Australian Capital Territory

Heritage (Decision about Registration of the Orroral Geodetic Observatory, Tennent) Notice 2016

Notifiable Instrument NI2016—271

made under the

Heritage Act 2004, s40 (Decision about registration)

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1 Name of instrument

This instrument is the *Heritage (Decision about Registration of the Orroral Geodetic Observatory, Tennent) Notice 2016.*

2 Decision about registration

On 2 June 2016, the ACT Heritage Council (the **Heritage Council**) decided to register the Orroral Geodetic Observatory, part Block 88, Tennent (the **Place**).

3 Registration details of the Place

The registration details of the Place are in the schedule.

4 Reasons for the decision

The Heritage Council decided to register the Place because it has heritage significance as it meets one or more of the heritage significance criteria in section 10 of the *Heritage Act 2004*, as set out in the schedule.

5 Date registration takes effect

The registration of the Place takes effect on the day after this notice is notified.

6 Revocation

The *Heritage (Decision about Provisional Registration of the Orroral Geodetic Observatory, Tennent) Notice 2016* NI2016—72 is revoked.

Fiona Moore
A/g Secretary (as delegate for)
ACT Heritage Council
2 June 2016

Schedule
(See Section 3 and 4)

ACT Heritage Council

AUSTRALIAN CAPITAL TERRITORY

HERITAGE REGISTER

For the purposes of s. 40 of the *Heritage Act 2004*, an entry to the heritage register has been prepared by the ACT Heritage Council for the following place:

Orroral Geodetic Observatory

Block 88 (part), Tennent

DATE OF DECISION

2 June 2016 Notifiable Instrument: 2016–

Copies of the Register Entry are available for inspection at ACT Heritage. For further information please contact:

The Secretary
ACT Heritage Council
GPO Box 158
CANBERRA ACT 2601
Telephone 13 22 81

This statement refers to the location of the Orroral Geodetic Observatory as required in s. 12 (b) of the *Heritage Act 2004*.

LOCATION OF THE PLACE

Orroral Geodetic Observatory, Block 88 (part), Tennent. The place is at the top of a ridge to the west of the Orroral Valley Tracking Station in the valley floor. It is situated at the end of a trail, called the 'Granite Tors Walking Track.'

This section refers to the description of the Orroral Geodetic Observatory as required in s.12(c) of the *Heritage Act 2004*. The attributes described in this section form part of the heritage significance of the place. For the purposes of s. 12(c) of the *Heritage Act 2004*, the boundary of the place is at Image 1.

DESCRIPTION OF THE PLACE

The Orroral Geodetic Observatory, consisting of the following attributes:

- The Observatory, consisting of:
  - 9 metre diameter hemispherical dome surmounting a grey-brick cylindrical building.
- Footprint indicating location of survey pillar NM/C/106, consisting of:
  - Trapezoid fenced area atop granite boulder, 22.6 metres south east of the observatory dome.

This statement refers to the heritage significance of the Orroral Geodetic Observatory as required in s.12(d) of the *Heritage Act 2004*.

STATEMENT OF HERITAGE SIGNIFICANCE

The Orroral Geodetic Observatory was one of two geodetic observatories in the southern hemisphere between 1974 and 1999, and the only such facility in the ACT until its functions were transferred to the Mt Stromlo Observatory in 1999. It was Australia's fundamental geodetic facility, boasting caesium atomic clocks providing Australia with its official time, and a range of sensitive instrumentation catering to Satellite Laser Ranging and Global Positioning Systems, enabling measurement of the Earth's geoid with millimetre accuracy *[criteria (a), (b)].*

The facility is represented by a distinctive structure that is easily recognisable as a terrestrial observatory. It gathered data that confirmed plate tectonic theory, and informed national and international research on natural phenomena and disasters. Further, the survey pillar associated with the place remains an integral part of the ACT geodetic survey mark network that continues to record Australia's latitude and longitude with an accuracy permitting the integration of Australia's National Coordinate System (the Geocentric Datum of Australia 1994) to the Global Geodetic Reference Frame *[criterion (c), (d)].*

CONSERVATION OBJECTIVE

The guiding conservation objective is that the Orroral Geodetic Observatory shall be conserved and appropriately managed in a manner respecting its heritage significance.

The ACT Heritage Council may adopt heritage guidelines applicable to the place under s25 of the *Heritage Act 2004*.

For further information on guidelines applicable to the place, or for advice on proposed works or development, please contact ACT Heritage on 13 22 81.

REASON FOR REGISTRATION

The Orroral Geodetic Observatory, Tennent, has been assessed against the heritage significance criteria and been found to have heritage significance when assessed against criteria (a) (b) (c) and (d) under s.10 of the *Heritage Act 2004*.

ASSESSMENT AGAINST THE HERITAGE SIGNIFICANCE CRITERIA

The Council's assessment against the criteria specified in s.10 of the *Heritage Act 2004* is as follows.

In assessing the nomination for the Orroral Geodetic Observatory, Tennent, the Council considered:

- the original nomination and documentary evidence supplied by the nominator;
- information provided by a site inspection on 2 October 2015 by ACT Heritage;
- the ACT Heritage Council's *Heritage Assessment Policy*, February 2015; and
- the report by ACT Heritage titled, *Background Information Orroral Geodetic Observatory,* June 2016, containing photographs and information on history, description, condition and integrity.

Pursuant to s.10 of the *Heritage Act 2004,* a place or object has heritage significance if it satisfies one or more of the following criteria. Future research may alter the findings of this assessment.

(a) importance to the course or pattern of the ACT's cultural or natural history;

Orroral Geodetic Observatory, Tennent, meets this criterion.

The Orroral Geodetic Observatory is important to the course of the ACT's cultural history as it represents the ACT's contribution to the advancement of global geodesy. As a host to Satellite Laser Ranging (SLR) facilities, Global Positioning System (GPS) receivers, caesium atomic clocks, a survey pillar, and a DORIS[1] receiver, it was Australia's fundamental geodetic facility during its time of operation, and one of only two geodetic observatories in the southern hemisphere. It provided Australia with its official time and took SLR readings that confirmed long-standing global theories on plate-tectonics. In its function as a geodetic survey pillar, it enabled latitude and longitude to be measured in Australia with unprecedented accuracy, and on the strength of these readings, connected Australia's National Coordinate System to the rest of the world.

(b) has uncommon, rare or endangered aspects of the ACT's cultural or natural history;

Orroral Geodetic Observatory, Tennent, meets this criterion.

The place has rare aspects of the ACT's cultural history as it was the only Geodetic facility in the

[1] Doppler Orbitography and Radiopositioning Integrated by Satellite

ACT while in operation (1974-1999). While the SLR telescope, receiving dishes, and other technical components were removed from the Orroral Geodetic Observatory in 1999, the place still retains a characteristic, semi-circular dome atop a cylindrical base, designed to accommodate a telescopic laser. The remaining fabric is highly evocative of terrestrial observatories with enough remaining integrity to meet thresholds for inclusion under this criterion.

(c) potential to yield important information that will contribute to an understanding of the ACT's cultural or natural history;

Orroral Geodetic Observatory, Tennent, meets this criterion.

The Orroral Geodetic Observatory formed part of an SLR network that measured the Earth's geoid to the millimetre level, enabling unprecedented accuracy in the study of plate tectonics, sea-level rise, earth rotation, and glacial retreat. Although closed in 1999, the satellite data collected by the facility is still used by surveyors and geodesists in organisations such as the International Laser Ranging Service, Geoscience Australia (Commonwealth) and the Office of the Surveyor-General (ACT Government). These organisations compare that data with new geodetic information to measure temporal changes on the Earth's surface, specifically, in the geographic region of the ACT. From these comparisons such organisations are able to build projection models on climate change and earthquakes, which then aid in developing management strategies for plate movement and global warming for the local region and internationally as data is added to global co-ordinate systems and the International Terrestrial Reference Frame. In essence, the data collected by the facility formed part of a global baseline dataset to which current changes to the surface of the Earth can be compared.

In addition, the ACT Office of the Surveyor-General takes satellite readings of survey pillar NM/C/106 multiple times per decade. Because the pillar was positioned with the millimetre-accuracy of SLR technology, its precise location on the Earth's surface has been recorded. Therefore it remains a crucial monument in maintaining the accuracy of the ACT section of the Geodetic Datum of Australia 1994 (GDA94). As such, ACT surveyors draw satellite readings though it in order to update Australia's National Co-ordinate System, and will continue to do so as these systems are updated in the future.

(d) importance in demonstrating the principal characteristics of a class of cultural or natural places or objects;

Orroral Geodetic Observatory, Tennent, meets this criterion.

The place, with its cylinder building and dome top, has the evocative and recognisable form of a terrestrial observatory. Further, the trapezoid enclosure on the granite platform clearly demarcates the footprint of survey monument NM/C/106. While the SLR technology has been removed from the place, these remnant physical characteristics demonstrate the scale of facility and the former relationships between its technical components, with enough heritage fabric to enable meaningful interpretation.

(e) importance in exhibiting particular aesthetic characteristics valued by the ACT community or a cultural group in the ACT;

Orroral Geodetic Observatory, Tennent, does not meet this criterion.

The place is situated in a picturesque visual setting, however, it does not possess landmark qualities, artistic excellence, or visual prominence demonstrated to be valued by the wider ACT community or a cultural group. While the place is valued by professional and special interest groups, these are not connected through the same way of living, which has been transmitted from one generation to another, and do not share a cultural or ethnic background, and therefore do not fall within the definition of a cultural group as defined by the Council in its *Heritage Assessment Policy, February 2015*.

(f) importance in demonstrating a high degree of creative or technical achievement for a particular period;

Orroral Geodetic Observatory, Tennent, does not meet this criterion.

While the place was an important geodetic observatory for the southern hemisphere, capable of extensive data reception and transmission while operational, its technical significance is no longer evident in the physical fabric of the place. Further, although the survey monument at the place is important and continuously used, there is no evidence suggesting the marker itself represents a significant technical achievement.

(g) has a strong or special association with the ACT community, or a cultural group in the ACT for social, cultural or spiritual reasons;

Orroral Geodetic Observatory, Tennent, does not meet this criterion.

The place is important to interest and professional groups, and previous employees of the organisation managing the facility. However the association does not extend to the ACT community or a cultural group, is not easily recognisable to the broader ACT community, and is not an association beyond the ordinary. These groups are not connected through the same way of living, which has been transmitted from one generation to another, and they do not share a cultural or ethnic background, and therefore do not constitute a cultural group defined by the Council in its *Heritage Assessment Policy, February 2015.*

(h) has a special association with the life or work of a person, or people, important to the history of the ACT.

Orroral Geodetic Observatory, Tennent, does not meet this criterion.

Orroral Geodetic Observatory has an association with NASA, the United States Government body which has been prominent international space exploration since the mid twentieth century. NASA made an important contribution to the history of the ACT in signing the Hornig agreement with the Australian Government, facilitating the sharing of scientific information. However, this association is not readily identifiable in the physical fabric of the place to a degree high enough to warrant inclusion under this criterion.

SITE PLAN

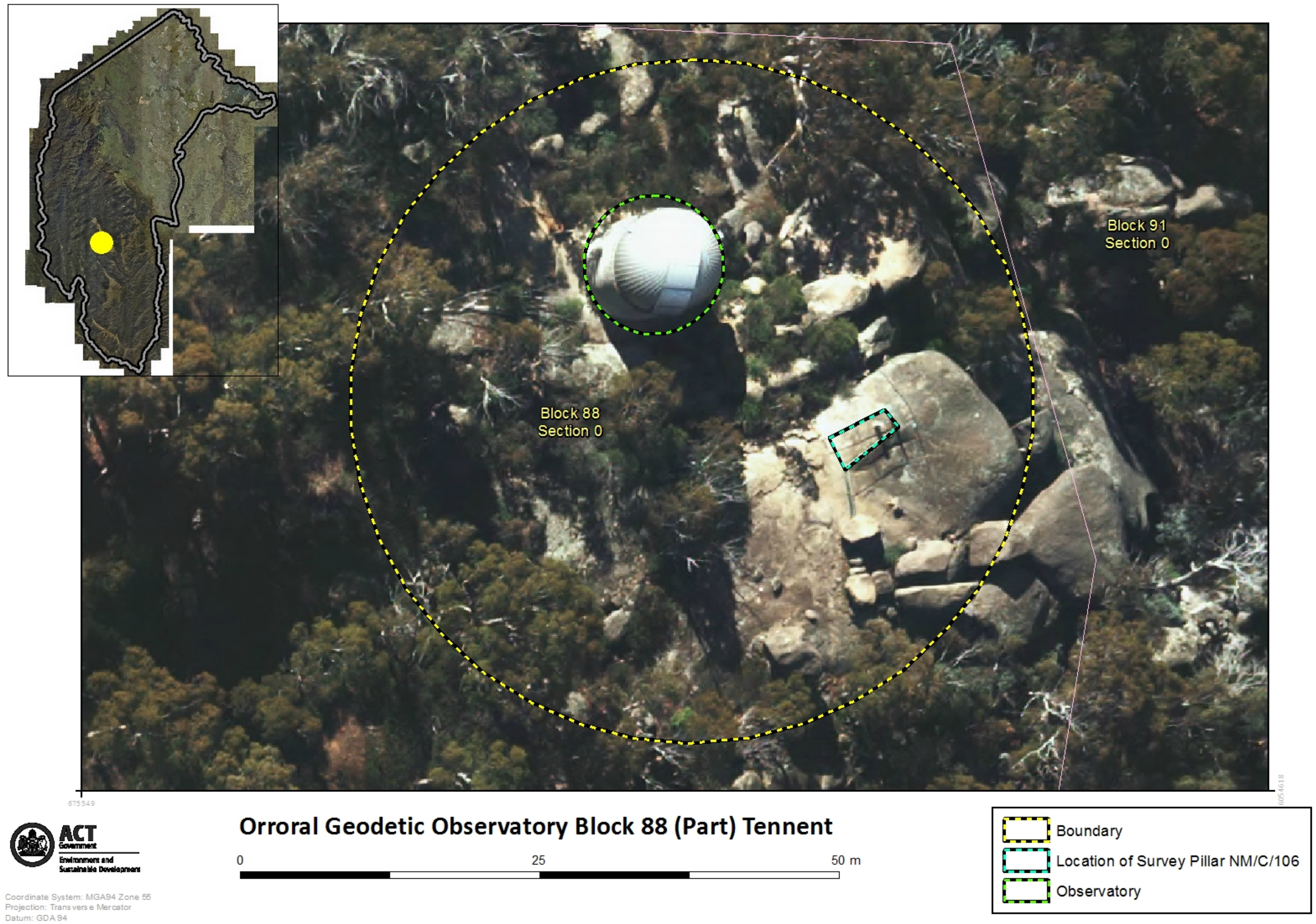

Image 1 Site Boundary, Orroral Geodetic Observatory.

ACT Heritage Council

BACKGROUND INFORMATION

Orroral Geodetic Observatory

Block 88 (part), Tennent

At its meeting of 2 June 2016 the ACT Heritage Council decided that the Orroral Geodetic Observatory was eligible for registration.

The information contained in this report was considered by the ACT Heritage Council in assessing the Orroral Geodetic Observatory against the heritage significance criteria outlined in s10 of the *Heritage Act 2004*.[1]

HISTORY

(See Glossary below for additional definitions)

In considering the history of the Orroral Geodetic Observatory, the ACT Heritage Council acknowledges that the Ngunnawal people are traditionally affiliated with the lands in the Canberra region within and beyond contemporary ACT borders. 'Orroral' could come from the Aboriginal word 'Urongal,' meaning, 'tomorrow,' indicated as such in sir Thomas L. Mitchell's 1834 map of the area. In this citation, 'Aboriginal community' refers to the Ngunnawal people and other Aboriginal groups within the ACT for whom places within the Canberra region are significant. These places attest to a rich history of Aboriginal occupation extending from 25, 000 years ago, as indicated by the Birrigai Rock Shleter, into the 19th century colonial period. They show that Aboriginal people continued living traditionally in the region through to the 1870s-80s. During the 19th century, traditional Aboriginal society in colonised areas suffered dramatic de-population and alienation from traditional land-based resources. In the Canberra region some important institutions such as intertribal gatherings were retained in some degree at least until the 1860s.

The Orroral Geodetic Observatory was built in 1974 as part of an agreement between the United States (US) and Australia called the Hornig treaty, a co-operation in science and technology. The Division of National Mapping (NATMAP) and the National Aeronautics and Space Administration (NASA) were the signatories (Geoscience Australia 2015a). In the late 1980s NATMAP became the Australian Surveying and Land Information Group (AUSLIG), which subsequently became Geoscience Australia.

Hornig saw the beginning of Australia's Lunar and Satellite Laser Ranging (SLR) Program. Using a laser, SLR measures the distance to Earth orbiting satellites which revolve around the Earth's centre of mass. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. It is a device for producing a narrow beam of light of a single frequency or colour and constant relative phase (Clark 2012: 92).

SLR is important in the study of geodesy. Geodesy is the science of accurately measuring and understanding three fundamental properties of the Earth: its geometric shape, its orientation in space, and its gravity field — as well as the changes of these properties with time. Geodesists must accurately define the coordinates of points on the surface of the Earth in a consistent manner which is aided by SLR (NOAA 2015).

SLR works when measurements are made by transmitting pulsed laser beams from Earth ground stations to the

[1] Minor corrections were made to this document in 2018 in the interests of maintaining accurate and up to date information. These corrections do not affect the decision made on 2 June 2016 (NI2016-271).

satellites. The laser beams then return to Earth after hitting the reflecting surfaces; the travel times are precisely measured, permitting ground stations in different parts of the Earth to measure their separations to better than one inch in thousands of miles (NASA 2015).

Data from a global network of SLR stations is used to estimate the orbital parameters of satellites which revolve around the Earth's centre of mass, providing permanent reference points so that the Earth's progress can be tracked relative to the satellite, as opposed to traditional satellite tracking where the satellite's progress is tracked relative to the Earth (Earth Observation Portal 2015). Therefore the position of the Earth's geocentre (the origin of the Global Geodetic Reference Frame, see **Endnote 1** on page 7) can be monitored through time. SLR has become an important geodetic instrument used for the establishment of an accurate global geodetic infrastructure and Earth monitoring science (Geoscience Australia 2015a).

SLR contributes to:

- The definition of the International Terrestrial Reference Frame (ITRF see **Endnote 2** on page 7) by being the only space geodetic technique which defines the Earth's centre of mass.
- Monitoring Earth rotation and polar motion to provide the relationship with the International Celestial Reference Frame (ICRF, see **Endnote 2**).
- Modelling the temporal and spacial variation of the Earth's gravity field.
- Determination of the ocean and Earth tides.
- Monitoring tectonic plates and horizontal and vertical crustal deformation.
- Orbit determination for spaceborne altimeters and radar measurements for studies in global ocean circulation and changes in ice masses (Geoscience Australia 2015a).

As a contributor to the SLR network, the Orroral Geodetic Facility was part of a system of measurement which for the first time was able to measure the motion of the tectonic plates, providing an explicit and independent verification of the theory of plate tectonics, a theory which today still underpins all geological science (J. Dawson personal communication 14 August 2015).

The Orroral Geodetic Observatory took its first observations of the LAGEOS satellite in 1984 (Geoscience Australia 2015a). LAGEOS (Laser Geodynamic Satellite) was the first satellite dedicated wholly to SLR, able to determine position points on Earth due to highly stable orbits (Earth Observation Portal 2015). It was a US satellite constructed using a brass core covered with an aluminium shell, holding 426 corner-cube reflectors resembling shiny golf-balls, from which SLR stations took readings (Clarke 2012: 92).

There are numerous SLR satellites orbiting Earth, and the LAGEOS mission is still operational, providing orbital benchmarks for geodynamical studies of the Earth. The high mass-to-area ratio and the precise, stable (attitude-independent) geometry of the LAGEOS spacecrafts, together with the extremely regular orbits, make these satellites the most precise position references available (NOAA 2015).

The LAGEOS mission consists of the following key goals:

- Provide an accurate measurement of the satellite's position with respect to Earth.
- Determine the planet's shape (geoid).
- Determine tectonic plate movements associated with continental drift (NOAA 2015).

Broadly, SLR has an origin in Lunar Laser Ranging (LLR), where laser pulses were fired to the moon and were bounced back by retroreflectors placed on the lunar surface by astronauts of the Apollo program. Measurement of the pulses enabled calculations on continental drift. It took about 2.5 seconds for the laser pulses to cross the 385,000km between Earth and the Moon, and back again. LLR proved problematic since the Moon travels away from the Earth by around 8cm per year, therefore, the focus of laser ranging moved to SLR, as satellites could provide orbiting benchmarks (J. Manning personal communication 31 July 2015; 2015; NOAA 2015).

In addition to SLR, eventually the Orroral Geodetic Observatory also hosted:

1. Global Positioning System (GPS) receivers.
2. A geodetic survey pillar.

3. Four caesium atomic clocks.
4. A Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) receiver (Barrow 1999).

1. GPS is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the US Department of Defence. GPS was originally intended for military applications, but in the 1980s, the US government made the system available for civilian use. GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. The GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Then, with distance measurements from several more satellites, the receiver can determine the user's position (Garmin 2015).

   A GPS receiver must be locked on to the signal of at least three satellites to calculate a two-dimensional position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's three-dimensional position, that is, latitude, longitude and altitude (Garmin 2015).

   While GPS determines a receiver's location on Earth, this must be expressed on a map. Over time, maps of the surface of Australia and Earth have become more accurate with development of Australia's national, and the global coordinate system, otherwise known as the geodetic reference. This system is a set of reference stations, constructed at various locations on Earth's surface to serve as reference points against which latitude, longitude, and altitude can be determined. The Orroral Geodetic Facility functioned as a reference station, and as its exact location on Earth could be found by satellites, it helped to refine the national coordinate system and enabled latitude and longitude in Australia to be connected to the rest of the world with unprecedented accuracy (Geoscience Australia 2015a; J. Dawson personal communication 14 August 2015).

2. Survey pillar NM/C/106 acted as a reference station at the observatory. It is located adjacent to the decommissioned Orroral Geodetic Observatory. This survey pillar was extensively used during the operational life of the geodetic observatory. The Office of the Surveyor-General, (ACT Government), still uses NM/C/106 in survey projects, as it remains an integral part of the ACT geodetic survey mark network.

   For example, since 2012 the Office of the Surveyor-General in the ACT has been working on the ACT contribution to the National Datum Modernisation project. This project aims to update the Geocentric Datum of Australia 1994 (GDA94 – see Glossary). The modernised datum will shift horizontal coordinates by 1.8m, but align Australia's datum more closely with the ITRF – see Glossary. (PCG 2015).

   Between 2012 and 2015 the pillar was frequented on around 10 occasions. Between October 2015 and July 2016, it is estimated that the pillar will be visited three times. After this time, readings will be taken from the pillar once annually (G. Evans personal communication 25 November 2015).

   Readings are taken when Global Navigation Satellite System equipment is attached to the pillar and left for a period of time (usually overnight), taking readings from satellites that record the pillar's position on Earth, which is then included into the ACT geodetic survey mark network. The SLR technology in use at the Orroral Geodetic Observatory assisted with determining the position of the pillar on the Earth's surface with notable accuracy.

3. The four caesium atomic clocks at the facility were so precise in their measurements that they could determine the travel time of a laser pulse to the Moon to within a nanosecond (a thousand millionth part of the second). One clock was designated as the national primary standard of time, and was maintained with the objective of keeping Australian time accurate to 100 nanoseconds. Time from the clocks on site was fed into the global time system, contributing to the determination of Universal Time, and issuing of leap-seconds (Barrow 1999; J. Manning personal communication 31 July 2015).

   Time is critical for SLR, for multiple reasons. First, as a station must link in and synchronise with other stations measuring satellites, and the time of flight of each laser "packet" sent and received by a station must be recorded. As such, accurate caesium clocks are essential components of SLR stations. Second, SLR stations must also keep accurate time in order to measure the speed of rotation of Earth, which is slowing (J. Manning personal communication 31 July 2015 and 22 August 2015).

4. DORIS, a French satellite system, specialises in precise positioning and measuring of the flow of glaciers. 50-60 DORIS stations exist worldwide, with two in Australia (one at Mt Stromlo Observatory, Canberra). The orbit produced from the DORIS system is at the centimetre level, also making it ideal for satellite missions that observe the ocean's topography (Geoscience Australia 2015b).

Following Orroral's closure, the atomic "time clock" was given to the CSIRO's National Measurement Laboratory, coordinator of the National Timescale Service. One atomic clock was sent to Mt Stromlo and the third to a laser ranging station near Geraldton (WA). The fourth clock is defunct (Barrow 1999).

The Orroral Geodetic Observatory's functions were transferred to Mt Stromlo in the late 1990s, its internal components, such as the laser and telescope, had been removed by December 1999, although the dome-shaped shell was left standing.

At its time of operation Orroral Geodetic Observatory was the only geodetic station in Australia capable of the diverse functions outlined above. This made it Australia's fundamental geodetic facility, hosting a range of instrumentation developed by different countries. Having the SLR, survey marker, DORIS, GPS and atomic clocks collocated at the facility enabled measurements from disparate systems and satellites to be linked for mutual benefit and science outcomes. Data collected from the facility is still in use by the international science community. As new data is observed by upgraded observatories, the information collected by the Orroral Geodetic Facility is used by agencies such as Geoscience Australia and the Officer of the Surveyor General (ACT Government) to contribute to the ongoing refinement of the global coordinate system which underpins present day understanding of tectonic plate motion, sea-level change, crustal deformation and Earth rotation (J. Dawson personal communication 14 August 2015).

The facility gathered data contributing to national and international research that may inform future strategies managing natural phenomena and disasters. Accurate study in these fields requires measurement of temporal changes on Earth in very small magnitudes (at the millimetre level). As such, the necessary observations must be spread over decades. The Orroral Geodetic Observatory received this data, and the information collected from decades of recording is continuously used in geodetic studies that inform strategies to manage climate change and earthquakes (Barrow 1999; J. Dawson personal communication 14 August 2015). In summary, data from the facility contributed to a global baseline dataset from which current changes to the surface of the Earth (caused by factors such as climate change) can be related (J. Dawson personal communication 5 January 2016).

DESCRIPTION

The Observatory

The Orroral Geodetic Observatory is a 9 metre hemispherical dome installed atop a cylindrical observatory building (see Images 2 and 3) on a ridge of granodiorite on the western slopes of the Orroral Valley (Luck 1990; Simpson 1974). Observatory domes are typically lightweight, permitting spherical movement and protection of instrumentation from snow and temperature change. When functioning as an SLR facility, it was equipped with internal instrumentation and external appendages. For example, the 10m laser and telescope protruded slightly from the dome during observation, and mounts for the DORS satellite and a dish and an awning were among multiple features outside the dome. As of 2015, several discrete pads and cut off poles indicate the former locations of mounts for antennae, transmitters, and dishes (see Images 4, 5, and 6).

Before the Orroral Geodetic Observatory was constructed, a geological investigation determined that it would be founded on a boulder of grandiorite which was underlain by approximately 2 metres of weathered material, meaning the foundation for the structure would be capable of moving independently of surrounding rocks. This meant that tiltmetres needed to be installed at the site to monitor any movements which would compromise accuracy of SLR readings (Simpson 1974). The locations of these are still evident on the perimeter of the cylindrical brick building (see Image 7).

There is no currently accessible information on the rationale behind the material choice of the structure. It is not known why brick was chosen to construct the cylinder, when other similar buildings in the ACT – such as those at the Mt Stromlo Observatory – were built of concrete or reinforced steel. It is possible that bricks were more cost-efficient and more easily transportable up the steep and remote Orroral ridgeline than other materials available at the time.

Pillar NM/C/106

Survey pillar NM/C/106 is located atop a granite boulder, 22.6 metres south east of the observatory dome (see Image 8). It consists of a brass centre mark set in the top of a (1.3m high, 0.36m diameter) reinforced concrete pillar. Its location is clearly marked by a substantial metal fence, drilled into the boulder, which encloses the pillar in a trapezoid shape.

There are three other survey observation pillars included within the boundary of the site which are no longer in use (see Image 9).

A 7 km walking track leads up to the facility. Referred to as the 'Granite Tors Walking Track' in Namadgi National Park, it begins near the former tracking station, and ends at the dome. The track and facility are frequently maintained by Territory and Municipal Services Directorate, as in 2015 on the date of inspection, the trail and observatory had been cleared of vegetation.

Physical condition and integrity

The observatory building is in very good condition. The location of previous entrances is evident where they have been 'bricked in.' Only several bricks are missing from the cylinder (see Images 10 and 11), and a small drainage issue has resulted in the wearing of concrete down to aggregate at the base of the building (see Image 12). Some small cracks are evident in the survey pillar, but it is otherwise stable and functioning.

The discrete pads for antennae, collimation tower, and receivers as discussed above (and seen in images 4, 5, and 6) are not visually defined or prominent. They are not strong interpretive features in comparison to, for example, the antennae and buildings pads at Orroral Valley Tracking Station and Honeysuckle Creek Tracking Station. They appear to have markedly deteriorated over time and in places are barely distinguishable from underlying granite.

GLOSSARY

AUSLIG: Australian Surveying and Land Information Group. AUSLIG was amalgamated with the Australian Geological Survey Organisation (AGSO) to become Geoscience Australia in 2001.

Earth Rotation and Reference Systems Service: IERS is an organisation providing and co-ordinating data, general information, and publications on the ICRF and ITRF (see below).

Caesium Atomic Clock: Caesium atomic clocks provide the most accurate time available.

DORIS: Doppler Orbitography and Radiopositioning Integrated by Satellite, a French satellite system, specialises in precise positioning and measuring of the flow of glaciers. 50-60 DORIS stations exist worldwide, with two in Australia (one at Mt Stromlo Observatory, Canberra). The orbit produced from the DORIS system is at the centimetre level, also making it ideal for satellite missions that observe the ocean's topography (Geoscience Australia 2015b)

Geocentre: The centre-of-mass (CM) of the total Earth system, that is the solid Earth and its fluid envelope, is usually referred to as the geocenter (Wu and Ry, et al 2012; Petit and Luzum, 2012).

Geodesy: The science of accurately measuring and understanding three fundamental properties of the Earth: its geometric shape, its orientation in space, and its gravity field — as well as the changes of these properties with time. Geodesists must accurately define the coordinates of points on the surface of the Earth in a consistent manner which is aided by SLR (NOAA 2015).

Geodetic Reference: a reference system for positioning a point on the Earth. Any type of map is based on a positional reference system: each point on the Earth's surface corresponds to a point referenced on the map. In other words, it allows an exhaustive description of the earth's surface (OECD 2005).

Geoid: The geoid is a model of global mean sea level that is used to measure precise surface elevations (NOAA 2015).

Global Geodetic Reference Frame: The Global Geodetic Reference Frame (GGRF) is a generic term describing the framework which allows users to precisely determine and express locations on the Earth, as well as to quantify changes of the Earth in space and time (UN-GGIM 2015).

GPS: The Global Positioning System is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the US Department of Defence. GPS was originally intended for military applications, but in the 1980s, the US government made the system available for civilian use. GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. The GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Then, with distance measurements from several more satellites, the receiver can determine the user's position (Garmin 2015).

International Celestial Reference Frame: A 'framework' of stellar objects that provides a context in which to measure the Earth's rotation in space.

International Terrestrial Reference Frame: The Earth is constantly changing shape. To be understood in context, when the motion of the Earth's crust is observed, it must be referenced. A terrestrial reference frame provides a set of coordinates of some points located on the Earth's surface. It can be used to measure plate tectonics, regional subsidence or loading, and/or used to represent the Earth when measuring its rotation in space (ITRF 2014).

Lunar Laser Ranging: LLR required laser pulses being fired to the moon. These were bounced back by retroreflectors placed on the lunar surface by astronauts of the Apollo program. Measurement of the pulses enabled calculations on continental drift. It took about 2.5 seconds for the laser pulses to cross the 385,000km between Earth and the Moon, and back again (NOAA 2015).

National Coordinate System: Officially known as the Geocentric Datum of Australia 1994 (GDA94), this is the official geodetic datum adopted nationally in Australia. GDA94 replaced the Australian Geodetic Datum 1966 (AGD66) and Australian Geodetic Datum 1984 (AGD84). GDA94 is a coordinate reference system that best fits the shape of the earth as a whole. It has an origin that coincides with the centre of mass of the Earth (the geocentre, see above), hence the term 'geocentric.' GDA94 is a static coordinate datum based on the International Terrestrial Reference Frame (ICSM 2015).

NATMAP: The Division of National Mapping (Australia). Preceded AUSLIG (see above).

Satellite Laser Ranging: Satellite Laser Ranging (SLR), ranges (or measures distance) to Earth orbiting satellites using a powerful laser to detect a satellite's variation from its predicted orbit. It is uniquely suited to accurately determining the variation of the Earth's centre of mass, along with the orbit parameters of satellites orbiting the Earth (Geoscience Australia 2015).

ENDNOTES

1. The Global Geodetic Reference Frame (GGRF) is a generic term describing the framework which allows users to precisely determine and express locations on the Earth, as well as to quantify changes of the Earth in space and time. Most areas of science and society at large depend on being able to determine positions at a high level of precision. At present the GGRF is realized through the International Terrestrial Reference Frame (ITRF, see footnote 2), International Celestial Reference Frame (ICRF, see footnote 2) and physical height systems (UN-GGIM 2015).

2. The Earth is constantly changing shape. To be understood in context, when the motion of the Earth's crust is observed, it must be referenced. A terrestrial reference frame provides a set of coordinates of some points located on the Earth's surface. It can be used to measure plate tectonics, regional subsidence or loading, and/or used to represent the Earth when measuring its rotation in space. This rotation is measured with respect to a frame tied to stellar objects, called a celestial reference frame. The International Earth Rotation and Reference Systems Service (IERS) was created in 1988 to establish and maintain a Celestial Reference Frame, the ICRF and a Terrestrial Reference Frame, the ITRF (ITRF 2014).

SITE PLAN

Image 1 Site Plan Orroral Geodetic Observatory


Image 2 Orroral Geodetic Observatory showing dome on top of brick cylinder (ACT Heritage 2015)


Image 3 Orroral Geodetic Observatory showing dome on top of brick cylinder (ACT Heritage 2015)


Image 4 Cut-off poles drilled into rock. Used to mount equipment (ACT Heritage 2015)


Image 5 Faint remnant pad used to mount equipment (ACT Heritage 2015)


Image 6 Fain remnant pad used to mount equipment (ACT Heritage 2015)


Image 7 Tiltmetre used to detect movement at the observatory (ACT Heritage 2015).

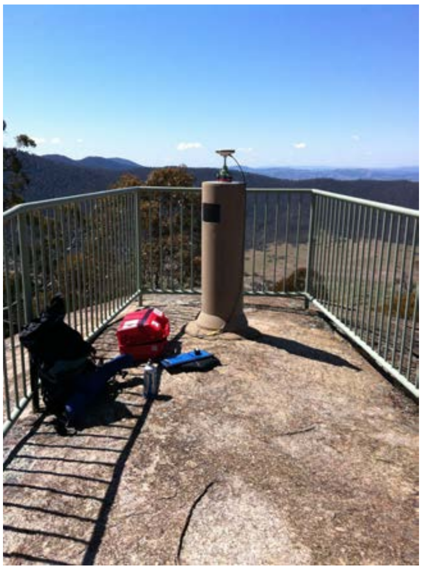

Image 8 Survey pillar NM/C/106 (ACT Heritage 2015)

Image 9 One of three survey observation pillars around the observatory (ACT Heritage 2015)

Image 10 Missing brick at observatory (ACT Heritage 2015)

Image 11 Another missing brick at observatory (ACT Heritage 2015)

Image 12 Exposed aggregate at base of observatory (ACT Heritage 2015)

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