Center for Computational Engineering

Computational engineering plays an increasingly important role in economic competitiveness, national security, environmental stewardship, and public safety. Indeed, computational engineering is central to all engineering endeavors, from the development of appropriate mathematical models to the prediction of mechanical, electrical, chemical, and biological phenomena and the design of complex natural and engineered systems. Computational engineering has now reached the stage in which further progress—to reach full potential as a pervasive enabling technology—requires the development of new interdisciplinary education and research models.

In fall 2008, the Center for Computational Engineering (CCE) was formed in the School of Engineering to support computational engineering research and education at MIT. Seventy-four faculty and researchers representing 13 academic programs from across the School of Engineering, the School of Science, and the MIT Sloan School of Management are currently affiliated with CCE. We focus on computational approaches to engineering problems: formulation and implementation of new approaches that are more efficient and capable and informed application of existing approaches to important engineering and scientific questions. Our emphasis is on the development of the "next generation" of innovators and innovations in computational engineering.

Graduate Education

CCE offers two educational programs, the interdisciplinary Master of Science Program in Computation for Design and Optimization (CDO) and the Doctoral Program in Computational Science and Engineering (CSE). Nicolas Hadjiconstantinou and Youssef Marzouk serve as co-directors of the graduate programs.

Master's Program

The total CDO enrollment in AY2015 was 32 students, 12 of whom were first-year students. Three CDO students were on the September 2014 degree list, three graduated in February 2015, and six graduated in June 2015, increasing the total number of CDO alumni to 136 as of June 2015.

CDO conducted its 11th admissions cycle this past winter and spring. Serving on the admissions committee were Youssef Marzouk (chair), Nicolas Hadjiconstantinou, Saurabh Amin, and Ben Forget. Ninety-five applications were submitted in January 2015, an 11.76% increase over the January 2014 pool. Fourteen applicants were offered admission, and nine accepted and plan to begin pursuing their SM degree in September 2015; one student deferred admission to September 2016.

Doctoral Program

The total CSE enrollment in AY2015 was 22 students; 10 were first-year students and 12 were current MIT doctoral students who transferred into the program. The first two CSE graduates were on the February 2015 degree list. No CSE students graduated in September 2014 or June 2015.

CSE conducted its second admissions cycle this past winter and spring, receiving 60 applications, an increase of 161% over the first admissions cycle. As CCE reviewers, Youssef Marzouk and Nicolas Hadjiconstantinou read all applications and passed the names of the most qualified applicants along to the indicated home department for review. Of the 60 applicants, 14 were offered admission; 10 students accepted and plan to begin their degree work in September 2015. A breakdown of the second admissions cycle is shown in Table 1.

Table 1. Breakdown of Applicants by Department during the Second CSE Admission Cycle

Department	Applications Received	Admitted	Accepted
Civil and Environmental Engineering	30	5	4
Mechanical Engineering	13	4	2
Chemical Engineering	3	1	1
Aeronautics and Astronautics	9	3	2
Nuclear Science and Engineering	5	1	1

Research

The emphasis of CCE research activities is on the development of new computational methods and on the innovative application of computational techniques to important problems in engineering and science.

Our research projects are focused on several major methodology themes and several major applications themes. The methodology themes are high-performance computation and computational foundations; multiscale, multiphysics, multifidelity simulations; computational design, optimization, and control; integration of data and simulation; and computational geometry and scientific visualization. The applications themes are materials and manufacturing, nano/micro systems, biological and biomedical processes/systems, infrastructure systems and services, and energy, environment, and transportation.

CCE faculty members are playing important roles in the national computational science and engineering community through leadership positions in professional societies (such as the Society for Industrial and Applied Mathematics [SIAM]) and through senior editorial positions with the leading computational science and engineering journals. In addition, faculty affiliated with CCE continue to bring visibility to MIT's computational science and engineering presence in the nation:

- The Department of Energy DiaMonD center, which includes CCE faculty members Karen Willcox, Youssef Marzouk, and Ruben Juanes, is now in its third year of operation.
- Michael Demkowicz (along with researchers at the University of Nebraska) won a Nuclear Energy Enabling Technologies Program research and development award for the project "Radiation Tolerance and Mechanical Properties of Nanostructured Amorphous-Ceramic/Metal Composites."

- David Darmofal coauthored a report titled "CFD Vision 2030 Study: A Path to Revolutionary Computational Aerosciences." The report, funded by the National Aeronautics and Space Administration (NASA), envisioned computational fluid dynamics in the year 2030.
- A team led by Karen Willcox was awarded a Multidisciplinary University Research Initiatives (MURI) Program grant by the Air Force Office of Sponsored Research. The MURI team includes Youssef Marzouk along with researchers from Texas A&M University, Arizona State University, Cornell University, the University of Michigan, and the Santa Fe Institute. The project will develop new approaches for managing multiple information sources in the design of multidisciplinary systems and aims to create a scalable framework for solving multidisciplinary design problems under uncertainty.

Accomplishments

With increased promotion, targeted recruitment, and a social media campaign, we were able to increase the application pools (and thereby increase our selectivity) for both the CDO and CSE programs during the past admissions cycle.

The Association of Computational Science and Engineering Students (ACSES), CCE's graduate student group, was founded in summer 2014. Founding members were Aziz Albaiz (president), Rongsha Li (vice president), Jeffry Liu (secretary), Yiqun "Agnes" Hu (treasurer/co-social chair), and Wichinpong "Park" Sinchaisri (co-social chair). The group received official Association of Student Activities recognition as an MIT sponsor-funded student group during AY2015. The mission of ACSES is to facilitate social bonding among students in the CDO, CSE, and other computation-related programs; offer a platform for students to gather and discuss ongoing research and popular computational science and engineering topics; and promote the CDO and CSE programs to more students and scholars who are interested in computational science and engineering. During its inaugural year, ACSES offered study groups for three of the four core CDO subjects and hosted a welcome meeting in September; social events such as a holiday gathering, movie nights, and study breaks throughout the year; and an end-of-the-year celebration in June.

ACSES was also responsible for organizing the fifth annual CCE Student Symposium, held on March 12, 2015, in conjunction with the CCE open house for newly admitted CDO and CSE students. William Morokoff, managing director of the Quantitative Analytics and Research Group at Standard & Poor's Ratings Services, gave a keynote address on "Applications of Machine Learning to Credit Risk and Economic Forecasting." Eleven students representing seven different departments and programs participated in the poster session blitz, presenting their work and giving a two-minute overview. More than 80 students, faculty, postdocs, and staff attended the event.

During AY2015 the MIT SIAM chapter, in collaboration with CCE, ran the second year of a student seminar series. These seminars serve as a means of bringing together members of the diverse MIT community with a common interest in applied mathematics and computational sciences. This past year, the SIAM group hosted talks from two doctoral students, four postdoctoral associates, and three early-career faculty members;

in combination, this group represented six departments at MIT as well as two external institutions (Stanford and Harvard).

During the 2015 Independent Activities Period, CCE and NSE cosponsored a noncredit activity, "Massively Parallel Multiphysics Simulation Simplified by MOOSE," run by Nuclear Science and Engineering/CSE student and former Idaho National Laboratory researcher Derek Gaston. The four-day session was attended by students from numerous departments and programs and focused on how to use the Multiphysics Object Oriented Simulation Environment (MOOSE) software to simulate complex systems of partial differential equations.

Faculty Highlights

Raul Radovitzky was named an American Institute of Aeronautics and Astronautics (AIAA) Associate Fellow in November 2014. AIAA Associate Fellows are "individuals of distinction who have made notable and valuable contributions to the arts, sciences, or technology of aeronautics or astronautics."

Luca Daniel was promoted to full professor in February 2015.

Markus Buehler was named a fellow of the American Institute for Medical and Biological Engineering in March.

In May, Qiqi Wang, an expert in high-fidelity simulation methods and chaotic systems, was promoted to associate professor without tenure.

Also in May, Alfredo Alexander-Katz, the Walter Henry Gale (1929) Career Development Professor in the Center for Materials Science and Engineering, was awarded tenure.

Dimitris Bertsimas won the 2015 Military Operations Research Society Journal Award.

Graduate Students

CDO student Nisha Chandramoorthy received the Ida Green Fellowship from the Office of the Dean for Graduate Education. The nine-month full fellowship for academic year 2015 included $44,720 in tuition, $26,748 in stipend payments, and $2,268 for individual health insurance coverage (a total award of $73,736).

In February 2015, CDO student Suma Desu finished first in the prediction category of the MIT Big Data Challenge, organized by the MIT Big Data Initiative at the Computer Science and Artificial Intelligence Laboratory (CSAIL) in partnership with the City of Boston and Transportation@MIT.

CDO/CSE student Chi Feng produced and directed the video Research for a Thirsty World, which won first place ($1,000 cash prize) in the second annual Course 1 Video Competition on March 12, 2015. The video was narrated by CDO student Reetik Kumar Sahu. Feng also produced and directed Recycling Plastic Bags, which won the MassRecycle 2015 Don't Recycle That There! Recycle That Here! College Competition ($1,000 scholarship prize).

CDO student Ming Qing Foo received the Wellington and Irene Loh Fund Fellowship from the Office of the Dean for Graduate Education. This one-term fellowship for spring 2015 provided $22,360 in tuition coverage, $12,469.50 in stipend payments, and $1,323 in individual health insurance coverage (a total award of $36,152.50).

CDO student Xiaojing "Ruby" Fu was selected as an honoree during the MIT Graduate Women of Excellence biennial celebration in April 2015.

In December 2014, CSE student Derek Gaston and his former research group at the Idaho National Laboratory received an R&D 100 Award from R&D magazine for their MOOSE computer software.

CSE student Sri Venkata Tapovan Lolla won a travel award to attend the 2015 SIAM Conference on Dynamical Systems in Snowbird, UT. In addition, Tapovan Lolla and CDO/CSE student Deepak Narayanan Subramani won an honorable mention award in the Graduate Science category at the 2015 de Florez Design Competition for their project "Optimal Path Planning in Dynamic Environments."

Deepak Narayanan Subramani also won the Best Poster Award at the CCE Student Symposium on March 12, 2015, for his CDO SM thesis "Energy Optimal Path Planning Using Stochastic Dynamically Orthogonal Level Set Equations." Subramani received a best student poster runner-up award for the same poster at the Dynamic Data Driven Environment System Sciences Conference in Cambridge, MA.

Future Plans

Our plans for the coming year include continuing to build a solid foundation to ensure the future success of the CSE PhD program. This includes additional targeted outreach in publicizing the program both within and outside of MIT. As appropriate, we will also explore other opportunities to increase the number of departments participating in the CSE program.

This September is the 10th anniversary of the CDO program, and we are using the milestone to focus on alumni outreach. We plan to reconnect with alumni of both the CDO and CSE programs with a biannual electronic newsletter, invite them to return to campus for CCE events, and invite them to reconnect with us in a variety of forums. Other plans for the coming year include continued targeted outreach in an effort to increase recruitment of underrepresented minorities into the CDO and CSE programs.

Anthony T. Patera, Co-director
Ford Professor of Engineering
Professor of Mechanical Engineering

Karen Willcox, Co-director
Professor of Aeronautics and Astronautics