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REPORT TO THE LRP BY THE GROUNDBASED ASTRONOMY COMMITTEE (GAC)

J. B. Hutchings, Jo-Anne Brown, Tim Davidge, Gil Holder, Roland Kothes, Kim Venn, Tracy Webb, Chris Willott
HIA, Univ of Calgary, McGill University, UVIC
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ABSTRACT

The GAC has reviewed the current and envisioned Canadian ground-based observatories over the next decade, together with their operational capabilities and choices. This report is based on information we have gathered, and from LRP reports for several individual facilities. We attempt to outline the suite of facilities that would serve the Canadian community best, and offer comments on some of the difficult choices and uncertainties that lie ahead. In this short report we have omitted many details and note only the major issues we see. We also have not discussed detailed costs of facilities or choices.

1. INTRODUCTION

Canadian institutions own and operate a number of observatories within the country - principally DAO, DRAO, Megantic, and Rothney. Canada is partner in offshore facilities JCMT, CFHT, Gemini, ALMA, EVLA, and is involved in planning future partnerships in TMT, ASKAP, SKA, and an Arctic small telescope. We also have had discussions on joining ESO or becoming a partner in the EELT.

Having access to excellent facilities has kept Canada at the frontier of many branches of astronomy over the past decades. Every one of these facilities is funded and operated separately, so that the links between them are tenuous, and funding their operation and instrument upgrades is a complex exercise. GAC feels that a range of forefront observational facilities both in operation and future planning, is essential for continued success in astronomical research, and our consequent international reputation and networking. We summarize the current status and choices for individual facilities. Figure 1 shows the proposal pressure for Canadian time on our offshore telescopes.

2. SMALL ONSHORE TELESCOPES.

Several telescopes support visiting observers, and details are given in the white paper by Bastien and Bohlender. The DAO telescopes are slightly oversubscribed, increasingly in recent years, and are the source of some 15 published papers per year. They are also used for asteroid searches, reported in some 30 circulars per year. The telescopes remain scientifiically productive, and appear to be well worth the relatively minor staffing and budget support they require.

The OMM went through a funding crisis this year over its status as a national facility. It is settled for now but needs ongoing support for the future. It is moderately oversubscribed, productive, and has been an important testbed for new instrumentation.

The Rothney Observatory (RAO) at U Calgary, houses a 3.3 m radio telescope, 4 optical telescopes, and a 1.8m IR telescope. RAO is used for teaching, research, outreach, and will include satellite tracking from 2011. RAO received the ASTech foundation outreach award in 2008.

These telescopes fill a signifcant role in Canadian astronomy and should remain in operation. The UWO 1.2m telescope is mostly used in-house for high resolution spectra. DDO is no longer operational.

The DRAO 26m radio telescope will observe the Northern component of the Galactic Magneto-Ionic Medium Survey (GMIMS) through 2011. The DRAO Synthesis Telescope completed the CGPS in Feb 2009, and supports ongoing research by DRAO-associated students and faculty. The telescope is now in full-time proposal mode, for its specialized and unique capabilities.

Largely as a result of the CGPS, Canada has become a world-leader in wide-field, high dynamic range radio observations, particularly polarimetry. For Canada to maintain this status, DRAO must continue to develop calibration, imaging, instrumental, and observing techniques, and to recruit and train high quality scientists. This is especially important in maintaining the HQP for future iniatives such as SKA. DRAO, in partnerships with U. of Calgary and and UBC-Okanagan, plans to develop as a major training facility, funded as a component of an NSERC CREATE grant.

3. OPERATING OFFSHORE TELESCOPES

3.1. *CFHT*

The last LRP noted that CFHT may be linked to participation in a VLOT, possibly in the same site. Developments have not gone that way as the largest telescope that could fit the CFHT footprint is about 20m. The role of CFHT must thus fit with larger facilities, currently limited by collecting area and image quality. New specialised Megaprime filters could be an effective way of extending its unique capabilities. The simplest facility upgrade would be a ventilated dome to improve seeing. An upgrade of the telescope would involve a new primary, and possibly a more modern larger telescope. These would be expensive and would require major partnership negotiations. Among a few new instrument proposals, we note two distinct major new capabilities for the telescope as it is. 1) A wide field GLAO imaging system, IMAKA. The system would have a wide field of view, with detectors covering g through z bandpasses, and the intent is to have image FWHM of order 0.3". 2) Wide field (1 degree) multi-object spectroscopy. There are several proposals for this capability, each supporting specific programs.

While there is technical risk with the GLAO capability, it will probably have the highest impact on feeding ALMA, TMT, the JWST, and the SKA. The wide field spectroscopy will offer more limited support capabilities, due to the modest CFHT aperture and their 'mission-

specific' may affect their versatility.

The CFHT future requires negotiation among existing and possible future partners. Its unique 'best' site however, argues strongly that Canada should remain a partner in whatever future CFHT has. Any new instrumentation should address the basic image quality offered by CFHT in its present form, and it use as a 'feeder' survey facility for larger telescopes.

3.2. *JCMT*

JCMT has awaited delayed commissioning of SCUBA2, and as ALMA ramps up, the level of support for extended operations by its current partners is unclear. There is a group of strong Canadian SCUBA2 supporters, but in the overall funding situation for new facilities, it may be difficult to extend JCMT beyond its 2012 deadline for renewal. If operational costs can be reduced, the current partnership may agree to extension for a couple of years to enable the exciting SCUBA2 science. The essential issue is the instrument performance, which remains problematic at the time of writing. Potentially JCMT offers a key capability for the next few years, which can only enhance our exploitation of ALMA. We need continuing sub-mm continuum mapping capability either at the JCMT or elsewhere to take us into the ALMA era.

It is important to be involved in ways to make use of SCUBA2 and other JCMT instruments on another southern facility - possibly the CCAT - and to retain Canadian access. Thus, while Canada expects to pull out of JCMT sometime, and focus on use of ALMA, the timing and access to SCUBA2 are of high concern to many Canadian astronomers.

3.3. *GEMINI*

The partnership and funding situation with the Gemini observatory is complex, and likely to change significantly. The existing partnership agreement will be renewed in 2012, and the UK will withdraw. NOAO/NSF plans to assume it under their umbrella for operations have been abandoned, and we consider that the current arrangement of Gemini support groups, particularly in Canada, are serving the users well. The project at the moment lacks strong leadership, and the UK time is not being picked up by anyone. Implications appear to be a shrinking budget and re-allocation among existing partners, which might amount to the US having a majority share. Without the UK, Gemini would effectively become an 'Americas' viable alternative to ESO, especially as a complementary facility for ALMA. It might be worth considering offering the CFHT as a contribution to that, depending on other CFHT partner plans.

The Gemini telescopes can serve Canadian needs well, and feed ALMA and TMT programs, but future instrumentation is a significant concern. The Gemini Planet Imager (GPI) will provide advanced high contrast AO system with imaging, IFU and polarization, in 2011. We note in passing that the recent Gemini user survey indicated low interest in GPI among the 33 who responded. GAC supports our continued membership of Gemini as vital for the next decade, unless there is a radical change such as joining ESO (see below).

3.4. *ALMA*

Noted as 'Canada's highest priority for participation in a major ground-based observatory' in the first LRP, ALMA construction began in 2003. Early Science is planned for January 2011, and construction ends in April 2013. Despite some descoping, ALMA still produce transformational science in the mm and submm regime. Canadian funding for ALMA construction has come from NRC and a CFI grant to the University of Calgary. Our main construction contributions are complete (the site fee and software personnel), and delivery of the Band 3 receivers is on track. Our participation in ALMA was linked to the new correlator for the EVLA. Built by the HIA DRAO, this is key to the EVLA delivering transformational science in the cm regime, and will be an important resource. Canada has seats on the ALMA Board and on the ALMA Science Advisory Committee, and is frequently represented on other ALMA committees. Over the next few years, the important issues for Canadian participation are to: (1) identify and secure complete Canadian funding for ALMA operations; (2) prepare the Canadian community to be effective ALMA users; (3) position ourselves to lead or be involved in future ALMA development projects. One such is the Band 1 receivers, for which HIA hosted a scientific and technical meeting in fall 2008.

GAC is very pleased at the progress and scientific promise of this project, and Canada's central position in it.

4. FUTURE FACILITIES AND PARTNERSHIPS

4.1. *TMT*

Canada has done a major share of the design work to now and remains a central player, with many Canadians filling key roles in the current organisation. The project will be ready for construction by Oct 2011, provided partnerships and funding are in place, and would have first light in 2018. There are no significant technical or design issues. Mirror segments are a pacing item but are not on the critical path now. The Mauna Kea site is the preferred one and so far has not encountered any showstoppers from the mountain planning. There is considerable involvement of astronomers in the TMT design and planning, apparently in contrast with the EELT so far, where design problems are not yet well appreciated (see below).

The principal difficulties are partnerships and funding. Japan and China are now 'participants', and India and Brazil are seriously interested. The participation levels are not clear for these partners yet. Given the funding uncertainties and lack of detailed coordination among the funding bodies, construction seems unlikely before 2013, and indeed the whole collaboration may possibly fail. The Canadian submission to cabinet, for a 25% share in TMT, has been delayed for this reason. The LRP might consider what minimum participation level is acceptable in this changing landscape.

The TMT initial instrument plan is highly complementary to JWST and ALMA. Given the level of effort to date by Canada, and the science incentive, it seems very important to GAC that Canada pursue partnership in TMT very vigorously, through ACURA, NRC, and all available funding avenues. The Coalition for Astronomy need to keep up their lobbying efforts, and there is a known interest among MPs for the project.

4.2. *EELT*

Canada is welcome to join ESO, or the EELT on its own. The EELT is in an earlier stage of design than TMT, currently awaiting a cost estimate from industries. It is considered possible that the current cost estimate of

1B Euros may be significantly low, but this should be known during the next few months. It is also said that the current design has low optical throughput and operational flexibility that essentially lose the gains of the larger aperture. Thus, redesign is possible, but they may well catch up to TMT in schedule. The costs for Canada to join EELT depend on how many countries sign up, but for a likely 10% share, Canada's cost would be comparable to the (larger) share in TMT, but could include full membership in all ESO facilities over the construction period. Joining ELT alone would be cheaper but does not include labour in instrument construction. Possible deals with our ALMA involvement and even the CFHT might alleviate some of these costs.

It seems very advisable to look carefully at the EELT details, and retain the option until the TMT future is decided. It is vital that we join one ELT partnership. The possibility of joining ESO fully and leaving Gemini also is a major issue that warrants careful attention.

4.3. *SKA and ASKAP*

Canada has played a leadership role in SKA for years. GAC endorses SKA as the most important new ground-based project for Canada the 2020 decade. It is essential that we remain involved and funded to retain our leading position, both scientifically and technically.

The international design effort for the SKA (PrepSKA), is a European Commission FP7 project. In Canada the NRC and The University of Calgary are signatories to the EC contract. PrepSKA reached its midpoint in August 2009, and the remaining SOW reinforces and expands the Canadian design contribution, with responsibilities in a number of key areas.

The overall project timeline is: system design and site decision to 2012; detailed design and production engineering to 2014; construction and first experiments to 2018; completion and commissioning to 2023. The target cost for construction of the full SKA is 1.5B Euros.

Canadian participation in the design is funded through 2012 from sources including NRC, NSERC, CANARIE and the University of Calgary. Funding beyond 2013 has not been identified. Canadian funding requirements total $180M for 10% partnership in the complete SKA.

The Australia SKA Pathfinder (ASKAP) involves NRC and U Calgary, and there are 20 Canadians involved in planning the ten major survey projects which will begin in late 2012. GAC trusts this will enhance our full SKA partnership.

4.4. *Arctic telescope*

Site testing in Ellesmere Island has been performed, in conjunction with the DND. There is an LRP white paper on the subject. The site is the closest land to the pole, and better than the Antarctic Dome C site. The long winter night has long periods of calm weather with exceptional seeing, and the island has military infrastructure that makes transport and logistics feasible. The science case, presumably for a small synpotic monitoring telescope needs to be made in detail, along with a costable proposal for such a facility. Overall, GAC feels this possibility is interesting enough that it should be pursued.

4.5. *Synoptic survey telescopes*

The CFHTLS and other large surveys have enabled many high profile Canadian science results of the past decade, and provided targets for follow-up with larger telescopes. This situation will be challenged by new wide-field imaging facilities such as HSC at Subaru, Pan-STARRS and LSST, which have no Canadian participation. It is not clear that data from Pan-STARRS and LSST will be made public, without partnership.

Such facilities will make the deepest multi-filter optical surveys, enabling big advances in many fields of astronomy. They will also revisit patches of sky many times and open up new areas of *time domain* astronomy. Their wide appeal to Canadian astronomers is evident from frequent reference in science LRP white papers, but no action has been taken to join them. Canada has much relevant expertise to bring to such a partnership. Much of the productive science from the largest telescopes is made via access to the best wide-field facilities. In the era of TMT we recommend that Canada be involved in the best supporting telescopes, such as LSST, unless a major CFHT upgrade is envisioned. As it may require an expensive buy-in to access the LSST data at all, this needs serious consideration, but may not be an easy decision. A space-based wide field imager is also an important alternative to consider.

5. SUMMARY

The LRP occurs in a period of considerable uncertainty and decision-making in several of our major facilities. Thus, the situation will certainly change between the time of writing this report, the final publication of the LRP, and beyond. We refer principally to JCMT, TMT, Gemini, and CFHT. We feel that to maintain Canadian strength in our science we need to be a strong partner in the optical facilities just mentioned, while it seems advisable to make the transition from JCMT to ALMA in a timely way. It is vital to maintain the smaller facilities in Canada, as there is strong demand, they have important niche capabilities, are are platforms for instrumental development, student training, and outreach. We must maintain our current offshore facilities at a competitive level, while the longterm larger projects are still in development. We need to continue our leadership role in the SKA, the new project whose science we rank as our highest priority for 2020 and beyond. The combined set of planned facilities will provide Canadian scientists with state of the art access to a wide range of wavelengths and instrumentation, and maintain our position at the forefront of research and technical capability.

We note that our position as a major partner in CFHT has been of great value in enabling large programs, and that our smaller share of other facilities is clearly less successful. Thus, we strongly support a major partnership in TMT. However, the alternative of joining ESO is a serious alternative to TMT and Gemini that needs LRP consideration.

It is clear that funding construction and operations of the future facilities is an enormous challenge. We probably need better public outreach and lobbying power with funding sources. The synergy between NRC, CSA, ACURA, and industry is a vital aspect to nuture, and we need to improve communications and co-operation between funding and operating agencies of our international partnerships. The future planning and operation for Gemini and CFHT are very uncertain, and need close attention by the LRP. Finally, we need to nurture the scientific community by ensuring adequate research grants, and improving postdoctoral and junior job openings in both Universities and NRC.

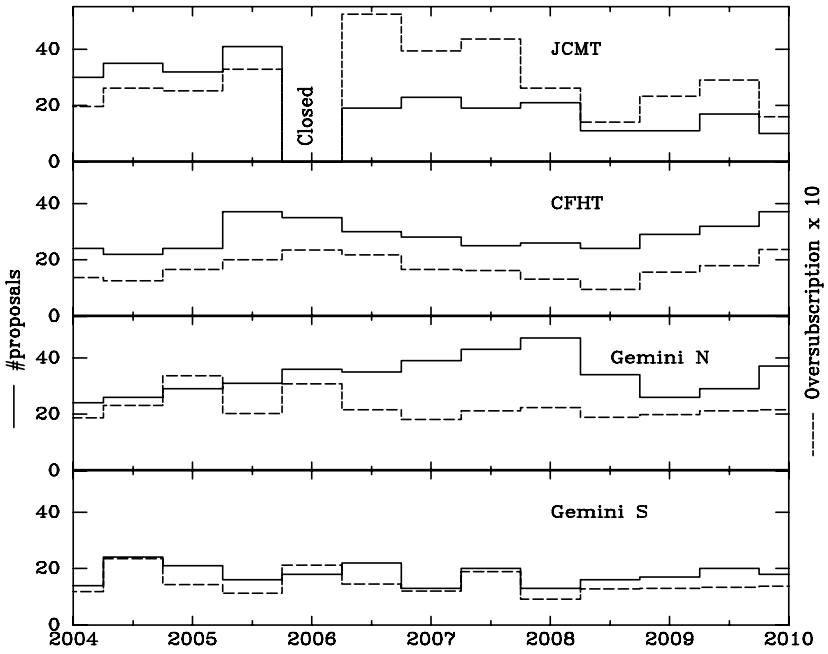

FIG. 1.— Proposal and subscription rates for offshore telescopes for the decade. The dashed lines are the oversubscription ratios times 10 - i.e. 20 is 2 times oversubscribed. The solid lines and labelled Y-scale are the number of proposals. We note the rising CFHT and Gemini N demand in recent semesters, the overall low level for Gemini S, and the gradual decline for JCMT. Instrument changes in Gemini S and JCMT are expected to raise demand for both.