PILOT—WHERE TO NEXT FROM HERE?

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\textbf{Abstract.} The Phase A design study of PILOT—the Pathfinder for an International Large Optical Telescope—has demonstrated that a wide-field 2.5 m optical/IR telescope can be constructed at Concordia for a reasonable cost. There are no technical “show stoppers”, and the cost of logistics is also quantifiable and reasonable. A strong science case has been developed and published as three separate papers. In order to proceed further, the next step is to undertake a detailed design study and identify potential manufacturers.

1 Introduction

In the eighteen months since the ARENA II meeting in Potsdam (Zinnecker \textit{et al.} 2008) there has been considerable progress, both technically and in the development of the scientific case, for a 2.5 metre class optical/infrared telescope at Dome C. The importance of this project is two-fold: as the first Antarctic telescope of this size, PILOT can take advantage of the superb atmospheric conditions at Dome C to make important new scientific discoveries; as the first telescope large enough to be properly challenged by the environmental difficulties of the site (eg., the rapid temperature variations within the boundary layer) PILOT can be a pathfinder—a necessary next step towards the development of a future large-scale observatory.

With the Phase A study of PILOT now complete (see Saunders \textit{et al.} 2008a for an almost final summary) and a comprehensive science case published (Lawrence \textit{et al.} 2009a,b,c), PILOT is ready to move into the next phase—the Preliminary Design Stage. However, it is useful at this point to re-examine the goals of PILOT, both scientifically and technically, and to consider the various options currently available to allow the project to move forward.

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2 Current status of PILOT

2.1 Costings

The Phase A study of PILOT, funded largely through a EUR600k grant from the Australian government, produced a viable design for the telescope and its enclosure, and defined the logistics requirements. A suitable instrument suite has also been defined (Saunders et al. 2008b), and careful study carried out on the infrared camera (Mora et al. 2008). Based on quotes from potential suppliers, and reasonable estimates of the FTE requirements for project management and software development, the costs could also be derived. The total cost of the telescope, enclosure and tower comes to EUR23M, with the three major instruments costing an additional 5M each.

To this must be added the cost of additional infrastructure to support PILOT’s antarctic deployment. This is considered to include a 100kW solar photovoltaic plant, support buildings, satellite communications, an additional traverse tractor and three new sleds, plus shipping and deployment costs. Also required to make a complete observatory are data downloading and archiving facilities in Australia and Europe. This adds a further EUR3.4M to the capital cost.

The annual cost of operating PILOT, including the attributable cost of Concordia operations, satellite rental, and support of the astronomical staff (assumed to be at the Anglo-Australian Observatory and at a suitable European site), is estimated to be EUR3.1M.

Including decommissioning, the whole-of-life or “cradle-to-grave” cost over a ten-year operational life thus amounts to EUR75M.

In examining these costs, it is important to bear in mind that they are not greatly different from (in fact, only about 20% higher than) the cost of constructing and operating a 2.5 metre telescope at a temperate site. Most—if not all—of this additional cost could be in the form of funding to the polar agencies. Astronomers are, in general, not used to rigorous assessments of whole-of-life costs, and when a properly costed Antarctic telescope is compared with the “assumed” costs of a university-style observatory, it is natural to think that the high cost of the Antarctic facility is as a result of the environmental harshness and difficulty of working in Antarctica. It is not. The experience of the US with major projects such as the South Pole Telescope (Ruhl et al. 2004) is a valuable “sanity check” on costs.

Nevertheless, PILOT is a sufficiently ambitious project that raising the necessary resources is well beyond that of a single institution and, in the current economic climate, possibly that of a single country. A coordinated international effort is thus required.

2.2 Design review

The PILOT project held an independent design review in July 2008, with a distinguished international panel made up of:
This panel was unanimous in making the over-arching recommendation that “If resources are available, the PILOT project should be carried to a full Preliminary Design stage to be completed no later than September 2010.”

However, funding for this next phase of PILOT has not yet been forthcoming. A further review of the project by the Astronomy NCRIS Strategic Options Committee (ANSOC) highlighted the current limitations to understanding of environmental problems such as humidity, and stressed the importance of formalising the international agreements. ANSOC noted that: “The international collaborators are not yet committed to the construction of a telescope at Dome C and have not agreed to project plans to do so. The ANSOC considers international collaboration to be essential in order to optimise the prospects for the future construction and operation of such a telescope.”

2.3 The Preliminary Design Phase

A proposal for a full Preliminary Design study has been put together by RAMS-CON and circulated at this meeting (Ansorge & Storey 2009). The complete activity is estimated to require 322 person-months, spread over two years and costing EUR2.5–3.4M. Options for funding this next phase include the EU, and national agencies in Europe, Australia and other countries.

3 Site testing and Environmental data

The original PILOT proposal, which dates back to 2004, was predicated on the assumption that the Dome C site would be fully characterised by the time PILOT was ready to apply for major funding. However, at the present time (mid 2009) there still remain important uncertainties, as flagged by Lawrence et al. (2009) and Saunders et al. (2009) in these proceedings. These include meteorological data for the lowest 30m of the atmosphere (essential for the telescope and enclosure design) and hard data on the astronomical observing conditions that can be compared directly with those from other sites (essential to justify a major funding bid).

One particular area of concern is the free-atmosphere seeing. If a telescope project is to be sold to funding agencies on the basis that atmospheric conditions are significantly better than at other, more convenient sites, it is not unreasonable that the agencies will ask for proof. From Mauna Kea, there are now three years of data giving a median free-atmosphere seeing of 0.32″ (Els et al. 2009). From Dome C, there are a mere six weeks of data with an identical instrument, showing
a median free-atmosphere seeing of 0.24″ (Lawrence et al. 2004). Does this mean that Dome C is 25% better than Mauna Kea, or were those 6 weeks of data atypical? Comprehensive, detailed DIMM measurements over three years at Dome C suggest a value of 0.34″ (Aristidi et al. 2009). Does this mean that the free atmosphere is no better than that at Mauna Kea (unlikely, if atmospheric models are to be believed), or is a difference in measurement technique masking a real advantage for Dome C?

What is certain is that several years of data, directly comparable with that from competing sites, are required before a major telescope can be funded on the basis of potentially improved image quality. While such a systematic site-testing program should be started as soon as possible, it is also true that some properties of the site are beyond doubt—even though they have not yet been directly measured. We have known for 200 years that Antarctica is cold, and it is straightforward to calculate the minimum gains that this will deliver in the thermal infrared. A project such as PILOT should therefore proceed, at least through the design phase, on the basis of such knowledge.

4 De-scoping PILOT

Because PILOT is seen as an expensive and “high-risk” project, it is natural to explore ways in which the project could be either de-scoped, or carried out as a series of smaller steps. While some modest cost savings can be achieved in this way, along with a reduction in the overall risk, it is also important to keep the whole-of-life cost of the project in mind. PILOT must ultimately be cost-effective, consistent with being fundable. As an example, suppose the tower were to be eliminated completely. Including deployment and installation costs of the tower, this would only save about EUR2M, just 3% of the project cost.

One option is to eliminate the diffraction-limited optical capability, as described in Saunders et al. (2009, these proceedings). This version of a “PLT” (PILOT-Like Telescope) appears to satisfy the majority of the community’s science goals, while eliminating some of the riskier and more technically challenging aspects of the original PILOT design.

5 PILOT the pathfinder

If PILOT is to represent a significant technological step forward, and hence perform as a useful pathfinder for later projects, it must address challenges that have not already been solved. It is worth recalling that the 80cm IRAIT will be operational within a year or two (Guandalini et al. 2008), that it is already fifteen years since the 60cm SPIREX telescope was operational at South Pole (Hereld 1994), and over two decades since the first night-time optical astronomy was carried out from Antarctica (Taylor et al. 1988). PILOT must build on this existing state-of-the-art, and develop engineering solutions to new challenges.

We already know that it is possible to operate a metre-class infrared telescope on a 7.5 metre tower throughout the Antarctic winter, using a large-format in-
frared array with closed-cycle cooling and a CCD-based guider system with fast tip/tilt secondary mirror (Fowler et al. 1998). We know that an optical telescope can be used productively for time-series observations (Taylor 1990), and we know from major projects like AMANDA (Halzen 1998) that it is possible to acquire, store and return vast amounts of data from Antarctica. What, then, are the new technical challenges that PILOT must solve if it is to be a true pathfinder; i.e., if it is to meaningfully buy down the technical risks on behalf of future projects?

PILOT pushes the telescope size up by a factor of a few, but this in itself is unlikely to reveal new technical issues. More important is image quality. Both IRAIT and SPIREX are small enough that they could be diffraction-limited (at 10µm and 3.5µm respectively) even when heating the mirror above ambient to avoid frost formation. With PILOT, this option is not available, and the mirror must be well matched to the local temperature if the higher spatial resolution promised by the larger mirror diameter is to be achieved. As the air within the Dome C boundary layer is usually supersaturated (Durand et al. 2008), this implies that drier, cooler air must be found and heated (or air at the right temperature found and dried—a more difficult task) and flushed over the mirror. Furthermore, as the temperature within the stable boundary layer can change rapidly, the temperature control of the air-conditioning system must be sufficiently agile and the mirror of sufficiently low thermal inertia to track these changes. Finally, the interface between the enclosure and the outside air must be designed in such a way that the excellent seeing conditions are not degraded.

These challenges have nothing to do with the remoteness of Antarctica, and little to do with the extreme cold. To solve the image-quality problem requires extensive modelling with CFD (Computational Fluid Dynamics), and possibly the construction of physical models as well.

A solution to the problem of achieving good image quality in the presence of supersaturated air is required for all HAR (high angular resolution) telescopes and interferometers proposed for Dome C. This will be perhaps PILOT’s most important and enduring technical legacy.

6 Conclusions

The need for a 2.5 metre optical/IR telescope at Dome C is as great as it always has been. The PILOT proposal, for a fully instrumented wide-field telescope that is diffraction-limited down into the visible has been studied, and costed at EUR75M whole-of-life. Various ways have been proposed to make a modestly de-scoped version of PILOT; for example by infrared-optimising the telescope and relaxing the image quality. Such a PILOT-Like Telescope could be significantly cheaper.

However, if PILOT is to give the maximum return for the resources invested in it, it must also strive to retain as much of its pathfinder role as possible. This is particularly so for interferometry and for submm applications, but also applies to possible solar astronomy during the daytime.

Even if most of the optical capability is compromised, PILOT must retain some functionality at visible wavelengths. For one thing, it makes the telescope much
easier to align. Secondly, as a prototype for a dedicated near-earth-debris search telescope, PILOT can appeal to both the astronomical and the space-research communities.

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