THE CANADA/NORWAY STUDENT SOUNDING ROCKET PROGRAM (CANOROCK)[1]

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SUMMARY

The Canada–Norway Student Sounding Rocket (CaNoRock) program is a multi-university collaboration to train undergraduate students in space science or engineering, and to recruit them into space related graduate studies or industry.

Space weather, the volatile near-Earth magnetic, plasma and radiation conditions caused by the interaction of the Sun's output with the Earth's magnetic field, is increasingly recognised as a significant risk to ground and space infrastructure. For example, the senior US and UK science advisors recently estimated the potential cost of a severe space weather event at "$2 trillion during the first year in the United States alone, with a recovery period of 4 to 10 years" [1]. The future prediction and mitigation of space weather effects requires a better understanding of the underlying space physics plasma processes.

Continued progress in space physics requires ongoing and expanded in-situ measurements from near-Earth space and the training of the next generation of highly qualified engineers and scientists. The spacecraft which provide these measurements typically cost tens to hundreds of millions of dollars and operate on decade long timescales. This poses a particular challenge for space physics education. Student participation can be viewed as an intolerable risk given the cost of the mission. Additionally, when students are involved, they see only pieces of the process as their academic program spans a fraction of the mission duration.

The governments of Norway and Canada have both recognized the need to foster expertise in space to maintain and expand their objectives in space research and technology development. The Canada/Norway Sounding Rocket Program (CaNoRock) uses student rocket activities as a high profile talent magnet to attract undergraduate students into space-related career paths, to enhance discovery learning through practical hands-on instruction, and to create an exceptional learning environment for undergraduate students. The ultimate goal of CaNoRock is to build scientific and technological research capacity by helping undergraduate students to transition into space-related graduate study and industry. This paper describes the on-going program, the student recruitment success, and proposed additional programs, all designed as an innovative approach to developing the future space workforce.

THE CANOROCK PROGRAM

CaNoRock is a collaboration between the Canadian Universities of Alberta, Calgary and Saskatchewan; the Norwegian Universities of Oslo, Tromsø, Bergen, and the University Centre at Svalbard (UNIS); the Andøya Space Center; and the Norwegian Centre for Space Related Education (NAROM). The program, which is undertaken with the financial support of the Canadian Space Agency, was officially opened by the Canadian ambassador, John Hannaford (Fig. 1) in January 2011.

1. An earlier version of this manuscript was presented at the 63rd International Astronautical Congress, Naples, Italy, 1–5 October 2012.

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Fig. 1 CaNoRock students with Canadian ambassador John Hannaford (centre).

CaNoRock was conceived as a ten year program to train undergraduate and graduate students in experimental space science. Two CaNoRock courses are run each year – one in the spring term and one in the fall term. For each program, twenty Canadian and Norwegian undergraduate students travel to the Andøya Space Center in northern Norway and undertake a complete, but scaled down, sounding rocket campaign. This allows the course to cover all the phases of an experimental space physics mission compressed into five days.

Fig. 2 Launch of a CaNoRock student sounding rocket.

A WEEK OF EXPERIMENTAL SPACE PHYSICS AND ENGINEERING

In five days the CaNoRock students build and test instrument payloads, integrate them with a student sounding rocket, participate in all aspects of the rocket launch (Fig. 2), and analyse the resulting data. The students work under the guidance of scientists, engineers, technicians and other professionals from NAROM and the Andøya Space Center. Instructional topics include: introduction to rocketry, trajectory analysis, payload integration, data analysis, space and atmospheric science, and telemetry. There are also keynote lectures given by leading academics from Canada and Norway, as well as guided tours of facilities at the Andøya Space Center and the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR). The students deliver a final report to their home university and are eligible for five credits in the European Credit Transfer and Accumulation System (ECTS) from the course through the University of Oslo.

The CaNoRock learning environment is demonstrated by one of the conceptually simple challenges given to the students: to predict and then measure the altitude of the rocket flight. The students are divided into groups, each is assigned an aspect of the problem to focus on under the supervision of a topic expert, they complete their tasks in parallel, and finally they integrate their findings to complete the challenge.

One group of students begins by modelling the nominal rocket trajectory. After applying the well understood rules of mass, force, and drag they quickly discover that the calculation is sensitive to the aerodynamics of the rocket, as well as the wind on the ground and at altitude. Fortunately, another group has been studying atmospheric science and measures the wind profile using a meteorological balloon. Combining this data and the developed model gives a nominal flight profile and altitude sufficient for the student instrument group to implement and optimise an altimeter using a car-tire pressure sensor. The student payload group interfaces this altimeter to the on-board computer and radio link. Finally, the student telemetry group has trained to operate the space center's steerable antennas and has configured the signal processing equipment at the center to match the frequency, encoding, and data format transmitted by the student rocket. After launching the rocket, the students work together to analyse the data, comparing their predicted flight profile with the altitude inferred by their measurements of the in-situ atmospheric pressure (Fig. 3).

In addition to formal technical instruction such as this, CaNoRock also provides exceptional networking opportunities for the undergraduate participants. During the five day residential course, the students live, work, and eat at the Andøya Space Center. This provides many opportunities to mingle and interact socially with space center personnel, university lecturers as well as space scientists and engineers from other sounding rocket campaigns that may be active at the space center at the same time. CaNoRock alumni have reported that these informal interactions made space-related studies feel less intimidating and encouraged them to consider space as a viable career choice. Participants are also asked to do outreach for the program when they return to their home institutions to help recruit the next contingent of undergraduates (Fig. 4).

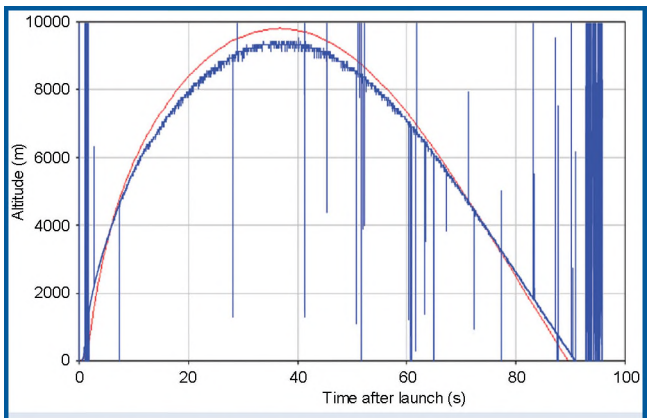

Fig. 3 Comparison of the predicted (red) altitude versus the measured (blue) altitude profile from a CaNoRock student sounding rocket.

Fig. 4 CaNoRock student Katherine Maguire presents at the 2011 ISSET Space Exploration Symposium at the University of Alberta. Photo credit: Katherine Maguire.

CANADIAN STUDENT SURVEY RESULTS

A follow up survey was completed with the alumni from the first seven CaNoRock courses to assess the impact of the program. The survey focused on concrete outcomes where students had entered or completed space related academic or industry positions. The survey was conducted by email in March 2013 and received 30 responses from a possible 65 alumni (46% response rate). The responses indicated that:

- 20% of respondents had applied to work or were working for a company in the aerospace industry; an additional 20% intended to apply when they graduate.
- 67% of respondents had completed an undergraduate research program, design project, or summer student position; 65% of these projects were space related.
- 57% of respondents had applied to or enrolled in graduate studies; an additional 20% intended to apply when they graduate.

Overall, the course was highly rated by the Canadian participants with feedback such as: "Great experience. It's a good eye-opener for undergraduate physics students who don't otherwise have any exposure to space science."

STUDENT CASE STUDIES

CaNoRock attracts students who have a demonstrated interest in space science or engineering, as well as students who are uncertain about career options but have aptitudes in applied physics and engineering. Alumni of the program have gone on to pursue both academic and industrial career paths in space-related fields. The following three case studies illustrate the role of CaNoRock in helping students define their career objectives.

Eric Grono – University of Calgary

Eric Grono was a third-year physics student at the University of Calgary when he was selected to attend CaNoRock in October 2010. Being in Norway made such an impression on him that he decided to finish his degree at the University of Oslo. Through careful planning, Eric was able to complete all course requirements (including General Relativity, Gas Dynamics, Quantum Mechanics, and a research project on craters on Mercury), and transfer credits back to Calgary without delaying his graduation. CaNoRock also inspired Eric to pursue a Master's degree and now a PhD in Space Physics at the University of Calgary using the aurora to investigate magnetospheric plasma processes under the supervision of Professor Eric Donovan.

Aarya Shahsavar – University of Saskatchewan

Aarya Shahsavar was in his second year of Engineering Physics at the University of Saskatchewan when he was encouraged to apply to CaNoRock by an alumnus of a previous campaign. Mr. Shahsavar was the president of the University of Saskatchewan Space Design Team (USST) when he travelled to Norway; his team was competing in the Canadian Satellite Design Challenge (CSDC) to design a student nanosatellite [2]. While in Andøya, Mr. Shahsavar had access to telemetry experts at the Space Center with whom to discuss design elements of the USST telemetry systems. Mr Shahsavar credits his time at the Andøya for the USST finalizing their telemetry system in time for the Critical Design Review, and for their success in the CSDC competition.

Mr. Shahsavar feels that CaNoRock enhanced the professional and personal development of the students involved and that the cultural elements are important regardless of a participant's future career choices. Mr Shahsavar has built on his successes; in 2012 he was invited to present a talk titled "Space – The Next Real Marketplace?" [3] at TEDx Winnipeg's "The Next Big Thing" event (Fig. 5).

Fig. 5 CaNoRock student Aarya Shahsavar presents at a 2012 TEDx event in Winnipeg. Photo credit Jamie Townsend.

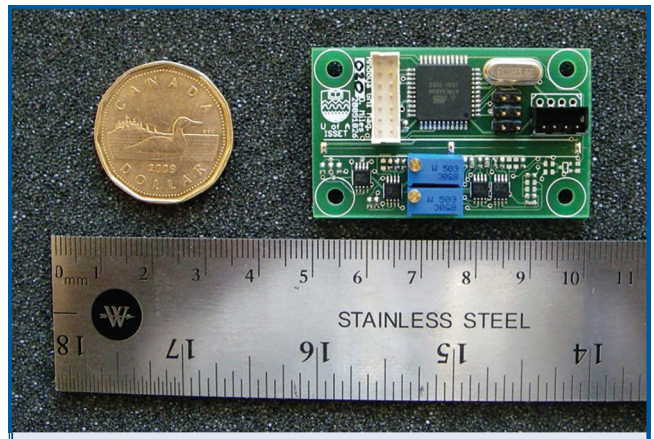

Fig. 6 Prototype giant magnetoimpedance effect magnetometer test flown on the first CaNoRock student sounding rocket.

David Miles – University of Alberta

David Miles was an MSc student at the University of Alberta when he was invited to be a Co-Investigator on the first CaNoRock campaign. In addition to completing the field course in Norway, Mr Miles developed a miniaturised magnetometer (Fig. 6) based on the giant magnetoimpedance effect in a nanofibre, calibrated the instrument, and test flew it on a CaNo Rock student sounding rocket. The success of this experience set the precedent for an additional laboratory component of the program now being developed at all three Canadian Universities in which undergraduate students develop scientific instruments to be flown during the week-long Norwegian field course.

Mr Miles successfully defended his MSc thesis "Towards a Radiation Hardened Fluxgate Magnetometer for Space Physics" [4] in 2012 and began PhD studies. Based in part on the successful CaNoRock collaboration, Mr Miles and his supervisor were offered science team membership in the Norwegian Investigation of Cusp Irregularities (ICI) sounding rocket program and a no-cost flight of their fluxgate magnetometer on the Norwegian ICI-4 sounding rocket which launched successfully in February 2015. Mr Miles is using the instrument flight and science data from ICI-4 as part of his PhD thesis. Mr. Miles was also invited to join the Canadian Space Agency Cassiope/e-POP satellite science team for which he handles the day-to-day operations of the magnetometer payload, coauthored the instrument paper [5], and developed software to transform the raw magnetometer data into an operational data product for international dissemination.

CANOROCK-STEP FOLLOW-ON PROGRAMS

The on-going CaNoRock undergraduate program has been successful in increasing student interest in space related

graduate studies and careers. The follow-on Canada-Norway Rocket Science Training and Educational Program (CaNoRock-STEP) program is intended to help participating students transition from graduate studies into scientific research by providing mobility funding and hosting PhD summer schools. CaNoRock-STEP creates opportunities for joint Canada-Norway collaborative, research-led active training and education that builds on the educational content of CaNoRock. CaNoRock-STEP received a $2 million NOK grant in 2012 from the Norwegian Centre for International Cooperation in Education (SIU), which is a public Norwegian agency promoting international cooperation in education and research.

The first CaNoRock-STEP PhD school was held in November of 2013 at the University of Calgary's Barrier Lake Research Station in the mountains near Kananaskis, Alberta, Canada. The course focused on large statistical studies using ground-based data from the SuperDARN radars and space-based data from the CHAMP and AMPERE satellite missions. The school led to a publication in the Journal of Geophysical Research: Space Physics [6] on frictional heating in the ionosphere and a second manuscript on pointing flux in the ionosphere which is in revision. The second PhD school ran at the Andøya Space Center in summer 2014 and focused on using data from the recently launched Swarm satellites to understand the creation and evolution of polar cap electron patches. In two weeks, the nine students and their advisors selected events, analysed data, and developed two manuscripts which were published in Geophysical Research Letters [7,8].

CONCLUSIONS

The on-going CaNoRock student sounding rocket program has demonstrated its effectiveness in attracting and retaining undergraduate students in space related studies. Future programs will provide additional learning opportunities including student exchanges, participation in scientific sounding rocket campaigns, and cube-satellite projects. These ongoing and future programs will provide hands-on undergraduate and graduate level opportunities to train the next generation of highly qualified space personnel.

ACKNOWLEDGEMENTS

This program was undertaken with the financial support of the Canadian Space Agency and the University of Alberta Teaching and Learning Enhancement Fund. This collaboration would not have been possible without the support and cooperation of: the Canadian Space Agency; the Andøya Space Center; the Norwegian Centre for Space-related Education, the Institute for Space Science, Exploration and Technology (ISSET); and the Universities of Oslo, Tromsø, Bergen, UNIS, Calgary, Saskatchewan and Alberta. Miles is supported by a Canadian NSERC PGSD2 graduate scholarship. Canada-Norway Mobility funds for the CaNoRock STEP were provided by the Norwegian Centre for International Cooperation in Education (SiU), project NNA-2012/10099. This project has also received economic support from the Research Council of Norway, grant 230996.

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