

# Report of the ESO Working Group to the LRP2010 Panel 13 August 2010

## Executive summary

The ESO Working Group of the LRPP finds, from the perspective of both scientific return and cost, that pursuing participation in an ELT via joining ESO is an alternative worthy of further exploration.

## 1. INTRODUCTION

### Remit

As described more fully in Appendix 1 (Terms of Reference for the ESO Working Group):

*“The LRPP remains committed to Canadian participation in the TMT project provided that the telescope can be advanced in a timely fashion. ... there is every expectation that TMT can accommodate our drive to be a “second-to-none” partner in this telescope. However, there are problems at the present time. We do not know what Astro2010 will recommend in its report later this year... There are also concerns about starting construction in a timely manner. ... The LRPP would be remiss if it did not exert due diligence in investigating a “credible alternative” to TMT. ... An earlier ACURA report (Feb 2010) found that membership in ESO [European Southern Observatory] would provide us with access to an E-ELT for a cost (amortized over 20 years) nearly identical to that of staying with the TMT project (and remaining in Gemini and NAPRA). The LRPP now proposes a more detailed fact-finding mission that will investigate technical matters related to TMT, and look more carefully at the implications of ESO membership for Canadian astronomy.”*

*“The primary purpose of the Working Group is to investigate whether joining ESO (and obtaining access to an E-ELT through that route) is feasible, and under what conditions and circumstances such a decision should be taken.”*

The focus was to be on two areas: (i) the ESO ELT (E-ELT) itself and compared to the TMT, and (ii) the implications of ESO membership for Canadian astronomy.

The Working Group (WG) did indeed go over ground well covered by the ACURA report and our conclusions are not dissimilar. We hope that the extra scrutiny and additional documentation provided here will be useful input to the challenging deliberations of the LRPP.

### Composition of the WG

The WG consisted of Peter Martin (chair, University of Toronto), Bill Harris (McMaster University) and Marcin Sawicki (St. Mary's University), nominated by the LRPP, ACURA, and CASCA, respectively. As anticipated in the remit, Paul Hickson (UBC) acted as consultant to the WG, particularly for technical comparisons between the TMT and ELT and their instrument complements (formal report provided as Appendix 5).

## **Activities of the WG**

After the WG was struck in 2010 June, we met by telecon to plan the visit to ESO headquarters in Garching. ESO welcomed the prospect of a visit, and planning was ably facilitated by Rowena Sirey, delegated by DG Tim de Zeeuw. We met with ESO staff during 2010 July 15 and 16 at ESO. As will be seen from the schedule (attached as Appendix 2) we met nine senior ESO staff, with presentations and discussions covering observatory governance, international relations, telescope operations, VLT instruments, and a thorough overview of the E-ELT project. We also subsequently received copies of the slides from many of the presentations (indexed in Appendix 3). We refer to these using [...]. They might be of continuing value for future deliberations by the LRPP, but we request that they be kept confidential.

## **Structure of the report**

In the spirit of “best efforts” on a short timescale, we first present small sections on issues that we think need to be considered, all building to a comprehensive discussion. These summarize some of our opinions and the background documentation informing these opinions.

Then we answer the specific questions in the Remit (Appendix 1). To some extent this might be repetitive, but the preamble is an opportunity to cross-cut arguments and to present new considerations as well.

We finish with a recap with pros and cons, some recommendations for further study, and comments on the timeline for decisions.

## **2. DISCUSSION POINTS**

### **The evolving ELT landscape**

Virtually all major industrial countries and now many developing ones are moving towards owning a share in an ELT, which will enable discoveries out of reach of the current-generation telescopes. This reinforces the wisdom of the decision by Canadian astronomers to take an early leadership role in one such promising project (TMT). In fact, given the strengths and focus of Canadian astronomy, participation in an ELT is probably more critical for us than for many other countries that either (by virtue of size) are engaged in a broader range of activities or do not have Canada’s particularly strong track record in optical-infrared ground-based astronomy.

In our view, TMT remains a great option. However, the TMT partnership has evolved considerably since Canada joined as “second-to-none” among a small number of very experienced partners, and because of both funding and site considerations the TMT has not progressed toward a construction start quite as quickly as originally anticipated. Furthermore, after a false start, the E-ELT has made up ground and emerged as a strong, and in our view credible, competitor.

If one adopts the view that both TMT and E-ELT will get built, then one still has the questions (i) which will be “better”; and, mindful of the Keck experience, (ii) which will be first and stay first. In our judgment, both the TMT and E-ELT are technically sound and have a similar potential to be transformative (Appendix 5).

## **Being first**

ESO hopes to begin construction in 2011 with first light in 2019 [1, 2]. The main hurdles are (i) an external technical Construction Review to be completed imminently in 2010 September [2] and (ii) having the full funding in place (required by the ESO Council) [1, 3]. Given the advanced state of design, planning, and retirement of risks [1, 2] and the work on the financial fundamentals including membership for Brazil [1, 3], this optimistic schedule might well be met. Staying first requires a long-term plan for funding and bringing on line more instrumentation. Here the track record with the VLT [1, 6, 8] and the stable long-term governance and financial model [9], including operations, also auger well that the ambitious instrumentation plan for the E-ELT [4] including the all-important AO [5] will not founder.

TMT has been equally ambitious in its schedule, and being initially a bit ahead has had more opportunity for the potential pitfalls to become apparent. Getting a construction permit is not an issue for E-ELT, but still looms large for TMT at the Mauna Kea site. And, to repeat, the partnership and full funding (including Canada’s portion) are not in place. If NSF is to be an important player, the signals being issued by some of its officials that it cannot react quickly, are cautionary. One should not underestimate the ability of US political forces to speed things up, or equally, to get into a stalemate or quagmire.

It is difficult to assign a number to what would be a tipping point that would firmly decide which route Canada should favor. However, to take extreme cases, if first light for one project could be determined to be five years ahead of the other, then surely that would be a persuasive argument. On the other hand, a one-year predicted difference, relative to the time frame of eight years to first light, seems acceptable. It should always be kept in mind as well that the discovery potential of an ELT comes from its instruments as much as from the raw telescope. Thus the first-generation instrument suite for each case carries a lot of weight.

## **The ESO framework for the E-ELT project**

ESO’s self-stated mandate is, in broadest terms, to provide the most advanced telescopes and instruments in the world for the benefit of the astronomers in its member countries. Starting with 5 member states in 1962, it has now grown to 14 and is in negotiations with its first non-European member (Brazil) [1,9]. The original small retinue of ESO telescopes on La Silla has continuously expanded, now including VLT, VST, and VISTA on Paranal, and a share of ALMA at Chajnantor [1].

The E-ELT is the logical next step for this organization and it is the “highest-priority ground-based astronomy project” [1]. In what appears to be an astute decision, the E-ELT will be located on a very competitive site, Cerro Armazones, near Paranal and will be run as an integrated part of the observatory from Paranal. This will “strengthen Paranal with another

unique capability, ensuring its long-term scientific future, making it an undisputed world-leading ground-based observatory” [1]. With its integrated “system” of telescopes it will certainly be in a unique and enviable position. There will be attendant logistical simplicity and considerable operational savings compared to a stand-alone site.

## **Membership and governance**

Each Member State (MS) contributes an annual membership payment that is proportional to its Net National Income (NNI), calculated by a weighted average of the NNI over the previous three years. Although the Member States pay widely different annual fees, each of them has the same presence on the governing Council – two delegates per country, at least one of whom must be an astronomer, and one delegate to the Finance Committee. The makeup of Council ensures that scientific priorities drive the direction of the Observatory. The governance is stable (although changeable) and has withstood the test of time through great growth of ESO. The financial structure makes long-term planning possible. See [9, 11].

## **Financing the E-ELT**

As described, the E-ELT project is now well planned out and on track with no obvious political or technical barriers. However, ESO still needs some more funding to finance the full project and ensure the continued growth of the observatory. As spelled out in the scenarios in [3], the preferred approach is to make strategic additions of new Member States according to two criteria (i) enough economic strength to make significant additions to ESO’s income; and (ii) a strong track record in astronomy and a high level of technical and industrial expertise.

## **How Canada fits in**

As the WG was told clearly by the Directorate, Canada fits this bill very well and we would be a welcome new MS. We can flatter ourselves, with some justification, re criterion (ii), but it is also the case that Canada joining up (along with Brazil) would actually enable the EELT project without forcing ESO into extra kinds of temporary financing. (ESO’s position is that even Brazil joining would be enough to enable the project [1] but – because of ALMA-related cashflow issues – with either a delayed starting time or the need for a loan [3].)

Consequently, Canada would have a certain amount of bargaining power during Membership negotiation right now. Four or five years from now, we might still negotiate for ESO membership, and might still be welcomed, but we would not have the same leverage on the process, or any chance to bid on major components like the dome construction or the first instruments. In short, a wait-and-see attitude is not the optimal approach for us.

## **Partnership in the E-ELT vs. full membership in ESO**

We discussed the option whereby Canada might have a limited partnership in the E-ELT alone. Our clear impression is that this is not the preferred mode of participation for ESO, and so there is less flexibility and opportunity to make a “good deal.” In one model presented, Canada could pay for 10% of the cost of the E-ELT, yet when allowances are made for other investments, end up with only 7% of the telescope time [10].

As described in more detail in Appendix 4, full membership requires both an annual contribution and an accession fee [10, 11], and because it gives immediate access to all ESO facilities, including the VLT, etc., it is more costly than a limited E-ELT-only partnership. However, it brings many more benefits [10]. Furthermore, it might well displace costs that Canada would otherwise be paying for alternative complementary facilities (e.g., Gemini).

## **Costs**

Canada as an ESO Member State would according to formulae contribute an approximate 10% share of the new total budget [11]. With due diligence, Canada might be expected to gain a similar share of the telescope time and of the contracted work relating to construction and instrumentation upgrades.

The annual fee would be \$20 M/y. The accession fee would be \$129 M (the investment that Canada has already made in ALMA would count (indirectly – see Appendix 4) towards its accession fee, which would result in a very significant cost reduction of \$61 M [11]). An extra levy for the E-ELT might amount to \$41 M for Canada over the construction phase.

The 2010 February ACURA report (Appendices C and D) used similar numbers to estimate the costs of participating in an ELT project under three scenarios: (i) continuing with TMT; (ii) a restricted partnership for only the E-ELT but continuing the present arrangements with Gemini and ALMA; and (iii) full membership in ESO. With the same (reasonable) assumptions and more or less the same input (numbers do get updated, but the underlying formulae are the same), we would come to a similar conclusion that the costs are similar to better than the usual “astronomical accuracy.”

All scenarios are expensive compared to current spending, which restates that on an NNI (or GDP) basis Canada spends much less per capita on astronomy than most peer countries. A relevant question is then: which scenario would be most attractive of government funding?

## **Instrumentation contracts**

On an ongoing basis, contracts are expected to be available for instrumentation on several telescopes: the E-ELT, the four VLTs, and ALMA, all of which Canada and especially HIA should be in a position to bid on. Predictions again are difficult but something like two contracts per year at any given time could be expected to be open to bids. Competitive bidding with the other national labs within ESO are a part of their normal operation, but in the long term Canada could anticipate gaining its nominal share of these as long as HIA and our industrial partners maintain their capabilities.

Project sharing among the ESO partners (e.g., joint construction of instruments) is also a normal procedure, and is an approach HIA is now familiar with.

## **Timing and bargaining points**

How the accession fee is paid (up-front lump sum, instalments, etc.) can be settled as part of the membership negotiation process. In addition, up to 25% of the value of the accession fee

can be made through in-kind contributions; probably even the 25% is open to bargaining. The concept of “window of opportunity” arises here; joining any project late limits influence and options.

Potential in-kind Canadian contributions could include:

- E-ELT enclosure construction. In the event of DSL winning the E-ELT enclosure contract, it might be possible to have part of that work funded by Canada as part of our accession fee, rather than having the entire enclosure funded by ESO.
- Some guaranteed contribution to the AO systems (HIA expertise has been noted)
- Some guaranteed contribution to the instruments at an early stage, be they for E-ELT, VLT or ALMA
- Transfer of Canadian share of CFHT to ESO – under future VLT instrumentation there is an interest in wide-field MOS capability, possibly on a 4-m [6]
- Do not pay the extra levy that the current ESO Members have been asked to contribute to ensure the health of the ESO operation as a whole

### **Revisiting the ESO option**

The “ESO option” for Canada should be seriously considered.

The alternative of Canada joining ESO has come up in previous planning cycles, for example LRP2000, and before that in the run-up to the 8-m (Gemini) era. Traditional concerns raised against it have centered on perceptions that ESO partnership would be less convenient than our current US-centered collaborations, would represent a culture change for Canadian astronomers, and would also lead to loss of independence.

*Convenience and culture change.* The landscape has changed considerably compared to these earlier times. Canada has thoroughly bought into the international facilities approach. Canadian astronomers travel regularly for meetings and collaborations with our current international partners in Hawaii, Chile, France, the UK, and to a lesser extent Australia, Sweden, and elsewhere. We are already part of several facilities with European partners (CFHT, JCMT, Gemini, JWST, Herschel, Planck). Thus shifting more emphasis to Europe would be a much less significant change than it might have been in the past, and continued developments in (e.g.) videoconferencing technologies will help everyone.

*Independence.* The “independence” criterion is harder to quantify, but it appears that to a large extent ESO membership is what you make of it. Its biggest advantage in day-to-day terms may simply be that it provides a rather stable and comprehensive platform within which the member astronomers can operate. It is rather transparently an equal-opportunity organization where no single member state has a dominant share or influence. In practice it would be rather close to the “second to none” banner that we aim for.

### 3. SPECIFIC QUESTIONS IN THE REMIT

#### (i) E-ELT as an option for Canada:

##### What are the pros and cons of the E-ELT design relative to TMT design?

These are detailed in Appendix 5, the report prepared by Paul Hickson. Extracting from the summary: *“This report compares and contrasts scientific and technical aspects of the TMT and E-ELT projects. The emphasis is on aspects in which the projects differ, in ways that impact performance. ... While there are many similarities between the two projects, there are clear differences, not the least of which is the difference in aperture size. In the final section of this report, I consider the impact of this and other differences on scientific capability and productivity. The impact depends on the assumed fraction of time spent on diffraction-limited observations and, to a lesser degree, the science targets.”*

##### Does the E-ELT design satisfy Canadian needs?

We take an empirical approach to answering this. We assume that the TMT plus its intended set of instruments reasonably satisfy Canadian needs for a VLOT design. Thus if the E-ELT provides a similar product like  $S^2D^4$  (Strehl ratio  $S$ , aperture diameter  $D$ ) and a suite of instruments with similar capabilities, then it too would satisfy Canadian needs. Detailed assessment of the E-ELT instruments (Appendix 5) shows that they overlap almost completely with the TMT slate, with one addition (CODEX, for high-resolution, high-stability spectroscopy) that is not provided by TMT. In short the E-ELT design appears to fit in with Canadian aims well.

##### What are the risks in the E-ELT design, and how plausible are the costs?

The E-ELT effort was re-oriented at the end of 2005 towards “the best affordable ELT Facility that can be built on a competitive basis with acceptable risks” [2]. The E-ELT has been in Phase B since Jan 2007, the goal being a proposal for construction by the end of 2010. We had a presentation on the philosophy of the detailed design phase of the E-ELT. From conceptual design and feasibility studies on, a focus has been for close industry involvement, as illustrated by these statements: “industry has designed this telescope” and “don’t design risk for industry – let them do it from the beginning.” There is formal tracking of risks through “risk registers” at ESO complemented by those from the contractors. We were told that the process is iterated, about three times. The last step is call FEED (Front End Engineering Design), which generates “fixed price offers.” About 80% of the E-ELT hardware costs are under FEED. ESO is not obliged to act on any of these contract offers, but they serve the purpose of refining the cost and support the notion that the risk is transferred to industry. ESO is most likely to use the output of the FEED stage as the basis for tendering.

Although not so familiar to us, FEED appears to be in widespread use in industry, e.g., <http://www.chiyoda-corp.com/service/en/plant/feed.html>  
<http://www.genesisoilandgas.com/feed.asp>

In any case, most of the major work is supposed to be completed before the Construction Review in 2010 September. One interesting number is that the dome cost is presently 20% of the telescope plus dome cost of 900 M euros (including 15% contingency) [3].

*What de-scoping options are being considered, or may occur?*

If ESO ends up with a relatively small shortfall in project funding then some sort of descoping might occur; otherwise, their strategy is simply to add enough new member states to get the funding they need. At present, two new ones at the level of Brazil or Canada are predicted to be enough [1, 3]. There may also be the option of simply delaying construction by a couple of years while keeping the telescope design as is. With Brazil joining, and the planned increase in annual member contributions going through, there is even now sufficient money to start construction in ~2013. Canada's accession would overcome any cashflow issues remaining at this point and so would enable immediate construction. Otherwise, the goal of a 2011 construction start would require a loan, and the rate of construction might be slowed to minimize the size of loan required.

*What is the timescale for cash flow and construction, and is this reasonable?*

At time of writing (Aug 2010) their plan is for project approval by the ESO Council in December 2010, construction beginning in 2011, first light in late 2019, and beginning of science operations early 2020 [1]. The first-light instrument concepts have been selected to be MICADO and HARMONI along with some form of MCAO. Their plan for tendering and construction seems reasonable given the ~5 year lead-time necessary for constructing an instrument.

**(ii) Implications of ESO membership for Canadian astronomy:**

*Is full ESO membership preferable to a more restricted E-ELT partnership?*

Full membership looks preferable from both ESO's and Canada's viewpoints. ESO is willing to negotiate a partnership restricted only to the E-ELT, but would much rather have full involvement and participation from its member states. From Canada's perspective, either full membership or restricted partnership would cost about the same for our total budget including related facilities but full membership would deliver access to a more powerful range of facilities and numerous side benefits [10], as well as much more influence within the organization.

On the other hand, by paying the ~10% of ESO costs Canada would not automatically be getting ~10% of ESO telescope time. The observing time is in open competition and no strict year-by-year proportional allocations are mandated. Canadians would likely constitute fewer than ~10% of the pool of ESO astronomers competing for time: we have ~325 PhD-level astronomers, but ESO has ~5000 and the balance between observers and theorists is similar. Current ESO oversubscription rates are 4x (and 8x for some instruments), compared to factors of 2-3x traditionally for Canada.

Viewed differently, the ESO array of facilities is so large that we might well be gaining all the dataflow we could manage and the question of “shares” might be somewhat moot. (For example, 7.5% of four 8-m telescopes would be roughly equivalent to 15% of two such telescopes.) In addition, with many projects now being carried out by large international teams of colleagues, the whole question of parceling out by nationality is less obvious. Given past productivity, it could also be argued that, astronomer-for-astronomer, Canadians can supersede numerical disadvantages. The LRPP might wish to look into this issue more carefully.

*Do other ESO facilities (especially VLT) satisfy our needs?*

Yes. Complete access to Paranal and La Silla would give a much wider range of telescopes and instrumentation, particularly at the 8-m level, than we now have. It is important to note that ESO has a credible and well-funded instrumentation plan [6] that adds to the appeal of these facilities.

*How will HIA be affected by joining ESO? Will restructuring be required?*

It is not obvious that major restructuring would be required. As long as HIA maintains its recognized ability to build competitive instruments and components for (e.g.) VLT, ALMA, and E-ELT, it can easily fit into the current ESO scheme of operation. New projects are bid on, and over the medium to long term the number of contracts gained is expected (but is not guaranteed) to be in proportion to the national membership share.

For a more detailed prediction of the implications, one would need to compare the current HIA instrumentation budget and contracts with the value of (say) 10% of the ESO instrumentation contracts, both now and in the E-ELT era. Matching funds should also be taken into account. The WG has not attempted to work through these numbers.

In the medium to long term, HIA would settle into a new equilibrium as one of the national labs working with a steady stream of instruments and designs. In the shorter term, some kind of transition would have to be made away from CFHT, Gemini, and TMT (but not ALMA) and it is not clear how this would be handled. Part of the negotiation for joining ESO could, however, include the chance for HIA to join rapidly with one or more of the E-ELT or VLT instrument projects.

*How will the university community be affected?*

There should be generally positive effects on the university community, including readier access to a wider and deeper pool of colleagues; automatic funding for observatory travel; enhanced opportunities for our students to obtain ESO postdoctoral fellowships that include the opportunity to – in their 3<sup>rd</sup> year – work back in their home country. There are no obvious downsides once the transition is made.

What are the implications for our partnership with Gemini and the CFHT?

Purely for national funding pressures we would almost certainly need to withdraw from both Gemini and CFHT – in some orderly fashion but in the near future. In the longer term, the array of VLT telescopes and their large suite of instruments would open up more research paths than Gemini. The attraction of continuing with CFHT (perhaps with MCAO operations) is real but must be balanced against the “ESO option” of VISTA, VST, and La Silla. We note that there is some possibility that the Canadian share of CFHT could be transferred to ESO as part of Canada’s accession fee.

How will our access to ALMA be handled?

Three possibilities were raised with us by the ESO Director General:

(i) We simply switch ALMA allegiance from the North American channel to the ESO channel. The NA and ESO total shares would remain equal, which would have the effect of removing pressure from the US side and adding pressure to the ESO side. In this scheme we could expect to have a Canadian on the ALMA Board from time to time but not all the time.

(ii) We join the ALMA share of ESO but also keep our NA share along with our seat on ALMA Board. ESO would have no objection to this but it would probably not be affordable from our side because of the impact on the accession fee and the ongoing costs to support the NA share.

(iii) We switch all our ALMA involvement to the ESO side, and a negotiation takes place between ESO and NSF to rebalance their total shares more rationally. The outcome of that is difficult to predict, but the DG has offered to try it.

In addition, the DG noted that it could be part of our negotiation for joining ESO that we would have one of the ESO seats on the ALMA Board for some to-be-defined period of years after we join.

In short, the effects on ALMA need to be carefully considered, but at the present time they do not appear to be “tipping points” or critical factors in the decision re the E-ELT.

Can we embed our involvement in SKA within the ESO membership? What are the implications?

SKA does not yet have any kind of official presence within ESO, and so no clear reply to this question is possible at present. ESO does not foresee the ability to initiate a new major project until 2019 [1].

## 4. CLOSING COMMENTS

### Recap: summary of pros and cons for joining ESO

#### *Perceived advantages*

- Partnership within an ambitious, large-scale organization with few political or governmental issues, thus long-term stability
- Because ESO membership is via a binding inter-government treaty, and because funding levels are stipulated by that treaty [9, 11], were Canada to join ESO, Canadian funding for astronomy infrastructure would be put on a stable footing for years to come.
- International cooperation and equal-opportunity attitude within the partnership is well understood and well established
- The E-ELT project is thoroughly planned out and on a clear road to completion
- Over the longer term, numerous ongoing opportunities for instrument and development contracts from the combination of E-ELT, VLT, and ALMA. Note that ESO has a well-defined instrumentation program (and funds!) for VLT in the E-ELT era [6], which is a distinct advantage over the current situation that Canada is in.
- Large, open, and diverse community of scientists
- Large pool of instrumentation contracts to bid on over the long term
- Side benefits include observatory travel funding and ESO postdoctoral fellowship program, thus leveraging our pressured NSERC grants.

#### *Perceived disadvantages*

- Short-term but fairly major transition would be needed for orderly withdrawal from TMT, Gemini, CFHT
- Canadian plans have been that a major contribution to TMT would be the dome construction, provided by DSL, though this has yet to be negotiated with the TMT Board. Chances are smaller, but non-zero, that a similar in-kind contribution could be negotiated for the E-ELT.
- The E-ELT design does not emphasize ultra-high Strehl ratios that TMT aims for
- Canada's ~10% share of the costs may result in a less-than-10% share of telescope time (though this fraction needs to be multiplied by the number of annual telescope-hours over the whole observatory to be converted to actual data gained).
- The Canadian astronomy community might become less cohesive as people start collaborating on large international teams with colleagues from ESO rather than looking at maximizing their share of Canada-specific dedicated time on Gemini, CFHT, etc. This might not be a bad thing, however, given that this appears to be the direction in which science is moving world-wide.

### Recommendations for further study

- It is not clear whether ESO could start construction immediately upon Brazil joining, or whether a cash-flow problem would delay construction for ~2 years unless Canada joined.

In the event of the latter, construction won't start until either Canada joins, or until ~2013, and this gives us a little more breathing room to work on our funding.

- It remains somewhat unclear how far advanced the E-ELT design is. Are they nearly ready to build? A more detailed review of the E-ELT design by our TMT experts would be beneficial in this light. This will be addressed by the 2010 September four-day External Review of the E-ELT Construction Proposal by a board of technical experts (TMT, GMT, LSST...) chaired by Steve Sackett [2].
- In-kind contributions to the E-ELT.
- What would be the expected share of telescope time for Canadians: the 10% cost does not necessarily translate into a 10% share of telescope time given that Canadians would potentially constitute less than 10% of the ESO astronomer pool.

### **Timeline, significant dates**

ESO has an aggressive timeline for the E-ELT. This is probably somewhat dynamic, given the key milestones yet to be met. The timing of any Canadian decision to participate in ESO/E-ELT is arguably critical, though how quickly things will progress is not really known. Thus there is a "window of opportunity," though ill defined.

- 2010 August – Astro2010 announced
- 2010 September – review of E-ELT construction proposal (and costing)
- 2010 December – proposal to ESO Council
- 2010 fall – LRPP preliminary report confirming priority for participation in an ELT? Preferred collaboration?
- 2011 winter – Canadian budget
- 2011 – E-ELT construction start
- 2011 (late) – call for tender for first light E-ELT instruments

## **APPENDIX 1: Remit of LRP2010 ESO Working Group**

### *Introduction*

The LRPP remains committed to Canadian participation in the TMT project provided that the telescope can be advanced in a timely fashion. The TMT project represents an excellent match to Canadian scientific requirements, and we reaffirm the MTR 2005 assessment of this project. Furthermore, our experiences to date give us confidence that the telescope can be built and will operate as planned. We have an established working relationship with the existing partners, there are very real assurances that other international partners are interested, and there is every expectation that TMT can accommodate our drive to be a "second-to-none" partner in this telescope.

However, there are problems at the present time. We do not know what Astro2010 will recommend in its report later this year; if it does not recommend a GSMT as the highest priority new ground-based facility, it will take considerably longer to sort out the timescale on which the project can go ahead. A lesser concern is that TMT may not be selected by NSF in the down-select of which GSMT goes forward. There are also concerns about starting construction in a timely manner (for example if NSF involvement requires a Federal US environmental impact statement, or if legal challenges in Hawaii cause delay). (There is of course the separate problem of funding in Canada.)

The LRPP would be remiss if it did not exert due diligence in investigating a "credible alternative" to TMT, while we await the outcome of Astro 2010 in the US. An earlier ACURA report (Feb 2010) found that membership in ESO would provide us with access to an E-ELT for a cost (amortized over 20 years) nearly identical to that of staying with the TMT project (and remaining in Gemini and NAPRA). The LRPP now proposes a more detailed fact-finding mission that will investigate technical matters related to TMT, and look more carefully at the implications of ESO membership for Canadian astronomy.

### *Terms of Reference for the ESO Working Group*

Purpose: to investigate the feasibility of Canada joining ESO as a full member.

Deliverable: A short confidential report to the LRPP, to be delivered before the end of August 2010. The report should assess pro's and con's of joining ESO; a statement indicating under what circumstances and conditions Canada should join; and problems for further study.

Membership: One member to be chosen by each of LRPP, CASCA and ACURA. Paul Hickson will be an additional "resource member".

Background Material: The ACURA VLOT report (Feb 25, 2010). The WG may also wish to refer to the GCAR reports on GMT and TMT.

## Details

The primary purpose of the Working Group is to investigate whether joining ESO (and obtaining access to an E-ELT through that route) is feasible, and under what conditions and circumstances such a decision should be taken.

Many of the financial comparisons and implications of joining ESO have been discussed in the ACURA VLOT document, and need not be repeated.

It is expected that the WG will travel to Europe once to visit with ESO management and to talk to members of the E-ELT team. A meeting or telecon with the UK may also be beneficial to understand that country's experiences joining ESO.

The purpose of this WG is to investigate whether ESO membership satisfies Canada's needs and is worthy of a further detailed follow-up study. The purpose is *\*not\** to negotiate membership in ESO. Time is of the essence: the WG will have to act quickly, and it is expected that the WG Report will identify a number of questions and problem areas for further study.

There are two areas to be investigated by the WG. The WG should feel free to add to the list below.

1. *ESO E-ELT* - What can be built, for how much, with what risks, and when? Specifically:

- What are the pro's and con's of the E-ELT design relative to the TMT design?
- Does the E-ELT design satisfy Canadian needs?
- What are the risks in the E-ELT design, and how plausible are the costs?
- What de-scoping options are being considered, or may occur?
- What is the timescale for cash flow and construction, and is this reasonable?

2. *Implications of ESO membership for Canadian astronomy* - It would be useful for the committee to first confirm the earlier findings that full ESO membership is preferable to an E-ELT partnership.

- Do other ESO facilities (esp. VLT) satisfy our needs?
- How will HIA be affected by joining ESO? Will restructuring be required?
- How will the university community be affected?
- What are the implications for our partnership with Gemini and CFHT? (Exit fees and exit dates for these facilities are a matter for HIA and the LRPP to sort out.)
- How will our access to ALMA be handled? (NAPRA and EVLA access are a matter for HIA/LRPP.)
- Can we embed our involvement in SKA within the ESO membership? What are the implications?

Joining ESO may stimulate closer relations with ESA. How does CSA feel about this? (This may be a matter for the LRPP to ask about; it goes beyond the issue of joining ESO.)

## APPENDIX 2: Schedule for WG Site Visit

Visit by Canada's Long Range Plan 2010 Panel Working Group to ESO Garching 15-16 July, 2010 in the Council Chamber on 15 July and Room 231 on 16 July

### Thursday, 15 July

Time	Who	Position	Topic of discussion
09:00 (60 mins)	Tim de Zeeuw	DG	Welcome and overview of ESO programme
10:00 (30 mins)	Peter Martin and the WG	WG Chair	Canadian Astronomy, the Long Range Planning exercise and WG remit
10:30 (15 mins)	<b>COFFEE</b>		
10:45 (45 mins)	Roberto Gilmozzi	E-ELT Principal Investigator	The E-ELT instrumentation studies
11:30 (30 mins)	Luca Pasquini	Deputy Head of Instrumentation	VLT Instrumentation developments
12:00 (15 min)	Luca Pasquini		Opportunities for Canada in future ESO instrumentation
12:15 (30 mins)	Discussion		
12:45 (1 hour)	<b>LUNCH</b>		
13:45 (15 mins)	Rowena Sirey	Head of International Relations	ESO: Membership and Partnership
14:00 (30 mins)	Renate Brunner	Deputy Head of Finance Department	Special Contribution and Annual Contribution; and financial aspects of partnership
14:30 (45 mins)	Tim de Zeeuw		The in-kind part of the Special Contribution and ALMA
15:15 (15 mins)	<b>COFFEE</b>		
15:30 (20 mins)	Roberto Gilmozzi		E-ELT programme status
15:50 (30 mins)	Yves Wesse	Head of Contracts and Procurement	ESO procurement policy and E-ELT tendering
16:20 (25 mins)	Rowena Sirey / ??		Round-up: stock-take of day's discussions and identification of additional issues
16:45	<b>CLOSE</b>		
19:00	Dinner - Buergerstuben, Garching: Canadian WG, Tim de Zeeuw, Adrian Russell, Roberto Gilmozzi, Rowena Sirey		

**Friday, 16 July**

<b>Time</b>	<b>Who</b>	<b>Position</b>	<b>Topic of discussion</b>
09:00 (30 mins)	Markus Kissler-Patig	E-ELT Project Scientist	Science with the E-ELT
09:30 (60 mins)	Jason Spyromilio	Head, E-ELT Telescope Project Office	E-ELT Design and industrial components
10:30 (15 mins)	<b>C OFFEE</b>		
10:45 (15 mins)	Jason Spyromilio		E-ELT telescope adaptive optics
11:00 (15 mins)	Norbert Hubin	Head of Adaptive Optics Department	Adaptive optics for E-ELT instrumentation
11:15 (60 mins)	Roberto Gilmozzi / Jason Spyromilio/ Roberto Tamai	Head of TEC Div & E-ELT programme System Engineer	Discussion
12:15 (60 mins)	<b>LUNCH</b>		
13:15 (60 mins)	Review of discussions; identification of actions/further information		
14:15	<b>CLOSE OF MEETING</b>		
Afternoon	Canadian WG Private meeting and report preparation – Room 231		

### APPENDIX 3: Slides from presentations

These documents are referenced in the text of the report by number [n].

Note that these are not quite in the order of the schedule in Appendix 2, which depended on availability of personnel (nor was the schedule followed precisely!). Instead, the documents have been grouped by topic to be more useful to this report.

The presentation by Brunner has been split into its distinct parts (3 and 11) and likewise the presentation by Pasquini (6 and 7).

**Our expectation is that the LRPP will treat these documents as confidential, not for broadcast.**

n	Presenter	Topic	PDF Document name
		<b>The Project</b>	
1	de Zeeuw	ESO and the E-ELT Project	ESO_E-ELT_Overview
2	Gilmozzi	E-ELT programme status	E-ELT_Status
3	Brunner	E-ELT financing	E-ELT_Financing
		<b>Instrumentation</b>	
4	Gilmozzi	E-ELT instrumentation plan	E-ELT_Instrumentation
5	Hubin	Adaptive optics for E-ELT instrumentation	E-ELT_AO
6	Pasquini	VLT instrumentation	VLT_Instrumentation
7	Pasquini	Instrumentation opportunities for Canada	Instrumentation_Opportunities
8	Wesse	ESO procurement process and E-ELT tendering	ESO_Procurement
		<b>Membership</b>	
9	Sirey	ESO governance and membership	ESO_Governance_Membership
10	Sirey	Membership options	Membership_Partnership
11	Brunner	ESO annual and accession costs	ESO_AnnualandAccession

## **APPENDIX 4: Aspects of financial contributions and return**

### **Member State Annual Contribution**

This is based on the NNI via a long-standing formula. Current analysis [10,11] is that this would be **\$20 M/y** [11].

### **ESO plan to increase MS contributions over next decade**

As part of its E-ELT financing strategy, ESO is planning that the MS pay the equivalent of 13 annual contributions over the next 10 years [1, 3]. Part of this is a real 2% annual growth in the MS fees each year, leaving ESO in better shape on an on-going basis after the 10 years. For Canada the accumulated fee over 10 years would then be \$219 M, whereas 13 payments would be \$260 M. The **\$41 M** difference can be considered an extra capital contribution toward the major projects (E-ELT). When asked, the DG indicated that Canada would not have to pay this extra \$41 M; or that it was certainly negotiable. This is an important point as it is a significant amount compared to the Accession Fee.

### **Special Contribution or Accession Fee**

A new Member State gains immediate access to all ESO facilities, without having capitalized them and so is charged an Accession Fee based on the present depreciated asset value of ESO [11]. Current analysis [10, 11] is that this would be **\$129 M** or \$193 M, the \$61 M difference depending on whether the ALMA assets of ESO were included.

Canada would probably choose the former to minimize additional costs, having already paid significant ALMA costs through its American affiliation. Whether Canada has actually paid more or less than this \$61 M is not an issue for ESO, but might be for Canada.

The rate at which a new Member State pays the Accession fee is negotiable, but it would be needed during the E-ELT construction period.

Up to 25% of the Accession Fee can be in kind (thus < \$32 M). However, even then the in-kind contribution has to create a new capability, e.g., to help E-ELT. However, we got the sense that this was negotiable. Could it be as large as the construction contract for the dome? There would have to be major benefits to ESO, e.g., in lowering the cost (with present design, the cost of the dome is 20% of the cost, which is high) and/or in performance (lower wind shake and turbulence helping AO?). Obviously, there is a limited window of opportunity before the design is frozen.

### **Juste Retour**

On a total Member State budget of 135 M euros/y [11], ESO issues about 50 – 100 M euros/y in contracts [8], say 50%. There is no formal policy of juste retour, but ESO is being proactive to make sure that the industrial return for any Member State does not fall below 70% of its proportionate share [8]. The proportionate share for Canada would be about **\$10 M/y**.

## **APPENDIX 5: A Technical Comparison of the TMT and the E-ELT**

This report prepared by Paul Hickson is available as a separate PDF file, TMT\_E-ELT.