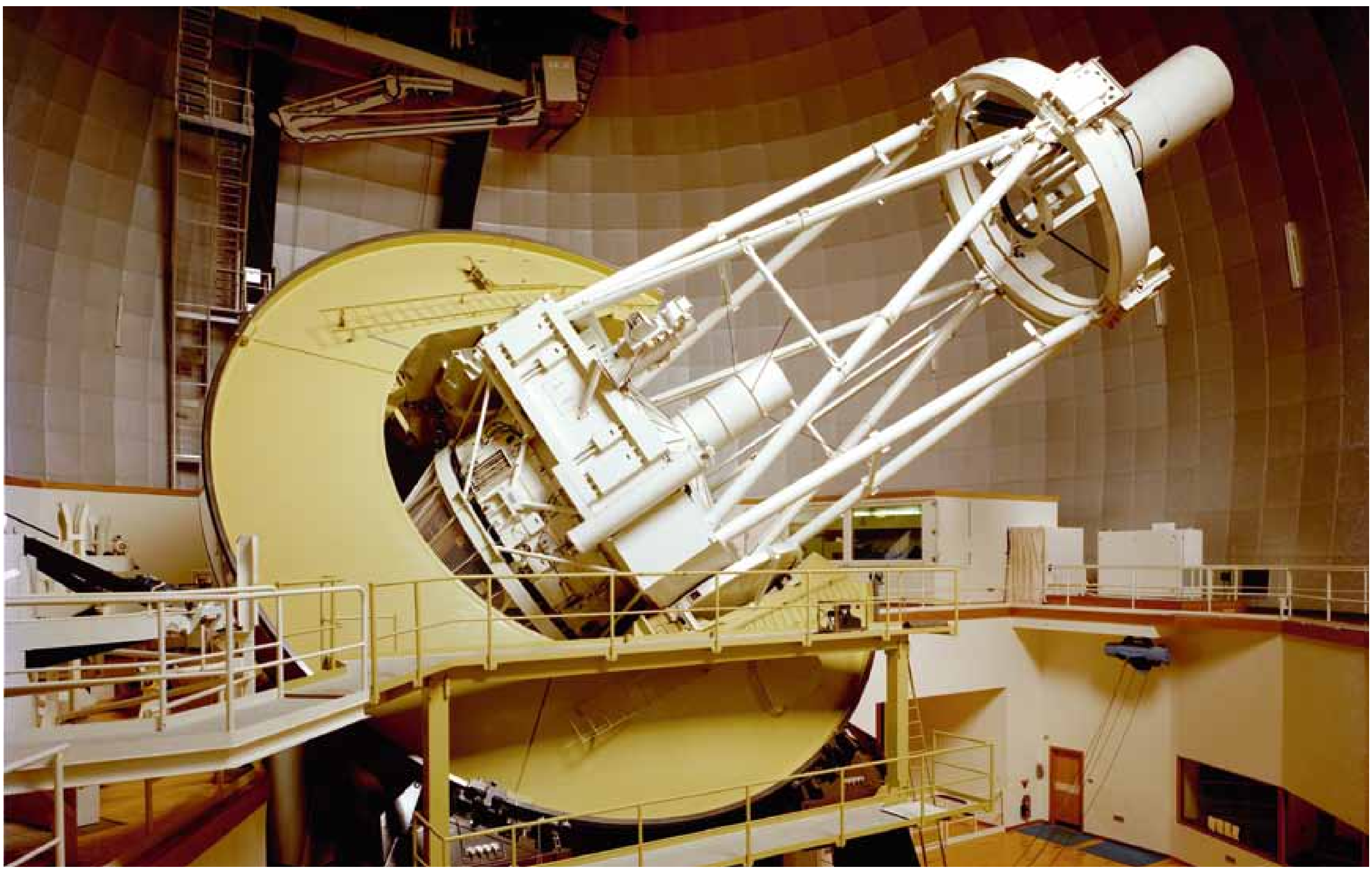
>>> SEAN McGOWAN REPORTS

When star gazing, seeing is believing

It's not often that bi-national relations, science and the advancement of human knowledge will hinge on the successful overhaul of an HVAC system. It's even rarer when it occurs in outback New South Wales, as Sean McGowan discovered.



The Telescope. Image credit David Malin.

Siding Spring is the official home of Australian astronomy, located in surroundings of the Warrumbungle National Park, some 30km west of the New South Wales town of Coonabarabran.

Along with being home to 13 different telescopes, it is the site of the Anglo Australian Observatory, a world class observational facility funded jointly by the Australian and British Governments. This observatory operates Australia's largest optical telescope, the 4m class Anglo Australian Telescope (AAT), as well as the UK Schmidt telescope on behalf of the astronomical communities of both countries.

The Anglo Australian Observatory is a world leader in astronomical research, as well as in the development of innovative telescope instrumentation, and takes a leading role in the formulation of long-term plans for astronomy in Australia and the United Kingdom.

The Anglo Australian Telescope

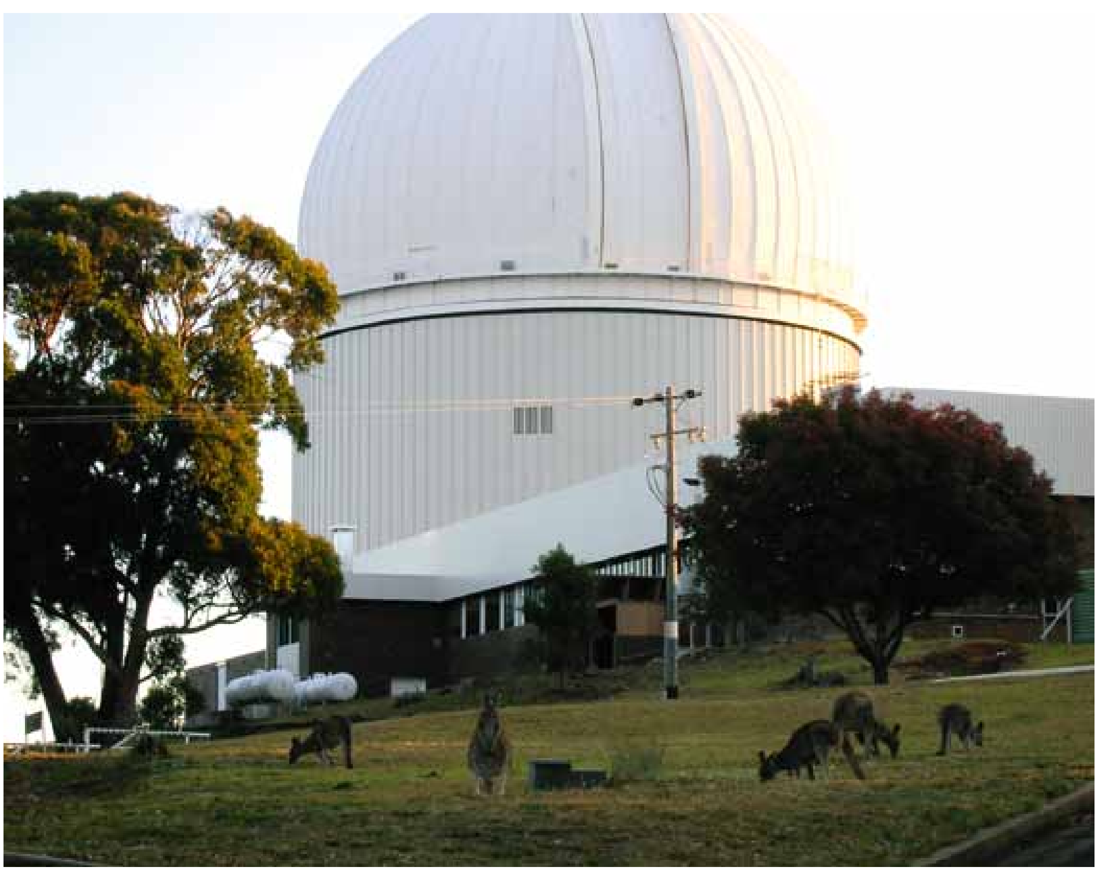
Commissioned in 1974, the AAT was one of the last 4m equatorially mounted telescopes to be built, with its excellent optics, mechanical stability and precision computer control making it one of the most highly regarded telescopes in the world.

Up until the 1970s, most of the world's largest telescopes had been constructed in the northern hemisphere – despite the fact that some of the most interesting regions of the night sky were difficult, if not impossible, to view from northern latitudes. As such, the AAT was built in Australia to allow astronomers world-wide the ability to explore in detail regions of the southern sky including the centre of our own Milky Way Galaxy and its nearest neighbours, the Magellanic Clouds, along with a host of globular clusters and radio galaxies.

In fact, the AAT is now the number one ranked telescope of its size in the world for both its productivity and impact on the scientific world, and is currently used in a program searching for planets around 240 nearby stars, in the hope of answering man's eternal question – is there life beyond Earth?

According to the Observatory, the AAT can be used in many configurations, each requiring a different instrument or detector to collect and anaylse light. Most astronomers use charged-coupled devices (CCDs) – highly sensitive solid-state devices which convert feeble light into digital signals which are then collected and stored on computers for further analysis, much like an electronic photograph.

A chiller in use at the Anglo Australian Observatory.



The Anglo Australian Observatory. Image credit David Malin.

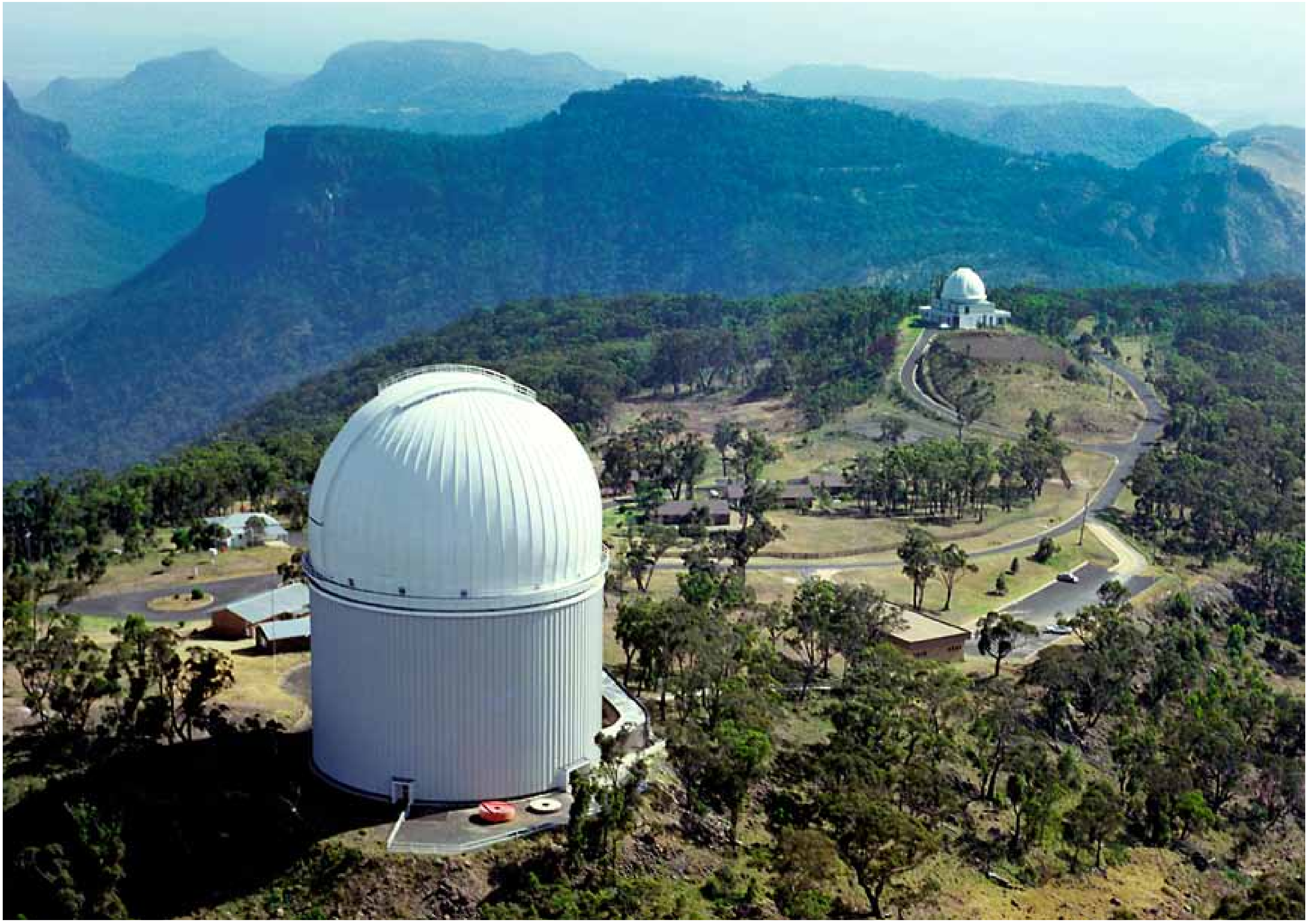
The most commonly used instruments, however, are its spectrographs, which split light from distant objects into its constituent colours. The resulting spectrum of colours can then be studied in detail to measure important properties revealed by the spectrograph, including temperature, chemical composition, velocity or distance of an object; revealing vital information about distant stars and galaxies that photographs do not show.

Other instruments collect light energy from the infrared region of the spectrum, thus being sensitive to the temperature of objects too cool to emit visible light. This is where the Observatory has taken a leading role in designing and building IR instrumentation, the latest of which is IRIS-2, providing both images and spectra of the night sky.

In recent times, it has also pioneered the use of optical fibres in astronomy, currently leading the world in this work with the Two-Degree Field facility using flexible optical fibres to collect the light from up to 400 faint stars or galaxies from a two degree field of view.

Two degrees of the night sky is roughly equal to four Moon diameters across. The Two-Degree Field facility in effect increases the AAT's prime focus four-fold. In doing so efficiency is also improved as the telescope had traditionally only been able to observe one object at a time.

Critical to this observation, however, is the temperature of the dome in which the AAT is housed.



The Anglo Australian Observatory is set among the Warrumbungle National Park – 30km west of the New South Wales town of Coonabarabran. *Image credit David Malin.*

Temperature and observation at the AAO

According to Doug Gray, operations manager for the Anglo Australian Observatory at Siding Spring, the image quality of a telescope is greatly affected by thermal gradients that occur in the optical light path of the telescope due to the changing refractive index.

In fact a vast amount of research has been conducted on the subject.

"R. Racine et al in 1991 established that image quality, known as the 'seeing', is greatly affected by the temperature differential between the night time air temperature and the internal dome air temperature, known as 'dome seeing'; and the mirror surface temperature and the dome air temperature, known as 'mirror seeing'," Gray explains.

Efforts to address this issue have been ongoing at the AAO since the late 1970s, when the dome's hammerhead was first identified as a major contributing interior heat source.

In 1982, a venting system (two large fans) was installed which recycled the air contents of the dome within four minutes, just prior to observation. This venting effect was designed to equalise the temperature gradient between the dome internal temperature and the outside ambient temperature.

It continued to be used for almost 20 years until other heat sources in the dome were investigated. Due to the large thermal inertia of the telescope and the dome structure, additional active cooling was soon recognised as being required.

"It was later found that the hydraulic oil system that supports the 260 tonne telescope was also dissipating heat into the dome," says Gray. "This was quickly resolved by actively cooling the hydraulic oil."

In the early 2000s, further analysis concluded that "seeing" would be improved if a cooling system was introduced which cooled the entire dome interior during the day to the predicted ambient temperature of that evening. This would, in theory, leave no differential between the night time ambient temperature and the internal dome temperature.

Consulting mechanical engineers, John Humphreys and Associates, based in Kelso near Bathurst, were thus engaged to design the "Domeair" system which would operate in both summer mode and winter mode, with the summer mode utilising building chilled water circulating at 5°C from the main centralised plant room. In winter mode, a glycol/water mixture was provided at -5°C from a water-cooled Carrier reciprocating chiller located within the dome building.

The "Domeair" project, completed in 2005, proved successful – considerably improving the "seeing" of the telescope and providing astronomers with enhanced image quality for a number of years.

In a research paper completed by Tim Connors in July last year titled '*Dome air conditioning effects on the seeing as a function of the mirror, dome and external temperatures and weather conditions'* it was concluded that while the previous "Domeair" project had measurably improved the "seeing" in as many as five months, it had little effect in other months.

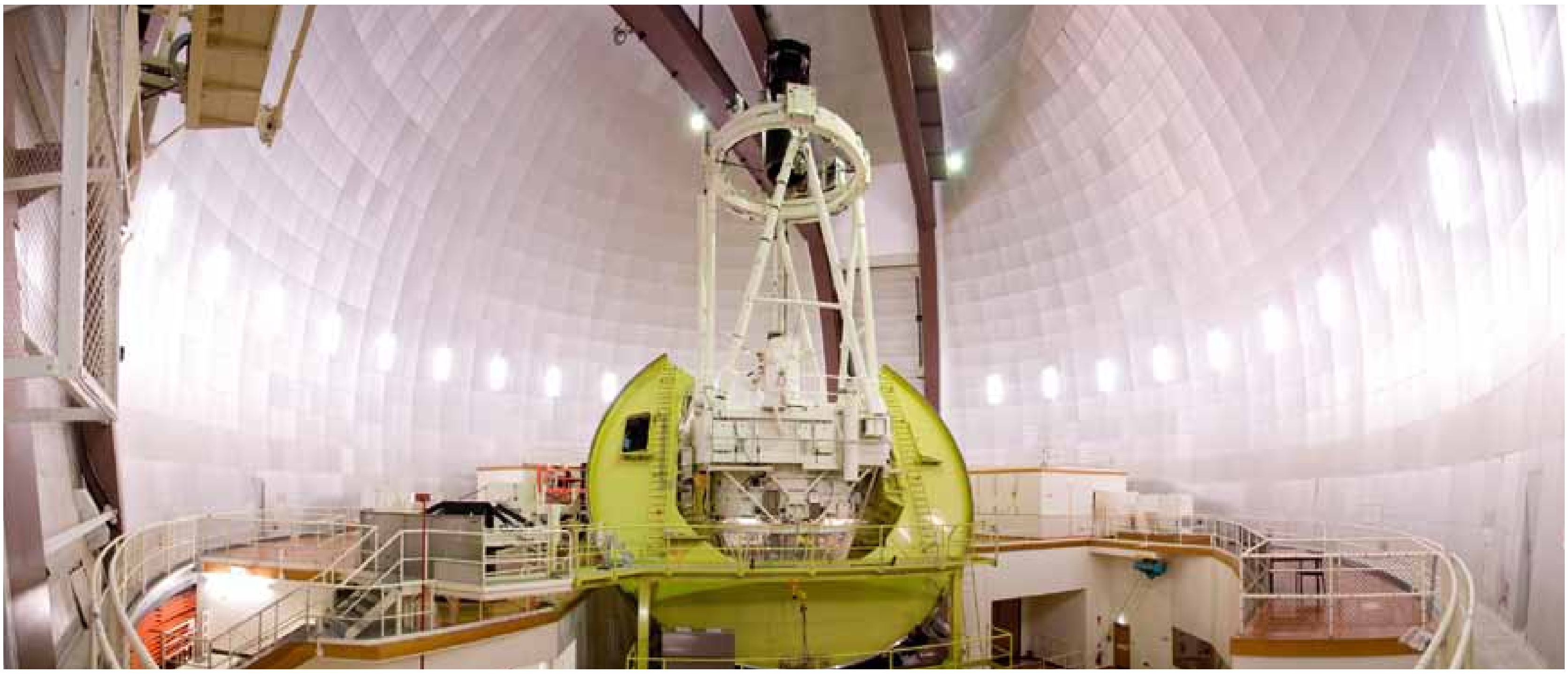
Furthermore, it was determined that while the system had effectively cooled the dome, it had not been as effective in cooling the telescope's large, 16 tonne mirror – a critical component to improved "seeing".

"We show that when the mirror is cooler than the dome, we always experience good seeing even during conditions that may indicate adverse site seeing, and conversely, that when the mirror is warmer, the seeing is quite often poor even when the site seeing should be good as indicated by meteorological data," explains Connors.

"This confirms that the mirror-dome interface is the primary factor for determining the seeing, and that when the mirror is warmer than the dome, we are likely missing out on good siteseeing."

Work is ongoing to reduce the temperature differential between the dome ambient air temperature and the primary mirror temperature.

Last year, however, as part of a proposed $4.1 million refurbishment program to ensure the AAT continued to operate as a world-class telescope well into the next decade, a long-term maintenance plan was developed and identified various systems requiring replacement, including the HVAC.



Inside the Anglo Australian Observatory's dome. Image credit Barnaby Norris.

HVAC overhaul

With funding from the Commonwealth Government's National Collaborative Research Infrastructure Strategy (NCRIS) in place, the AAT's HVAC refurbishment program began in late 2008.

While improvements to "seeing" were sought, efficiency improvement was the number one priority, given the facility's continuing reliance on HVAC equipment up to 35 years of age. This was further compounded by the inherent use of the HVAC system which saw it operate on a constant basis, but more often at partial load.

As such, much of this original equipment was chalked up for replacement, including the original chillers that provided the building chilled water for the dome, which were to be replaced with the most energy and water efficient alternatives available.

"John Humphreys and Associates were (again) engaged to design a system to replace the aging plant with something significantly more efficient," says Gray.

According to Humphreys, the brief was to provide a design incorporating energy efficient features, especially in the area of part load chiller operation; as well as to replace the air conditioning plant originally installed in the 1970s and to serve the recently installed air handling plant for dome cooling and dehumidifying.

Following a meeting with Powerpax at 2008's ARBS Exhibition in Melbourne, it was decided that the company's oil-free Turbocor compressors fitted to Powerpax chillers would deliver the efficiency the Observatory was seeking.

"They were chosen for their economy of operation, especially at low to medium loads where this plant will spend a lot of operating time," Humphreys explains.

Typical chiller and boiler plant operating temperatures were required; 6°C/11°C flow and return chilled water temperatures, and 80°C/70°C heating water flow and return temperatures.

"In this case, some of the chilled water flow is used for the purpose of heat removal from an ethylene glycol low temperature chiller via a heat exchanger," adds Humphreys.

Newcastle-based contractor, Thermaline, was responsible for the installation of the system. According to project manager, Mark Rothery, the remote location of the installation required extra attention.

"The remote location to any substantial suppliers, both mechanical and electrical, was an issue that was resolved with careful planning and procurement. Occasionally we got caught out, but local suppliers in Coonabarabran went out of their way to assist where they could," Rothery says.

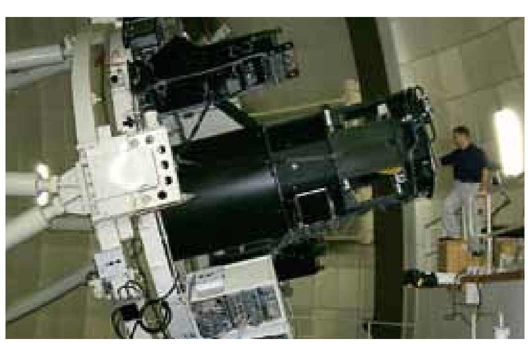
During the installation, the plant was required to remain operational so as not to interfere with the observational work being conducted by the telescope. This was achieved through the installation of a temporary Aggreko chiller adjacent to the plantroom with purpose-manufactured pipework allowing for an easy changeover and minimal downtime.

Specialist contractors were also difficult to locate in the region, resulting in Thermaline taking their usual Newcastle team to the site including sheetmetal, civil, water treatment and commissioning subcontractors.

"Due to the remoteness of the site we wanted to be able to trust the installation and reduce the likelihood of return visits to site for issues that could be resolved with correct installation techniques," Rothery says.

Given the climatic conditions and elevated position of the Observatory at Siding Spring (it sits at 1134m above sea level), water supply also proved challenging, necessitating the use of Aqua Cool hybrid wet cooling towers to limit water use.

"There is an ongoing issue with the use of water on the site, being so remote and sitting on top of the mountain," explains Humphreys.



The Anglo Australian Observatory. Image credit David Malin.

"A water collection tank was installed to catch the run-off from the workshop/plantroom roof areas, which supplies water to the cooling tower sumps with backup from the mountain water supply when required," he explains, adding that this issue dictated the use of closed circuit heat removal in the towers.

"This type of tower has a very economical footprint and offers better value for money than most other low water usage heat removal equipment."

These towers operate in either an air-cooled mode in low load situations, by circulating the condenser water through the coils, similar to a dry evaporator or when load is high during high ambient temperatures, revert to a typical system which evaporates water to provide additional cooling.

The system also required a glycol solution of 10 per cent to be mixed with the condenser water to prevent freezing during the sometimes extreme weather conditions experienced on the mountain.

Additionally, a decision was made as part of the contract to replace the fan coil unit which provided heat to the mechanical workshop adjacent to the plantroom, and add an additional heating coil to the fan unit to reclaim low grade heat from the condenser water to assist with heating of the workshop.

"The entire installation was one of the best I've been involved in," remarks Rothery.

"This was mainly due to the thorough design by John Humphreys and the understanding and assistance given to us by Doug Gray and the AAO staff."

Since the completion of the HVAC overhaul and dome refurbishment earlier this year, the AAT has continued to operate as a world-class facility, while energy and water consumption has been significantly reduced.

According to the facility, the new installation is using a thrid of the power of the original installation. The overhaul of the HVAC system has been a success, but further work will be required to improve the seeing of the telescope by addressing the temperature differential between the dome and the primary mirror, according to Gray.

It seems the world of HVAC, and man's knowledge of the universe around him, are more closely aligned than we thought. ▲