CANADIAN CENTRE FOR EXPERIMENTAL ASTROPHYSICS

A Proposal

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1 GENERAL PERSPECTIVE

For the period between 1990 and 2020, Canada will have spent about $100,000,000 on building and operating the Gemini Observatory. It is imperative that the Canadian astronomical community achieve the best science and the best graduate student training from this major national investment. However the weakness of instrumentation science in Canadian universities may jeopardize our objectives.

I consider that the university-based capability in optical-ir astronomy is at risk nowadays with the severe budget restrictions to which Canadian universities have been subjected to in the recent years. For example the small astronomical instrumentation groups (UBC, U of Alberta, University of Lethbridge, University of Western Ontario, Université de Montréal, Université Laval) that were active in several Canadian universities have disappeared or shrunk well below critical size. While Gemini has helped greatly in "rejuvenating" the Herzberg Institute of Astrophysics (HIA) in recent years (despite the drastic funding cuts there also), there has been so far little impact in Canadian universities. Unfortunately, very few of the remaining groups or individuals have been strong or competent enough to participe, this even in a very modest way, in Canadian Gemini work packages, which are being handled completely – and very successfully – by NRC-HIA. This is contrary to what happened with the Canada-France-Hawaii Telescope in the late 1970s when some instruments were built in the universities. HIA tried several times unsuccessfully to involve university groups in the past (e.g. for building the AO system for CFHT). Announcements of opportunity for Gemini instruments have been circulated to potential university groups, but no response has been forthcoming. I believe that Canadian universities do not have at present the capability to tackle important instrument building projects. Sadly, university astronomers cannot build the instruments they use on large telescopes! We need to corrrect this dramatic evolution of the university astronomical community whose members risk to become "passive user" clients.

The instrumentation science inadequacy in universities must be corrected, because the strength of astronomy in Canadian universities is absolutely vital for the competitive scientific use of the Gemini Telescopes (and other astronomical facilities), and also for the continuing health of HIA. Also the participation of universities in the design and building of major astronomical instruments (like for Gemini) is essential for the intellectual training the required future manpower in the challenging areas of space and ground-based astronomy and related technological areas. The instrumentation expertise gap in universities may be fatal for our competitiveness: if one cannot build, one is at risk of not understanding and not following the technology which is crucial for building forefront instruments; if one does not build state-of-the-art instruments, no "new blood" will be coming in instrumentation science. The new blood in both science and engineering comes from universities.

In this proposal, I show that we must rebuild competitive instrumentation capability in Canadian universities and I explore a specific avenue on how to do this for astronomy. Although I address issues related more specifically to participation in the Gemini Project, my concerns and proposed solution can be extended to participation in other large astronomical and space astronomy insruments or facilities.

1.1 Re-vitalizing instrumentation science in universities

Nowhere is the need for re-vitalization of instrumentation science in universities more specifically expressed as in the views and comments expressed by the external evaluators of GSC17 during the 1998 Re-allocation exercise by NSERC. These comments, reproduced below, emphasize the weakness, the strength and the future directions for the community.

COMMENTS (excerpts by JRR) FROM NSERC REALLOCATION REVIEWERS

- *"Canadian Astronomy, Space and Relativity scientists are poised to address some of the most fundamental questions about our Universe with an array of new experimental tools and an excellent theoretical team working at the forefront of these fields... An excellent case is made for increased funding to be devoted to collaborative projects, particularly those devoted to the new instruments about to turn on: the Gemini telescopes and new satellite-based experiments."*

  "Canadian scientists have been in the forefront of these studies and will address

central questions with the new Gemini telescopes, including the evolution of the structure of our Universe."

"The specific proposals for the use of reallocated funds are 'Space, Astrophysics and Relativity Project Grants' and a 'Gemini/Satellites Science Fund'. These are both excellent ideas for cooperative projects which will make the most of new equipment turning on within the next few years... The Gemini/Satellite Science Fund would be very important for the proper use of the new facilities which are about to come on line. It is essential that operating funds be made available for Canadians to use these new facilities in which Canada has made substantial capital investments. Funding for the science made possible by the Gemini telescopes and the satellite measurements will enable Canadian scientists to take the next steps in all of the important scientific questions discussed in the vision statement." (Reviewer A)

- *"The advent of satellites has opened up new windows on the universe, and the construction of large groundbased telescopes, including the Gemini telescopes, is proceeding at an unprecedented pace."*

  "The best argument for enhancing support of astronomical research is that such support will be necessary to exploit fully the observational opportunities that will be coming on line during the next few years. The Gemini telescopes, for example, will be immensely powerful and will offer unprecedented image quality, but will require more effort to use than existing telescopes. Greater effort will be required to plan observations and also to extract information, both because of the greater complexity of the instrumentation and the higher information content that it offers, and because of problems of dealing with variable point spread functions provided by adaptive optics.... The second proposed enhancement is to support Gemini and satellite science, and again such enhancement will be required if Canadian astronomers are to reap the full benefit of their investment in the construction phase of these projects. Simply transferring grant funds from old projects to new ones will not be sufficient. Rather, the acquisition and reduction of data from the new groundbased facilities and satellites are going to be more expensive for the reasons mentioned above in connection with the Gemini telescopes." (Reviewer B)

- *"The Canadian astrophysics community has world-wide connections, particularly with France, the UK and the US. The connections with the UK and the US will be strengthened even more by Canada's involvement in the Gemini Project."*

  "Astrophysics nowadays is a science which requires in almost all of its aspects the synthesis of space- and ground-based observations. Canada has a substantial involvement in the Gemini Telescopes project, which will provide excellent opportunities for

optical and infrared observations over the whole sky. It would be extremely short-sighted to diminish the opportunities opened up by Gemini by stinting the marginal funds required for data analysis and interpretation." (Reviewer C)

- *"Taking a broad view of the astronomical opportunities available, I would strongly agree that an expansion of Canada's involvement in Gemini, microwave background studies and theoretical research is crucial..."* (Reviewer D)

- *"Canada has also taken the lead in two of the most important instrumentation programs for Gemini, the construction of the deep optical multiobject spectrograph and the IR/optical adaptive optics package... The scientific community in general is just now beginning to recognize the great importance of instrumentation builders, and the best way to train such people, even if they proceed to work in other areas of research, is by involving them in first class, innovative instruments and facilities."*

  "... The driver here is that many of us believe that the study of star formation needs/is ready for a major breakthrough and that such a breakthrough is likely to be driven by new, high angular resolution observations in the radio and IR. Canada is well positioned in the IR part of the spectrum with the development of adaptive optics for Gemini." (Reviewer E)

1.2 Gemini on-going instrumentation program

The Gemini Observatory will devote to on-going instrumentation and facility developement US \$3 M yr^{-1}. This corresponds for Canada's 15% share of Gemini to CD$\sim$\$650,000 yr^{-1}. Furthermore, only HIA/NRC has, at present, the appropriate resource to take Gemini instrumentation contracts or other international packages. This will – and should – continue to be so in large international endeavours, but I strongly believe that an overall more distributed effort with involvement of strong university groups is needed; this is also the wish of HIA whose vitality depends on well trained students and on the quality of intellectual and scientific input from a strong and competent community. We can gain enormously from a greater synergy between HIA/NRC and university instrumentation science groups.

BUT........ due to severe cuts at NSERC and in universities since the late eighties, university-based instrumentation groups have been drastically reduced. How can we rebuild strong instrumentation groups capable of playing active intellectual roles in the design of future astronomical instruments, and with the required technological and managerial know-how, to take at least sub-contracts in large instruments for international facilities?

1.3 Re-allocation budget for GSC 17

As part of the Reallocation exercise, NSERC will be injecting annually more money into Grant Selection Committee 17, reaching a total of \$579 000 yr^{-1} at the end of this four years cycle, "to take advantage of the Gemini Telescopes and of available satellites". Kate Wilson of NSERC has informed me that it was not yet clear in what form this money could be applied for, but it is obvious that the community must be willing and ready to prepare a strong case. I have also been informed by Kate Wilson and Nigel Lloyd of NSERC, that to support important Gemini activities in the universities, astronomers may apply for a Major Facility Access grant. My proposal for a university-based Gemini Scientist (see appropriate document) is a first step in this direction.

$\Rightarrow$ WE MUST BUILT UP THE STRONGEST SCIENTIFIC CASE TO ACCESS AND USE NSERC ADDITIONAL FUNDING FOR GEMINI AND SATELLITES!

However, I believe that NSERC programs, though they can and will contribute in most helpful ways, are insufficient to reach our objectives. We must create a university based entity with the critical mass and expertise in instrumentation science. New ideas and ventures must exploit some of the newer avenues of funding, such as special programs of regional developement, the Canadian Foundation for Innovation, and the partnerships with institutions and industries through the University-Industry programs at NSERC and NRC.

2 A university Centre for Experimental Astrophysics

Technological developments offer fresh and exciting possibilities to astronomy. However, with the increasing complexity of modern technology, astronomers find that in order to realise these possibilities in successful instruments they need to have at hand the services of teams of engineers, technicians and craftsmen. Astronomy usually seeks to use technology already developed for other applications, but occasionally the development of new devices is required. In both cases, the technological problems posed are fascinating and challenging for the scientist or the engineer, and up to the highest standards for the quality of training of students in applied physics and engineering. To resolve the issues above and to match our science and training objectives, I propose the creation of a university-based Canadian Centre for Experimental Astrophysics (CCEA).

The CCEA will be project oriented and have as part of its mission the training of high-quality personnel in advanced technology instrumentation for astronomy and space sciences. It will concentrate on design, development and manufacture of astronomical equipment and systems that are not commercially available. The aim will be, in working jointly with HIA/NRC scientists, to produce facility-class common user instruments to be used on university telescopes, and on national or international facilities such as the Gemini Telescopes.

The CCEA must be associated with a strong observational group. The development of good instruments and analytical software happens at institutions with strong observational programs with astronomers eager to use the equipement and feed-back to the builders. Exchanges and visits by researchers, students, and engineers between HIA/NRC, the CCEA, international facilities partners, and industries should be an appropriate mean to keep the CCEA at the forefront of instrumentation science in astronomy.

2.1 Areas of expertise

I propose that the main area of expertise to be developed at the CCEA be near and mid infrared astronomy, – imagery, spectroscopy and polarimetry. Infrared array technology in the near and mid infrared is evolving very rapidly, and substantial development, evaluation and application work are still needed. There is a particular need for exploring various multiplexing options in spectroscopy to better exploit the array dimension perpendicular to the dispersion. Infrared optimized telescopes and instruments, equipped with modest adaptive optics, can allow imaging through the 1–20 μm atmospheric windows with an unprecedented spatial resolution from the ground. New scientific windows are opened to study the formation of stars and planetary systems, to explore the universe hidden by the ubiquitous dust and to access a wealth of new spectral features. Many upcoming space missions (e.g. SIRTF, SOFIA, Next Generation Space Telescope, FIRST) are IR oriented, so the group may get non-Gemini work. A specialized approach might increase chances of getting collaborative work on non-Canadian instruments.

In having the CCEA specialising in infrared astronomy and technology, I recognize the need to complement the well-established expertise of HIA in adaptive optics, ultraviolet and optical instrumentation, and I wish to build from the already existing infrared expertise in a few Canadian universities. It is expected the CCEA will create and maintain expecially close links with HIA. They ought to merge their complementary strengths and members, particularly scientists must be able to move easily between them. Coop-students program could be used to further the link with industry. A university-based centre offers on the same spot a wide range of expertise (e.g. from electronics and mechanics engineers, physicists, software people, vacuum and cryogenics services, etc.), while HIA/NRC has an even wider range of expertise or technical support, and can provide exceptional shop and testing facilities.

3 Staffing

The creation of a Canadian Centre for Experimental Astrophysics will require new people and new expertise. I have based the staffing requirement of the CCEA (Table 1) on requirements for a critical mass to participate jointly (or separately for small packages) with HIA/NRC in large international instrumentation projects.

What I have in mind is a group size which would have the capability to construct a USD $1 M instrument. An example is the University of Florida Group of Mid-Infrared astronomy, under Charles Telesco, who is building the Mid-infrared camera MIRI for the Cerro Pachon Gemini Telescope. The group of seven researchers and senior engineers at University of Florida corresponds to the size of the team I propose in the budget of Table 1. See Appendix I for more details on the University of Florida group in mid-infrared astronomy.

In a joint HIA-University effort over a limited period (e.g. 2–3 years), NRC could provide two NRC funded engineers who will assist the CCEA at the beginning. These engineers would spend 2 to 3 years helping the centre to start the instrumentation effort at the CCEA, to train the appropriate engineer staff, and to give the necessary managerial expertise.

4 Budget

I present in Table 1 an annual budget for the CCEA which would represent the normal operating budget for the "permanent" staff. It is expected that contract money could increase this budget due to additional hiring and staffing at critical time of contracts; Andy Woodsworth of HIA/NRC estimates that this could represent an annual income of the order of $150 K. Note that none of presumed funding sources have made any commitment. In the TBD source, I include some contract money, but I expect most of TBD funding to come from sources yet to be identified. Furthermore, there are benefits of around 20% on top of the salaries, and several of my figures are probably underestimate of the real costs.

At present, while searching for new people to involve in the operations of Gemini, in the building of its instruments, and in the various advisory bodies, one realizes quickly how limited the pool of competent and available persons is. Therefore there is a need to explore new initiatives to have any chance to increase our numbers and competence. While doing so, one must also be aware that traditional sources of funding such as NSERC and NRC are almost frozen for the near future. We must position ourselves to tap other sources of funding for starting new initiatives and for the hiring of new young competent

Table 1: Budget for CCEA

Task	Amount	Source
2 University scientists	\$200,000	University
1 software & system engineer	\$100,000	TBD
3 engineers	\$200,000	TBD
3 Postdoctoral fellows	\$120,000	NSERC
3 technicians	\$150,000	NSERC
4 graduate students	\$60,000	NSERC
Travel	\$50,000	NSERC
Operation, small equipments, communication, computers, tools	\$120,000	TBD
Total	\$1,000,000	All sources

university staff. The recent increase of the NSERC budget raises some hope. The budget for the upcoming 1999 NSERC-MFA competition has been tentatively set at \$ 5.4M, up \$ 2M from what was previously budgeted. This amount may be revised in November 1998 in light of the demand on the program. The additional \$ 2M (the total increase is \$ 4M) will be used for support of important new facilities, which may arise in non-competition years. Further details on the mechanism for this will be released later.

Another important issue for universities is the question of indirect costs. For example, Gemini does not pay "indirect costs" or overheads! International funding is provided for ~2/3 of the real cost of an instrument... Consequently how can we fund the total real costs of building Gemini instruments or parts of instruments (or other large astronomical instruments) in Canadian universities?

APPENDIX I
U of Florida Mid-Infrared Astronomy Group

The University of Florida mid-infrared astronomy group is building the Mid-Infrared Camera (T-ReCS) for the Gemini Telescope at Cerro Pachon. The instrument will cost about USD\$1.3 million. and is a relatively small instrument by Gemini standard. The group has previous exprience in building such an instrument with OSCIR.

C. Telesco (professor of astronomy, and T-ReCS P.I.) – Science direction, mechanical-optical design (role is a "high-level" one, in the sense that he often does the overall mechanical/optical layout of a system based on the knowledge of what science the system should do, and the other people handle the detailed implementation under his direction).

Robert Pina (assistant professor of astronomy) – Science direction, data-acquisition software. Robert has an excellent knowledge and experience in the kinds of software that must be implemented to make an IR system work well at the telescope. Although he wrote all of the OSCIR software (when he was a post-doc here), for most other projects he directs that effort, since he now has heavy teaching responsibilities.

Jeff Julian (senior thermal-mechanical engineer) – Jeff Julijan is very good at mechanical design and thermal analysis of infrared detector systems. He is an all-around expert at taking ideas through the machine shop and integrating the systems mechanically. Very importantly, he is also expert at using AutoCad software, thermal analysis software, and finite-element-analysis structural software.

Kevin Hanna (senior electronics engineer) – Kevin Hanna is an all around excellent electronics engineer with special expertise in the design and development of the kinds of high-speed elesctronics needed to drive thermal-IR detector systems.

David Hon (senior software engineer)–David Hon is currently a contractor, but U of Fl is in the process of hiring him full time as a University employee. He is doing all the complex software (under the direction of Robert Pina) required to interface MIRI (now T-ReCS).

Tom Kisko (T-ReCS Project Manager)–Tom Kisko is working with the gorup perhaps only for the duration of the MIRI project, so he is not really a member of the permanent team. However, it has proven very useful to have him most of the administrative tasks for this project.

In summary, there is one person on each of the key tasks. However, the group is still missing an optics designer. As a result, Telesco is now using a contractor optics designer (who runs ray traces, does tolerance analyses, etc) who lives in Maryland. That's very inconvenient, but it's currently the best they can do. With an optics designer, the team would be complete. It would also be nice to have several technicians who can do some of the lower-level work (e.g., drafting), but that's a luxury that the small program at U of Fl cannot yet afford.

APPENDIX II
Organization

I recommend that the CCEA be managed by a Board of Directors, whose membership will consist of scientists, managers and/or engineers from the universities, from Governments agencies and from industry.

The Centre will be led by two university based scientists who would assume normal teaching and research duties. One of the two scientists would act as the Director of the Centre, while the other would be the Associate Director.

The Centre Director will be responsible to the Board for the overall conduct of the Centre. The Director will define and carry out the overall scientific mission of the Centre as approved by the Board. The Director will provide scientific and management leadership of the Centre. The Director will maintain effective communications between the Centre, the HIA/NRC instrumentation group, the Canadian Gemini Office and the various university groups. The Associate Director will be responsible for the scientific quality, services and capabilities of the Centre in harmony with the objectives of forefront instrumental capability in universities. The main challenge is to recognize the need and desire for university and government astronomers to work together and the necessary hurdle of so doing.

The two university scientists would be assisted by three senior engineers: one with managerial experience who would act as the Centre Manager; I consider the area of project management vital to produce world-class instrument in a timely and cost-effective manner. Another engineer would specialize in cryogenics and infrared technologies, while the third would be an expert in opto-mechanical design and construction. A junior engineer would lead the software effort. The Centre will receive advise and assistance from the scientists of the Canadian Gemini Office and the member of the HIA Instrumentation groups with whom it will interact very closely. The Gemini Scientist will also be a close participant.

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