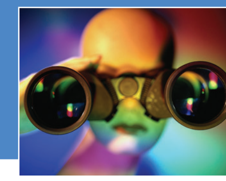


Industrial control below zero

Antarctica offers the best conditions available for astronomy on Earth, but the inhospitable conditions make the construction of a telescope at Dome C an almost impossible task. Sydney's Fast Automation was up to the challenge, to consult on a control system, remote interface and effective data transfer.

THE Antarctic Plateau is considered the most inhospitable inhabited place on Earth. At Dome C, within the Australian Antarctic Territory, mid-winter minimum temperatures drop to -81° Celsius, and access to and from the outside world becomes impossible outside the very small window of twelve weeks during which time the sun rises above the horizon. It is sobering to consider that CO_2 freezes before this temperature is reached, and mild steel undergoes changes which effectively swap stiffness with ductility, enabling a builders hammer to penetrate a 200 litre drum without a great deal of effort. Even mid summer temperatures don't rise above -25°.

Dome C (75.6S 123.21 E), with an altitude of 3250m above sea level, has been the subject of intense interest since the announcement by the French and Italian Antarctic programs that a permanent, year-round station called Concordia, would be constructed there. The establishment of the base has enabled science to better define the environment, during which a real opportunity for astronomy has been demonstrated. The intense cold, high altitude, and stable atmospheric conditions combine to promise sensitivities and image quality that surpass those found anywhere else on the planet, and perhaps even matching the powerful Hubble Space Telescope. Most importantly, an Antarctic telescope can out-perform a similar telescope at a temperate location that is several times the diameter and therefore much more expensive. For many, of the most compelling scientific investigations, an Antarctic telescope may deliver the most cost-effective solution, and with the cost of new telescopes into the hundreds of millions of dollars, investigating the Antarctic opportunity becomes much more important.

Ironically, the very conditions that make the site ideal for astronomy also make it one of the most difficult to execute. Besides the effect of prevailing temperature on common materials precluding the utilisation of temperate engineering solutions to astronomical requirements, the site offers many engineering challenges as a result of the surprising rate of temperature change with height (1°C/m); the regular presence of "diamond dust" (very small ice particles) that permeates any small aperture and seals and settles on all surfaces; the remoteness and small window of access; altitude; the lack of solid foundation (the Antarctic Plateau is essentially a great dome of moving ice (3000m deep at Dome C) and the constant icing of all surfaces as they lose heat to the night sky and encourage ice formation.

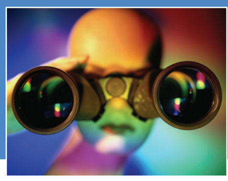
> The very conditions that make the site ideal for astronomy also make it one of the most difficult to execute, from the low temperatures to its challenging remoteness.

PILOT, the Pathfinder for an International Large Optical Telescope, was proposed as an intermediate scale facility to explore solutions to these issues and engineering solutions, providing a pathway to a large optical telescope in the Antarctic.

The world's best resources were assembled in Anglo-Australian Observatory laboratory in Epping NSW, for several meetings regarding the feasibility of such a project.

Sydney based Automation consultancy Fast Automation was seconded to the project – along with five other

(Continued on page 16)



(Continued from page 15)

Australian industry experts representing engineering design, simulation and analysis, design for manufacture and material expertise – to advise on a controls system, a remote interface in Australia, and the most appropriate and effective data transfer system for a remote control 2m class telescope to be deployed to Dome C in Antarctica.

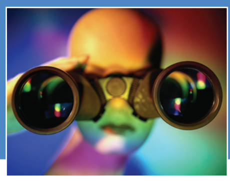
David Askew, Director of Fast Automation was the lead controls consultant and considered the project amongst the most unusual his company has encountered. “We have been involved in a number of critical systems but none with as many constraints as this. The system has to physically get there and then survive the most extreme environmental conditions imaginable. It must also be self-powered, operate remotely, tolerate compounded failure scenarios, and then deal with large volumes of data in a location that has limited communications at best. We quickly realized that the technical issues were going to require many unique and innovative solutions. To compound the difficulties, as mechanical engineering peeled back each issue, another group of issues emerged, each highlighting more constraints. The volume of control ultimately required was exceptional.

“Even transportation to the proposed site presented several challenges. The equipment is required to be transported to Hobart, where it is then transferred to the IPEV icebreaker l’Astrolabe, for shipping to Dumont d’Urville. Once unloaded and placed on sleds, the equipment is be towed overland to Dome C on a “train” (a modified caterpillar dozer capable of pulling more than 400 tonnes over the icy landscape). A typical traverse takes 11 days to reach Dome C from the coast. Add this to the altitude constraint (the reliability of conventional hard-drives is questioned at this altitude), and the very limited communications bandwidth available at the Antarctic, and even the normally straightforward resolution of data storage became a large challenge all of its own.”

Due to the cost of communications the concept design recommended physical transportation of a single 100TB storage array every summer.

“Primarily science groups have very difficult applications and typically construct their own low level controllers. Projects can run for long periods consuming key resources in extremely specialised fields. This encourages a general reluctance to embrace new ways of doing things. It was very clear that the use of industrial controls would provide a far superior solution in terms of reliability, redundancy, cost, the volume of control and the monitoring requirements. Overcoming the scientific reluctance to move away from ‘the

(Continued on page 18)



(Continued from page 16)

tried and true' was not easy, even if the benefits were clear.

"The design lent itself very nicely to the use of PLCs and decentralised control solutions due to the large volume of I/O and drive handling. The primary control involves a lot of interlocks and sequencing to bring components to temperature. Obviously the system generally has a lot more control on it for monitoring and protection purposes, given its inaccessibility. As the preferred solution to each issue was identified, the control requirement grew to enable the solution. The housing of components, etc., requires environmental control, which in turn requires more control!

"Once we had worked out the areas of control, a strategy for overcoming the limitations in a broad sense was agreed. We then produced various FMEA studies and demonstrated that the industrial controller approach offered substantial cost benefits and the safest way forward."

Unusual key design parameters that had to be analysed by Fast Automation and the team included environmental suitability, shock resistance, remote supportability, through life support, critical redundancy and maintainability of the system.

A difficult constraint was the need to maintain the primary mirror temperature constant (despite the fact that the surrounding air may vary by 2°C across its diameter when at maximum angle), and to have less than 0.5 degree variation between the mirror surface, and the local ambient temperature to maintain optical performance to requirements (the refractive index of air varies with temperature). This represented a major challenge to the team and resulted in the exploration of innovative applications of the latest materials and manufacturing techniques. The impact of wind – even if

very low speed – added to the temperature element, as wind turbulence could introduce colder air from below the telescope, rapidly changing its optical capability. A closed loop-controlled wind deflection system to maintain an optimised fluid flow was suggested.

Another general aspect of telescope control is tracking and guiding it to point to an accuracy in the order of nanometres. This is achieved by using drive control and image sensing, then using 'guide stars' (known stars from patterns in the sky) and locking on to them. As the world rotates, maintaining a still image becomes a very high resolution motion control application. The design complexity arises from the mechanical restraints. For example, at certain angles the truss may exhibit unusual twisting and bending which would cause large distortions in the image.

With the serious benefits to the science world, and the immediate interest generated within the general public, the PILOT telescope would be under very close scrutiny. Considering the remote location and general concerns with the very possibility of remote operation of such a highly specified telescope within sections of the science, government and public demanded that the facility operate continuously without falter, and recover quickly from unforeseen factors.

"The design methodology had to be nuclear bomb proof, and this had the implication of high cost. Fortunately we have been through similar systems design in the past; for instance we implemented a human injectable solutions system which exhibited extensive simulation testing and automated error checking. We also implemented a system with high criticality for Sydney Airport for the automatic explosive detection and tracking of checked baggage" said Askew. "The ability to test all possible scenarios is difficult due to the permutations of, and number of parameters to attempt it. To test it without layered and compounded simulation scenarios is not practical, and would also be subject to human error. The tools and indicators developed from past critical applications not only allowed realistic estimations to be made, but gave us the confidence to give the feasibility a positive outcome."

This push from industry to enable a high value solution to such a difficult need clearly reflects the innovative capacity, technical excellence and depth of experience available within Australian Industry. The same team is currently working on the preparation of a proposal to assist the CSIRO ANTF maximise science benefit and cost value on the Square Kilometre Array radio astronomy facility – the world's largest radio astronomy facility, which will ultimately consist of 5000 12m antennas working together in remote Western Australia.

For those wondering, the data storage included provision for 3 100TB Raid 60 arrays tolerating multiple failures of hard disks mounted within environmentally controlled pressurised enclosures, physically separated (in case of fire), with penetration and shock protection to cope with transport, and with a fire survival expectation of more than 1.5 hours.

For more information, visit www.fast-automation.com or contact David Askew on 0418 239 340.