

EXECUTIVE SUMMARY

ANDREW K.S. JARDINE, C-MORE DIRECTOR

INTRODUCTION

The following report summarizes work undertaken between Consortium members and C-MORE since the December 4, 2012, meeting.

NEW POSITION IN RELIABILITY

It is excellent news that the Department of Mechanical and Industrial Engineering has appointed Michael (Mike) Jong Kim in the area of reliability and maintenance. The appointment will begin on January 1, 2015, when Mike will take over the responsibilities of C-MORE Director. We expect Mike to attend our next Consortium meeting in December.

RESEARCH GRANT APPLICATION

Our current NSERC CRD on Condition Based Maintenance will end 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 funding of \$88,272 per year.)

C-MORE STAFF AND STUDENTS

STUDENTS

Maliheh Aramon, PhD candidate, has started writing her dissertation, "Integrating Maintenance Planning and Production Scheduling: Making Operational Decisions with a Strategic Perspective." Her PhD work resulted in four papers, one accepted, one submitted, and two under revision. She gave two presentations at the Toronto Intelligent Decision Engineering Laboratory (TIDEL) at University of Toronto. She was Chair of the Third Annual Operations Research Challenge (TORCH) an annual one-day free event for high school students; teams of three or four students solve a variety of OR-related questions in a contest setting.

Erik T.S. Bjarnason, MASc candidate, continued working in the area of spare parts provisioning and preventive maintenance policies. He developed a simulation model to determine the optimal inspection interval and inventory over finite planning horizon. The objective is to minimize the total cost. He presented a paper "Joint Optimization of Periodic Inspection and Inventory for a k-out-of-n System" at the Industrial and System Engineering Research Conference (ISERC) 2013, and submitted an abstract to the Reliability and Maintainability Symposium (RAMS) 2014.

Laurent Caudrelier, MASc candidate continued his research on establishing optimal breast cancer screening policies. His analysis was focused on evaluating the influence of prevalent cancers in the disease's progression. An initial analysis was performed for the women aged from

40-49 and then for those aged from 50-59. This analysis was able to evaluate the proportion of over-diagnosed cases with that screening policy – cancer cases that were correctly detected but that would not have developed clinically (i.e., not become dangerous). Laurent also attended several seminars related to public health and presented his work at ISERC 2013.

Allan Cesar Moreira de Oliveira, PhD candidate, joined us this spring from the Federal University of São Carlos (São Carlos, Brazil). He will stay at C-MORE for one year as a visiting student. His main research topic is advanced user interfaces, with a specialization in Augmented Reality. He is investigating a methodology for the development of Human Centred Augmented Reality Interfaces (user interfaces aware of users which can adapt to their situation) for the maintenance process, using the structure provided by E-Maintenance systems with a goal to provide technicians and engineers with real time data about their jobs.

Xinbo Qian, PhD candidate, has been visiting us from the Department of Hydropower and Information Engineering, Huazhong University of Science and Technology (Wuhan, China). Her dissertation is “Unit Maintenance Scheduling of Generation Companies based on Condition-based Maintenance in Power Market.” The goal is to improve the reliability and reduce the O&M cost of the generation companies under uncertainty using CBM decision policy. During the past nine months at C-MORE, she has done research about the optimal condition-based maintenance policy for generating unit in terms of the fluctuating downtime costs.

Soroush Sharife, PhD candidate, modified his PhD research topic “Maintenance Evaluation of Capital Equipment in Performance-based Contracts through Stochastic Programming” after meeting with Tim Jefferis from MOD. The new topic is more related to performance-based contracts and approaches that MOD should take. His supervisors are Professor Andrew Jardine and Professor Roy Kwon. He worked on his qualifying exam scheduled for June 2013 and researched performance-based contracts, stochastic programming and conditional value at risk. He is preparing a paper for submission to *The Engineering Economist*.

Janet Sung, PhD candidate, has created a myopic model that answers whether a replacement should occur and when the next inspection should occur. At each inspection point, the model determines whether it is better to replace now, or to do nothing, and decides when to schedule the next inspection. As a myopic model, it optimizes over one cycle; applied repeatedly, this can be used as a complete decision policy. She presented “Optimal Scheduling of Inspections in Condition-Based Maintenance Models: A Myopic Policy” at IIE Annual Conference in San Juan.

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. He is involved in the analysis of events data for the fleet of Manitoba Hydro transformers, along with Dragan. He gave a presentation “Risk Management: Applications to Industry,” at the Toronto Operations Research Challenge (TORCH) in March 2013.

Clayton Van Volkenburg, MASc candidate, worked on his course-work requirement during the last term. He prepared an abstract for RAMS titled “Effect of Deterioration and Damaged Repairables on Spare Parts Holding” where he will be investigating the effect of shelf-life and

damage-beyond-repair to repairable components on the spare parts inventory. Clayton also worked on the literature review for his thesis “Fleet Optimization of Similar Role Multi-Variant Fleets,” using insight gained from the consortium and discussions with Tim Jefferies. He will be investigating the effects of having a multi-variant similar role fleet and will determine at what time the fleet should move to a common platform.

Lorna Wong, PhD candidate, has taken maternity leave. We would like to welcome her newborn, David James Wun Yip Wong Watson, to the C-MORE family.

Melina De Araujo Souza and Daniel Meireles de Amorim are two of approximately 50 Brazilian exchange students at MIE this year. One of their requirements is to find summer research opportunities. To this end, students are asked to identify faculty members with whom they are interested in doing summer research. We are delighted that they have requested to complete their research placement with us based on their preferred area of research. I hope they enjoy their time at C-MORE.

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

Dragan Banjevic, Project Director, continued his collaboration with Manitoba Hydro on CBM for power transformers, with Stephan’s help; the classification of maintenance events (failures, repairs, etc.) was used to identify event histories for transformers in the maintenance category TRF001 (larger transformers, greater than 160 KV). He collaborated with all members of C-MORE Lab, particularly with the CHRP group, Janet on inspection intervals, Maliheh on scheduling problems, and Neil on case studies. He has been collaborating with Erick on k-out-of-n systems, with Ximbo on her research, and with Professors Jardine and Balcioglu in supervising graduate students.

Neil Montgomery, Senior Research Associate, continued his work collaborating with Consortium members. He went on site visits to IOC, Enmax, and OPG to discuss new collaborations and also worked on the CHRP project. He has packaged the spare simulation code on a CD for release to Consortium members. Neil continued to provide general support to C-MORE graduate students working on their research projects.

Daming Lin, Research Associate, worked on code and development of SMS new features culminating in the release of SMS Version 2.0. The work involved several tasks related to structure change in SMS to allow spare analysis on a list of components rather than just one component at a time for each project. Daming accepted an offer for a full-time biostatistician position at Mount Sinai Hospital, starting June 1. We wish him all the best and look forward to future collaborations.

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, and the Middle East. C-MORE held courses in Dubai (Leoron), Saudi Arabia (Leoron), China (in house course for Conoco Philips), and Peru (IPEMAN). C-MORE has been in close contact with Reliability Web to define joint programs between the two organizations.

Yasin Gocgun, PDF, pursued his work on the cost-effectiveness analysis of breast cancer screening policies for women in the Canadian population. He wrote a computer program for simulating breast cancer progression using R. The program includes input data generation, simulation of cancer progression, screening procedures, treatment procedures, and generation of simulation output. He created a preliminary set of input parameters for the simulation model using the available information from multiple resources and performed initial analysis of a number of mammography screening policies. Part of this analysis was used to test the accuracy of the simulation code.

Corey Kiassat, PDF, successfully defended his PhD dissertation on March 8, 2013; he started working on the AUTO21 project in January 1, 2013. The project involves measuring the effectiveness of simulator-based training of commercial drivers in eco-driving techniques. Corey has completed the Project Charter with the industry partner, City of Waterloo. A field study with 100 dump truck drivers of the city will be performed, putting half through simulator training and the other half through classroom training, for eco-driving techniques. He also secured a sponsor, FleetCarma of Waterloo, to provide the data loggers to monitor various aspects of vehicle performance, i.e. acceleration, deceleration, and idling. Corey recently accepted a tenure-track position in Industrial Engineering at Quinnipiac University in Connecticut. The start date is August 2013. This is great news and we wish him all the best.

Dana Shaevitch, Master's of Public Health candidate, Dalla Lana School of Public Health, joined C-MORE to work on the CHRP project. Her interest lies in the health economics aspect of breast cancer screening, particularly what pertains to cost-effectiveness. She is supervised by Dr. Bart Harvey and works closely with Yasin. Dana will be with us until September.

Hossein Mohammadian, PDF, has joined TTC to work on a nine-month contract related to inspection policies for railway tracks.

Professor Baris Balcioglu remains on research leave at Sabanci University in Turkey working on spare part problems and repair shop scheduling.

C-MORE ACTIVITIES WITH CONSORTIUM MEMBERS

Since December 2012, 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: Enmax continues to support the current CRD on condition-based maintenance models. Neil and Andrew visited in April to begin plans on new collaborations
- Greater Toronto Airports Authority: GTAA has joined the NSERC-funded Spare Parts research. Meanwhile, data collection on the life cycle costing problem of snow clearing equipment (VAMMAS) continues. The goal is to complete an asset plan for presentation to GTAA management in July 2013.

- **Hydro One:** Hydro One is a supporting company for the renewed NSERC CRD on Spare Parts Provisioning. Neil and Dragan provided initial assistance on a new project on the probabilistic analysis of switch interruptions with Bo Ji and Janny Li. We take this opportunity to thank Norm Hann who has represented H1 on the Consortium and provided excellent collaboration opportunities for C-MORE staff and students. We welcome Bo Ji and look forward to continuing close collaborations with H1.
- **Iron Ore Canada:** Neil and I made an inaugural site visit to IOC in January and gave a workshop on spares provisioning and other asset management topics. Plans were developed to commence new collaborations on spares provisioning and possibly on a longer term CBM project.
- **Manitoba Hydro:** Manitoba Hydro continued to support the project on CBM for power transformers.
- **Ministry of Defence UK:** Neil Montgomery completed the draft final report for the Gearbox CBM project with MOD UK.
- **Ontario Clean Water Agency:** OCWA joined the NSERC-sponsored research into Spare Parts Provisioning. The project with OCWA on centrifuge CBM is set for completion over the next few months, in collaboration with Neil Montgomery.
- **Ontario Power Generation:** Neil and Andrew met with OPG in April to begin plans on new collaborations; OPG has struck an asset management working group to manage this new work with C-MORE. Ken Sutton is retiring and we are sorry to see him go; he has always been a strong supporter of our research. However, we are happy that our collaboration with OPG will continue well into the future.
- **Teck:** Teck continues to use SMS and the spare simulation code in its asset management work. Rob Kalwarowski provided information for an article on spare parts provisioning that appeared in CIM Magazine.

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 most recent course, the five-day Certificate program in Physical Asset Management program, April 28-May 2, 2013, was a success, with 12 participants coming from across Canada, Norway, Dominican Republic and Saudi Arabia. Ali gave a one day workshop on Life Cycle Costing as part of the program on May 3.

THE INTERNATIONAL MAINTENANCE EXCELLENCE CONFERENCE (IMEC)

Plans for IMEC 2013 are on hold; we are waiting for an arrangement with a new partner to be finalized. Ali has been discussing the possibility of co-hosting with Reliability Web.

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.

A handwritten signature in black ink, appearing to be the name 'Ali', written in a cursive style.

May 22, 2013