Project Long-term Plans
High Performance Optimization: Theory, Algorithm Design and Engineering Applications

1. Longer Term Scientific Growth:

The scientific challenges addressed by this proposal are closely related to two recent important developments at McMaster University and the University of Waterloo. The first major development is the establishment of the **McMaster School of Computational Engineering and Science (MSCES)**. This initiative, spearheaded by Professor Tamas Terlaky as Founding Director, is aimed at creating a multidisciplinary environment to promote collaborative research as well as train university graduates with the skills necessary to effectively apply the exponentially growing computing power of technology to the numerous problems arising from applications in engineering and science. The urgency of this need has recently been highlighted in the United Stated through the NSF Atkins report, and the Presidential report on the importance of computational science. One of the three major research fields of the MSCES, Computational Optimization, Design and Control, is directly relevant to the scientific content of this project. The major developments in computational optimization in recent years have highlighted the importance of effectively integrating high performance computational methods with the leading-edge research activities in the engineering and physical sciences.

The second major development is the establishment of the **Electricity Markets Simulation and Optimization Laboratory (EMSOL)** at the University of Waterloo. This initiative, led by Professors Miguel Anjos and Kankar Bhattacharya, arises from the current trend towards deregulation of the power industry. The goal of deregulation is to enhance competition and provide customers with a range of choices and greater economic benefits. The process has necessitated the reformulation of established models for power system operations. Simultaneously, issues such as system reliability, control, and security, are being scrutinized and debated in this new deregulated environment. In Canada, several provinces have started restructuring their power sector in recent years, and electricity markets have been established in some of them. There is therefore an urgent need for researchers in this area to address issues such as optimal generation scheduling, and optimal power pricing in a real-time setting.

Both of these initiatives are strongly supported by their respective universities. McMaster University is investing significant resources to affirm the status of the MSCES as a flagship graduate school. Resources already committed include one new faculty position, and a budget of about $100,000 for the first year of operation. Once accreditation is complete, funds for student support of up to $250,000 are also expected for the first year of student intake (2006/07). Once steady-state is reached, the MSCES is expected to have up to 70 graduate students, corresponding to a space commitment of over 4,000 sq.ft and up to five additional faculty appointments.

The EMSOL will be housed in a newly renovated space of over 1200 sq.ft which can support the activities of up to 20 graduate students, and in which the University of Waterloo is investing nearly $50,000. The high-performance computing needs of this research have been met by a major CFI New Opportunities Grant totalling over $450,000 to the two lead researchers, and student support is currently being provided by various sources, including our partners Bell Canada and ABB from industry, and MITACS and CITO from the government sector.

The timing of these two initiatives coincides with an increase in collaborative work between researchers at these two institutions, much of which is already being supported by MITACS. The support by MITACS of this proposal will allow us to bring new members from both universities into our team. These new members strengthen both the mathematical optimization (Anjos, Deza, Fuller, Vannelli) and engineering optimization (Cañizares, Bhattacharya) subfields. Together with our collaborators from the University of Windsor, it is our expectation that the interactions that will take place thanks to the support of this proposal will build a collaborative research and training network which will be sustained through these two major initiatives for many years beyond the termination of NCE funding.

Finally, it is expected that around the time the NCE funding terminates, the EMSOL will have established itself as a strong research unit, and that it will expand into a self-sustained **Center for Electricity Markets and Optimization Research** at Waterloo. The resulting synergy with the MSCES and the **Advanced Optimization Laboratory (AdvOL)** at McMaster will form a world-class research and HQP training cluster in the area of Optimization and Engineering Applications.

2. Funding Growth Plan:

Industry and Other Partners:

Our research is currently funded by Rogers and Bell Canada. The activities of the EMSOL will bring funding from ABB to support this research. Although this support is typically only granted for one year at a time, our track record with MITACS so far shows that we have always been able to generate sufficient matching funds to fully take advantage of our MITACS allocation.

Government Partners:

Beyond the matching of our industry funding through MITACS, we expect to generate additional funds from Ontario sources through CITO and/or the new Energy Centre.

MITACS:

As mentioned above, our project team is expanding through the addition of new members from both McMaster (Deza) and Waterloo (Anjos, Bhattacharya, Cañizares, Fuller). This increase in the number of researchers comes with a corresponding increase in the number of graduate students and postdoctoral fellows that will be involved in the project. Much of this additional research is also accompanied by additional industry funds, and this is the rationale for our request in this proposal for an increase in funding from MITACS.

Specifically, **we are requesting an increase in the base funding to $220,000 per year, plus a yearly allocation of $30,000 in internship funds specifically to our project.**

3. New HQP, Networking and Technology Transfer Plans:

We intend to continue a number of networking and training activities that have been carried out regularly in recent years. These include the weekly student seminar series and the Advanced Optimization Seminar Series at McMaster, the monthly Industrial Optimization Seminar Series at the Fields Institute, and the Modelling and Optimization: Theory and Algorithms (MOPTA) annual conference that moves between the three Universities involved

in this project (McMaster in 2001 to 2004, Windsor in 2005, Waterloo in 2006, back to McMaster in 2007).

We also intend to continue organizing special focus research workshops, such as the Large Scale Nonlinear and Semidefinite Programming Workshop at Waterloo in 2004, the McMaster Optimization Day in 2004, the Workshop on Mathematical Programming in Data Mining and Machine Learning and the Franco-Canadian Workshop on Combinatorial Algorithms, both held at McMaster in 2005. Currently planned special events for the next two years include holding a Workshop on Optimization in Engineering at the Banff International Research Station in 2006, and hosting the triennial International Conference on Continuous Optimization (ICCOPT) at McMaster in 2007. The latter will offer HQP training in the form of a Summer School on Computational Optimization.

Apart from all the aforementioned activities, we intend to initiate a new series of high-profile guest speakers at the MSCES. The launch of the EMSOL will also initiate a series of seminar speakers in electricity markets and optimization at Waterloo.

There has been a marked increase in recent years in the collaboration between members of our project. For instance, Professor Vannelli spent a sabbatical leave at McMaster in 2005, and together with Professor Anjos, they make weekly visits to the AdvOL to pursue joint research work. Furthermore, several of the activities mentioned above are jointly organized by researchers at different institutions, and the administration of the project itself is carried out across institutional lines. For example, although the Project Leader is at McMaster, the web page is hosted at Waterloo. Industrial funding has also been obtained from various sources by different project members.

Finally, we anticipate an expansion of the number of industrial internships with our industrial partners, as part of the increased opportunities arising from the creation of the MSCES and the EMSOL. For example, HydroOne curently supports a Master of Engineering Program in Electrical and Computer Engineering at Waterloo. The University of Waterloo is now discussing with HydroOne broader support of research activities in sustainable energy, energy markets, and optimization. This justifies our request above for an allocation of MITACS internship funds specifically to our project.

4. Technology Spin-offs:

The development of software for optimization and engineering will continue with respect to McIPM and its variants: a public domain, open source, interior-point optimization package.

Recent initiatives that will mature under this proposal include:

1. The development of the solver SeDuMi, whose development was recently taken over by the AdvOL. We intend not only to keep it as one of the best SDO solvers in the world, but also to extend its abilities to include a powerful parallel version.
2. The testing of our novel fast approximation algorithms for VLSI routing problems, and the development of a package that can be used to apply them to real-life, large-scale routing problems.