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# AUTOMATED SITE TESTING FROM ANTARCTICA

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**Abstract.** Over the past decade we have developed a series of increasingly sophisticated robotic instruments for site testing in Antarctica. These range from exceedingly low power cloud monitors to fully autonomous 30 cm telescopes, and cover from the ultraviolet to the submm. These instruments have been very successful at characterising the Antarctic sky, and have demonstrated beyond doubt the advantages Antarctic plateau sites offer over observatories at temperate locations.

## 1 Site Testing Laboratories

The unique Antarctic environment requires unique engineering solutions be applied to astronomical site testing experiments. The isolation and extreme conditions of Antarctic plateau sites necessitate facilities with reliable power and heat generation systems, and autonomous control and communications systems. The University of New South Wales has deployed two Antarctic site testing facilities, the Automated Astrophysical Site Testing Observatory (AASTO) at the US Amundsen Scott South Pole station, and the Automated Astrophysical Site Testing INternational Observatory (AASTINO) at the French/Italian Dome C station.

### *1.1 AASTO*

The AASTO is a modified Automated Geophysical Observatory that was deployed to the South Pole in 1997. It is an insulated fibreglass structure with a series of instrument ports on the roof, as shown in Figure 1. Heat and power to the instruments was originally provided by a Thermo-Electric Generator. This proved unreliable, however, and the AASTO has thus been powered mostly from the station. A central supervisor computer was used for instrument control and communications through the existing South Pole satellite link. In collaboration with the Australian National University (ANU), a general purpose mount and control system for small telescopes, the GMOUNT was also developed at this site.

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**Fig. 1.** The AASTO at South Pole station.

### 1.2 AASTINO

The AASTINO laboratory was deployed to Dome C station in January 2003. This was well before the station was due for manned winter operation, necessitating a completely self-reliant system. The AASTINO structure, shown in Figure 2, consists of an igloo-shaped outer fibreglass casing with internal polyurethane insulation, and instrument ports on the roof (similar to the AASTO).

The primary power source for the AASTINO is the WhisperGen 24 VDC engine, a co-generation system based on a small four-cylinder double-acting Stirling engine. Two complete fully independent engine systems are installed in the AASTINO for redundancy. Additionally, two solar panels are installed to reduce fuel consumption through the summer months. The AASTINO communicates via the low bandwidth Iridium satellite network. Similar to the AASTO a central supervisor computer controls all AASTINO systems.

## 2 Instruments

We have developed and deployed a number of Antarctic site testing instruments as part of the AASTO and AASTINO facilities. Similar to the instrument power and control system, Antarctic site testing instruments themselves require specific design features. We have been driven towards instruments that are simple, with few moving parts; modular, so that electronics components, for example, can be shared; and accessible, so they can be readily serviced in the field. Materials and component selection and low temperature testing has proven essential. Instruments all need robust computing systems with autonomous power-cycling/reset

**Fig. 2.** The AASTINO at Dome C station.

capability. Additional care has been required to avoid ice formation on internal or external instrument windows. We mostly employ hermetically sealed heatable instruments with an internal supply of dessicant.

### 2.1 Sky Emission and Opacity

We have measured the Antarctic infrared sky emission with two instruments: the Mid Infrared Sky Monitor (MISM) and the Near Infrared Sky Monitor (MISM). These instruments, shown in Figure 3, have both been operated at the South Pole station as part of the AASTO over several winter seasons. Both instruments determine the sky emission and opacity via a differential detection technique that calibrates the sky zenith signal against a blackbody of known temperature (Storey *et al.* 1999). The MISM uses a HgCdTe photoconductor and a series of filters to give wavelength coverage from 4-14 $\mu$m. NISM uses an InSb photodiode and a single filter operating in the $K_{dark}$ (2.4 $\mu$m) window. These instruments have demonstrated the very low infrared sky background observed at the South Pole station site (Chamberlain *et al.* 2000; Lawrence *et al.* 2002).

The sub-millimetre sky opacity and temperature has been measured with the SUMMIT (SUB-MilliMetre Tipper) instrument shown in Figure 3. SUMMIT measures the 350 $\mu$m atmospheric flux at a range of airmasses with a Barnes pyroelectric detector fed by a rotating parabolic off-axis mirror. The sky temperature and opacity is then determined by calibration against two blackbodies maintained at different temperatures. This instrument has been operated in winter from the AASTO at South Pole and from the AASTINO at Dome C (Calisse *et al.* 2004).

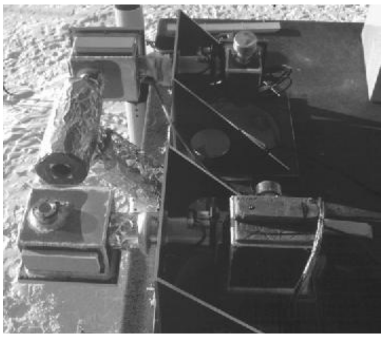

**Fig. 3.** Left picture: NISM and MISM installed on the AASTO roof. Right picture: SODAR and SUMMIT installed on the AASTINO roof.

The visible South Pole atmosphere has been investigated with the Antarctic Fibre Optic Spectrometer (AFOS). AFOS consists of a 30 cm telescope mounted on the GMOUNT (Figure 4) that injects light through a series of optical fibres to a UV-visible grating spectrometer inside the AASTO. AFOS has operated through several Antarctic winters, and has examined the sky transparency and UV cut-on, and the auroral line sky emission via observations of stellar spectra (Dempsey *et al.* 2004).

### 2.2 Cloud Cover

We have measured the Antarctic cloud cover statistics via two different instruments. The first, ICECAM, consists of a low light level visible CCD camera observing a 30 degree field (Ashley *et al.* 2003). This instrument, powered by a lithium battery bank, originally operated independently at Dome C station and communicated via the ARGOS satellite network. Since 2003 it has been powered by the AASTINO laboratory. The second cloud monitor, COBBER (Cloud OBservER) measures the atmospheric thermal emission with a mid-infrared Perkin-Elmer TPS534 thermopile detector imaged by a ZnSe hemispheric lens (Dempsey *et al.* 2003). Cloud cover is then inferred from the temperature differential between ground and sky.

### 2.3 Meteorology

Ground level meteorological conditions are also a useful indicator of site quality. We have thus installed a set of standard meteorological sensors measuring external temperature, ground wind speed and direction, and ground level pressure close to the AASTINO at Dome C. Additionally, the AASTINO system provides power to and collects data from a Vaisala FD12 Visibility Meter (installed in collaboration with the Joseph Fourier University of Grenoble), which determines the rate of snow accumulation and precipitation.


**Fig. 4.** Left picture: AFOS and ADIMM installed on the GMOUNT at the South Pole. Right picture: MASS and feed optics installed inside the AASTINO at Dome C.

### 2.4 Turbulence

We have used three different instruments for measurements of atmospheric turbulence. A Differential Image Motion Monitor, developed by ANU (Dopita *et al.* 1996), was installed at the South Pole station on the GMOUNT, shown in Figure 4, in 2001. This instrument, incorporating a Shack-Hartmann wavefront sensor with a 35 cm telescope, has provided a direct measurement of the South Pole wintertime seeing (Travouillon *et al.* 2003a), confirming earlier balloon borne microthermal measurements.

A commercially available acoustic wind profiler, SODAR, has determined the turbulence in the layer from 30-900 m above ground level. The SODAR, shown in Figure 3, has operated at both South Pole and Dome C during the winter months and has demonstrated very low and stable boundary layer turbulence at both these sites (Travouillon *et al.* 2003b, 2003c).

In 2004, we installed a Multi-Aperture Scintillation Sensor (MASS), in collaboration with the Cerro Tololo Inter-American Observatory, in the AASTINO at Dome C. This instrument derives the vertical turbulence profile of the atmosphere based on single star scintillation measurements. The AASTINO MASS uses a unique feed optics system consisting of an 85 mm refracting telescope and sidereostat mirror, which is mounted on one the internal AASTINO fuel tanks, and looks through a thick glass window in the AASTINO roof, as shown in Figure 4. The MASS, in combination with the SODAR, has demonstrated extraordinarily good wintertime atmospheric seeing at Dome C (Lawrence *et al.* 2004).

### 2.5 Future Instruments

The modularity of the AASTINO control system allows for the easy addition of new instrumentation. Several instruments are thus currently under development. NIGEL will employ a fibre fed spectrometer to measure the visible sky emission spectrum and calibrate the auroral line intensity. In collaboration with Caltech a series of sonic anenometers will be mounted on a 30 m tower to determine the turbulence conditions in this layer. SHABAR (a collaboration with Arcetri Observatory) will consist of a photodiode array measuring lunar scintillation to determine the low altitude turbulence.

## 3 Conclusion

Despite its remote location, the atmospheric conditions at the South Pole station are very well characterised, due in large part to the AASTO facility and its associated instruments. These conditions are advantageous for many types of astronomy. Recent results from the AASTINO have demonstrated the extraordinary conditions at Dome C for astronomy and have generated much interest from the international astronomical community in the development of future telescopes at this site.

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