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The PLATO Robotic Antarctic observatory design and development program

J. W. V. Storey[1]*, M. C. B. Ashley[1], Y. Augarten[1], C. S. Bonner[1],
M. G. Burton[1], L. Bycroft[1], J. R. Everett[1], J. S. Lawrence[2],
D. Luong-Van[1], S. McDaid[1], C. McLaren[1] and G. Summers[1]
[1]*School of Physics, University of NSW, Sydney 2052, Australia*
[2]*Australian Astronomical Observatory, PO Box 296, Epping NSW 1710, Australia*

Abstract. Because of the remoteness of the Antarctic plateau, robotic observatories provide the ideal way to gather both site-testing and astronomical data. The "PLATO" series of observatories are designed to operate autonomously for a year at a time, supporting not only site-testing instrumentation but also small telescopes and other robotic instruments. The latest version, PLATO-F, is a development of the successful PLATO observatory currently operating at Dome A, Antarctica. Additional PLATOs are also under construction for Dome A and for a new site, Ridge A.

Keywords : Antarctica – site testing – robotic observatory

1. Introduction

The Antarctic plateau offers some of the best observing sites on the planet, with a combination of low and stable sky backgrounds, excellent atmospheric transmission, superior image quality, improved photometric precision and the possibility of very long, unbroken periods of continuous observation (Storey 2005, 2007; Burton 2010). A substantial amount of site-testing work has already been conducted from Antarctic locations with robotic observatories (Lawrence et al. 2004; Ashley et al. 2005; Storey et al. 2005; Kenyon et al. 2006; Zou et al. 2010; Bonner et al. 2010; Yang et al. 2010; Moore et al. 2010; Sims et al. 2010), and a growing body of novel astronomical data is being acquired (e.g. Zhou et al. (2010)). The advantages of conducting research in Antarctica with a robotic observatory are obvious, for nowhere else on the planet is it so difficult to support a manned station.

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*email: `j.storey@unsw.edu.au`

In addition to the normal design requirements for a robotic observatory, an Antarctic facility poses the following challenges:

- At remote locations on the Antarctic plateau there is no infrastructure at all. Thus, all power, heat and communications must be provided by the robotic observatory itself. Although a wind turbine could make some contribution to power generation, the very low (often zero) wind speeds on the plateau make this largely impractical.
- For several months of the year there is no sun. Thus, although solar power generation is effective during the summer, only an engine-driven generator can provide kilowatt levels of power throughout the winter.
- Because the harshness of the Antarctic winter makes travel difficult, servicing can take place only during a brief summer period. The observatory must therefore be available to operate autonomously, and without servicing, for up to 11 months at a time.
- At locations south of −75°, access to geostationary satellites is difficult, if not impossible. All communications must therefore be via satellites in non-geostationary orbits.
- The high elevation (4,100m at Dome A) and attendant low atmospheric pressure poses difficulties for air-cooled electronics modules, and reduces the achievable power output from air-breathing engines.
- Finally, the very low ambient temperatures (down to −80°C) dictate that care must be taken with the thermal design and management–although this turns out to be one of the easiest issues to solve.

In this paper we briefly outline the design, development and operation of the “PLATO” series of robotic Antarctic observatories.

2. PLATO

The first PLATO was built during 2007 at the University of New South Wales. The design owes much to the earlier “AASTO” (Storey et al. 1996) and “AASTINO” (Lawrence et al. 2005) observatories, which were powered by thermoelectric generators and Stirling engines respectively.

PLATO (Lawrence et al. 2009; Yang et al. 2009; Ashley et al. 2010a) consists of two modules–an *Engine Module* (EM) and an *Instrument Module* (IM). The EM houses six single-cylinder, air-cooled, naturally aspirated diesel engines (Hengst et al. 2010), coupled to high-efficiency brushless alternators. A fuel tank, internal to the EM, contains 4,000 litres of Jet-A1. During the summer, six solar panels provide additional power, while fluctuations in the power demand are handled by a 28V bank of sealed lead-acid batteries.

Within the IM, two *Supervisor* computers manage the system housekeeping, data acquisition and communications interface. These computers run Debian Linux on a PC/104 platform. Communications within PLATO take place via Controller Area Network (CAN) bus and Ethernet. Two data modems then communicate with the outside world via the Iridium satellite network.

PLATO was deployed to Dome A in January 2008 by the Chinese National Antarctic Research Expedition. In the first year PLATO ran for 204 days before an exhaust fault shut it down. Since being serviced in January 2009 by the twenty-fifth Chinese expedition team, PLATO has run without stopping; at the time of writing (August 2011) it has run continuously for 952 days. During this time, PLATO has supported a number of instruments: CSTAR, Gattini, Nigel, HRCam, preHEAT, Snodar, a submillimetre FTS, and a meteorological tower.

3. PLATO-F

PLATO-F is an evolution of the original PLATO design, and incorporates a large number of improvements (Ashley et al. 2010b). These are summarized below.

3.1 Construction

PLATO-F has the same shape and size as a pair of ten-foot shipping containers, and has container-compatible corner fittings. However, because of the need to reduce the

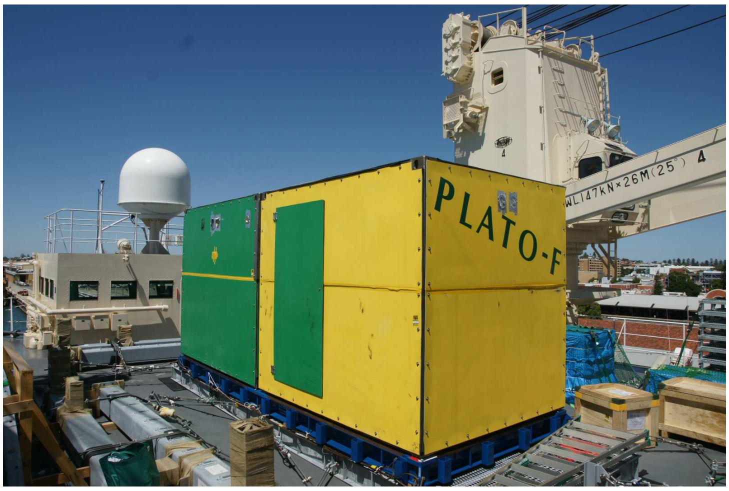

Figure 1. PLATO-F on board the Japanese *Shirase* icebreaker, about to begin its journey to Antarctica in November 2010.

weight to below 1.8 tonnes per module for helicopter transport, PLATO-F uses a novel construction technique. Whereas the original PLATO was housed in two ten-foot steel shipping containers, PLATO-F uses a stainless steel frame and fibreglass-foam-fibreglass sandwich panels. A 6,000 litre fuel bladder replaces the heavier aluminium fuel tank of PLATO. Further weight saving is achieved by the use of lithium batteries as described below.

3.2 Batteries

Instead of sealed lead-acid batteries, PLATO-F uses lithium iron phosphate ($LiFePO_4$) cells. The advantages of this newer technology include around twice the energy density, a very low temperature coefficient, tolerance to deep discharging, and a much longer cycle life. Against this must be weighed the need to precisely monitor every individual cell (108 in the case of PLATO-F) and provide explicit charge balancing of each cell. In addition, despite claims to the contrary on the data sheet, the $LiFePO_4$ cells will only operate down to about −25°C. PLATO-F uses LFP60 cells manufactured by Thundersky, and a custom battery monitoring system manufactured by Tritium Electronics.

PLATO-F also moves from the previous 28V nominal DC bus to a 120V DC bus. This greatly reduces the effect of voltage drops, including the resistive losses in the connecting cables.

3.3 Iridium OpenPort

Because of the very low elevation of geostationary satellites as seen from Antarctica (in fact, south of about −80° latitude all such satellites are below the horizon), there are a few options for communication with the outside world. One of the most suitable is the Iridium satellite network, whose 66 polar-orbiting satellites provide continuous coverage of the entire globe. PLATO-F uses two conventional Iridium modems to provide redundant system control and monitoring of health and status data.

For the science data, however, a single Iridium OpenPort system is used. This provides a data rate of up to 128kbps. Because the RF block and antenna (known as the “Above-Decks Equipment” in Iridium parlance) is only rated down to −30°C, we have housed it in a custom fibreglass/foam sandwich box. Although electric heating is provided, we find that the heat generated by the RF block itself is often sufficient to keep the system at a satisfactory operating temperature. The small amount of signal attenuation created by the polyester/fibreglass/polyurethane-foam box does not appear to have any deleterious effect on the operation.

Figure 2. The PLATO-F $LiFePO_4$ battery pack, consisting of three parallel strings of 36 cells. The pack is in a separate polyurethane insulated box within the PLATO-F Instrument Module, to allow the cells to be kept warm with low power dissipation. The lid of the box is open in this photograph.

3.4 Power

As in the original PLATO, PLATO-F uses 350cc single cylinder-diesel engines manufactured by Hatz. These have been tested under simulated high altitude conditions in the laboratory (Hengst et al. 2010) and have since proven themselves to be reliable performers at Dome A (Luong-van et al. 2010). Five engines are used, providing both a high level of redundancy and, by using more than one engine at a time, some flexibility in the engine loading is required for given power output. Normally, only one engine is running. In general, the engines should be loaded to at least 50% of their rated torque in order to avoid problems from bore glazing or wet-stacking.

Each engine is directly coupled to a bearing-less, brushless motor/alternator, manufactured by eCycle. Control of the motor/alternator is via a “WaveSculptor” motor

Figure 3. Inside the PLATO-F Engine Module, showing three of the five diesel engines. A fuel bladder, containing 6000 litres of Jet-A1, is immediately below the aluminium plate at the bottom of the figure.

controller manufactured by Tritium. Originally designed for use as motor controller for solar-powered cars, the WaveSculptor synchronously rectifies and steps the output voltage (about $90\mathrm{V_{rms}}$, 3 phase AC) of the alternator up to an appropriate level for the main power bus. The WaveSculptor is also used to start the engines from the 120V main bus.

Eight solar panels are used, arranged in four banks of two. Under Antarctic conditions, solar panels typically generate at least 25% more power than their nominal rating (Lawrence et al. 2005). This is a result not only of the high solar flux (enhanced by snow reflection) but also the negative temperature coefficient of the output voltage of the silicon cells. Each pair of solar panels has its own Maximum Power-Point Tracker (MPPT). The power electronics modules for these (Drivetek AG, Switzerland) are combined with control electronics developed by the UNSW *Sunswift* solar-car team.

With optimum use of solar power when available, and a fuel load of 6,000 litres, PLATO-F is designed to supply an average electrical load of 1 kW for two years. This is sufficient to support several optical photometers and small wide-field telescopes.

3.5 Deployment

PLATO-F was deployed to Dome F (Dome Fuji) by the 52^{nd} Japanese Antarctic Expedition, and put in operation in January 2011. Dome F is the centerpiece of the Japanese astronomical program in Antarctica (Ichikawa 2010), and will eventually support several robotic telescopes including a 40 cm infrared telescope (Okita et al. 2010).

4. Future developments

A second PLATO for Dome A is currently under construction, and will incorporate all of the improvements that were developed for PLATO-F. It will be deployed to Kunlun Station, Dome A, by the Chinese National Antarctic Research Expedition at the end of 2011.

Another, smaller PLATO, called PLATO-R, is under construction for Ridge A. Ridge A has been identified by Saunders et al. (2009) as potentially the very best astronomical site on the Antarctic plateau. As no-one has ever been there, there are currently no in-situ measurements of site conditions. PLATO-R will use the same technologies as the current generation of PLATOs, but will have only two engines and 800 litres of fuel. Each of the two modules (EM and IM) will split in half; the four half-modules must be small enough to fit into the Twin Otter aircraft that will be used for deployment.

PLATO-R will house a number of site testing instruments, plus the "HEAT" terahertz observatory. HEAT is a small (50-cm) telescope, receiver and digital filter-bank based on the original "preHEAT" experiment (Kulesa et al. 2008) and will map the galaxy in [CI] and warm carbon monoxide emission. PLATO-R is scheduled for deployment in January 2012 by the US National Science Foundation.

5. Conclusion

The PLATO concept offers a highly cost-effective way to acquire data year-round from remote Antarctic sites. PLATO can provide up to 1 kW of continuous power (more, if sufficient fuel is available), along with satellite communications and a warm environment for data acquisition computers and other instruments. In addition to acquiring astronomical and site-testing data, the PLATO concept can be extended to meteorological and geophysical measurements. In many ways, PLATO is perhaps the ultimate "Robotic Observatory".

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