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CANADIAN ASTRONOMY INSTRUMENTATION AND INDUSTRY

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ABSTRACT

Canadian astronomy has enjoyed considerable success as a result of a good balance between observational and theoretical facilities and resources. Instrumentation for modern telescopes tends to be very large, sophisticated, expensive, and highly integrated with the host facility. Ideally, instruments must be scientifically competitive but should also be built quickly, on budget and schedule, and be very robust and reliable. It is a challenge to achieve all these goals. Because of this, and the increasing scale and cost of future instruments, we believe that new approaches for partnership with industry and sizable collaborations of engineers and scientists in universities and national labs are required. Building on our heritage and existing strengths, we have an opportunity to forge better alliances that will enable Canadian scientists to remain at the forefront of astronomy worldwide, while at the same time assisting Canadian Industry to become more competitive in advanced technologies.

Subject headings:

1. INTRODUCTION

Canada has a proud tradition of being a world leader in observational astronomy, beginning with the study of our Milky Way with the largest telescope in the world in 1918. Most of our successes were facilitated or enabled by state-of-the-art, internationally competitive instruments. Some examples of these were discussed during the heritage session of CASCA in 2008 (e.g., Crampton 2008). In recent history, Canada provided the two most popular and productive instruments on Gemini (GMOS and Altair). We are also playing the largest role in the Gemini planet finder consortium. At radio wavelengths, Canadian engineers and industry are providing arguably the worlds most capable correlator for NRAO's EVLA in New Mexico. The 73 state-of-the-art low noise cryogenic receivers that Canada is providing for the international ALMA project are absolutely critical to successful ALMA operation since they will be used for commissioning as well as science.

Up until ∼1979, when CFHT was commissioned, many labs in Canada were able to construct appropriate instruments. During the 80 and 90s, the expense and size of instrument projects began to demonstrate the need for more professional engineering and project management expertise. This, in turn, encouraged the formation of larger teams of scientists, engineers, students, technicians, and procurement/administrative support more typically found in a national lab like HIA rather than academia. To further complicate matters, most instrument projects are now awarded on a competitive basis. A very significant, usually underfunded, effort from a strong scientific and technical team is required to respond to the opportunity to be involved in forefront instrumentation and its scientific potential. However, there is always a considerable (many months to years) delay while proposals are assessed and the requisite funding is allocated - and there is no guarantee that one will win or, indeed, if the project will proceed. Thus, to adequately respond, it is essential to be able to rapidly mount an exceptionally strong team and demonstrate that it is capable of delivering a superior instrument but then be able to support that team via other projects or resources until an award is made to begin the project. The uncertainties involved in the process is thus much more like the challenges commonly faced by industry than scientific institutions - industry must be able to weather the famines between projects and the challenges that occur when many projects are funded simultaneously. Industries typically also bring experience with process and quality control and risk management. But an extremely strong scientific motivation is first and foremost essential to the success of a project, backed by a multi-disciplinary team experienced in translating the scientific requirements into concepts that take advantage of the latest technological advances.

Another recent trend is for successful instrument projects to be multi-national. This not only brings the possibilities of tapping into the best expertise and technologies in more than one nation but it is also frequently seen as an advantage by managing and funding agencies. Successful international collaborations are built on first-hand discussions among scientific peers and trusted engineering colleagues. We believe that to be prepared for the instruments of tomorrow we need a nimble combination of scientists, engineers experienced with astronomical technologies (often provided by a national lab or a large university based instrumentation group), and much more direct support/interaction with industry.

Large astronomy instrumentation projects in Canada, which are generally funded by governments, bring on themselves questions about the return on the taxpayers' investment. Apart from the genuine interest and need that the public feels about the exploration of the Universe, the economic returns are the development of Canadian industry expertise and knowledge, the reduction in investment risk, and the development of new products with wider applications. Industry partners are able to increase the capabilities of businesses, developing domestic and foreign markets for high value added goods. As-

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tronomy procurement contracts fund the critical early adoption market of the innovation lifecycle.

In the past, because of their uniqueness and specialized nature, instruments would have been largely integrated and tested in astronomy labs, with most of the components purchased from or built by industry. Frequently, unusual requirements led to an extension of a company's existing technologies. In some cases, Canadian industries became intimately involved in the development of technology and were able to use the expertise they gained in other areas, but their involvement was minimal.

We argue here that increased involvement of Canadian industries is essential to future astronomy instrumentation for many reasons, and provide examples from NRC-HIA projects, only because we are most familiar with them: there are many other examples in the astronomy community.

Rather than explaining or spelling out the many acronyms and references used in the text, they are collected together at the end of this document

2. INSTRUMENTATION 2000 – 2010

Canadian industries are playing an increasing role in providing components, even very specialized components that are state of the art. A few decades ago this was rare: many or most items were fabricated in-house, by specialized workers. New demands, coupled with advanced computer-aided design and manufacture on high precision machines, has altered that: specialized industries now have the relevant infrastructure and resources and can be extremely cost-effective.

Several HIA projects have realized the benefits of "smart procurement". Basically, smart procurement means that companies are selected to work on a project based on their capacity to innovate under a certain amount of scientific and technical guidance. The goal, of course, is to enable them to produce components in a cost-effective way that can meet requirements that often appear extreme when judged against current commercial needs. This can be a very effective mechanism for knowledge transfer. For example, the processor boards developed for the EVLA and built by BreconRidge in Ottawa are among the most complex boards ever built. The receiver prototype developed for the JCMT correlator was optimized for manufacture by Murandi Communications, Calgary. It is now used as a marketing tool to demonstrate the companys enhanced capability and it enabled them to enter the pervasive Wi-max market very early.

Instrument projects are also becoming sufficiently large and/or they may have so many identical components that industrial production becomes of interest, as in the ALMA Band 3 receiver project. Nanowave Technologies (Toronto) successfully produced hundreds of the extraordinarily low noise, very high bandwidth, radio frequency amplifiers and is assembling the cryogenic mixers while Daniels Electronics (Victoria) is providing key quality assurance, purchasing and assembly aspects of the 73 receiver cartridges. The performance of these components and complete receivers far exceeds anything previously built, anywhere. Considerable time and effort is required to transfer the know-how (much more than just "detailed specifications") required, and to work closely with industry to ensure successful delivery of instruments such as these. On the other hand, their production manufacturing knowledge, systems, and capacity is of direct benefit to projects such as the ALMA Band 3 receiver effort.

Co-development is another approach to working with industry: designers can work with a company in the early product development stages so that commercialization can occur more quickly and lower the cost. One win-win project of this type involves co-development of a signal processing board for the TMT and SKA with Lyrtech Signal Processing, Quebec. This type of board has applications outside astronomy. Co-development with NRC/HIA reinforced the companys reputation, opened markets, validated its use and enabled the development of a new product line by lowering the cost and risk of research and development. The benefits to astronomy are similar: prototyping is more rapid, industrial expertise is leveraged, design time, cost and risk are reduced with a potential follow-on commercial pay off.

Here are some quotes from industrial collaborators:
"Without the collaboration with NRC, it would have been very difficult for a small company like ours to secure a contract with the Thirty Meter Telescope project. The collaboration added credibility to the company and allowed us to be considered for a small share of this big project. We would not have been considered as a potential supplier without the NRC experience." Maxime Dumas, Business Development Manager, Lyrtech.
"We believe that the technology licensed from NRC could open up new markets for commercial and defense radar and satellite communications." Dr. Justin Miller, President of Nanowave Technologies.

3. INSTRUMENTATION 2010 –

Most astronomical instruments that are being planned for future facilities are physically large as well as being increasingly sophisticated. Several of the instruments and Adaptive Optics systems being planned for the Thirty Meter Telescope Project (TMT) have characteristic dimensions of 8m and estimated costs of up to $80M. Thus they may be similar in size, cost and complexity to an 8m telescope. Another decadal project, the Square Kilometer Array, presents very large data challenges and offers opportunities for early engagement in research and development with the ICT industry. The physical capabilities and resources to manage and deliver projects of this magnitude are beyond most astronomy labs and, furthermore, since these projects are not initiated very often, it doesn't make sense to develop infrastructure that may be idle in between projects. Partnerships with relevant industries will be essential if we are to build them in a timely, cost-effective manner.

As mentioned in the introduction, instrument projects are usually awarded via a competition. A compelling science case, supported by analyses and simulations from an internationally-recognized team is critical, as are credible designs and analyses from a core base of professional engineers with specialized experience, expertise and reputation. Ideally, elements of the proposal will take advantage of new and emerging technologies based on the latest research by university faculty and students. Early industrial participation lends credibility that components are realizable at a realistic cost and schedule, as well as assurance that the relevant resources are likely to be available when required.

Large projects of the future will rely on industry to bring costs down through economies of scale. As well, early involvement by industry will help develop specs that are realistic within the budget limitations given. While there is some room for business to make internal investments based on the long term benefit of getting involved at an early stage, it has to be based on an end promise and a path to recover the outlays. Small studies, done by industry at early stages is one way to ensure that industry gets engaged in projects and sees the whole project, while contributing to the robustness of design.

Future projects then, would ideally have contributions from university astronomy and engineering departments, national labs like HIA, and industrial partners. Strong partnerships and integration between the practical, theoretical and the strategic aspects are necessary to take the technologies from vision to design to a real instrument. Business and funding models need to respond to industry's fiduciary pressures. Working with industry will also help the public understand that expenditures on astronomy are not solely targeted for academic research.

The Canadian university student co-op programs are exceedingly effective and, somewhat surprisingly, give Canada an advantage compared to the US and UK which don't appear to have anything comparable, at least from our experience with astronomy instrument groups there. Similarly, the involvement of faculty and students from *both* science and engineering faculties at Canadian universities in instrument projects appears to be a uniquely Canadian asset, and an extremely valuable one. The importance of these programs should be more clearly recognized, and some of the impediments that currently exist in jointly funding students should be alleviated and streamlined.

Our experience indicates that building collaborations in such a large and diverse country such as Canada is not at all easy. It is surprisingly difficult to even identify where the expertise in universities, labs or the industrial sector resides, and where the interest might be. We believe that this should and could be resolved by the establishment of the equivalent of a kind of "wikipedia" for science and high technology capabilities in Canada: "CanTechWiki?"

Funding for large science projects in Canada is currently not well organized and often appears to be ad hoc. In some instances there are significant barriers to the types of collaboration that we advocate. Examples include the fact that CFI (and other) funds cannot be spent in government labs, and significant administrative barriers between university and national labs constrain the effective and efficient use of students in many projects. As well, few institutions are willing, or prepared, to take on the responsibility and risk of delivering instruments on budget and schedule that may be worth $100M, especially when nothing equivalent has ever been built before. Perhaps a new model is needed to manage large projects, with more efficient and effective processes for all partners to work together.

The role that astronomy instrumentation plays in advancing high-tech Canadian industry should be recognized beyond the barriers erected by the procurement process. Early consultation at the strategic and design level, with accompanying funds, would help move the benefits of astronomical instruments to the wider Canadian economy.

4. SUMMARY

Astronomy instrumentation exists on the technology frontier. Being involved can give companies first mover advantages as those leading-edge technologies become mature and transition to the commercial and consumer market. Our skill and experience in designing, building and commissioning instruments is a precious resource but stronger and more innovative university-labs-industry collaborations are likely to be essential in the future. New funding models may facilitate and expedite our role in international astronomy projects while advancing our high tech industrial competitiveness. Finally, we advocate the creation of a new "wikipedia" for science and technology in Canada.

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REFERENCES

ALMA: Atacama Large Millimetre Telescope: www.almatelescope.ca

Altair: Gemini Adaptive Optics System

Breconridge: www.breconridge.com

CASCA: Canadian Astronomical Society

COM DEV: http://www.comdev.ca/

CFHT: Canada-France-Hawaii Telescope:

Crampton 2008, JRASC, 102, 179

Daniels Electronics: www.danelec.com

EVLA: Extended Very Large Array: http://www.aoc.nrao.edu/evla/

Gemini: www.gemini.edu

GMOS: Gemini Multi-Object Spectrograph

HIA: Herzberg Institute of Astrophysics, National Research Council of Canada

JCMT: James Clerk Maxwell Telescope:

Lyrtech: www.lyrtech.com

Nanowave: www.nanowavetech.com

NRC: National Research Council of Canada: http://www.nrc-cnrc.gc.ca

NRAO: (US) National Radio Astronomy Observatory

SKA: Square Kilometer Array:

VLA: Very Large Array: http://www.aoc.nrao.edu

TMT: Thirty Meter Telescope: http://lot.astro.utoronto.ca/; www.tmt.org