Enhanced training through the NSERC CREATE program on New Technologies for Canadian Observatories (NTCO)

Kim Venn*[b], Simon Thibault[a],Tammy McLash[b], Clare Higgs[b,p], Dave Andersen[b,c,m], Colin Bradley[b], Olivier Daigle[d], René Doyon[e], Bryan Gaensler[f,k], Frederic Grandmont[g], JJ Kavelaars[c], Scot Kleinman[h], Brenda Matthews[c], Neil Rowlands[i], Stephen Se[j], Luc Simard[c], Suresh Sivanandam[k], Christine Wilson[l]

[a]Université Laval, QC; [b]University of Victoria, BC; [c]National Research Council of Canada - Herzberg Astronomy and Astrophysics Research Centre, BC; [d]NüVü Cameras, QC; [e]Université de Montréal , QC; [f]University of California Santa Cruz, CA, USA; [g]ABB, QC, [h]Gemini Observatories, HI, USA; [i]Honeywell, ON; [j]Teledyne FLIR, BC; [k]University of Toronto, Dunlap Institute, ON; [l]McMaster University, ON, [m]TMT International Observatory, CA, USA, [p]Rubin Observatory, AZ, USA

*Corresponding author email: kvenn@uvic.ca

ABSTRACT

The NSERC CREATE training program on New Technologies for Canadian Observatories (NTCO) has been a unique collaboration between academia, government, and industry to advance innovation in astronomical instrumentation while fostering knowledge exchange as part of an advanced student training program. Through strategic partnerships and funding support, NTCO facilitated the creation of industrial internship opportunities for graduate and undergraduate students in physics, astronomy, and engineering, enabling them to gain valuable professional experience while making high impact contributions to cutting-edge research projects. The NTCO program included nearly 200 supervisors (a third in industry) working together to successfully bridge the gaps between academia, government, and industry, through 70 industrial internships (37 graduate, 33 undergraduate) over the 7 year duration of the program. This paper will outline the key activities and outcomes of the NTCO program, ranging from our strategies in recruiting a diverse group of students and matching them with appropriate industrial internship experiences, to the benefits of advanced summer school training, peer support, annual general meetings, and professional skills development courses for our participants.

Keywords: Training, Optics, Observatories, astronomical, hand-on, internship, professional skills, academia, industry.

1. INTRODUCTION

The NSERC CREATE training program in New Technologies for Canadian Observatories (NTCO) was originally proposed to address the need for technological innovation in the next generation of astronomical instrumentation. We foresaw in the coming (now here) decade that innovative approaches to instrumentation would be necessary to maximize Canada's scientific and industrial investments in astronomical research. These would most likely include advances in detector designs, optics and photonics applications, focal plane imaging techniques, and manufacturing technologies, and from experience we knew that cooperation between scientists and engineers improves technology developments. Our NTCO industrial-stream[1] program was designed to appeal to students who wanted to be involved in cutting-edge technologies with profound downstream industrial

[1] The NSERC CREATE industrial-stream has since been eliminated. Industrial participation in CREATE initiatives is now encouraged, but the extent and nature of industrial participation is determined by the applicants and their industrial partners.

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applications. Our program placed highly qualified students into primarily industrial and government research labs to study new and innovative directions in design, applications, data analysis, and technologies related to astronomical science and engineering projects. Graduate students provide an excellent means to transfer information between academic and government labs and industry, as well as between scientists and engineers; new ideas, new applications, and especially exploration of problems that can be solved in one environment but not the others. Canadian industry also gained new opportunities to have students explore new technological developments that may otherwise not be possible under the restrictions of commercialization. The training opportunities were industrially relevant, producing internationally recognized research that involved hands-on training in leading edge research centers. Professional skills training was also integrated into the program through new specific modular course offerings and a selection of Mitacs Step workshops. The mission was to train HQP for necessary innovation in technologies for the next generation of Canadian astronomical facilities. We believe that we met that goal.

2. THE NTCO PROGRAM RATIONALE

Astronomy is a research strength in Canada, a specialization that has been regarded as a comparative advantage in North America (e.g., see the Science, Technology and Innovation in Canada Report 2010), and which attracts young minds into science and engineering programs. We also recognized a need to better prepare graduate students for innovative opportunities in Canada's high tech industry, as well as bring new opportunities for innovation from Canada's astronomy-related government and academic labs into industry. All of the next-generation astronomical instruments would require innovation in detector technologies, optics and photonics, instrument multiplexing, manufacturing precision, and overall instrument design to meet the science needs. The timing was excellent since the demand coming from the next-generation facilities (e.g., the Thirty Metre Telescope, the James Webb Space Telescope, and the Square Kilometre Array) were motivating Canadian industry to collaborate with our scientists, engineers and students in highly innovative areas. Thus, to satisfy the needs of the Canadian astronomical community and industry, we proposed to combine the expertise at Canadian universities with that at the NRC-Herzberg government laboratories and Canadian industrial facilities to develop a program in advanced instrumentation for engineering and science students.

While motivated to develop a program where Canadian academic and government research facilities could work directly with research partners in the industrial sector, our long term goals were the following:

1. To establish an innovative training program for graduate students that exposes them to the professional skills that make them job ready and prepared to be innovative whether working in the Canadian academic, government, or industrial sectors.
2. To establish a new level of professional interactions between researchers in Canadian academic, government, and industrial labs.
3. To develop a new generation of highly skilled researchers and innovative technical leaders who will contribute substantially to the next generation of technical challenges in Canadian Observatory facilities.
4. To stimulate new project ideas and technologies to be developed for astronomical instrumentation at the next generation of Canadian Observatory facilities.
5. To increase the partnerships between Canadian academic, government, and industrial labs, and knowledge transfer between these different institutions.

6. To build stronger teams that are prepared to work together to compete for increasingly complex technical projects on a global scale, primarily in astronomical instrumentation and telescope technologies, but with industrial downstream applications that improve the lives of Canadians.
7. To advance global scientific and technological knowledge, contributing to Canadian leadership and expertise in astronomical instrumentation and scientific discovery.

The overarching goal of NTCO was to elevate Canada's global position in emerging optics and instrumentation technologies, and prepare Canada to maximize on its investments in multi-national ground-based, space-based, remote-orbiting and space-cruising observatories.

3. THE NTCO TRAINING PROGRAM

The NTCO training program objectives were developed to provide an enhanced training program related to astronomical instrumentation that would deliver job-ready HQP to meet the next generation of technological challenges. These included:

1. Student training experiences through co-supervised industrial internships.
2. An integrated thesis/dissertation that incorporates the internship experience.
3. A summer school in astronomical instrumentation or equilvalent for all graduate trainees (undergraduate trainees were invited but not required to attend), in addition to their regular coursework and other degree requirements at their home institutes.
4. Professional skills workshops to reinforce and support the internship experience and increase job readiness. A minimum of one workshop was required for all graduate students per year in our program.
5. Attendance at the Annual General Meeting (AGM) for all graduate trainees (undergraduate trainees were invited but not required to attend) to increase communications and synergy within the NTCO team, practice professional skills, and foster relationships with potential employers.

The first two of our training program objectives (above) are related to the industrial internships, which were our core program element, providing unique interaction between academic and government researchers with industry and students. Students particularly benefited from co-supervision with experts in different research environments. A Program Committee met regularly (2-4x annually) to review internship prospects and integrated thesis/ dissertation topics for the graduate NTCO students. This core component was the most challenging aspect of our program for our non-engineering students; however we built relationships and trust with our industry partners such that they were able to recognize and appreciate the skills that our non-engineering students had and could bring to their teams, particular in software developments, data management, and domain knowledge. Overall, Figure 1 shows the distribution of industrial internships for our students (left) and the locations of the student home universities (right). Most of the students traveled from their home institutes to carry out their industrial internship, and 40% traveled to new locations (new provinces or internationally). Nine students traveled internationally, including six students who completed industry-like internships at the Gemini Observatory (Maunakea, HI and La Serena, Chile), and the others at the Canada-France-Hawaii Telescope (Maunakea, HI), the ALMA Observatory (remote, pandemic) and the Thirty Metre Telescope Project Office (remote, pandemic).

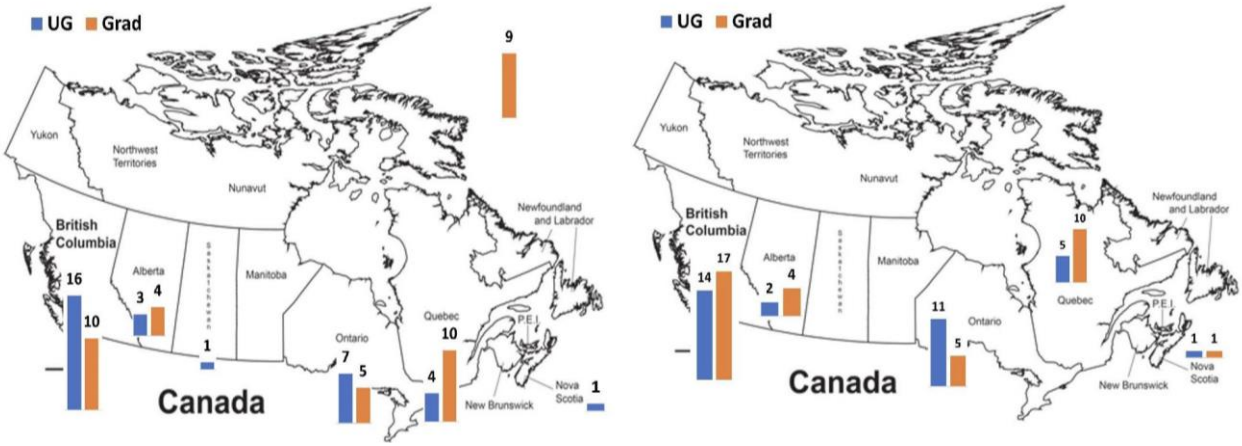

Figure 1: NTCO Student internship locations (left) and home universities (right). There were 9 graduate students who worked internationally, otherwise 85% of NTCO student industrial internships were completed within Canada.

The third training program objective (above) entails a summer school in astronomical instrumentation (or equivalent). The majority of our students (graduate and undergraduates) attended the Dunlap Institute Summer School in Astronomical Instrumentation at the University of Toronto, a five-day summer school that provides an introduction to cutting-edge astronomical instrumentation through both lecture and hands-on laboratory activities. This summer school is led by astronomers from Canada, and around the world, who specialize in the development of astronomical instruments. Furthermore, our NTCO program partnered with the Dunlap Institute, who graciously provided all local expenses for up to 5 NTCO undergraduates per year. Alternative summer schools were considered when relevant to the specific expertise and interests of the student and supervisors (also, some students participated as MSc students and then again as PhD students, requiring them to take a second and new summer school). Examples ranged from the international summer school on Adaptive Optics (UCSC, 2017, 2019), to Deep Learning and Reinforcement (Vector Institute, Toronto, 2018) and 16th Synthesis imaging workshop (VLA, Socorro, NM, 2018), and more recently a course on Systems Engineering at Large Telescopes (SPIE, Montreal, 2022).

The fourth and fifth training program objectives (above) were aimed at helping students to develop and reinforce professional skills, through both courses and participation at our annual general meetings (AGMs). A variety of professional skills workshops were offered over the course of our program, as follows:

1. 2017: Mitacs Program Management (I & II) at the University of Victoria (with AGM at UVic)
2. 2018: *Create your Career & Get the Job* and *Keep the Job & Continue to Grow*, two workshops with expert facilitator Alaina Levine at Laval (with AGM at Laval)
3. 2019: Time Management at UBC Okanagan (with AGM at NRC-DRAO, Penticton)
4. 2020: Anti-racism and Indigenous Acumen Training (remote AGM, offered via UVic)
5. 2022: EDI lunch sessions during SPIE in Montreal (with AGM at UdeM, Montreal). Students who attended the SPIE 2022 meeting participated in at least 2 EDI lunch sessions, hosted by SPIE professionals (which included over 150 people per session, a panel of experts' discussion, and hands-on activities).

6. 2020-2024: Mitacs Step Courses offered remotely (for individuals not attending the AGMs, or who wanted or needed additional professional skills training)

The NTCO training program was aimed at both graduate and undergraduate students. Graduate students could participate in the NTCO as either MSc or PhD students. Students were recruited into one of the following categories in the NTCO program:

- MSc program, which was a 2-year program available to MSc students in good standing at their home institutes in astronomy, physics, or engineering, and required a minimum of 4-months of industrial internship. NTCO contributed to the student stipends up to $12K/yr for 2 years. The average length of time for the NTCO internship for MSc students in our program was 4.04 weeks.
- PhD program, which was a 3-year program available to PhD students in good standing at their home institutes in astronomy, physics, or engineering, and required a minimum of 6-months of industrial internship. NTCO contributed to the student stipends up to $15K/yr for 3 years. The average length of time for the NTCO internship for PhD students in our program was 6.24 weeks.
- UG program, which was a 4-month program available to undergraduate students in good standing at their home institutes in astronomy, physics, or engineering, and required a minimum of 1 month in an industrial internship. NTCO contributed $6K to $12K to these student stipends, depending on field of study, internship partner, and time in program (there were significant funding increases for undergraduate coop students during the time frame of the NTCO program, as well as disparity between engineering and science undergraduate students). The average length of time for the NTCO internship for UGs in our program was 3.73 weeks.

Students were initially recruited primarily through our team members, word-of-mouth, presentations at Canadian astronomy meetings (CASCA), and our NTCO website. We found this was insufficient to reach a wide variety of students, particularly undergraduates who were considering MSc programs. One of our program coordinators had experience in recruiting at the UVic School of Engineering and developed progressive methods for finding and reaching out to students; these included contacting science and engineering coop offices at universities across Canada, monitoring for and sending emails to any undergraduates presenting posters at Canadian physics, astronomy, or engineering conferences, and we joined the AISES [1] (Advancing Indigenous Peoples in STEM) to post our program and internships for students in their Employer Tools.

Students who successfully completed the NTCO UG program could apply for the MSc program, and similarly those who successfully completed the NTCO MSc program could apply to the NTCO PhD program. The movement of students between training sites was also encouraged to improve communications throughout the group, expose students to a wider variety of project management, research styles, and resources, and to help to build new collaborations. We found that 40% of the NTCO students left their province for the industrial internships, and all graduate students traveled for at least one of the NTCO AGM meetings during their programs. As shown in Figure 2, 70 Canadian highly qualified students completed all training components of our program: 33 UGs (47%), 21 MSc (30%), 16 PhD (23%). Of these students 43 identify as male (62%), 22 as female (31%), and 5 undeclared (7%).

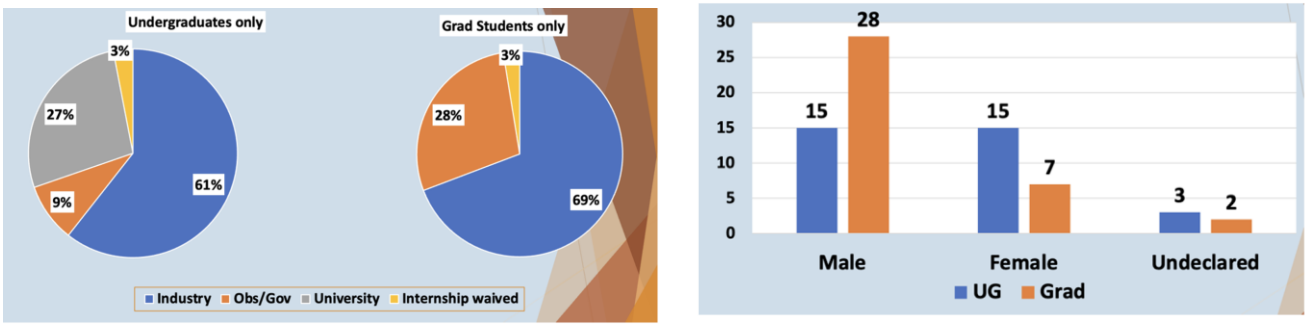

Figure 2: Types of industrial internships (left panel), separating the undergraduates (leftside) and graduate students (rightside). Gender of NTCO students (right panel, self-identifying).

4. THE NTCO TEAM AND COLLABORATORS

Over the years, our NTCO team accumulated 169 research supervisors from across Canada at universities, government labs, observatories, and in industry, including 7 provinces, and internationally (USA, Chile). This team provided students with unique, hands-on experience in instrumentation technologies, which is missing in the standard graduate curriculum. A breakdown of the types of employment for the NTCO supervisors is shown in Figure 3, which also includes a breakdown by gender. Efforts were made to recruit women supervisors throughout the partnership; our experience suggests that these gender breakdowns may reflect the actual distribution of the employment statistics in each sector. We were also curious if there was a preference for women students for women supervisors, but found no indication for any preferences.

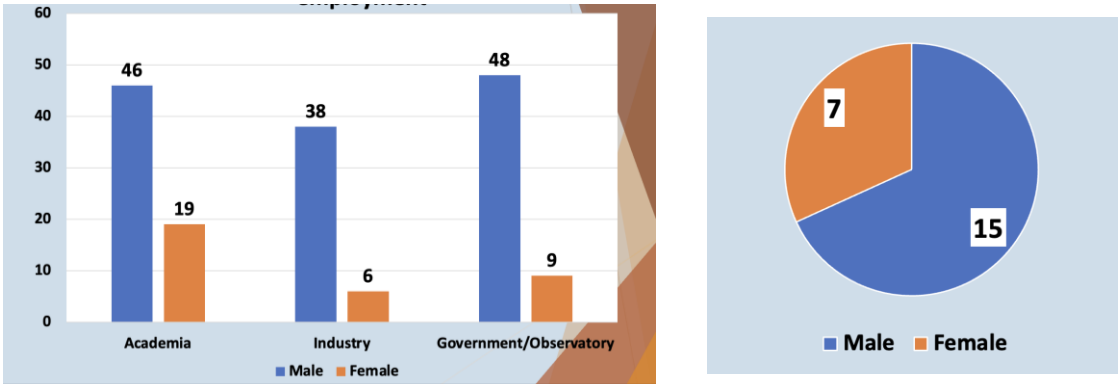

Figure 3: Breakdown of the types of employment for the team of 169 NTCO supervisors (left panel), which includes 65, 44, and 57 supervisors in academia, industry, and government labs (3 people are undeclared), respectively. An examination of the gender breakdown of the students of the female supervisors in our program (right panel) shows no clear preference.

5. NTCO PROGRAM FUNDING, FEEDBACK & SUSTAINABILITY

Our NTCO program was primarily funded through an NSERC CREATE graduate training award. As such, over 80% was assigned to student stipends, while the remaining 20% was used for student travel, to fund the annual general meetings and corresponding professional skills workshops, and also for help from a program coordinator (full time in the first 2 years, part time for the duration of the program). Additional funds were

negotiated with the Gemini Observatory, who were one of the founding members of this program, to contribute to the funding for the graduate students who worked there. Also, several of our industrial partners provided additional funding (or top-up funding) to the salaries for the students who worked with them.

We were encouraged that this program was quite successful, with over half of the NTCO students deliberately choosing and finding competitive employment positions in industry. Some students were offered jobs from their industrial internship hosts upon graduation (e.g., FLIR/Teledyne in Richmond BC, Honeywell in ON, NuVu Cameras in Montreal QC). Some students found competitive positions in industrial research labs that were unrelated to the NTCO program (e.g., Oceans Network Canada in BC, ESA Netherland, and Ericsson in Stockholm, Sweden). Most other students in our program proceeded to postdoctoral research positions or to/through graduate school. Some highlights include one student who is now a PDF researcher with the Thirty Metre Telescope Project Office (remote work, USA), another who is a PDF in the New Earth research lab at NRC-Herzberg. One of our successful PhD students is now a Resident Astronomer at the Canada-France-Hawaii Telescope (Maunakea, HI), and one of our top undergraduate students is pursuing her PhD in Astronomy at the University of Cambridge with Nobel Prize winner Prof. Didier Queloz (Cambridge, UK). During our end-of-program feedback surveys, students identified the NTCO program as substantially contributing to their career decisions and to their workforce preparation. Simultaneously, our end-of-program surveys of the NTCO supervisors similarly showed that they were happy to have access to this group of students and that our program was meeting their needs for preparing students to be workplace ready. We are proud of all of the students who completed our NTCO program, gained professional skills and unique opportunities, and found a variety of options for success upon graduation.

Figure 4: Word clouds from our end-of-program surveys of the NTCO students (left panel) and NTCO supervisors (right panel).

Given the success of the NTCO program, we pursued a number of approaches to promoting, sharing, and hopefully continuing this program after the end of the NSERC CREATE funding grant (6 year maximum limit, no renewals, no repeats). These included.

1. Funding via NOIRlab [2], the National Science Foundation's USA research center for ground-based, nighttime optical astronomy, which includes the Gemini Observatory (a founding NTCO partner). In 2023, NOIRlab submitted a funding request ($20M, 2023-2027) to NSF for a new program to enhance their instrumentation and technology development capabilities. This program included a component for student training and mentoring opportunities, and workforce pipelines, using our NTCO program

as a successful example and starting point. While funding was successful, the training program aspect was not included.

2. Presentation at the Canadian Science Policy Conference in Nov 2021 (remote, pandemic). We presented our NTCO program and its success for training the next generation of talent, and pointed out that there was nowhere to go with this program as there were no follow-up funding programs and the NSERC CREATE training programs cannot be renewed or repeated. While the presentation was successful, there was no further outcome.
3. Slack Channel for NTCO student participants and connections to other student groups interested in astronomical instrumentation (particularly NYRIA[3], the Network of Young Researchers for Instrumentation in Astronomy). This group holds yearly workshops around the world, and in 2020-2022 we held several informal meetings between this group and our NTCO students.
4. Working with MITACS (Internship programs, EDGE training programs). We found the MITACS EDGE (Step) training programs became broader and easier for our students to access to fulfill their professional skills development needs, and we will continue to recommend those to our non-NTCO students. MITACS also provides many internship programs that usually require matching funds in an industry partnership. Our industry partners were uniformly in agreement that their companies can rarely take chances on non-engineering students, and there was no incentive to "spend money" to host a MITACS internship when the NTCO program could provide students without a need for matching funds. One approach suggested by our industry partners would be to allow NSERC CREATE training program funds to pay for the matching funds required by MITACS for an industrial internship, allowing them to take chances on non-engineering students and extend the NSERC CREATE funds to more students.

5. SUMMARY & CONCLUSIONS

The NSERC CREATE training program on New Technologies for Canadian Observatories (NTCO) has been a unique collaboration between academia, government, and industry to advance innovation in astronomical instrumentation while fostering knowledge exchange as part of an advanced student training program. Through strategic partnerships and funding support, NTCO facilitated the creation of industrial internship opportunities for graduate and undergraduate students in physics, astronomy, and engineering, enabling them to gain valuable professional experience while making high impact contributions to cutting-edge research projects. The NTCO program included 169 supervisors (a third in industry) working together to successfully bridge the gaps between academia, government, and industry, through 70 industrial internships (37 graduate, 33 undergraduate) over the 7 year duration of the program. The industrial internships were supported by advanced summer school training in astronomical instrumentation (or equivalents), peer support, annual general meetings, and professional skills development courses for all of our participants. We were able to meet the NSERC CREATE training program requirements that over 80% of the funding be allocated directly to student stipends, while also providing travel support to our students. We believe we met our challenges and did bridge the gap between different research sectors in Canada, and hope that changes to Canadian science policies might permit programs like this to continue and grow in the future.

REFERENCES

[1] AISES (Advancing Indigenous Peoples in STEM): https://aises.org/
[2] NSF's NOIRlab: https://noirlab.edu/public/
[3] NYRIA: https://nyriastronomy.github.io/