Submission No. 1
(Australian SKA Pathfinder Radio Telescope)

STATEMENT OF EVIDENCE TO THE PARLIAMENTARY STANDING COMMITTEE ON PUBLIC WORKS

Proposed Australian SKA Pathfinder (ASKAP) Radio Telescope

Western Australia

June 2008

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1 Introduction

1. This submission to the Parliamentary Standing Committee on Public Works (PWC) is for the construction in Western Australia of the proposed Australian Square Kilometre Array Pathfinder (ASKAP) radio telescope.

2. ASKAP will be an array of up to 36 parabolic dishes, each of 12 metres diameter. Phased array feed receivers at the focus of each dish will measure radio waves received from astronomical sources at frequencies between 800MHz and 1700 MHz. The signals will be electronically combined, and transported to a large supercomputer that will further process the information.

3. ASKAP will be the fastest survey radio telescope in the world. The ASKAP telescope will facilitate ground breaking scientific programs, and will deliver world-leading performance in a wide range of applications including cosmology, the study of transient radio sources, pulsar astronomy, and the study of the structure and magnetic field of our own galaxy.

4. It is proposed that the ASKAP antenna array be constructed in the Mid West of Western Australia at the Murchison Radio-astronomy Observatory (MRO). The MRO is approximately 315 km north east of Geraldton, on Boolardy Station pastoral lease. Support and remote operation facilities will be located at Boolardy Station, and at Geraldton.

5. Successful operation of ASKAP on the MRO site will significantly strengthen Australia's site bid for the international Square Kilometre Array (SKA) radio telescope project.

6. This submission comprises construction of the ASKAP radio telescope in Western Australia and associated infrastructure and support facilities. Components of the proposed works are summarised below, and described in detail in the Sections following:

- *i.* Construction of the radio telescope in Western Australia, known as the Australian Square Kilometre Array Pathfinder (ASKAP), comprising up to 36 parabolic antennas spaced over the Murchison Radio-astronomy Observatory (MRO) site, together with essential electronics, data processing and computing infrastructure
- *ii.* Construction of a central compound for control and maintenance of ASKAP, including infrastructure for operations, and equipment storage
- *iii.* Remote power generation infrastructure, utilising some renewable energy sources, sited within the MRO
- *iv.* Temporary compounds at the MRO site for construction worker accommodation and operations during construction of ASKAP
- *v.* Upgrades to roads on Boolardy Station for access to the MRO
- *vi.* Upgrades to some existing structures and power generation infrastructure at Boolardy Station homestead precinct, located 40 kilometres south of the MRO, to provide facilities and accommodation for technical and maintenance staff
- *vii.* Construction of the MRO Support Facility (MSF) in Geraldton-Greenough, 315 kilometres south west of the MRO, comprising offices, laboratories and data storage areas
- *viii.* Construction of an optic-fibre cable connection between the MRO and the MSF in Geraldton-Greenough.
- *ix.* Connection to radio telescope infrastructure in NSW to achieve high resolution pictures of the sky and to demonstrate cross-continent connectivity at astronomically useful data rates.

2 Background

2.1 CSIRO and ASKAP governance

7. The ASKAP project will be managed by the CSIRO Australia Telescope National Facility (ATNF), and is subject to a robust advice and oversight structure both inside and outside CSIRO. CSIRO ATNF is the largest single astronomical institution in Australia, and has headquarters in Marsfield, NSW.

8. CSIRO is Australia's premier research organisation, delivering science and innovative solutions for industry, society and the environment. With an annual turnover of about $1 billion, it is one of the largest and most diverse scientific research organisations in the world.

9. CSIRO has a total staff of about 6300, approximately 55% of whom are research scientists. Collectively they provide expertise in almost every major scientific discipline, allowing the organisation to draw on a large and diverse pool of individual skills to meet almost any scientific or technological challenge.

10. In order to fulfil its role, CSIRO consults and collaborates extensively with industry and maintains close and mutually beneficial relationships with universities and Research and Development agencies of the various State governments.

11. CSIRO is managed by an Executive Team led by the Chief Executive Officer. The Executive Team is responsible for the development and implementation of organisational strategy. The Chief Executive is a member of the 10-person CSIRO Board and is accountable for the organisation's performance to the Minister for Innovation, Industry, Science and Research.

12. CSIRO is organised into 16 Business Units, which are the "homes" of the disciplinary capabilities and the skills that are available. The delivery of CSIRO's outcomes and impacts are organised through Themes, and CSIRO is currently addressing approximately 100 Themes.

13. CSIRO also manages a number of national collections and national facilities, including the Australia Telescope National Facility (ATNF).

14. ASKAP is a Theme within the ATNF, and the ASKAP team receives capability input principally from the Business Units ATNF, the CSIRO ICT Centre, and the CSIRO Division of Energy Technology, as well as from central CSIRO functional groups such as Legal, Business Development, and Property Services.

15. CSIRO strategic priorities are laid out in the Strategic Plan 2007-11, and Broad Direction Setting is determined annually. Implementation of priorities is conducted through the annual Science Investment Process (SIP) which sets investment levels and priorities for all Themes within CSIRO based on criteria of impact, relevance and capability. ASKAP has received the top "A" ranking and been fully supported in the SIP process since its inception.

16. The design and development work for ASKAP also involves collaboration with international partners and industry. Collaborations have been established with institutions in Canada, the United States, South Africa and the Netherlands to address issues such as the design of antennas, feed and digital systems, and the design and implementation of telescope control software.

2.2 Historical Background

17. Astronomy is one of the oldest scientific disciplines. From ancient times to the present day, people have gazed to the heavens in order to understand their origins and their place in the Universe. It is through developments in astronomical techniques and scientific thinking that we are able to piece together how the Universe began, how it evolved and the underlying laws that govern it.

18. Australia has been a world-leader in radio astronomy since the earliest days of the discipline and, as a country, we "punch above our weight" in this area of science.

19. The Division of Radiophysics at the CSIRO was established in 1939 to carry out research and development into the new technique of radar. Following the end of the Second World War, a group of researchers began studying the skies with the same radar antennas. The post-war decade saw the development of facilities in Dover Heights and Potts Point in Sydney specifically to study and image the Sun. In the mid 1950s, radio emission from hydrogen gas in our Galaxy was detected and the Radiophysics Division led the world in mapping the weak signals from the hydrogen atom. Following the building of antennas capable of doing interferometry at the Fleurs site in Sydney, the next major advance was the construction of the 64-metre diameter Parkes radio telescope dish, then and now the biggest astronomical telescope in the southern hemisphere. Commissioned in 1961 and upgraded many times since, it remains one of the world's great research instruments.

20. Solar physics was also undertaken with the operation of the radio heliograph near Narrabri in northern New South Wales. The site was later chosen as the location for the Australia Telescope Compact Array, which consists of six 22-metre antennas and which has been in operation since 1988. The Compact Array can operate at frequencies between 1 and 100 GHz and provides high angular resolution images of the sky.

21. Radio astronomy is now on a cusp of a revolution. Currently, radio telescopes consist of large, heavily engineered dishes. The receivers are super-cooled, highly labour intensive devices capable of only observing one spot on the sky at a time. In the future, radio telescopes will consist of thousands to millions of small, cheap devices capable of being steered and combined electronically to provide multiple simultaneous views of the sky. Massive parallel computing will be required.

22. It is also apparent that large fractions of the Earth's surface are no longer suitable for carrying out sensitive radio astronomy observations. Terrestrial and satellite interference, mainly arising from the explosion in communications devices, occupies much of the radio spectrum rendering large sections of the spectrum unsuitable for astronomy observations. Western Australia has been identified as one of the few places left on Earth free from the harmful effects of radio interference.

23. In order to re-invest in Australian radio astronomy infrastructure on a radio-quiet site, and present the strongest possible case for an Australian site and for the use of Australian technology in the international Square Kilometre Array (SKA), the Australian Government has provided funding of $111million to CSIRO for the design, construction and operation of ASKAP. ASKAP is due to be operational in 2013, some 25 years since the commissioning of the Australia Telescope Compact Array at Narrabri.

24. In addition to the Commonwealth funding, the Western Australian Government has allocated $4.08M to support the radio astronomy projects in the Mid West of WA.

2.3 The Square Kilometre Array radio telescope project

25. The SKA is a proposed AUD$1.8 billion next-generation radio telescope project under development by scientists from 50 institutions across 19 countries (Australia, New Zealand, and countries in Europe, Asia, Africa, and the Americas). Notionally, the funding for SKA is anticipated to flow in equal portions from Europe, USA and the rest of the world. The SKA will be one of the largest scientific projects ever undertaken anywhere in the world.

26. In 2005, in response to a call for proposals by the International SKA Steering Committee, four countries, (Australia, Argentina, China and South Africa), submitted proposals to host the SKA. In September 2006, Australia and Southern Africa were short-listed as being acceptable sites.

27. The Australian SKA site proposal would locate the central SKA core in the Mid West of Western Australia, at an area now referred to as the Murchison Radio-astronomy Observatory (MRO). The MRO is sited on Boolardy Station, a pastoral station located approximately 315 km North East of Geraldton. The region of the site is very sparsely populated and superbly radio-quiet.

28. In recognition of:

    i. the value of large international science projects to Australia and to Western Australia; and

    ii. the potential benefits of ASKAP and SKA to radio astronomy and to Australian science more generally

the Australian Government and the Government of Western Australia have signed a Memorandum of Understanding to provide a basis for the Governments to work together towards a successful bid for Australia to host the SKA. An intergovernmental committee, the Australian SKA Coordination Committee, with Secretariat support provided by the Department of Innovation, Industry, Science and Research (DIISR), advises the Governments on the Australian SKA project and takes day-to-day decisions to advance the Australian SKA project.

29. A final decision on the site of the full SKA is scheduled in 2011-2012 by the international SKA project.

3 Project Objectives

3.1 ASKAP Strategic Objectives

30. The Australian Square Kilometre Array Pathfinder (ASKAP) project is a response by the Australian Government and the Western Australian State Government (facilitated through the CSIRO) to establish the world's most effective survey radio telescope, intended for international research. The ASKAP telescope will be available to the international community on the basis of scientific merit, a practice that applies to Australia's existing radio astronomy national facilities, and which has led to very productive international collaborations.

31. Australia is currently a world-leader in the science of radio astronomy and ASKAP will secure Australia's continuing lead in this field through 2020 and beyond.

32. The radio-frequency environment on the more populated east coast of Australia is deteriorating (as it is over most of the earth's surface) due to increasing man-made radio-frequency emissions. A site of exceptional radio quietness, the Murchison Radio-astronomy Observatory (MRO) in Western Australia is considered to be one of the best sites for meter/centimeter-wave astronomy in the world. Re-investment in Australian radio astronomy infrastructure through ASKAP on the superb MRO site will secure maximum benefit to Australia from future international radio astronomy developments.

33. Successful operation of ASKAP on the MRO will also strengthen Australia's site bid for the SKA through:

    i. successful demonstration of innovative radio astronomy technologies that will facilitate a detailed system design and costing for Phase 1 of the SKA;
    ii. successful demonstration of remote operation of radio astronomy equipment in the Australian environment;
    iii. successful demonstration of the radio-quietness of the MRO through the acquisition of high-quality scientific data;
    iv. successful demonstration of cross-continent optic-fibre connectivity between the WA and NSW radio astronomy facilities; and.
    v. successful demonstration of the approvals and joint governmental structures needed to deploy infrastructure and operate a facility.

34. More generally, ASKAP and the SKA projects have the potential to benefit Australia, and international science more broadly, in many ways:

    i. cultural and scientific value through the advancement of fundamental knowledge about the Universe;

ii. educational value through the inspiration provided by hosting and involvement with an iconic international scientific project. The telescope will be available for classroom experiments as the Parkes radio telescope currently is through the Pulse@Parkes program;

iii. industrial value through the opportunities for Australian industries to collaborate in leading developments in information and knowledge processing technologies, and radio science areas with commercial spin-off potential; and

iv. national, and regional value through the employment and infrastructure provision in remote areas of Australia that could support communities for the expected greater than 30 year lifetime of ASKAP and 50 year lifetime of the SKA facility.

3.2 ASKAP Science Objectives

35. The innovative design and technology of ASKAP and the quest for a radio-quiet site have been driven by the science imperatives. A number of Key Science Projects have been identified for ASKAP, which take advantage of ASKAP's wide field of view and consequent rapid surveying capability.

36. The four main science drivers for the ASKAP telescope are:

i. understanding the evolution of gas and galaxies
ii. understanding the origins and evolution of magnetic fields
iii. revolutionising our knowledge of the transient radio sky
iv. obtaining a deep understanding of the Galaxy in which we live.

37. In the last two decades astronomers have come to the remarkable conclusion that the atoms that make up stars, planets and people constitute only a few percent of the Universe by mass. The majority of the Universe is made up of so-called Dark Matter (which affects the formation and evolution of galaxies) and so-called Dark Energy (which affects the expansion of the Universe as a whole). This observation is made all the more sobering by the fact that the composition of dark matter, and the form of dark energy, are not understood.

38. With ASKAP, CSIRO can forge a pathway towards the resolution of these issues which can ultimately only be answered by the full SKA. ASKAP will detect the very weak signals given off by the reservoirs of hydrogen gas within distant galaxies. Because this signal is so weak, only a few thousand such galaxies are known today. ASKAP should detect close to one million of these galaxies in a volume of space at least one thousand times larger than known today.

39. Magnetic fields appear to be ubiquitous throughout the Universe. Planets, stars and galaxies have ordered magnetic fields, and the vast spaces between the galaxies are permeated by magnetic fields. Magnetic fields play a crucial role in the formation of galaxies and stars and in the way they evolve. Yet, in spite of their importance, the evolution and origin of magnetic fields is still an open question in astronomy. Nearly everything known about cosmic magnetism comes through the detection of radio waves. The next generation of radio telescopes such as ASKAP, with its high sensitivity and wide field of view, are uniquely placed to answer questions about the origin and evolution of magnetic fields.

40. The variable and transient radio sky is largely uncharted territory and one in which ASKAP can make huge advances because of its high sensitivity and large field of view. Much is already known of many types of transient and variable objects; objects such as brown dwarfs, pulsars, X-ray binaries and supernovae. One of the great discoveries of the past decade is that hugely energetic events called gamma-ray bursts, which can be seen out to the edge of the visible Universe, are caused by the explosions of high mass stars. The solution of the mystery of the gamma-ray bursts required a multi-wavelength approach and very accurate positions. More intriguing than the transient objects which are already known, are the transient sources for which there is currently no clear idea as to their identification or origins. This exciting discovery space is wide open to the next generation of telescopes such as ASKAP, which are capable of observing the entire sky to good sensitivity on a regular basis, and providing accurate positions necessary for follow-up at other wavebands.

41. The earth is located on the outskirts of a massive spiral galaxy which contains over one hundred thousand million stars. This causes both opportunities and problems in astronomy; galaxy evolution can be observed in detail, but being embedded in the system makes it challenging to see the whole picture clearly. Galaxy evolution is one of the great puzzles in current astrophysics, incorporating how galaxies assemble and evolve from the beginning of the universe to the present day. Unfortunately, knowledge of the fundamental processes of galaxy evolution is limited by lack of understanding of the evolutionary cycle of our own Galaxy. The life cycle of the Milky Way involves a constant process of stars ejecting matter and energy into the interstellar mix, from which new stars then condense. Somehow matter makes the transition from hot, ionised stellar by-products to become the cold molecular clouds from which stars are formed.

42. Studies of our own Galaxy probe the evolutionary cycle with sensitivity and resolution unattainable in external galaxies; it is only in the Milky Way that the evolution of the interstellar medium on scales ranging from the tiny to the large scale can be observed. Furthermore, the evolution of the Galaxy is controlled by the Galactic and local magnetic fields, yet these components are largely unknown.

43. The scientific outputs of ASKAP will be complementary to the science capabilities of the Parkes 64-m radio telescope and the Australia Telescope Compact Array (ATCA) in Narrabri. The Parkes telescope, in operation since 1961, is extremely sensitive but has rather poor resolution. It is ideally suited for the discovery and timing of radio pulsars, large-scale polarization, galactic spectral line work, and some extragalactic applications.

44. The ATCA, in operation since 1988, is a 6 element interferometer - it provides similar resolution to ASKAP but has less sensitivity and a much smaller field of view. Its great strength is its frequency coverage - it is capable of observing from 1 to 100 GHz.

45. In order to make the highest resolution images of the sky, ASKAP could be linked together with telescopes throughout Australia and other parts of the world to make a Very Long Baseline Interferometer. Such a system is capable, for example, of probing the very inner regions of galaxies where massive black holes reside.

46. The southern hemisphere is the site of many of the world's largest optical telescopes, including the Anglo-Australian Telescope in Siding Springs and the Gemini telescopes in Chile and Hawaii. These and other optical telescopes will carry out surveys of large swathes of the southern sky. In combination with radio observations from ASKAP, and observations from ALMA being built in Chile, they will provide a vast body of knowledge about the evolution of galaxies in the nearby Universe.

3.3 Need for ASKAP

47. The Memorandum of Understanding on the Australian SKA project states that the overall goal of the Governments is to establish the world's premier site for radio astronomy by:

i. establishing the Murchison Radio-astronomy Observatory (MRO);

ii. siting ASKAP on the MRO; and

iii. securing the siting of SKA in Australia on acceptable terms.

48. The work described in this submission will lead to the establishment of ASKAP on the MRO and the international recognition of the quality of the MRO as the best site in the world for the SKA.

49. ASKAP will also deliver the world's best survey radio telescope and develop and demonstrate essential technologies for the SKA.

50. ASKAP will incorporate significant new technologies developed by CSIRO. Up to 36 antennas and highly parallel radio-wave receiving systems (roughly 200 per antenna, 8000 total) demand that its components must be mass-manufactured and designed for low-maintenance field operation. These highly parallel systems will lead to stronger links between radio astronomy and industry due to, for example, the need for mass manufacturability of components. There is potential for spin-off benefits to industry from radio astronomy in areas such as radio-science, high bandwidth data transport and signal processing.

51. In summary, ASKAP addresses the national/international needs to:

i. secure the continued high international profile of Australian astronomy and Australian science;

ii. provide a demonstration that Australia is the best location for the International SKA;

iii. encourage the adoption of advanced technologies developed within Australia for the SKA and for broader application in ICT areas;

iv. forge international collaborations in research and development; and

v. provide a mechanism for Australian industry to participate in SKA-related research and development.

3.4 Alternatives Considered

3.4.1 Siting

52. It is planned to site ASKAP on the Murchison Radio-astronomy Observatory (MRO), which is Australia's candidate SKA site. The Boolardy Station site was selected after an extensive national site search and selection process for Australia's candidate SKA site.

53. A range of site selection criteria, including radio-quietness, climatic and atmospheric properties, proximity to infrastructure, and compatibility of local activities, were used to select the Australian candidate site

54. Infrastructure, including radio-quietness protection, is already being provided for the MRO. ASKAP will be able to take advantage of provisions being put in place in support of Australia's SKA site bid, including Commonwealth and State Government mechanisms for collaboration, acquisition of the land for the MRO, and radio-quietness protection across the SKA frequency range (the ASKAP frequency range is a subset of the SKA frequency range)

55. Initial research, in collaboration with the Governments of New South Wales, Western Australia, and South Australia, identified SKA candidate sites in all three states. When the international Request for Proposals for siting the SKA in Australia was received by the (then) Australian SKA Consortium in September 2004 the criteria in the international request for proposals were used to appraise candidate sites. The process was managed by the Site Working Group of the Australian SKA Consortium. A site in Western Australia was selected in November 2004, with a nominal centre on Mileura Station in Murchison Shire.

56. A proposal to site the SKA in Australia was prepared by CSIRO in collaboration with the Government of Western Australia and submitted to the International SKA Project Office in December 2005. There was extensive stakeholder consultation throughout the process of compilation of the site bid document.

57. Australia was shortlisted in September 2006, along with Southern Africa, as an acceptable site for the SKA. In November 2006, mining and radio astronomy stakeholders met with Western Australian government representatives in a meeting facilitated by the Department of Industry and Resources (WA) and the Western Australian Radio Astronomy Committee. It was decided at that meeting that Boolardy

Station, approximately 90 kilometres west of Mileura, was likely to provide the optimum location for radio astronomy in the Mid West.

58. Investigations of the feasibility of the Boolardy Station site were conducted over December 2006 and January 2007 and, in mid-February 2007, the Western Australian Premier announced that the Boolardy Station site was the favoured site for radio astronomy activities in Western Australia

3.4.2 Technology

59. Traditionally, radio telescopes have very high sensitivity but can only see a small patch of the sky at any one time. The sensitivity comes either through building extremely large dishes (such as the Parkes 64-metre) or by building a number of smaller dishes (such as the 6 dishes of the CSIRO Australia Telescope Compact Array).

60. However, ASKAP and the SKA need a combination of a large field of view AND high sensitivity in order to answer the big questions - what is the nature of dark energy? what is the origin of magnetic fields? is Einstein's theory of gravity correct?

61. Achieving this combination of large field of view and high sensitivity is one of the big challenges for the SKA. There are 3 competing choices:

i. build small (5 metre) dishes which intrinsically have a large field of view. Vast numbers are needed to provide the sensitivity required. International assessment indicates that this technology is too expensive for the SKA as most of the money goes into (expensive) antennas instead of (increasingly cheaper) electronics;

ii. eliminate expensive antennas altogether. Receiving elements are very simple and beams are formed electronically. This is the so-called Aperture Array solution. In CSIRO's view this process will remain too expensive a technology over likely SKA construction timescales because the cost of the beam former and backend computing is prohibitive;

iii. the solution chosen for ASKAP is to have medium sized dishes (12 metre diameter), each equipped with electronics at its focus that provides a large field of view. This combines the best of both worlds - it uses a dish size near the minimum of the cost per square metre curve to economically deliver the sensitivity required and sufficient electronics to provide the field of view. This solution has been incorporated into the international Reference Design for the SKA.

3.4.3 Do Nothing Scenario

62. If Australia does not build ASKAP:

i. Australia will not remain competitive in the international radio astronomy community;
ii. Australia will lose the opportunity to provide a telescope in Australia which, independently of the overall SKA situation, is world class in its own right, will eventually replace Australia's current, ageing, radio-telescopes, and help maintain the world-class standing of Australian astronomy and of Australian science more broadly, for decades to come;
iii. establishment and validation of the radio-quiet site in Western Australia for the SKA will be set back;
iv. Australia will have reduced ability to recruit key scientists and engineers in radio astronomy/radio communications technology.
v. Australia's chances of winning major technology contracts for the SKA, whether it is built in Australia or South Africa, will be significantly weakened;

vi. Australian industry will not be well-positioned to target path-breaking new communications technologies with potentially major economic spill-over benefits; and

vii. Australia will lose opportunities to cement valuable international science alliances, notably with the United States, Europe, Canada, China and India;

63. Attracting, training and retaining scientists and engineers are vital to underpin the human resource base to sustain Australian economic growth. The SKA will be a globally iconic science project, the largest ground-based telescope to be built anywhere in the world. ASKAP will send a powerful signal, globally and throughout Australia, of the Australian Government's commitment to science, and will thereby provide important inspiration to young people to consider careers in science.

64. The SKA project provides a unique opportunity for Australia to host a megascience project, building on its already world-leading expertise in both the science of astronomy and the underpinning engineering and technology development. There is no other major international science project currently proposed for which Australia has such a strong, natural siting advantage and such a strong chance of hosting. This means that the SKA represents the best option for Australia to engage in a major international science project.

4 Local Community and National Impacts

4.1 Local Impacts

65. The local community (Murchison Shire) has a population base of between 100 and 160 people. Through ASKAP construction and operations, the expected impact on this community will be as follows:

66. *Employment opportunities*: The ASKAP telescope is in proximity to the Pia Wajarri remote Aboriginal community and may provide employment opportunities for the residents of the remote community, as well as for other members of the local Indigenous population and other residents of Murchison Shire. CSIRO representatives have visited and spoken to the Pia Wajarri community and elders have expressed support for the project. The city of Geraldton-Greenough (Geraldton) is the closest centre with a substantial industry and population work-base. It is anticipated that many local contractors from Geraldton-Greenough will be used in the construction of ASKAP. Geraldton will also be the location for the Murchison Radio-astronomy Observatory (MRO) Support Facility.

67. *Local economics*: the relatively large number of workers, engineers, and astronomers (relative to the population base) will bring significant income into the Murchison region through provision of support services.

68. *Tourism*: Telescopes usually generate tourist interest. Tourists will be discouraged from directly visiting the MRO, due the potential to degrade the radio-quietness. However, the Murchison Shire intends to develop an interpretive centre at the Murchison Settlement, and an interpretive centre will be established as part of the MRO Support Facility in Geraldton. It is expected that these facilities will generate local and regional income directly and indirectly through attracting visitors to the area.

69. *Education*: Primary, secondary and tertiary education is likely to benefit from astronomy outreach activities. CSIRO has already run a hands-on radio science project in Geraldton, and is running a science education program in remote Mid West schools. CSIRO will establish ASKAP community outreach and education programmes within the area to stimulate interest in science for students and the wider community.

70. *Restrictions* on other economic developments: ASKAP itself will not generate any restrictions on economic developments. Pastoral activity will be able to continue on Boolardy Station and surrounding pastoral stations. The radio-quiet zone being introduced to support the MRO and SKA site bid has introduced restrictions on activity and ASKAP operation will benefit from these restrictions.

4.2 National Impacts

71. ASKAP will send a powerful signal, globally and throughout Australia, of the Australian Government's commitment to science. This will have positive effects for the attraction, training and retention of scientists and engineers, and for young peoples' attitudes to science and engineering – vital issues for underpinning the human resource base for sustaining Australian economic growth.

72. Astronomy is a powerful tool for attracting young people to science, and ASKAP will be partially available for education purposes, as is currently the case for the Parkes dish through the Pulse@Parkes program.

73. ASKAP has the potential to be a showcase of Australian industry capability, and the project is already drawing on many existing local capabilities. Industry engagement principles are captured in the ASKAP Master Plan, and opportunities for industry will be detailed in the ASKAP Capability Requirements Plan. Requests for Tenders will reference an Australian Industry Participation Plan (AIPP) reflecting AusIndustry guidelines set by DIISR.

74. The SKA is a globally iconic science project. The importance of SKA to industry in Australia has been recognized through SKA's adoption as a signature project of the Electronics Industry Action Agenda, and the formation of an industry-led SKA Industry Cluster. More than 100 businesses in Australia have registered interest in supplying SKA-related capabilities, including Cisco Systems, BAE Systems Australia, Boeing Australia, Connell Wagner, and Raytheon Australia. Business opportunities range from the supply of antenna design and construction services, and high-performance receivers and amplifiers, to the on-site housing of control systems and the provision of maintenance services.

5 Consultation

75. CSIRO has regularly consulted over the last five years on the development of the ASKAP and SKA projects with:

i. Australian Government Departments and agencies (principally Department of Innovation, Industry, Science and Research, Department of the Prime Minister and Cabinet, the Attorney General's Department, Department of Environment, Water, Heritage and the Arts, the Australian Communications and Media Authority and the Department of Finance and Deregulation), through the Australian SKA Coordination Committee (ASCC) and its Secretariat provided by DIISR;

ii. Western Australian State Government Departments and agencies (principally Department of Industry and Resources, WA Office of Native Title, Department for Planning and Infrastructure, Department of Environment and Conservation, and the Department of the Premier and Cabinet), through the Australian SKA Coordination Committee and its Secretariat, provided by DIISR:

iii. Yamatji Land and Sea Council;

iv. Mid West Development Commission (WA);

v. Murchison, Cue and Meekatharra Councils;

vi. Industry (through the Australian SKA Industry Consortium); and

vii. the astronomy community through the Australia Telescope Steering Committee, the National Committee for Astronomy and Astronomy Australia Ltd.

76. The ASKAP Project Team works within a wide range of stakeholder bodies:

i. ASCC - Australian SKA Coordination Committee, the joint Commonwealth/State intergovernmental committee overseeing the "Team Australia" approach to positioning Australia for the SKA;

ii. MROCC - The Murchison Radio-astronomy Observatory Coordination Committee, consisting of members of the projects using the MRO, and CSIRO and Western Australian Government Departmental officials;

iii. The ASKAP Science Group, containing members of the national and international science community;

iv. ATSC – Australia Telescope Steering Committee, a ministerially appointed body to provide advice to the ATNF Director;

v. AAL – Astronomy Australia Limited, incorporated to oversee the NCRIS funds to astronomy;

vi. ASKAIC – Australian SKA Industry Consortium; and

vii. the international radio astronomy community, through the international SKA bodies and the European Union Preparatory Study on the SKA.

77. Within the ASCC the decision making and advisory structures for the project provide for Advisory Groups reporting to the ASCC. Existing groups include the Science and Technology Advisory Group comprising representation from key science and technology advisers and the Industry Participation and Procurement Advisory Group with representation from peak industry groups, and Commonwealth and State government industry departments.

78. A Regional Stakeholders Advisory Group is being established; this role will be undertaken by a modified and expanded Western Australian Radio Astronomy Committee. (WARAC). An Education Advisory Group is also being formed to provide an information conduit to and from educators regarding ASKAP.

79. An international SKA Forum was held in Perth on 9 April 2008. The Forum brought together a range of people who are either actively engaged in SKA preparatory work or who have an interest in learning more about it. The Forum program was designed to provide a comprehensive understanding of the SKA, including ASKAP and its role, and allowed attendees to contribute views and ideas on the forward path.

80. In the order of 200 people participated in the Forum including international and domestic participants. Domestic participants included representatives from the Murchison Shire region, industry, members of the registered native title claimant group, Commonwealth, State and local government and the current Boolardy Station leaseholder. The Forum was enthusiastically addressed by Senator the Honourable Kim Carr Minister for DIISR, and the Honourable Alan Carpenter MLA, Premier of WA, who both expressed their strong support for the SKA program in Australia.

6 Timescales/Urgency

81. For ASKAP to be sure of meeting its project milestones of having science output from the first six ASKAP antennas by 2010, and successful demonstration of full ASKAP construction on site by 2011, CSIRO must be able to issue the large-scale construction contracts for antennas and optic-fibre cable by late 2008, and construction should start on site by mid 2009.

82. The European Union has allocated €5.5 million (approximately $8.3 million) to a Framework Program 7 Preparatory Study on the SKA (PrepSKA). This is supported by matching funds of €10 million (aproximately $16.6 million) from other participating countries including Australia. The PrepSKA program started in April 08 and will run until 2011 with the possibility of extension for a further year.

83. PrepSKA will study site characteristics of the two shortlisted SKA sites (in Australia and Southern Africa), technical design for the first phase of the SKA, and policy work packages such as funding, governance and procurement for SKA. The outcome of PrepSKA will be a defined implementation path for the SKA.

84. ASKAP will effectively demonstrate Australia's candidate site for SKA, whether Australian technology solutions are adopted for the SKA, and whether the international community have confidence in Australian governments' approvals processes for infrastructure development. It is essential that ASKAP progress expeditiously in order that lessons learnt from ASKAP can influence outcomes from PrepSKA.

85. Many of the site acquisition and detailed design processes for ASKAP are currently underway, and it is necessary for a successful outcome that the approvals processes, to the extent possible, run in parallel, in order that project milestones be met.

7 Project Scope

86. ASKAP comprises the following:

i. the *antenna array*, consisting of up to 36 parabolic antennas, mounted on concrete footings, and distributed over the Murchison Radio-astronomy Observatory (MRO) site. Each antenna has a 12 metre diameter reflector. Each antenna site will be provided with lightning protection in the form of an earth mat and will be provided with in-ground power and data connection. The antennas will be equipped with sophisticated phased array feed receivers at the focus of the dish reflector, and beamformer and other electronics in the antenna pedestal;

ii. a *central compound*, located within the MRO site, containing a control building, site services and areas for storage;

iii. a *remote power generation facility,* adjacent to the central compound;

iv. renovated facilities within the *Boolardy Station homestead precinct* to provide accommodation, working, and recreational facilities for additional staff and visitors to the MRO. The facilities will provide for after-hours remote monitoring of the equipment at the MRO;

v. an MRO *Support Facility (MSF)* located at the Geraldton Universities Centre in Geraldton-Greenough, WA. This facility will contain a telescope control room, computer room, monitoring and processing equipment, electrical and mechanical workshops, office and meeting space and amenities. The building will also include an education/outreach centre;

vi. *access and services infrastructure*, including access corridors at the MRO, fencing, power reticulation, data and communications cabling, water and waste water management.

vii. high bandwidth *optic-fibre cabling* connecting the MRO to the MSF to provide essential data connectivity

viii. *radio telescope infrastructure in NSW* to connect to ASKAP in Western Australia to achieve high resolution pictures of the sky and to demonstrate cross-continent connectivity at astronomically useful data rates.

87. The design of facilities is intended to provide scientists and operational personnel with comfortable, fit for purpose working and living accommodation that is appropriate to the remote location and climate of the MRO. In planning the facilities, CSIRO has taken into account:

i. the need to provide infrastructure that provides functional, flexible and adaptable facilities at minimum cost to fit within the overall project budget, at the same time ensuring that ASKAP is sustainable;

ii. the need to ensure that the facilities are low maintenance and can be economically constructed at the MRO;

iii. the fact that ASKAP will primarily be controlled remotely, from the MSF in Geraldton and from other CSIRO facilities in Perth and Sydney. To this end, only the MSF is expected to have a constant, full time staff presence.

Facilities at the MRO and the Boolardy Station homestead precinct will cater for short term and semi-permanent staff only;

iv. heritage and Native Title considerations in the refurbishment of existing facilities at Boolardy Station homestead precinct;

v. that the MSF should provide an appropriate public face for visitors and act as a catalyst and attractor for CSIRO's work;

vi. the requirement that all buildings, services and external infrastructure comply with all relevant Commonwealth, State and local planning, building, health and safety requirements, the Building Code of Australia and relevant Australian Standards; and

vii. the requirement that all consultant agreements and construction contracts shall be compliant with the Australian Government National Code of Practice for the Construction Industry and the Building and Construction OHS Accreditation Scheme.

8 ASKAP Sites

88. ASKAP comprises a number of sites that together support the ASKAP project:

i. the Murchison Radio-astronomy Observatory (MRO) (containing the ASKAP antenna array, power generation facility, central compound). Temporary compounds will also be required during construction;

ii. the Boolardy Station homestead precinct (containing upgraded accommodation facilities for visiting scientists and associated power, water and waste water infrastructure);

iii. the Geraldton Universities Centre, where the MRO Support Facility will be sited;

iv. the fibre optic cable link between the MRO and the MSF; and

v. an existing radio astronomy site in NSW.

8.1 The Murchison Radio-astronomy Observatory

8.1.1 Site Description

89. The MRO site is approximately 315 km north east of Geraldton and 40 km north of the Boolardy Station homestead, on Boolardy Station.

90. Boolardy Station is a 346,748 hectare pastoral lease property in an arid rangeland region of Australia. The land is WA Crown Land, held under a pastoral lease, with the next pastoral lease renewal period being 2015. The WA Pastoral Lands Board has indicated that it plans to extend leases in the area.

91. The terrain at Boolardy Station includes sandplains, hardpans and stony plains interspersed with low granite hills, quartz ridges, and laterite "breakaways". Soils are typically gravelly sands, red hard pan clay loams or a gradation between these two soil types. Saline soils exist at the foothills of breakaways.

92. Within Boolardy Station, but not forming part of the MRO, is a 7,020 hectare area of high environmental conservation value. This area is set aside as a reserve and managed by the WA Department of Environment and Conservation.

93. The MRO will occupy 12,674 hectares of Boolardy Station and the ASKAP project will occupy 0.2% of the land area of the MRO.

8.1.2 Site Selection

94. The MRO location was selected for ASKAP as it is Australia's candidate SKA site, which was chosen after an extensive national site search and selection process for Australia's candidate SKA site.

95. The site selection criteria included the need for the site to be flat, above the floodplain, on unfavoured pastoral land and situated sufficiently far from radio-frequency interference such as mining activity and sufficiently close to other infrastructure such as roads.

96. The MRO is also the site of the world's most effective radio-quiet zone, to protect the observing environment for radio astronomy experiments. In the Memorandum of Understanding on the Australian SKA Project between the Government of Western Australia and the Commonwealth Government the Governments agree to… "*Establish and safeguard a radio quiet zone in the Mid West of Western Australia, with appropriate development and other controls for 30 km radius, 70 km radius and up to 260 km radius."*

97. ASKAP's site selection will benefit from the Mid West Radio Quiet Zone (RQZ) and will need to comply with the requirements of the radio-quiet zone. The RQZ, centred on the MRO, will coordinate and restrict use of devices emitting radio frequencies between 100 megahertz and 25 gigahertz.

98. If SKA does not proceed in Australia, the MRO and the RQZ will still be maintained (at the full frequency range) for experiments that may use the MRO site in the future, including ASKAP.

8.2 Boolardy Station Homestead Precinct

99. The Boolardy Station homestead is located approximately 40 km south of the MRO. The homestead precinct comprises a collection of buildings and out houses that are utilised by the current station management. These include:

i. The Homestead, Wittenoom House, Worker's Quarters, Cook's Quarters and Roo Shooters Cottage, all of which provide varying standards of residential accommodation;

ii. Equipment and machinery sheds, including the Blacksmith's shop and quarters;

iii. Various sheds and store buildings.

100. Facilities and buildings within the homestead precinct are serviced by locally generated electricity, and water from an underground bore. The homestead precinct is currently occupied and used for pastoral activities. Septic tanks are used to capture waste water.

101. The buildings and structures on the site are a mixture of stone, timber framed, fibre cement and metal clad construction with metal deck roofing. Some of the buildings on the site have been identified on the WA State Heritage Register.

102. The Boolardy Station homestead precinct will be used to provide short-term residential, recreational and general accommodation for staff and visitors to the MRO as well as after-hours remote monitoring of the equipment at the MRO.

103. The Boolardy Station homestead precinct was selected as it was sufficiently far from the MRO to reduce radio-frequency interference to the antenna array, and is the only nearby site where support infrastructure is available.

8.3 Geraldton Universities Centre in Geraldton-Greenough

104. Remote operations capability and support will be established in a purpose built building at the Geraldton Universities Centre. This site is located within the university precinct in Geraldton and the new ASKAP building forms part of the master plan for the campus.

105. The MSF site was selected at the request of the Government of WA, the Mid West Development Commission and the Geraldton Universities Centre. Siting the MSF within the University Centre campus provides shared infrastructure and a collegiate community.

8.4 Optic-fibre link

106. High bandwidth optic-fibre transmission between the MRO and the MSF will be provided through underground cable. A detailed design study is presently being undertaken by the Australian Academic and Research Network (AARNet) under contract to CSIRO. The optic-fibre cable route has been selected to minimise environmental impact, is flexible and will manoeuvre around environmental or social constraints. As required, the use of directional boring will also be used to avoid sensitive areas.

107. A full study report, including details of site selection, will be provided when the study is complete, scheduled for late June 2008.

8.5 NSW Site

108. Several options have been studied by the ASKAP science and technical teams for NSW connectivity to ASKAP in Western Australia.

109. Based on advice received from the Science and Technology Advisory Group of the Australian SKA Coordination Committee the ASKAP team are undertaking further scientific and technical studies on the option of adding ASKAP capability to the existing Parkes radio telescope infrastructure.

110. Existing radio astronomy support infrastructure and sites will be used.

9 Approvals

9.1 Environmental Considerations

111. The Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act) protects matters of national environmental significance in relation to Commonwealth actions, and actions on (or impacting upon) Commonwealth land.

112. Pursuant to the EPBC Act, CSIRO will refer the ASKAP project to the Department of the Environment, Water, Heritage and the Arts (DEWHA) for determination by the Minister as to whether approval is necessary and, if so, the type of assessment that will be undertaken.

113. As the MRO will be located on pastoral leasehold WA Crown Land, the ASKAP project will also be assessed under the Western Australian Environment Protection Act 1986.

114. In the event that the project is determined to be a Controlled Action under the EPBC Act, DEWHA would seek to accredit the WA process under the Commonwealth Act.

115. An environmental assessment of the MRO was undertaken on January 2008. This assessment included environmental constraints and likely on-site, off-site and regional impacts of the MRO on land units, vegetation communities and flora and fauna of conservation significance. Local, regional, State and Commonwealth threatened species were identified.

116. Preliminary ecological assessment on Boolardy Station suggests the Western Spiny-tailed Skink is the only nationally listed threatened animal known or likely to occur in the MRO and adjacent areas.

117. Mammals recorded on site include bats, Red Kangaroo (Macropus rufus) and Woolly's Pseudantechinus (Pseudantechinus woolleyae). Species of bird recorded are typical of the Murchison bioregion.

118. Feral goats are present on the site, as are rabbits, foxes and cats.

119. Direct and indirect impacts of the proposal on the ecosystem within the ASKAP sites and surrounding areas may include:

i. clearing of native vegetation and loss of habitat;

ii. changes to surface flows;

iii. death or injury to wildlife through vehicle collision;

iv. obstruction of existing fauna corridors;

v. introduction of weed species;

vi. increased feral animal activity in response to human activity and food resources;

vii. dust generation;

viii. pollution through construction activities and vehicles emissions;

ix. wildlife disturbance through light, vibration and noise.

120. With appropriate environmental management, these impacts can be avoided, or where necessary mitigated through the design and construction processes. Where the impacts cannot be avoided they will not be significant because the proposal:

i. Will involve a low level of human presence once construction is completed and ASKAP moves into its operational phase;

ii. Will not include large-scale clearing of native vegetation and associated habitats. For example, the total footprint of clearing for the antennas, including access corridors and the compound is 2.2 hectares, of order 0.2% of the total MRO area. There is flexibility in the detailed siting of the antennas and the compounds, which will enable sensitive habitats to be avoided;

iii. Will not significantly fragment or reduce available habitat;

iv. Will not disturb the habitat of significant species, including rare or threatened species; and

v. Will not disturb the environmentally sensitive areas of rock outcrops.

121. Detailed impacts of the proposal on flora and fauna are being assessed as part of the environmental approvals processes.

122. Boolardy Station will continue to be managed as a pastoral property.

9.2 Heritage Considerations

123. Boolardy Station homestead precinct, consisting of the late 1800s original station homestead and additional outbuildings constructed over the following 60 years, is listed on the Western Australian State Register of Heritage Places.

124. The proposed action will involve an upgrade to two buildings of the Boolardy Station homestead precinct.

125. Other sites listed on the Western Australian State Register of Heritage Places will not be affected by this proposal.

126. In support of the proposed actions on Boolardy Station, the following preliminary heritage assessments have been carried out:

i. Heritage Assessment of the Early Research Area within the MRO, June 2007. The preliminary heritage assessment involved Wajarri Yamatji Native Title Claimants, anthropologists from the Aboriginal native title representative Body for the Yamatji and Pilbara regions of Western

Australia, archaeological consultants, and representatives from relevant government agencies. The assessment identified indigenous heritage values within the Early Research Area and surrounding area through cultural or archaeological sites. A site template has been used to ensure that all telescope and other infrastructure placements lie outside agreed buffer zones placed around indigenous heritage sites;

ii. Assessment of the proposed works to Boolardy Station homestead precinct in terms of heritage values, January 2008. These works have a letter of support from the Heritage Council, Western Australia.

9.3 Local Council Requirements

127. The MRO and Boolardy Station site are within the Shire of Murchison. Local Council approval is also being sought for the development.

9.4 Land Access

128. Currently, a Deed of Licence, issued to CSIRO by the WA Government through the Minister for Lands, allows for low-impact radio astronomy activity on an Early Research Area within the MRO. Cultural heritage and environmental monitoring mechanisms are in place whenever work with the potential for ground-disturbance is undertaken.

129. Processes are in place to facilitate CSIRO access to the MRO by April 2009.

130. Dependent on the PWC outcome the CSIRO intends to issue a contract for construction of the optic-fibre link by the end of 2008. Satisfactory completion of all appropriate approval processes will be required by a successful contractor.

131. The Geraldton Universities Centre (GUC) has agreed in principle to provide a site in the GUC campus for the MRO Support Facility to be based at Geraldton. The site is included in GUC's master plan for its campus.

132. The NSW infrastructure will be located on an existing radio telescope facility owned by CSIRO.

10 Technical solution

10.1 Antenna Array and Correlator

133. Up to 36 parabolic dish antennas, each of 12 metres diameter, will be positioned within the MRO. Individual antennas will be supported on concrete foundations, with each antenna being able to sweep out an area of diameter 17 metres. There will be landscaping and erosion mitigation management surrounding each antenna. Each antenna may be fenced in order to keep cattle away, but it is envisaged that cattle will still be run throughout the MRO. Each antenna site will be provided with lightning protection in the form of an earth mat and will be provided with in-ground power and data connection. The antennas will be equipped with sophisticated phased array feed receivers at the focus of each dish, and beamformer and other electronics in the antenna pedestal.

134. The beamformers within the antenna pedestal process the radio-frequency signals received from a region of the sky. These signals are fed from each antenna to the central correlator housed in the control building. The correlator combines the signals from each antenna and compresses the data ready for transport to the MSF for further processing.

135. Buried fibre optic cable will connect each antenna with the control building. Power for the antennas will be supplied from a power generation facility situated adjacent to the central compound and will be delivered to each antenna in the same trench as the fibre optic cable. Access corridors for both assembly and maintenance of the antennas are included in the design and the power and data cabling will be laid within those corridors.

136. The configuration on the ground for the antenna array is determined by science considerations. Analysis by the ASKAP Project Science Team has been reviewed by the international ASKAP Science Group in order to ensure optimum science capability from the antenna array.

137. The antenna design is being selected through a rigorous review process of responses to a Request for Tender issued by CSIRO on March 17 2008.

10.2 Central Compound and Buildings

138. The central compound area will be 6.25 Ha and will be fenced to prevent access by stock and feral animals. The central compound will contain the control building, as well as equipment and services required to support telescope maintenance. Technical staff will be provided with a habitable work environment for day tasks. The building will accommodate two to five staff up to four days per week carrying out primarily office/workshop based tasks. After working hours, staff will relocate to the homestead precinct for accommodation and recreation needs.

139. The central compound comprises the following facilities:

i. Control building;

ii. Hardstand area for the storage of shipping containers and the manoeuvring and parking of vehicles.

iii. Engineering support and services infrastructure.

140. The control building will be 635 m^2 gross floor area and will contain:

i. Operations room - for the operation of the telescope and collaborator experiments;

ii. Shared office accommodation to support up to 10 people for short-term use during construction and commissioning of the telescope, and up to 5 for longer term working arrangements;

iii. Correlator room (the dedicated computer for initial data processing);

iv. Specialist equipment rooms for dedicated aspects of the array operations and control, including reference frequency and local oscillator generation and optic fibre distribution;

v. Mechanical workshop for minor mechanical fabrication and repairs;

vi. First aid room for staff;

vii. Miscellaneous areas including kitchenette, stores area and amenities; and

viii. Plant room - for mechanical services equipment.

141. Based on the functional and operational requirements, the control building has been designed to be a robust facility constructed in a rectangular shape using standard construction materials and technologies. It is proposed that the base structure will be concrete slab poured in situ and forming an apron around the building for additional storage areas. The building will generally be framed in a steel structure and wall and roof cladding will be lightweight metal sheet installed to perform as a radio-frequency interference shield.

142. Extensive verandas around the perimeter of the building will provide shading for better thermal outcomes as well as additional covered storage areas.

143. The building has been designed with consideration for the requirements of the Building Code of Australia (BCA). This includes the number of amenities required, access and egress and disability access.

144. The building is required to be Radio Frequency Interference (RFI) shielded and will be designed specifically for the specialist equipment within, and to prevent any RFI contamination of the MRO. All major electrical and electronic equipment in the control building will be contained within high integrity Faraday housing. The Correlator Room and Specialist Equipment Room will be separately lined with lightweight metal sheet and include wave attenuators for services penetrations and attenuated doors to provide RFI shielding. Minor specific items outside these rooms will be individually shielded and managed in their use. The building fabric itself will have some additional RFI shielding capabilities.

145. The central compound will have a high bandwidth buried fibre-optic connection to the homestead and to the MRO Support Facility in Geraldton.

10.3 Boolardy Station Homestead Precinct Buildings

146. The primary purpose of the Boolardy Station homestead precinct for the ASKAP project will be to provide residential accommodation for visiting technical and maintenance staff, as well as recreational facilities and remote monitoring of the MRO. The spaces to be provided are as follows:

i. Individual bedroom accommodation for up to 12 staff;

ii. Open plan working accommodation for remote monitoring of the MRO systems and security networks;

iii. Kitchen/Dining and recreation area for up to 12 staff;

iv. Bathroom amenities.

147. Subject to reaching satisfactory agreement with the leaseholder of Boolardy Station, CSIRO proposes to reuse and refurbish Wittenoom House and the Workers Cottage within the Boolardy Station homestead precinct to accommodate personnel. Upgrade works will retain the overall structure and exterior design of the buildings.

148. The WA Department of Housing and Works have prepared refurbishment designs which are consistent with maintaining the heritage values of the homestead precinct and individual buildings. These works have been approved by the Western Australian Heritage Council.

149. Works will also include additional water storage and treatment, waste water treatment and power generation adjacent to the existing buildings.

10.4 MRO Support Facility (MSF)

150. The proposed support facility building at Geraldton will accommodate ten full time staff, with additional allowance for five visiting or collaborating personnel. The general spaces are described as follows:

i. lobby / entry including a visitor / educational facility;

ii. working accommodation for staff including meeting rooms, single office space and open plan offices for up to ten permanent staff;

iii. open plan office space for visiting support and collaborator staff;

iv. kitchenette and recreational space (informal meetings and relaxation areas);

v. operations room - for the operation of telescope and collaborator experiments;

vi. communications Hub - various computer equipment rooms for storage of data, server equipment and termination of incoming fibre from the MRO site;

vii. technical support rooms (2 off) for the conduct of electronic equipment testing, repair and maintenance;

viii. mechanical workshop for minor mechanical fabrication and repairs; and

ix. miscellaneous areas including stores area, toilets, showers, first aid room and plant room.

151. The MSF has been designed and oriented to suit the existing campus master plan of the Geraldton Universities Centre, responding to the site's main pedestrian spines, proposed vehicle access and environmental conditions. The external architecture will provide a public face for CSIRO appropriately signifying their operations and methodologies. Simple steel framing, sustainable local timbers and masonry will be used to configure a series of dynamic volumes, capturing natural light and expressing the progressive nature of CSIRO's work.

152. Internal planning has been developed to provide flexible open and dedicated work spaces to support a number of collaborative and individual situations. Strong relationships with outdoor areas are offered from within high occupation areas. The functional needs for the facility are best accommodated within a single storey building. The design will comply with BCA standards, including all circulation, access and sanitary requirements for disabled persons.

153. The design of the building form will provide:

i. a public interface for clients and visitors;

ii. a catalyst and attractor for promotion of CSIRO's work;

iii. medium and long term flexibility and adaptability; and

iv. quality working facilities for research.

154. The proposed landscape design will seek to respect the formality and cultural values of the existing buildings in the campus and to respond to the proposed new architectural elements.

155. Vehicular access, car and bicycle parking will be provided.

156. Site security will be provided with access control and monitoring to all external doors. Perimeter lighting will be provided to improve night security.

10.5 Services and Access Infrastructure

10.5.1 Power Generation and Reticulation

157. Due to the high capital cost of providing power to a remote site such as the MRO, overall demand side management will be closely monitored. For ASKAP, passive solar design and ground coupled cooling systems will significantly reduce the base load and peak power requirements. Technologies and providers of such systems have been identified. Power for ASKAP will be part of an integrated energy design package that minimises the overall demands.

158. The base load power requirement for the MRO site has been calculated at 450 kW.

159. The power supply and reticulation system to the MRO site will involve several major elements:

10.5.2 Power generation - MRO

160. It is proposed that 100 kW of the required 450 kW base load power requirements of the MRO site will be provided by a solar photovoltaic system. The remaining base power needs, and peak in-fill will be supplied by diesel (including bio-diesel) powered generation. Whilst solar photovoltaic cells are a proven technology, and CSIRO has examined the possibility of providing 100% of the site power through solar photovoltaic generation, the cost of the required photovoltaic cells and storage batteries would be very high and is not supported by the current ASKAP budget.

161. The power generation equipment will be sited in the MRO adjacent to the central compound.

10.5.3 Power transmission - MRO

162. The antenna power, approximately 280 kW, has to be transmitted to the antenna sites which are located up to 8km from the power generation facility. The remaining 170kW is distributed to the central compound.

163. The MRO site power distribution will have two (2) voltage systems:

i. HV, (22kV) Transmission will be provided via underground power supply to all individual antenna sites.

ii. LV, (400/230V) Distribution will be provided via underground power supply to all central compound buildings and facilities.

164. Due to the high level of Radio Frequency Interference (RFI) screening required, the HV Transmission Lines will be underground cables.

165. There is to be provision for Low Pass Filters (LPF) to be installed on the 22kVmain feeder.

10.5.4 Power generation at Boolardy Station homestead

166. The homestead currently has a small solar array, a wind generator, batteries and a diesel generator.

167. This system provides sufficient power for existing pastoral management activities. However, the additional accommodation and functions to be incorporated in the refurbished facilities will require an increase in power generation capacity. This will be provided by the installation of additional solar PV cells and battery storage, and an upgrade to the generator back-up.

10.5.5 Power at MRO Support Facility

168. The estimated 300 kVA electrical load for this building will be met from the domestic mains.

10.5.6 Access roads and corridors in the MRO.

169. The main civil works will involve the access corridors within the MRO (approximately 36km of access corridors will be required to connect the antenna sites) and the track from the Murchison Shire road (from 20km north of the homestead) to the MRO site, a distance of some 9km. Access from the area known as Top Shed to the central compound will need a degree of upgrading, consistent with standard pastoral practice. During periods of rain, access to portions of the site will be restricted to ensure that the ground surface is not damaged

170. One-way roads to each antenna site will be sufficient. Management controls for a one-way system and construction of turning areas at each antenna site will be maintained.

171. Local material will be utilised for any gravel or fill required for the roads.

10.5.7 Aircraft access

172. There is an existing airstrip that will be maintained to an acceptable standard for use by the Royal Flying Doctor Service (RFDS)

10.5.8 Hydraulic services

173. A new bore water supply will be provided to service the control building and associated facilities. Some additional water quality treatment will also be provided, to ensure a potable supply. An adequately sized septic system will provide treatment for waste water.

174. Additional bore water supply and septic waste water treatment will also be provided at the Boolardy Station homestead precinct.

175. Hydraulic services for the MSF at Geraldton will be provided by connection to the town water and sewer mains.

10.5.9 Optic-fibre cable

176. The optic-fibre cable will be laid underground and sufficient cable cores will be provided to ensure capacity for SKA, as well as the much lower ASKAP demand, and use by the general public.

10.5.10 Earthing and lightning protection

177. The lightning protection system will be designed in accordance with the relevant Australian standards.

178. Lightning arrestors shall have their own earthing connectors and earthing rods. These rods may be interconnected with the equipment earthing loop.

179. Major steel structures and antennas will be earthed by direct earthing at their base. These earthing rods shall be connected to the earthing grid.

180. Metal framed buildings or structures will be protected by bonding of the sections of frame and connecting the metal frame to earthing rods.

181. All metal structure including buildings, reinforcing, structure steel works and metal piping shall be connected to a lightning protection system and earth termination network.

10.5.11 Mechanical services

182. High reliability proven systems will be used at the MRO to minimise any extensive ongoing maintenance. A high level of redundancy will be inbuilt due to delays for spare part replacement in the remote location.

183. Climate control within the general working areas of the buildings constructed at the MRO and MSF will maintain operational parameters.

184. Building management systems will be provided to support the mechanical services and will provide remote monitoring and alarm reporting.

10.5.12 Fire protection

185. A 3-4 metre wide firebreak along perimeter fences will be maintained and a water supply kept for emergency use, consistent with current pastoral practice in the area.

186. Fire protection to the control building will include:

i. provision of a Fire Indicator Panel (FIP) linked to detection measures including thermal detectors and smoke detectors, for designated areas;

ii. provision of Multi Point Aspirating Smoke Detection to the correlator room, RF/LO generator room, operations room and fibre termination room to provide early warning of a fire;

iii. provision of alternate photo-optical and ionisation smoke detectors to the correlator room, RF/LO generator room, operations room and fibre termination room for the initiation of the gas suppression system;

iv. provision of a total flooding inert gaseous suppression system such as "Inergen" or equivalent will be installed to protect the critical equipment located within the correlator room, RF/LO generator room, operations room and fibre termination room;

v. portable fire extinguishers to be positioned in accordance with BCA and Australian Standards;

vi. the correlator, RF/LO generator, operations and fibre termination rooms will have a 2 hour fire separation construction from the remainder of the building.

187. Fire protection to the homestead shall include provision of other fire detection measures such as thermal detectors and smoke detectors to the relevant Australian standards.

188. Fire protection to the MSF building at Geraldton shall include:

i. a Fire Indicator Panel (FIP);

ii. multi Point Aspirating Smoke Detection to the fibre termination, computer and lab rooms;

iii. other fire detection measures such as thermal detectors and smoke detectors to the fibre termination, computer and lab rooms;

iv. provision to supply gas suppression to the computer zone, labs and fibre termination room.

10.5.13 Acoustics

189. Noise level predictions will be performed in accordance with the requirements of the Western Australia EPA 'Environmental Protection (Noise) Regulations 1997. Feasible noise mitigation measures will be presented (if required) to ensure that the Assigned Noise Levels will be met for both sites.

190. The internal noise environment for all facilities will be determined and room finishes and noise mitigation measures presented to achieve the recommended designed noise levels for the various areas of occupancy.

10.5.14 Occupational health and safety

191. CSIRO pursues an active occupational health and safety policy within the workplace and this will be extended to include all ASKAP facilities. Strict compliance with these requirements will be adhered to in all construction work and ongoing operation and maintenance of the facilities.

192. Construction activity will also be conducted by contractors accredited under the Federal Safety Accreditation Scheme, where applicable, and be monitored by the Federal Safety Commissioner.

11 Sustainability

193. The proposed design options will be fit for the local climate, and also fit for the economic, social and environmental realities.

194. The local climate of the MRO and Boolardy Station homestead precinct, although extreme, has some characteristics which can be used to advantage. Whilst the days are extremely hot in summer, the nights are relatively cool. Humidity is almost always low, and while the winters can be cold, the mid seasons are relatively comfortable. Design initiatives are to include relevant Ecologically Sustainable Design (ESD) features which take advantage of these harsh conditions.

11.1 Energy Sustainability

195. A significant component of sustainable power generation and energy efficiency in building operations will be implemented for this project.

196. The power requirements of the MRO will be in the order of 450 kW. Given the size of this demand and the remote location of the MRO, it is not feasible to provide this power requirement from the grid or by gas fired power generation.

197. Both wind and solar generation have been examined. The inland location of the site and the electrical characteristics of wind turbines preclude the practicable use of wind power on the MRO. Solar power and storage is feasible but very expensive given that ASKAP will operate 24 hours per day.

198. In order to maximise the cost-efficiency of the ASKAP project while still progressing towards sustainability goals, CSIRO proposes that power generation be by on-site diesel power, supplemented with 100kW of solar photovoltaic generation. This will enable a significant proportion of base load to be met with sustainable energy, with diesel power to provide the balance.

199. The power generation system will be designed to have a readily expandable renewable component. This will allow flexibility to accommodate new and more cost effective technologies in future, as they become available.

200. Energy sub-metering shall be provided to all major energy uses in all buildings. This will allow an energy audit to easily identify potential energy saving initiatives when the buildings are running.

11.2 Passive Energy Design

201. The building fabric for all new buildings is being designed to suit the local climate and the operation of the building. A mixture of highly insulated building elements and use of strategically placed thermal mass is being explored as a design philosophy in the detailed building design. The high range of diurnal temperature at the MRO indicates that thermal mass storage can aid the creation of more stable temperatures within the built spaces there.

202. The building fabric of the MSF is being designed to suit the external coastal climate and the proposed operation of the building. Mixtures of highly insulated parts and use of strategically placed thermal mass is being explored. Furthermore the following passive design options will also be utilised:

i. shading glazed building components appropriately;

ii. optimum building layout enabling maximisation of day–lighting conditions for offices and work areas. High level glazing will be placed in working areas to enhance indoor environment quality and reduce the need for artificial lighting.

11.3 Mechanical Services

203. All mechanical services systems have been selected on the basis of achieving optimum energy efficiency for the required building environmental conditions. Design features such as zoned ducting and associated load balancing will be included as part of the final design solution.

204. A mixed mode system will be utilised for the homestead refurbishment and the Geraldton facility to allow natural ventilation and a potential night purge in the appropriate areas. This would utilise control systems on the windows. Such a system cannot be incorporated into the MRO control building due to the need for stringent radio-frequency interference screening.

11.4 Electrical Services

205. The following lighting solutions are to be utilised for all buildings:

i. Passive infra-red and ultrasonic detectors to activate/deactivate lighting to all rooms;

ii. Zone controlled lighting to allow switching off areas that aren't in use; and

iii. Either compact fluorescent or light emitting diodes (LED) to reduce the lighting energy consumption.

11.5 Building Materials

206. A mixture of highly insulated building elements and use of strategically placed thermal mass is being explored as the preferred design philosophy for all buildings. As the design process is completed, the following material properties will be considered:

i. recycled material and / or recyclability (eg. recycled concrete);

ii. containing eco-preferred content (eg. HDPE as preferred to PVC);

iii. its manufacturing process and / or chain of custody credentials (eg. ASF or FSC accredited timber);

iv. low VOC carpets, paints, furniture and adhesives and sealants to be specified; and

v. low formaldehyde joinery to be specified.

11.6 Radio-frequency Mitigation

207. Radio astronomy uses very sensitive receiving systems for reception of radio-wave emissions from the Universe. Thus, it is highly susceptible to interference by unwanted emissions from other radio communication services and electrical equipment.

208. The MRO sits within a radio-quiet zone being created by the Australian Government and Western Australian Government in support of the SKA project and future radio astronomy in Australia. It is necessary for ASKAP to minimise radio-frequency emissions from its own operations.

209. Careful design and testing of all ASKAP telescope components prior to field deployment is being undertaken to ensure compliance with radio-quiet standards.

12 Costs

210. The ASKAP project has a total budget of $111 million. A confidential cost breakdown is provided separately.

13 Project Delivery and Construction program

211. It is anticipated that subject to a favourable report from the Parliamentary Public Works Committee and Parliamentary approval, and completion of environmental approvals and land acquisition, construction on site would start in May 2009.

212. Construction program milestones include:

i. optic-fibre tender issued Feb 2009

ii. start construction of MRO infrastructure May 2009

iii. critical design review for ASKAP system June 2009

iv. optic-fibre link in place Sept 2009

v. first antenna deployed Nov 2009

vi. commissioning of Boolardy Experimental Test Array 6-dish system complete Dec 2010

vii. first science with 6-dish system Dec 2010

viii. ASKAP digital system installed Nov 2011

ix. ASKAP complete Nov 2012.

213. With respect to procurement and development for ASKAP, CSIRO is:

i. the originator and developer of key technologies to a stage where they are suitable for manufacture, primarily in the areas of the feeds and receivers, special purpose hardware (beamformer, correlator) and astronomical software systems; and

ii. the prime contractor for the entire ASKAP system with responsibilities including project management of building and commissioning, in some instances by external sub-contractors, and specification of the technical requirements for outsourced components (e.g. antennas, fibre optic and MRO infrastructure).

214. ATNF projects are managed within a rigorous project management framework. Each work package within the overall effort to deliver ASKAP will be subjected to appropriate oversight processes.

14 Conclusion

215. This submission is for the construction of the proposed Australian Square Kilometre Array Pathfinder (ASKAP) radio telescope in Western Australia.

216. CSIRO is satisfied that the proposed works as described in this submission are the most appropriate, timely and cost effective means by which to achieve the foregoing objectives.

217. The design properly reflects the CSIRO functional requirements and will cater for future changes in research activities and priorities.

15 Associated Drawings

218. Sketch plan drawings:

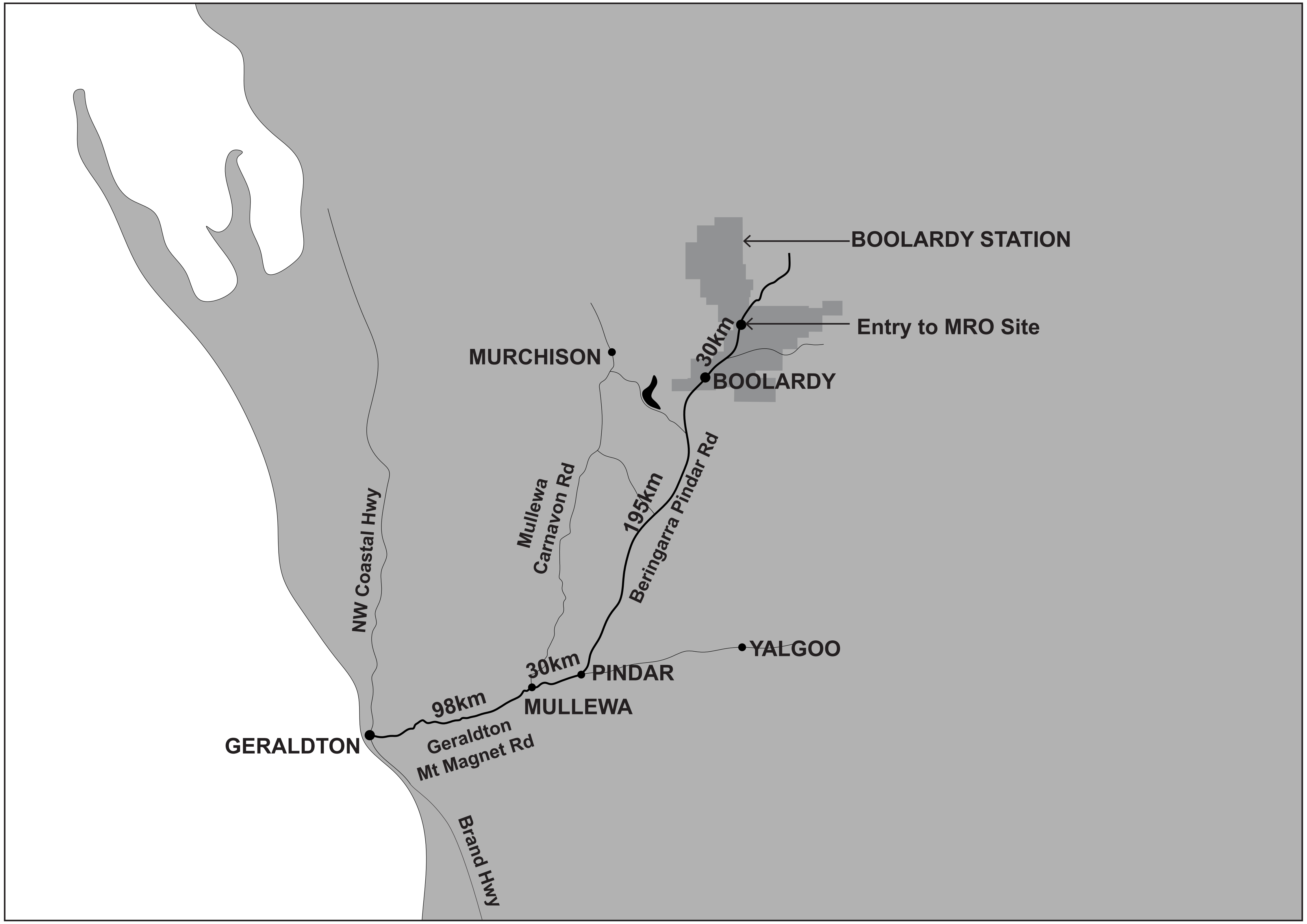
i. Location Diagram
ii. Location Diagram: Geraldton - Boolardy Station
iii. Location Diagram: Boolardy Station
iv. General View MRO Site
v. Boolardy Station: MRO General Layout
vi. Artists Impression of Antenna Site
vii. Indicative Antenna
viii. Boolardy Station: Central MRO Compound Proposed Site
ix. Boolardy Station: Proposed Central Compound Control Building
x. Boolardy Station: Central Compound Control Building Perspective
xi. Photo: Existing Boolardy Homestead Precinct
xii. Boolardy Station: Homestead Precinct Proposed Site Plan
xiii. Photo: Existing Boolardy Homestead Precinct: 1890's Homestead
xiv. Location Diagram: Geraldton - Geraldton Uni. Location Plan
xv. MRO Support Facility Geraldton: Site Plan - Geraldton Uni
xvi. MRO Support Facility Geraldton: Proposed Floor Plan
xvii. MRO Support Facility Geraldton: Perspective

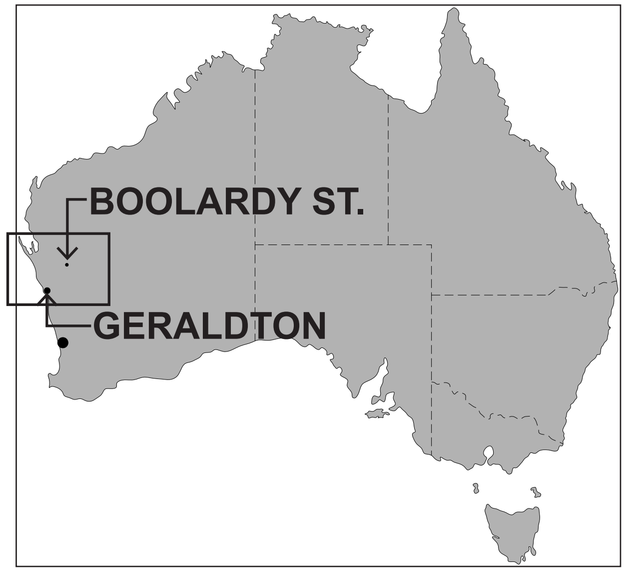
CSIRO

NORTH

CSIRO PROPOSED ASKAP RADIO TELESCOPE
LOCATION DIAGRAM

SKM





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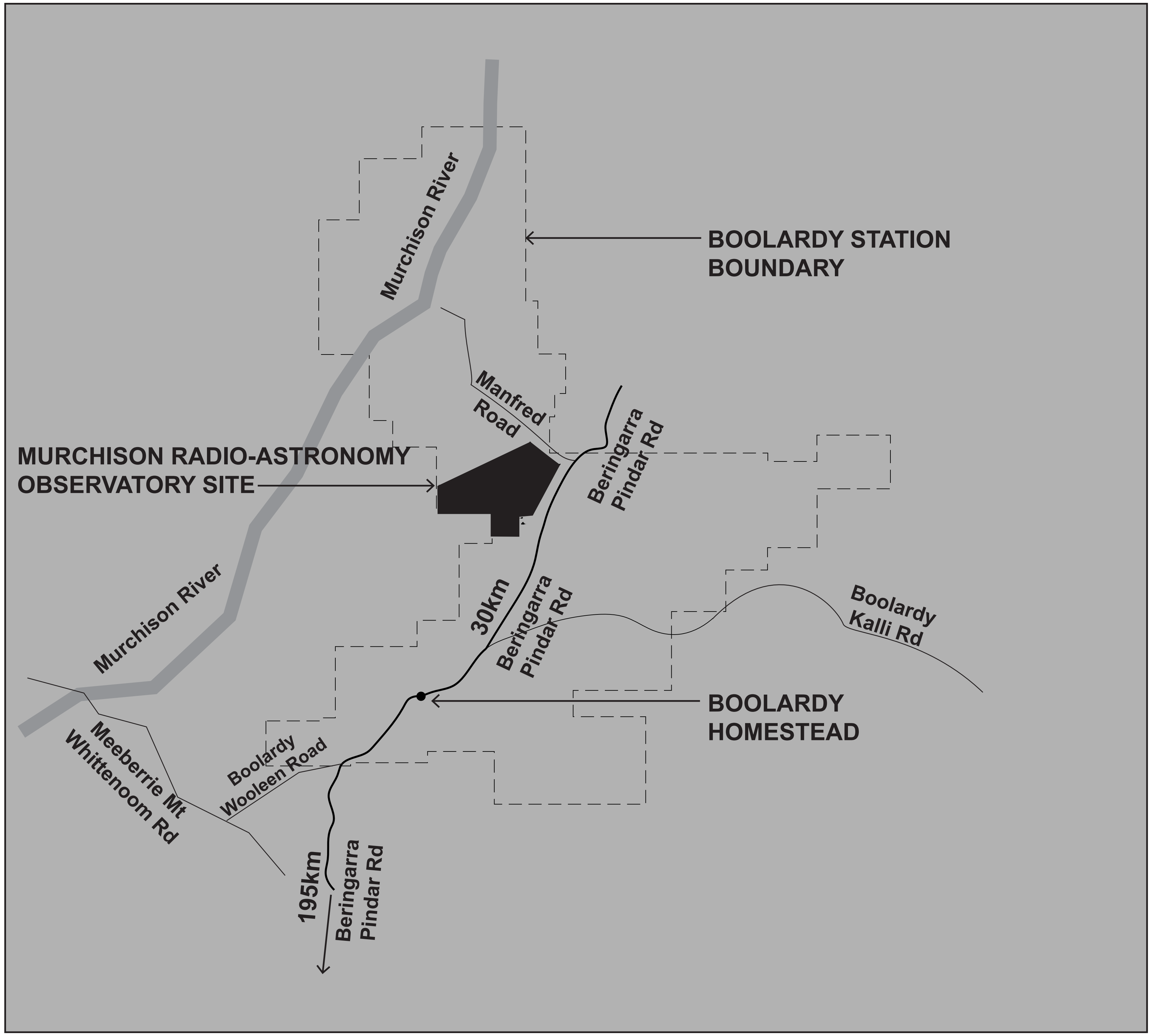
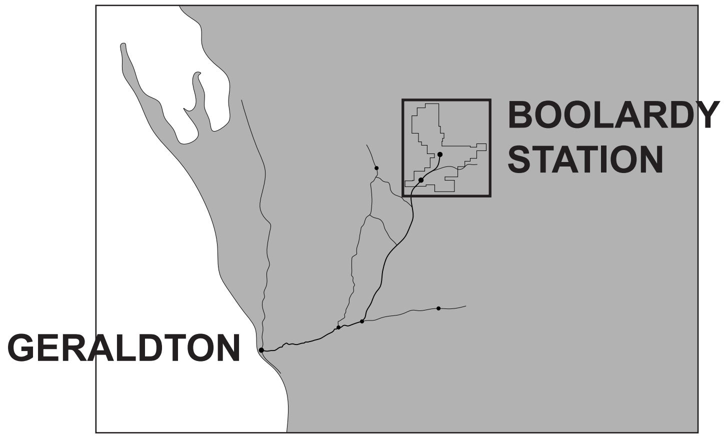
CSIRO PROPOSED ASKAP RADIO TELESCOPE
LOCATION DIAGRAM: GERALDTON - BOOLARDY STATION

SKM





NORTH

CSIRO PROPOSED ASKAP RADIO TELESCOPE
LOCATION DIAGRAM - BOOLARDY STATION

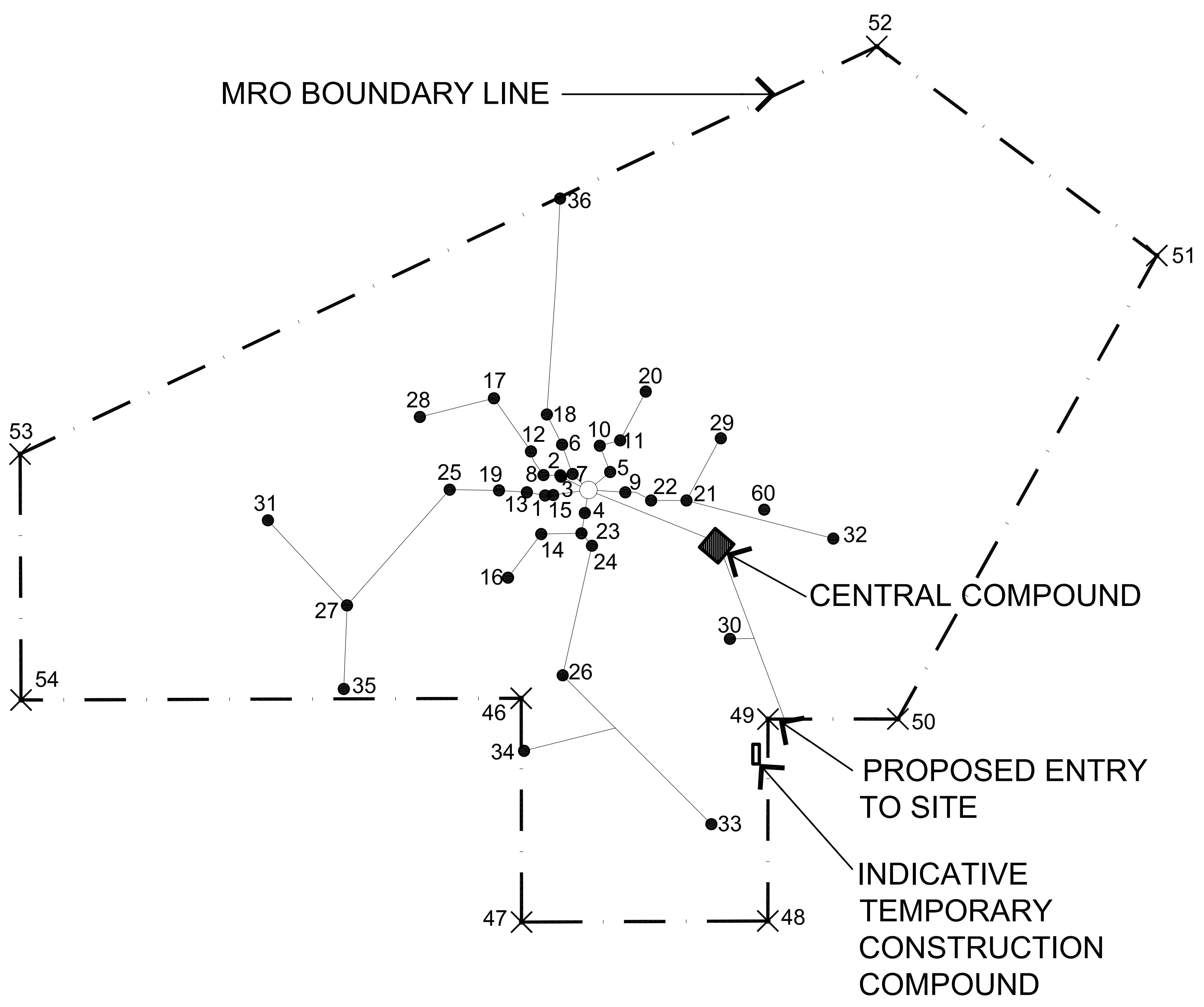
CSIRO

SKM

CSIRO

CSIRO PROPOSED ASKAP RADIO TELESCOPE
GENERAL VIEW OF MRO SITE

SKM



LEGEND

BOUNDARY SETOUT POINTS

ANTENNA DISH GPS CO-ORDINATE POINTS

ACCESS CORRIDOR ROADS

TOTAL LENGTH OF ROAD: 38KM

0 5000m

NORTH

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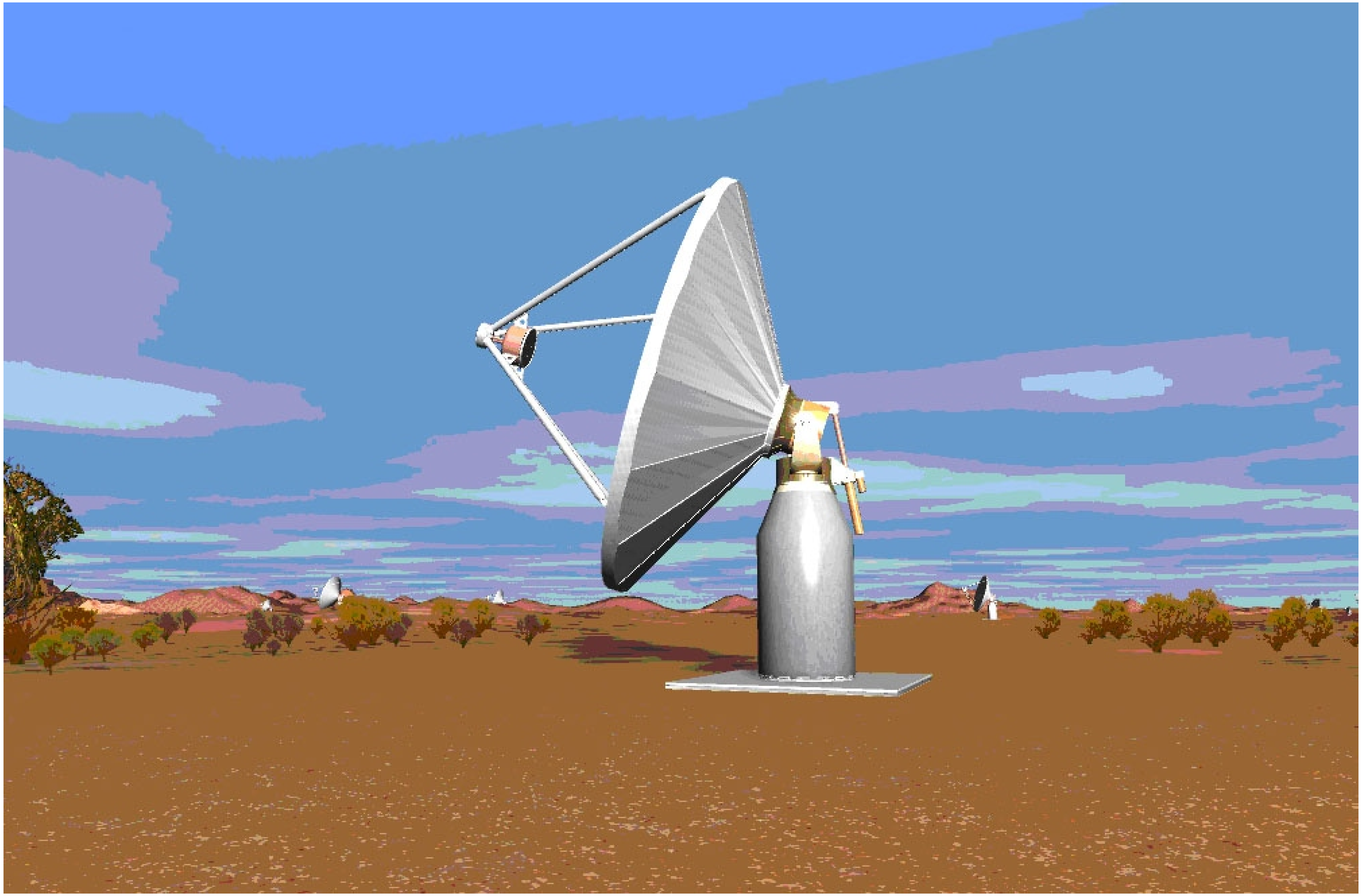
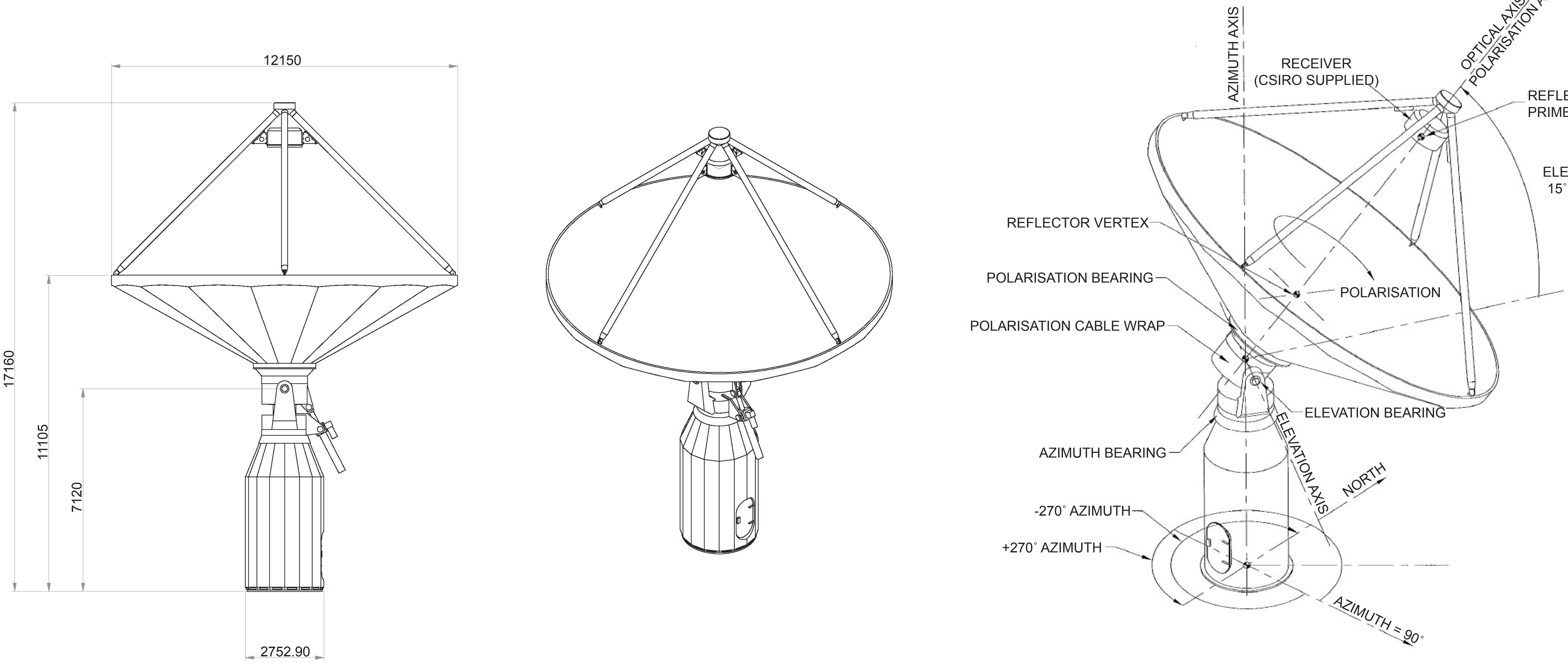
CSIRO PROPOSED ASKAP RADIO TELESCOPE
BOOLARDY STATION: MRO GENERAL LAYOUT

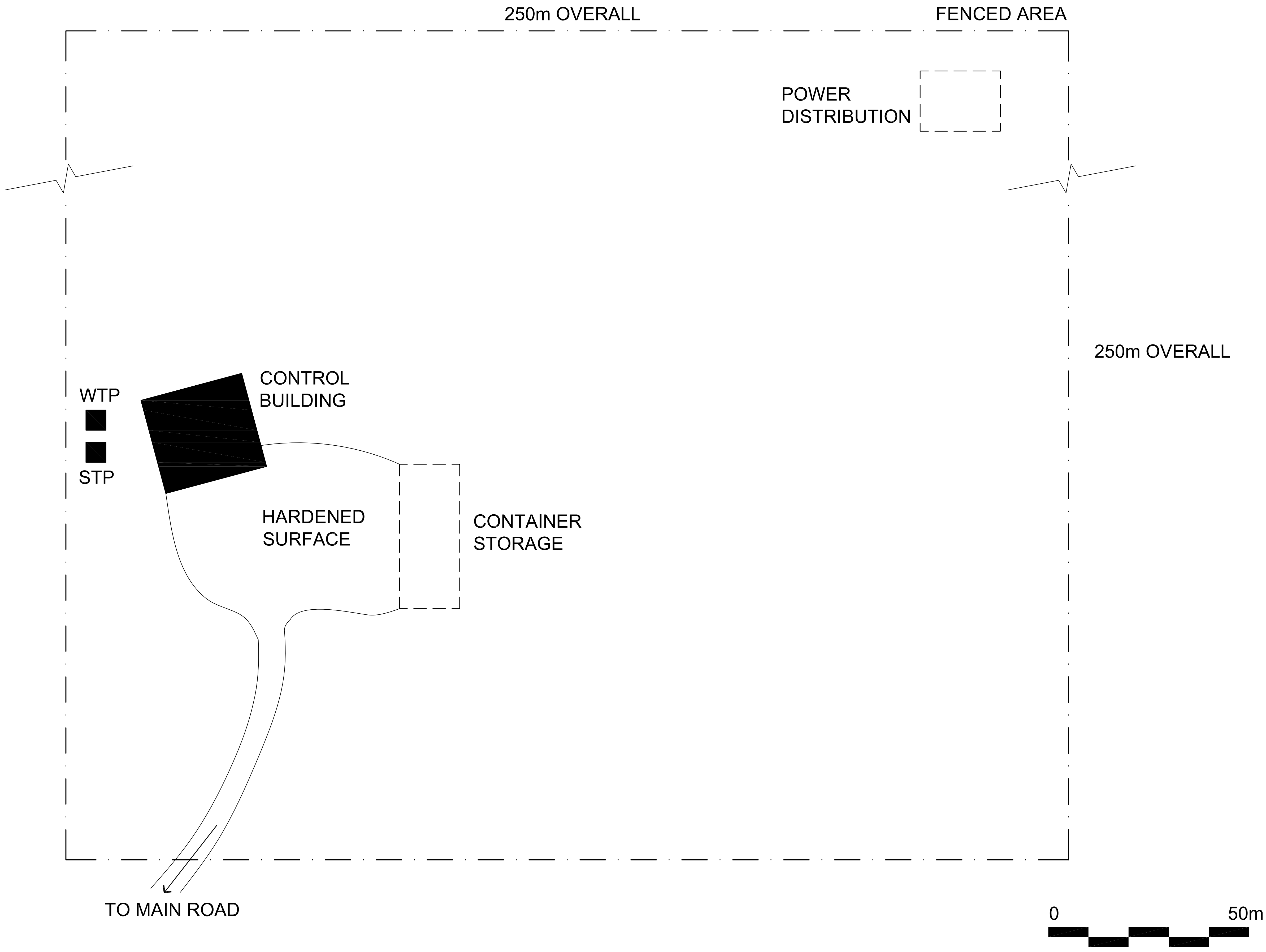
SKM



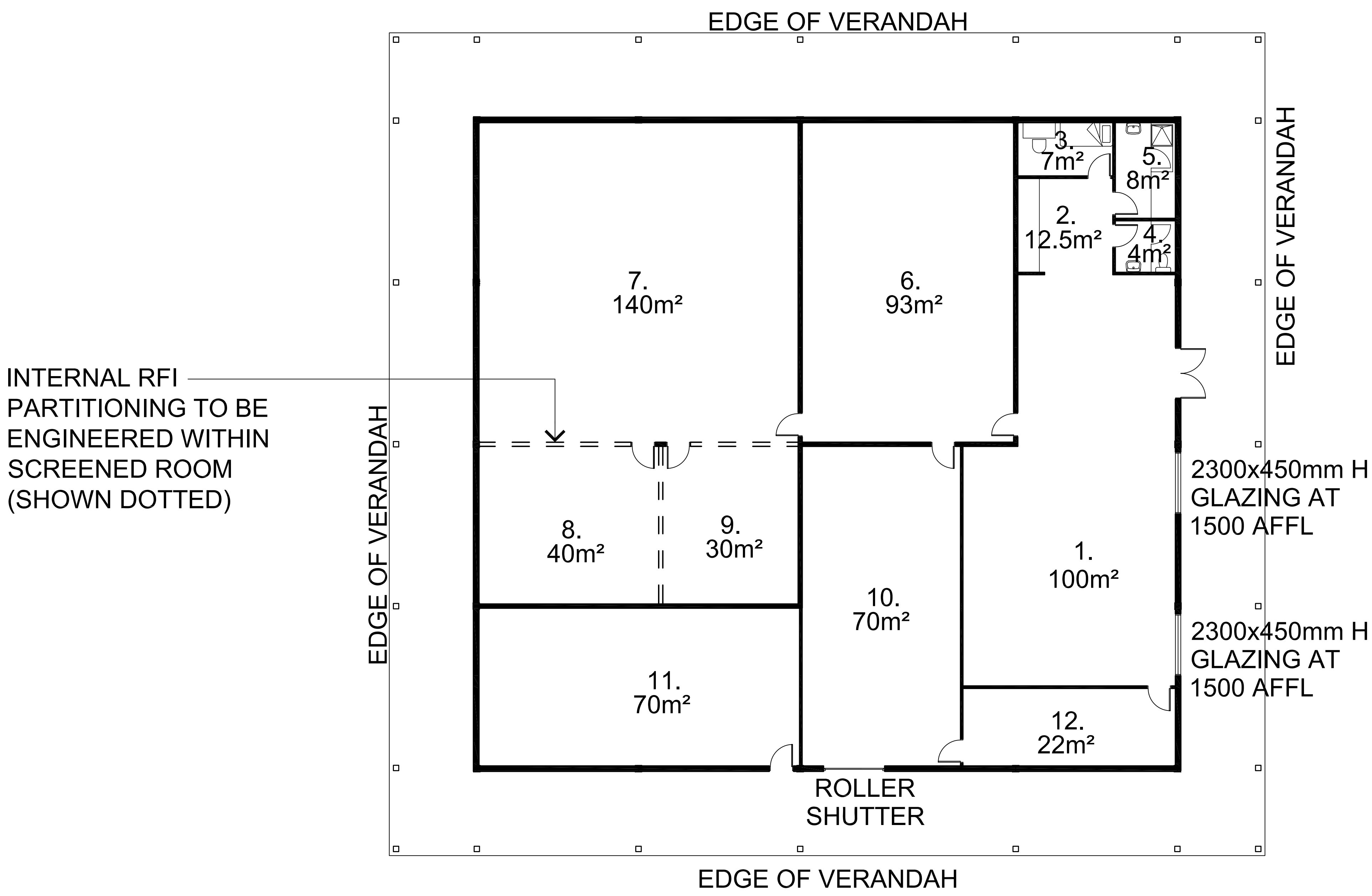
CSIRO PROPOSED ASKAP RADIO TELESCOPE
ARTISTS IMPRESSION OF ANTENNA SITE



CSIRO PROPOSED ASKAP RADIO TELESCOPE
INDICATIVE ANTENNA



CSIRO PROPOSED ASKAP RADIO TELESCOPE
BOOLARDY STATION: CENTRAL MRO COMPOUND PROPOSED SITE PLAN



LEGEND

1. SHARED OFFICE
2. KITCHEN
3. FIRST AID
4. MALE/FEMAL WC
5. SHOWER
6. OPERATIONS ROOM
7. CORRELATOR
8. FIBRE TERM.
9. RF/LO GEN
10. WORKSHOP
11. PLANT
12. STORE

TOTAL GROSS AREA: 635 m²

0 5m

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CSIRO PROPOSED ASKAP RADIO TELESCOPE
BOOLARDY STATION: PROPOSED CENTRAL COMPOUND CONTROL BUILDING

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CSIRO PROPOSED ASKAP RADIO TELESCOPE
BOOLARDY STATION: CENTRAL COMPOUND CONTROL BUILDING PERSPECTIVE

SKM

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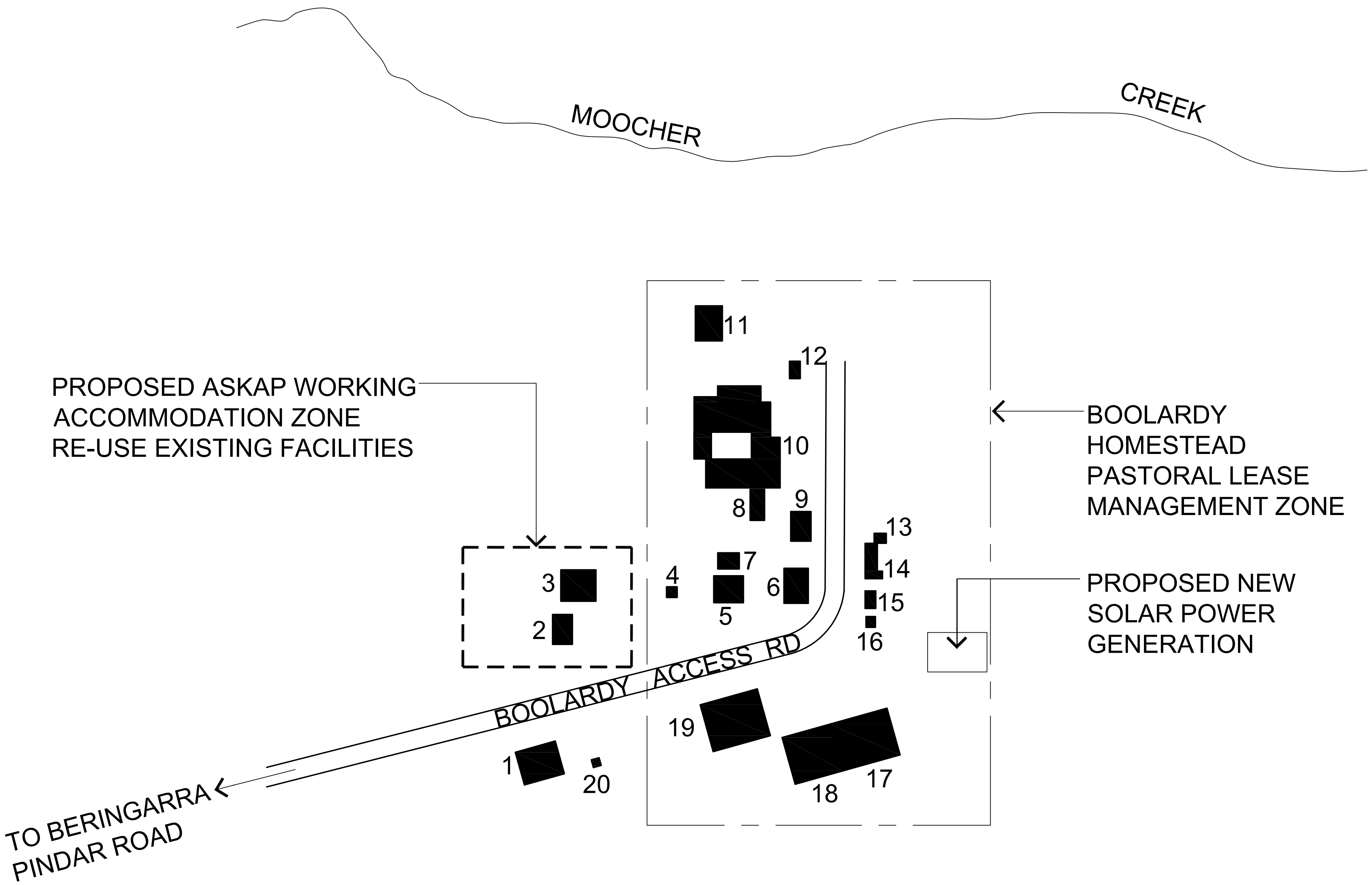
CSIRO PROPOSED ASKAP RADIO TELESCOPE
EXISTING BOOLARDY HOMESTEAD PRECINCT

SKM



LEGEND
1. ROO SHOOTERS
2. WORKER'S QUARTERS
3. WITTENOOM HOUSE
4. SHED
5. ACCOMMODATION
6. CORNER STORE
7. UNDERGROUND WATER TANK
8. MEAT HOUSE
9. COOK'S QUARTERS
10. BOOLARDY HOMESTEAD
11. POOL
12. SHED
13. FEED STORE
14. FUEL
15. BLACKSMITHS WORKSHOP
16. BLACKSMITHS QUARTERS
17. CART SHED
18. EQUIPMENT SHED
19. VEHICLE SHED
20. WATER TANK

0 100m

NORTH

CSIRO PROPOSED ASKAP RADIO TELESCOPE
BOOLARDY STATION: HOMESTEAD PRECINCT PROPOSED SITE PLAN

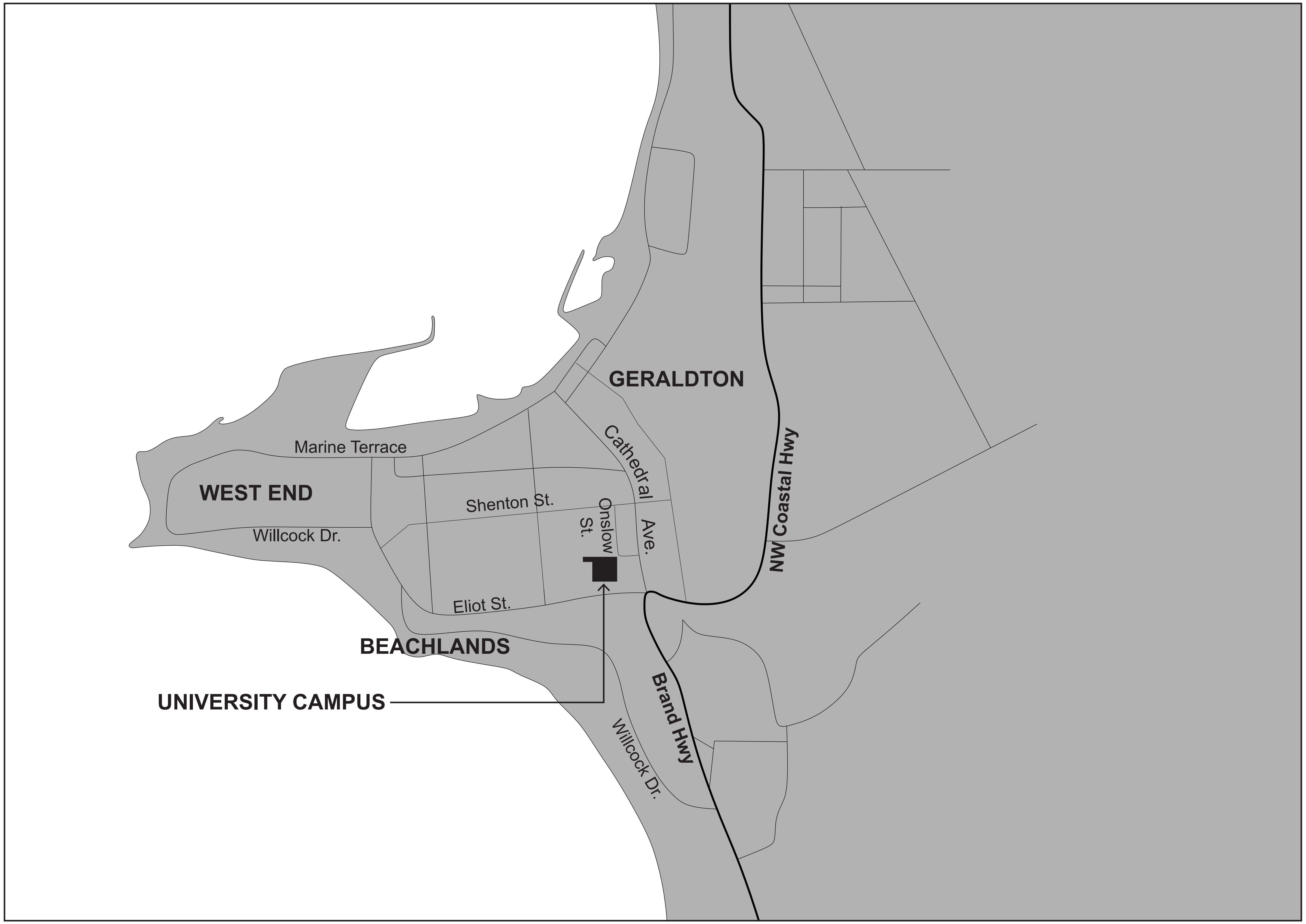
CSIRO

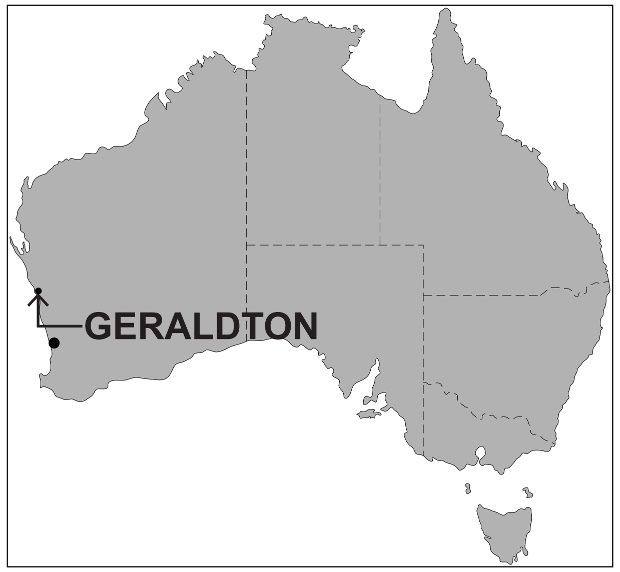
SKM

CSIRO

CSIRO PROPOSED ASKAP RADIO TELESCOPE
EXISTING BOOLARDY HOMESTEAD PRECINCT 1890'S HOMESTEAD

SKM

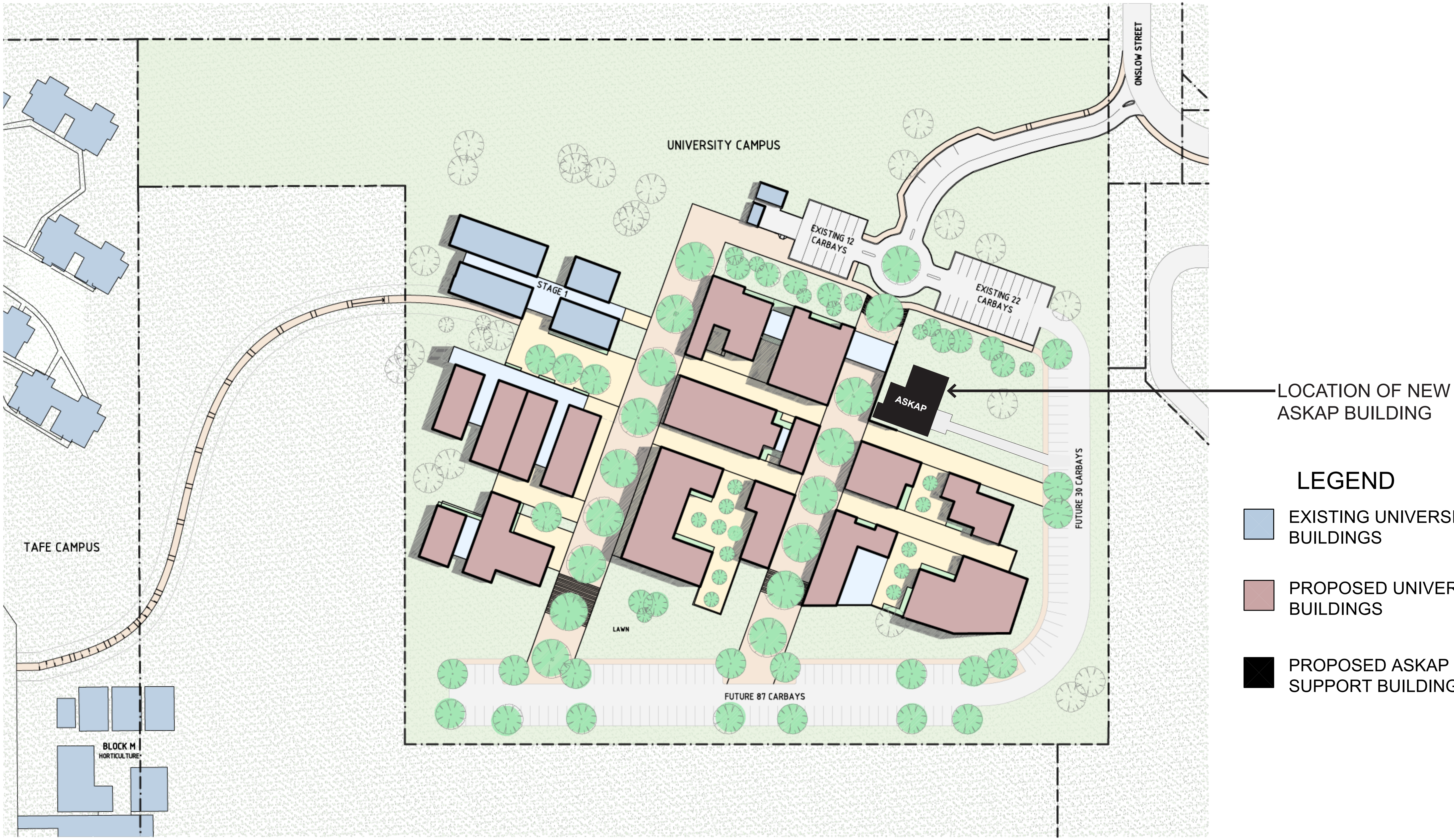




NORTH

CSIRO PROPOSED ASKAP RADIO TELESCOPE
LOCATION DIAGRAM: GERALDTON - GERALDTON UNI. LOCATION PLAN

SKM



LEGEND

- EXISTING UNIVERSITY BUILDINGS
- PROPOSED UNIVERSITY BUILDINGS
- PROPOSED ASKAP MRO SUPPORT BUILDING

PROPOSED MRO SUPPORT FACILITY LOCATED ON EXISTING CAMPUS MASTERPLAN.

0 25m

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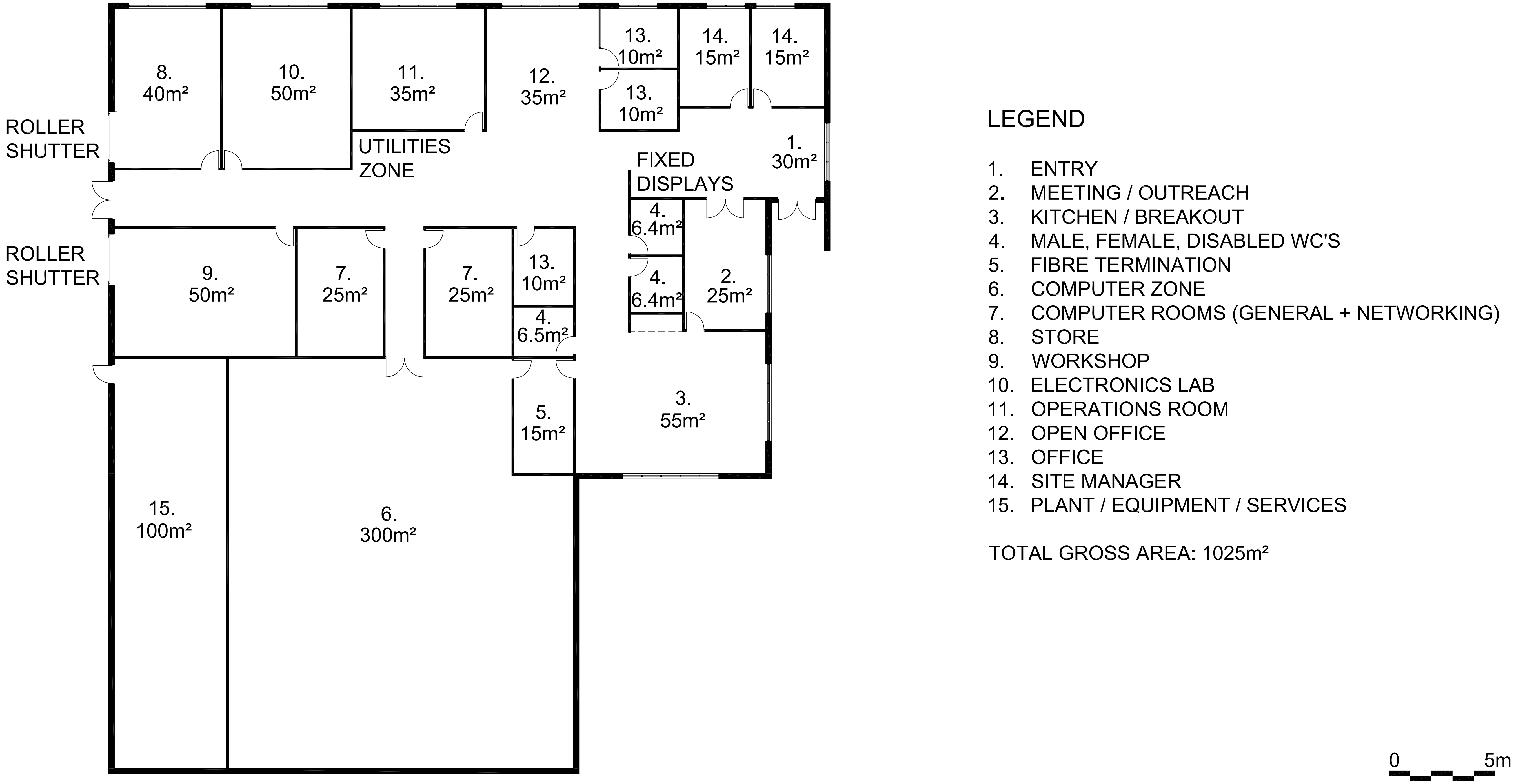
CSIRO PROPOSED ASKAP RADIO TELESCOPE
MRO SUPPORT FACILITY GERALDTON: SITE PLAN - GERALDTON UNI

SKM



LEGEND

1. ENTRY
2. MEETING / OUTREACH
3. KITCHEN / BREAKOUT
4. MALE, FEMALE, DISABLED WC'S
5. FIBRE TERMINATION
6. COMPUTER ZONE
7. COMPUTER ROOMS (GENERAL + NETWORKING)
8. STORE
9. WORKSHOP
10. ELECTRONICS LAB
11. OPERATIONS ROOM
12. OPEN OFFICE
13. OFFICE
14. SITE MANAGER
15. PLANT / EQUIPMENT / SERVICES

TOTAL GROSS AREA: 1025m²

CSIRO

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CSIRO PROPOSED ASKAP RADIO TELESCOPE
MRO SUPPORT FACILITY GERALDTON: PROPOSED FLOOR PLAN

SKM

CSIRO PROPOSED ASKAP RADIO TELESCOPE
MRO SUPPORT FACILITY GERALDTON: PERSPECTIVE

16 Acronym list

AAL	Astronomy Australia Ltd
AARNet	Australian Academic Research Network
ALMA	Atacama Large Millimetre Array
ASCC	Australian SKA Coordination Committee
ASKAIC	Australian Square Kilometre Array Industry Consortium
ASKAP	Australian Square Kilometre Array Pathfinder
ATCA	Australia Telescope Compact Array
ATNF	Australia Telescope National Facility
ATSC	Australia Telescope Steering Committee
BCA	Building Code of Australia
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEWHA	Department of the Environment, Water, Heritage and the Arts
DIISR	Department of Innovation, Industry, Science and Research
EPA	Environmental Protection Authority
EPBC Act	Environmental Protection, Biodiversity and Conservation Act
GUC	Geraldton Universities Centre
ICT	Information and Communications Technologies
MRO	Murchison Radio-astronomy Observatory
MROCC	Murchison Radio-astronomy Observatory Coordination Committee
MSF	Murchison Radio-astronomy Observatory Support Facility
NCRIS	National Collaborative Research Infrastructure Strategy
NSW	New South Wales
PrepSKA	European Union Framework Program 7 Preparatory Study on the SKA
PWC	Public Works Committee
RFI	Radio-frequency interference
RF/LO	Reference Frequency and Local Oscillator
RQZ	Radio-quiet zone

SIP	Science Investment Process
SKA	Square Kilometre Array
VLBI	Very Long Baseline Interferometry
WARAC	Western Australian Radio Astronomy Committee