Aqualand B Development Holding Pty Ltd
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Commercial-in-Confidence

Sky View Impact Assessment for Barangaroo Concept Plan (06_0162) Modification 9

Prepared by AECOM on behalf of Infrastructure NSW

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Prepared on behalf of: Infrastructure NSW

Prepared by

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			Name/Position	Signature
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1	19-Jan-2021	For Issue	Frank Ciancio Associate Director	
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4	17-Sep-2021	Final Report	Frank Ciancio Associate Director	
5	17-Nov-2021	Final Report	Frank Ciancio Associate Director	

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Executive Summary

This report was prepared to address the additional development height of the proposed Modification 9 (MOD 9) Central Barangaroo development to satisfy the concerns raised by Sydney Observatory, the Sydney Observatory specific requirement in the Modification 6 (MOD 6) Director General's Requirements (DGR's), as well as to support the MOD 9 DGR's.

Previously, the Sydney Observatory requested clear view corridors within the night sky to continue their viewing of specific celestial objects of interest. The Central Barangaroo development envelope sits within the required clear corridors, however the viewing angle from Sydney Observatory to the building envelope is lower than the practical angle of viewing, and therefore there are no new impacts that will adversely affect the practical sky view from the Sydney Observatory.

Lighting of the Central Barangaroo development was also considered as part of the impact to sky view from the Sydney Observatory. Due to the relatively low building envelope heights in Central Barangaroo and the highly illuminated environment it will sit within, there is expected to be very limited additional light spill. Light spill mitigation measures are also expected to be incorporated in line with current standards. This will further reduce any negative impact on night sky viewing.

1.0 Introduction

This report has been prepared to address: a section of the MOD 8 DGR's specific to Sydney Observatory; concerns raised by Sydney Observatory about the impacts of the Barangaroo Development on sky view; and to support the MOD 9 DGR's. The focus of this report will be the MOD 9 Proposed Concept Plan. A previous study was carried out by Lendlease for Barangaroo South, Modification 8 (*Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment*, 2014)[1].

Technical astronomical information within this report is summarised from the Sky View Impact Assessment by George Georgevitis (UNSW Unisearch), refer Appendix 1. The astronomical technical information provided in the above-mentioned report has been simplified here to explain the effects of the proposed Central Barangaroo MOD 9 building envelope on the ability of Sydney Observatory to see the night sky.

This report is a supplement to the modification to Concept Plan (MP06_0162) submitted to the Minister for Planning and Infrastructure pursuant to Section 75W of Part 3A of the Environmental Planning and Assessment Act 1979 (EP&A Act).

NB: all RL heights are measured against the Australian Height Datum.

2.0 Site Location

Barangaroo

Barangaroo is located to the west of the Sydney central business district. The site sits along the edge of the Sydney Harbour, north of the King Street Wharf Precinct. The Harbour sits to the west and north of the site. Central Barangaroo lies adjacent to Millers Point.

Previously a disused container terminal, Barangaroo is in the process of being transformed into a waterfront precinct which will include - in addition to the completed International Towers Sydney and Barangaroo Reserve - further commercial and residential buildings; active frontages including restaurants, cafes and retail; a hotel and casino, all set within public open space.

Barangaroo consists of three separate sections; Barangaroo Reserve is the northern section, Barangaroo South is the south section, and Central Barangaroo is the area between. This concept plan amendment known as MOD 9 relates to Central Barangaroo. Refer Figure 1 for the Barangaroo site context.

Sydney Observatory

The Sydney Observatory is a museum and education centre set on top of Observatory Hill overlooking Sydney Harbour. It is a historic landmark for Sydney, recognised as an item of 'state significance' by the New South Wales Government. Built in 1858, the Observatory has a history of timekeeping, meteorology, navigation and astronomy.

The Observatory is now part of the Museum of Applied Arts and Sciences. It acts as a museum and astronomy education centre, providing public telescope viewing. The Observatory is no longer used for professional astronomical viewing.

Located at 1003 Upper Fort Street, Millers Point, the Observatory sits on top of Observatory Hill. The Bradfield Highway runs along its eastern edge, Fort Street Public School is to the south, and Millers Point Heritage Conservation area to the north and west. It sits to the east of the proposed Central Barangaroo development site.

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[1] https://majorprojects.accelo.com/public/a81207969c5246a2d138b4b22086bb82/Y_SkyViewImpact.pdf

The Sydney Observatory is on high ground, which affords views out to Sydney Harbour to the north and west. The Sydney Observatory north dome sits at approximately 54m RL AHD (Australian Height Datum), with the Barangaroo ground level RL at 3.5m. Subsequent sections detail the heights of the proposed building envelopes in the MOD 9 development and their effect on the view from the Sydney Observatory.

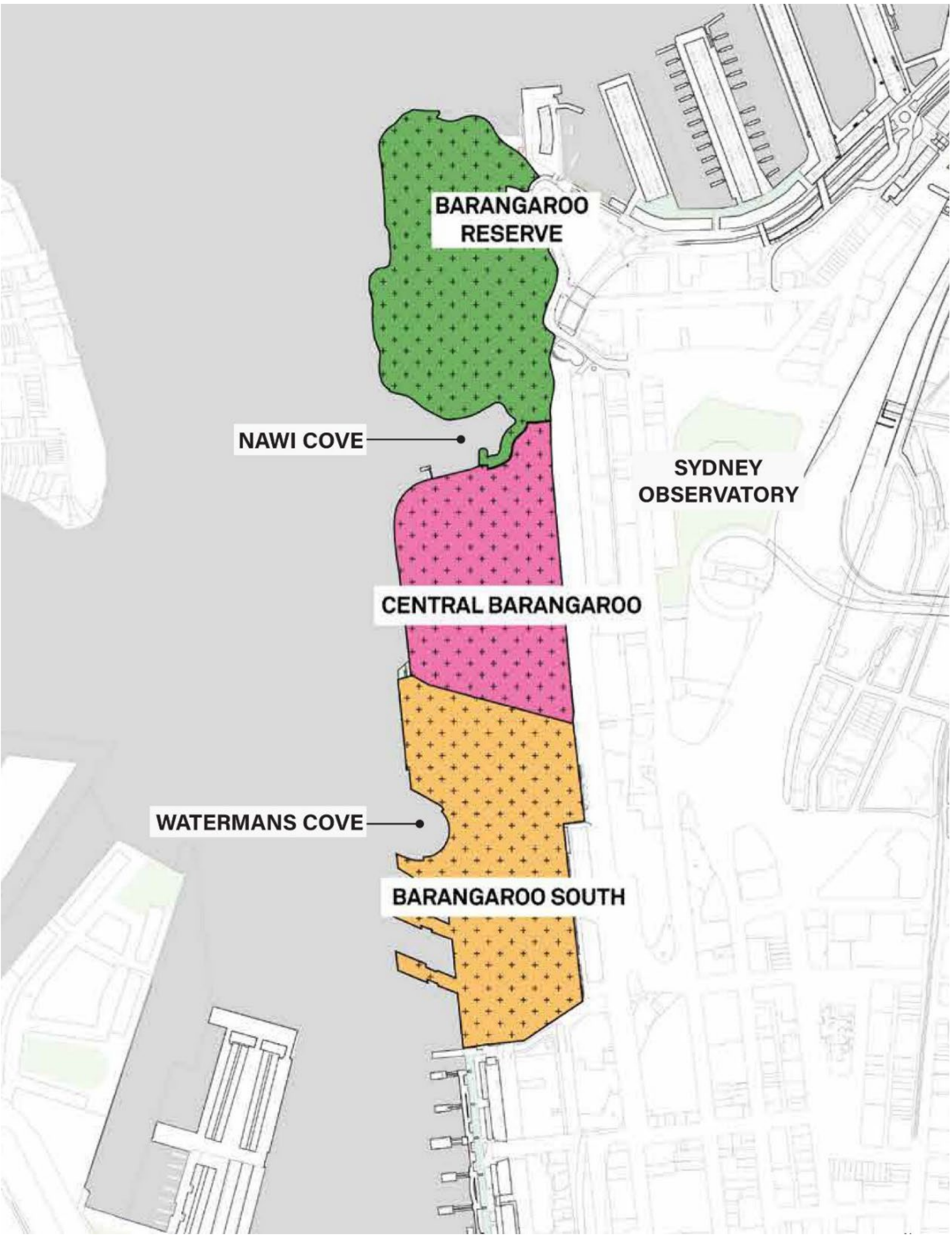

Figure 1. Barangaroo site context. Sydney Observatory sits to the east of the northern edge of Central Barangaroo.
Source: amended by AECOM from figure prepared by Hassell, November 2020.

3.0 Background

3.1 Overview of Proposed Modification

The proposed MOD 9 to the Concept Plan (MP06_0162) includes:

- increase in GFA;
- redistribution of GFA and land uses across development blocks;
- modification to block and building envelopes; and
- redistribution of public domain areas.

Pertinent to this report is the form, height and location of the building envelopes. The highest building envelope in MOD 9 is in the north western corner (73.7m). Refer Figure 2 and Figure 3.

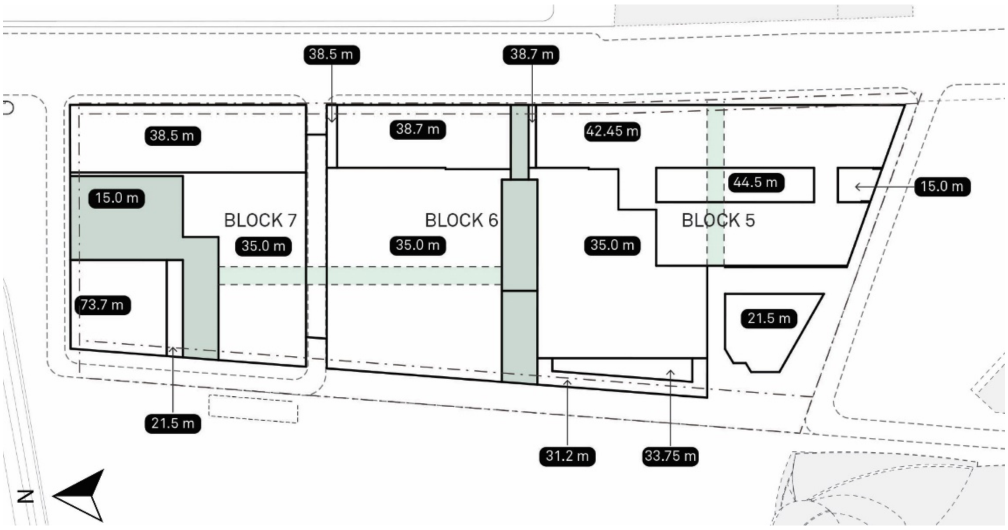

Figure 2 - Central Barangaroo building envelope plan view. Source: Hassell 2021.

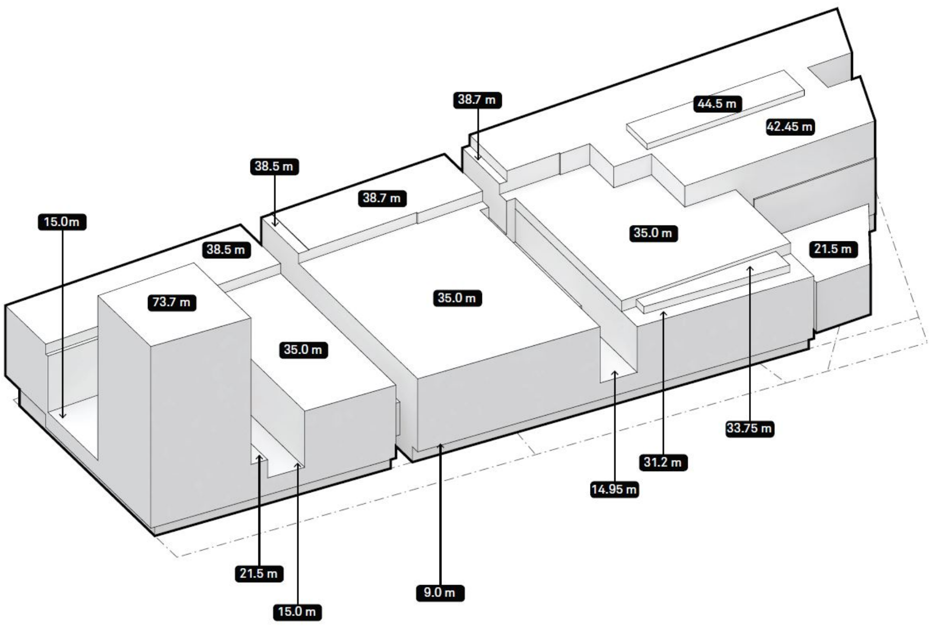

Figure 3. Central Barangaroo building envelope axonometric view. Source: Hassell 2020.

3.2 Considerations in the Sky View Impact Assessment

3.2.1 Director General's Requirements

Within the 'Key Issues' of the Director General's Requirements (DGR's) for the Mod 8 Concept Plan (MP06-0162)[2], there was a requirement to address the potential impact of the development on the Sydney Observatory.

The subsequent DGR's for the MOD 9 development do not include this requirement, however due to the proposed changes to the building envelope, INSW have requested that a review is undertaken to assess MOD 9 with the relevant Mod 8 DGR's below.

19. Prescribed Airspace for Sydney Airport and Sydney Observatory Impacts

- *Undertake and analysis of potential sky view loss and resultant impacts on the functioning of the Sydney Observatory*

This report also supports requirements under the MOD 9 DGR's[3], specifically plans & documents item 7, visual catchment:

- *Potential visual catchments and view locations, including contours (areas from which the development is visible) should be identified. This must include, but is not limited to … Sydney Observatory,….*

3.2.2 Sydney Observatory Concerns and Comments Background

The Sydney Observatory made a submission to the former Barangaroo Development Authority on the 20th of June 2011 regarding Modification 4 for the Central Barangaroo development proposal[4].

The Sydney Observatory subsequently provided notes on 'clear view corridors' to Lendlease titled *Clear View Required to Western Sky from Sydney Observatory, 2013*[5], which details the required viewing envelope for the sun, moon, stars and planets - that they would like to retain.

Lendlease met with Sydney Observatory in December 2013 to discuss their concerns in regard to the MOD 4 development (documented in the *Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment*, 2014[6]).

As no new concerns have been raised by Sydney Observatory since their consultation with Lendlease in 2013, the following issues, as stated in the Lendlease Sky View Impact Assessment, 2014, are still relevant to this report.

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[2] https://majorprojects.accelo.com/public/8ff3a177308a80d7433648da67e7367c/B_Final%20issued%20DGRs.pdf

[3] https://majorprojects.accelo.com/public/3b04f77739e32bfa3ebac04b22547bcc/Final%20Modified%20DGRs%20150414.pdf

[4] Appendix 2 of the Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment, 2014 (https://majorprojects.accelo.com/public/a81207969c5246a2d138b4b22086bb82/Y_SkyViewImpact.pdf)

[5] Appendix 3 of the Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment, 2014 (https://majorprojects.accelo.com/public/a81207969c5246a2d138b4b22086bb82/Y_SkyViewImpact.pdf)

[6] Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment, 2014 (https://majorprojects.accelo.com/public/a81207969c5246a2d138b4b22086bb82/Y_SkyViewImpact.pdf)

A summary of the concerns and comments from Sydney Observatory are:

Clear View Requirements to the Western Sky

Important view corridors were determined in consultation with the Sydney Observatory and Lendlease[7]. They are listed below as an excerpt from *Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment*, Lendlease, 2014: (Note: the 'Azimuth' is the angle measured from North to East in an anticlockwise direction):

Sun, Moon and Planets:

The Sun:

Winter solstice - 298° Azimuth, and;
Summer solstice - 241° Azimuth.
The Moon: +/- 5° further North or South of the Sun (i.e. between 236° and 303° Azimuth).
The Solar System Planets: Less than 5° from the Sun at Sunset (i.e. between 236° and 303° Azimuth).

The Southern Cross and nearby objects (Jewel Box, Alf-Cen, Omega-Cen[NGC5139]):

The Southern Cross (Crux), Jewel Box Cluster (Kappa Crucis Cluster [NGC4755]), and Pointers (Alpha-Centauri and Beta-Centauri, also known as Rigil Kentaurus and Hadar respectively): From 225° up to 210° Azimuth.
Omega-Centauri (NGC5139) globular duster: Up to 298° Azimuth at 18° altitude.

Ring Nebula and Star Albireo:

To the North the Ring Nebula (M57, a dead star) and Albireo (Beta Cygni, a multi-coloured twin star): From 303° Azimuth at 15° altitude.

In summary, the view corridors can be determined as:

Between 210° and 225° Azimuth at 18° altitude, and;
Between 236 ° and 303 ° Azimuth.

Light Spill

Concern about poor quality lighting at night from Sydney Observatory is referenced in their 20 June 2011 letter[8]. A number of lighting strategy considerations were requested by Sydney Observatory, a summary of which has been taken from *Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment*, Lendlease, 2014[9].

Light direction: No light directed up to the sky or horizontally. Light should be directed downward and spill minimised.
Minimising glow and potential uses of the site: Reduce light-reflecting surfaces, and large areas of light emissions producing a glow. Creation of distinct 'night' from 'day approach to not 'flood' the site at night time.
Light timers: To reduce lighting at night.
Specific lighting recommendations: Use lowest level of lighting as allowed by Australian Standards, light fittings with full cut off with zero UWLR, correlated colour temperature of the light sources should be 2700k (warm white) or less, and minimise unnecessary outdoor lighting.

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[7] Appendix 3 of the Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment, 2014 (https://majorprojects.accelo.com/public/a81207969c5246a2d138b4b22086bb82/Y_SkyViewImpact.pdf)

[8] Appendix 3 of the Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment, 2014 (https://majorprojects.accelo.com/public/a81207969c5246a2d138b4b22086bb82/Y_SkyViewImpact.pdf)

[9] (https://majorprojects.accelo.com/public/a81207969c5246a2d138b4b22086bb82/Y_SkyViewImpact.pdf)

4.0 View Analysis

The View Analysis is provided in three sections. The first two sections address the two clear view corridors requested by Sydney Observatory, as detailed in Section 3.2.2, to retain their views to the western sky. The ranges are as follows; Azimuth 210° to 225°, and Azimuth 236° to 303°. The last section will look at lighting within Central Barangaroo and its impact on Sydney Observatory.

4.1 Clear View Requirements Azimuth Corridor 210° to 225°

Figure 4 is a plan showing the extent of the clear view azimuth corridor 210° to 225° and the Barangaroo South building envelope obstructions. This azimuth range crosses Block 5 and a small portion of Block 6 within the Central Barangaroo building envelope. The azimuth range does not cross Block 7, and therefore is not considered as part of this azimuth assessment.

The Sydney Observatory north dome sits at an RL of 54m and therefore only building envelopes above RL 54m and within this azimuth corridor would be considered for assessment. The highest building envelope in Blocks 5 and 6 is 44.5m, and therefore will not impede views from the north dome. No further assessment is required for this azimuth range.

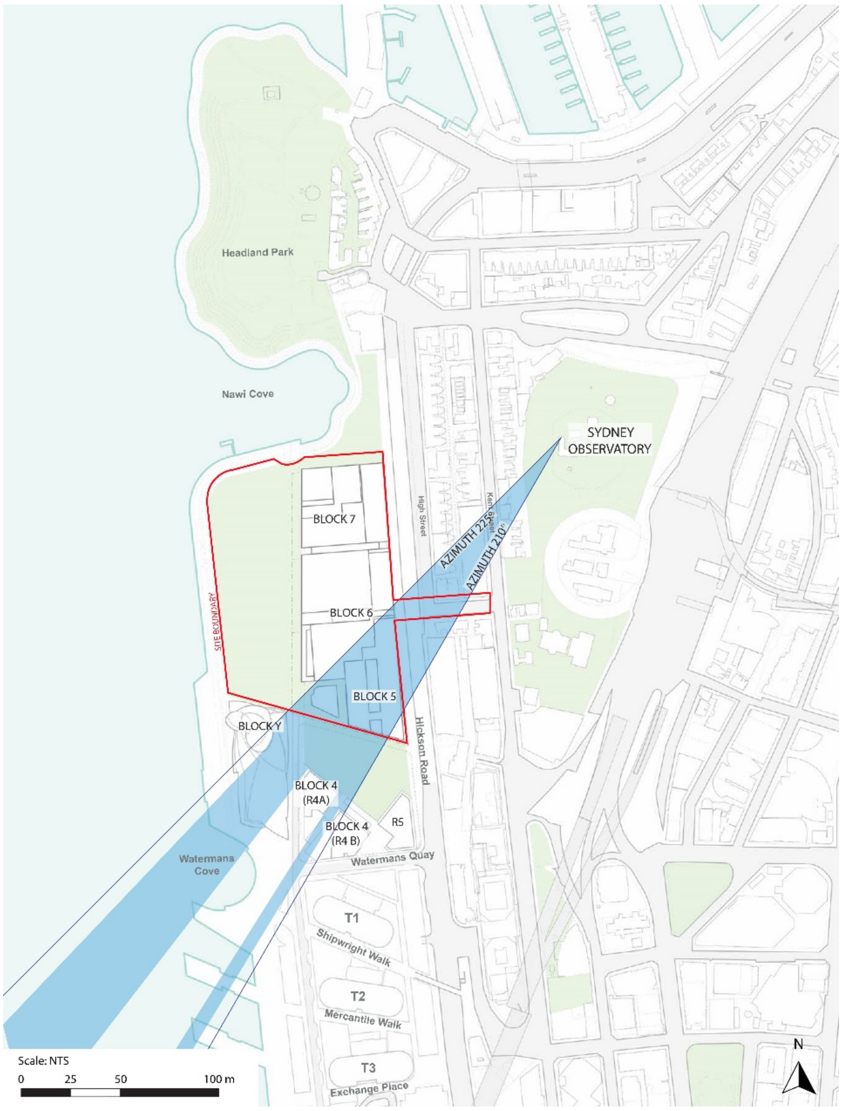

Figure 4. Azimuth clear zone range 210° to 225° in relation to the Barangaroo development. Source: amended by AECOM from figure prepared by Hassell, June 2021.

4.2 Clear View Requirements Azimuth 236° to 303°

Figure 5 is a plan showing the extent of the clear view azimuth range 236° to 303°. This azimuth range crosses Block 7 and a portion of Block 6 within the Central Barangaroo building envelope.

As previously stated in Section 4.1, there are no building envelopes high enough within Block 6 to impede views from the Sydney Observatory northern telescope. The tallest component of Block 7 sits at RL 73.7m and has been assessed.

As stated in the *Central Barangaroo - Sydney Observatory Sky View Impact Assessment*, UNSW Unisearch, 2021 (refer Appendix 1), the "practical lower altitude limit" for effectively viewing the night sky is 10°. Figure 6 shows the viewing angle to the highest building envelope within Block 7 is 8.82° (5.52° plus a 3° margin for the effects of finite telescope field of view and light spillage[10]). Refer to Figure 5 for the location of the section line on a plan.

Therefore, there are no building envelopes within Block 6 or Block 7 that will impact on the practical sky view from the Sydney Observatory.

Figure 5. Azimuth clear zone range 236° to 303° in relation to the Barangaroo development. Source: amended by AECOM from figure prepared by Hassell, June 2021 .

[10] Central Barangaroo Sky View Impact Assessment, UNSW Unisearch, 2021 (refer Appendix 1)

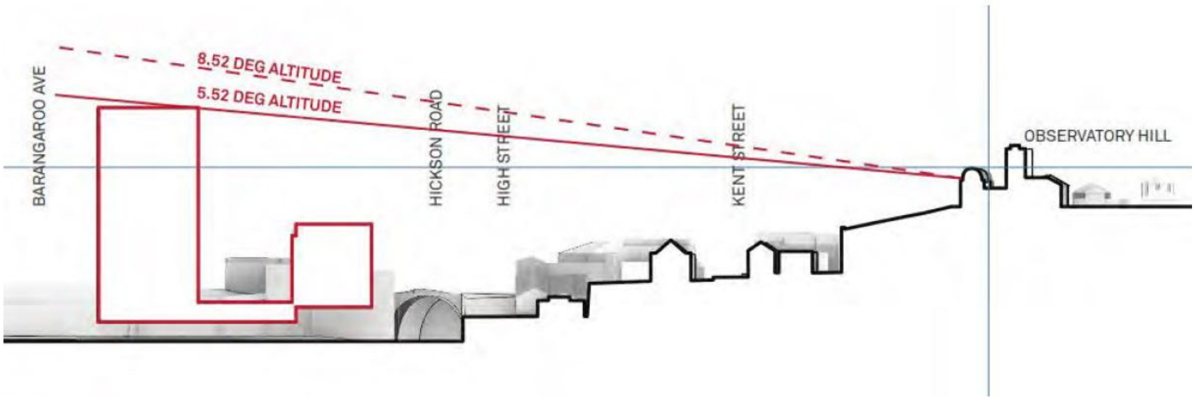

Figure 6. Sectional Elevation A, cut from Sydney Observatory through Block 7 of Mod 9, Central Barangaroo. Source: Hassell, November 2020.

4.3 Lighting Impact

As noted above, the Sydney Observatory no longer functions as a professional astronomical observatory; it is a museum that provides astronomy education and public sky viewing.

The location of the Sydney Observatory - in the middle of a densely populated city – places limitations on astronomical observations. Light glare, cloud cover, smog, pollution and building envelope all serve as factors that diminish the ability of the Observatory to view the night sky.

The viewing angle from the Sydney Observatory to Blocks 5, 6 and 7 in Central Barangaroo MOD 9 are less (8.52° and lower) than the 10° "practical lower altitude limit" for effective viewing of the night sky, as stated in the *Central Barangaroo - Sydney Observatory Sky View Impact Assessment*, UNSW Unisearch, 2021 (refer Appendix 1).

Due to the highly illuminated environment within which the Central Barangaroo MOD 9 building envelope would sit; it is unlikely that the proposal will contribute significantly to the light spill already affecting the Sydney Observatory.

No specifics have been provided for the intent of the lighting strategy for Central Barangaroo MOD 9 buildings. However, the previous Sky View Impact Assessment for Barangaroo South[11] stated that light spill would be minimised in accordance with AS4282 and the requirements of EMI-7 Green Star Light Pollution Credit, which can be expected to also be applied to MOD 9. The following specific measures were also proposed in that report:

Brightly lit surfaces are kept to a minimum;
Luminaires will have glare shields;
3000 degrees K is used for the majority of light sources;
Up lighting has been kept to a minimum (by not exceeding a 5% Upward Light Output Ratio or by not exceeding 0.5 Lux for any initial point of illuminance to the site boundary and no greater than 0.1 Lux to 4.5 metres beyond the site into the night sky);
Light sources are down facing, the proposed blue lights along the shore line play through trees and illuminate grey paving with no light trespass and/or light pollution;
Light levels decrease on approach to the water's edge, and;
Light levels are provided for pedestrian safe movement.

It would be expected that similar light spill mitigation measures would be put in place for Central Barangaroo MOD 9.

[11] Barangaroo South Mod 8 (MP06_0162 MOD 8) Concept Plan, Sydney Observatory Sky View Impact Assessment, 2014 (https://majorprojects.accelo.com/public/a81207969c5246a2d138b4b22086bb82/Y_SkyViewImpact.pdf)

5.0 Conclusion

In completing the Sky View Impact Assessment, the following elements were assessed in response to the Mod 6 DRG requirements and the concerns raised by Sydney Observatory regarding:

- clear view requirements azimuth 210° to 225°;
- clear view requirements azimuth 236° to 303°; and
- lighting impacts.

For the azimuth range 210° to 225°, the Block 5 and Block 6 building envelope heights are lower than the Sydney Observatory north dome and there is therefore no new sky view obstruction for this azimuth range by Central Barangaroo building envelope.

For the azimuth range 236° to 303°, the Block 7 tower element is higher than the Sydney Observatory north dome, however due to the viewing angle from the Observatory to the Block 7 tower being less than the practical viewing angle of 10°, there will be no practical impact on the sky view in this azimuth range.

Due to the relatively low building envelope heights in Central Barangaroo and the highly illuminated environment that it will sit within, there is not expected to be significant negative impact from the Central Barangaroo development on the ability of the Observatory to view the night sky. Light spill mitigation measures are also expected to be incorporated in line with current standards. This will further reduce any possible impact.

In conclusion, this report finds that there will be no practical additional reduction in sky view as a result of the Central Barangaroo MOD 9 development, and very limited to no impact arising from additional light spill.

6.0 Appendices

6.1 Appendix 1 – Central Barangaroo - Sky View Impact Assessment by George Georgevits, 2021

COMMERCIAL-IN-CONFIDENCE
Report prepared on behalf of Unisearch Expert Opinion Services
A business of the University of New South Wales

CENTRAL BARANGAROO - SYDNEY OBSERVATORY SKY VIEW IMPACT ASSESSMENT

Modification to the Concept Plan (06-0162) (MOD 9)

for

Infrastructure NSW

by

George Georgevits (BE Hons, PhD)
Astrophysicist & Consulting Engineer

Date of Issue: 15 September 2021
Our Reference: UN59699

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1. EXECUTIVE SUMMARY AND CONCLUSIONS

1 The purpose of this report is to assess the impact of MOD 9 for Central Barangaroo on the sky view from Sydney Observatory.

2 The proposed development of Central Barangaroo consists of Blocks 5, 6 and 7, with the indicative reference design illustrating each block as containing three buildings.

3 Due to their low height, the buildings in Blocks 5 and 6 do not obstruct the sky view from Sydney Observatory.

4 Of the three buildings in Block 7, only the taller tower building envelope is high enough to obstruct the sky view from Sydney Observatory, but the area of sky obstructed is all less than 10º above the horizon, in the area of sky where it is too low to permit viable observing.

5 Of the sky objects stated as being of interest to Sydney Observatory, only the planets and the Moon can potentially pass through the obstructed area of sky, and for all of these, observing is not viable due to them being too close to the horizon at the times when they are visible during Observatory opening hours.

6 In addition, unlike the stars and deep sky objects (e.g., galaxies) that are essentially fixed in the sky plane, the planets and the Moon move through the sky plane along paths that are always in close proximity to the ecliptic (the plane of the Earth's orbit projected onto the sky plane), and the ecliptic only passes through the obstructed area during a single observing session in the months of September and December of each year.

7 Thus the presence of the proposed taller tower building envelope in Block 7 will have no adverse effect on the sky view from Sydney Observatory.

2. TERMS OF REFERENCE AND BACKGROUND

2.1 QUALIFICATIONS

8 This report was prepared by George Georgevits, managing director of and principal consulting engineer for Power and Digital Instruments Pty Ltd (**PDI**).

9 I hold a PhD in Astrophysics (University of NSW).

10 My PhD work entailed the use of the 1.2 metre UK Schmidt Telescope (see Appendices 3 and 4) and the 0.5 metre Automated Patrol Telescope, both located at Siding Spring Observatory, Coonabarabran NSW.

11 I have conducted presentations of my work at a number of overseas and Australian conferences on astrophysics.

12 An article referencing my work has appeared in Science magazine (see Appendix 3), and it has been cited in a paper appearing in Nature.

13 I have co-authored a chapter in a textbook on the outer Solar System.

14 I have also owned and operated a number of small astronomical telescopes over the years.

15 I am thus very familiar with observational astronomy and also the astronomical objects that are the subject of this matter.

16 In addition, I have an honours degree in electrical engineering (University of NSW) and 40 years experience as a consulting engineer, specialising in the fields of communications, electronics and power.

17 A brief CV for George Georgevits is provided in Appendix 2 and a brief capability statement for PDI is provided in Appendix 5.

2.2 Terms of Engagement

18 I have been engaged by the Central Barangaroo Developer to provide astronomical advice in relation to this matter.

19 The matter concerns an assessment of the loss of sky view from Sydney Observatory as a result of the proposed construction of new buildings associated with the Central Barangaroo development.

20 We would like to acknowledge the Gadigal people who are the Traditional Custodians of this land. We would also like to pay respect to the Elders both past and present of the Eora Nation and extend that respect to all Aboriginal people.

3. INSTRUCTIONS

21 This report has been prepared to support the proposed MOD9 to Barangaroo Concept Plan for Central Barangaroo.

22 The Sydney Observatory Sky View Impact Assessment has been prepared by UNSW to address, in part, the ‘Visual Impact Assessment’ requirements of the MOD 9 DGRs for Central Barangaroo (specifically DGR 6. Visual Impact Assessment & Plans and Documents requirement 7. Visual Impact Assessment – Sydney Observatory). As part of a broader visual impact assessment, the Sydney Observatory Sky View Impact Assessment provides an analysis of the potential sky view loss and resultant impacts associated with the building envelopes proposed under MOD 9 proposals and any consequential impacts on the functioning of the Sydney Observatory astronomical sightlines.

4. OBSERVATIONAL ASTRONOMY – A PRIMER

4.1 BASICS

23 In the southern hemisphere, the night sky appears to rotate clockwise around a point in the sky known as the South Celestial Pole (see Fig.1).

24 This point represents the intersection of the extension of the southern end of the Earth's axis of rotation with the sky plane.

25 Thus, when viewed from the surface of the Earth, the sky plane completes one rotation every 24 hours, which means it rotates at a constant angular velocity of 15º per hour.

26 In order to observe a sky plane object, a telescope must first locate the object in the sky plane and then track it as the sky rotates.

27 In addition to this, the Earth moves in its orbit around the sun, completing one revolution approximately every 365.25 days.

28 Thus, at any particular time (e.g. 8:00pm) and at any particular altitude and azimuth (**alt/az**) co-ordinate in the sky plane (e.g. 26º, 210º), a different part of the sky will appear at that co-ordinate location at 8:00pm on each day of the year.

29 Another way of looking at this is that the same part of the sky will now be at another location.

30 For example, on 1 September, at 8:00pm, α Centauri is at alt/az 43º, 216º.

31 On 1 October, at 8:00pm, it is at alt/az 23º, 213º, the change being due to the fact that the Earth has moved further along in its orbit around the sun.

4.2 The Solar System

32 The Solar System consists of the Sun and all of the objects and other matter that orbit around the Sun.

33 The largest of these objects are the eight planets.

34 Of these, only Venus, Mars, Jupiter, Saturn and the Moon are of concern for the matter at hand.

35 The plane of the Earth's orbit is known as the Ecliptic Plane (**the ecliptic**).

36 The orbital planes of all of the planets and the Moon are closely aligned with the ecliptic.

37 The ecliptic is usually represented on star charts by a line (see Fig. 7 for example).

38 The orbital periods of the planets (i.e., time taken to complete one orbit) increases with distance from the Sun, from 225 earth days for Venus to 29 earth years for Saturn.

39 When considering sky view from any particular location on Earth:

- The planets and the Moon always appear in the sky close to the ecliptic (i.e., within a few degrees of it), because they orbit in nearly the same plane as the Earth's orbit.
- The position of the ecliptic in the sky changes with the Earth's orbital motion around the Sun.
- The position of each planet also changes with its position along its orbital path around the Sun.
- The position of the Moon changes with its position along its orbital path around the Earth.
- Each planet is only visible for part of the year, and so the opportunity for viewing it is dependent on its position in its respective orbit.

- The Moon is similarly only visible from any point on Earth for part of its orbit, with it being below the horizon for the rest of the time.

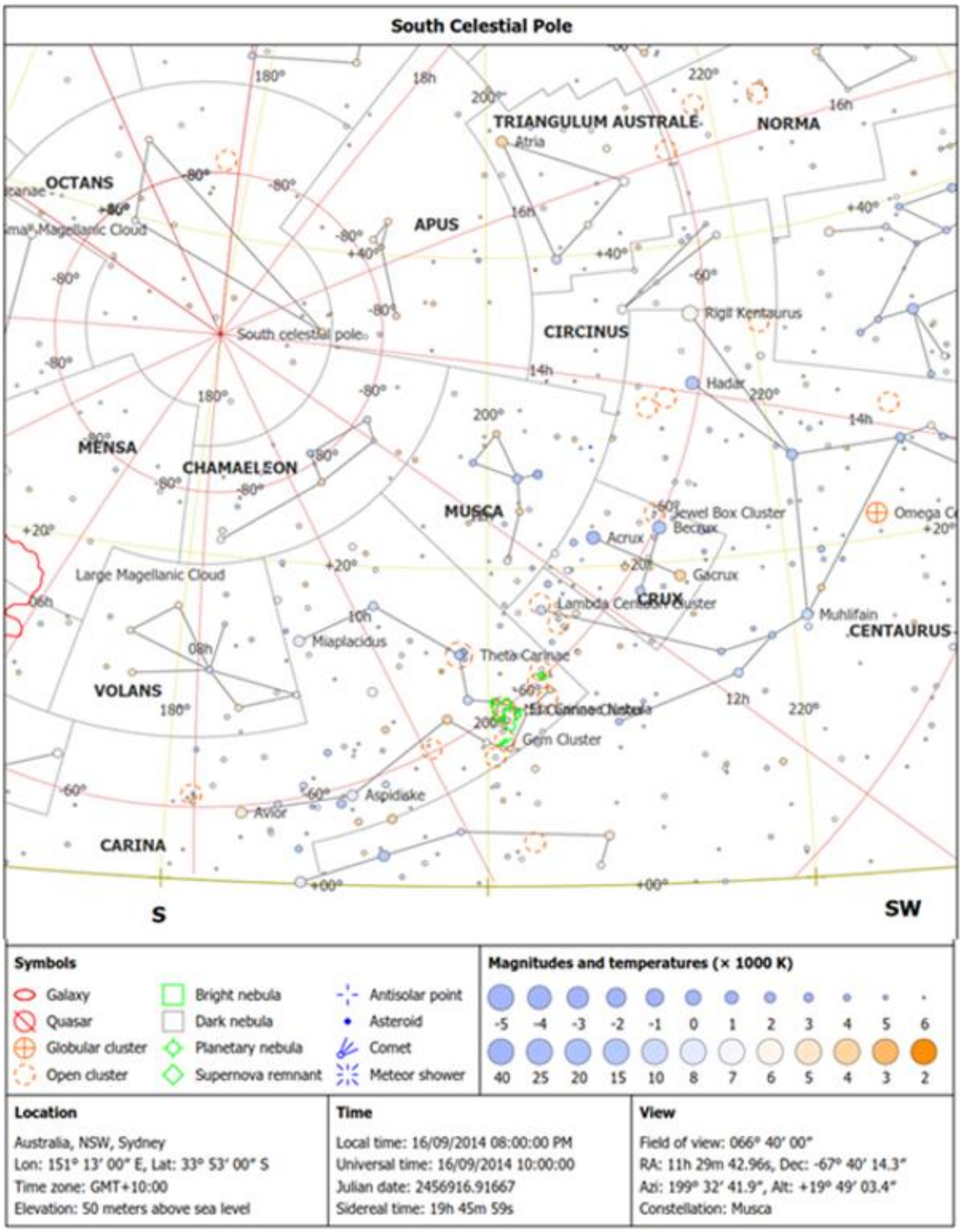

Fig. 1 – Map of the night sky showing the location of the South Celestial Pole and some of the sky objects of interest (Southern Cross, Jewel Box cluster, Alpha Centauri, Omega Centauri), as they appeared on 16 September 2014 at 8pm.

5. OBSERVING AT SYDNEY OBSERVATORY

40 Sydney observatory conducts public observing nights with a range of small telescopes, the largest being the 40cm Meade telescope installed on the first floor in the north dome (see Photo 1).

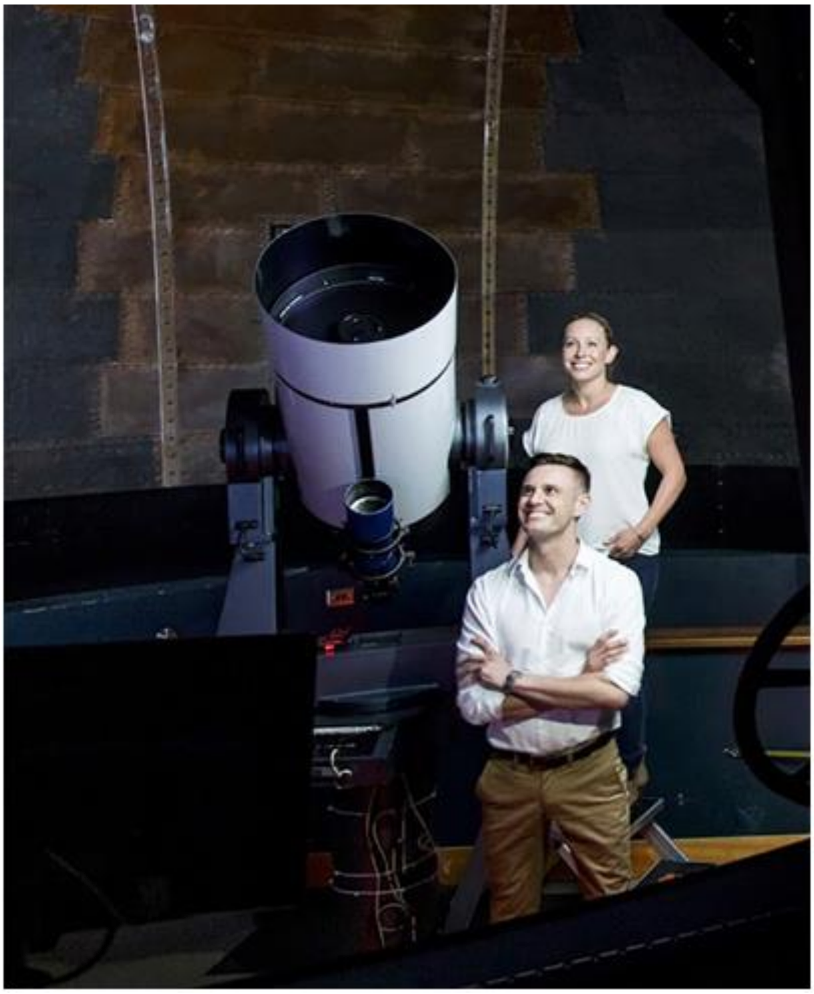

Photo 1 – Sydney observatory's 16" Meade telescope

5.1 FACTORS THAT LIMIT ASTRONOMICAL OBSERVING

41 A number of factors affect the ability to conduct astronomical observations from any particular location.

42 These factors determine whether observing is even possible, and if so, the quality of the image presented by the telescope.

5.2 Cloud Cover

43 Depending on the nature of the clouds, cloud cover can degrade the transparency of the atmosphere to the point where it becomes opaque, making observing impossible.

44 With translucent clouds, observing is possible, but scattered light from the various bright city light sources (e.g. Harbour Bridge) will degrade the observed images by degrading the contrast and altering the colours.

45 The Bureau of Meteorology statistics state the following for the weather station at Observatory Hill:

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
Mean number of clear days	6.8	5.3	7.1	9.1	9.5	9.1	12.0	13.4	10.9	8.1	6.0	6.6	103.9	56	1955 2010
Mean number of cloudy days	13.4	13.0	12.8	10.7	10.8	10.9	8.7	7.7	8.5	11.4	12.5	12.8	133.2	56	1955 2010

Fig. 2 – 56 year average BOM weather data for Observatory Hill

46 From this, we can assume that there will be a roughly ~50% chance of cloud at any particular time/date when viewing any particular sky plane object.

5.3 Smog and Particulate Pollution

47 Smog and particulate pollution affects the transparency of the atmosphere.

48 It causes selective absorption of the short wavelengths of light (blue end of the spectrum), making images look redder (hence the bright orange sunsets during bushfire season).

49 The effect of smog is worse when looking at low altitude above the western suburbs of Sydney, and it tends to be worse in summer under certain weather conditions.

50 It can also be bad during the bushfire season and during ground cover burn off activities in winter and spring.

51 Smog will also scatter light from nearby bright ground based sources (e.g. Harbour Bridge), thereby increasing the overall background sky brightness.

52 These effects will degrade the observed image because the image contrast is reduced and the colours are changed.

5.4 SCINTILLATION

53 Scintillation is caused by air density variations due primarily to air movement (e.g., turbulence, wind).

54 It results in image distortions that fluctuate with time.

55 Scintillation is also a function of the air mass.

56 The minimum column of air through which the light has to pass occurs for targets directly overhead (i.e. at zenith).

57 By definition, at zenith the altitude of a sky target is $\phi = 90^o$, and the corresponding air mass through which the sky target is observed is defined as 1.0.

58 As we move away from zenith towards the horizon, the column of air we have to look through (and the turbulence it contains) increases.

59 The air mass at 30^o elevation is twice that at zenith (90^o elevation), and therefore the scintillation effects are much worse.

60 These effects then worsen rapidly as the horizon is approached.

61 Scintillation effects also worsen with increasing air temperature (heat haze) and with increasing humidity.

5.5 Practical Limits on Observing at Low Altitudes

62 Assuming the large existing fig trees surrounding Observatory Hill are not present, the lower limit of altitude angle for observing is theoretically $\phi = 0^o$.

63 In practice, there is a finite lower altitude angle limit well before $\phi = 0^o$ is reached, and observing sky targets below this altitude becomes impractical.

64 This is because as the altitude decreases, the air mass through which the sky target is observed increases, and as a consequence, so does atmospheric scintillation distortion, reddening and air glow.

65 As the sky target moves away from zenith, its altitude decreases and the corresponding air mass through which it has to be observed increases.

66 Neglecting the curvature of the earth, air mass may be approximated by the trigonometric relationship:

$$\text{Air mass} = 1/\sin(\phi)$$

67 Thus for a sky target at altitude

$\phi = 90^o$, air mass = 1

$\phi = 30^o$, air mass = 2

$\phi = 20^o$, air mass ~ 3

$\phi = 15^o$, air mass ~ 4

$\phi = 10^o$, air mass ~ 6

$\phi = 5^o$, air mass ~ 11

68 My experience with recreational observing near sea level under typical Sydney seeing conditions is that the quality of the image for sky targets much below about 10^{o} altitude is so poor as to make it not worthwhile, particularly for faint objects (e.g. ω Centauri), or for objects that require significant magnification (e.g. the Jewel Box cluster, the planets).

69 For the purposes of this report, I shall assume a practical lower observing altitude limit of 10^{o}.

5.6 Observing Sky Objects Near Sources of Bright Light

70 The field of view of a telescope is defined as the maximum number of degrees of visual angle that is visible at the eyepiece.

71 The actual field of view is generally smaller than this, because it varies with magnification, which in turn is dependent on the characteristics of the eyepiece in use.

72 When one is observing a faint sky object near a source of bright light (e.g., the full moon, or a building containing bright lighting), the bright light source must remain well outside of the telescope's field of view in order for the target object to be observable with reasonable image quality.

73 If the bright light source is outside the field of view, but in close proximity to it, imperfections in the telescope optics (diffraction in particular) cause some of the light to be redirected to the eyepiece (light spillage) and this will degrade the quality of the target image.

74 Thus it is necessary to allow a margin around the edges of the silhouette of buildings as projected onto the sky plane, in order to take into account the effects of light spillage and the field of view of the telescope.

75 For the case of the observatory's Celestron telescope, the field of view is 5.7º, so assuming the target object resides at the centre of the field of view, an allowance of at least half this angle is needed in both azimuth and elevation when observing near buildings so as to avoid having part of the building (and its associated bright light sources) in the field of view.

76 In the assessment that follows, I have allowed a conservative 3º margin around buildings in both altitude and azimuth.

77 The margin increases the effective maximum altitude of each building, when viewed from the observatory, by 3º, and the total azimuth angle to be considered by 6º (3º for each side of the building).

5.7 SYDNEY OBSERVATORY OPENING TIMES

78 Sydney Observatory is only open for observing at specific times on specific days.

79 Thus in order to assess the impact on viewing caused by any particular obstruction, the required target object locations must be tracked throughout the year so as to determine when or even if they intersect with the obstructed area of sky, and if so, for what proportion of the observatory's opening hours on observing nights.

6. SYDNEY OBSERVATORY'S LOSS OF SKY VIEW CONCERNS

80 In a submission from the Museum of Applied Arts and Sciences dated 7 May 2015 to the then NSW Department of Planning and Environment, Sydney Observatory indicated that their sky area of concern covers the azimuth angle between 210º and 225º, and between 236º and 303º.

81 In addition, it indicated that viewing of the following night sky objects is of interest:

- The Southern Cross
- The Pointers (Alpha and Beta Centauri)
- The Jewel Box Cluster (open star cluster)
- ω Centauri (globular star cluster)
- The Moon
- The planets
- The Ring Nebula (M57)
- The star Albireo (Beta Cygni, a multi-coloured twin star)

7. THE CENTRAL BARANGAROO DEVELOPMENT – BLOCKS 5, 6 AND 7

82 For the matter at hand, the Central Barangaroo Developer has provided a set of reference design drawings illustrating proposed building envelopes for the three Central Barangaroo development blocks of interest.

83 Fig. 3 shows the boundaries for Blocks 5, 6 and 7 of the Central Barangaroo development.

84 Each of these blocks contains three buildings.

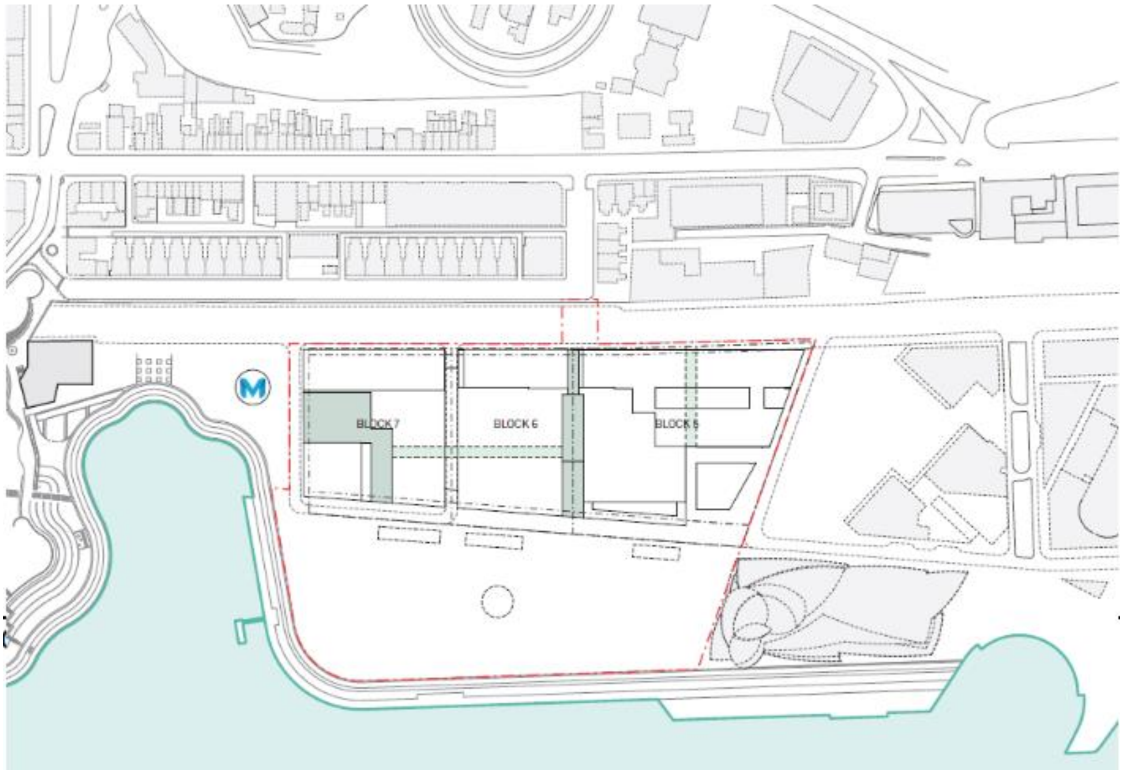

Fig. 3 – The Central Barangaroo development, showing the boundaries and proposed mod 9 envelope of Blocks 5, 6 and 7. The Sydney Observatory is located to the east of Block 7.

85 The buildings proposed for each block are shown in Fig. 4.

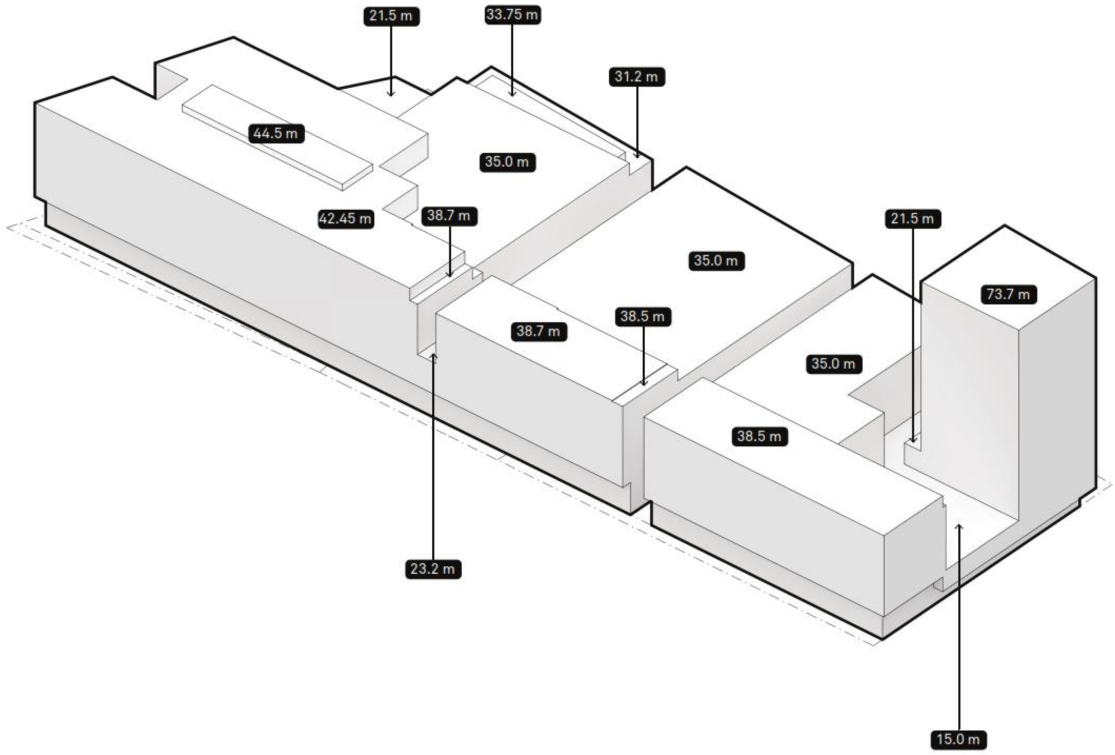

Fig. 4 – The proposed Central Barangaroo development, illustrating the taller tower structure on the right. The maximum height of each building envelope is also shown.

8. EFFECT OF THE CENTRAL BARANGAROO BUILDINGS ON THE SKY VIEW FROM SYDNEY OBSERVATORY

86 The Reduced Level (**RL**) for the Barangaroo site ground level is 3.5.

87 The height of the highest building in each block is as follows:

BLOCK 5 (SOUTHERN MOST DEVELOPMENT BLOCK):

- the maximum RL for the block is 44.5m.

BLOCK 6 (MIDDLE DEVELOPMENT BLOCK):

- the maximum RL for the block is 38.7m.

BLOCK 7 (NORTHERN MOST DEVELOPMENT BLOCK):

- the maximum RL for Block 7 is 73.7m.
- the altitude angle of the highest point on the block, when viewed from Sydney Observatory south dome, is 8.5^{o} (see Fig. 5).

88 The viewing levels on the first floor of observatory’s north and south domes are both at approximately RL54.0m.

89 Given that the tops of all of the buildings in Block 5 and Block 6 are well below this level, the buildings in these blocks will not obstruct the sky view from Sydney Observatory.

90 Block 7 contains three buildings, but only the Tower Block (RL73.7m) is high enough to possibly cause some sky view loss from Sydney Observatory.

91 The other two buildings have RL38.5m and RL35.0m.

92 Hence further assessment is required.

93 For the following analysis, I have assumed that there are no trees in the park at Observatory Hill, and a practical lower altitude limit of 10^{o} for observing, for the reasons given in Section 5.5 above.

94 Fig. 5 shows the building elevation envelope of the Tower Block, with a sight line drawn from Sydney Observatory south dome to the top.

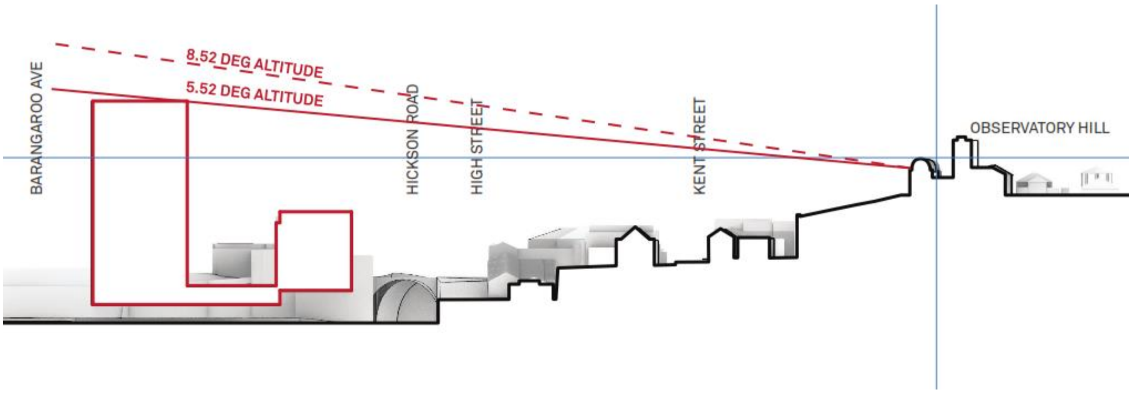

Fig. 5 – Sight line from Sydney Observatory south dome to the highest point on the taller tower building envelope (azimuth angle 258.2°).

95 Fig. 6 shows a plan view of the three buildings that are located in Block 7, with the azimuth angle projected by the taller tower building envelope extremities when viewed from Sydney Observatory south dome.

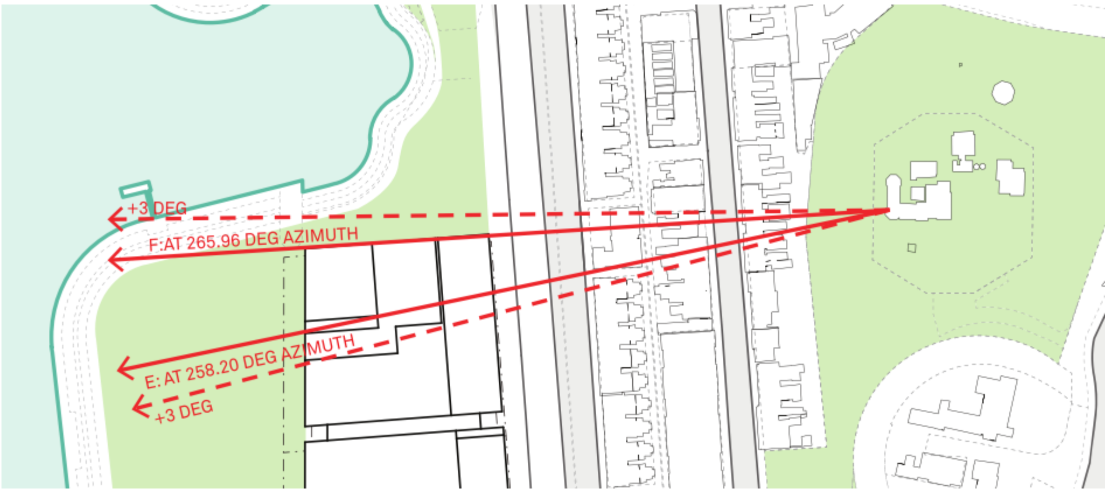

Fig. 6 – Plan view of the taller tower building envelope footprint showing the azimuth angle projected by the building extremities when viewed from Sydney Observatory south dome.

96 When assessing the possible obstructing effect of this building on the sky view from Sydney Observatory, a margin of 3° must be added to the extremities to allow for the effects of finite telescope field of view and light spillage (see Section 5.6 for explanation).

97 Hence, from Figs. 5 and 6, the sky view obstruction area for the taller tower building envelope is 8.5º in altitude, and 255º to 269º in azimuth angle, including a margin of 3º (hereafter referred to as the **obstructed area**).

98 Observing sky objects inside the obstructed area is not viable due to the presence of the taller tower building envelope.

99 The sky objects of interest to Sydney Observatory are listed in Section 6.

100 Of these, only the planets and the Moon can potentially pass through the area of sky obstructed by the taller tower building envelope, and of these, only Venus, Mars, Jupiter, Saturn and the Moon are of concern, because the others are either too faint or do not enter the obstructed area.

101 Fig. 7 shows the sky view from the observatory in the direction of the taller tower building envelope as it will appear on 25 September 2025 at 7:15pm, just before Mars enters the obstructed area and near the end of the observatory’s first observing session for the night.

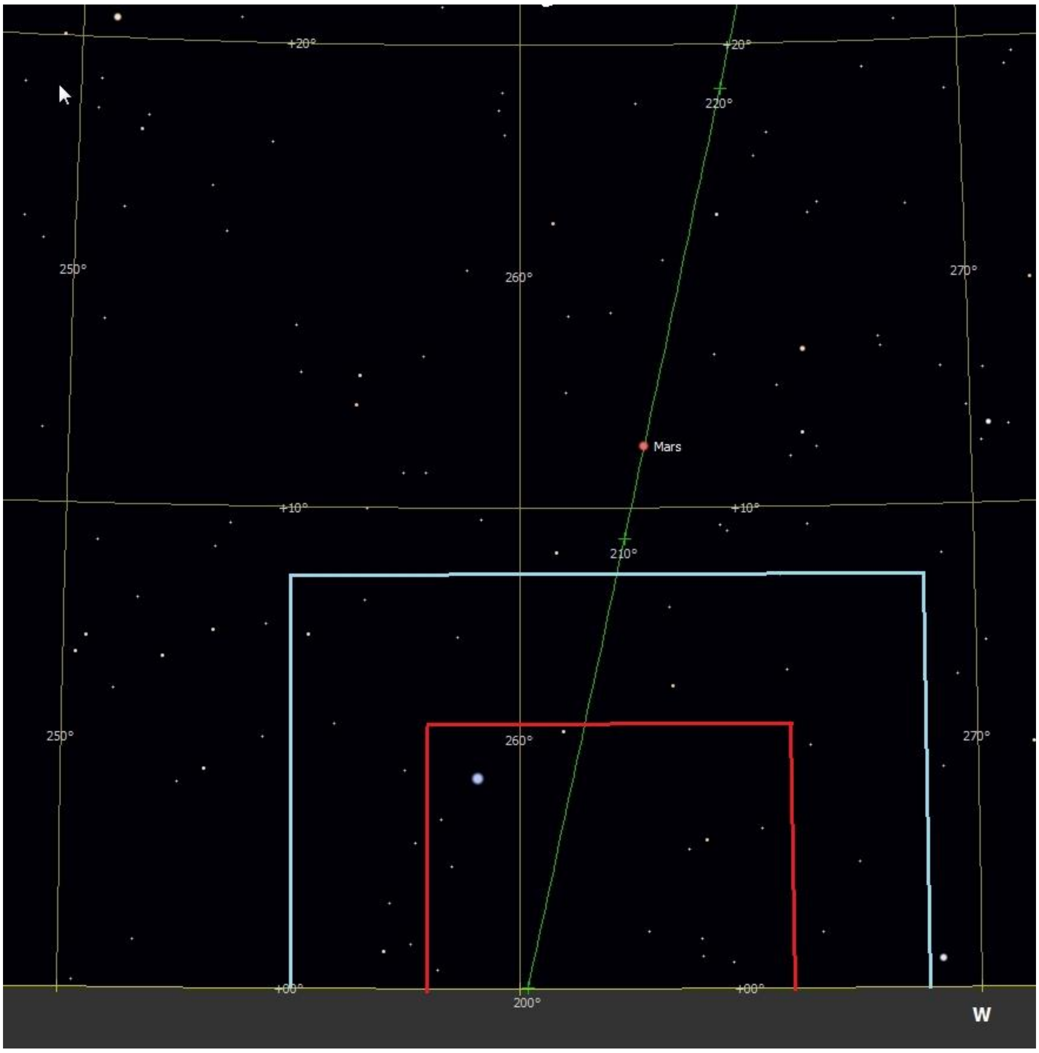

Fig. 7 - Sky view from the observatory looking towards the taller tower building envelope, showing the sky as it will appear on 25 September 2025 at 7:15pm, when Mars is about to enter the obstructed area. The silhouette of the taller tower building envelope is shown in red. The obstructed area is shown in blue. The blue includes the required 3º margins. The ecliptic is represented by the green line.

102 Fig. 8 shows the entire night sky at the same time and date as that shown in Fig. 7, so as to give a better idea of the true size of the obstructed area, shown as the blue rectangle near the bottom centre of the chart.

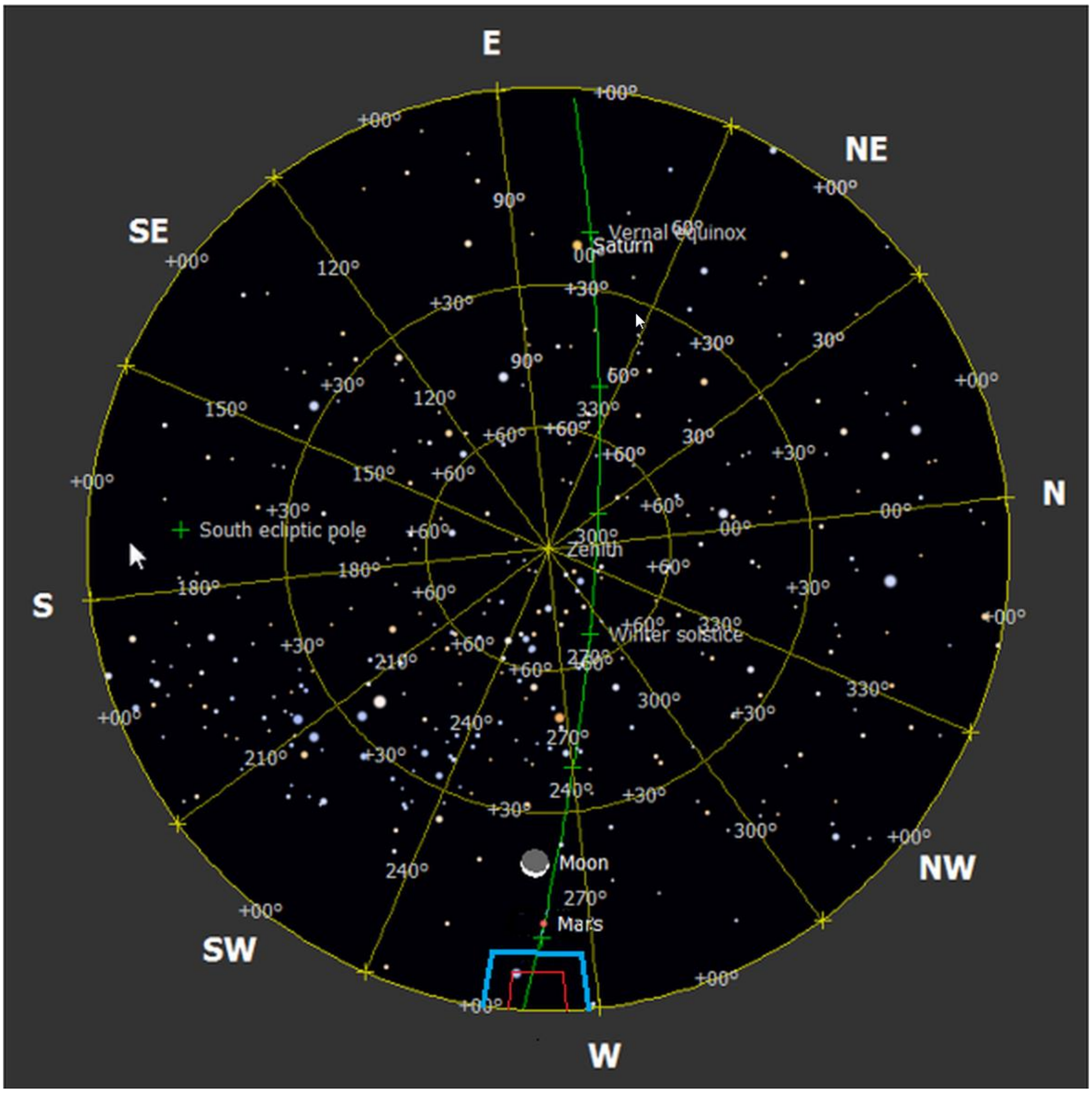

Fig. 8 – Star chart for the entire night sky shown with the same orientation and at the same time and date as Fig. 7, but with less stars for clarity. The obstructed area is represented by the blue line. The building outline is represented by the red line. The ecliptic is represented by the green line.

103 Fig 8 illustrates that the obstructed area is very small and estimated to be an area representing less than 1% of the total night sky.

104 Furthermore, the obstructed area created by the taller tower form lies less than 10° above the horizon, in the area where observing is not viable.

9. CONCLUSIONS

105 The purpose of this report is to assess the impact of MOD 9 for Central Barangaroo on the sky view from Sydney Observatory.

106 The proposed development of Central Barangaroo consists of Blocks 5, 6 and 7, with the indicative reference design illustrating each block as containing three buildings.

107 Due to their low height, the buildings in Blocks 5 and 6 do not obstruct the sky view from Sydney Observatory.

108 Of the three buildings in Block 7, only the taller tower building envelope is high enough to obstruct the sky view from Sydney Observatory, but the area of sky obstructed is all less than 10º above the horizon, in the area of sky where it is too low to permit viable observing.

109 Of the sky objects stated as being of interest to Sydney Observatory, only the planets and the Moon can potentially pass through the obstructed area of sky, and for all of these, observing is not viable due to them being too close to the horizon at the times when they are visible during Observatory opening hours.

110 In addition, unlike the stars and deep sky objects (e.g., galaxies) that are essentially fixed in the sky plane, the planets and the Moon move through the sky plane along paths that are always in close proximity to the ecliptic (the plane of the Earth's orbit projected onto the sky plane), and the ecliptic only passes through the obstructed area during a single observing session in the months of September and December of each year.

111 Thus the presence of the proposed taller tower building envelope in Block 7 will have no adverse effect on the sky view from Sydney Observatory.

George Georgevits
B.E. Hons, PhD
Astrophysicist

Level 2, South Wing, Rupert Myers Building
Gate 14, Barker Street
UNSW SYDNEY NSW 2052

APPENDIX 1

Sydney Observatory Public Viewing Schedule

sydney observatory
PART OF THE POWERHOUSE MUSEUM

Hours and charges

- Hours and charges
- Night visit (online bookings)
  - Night group visit
- Day visit
  - Day group visit
- Special events
- School holiday program
- Private telescope viewing
- Booking conditions
- How to get here
- Facilities, food, access
- Birthday parties
- Tourist operators

Certificate of Excellence
2014 WINNER
tripadvisor
Sydney Observatory

NIGHT VISIT

Open nightly Monday to Saturday except Good Friday, Christmas Day and Boxing Day holidays. Open Sunday nights during school holidays.

Bookings are necessary for night sessions (of approximately 90 minutes duration). Phone (02) 9921 3485 or **book online**.

Night telescope/3D theatre session times
April to September – 6.15pm and 8.15pm
October and November – 8.15pm
December and January – 8.30pm
February and March – 8.15pm

Night charges for telescope/3D theatre sessions
Adult – $18
Child (4 to 15 years) – $12
Concession – $14
Family (1 adult and up to 3 children;
or 2 adults and up to 2 children) – $50
Member (adult) – $16
Member (child) – $11
Member (family) – $43

Sessions are held regardless of weather. If viewing through the telescopes is not possible due to sky conditions, a fun digital planetarium session is provided instead.

All night visits must be booked and prepaid prior to arrival at the Observatory. Payment for night tickets is not refundable. However if you notify us by phone on 9921 3485 by noon on the day you are scheduled to attend your night visit, we can either transfer your booking to another available night; or offer you a 'rain check' ticket, valid for three months from first booking, to the same value as your original booking.

Debit and credit card fees: As part of a NSW Government requirement, Sydney Observatory applies a surcharge on all transactions made by debit or credit cards. Surcharge rates are determined on a cost-recovery basis only. No surcharge is incurred when paying with EFTPOS, cheque or cash. Payments made on VISA and Mastercard attract 0.40%

Review your visit on facebook
Would you like to tell others about your visit to Sydney Observatory? Then you might like to **review your visit on facebook**.

DAY VISIT

Open 10am – 5pm daily
except Good Friday, Christmas Day and Boxing Day holidays
Open 10am – noon New Years Eve

Day telescope/3D theatre session times
Monday to Friday (school term) – 2.30pm, 3.30pm and 4.00pm
Weekends and school holidays – 11am, noon, 2.30pm and 3.30pm
Bookings are not required for day sessions.

Day charges for telescope/3D theatre sessions
Adult – $10
Child (4 to 15 years) or concession – $8
Family (1 adult and up to 3 children;
or 2 adults and up to 2 children) – $26
Member adult – $6
Member child (4 to 15 years) or concession – $4
Member family (1 adult and up to 3 children;
or 2 adults and up to 2 children) – $16

Daytime admission for a self-guided visit to the gardens and the Observatory exhibitions is free – but does not include visits to the telescope towers, telescope viewings and 3D theatre sessions.

Debit and credit card fees: As part of a NSW Government requirement, Sydney Observatory applies a surcharge on all transactions made by debit or credit cards. Surcharge rates are determined on a cost-recovery basis only. No surcharge will be incurred when paying with EFTPOS, cheque or cash. Payments made on VISA and Mastercard will attract 0.40%

The Powerhouse Museum is an Affiliate of the NSW Government's Department of Ageing, Disability and Home Care's Companion Card program. This means that carers who accompany a person with a disability will be eligible for free entry on presentation of their Companion Card. For more information visit **www.companioncard.org.au**

Share this: Twitter 4 | Facebook 5K+ | StumbleUpon | Email | Print

Visit the Powerhouse Museum

1003 Upper Fort St, Millers Point, NSW, 2000.
Bookings / enquiries: PH: (02) 9921 3485
NSW Government

email: observatory@phm.gov.au

Select Language
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APPENDIX 2

Curriculum Vitae

Unisearch Expert Opinion Services

CURRICULUM VITAE	Dr George GEORGEVITS

Qualifications

- Bachelor of Engineering (Electrical) (Hons)
  Specialising in Communications, Electronics & Power
  The University of New South Wales, 1974
- PhD Physics (Astrophysics)
  The University of New South Wales, 2018

Present Position

Consulting Engineer, Managing Director & Principal Consultant Power and Digital Instruments Pty Ltd (PDI)

PDI specialises in providing engineering consultancy in the fields of communications, electronics, power and astronomy.

Areas of Expertise/ Special Interests

- Astronomy and astrophysics
- Cabling systems and components - design, testing and certification for standards compliance
- Data communications networks, systems and devices
- LANs, computer networks and computer technology
- Voice communications and telephony technology
- Communications service providers and Carriers
- Mobile phones, mobile networks and billing system analysis
- Radio communications, HF, VHF, UHF and microwave
- Audio systems and audio engineering
- Electrical fire investigations
- Lightning, lightning protection and earthing systems - design and testing for standards compliance
- Investigation and assessment of damages claims for communications, power and gas infrastructure
- Damages claims for electrical/electronic devices & systems
- Electronics design, manufacturing and test & measurement
- Equipment and component testing and performance certification
- Regulatory and legal aspects of communications and power
- Standards compliance and best practice
- Patent specification technical preparation and advice

- Advanced mathematics and physics, analysis of data, errors in measurements
- I am a member of three Standards Australia committees
- I speak fluent Hungarian and basic French

Professional Experience

1980 - Present

Managing Director & Principal Consulting Engineer
Power and Digital Instruments Pty Ltd

Fields of expertise are as described in the company capability statement (provided separately). PDI has successfully completed thousands of assignments for more than 200 corporate and government clients over a 40 year period.

Major multi-national corporate clients have included:

- Acheron Project (DEEPSEA Challenge Expedition for film director Jim Cameron – Avatar fame)
- Amphenol (Canada & China)
- Belden USA
- CommScope
- Lantek (Taiwan)
- LS Cable Co (Korea)
- Molex (USA and Aus)
- Molex Industrial Division (USA)
- Schneider Electric Asia Pacific (Hong Kong)
- Sunf Pu Technology Co Ltd (Taiwan and China)
- Tyco Electronics Inc. (China and Aus)
- Surtec Industries (Taiwan)

Corporate Australian clients have included:

- Acciona Australia (Sydney Light Rail Project)
- Amber Technologies P/L
- Allianz Insurance
- Barry Nilsen Lawyers
- Bluescope Steel Port Kembla Steelworks
- Campus Living Villages P/L
- CGU Insurance Ltd
- Charles Taylor Adjusting
- Clipsal Aust P/L
- Coffey Geosciences P/L
- Connection Magazines
- Crawford & Co (Loss adjusters – all states)
- Cunningham Lindsay (loss adjusters)
- Eaton Powerware P/L
- Echelon Adjusting P/L
- FDC Technologies Pty Ltd

- Hall & Wilcox, Lawyers
- Hicksons, Lawyers
- Holman Webb Lawyers
- Jarman McKenna Lawyers
- Jardine Lloyd Thompson
- Jeffery & Katauskas P/L (Geophysics)
- Lumley General Insurance
- McCabe Terrill Lawyers
- Novis health Care
- NRMA
- Omega Power Equipment Pty Ltd
- Pells Sullivan Meynink (Engineering Consultants)
- Prysmian Cables Australia (was Pirelli)
- QBE Insurance Ltd, (all states + overseas)
- Stowe Electrical
- Technical Assessing Pty Ltd
- Thiess Ltd.
- Underwriting Agencies of Australia
- Wotton & Kearney, Lawyers
- ZIP Heaters
- Zurich Insurance Ltd

Government & semi government clients have included:

- ACT Electricity & Water (ACTEW, now TransACT)
- Anglo Australian Observatory
- Aust Bureau of Statistics
- Aust. Tax Office
- Aust. National University
- Civil Aviation Authority
- NSW Crown Solicitor's Office
- NSW Police Service
- Queensland Health
- RAN
- Sydney Market Authority
- Tasmania Police
- State Rail Authority of NSW
- Unisearch
- University of NSW Voice Services Group
- Western Power Corporation

1980 - 1982

Senior Consulting Engineer
Laurie Systems Engineers.

Design and oversee installation of communications systems and networks for Woodside LNG project, North-West Shelf, Western Australia and Santos Ltd, Cooper Basin oil and natural gas projects, South Australia.

1974 - 1980 **Various Telecommunications Engineering Positions**

- PMG's Dept, then
- Telecom Australia, then
- Telstra, including two years with Lines Practices and Protection Section
- Four years on exchange installation projects;
- the last position held at Telstra prior to resigning was senior engineer in charge of the State Design Laboratory, New South Wales

Specific Areas of Work

- Physics and astronomy
- Testing and Certification of Cat 7, 6A, 6, 5e, 5 and Twisted Pair Cabling Components, Cables and Installations to EIA, ISO & Australian standards
- Cat 6A, Cat 6 and Cat 5e Cabling Connector Design and Testing
- Troubleshooting and Testing Installed Cabling Networks
- Lightning and Surge Protection System Design and Testing
- Earthing System Design and Testing and Power Co-ordination
- Power Systems and Cabling, including Magnetic Field Radiation Surveys
- RF Test and Measurement (PDI has a well equipped test lab)
- Radio Interference, Noise, EMC investigations and RF Sweeps for Debugging
- Optical Fibre Cabling Technologies, including Testing
- Investigation and Assessment of Damages Claims for Insurance Purposes
- Computer Systems, Software, Hardware and Networks
- Troubleshooting Electronics Circuits and Systems
- Electronics Design - Analogue, Digital and RF
- Electronics Manufacturing and Reliability Engineering
- Specialised Software Development and Interface
- Process Control, PLC’s, Instrumentation and Data Acquisition
- Telecommunications Networks and Broadband Technology
- Fixed Line and Mobile Telephone Telephony
- PABX Systems, Key Systems and Cordless Telephony

Methodology

PDI was established in 1980, and has a well-proven track record in engineering consultancy, test & measurement and project management. PDI has a well-equipped lab, with balanced pair RF transmission measurements as required for LAN cabling systems and components being a house specialty.

Consultancy work is carried out primarily by the Principal, Mr George Georgevits. In addition, suitably qualified associates may be called upon from time to time as required to meet the specialised demands of particular projects.

Mr Georgevits has an Honours degree in Electrical Engineering, a PhD in Astrophysics and over 40 years experience in the industry as a consulting engineer.

APPENDIX 3

Science Article

ASTRONOMY

Twinkling Stars May Reveal Stuff of Early Solar System

Australian researchers say dips in the brightness of stars may tell of a vast array of objects beyond the planets, but others aren't so sure

CATANIA, ITALY—The Kuiper Belt, resting place of much of the detritus left over from the creation of the solar system, may contain many more small objects than previously thought. Australian astronomers scanned the outer reaches of the solar system by looking for a brief dimming of the light of distant stars as subkilometer-sized bodies passed in front of them. Preliminary results presented at a workshop here earlier this month* suggest that huge numbers of such objects lurk beyond the orbit of Neptune. Although most Kuiper Belt researchers are cautious, studies by some other teams suggest the Australians may be onto something. "If this is true, it would be fantastic," says Alessandro Morbidelli of the Observatoire de la Côte d'Azur in Nice, France, because information about the smaller denizens of the Kuiper Belt cannot be found any other way.

Astronomers have found more than 1000 bodies in the Kuiper Belt, including an object known as 2003 UB_{313} (nicknamed Xena) that is slightly larger than Pluto. But because they are several billion kilometers away, even the most powerful telescopes can't see Kuiper Belt objects smaller than about a hundred kilometers across. Researchers are keen to know more about their size distribution, as it would shed light on the early youth of the solar system.

An effort to fill that gap has been going on since last year. The Taiwanese-American Occultation Survey (TAOS) operates three automated 50-centimeter telescopes at Lu-Lin Observatory, Taiwan, which scan starlight for telltale dimming that signals a Kuiper Belt object passing in front of, or "occulting," the star. So far, the survey has drawn a blank. Team member Federica Bianco of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts, says TAOS can't observe very brief dips in brightness, so it is capable of spotting only the relatively rare objects larger than a few kilometers in diameter.

But George Georgevits and Michael Ashley of the University of New South Wales in Sydney and Will Saunders of the Anglo-Australian Observatory in Siding Spring say the Kuiper Belt may teem with objects too small for TAOS to see. Using a fast detector at the 1.2-meter U.K. Schmidt Telescope in Siding Spring, they saw well over a thousand brief brightness dips, each lasting for a tenth of a second or less, while monitoring dozens of stars for about 2 weeks.

"It's very important work, and they should certainly continue," Morbidelli says. "But the results so far are very strange," because current theories of the evolution of the solar system do not predict huge numbers of small Kuiper Belt objects. Michael Brown of the California Institute of Technology in Pasadena, who discovered 2003 UB_{313}, adds that "the believability factor [of these results] isn't very high. Unfortunately, you can never go back and check." But Georgevits counters that he has checked and ruled out every other possible cause of the stellar winks.

So are the results real? "Well, it seems they are observing *something*," says David O'Brien of the Planetary Science Institute in Tucson, Arizona, although he adds that no one has yet carried out a detailed statistical analysis of the Australian results. According to O'Brien, collisions in the Kuiper Belt may have produced hordes of small objects. "If confirmed, these results could tell us something about the strength properties of Kuiper Belt objects," he says.

Some other studies support the Australian results. Taiwanese astronomers have uncovered similar brief occultations of the well-known x-ray source Scorpius X-1 in data from NASA's Rossi X-ray Timing Explorer satellite. A team led by astronomer Ping-Shien Wu of the National Tsing Hua University in Hsinchu presented the finding in April at the Chinese Astronomical Society Taiwan's meeting in Taichung and is due to publish it in *Nature* next month. And at the Catania workshop, Françoise Roques of the Paris Observatory described three brief occultations detected with the 2-meter Bernard Lyot Telescope in the French Pyrenees, which Roques says may also represent small Kuiper Belt objects.

When worlds collide. Two icy bodies crash in the Kuiper Belt in this artist's depiction. Could such collisions have populated the belt with tiny objects?

Not everyone is convinced. "They have to do more checks on possible false alarms," says Matthew Lehner of CfA. For instance, the dips might be caused by unknown effects in Earth's atmosphere. To avoid these, you need to observe from space, says Lehner, who is part of a team that has pitched to NASA a \$425 million occultation mission called Whipple, which would detect Kuiper Belt objects as well as comets in the much more distant Oort Cloud.

Meanwhile, Georgevits hopes to raise half a million dollars for a purpose-built ground-based telescope equipped with a very fast video camera. Such a device could survey the whole Kuiper Belt for a fraction of the cost of a space mission, he says. And although his team's preliminary results raised some eyebrows, everyone agrees on the need for a more comprehensive search. Says O'Brien: "Small Kuiper Belt objects will never be observed directly. Occultation surveys have a lot of potential to fill in this gap."

–GOVERT SCHILLING

Govert Schilling is an astronomy writer in Amersfoort, the Netherlands.

CREDIT: DAN DURDA/FIAAA

* Trans Neptunian Objects: Dynamical and Physical Properties, Catania, Italy, 3–7 July.

APPENDIX 4

The UK Schmidt Telescope

Fig. 9 – The 1.2m UK Schmidt telescope located at Siding Spring Observatory

APPENDIX 5

Capability Statement for PDI

POWER AND DIGITAL INSTRUMENTS PTY LTD.

PDI

Electronics and Communications Consulting Engineers

POSTAL:
P.O. BOX 422
ROSEVILLE NSW 2069

BUSINESS OFFICE:
66A FINDLAY AVE
ROSEVILLE NSW AUSTRALIA

TEL: +61 2 9411 4442

ABN 21 002 065 769

Aug'18

CAPABILITY STATEMENT

FIELDS OF EXPERTISE:

- Balanced pair data cabling systems and components - design, testing and certification
- Voice and data communications, mobile and fixed line telephony technology
- Radio communications, HF, VHF, UHF and microwave
- Power systems, power distribution networks and service providers, power equipment
- Assessment of damages claims - communications, power, gas & water Infrastructure and electrical equipment, including industrial equipment and domestic appliances
- Electrical fire investigations and equipment testing to determine source of ignition
- Lightning protection, earthing systems and surge protection
- Electronics design, manufacturing, troubleshooting and test & measurement
- Reliability engineering
- Electrical equipment and component testing and certification - analogue, digital and RF
- Computer networks and computer technology
- Communications equipment and service suppliers and Carriers
- Project management and specification
- Regulatory and legal aspects of power and communications systems, networks and equipment, and standards compliance, particularly electrical safety standards
- Patent specification technical preparation and advice
- Astronomy and astrophysics

SOME SPECIFIC AREAS OF WORK:

- Testing and certification of balanced pair Cat 7A, 7, 6A, 6, 5e, 5 cabling systems and components to EIA, ISO & Australian standards
- Balanced pair data cabling connector design - Cat 6A, Cat 6 and Cat 5e
- Fibre optic communications cabling technologies
- Troubleshooting installed communications cabling systems
- Power systems, LV reticulation networks and equipment
- 50Hz magnetic field radiation surveys
- Lightning and surge protection - system design and testing
- Earthing system design, testing for standards compliance and power co-ordination
- RF test and measurement (PDI has a well equipped test lab)
- Radio interference, noise, EMC investigations, RF sweeps for covert devices
- Troubleshooting electronics and computer circuits and systems
- Specialised software development and interface
- Process control, automation, instrumentation and data acquisition

METHODOLOGY

Dr Georgevits is managing director of and principal consulting engineer for PDI (established 1980). Dr Georgevits has an honours degree in Electrical Engineering, a PhD in Astrophysics, and over 35 years experience industry experience as a consulting engineer.

PDI has a proven track record in engineering consultancy, test & measurement, electronics design and troubleshooting, and computer technology.

PDI operates a well-equipped test and measurements laboratory and has successfully completed thousands of engineering projects for some 400 corporate and government clients.

ENGAGEMENT

Engagement to perform consultancy work is carried out on a contract basis. Fees may be structured on a fixed lump sum basis for clearly defined tasks, or on an hourly rate for other work, as required and mutually agreed with the Client.

PDI offers a completely independent advisory service. PDI has no affiliations with suppliers of equipment or services.

BRIEF LIST OF REFERENCES

Some Current Clients:

- Amphenol Canada Corporation - connector manufacturer
- Coffey Testing Services/Acciona – Eastern Suburbs Light Rail project
- Expert Consulting Pty Ltd. – ongoing, various consultancy projects
- Experts Direct – ongoing, various consultancy projects
- Expert Experts – ongoing, various consultancy projects
- Unisearch Expert Opinion Services – ongoing, various consultancy projects
- Fire Forensics – ongoing, various fire related investigations
- Omega Power Eqpt Pty Ltd. - electrical wholesalers and importers
- Piper Alderman (solicitors) – large damages claim - industrial equipment
- PRYSMIAN Cables Australia Pty Ltd - cable manufacturer and importer
- Voltex Pty Ltd. - electrical wholesalers and importers

Some Completed Assignments:

- Acheron Project – Deepsea Challenger submarine, James Cameron (Terminator fame)
- Australian Astronomical Observatory – SSO lightning protection design and testing
- Australian National University (ANU) – Mt Stromlo lightning protection design & testing
- Barry Nielsson Lawyers – various litigated damages claims
- Barangroo South Crown Hotel – obstruction of sky view from Sydney Observatory
- Clayton Utz Lawyers – Master Home Improvements – Infinity power cable safety recall
- Crawford & Co (Loss Adjusters)
- Lantek Electronics – Taiwan (connector manufacturer)
- Leighton Contractors (major projects contractors) - M2 tunnel widening instrumentation
- NSW Crown Solicitor's Office – mining site fatality involving PLC controlled equipment
- QBE Insurance (Aust) Ltd (all states) – many damages claims
- Surtec Industries Inc. – Taiwan (connector manufacturer)
- Technical Assessing Pty Ltd (loss adjusters)
- Tenix Group (major projects construction & defence contractors)
- Thiess Ltd. – QCLNG Project – troubleshooting power cabling problems
- UNSW Sydney, Communications Services Group – lightning protection all UNSW sites