Current and Future Ground Segment Options for Western Australian Satellite Technology and Applications Consortium

FINAL REPORT

Prepared by

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PREFACE

This report provides the Western Australian Satellite Technology and Applications Consortium (WASTAC) Standing Committee with options to modernise and expand its Earth Observations from Space (EOS) satellite reception capabilities. The purpose is for WASTAC to remain relevant as a key EOS reception and dissemination node as part of a coordinated nationally-stitched network of EOS ground stations. Supporting this Siting Study is a review of policy and investment drivers. The Study does not seek to develop a complete business case for asset modernisation; rather it presents to the WASTAC Board a plan to enable confident decisions about future investment choices.

EXECUTIVE SUMMARY

The Western Australian Satellite Technology Application Consortium (WASTAC) is a group of state and federal departments and universities comprising Geoscience Australia (GA), Landgate (Western Australian Land Information Authority), the Bureau of Meteorology (BoM), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Curtin University and Murdoch University. WASTAC came into legal existence on 24 January 1989 with the purpose of maintaining a reliable, comprehensive and accessible archive of Earth Observations from Space (EOS) data.

There will remain an increasing national demand for, and reliance on, EOS data and associated products and services relating to the Australian continent and its surrounding Exclusive Economic Zone (EEZ). In seeking to meet this need, WASTAC is investigating future investment options in hardware upgrades and capacity building to bolster its role as a key node in a coordinated, nationally-stitched strategic EOS ground station network. The potential to be competitive as a ground-segment partner in future international missions is also of interest.

This independent, medium to long-term Siting Study by Shoal Engineering Pty Ltd (Shoal)—commissioned by WASTAC in consultation with the Space Coordination Office (SCO)—builds on previous work conducted by WASTAC member agencies in response to the recognition that key elements of the EOS supply chain are failing and Australia remains reliant on satellites built by international partners. In support of ensuring the continuity of EOS data for Australia, this document examines the *policy* drivers supporting improvements to a national strategic EOS supply chain network, and the development of siting options for the *expansion* of WASTAC reception assets.

Eight potential sites around Western Australia were initially investigated of which three were selected by the WASTAC Standing Committee for detailed investigation. These were the *BoM facility at Learmonth Airport (LEA)*, the *Yarragadee Geodetic Observatory* (YGO) north west of Mingenew, and the *CSIRO Australian Academic and Research Network fibre repeater* at Mullewa. Selection metrics included the secure and long-term availability of required land, spectrum, suitable power and fibre communications, site accessibility and travel time, availability of technical expertise, radio quietness, and a favourable horizon mask and climate. To avoid the expense of establishing a greenfield site, colocation with existing related facilities was deemed the most cost-effective selection methodology.

The recommended site preferences are: (1) YGO and LEA, (3) Mullewa.

The outcomes of this report are offered to the WASTAC Standing Committee and Board for their consideration and application. On a wider canvas, the Study can support a national vision to enrich current EOS infrastructure and enable better utilisation of expanding national data networks and computing infrastructure.

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

Acronym	Meaning
AARNet	Australian Academic and Research Network
ACMA	Australian Communications and Media Authority
AEOCCG	Australian Earth Observation Community Coordination Group
AGDC	Australian Geoscience Data Cube
AGEOSWG	Australian Government Earth Observations from Space Working Group
ARC	Australian Research Council
ASKAP	Australian Square Kilometre Array Pathfinder
ASUP	Australia's Satellite Utilisation Policy
BCRCP	Business Cooperative Research Centres Programme
BoM	Bureau of Meteorology
CAPEX	Capital Expenditure
CASA	Civil Aviation Safety Authority
CRCSI	Cooperative Research Centre for Spatial Information
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSO	Communication with Space Object
CUDEM	Civil Use of the Defence Estate Manual
DIIS	Department of Industry, Innovation and Science
DOLA	Department of Land Administration Legal Services
DORIS	Doppler and Radiopositioning Integrated by Satellite
DSZ	Defence Secure Zone
EESS	Earth Exploration Satellite Service
EEZ	Exclusive Economic Zone
EOS	Earth Observations from Space
ESA	European Space Agency
GA	Geoscience Australia
GNSS	Global Navigation Satellite Systems
HV	High Voltage
IATA	International Air Transport Association
JPSS	Joint Polar Satellite System
km	kilometre
LEA	Learmonth Airport
LEF	Licence Establishment Fee
LEP	Local Enhancement Projects
LG	Landgate
LIEF	Linkage Infrastructure Equipment and Facilities
Mbps	Megabits (10^6 bits) per second
MetOp	Meteorological Operational Satellite Program
MoU	Memorandum of Understanding
MRO	Murchison Radio-astronomy Observatory
MRP	Major Residential Projects
NAP	Network Access Point
NASA	National Aeronautics and Space Administration
nbn™	National Broadband Network
NCF	National Collaboration Framework
NEOGSTC	National Earth Observation Ground Segment Technical Committee
NEOS-IP	National Earth Observations from Space - Infrastructure Plan

Acronym	Meaning
NOAA	National Oceanic and Atmospheric Administration
NPP	National Polar-orbiting Partnership
NREN	National Research and Education Network
OPEX	Operational Expenditure
PB	Petabyte (10^{15} bytes or 1000 terabytes)
PBH	Patience Bulk Haulage
PUO	Public Utilities Office
PV	photovoltaic
RAAF	Royal Australian Air Force
RALI	Radiocommunications Assignment and Licensing Instruction
RDSI	Research Data Storage Infrastructure
RFI	Radio Frequency Interference
RFQ	Request for Quotation
RNSS	Radionavigation-Satellite Service
ROM	Rough Order of Magnitude
RRL	Register of Radiocommunications Licences
Rx	Receive or Reception
SCC	Space Coordination Committee (Australian Government)
SCO	Space Coordination Office
SLR	Satellite Laser Ranging
SSC	Swedish Space Corporation
SUPP	State Underground Power Program
TERSS	Tasmanian Earth Resources Satellite Station
TOB	Television Outside Broadcast
Tx	Transmit or Transmission
UPS	Uninterruptible Power Supply
USN	Universal Space Networks
UTAS	University of Tasmania
VLBI	Very Long Baseline Interferometry
WA	Western Australia(n)
WAER	Western Australian Electrical Requirements
WASTAC	Western Australian Satellite Technology and Applications Consortium
WMO	World Meteorological Organization
YGO	Yarragadee Geodetic Observatory

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1 SETTING THE SCENE

1.1 STUDY RATIONALE

1.1.1 The Demand

Most of Australia's environmental and economic interests (including Antarctica) are difficult to access; information can only be cost effectively gathered using satellites. However, there are no nationally owned Earth Observations from Space (EOS) space-based assets. The country is therefore completely reliant on international partners for access to over 40 foreign owned and operated satellites, although a significant number of these—with applications to monitor forests, lands and oceans, detect forest fires, better understand earthquake risks and enable topographic mapping—have, or are rapidly, reaching, their end of life.[1] Moreover, Australia's demand for EOS data is expected to increase notably over the next decade, with an annual increase in EOS data storage needs conservatively estimated at 1.2 petabytes (PB); this represents a twenty-fold increase on 2013 annual EOS data storage assets. These estimates do not include meteorological applications, research and development activities, or new sensor technologies.[2]

1.1.2 Our Strengths

In its favour, Australia's unique geography offers the opportunity to host ground stations, regional data hub services and calibration facilities as an international EOS partner.[3] Our EOS community also contributes to overseas programs through global satellite calibration, direct downlink and return of data back to owner countries, participating in international science teams and developing new EOS applications.[4] Australians also analyse and apply EOS data to challenges, including:

a. climate change;

b. water availability;

c. natural disaster mitigation;

d. safe and secure transport;

e. energy and resources security;

f. agriculture, forestry and ecosystems;

g. coasts and oceans; and

h. national security.

[1] Australia is one of the largest users world-wide (by volume and variety) of EOS data provided by foreign satellites.

[2] Geosciences Australia, 2013, p 43.

[3] Ibid, p 23.

[4] CSIRO, 2012.

1.1.3 The Benefits

Australia derives significant and essential benefit from EOS through applications such as daily weather prediction, safeguarding agricultural production, biosecurity and environmental monitoring. Table 1 summarises the economic gains.[5]

Table 1. Significant and essential benefits derived from EOS

Beneficiary	2015 Benefit ($m)	2025 Benefit ($m)
Direct Economic Benefit	$496	$1,694
Social and Environmental Benefit	$861	$1,329
Employment Benefits	$9,293	$15,997
Gross Economic Benefit	$10,650	$19,020

1.1.4 Our Dilemma

While Australia's geography provides opportunity to host EOS-related facilities, this competitive advantage is not leveraged to the full extent possible. Key elements of the EOS supply chain (shown in Figure 1) are now failing, due in part to outmoded infrastructure, communications capacity constraints, discrete portfolio funding and spectrum availability pressures. Other challenges include a growing demand for spectrum, leading to increased costs around spectrum licensing and increasing spectrum noise. Planning and resources are therefore needed to ensure continuity and secure access to key future systems. If no action is taken, Australia will lose its capability to access, analyse and manage information on fires, floods, crops, forests, coasts and oceans. Without action, Australia could also compromise its continuous historical record of satellite observations[6] that is proving to be fundamental to understanding the country, and how it is changing.[7] These issues point to the reasons for this Study.

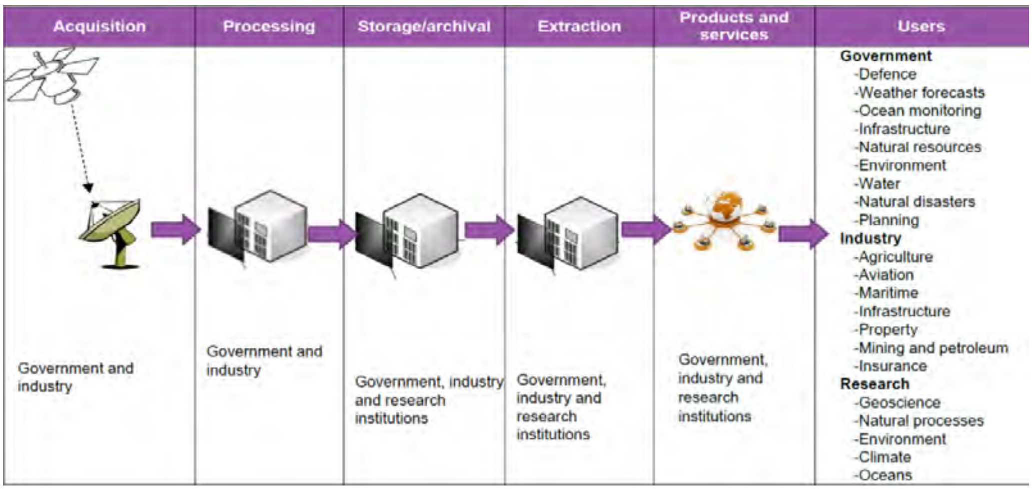

Figure 1. The Earth Observation from Space supply chain[8]

[5] ACIL Allen Consulting, 2015.

[6] A climate epoch is 20-25 years. Current data archives therefore have one data point along this continuum.

[7] Geoscience Australia, 2013, p. 1.

[8] Sourced: Geoscience Australia and ACIL Allen Consulting

1.2 THE CONSORTIUM

1.2.1 Background

WASTAC came into legal existence in January 1989[9] with the purpose of maintaining a reliable, comprehensive and accessible archive of EOS satellite data.[10] WASTAC is forward focussed to modernise its ground station facilities and networks, thus securing and enhancing its contribution to a national strategic capability. One driver for this initiative was the recent release of the Australian Government's requirement for a consolidated National Earth Observations from Space Infrastructure Plan (NEOS-IP). To best achieve this goal, this comprehensive independent examination ('Siting Study') seeks to identify how best to achieve WASTAC's earth observation satellite reception capabilities. The purpose of this Study is not to develop a full business case for asset modernisation, rather it is to present to the WASTAC Standing Committee a comprehensive plan, supported by analysis in sufficient detail, to allow for confident decisions to be made about preferred option(s) for WASTAC's reception facilities.

1.2.2 Accessed satellites

Table 2 lists the EOS satellites currently accessed by WASTAC; Table 3 lists those missions of future interest. These tables show that all satellites are in polar, or sun-synchronous, orbit and that many of the current missions have reached, or are nearing, their design life. This raises two issues of concern: *first*, Australia needs to remain current with global broadcast EOS capabilities to retain the benefits derived from access to EOS data; *second*, Australia will require fit-for-purpose ground station infrastructure to take advantage of upcoming and future generations of EOS satellites and, should the opportunity arise, to be seen as an attractive mission partner.

Table 2. EOS satellites currently accessed by WASTAC

Name	Operator	Launch	Inclination (deg)	mean alt (km)	period (min)	Rx band	downlink frequency	Equatorial Crossing	design life (yr)
Terra	NASA	1999	98.5	705	99	X	8212.5	1030 LTDN	5
Aqua	NASA	2002	98.2	705	98.8	X	8160	1330 LTAN	6
Fenyung 3-B	CMA	2010	98.75	836.4	101.49	X&L	7775	1400 LTDN	3.5
Fenyung 3-C	CMA	2013	98.75	836	101.49	X&L	7775	1000 LTDN	3.5
Metop-A	EUMETSAT	2006	98.7	817	101.36	L	1707	2129 LTAN	5
Metop-B	EUMETSAT	2012	98.7	817	101.36	L	1701.3	2130 LTDN	5
Suomi NPP	NOAA	2011	98.74	824	101.44	X	7812	1030 LTDN	5
NOAA 15	NOAA	1998	98.77	807	101.1	L	1702.5	1715 LTAN	2
NOAA 18	NOAA	2005	99.17	854	109.97	L	1707	1632 LTAN	2
NOAA 19	NOAA	2009	98.97	870	101.99	L	1698	1359 LTAN	2

[9] DOLA Legal Services, 2003.
[10] WASTAC's history is available at http://www.wastac.wa.gov.au/complete_history.html

Table 3. Future EOS satellites being considered by WASTAC

Name	Operator	Launch	Inclination (deg)	mean alt (km)	period (min)	Rx band	downlink frequency	Equatorial Crossing	design life (yr)
JPSS-1 (NOAA-20)	NOAA	2017	98.7	824	101	X^1&Ka^2	7812	1330 LTAN	7
JPSS-2	NOAA	2022	TBA	TBA	TBA	X^1&Ka^2	7812	TBA	7
JPSS-3	NOAA	TBA	TBA	TBA	TBA	X^1&Ka^2	7812	TBA	7
JPSS-4	NOAA	TBA	TBA	TBA	TBA	X^1&Ka^2	7812	TBA	7
FenYung-3D	CNSA	2016-21	98.75	836	101.49	X&L	7820	1400 LTDN	3.5
FenYung-3E	CNSA	2017	98.75	836	101.49	X&L	TBA	1000 LTDN	3.5
FenYung-3F	CNSA	2019	98.75	836	101.49	X&L	TBA	1400 LTDN	3.5
FenYung-3G	CNSA	2021-25	98.75	836	101.49	X&L	TBA	TBA	3.5
Metop-C	EUMETSAT	2018	98.7	817	101	TBA	1707	TBA	5
Metop-SG	EUMETSAT	2021	SSO	817	100	X3&Ka4	TBA	0930 LTDN	8.5

1.2.3 Siting Study

In response to these concerns—and also recently issued national guidance, such as the NEOS-IP issued in 2013 by the Federal Government—WASTAC, in consultation with the Space Coordination Office (SCO), announced that it required an independent medium to long-term study to develop options for the modernisation and expansion of WASTAC reception facilities (capacity building). Shoal Engineering Pty Ltd (Shoal) was commissioned to conduct this independent study, which builds on previous work conducted by WASTAC member agencies, including numerous seminal reports.

The Siting Study does not seek to develop a full business case for asset modernisation and relocation. Instead, it provides the WASTAC Standing Committee with options based on technical considerations, policy drivers and related investments that inform recommendations to the WASTAC Board on future infrastructure considerations.[11]

1.2.4 Earth Observations from Space

EOS and related products and services are enabling technologies. While not generally an end product in themselves, they are rather inputs at the start of a supply chain that can involve many stages of value adding and application development towards an end product or service; many of these can be critical to life by providing key information on fires, floods, crops, forests, coasts and oceans. Key to the supply chain is a distribution mechanism in the form of fit-for-purpose infrastructure that supports the operational capture and analysis of EOS and the delivery of the resulting information to decision makers. EOS can also be used to inform good policies and decisions on issues such as the environment, water

[11] On 4 May 2016 Curtin University commissioned Shoal under the RFQ 01-16 Procurement Agreement, 'Provision of a Report of Current and Future Ground Segment Options for Western Australian Satellite Technology and Applications Consortium (WASTAC)'.

resources, food security, border control, disaster management and sustainability.[12]

While primarily focussed on the supply-side, demand-side pressures of economic growth, an expanding world population and global climate change are implicit factors that ultimately drive growth in EOS-derived products. The impacts of these pressures domestically are evident and include drought, floods, changing rainfall patterns, increased cyclonic activity. To manage these interrelated pressures WASTAC's ambition is to think globally, but act locally.

Australia must maintain access to existing and future space systems that provide essential EOS data, and modernise the infrastructure on which access, distribution and analysis depend. Failure to do so will expose Australia's population and industry to a spectrum of risks, such as inconvenience in not knowing the five-day forecast, to loss of life and property through an inability to predict fire and flood.

1.3 STAKEHOLDERS

The *Department of Industry, Innovation and Science* (DIIS) is the federal agency responsible for Australian civil space activities. National coordination is realised through chairing and providing secretariat support to the Australian Government *Space Coordination Committee* (SCC), supported by technical working groups.

Geoscience Australia (GA) is the lead agency for the non-meteorological operational use of EOS in Australia, and operates ground stations and communication links to acquire EOS data directly from satellites under agreements with satellite operators. GA also cooperates with satellite operators to maintain and share global satellite imagery archives and knowledge for reliable acquisition and distribution of EOS data. A key driver of the GA work programme is implementation of the NEOS-IP.

The *Western Australia Land Information Authority* is a Western Australian (WA) statutory authority that operates under the business name of *Landgate* (LG) and is accountable to the Minister for Lands. LG is the guardian of property ownership in Western Australia and is the custodian of the State's location information asset through provision of a secure land titles system and authoritative location information.[13]

The *Bureau of Meteorology* (BoM) operates under the authority of the Meteorology Act 1955 and the Water Act 2007 which provide the legal basis for its activities. The BoM is Australia's national weather, climate and water agency whose expertise and services contribute to national social, economic, cultural and environmental goals by providing observational, meteorological, hydrological and oceanographic services spanning the Australian region and Antarctic territory. Research into climatic records, water information, scientific understanding of Australian weather and climate also support its operations and services. The BoM

[12] ACIL Allen Consulting, 2015, p 1.
[13] [online] Sourced from: https://www0.landgate.wa.gov.au/

fulfils Australia's international obligations under the Convention of the World Meteorological Organization (WMO) and related international meteorological treaties and agreements.[14]

The *Commonwealth Scientific and Industrial Research Organisation* (CSIRO) is jointly responsible for EOS capabilities with the BoM and GA. It invests approximately $15 million per annum in EOS and leads multi-million-dollar national EOS related investments in research infrastructure. The CSIRO also co-chairs (with GA and the BoM) the Australian Government Earth Observation from Space Working Group (AGEOSWG). AGEOSWG was established in 2013 to provide a link to the SCC for Commonwealth agencies using EOS data.[15]

Curtin University is a global university known for its research and strong industry partnerships. Although WASTAC was begun as a cost-sharing mechanism when Australian satellite reception was in its infancy, Curtin now views its membership both as way of maintaining contact with other research institutions and relevant government agencies, and adding to the university's international profile. This assists with developing collaborations, sharing skills and experience, and staying current with new research. Curtin has also expressed a desire that WASTAC be more active in lobbying government for funding for international collaborations and the development of a national Australian space agency.

Murdoch University is internationally recognised as a research-led institution with active research programs into the analysis and use of satellite data for Environmental Science. Murdoch primarily uses satellite data for research and teaching purposes and therefore rarely requires real-time satellite data. Although Murdoch hosts one of WASTAC's reception stations, the university finds it more useful to obtain the bulk of its satellite data from other organisations, such as NASA, which provide value-added data products. As WASTAC is at least in part a consortium of remote sensing scientists and other users of EOS data within WA, Murdoch maintains a favourable view of its membership as an active participant in the research community.

While not a direct stakeholder for this Study, the *Cooperative Research Centre for Spatial Information* (CRCSI) has contributed significantly to the EOS community and dialogue in Australia. The CRCSI is an international research and development centre set up in 2003 under the Business Cooperative Research Centres Programme (BCRCP) and is administered by the DIIS. The CRCSI aims to create a coordinated national network of satellite system reference stations, undertake research into the establishment of an Australian and New Zealand spatial information market place, automate the production of essential spatial information products, and combine existing data stores with the rapidly increasing stream of data from Earth observation satellites.

Again, while not a direct stakeholder, constructive dialogue and compliance with the *Australian Communications and Media Authority* (ACMA) is key to any

[14] [online] Sourced from: http://www.bom.gov.au/

[15] Australian Government Space Coordination Committee, 2015, p 23.

successful siting option. The ACMA is a government agency established to regulate broadcasting, the internet, radiocommunications and telecommunications. Their responsibilities include:[16]

a. promoting self-regulation and competition in the communications industry, while protecting consumers and other users;

b. fostering an environment in which electronic media respect community standards and respond to audience and user needs;

c. managing access to the radiofrequency spectrum; and

d. representing Australia's communications interests internationally.

[16] Online. Available at http://www.acma.gov.au/theACMA/About/Corporate/Authority/role-of-the-acma

2 STUDY DEFINITION

2.1 PURPOSE

Assist WASTAC to be part of a coordinated nationally-stitched strategic EOS operational and research capability.

The purpose of this Study is to enable WASTAC to remain a key EOS reception and dissemination node as part of a coordinated nationally-stitched strategic network of EOS ground stations.

2.2 OBJECTIVE

Equip the WASTAC Board with information of sufficient detail to assess options for the long-term modernisation of WASTAC and expansion of its assets.

This Study seeks to equip the WASTAC Board with information of sufficient detail to assess options for the long-term modernisation of WASTAC and expansion of its assets. Stimulus for the analysis was a need to update reception assets and recognise reforms in federal, state and tertiary sector strategic guidance. Shoal notes the need to meet the potentially diverse needs of key stakeholders as they may not be in explicit alignment with sector policy drivers and each will understandably promote its own interests.

2.3 DELIVERABLE

Provide evidenced-based options to support decision-making on capital expenditure for a Western Australian EOS reception ground station.

This Study does not present a full business case for asset relocation. Instead, it seeks to support the WASTAC Board (through the Standing Committee) in its deliberations and decision-making on which option should be selected for capital expenditure on a WA EOS reception ground station.

The Study considers Government expectations for a coordinated national EOS infrastructure plan, options for the upgrade of WASTAC's existing assets, options for the long-term expansion of WASTAC reception infrastructure to new locations within WA, spectrum noise and long-term licencing issues, and suggests options for reliable EOS data delivery to WASTAC partners. The Study also seeks to anticipate changes in technology that will certainly require consideration of infrastructure that, while not required today, are anticipated in the medium to long term.[17]

[17] This refers to the possible inclusion of Ka band in reception design options.

2.4 SCOPE

To achieve the Purpose, Objective, and Deliverable, this Study:

a. reviewed the NEOS-IP in the context of background documentation identified at the federal, state and tertiary sector levels;

b. identified medium and long term policy drivers that support the requirements for EOS data;

c. gathered and interpreted industry intelligence on communications, frequency, availability and power infrastructure based on focus sites agreed with the WASTAC Standing Committee and Board;

d. gathered information on other government investment (and anticipated investment) in satellite ground station and related infrastructure (e.g., scheduling systems and 'data hubs') by WASTAC member agencies, and interpreted this information to ensure that WASTAC investments contribute to a coordinated nationally-stitched EOS satellite ground segment; and

e. developed options for modernisation and the long-term siting of WASTAC ground reception facilities as a basis for future investment.

Table 4 shows what was considered and excluded in the Study.

Table 4. Project scope summary

What's In	What's Out
Review EOS-related policy documents	Analyse Australia's EOS activity
Discuss internal WASTAC drivers	Translate Workshop outcomes[18]
Modernisation options for Curtin and Murdoch	Investigate upgrades or urban options
Develop options for reception evolution	Stipulate infrastructure requirements
Gather and interpret siting measures/quanta	Develop siting plans

2.5 APPROACH

The approach was of sufficient breadth and detail to furnish options that could be debated with a high degree of confidence. In particular, key considerations of the modernisation and expansion components of the Study included:

a. long-term leasing or sub-leasing arrangements;

b. long-term spectrum certainty;

[18] Refers to the 'Future of WASTAC' Workshop held in Melbourne on 31 August-1 September 2016.

c. connectivity to 100 megabits per second (Mbps) fibre communications;[19] and

d. minimising ongoing cost drivers, such as:

   1. logistics, through the commonality of infrastructure and sparing;

   2. providing access to specialist labour; and

   3. colocation with similar assets for estate and access to utilities (power and communications).

2.6 STRUCTURE AND CONTENT

This Study is divided into three primary sections: Policy, Modernisation, and Evolution. The content of each section is summarised below:

a. **Policy**. The starting point was to understand the stakeholder expectations for a consolidated EOS infrastructure plan. A review and analysis of federal, state and tertiary sector investment strategies was therefore conducted to ascertain drivers for WASTAC being part of a national ground station network. The review also considered research directions, such as relationships with high performance computing facilities.

b. **Modernisation**. The 2.4 metre L-band antenna at Curtin University failed in March 2016 and will not be replaced. Therefore, no modernisation options were considered and efforts were focused on potential sites for WASTAC redeployment and/or expansion.

c. **Evolution**. The Study then reviews a number of potential sites within Western Australia that WASTAC could consider for the future location of a reception facility. This provides an evidence base on which future capital expenditure decisions can be made and a means to attract investment.

2.7 POTENTIAL OPPORTUNITIES

In addition to meeting the criteria and intent of the contract, this Siting Study could also be used to:

a. promote Australia as a preferred location for ground stations;

b. make contributions to international projects and develop local expertise;

c. manage the over-dependence on international systems;

d. establish long-term spectrum certainty;

[19] Possibly through the Australian Academic and Research Network (AARNet); see Section 5.2.2.

e. provide a national integrated EOS data repository;

f. strengthen domestic and international partnerships;

g. improve scientific analysis in operational mapping and monitoring;

h. strengthen data and knowledge sharing; and

i. progress the efficiency of accessing EOS information through open data policies.

2.8 CONSULTATION

Consultation activities with prime stakeholders and supporting agencies (e.g. ACMA) were held either by telephone conference, or face-to-face meetings. Specific persons with whom Shoal consulted are listed in Table 5.

Table 5. Stakeholders

Organisation	Stakeholder Type
LG	Prime
GA	Prime
BoM	Prime
CSIRO	Prime
Curtin	Prime
Murdoch	Prime
ACMA	Supporting
Defence Spectrum Office	Supporting
Department of Defence	Supporting
Telstra	Supporting
Horizon Power	Supporting

3 POLICY AND OTHER DRIVERS

3.1 INTRODUCTION

Improvements in the performance of satellite-based imaging and instrumentation and the falling cost of data collection, processing, storage, and analysis is leading to a growing demand for imagery and imagery-based products. Governments and private firms worldwide have therefore begun participating in Earth Observation activity. Newly created entities are also providing speciality and tailored products in the data supply chain. It is important to note that while commercial EOS is growing rapidly, its ultimate role and size will be driven by national policies.[20]

Major ground stations for EOS data reception are designed and operated primarily to serve the defined purposes of the BoM (for national weather, climate, water and related services), GA (for national mapping, navigation and other geophysical purposes), the specific and extensive EOS data needs of Western Australia (through the Perth-based WASTAC consortium) and the needs for research and applications over the Southern Ocean and Antarctica (through the Hobart-based Tasmanian Earth Resources Satellite Station (TERSS) consortium). The CSIRO is involved in the two consortia and in data access aspects for all these networks.[21]

3.2 POLICY RELATING TO EARTH OBSERVATIONS FROM SPACE

3.2.1 ACMA Earth Station Siting Paper

On 11 August 2011 the ACMA issued a discussion paper, Earth station siting – Guidance on the establishment of new Earth stations and other space communications facilities or the expansion of existing facilities, signalling its intention to develop a long-term strategy for the sustainable siting of satellite Earth stations. The 21 October 2011 WASTAC response to this paper advised that WASTAC and its partners were experiencing an increase in responsibilities and expectations, particularly for the long-term global monitoring of Earth’s environment, and for increasingly high-resolution near-term forecasts and severe weather warnings. WASTAC’s fulfilment of its responsibilities necessitated the availability of real time observations from present and future remote sensing systems. Therefore, ongoing access to this part of the spectrum is of great concern to WASTAC. However, WASTAC was quite critical of ACMA's view that non-economic applications, such as EOS, were not allocated a high priority. Options that will ameliorate these concerns will be remote locality sites (that of course meet WASTAC’s siting requisites), rather than urban. These could include already established satellite hubs located in regional and remote Western Australia.

3.2.2 Australia’s Satellite Utilisation Policy

The federal government released Australia’s Satellite Utilisation Policy (ASUP) on 9 April 2013. It represents the government’s recognition of the strategic and

[20] Lal, et.al., 2015.

[21] Australian Academy of Science, 2009. p 4.

economic importance of the satellite services industry, and provides the government's vision for the Australian satellite services market. One of two infrastructure plans identified was the NEOS-IP, which is aimed at supporting industry, researchers and government agencies to realise the national benefits of EOS data. In summary, the ASUP sought to provide guidance on:

a. ground reception investment for access to and the use of EOS imagery;

b. modernising Australia's national observatory networks and calibration facilities;

c. strengthening domestic and international partnerships;

d. improving scientific analysis and operational mapping and monitoring;

e. strengthening data and knowledge sharing, and the efficiency of accessing this information through open data policies; and

f. how best to support industry, researchers and government agencies to realise the national benefits of EOS data.

3.2.3 *Department of Industry*

The Department of Industry 2013-14 Annual Report noted that GA continued to implement the NEOS-IP endorsed by the Government in 2013. A key achievement was the use of the newly established national governance framework to coordinate the work of agencies and target national priorities. This includes engaging with foreign satellite operators, facilitating scientific collaboration, promoting better preparation for new data streams (and to guide and prioritise investment decisions). The DIIS 2014-15 Annual Report noted that GA is continuing to work with other agencies to promote appropriate aspects of the NEOS-IP, but at this stage it is not expected that the full document will be released.

3.2.4 *NEOS-IP*

The NEOS-IP is accompanied by a number of discussion papers. Of most relevance to this study is *Discussion Paper 3: Ground infrastructure and communications* by GA and BoM. The discussion paper highlights Australia's reliance on foreign-owned EOS satellites, access to which has in the past been helped by a number of unique features such as Australia's location and geography and ability to host ground stations and cooperate with international partners. These advantages are now being reduced through capacity constraints in communications infrastructure, distributed portfolio funding and current and anticipated spectrum pressures. Securing ongoing access to EOS services therefore requires a revitalisation of Australia's ground segment, achieved through the following:

a. a coordinated nationally-stitched network of EOS ground stations providing geographic coverage of the continent and surrounding Exclusive Economic Zone (EEZ) and territories as shown in Figure 2;

b. security of spectrum licence for a multi-decade period through mechanisms such as remote location and designation of 'space parks' at appropriate locations;

c. access to assured, affordable, high-speed communications; and

d. establishment of internationally valuable calibration and validation facilities to raise Australia's international profile.

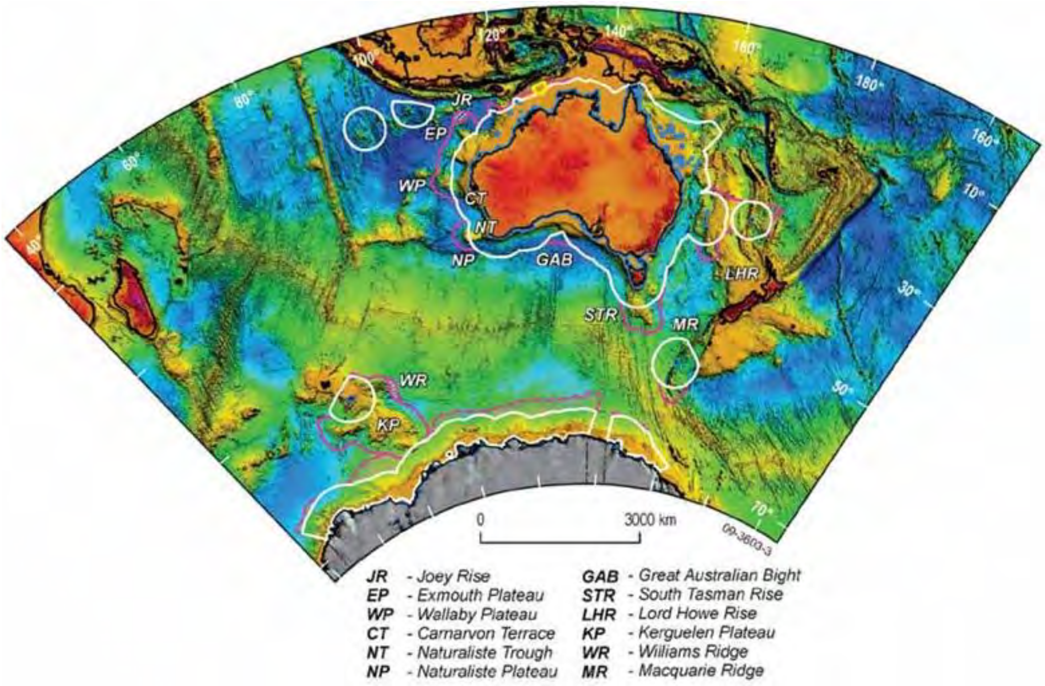

Figure 2. Australia's EEZ and territories[22]

3.2.5 ACMA Five-year Spectrum Outlook

The ACMA Five-year Spectrum Outlook 2013-2017, published in September 2013 notes that there is concern within the space science sector that because scientific usage of the spectrum generates benefits that are generally difficult to gauge financially, such usage is likely to experience pressure from commercial users (Note that WASTAC considered the basis of this argument to be seriously flawed). To reduce the consequent spectrum denial as much as possible, the ACMA has actively encouraged the location of proposed new stations, in areas where spectrum demand is likely to be low. This may impose additional costs on the operator of the ground station, including large capital investments that may reduce the operator's ability to provide scientific services that could be of great value to the community. Feedback from these operators highlights claims that the costs of relocating equipment, establishing and maintaining the associated high-speed data communications to data collection facilities and power supply to

[22] The EEZ area is made up of 8.2 million km^2 off Australia and its remote offshore territories, 2 million km^2 off the Australian Antarctic Territory and extends not more than 200 nautical miles from the territorial sea baseline. Geoscience Australian. Available at: http://www.ga.gov.au/scientific-topics/national-location-information/dimensions/oceans-and-seas

remote locations may be prohibitive. It is also expected that the communication components of the Earth Exploration Satellite Service (EESS) will use higher frequencies and wider channel bandwidths in the future. This is driven by the ongoing demand for higher data rates, which are expected to increase rapidly over the target period of the Outlook. Table 6 shows the main frequency bands used by science services (from Table 4, *ACMA Five-year Spectrum Outlook 2013-2017*)

Table 6. Main frequency bands used by the science services

Frequency band	Service	Main Australian licensee	Usage
UHF	MetAids	BoM	400.15–401 MHz—radiosonde data downlink.[23]
	MetSat (d/u**)	AAD[24] AMSA	401–403 MHz—uplink for meteorological data sensed at data collection platforms. 460–470 MHz—interrogation downlink for data collection platforms.
		GA	401.25 MHz—ionospheric correction signal for the DORIS system for position tracking.[25]
L-band	EESS (a†)		1215–1300 MHz—L-band synthetic aperture radars (SAR) on Japan's ALOS and Argentina's SAOCOM satellites.
	RAS	CSIRO	1400–1427 MHz & 1610.6–1613.8 MHz—Parkes, Narrabri and Tidbinbilla stations.
	MetSat (d)	BoM GA CSIRO	1670–1710 MHz—meteorological satellite data downlink (NOAA POES, FengYun, GOES, Meteosat and MTSAT and OrbView-2 satellites).
S-band	EESS (u/d) SRS (u/d) SOS (u/d)	2025–2110/2200–2290 MHz—primary TT&C uplink/downlink, used by almost all satellites in the EESS and SRS.	
		Inmarsat	European Space Agency's (ESA's) ESTRACK stations support: Perth—XMM-Newton and Cluster II missions New Norcia—Mars Express, Rosetta and Venus Express Both stations—LEOP support for several ESA missions.
		CSIRO	Deep-space stations at CDSCC, which communicate with many spacecraft in the SRS and EESS.
		USN	Provides TT&C from the Yarragadee Geodetic Observatory (Yatharagga) in WA under PrioraNet network.
		GA	2036.25 MHz—main Doppler signal for DORIS.

[23] Radiosondes are meteorological sensors mounted on weather balloons.
[24] Australian Antarctic Division.
[25] Doppler Orbitography and Radiopositioning Integrated by Satellite, used by Jason-2, SPOT-2 and Envisat.

Frequency band	Service	Main Australian licensee	Usage
	SRS (deep space) (u/d)	Stratos Global CSIRO	2110–2120/2290–2300 MHz—deep-space uplink/downlinks to the tracking stations at New Norcia, and Canberra.
S-band	RAS	CSIRO	2690–2700 MHz—Parkes and Narrabri stations.
C-band	EESS (aS††)		3100–3300 MHz—Envisat's Radar Altimeter (RA-2).
	FSS (d)		4033–4042 MHz—meteorological data dissemination service (GEONetCast).
	RAS	CSIRO	4800–5000 MHz—Parkes and Narrabri stations.
	EESS (a)		5250–5570 MHz—radar altimeters, SARs and scatterometers for the determination of wind speed.
	EESS (p‡)		6700–7075 MHz—advanced microwave scanning radiometer (AMSR) and the Windsat radiometer.
X-band	SRS (u)	Stratos Global (Xantic B.V.) CSIRO	7145–7235 MHz—X-band command uplinks from tracking stations at Perth, New Norcia and Canberra. Deep-space missions operate in the 7145–7190 MHz band.
	MetSat (d)		7450–7550 and 7750–7850 MHz—limited current use.
	EESS (d)	GA USN	8025–8400 MHz—primary data downlink for EESS satellites (data from Terra, Aqua, Landsat-5 and -7, ALOS, EO-1, Radarsat-1, Resourcesat-1 and ERS-1 and -2 are received in Australia).
	SRS (d)	Stratos Global (Xantic BV) CSIRO	8400–8500 MHz—primary SRS data downlink, used by Perth, New Norcia and Canberra tracking stations. Deep-space missions in the 8400–8450 MHz band.
	EESS (a)		9500–9800 MHz—SAR on TerraSAR-X.
	ESS (p)		10.6–10.7 GHz—AMSR, the Tropical Rainfall Measuring Mission (TRMM) microwave imager (TMI) and the Windsat radiometer.
Ku-band	EESS (a)		13.25–14.3 & 17.2–17.3 GHz—radar altimeters, the SeaWinds scatterometer, the TRMM precipitation radar and the Jason Microwave Radiometer.
	SRS (d/u)	CSIRO	13.75–15.35 GHz—spacecraft tracking from Perth and Canberra.
Ka-band	EESS (d/u) SRS (d/u)	Stratos Global (Xantic BV) CSIRO	25.5–27 GHz—Ka-band downlink—at Canberra and New Norcia. 28.5–30 GHz—MTSAT Ka uplink (not in Australia).

Frequency band	Service	Main Australian licensee	Usage
	SRS (d/u)	Stratos Global (Xantic BV) CSIRO	31.8–32.3 GHz / 34.2–34.7 GHz—communications to/from Canberra deep space station and New Norcia.
	SRS (d/u)		37–38/40–40.5 GHz—planned links to/from Canberra and New Norcia.
	EESS (p)		Various bands between 18.6 and 24 GHz, and 36–40 GHz—AMSR, TMI, advanced microwave sounding unit (AMSU), special sensor microwave imager (SSM/I), and other microwave radiometers.
	EESS (p)		50.2–59.3 GHz and 86–92 GHz—AMSU, TMI, SSM/I and AMSR. 100 GHz—AMSU.
> 50 GHz	**EESS (a)**		94–94.1 GHz—cloud-profiling radar (Cloudsat).

Key: * d: downlink, ** u: uplink, † a: active, †† S: secondary allocation, ‡ p: passive

3.2.6 State of Space Report

The 2015 State of Space Report by the SCC provides a consolidated summary of civilian space-related activities being conducted by nine Commonwealth Government agencies and outlines their involvement in key civil space activities as they relate to policy principles set out in ASUP. The document noted that EOS infrastructure remains a key goal beyond 2015, with short-term goals being critical upgrades to the ground infrastructure segments. Longer-term priorities include new investment to fully implement and operationalise EOS infrastructure, driven by the widespread economic benefits that assured access to fundamental EOS will deliver Australia.

3.2.7 Satellite Calibration and Validation

In January 2015 the CSIRO, in conjunction with GA, released a report, *An Audit of Satellite Calibration and Validation Facilities and Activities in Australia*. The report recognised the clear need for a coordinated national approach to the acquisition and handling of EOS data, a framework to coordinate and to help target national investments in EOS, and that Australia has recognised geographical advantages and inherent expertise in EOS. Furthermore, the Australian Government has identified calibration and validation infrastructure and activity as a key priority in its national planning for EOS.

3.2.8 Prime Minister

In his *National Innovation and Science Agenda*, released on 7 December 2015, the Prime Minister advised that the Government will invest $1.1 billion in four priority areas, one of which will be investment in technology and data to deliver better quality services. In addition, the *Driving Innovation through Procurement, Cyber Security and Open Data Policy*, also released on that day, noted that spatial data, in particular, is becoming increasingly important to the economy and Government agencies will be required to make appropriate data openly available by default.

3.2.9 *Value of Earth Observations*

GA, the BoM and the CSIRO jointly commissioned the CRCSI to provide three linked studies examining the value of EOS to the Australian economy, the principle risks associated with critical EOS data supply chains, and the use of EOS by Australian government programmes. *The Value of Earth Observations from Space to Australia* report[26] examines the use of EOS in seven key application areas: weather forecasting; ocean observation; monitoring land use and landscape change; agriculture; water; natural hazards and insurance; and onshore mining. Through a series of detailed case studies, the report establishes the value of the contribution of EOS in each application area and to the Australian economy as a whole. Key points of the report are:

a. It is estimated that EOS-using industries already contribute around $3.8 billion to the economy, and that use of EOS services has resulted in more than 9,000 jobs in 2015.

b. EOS-using industries could contribute over $5.5 billion per year to our economy by 2025, with use of EOS services projected to generate over 15,000 additional jobs.

c. The report provides a roadmap that industry and researchers can use to help focus their efforts towards the most lucrative opportunities.

d. The global nature of satellite data means that products developed by Australians for Australia also have enormous potential to be exported to the world.

3.2.10 *Spectrum Regulation*

During 2015, the ACMA has reviewed some of the regulatory arrangements associated with the radiocommunications licensing of some satellite services. This includes a proposal to reassign the Radiocommunications (Communication with Space Object (CSO)) Class Licence 1998 (the CSO class licence) to the Radiocommunications (Radionavigation-Satellite Service) Class Licence 2015 (the RNSS class licence).

3.2.11 *Risks of Data Supply*

The Risks of Data Supply of Earth Observations from Space for Australia report[27] examines the requirements for Australian applications of EOS in the same case

[26] ACIL Allen Consulting, 2015.
[27] Symbios Communications, 2015.

study areas as the ACIL Allen report. The report identifies the priority data sets for Australian applications and examines the risk and continuity profile of each data type. Key points are:

a. the nature of the best available public good data streams will change,

b. supply for public good data is expected to remain strong,

c. additional data streams coming online in 2015-2016 will greatly increase data volumes,

d. ground segment and data management solutions like the Australian Geoscience Data Cube (AGDC) will be important in enabling users to manage and make use of this new data,

e. the cost of investing in a dedicated satellite space segment has reduced with advances in small satellite technology, and

f. engagement with international partners and suppliers is critical to ensure Australian access to needed EOS data streams.

3.2.12 EOS Data Requirements

The Australian Government Earth Observation Data Requirements to 2025[28] (to be published in 2016, GA and BoM), will examine the current and projected EOS requirements of 140 Australian government programmes. Based on the programme requirements, the report will assess the availability, continuity and data volumes and storage costs associated with the six most critical categories of EOS for Australia. Key points are:

a. Australia continues to be entirely reliant on foreign owned and operated satellites for EOS data.[29]

b. Supply risks have been reduced with the launch of new public good satellites, but government programmes would be severely impacted were there interruptions to the supply of key EOS data.

c. Supply risks could be mitigated through algorithms and systems that are less dependent on specific sensors and by making analysis ready data available to Australian EOS users.

d. Australia's EOS storage requirements are expected to increase to approximately 42.5 PB by 2025.

e. The cost of storing this volume of data is estimated to be between $4-10 million per year.

[28] CRCSI, 2016.

[29] ACIL Allen Consulting, 2015, p 4.

f. Australia must continue to engage with international partners such as the United States Geological Survey, European Space Agency and the Japan Aerospace Exploration Agency to ensure ongoing access to critical sources of EOS.

3.3 SPECTRUM

Historically, a number of ground station facilities were situated in city urban areas due to: the need to collaborate, satellite tracking was an innovative technology, a lack of reliable broadband infrastructure, and the need for staff and operational support to be located nearby. These facilities represented high-value use of available radiofrequency spectrum. However, Australia has needed to balance the growing demand for access to spectrum by new technologies and uses against the legitimate requirements of existing users for ongoing use of spectrum. It must also strike the balance between government use of the spectrum—for example, for defence, emergency and public safety services, scientific and other applications that may be inappropriate to leave to market forces to address—and its availability for use by the broader community. This is achieved by managing access to radiofrequency spectrum bands through radiocommunications licence arrangements, and resolving competing demands for that spectrum through price-based allocation methods.[30]

Key to siting options is secure and long-term access to suitable spectrum. This was emphasised in WASTAC's response to the 2011 Australian Communications and Media Authority's Siting Study.[31] WASTAC and its partners are experiencing an increase in responsibilities and expectations, particularly for the long-term global monitoring of Earth's environment, and for increasingly high-resolution near-term forecasts and severe weather warnings. These responsibilities dictate availability to real-time observations, which are directly dependent on assured, continued access to relevant spectrum. However, ACMA considered such applications as not having direct economic benefit and so were not allocated a high priority. However, the ACIL Allen report[32] disputed this economic conjecture. Nevertheless, detailed constructive dialogue with the ACMA during this Study afforded a cooperative response to early engagement in identifying spectrum requirements. Accordingly, ACMA's abovementioned economic conjecture was not borne out in practice.

[30] Australian Communications and Media Authority, 2015, p 40.
[31] Australian Communications and Media Authority, 2011.
[32] ACIL Allen Consulting, 2015.

4 MODERNISATION

4.1 OVERVIEW

Current WASTAC assets are an L-band facility at Curtin University that began in 1983, and an L/X-band facility at Murdoch University that was commissioned in 2001. However, as noted below these instruments will no longer serve as primary WASTAC reception stations. Moreover, spectrum restrictions will prevent any new licences being issued and therefore relocation to a non-urban site remains the only feasible option for continued operations.

4.2 CURTIN UNIVERSITY

The 2.4 metre L-band antenna at Curtin University became defunct in March 2016 and the decision has been made to dispose of the spent hardware and relocate the capability to a non-urban locality. Orbital Systems has been selected by the BoM as the preferred vendor for the L/X-band replacement (see Section 5.1.3). Note that before failing, the Curtin facility accessed 500-600 satellite passes per month.

4.3 MURDOCH UNIVERSITY

The Murdoch L/X band Rx was supplied by SeaSpace Corporation. It consists of a 3.6 metre antenna in a fiberglass dome and an antenna controller computer. This facility receives data from Aqua, Terra, MetOp, Suomi-NPP, FY3-B and FY3-C, as well as the L-band satellites. The Murdoch reception facility, maintained by LG and Murdoch University staff, is now 15 years old. However, it will remain a research instrument for Murdoch.

5 EVOLUTION

5.1 INTRODUCTION

5.1.1 Sites Considered

Eight sites, shown in Table 7, were proposed by WASTAC members for preliminary investigation. A number of other West Australian sites were considered (e.g. Defence land on Garden Island, nbn™ sites at Geraldton and Kalgoorlie, and the NewSat teleport in Bassendean), however, these were discounted based on unavailability, security issues[33], RFI interference, or the concentrated heavy use of mobile communications (e.g. by the mining industry).

Table 7. Sites selected for preliminary review

Site	lat (°S)	long (°E)	elev (m)	dist to coast (km)	dist to Perth (km)	time to Perth (hr)
Learmonth (LEA)	22.20	114.09	5	27	1,220	a: 2.5, r: 12.5
Mingenew (YGO)[1]	29.05	115.3	268	51	403	a: 1.0 + r: 0.9
Mullewa (CSIRO)	28.53	115.50	299	92	470	a: 1.0 + r: 0.9
Boolardy Station (ASKAP)[2]	26.98	116.54	328	265	713	r: 13.7
Yannarie Station	23.03	115.04	109	251	1,193	r: 12.75
Yarrie Station	20.67	120.20	106	463	1,569	r: 18.75
Gingin (Defence Estate)	31.27	115.83	64	20	108	r: 1.25
Gingin (RAAF Airfield)	31.46	115.86	81	27	87	r: 1.15

[1]Yarragadee Geodetic Observatory; [2]Australian Square Kilometre Array Pathfinder; a = air; r = road.

Following submission of the Preliminary Report on 27 July 2016 and additional deliberations at the *Future of WASTAC Workshop* on 31 August 2016, the WASTAC Standing Committee down selected to three sites for more detailed investigation, given in Table 8. Selection was based on the degree to which each site met the metrics noted in Section 5.1.2.

Table 8. Sites selected for final detailed investigation

Site	lat (°S)	long (°E)	elev (m)	dist to coast (km)	dist to Perth (km)	time to Perth (hr)
Learmonth (LEA)	22.240639	114.097026	5	27	1,220	a: 2.5, r: 12.5
Mingenew (YGO)	29.046725	115.346068	268	51	403	a: 1.0 + r: 0.9
Mullewa (CSIRO)	28.538971	115.502449	299	92	470	a: 1.0 + r: 0.9

5.1.2 Site Evaluation Metrics

Each of the sites were analysed against the following metrics:

a. **Leasing:** the ability for long-term lease of suitable land, including any lease or sub-lease arrangements;

[33] Space Academy, 2012.

b. **Power:** the availability of power suitable for the expected Orbital Systems equipment;

c. **Communications:** fibre with a minimum capacity of 100 Mbps;

d. **Spectrum:** availability and long-term security of required spectrum;

e. **Horizon Mask:** a 3° horizon mask is preferred; and

f. **Access:** the availability of on-site technical staff, or the time and complexity required to travel to the site, primarily for logistics support.

5.1.3 Proposed Reception Equipment

The BoM is proposing to be the coordinator of equipment supply and logistics support for WASTAC. Accordingly, it is important to note that the antenna expected to be used is the 2.4AEBP antenna positioner by Orbital Systems[34], as shown in Figure 3. This unit is designed to provide high reliability and to withstand severe environmental conditions. It uses a high-precision elevation-over-azimuth satellite tracking system suitable for operation at X-band and below for service in remote locations and hostile climates. The specifications of the system are provided in Annex A and summarised in Table 9. These show that only mains power is required, with a maximum power requirement of 3.6 kW; note that this could also be met by a commercial solar/battery backup power supply. BoM propose to mount the dish on a pillar. This uses a standard template, but is designed for each specific application by the BoM's engineering contractor.

Figure 3. Orbital Systems 2.4AEBP antenna positioner

[34] Online. Available at: http://www.orbitalsystems.com

Table 9. Specifications of the Orbital Systems 2.4AEBP antenna positioner

Parameter	Specification
Input Voltage, Frequency	208 -240 VAC, 20 A, 50/60 Hz, Single Phase
Input Amperage	Typical 5 A; Maximum 15 A; std 20A Breaker
Operating Temperature	-40° C to +55° C
Operating Maximum Wind Speed	88 km/hr
Maximum Wind Speed With Stow Pins	200 km/hr
Non-Operating Maximum Rain Load	25 cm/hr
Maximum Ice Load	13 mm
Weight	565 kg

5.2 SOME SUPPORTING NOTES

5.2.1 *Notes on Power*

5.2.1.1 West Australian Electrical Requirements

The West Australian Electrical Requirements (WAER)[35] enacted from 1 January 2016 were required, in part, due to significant damage caused to Western Power's overhead network during severe storms in 1994. The State Underground Power Program (SUPP) was introduced to convert areas of overhead wires and poles to underground infrastructure. The SUPP is administered by the Public Utilities Office (PUO) at the Department of Finance. Local governments can nominate areas to be converted to underground power, assessed against social, economic and technical criteria by the SUPP Steering Committee.[36] The SUPP has two streams: Major Residential Projects (MRP) and Local Enhancement Projects (LEP).

5.2.1.2 Cost of Power Reticulation

Western Power and Horizon Power are two corporations owned by the Western Australian Government with active roles in the electricity supply chain. Western Power is the asset owner of the power infrastructure at the Mingenew and Mullewa sites. Horizon Power is the asset owner of the power infrastructure at the Learmonth site. Should the decision be made to proceed with network supplied power, further investigations (by the asset owners and/or an electrical consultant) are required to assess whether any additional electrical infrastructure is required and for a formal quote. The processes involved in initiating further investigation for the aforementioned asset owners are as follows:

a. Western Power require the submission of a New Connection application[37], and are able to provide a formal quote for the work to be undertaken within 3 weeks. Note that considerable detail is required as part of this application, and it is likely that the services of an electrical consultant will be required. This

[35] Government of Western Australia, 2015.
[36] The SUPP Steering Committee comprises the PUO, Western Power and the WA Local Government Association.
[37] Details regarding the Western Power New Connection application are available online at https://www.westernpower.com.au/connections/new-connections/

application can be preceded by a request for a Feasibility Study[38] to be undertaken, for which a design and quote can be provided within 9 weeks depending upon the required level of detail. This Feasibility Study can then form part of the New Connection application.

b. Horizon Power require the submission of a Connection Application[39], prompting them to commence preparation of a detailed design and formal quote.[40] The services of an electrical consultant may be required to complete some sections of the Connection Application form.

5.2.1.3 Alternative Power Options

Accordingly, consideration could be given to alternate power sources, particularly given the peak operating power requirement of around 4 kW. Whether used for primary supply or as backup, a 4-6 kW solar photovoltaic (PV) system could be installed. Another consideration should be the inclusion of an Uninterruptible Power Supply (UPS) to provide emergency power, regardless of the power source used.[41] The on-battery runtime of most UPSs is relatively short (only a few minutes), but is sufficient to start a standby power source or properly shut down protected equipment.

5.2.2 Notes on Communications

5.2.2.1 Communication Requirements

The Siting Study requirements specified 'efficient near real-time delivery of acquired remote sensing digital data into the national research network AARNet'.[42] However, subsequent dialogue with WASTAC members determined that AARNet access is not desired by all and commercial fibre is in fact preferred.[43] Nevertheless, for completeness, the communications metric in each site analysis will consider both the availability of commercial 100 Mbps fibre communications as well as access to the AARNet.

5.2.2.2 Australian Academic and Research Network

Figure 4 provides a map of the AARNet international network as at September 2013, showing onward connection to peers in the National Research and Education Network (NREN). Figure 5 shows the domestic AARNet as at June 2015. Figure 6 shows data storage facilities operated by the Research Data Storage

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[38] Details regarding the Western Power Feasibility Study application are available online at https://www.westernpower.com.au/services/feasibility-study/

[39] The Horizon Power Connection Application is available online at http://horizonpower.com.au/media/1435/ connection-application-form-hp_3_17433-140416.pdf

[40] Horizon Power may request upfront non-recoverable payment of $6,000 for investigation/design costs. This design fee is included within the formal quote.

[41] A UPS differs from an auxiliary or emergency power system, or standby generator in that it will provide near-instantaneous protection from input power interruptions by supplying energy stored in batteries, or other storage devices.

[42] Curtin University, 2016, para 3 (ii), p 5.

[43] For example, the BoM don't have direct access to the AARNet, other than via another consortium member.

Infrastructure (RDSI) to enhance distributed data centre development and support collaborative access to research data assets of national significance.[44] A total of 53 participating organisations are involved in the operation and use of this national distributed set of facilities. The AARNet is a preferred terrestrial communications modality by some WASTAC members as it provides known Network Access Points (NAPs), such as the Pawsey High Performance Computing Centre in Perth. However, its use is not favoured by other WASTAC members (BoM, GA, LG) as they are not academic institutions and therefore have no direct access. Accordingly, this report focussed on access to commercial fibre with at least 100 Mbps capacity.

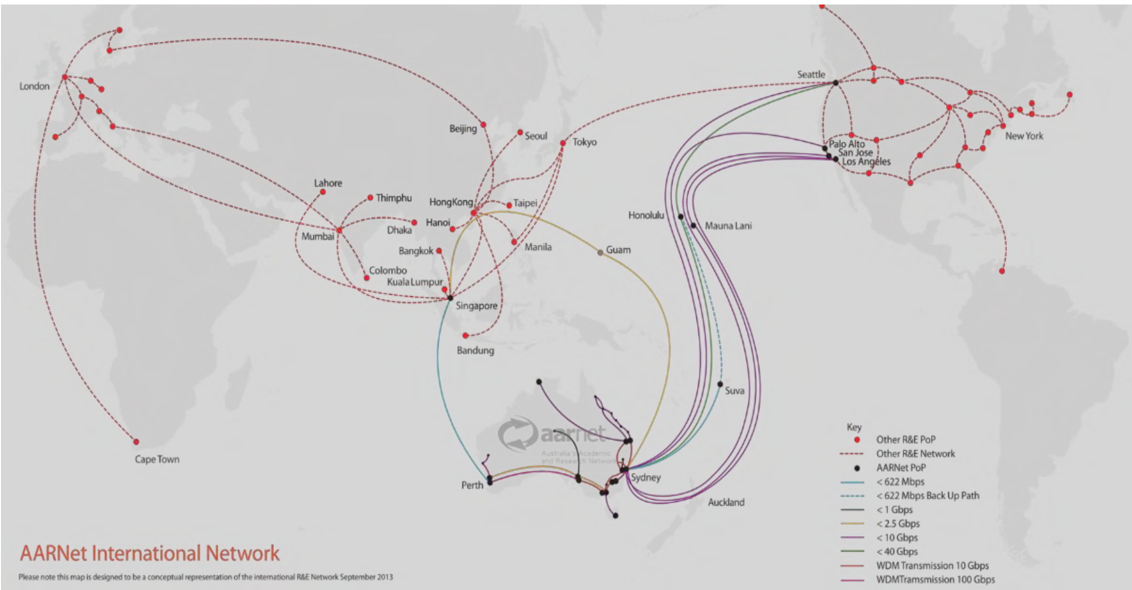


Figure 4. The AARNet international network (September 2013)

[44] Middleberg, A., 2014. pp 3-4.

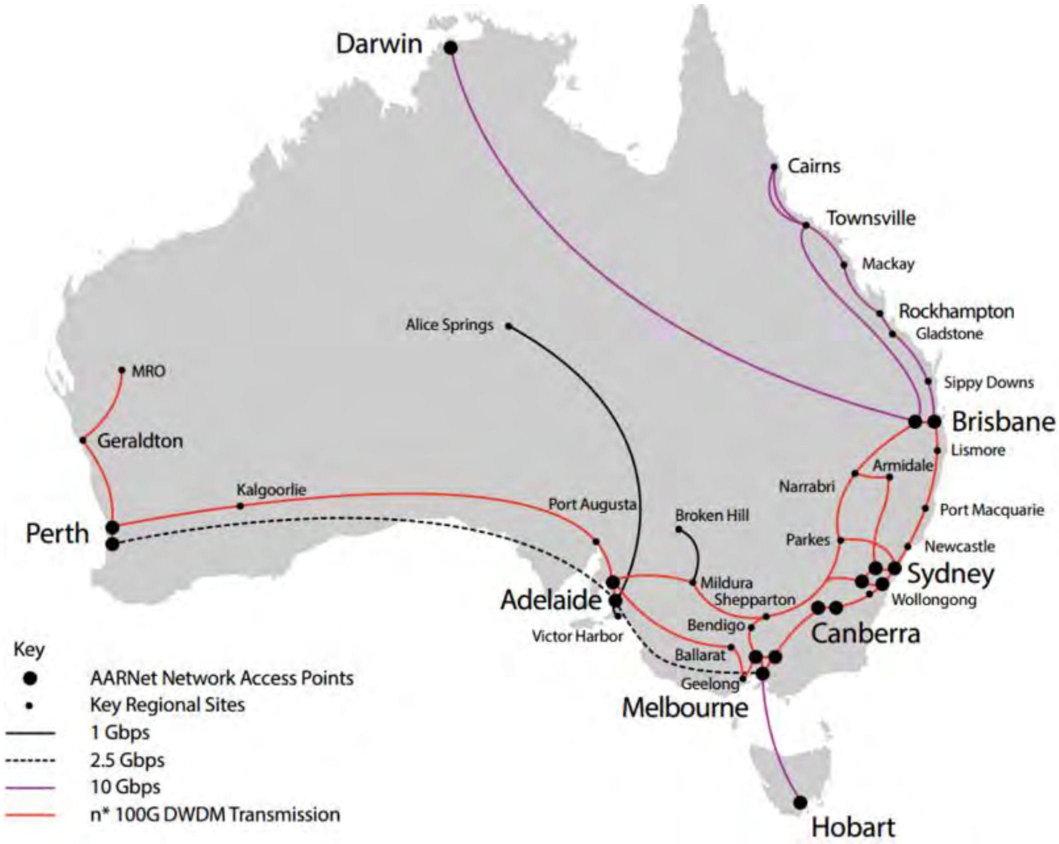
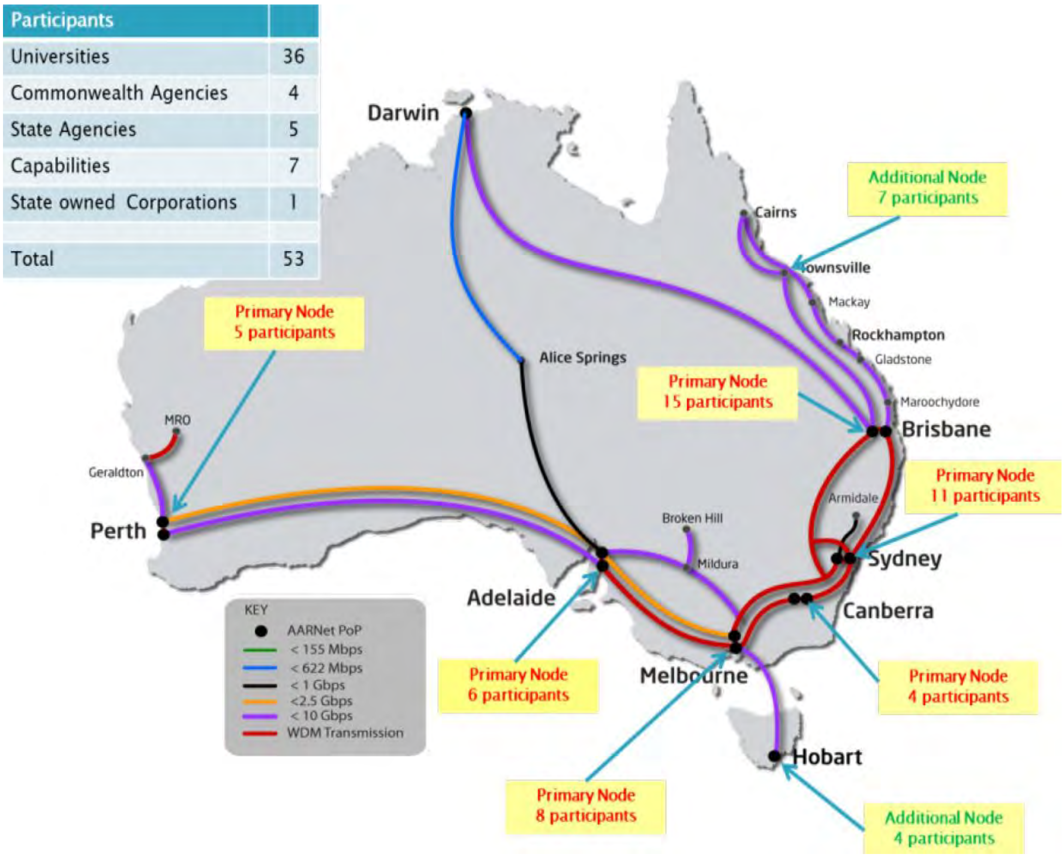


Figure 5. The AARNet domestic network (June 2015)



Participants	
Universities	36
Commonwealth Agencies	4
State Agencies	5
Capabilities	7
State owned Corporations	1
Total	53

Figure 6. Data storage facilities operated by the RDSI

5.2.2.3 Commercial Fibre Communications

Telstra have advised that 100 Mbps commercial fibre communications can be delivered to all sites once any required enterprise works to extend the communications infrastructure have been completed. Additional costs for realisation of 100 Mbps fibre communications would include once-off Capital Expenditure (CAPEX) and monthly Operational Expenditure (OPEX). Formal costing may be obtained upon completion of a Detailed Feasibility Study[45].

5.2.3 Notes on Spectrum

5.2.3.1 Frequencies of Interest

This study has liaised closely with the ACMA to ensure any issues that could compromise the long-term viability of a site due to spectrum availability were clearly understood. One aspect that Shoal considers important is to preserve the option of a reception facility being attractive for future anchoring, or command and control functions; this would broaden the business case and negotiation options for the utility, versatility, potential income, or quid-pro-quo arrangements with international EOS providers. Therefore, S-band should be a consideration in any spectrum request.

5.2.3.2 Embargoes

Spectrum embargoes are an administrative tool used to facilitate orderly spectrum planning and a notice of intention by the ACMA to restrict the allocation of new licences in a band. They have the effect of preserving an area around the site for Earth station users against in-band emissions. They also alert industry to the start of a planning process. An embargo includes details of the frequency band, date of effect, coverage area, time frame, instructions, reasons and supplementary comments. For example, embargoes relevant to this Study are:

a. **Embargo 23:** new assignments to support television outside broadcast and future replanning activities; frequencies: 1980–2010 MHz, 2010–2110 MHz, 2170–2200 MHz and 2200–2300 MHz (Annex B refers).

b. **Embargo 49:** frequency assignments for terrestrial radio communication services within the Yarragadee Geodetic Observatory (YGO)[46] (Section 5.3.2.8 and Annex C refer).

c. **Embargo 69:** a restriction on all new frequency assignments to preserve future planning options for terrestrial fixed, mobile and radio determination services; frequencies: 24.25-27.5 GHz, part of Ka-band (Annex D refers).

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[45] Business Development Manager (Telstra Business) is able to assist with the Detailed Feasibility Study process.
[46] Also known as the Yatharagga Satellite Station. Online at http://www.sscspace.com/yatharaggaaustralia-4

5.2.3.3 Longevity and Risk

As with any valuable and competitive resource, forecasting the future of spectrum licensing is not possible given that related legislation is flexible based on demand. Hence general advice from the ACMA is to consider locations away from populated areas where existing arrangements are in place to support and preserve spectrum into the future. Examples of such locations are the YGO and the Murchison Radio-astronomy Observatory (MRO). Also, the ACMA does not reserve frequencies, so if long term certainty is required to support a future satellite mission, then embargoed sites are the only ones that the ACMA can guarantee enduring access (including S-band). That said, the further north in Western Australia that a site is located, the less likely there will be for any future changes (e.g. 30 years from now) that could disrupt operations. However, there are no guarantees and local area activities will ultimately dictate spectrum availability. Risk can also be assessed by considering what other services might be sharing the spectrum, either at the Spectrum Plan level, or a more detailed fixed point-to-point link analysis (e.g. the Radiocommunications Assignment and Licensing Instruction (RALI) FX3, *Microwave Fixed Services Frequency Coordination*).[47] Another factor is whether the bands are being considered for future services (e.g. mobile broadband services), which is a primary reason for avoiding populated areas.

5.2.3.4 Spectrum Application Process

The key point to be made here is that confirmation of spectrum availability cannot be given by the ACMA until formal specific application is made. At the 'Future of WASTAC' Workshop on 31 August 2016, an attendee from the BoM[48] noted that they manage all spectrum applications for BoM sites. This service was offered to WASTAC should the preferred site require a formal spectrum license application to be submitted. Based on this offer this report will not elaborate on submission requirements, which depend on location and the spectral band required. An Accredited Assigner can also provide additional analyses for licence applications.

5.3 SITING OPTIONS

5.3.1 Learmonth (BoM Facility at Learmonth Airport)

Learmonth (LEA)	lat (°S)	long (°E)	elev (m)	dist to coast (km)	dist to Perth (km)	time to Perth (hr)
	22.240639	114.097026	5	27	1,220	a: 2.5, r: 12.5

[47] RALI FX3 provides details the channel arrangements and assignment instructions for each microwave frequency band and the regulatory rules for system planning relevant to frequency coordination, in addition to other general information helpful to these processes.

[48] BoM Satellite Operations Manager.

5.3.1.1 Background

RAAF Learmonth[49] is a joint-use facility and hosts Learmonth Airport (LEA[50]) under a lease arrangement with the Exmouth Shire Council. The location of Learmonth in Western Australia, 32.8 km south of the town of Exmouth on the North West Cape, is shown in Figure 7 and Figure 8. The RAAF Base (and airport) are positioned within a Defence Secure Zone (DSZ), the green shaded area shown in Figure 9. Accordingly, any civilian land use (or changes to current use) within the DSZ requires a formal agreement through the Department of Defence (DoD).

Figure 7. Relative position of Learmonth in Western Australia

[49] RAAF Learmonth was named in honour of Wing Commander Charles Learmonth DFC and Bar, who, while leading No. 14 Squadron, was killed in a flying accident off Rottnest Island, Western Australia on 6 January 1944.

[50] International Air Transport Association (IATA) airport code: LEA.

Figure 8. Relative position of the Learmonth area

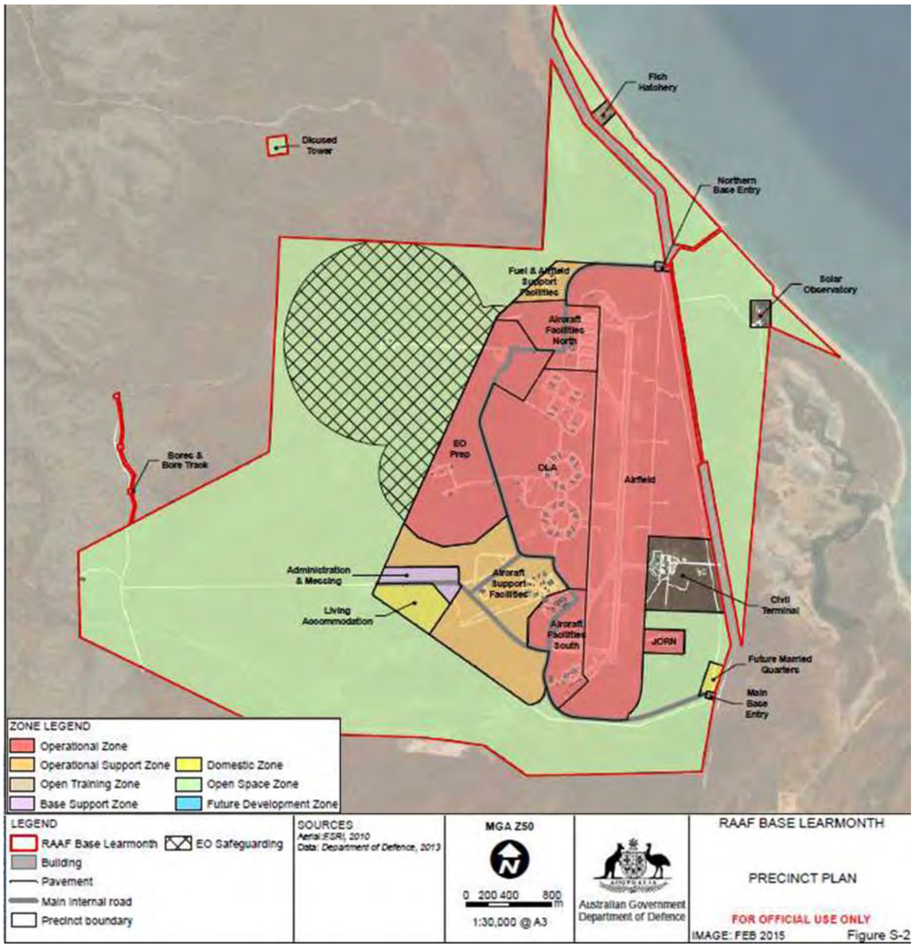

Figure 9. Defence Secure Zone surrounding Learmonth Air Force Base

5.3.1.2 Potential Site

The BoM currently lease land from the DoD adjacent to the Learmonth Airport, as shown in Figure 10 and Figure 11; Figure 12 shows the BoM facilities on this land. While the WASTAC Preliminary Report suggested locating a WASTAC reception facility at the old 'fisheries' site, approximately 4 km north of the airport, the BoM subsequently advised that they could host WASTAC assets on their leased land. Accordingly, the LEA site was assessed against the selection metrics. However, any proposed business case for a proposed LEA site must recognise the BoM's responsibility to negotiate with Defence regarding any new activities at that facility that may affect their current lease agreement. This is discussed in detail in the following section.

Figure 10. BoM facility at Learmonth airport

Figure 11. BoM facility at Learmonth airport

Figure 12. BoM facility at Learmonth airport

5.3.1.3 Leasing

While the proposed WASTAC site is on a BoM facility, it still remains on leased DoD land within the DSZ. Accordingly, amendments to the existing lease arrangements between the BoM and the DoD covering any additional development will need to be negotiated. The following provides a guide to requirements that need to be met prior to committing to this location as a future WASTAC site.[51]

5.3.1.3.1 **Memorandum of Understanding**

Meteorological Offices and associated instrumentation located on Defence estate are covered by a national Memorandum of Understanding (MoU) between the DoD and the BoM[52], where provisions of the licensor (Defence) and licensee (BoM) are detailed in a license-type format; all BoM sites on Defence estate are listed at Annex A to the MoU. Some licensing provisions in the MoU (specifically relating to use of the premises by the licensee) include the following:

a. The licensee shall not without the prior approval of the licensor, which such approval shall not be unreasonably withheld, use or permit the use of the premises for any purpose other than the carrying out of the normal operational practices of the BoM in discharge of its functions pursuant to the Meteorological Act 1955.

b. The licensor and its duly authorised servants or agents shall consult with the licensee and its duly authorised servants or agents prior to the installation

[51] This Information was provided by the Director Estate and Facilities Services, Service Delivery-Central and West, Estate & Infrastructure Group, Department of Defence, Leeuwin Barracks; by email on 20 September 2016.

[52] Memorandum of Understanding between Department of Defence and Bureau of Meteorology; current term is 1 October 2009 to 30 September 2019.

of any new plant and/or equipment or the modification of existing plant or equipment in or adjacent to the licensed premises.

5.3.1.3.2 **Civil Use of Defence Estate**

The other principal document pertinent to locating a EOS reception facility on the BoM facility at Learmonth Airport is the *Civil Use of the Defence Estate Manual* (CUDEM). The CUDEM states that:

Defence is committed to managing its estate assets effectively and efficiently to support Defence capability, its personnel, and its broader Commonwealth objectives. Civil use of Defence estate assets must be properly authorised to ensure transparent and accountable decision making, and managed to ensure appropriate use of Defence's resources. Failure to do so exposes Defence to the risk of non-compliance with legislation and Commonwealth policy, and the misuse of its resources.

Specifically, Section 2.8 of the CUDEM addresses the installation of structures and facilities and/or gaining use of existing facilities and land. For non-Defence organisations to establish facilities, equipment and/or a presence on Defence estate, Defence sponsorship is first required, then the requirement is assessed against the relevant policies. Other assessments including site selection approvals must also be satisfied.

5.3.1.3.3 **Key Requirements for the use of Defence Estate**

From these documents, the central principle guiding any proposed use (or amended use) of Defence estate requires the demonstration of a net benefit to Defence and/or the Commonwealth. Accordingly, the conditions to establishing any new capability on the BoM facility at Learmonth Airport are to:

a. establish specific sponsorship from a Defence entity, unless the BoM can justify the addition of an EOS reception facility as an extension of existing operations covered under the MoU; and

b. demonstrate how the CUDEM principles for use of the Defence estate can be satisfied.

If these can be met, then a more detailed assessment can be considered; this would include a Site Selection Board with all stakeholders to ensure that issues such as building codes (e.g. Exmouth Shire to meet local flooding and tidal storm surge minima) and regulatory clearances (e.g. the Civil Aviation Safety Authority and Airservices Australia for structures near an airport) are met.

5.3.1.4 Power

Horizon Power have advised that the existing overhead high voltage (HV) line which comes into the RAAF base, enters at the northern boundary for approximately 200 m before the existing substation / HV metering location is reached. This is Horizon Power's point of supply for the RAAF base property, and is where Horizon Power's network ownership ends, with all electrical infrastructure past this point classed as internal electrical reticulation being owned and controlled by the customer. Usage of the existing HV supply / connection would require an agreement with the RAAF, and any works beyond the supply point would require the engagement of an electrical contractor.[53]

If provision of an alternate point of supply within the RAAF property was required, it would have to adhere to the WAER multiple points of supply policy. Extension of Horizon Power's existing infrastructure would be required from the existing distribution poles outside of the RAAF northern boundary to the new point of supply (approximately 3 km).

Given the proposed siting location is on the BoM leased land, usage of the existing power infrastructure of the BoM facility would represent the most cost effective option. Whilst agreement with the RAAF would still be required, a sub-metering arrangement could likely be established.

If this site is selected, it is recommended that a feasibility study be undertaken by an electrical consultant (as Horizon Power's asset ownership ends at the existing HV point of supply) to determine the requirements for usage of the existing power infrastructure of the BoM facility. Alternatively, a Connection Application could be submitted (utilising the services of an electrical consultant) to prompt Horizon Power to commence detailed design investigations and a formal quote (as discussed in Section 5.2.1.2) for extension of their network. An electrical contractor will need to be engaged for any internal electrical reticulation.

5.3.1.5 Communications

Telstra has advised that fibre communications infrastructure exists within the precinct of Learmonth Airport. However, significant enterprise works would be required to extend the fibre to the proposed site.[54] Additional CAPEX and OPEX costs for the provision of 100 Mbps commercial fibre communications would also be expected (as eluded to in Section 5.2.2.3).

5.3.1.6 Spectrum

Spectrum Rough Order of Magnitude (ROM)[55] charges for Learmonth would be $8,985 per annum with a Licence Establishment Fee (LEF) of $1,260 in the first

[53] Email correspondence with Horizon Power Carnarvon depot on 18 October 2016.
[54] Email correspondence with Business Development Manager (Telstra Business) on 9 September 2016.
[55] A ROM estimate is an estimation of a project's level of effort and cost to complete and will have an accuracy of about plus or minus 50%. A variance of -25% to +75% is common for ROM estimates.

year.[56] Analysis conducted in cooperation with the BoM regarding the future availability of spectrum at the Learmonth site revealed the following[57]:

a. **X-band:** A search on the ACMA Register of Radiocommunications Licences (RRL)[58] yielded no Fixed Service (terrestrial microwave, or point-to-point link) frequency assignments that overlap the X-band satellite downlinks of interest to WASTAC within a 200 km radius of the Learmonth Solar Observatory (2 km northeast of Learmonth Airport). Increasing the radius to 300 km there are 7 frequency assignments, 400 km there are 38 frequency assignments and 500 km there are 87 frequency assignments. Noting that the Crib Point polar tracking antenna is currently receiving the same X-band satellite downlinks without interference, despite almost 700 overlapping frequency assignments within a 200 km radius, suggests that there should be no X-band interference of consequence at the Learmonth site.

b. **Ka-band:** The frequency band 31.3-31.8 GHz has a primary allocation (both internationally and domestically) to passive EOS services. As this band is not shared with a fixed service, it is not considered to pose issues into the future.

c. **S-band:** S-band (notably MHz) has an Australia-wide embargo due to the introduction of Television Outside Broadcast (TOB) Services. Accordingly, Tx and Rx from satellites in this band would need to be coordinated with a broadcaster allocated an overlapping spectrum. The BoM advise that coordination with TOB services is only really proving to be an issue when the earth station (Tx) site is within a few hundred kilometres of a capital city. As this is not the case for Learmonth, Tx in S-band from the Learmonth site is not deemed precluded. Rx in S-band, as long as any interference from TOB operations in the area can be tolerated, would be deemed acceptable.

Confirmation of these judgements would not be available until specific application was made to the ACMA, as discussed in Section 5.2.3.4.

5.3.1.7 Horizon Mask

Topographic placement of the proposed site is given at Figure 13 and elevation is shown in Figure 14. The Cape Range runs approximately north-south along the North West Cape and rises to around 320 m to the north-west of the site. However, this obstruction is expected to be ameliorated by the BoM's method of mounting the antenna on a custom-made pedestal.

[56] Estimates provided by BoM Satellite Operations Manager based on the ACMA Apparatus Licence Fee Schedule.

[57] Courtesy of BoM Satellite Operations Manager. Also correspondence on 27 July 2016 with Manager Spectrum Engineering & Space (Spectrum Planning and Engineering Branch, Communications Infrastructure Division, the ACMA).

[58] See: http://www.acma.gov.au/Industry/Spectrum/Radiocomms-licensing/Register-of-radiocommunications-licences/spectrum_15

5.3.1.8 Access

This site option provides availability to suitably qualified on-site BoM technical staff. The site is also regularly serviced by direct flights from Perth (2.5 hours).

5.3.1.9 Learmonth Summary

While the LEA site is a favourable option, there are significant procedural requirements regarding lease amendments and spectrum access that require resolution before a WASTAC reception facility can be located on the BoM facility. These can only be progressed once a decision to proceed with this option is made.

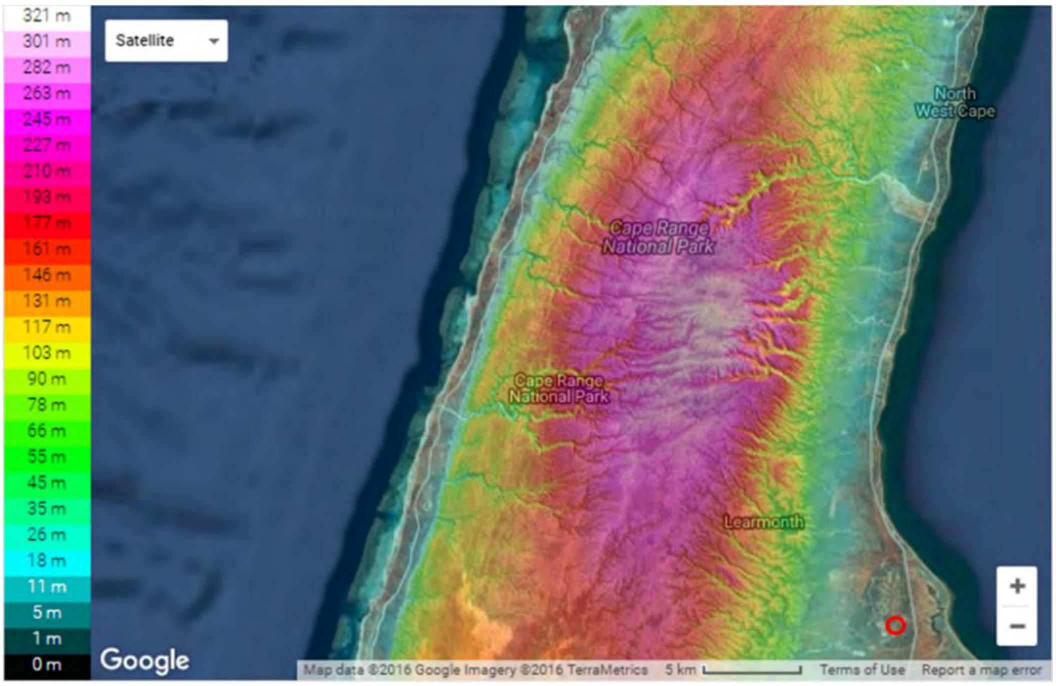

Figure 13. Topographic placement of the LEA site[59]

Figure 14. Elevation of the LEA site (5.00 m)[60]

[59] Map data ©2016 Google Imagery ©2016 CNES / Astrium, Cnes/Spot Image, DigitalGlobe, Landsat
[60] Online at http://www.altitude.nu/

5.3.2 Mingenew (YGO at the Western Australian Space Park)

Mingenew (YGO)	lat (°S)	long (°E)	elev (m)	dist to coast (km)	dist to Perth (km)	time to Perth (hr)
	29.046725	115.346068	268	51	403	a: 1.0 + r: 0.9

5.3.2.1 Background

Recognising the increasing difficulty of locating Earth stations in high spectrum use areas and planning for communication alternatives, the ACMA established a 114-hectare Space Park in 2009 on the Yatharagga property situated 24.4 km (21 minutes) northwest of Mingenew (population 310). The route from Perth is shown in Figure 15 and its relative position to Mingenew is shown in Figure 16.

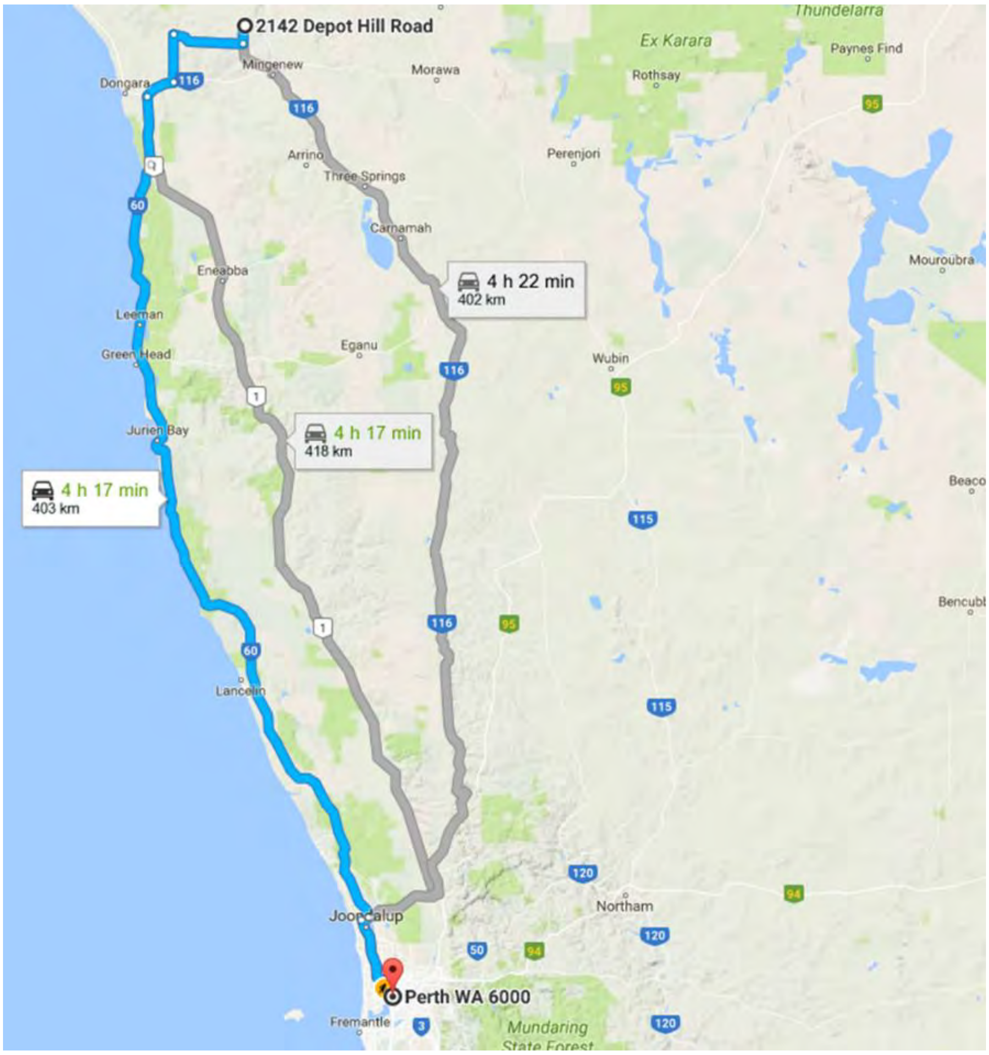

Figure 15. Route from Perth to the YGO

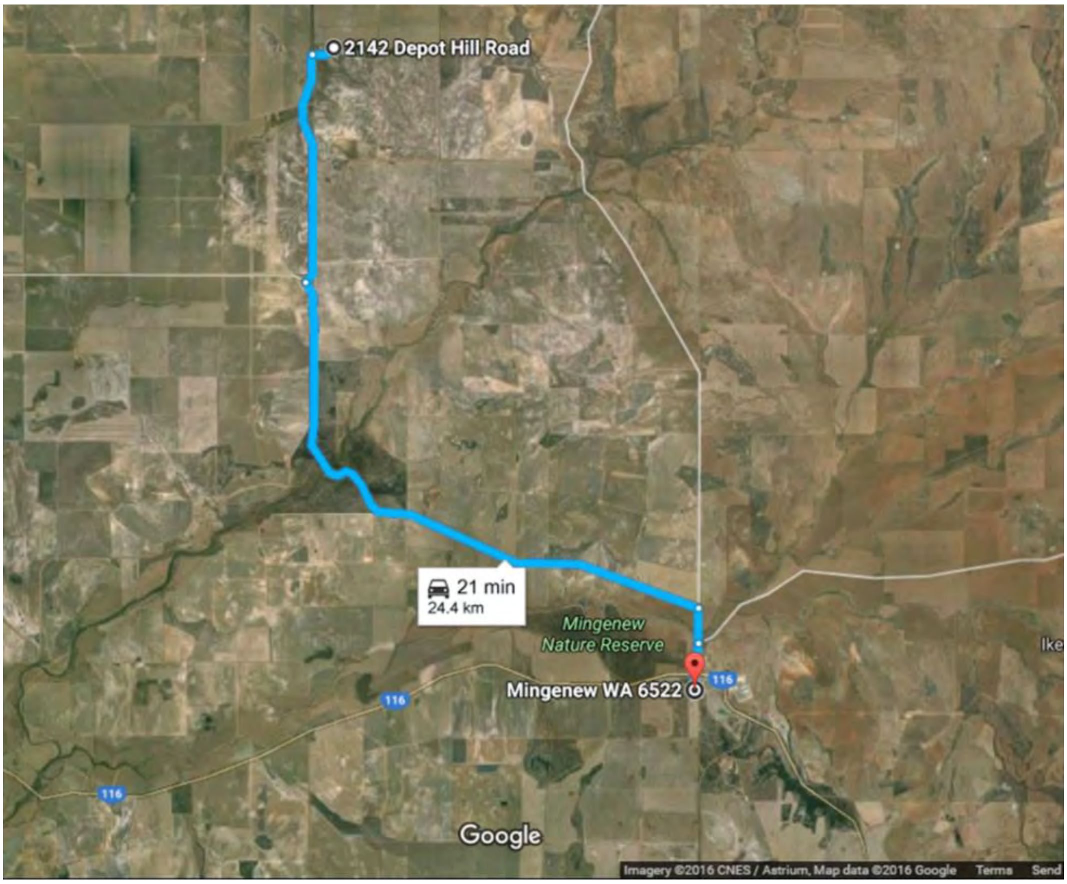

Figure 16. Relative position of the YGO to Mingenew

5.3.2.2 Universal Space Network

The Space Park is owned and operated by Space Australia, a subsidiary of the Swedish Space Corporation (SSC), which invested $8 million in the project.[61] SCC operates the Universal Space Network (USN) tracking station (Figure 17), which was founded by former astronaut Peter Conrad with the intention of providing data and pictures to the public within 15 minutes of being downloaded.

Figure 17. Universal Space Network tracking station

[61] The SSC is the largest commercial operator of satellite tracking ground station facilities

5.3.2.3 Yarragadee Geodetic Observatory

Adjacent to the USN, the SCC leases 20 hectares[62] to GA for the YGO. The area of the Space Park and the perimeter of the YGO are shown in Figure 18. A number of ground stations have been installed at the YGO. These include:

a. the National Aeronautics and Space Administration's (NASA) Moblas 5 Satellite Laser Ranging (SLR) facility[63] (managed and operated by GA);

b. the University of Tasmania's (UTAS)[64] 12-metre Very Long Baseline Interferometry (VLBI) radio telescope, established as part of the AuScope program[65]; and

c. Global Navigation Satellite Systems (GNSS) receivers, along with a Doppler and Radiopositioning Integrated by Satellite (DORIS)[66] transmitter and time reference equipment.[67]

Figure 18. Perimeter of the YGO

[62] Department of Industry, 2013, p 11.

[63] Moblas 5 plays an important role in the Australian and international geodetic framework.

[64] The UTAS facility is located on GA's lease and operations are funded by GA.

[65] AuSCOPE Limited, 2014. AuSCOPE is the national provider of integrated research infrastructure to realise the collective potential of Australian Earth and Geospatial Science researchers. See http://www.auscope.org.au/

[66] The DORIS instrument is operated by GA in partnership with the French space agency. Overview at http://space-geodesy.nasa.gov/docs/2012/DORISOverview_Lemoine_120607.pdf

[67] There are around 55 Dual-Frequency Doppler Beacons (2.036 Ghz and 401.25 Mhz) distributed around the world. Available at http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/geodetic-techniques/satellite-laser-ranging-slr

5.3.2.4 Potential Site

The potential WASTAC site would be located to the right of the YGO entrance[68]. During the site visit on 19 September 2016 a specific location was identified in a vacant area of land as shown in Figure 19 and Figure 20. Figure 21 and Figure 22 provide a panoramic view of the potential site.

Figure 19. Proposed WASTAC site at the YGO

Figure 20. Location of utilities adjacent to the proposed WASTAC site

[68] Address: 2142 Depot Hill Rd, Nangetty WA 6522

Figure 21. Panoramic view to northeast of the proposed WASTAC site

Figure 22. Panoramic view to northwest of the proposed WASTAC site

5.3.2.5 Leasing

GA have advised that leasing arrangements for a WASTAC reception facility could be made under the current agreement with the SCC.[69]

5.3.2.6 Power

The YGO has comprehensive power infrastructure adjacent to the proposed site (within approximately 40 m), including mains power, UPS and a backup power generator.[70] Figure 23 shows the building containing the UPS and the backup generator building. Figure 24 shows inside the UPS building, which also houses the fibre communications hub and access point.

The YGO connection to the Western Power 3-phase distribution lines is via a pole mounted transformer (visible in Figure 20) to a meter box at the base of the distribution pole. Connection to this existing infrastructure would require a sub-metering arrangement (downstream of the meter box) as is currently in place for other users, however an agreement with the SCC through GA would likely need to be established.[71]

If this site is selected, it is recommended that a feasibility study be undertaken by an electrical consultant (as Western Power's asset ownership ends at the main meter) to elicit the detailed requirements for the power infrastructure downstream of the main meter. It is likely that an electrical contractor will then need to be engaged for internal electrical reticulation.

[69] Communication with Section Leader Geodesy and Seismic Monitoring Group (GA) on 20 July 2016 and site visit on 19 September 2016.

[70] Loc cit.

[71] Communication with YGO Operations Staff (GA) on 31 October 2016.

Figure 23. UPS and backup generator adjacent to the proposed site

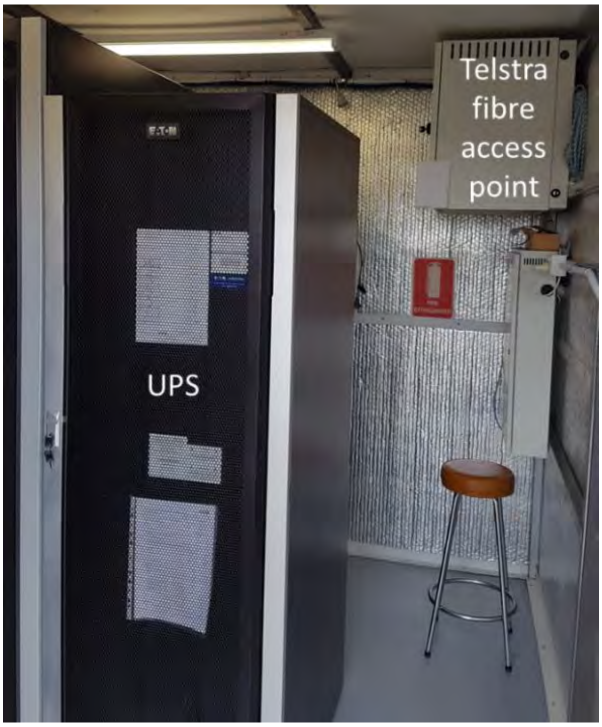

Figure 24. Inside the UPS/Communications building

5.3.2.7 Communications

The YGO site has commercial fibre communications provided by Telstra as shown in Figure 24, Figure 25 and Figure 26. As GA budgeting issues have precluded using this utility, GA and UTAS freight their data from the site to Geraldton. However, a 2016 Australian Research Council (ARC) Linkage Infrastructure Equipment and Facilities (LIEF) grant may provide funding for connection to the AARNet fibre from the MRO, running through Mullewa, the closest connection point. The rejoinder was submitted in June 2016 and the ARC LIEF announcements were due in November 2016.[72] If successful, the AARNet will connect to the YGO through the same access location as the commercial fibre.

[72] Communication with Section Leader Geodesy and Seismic Monitoring Group (GA), 25 July 2016.

Alternatively, fibre installation and connection to the proposed site from an existing Telstra fibre Point of Presence (i.e. the fibre communications hub) would incur minimal enterprise works charges.[73] Additional CAPEX and OPEX costs for the provision of 100 Mbps commercial fibre communications would also be expected (as eluded to in Section 5.2.2.3).

Figure 25. Telstra fibre communications access point

Figure 26. Inside the Telstra fibre communications access point

[73] Email correspondence with Business Development Manager (Telstra Business) on 28 September 2016.

5.3.2.8 Spectrum

The Space Park was established to provide Earth station operators an opportunity to reliably plan future systems operating in **any space band**, while still preserving the broader radio environment. This protection is reflected in Spectrum Embargo 49 (refer Table 10); evidently, coordination is required between adjacent services in accordance with normal procedures.[74]. This radio quiet zone also prevents any interference to telescopes like those at the MRO. Accordingly, from a spectrum perspective, this site is eminently suited to WASTAC's current and future purposes.

Table 10. Frequencies covered under the ACMA's Embargo No 49[75]

ACMA Embargo No 49			
Frequency Range	**Band**	**Frequency Range**	**Band**
2015–2100 MHz	S	8540–8660 MHz	X
2100-2130 MHz	S	10700–14800 MHz	X/Ku
2190–2280 MHz	S	15349-15410 MHz	X/Ku
2280-2310 MHz	S	15430-15630 MHz	X/Ku
3400–4200 MHz	S/C	17200-21400 MHz	Ku/K
5850–7075 MHz	C	22200-22510 MHz	Ku/K
7135–7245 MHz	C	24750-25250 MHz	Ku/K
7250–7750 MHz	C	25500-31000 MHz	K/Ka
7900–8390 MHz	C/X	33400-36000 MHz	K/Ka
8390-8460 MHz	X	37500-43500 MHz	K/Ka
8460-8510 MHz	X	47200-51400 MHz	

Spectrum ROM charges for the YGO would be $18,396 per annum with an LEF of $1,440 in the first year.[76] The difference between Learmonth and Mingenew (YGO) spectrum charges is a direct result of the difference in location; Learmonth is located in a Remote Density Area, whereas Mingenew is located in a Low Density Area. WASTAC is not eligible for exemptions under the Apparatus Licence Fee Schedule April 2016.[77]

An additional consideration is the potential interference from the Moblas 5 station located 70 m north-east from the identified site. It has been suggested[78] that a survey would be required to quantify this metric should the YGO be considered the favourable location.

[74] Australian Communications and Media Authority, 2011, p 18.
[75] Australian Communications and Media Authority, 2016.
[76] Estimates provided by BoM Satellite Operations Manager based on the ACMA Apparatus Licence Fee Schedule.
[77] Appendix E to Australian Communications and Media Authority, 2016 (2).
[78] Communication with Curtin University WASTAC member on 16 November 2016.

5.3.2.9 Horizon Mask

The topographical placement of the proposed YGO site is shown in Figure 27 and elevation is shown in Figure 28. These show that the proposed site is elevated and has a minimal horizon mask.

Figure 27. Topographic placement of the YGO

Figure 28. Elevation of the YGO (268.18 m)[79]

5.3.2.10 Access

Access to the YGO is via a 1-hour plane trip from Perth to Geraldton and an estimated 57-minute drive through regional Western Australia (see Figure 29). Also, the professionally qualified GA staff at the YGO have indicated their availability to provide technical support should it be required for the WASTAC reception facility. The site also offers room for expansion.

[79] Online at http://www.altitude.nu/

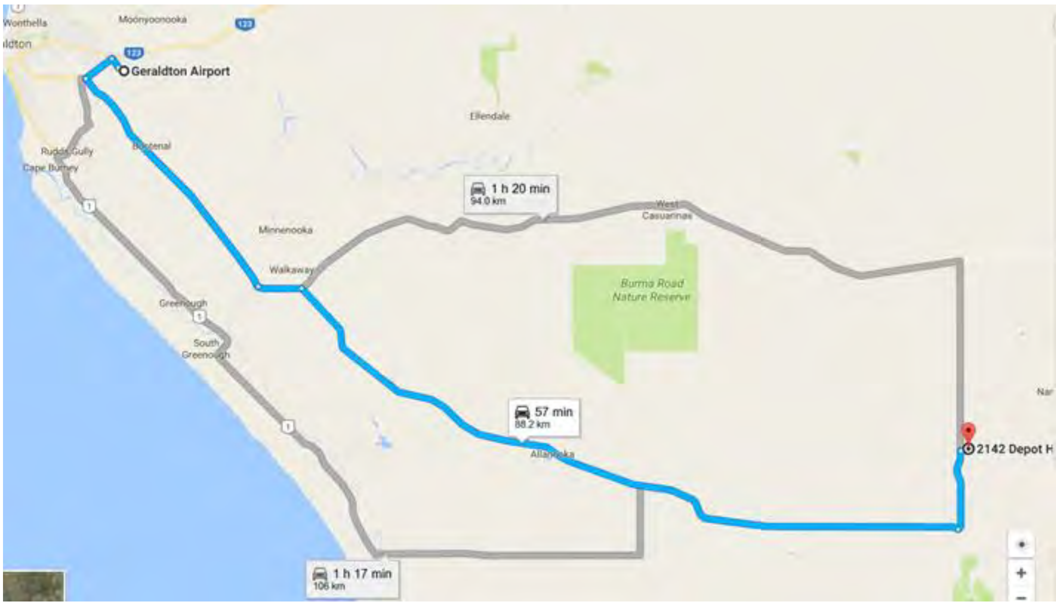

Figure 29. Route from Geraldton Airport to the YGO

5.3.2.11 Mingenew (YGO) Summary

The key advantage of the YGO site is that the ACMA has established an embargo for all bands of current and potential interest to WASTAC, including S-band. Importantly, licenses for S-band will no longer be issued due to interference with outside television broadcast and future replanning activities[80] and the ACMA advise that the YGO is the only location in Western Australia where WASTAC is likely to obtain such a license. Potential interference from the Moblas 5 station 70 m from the proposed site would need to be quantified.

5.3.3 Mullewa (MRO Fibre Repeater)

Mullewa (CSIRO)	lat (°S)	long (°E)	elev (m)	dist to coast (km)	dist to Perth (km)	time to Perth (hr)
	28.538971	115.502449	299	92	470	a: 1.0 + r: 0.9

5.3.3.1 Background and Potential Site

Mullewa (population around 729) is a town in the Mid-West region of Western Australia. The route from Perth to Mullewa is shown in Figure 30. Discussions with CSIRO staff advised that Mullewa is along the AARNet fibre communications route from the MRO to Geraldton and a fibre repeater hut is located to the north-west of the town. Accordingly, locating a WASTAC reception facility near the repeater could be a possibility. The green line in Figure 31 indicates the routing of the AARNet fibre from the MRO to Geraldton; the repeater hut is circled in red. A street view of the repeater hut is given in Figure 32.

[80] Australian Communications and Media Authority, 2013 (Embargo 23).

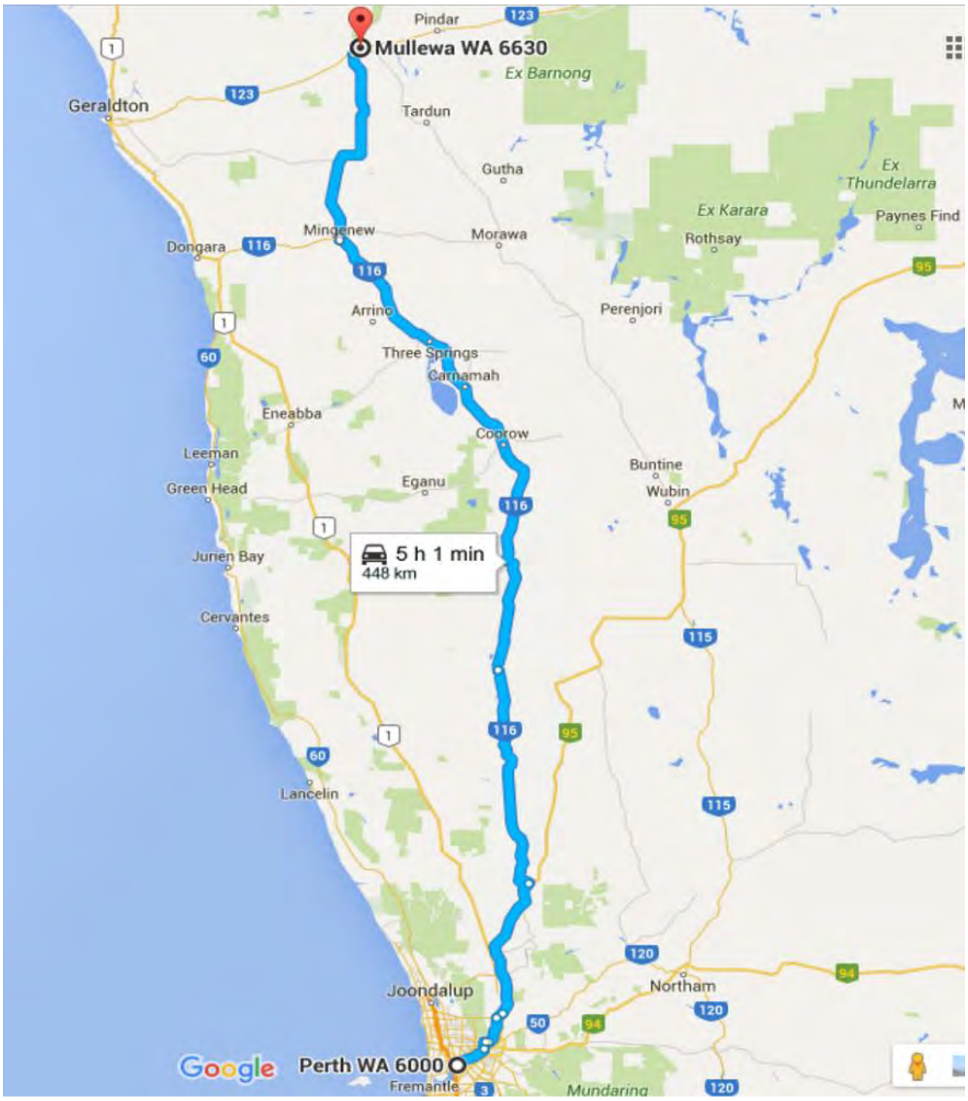

Figure 30. Route from Perth to Mullewa

Figure 31. Route of fibre from the MRO and location of fibre repeater hut

Figure 32. CSIRO's MRO fibre communications repeater hut at Mullewa

5.3.3.1 Leasing

The site visit on 19 September 2016 revealed that the repeater is situated within the red enclosed area shown in Figure 33. , being Lot 1 on Diagram 60307.[81] In addition to the repeater, this land area also lodges a miners' camp operated by Patience Bulk Haulage (PBH) and a campground. Being freehold land, locating a WASTAC asset adjacent to the repeater (probably to the west) could be achieved through negotiating a lease with the registered land owner,[82] assuming similar arrangements for the repeater.

Figure 33. Parcel of land surrounding the CSIRO AARNet repeater hut

Locating the WASTAC asset in the paddock to the of the west of the delineated area (Lot 23 on Plan 235009) would need to be done via the Department of Lands

[81] A snapshot from Locate provided by Product Delivery, Landgate.

[82] A Mr Freeman; based on advice from Landgate, 14 November 2016.

given that this is Crown Land. Advice from Landgate is that this should be possible provided a State Government department took responsibility for management of the land. If required, copies of Certificates of Title can be purchased from Landgate for $24.85 each.

5.3.3.2 Power

Mains power is readily available at the proposed Mullewa site (refer to Figure 32). Western Power has advised that a green dome[83] and meter exist on Lot 1 in the vicinity of the miners' camp. As such, a sub-metering arrangement could likely be established, with agreement from the land owner. Being beyond the point of Western Power's asset ownership, this would require the services of an electrical contractor. Alternatively, Lot 23 does not have an existing point of supply, and thus a new connection could be established noting that overhead lines border the southern and western boundaries of the land.

If this site is selected, it is recommended that a Feasibility Study be undertaken, either through Western Power (refer to Section 5.2.1.2) or an electrical consultant to elicit the detailed requirements for the power infrastructure. If required, a New Connection application could then be submitted and/or an electrical contractor engaged for internal electrical reticulation.

5.3.3.3 Communications

Telstra has advised that extension of their fibre communications infrastructure to the proposed site would require significant enterprise works.[84] Additional CAPEX and OPEX costs for the provision of 100 Mbps commercial fibre communications would also be expected (as eluded to in Section 5.2.2.3).

Figure 31 and Figure 32 show that fibre communications via connection to the AARNet from the MRO is available at the proposed Mullewa site. However, as noted in Section 5.2.2.1, commercial fibre is preferred by the likely users of any future 'WASTAC' site. Also, as noted in Section 5.3.2.7, a successful ARC LIEF grant application for connection of the YGO to the MRO AARNet fibre link via Mullewa would make this location redundant.

5.3.3.4 Spectrum

Spectrum ROM charges for Mullewa would be $18,396 per annum with an LEF of $1,440 in the first year.[85] Discussion with the ACMA indicate that spectrum is likely to be available at the Mullewa site. However, as discussed in Section 5.2.3, formal application will be required to ascertain spectrum availability based on local activities and sharing with fixed links. Given the extrapolation in the above section, this analysis is not deemed worthwhile.

[83] A green dome or pillar, which contains live electrical wires, is placed inside a property boundary where underground power has been installed.

[84] Email correspondence with Business Development Manager (Telstra Business) on 9 September 2016.

[85] Estimates provided by BoM Satellite Operations Manager based on the ACMA Apparatus Licence Fee Schedule.

One issue that may impact reception is the prevalence of radio communications from vehicles travelling along the adjacent Geraldton-Mount Magnet Road. The potential interference would need to be quantified should Mullewa be considered the preferred site.

5.3.3.5 Horizon Mask

Elevations shown in Figure 34 and Figure 35, together with the BoM mounting technique, indicate that there are no limitations to the horizon mask.

5.3.3.6 Access

As with the YGO, access to Mullewa is via a 1-hour plane trip from Perth to Geraldton and an estimated 57-minute drive through regional Western Australia (see Figure 36). However, there are no suitably qualified staff within 60 km of the site (at the YGO) to provide technical assistance and logistics support.

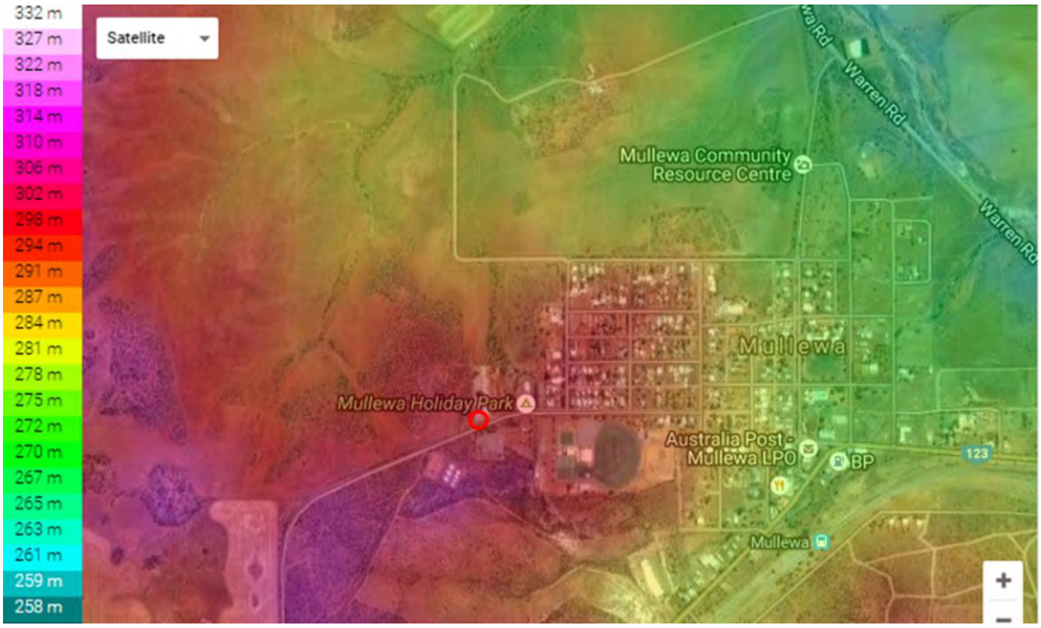

Figure 34. Topographic placement of Mullewa site

Figure 35. Elevation of Mullewa Site (299.24 m)

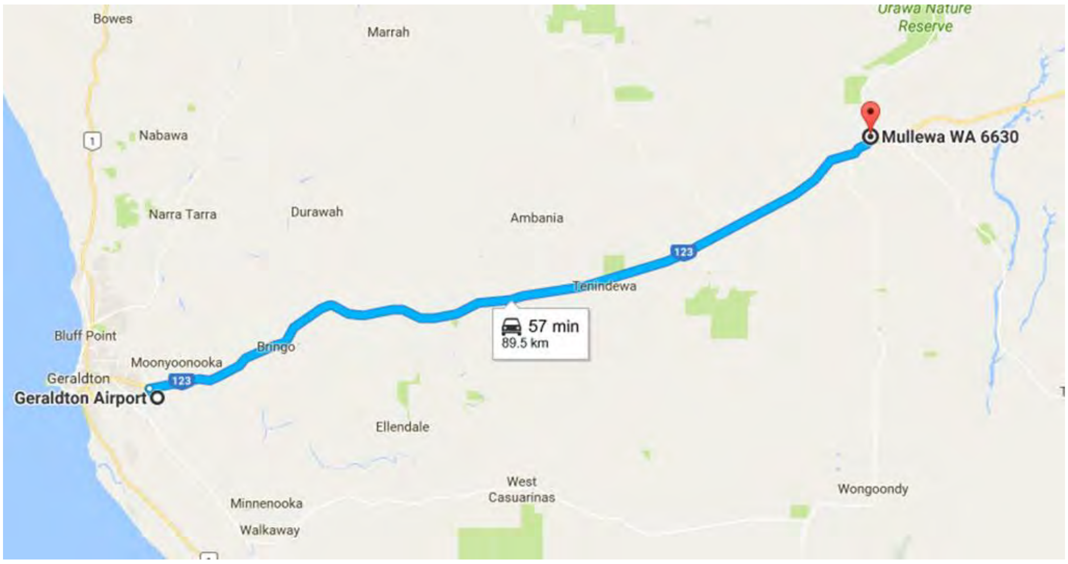

Figure 36. Route from Geraldton Airport to Mullewa

5.3.3.7 Mullewa Summary

Mullewa has proximate access to power and AARNet fibre communications. It is also reasonably remote from any major population centre and therefore holds promise in accessing required spectrum. The site visit on 19 September 2016 determined that the AARNet repeater is located on freehold land and therefore a WASTAC asset could be situated there through negotiating a lease arrangement. However, there are no suitably qualified staff within 60 km to provide technical assistance and logistics support if required. Finally, a successful ARC LIEF outcome for the YGO would make this location redundant.

6 SUMMARY OF FINDINGS

The Siting Study findings are summarised in Table 11, Table 12 and Table 13. The YGO and LEA sites present the least uncertainties, have lower establishment costs and on balance, are equally favourable. The YGO offers guaranteed spectrum access across all bands, while the LEA site is further north. Note that for the LEA site, Defence leasing arrangements will need to be reviewed for equipment and activities outside the existing BoM/Defence MoU. Mullewa remains an option but may be nullified if the ARC LIEF grant for AARNet connectivity is successful.

Table 11. Summary of siting study findings

Site	lat (°S)	long (°E)	elev (m)	dist to coast (km)	dist to Perth (km)	time to Perth (hr)	spectrum				horizon				access to services				climate		lessor
							L	X	S	Ka	N	S	E	W	power	comms	skills	sealed road	temp (°C)	mean clear days	
Learmonth (LEA)	22.240639	114.097026	5	27	1220	a: 2.5, r: 12.5	P	P	P	P	~3	~3	~3	~3	Y	Y	Y	Y	17.7-31.9	230	Defence
Mingenew (YGO)	29.046725	115.346068	268	51	403	a: 1.0 + r: 0.9	Y	Y	Y	Y	~3	~3	~3	~3	Y	Y[1]	Y	N	12.6-27.7	150	SSC
Mullewa (CSIRO)	28.538971	115.502449	299	92	470	a: 1.0 + r: 0.9	P	P	N	P	~3	~3	~3	~3	Y	Y	N	Y	13.2-27.9	147.2	Private

[1]AARNet connectivity subject to a 2016 ARC LIEF bid (to be announced Oct/Nov 16); a: air; r: road; P: possible

Table 12. Traffic light summary of findings

Site	lease	power	comms	spectrum	masking	road access	technical staff
Learmonth (LEA)							
Mingenew (YGO)			ARC LIEF				
Mullewa (CSIRO)							

LIEF: Linkage Infrastructure Equipment and Facilities

Table 13. Pros and cons summary of findings

Site	Pros	Cons
Learmonth (LEA)	accessible commercial fibre mask power technical staff	lease-CUDEM AARNet spectrum
Mingenew (YGO)	accessible commercial fibre lease mask power spectrum technical staff	AARNet (LIEF dependent) potential Moblas 5 interference
Mullewa (CSIRO)	AARNet accessible mask power	commercial fibre spectrum technical staff potential transport radio interference

ANNEX A - ORBITAL SYSTEMS 2.4AEBP ANTENNA POSITIONER SPECIFICATIONS

Orbital Systems

2.4AEBP

Elevation-Over-Azimuth 2.4m Antenna Positioner

The Orbital Systems, Ltd. 2.4AEBP antenna positioner is designed and built to provide high reliability and to withstand severe environmental conditions. It is a high-quality, high-precision elevation-over-azimuth satellite tracking system suitable for operation at X-band and below. The 2.4AEBP utilizes the proven orbital data bus (ODB) technology to provide integrated control of the antenna positioner and RF payload. Superior engineering, precision manufacturing, and strict quality control standards result in maintenance-free operation, which makes the 2.4AEBP the optimal choice for service in remote locations and in hostile climates.

Standard System Features

The Orbital Systems, Ltd. 2.4AEBP antenna positioner is available with multiple reflector options. Standard equipment includes feed mounting poles, ACU-2 antenna control unit, and a complete tool kit. Gold-on-gold contact slip rings facilitate unlimited azimuth rotation. The 2.4AEBP antenna positioner operates on one or two RF channels to a maximum of 4 Ghz. The 2.4AEBP antenna positioner also is available with standard options to provide AC or DC power and 100BASE-T Ethernet on the elevation arm

System Control and Tracking

- ACU-2 antenna control unit is standard and enables flexible control options
- Tracks satellites at X-band and below without keyhole effect
- Customized controller interface options are available

Motors and Gears

- Mechanical system components are fully integrated, with IP65-rated brushless servomotors and integrated brakes, matched and tuned motor drives, and heavy duty gears.
- Gears are automatically heated to maintain optimal performance at temperatures as low as -40°C
- Gears are completely enclosed in a cast housing and operate inside a controlled, optimal environment to increase their service life; no annual lubrication is required

Pressurization

- Antenna positioner and feed are pressurized with dehydrated air or nitrogen to prevent corrosion of system components
- Dry air is supplied using conventional transmission line dehydrator technology
- Temperature and humidity sensors in the electrical cabinet and feed are monitored by the antenna control unit, which automatically purges the system of moisture
- System remains operational if pressurization fails

Reflectors and Feeds

- Supplied with a 2.4 m spun aluminum reflector; see 2.4AEBP-3m data sheet for 3.0m version
- Equipped with feed poles for use with Orbital Systems, Ltd. feeds
- Many feeds are available with optional downconverters and polarity switching
- Orbital Systems, Ltd. feeds are equipped with purge valves to expel moisture from the system
- Feed communication is integrated into the antenna control unit over ODB
- Typical 2.4 m X- and L-band system performance is 24.5 dB/K and 8 dB/K, respectively

Special Order Options

- Mains A/C power supplied through antenna positioner for elevation arm-mounted electronics
- Gigabit Ethernet through antenna positioner
- Additional RF channels through antenna positioner
- Additional data pairs through antenna positioner
- Optical multimode fiber through antenna positioner

Applications

The 2.4AEBP antenna positioner and its ancillary RF components are typically used for the following applications.

- Tracking LEO and MEO satellites; suitable for the following EOS X-Bandsatellites:
  - TERRA
  - AQUA
  - NPP
  - FY3
  - EOS L- / S-band satellites: NOAA, FY1, DMSP
- General satellite uplink and downlink telemetry (TT&C), including microsats
- 3D radar applications for advanced meteorological and environmental analysis
- Auto-tracking applications, including UAS/UAV aircraft and missile tracking
- SARSAT reception of MEO satellites in S- and L-bands

2.4AEBP Antenna Positioner Specifications

Operational Specifications (Subject to change without notice)

	Required	Continuous Capable
Azimuth Maximum Velocity	57°/ Sec	>60°/ Sec
Azimuth Maximum Acceleration	39°/ Sec ^{2}	>60°/ Sec ^{2}
Azimuth Maximum Torque	900 Nm (664 ft/lbs)	>1500 Nm (1106 ft/lbs)
Azimuth Maximum Travel		Continuous Rotation
Elevation Maximum Velocity	9°/ Sec	>20°/ Sec
Elevation Maximum Acceleration	0.9°/ Sec ^{2}	>60°/ Sec ^{2}
Elevation Maximum Torque	900 Nm (664 ft/lbs)	>936 Nm (>690 ft/lbs)
Elevation Maximum Travel		184°
Brake Holding Torque		2300 Nm (>1696 ft/lbs)
Mechanical Total Tracking Accuracy		0.10°
Absolute Position Feedback Accuracy		±0.02°

Electrical, Mechanical, and Environmental Specifications

Input Voltage, Frequency	208 -240 VAC, 20 A, 50/60 Hz, Single Phase
Input Amperage	Typical 5 A; Maximum 15 A; Uses Standard 20 A Breaker
Operating Temperature	-40° C to +55° C
Operating Maximum Wind Speed	88 km/h (55 mph)
Maximum Wind Speed With Stow Pins Installed	200 km/h (125 mph)
Non-Operating Maximum Rain Load	25 cm (10 inches) Per Hour
Maximum Ice Load	13 mm (0.5 inches)
Weight	565 kg (1245 lbs)
Safety, Emissions, and Machinery Directive Ratings	CE Compliant; Tested in Independent Labs

CE Machinery Directive Compliance

2.4AEBP antenna positioners are compliant with CE International Machinery Directive IEC 60204-1. The electrical cabinet is equipped with the following safety devices:

- Emergency stop switch
- Visual warning indicator
- Audible warning annunciator
- Padlocks to lock the left and right sides of the electrical cabinet

Visual Warning Indicator (Left)
And Emergency Stop Switch (Right)

Padlock
(Typical Left and Right Sides)

ANNEX B - ACMA EMBARGO 23

EMBARGO 23

FREQUENCY RANGE(S):	1980–2010 MHz 2010–2110 MHz 2170–2200 MHz 2200–2300 MHz
SUBJECT:	Embargo on new assignments to support television outside broadcast and future replanning activities
DATE OF EFFECT:	April 1996 (last revised September 2013)
COVERAGE:	See instructions below
TIME FRAME:	Ongoing

INSTRUCTIONS

1. No new assignments are to be made Australia-wide in the 1980–2010 MHz and 2170–2200 MHz frequency bands except for those for television outside broadcasting services.
2. No assignments of fixed or mobile services are to be made in the 2010–2110 MHz and 2200–2300 MHz frequency bands inside the areas detailed in Attachment 1. Application for television outside broadcast services will be considered on a case-by-case basis by the Manager Spectrum Engineering Section.
3. Assignments for Earth stations (Earth receive and Fixed earth licence options) in the frequency range 2010-2110 MHz and 2200-2300 MHz will be considered on a case-by-case basis by the Manager Spectrum Engineering Section.
4. No frequency assignments are to be made Australia-wide in the frequency ranges 1980-2010 MHz and 2170-2200 MHz for Ancillary Terrestrial Component (ATC) and Complementary Ground Component (CGC) services where they support or form part of a mobile-satellite service.

REASONS

Instruction 1 & 2: This serves to facilitate the introduction of television outside broadcast services in accordance with the *Television Outside Broadcast Services (1980-2110 MHz and 2170-2300 MHz) Frequency Band Plan 2012*. It also serves to preserve planning options for 1980-2010 MHz and 2170-2200 MHz while the future use of the band is under review.

Instruction 3: This provision supports potential planning activity associated with current public consultation on the siting of Earth stations particularly in relation to those within propagation distance of areas of high density radiocommunications.

Instructions 4: This serves to limit the further use of the 1980–2010 and 2170–2200 MHz bands by Ancillary Terrestrial Component (ATC) and Complementary Ground Component (CGC) services while the ACMA considers its position on international developments for use of these bands. Note while this restriction is covered by instruction 1, it is maintained to provide clarity.

HISTORY

Embargo 23 was originally issued in January 1993. The embargo has been revised several times between April 1994 and June 2002 and has changed significantly from its original form. More recent changes of relevance include the following:

In August 2005 the embargo was extended to include fixed and mobile assignments in the 2025–2110 and 2200–2300 MHz bands.

In October 2005 the embargo was removed from remote density areas in the 2025–2110 and 2200–2300 MHz bands.

In September 2007 the embargo was revised to remove the reference to exemptions for the Melbourne 2006 Commonwealth Games, and to include some editorial and formatting changes.

In November 2010, the embargo was extended to include Ancillary Terrestrial Component (ATC) and Complementary Ground Component (CGC) services in the 1980–2010 and 2170–2200 MHz ranges. These services provide terrestrially based supplementation of services provided by stations in the mobile-satellite service. While there was international consideration of the approval for these services, this embargo provided the ACMA the ability to consider its position.

In April 2012, the embargo was revised in included the 2010-2025 MHz frequency band. That band was previously included in embargo 38 which has now been revoked. The embargo was also extend to facilitate the introduction of television outside broadcast services in the 1980-2110 MHz and 2170-2300 MHz frequency bands.

In May 2012, the embargo was revised to remove the area around Darwin for the 2200-2300 MHz frequency band that had been included by error.

In September 2013, instruction 1 of the embargo was revised to remove the restriction on television outside broadcast services in the bands 1980-2010 MHz and 2170-2200 MHz. The embargo on all other services is to preserve planning options while the future use of the band is under review as part of considerations future spectrum requirements for mobile broadband.

In September 2013, instruction 2 was revised to allow application for television outside broadcast services to be considered on case-by-case basis by the Manager Spectrum Engineering Section pending finalisation of coordination arrangements for television outside broadcast services in the bands 2010-2110 MHz and 2200-2300 MHz

EMBARGO AUTHORISATION

[signed] 16/09/2013

Mark Arkell
Manager
Spectrum Engineering Section
Spectrum Planning and Engineering Branch
Australian Communications and Media Authority

Attachment 1:

1. No assignments are to be made for fixed or mobile services in the 2010-2110 MHz frequency band in the geographic area described by a circle with a radius of 210 kilometres whose centre is located at a point specified in Table 1.
2. No assignments are to be made for fixed or mobile services in the 2200-2300 MHz frequency band in the geographic area described by a circle with a radius of 210 kilometres whose centre is located at a point specified in Table 2.
3. No assignments are to be made for fixed or mobile services in the 2010-2110 MHz and 2200-2300 MHz frequency bands inside or within 60 kilometres of the geographic area whose boundary is described by the coordinates specified in Table 3.

The datum used for all geographic coordinates in this attachment is the *Geocentric Datum of Australia 1994*.

Table 1

° South	° East
31.95075	115.87204
31.953254	115.855373
32.012419	116.061762
32.008252	116.083985
31.878253	115.859817
32.057978	115.751210
12.463580	130.835066
12.464135	130.844233
12.448302	130.836455

Table 2

° South	° East
31.95075	115.87204
31.953254	115.855373
32.012419	116.061762
32.008252	116.083985
31.878253	115.859817
32.057978	115.751210

Table 3

° South	° East
31.998556	136.001359
31.998546	137.001345
31.998537	138.001335
31.998521	139.001320
31.998513	140.001305
31.998499	141.001291
32.998503	141.001301
32.998492	142.001289
32.998484	143.001274
33.998489	143.001286
33.998479	144.001273
33.998470	145.001258
33.998459	146.001242
33.998450	147.001227
32.998449	147.001211
32.998441	148.001196
31.998441	148.001188
30.998441	148.001176
30.998435	149.001159
29.998435	149.001149
28.998437	149.001143
28.998431	150.001125
27.998425	150.001112
26.998429	150.001100
25.998434	150.001089
24.998427	150.001086
24.998434	149.001105
23.998440	149.001093
23.998448	148.001103
22.998453	148.001095
21.998461	148.001086
20.998461	148.001080
20.998461	147.001099
20.998467	146.001113
19.998468	146.001105
18.998468	146.001098

° South	° East
18.998472	145.001108
17.998480	145.001094
16.998479	145.001085
15.998479	145.001090
15.998478	146.001078
15.998474	147.001067
16.998469	147.001072
17.998465	147.001078
18.998465	147.001089
18.998456	148.001071
18.998451	149.001058
19.998451	149.001064
19.998441	150.001050
20.998438	150.001056
20.998432	151.001042
21.998429	151.001049
22.998434	151.001058
22.998420	152.001041
23.998428	152.001046
23.998411	153.001033
23.998405	154.001018
24.998402	154.001025
25.998401	154.001033
26.998397	154.001041
27.998398	154.001049
28.998397	154.001059
29.998395	154.001068
30.998395	154.001078
31.998395	154.001088
31.998405	153.001103
32.998404	153.001116
32.998415	152.001132
33.998414	152.001145
34.998416	152.001158
34.998426	151.001172
35.998427	151.001188

° South	° East
36.998431	151.001203
37.998434	151.001218
37.998444	150.001236
37.998457	149.001255
38.998459	149.001268
39.998464	149.001286
40.998469	149.001304
41.998475	149.001323
42.998481	149.001343
43.998488	149.001364
43.998499	148.001382
43.998511	147.001401
43.998522	146.001418
43.998534	145.001436
42.998527	145.001413
41.998522	145.001384
41.998531	144.001408
40.998524	144.001387
40.998536	143.001403
39.998529	143.001383
38.998522	143.001358
38.998534	142.001379
38.998546	141.001393
38.998557	140.001407
37.998545	140.001384
37.998562	139.001401
36.998554	139.001381
36.998567	138.001396
36.998578	137.001408
36.998590	136.001420
35.998576	136.001402
34.998562	136.001392
33.998560	136.001384
32.998557	136.001369
31.998556	136.001359

ANNEX C - ACMA EMBARGO 49

EMBARGO NO. 49

FREQUENCY RANGE(S):

2015–2100 MHz
2100-2130 MHz
2190–2280 MHz
2280-2310 MHz
3400–4200 MHz
5850–7075 MHz
7135–7245 MHz
7250–7750 MHz
7900–8390 MHz
8390-8460 MHz
8460-8510 MHz
8540–8660 MHz
10700–14800 MHz
15349-15410 MHz
15430-15630 MHz
17200-21400 MHz
22200-22510 MHz
24750-25250 MHz
25500-31000 MHz
33400-36000 MHz
37500-43500 MHz
47200-51400 MHz
52590-59300 MHz

SUBJECT: Embargo on new frequency assignments for terrestrial radiocommunication services

DATE OF EFFECT: 2 April 2009 (last revised July 2015)

COVERAGE: Within the following distances from Depot Hill Road site, Yarragadee, 18.5 kilometres NW of Mingenew, Western Australia (29 degrees, 2 minutes, 47 seconds South Latitude and 115 degrees, 20 minutes, 35 seconds East Longitude):

- 300 kilometres for 2100-2130 MHz, 2280-2310 MHz;
- 190 kilometres for 7135-7200 MHz and 8390-8460 MHz; otherwise
- 150 kilometres for bands below 12 GHz;
- 100 kilometres for bands above 12 GHz.

TIME FRAME: Until further notice

INSTRUCTIONS

No new frequency assignments for terrestrial services are to be made within the specified distances of the Mingenew site, Western Australia in the frequency bands listed above. This includes assignments for existing licensees seeking to expand or modify their communications systems in the bands.

Terrestrial services are all services other than the space research service and Earth stations communicating with space objects (GSO and non-GSO communications satellites).

The embargo does not apply to stations operated by Australian Defence Force or the Department of Defence in the band 8500-8510 MHz.

Exceptions to this embargo require case-by-case consideration and the approval of the Manager, Spectrum Engineering Section.

REASONS

The purpose of this embargo is to support the development of space communications facilities in the general area of the Mingenew site. Space communications stations typically have particular interference protection requirements and can result in unacceptably large areas of spectrum denial to terrestrial services. In addition, consequences of communications failure due to interference can have unacceptable consequences for some space activities particularly space exploration in the space research service. The potential impact of space communications services on spectrum availability for other services is such that ACMA encourages restriction of their operation to locations beyond propagation range of areas of significant spectrum use by other services.

COMMENTS

Lead times for planning space communications, including deep space for space research, are typically many years. In order for such planning to have certainty of spectrum access it is necessary for spectrum to be withheld from other services for considerable periods of time. This requirement can be difficult to satisfy in areas of spectrum demand by terrestrial services. Considering this, ACMA encourages the siting of such stations at locations beyond propagation range of areas of spectrum demand in order to minimise the impact on spectrum availability for other services. The Mingenew site is one such location which ACMA intends to protect for space related communications activities.

The 300 kilometres criterion for 2100-2130 MHz and 2280-2310 MHz and the 190 kilometres criterion for 7135-7200 MHz and 8390-8460 MHz recognise the particular requirements for deep-space communications involving space exploration missions and the interference protection levels specified in the Radio Regulations of the International Telecommunication Union.

Note that embargo 23 also applies limitation on the bands 2190-2300 MHz and 2015-2110 MHz to facilitate the introduction of television outside broadcast services. Arrangements for the coordination and operation of TOB services with respect to Mingenew are contained in RALI FX 21 and that RALI should be referred to when considering assignments for TOB services in bands covered by this embargo.

HISTORY

This embargo was put in place in April 2009 to support the development of space communications facilities in low spectrum impact areas.

This embargo was updated in July 2015 to include minor additions (2015-2025 MHz, 2190-2200 MHz, 7200-7245 MHz and 8500-8510 MHz) to existing frequency ranges to further encourage the support the development of space communications facilities in the general area of the Mingenew site.

EMBARGO AUTHORISATION:

Approved 24/07/2015

Mark Arkell
Manager, Spectrum Engineering
Spectrum Planning and Engineering Branch
Australian Communications & Media Authority

ANNEX D - ACMA EMBARGO 69

EMBARGO 69

FREQUENCY RANGE(S):	24.25 – 27.5 GHz
SUBJECT:	Restriction on all new frequency assignments to preserve future planning options for terrestrial fixed, mobile and radiodetermination services.
DATE OF EFFECT:	2 March 2016
COVERAGE:	High Density Population Areas (HDPAs)
TIME FRAME:	Until further notice

INSTRUCTIONS
Any applications for apparatus licences in HDPAs, as described at Attachment 1, in the frequency range 24.25-27.5 GHz are to be referred to the Manager, Spectrum Engineering Section for consideration.

REASONS
The purpose of the embargo is to preserve future planning options in the band for possible terrestrial fixed, mobile and radiodetermination (body scanners) services and minimise the impact that a future possible change in highest value use of the band might cause.

COMMENTS
WRC-19 Agenda item 1.13 is to consider identification of frequency bands for the future development of International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis. The 24.25-27.5 GHz band is one of the bands being considered under this Agenda item. This is the lowest frequency band being considered under WRC-19 agenda item 1.13 and there has been extensive mobile broadband technology developments in adjacent bands, therefore it is likely to be highly valued for mobile broadband services.

Currently there are relatively few assignments in the 24.25-27.5 GHz band Australia-wide. However, there is increasing interest in access to the band, this includes by Ka-Band satellite services, space research services and body scanners.

Given the band may undergo a change in use in the future, any services deployed in highly populated areas may be affected. Of particular concern are those services with long term requirements and/or significant infrastructure associated with them. Due to the relatively low level use of the band at present, the ACMA therefore considers it prudent to restrict the issue of new apparatus licences in HDPAs to preserve future planning options and deter any potential new licensees that would be adversely affected by a future change in use of the band.

EMBARGO AUTHORISATION:

[signed] 2/03/2016

Mark Arkell
Manager
Spectrum Engineering
Australian Communications and Media Authority

ATTACHEMENT 1:

HDPAs are described by the following HCIS identifiers:

ADELAIDE

HCIS Identifiers
IW3J, IW3K, IW3L, IW3N, IW3O, IW3P, IW6B, IW6C, IW6D, IW6F, IW6G, IW6H, IW3E5, IW3E6, IW3E8, IW3E9, IW3F4, IW3F5, IW3F6, IW3F7, IW3F8, IW3F9, IW3G4, IW3G5, IW3G6, IW3G7, IW3G8, IW3G9, IW3H4, IW3H5, IW3H6, IW3H7, IW3H8, IW3H9, IW3I2, IW3I3, IW3I5, IW3I6, IW3I8, IW3I9, IW3M2, IW3M3, IW3M5, IW3M6, IW3M8, IW3M9, IW6A2, IW6A3, IW6A5, IW6A6, IW6A8, IW6A9, IW6E2, IW6E3, IW6E5, IW6E6, IW6E8, IW6E9, JW1E4, JW1E7, JW1I1, JW1I4, JW1I7, JW1M1, JW1M4

BRISBANE

HCIS Identifiers
NT9, NT5G, NT5H, NT5K, NT5L, NT5O, NT5P, NT6E, NT6F, NT6G, NT6H, NT6I, NT6J, NT6K, NT6L, NT6M, NT6N, NT6O, NT6P, NT8C, NT8D, NT8G, NT8H, NT8K, NT8L, NT8O, NT8P, NU3A, NU3B, NU3C, NU3D, NU3F, NU3G, NU3H, NT5C4, NT5C5, NT5C6, NT5C7, NT5C8, NT5C9, NT5D4, NT5D5, NT5D6, NT5D7, NT5D8, NT5D9, NT6A4, NT6A5, NT6A6, NT6A7, NT6A8, NT6A9, NT6B4, NT6B5, NT6B6, NT6B7, NT6B8, NT6B9, NT6C4, NT6C5, NT6C6, NT6C7, NT6C8, NT6C9, NT6D4, NT6D5, NT6D6, NT6D7, NT6D8, NT6D9, NU2C1, NU2C2, NU2C3, NU2D1, NU2D2, NU2D3, NU2D5, NU2D6, NU2D8, NU2D9, NU2H2, NU2H3, NU3E1, NU3E2, NU3E3, NU3E5, NU3E6, NU3E8, NU3E9, NU3I2, NU3I3, NU3J1, NU3J2, NU3J3, NU3K1, NU3K2, NU3K3, NU3L1, NU3L2, NU3L3

CANBERRA-QUEANBEYAN

HCIS Identifiers
MW4D, MW4H, MW4L, MW5A, MW5B, MW5E, MW5F, MW5I, MW5J, MW1P4, MW1P5, MW1P6, MW1P7, MW1P8, MW1P9, MW2M4, MW2M5, MW2M6, MW2M7, MW2M8, MW2M9, MW2N4, MW2N5, MW2N6, MW2N7, MW2N8, MW2N9, MW4P1, MW4P2, MW4P3, MW5M1, MW5M2, MW5M3, MW5N1, MW5N2, MW5N3

DARWIN

HCIS Identifiers
GO7C, GO7D, GO7G, GO7H, GO7K, GO7L, GO8A, GO8E, GO8I

HOBART

HCIS Identifiers
LY8L, LY8P, LY9I, LY9J, LY9K, LY9L, LY9M, LY9N, LY9O, LY9P, LZ2D, LZ2H, LZ3A, LZ3B, LZ3C, LZ3D, LZ3E, LZ3F, LZ3G, LZ3H, LY8H4, LY8H5, LY8H6, LY8H7, LY8H8, LY8H9, LY9E4, LY9E5, LY9E6, LY9E7, LY9E8, LY9E9, LY9F4, LY9F5, LY9F6, LY9F7, LY9F8, LY9F9, LY9G4, LY9G5, LY9G6, LY9G7, LY9G8, LY9G9, LY9H4, LY9H5, LY9H6, LY9H7, LY9H8, LY9H9, LZ2L1, LZ2L2, LZ2L3, LZ3I1, LZ3I2, LZ3I3, LZ3J1, LZ3J2, LZ3J3, LZ3K1, LZ3K2, LZ3K3, LZ3L1, LZ3L2, LZ3L3

MELBOURNE

HCIS Identifiers
KX3J, KX3K, KX3L, KX3N, KX3O, KX3P, KX6A, KX6B, KX6C, KX6D, KX6E, KX6F, KX6G, KX6H, KX6I, KX6J, KX6K, KX6L, LX1I, LX1M, LX1N, LX1O, LX4A, LX4B, LX4C, LX4E, LX4I, KX3E9, KX3F5, KX3F6, KX3F7, KX3F8, KX3F9, KX3G1, KX3G2, KX3G4, KX3G5, KX3G6, KX3G7, KX3G8, KX3G9, KX3H4, KX3H5, KX3H6, KX3H7, KX3H8, KX3H9, KX3I3, KX3I6, KX3I8, KX3I9, KX3M2, KX3M3, KX3M4, KX3M5, KX3M6, KX3M7, KX3M8, KX3M9, LX1E4, LX1E7, LX1E8, LX1E9, LX1J1, LX1J4, LX1J5, LX1J6, LX1J7, LX1J8, LX1J9, LX1K4, LX1K7, LX4F1, LX4F2, LX4F4, LX4F5, LX4F7, LX4F8, LX4J1, LX4J2, LX4J4, LX4J5, LX4J7, LX4J8

PERTH

HCIS Identifiers
BV1I, BV1J, BV1K, BV1L, BV1M, BV1N, BV1O, BV1P, BV2I, BV2J, BV2M, BV2N, BV4A, BV4B, BV4C, BV4D, BV4E, BV4F, BV4G, BV4H, BV4I, BV4J, BV4K, BV4L, BV5A, BV5B, BV5E, BV5F, BV5I, BV5J, BV1E7, BV1E8, BV1E9, BV1F7, BV1F8, BV1F9, BV1G7, BV1G8, BV1G9, BV1H7, BV1H8, BV1H9, BV2E7, BV2E8, BV2E9, BV2F7, BV2F8, BV2F9, BV4M1, BV4M2, BV4M3, BV4N1, BV4N2, BV4N3, BV4O1, BV4O2, BV4O3, BV4P1, BV4P2, BV4P3, BV5M1, BV5M2, BV5M3, BV5N1, BV5N2, BV5N3

SYDNEY

HCIS Identifiers
NW1, MV9I, MV9J, MV9K, MV9L, MV9M, MV9N, MV9O, MV9P, MW3C, MW3D, MW3G, MW3H, MW3K, MW3L, MW3O, MW3P, NV4N, NV4O, NV4P, NV5M, NV5N, NV5O, NV5P, NV7B, NV7C, NV7D, NV7E, NV7F, NV7G, NV7H, NV7I, NV7J, NV7K, NV7L, NV7M, NV7N, NV7O, NV7P, MV9D6, MV9D9, MV9E4, MV9E5, MV9E6, MV9E7, MV9E8, MV9E9, MV9F4, MV9F5, MV9F6, MV9F7, MV9F8, MV9F9, MV9G4, MV9G5, MV9G6, MV9G7, MV9G8, MV9G9, MV9H3, MV9H4, MV9H5, MV9H6, MV9H7, MV9H8, MV9H9, MW3B2, MW3B3, MW3B5, MW3B6, MW3B8, MW3B9, MW3F2, MW3F3, MW3F5, MW3F6, MW3F8, MW3F9, MW3J2, MW3J3, NV4I5, NV4I6, NV4I8, NV4I9, NV4J4, NV4J5, NV4J6, NV4J7, NV4J8, NV4J9, NV4K4, NV4K5, NV4K6, NV4K7, NV4K8, NV4K9, NV4L4, NV4L5, NV4L6, NV4L7, NV4L8, NV4L9, NV4M2, NV4M3, NV4M5, NV4M6, NV4M8, NV4M9, NV5I4, NV5I5, NV5I6, NV5I7, NV5I8, NV5I9, NV5J4, NV5J5, NV5J6, NV5J7, NV5J8, NV5J9, NV5K4, NV5K5, NV5K6, NV5K7, NV5K8, NV5K9, NV5L4, NV5L5, NV5L6, NV5L7, NV5L8, NV5L9, NV7A2, NV7A3, NV7A4, NV7A5, NV7A6, NV7A7, NV7A8, NV7A9

The HCIS is described in the Australian Spectrum Map Grid 2012. The Australian Spectrum Map Grid 2012 is available on the ACMA website at: *www.acma.gov.au*.