Museum of Applied Arts & Sciences

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MUSEUM OF APPLIED ARTS AND SCIENCES

SUBMISSION TO NSW PLANNING AND ENVIRONMENT
BARANGAROO SOUTH
Mod 8 Concept Plan (MP06_0162 MOD 8)

BACKGROUND

The Museum of Applied Arts and Sciences encompasses the Powerhouse Museum (Ultimo) Sydney Observatory (Millers Point) The Discovery Centre (Castle Hill). This submission responds to the submission to NSW Planning and Environment of the Development Application by Lend Lease for the development of Barangaroo South Mod 8 Concept Plan (MP06_0162 MOD 8) and the Sydney Observatory Sky View Impact Assessment, which forms part of the Development Application.

The affected areas which have significance for Sydney Observatory visitors are the Southern Cross and Pointers (including star Alpha Centauri), Omega Centauri and the Jewel Box. Viewing of these objects is affected for part of the year by the Barangaroo South development. The Southern Cross is the most popular object with tourists and locals.

The Moon, the Sun and planets lie in the east, north and western sky as viewed from Sydney Observatory and are not affected by the Barangaroo South development.

Sydney Observatory's operating model is based on two guided astronomy sessions conducted each night. Each session is limited by site/building capacity. Sessions are held from 6.15pm winter, 8.15pm summer to maximise throughput and viewing times.

IMPACT OF THE CONCEPT PLAN ON SYDNEY OBESERVATORY OPERATIONS

Sydney Observatory has assessed the impact of the Concept Plan on night viewing as follows:

Building H1 limits viewing of the globular cluster Omega Centauri.

Buildings R4A and R4B limit viewing of the constellation Southern Cross, the star Alpha Centauri (and its companion Pointer star Beta Centauri) and star cluster the Jewel Box.

Building H1 limits viewing of Omega Centauri during both the first and second evening viewing sessions. In the first session it causes a loss of viewing on 28 days, or 15% of the presently available viewing days. It causes a loss of viewing for 20 hours and 46 minutes, or 8% of the presently available viewing time. In the second viewing session it causes a loss of viewing on 41 days, or 21% of the presently available viewing days. It causes a loss of viewing for 27 hours and 23 minutes, or 11% of the presently available viewing time.

Buildings R4A and R4B limit viewing of the star Alpha Centauri during the second viewing session only. They cause a loss of viewing on 57 days, or 25% of the presently available viewing days. They cause a loss of viewing for 45 hours and 11 minutes, or 15% of the presently available viewing time.

Buildings R4A and R4B limit viewing of the Southern Cross during both the first and second sessions. In the first session they cause a loss of viewing on 32 days, or 18% of the presently available viewing days.
They cause a loss of viewing for 24 hours and 38 minutes, or 9% of the presently available viewing time. In the second session they cause a loss of viewing on 41 days, or 21% of the presently available viewing days. They cause a loss of viewing for 27 hours and 7 minutes, or 10% of the presently available viewing time.

Buildings R4A and R4B limit viewing of the Jewel Box during both the first and second sessions. In the first session they cause a loss of viewing on 22 days, or 12% of the presently available viewing days. They cause a loss of viewing for 15 hours and 55 minutes, or 6% of the presently available viewing time. In the second session they cause a loss of viewing on 46 days, or 22% of the presently available viewing days. They cause a loss of viewing for 29 hours and 8 minutes, or 11% of the presently available viewing time.

The whole Barangaroo South precinct, but particularly buildings R4A, R4B and H1, will spill light to the sky reducing the contrast between the background sky and objects viewed from Sydney Observatory making objects more difficult to view.
Summary of Impacts

Conclusion

- The Mod 8 concept plan buildings have significant impact on viewing of the Southern Cross, Alpha-Centauri, the Jewel Box, Omega Centauri and other objects both by way of increased light spill and by blocking the view at certain times of the year.
- From 12 to 25% of available viewing days and from 6 to 15% of the available viewing time of these iconic objects will be lost if the Mod 8 buildings are constructed.

RESPONSE TO THE UNSW GLOBAL IMPACT ASSESSMENT

Sydney Observatory was not consulted in the course of the completion of the Report prepared by Mr George Geogevits on behalf of Expert Opinion Services, a business unit of UNSW Global.

The Report prepared by UNSW Global states the impacts and functioning of Sydney Observatory due to the Mod 8 Concept Plan ‘are negligible’.

Sydney Observatory’s impact assessment as detailed above in the summary response above, and in the detailed analytical response which follows.

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The detailed assessment indicates:

- Building H1 is excluded from the report. The Crown casino and residential tower is included in the Concept Plan and will impact night sky viewing and will cause light spill.

- The Report is based on information 'determined in consultation with Sydney Observatory' in mid-2013. The data was provided prior to the announcement of the scale of the Barangaroo South Development.

  The Report (section 2.1) has misquoted and included erroneous information and interpretation of the viewing corridors provided by Sydney Observatory in November 2013.
  The data provided relates to the altitudes and azimuths required to view the Southern Cross, Jewel Box, Alpha Centauri and Omega Centauri.

  The view corridors included in the View Impact Assessment were not determined in consultation with Sydney Observatory and represent the principal difference in impact assessment that informs the comments provided in this submission.

- Sydney Observatory is in agreement with most of the statements in Section 3.2 and 3.3, excepting those relating to the building H1. The Report uses a mistaken definition of the view corridor, quoted as 210 to 225 degrees (section 3.2). This should be 210 to 235 degrees. The impact of the difference in the Azimuth Range is as follows:

  - (Section 3,3) claims the impact of the 275 metre Crown Casino and Residential Tower (H1) will not obstruct any of the Sydney Observatory view corridors. The HI Tower will affect viewing of Omega Centauri.

  - The tables and impact times (Section 4.2) for the 250 metre residential tower (R4A) and the 210 metre residential tower (R4B) contain errors. These include viewing times when an object is behind the buildings.

- The data based on the impact of cloud cover is based on Bureau of Meteorology records made at 9.00am and 3.00pm. These indicate that 50 percent of **days** are affected. Sydney Observatory records the impact of cloud cover on **night** viewing. These records indicate successful night viewing occurs on 70 percent of nights in the months August to October.

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- The Report (section 4.2) claims that the impact of the developments on night viewing can be reduced by changes to the structure and conduct of the night viewing program. This is not an option, for a number of operational reasons. The Building Code of Australia, not the facility, requires group size of maximum 22 people in the existing telescope domes.

  The Report claims the viewing schedule can be adjusted to enable the affected targets to be viewed first. This cannot be achieved across multiple groups in the April-September period. To maximise viewing in this period, the program is structured to provide 3 or 4 groups of 20 within a 90 minute period in each session, based on two sessions per night.

- Smog and Particulate Pollution (section 4.4) as well as scintillation do not impact a public observatory to the same extent as a research observatory. NSW Office of Environment and Heritage Air Quality data indicates a rolling fluctuation in Sydney, which is not increasing.

- The Report (section 1.3) refers to concerns expressed by Sydney Observatory about the impact of light spill, in a letter dated June 2011. These comments were in response to Modification 4 of MP06_0162, not the Modification currently on exhibition.

  The comments were made when the concept for Barangaroo South included a 170m high casino, hotel and residential tower. The residential hotel/casino is now proposed at 275 metres in height. The emphasis in this letter was on Barangaroo Central, transport, the Headland Park and cultural linkages.

- The lighting impact analysis (Section 5.0) should take into account the 2011 letter and eliminate up-lighting, not use blue lighting and recommend sensor lighting. It does not reference the impact of light spill from the eastern facades of the three residential towers, will likely feature extensive use of glass, to maximise views to the city and Sydney Harbour.

- Sydney Observatory is in agreement with the Report (Section 3.1) that Barangaroo Central does not impact the Sun, Moon, Planets, Ring Nebula and Star Albireo.

- The Report (Section 6.0) concludes the development will affect ’53 viewing nights out of 326 annual viewing nights’. This represents 20% of the night viewing program. The Observatory agrees with this in terms of direct blockage but, because this does not indicate the year-long impact of light-spill from predominantly residential towers, and because the tables are based on seeing part of the Southern Cross as acceptable, the Museum disputes the author’s conclusion that this impact is ‘negligible’.

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DETAILED RESPONSE
The following are detailed responses to the Lend Lease and UNSW Global Sydney Observatory Sky View Impact Assessment:

1.0 Introduction

1.1 Overview of Proposed Modification
Details of the Mod 8 buildings were provided to Sydney Observatory on 2 December 2013.

1.2 Site Location
No comment

1.3 Paragraph 1: this is an accurate summary.
Para 3: Lend Lease and Barangaroo Delivery Authority first met with Sydney Observatory on 30 October 2013.

The Report includes two quotes from a submission made by Sydney Observatory Manager Ms Toner Stevenson in 2011, (Appendix 2) regarding overall Barangaroo concept planning, transport links and lighting of the headland park.

Subsequently, in December 2013, Sydney Observatory was informed of the Mod 8 buildings.

2.0 Sydney Observatory Concerns

This is a reasonable short summary of the Observatory's concerns.

2.1 Clear View Requirements to the Western Sky
The Report quotes from an old document prepared by astronomer Dr Andrew Jacob (this is included in the Report as 7.3 Appendix 3). The Report was prepared on 30 October 2013 and predated detailed knowledge of the three Barangaroo precincts and specifically the Mod 8 plan.

The section titled "The Southern Cross and nearby objects…" contains misquotations. "From 225-deg up to 210-deg azimuth" should read "up to and including azimuths of 210-deg (at 18-deg altitude)". "Up to 298-deg azimuth" should read "up to an azimuth of 225-deg azimuth".

The other sections. "Sun, Moon and Planets", "Ring Nebula and Star Albireo" are reasonable paraphrases of Dr Jacob's document.

The Summary paragraph is not a faithful paraphrase of Dr Jacob's document.

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The Report states:
"…the view corridors can be determined as:
Between 210deg and 225deg azimuth at altitude 18deg, and
Between 236deg and 303deg Azimuth"

Dr Jacob's summary, included in Section 7.3 Appendix 3 of the Report, states:
"…any obstruction to the SW must be limited to azimuths between 225 & 236 deg at most, up to an altitude of 18deg. Any obstruction to the NW must be limited to azimuths greater than 303deg (318deg) and up to an altitude of 15deg."

The Report has misinterpreted Sydney Observatory's requirement and assumed any obstruction within azimuths 225 to 236deg is acceptable.

The Report's azimuth range "210 to 255 degree" appears to originate in a Lend Lease report titled "Sydney Observatory Sight Lines". This report is dated November 2013, but was not provided to Dr Jacob until 2 December 2013.

The Consultant, in Section 4.2,5 states a different azimuth range again of "210 and 218".

Figures 1 and 2 illustrate the difference in Sydney Observatory's requirements and the Lend Lease interpretation.

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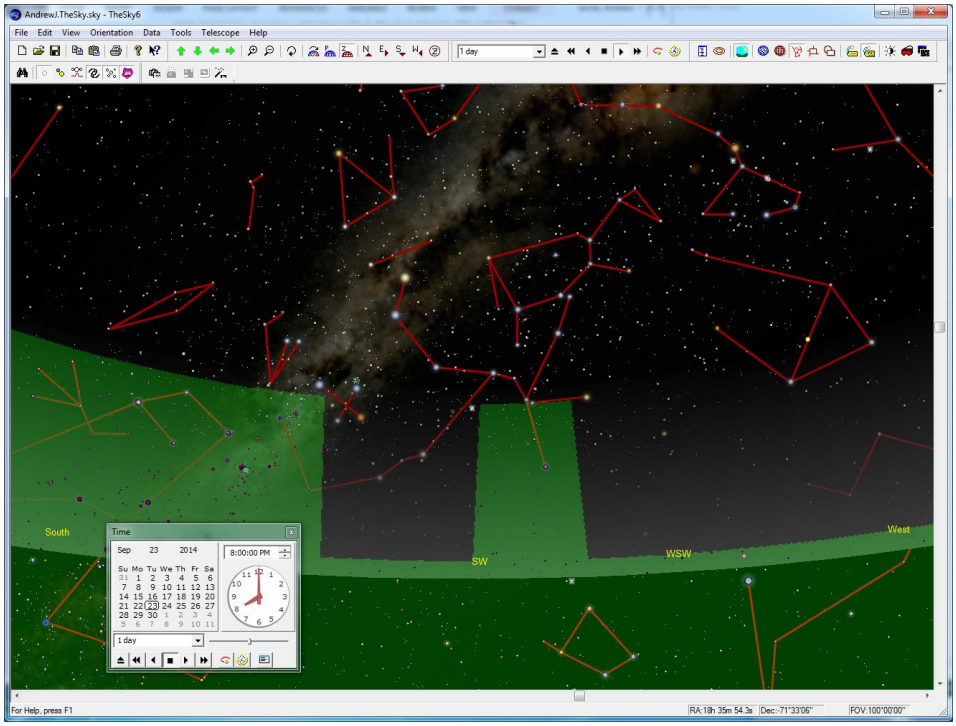

Fig. 1 – Sydney Observatory requirements

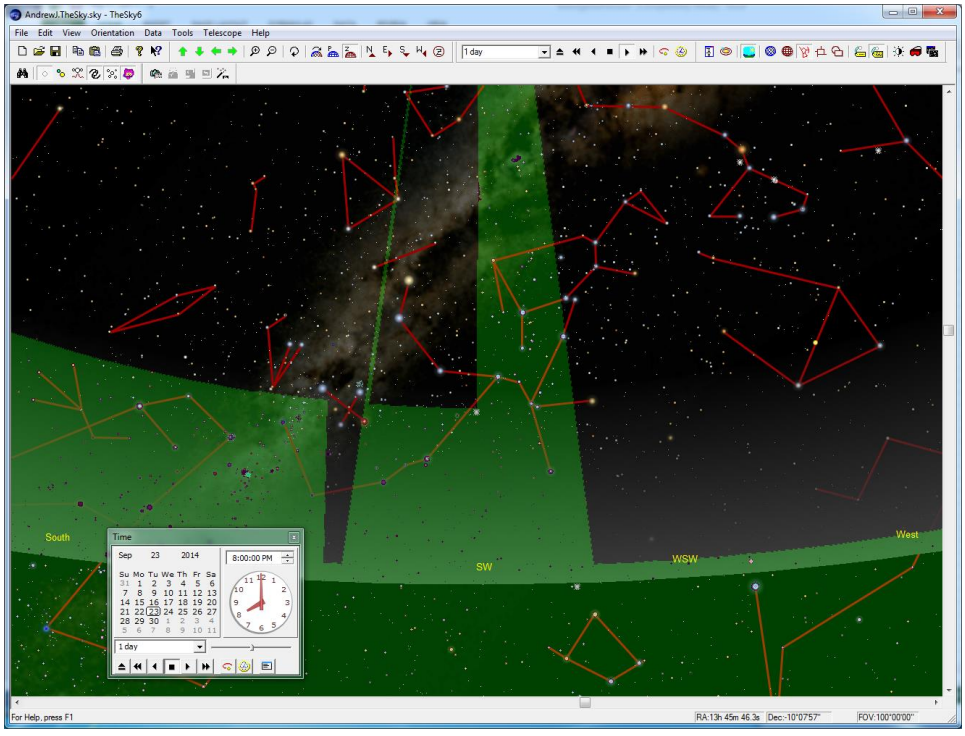

Fig. 2 – Lend Lease Interpretation

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2.2 Light spill

This is a largely satisfactory summary of the document in Section 7.2 but it excludes mention of the biological effects of light, particularly blue wavelengths.

3.0 View Analysis

While Sydney Observatory was supplied with a digital 3D model and drawings similar to those included in Appendix 4, no sightlines were quantified, despite being requested. Sydney Observatory measured all azimuth and altitude angles of the buildings from the 3D model and supplied drawings.

The Report's incorrect summary in Section 2.1 meant the impact of Casino and residential tower (H1) on views was not investigated.

3.1 Sun, Moon Planets, Ring nebula and star Albireo; Western View Assessment

Sydney Observatory agrees with the first paragraph. Views to solar system objects, Ring Nebula and Albireo are clear and unobstructed between azimuths of 236-deg and 303-deg by the Mod 8 buildings.

3.2 The Southern Cross and Nearby Objects…South Western View Assessment

The drawing shows view lines drawn from the South Dome not the North Dome, however, the difference is negligible.

The Report's erroneous summary in Section 2.1, stating the incorrect azimuth range of "210-225deg" now informs all impact assessments included in the Report. Here it results in the impact of the Casino H1 not being investigated.

The Report includes four dot-point Results:

Dot Point 1: This is incorrect, H1 is over 18-degree altitude and does affect viewing of Omega Centauri
DP2: R5 is in the Sydney Observatory view corridor but the Observatory's calculations show it is too low to block views from Sydney Observatory
DP3: re R4A – Sydney Observatory agrees with this statement
DP4: re R4B – Sydney Observatory agrees with this statement

Sydney Observatory accepts the Lend Lease values for the azimuths of the buildings R4A and R4B and these are used for the further comments included in this response. For previous work done by Sydney Observatory these azimuths were measured from drawings and the digital 3D model supplied by Lend Lease, but the differences are small.

Fig 4: In this figure azimuth angles are drawn from the South dome, not the North dome. The view corridor excludes H1.

Fig 5: The altitude of H1 is not shown.

3.3 View Analysis Summary

The Report includes four dot-point observations:
DP1: Sydney Observatory agrees with this statement.
DP2: This is incorrect due to the incorrect summary in Section 2.1. Hotel H1 does impact Sydney Observatory's view to Omega-Centauri.
DP3: Sydney Observatory agrees with this point excepting that Omega-Centauri should not be included in this statement. Views to Omega Centauri are impacted by Hotel H1 but not by R4A and R4B.
DP4: Sydney Observatory agrees with this statement.

4.0 Timing Analysis

Para 1 and dot-points: The effect of H1 on views to Omega Centauri is not included. Omega-Centauri is not affected by R4A and R4B in azimuth range 210-218-degrees.

Para 2: Sydney Observatory agrees, and agrees no further assessment of the effects of Barangaroo *South* is required here in regard to the named objects.

Para 3: No comment. Comments on the Consultant's report are included below.

Para 4: The telescope's field of view is not relevant. However, it is not 5.7-degrees but depends on the eyepiece being used - typically Sydney Observatory uses a field of view of about 0.25 to 0.5. The Observatory agrees with the use of a margin of error and a larger impact area but, to account for the view impact of the Casino and Residential Tower H1, the azimuth range should increase to be 210 to X degrees (where X is the azimuth of the right-hand side of H1) and altitude range should increase to be 18 to Y degrees (where Y is the altitude of H1 subtended at the North dome). From drawings supplied by Lend Lease Sydney Observatory measured X to be 231degrees and Y to be 29 degrees.

Para 5: This is incorrect. Whilst Sydney Observatory has focussed on four iconic or key objects, the Observatory has not claimed that there were no other objects impacted.

Other objects that are viewed from time to time include stars Achernar and eta-Carinae; the Homunculus nebula and the Blue Planetary nebula and a few star clusters near eta-Carinae.

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4.1 Sydney Observatory Operation and Night Time Viewing Hours

Para 1: This is a reasonable summary of the Observatory's status.

Para 2: This paragraph contains several misunderstandings about the nature of Sydney Observatory. Sydney Observatory is presently not involved in research astronomy however, it *is* an astronomical observatory. It is registered as a Designated Observatory number 2-9 on the list held by the Astronomical Society of Australia (http://asa.astronomy.org.au/observatories.html). The Australian Astronomical Observatory is a national facility, it does not serve NSW.

Para 3: The Report quotes Sydney Observatory's web page for opening times. Sessions are described as "approximately 90 minutes" long. However, in practice observing does occur from 6pm to 8pm and from 8pm to 10pm (or 8:15 to 10:15pm in summer), and viewing has continued until 10:30pm at times. However, for comparison with the Report and for the purposes of this analysis Sydney Observatory has adopted the assumption that sessions are only 90 minutes long.

Para 4 and dot-points: We refer to the comment on paragraph 3 above.

Para 5: The figures quoted for number of sessions, days, etc. are close to correct. Actual figures for 2014 were: 161 nights of double night viewings and 159 nights of single night viewings totalling 320 nights. There were 481 sessions and 722 hrs (at 90min/session) of viewing available.

4.2 Sky View Assessment against Night time visit hours

Para 1: The four objects are impacted from the beginning of August to mid-October, not from "…end of August and through September".

Para 2 and Fig 6: The objects are correctly identified. The red obstruction box should be enlarged according to Sydney Observatory's comments in Section 4.0 (above) to be azimuths of 210 to 231 degrees and altitudes of 18 to 29 degrees.

Sydney Observatory has analysed the impact of the Mod 8 buildings on views to the four objects. The analysis is complex due to the effects of the change to Australian Eastern Daylight Time (termed Daylight Saving Time or DST hereafter) on 5 October, the slowly varying time of sunset and civil twilight and the progressive loss of the objects behind the buildings across the course of time.

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The impact on star Alpha-Centauri is presented in graphical form to indicate the proportion of viewing time lost to obstruction by the Mod 8 buildings. Tables of impact are included to quantify this impact.
For this analysis the Sunday night and Good Friday closures of Sydney Observatory were ignored due to the added complexity they introduce. The effect of this on our conclusions will be negligible because these days are common to both “with Mod 8” and “without Mod 8” cases.

Alpha Centauri

Comments on the Report:

The Report’s table (on page 15) contains errors. It claims that we can observe Alpha-Centauri after it moves *below* the Report’s Obstruction Box. However at that position the building is still blocking the view. This error occurs in the last row of the table in the columns for 22-September, 29-September and 6-October.

Although the two Pointers together are a worthy object for the public to view from the North dome, Sydney Observatory has always emphasised the importance of viewing just Alpha-Centauri (the brighter of the two Pointer stars and the closest star system to the Sun). The Sydney Observatory analysis only concerns Alpha-Centauri.

The Report concludes that “there will be no viewing sessions where it will not be possible to view The Pointers…if the…schedule is arranged appropriately”. Fig 3 and Table 1 show this conclusion to be incorrect – from 18 October to 6 November the Mod 8 buildings completely obstruct Alpha-Centauri from the start of the 8:15 viewing session. Without the Mod 8 buildings Alpha-Centauri is observable in this period.

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Sydney Observatory analysis

Figure 3 shows the impact of the buildings on viewing of Alpha-Centauri.

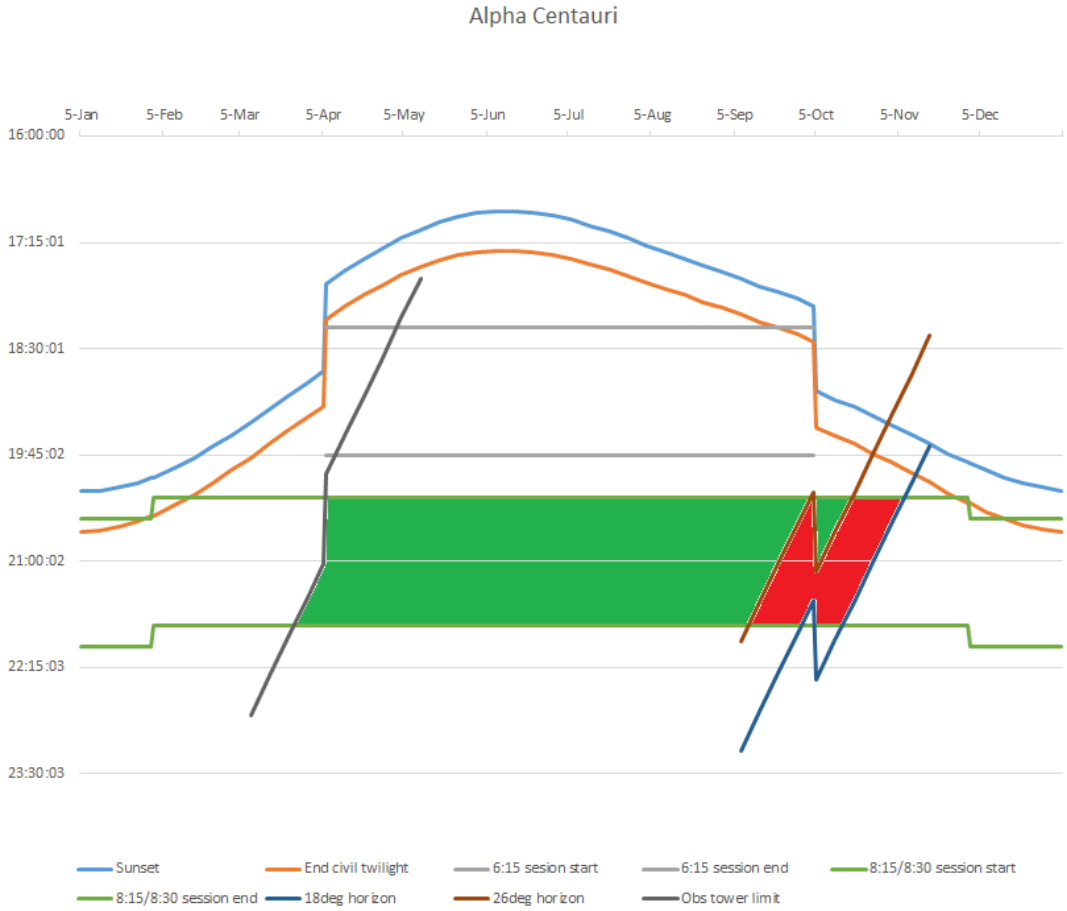

Fig 3: A graphical representation of the impact of Mod 8 buildings on Sydney Observatory's viewing of Alpha-Centauri. Viewing is presently possible in the green plus red region. The Mod 8 plan would block viewing in the red region.

The following points will assist interpretation of this figure.

The graph shows time on the vertical axis increasing downwards and date on the horizontal axis. Sunset is shown by the blue curve. The orange curve shows the end of civil twilight – the steps are caused by daylight saving time changes.

The grey lines are the beginning (6:15pm) and end (8:15pm) of the first viewing session.

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The green lines are the beginning (8:15 or 8:30pm) and end (9:45 or 10:00pm) of the second viewing session.

The diagonal dark grey line represents the viewing limit imposed by Sydney Observatory's own tower. Viewing of Alpha-Centauri is possible only to the right of this line.

The diagonal brown line represents the 26-degree limit caused by the Mod 8 buildings. With the Mod 8 buildings viewing is possible only to the left off this line.

The diagonal blue line represents the 18-degree altitude limit imposed by presently existing buildings and a tree. Viewing is possible presently only to the left off this line

Viewing of Alpha-Centauri is presently possible in the green shaded region plus the red shaded region. That is, after it rises above the Observatory's tower (late March) and before it sets behind existing buildings and a tree (October).

With the Mod 8 buildings present viewing would be possible in the green shaded region only.

Graphs for other objects appear similar, but with the dark grey and brown diagonal lines shifted to left or right.

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Table 1 summarises the impact of Mod 8 buildings on viewing of star Alpha Centauri.

	Without Mod 8	With Mod 8	Time lost [days or h:m]	Loss, %
First Viewable	27-Mar	27-Mar	0	
First full (90min) session	6-Apr	6-Apr	0	
Last full (90min) session	15-Oct	10-Sep	35	
Last viewable	6-Nov	18-Oct	19	
Total viewable days	225	206	19	
Viewing time available [h:m]	308:47	263:36	45:11	15

First day impacted	11-Sep	
Last day impacted	6-Nov	
Total days impacted (ie lost or partially lost to Mod 8)	57	25%

Table 1: The impact of Mod 8 buildings on viewing of star Alpha Centauri.

Summary of impact on Alpha-Centauri

Only buildings R4A and R4B obstruct viewing of Alpha-Centauri.

The Mod 8 buildings do not affect viewing of Alpha-Centauri during the 6:15 session.

Alpha-Centauri is presently viewable for 308 hours and 47 minutes over 225 days from 27March to 6 November.

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With the Mod 8 buildings Alpha-Centauri would be viewable for 263 hours and 36 minutes over 206 days from 27 March to 18 October.

The Mod 8 buildings obstruct Alpha-Centauri on 57 days, from 11 September to 6 November, or 25% of the presently available viewing days.

The Mod 8 buildings obstruct Alpha-Centauri for a total integrated time of 45 hours and 11 minutes or 15% of the presently available viewing time.

The Southern Cross
Comments on the Report

Sydney Observatory analysis
Figure 4 shows the impact of the buildings on viewing of the Southern Cross.

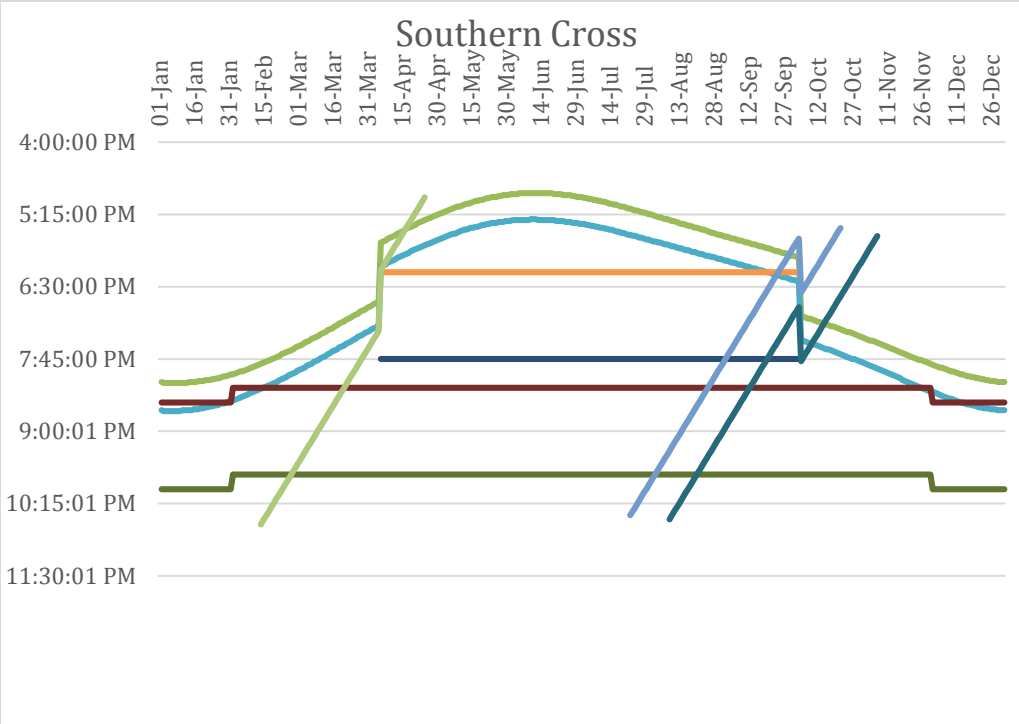

Figure 4: A graphical representation of the impact of Mod 8 buildings on Sydney Observatory's viewing of the Southern Cross. The Cross is assumed to be impacted as soon as just one of its stars is obstructed.

Table 2 summarises the impact of Mod 8 buildings on viewing of the Southern Cross during the first (6:15-7:45pm) session.

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Summary of impact on the Southern Cross for the first viewing session

Only buildings R4A and R4B obstruct viewing of the Southern Cross.

The Southern Cross is presently viewable for 266 hours and 23 minutes over 182 days from 6 April to 4 October.

With the Mod 8 buildings the Southern Cross would be viewable for 241 hours and 45 minutes over 173 days from 6 April to 25 September.

The Mod 8 buildings obstruct the Southern Cross on 32 days, from 3 September to 4 October, or 18% of the presently available viewing days.

The Mod 8 buildings obstruct the Southern Cross for a total integrated time of 24 hours and 38 minutes or 9% of the presently available viewing time.

	Without Mod 8	**With Mod 8**	**Time lost [days or h:m]**	**Loss, %**
First Viewable	6-Apr	6-Apr	0	
First full (90min) session	6-Apr	6-Apr	0	
Last full (90min) session	20-Sep	2-Sep	18	
Last viewable	4-Oct	25-Sep	9	
Total viewable days	182	173	9	
Viewing time available [h:m]	266:23	241:45	24:38	9

First day impacted	3-Sep	
Last day impacted	4-Oct	
Total days impacted (ie lost or partially lost to Mod 8)	32	18%

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Table 2: The impact of Mod 8 buildings on viewing of the Southern Cross in the first (6:15-7:45pm) session.

Table 3 summarises the impact of Mod 8 buildings on viewing of the Southern Cross during the second (8:15-9:45pm) session.

Summary of impact on the Southern Cross for the second viewing session

Only buildings R4A and R4B obstruct viewing of the Southern Cross.

The Southern Cross is presently viewable for 263 hours and 28 minutes over 198 days from 27 February to 12 September.

With the Mod 8 buildings the Southern Cross would be viewable for 236hours and 21minutes over 180 days from 27 February to 25 August.

The Mod 8 buildings obstruct the Southern Cross on 41 days, from 3 August to 12 September, or 21% of the presently available viewing days.

The Mod 8 buildings obstruct the Southern Cross for a total integrated time of 27 hours and 7 minutes or 10% of the presently available viewing time.

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	Without Mod 8	With Mod 8	Time lost [days or h:m]	Loss, %
First Viewable	27-Feb	27-Feb	0	
First full (90min) session	22-Mar	22-Mar	0	
Last full (90min) session	20-Aug	2-Aug	18	
Last viewable	12-Sep	25-Aug	18	
Total viewable days	198	180	18	
Viewing time available [h:m]	263:28	236:21	27:07	10

First day impacted	3-Aug	
Last day impacted	12-Sep	
Total days impacted (ie lost or partially lost to Mod 8)	41	21%

Table 3: The impact of Mod 8 buildings on viewing of the Southern Cross in the second (8:15-9:45pm) session.

The Jewel Box

Comments on the Report

The Report's table (on page 13) contains errors. It claims Sydney Observatory can observe the Jewel Box after it moves *below* their Obstruction Box. However at that position the building is still blocking the view. This error occurs in the last row of the table in the columns for 8 September, 15 September and 29 September.

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Discovery Centre
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Castle Hill NSW 2154
+61 2 9762 1300

Sydney Observatory analysis

Figure 5 shows the impact of the buildings on viewing of the Jewel Box.

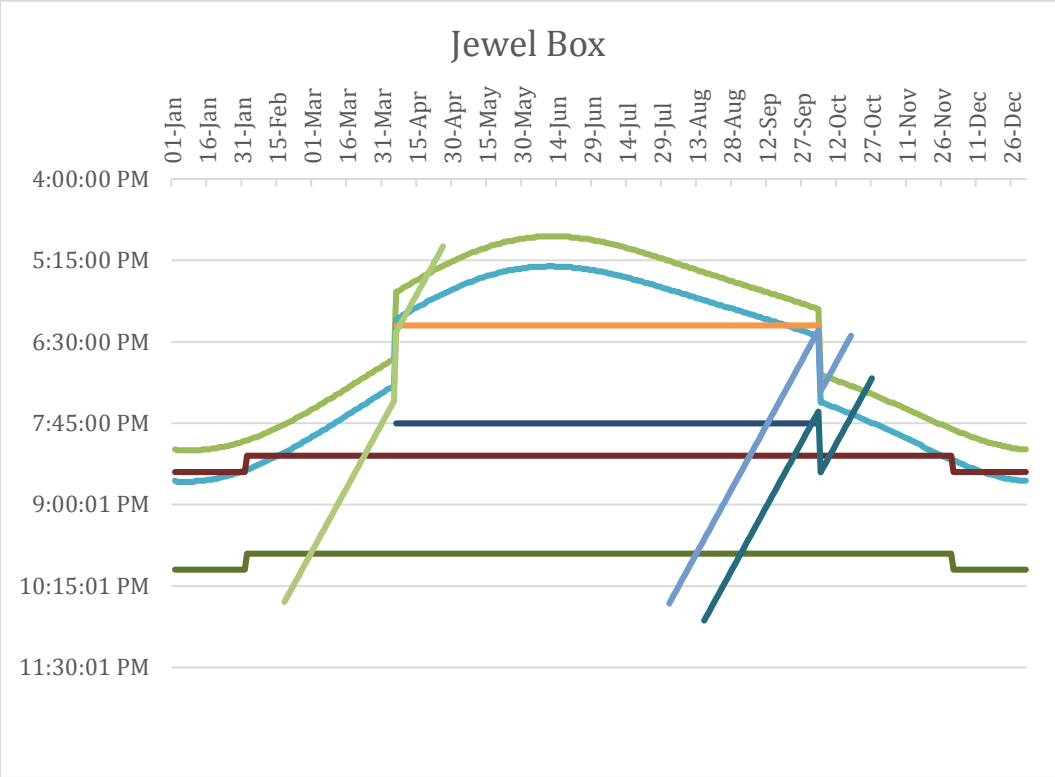

Figure 5: A graphical representation of the impact of Mod 8 buildings on Sydney Observatory's viewing of the Jewel Box.

Table 4 summarises the impact of Mod 8 buildings on viewing of the Jewel Box during the first (6:15-7:45pm) session.

Summary of impact on the Jewel Box for the first viewing session

Only buildings R4A and R4B obstruct viewing of the Jewel Box.

The Jewel Box is presently viewable for 272 hours and 32 minutes over 182 days from 6 April to 4 October.

With the Mod 8 buildings the Jewel Box would be viewable for 256 hours and 37 minutes over 182 days from 6 April to 4 October.

The Mod 8 buildings obstruct the Jewel Box on 22 days, from 13 September to 4 October, or 12% of the presently available viewing days.

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The Mod 8 buildings obstruct the Jewel Box for a total integrated time of 15 hours & 55 minutes or 6% of the presently available viewing time.

	Without Mod 8	With Mod 8	Time lost [days or h:m]	Loss, %
First Viewable	6-Apr	6-Apr	0	
First full (90min) session	8-Apr	8-Apr	0	
Last full (90min) session	1-Oct	12-Sep	19	
Last viewable	4-Oct	4-Oct	0	
Total viewable days	182	182	0	
Viewing time available [h:m]	272:32	256:37	15:55	6

First day impacted	13-Sep	
Last day impacted	4-Oct	
Total days impacted (ie lost or partially lost to Mod 8)	22	12%

Table 4: The impact of Mod 8 buildings on viewing of the Jewel Box in the first (6:15-7:45pm) session.

Table 5 summarises the impact of Mod 8 buildings on viewing of the Jewel Box during the second (8:15-9:45pm) session.

Summary of impact on the Jewel Box for the second viewing session

Only buildings R4A and R4B obstruct viewing of the Jewel Box.

The Jewel Box is presently viewable for 277 hours and 14 minutes over 211 days from 1 March to 8 October.

With the Mod 8 buildings the Jewel Box would be viewable for 248 hours and 6 minutes over 188 days from 1 March to 4 September.

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The Mod 8 buildings obstruct the Jewel Box on 46 days, from 13 August to 8 October, or 22% of the presently available viewing days.

The Mod 8 buildings obstruct the Jewel Box for a total integrated time of 29 hours and 8 minutes or 11% of the presently available viewing time.

	Without Mod 8	With Mod 8	Time lost [days or h:m]	Loss, %
First Viewable	1-Mar	1-Mar	0	
First full (90min) session	24-Mar	24-Mar	0	
Last full (90min) session	31-Aug	12-Aug	19	
Last viewable	8-Oct	4-Sep	34	
Total viewable days	211	188	23	
Viewing time available [h:m]	277:14	248:06	29:08	11

First day impacted	13-Aug	
Last day impacted	8-Oct	
Total days impacted (ie lost or partially lost to Mod 8)	46	22%

Table 5: The impact of Mod 8 buildings on viewing of the Jewel Box in the second (8:15-9:45pm) session.

Omega Centauri

Comments on the Report

Buildings R4A and R4B do not block the view to Omega-Centauri. The presence of the Table in the Report (on page 14) makes no sense. However, building H1 does block the view to Omega-Centauri

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Sydney Observatory analysis

Figure 6 shows the impact of building H1 on viewing of Omega-Centauri.

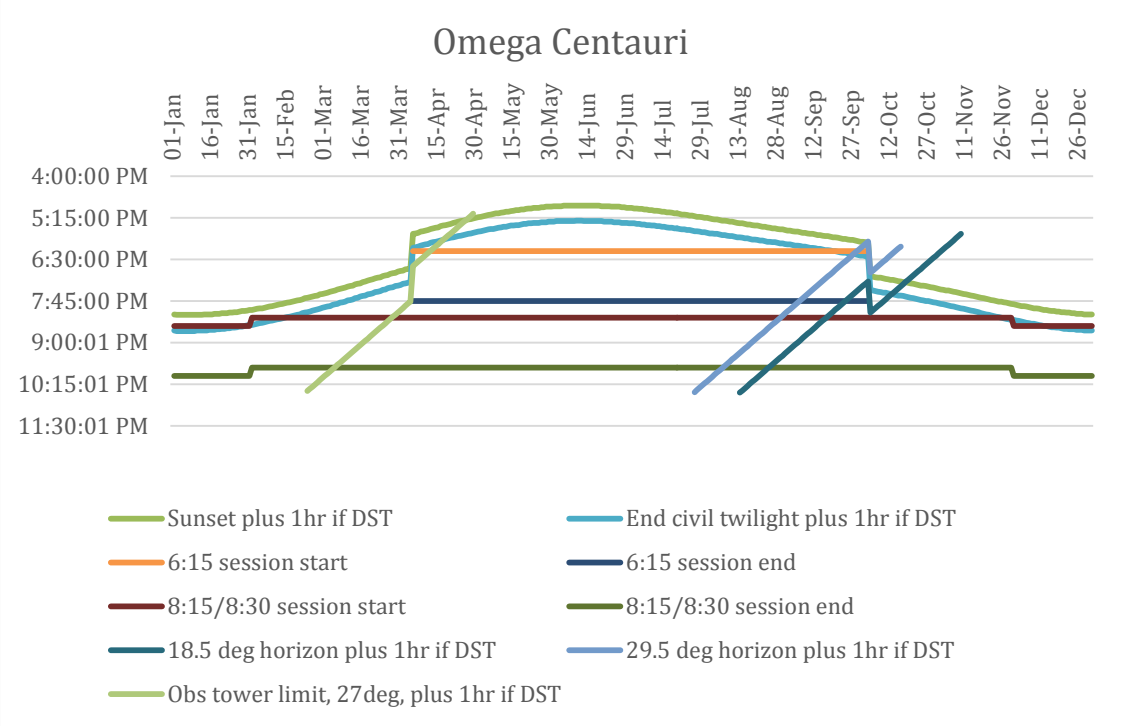

Figure 6: A graphical representation of the impact of Mod 8 buildings on Sydney Observatory's viewing of Omega-Centauri.

Table 6 summarises the impact of Mod 8 buildings on viewing of Omega-Centauri during the first (6:15-7:45pm) session.

Summary of impact on the Omega-Centauri for the first viewing session

Only building H1 obstructs viewing of Omega-Centauri.

On some nights (from 21 September to 4 October) Omega-Centauri is first viewed only after civil twilight ends. It is a fainter object than the Southern Cross, Alpha-Centauri or the Jewel Box and requires darker post-twilight conditions for viewing.

Omega-Centauri is presently viewable for 267 hours and 6 minutes over 182 days from 6 April to 4 October.

With the Mod 8 buildings Omega-Centauri would be viewable for 246 hours and 20 minutes over 176 days from 6 April to 28 September.

The Mod 8 buildings obstruct Omega-Centauri on 28 days, from 7 September to 4 October, or 15% of the presently available viewing days.

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The Mod 8 buildings obstruct Omega-Centauri for a total integrated time of 20 hours and 46 minutes or 8% of the presently available viewing time.

	Without Mod 8	With Mod 8	Time lost [days or h:m]	Loss, %
First Viewable	6-Apr	6-Apr	0	
First full (90min) session	13-Apr	13-Apr	0	
Last full (90min) session*	24-Sep	6-Sep	18	
Last viewable	4-Oct	28-Sep	6	
Total viewable days	182	176	6	
Viewing time available [h:m]	267:06	246:20	20:46	8

First day impacted	7-Sep	
Last day impacted	4-Oct	
Total days impacted (ie lost or partially lost to Mod 8)	28	15%

Table 6: The impact of Mod 8 buildings on viewing of Omega Centauri in the first (6:15-7:45pm) session.

*From 22 September civil twilight ends after 6:15pm. For this row of this table a “full session” is taken to be 90-minutes minus the time lost to civil twilight, the effect being common to both “with Mod 8” and “without Mod 8” cases.

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Table 7 summarises the impact of Mod 8 buildings on viewing of Omega-Centauri during the second (8:15-9:45pm) session.

Summary of impact on the Omega-Centauri for the second viewing session

Only building H1 obstructs viewing of Omega-Centauri.

Omega-Centauri is presently viewable for 259 hours and 9 minutes over 196 days from 6 March to 17 September.

With the Mod 8 buildings Omega-Centauri would be viewable for 231 hours and 46 minutes over 178 days from 6 March to 30 August.

The Mod 8 buildings obstruct Omega-Centauri on 41 days, from 8 August to 17 September, or 21% of the presently available viewing days.

The Mod 8 buildings obstruct Omega-Centauri for a total integrated time of 27 hours and 23 minutes or 11% of the presently available viewing time.

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	Without Mod 8	With Mod 8	Time lost [days or h:m]	Loss, %
First Viewable	6-Mar	6-Mar	0	
First full (90min) session	29-Mar	29-Mar	0	
Last full (90min) session	25-Aug	7-Aug	18	
Last viewable	17-Sep	30-Aug	18	
Total viewable days	196	178	18	
Viewing time available [h:m]	259:09	231:46	27:23	11

First day impacted	8-Aug	
Last day impacted	17-Sep	
Total days impacted (ie lost or partially lost to Mod 8)	41	21%

Table 7: The impact of Mod 8 buildings on viewing of Omega Centauri in the second (8:15-9:45pm) session.

4.3 Timing Analysis Summary

Dot point 1: Sydney Observatory agrees with this statement

Dot points 2-5: Correct data is noted above

Dot point 6: Sydney Observatory agrees the four target objects are lost to view in summer, but between August-October and February-April, but the buildings represent an *additional* time when they will be lost to view.

4.4 Current Observation Issues at Sydney Observatory

The effects mentioned are presently existing issues. They have a less significant effect on public astronomy than on research astronomy. With regard to scintillation, for example, it is the case that visual observing

(with an eye to the telescope) can provide better views than professional astronomy (where a camera is attached to the telescope). The Mod 8 buildings will cause an *additional* blocking impact on the view and *additional* light spill towards Sydney Observatory.

The cloud cover data is incorrect, as has already been explained.

	Clear	Cloud &/or rain, No viewing	Some Cloud but viewing successful	Closed Sunday or no information
2014	34	18	27	13
2013	46	6	24	16
2012	34	17	27	14
Sum	114	41	78	43
%	41%	15%	28%	16%

Table 8 provides figures for cloud cover and its present impact on viewing.

Table 8: The number of nights of various weather conditions during August, September and October in 2012, 2013 and 2014 at Sydney Observatory.

5.0 Lighting Impact

Sydney Observatory is an astronomical observatory, it is not a research observatory. The location, the atmospheric conditions and the various present constraints do not prevent public observing.

The Sydney Harbour Bridge is not the worst source of light pollution. The general aggregate light pollution from the city, and particularly city buildings are the most significant source of light pollution – additional buildings of Mod 8 plan would significantly increase the light pollution effect on Sydney Observatory. The Mod 8 buildings *cannot* have zero “increased light spill effect on Sydney Observatory”.

6.0 Conclusion

DP1: No physical impact (blocking of views), but increased light spill
DP2: Disagree. See analysis above. This does not account for multiple groups per session
DP3: Disagree. See analysis above
DP4: Disagree. Omega-Centauri Is not obstructed by R4A & R4B, but is obstructed by H1
DP5: It is true, but not relevant, that the objects are lost to view over summer months. Mod 8 causes *additional* impact/blockage to views

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DP6: Disagree. The Mod 8 buildings overlook Sydney Observatory and have direct line-of-sight to Sydney Observatory – they *cannot* have zero light spill effect.

Overall conclusions

The Mod 8 concept plan buildings have significant impact on viewing of the Southern Cross, Alpha-Centauri, the Jewel box, Omega Centauri and other objects both by way of increased light spill and by blocking the view at certain times of the year. From 12 to 25% of available viewing days and from 6 to 15% of the available viewing time of these iconic objects will be lost if the Mod 8 buildings are constructed.

Viewing of alternative objects is not reasonable. The four objects considered here are core objects, the brightest objects of their type and the most visually appealing and educationally effective objects for the public to view. This is the case regardless of how low in the sky these objects are viewed. Sydney Observatory views these objects more than others for these very good reasons.

The location of Sydney Observatory, the weather, scintillation, smog and existing light pollution are not relevant to this issue. The issue is the *additional* impact on viewing and *additional* light spill caused by the Mod 8 buildings and Barangaroo South.

The impacts on the functioning of Sydney Observatory by the Mod 8 Concept Plan will not be ‘negligible’. The conclusion drawn in the Report is incorrect and not supported by the evidence.

Rose Hiscock
Director

27 April 2015