user pays” models of operation

Biggest risks and threats

- Funding (especially for AAT, ANU 2.3m, ATCA)

- Lack of vision
- Underutilisation of capabilities to their best advantage
- Training of fundamental technical skills becoming more expensive / infeasible, alongside training of the next generation becoming a lower priority

Questions to consider within the community

- If/when do we shut down a facility, how do we ensure we've extracted the most from the data produced (and that we don't have a bunch of unusable data lying around that no-one can use)?
- Where do we go after SKA?
- Will the community be more susceptible to "group think" and less innovative in the era of mega-projects and mega-facilities?

FINDINGS: WG 2.2 TOWN HALLS

Two online town halls were held, on 20-21 June 2024 to gather community input on the National and University-scale facilities. Roughly 30 attendees participated in one or both sessions, with representatives from across the community (particularly more senior members of the radio/optical communities). At these sessions it was broadly recognised that there are enormous benefits to operating local observatories, which cannot be reproduced through paid access to offshore facilities. These include specialised science niches, workforce development, training of students, and flexibility of scheduling.

A critical feature of Australian observatories is the geographic position as the first major landmass to the west of Chile, which bestows an inherent advantage for follow-up of transients discovered by Rubin/LSST and other discovery engines. The essential requirement for high-performing astronomical infrastructure across multiple wavelength regimes in order to enable surveys and rapid response of the time domain/transient sky was a common theme.

It was acknowledged that the role of WG 2.2 is complicated by its interdependencies with the science and demographics/workforce working groups. In particular, the future of optical astronomy in Australia is intimately tied to the decision about whether or not to join ESO, and the repercussions for optical astronomy if full membership of ESO is not achieved. In the radio, the role of ATNF facilities in the SKAO era is of critical importance during the span of the coming decade, both in terms of active and ongoing upgrades to the CSIRO suite of telescopes that will empower niche discoveries and in terms of providing vital complementary support to realising the scientific and technical ambitions of the SKA in Australia and globally. Additionally, the specific role of UTas and CSIRO radio facilities (beyond the span of the current decade) in the SKA era in enabling VLBI observations of southern hemisphere objects with SKA-Mid was also emphasised.

Evidence for the very high degree of success of Australian astronomy based on National and University facilities and the critical expertise in instrumentation was discussed; much of this is captured in the facility submissions included in the Appendices. The flexibility and access of national/university facilities makes them indispensable. Australia's contributions to the international astronomy community are expertise, not just hardware. It was brought up that there is no longer a national optical astronomy organisation to coordinate investment and access. A recurring theme across all meetings is the need for adequate computing infrastructure to support all facilities, whether in terms of data processing or archiving/access.

FINDINGS: IN-PERSON TOWN HALL TOUR

We highlight the key points relevant to WG 2.2 that were raised in each of the in-person town hall meetings, based on the notes taken at these meetings and provided to us.

Melbourne (July 18th 2024, 13:00-16:00 AEST)

- Establishment of a nationally-recognised centre for optical astronomy as a priority (with relevance also to international optical facility involvement)
- Emphasis on coordination and resourcing of national/university facilities
- ASKAP mentioned as being a key facility to be enhanced in the SKA era
- Some overlap with WG 3.2 in the context of technical training initiatives

Brisbane (July 23rd 2024, 12:00-15:00 AEST)

- Emphasis on maintaining and enhancing facilities such as AAT
- Mention of improved coordination amongst existing national and university facilities to meet broader community goals
- Consideration of need for diverse technical career pathways for students and ECRs e.g. in instrumentation, data engineering, and statistics

Canberra (July 25th 2024, 13:00-16:00 AEST)

- Emphasis on ensuring to capitalise on SKA involvement and investment, especially via continued involvement with the SKA precursors and pathfinders
- Financial sustainability and long-term viability of facilities as a key concern, with a need for improvement in strategic planning and coordinated advocacy
- Mention of university facilities supporting national research priorities in a more enhanced or directed way
- Requirement for more predictable and stable funding for instrumentation and maintenance of facilities
- Need for balancing investment in international collaboration against national and university facilities for optimal strategic advantage
- Also for balancing facility upgrades versus the building of new facilities - to be driven by the science priorities and goals

Hobart (July 29th 2024, 13:00-15:00 AEST)

- Identified need to prominently mention funding of smaller university facilities in the Decadal Plan in order to avoid underfunding
- More emphasis on questions surrounding international facilities than on national and university facilities

Sydney (July 30th 2024, 13:00-16:00 AEST)

- Australia as being capable of leading in Milky Way research especially due to geographic location and existing facilities
- Importance of multi-wavelength facilities with improved data-sharing protocols
- Focus on optimising the use and development of facilities especially to support cutting-edge research
- ASKAP and MWA mentioned as facilities to both maintain and upgrade, integral to Australia's research structure and to international projects/collaborations
- Importance of new infrastructure investments locally to keep up with international developments and advances
- National facilities as places for both education and public engagement
- Mention of training programs to equip next generation with necessary skills
- Emphasis on ways to better synergise national and university facilities, to improve resource allocation and complementarity of these facilities

- Need for sustainable funding for maintenance and upgrades
- Greater collaboration between universities and national facilities, improving knowledge sharing and joint research initiatives

Perth (August 1st 2024, 11:00-14:00 AWST)

- AAT mentioned as critical in the WG 1.2 context
- WG 1.2 noted their need for optical, radio and computational facilities, both national and internationally
- WG 1.3 emphasising improvements in coordinated infrastructure for follow-up
- Australian community noted as being resourceful and adaptive in the leveraging of available resources, strengthened by national and university facilities

Adelaide (August 2nd 2024, 13:00-16:00 AEST)

- Mention of protecting facilities such as ATCA/Parkes from being adversely affected by new investments in high frequency radio astronomy

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FINDINGS: WG 2.2 MEMBERSHIP INPUT

The membership of Working Group 2.2 consisted of 21 members, including 2 co-chairs, across 10 different institutions, with several members also contributing to the activities of other Decadal Plan Working Groups. As part of the initial process of forming the WG, we collected input from members of the group in terms of their motivations, priorities, facilities of interest, perspective on the previous Decadal Plan, possible threats and questions to raise - the same questions which later formed the basis of input sought from the broader community. We summarise in this section the key findings and points raised within WG 2.2 as part of this process.

Motivations for involvement in WG 2.2

- A key motivation was the desire to balance smaller/medium-scale facility projects against the larger-scale projects, considering the impactful roles of national and university facilities in terms of enabling and developing critical skill sets. Other aspects raised that were related to this were to do with maintaining the technological innovation within the community and the flexibility, agility and impact of these instruments in their specific areas.
- There was a theme of emphasising the connections across all of the Facilities

working groups (WG 2.X) groups, noting that it is difficult to treat international/space, national/university, data/computing, and instrumentation as isolated aspects due to their degree of close overlap and relation to each other.

- The impact of the current sub-optimal operational models and funding schemes in certain cases (for example, the AAT) was highlighted, noting the specific extra challenges that face facilities that are operated on the university rather than national level in the absence of any wider coordination efforts
- Another key motivator was emphasising the role of national and university facilities in realising the vision of Australian involvement in SKA and ESO especially, and aligning national and university facilities to contribute optimally alongside these large projects

Suggested priorities to be considered as part of WG 2.2

- Identifying and protecting key facilities that are vital to advancing community goals in the coming decade, safeguarding their critical aspects and addressing risks to their continued operations
- Exploring opportunities to diversify university and national facility capabilities that will meet the evolving long-term goals of the community
- Seeking ways to facilitate a coordinated approach where possible, perhaps via a unified framework and increased visibility of the network of national and university facilities
- Progressing and strengthening international involvement that maximises return on investment in large projects (e.g. SKA) while preserving and amplifying the distinctive and valuable contributions made at national/university facility level
- Development of more sustainable funding models for national and university facilities that enable them to operate at their optimal level
- Ensuring that national and university facilities can play an effective and impactful role across various key areas such as training and development of expertise, outreach/communication and new technology demonstration
- Continuation of the MWA as the primary SKA-Low precursor telescope, until the SKA is operational

Impact of the previous Decadal Plan

- The unique role of local facilities was emphasised in some cases, and this was extremely important in enabling their continued impact and success
- Smaller facilities were felt to be largely overlooked or not mentioned, leading

to difficulties in securing and maintaining funding

- University-run facilities faced more challenges than facilities on the national scale
- Strong support for ESO engagement led to useful outcomes for strategically-driven collaborations, especially in the context of instrumentation and software, while other non-ESO projects and initiatives were less well-supported
- The change from the AAT being managed and directly funded by DISR to being managed by consortia of Australian Universities, and the removal of AAO from DSIR to instead become a university department led to increased instability and insecurity of funding, with widespread negative impacts on those involved as well as the optical community

Biggest risks and threats

- Potential of a shrinking funding pool alongside decrease in support for fundamental research especially threatens small and medium-scale facilities
- Overcommitment to large projects could undermine smaller facilities, diminishing national capability to develop world-class astronomers and conduct medium/high risk experiments of high impact
- Uncertainty regarding the nature of international engagements poses risks for the institutions and individuals heavily invested in these projects
- Reduced funding for maintenance and support threatens the ability of existing facilities to continue performing at the same world-class level
- Risk of perception that national and university facilities lose their relevance in the era of megascience projects, as opposed to becoming complementary or providing high-impact science in parallel
- Potential imbalance in funding and resources towards university, national, international and space facilities resulting in decline of overall research capability
- Commercial pressures on facilities may drive these facilities away from fundamental research, creating conflict between science-driven operations and the need for securing financial stability

Questions to consider within the community

Note: these are listed in their order of appearance in WG 2.2 input, without any associated or implied degree of importance.

- Why is ATNF, as part of CSIRO (being Australia's national science agency), limited only to radio astronomy in scope?
- Should the Australian community through AAL or some other mechanism more strictly enable/enforce adhesion and implementation of the Decadal Plan? Can/should the strategies presented in the Decadal Plan be linked with/flow down more directly and clearly to the strategies developed by Australian astronomy institutions and university departments? Should the community be held to account for adopting or not adopting the recommendations of the plan?
- Should the AAT be reclassified as a national facility? Without additional funding, it will close
- Should universities form something like AURA, a shared organisation to cooperate on the operation of small-scale facilities?
- Should Australia consider developing its own 8-10 m class national telescope capability?
- Are we at risk of losing critical hands-on skills in our broader astronomy workforce if the number and scale of university facilities continues to decline, or are there other/better ways to provide that training?
- Are data centres and computing resources considered national facilities?
- What facilities are we willing to lose? What capabilities do we want to keep/bring to the Australian facilities that are not covered by the large survey instruments?
- Should the Desert Fireball Network (DFN) be considered an astronomical facility?

FINDINGS: COMMUNITY CONSULTATION ON REPORT DRAFT

Prior to final submission of this report to the Decadal Plan Editorial Board, we circulated it via the ASA mailing list for community feedback, input and suggestions. It was sent out late AEST afternoon on Wednesday 28th August 2024, and we accepted input via comments on this document until the end of Monday 2nd September 2024. This section summarises the input and comments we received as well as indicating any changes or adjustments made to the report as a result of this community feedback.

High-level commentary/discussion/questions

- Mention of the possibility for Australia to develop the capability to deploy its own space telescope (in comparison to looking at sovereign 8-10 m class telescopes, which it was noted would need to be offshore to be effective). It was also noted that an Australian-built space facility might have more local appeal to funding agencies based on economic impact, and an additional comment suggested that "Hubble with a good coronagraph" would be useful scientifically.
    - *Noted these comments here, while also noting that consideration of this primarily lies with Working Group 2.1 which is focused on International and Space Facilities - will seek comment from the chairs of this group, and we can add in our "future trends" section a statement supporting whatever the main conclusion on this is from WG 2.1 based on the relationship of this to potential future national/university facility capability*
- Also in relation to Australian 8-10m class capability, it was noted that a faster solution would be to buy into an existing single telescope (e.g. Subaru), but that this is more limiting than ESO
    - *Included the above note in this section, but no change to the quoted comment included in this report*
- Suggestion for stronger emphasis on the impact of Australia's geographic location in terms of being able to offer a suite of different facilities for multiwavelength follow-up of transients (particularly, higher in the key recommendations and in relationship to resourcing and funding, as it was originally mentioned specifically as recommendation #9)
    - *Shifted this recommendation up in priority from #9 to #5 to better represent the importance of this contribution*
- Questions regarding possible large-scale upgrades of ATCA and the future of ATCA as a facility in the era of SKA/ngVLA/ALMA (e.g. more dishes, longer baselines, frequency range changes, etc)
    - *Sought input/comment from ATNF representatives on this topic, as well as noting the attachment of the ATNF vision document for the next decade as part of the appendices of this report*
    - *General status is that there is no formal plan for a major upgrade to ATCA capabilities after BIGCAT, however community sentiment/push via Decadal Plan/ATUC/other avenues will determine future plans based on strong science cases for possible upgrades (noted here)*

- Comments regarding the community input framed around what happens "after SKA" - noting there are different phases (e.g. commissioning, operational, end of life, etc) and also that (beyond this decade) there will at some point be consideration of possible upgrades to the SKA telescope itself (and potential evolution of the role/remit of SKAO)
    - *We note the above here, but keep the quote regarding SKA verbatim as submitted to the WG 2.2 community input form*
- Referring to an input suggesting universities might model a coordination network on AURA (in the US), it was noted that AURA is complex, similar in some ways to AAL, focuses only on optical and tends to be mainly about the larger facilities as opposed to smaller ones going via the NSF grant process. It was suggested that modifications to AAL might be an option to consider instead of a new body.
    - *Have included the above comment for additional consideration, but leaving the original comment as verbatim submitted to WG 2.2*
- Questions and discussion about the definition of a national facility, in the context of what determines the boundary between national/university facilities
    - *Definition provided by Ron Ekers, noting term National Facility was defined by ASTEC in a report to the Prime Minister in Jan 1984 ISBN0644031468: "It will be useful to define what is meant by the term 'national research facility'. In essence, the term denotes substantial instrumentation, equipment or other physical entity constructed or established to satisfy an identified national research need and which, because of expense or capabilities, is justified only on the basis of shared use by scientists of several organisations. The primary criteria are that the facility is specifically identified as being for national use, and that it is made available to scientists according to the merit of their proposals. Equipment or a facility established and owned by one organisation and made available for occasional use by 'outside' scientists does not constitute a national research facility."*
    - *Included the above definition for reference as part of this document, noting especially the importance of open skies and merit-based allocation of time as a key factor in determining national facility status*
- With respect to a WG 2.2 input about data and computing facilities being national facilities, it was noted that the above definition suggests that it depends on their ability to meet criteria (which also may have evolved since the initial definition), and suggested that this might be explored in the

mid-term review of the Decadal Plan as well as access policies captured in surveys

  - *We note that as part of the WG 2.2 Facility Input we included a question on facility access, which also specified asked about open skies - so this information is available for the facilities which submitted to our form and who answered that specific question - but we support the idea of capturing this information more broadly and systematically, perhaps in line with our Recommendation #2 with respect to improved coordination and visibility of the national/university facility landscape in Australia*

- Feedback from the community regarding the future ambitions in the area of gravitational wave, seeking to emphasise the ambitions for a pathfinder facility looking towards a full-scale gravitational wave facility towards the end of the next decade to align with the next generation of international facilities
  - *Added Recommendation #1d to highlight this, modified the summary of survey input to better reflect the community goals in this area and added extra contributed text to the future trend section where we discuss future capabilities sought by the community*

Specific changes/details

- Minor corrections to wording/terminology where relevant
- Note that reference to "agile scheduling" for ATCA is a little misleading in that it could be interpreted as dynamic scheduling compared with rapid-response for follow-up (and ATCA currently has a fixed schedule for the semester that is adjusted flexibly depending on the triggering of NAPAs and TOOs)
  - *Changed wording to "rapid response" to better reflect ATCA contribution*
- Correction to wording around existing access to ESO versus full membership
- Shifted Recommendation #9 (on geographic advantage of Australia) to #5 based on better reflecting the importance of this for the community in terms of transient follow-up and multi-messenger science, and incorporated some extra wording suggested from the community on the relation of this to joint campaigns
- Improvements to clarity of wording, especially in the executive summary and key recommendations
- Adjustment of the statement on international student levels to reflect the varied experiences of different institutions nationally

REFLECTIONS ON WG 2.2 IN THE 2016-2025 PERIOD

For details, we refer readers to the WG 2.2 report from the 2016-2025 Decadal Plan process, but here we briefly reflect on the similarities and differences between this report and the current report we have prepared here.

Changes in the national and university facility landscape

Many of the same observatories and facilities are represented in both cases, including AAO/SSO, ATNF, MWA and University of Tasmania. University of Southern Queensland was not represented in the previous plan, but its Mt Kent Observatory has emerged as a noteworthy addition to the university landscape in optical astronomy. A notable change is that the Molonglo telescope has been decommissioned as of 2023, and no longer features in the facility landscape. Work is underway to capture as much of its scientific and historic legacy, with a symposium having taken place in late 2023. Some facilities which had previously been represented in WG 2.2 have instead been captured via the efforts of other WGs due to their closer overlap (e.g. WG 2.3 Data and Computing or WG 2.4 Instrumentation), though we again note the strong and unavoidable overlap between all of the Facilities working groups in terms of their goals and recommendations.

The path to SKA and ESO

The megascience ambitions of the Australian community with respect to SKA and ESO engagement continue to feature strongly, although as noted above we have progressed to a further stage with both organisations. SKAO has begun construction of both SKA-Low and SKA-Mid at the Australian and South African sites respectively, and thus the SKA is no longer “on the horizon” in the same way it was in the previous decade. Similarly, the path to ESO membership is now at a critical stage with a strong community emphasis across our various collected inputs on directing effort and resources towards achieving this by the 2027 deadline.

Thus, even more than previously, it is of high importance to reflect on the composition of our national and university facility landscape and prioritise efforts on facilities which 1) support/complement/advance these megascience collaborations where possible, and/or 2) offer scientific capabilities and opportunities to the Australian community that are not possible or significantly less feasible within the largest projects the Australian astronomical community is invested in.

Virtual Observatory

Given the focus of WG 2.2 specifically on facilities not otherwise covered by other Working Groups, recommendations related to this aspect of our community have been channelled through the consultation and activities of WG 2.3 Data and Computing.

Antarctic and gravitational wave astronomy

Gravitational wave astronomy by its nature has been strongly represented in WG 2.1 International and Space Facilities, however we did receive community input across various town halls and other forms of input related to the importance of sovereign capability in gravitational wave astronomy in the coming decade. WG 2.2 received no submissions or community input related to Antarctic astronomy, but Antarctic astronomy has been mentioned in the context of WG 2.1 in relation to the IceCube Neutrino Observatory.

Evolution of the observing and operations model

Even more so than the previous decade, there is an increasing prevalence of large survey teams over smaller PI-driven teams in observational astronomy, and a greater emphasis on providing science-ready data products for users. We diverge slightly from the stance of the previous WG 2.2 report in that we firmly advocate for the continuation of effective knowledge transfer of the full observational astronomy workflow, including both how telescopes work and are operated even at lower/local levels. We note that at least a fraction of the future generation of astronomers must be equipped with a broad suite of technical knowledge if they are to be well-prepared to conceive and design the next phase of innovative instrumentation. This also requires a considered investment in developing and executing training approaches that meet the needs of our evolving community, addressing the arguably challenging balance between fundamental principles of telescope operations and the computationally-driven reality of modern telescope systems.

While there are undoubtedly further movements towards greater automation and autonomy of telescopes in Australia and worldwide (e.g. the autonomous operations of ASKAP and the ANU 2.3m telescope) alongside the rising impact of artificial intelligence (discussed in more depth by WG 2.3), this comes with an equally critical question about the role of the human expert in the coming decade and beyond, and where the (expensive) human resources can best be placed to optimise telescope operations and maximise return of high-quality science data. We believe this will be a key theme facing national and university facilities as they evolve in the coming decade.

Funding and the impact of Centres of Excellence

As noted in the previous Decadal Plan, astronomy-focused ARC Centres of Excellence have had a huge impact on the ability to progress astronomy in Australia, and this will also be true in the coming decade. While ASTRO 3D is now coming to an end, OzGrav will continue until 2029, alongside bids for new Centres of Excellence commencing in 2026 that will facilitate national coordinated efforts in astronomy. It is clear that the existence of Centres of Excellence aligned closely with astronomy, in particular with the parts of astronomy that make use of national and university facilities, will make a big difference to the successful continuation of these core facilities. Centres of Excellence have a key role in providing additional sources of funding to support the community and through their investment in the human expertise required to drive future facility development.

CHARACTERISTICS OF A HEALTHY NATIONAL/UNIVERSITY FACILITY ECOSYSTEM

Reflecting on the surveys, town halls, facility and community submission, and previous decadal plan, the authors found it useful in drafting this document to identify some broad, high-level characteristics of a healthy national/university astronomy environment. These are not necessarily complete but our view is that all of the detailed recommendations and priorities can be conceptualised in this framework.

Core Requirements: Science capability, broad access
Key Traits: Stable workforce, diversity (geography, wavelength and methodology), flexibility, innovation
Enabling Conditions: Funding, visibility, computing, science drivers
Potential Threats: Environment of decreased/redirected funding, narrow focus on applied research at the expense of pure science, pursuit of megascience ambitions without adequate support of the pathways to that activity

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DISCUSSION ON FUTURE TRENDS AND DIRECTIONS

In this section, we briefly consider and discuss broader trends that have emerged as themes across the various forms of community input and discussions in WG 2.2 which will have an impact on the future evolution of our facilities. We aim here to identify opportunities and challenges, and suggest these be considered by the Editorial Board in terms of their final synthesis of recommendations for the Decadal Plan 2026-2035 alongside similar themes emerging across other relevant working groups.

Future capabilities and instrumentation

We primarily defer the requirements for future capability as outcomes from the various science working group discussions, however we mention here several national and/or university scale capabilities that came up as part of the Decadal Plan process in the context of WG 2.2 (e.g. via town halls, the survey or other input).

- **Gravitational wave capability in Australia:** mentioned via town halls and in the surveys, there has been a case made for a gravitational wave facility in Australia to complement the international initiatives that Australian astronomers are already participating in. In addition to a pathfinder (a smaller scale facility for training, R&D, etc), this segment of the community seeks a pathway to funding and constructing a next-generation GW detector in Australia by the end of this next decadal cycle. 2035 is when the next-generation of US and EU detectors aim to start coming online and the ambition is to partner with them and other interested countries and use Australia's geographical advantages to contribute towards an optimal global network. We refer readers to WG 2.1 and the outcomes of the relevant science working groups for the more detailed case for this capability.
- **All-sky radio monitoring capability:** this topic surfaced in some of the town halls, via the community input form and via the survey, with specific mention of higher frequency capability that is currently missing worldwide (e.g. ~1 GHz compared with existing low-frequency all-sky monitoring arrays). A specific example put forward was CASSATTA, as a potential candidate all-sky monitor being explored by CSIRO. Such a capability is already being considered by the US and China, but the most relevant technologies have been developed in Australia.
- **Low-frequency VLBI capability:** mentioned via the survey and as part of the ATNF vision document submitted to this WG, this capability is framed around complementing and extending on the SKA-Low instrument by enabling higher resolution low-frequency observations. Early work in this space is currently being carried out at CSIRO, as part of the LAMBDA project.
- **Sub-mm and high-frequency capability:** mentioned in the surveys, to complement low and mid-frequency observations as well as CTA collaboration involvement in the areas of gamma-ray and cosmic-ray science. This would be in addition to ESO membership opening up access to the ESO share of ALMA time, and thus the opportunity to participate in/lead future ALMA upgrades.

- **National space capability:** during the community consultation phase of this report, there was mention of development of national space capabilities. The feasibility of solely-Australian capability versus becoming viable partners in international space programs was discussed, and reference was made to the Decadal Plan for Australian Space Science as a primary source of information for Australia's space ambitions. Australia's existing, diverse and widespread involvement in space was highlighted, with specific mention to partnerships in current space programs as well as longstanding partnerships for radio communications (e.g. Canberra Deep Space Communication Complex with NASA as part of Deep Space Network, New Norcia with ESA), and there was strong support for continuing and potentially growing this capability in the coming decade (e.g. in support of increasing requirements for communications in international space missions). For further detailed discussion on this topic, we defer to the report by WG 2.1 on International and Space Facilities.

University funding model changes and likely impacts

Changes to policy settings over the past decade and multiple governments have caused significant change to the university funding landscape. While governments have tried to encourage higher enrolment in STEM degrees, the broader focus on applied, rather than fundamental, research has led some universities to re-examine the role of their astronomy infrastructure. For some universities, international student numbers have never recovered to their pre-COVID levels, partly as a result of overseas policy change, and partly due to Australian government policy. Other universities have very recently found that international enrolment numbers have already hit their cap level. This may have a tendency to redistribute or reduce the overall pool of university money, so observatories could be expected to need to compete more with other disciplines for a shrinking pool of research dollars. Naturally, this could change somewhat unpredictably over the course of the Decadal Plan period.

One possible counterweight to this is the recommendation in the University Accord that access to tertiary education among regional and disadvantaged areas is desired to expand. As observatories are by their nature magnets for outreach and teaching, it is at least possible that more regional universities could decide to invest in astronomy, either in cooperation with existing observatories or as new facilities. The astronomical community should be prepared to communicate to university leaders the central role for astronomy in STEM outreach and education, and to demonstrate that the return value of astronomy investment far exceeds the dollar cost. For further insight into funding, we refer readers to the WG 3.4 Research Funding report.

Technology trends affecting national and university facilities

Key themes in terms of current global technology trends include digital transformation, automation/autonomy/collaborative intelligence, distributed/remote work, the rise of mixed and extended reality and (especially over the past year) artificial intelligence. All of these are already impacting the way we conduct astronomical research and collect observational data, and have important implications for the future of our national and university facilities. In addition, the scientific tendency towards open access and open data in a climate of increasing cybersecurity considerations creates a tension that will need to be addressed as part of the next decade.

Astronomy has generally been at the forefront of technology adoption, and arguably is well-placed already in terms of digital transformation compared to other fields, disciplines and industries. Our observatories and facilities are already becoming increasingly automated where possible, a trend that is being echoed by similar international facilities based on the gains in efficiency and cost savings. There was considerable mention across our various sources of input of the rising need for automated rapid response facilities across many wavelengths for time-domain and multi-messenger astronomy, and we expect the demand for this will grow in the coming decade. The role of AI and consequential evolution of the role of human experts will also be a key driving force in astronomy and broader scientific research in the coming decade, especially when it comes to the operations of astronomical facilities. We refer readers to the WG 2.3 report for a more detailed consideration of AI and its implications.

Another trend that will grow in its impact on national and university facilities is that of increasingly distributed and remote work. Many facilities in the current landscape already support a high degree of remote operations and management by necessity, due to a user base that is distributed nationally or even internationally. The increasing prevalence of hybrid and distributed work is likely to drive further need to be able to manage and operate facilities from anywhere, with implications for development of and access to facility control systems. For example, we have already seen over the past decade the establishment of dedicated remote observing rooms (e.g. at Macquarie University for the AAT, at CSIRO Marsfield/Kensington for ATCA and Murriyang, at Swinburne University for Deeper, Wider, Faster campaigns), and we expect this to continue alongside even more distribution in the locations requiring reliable facility access. In addition, there has been considerable growth in the availability, affordability and performance of mixed reality systems (including XR, VR and AR) over the past five years (e.g. Meta Quest as a standalone VR device), and while there are specific examples of their direct application in astronomy (e.g.

visualisation, communication and collaboration, see WG 2.3 report for details), we predict that this technology will have considerable impact on the ways we manage, develop and communicate about our national and university facilities in the coming decade.

In tension with the desirability for increased remote and open access, there is a need for increased security of systems that are exposed to the internet or for the direct addressing of security for legacy systems, archives and other points of data exposure. Worldwide, several major observatories have already suffered from cyberattacks (e.g., https://www.science.org/content/article/cyberattack-shutters-major-nsf-funded-telescopes-more-2-weeks), and the frequency of such attempts is highly likely to increase over the period of this plan. This could be exacerbated by geopolitical events, if, as expected, there are increasing ties between universities, space industry partners, and defence-adjacent government agencies. The trend of software toward open source solutions will bring further security challenges, although we note that open source can also lead to positive security improvements. It is critical as we navigate towards a resolution in this context that a pragmatic balance is found between the need to keep systems appropriately secure while preserving the ability of science to progress efficiently.

Preserving dark and quiet skies for astronomy

Rapid growth in the prevalence of satellites over the past decade, especially with respect to new satellite constellations and communication technologies, has caused significant concern in the global astronomical community, leading to an increase in the number of initiatives and activities to seek protection and preservation of dark skies (e.g. the IAU Executive Committee WG Dark and Quiet Sky Protection, the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference, engagement with the International Telecommunication Union, the DarkSky International organisation). This issue is one that affects astronomy across the electromagnetic spectrum, with many different manifestations of satellite interference in data. We refer readers to further material specifically on the topic of dark skies for astronomy, and note that finding effective solutions that preserve our ability to observe the faint and distant Universe will be critical in the next decade, both for our current facilities and upcoming instruments that will likely be even more sensitive to the impact of interference.

The changing climate, its impact on astronomy and astronomy's impact on it

Impacts from climate change globally have been accelerating in both frequency and severity, with numerous studies outlining the ways in which our observatories and facilities have already been affected (e.g. Cantalloube et al. 2020, Haslebacher et al. 2022) as well as characterising the ways in which activities in astronomy contribute directly to climate change (e.g. Stevens et al. 2020, Burtscher et al. 2020, Knodlseder et al. 2022, Gokus et al. 2024, Knodlseder et al. 2024). Initiatives in the global community have emphasised collective consideration of this, e.g. via comprehensive coverage in Nature Astronomy and detailed compilations of relevant information such as "Climate Change for Astronomers" (Rector et al. 2024). And recently, beyond astronomy, a clear message has been sent: there is "no research on a dead planet" (Thierry et al. 2023).

The coming decade will undoubtedly see the continued impact from climate change on astronomy, and an increasing emphasis on reducing emissions produced as part of astronomical activities. The public sector of Australia is committed to net zero by 2030, and many universities have similar or more ambitious targets (e.g. Swinburne to be carbon neutral by 2025, Western Sydney University achieving carbon neutrality in 2023, and the University of Tasmania having been certified carbon neutral since 2016). The biggest contributing factors to the astronomy carbon footprint are infrastructure (especially supercomputing and observational facilities) and travel, so we predict there will be a particular emphasis on the use of renewable energy, optimisation and increase in efficiency of facilities and reduction of travel to the most impactful and useful purposes (alongside increased reporting on and accountability for carbon emissions), all of which will have direct consequences for how we manage our suite of national and university facilities in Australia.

Collaboration with Traditional Owners in the facility context

A growing area in which we anticipate further development over the coming decade is the degree to which facilities are closely engaged with Traditional Owners and Indigenous communities. Some examples of this type of engagement can be drawn from the submissions of facilities to our working group, such as:

- Awareness and acknowledgement of Country that facilities are located on
- Formal Indigenous land use agreements (e.g. the Indigenous Land Use Agreement established in 2022 for Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory)
- Working with Traditional Owners to adopt Indigenous names of facilities and observatories (e.g. Murriyang, CSIRO's Parkes radio telescope and Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory)
- Direct collaborations such as in the form of artistic works (e.g. works associated with MWA, ASKAP and the Pawsey Supercomputing Research

Centre, or SKAO's Cosmic Echoes exhibition featuring contributions by Australian and South African Indigenous artists)

- Working with Indigenous-owned businesses and proactive employment across sites of Indigenous peoples
- Ongoing meetings and consultation between facilities and Traditional Owners
- Regular community engagement and outreach with local communities
- Recognition of NAIDOC and Reconciliation Week by observatories, with associated activities and events

Both nationally and globally, we emphasise the importance of continuing work in this area to ensure that our future facilities and research are ultimately contributing positively in this area, drawing from contemporary best practice. We refer readers of our report to that of WG 1.5 Aboriginal and Torres Strait Islander Astronomy for specific guidelines and recommendations.

CONCLUSIONS

We conclude our report by reflecting briefly on the richness and diversity of the national and university facility landscape in Australia, a testament to the successes of previous Decadal Plans and other strategic processes as well as the constructive collaboration of the astronomy community. Across the electromagnetic and multimessenger spectrum, a diverse collection of institutions and on many different scales, our facilities are delivering world-leading high-impact science alongside many other tangible benefits to the nation as evidenced above. We thank everyone who generously and constructively provided their input and feedback into shaping this report to be as reflective of the Australian astronomical community as possible, with contributions from within WG 2.2, other WG Chairs and the broader community.

As highlighted in our key recommendations, the next decade is certainly one of increasing megascience ambitions for Australian astronomy. We look forward to seeing continued critical contributions on the national and university scale in support of these ambitions, and to ensuring the persistence of the creative ingenuity and agile experimentation that has defined Australian astronomy thus far.

LIST OF COMMITTEE MEMBERS

Dr Vanessa Moss (co-chair)
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Professor Jeff Cooke
Professor Scott Croom
Professor Simon Ellingsen
Dr Roger Haynes
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ONLINE VERSION OF THIS REPORT

https://docs.google.com/document/d/1PsiQdMYJZE_GnaZQHXrgoVR67yBrY47IU3YCCO2TeKY/edit?usp=sharing *(note: may not stay available in the long term)*

APPENDIX 1: Definitions and acronyms

Working Groups of the 2026-2035 Decadal Plan

- 1.1 Galaxies and Cosmology
- 1.2 Stars, Planets, and the Galaxy
- 1.3 Time Domain and Multi-Messenger Astrophysics
- 1.4 Theoretical Astrophysics
- 1.5 Aboriginal and Torres Strait Islander Astronomy
- 2.1 International and Space Facilities
- 2.2 National and University Facilities
- 2.3 Data and Computing
- 2.4 Instrumentation
- 3.1 Demographics, Society, and Workforce
- 3.2 Outreach, Education and Training
- 3.3 Industry and Translation
- 3.4 Research Funding

Acronyms

- AAL: Astronomy Australia Limited
- AAO: Australian Astronomical Optics / Australian Astronomical Observatory
- AAT: Anglo-Australian Telescope
- ALMA: Atacama Large Millimeter/submillimeter Array
- ANU: Australian National University
- AR: Augmented Reality
- ARC: Australian Research Council
- ASA: Astronomical Society of Australia
- ASKAP: Australian SKA Pathfinder
- ASTEC: Australian Science, Technology and Engineering Council
- ATCA: Australia Telescope Compact Array
- ATNF: Australia Telescope National Facility
- AURA: Association of Universities for Research in Astronomy
- CTA: Cherenkov Telescope Array
- DREAMS: Dynamic REd All-sky Monitoring Survey
- DSIR: Department of Industry Science and Resources
- ECR: Early Career Researcher
- ESA: European Space Agency
- ESO: European Southern Observatory

- DFN: Desert Fireball Network
- DSN: Deep Space Network
- DSIR: Department of Industry Science and Resources
- ESO: European Southern Observatory
- GW: gravitational wave
- IAU: International Astronomical Union
- LAMBDA: Low-frequency Australian Megametre Baseline Demonstrator Array
- LIGO: Laser Interferometer Gravitational-Wave Observatory
- LBA: Long Baseline Array
- LSST: Legacy Survey of Space and Time
- MWA: Murchison Widefield Array
- NAIDOC: National Aborigines and Islanders Day Observance Committee
- NASA: National Aeronautics and Space Administration
- NCRIS: National Collaborative Research Infrastructure Strategy
- ngVLA: next-generation Very Large Array
- NIR: near infrared
- OIR: optical/infrared
- RSAA: Research School of Astronomy & Astrophysics
- SKAO: SKA Observatory
- SSO: Siding Spring Observatory
- UKST: United Kingdom Schmidt Telescope
- UTas: University of Tasmania
- VR: Virtual Reality
- VLBI: Very Long Baseline Interferometry
- XR: eXtended Reality

APPENDIX 2: Facility input submissions

Note: our final PDF submission contaian each submission attached, but we also have compiled them in a Drive folder here for review (noting that we cannot necessarily guarantee the accessibility of this folder on longer timescales). All documents from the above folder are also attached to this document.

WG2.2-Appendices

drive.google.com/drive/folders/1huaEvVuFGnzTTclpYuszbCVgrQC7E5SL?usp=sharing

Facility Input Sections

Brief description (< 200 words)

Overview of the facility in question, including limited information about specifications and references to where further information can be accessed.

Located at Siding Spring Observatory, the 3.9-metre Anglo-Australian Telescope (AAT) is the largest optical telescope in Australia. Five facility-class instruments are on the AAT: 2dF+AAOmega, 2dF+HERMES, KOALA, Hector and Veloce, providing low to high resolution IFU spectra of single sources (KOALA and Veloce), low to medium resolution spectra of up to 392 sources simultaneously (2dF+AAOmega, 2dF+HERMES), and medium resolution IFU spectra of 21 sources simultaneously (Hector). Visitor instruments can also be mounted.

Owned by the Australian Government and operated by the ANU, the AAT is funded by a consortium of 11 Australian Universities.

Further information is available from https://aat.anu.edu.au.

Main purpose/s and strategic value (< 200 words)

Role and purpose within the broader landscape of national and university facilities, including consideration of the strategic value of this particular facility or facilities in terms of advancing the goals of the community and Decadal Plan.

The AAT and its suite of instruments provides consortium members with capabilities that are unique in the southern hemisphere (2dF+AAOmega), unique in the world (2dF+HERMES and Hector) or at cutting edge (Veloce).

The AAT allows consortium members to run programs requiring many hundreds of nights of telescope time (e.g. GALAH, Hector, SAMI, GAMA, OzDES, etc.) to conduct major programs that directly address four of the six fundamental questions listed the 2016-2025 Decadal Plan – e.g., what is the nature of dark energy (OzDES), how do galaxies form and evolve over cosmic (SAMI, Hector, GAMA), how do stars and planets form (GALAH, Veloce), how are elements produced by stars and recycled through galaxies (SAMI, Hector, GALAH).

The AAT also serves as a training ground for students and early career researchers and as a test bed for novel instruments and ideas.

Current and future user community

Description of the user community, including demographics (e.g. local vs. national vs. international users) and any plans for diversifying this user community in the coming decade.

There are three types of time on the telescope: reserved time, shared time and paid time. Reserved time and shared time are available to astronomers affiliated to a university that is a member of the AAT Consortium. Paid time is available to anyone.

The split between reserved time and shared time is about 50:50. The following plots show the gender and student fractions for these two types of time for the past five semesters.

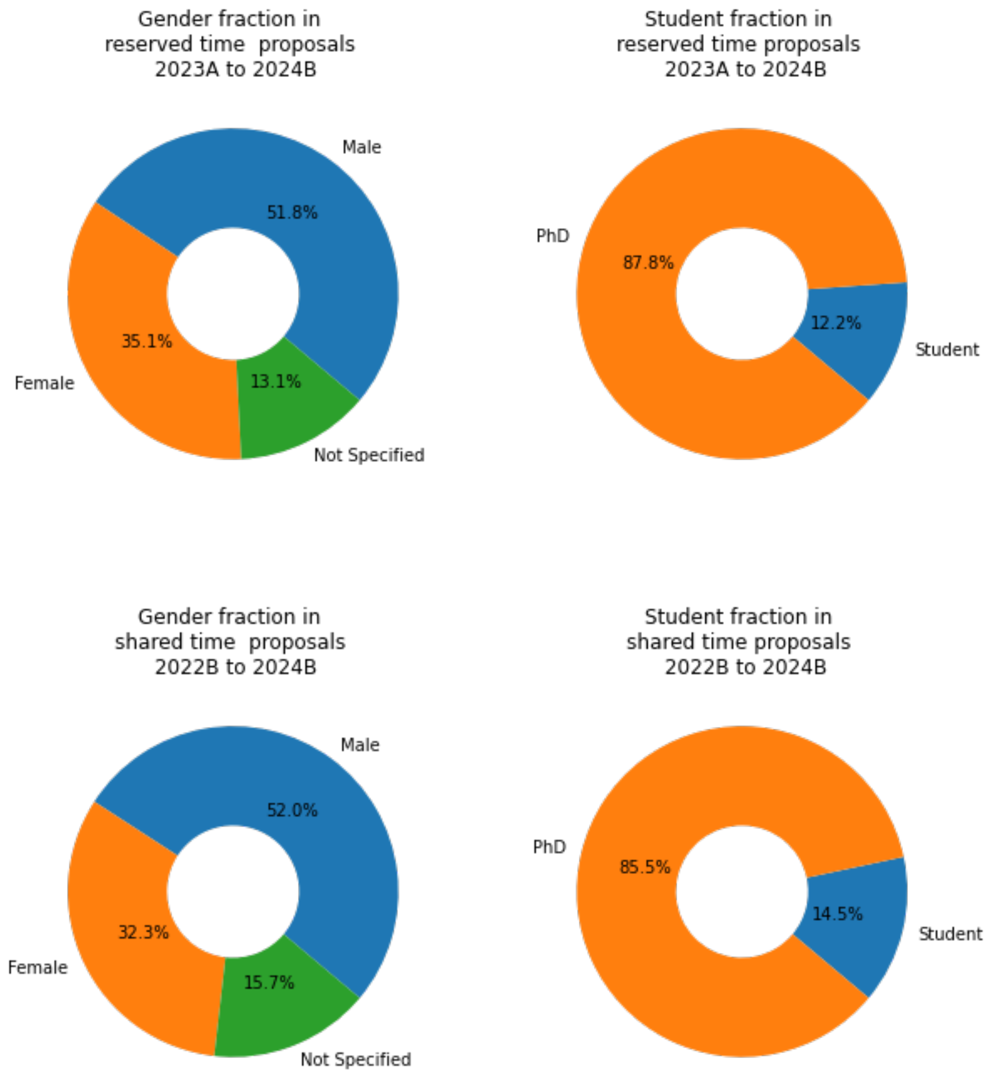


Figure 1: Gender and student fractions for reserved and shared time on the AAT.

Facility access

Current methods of accessing the facility and its data products, covering whether it is open skies, whether it involves a review process and the nature of this review process, any plans to change this process and current (over)subscription rates to the facility.

In the current consortium, about 90% of time on the telescope is available to researchers based at one of the consortium member universities. Consortium members can choose to reserve the time for their own use or contribute to a pool of shared time that is assessed by an independent time allocation committee (ATAC). About 10% of the time is allocated to paid time programs (open to anyone in the world). Further information is available from https://aat.anu.edu.au/science/observing/apply-for-observing-time.

Pending the outcome of an ARC grant proposal, a new AAT Consortium consisting of 9 Australian universities will be formed. The plan is to operate the AAT from July 2025 to the end of 2028 In the new consortium, up to 65% of the time will be dedicated to 4 key projects (all Australian-based astronomers can join these projects), 25% of the time will be open to smaller projects (all Australian-based astronomers can submit proposals for this time) and 10% of the time will be paid time (open to anyone in the world). ATAC will have oversight of the proposal selection process for both key and smaller projects.

Over the past ten years, subscription factors have varied between 1 and 3, as can be seen in the plot below. Since the transition in 2018, subscription factors have averaged around 1.5.

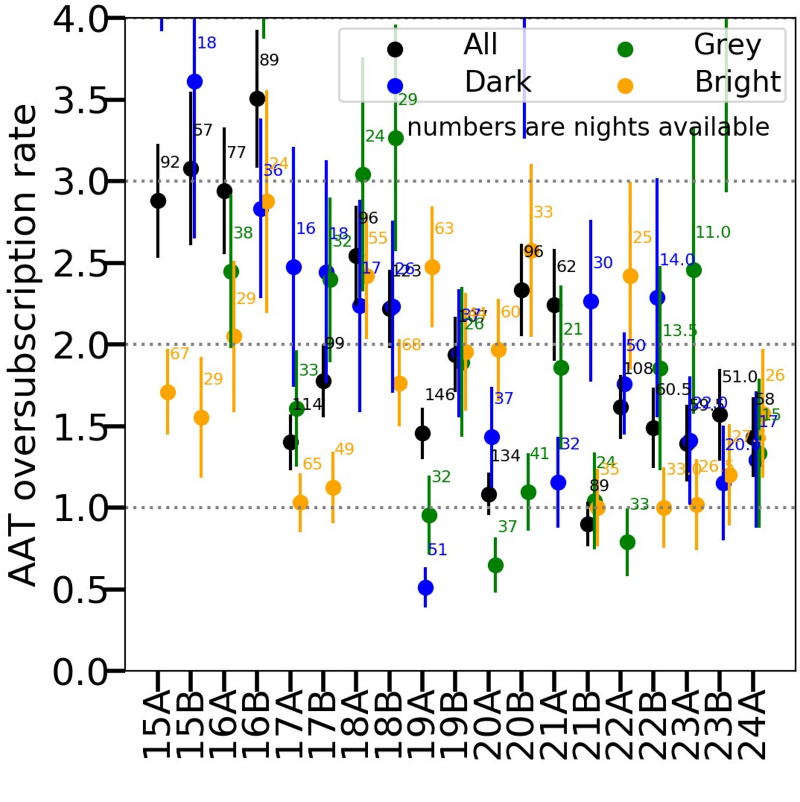


Figure 2: Subscription factors split by lunation

About 75% of operations are done remotely.

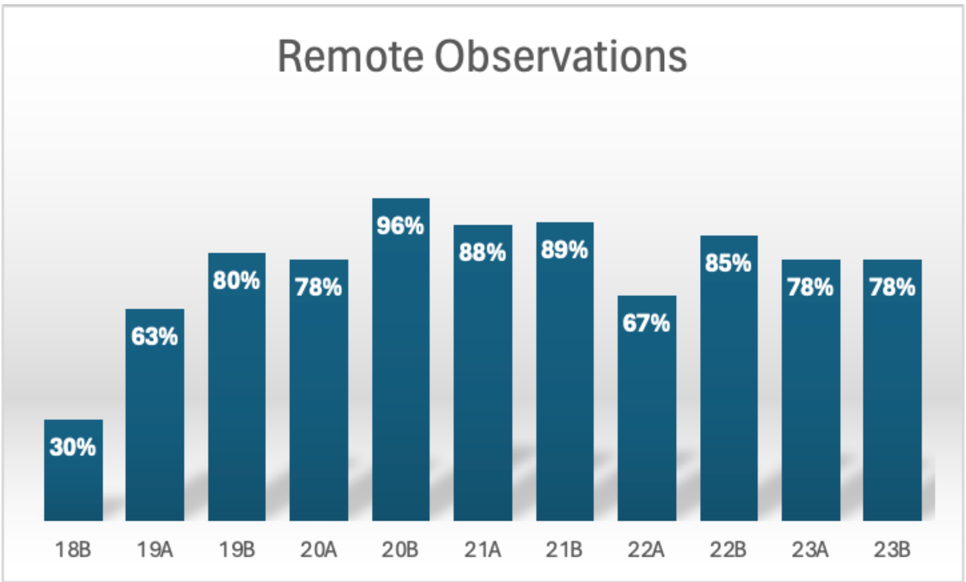


Figure 3: Fraction of observing runs done remotely. The high fraction in 2020B occurred during the COVID-19 pandemic.

Operations and staff

Current and predicted future operational requirements of the facility, including information about staffing, staff composition (including consideration of diversity) and career opportunities, funding situation for the facility, estimated lifetime if known, the management and leadership structure and any planned changes to the overall facility operation in the 2026-2035 period.

The current AAT consortium agreement ends on 30 June 2025. A new consortium of 9 Australian universities to run the telescope until the end of 2028 is being formed.

The telescopes at SSO (AAT, 2.3m, SkyMapper, and other telescopes) are maintained and operated by a single team. Three staff, including the SSO Director, form the managerial team. There is one administrator, 22 technicians, and 5 casual support astronomers. The org chart is shown below. Positions in bold are currently unfilled. 5 of the positions listed below are filled by females.

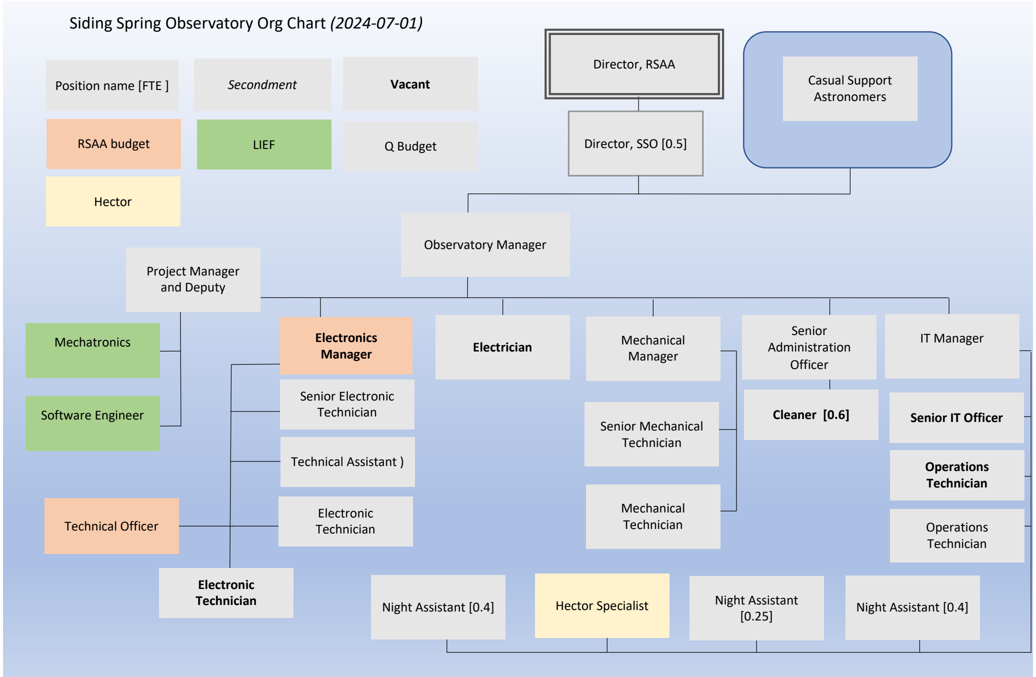


Figure 4: SSO Org chart as of 01 July 2023. Positions funded by the AAT Consortium are shaded in grey, together with an indication of the fulltime fraction. Positions funded by ANU (in coral), U. Sydney (yellow) and ARC (green are also shown).

Recruiting staff to work at the AAT and retaining them is difficult, as can be seen with the number of positions (in bold) in Fig. 4 that are currently unfilled. This is in part due to short funding horizons and salaries that are lower than those paid at equivalent technical organisations located nearby.

There are no plans to change the management and leadership structure of the organisation or to operations.

Facility metrics and outputs

Research output statistics and metrics from the facility such as publications, citations, availability of archival data products and legacy value of facility outputs.

The number of publications split by year from the AAT is shown in the following figure. Over the past decade, the number of publications has doubled.

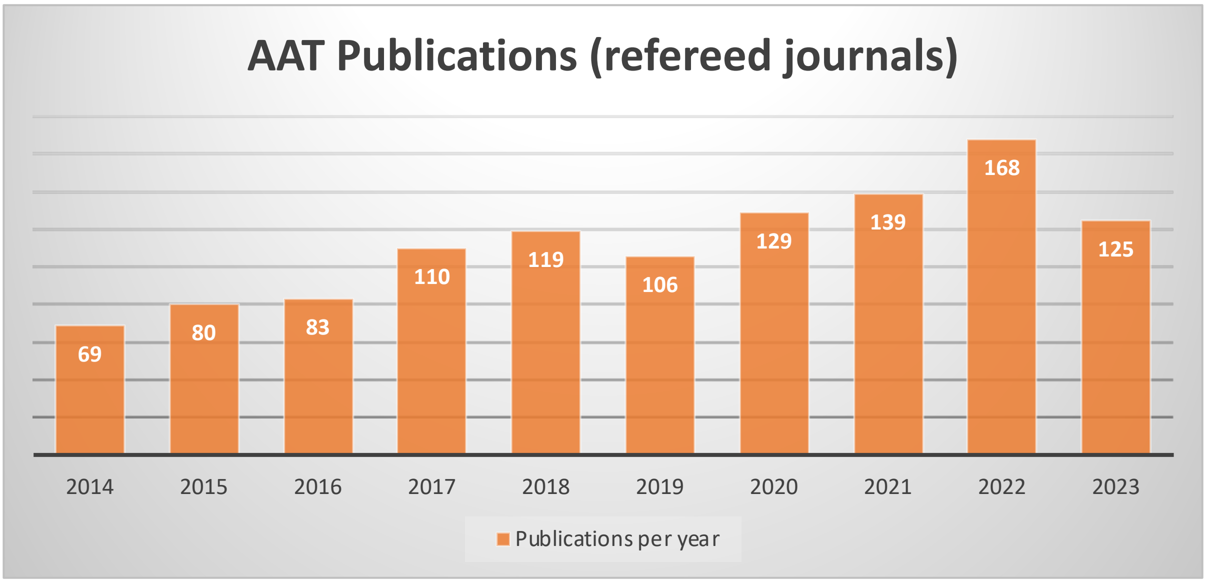


Figure 5: The number of papers including AAT data per year over the past decade. Note the gradual increase over time. Most papers come from large programs.

All data obtained at the AAT is archived at Data Central - https://archives.datacentral.org.au. The proprietary period is 18 months.

The following figure compares the AAT with other major international observatories. Total impact (citations per paper divided by median citations per paper in that year, summed over all papers) is plotted against Median Impact per Paper (MIPP). Shading shows the Fraction of High Impact Papers (FHIP) and the size of the symbol represents the number of Papers per Telescope (PpT). High-impact telescopes have large light-coloured symbols closer to the top right corner. The AAT has greater impact than most other telescopes despite its modest funding and site conditions.

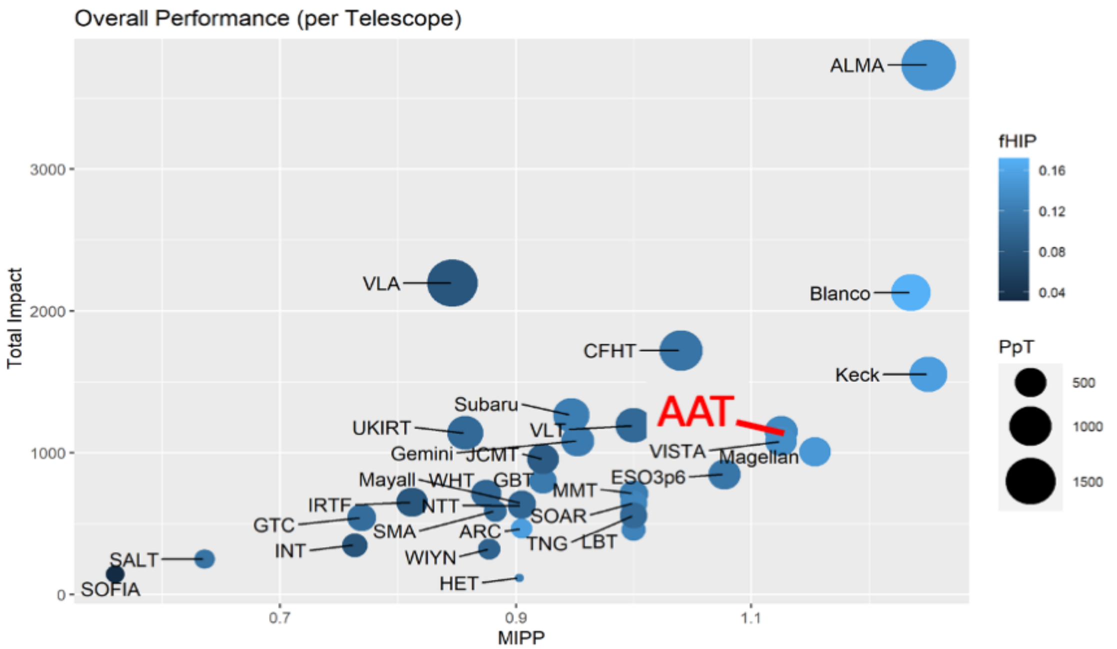


Figure 6: Comparison of global telescope performance in multiple metrics.

User satisfaction is high and constant.

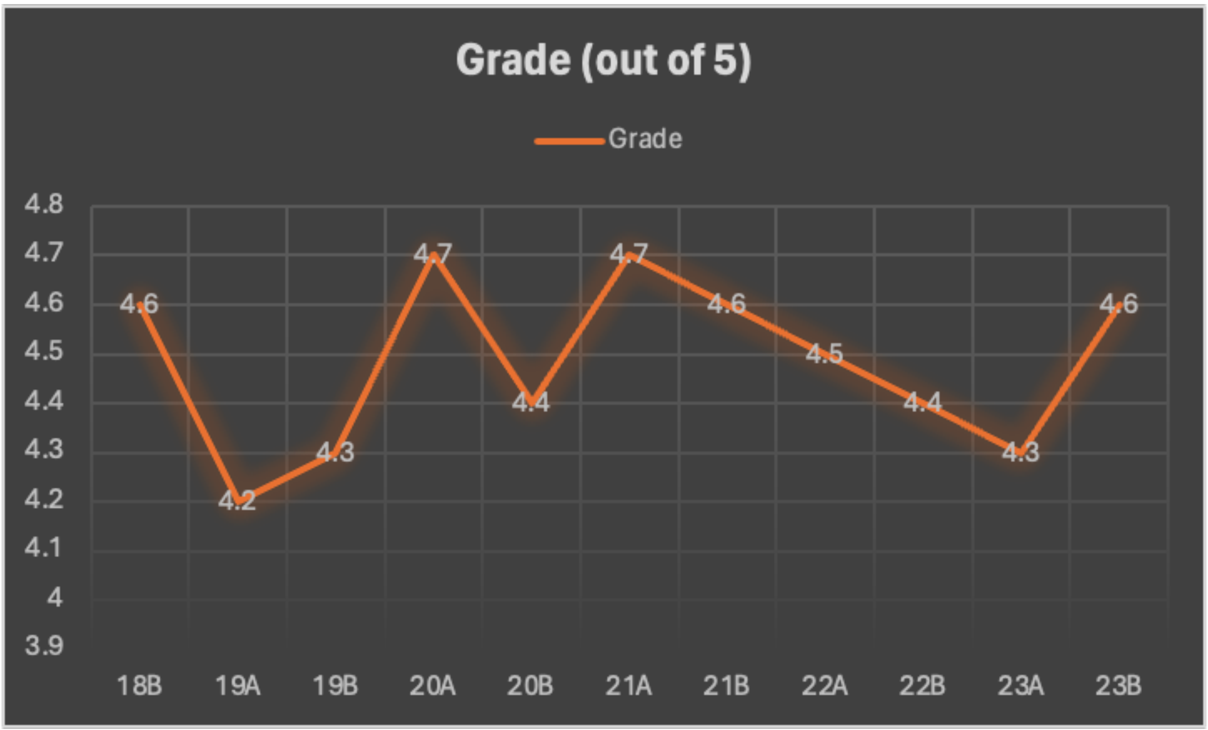


Figure 7: Average user satisfaction

Weather losses over the past 14 semesters is close to the long-term average, i.e. 30% and technical downtime mostly remains below the 5% target threshold.

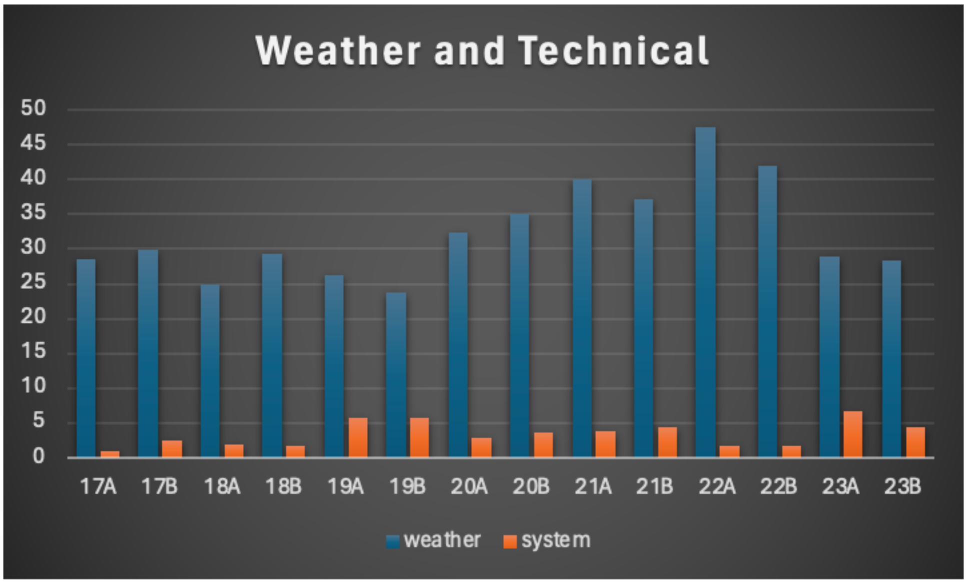


Figure 8: Downtime due to weather and technical faultss

Broader facility impact

Impact of the facility beyond the immediate purpose, including but not limited to economic impact if measured, commercial or external collaborations based around the facility, non-

astronomy technical benefits, cross-disciplinary projects and collaborations, connections/support of international facilities, etc.

About 30,000 people a year visit the AAT and SSO. It is an important tourist drawcard for the local region.

All full time AAT staff live in the local area surrounding the telescope. The annual wage bill is around $2M. Much of that will be spent in the local community. Additionally, several services (electrical, transport, cleaning, maintenance) are contracted out to local companies.

The aluminising tank at the AAT is used to coat the primary mirrors of the ANU 2.3-metre, KMTNet and Faulkes primary mirrors.

SSO lies within Australia's first internationally recognised dark sky park.

Time on the AAT can lead to significant international connections and involvement in large international projects. Here is one example.

Unlocking the mystery of dark energy is one of the key goals of the current Decadal Plan. Until recently, the Lambda-CDM model had survived the enormous improvement in constraints achieved since the original discovery of the accelerating universe. However, recent results from the Dark Energy Survey (DES) are putting the Lambda-CDM under pressure. A better model is a model in which dark energy changes with time. If verified, this would rule out Einstein's cosmological constant as the reason for the accelerating universe and represent a substantial breakthrough.

Data from AAT were crucial to the DES results. In a companion survey called OzDES, Australian researchers obtained the redshifts of supernova host galaxies with the 2dF+AAOmega spectrograph. It is an excellent example of where an in-kind contribution from Australia (in this case AAT time and human resources to run OzDES) can lead to participation in a much larger international project. DES has published over 300 papers to date.

Indigenous links and connections

Any connections of the facility to indigenous knowledge or traditional owners, collaborations with indigenous landowners, actions taken by the facility to promote First Nations involvement in the facility, etc.

The involvement with the traditional landowners is managed by the SSO Director. Over the past 12 months, the following initiatives were started

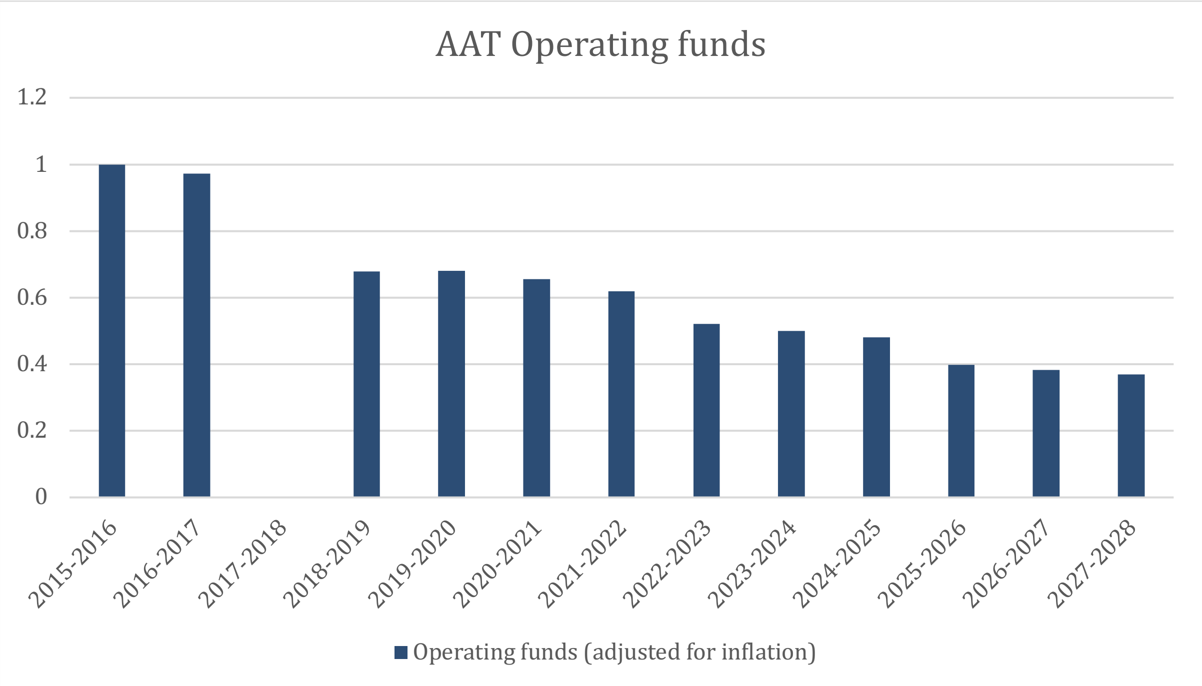
- Monthly meetings between the SSO Director and the Chair of the Local Aboriginal Lands Council
- Installation of a yarning circle at SSO
- Creation of new content highlighting indigenous astronomy for the SSO Exploratory
- Representatives from the local aboriginal community have been invited to the AAT 50th Anniversary Symposium.

Input required from the community

Outlining any input required from the broader community in terms of shaping the future of the facility or its role in the 2026-2035 Decadal Plan period, any plans for consultation with the community or any outstanding questions for the community to be aware of.

What is the role for the AAT in the 2030s once the current generation of surveys with Hector and Veloce are completed?

More immediately, how will the AAT be funded from mid-2025 onwards? Contributions from Australian universities sine the transition in June 2018 have been dropping with time and the funds available in 2027-2028 will only be 37% of the funds that were available in 2015-2016. A LIEF bid has been submitted to fill the gap to the end of 2028, but what happens if the LIEF bid is not successful?



Associated capabilities table from centralised DP process

Based on aligning scientific requirements with capabilities - e.g. capabilities required and wavelengths etc. Submitting facilities should make a copy of the Google spreadsheet containing the capabilities table, fill it in accordingly, and add any comments or follow-up in this section. Template table: [CapabilitiesTable-DP.xlsx] *(please include a URL link to the direct sheet when you submit this document, as well as a PDF version of the filled-in table)*

See the attached, which includes all facilities at SSO.

Appendices

Please use this section to attach any appendices, such as tables, figures, etc. They may also be included in the main body of the input, if preferred.

Facility name	Operated by	Spatial resolution					Spectral resolution					Other capabilities										Wavelength coverage									Multimessenger		Computation and theory							
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
AAT / KOALA	ANU	No	Yes	No	No	No	No	No	Yes	Yes	No	No	NA	Yes	No	Unsure	No	No	No	NA	No	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
AAT / Veloce	ANU	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No	NA	Yes	No	Unsure	Yes	No	Yes	NA	No	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
AAT / Hector	ANU	No	Yes	No	No	No	No	No	Yes	Yes	No	No	NA	Yes	Yes	Unsure	No	No	No	NA	No	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
AAT/ 2dF	ANU	No	Yes	No	No	No	No	No	Yes	Yes	Yes	No	NA	No	Yes	Unsure	No	No	No	NA	No	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
2.3m / WiFES	ANU	No	Yes	No	No	No	No	No	Yes	Yes	No	No	NA	Yes	No	Unsure	No	No	No	NA	Yes	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
SkyMapper	ANU	No	Yes	No	No	No	NA	NA	NA	NA	NA	Yes	NA	No	No	Unsure	No	No	No	No	Yes	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
DREAMS	ANU	No	Yes	No	No	No	NA	NA	NA	NA	NA	Yes	NA	No	No	Unsure	No	No	No	No	Yes	No	No	No	No	Yes	No	No	No	No	No	No	No	Unsure	Unsure	No	No	No	No	No
LCO	LCO	No	Yes	No	No	No	No	No	Yes	Yes	Yes	No	NA	Yes	No	Unsure	No	No	No	NA	Yes	No	No	No	No	No	Yes	No	No	No	No	No	No	Unsure	Unsure	No	No	No	No	No
KMTNet	KASI	No	Yes	No	No	No	NA	NA	NA	NA	NA	Yes	NA	No	No	Unsure	No	No	No	No	Yes	No	No	No	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No

ASKAP radio telescope

Brief description (< 200 words)

ASKAP is a rapid radio survey national facility that uses Phased Array Feed technology to observe a 30 square degree field of view with 288 MHz of instantaneous bandwidth tunable between 700 MHz and 1800 MHz. 36 antennas form an interferometer with excellent snapshot imaging quality and good sensitivity to extended emission, with baselines up to 6 km providing spatial resolution down to roughly 10” depending on the observing frequency. A unique antenna drive system with three axes of rotation provides excellent primary beam and polarisation stability. We offer observing modes that cover continuum, polarisation, spectral line and time domain science cases.

ASKAP is located in one of the most radio quiet sites on Earth at Inyarrimanha Ilgari Bundara, our CSIRO Murchison Radio-astronomy Observatory, near the site selected for SKA-Low. With an autonomous operations model and integrated supercomputing that produces science-ready data products that are released to its public archive, ASKAP makes the radio sky accessible to the world.

Additional information can be found in the following locations:

- https://research.csiro.au/askap-guide/
- https://www.atnf.csiro.au/projects/askap/index.html
- https://www.csiro.au/askap

Main purpose/s and strategic value (< 200 words)

ASKAP’s primary mission for the next five years is to observe nine large-scale Survey Science Projects with a wide range of science goals that align very well with the Decadal Plan. These include studying the structure and evolution of galaxies, in both continuum and neutral hydrogen emission, searching for transient sources and developing a new understanding of the dynamic radio sky, using source polarisation to study magnetic fields, and so on. These projects were shaped by community input and ASKAP will be one of the most prolific and significant sources of Australian astronomy data for the next decade. ASKAP is already providing real-life data challenges for the Australian SKA Regional Centre, which has active collaborations with many of the Survey Science Teams.

In addition, ASKAP offers Guest Science Project and Target of Opportunity time to ensure it remains accessible to the wider community and can respond quickly to emerging priorities.

Current and future user community

The ASKAP Survey Science Teams range in size and scope from dozens to hundreds of astronomers from Australia and internationally. We are actively seeking to promote the public availability of existing data products such as the Rapid ASKAP Continuum Survey in order to increase the impact of the telescope.

Facility access

Most of ASKAP's time is dedicated to the ongoing Survey Science Projects, but many of these projects are open collaborations that any astronomer can join. All data products deemed of sufficient quality are released promptly to the public, so everyone can make use of them. We also offer open access to merit-based time allocation each ATNF observing semester through the Guest Science Project program, and astronomers can request Target of Opportunity time that is well aligned with ASKAP's unique capabilities. Data products are accessible via the VO-compatible archive CASDA:

- https://research.csiro.au/casda/

Operations and staff

Our current vision for ASKAP is to (1) carry out an effective program of ASKAP surveys and (2) to explore telescope upgrade pathways. Such upgrades are being planned, which may improve the sensitivity of the receivers, provide larger bandwidths and/or increase the scientific capabilities of the telescope. ASKAP science depends on supercomputing facilities, such as the Pawsey supercomputing research centre, which itself will be upgraded in the future.

Facility metrics and outputs

Around 7 PB of ASKAP science-ready data is now available in our science data archive, CASDA, including early science, pilot surveys and data from the full surveys which commenced in November 2022. The already large number of ASKAP-related publications continues to grow and Guest Science Project time was oversubscribed by a factor of 2.8 in the October 2024 semester.

- https://www.atnf.csiro.au/projects/askap/askap-publications.html
- Various facility metrics are reported in the annual reports: https://www.atnf.csiro.au/the_atnf/annual_reports/index.html.

Broader facility impact

ASKAP has been used to demonstrate the effectiveness of the Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, radio-quiet site and phased array feed technology. ASKAP data sets are used to develop and test algorithms and data processing and access methods of direct relevance for future telescopes, such as the SKA project. The data processing challenges continue to lead to numerous cross-disciplinary projects in terms of, for example, astronomical data reduction and visualisation.

Indigenous links and connections

There are direct connections between ASKAP and Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, radio-quiet site and the Indigenous community. An Indigenous Land Use Agreement was set up for the initial observatory site in 2009, and again for the expanded site in 2022. Each survey science project is represented by an original artwork from a Wajarri Yamaji artist, and each ASKAP dish has a name in the Wajarri language. There are regular outreach and education activities between CSIRO and the local Wajarri community.

Input required from the community

CSIRO ATNF have developed their own document to support the 2026-2035 Decadal Plan, which describes our vision for our instruments and future pathway. We are currently accepting feedback on that document and will produce a final version on a similar timescale to this document.

Associated capabilities table from centralised DP process

ASKAP CapabilitiesTable-DP.xlsx

Facility name	Operated by	Spatial resolution					Spectral resolution					Other capabilities										Wavelength coverage									Multimessenger		Computation and theory							
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
ASKAP	CSIRO	Yes	Yes	Partial	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	Partial	Partial	Yes	Yes	Yes	Yes	Yes	Yes	NA	NA

Australia Telescope Compact Array (ATCA)

Brief description (< 200 words)

The Australia Telescope Compact Array (ATCA), at the Paul Wild Observatory, is an array of six 22-m antennas used for radio astronomy. It is situated near the town of Narrabri in NSW. Details are available from https://www.narrabri.atnf.csiro.au/. It has flexible array configurations with a maximum baseline length of 6km. The receiver fleet covers bands from 1 GHz to 105 GHz and the backend instrumentation allows for various scientific observing modes.

Main purpose/s and strategic value (< 200 words)

The ATCA is a versatile interferometer with a rapid response mode for quick, frequency-agile, follow-up of astronomical events as well as a wide frequency coverage and significant observing time available for long-term monitoring programs. It is an extremely flexible instrument and, over decades, has been used for numerous discoveries. ATCA is also an integral part of the Long Baseline Array and international VLBI programs.

Current and future user community

ATCA is part of the Australia Telescope National Facility and details of the user community can be obtained from the annual reports that are available from https://www.atnf.csiro.au/the_atnf/annual_reports/index.html. We continually look for ways to increase and diversify our user community and the new BIGCAT backend system will enable new research areas by providing 8 GHz bandwidth and flexible GPU-based astronomy modes will enable a new range of science capabilities. We provide options for our users to apply through a time-allocation-process and also through the purchase of observing time.

Annually, we also hold a Radio School in which we invite students and researchers to become acquainted with the technology, and hear from CSIRO researchers and engineers developing the technology to enable great science.

Facility access

The Australia Telescope National Facility has two open calls for proposals each year. Each proposal is anonymised and reviewed by the ATNF Time Assignment Committee (TAC). The oversubscription rates are reported in the annual reports: https://www.atnf.csiro.au/the_atnf/annual_reports/index.html. Data products are currently made available through the Australia Telescope Online Archive (https://atoa.atnf.csiro.au/), but the archive will soon be hosted within the CSIRO ASKAP Science Data Archive (CASDA;

https://research.csiro.au/casda/). ATCA also accepts Target of Opportunity proposals for unforeseen events, however ATNF strongly encourages potential users to submit proposals via the standard call for proposals.

Operations and staff

As part of the ATNF, ATCA is supported by CSIRO staff across all our sites in addition to staff based at the Paul Wild Observatory. We are actively searching for additional external funding to support the operation of the ATCA into the 2026-2035 period. External funding (e.g. through the sale of telescope time) will allow us to transition ATCA to new roles as some of its core capabilities become substantially, but not entirely, supplanted by SKA-Mid. The control and power systems of the six antennas is currently undergoing infrastructure upgrade to improve safety, maintainability and reliability.

Facility metrics and outputs

Various facility metrics are reported in the annual reports: https://www.atnf.csiro.au/the_atnf/annual_reports/index.html.

Broader facility impact

As well as astronomical observations ATCA is planned for use in spacecraft tracking and space situational awareness experiments. ATCA also serves as a practical training ground for emerging radio astronomers, providing invaluable hands-on experience and part of international VLBI networks. The observatory site also hosts a visitors centre which is open to the public, offering educational exhibits and general information about our facilities to enhance visitors' understanding of astronomy and space science.

Indigenous links and connections

We are working with the local Indigenous Gomoroi community towards the naming of the telescope and to develop further connections with the Traditional Owners.

Input required from the community

CSIRO ATNF have developed their own document to support the 2026-2035 Decadal Plan, which describes our vision for our instruments and future pathways. We are currently accepting feedback on that document and will produce a final version on a similar timescale to this document.

Associated capabilities table from centralised DP process

ATCA CapabilitiesTable-DP.xlsx

Facility name	Operated by	Spatial resolution					Spectral resolution				
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution
ATCA	CSIRO	Yes	Yes	Partial	No	No	Yes	Yes	Yes	No	No

Facility name	Other capabilities									
	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering
ATCA	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Facility name	Wavelength coverage									Multimessenger	
	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle
ATCA	No	Yes	Yes	No	No	No	No	No	No	Partial	Partial

Facility name	Computation and theory							
	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
ATCA	No	Partial	Yes	Yes	No	No	NA	NA

CSIRO

Australia's National
Science Agency

The Australia Telescope National Facility from now to 2035

August 2024

1 Overview

This document describes our 10-year vision for CSIRO's Australia Telescope National Facility (ATNF) and is provided as an input to preparing the Australian Astronomy Decadal Plan for the period 2026 to 2035. The principles included here have been developed in consultation with ATNF staff, the ATNF Steering Committee and the user community as described in the final section.

Once operational, the two SKA telescopes – SKA-Mid and SKA-Low – will undoubtedly dominate the radio astronomy landscape in their specific research areas. Smaller, more agile instruments will complement the SKA telescopes and will remain essential for long-term monitoring, probing high angular resolutions, flexibly responding to new areas of research and exploiting changing technology to develop future instrumentation.

Enhancements to our facilities will be driven by the evolving science cases made possible by the next generation of telescopes, not only from the SKA telescopes and others operating across the electromagnetic spectrum but also from gravitational wave observatories and neutrino detectors. Such upgrades will maintain the ATNF for the wide-ranging science carried out by the global astronomy community. We aim to maximise Australia's investment in joining and co-hosting the SKA project in part by using the ATNF facilities explicitly to support, extend and complement the SKA telescopes.

This document has two primary goals:

- to be CSIRO's stand-alone submission to the National Committee for Astronomy describing CSIRO's vision for the role of the ATNF in the era of science conducted with the SKA telescopes, and
- to respond to Decadal Plan Working Group 2.2 National and University Facilities on the capabilities of the ATNF over the coming decade.

Our current facilities, capabilities and planned upgrades are described in Section 2 and summarised in the Appendix. Our vision for the ATNF in the SKA era is presented in Sections 3 and 4.

2 CSIRO's Australia Telescope National Facility

CSIRO operates several radio astronomy observatories and data archives that are collectively known as the Australia Telescope National Facility (ATNF). We are comprised of specialists who work across operations, research and technology. Our technology development program is the cornerstone of the ATNF and is an internationally recognised source of innovative radio astronomy instrumentation, which can lead to industrial spinoffs.

Modern radio astronomy has become dependent on robust firmware, sophisticated embedded computing infrastructure, large-scale data archives, real-time processing algorithms and specific expertise. The ATNF boasts a comprehensive range of expertise, spanning from the intricacies of front-end receivers to deploying machine learning algorithms for analysing the vast data volumes contained within our archives to evolving observatory operations to be increasingly autonomous.

The ATNF includes:

- Our technology, science, operations and software groups which drive new research, technologies and operate our instruments and sites,
- the ASKAP radio telescope with its wide field of view in a legislated radio quiet zone,
- the Australia Telescope Compact Array (ATCA) with its wide frequency coverage, quick response times and flexible configurations,
- Murriyang, our Parkes radio telescope, which is the only large single dish radio telescope dedicated to science observations in the southern hemisphere,
- the Long Baseline Array (LBA) providing VLBI baselines across Australia,
- the Mopra antenna, which is used for single-dish observations, particularly at millimetre wavelengths and as part of the ATNF during LBA sessions, and
- astronomical data archives that currently provide 10PB of data, as well as various catalogues, databases and software packages used for obtaining and processing data from our facilities.

For two semesters per year, the ATNF accepts Principal Investigator-driven proposals from the national and international community. ASKAP also carries out long-term science programs driven by large science teams.

The ATNF activities are detailed in our annual reports. We acknowledge support for our operations from the National Collaborative Research Infrastructure Strategy (NCRIS) as well as the sale of telescope time for astronomy or for space-related activities and the sale of our technology to other observatories.

Figure 1: Wajarri artist Margaret Whitehurst's artwork, *RACS*, was commissioned to celebrate ASKAP's first all-sky survey. ASKAP operates on the traditional lands of the Wajarri Yamaji at Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory. As part of broader initiatives within CSIRO, there is a commitment to invest in Aboriginal and Torres Strait Islander cultural knowledge in relation to science, and the greater participation of Aboriginal and Torres Strait Islander peoples in Australia's research and innovation landscape. This commitment will continue across the ATNF through employment opportunities, naming of instruments and infrastructure, and many other initiatives.

Current ATNF capabilities

Technology development

The world-leading ATNF instrumentation group works closely with our science and operations teams to develop and deliver innovative technologies for radio astronomy and industry. Recent ground-breaking instruments include novel wide-field receivers, such as the phased array feeds for Murriyang and ASKAP, as well as receiver and digital signal processing systems with unparalleled bandwidths, such those that power ATCA and Murriyang. Continued support for this technology development capability is essential to drive future innovation, both for our own unique national facility telescopes as well as for any prospective upgrades to the SKA project.

Murriyang, our Parkes radio telescope

Murriyang, on Wiradjuri Country, is used for high cadence monitoring campaigns of large numbers of sources such as pulsars, studying atomic hydrogen, and carrying out continuum and polarisation surveys. Being the primary single-dish telescope in the southern hemisphere, it provides zero-spacing data for interferometric data sets for surveys of diffuse radio sources and Galactic hydrogen. Murriyang remains an integral component of the Long Baseline Array (LBA).

The GPU-based backend instrument is highly flexible allowing commensal observations of spectral line, continuum and high-time resolution data sets. Murriyang will be expanded with a suite of wide-bandwidth receivers operating from 700 MHz to 27 GHz along with a survey capability stemming from a new cryogenically cooled phased array feed receiver (CryoPAF).

With new survey capability from the wide field of view available with the CryoPAF, Murriyang will survey large sky areas with both high time resolution and high spectral resolution.

Australia Telescope Compact Array (ATCA)

ATCA, on Gomeroi Country, responds extremely quickly to automatic triggers of astronomical events, has wide frequency coverage, and flexible array configurations. The backend system is currently being upgraded with a more flexible system (known as BIGCAT) that will increase the available bandwidth up to 8 GHz and allow for the formation of sub-arrays. ATCA is a key element of the LBA and international very long baseline interferometry (VLBI) networks.

The astronomical community is increasingly using ATCA for time-sensitive observations, capitalising on its extensive frequency range to complement discoveries from high-energy space telescopes and gravitational wave detectors. ATCA also serves as a practical training ground for emerging radio astronomers, providing invaluable hands-on experience.

Looking ahead, some of ATCA's mid frequency capabilities will be superseded by the SKA-Mid telescope and we are actively seeking ways to transition ATCA to new roles in order to ensure its financial future. Opportunities currently under consideration include expanding its contributions to spacecraft tracking and space situational awareness.

ASKAP radio telescope

With its wide field-of-view, spatial and spectral resolution, frequency coverage, direct links to high performance computing infrastructure, remote autonomous operations model and situation on a legislated radio-quiet site, ASKAP, on Wajarri Yamaji Country, is an ideal survey instrument.

Already it has made completely unexpected discoveries from giant odd radio circles to ultra-long-period transient sources, found millions of galaxies and has significantly increased the number of fast radio bursts localised to their host galaxies. With its unique three-axis rotation, ASKAP has exceptional polarisation capabilities, which are being exploited in studies of cosmic magnetism.

ASKAP commenced the full surveys for which it was designed in late 2022, and these are expected to take around five years to complete.

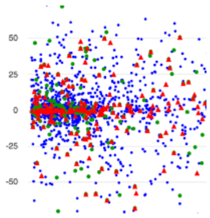
Current plans for ASKAP upgrades include improving high-performance computing reliability and data flow. Later upgrades to ASKAP would include increasing its sensitivity with the next generation of phased array feed receivers.

Long Baseline Array (LBA)

The LBA is the only VLBI network in the southern hemisphere and will be enhanced by the upgrades to the component elements described in the telescope sections above.

The LBA currently operates in the mid and high radio frequency bands generally scheduled during a few weeks each year. The primary goal of the LBA is to provide the highest possible angular resolution for imaging and for astrometry.

Incremental upgrades in bandwidths will become available from 2025. This will progressively allow bandwidth increases up to a factor of eight. Phased-array feeds operating across the same band at both ASKAP and Murriyang will enable a new capability of a single VLBI baseline over the overlapping bands between the ASKAP and Murriyang receivers.



Data processing and archives

Data processing pipelines and archives are now an integral part of the ATNF:

- Our high-time-resolution datasets from Murriyang are archived in the CSIRO Data Access Portal.
- Data from ASKAP are processed automatically using online pipelines and science-ready data products are then made available in the CSIRO ASKAP Science Data Archive (CASDA).
- Spectral line and continuum observations from Murriyang as well as data from ATCA are archived in the Australia Telescope Online Archive (ATOA). These are currently being migrated into CASDA.

These data archives are increasing at approximately 4PB/year, and this growth rate will double in a few years. Our continued upgrade path relates to improved pipeline data processing methods and towards cloud-based processing and access methods.

3 The role of the ATNF in the SKA era

The ATNF already supports and complements the current generation of radio telescopes such as the highly sensitive Five-hundred-meter Aperture Spherical Telescope (FAST), the Atacama Large Millimeter/submillimeter Array (ALMA) at high radio frequencies, and the Giant Metrewave Radio Telescope (GMRT) and the Murchison Widefield Array (MWA), which observe at low frequencies. We also operate alongside the current generation of optical, high-energy, gravitational wave and other multi-messenger observatories.

The incoming generation of radio telescopes will include the SKA telescopes themselves, large single telescopes such as the Qitai radio telescope and the optical Vera Rubin Observatory. Various large-scale radio instruments are proposed and likely to become operational during the period of the decadal plan, including the ngVLA and the DSA-2000, both in the northern hemisphere and both with capabilities that overlap with our instruments. As described in the remainder of this section the ATNF has a variety of roles to play alongside these observatories.

Extending the capabilities of the SKA telescopes

The ATNF has been involved with the SKA project from its initial planning. ATNF staff have provided intellectual contributions to its design and to delivering instrumentation and local infrastructure in Australia. The ATNF's locations, telescopes and engineering expertise are in an excellent position to support and extend the science goals of the SKA telescopes over the next decade.

Improving the resolution of SKA-Low

SKA-Low is designed for baselines up to 74 km. With our observatory sites on the eastern side of Australia we could extend these baselines to over 3000 km. This would enable the resolution of SKA-Low to match that of the James Webb Space Telescope (JWST). Our Low-frequency Australian Megametre-Baseline Demonstrator Array (LAMBDA) is being developed for this purpose. A fully operational LAMBDA would provide a major addition to the SKA-Low capabilities, allowing many of the SKA VLBI science cases to be achieved, including the study of distant galaxies from the early Universe at sub-Galactic scales as well as the detection and imaging of the non-thermal radio emission from extra-solar planets, which requires sub-arcsecond resolution. As a pathway towards this longer-term goal, we are currently developing an early prototype and increasing our staff expertise in low-frequency VLBI.

Complementing SKA-Low with precision radiometers

Our development of precision radiometers, such as the Global Imprints from Nascent Atoms to Now (GINAN) system, advances our strength in developing high performance antennas and receivers operating in and around the SKA-Low observing frequencies. Such radiometers will provide the absolute calibration of the radio sky required for setting the flux density scale needed for SKA-Low measurements. Additionally, such systems enable niche, high-risk, high-gain science measurements of the global cosmological 21-cm signal that are complementary to the Epoch of Reionisation science to be carried out with SKA-Low.

Complementing the SKA telescopes with our current facilities

Our current ATNF facilities, ATCA and Murriyang, will provide larger instantaneous bandwidths than available with the SKA telescopes, long-term monitoring with high cadence observations and smaller-scale PI-driven science. Murriyang will also provide zero-spacing single-dish data sets, while ATCA will provide fast triggered follow-up observations. As foreshadowed by Fender et al. (2024) there is strong scientific benefit of such an array in the southern hemisphere.

SKA-Mid will lack the high resolution required to meet many of its scientific goals. This will come from the SKA telescopes acting as a sensitive element within existing VLBI arrays, or through the follow-up of SKA-led discoveries with independent VLBI arrays. The LBA has already demonstrated effective VLBI networks with the Hartebeesthoek telescope in South Africa and hence will continue to provide the southern hemisphere VLBI network in the SKA era.

Situated alongside SKA-Low, ASKAP will have a direct role in commensal observations. An exciting new science area for SKA-Low is the study of space weather, which has both societal applications and astrophysical interest. Through the study of interplanetary scintillation, SKA-Low will probe the magnetic field of coronal mass ejections at relatively large solar radii. Commensally, ASKAP will probe the same events, but at much closer radii. Together they will allow us to probe how space weather events evolve across interplanetary space.

Supporting the community through computing and algorithm development

We continue to take an active role in exploring, implementing and testing new algorithms relevant for next-generation radio astronomy facilities, including high dynamic range wide-field, spectral and polarimetric imaging, transient detection, efficient dedispersion and anomaly detection methods. The primary drivers are increasing the parameter space that we probe with our telescopes, maximising the probability of identifying signals of interest, while minimising the friction between observations and analysis. We also collaborate with international partners on distributing and exchanging expertise in efficient observatory operations.

Computing, algorithms and data centres are therefore fundamental to our goals. Computing technology evolves fast and the ATNF will maintain a research focus in this area to ensure that our solutions remain compatible with current and future, even speculative, advances. High-performance computing (HPC) and machine learning algorithms will continue to be an important focus, but quantum computing technology is advancing quickly. The dominant technology choice is yet to emerge and the potential applications to radio astronomy still need to be explored.

The SKA regional centres (SRCs) will provide access to the SKA telescopes' data products as well as providing platforms for advanced scientific analysis. The ATNF is a major participant in these data centres and the Australian SKA Regional Centre (AusSRC) is already enhancing its functionality through the processing of ASKAP survey data.

Mitigating the risks of radio frequency interference

Radio frequency interference (RFI) is currently a limiting factor for our ATNF telescopes in many of their primary observing bands. At the ATNF we are developing and implementing mitigation methods through software, hardware or legislative means. This work is essential for continued ground-based radio astronomy. We continue to be at the forefront of research into mitigation strategies and across all aspects of spectrum management for Australian astronomy. Such work will be invaluable across the coming decade, with our infrastructure ideal for assessing methods.

A pathway towards new capabilities for Australian astronomers in the SKA-era

Upgraded phased array feeds for ASKAP

Our technology and instrumentation development program is world-leading in the development of phased array receivers that have led to wide field-of-view survey instruments. Next-generation phased array feeds (PAFs) installed on the ASKAP antennas would revitalise the telescope in the SKA science era. In particular, we are planning a factor of two improvement in the current system temperature of the ASKAP PAFs. ASKAP will then be comparable to SKA-Mid for wide-area surveys, but with significantly more available observing time, at a tiny fraction of the cost and without the computational overheads required to process the data streams (and hence enable surveys with high-time or high-frequency resolution over wide sky areas). An upgraded ASKAP would be complementary to SKA-Mid, which is better suited for deep, pointed observations. We are currently developing a prototype next-generation PAF which will be installed on an ASKAP antenna as a demonstrator. This prototype will demonstrate the performance of the system and test the feasibility of a major upgrade of all the antennas. We will work with the wider astronomy community to develop the science case for a fully upgraded ASKAP, for which new funding would be needed.

Figure 2: Phased array technology is driving much of our technology development. This picture is of the cryogenically cooled phased array feed receiver (CryoPAF) for Murriyang being worked on by Santiago Castillo, our Senior Research Technician; we are also developing new systems for ASKAP and leveraging our expertise in phased-array technology for both commercial and astronomical applications.

An all-sky radio monitor

An obvious extension of our phased array technology is an aperture array with sufficient processing capacity to allow a significant section of the sky to be observed from a given site. Continuous monitoring, with sufficient sensitivity and frequency coverage, would complement all existing radio telescopes. Such an instrument would allow the detection of whole populations of transient sources as well as continuous monitoring of known sources from rise to set on a daily cadence. We are exploring the possibility of using LAMBDA (or similar) to form a low-frequency all-sky monitor, which will explore the transients at low frequencies. There is also a long-term goal where an aperture array with the sensitivity of Murriyang in the 0.5 to 1 GHz range and outriggers to > 10 km allows millions of fast radio bursts to be detected and localised. Such data sets would dominate cosmological studies out to high redshift, while being an ideal multi-messenger instrument. These will identify radio events linked to sources detected in any other waveband, and other multi-messenger all sky detectors, such as the gravitational wave instruments.

4 CSIRO’s vision for the upcoming role of the ATNF

During the 2026-2035 Australian Astronomy Decadal Plan period, CSIRO’s vision is to:

- continue to support a world-class technology and instrumentation development program (including software, hardware, the exploration of novel science that drives our instrumentation and cutting-edge experimentation) for future Australian and global radio astronomy,
- carry out an effective program of ASKAP surveys and explore telescope upgrade pathways,
- continue to operate Murriyang with a substantial program of external revenue to help fund its availability for science. The development of the UWB/M-H receiver will significantly increase its capabilities,
- transition ATCA to new roles as some of its core capabilities become substantially, but not entirely, supplanted by SKA-Mid,
- work with the community to define the SKA-era VLBI model, which will include continuing participation in mid-frequency VLBI and increasing our capability in low-frequency astronomy,
- include Aboriginal and Torres Strait Islander cultural knowledge in relation to science, and have greater participation of Aboriginal and Torres Strait Islander peoples in Australia’s research and innovation landscape.

We will continue to maintain a ‘ready to serve’ stance regarding broad priorities of the Australian astronomy community, not just in radio astronomy, and will continue to engage in national discussion about how best to support government in forming a compelling case for Australian full membership in the European Southern Observatory (ESO) and third-generation gravitational wave detectors.

We acknowledge the Traditional Owners of the lands of all our sites and pay our respect to their Elders past and present:

The Astrophysics Lab, Marsfield, Wallumattagal People

Paul Wild Observatory, Narrabri, Gomeroi People

Parkes Observatory, Parkes, Wiradjuri People

Mopra Observatory, Coonabarabran, Gamilaroi People

ARRC, Kensington, Whadjuk People of the Noongar Nation

Murchison Support Facility, Geraldton, Nhanhangardi, Naaguja, Wilunyu and Amangu Peoples

Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory, Wajarri Yamaji People

Further reading

This document was initially based on the outcomes of a set of working groups in 2023 who considered the ATNF of the Future in the following documents:

- Future developments and opportunities in broad-EM and multi-messenger astronomy
- ATNF Science and Users
- Computing, algorithms and data centres
- Operating models and technology pathways for ATNF
- Working with and supporting the SKA

We also made use of the following publicly available documents:

- ATCA Future Science Plan 2020 [*14MB PDF*]
- Parkes Future Science Case 2020 [*37MB PDF*]
- ASKAP in the era of the SKA 2022 [*5MB PDF*]
- Tracking space weather events with ASKAP and Parkes 2022 [*2MB PDF*]
- Fender et al. (2024), https://arxiv.org/pdf/2402.04698

We acknowledge the ATNF of the Future discussions and working groups coordinated by George Heald and the ATNF User Committee meetings and science days. The first draft of this document was prepared by George Hobbs, Elizabeth Mahony, Mark Bowen and Eric Bastholm. We acknowledge significant contributions to this document from Rachel Rayner and Elaine Sadler.

Appendix: Summary of facility capabilities

Existing facilities of the ATNF, and those currently under development, are listed here with their current capabilities and improvements planned over the next four years. This table is designed to provide an overview of the current facility and the initial commitments which support our vision for the Decadal Plan.

	Facility	Description	Current capabilities	Planned upgrades
Existing	**ASKAP**	36 12-m antennas with a fixed array configuration. The dishes can rotate around the optical axis.	Phased array feeds providing 36 beams between 0.7 and 1.8 GHz. Embedded high performance computing and production of science-ready data products. Autonomous remote operations.	**2024+:** More stable high-performance-computing infrastructure. **2027+:** Improved sensitivity through new phased array feeds and potentially increased bandwidth.
	ATCA	Six 22-m antennas with flexible array configurations with a maximum baseline length of 6 km.	Frequency coverage: 1.1-3.1 GHz, 4-12 GHz, 16-25 GHz, 30-50 GHz, 83-105 GHz Two 2048 MHz bands, zoom-bands, pulsar-binning	**2025:** Backend upgrade to allow 8MHz bandwidth and flexible GPU-based astronomy modes. Infrastructure upgrade to ensure viability of continued ATCA operations.
	LBA	Long-baseline array consisting of the ATNF telescopes (Murriyang, ATCA and Mopra) as well as other national (Hobart, Ceduna, AuScope) and international telescopes.	Frequency coverage from 1.3 to 24 GHz Mopra/ATCA+international: 44 and 88 GHz VLBI	**2026+:** Bandwidth increase by up to a factor of 8. Potential ASKAP inclusion into the LBA. Potential ASKAP-Murriyang 700 MHz VLBI.
	Mopra	Single dish 22-m radio telescope, which is an integral part of the LBA, but not currently available for single dish, principal-investigator driven proposals.	Frequency coverage available in the following bands: 1.2–1.8, 2.2-2.8 GHz; 4.0–6.7 GHz and 8.0–9.2 GHz; 16–27 GHz; 30–50 GHz; and 76–117 GHz	Matching frequency coverage with ATCA, BIGCAT-style backend and realtime connection between Mopra and the BIGCAT correlator at ATCA.
	Murriyang	Single dish 64-mradio telescope at the Parkes Observatory	Wide-bandwidth single pixel receiver operating between 704 and 4032 MHz	**2024**: Cryo-PAF providing up to 72 beams between 700 MHz and 2 GHz

			8.1-8.5 GHz single pixel receiver Flexible GPU-based backend system providing commensal high-frequency and high-time resolution data streams and pulsar binning.	**2027:** wide-bandwidth, single pixel receivers operating between 4 and 27 GHz.
	Data archives and access	Either the raw data sets are directly archived (for Murriyang, ATCA and LBA), or after pipeline processing scripts have been applied for ASKAP.	CSIRO's Data Access Portal contains pulsar and fast radio burst data sets from Murriyang. The ATOA contains spectral line and continuum data from Murriyang as well as ATCA files. The CASDA archive stores ASKAP science-ready data products.	**2024:** The ATOA is currently being migrated to CASDA. **2025+** We expect more automated processing as data volumes are becoming prohibitive for storing all the raw data sets. Explore the use of cloud-based platforms for users to access and process data.
Moving towards	**LAMBDA**	Low-frequency VLBI capability to extend the SKA-Low in the ~150 to 350 MHz frequency band.	Test-bed systems currently being designed	Potential for three or more stations each with 256-elements across Australia with initial stations on our existing East-coast sites.
	Ginan	Low-frequency precision spectral radiometer	Ongoing development	Installation initially at Inyarrimanha Ilgari Bundara, our Murchison Radio-astronomy Observatory
	All-sky monitors	Aperture arrays providing very wide field-of-views and continuous monitoring.	Test-bed systems currently under consideration including a GREX antenna and our own instrumentation	Potential for a range of all-sky monitors from compact, insensitive systems to large collecting area facilities operating in the ~700 to 1000 MHz band and a potential all sky backend for the LAMBDA stations to operate at low frequencies.

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Long Baseline Array (LBA)

Brief description (< 200 words)

The Long Baseline Array (LBA) is a partnership between CSIRO, the University of Tasmania, SpaceOps NZ, and SARAO, which CSIRO manages. By joining ATNF instruments with radio telescopes across the southern hemisphere, very long baseline interferometry, or VLBI, is achieved. The fine angular resolution achieved by having telescopes spread between continents means astronomical phenomena can be studied in such detail that the physics behind their origin can be probed.

Main purpose/s and strategic value (< 200 words)

The LBA is the only cm-band astronomical VLBI array in the southern hemisphere and so provides the highest-angular resolution imaging available. It has good frequency overlap with SKA-Mid and so will be critical to providing good (u,v) coverage for southern hemisphere sources in the SKA era.

Current and future user community

The LBA user community is a mix of Australian and international users. Follow-up of ASKAP-detected sources is likely to increase and diversify the LBA user community, a trend which has already started.

Facility access

The LBA operates as an ATNF facility with open skies and the same anonymised peer-review process, such as with other ATNF telescopes.

Operations and staff

It is difficult to put a number on the staffing levels of the LBA, as all facilities have their own local staff providing maintenance, upkeep and operations. Within ATNF there is approximately 2 FTE spread over a handful of people providing LBA support, from scheduling and interfacing with PIs, to observing support, and data correlation.

Facility metrics and outputs

Various facility metrics are reported in the annual reports:
https://www.atnf.csiro.au/the_atnf/annual_reports/index.html.

Broader facility impact

Apart from regular astronomical observations, the LBA (and LBA elements) have participated in astrometric and geodetic observations, making contributions to other areas of research. DiFX, developed at Swinburne by Adam Deller for LBA data correlation, has become the international standard software correlator, and ATNF staff contribute to its ongoing development. ATNF staff also contribute to the international VLBI community via technical working groups, and a developing Global VLBI Alliance.

Indigenous links and connections

This is managed directly by individual facilities rather than by the LBA. Within CSIRO, instruments of the LBA: Murriyang, ATCA and Mopra, have strong and growing engagement with Traditional Owners.

Input required from the community

CSIRO ATNF have developed their own document to support the 2026-2035 Decadal Plan, which describes our vision for our instruments and future pathway. We are currently accepting feedback on that document and will produce a final version on a similar timescale to this document.

Associated capabilities table from centralised DP process

LBA CapabilitiesTable-DP.xlsx

Facility name	Operated by	Spatial resolution					Spectral resolution					Other capabilities										Wavelength coverage									Multimessenger		Computation and theory							
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
LBA	CSIRO	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	Partial	Partial	No	Partial	Yes	Yes	No	No	NA	NA

Brief description (< 200 words)

Overview of the facility in question, including limited information about specifications and references to where further information can be accessed.

Minerva-Australis is an array of (1x0.8m and 4x0.7m) telescopes feeding a high-resolution spectrograph. All telescopes also have precision photometric capability. Its main purpose is precise radial velocities for exoplanet mass measurements.
https://ui.adsabs.harvard.edu/abs/2019PASP..131k5003A/abstract
SONG-Australia consists of an array of 0.7m telescopes feeding a second high-resolution spectrograph to obtain precise radial velocities of stars for asteroseismology.

Main purpose/s and strategic value (< 200 words)

Role and purpose within the broader landscape of national and university facilities, including consideration of the strategic value of this particular facility or facilities in terms of advancing the goals of the community and Decadal Plan.

Minerva-Australis is Australia's most precise radial velocity instrument, playing a valuable role in the characterisation and confirmation of exoplanets, in particular engagement with the NASA Transiting Exoplanet Survey Satellite (TESS) mission.
SONG-Australia is part of the global Stellar Oscillations Network Group, and its longitude is critical for the network's global time coverage (other nodes in Tenerife and China, with a US node coming online in late 2025).

Current and future user community

Description of the user community, including demographics (e.g. local vs. national vs. international users) and any plans for diversifying this user community in the coming decade.

Minerva-Australis: Accessible by consortium members and their close collaborators.
Competitive proposal-based access to US PIs until September 2026.
SONG: Accessible by consortium members and their close collaborators.

Facility access

Current methods of accessing the facility and its data products, covering whether it is open skies, whether it involves a review process and the nature of this review process, any plans to change this process and current (over)subscription rates to the facility.

NASA access by competitive proposals has oversubscription of 1.0-1.4.
All Minerva-Australis data products from all programs are freely accessible on the NASA Exoplanet Archive.

Operations and staff

Current and predicted future operational requirements of the facility, including information about staffing, staff composition (including consideration of diversity) and career opportunities, funding situation for the facility, estimated lifetime if known, the management and leadership structure and any planned changes to the overall facility operation in the 2026-2035 period.

Ops staff: 1.0FTE (fixed-term) plus 0.5FTE (continuing)
Management: Rob Wittenmyer, UniSQ (Lead CI, fixed-term)
Hardware lifetime: Estimated at 20 years, commissioned 2018.
Funding: Ongoing operations funded by NASA JPL contract expected to support operations through 2026. UniSQ has made no explicit commitment to internal funding of maintenance thereafter.
Ops staff and Lead CI are on fixed-term contracts expiring in 2026.
Further funding for operations staff contingent on ARC DP25 outcomes.
Further funding for the Lead CI is at present unknown.

Facility metrics and outputs

Research output statistics and metrics from the facility such as publications, citations, availability of archival data products and legacy value of facility outputs.

The Minerva-Australis facility has an h-index of 17, with 36 refereed papers and over 1000 citations in the five years since its commissioning.

Broader facility impact

Impact of the facility beyond the immediate purpose, including but not limited to economic impact if measured, commercial or external collaborations based around the facility, non-astronomy technical benefits, cross-disciplinary projects and collaborations, connections/support of international facilities, etc.

– Support of NASA spacecraft mission (Transiting Exoplanet Survey Satellite)
– DLR German Space Agency has a space debris monitoring telescope on-site through a leased-space arrangement.

Indigenous links and connections

Any connections of the facility to indigenous knowledge or traditional owners, collaborations with indigenous landowners, actions taken by the facility to promote First Nations involvement in the facility, etc.

N/A

Input required from the community

Outlining any input required from the broader community in terms of shaping the future of the facility or its role in the 2026-2035 Decadal Plan period, any plans for consultation with the community or any outstanding questions for the community to be aware of.

Given the uncertain optical astronomy/spectroscopy landscape in Australia (e.g the status of Veloce and the AAT), what capabilities would the community want from Minerva to further their science in the next 10 years?

Associated capabilities table from centralised DP process

Based on aligning scientific requirements with capabilities - e.g. capabilities required and wavelengths etc. Submitting facilities should make a copy of the Google spreadsheet containing the capabilities table, fill it in accordingly, and add any comments or follow-up in this section. Template table: CapabilitiesTable-DP.xlsx (please include a URL link to the direct sheet when you submit this document, as well as a PDF version of the filled-in table)

R~80,000 stabilised spectrograph, precise radial velocities for stars V<11.

Appendices

Please use this section to attach any appendices, such as tables, figures, etc. They may also be included in the main body of the input, if preferred.

Facility name	Operated by	Spatial resolution					Spectral resolution					Other capabilities										Wavelength coverage									Multimessenger		Computation and theory							
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
Minerva-Australis	UniSQ	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	No	Yes	No	Partial	No	No	No	No	No	Yes	No	No	No	No	No	Yes	No	No	No	No	No	No	No

Mopra

Brief description (< 200 words)

Mopra is a 22m diameter dish located near Siding Springs. It has not been offered as a National Facility instrument for single-dish observing since October 2012, but has been provided on a user-pays basis to several collaborations since then. It is still used as an element of the Long Baseline Array. Possible use for Space Situational Awareness or as a tracking station are under investigation.

Main purpose/s and strategic value (< 200 words)

Mopra is a key element of the LBA, providing the shortest baseline (Mopra–ATCA) and ensuring sufficient array elements for uv-coverage and redundancy for self-calibration during LBA imaging.

Current and future user community

The primary Mopra science community is the Long Baseline Array community. However, Mopra can be used for high-frequency single-dish radio observations through purchased time. We are exploring the use of Mopra for space-related activities (such as spacecraft tracking and space situational awareness).

Facility access

Mopra is only available as a single dish by purchasing time

Operations and staff

Mopra is supported and maintained by staff at Narrabri and Marsfield.

Facility metrics and outputs

N/A

Broader facility impact

As well as astronomical observations Mopra is planned for use in spacecraft tracking and space situational awareness experiments.

Indigenous links and connections

Within CSIRO, instruments of the Long Baseline Array including Mopra, have strong and growing engagement with Traditional Owners.

Input required from the community

CSIRO ATNF have developed their own document to support the 2026-2035 Decadal Plan, which describes our vision for our instruments and future pathway. We are currently accepting feedback on that document and will produce a final version on a similar timescale to this document.

Murriyang, CSIRO's Parkes radio telescope

Brief description (< 200 words)

Murriyang, CSIRO's Parkes radio telescope is a 64m-diameter single dish telescope situated near Parkes, New South Wales. The receiver suite is currently being upgraded and within a few years will consist of a range of ultra-wide-bandwidth, single pixel receivers operating from 700 MHz to around 30 GHz as well as a phased array feed providing a wide-field-of-view primarily for survey observations. Further information is available at https://www.parkes.atnf.csiro.au/ or https://www.csiro.au/en/about/facilities-collections/ATNF/Parkes-radio-telescope-Murriyang.

Main purpose/s and strategic value (< 200 words)

Murriyang is a single-dish radio telescope, which is an integral part of the Australia Telescope National Facility, and an SKA pathfinder instrument. It is a stand-alone instrument as well as part of the Long Baseline Array. Murriyang is an extremely flexible instrument and, over decades, has been used for numerous discoveries. Over the upcoming decade it will be equipped with a modern receiver suite allowing observations from 700 MHz to around 30 GHz and have both single-pixel and multi-beam capability. It will be used as a sensitive instrument for monitoring new discoveries, providing ultra wide-bandwidth observations, as well as a technology test-bed system for new technologies.

Current and future user community

Murriyang is part of the Australia Telescope National Facility and has a national and international user community. Details of the user community demographics, and the details of the work produced by the user community, can be obtained from the annual reports that are available from https://www.atnf.csiro.au/the_atnf/annual_reports/index.html. We continually look for ways to increase and diversify our user community, including anonymised application processes. We provide options for our users to apply through a time-allocation-process and also through the purchase of observing time.

Facility access

Access to the facility is through two ATNF open calls for proposals each year, as well as target of opportunity requests. Each proposal is anonymised and reviewed by a committee. Decisions are based on merit. The oversubscription rates are outlined in the annual reports: https://www.atnf.csiro.au/the_atnf/annual_reports/index.html. Our expectation is that the over-subscription rate of Murriyang will increase in the short-term because of the addition of new receivers.

Access to the facility (for both astronomical use, spacecraft tracking and other purposes) is also available through the purchase of telescope time, and this is handled on a case-by-case basis.

Access to high-time-resolution data products are available in the CSIRO data archive (data.csiro.au) soon after the completion of the observation. The spectral line and continuum observations are made available from the Australia Telescope Online Archive (https://atoa.atnf.csiro.au/). These are usually embargoed for use by the observing team for a period of 18 months and then made publicly available.

Operations and staff

Murriyang is supported by CSIRO staff at the Parkes site and elsewhere. Significant technical support continues to come from our partners (such as Fourier Space). Sale of telescope time helps ATNF sustainably operate Murriyang for merit-based radio astronomy.

CSIRO has diversity, inclusion and belonging initiatives which support leaders and staff to build and maintain a diverse and inclusive organisation. More on these can be found at https://www.csiro.au/en/careers/life-at-csiro/Diversity-inclusion.

Facility metrics and outputs

Various facility metrics are reported in the annual reports: https://www.atnf.csiro.au/the_atnf/annual_reports/index.html.

Broader facility impact

Murriyang has huge impact from science to commercial impact (in terms of e.g., sale of telescope time for spacecraft tracking) to outreach and education impact in terms of the iconic status of the telescope. It supports international facilities directly through VLBI observations, but has also been used directly to support the commissioning and calibration of the FAST and MeerKAT telescopes. Instruments originally designed for Murriyang (e.g., multibeam receivers) have subsequently been developed and installed at a wide-range of international facilities. The Parkes Observatory Visitors Centre sees nearly 100,000 people every year, CSIRO's largest touchpoint with the community.

Indigenous links and connections

There are direct links between Murriyang and the local indigenous community. In particular when Wiradjuri Elders provided its traditional name, along with names for the other two telescopes at the observatory, during NAIDOC Week in 2020 and with continued links across the entire Parkes site with the Indigenous community. NAIDOC Week and Reconciliation Week are both recognised within CSIRO, with regular events, initiatives and celebrations.

Input required from the community

CSIRO ATNF have developed their own document to support the 2026-2035 Decadal Plan, which describes our vision for our instruments and future pathway. We are currently accepting feedback on that document and will produce a final version on a similar timescale to this document.

Associated capabilities table from centralised DP process

Murriyang CapabilitiesTable-DP.xlsx

Facility name	Operated by	Spatial resolution					Spectral resolution					Other capabilities										Wavelength coverage									Multimessenger		Computation and theory							
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
Murriyang	CSIRO	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No	No	Partial	Partial	Yes	Yes	Yes	NA	NA	NA	NA	NA

Facility Input Sections

Brief description (< 200 words)

Overview of the facility in question, including limited information about specifications and references to where further information can be accessed.

The Murchison Widefield Array (MWA) is the low frequency precursor for the Square Kilometre Array (SKA). Located at Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, the MWA is owned and operated by Curtin University, on behalf of a large consortium of institutions across six countries: Australia; Canada; China; Japan, Switzerland; and the USA. The MWA is composed of 8,192 individual low frequency (70 – 300 MHz) antennas, distributed across approximately 30 square kilometres, with six kilometre maximum baseline length. Data are generated and processed on site, with visibility data transmitted to the Pawsey Supercomputing Research Centre in Perth, where users around the world access the data via an All Sky Virtual Observatory (ASVO) portal. Extensive details regarding the MWA are available at http://www.mwatelescope.org

Main purpose/s and strategic value (< 200 words)

Role and purpose within the broader landscape of national and university facilities, including consideration of the strategic value of this particular facility or facilities in terms of advancing the goals of the community and Decadal Plan.

The MWA's purpose is to undertake observations at low radio frequencies that support experiments in fundamental astrophysics. Observational programs are organised in themes, each of which has a science working group: Epoch of Reionisation; Galactic and Extragalactic Science; Time Domain; Space Weather; and Pulsars. The strategic purpose of the MWA, as an SKA precursor, is to build and prepare a large community of Australian and international astronomers and engineers for the future exploitation of the much larger SKA, realising the maximum benefit from Australia's historic investment in the SKA program. The MWA played a role in Australia being awarded hosting rights for the SKA, has hosted multiple generations of SKA prototyping efforts in the Murchison, and has supported hundreds of Early Career Researchers and PhD students to prepare for the SKA over the last decade. All of these objectives have been fully aligned with the Decadal Plan process in Australia and the MWA has been explicitly supported in those plans.

Current and future user community

Description of the user community, including demographics (e.g. local vs. national vs. international users) and any plans for diversifying this user community in the coming decade.

The current user community for the MWA consists of two parts. First, formal members of the MWA consortium are drawn from the member countries that financially subscribe to support the operations of the MWA. They are broken down as follows (and listed in detail on the MWA website): 127 individual members across eight Australian organisations; 16 individual members across eight Canadian organisations; 50 individual members across six Chinese organisations; 20 individual members across six Japanese organisations; 16 individual members across nine Swiss organisations; and 25 individual members across six US organisations. The MWA also has 12 individual associate members across 12 non-member organisations in a further 10 countries.

Second, due to the MWA's policy of making data public after an 18 month proprietary period, the number of MWA users outside the formal consortium has grown considerably in recent years. These users access public data and publish results based on those data. Defining an MWA user as an individual with authorship of at least three papers that used MWA data, the MWA has over 1,400 users of public data from around the world.

Recently, Switzerland joined the MWA consortium and diversified the user base. Switzerland, and other MWA members, have joined the consortium for the same strategic purpose, to build their capability ahead of the SKA. Other countries may take the same approach over the next five years, in advance of the SKA.

Facility access

Current methods of accessing the facility and its data products, covering whether it is open skies, whether it involves a review process and the nature of this review process, any plans to change this process and current (over)subscription rates to the facility.

The MWA is accessed via a competitive time assignment process, across Guaranteed Time (GT: for MWA members of the consortium) and Open Access (OA: open to any astronomer in the world) categories. Allocations under a Director's Discretionary Time process are also possible. The time allocation process is detailed at the MWA policy page: https://www.mwatelescope.org/about/#documentation. The members of the Time Allocation Committee are published at: https://www.mwatelescope.org/people/. Access to data are proprietary to MWA members under GT allocations for a period of 18 months, after which the data are made public (described under the Data Access policy). No plans are in place to change these policies. The observational program is well matched to the time available, resulting in a balanced subscription rate. However, it should be noted that telescopes such as the MWA, with an extreme field of view, can support large numbers of commensal programs and generate large volumes of data. Hence, a better metric than time on sky is the volume of data collected and the number of scientific programs supported per observation (or terabyte of data).

Operations and staff

Current and predicted future operational requirements of the facility, including information about staffing, staff composition (including consideration of diversity) and career opportunities, funding situation for the facility, estimated lifetime if known, the management and leadership structure and any planned changes to the overall facility operation in the 2026-2035 period.

The MWA has always run an extremely lean and highly constrained operations budget and staff. The operations team is composed of an 11 person Operations Team and a five person Management Team, listed at: https://www.mwatelescope.org/people/. Funding has been soft in nature for the entire duration of the facility, with large components coming from NCRIS, international partners, and in-kind contributions from Curtin University, as well as other ad hoc sources of funding. Project planning and the ability to offer long-term stable positions for operations staff have been severely compromised by this situation, with virtually all operations staff on rolling short term contracts for the last decade due to the uncertainty of financial arrangements (existence and size of next contract). The MWA has been a remarkable success in the face of these constraints. NCRIS funding has been secured for the next five year period, and significant funding from international partners to execute a Phase III facility upgrade over the next 12 months. With no change to our funding arrangements, we anticipate no change to our operational model for the next five years.

Facility metrics and outputs

Research output statistics and metrics from the facility such as publications, citations, availability of archival data products and legacy value of facility outputs.

In the period during which the MWA has been produced science-quality data (more than 10 years in 2024), 321 publications have been produced, listed at a publicly accessible ADS Library at: https://ui.adsabs.harvard.edu/public-libraries/SB5_iHeZTxCZDCj5kUuR6Q. These papers have attracted over 15,800 citations, and have an H-index of 53. Overwhelmingly, publication first authorship is dominated by Early Career Researchers and PhD students. The primary MWA system description paper, The Murchison Widefield Array: The Square Kilometre Array Precursor at Low Radio Frequencies, Tingay et al. 2013, PASA, 30, 7, has over 1150 citations, putting it into the top 0.03% of astronomy publications over the last decade. MWA publications have been recognised as a significant factor in raising the Impact Factor of Australia's sovereign astronomy journal, Publications of the Astronomical Society of Australia. The MWA's archive now sits at approximately 55 PB of publicly accessible data, making it one of the largest scientific datasets in the world. Progressively, sections of the archive are deemed as collections of national significance and archived for the long term under funding from the Australian Research Data Commons (ARDC).

Broader facility impact

Impact of the facility beyond the immediate purpose, including but not limited to economic impact if measured, commercial or external collaborations based around the facility, non-astronomy technical benefits, cross-disciplinary projects and collaborations, connections/support of international facilities, etc.

In 2022, the MWA commissioned an independent analysis of the Economic and Social Benefits of the MWA project to Australia, capturing return to the nation beyond the scientific value of the MWA facility. The full report, containing extensive analysis, can be found at: https://mwatelescope.org/wp-content/uploads/2022/08/Curtin_University_-_The_economic_and_social_impact_of_the_MWA.pdf.

Indigenous links and connections

Any connections of the facility to indigenous knowledge or traditional owners, collaborations with indigenous landowners, actions taken by the facility to promote First Nations involvement in the facility, etc.

It has to be noted that the MWA project is not, and never has been, funded to undertake a program of specific engagement of Indigenous communities. Everything we have done in this respect has been resourced out of other budgets and attached to the MWA project.

Most of our Indigenous engagement work has been focused around the Geraldton and Mullewa regions, in connection with our long-standing and close relationship with Yamaji Art (since 2009), an Indigenous art and community collective based in Geraldton.

A brief summary of our engagement with the Indigenous community is encapsulated in a case study: https://www.icrar.org/wp-content/uploads/2017/08/ICR1705-A4-IndigenousArtCaseStudy-Spreads-HiRes- 1103-01.pdf

Through the media of visual and performing arts depicting the night sky, astronomy has provided the basis for cross-cultural story-telling, perspective sharing, and education, in the spirit of Reconcilliation.

Please watch this video recording of Roni Kerley, Yamaji Art Manager, at the MWA ten year anniversary meeting. If you look at one thing as part of this particular response, watch this video (link to powerpoint slides as well: https://wiki.mwatelescope.org/download/attachments/99978704/MWA%2010%20Year%20Celebration%20Presentation%20%281%29.pptx?version=1&modificationDate=1690512725057&api=v2):

https://youtu.be/hR4ZURnpnGA (from 00:00 to approximately 32:00) Prominent examples (some covered in the video) include:

• The Ilgarijiri - things belonging to the Sky – project, started in 2009 and resulting in an exhibition that toured Australia, South Africa, New Zealand, Europe, and the US http://www.yamajiart.com/projects/ilgarijiri/. The entire exhibition sold out twice, involving hundreds of art works at average prices in the hundreds to thousands of dollars, a direct commercial benefit to the community. Since then, Yamaji Art has established an international reputation for “sky story” art and has sold hundreds more pieces over that time;

• Shared Sky, a re-boot of Ilgarijiri in 2014/25 for the five year anniversary of our relatoinship, which brought together Yamaji Art and South African Indigenous artists, celebrating the fact that Australia and South Africa shared the hosting rights for the SKA. Again, an exhibition was produced and has toured the SKA partner countries, which has been purchased in full by the SKA Observatory:

• Star Dreaming, an immersive, 180-degree dome movie, exploring Indigenous sky stories as seen through the eyes of Yamaji artists from WA’s Mid-West region, and astronomers. The movie has won multiple international awards and has been distr8ibuted internationally: https://www.icrar.org/wp-content/uploads/2023/07/ICR236-A4-Stargazing-SCREEN-SPREADS.pdf;

• In 2023, to commemorate 10 years of MWA telescope operations, the MWA Operations team created 3D printed models of a beam pattern of an MWA antenna tile, demonstrating how the telescope can point in different directions without having any moving parts. Emerging Artists from Yamaji Art painted a beam pattern and presented it to the MWA Collaboration at the 10-year Anniversary Celebration of MWA Operations; and

• Approximately a dozen additional, smaller scale projects that have spun out of the relationship over the last decade+.

We have long desired to undertake a comprehensive assessment of the economic and employment benefits of this relationship, as it is clear that they are qualitatively very significant. We would like to undertake a report similar to the EY report, but because of the emphasis on social benefit, we have not pursued this with a Big Four consultancy. We would prefer to use an Indigenous run consultancy. At any rate, we have never had the funding to do such an assessment.

We are currently in discussions with Lotterywest in Western Australia about them funding this important work (estimated at ~$150k over 12 months), this would be greatly appreciated and would result in quantitative and, I'm certain, impressive answers to your questions. We have appointed an Indigenous run business to undertake the work, if funds can be raised.

Input required from the community

Outlining any input required from the broader community in terms of shaping the future of the facility or its role in the 2026-2035 Decadal Plan period, any plans for consultation with the community or any outstanding questions for the community to be aware of.

No particular input is required from the community, beyond our constant on-going communication with our user base and partner member countries.

Associated capabilities table from centralised DP process

Based on aligning scientific requirements with capabilities - e.g. capabilities required and wavelengths etc. Submitting facilities should make a copy of the Google spreadsheet containing the capabilities table, fill it in accordingly, and add any comments or follow-up in this section. Template table: CapabilitiesTable-DP.xlsx *(please include a URL link to the direct sheet when you submit this document, as well as a PDF version of the filled-in table)*

Completed table attached.

Capabilities have been completed based on the full range of data products and observational modes accessible to the MWA, from the capture and processing of voltage data on a per tile basis, to the production and processing of tied array data, and standard visibility and image-based data products.

Appendices

Please use this section to attach any appendices, such as tables, figures, etc. They may also be included in the main body of the input, if preferred.

Facility name	Operated by	Spatial resolution					Spectral resolution					Other capabilities										Wavelength coverage									Multimessenger		Computation and theory							
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
Murchison Widefield Array	Curtin University	Yes	No	No	Partial	Yes	No	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No

Facility Input Sections

Brief description (< 200 words)

Overview of the facility in question, including limited information about specifications and references to where further information can be accessed.

Located at Siding Spring Observatory, the 2.3-metre Advanced Technology Telescope, SkyMapper, DREAMS, and UKST are wholly owned, operated and funded by the Research School of Astronomy and Astrophysics (RSAA) at the Australian National University (ANU).

Access to the 2.3-metre telescope is open to all Australian-based astronomers.

SkyMapper completed its survey of the Southern Sky earlier this year. Paid time access is available.

UKST is no longer actively used and has been placed into stasis. We will not comment further on the UKST in this report.

DREAMS will be installed at SSO in late 2024 or early 2025. We will not comment further on DREAMS in this report.

Further information is available from https://rsaa.anu.edu.au/observers.

Main purpose/s and strategic value (< 200 words)

Role and purpose within the broader landscape of national and university facilities, including consideration of the strategic value of this particular facility or facilities in terms of advancing the goals of the community and Decadal Plan.

In March 2023, the ANU 2.3-m was automated. It is the largest fully automatic telescope in the southern hemisphere. It is the premier facility in Australia for time-critical spectroscopic follow-up observations of transients and variable sources in the optical. We anticipate that the demand for time on the telescope will increase substantially once LSST starts in 2025.

Current and future user community

Description of the user community, including demographics (e.g. local vs. national vs. international users) and any plans for diversifying this user community in the coming decade.

ANU 2.3-metre telescope: As shown in the following figure, about 40% of the time is used by ANU researchers, another 40% is used by Australian-based astronomers not affiliated to the ANU and the remaining 20% is used by astronomers based at institutes overseas. 25% of the time on the telescope is used by students from the ANU, elsewhere in Australia, and overseas.

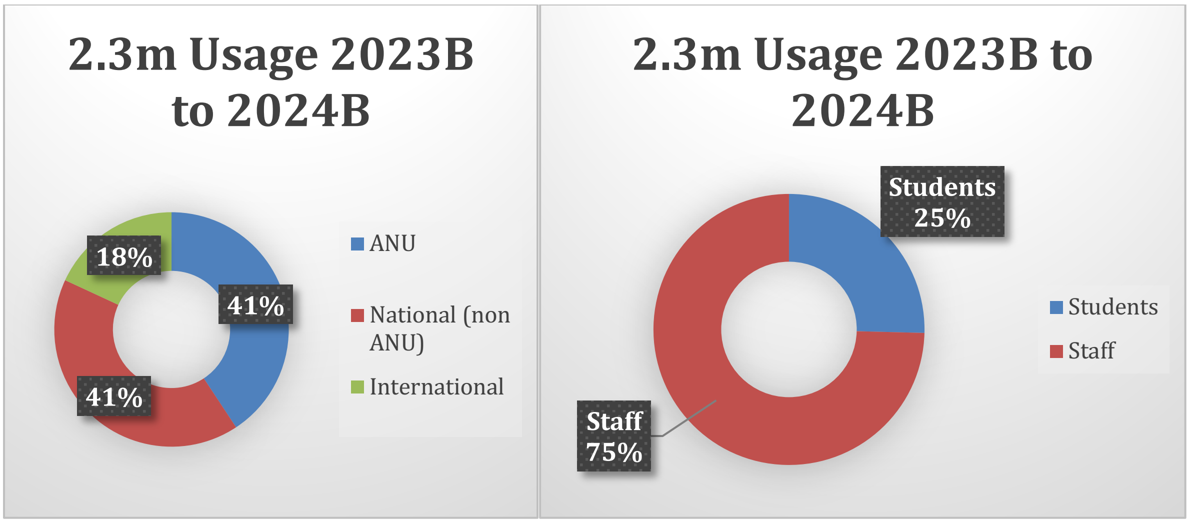


Figure 1: Usage of the ANU 2.3-metre telescope since it became automated in March 2023.

SkyMapper: The ANU SkyMapper Telescope was commissioned in 2014 with the aim of carrying out a six-filter survey of the complete Southern hemisphere. This survey is now complete, and a legacy dataset has been published (Data Release 4, Onken et al. PASA, 2024, see also https://skymapper.anu.edu.au). Currently, observing time at SkyMapper is available for purchase. The clients are almost exclusively international. A minor role is taken by follow-up to search for EM counterparts of GW events.

Facility access

Current methods of accessing the facility and its data products, covering whether it is open skies, whether it involves a review process and the nature of this review process, any plans to change this process and current (over)subscription rates to the facility.

Access to the 2.3-metre telescope is open to all Australian-based astronomers. Time can also be purchased. See https://rsaa.anu.edu.au/observers/applying-23m-time for details. Guaranteed time is also available to institutes that provide in-kind contributions (e.g. a subsystem or a new instrument).

All proposals submitted to the telescope, whether they be for open, paid or guaranteed time are assessed by the ANU Time Allocation Committee (ANUTAC). Membership of and the rules governing ANUTAC are available from the link above.

Excluding any consideration for time lost to poor weather (typically 30% at SSO), the telescope is fully subscribed. We anticipate that the demand for the 2.3-metre will increase once LSST starts.

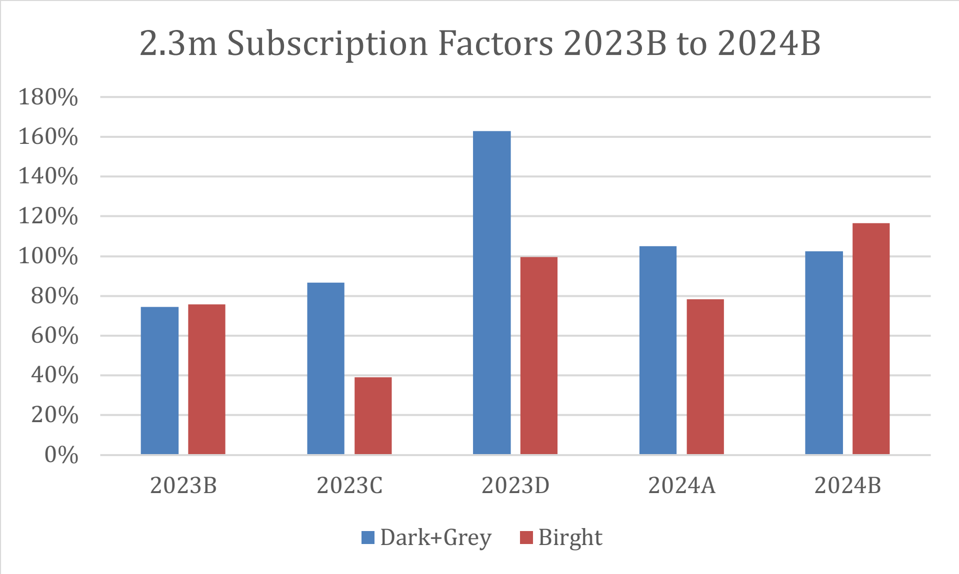


Figure 2: Subscription factors for the ANU 2.3-metre since it was automated. The telescope is fully subscribed. Once time lost to poor weather is taken into account, time on the telescope is currently 50% oversubscribed.

SkyMapper: Time purchased at SkyMapper comes with robotic observations following client-defined OB tables and default image processing (astrometry, instrumental and photometric calibration). Currently, half the field-of-view is available in the detector mosaic (2.4 x 1.2 deg) and nights are sold at a rate of $1,500 per night. However, there might not be enough demand to keep the telescope operating beyond August 2025.

Operations and staff

Current and predicted future operational requirements of the facility, including information about staffing, staff composition (including consideration of diversity) and career opportunities, funding situation for the facility, estimated lifetime if known, the management and leadership structure and any planned changes to the overall facility operation in the 2026-2035 period.

There are two FTE at SSO allocated to maintaining the ANU 2.3-metre, SkyMapper and UKST. Most of their effort is spent at the 2.3-metre. These positions are permanent. There is also about 0.25 FTE of effort from RSAA staff based in Canberra.

Currently, only one of the two positions at SSO are filled. The person filling that position is male. ANU is committed to running the telescope for the next 10 years, the duration of LSST. ANU is currently upgrading the telescope tertiary mirror mechanism to enable it to switch from the Nasmyth foci to the Cassegrain focus without having to change top ends .

The 2.3-metre telescope costs about $1,100 per night to operate. About one-third of the cost is recovered through time sold on the telescope.

SkyMapper: SkyMapper is currently operated and supported by a single RSAA staff member.

Facility metrics and outputs

Research output statistics and metrics from the facility such as publications, citations, availability of archival data products and legacy value of facility outputs.

RSAA does not keep a record of publication statistics from the ANU 2.3-metre.

In collaboration with MQ, ANU is upgrading the archive of the 2.3-metre telescope. All the data will be automatically reduced once ingested into the archive. The proprietary period for the data is 18 months.

Broader facility impact

Impact of the facility beyond the immediate purpose, including but not limited to economic impact if measured, commercial or external collaborations based around the facility, non-astronomy technical benefits, cross-disciplinary projects and collaborations, connections/support of international facilities, etc.

In addition to the broader impact already noted for the AAT in a sperate submission, the ANU 2.3-metre telescope is used to train undergraduate and postgraduate students on how to observe. Each year, about a week of time on the telescope is dedicated for this purpose.

Time on the 2.3-metre can lead to significant international connections and involvement in large international projects. Two current examples are the DEBASS survey (led by Dillon Brout from Boston University and Chris Lidman) and the Young Supernova Experiment (involving Katie Auchettl from the University of Melbourne).

SkyMapper: SkyMapper supports international clients in search for type-Ia supernovae in the infall region of the Shapley supercluster (PI Scolnic, Duke University) and for observations of small solar-system bodies. It is potentially attractive for users intending to control the telescope for entire nights, weeks or months to carry out intense monitoring of wider sky areas at a cadence of their own choosing.

Indigenous links and connections

Any connections of the facility to indigenous knowledge or traditional owners, collaborations with indigenous landowners, actions taken by the facility to promote First Nations involvement in the facility, etc.

The involvement with the traditional landowners is managed by the SSO Director. Over the past 12 months, the following initiatives were started

- Monthly meetings between the SSO Director and the Chair of the Indigenous Local Lands Council
- Installation of a yarning circle at SSO
- Creation of new content highlighting indigenous astronomy for the SSO Exploratory

Input required from the community

Outlining any input required from the broader community in terms of shaping the future of the facility or its role in the 2026-2035 Decadal Plan period, any plans for consultation with the community or any outstanding questions for the community to be aware of.

The ANU invites input from the community on ideas to equip the unused Nasmyth focus with a new instrument.

Associated capabilities table from centralised DP process

Based on aligning scientific requirements with capabilities - e.g. capabilities required and wavelengths etc. Submitting facilities should make a copy of the Google spreadsheet containing the capabilities table, fill it in accordingly, and add any comments or follow-up in this section. Template table: CapabilitiesTable-DP.xlsx *(please include a URL link to the direct sheet when you submit this document, as well as a PDF version of the filled-in table)*

See the attached. Note that the AAT, RSAA-owned facilities and other facilities at SSO are listed in the same Google spreadsheet.

Appendices

Please use this section to attach any appendices, such as tables, figures, etc. They may also be included in the main body of the input, if preferred.

Facility Input Sections

Brief description (< 200 words)

Overview of the facility in question, including limited information about specifications and references to where further information can be accessed.

Siding Spring Observatory is the largest optical astronomical observatory in Australia. Owned and run by the Australian National University (ANU), SSO hosts about a dozen facilities run by national and international consortia. A full listing of the facilities at SSO, including links to their web pages, is provided at the end in the appendix.

The Anglo-Australian Telescope and the ANU owned and operated facilities (ANU 2.3-metre telescope, SkyMapper, DREAMS, and UKST) are reported elsewhere. Here we describe the other facilities on the mountain.

Main purpose/s and strategic value (< 200 words)

Role and purpose within the broader landscape of national and university facilities, including consideration of the strategic value of this particular facility or facilities in terms of advancing the goals of the community and Decadal Plan.

SSO is located in the southern hemisphere and is west of the major observatories in Chile. When the sun is rising in Chile, the sun is setting in Australia. Facilities located at SSO (and elsewhere in Australia) are strategically well placed to follow astronomical transients discovered at the observatories located in Chile, such as the Vera Rubin Observatory. There is interest from several organisations working in space domain awareness (SDA) in establishing new facilities at SSO.

The science covered by the AAT and the ANU owned and operated facilities is covered elsewhere. The science done at other facilities at SSO are heavily skewed to studies in the time-domain, e.g. explosive transients and monitoring of variable sources.

SSO is a well-developed and well-maintained site, with access to power, water and a 10Gb link to the rest of the world. Technical support from ANU staff based at SSO is available to facilities that request it. The ANU charges a flat hourly rate for that support.

Current and future user community

Description of the user community, including demographics (e.g. local vs. national vs. international users) and any plans for diversifying this user community in the coming decade.

Excluding the AAT and the ANU run facilities, the facilities at SSO are run by broad range of organisations. Examples include universities located both in Australia (Macquarie University and Monash University) and overseas (University of Warwick, University of North Carolina), international institutes and organisations (JAXA, KASI, etc.) and private companies (LCO, iTelescope.net).

We do not have access to information that would allow us to describe the user community, other than to note that it is very broad and involves, professional astronomers, amateur astronomers, the public, students attending primary and high school, and commercial organisations.

The user community for ANU time on the LCO facilities is known and is shown in the following figure.

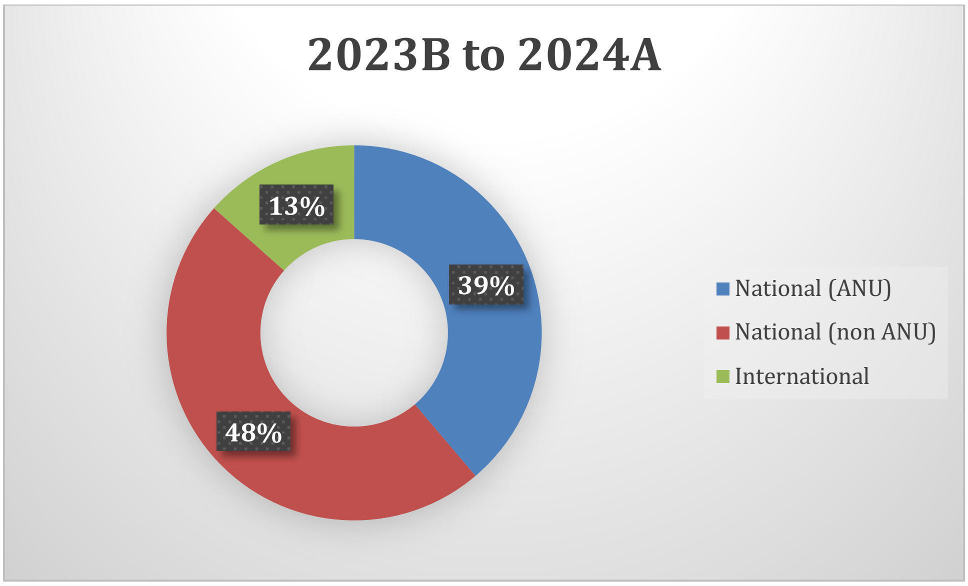


Figure 1: Usage of ANU time on LCO telescopes split into ANU, national (non-ANU) and international. Over the past year, 11 Australian-based Universities have used time on LCO facilities.

Facility access

Current methods of accessing the facility and its data products, covering whether it is open skies, whether it involves a review process and the nature of this review process, any plans to change this process and current (over)subscription rates to the facility.

The method of accessing time on these facilities varies greatly between facilities.

Most are only available to the members of the collaborations or institutes that run them. Examples includes GOTO-South (Monash and Warrick) and POLSA (Polish Space Agency).

In return for allowing other organisations to base their facilities at SSO, ANU asks some facilities to provide 10% of the time on their telescopes to the ANU for the ANU to use. This arrangement currently applies to two facilities: KMTNet and LCO. All Australian-based astronomers can apply for this time. For ANU time on the LCO telescopes, time can be used on any of their 25 telescopes distributed over 7 observing sites. Applications for time on these telescopes are submitted in the same way as time is applied for on the ANU 2.3-metre telescope. See https://rsaa.anu.edu.au/observers for further details.

iTelescope has a paid usage model. Private individuals and schools can apply for time on iTelescope telescopes.

Operations and staff

Current and predicted future operational requirements of the facility, including information about staffing, staff composition (including consideration of diversity) and career opportunities, funding situation for the facility, estimated lifetime if known, the management and leadership structure and any planned changes to the overall facility operation in the 2026-2035 period.

In addition to staff employed by the ANU, the details of which are reported elsewhere, only iTelescope, KMTNet and LCO have staff based at SSO.

Undoubtably, there are many more staff involved in operating these facilities; however, ANU does not have information on numbers, management structure or staff diversity.

The lifetime of these facilities varies from a few years to 10+ years. The default duration for the site licence agreement between the ANU and these facilities is 5 years typically.

The ANU anticipates that all the facilities listed in the table (see the appendix) as operational will continue to be operational for the coming decade. The ANU further anticipates that additional facilities will be established at SSO over the same time frame.

Facility metrics and outputs

Research output statistics and metrics from the facility such as publications, citations, availability of archival data products and legacy value of facility outputs.

ANU does not have access to the metrics of these observatories.

Broader facility impact

Impact of the facility beyond the immediate purpose, including but not limited to economic impact if measured, commercial or external collaborations based around the facility, non-astronomy technical benefits, cross-disciplinary projects and collaborations, connections/support of international facilities, etc.

Currently, 40% of site costs are covered the fees paid by these facilities. The remainder is covered by the ANU and the AAT Consortium. The funds provided by the non-ANU run facilities are a significant and their fraction of the total is increasing with time and expected to exceed 50% over the next few years.

SSO is increasingly used as a site to catalogue and monitor man-made objects in orbit around the Earth (often referred to as Space Domain Awareness – SDA). As for astronomical transients, the location of SSO lies at a longitude and latitude where there are few major observatories. Currently, three facilities at SSO (JAXA, POLSA, and iTelescope) do SDA either part of their prime mission or as a source of income.

Indigenous links and connections

Any connections of the facility to indigenous knowledge or traditional owners, collaborations with indigenous landowners, actions taken by the facility to promote First Nations involvement in the facility, etc.

Unknown.

Input required from the community

Outlining any input required from the broader community in terms of shaping the future of the facility or its role in the 2026-2035 Decadal Plan period, any plans for consultation with the community or any outstanding questions for the community to be aware of.

Is the community interested in establishing new facilities at SSO ensuring it remains viable after the AAT closes?

Associated capabilities table from centralised DP process

Based on aligning scientific requirements with capabilities - e.g. capabilities required and wavelengths etc. Submitting facilities should make a copy of the Google spreadsheet containing the capabilities table, fill it in accordingly, and add any comments or follow-up in this section. Template table: CapabilitiesTable-DP.xlsx (please include a URL link to the direct sheet when you submit this document, as well as a PDF version of the filled-in table)

Appendices

Please use this section to attach any appendices, such as tables, figures, etc. They may also be included in the main body of the input, if preferred.

Facility	Organisation	Status	Comment
AAT	DISR	Operational	Discussed elsewhere
2.3-metre	ANU	Operational	Discussed elsewhere
SkyMapper	ANU	Operational	Discussed elsewhere
DREAMS[1]	ANU + LIEF partners	Under construction	Discussed elsewhere
40”	ANU	Decommissioned	Not discussed
16”	ANU	Decommissioned	Not discussed
24”	ANU	Decommissioned	Not discussed
Uppsala Schmidt	ANU	Decommissioned	Not discussed
HAT-South	ANU / CfA / MPIE	Operational[2]	
LCO	Las Cumbres Observatory	Operational	10% of time available to Australian-based astronomers
KMTNet	KASI	Operational	10% of time available to Australian-based astronomers

[1] Located in the refurbished APT building
[2] Only one of the two telescopes operating.

GOTO-S	Warrick / Monash	Operational	
POLSA	Polish Space Agency	Operational	Commercial facility
PROMPT	University of North Carolina	Operational	
ROTSE	LANL	Decommissioned	
Huntsman	Macquarie University	Operational	
iTelescope	iTelescope.net	Operational	Commercial facility, pay for use
UKST	ANU	Not operational	Discussed elsewhere
JAXA	JAXA	Operational	Commercial facility
SOLARIS	Nicolaus Copernicus Astronomical Centre	Operational	
Flyeye	Italian Space Agency	Proposed	Commercial facility
iTelescope2	No / No	Proposed	Commercial facility

Facility: UTAS Greenhill Observatory

Brief description (< 200 words)

The University of Tasmania's optical/infrared astronomy research program is built around the interplay between our own Greenhill Observatory and large international facilities. This site was developed following the closure of Canopus Hill Observatory in the Hobart suburbs in 2014. The site, 65 km north of Hobart, hosts a 1.3m custom Ritchey-Chrétien telescope with a wide-field corrector triplet (commissioned 2015) and an 0.5m Planewave telescope on a fast mount capable of slewing at up to 20°/sec (commissioned 2022). Current instrumentation includes standard CCD and high-speed CMOS cameras, and a polarimeter as a visitor instrument. Both telescopes are fully remotely operable. Planned upgrades include a Teledyne NIR camera, a fibre spectrograph, and fully robotic operations. As the southernmost observatory in Australia, Greenhill Observatory has a unique perspective on the far southern skies and a complementary view to other Australian sites. While subject to cloud, the sky is dark and the seeing can be as good as 1.3" (median ~2").

Main purpose/s and strategic value (< 200 words)

The principal use of our telescopes for research is in the broad area of time-domain astronomy, allowing flexibly scheduled access to time-critical phenomena including but not limited to microlensing anomalies, occultations, eclipses/transits, variable stars, and eruptive/exoplosive stellar phenomena in the Milky Way and nearby galaxies. Both telescopes, especially the 0.5m, have a strong role in experimental astrophysics training for honours and PhD candidates and in outreach activities. In the context of the scientific priorities of the Decadal Plan, the main roles of the 1.3m are in the areas of exoplanet detection and densely-sampled follow up of relatively bright transient events, and as a platform for specialised instrumentation. The fast tracking and wide field of view of the 0.5m make it an ideal instrument space domain awareness.

Current and future user community

The vast majority of current users are University of Tasmania staff and students. We have active collaborations with the Institut d'Astrophysique de Paris, Osaka University, the University of Turku, the Ohio State University, and NASA/Goddard Space Flight Center. We are actively seeking partnerships in collaborations including ARC Centres of Excellence and other ways to take advantage of our location and instruments. Current PhD candidates are exploring the potential for simultaneous optical and radio space operations and tracking, which could open up usage on the commercial side.

Facility access

Access to Greenhill Observatory is currently scheduled within the discipline of physics by the optical astronomy group, and allocated within the broad framework of memoranda of understandings with major projects and external partners. PhD project observations are prioritised unless interrupted by targets of opportunity. The subscription rate is <1. Prospective external users are encouraged to contact UTAS staff with enquiries.

Operations and staff

Current support staff is 1 technical officer supported 50% by university operations and 50% by research/commercial income. This technical officer is a PhD astronomer. Additional support is shared with the University's Mt Pleasant Radio Observatory on an ad hoc basis, and a significant effort of ~0.4 FTE is contributed by honorary/adjunct appointees. Career opportunities are closely linked to funding levels, including physics teaching income, research grants, commercial contracts, and philanthropy. Greenhill Observatory is expected to continue operations beyond the end of the 2026-2035 Decadal Plan period, through some mix of teaching and research.

Facility metrics and outputs

Most data has been taken in support of larger projects. Operations since commissioning of the 1.3m have been impacted by remediation of a flaw in the primary mirror and the COVID-19 pandemic. Despite this, Greenhill Observatory data has formed the backbone of 6 UTAS honours projects (5 astronomy, 1 engineering), and has contributed to some half-dozen refereed papers, with ~120 citations as of mid-2024. All raw images are archived. They are hosted and accessed locally.

Broader facility impact

Our small telescopes are regularly used in a large network to obtain densely sampled lightcurves of microlensing events, allowing the facilities to contribute to preparations for the Roman Galactic Exoplanet Survey. The 50cm telescope is important for undergraduate and honours teaching and has commercialisation or defence potential in terms of fast tracking. Opto-mechanical analysis of the 1.3m telescope mount has contributed to UTAS engineering projects. The observatory has a strong outreach role in the Tasmanian community as a high-profile example of on-island scientific opportunity

Associated capabilities table from centralised DP process

See Table at CapabilitiesTable-DP UTAS Greenhill.xlsx

Notes:

1. *As of 1 August 2024, the 1.3m mirror is under contract to be refigured to improve the delivered optical quality.*
2. *Preparation of optical fibres to feed an existing spectrograph is in progress.*
3. *Polarimetric and Near-IR (1-1.6 µm) exist on the 1.3m telescope only. 50cm telescope is exclusively for imaging and fast-tracking moving targets.*

Facility name	Operated by	Spatial resolution					Spectral resolution					Other capabilities										Wavelength coverage									Multimessenger		Computation and theory							
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
Greenhill Observatory	UTAS	No	Yes	No	No	No	No	No	Partial	Partial	No	No	NA	No	No	No	Partial	Yes	Yes	No	Partial	No	No	No	No	Partial	Yes	No	No	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Facility: UTAS Radio

Brief description (< 200 words)

The University of Tasmania has a long history of radio astronomy. Current activity is based at the Mt Pleasant Radio Observatory in Cambridge, TAS. Other sites are in Ceduna (SA), Katherine (NT), and Yarragadee (WA). Mt Pleasant is home to UTAS staff and hosts a 26-metre dish as well as a 14-m dish and a 12-m AuScope antenna. The AuScope antenna is operated as one node of a geodetic VLBI network with identical antennas at Katherine and Yarragadee. Ceduna supports a 30-m dish and a 3-m fast-tracking antenna. The dishes are used for both single-dish and interferometric observations, making the UTAS network the only continent-wide VLBI facility entirely operated by a single university. UTAS capabilities are additionally characterised by fast tracking capability. All assets are operable from a control room on the University's campus in Sandy Bay (Hobart). Descriptions of the facilities are available at https://www.utas.edu.au/physics/space-tracking

Main purpose/s and strategic value (< 200 words)

UTAS radio astronomers contribute to a wide range of scientific efforts linked to Decadal Plan priorities, including pulsars, star formation, galactic structure, radio galaxies/AGN jets, and transients. The dishes form a major part of the CSIRO Long Baseline Array (LBA). Geodetic VLBI observations provided by the AuScope array are critical to establishing the celestial reference frame and Earth orientation parameters at a national and international level. The dishes have also been used for space operations uplink and downlink, in both government and private sectors.

Current and future user community

The principal users of the UTAS radio observatories are staff and students. The observatories also support private and public sector commercial activities. A major supporter of UTAS radio science is the International VLBI Service for Geodesy and Astrometry (IVS). The nature of the research and commercial partnerships are fundamentally international, but with a strong focus on distinctive Australian capabilities. The fast response time and continent-wide scale of facilities offer significant opportunities to grow the user community through commercial partnerships or participation in major scientific efforts in the priority areas of the Decadal Plan.

Facility access

Access to the UTAS radio observatories is currently scheduled within the discipline of physics by the radio astronomy group, and allocated within the broad framework of memoranda of understandings with major projects and external partners. PhD project observations are prioritised unless interrupted by targets of opportunity. The subscription rate is <1. Prospective external users are encouraged to contact UTAS staff with enquiries.

Operations and staff

Current support staff is 1 observatory manager assisted by ~3 technical officers supported in part or in full by external project income (e.g., AuScope/Geoscience Australia, Australian Research Council). Additional support is provided as needed on a casual basis. With consideration to staff workload and wellbeing, the University is in the process of reviewing operations to identify where additional support can be provided. Career opportunities are closely linked to funding levels, including physics teaching income, research grants, commercial contracts, and philanthropy. UTAS radio observatories are expected to continue operations beyond the end of the 2026-2035 Decadal Plan period, funded through some mix of teaching, research, and commercial income.

Facility metrics and outputs

Over the period of the previous Decadal Plan, 2016-2025, UTAS radio facilities have produced an average of nearly 7 refereed publications per year, amassing over 1000 total citations. Geodetic work on the celestial frame and support for position, navigation and timing observations via AuScope has high societal impact but typically does not result in refereed publications. At any given time, an average of 2-3 PhD candidates are working on projects based primarily on UTAS radio facilities.

Broader facility impact

UTAS radio observatories contribute strongly to the CSIRO Long Baseline Array and the International VLBI Service. Staff are deeply involved with fundamental work both in astronomy and geodesy, including the development of the VLBI Global Observation System (VGOS). A large cohort of leaders in the Australian radio astronomy community have been trained at the UTAS observatories. In the future, it is envisaged that an increasing proportion of funding and observing time will be devoted to the space sector. Through the Grote Reber Museum at Mt Pleasant, the radio observatories have a strong outreach role in the Tasmanian community as a high-profile example of on-island scientific opportunity.

Input required from the community

It is highly desirable to learn the requirements of the national community for continued VLBI capability at a variety of frequencies over the time period of the next decadal plan, the importance of celestrial reference frame determinations, and the level of support for continued access to capabilities such as LBA.

Associated capabilities table from centralised DP process

See Table at CapabilitiesTable-DP UTAS Radio.xlsx

Notes:

1. AuScope 12m dishes (Hobart, Katherine, Yarragadee) are primarily geodetic VLBI antennas but a significant proportion of time is available for radio astronomy, receiving from 2-14 GHz with dual linear polarization.
2. Hobart 26m was originally a Deep Space Network tracking antenna. It receives on L, S, C, X, and K-bands.
3. Ceduna 30m uses room temperature receivers between 2.2 and 22 GHz.
4. The Hobart 14m dish is primarily dedicated to teaching uses.

Facility name	Operated by	Spatial resolution					Spectral resolution					Other capabilities										Wavelength coverage									Multimessenger		Computation and theory							
		>10 arcsec spatial resolution	1-10 arcsec spatial resolution	<1 arcsec spatial resolution	<0.3 arcsec spatial resolution	Adaptive optics	<1 km/s	1-5 km/s	>5 km/s	>4,000 spectral resolution	>20,000 spectral resolution	>30' field of view	Large bandwidth/broadband	Integral Field Unit	High spectroscopic multiplex	High dynamic range	Precision calibration	Polarisation	High time resolution	Commensal/multi-messenger	Fast reaction/triggering	m	cm	mm	THz	IR	optical	UV	X-ray	gamma-ray	Gravitational waves	Astroparticle	High Performance Computing	Data centres	Storage/databases	High-throughput	Parallel compute - weakly coupled	Parallel compute - tightly coupled	Analytical theory	Computational theory
Mt Pleasant	UTAS	Yes	No	No	Partial	No	Yes	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
Ceduna	UTAS	Yes	No	No	Partial	No	Yes	No	No	No	No	Partial	Partial	No	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Katherine	UTAS	Yes	No	No	Partial	No	Yes	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Yarragadee	UTAS	Yes	No	No	Partial	No	Yes	No	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes	No	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Bisdee Tier	UTAS	Yes	No	No	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No

APPENDIX 3: WG 2.2 Submission Templates

We attach here for reference the templates we used to collect input, specifically the Facilty Input guidelines as circulated to the community and the Community Input Form.

WG 2.2 Facility Input Guidelines

v1.2 | Wednesday 31st July 2024

This document has been developed by WG 2.2 to collect systematic input from national and university facilities as part of the Decadal Plan 2026-2035 process. We provide below a schematic set of guidelines that are intended to be used to structure facility input submitted to WG 2.2 for consideration.

We are happy to accept input from all facilities that consider themselves part of the national and university facility landscape, but please note that input regarding international/space facilities, data/computing facilities and instrumentation is best done via WGs 2.1, 2.3 and 2.4 respectively. See the later section of this document for a list of facilities that was compiled by WG 2.2 as part of the demographic survey input: WG 2.2 Facility Input Guidelines

Please submit one of these input documents per facility, as it is designed to focus on a given facility. If your organisation or institute operates multiple facilities that share similar responses to some of the questions, then you may duplicate the responses in those cases.

All submissions received will be attached to the final WG 2.2 report as appendices and thus made available publicly to the community, which should be taken into account when providing input. We recommend maximal transparency when providing input, however any input considered to be confidential (e.g. for WG 2.2 consideration only) can be provided directly to the WG 2.2 Chairs:

Andrew Cole (University of Tasmania, andrew.cole@utas.edu.au)
Vanessa Moss (CSIRO, vanessa.moss@csiro.au)

We strongly recommend responses to all sections are kept as succinct and brief as possible (e.g. on the order of 200 words), directly addressing the question/topic of the section, but we will not impose a strict word limit. In cases where we feel the word limit is of particular importance or relevance, we have indicated this in the section heading.

You may submit your responses (including the capabilities spreadsheet) by uploading them to this Dropbox: **https://www.dropbox.com/request/KbI4eeiGjdIGk7p5PtWi**
(we prefer PDF format if possible to reduce the risk of formatting issues)

WG 2.2 will be accepting facility input until early August, so please submit your responses no later than **17:00 AWST on Friday 9th August 2024**.

You may also, as an individual, contribute your perspective via our community input form, which is accessible here: https://forms.gle/Ks4WwTMjMupNo6M48 (please feel free to pass this link on to anyone relevant to your facility who may like to contribute input, for example, staff or the associated user community)

Facility Input Sections

Brief description (< 200 words)

Overview of the facility in question, including limited information about specifications and references to where further information can be accessed.

Main purpose/s and strategic value (< 200 words)

Role and purpose within the broader landscape of national and university facilities, including consideration of the strategic value of this particular facility or facilities in terms of advancing the goals of the community and Decadal Plan.

Current and future user community

Description of the user community, including demographics (e.g. local vs. national vs. international users) and any plans for diversifying this user community in the coming decade.

Facility access

Current methods of accessing the facility and its data products, covering whether it is open skies, whether it involves a review process and the nature of this review process, any plans to change this process and current (over)subscription rates to the facility.

Operations and staff

Current and predicted future operational requirements of the facility, including information about staffing, staff composition (including consideration of diversity) and career opportunities, funding situation for the facility, estimated lifetime if known, the management and leadership structure and any planned changes to the overall facility operation in the 2026-2035 period.

Facility metrics and outputs

Research output statistics and metrics from the facility such as publications, citations, availability of archival data products and legacy value of facility outputs.

Broader facility impact

Impact of the facility beyond the immediate purpose, including but not limited to economic impact if measured, commercial or external collaborations based around the facility, non-astronomy technical benefits, cross-disciplinary projects and collaborations, connections/support of international facilities, etc.

Indigenous links and connections

Any connections of the facility to indigenous knowledge or traditional owners, collaborations with indigenous landowners, actions taken by the facility to promote First Nations involvement in the facility, etc.

Input required from the community

Outlining any input required from the broader community in terms of shaping the future of the facility or its role in the 2026-2035 Decadal Plan period, any plans for consultation with the community or any outstanding questions for the community to be aware of.

Associated capabilities table from centralised DP process

Based on aligning scientific requirements with capabilities - e.g. capabilities required and wavelengths etc. Submitting facilities should make a copy of the Google spreadsheet containing the capabilities table, fill it in accordingly, and add any comments or follow-up in this section. Template table: CapabilitiesTable-DP.xlsx (please include a URL link to the direct sheet when you submit this document, as well as a PDF version of the filled-in table)

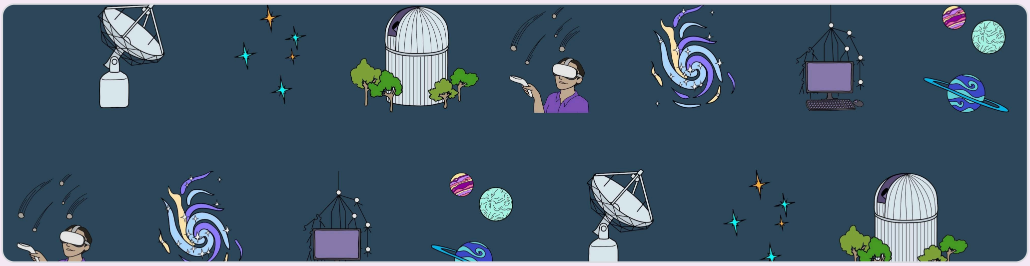
Appendices

Please use this section to attach any appendices, such as tables, figures, etc. They may also be included in the main body of the input, if preferred.

Example list of national and university facilities

We include the kinds of facilities we are considering below, noting that this list was used as part of the Decadal Plan individual survey questions.

Anglo-Australian Telescope (AAT)
ANU 2.3m telescope
Australian SKA Pathfinder (ASKAP)
Australia Telescope Compact Array (ATCA)
Canberra Deep Space Communication Complex
Desert Fireball Network
Long Baseline Array (LBA)
Macquarie Astronomical Observatory
Mopra
Mount Stromlo Observatory
Mount Pleasant & Ceduna Radio Telescopes
Murchison Widefield Array (MWA)
Murriyang, CSIRO Parkes radio telescope
Penrith Observatory
Siding Spring Observatory (other facilities)
SkyMapper
UniSQ Mt Kent Observatory
UNSW Observatory
UTAS Greenhill Observatory
UWA Zadko Observatory



WG2.2 Community Input Form

Please use this form to submit your perspective on aspects relating to Decadal Plan Working Group 2.2: National and University Facilities. These inputs will be viewed by WG 2.2 members in order to help inform and shape our WG report as input to the overall Decadal Plan 2026-2035 process.

More information about the Decadal Plan process can be found here: https://www.science.org.au/supporting-science/science-policy-and-analysis/decadal-plans-for-science/astro2035

If you have any questions about this form or WG 2.2, please get in touch with WG co-chairs Andrew Cole and Vanessa Moss at the #decadal-wg-2-2-townhall Slack channel, or contact us via email.

Note: We will seek to include any final last-minute submissions if they are made before 17:00 AWST on Wednesday 21st August 2024.

rhobslein63@gmail.com Switch accounts

Not shared

Email address:

Your answer

Full name:

Your answer

Affiliation:

Your answer

Decadal Plan Working Group membership (if relevant):

Your answer

List up to 3 priorities you propose to be considered as part of WG 2.2 National and University Facilities:

Your answer

List your facilities of interest / focus areas:

Your answer

Did the previous decadal plan work for your facilities of interest? If yes, in which ways, and if no, why not?

Your answer

What do you see as the biggest threat or risk to national and university facilities in 2026-2035?

Your answer

One "out of the box" question that you think is worth raising or discussing in the context of WG 2.2:

Your answer

If you have any other comments or questions, please leave them here:

Your answer

Submit

Clear form