MISG 2003 Report

The 2003 MISG, held in the first week of February at the City East Campus of the University of South Australia, brought together about 100 professional industrial mathematicians and industry researchers for 5 days of intense collaboration. The international delegates included special guests, Walter Murray (Stanford) and Bob Storer (LeHigh) from the USA and John King and Giles Richardson (both from Nottingham) in the UK. Six problems were considered.

- *A Submarine Lead Acid Battery Performance Model* for the Australian Submarine Corporation (ASC);
- *Analysis of Hierarchical Games* for the Defence Science and Technology Organisation (DSTO);
- *Particle transport through the froth layer in column flotation* for the Ian Wark Research Institute (IWRI);
- *Prediction of heat loss and energy requirements in steel making vessels* for New Zealand Steel;
- *Best utilisation of rolling stock assets to reduce costs while meeting customer demand* for Queensland Rail (QR); and
- *The effects of deadlock avoidance on rail network capacity and performance* for the Rail CRC.

MISG 2003 was a resounding success with good progress made on each of the problems. Although it is still too early to say much about the solutions that were developed or proposed we will include a brief description of the problems and try to indicate what was achieved.

Diesel electric submarines utilise a large flooded lead acid battery as a secondary energy storage medium. The battery is the only source of power for the submarine while it is submerged. The batteries are regularly charged from diesel electric generator sets that provide power for the submarine as well as for charging the batteries. Operating the diesel engines requires manoeuvring the submarine close to the surface while extending a snorkel on a mast above the surface to provide air for the engines. This operation is known as snorting. During this time the submarine is considered to be indiscreet and is extremely vulnerable to detection.
Battery data has been collected during typical surveillance and combat operations. The ASC asked MISG to develop a suitable model of the battery that could be used to explain this observed data and subsequently to use the model to decide on the most efficient charge and discharge regimes for each of the various tasks. The Moderators for this problem were Mark McGuinness and Basil Benjamin. The team spent a great deal of time developing partial differential equations to describe the chemistry of the charge and discharge processes. UK experts John King and Giles Richardson made excellent contributions to the modelling process. We expect the models to provide an excellent basis for the development of optimal battery management strategies. Industry representative Peter Tromans hopes the ASC can continue collaborating with MISG to complete this task.

A critical issue in the operation of any organisation is the training of individuals and the subsequent training of groups that must work together to achieve large and complex goals. One of the critical issues is the hierarchical structure of the tasks, which are often divided into many subtasks. The subtasks frequently permit diverse solution methods and different tactical approaches. Achievement of the larger goal may be dependent on the performance of the subtasks, and the dependence may not be a simple aggregation of subtasks. One might win the battle, but subsequently lose the war. The trainees must learn individual skills and team skills that enable them to work effectively and efficiently for the achievement of the larger goals. At the subtask level this may sometimes involve counter-intuitive strategies that appear suboptimal. DSTO asked MISG to consider a simple hierarchical game such as tennis where the goals are clear and the outcomes can be tested against the theory. DSTO believe that a better understanding of the critical factors in a simple game will provide insights into the management of large and complex logistics. Vladimir Ejov and Elliott Tonkes and their team developed a simple model to classify the relative importance of individual points in a game of tennis and related this classification to an optimal overall strategy. The investigation showed clearly that players would benefit by expending more effort to win the important points. MISG will help DSTO to extend these methods to more complex problems. George Galanis from DSTO wants to continue this collaboration.

The use of column flotation to separate metallic particles from the original heterogeneous ores is a well-established and widely used procedure. The column consists of two basic zones with a froth layer on top and a pulp layer below. Although some useful models have been developed to describe the capture and transport of material in the pulp the principal quantitative mechanisms that describe particle transport and fluid flow within the foam have not been successfully modelled. Stephen Lucas and Bill Whiten supervised an enthusiastic group of researchers who reviewed the literature and compared the relative merits of macroscopic and microscopic models. The macroscopic models are primarily concerned with the overall movement of particles and liquid through an idealised foam lattice, whereas the microscopic models look more closely at the detailed structures. By the end of the week the team had dispelled some myths about particles falling back into the pulp and had isolated the key mass-balance equations that should help IWRI to develop a useful model. George Tsatouhas and Sarah Schwarz from IWRI were enthusiastic members of the MISG team.

The K-OBM is a steel-making vessel consisting of a steel shell lined with refractory bricks. The vessel is used to convert batches of hot metal containing impure iron and steel scrap into steel by blowing oxygen through the bath. The oxidation of elements in the hot metal and scrap increases the temperature of the metal while changing its composition to that of refined steel. The purpose of the project is to improve the prediction of the end-point steel temperature by predicting the energy lost from the molten bath to the K-OBM vessel during each heat. This prediction would need to encompass the thermal history of the vessel between successive heats and sequences, and the lining wear through a vessel lifetime. An additional outcome may be a better prediction of the heating time required to bring a new vessel to the operating temperature. The Moderators, Robert McKibbin and Graeme Wake, believe that good progress was made on modelling this problem and the NZ Steel representatives, Neil McGillivray and Michael O'Connor, were very pleased with the work done by the MISG researchers.

Queensland Rail operates a heavy-haul coal business on five rail corridors in Queensland. The freight cost of hauling a tonne of coal varies for each rolling stock configuration. One of the main factors that influences cost is cycle time. This is the time that a train takes to travel to and from the mine and includes loading and unloading. The problem involves utilising the available rolling stock in the best possible way to find the lowest cost option. Some rolling stock configuration options may necessitate expenditure to increase loop length or reduce grades. These options may be considered if the freight cost reductions achieved over time outweigh the implementation costs. An enthusiastic group led by Jerzy Filar and Simon Dunstall managed to develop several independent solution algorithms with initial calculations suggesting savings of several million dollars each year. It is expected that more follow-up work will be done and that the savings will be increased. The QR representative, mathematics graduate Caroline Camilleri, delighted the research team by presenting each member with a QR t-shirt.

The Rail CRC is currently investigating the development of computer programs to generate optimal railway timetables. The method of generation is to use random variations on a simple despatch rule to generate a large number of possible alternative timetables. The minimum cost timetable is then selected. A significant problem with this method is that many apparently minor variations of a feasible plan can ultimately lead to deadlock. Most of Australia’s long-haul rail network is single-line track, with occasional crossing loops that allow trains to cross or overtake. For a pair of trains to pass each other, one train will pull off the main line and stop on the loop while the second train passes through on the main line. If trains cannot complete their journeys without at least one of them backing up then they are said to be in deadlock. Detailed train plans that specify future train movements, including nominal crossing locations and times, are developed by train planners. The methods used are substantially manual, and it can take many weeks to develop a timetable. On the day of operation a train controller may revise the train movements and crossing plans when responding to operational disturbances. The object of this project was to find efficient ways to avoid computer generated timetables that lead to deadlock. The Moderators, Peter Pudney and Graham Mills, and the MISG team have proposed some very promising methods. MISG expert Bob Storer, from LeHigh University in the USA, worked intensively on this problem and continued those discussions with CRC researchers at UniSA following MISG. The Rail CRC representative Paul Milevskiy from QR is convinced that the MISG work will lead to significant improvements in timetabling.