

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 1, 2009, Consortium meeting on the project *MORE (Maintenance Optimization and Reliability Engineering): CBM (Condition-Based Maintenance) and Beyond*.

WELCOME TO NEW MEMBER

It is a pleasure to welcome to this Consortium meeting our newest member: Ontario Power Generation (OPG).

Those who attended our December Consortium meeting will remember meeting our guests from OPG: Ken Sutton, Doug Radford, and Paul Vonhattens.

Ontario Power Generation (OPG) is an Ontario-based electricity generation company whose principal business is the generation and sale of electricity in Ontario. Its focus is on the efficient production and sale of electricity from their generation assets, while operating in a safe, open and environmentally responsible manner.

OPG's generating portfolio has a total capacity of over 21,000 megawatts (MW) making OPG one of the largest power generators in North America. Its generating assets include:

- 3 nuclear generating stations
- 5 thermal generating stations
- 65 hydroelectric generating stations

OPG also owns two other nuclear generating stations which are leased on a long-term basis to Bruce Power L.P.

Full details of OPG are at www.opg.com

NEW NSERC ENGAGE GRANT

Also attending our December meeting as guest was Frances Szto of Toronto Hydro-Electric System Ltd. We are delighted that we now have an NSERC ENGAGE project in place with them for \$24, 227 for 6 months. The purpose of that Grant is to explore with Toronto Hydro the topic of *Models for prediction of electrical distribution system performance*

NEW RESEARCH FUNDING: AWARDED BY NSERC

The Collaborative Research and Development (CRD) Grant application on *Advanced models, applications, and software for Condition-Based Maintenance*, at the level of \$264,816 over a 3 year period (\$88,272 per year) was submitted to the Natural Sciences and Research Council (NSERC) on November 11, 2009 and awarded on April 19, 2010. Professor Baris Balcioglu is the co-investigator on this project. This submission would not have been possible without the support of consortium members **Enmax, Manitoba Hydro, Ministry of Defence** and **Teck Resources** who confirmed to NSERC their support of the research program.

LETTER OF INTENT SUBMITTED TO OCE.

The funding situation at OCE is changing, with opportunities for both large projects and smaller, tightly focused projects with a clear path towards commercialization and benefits for Ontario. We have submitted an initial expression of interest that outlines the current plans we have for commercializing our latest research outputs. Our first hot opportunity is to embed recent substantial progress on our work on spare parts provisioning. Our collaborating companies in Ontario are keenly interested in these results and in easy to use and flexible software applications. We would like support from OCE to extend our current SMS prototype software.

C-MORE STAFF AND STUDENTS

STUDENTS:

We congratulate our senior PhD student Sharareh Taghipour who has won two prestigious Awards:

- Sharareh's paper "Reliability Analysis of Maintenance Data for Medical Devices" presented at the ACCE (American College of Clinical Engineering) conference won the ACCE Best Student Paper Award for 2010.
- Also Sharareh has been awarded the 2010 Asset Management Council PostGrad Student Award for Research. This will be presented to Sharareh at the forthcoming International Conference of Maintenance Societies being held in Adelaide, Australia, 22-24 June.

We were delighted to welcome a new Visiting PhD student, Yuan Yang from the School of Electrical Engineering, Beijing Jiaotong University, China, who is working under the supervision of Dr. Behzad Ghodrati, Post Doctoral Fellow. Her research topic focuses on reliability modeling and maintenance scheduling optimization for catenary subsystems in Chinese high-speed railways, notably, the Beijing-Tianjin Dedicated Passenger Line.

This afternoon we will have 4 presentations by graduate students:

- Industrial scheduling problems, a progress report by Maliheh Aramon;
- Recent results on human reliability research by Corey Kiassat;

- Optimization of inspection schedule for equipment subject to condition monitoring by Janet Sung;
- An inspection model for a system subject to hidden failures by Sharareh Taghipour;

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

Project Director, Dr. Dragan Banjevic has been actively involved with theoretical work oriented towards the students' research topics and topics of interest for further development. Dragan continued collaboration with Manitoba Hydro on CBM for power transformers with PhD candidate Lorna Wong. He started a new project with Manitoba Hydro on reliability growth of power generating units (collaboration with Tony Pavlicic) with active support from Sharareh Taghipour. He collaborated with all members of C-MORE Lab, in particular with Sharareh on inspection intervals, Nima and Maliheh on scheduling problems, and Neil on case studies. He collaborated with Prof. Jardine and Prof. Balcioglu in supervising graduate students and is working on development of new procedures for SMS software.

Neil Montgomery continued his collaboration on case studies with C-MORE Consortium members and is nearing completion of the case study with DSTL involving gearbox CBM. He began work with David Williams of Teck Metals and Dragan Banjevic, on a new spare parts problem. For Transcanada, he has completed the initial processing and analysis of an air compressor dataset provided by Dario Stojanac and Stéphane Lefebvre. The NSERC CRD major grant on Condition-Based Maintenance that Neil completed was approved by NSERC. He also completed and won an inaugural NSERC Engage grant to fund a six month exploratory collaboration with Toronto Hydro-Electric Inc.

PDF Dr. Ali Zuashkiani's research has continued on the topic of Maintenance Performance Management with a recent focus on the dynamics governing asset management. He is working on a procedure that companies can use to develop their performance measurement systems by drawing their dynamic maps. He is working with Nima on a joint research paper which deals with life cycle costing in cellular manufacturing systems and continues to be deeply involved in C-MORE educational programs.

PDF Dr. Nima Safaei is working on adding an efficient sensitivity analysis tool to the "Maintenance scheduling" software based on a ranking approach as well as improving the solution methods and code optimization. He has had a paper accepted in JORS, two accepted for conference presentation, and two under review. He is working on joint paper with Ali entitled: "Manufacturing System Design Considering Multiple Machine Replacement under Discounted Costs" and is involved in initial stages on a possible project with Bombardier, with Dragan Banjevic and Andrew Jardine.

PDF Dr. Behzad Ghodrati continues his work to merge the both internal and external influencing factors (covariates) on machine reliability characteristics to estimate the actual hazard (failure) rate. This helps to calculate the optimal number of required spare parts more close to reality. He also supervised our visiting doctoral student Yuan Yang. Behzad will return to Lulea University of Technology in Sweden in July to return to his position at the Division of Operation and Maintenance Engineering, Luleå University of Technology, Sweden. It has been a pleasure having him with us these past two years.

SOFTWARE

I am very pleased that subsequent to the superb collaboration we have had over the past three years with Hydro One Networks, Ministry of Defence (UK) and former Consortium member Arcelor Mital Dofasco, Dr Nima Safaei is able today to demonstrate the prototype of new software called MSOP (Maintenance Scheduling Optimizer) to assist members in scheduling their maintenance tasks.

C-MORE ACTIVITIES

C-MORE has been busy during the December 2009 – June 2010 period participating in conferences and meeting with consortium members. C-MORE is currently involved in the following projects with our industry partners:

- Ministry of Defence: *Gearbox CBM*
- Teck Metals: *A reliability estimation problem for pipelines and Using SMS at TECK Metals*
- Hydro One Networks: *EXAKT turned 180 degrees*
- Manitoba Hydro: *CBM of power transformer fleet and Reliability growth of power generating units*
- TransCanada Pipelines: *Optimal inspection frequency problem*

C-MORE EDUCATIONAL PROGRAMS

I am very pleased that Dr. Ali Zuashkiani has continued in his role as Director of Educational Programs with responsibility for developing various knowledge transfer activities through both new Master Classes and our regular International Maintenance Excellence Conference (IMEC). The objective is to combine high quality content delivered by leading instructors with the academic rigour of the University of Toronto

I am also very pleased that the Department has, in principle, agreed to offer a new Master's degree program in Engineering Asset Management. This is a natural outgrowth of our annual 8-day Certificate program in Physical Asset Management that has been offered since 2000.

CERTIFICATE PROGRAM IN PHYSICAL ASSET MANAGEMENT: NOVEMBER 1-10, 2010

The program is designed to provide practitioners with first-hand knowledge to make them more effective in their workplaces in a short period of time- through an intensive, interactive training environment.

THE INTERNATIONAL MAINTENANCE EXCELLENCE CONFERENCE (IMEC): THE ASSET MANAGEMENT CONFERENCE. SEPTEMBER 22-24, 2010

We are delighted that this year we are again working with Applied Technology Publications (ATP) as our media partner for IMEC-The Asset Management Conference, (www.IMEC.ca)

We believe that this agreement formalizes a mutually beneficial partnership that connects C-MORE's leading research and training in the area of asset management with the vast marketing and industry reach of ATP, a respected publisher of high-quality information for asset management practitioners in North America.

THE FUTURE

ADVISORY BOARD

While we have never had a formal advisory board I believe we should establish one. Until March 31, 2010 we always had a member of OCE staff as our Consortium Manager. With the change in funding at OCE at this moment we do not have financial support from OCE and so it is invaluable that we obtain guidance for our activities. I will therefore be approaching in the first instance long-standing members for their guidance to establish an Advisory Board.

THE C-MORE TEAM

We continue to have an excellent team of C-MORE staff and students. All continue to be excited about the future development of our research activities. As is always stressed, to continue such activities requires continuing close collaboration and contact with consortium members. We value what has been achieved and are confident that we can maintain the support of members through the excellent staff and students committed to the research program funded by members, OCE, and NSERC.

Andrew K S Jardine
June 8, 2010