

EXECUTIVE SUMMARY

ANDREW K.S. JARDINE, C-MORE DIRECTOR

INTRODUCTION

The following report summarizes work undertaken between Consortium members and C-MORE since the May 28, 2013, meeting.

INCOMING DIRECTOR OF C-MORE

Professor Jean Zu, Chair of the Department of Mechanical and Industrial Engineering, will introduce Professor Michael (Mike) Jong Kim, incoming Director of C-MORE, effective January 1, 2015.

NEW CONSORTIUM MEMBER

We are delighted to welcome Toronto Hydro to the Consortium.

RESEARCH GRANT APPLICATIONS

NSERC CRD

Our most recent NSERC CRD on Condition Based Maintenance ended on June 16, 2013. We will be preparing a new submission for a further three-year grant. Thank you to members DSTL, ENMAX, Hydro One, and Teck for their support over the past three years (NSERC provided total funding of \$264,816).

AUTO 21

We had the opportunity to seek funding for an additional year. A proposal has been submitted titled: Eco-driving and Life Cycle Costs with requested funding of \$ 40,500.

C-MORE ACTIVITIES WITH CONSORTIUM MEMBERS

Since May 2013, C-MORE lab members have been working on research, participating in conferences, and meeting with consortium members. C-MORE is currently involved in the following projects with industry partners:

- ENMAX: Two collaborations have begun since our May 2013 meeting: wood poles and transformer spares provisioning. These will be reported on at this meeting.
- Greater Toronto Airports Authority: A new collaboration with GTAA is expected to commence dealing with the analysis of some lighting circuit data.
- Hydro One: Neil Montgomery and Dragan Banjevic provided further assistance on the probabilistic analysis of switch interruptions with Bo Ji and Janny Li. Neil also helped with an outlier detection problem.
- Iron Ore Canada: We received a recent enquiry from IOC related to getting involved in a driver training project with data analysis. This was prompted by our AUTO 21 project on eco-driving.

- Manitoba Hydro: Manitoba Hydro has continued to support the project on CBM for power transformers.
- Ministry of Defence UK: Neil Montgomery has been collaborating with Tim Jefferies who provided a clothing order dataset for analysis for detection of interesting patterns and other possible information that can be extracted from the data. This will be presented at today's meeting.
- Ontario Clean Water Agency: Andrew Jardine and Neil Montgomery met with Scott Walker of OCWA to plan new collaborations concerning a maintenance database audit and the delivery of in-house training on physical asset management.
- Ontario Power Generation: As reported at our May meeting, OPG has struck an asset management working group to manage new work with C-MORE, with plans to commence projects when they are identified.
- Teck: Rob Kalwarowski provided initial data for a possible new CBM/health index problem relating to haul truck engines. It is possible that a Bayesian PHM approach will be used due to the small number of recorded failures

C-MORE STAFF AND STUDENTS

STUDENTS

Maliheh Aramon, PhD candidate, will defend her thesis on Friday December 13. The title is: "Integrating Maintenance Planning and Production Scheduling: Making Operational Decisions with a Strategic Perspective." For the past two months, Maliheh has taken on the responsibility of collaborating with ENMAX in two projects: one on maintenance resource planning for ENMAX distribution wood poles, and the second on substation transformers spare parts requirements. These collaborations will be reported in detail at today's meeting.

Erik T.S. Bjarnason, MASc candidate, continued with his work in the area of spare parts provisioning and preventive maintenance policies. Erik is currently developing a model that optimizes both the inspection and the inventory review intervals for k-out-of-n systems. This model is presented in a paper which has been accepted for the Reliability and Maintainability Symposium (RAMS) in Colorado Springs, January 27-30, 2014.

Laurent Caudrelier, MASc candidate, continued working on the modelling of breast cancer occurrence to help establish optimized screening policies. During the summer of 2013, Laurent took a three-month leave to work as an Associate Consultant Intern at Bain & Company, a global management consulting firm, on a project to redesign a client's business strategy to respond to various disruptive threats.

Allan Cesar Moreira de Oliveira, visiting PhD candidate, continued working on advanced user interfaces, with a specialization in Augmented Reality. He completed the Qualification Defense of his PhD project called "Human Aware Maintenance anytime and anywhere" this fall. He is collaborating with Embraer S.A. and CEMIG, a hydro electric industry in Brazil, and will present his work today.

Soroush Sharifi, PhD candidate, passed his qualifying exam in July. His PhD research topic is "Maintenance Evaluation of Capital Equipment in Performance-based Contracts through

Stochastic Programming.” Soroush will submit a paper to *The Engineering Economist* by the end of November.

Janet Sung, PhD candidate, has continued to work on dynamic scheduling of inspection intervals for thesis completion in 2014. Janet will present the key elements of her research today.

Stephan Trusevych, MASc candidate, continued work in the area of asset management for large electrical transformers, applying financial risk management techniques to hedge against the financial losses resulting from critical transformer failure. In June, Stephan submitted a paper to *The Engineering Economist*. He is now working on a new approach to the transformer spares problem, based on robust optimization techniques.

Clayton Van Volkenburg, MASc candidate, completed his course work over the summer. His paper, “Effect of Deterioration and Damaged Repairables on Spare Parts Holding,” was accepted for presentation at RAMS 2013. Currently Clayton is focusing on researching maintenance policy in the Canadian Armed Forces.

Lorna Wong, PhD candidate, has taken maternity leave.

Dana Shaevitch, Master’s of Public Health candidate, Dalla Lana School of Public Health, joined C-MORE to work on the CHRP project in summer 2013. She was supervised by Dr. Bart Harvey and Dr. Sharareh Taghipour and worked closely with Yasin Gocgun. Dana worked on optimizing breast cancer screening strategies in Canada by analyzing the sensitivity of screening and detection methods in the Canadian National Breast Screening Study. The results of her research culminated in the submission of a paper in October.

Melina De Araujo Souza was a Brazilian exchange student at MIE this past summer. Melina worked with me and with Frank Pilkington from Xstrata Nickel in Sudbury on a pump failure problem from May to July. The research was focused on critical and emergency spares, a topic in reliability and maintenance.

Xinbo Qian was a visiting fourth-year PhD candidate from Wuhan, China. She visited C-MORE for three months, from December to March, 2012, and returned from September 2012 to August 2013. During her time at C-MORE, she worked on her doctoral dissertation, “Unit Maintenance Scheduling of Generation Companies based on Condition-based Maintenance in Power Market.” The goal of her dissertation is to improve the reliability and reduce the O&M cost of generating companies under uncertainty using CBM decision policy.

C-MORE LAB STAFF AND POST DOCTORAL FELLOWS (PDF)

C-MORE welcomed new PDF Turuna Seecharan on September 18, 2013. Her postgraduate research has been in the area of Probabilistic Design and Degradation Modelling of Dynamic Systems with a focus on metamodel approximation, Principal Component Analysis using Singular Value Decomposition, Robust Design and Degradation Modelling using the Set-Theory Method. At C-MORE, Turuna will be working on the AUTO21 Project investigating the effect of eco-driving on life cycle costs.

Dragan Banjevic, Project Director, continued collaboration with all members of C-MORE Lab, particularly with the CHRP group (mostly with Yasin), Janet on inspection intervals, Maliheh on scheduling problems, Clayton on maintenance of armoured vehicles, and Neil on case studies.

He collaborated with Erick on k-out-of-n systems and with Professors Jardine and Balcioglu in supervising graduate students.

Neil Montgomery, Senior Research Associate, continued his work collaborating with Consortium members. He worked with Maliheh Aramon on the two ENMAX collaborations. He also worked on the CHRP project, started a new CBM project with Teck, and has been analyzing the MOD clothing order data. Finally, Neil provided general support to C-MORE graduate students working on their research projects.

Ali Zuashkiani, Research Associate, has been busy managing C-MORE's educational programs. He has been in contact with companies and training organizations in South America, Canada, Europe, and the Middle East. In the past few months, C-MORE has held courses in Dubai (through Leoron), Brazil (for AngloAshanti Gold), Fort McMurray (Syncrude), Mexico (Aistac) and Peru (IPEMAN).

Yasin Gocgun, PDF, continued his work on the cost-effectiveness analysis of breast cancer screening policies for women in the Canadian population. He explored the available data to estimate the parameters of his mathematical model for breast cancer progression. In particular, he extracted data from the database of the Canadian National Breast Screening Study (CNBSS) through a computer program. Using the CNBSS data for breast cancer progression and treatment, he estimated model parameters, working specifically on the estimation of state transition rates for the treatment component of the model. He then performed model validation with the goal of demonstrating that the output of his simulation model conforms to the real data. He enhanced certain stages of the model validation, after receiving feedback from the CHRP group.

Corey Kiassat, PDF, accepted a tenure-track position in Industrial Engineering at Quinnipiac University in Connecticut, starting August 2013.

C-MORE EDUCATIONAL PROGRAMS

Dr. Ali Zuashkiani has continued in his role as Director of Educational Programs with responsibility for developing various knowledge transfer activities through new Physical Asset Management Certificate programs around the world. The objective is to combine high quality content delivered by leading instructors with the academic rigour of the University of Toronto.

THE C-MORE TEAM

We continue to have an excellent team of C-MORE staff and students. All are excited about our ongoing and new research activities. We can't say it often enough: the continuation of such activities requires close collaboration and frequent contact with consortium members. We value what has been achieved and are confident that we can maintain the support of members through the hard work and dedication of our staff and students.



November 26, 2013