

Center for Computational Engineering

The critical role that computation plays across all engineering disciplines, as well as the industry-based demand for engineers who are literate in computational sciences, has created a clear need for research and educational programs to produce tomorrow's computational engineering leaders. In response to this need, in December 2004 the MIT faculty approved the creation of the integrated multidisciplinary Computation for Design and Optimization (CDO) master's degree (SM) program. 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. Sixty-nine faculty and researchers representing 14 academic programs from across the School of Engineering, the School of Science, and the MIT Sloan School of Management are currently affiliated with CCE.

Research

Computational engineering plays an increasingly important role in economic competitiveness, national security, environmental stewardship, and public safety. 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. The center's computational engineering focus is on building computational tools for engineering problems and on the development of new computational tools that are more efficient, more robust, or more capable, as well as the informed application of existing computational tools—in concert with modeling, experimental, and analytical approaches—to address particular engineering problems and questions.

CCE's research projects are focused on several major methodology themes and several major applications themes. The methodology themes are:

- High-performance computation and computational foundations
- Multi-scale, multi-physics, multi-fidelity simulations
- Computational design, optimization, and control
- Integration of data and simulation
- Computational geometry and scientific visualization

The applications themes are:

- Materials and manufacturing
- Nano/micro systems
- Biological and biomedical processes/systems
- Infrastructure systems and services
- Energy, environment, and transportation

Education

CCE's main educational presence is the CDO master's degree program; Markus Buehler and Nicolas Hadjiconstantinou served as CDO codirectors. In June 2013, Markus Buehler stepped down from the CDO codirector position to head the Department of Civil and Environmental Engineering, and we welcomed Youssef Marzouk as codirector.

During AY2013, total enrollment in CDO was 26 students, nine of whom were first-year students. One CDO student was on the September degree list, one CDO student graduated in February, and nine graduated in June, increasing the total number of CDO alumni to 120 as of June 2013. One student withdrew from the program during the spring 2013 term.

CDO conducted its ninth admissions cycle this past winter and spring. Serving on the admissions committee this year were Markus Buehler (chair), Nicolas Hadjiconstantinou, and Youssef Marzouk. Of the 76 students who applied, 17 were offered admission; 14 students accepted and plan to begin their SM degree in September 2013.

Accomplishments

Through a donation from Horizontal Software, a nine-month fellowship was established for academic year 2013 to support the work of a PhD student who wished to pursue research studies in the development of innovative interfaces (including scripting languages, graphical systems, hardware devices, dissemination, and web strategies) for scientific, engineering, and mathematical software with particular emphasis on design, optimization, control, parameter estimation, and uncertainty quantification. Electrical Engineering and Computer Science (EECS) graduate student Jeffrey Bezanson (advisor: Alan Edelman) was awarded the 2012 Horizontal Software Fellowship in Computational Engineering.

The third annual CCE/CDO Student Symposium in Computational Science and Engineering took place in March 2013. This year's event was coordinated to coincide with the open house for newly admitted students in both the CDO program and the Department of Aeronautics and Astronautics. The symposium's theme was the future of computation in engineering. The symposium featured 11 student posters and two keynote speakers. The keynote speakers were Stephen Wolfram, founder and chief executive officer of Wolfram Research and creator of Mathematica and Wolfram Alpha Computational Engine, who spoke on "New Directions in Computation and Their Implications for Engineering" and Alex (Sandy) Pentland of the MIT Media Laboratory who spoke on "The Future of Computation: New Areas of Application and Challenges."

Youssef Marzouk and Patrick Heimbach organized the Speaker Series in Computational Science and Engineering for AY2013. Ten leading researchers from across the country came to speak on various topics, for example, "From CFD to Computational Finance and Back Again" (Mike Giles), "It's All About Energy! The Impact of Computational Materials Science" (Giulia Galli), and, "From Sorcery to Science: How Hollywood Physics Advances Computational Engineering" (Eitan Grinspun).

CCE faculty members continue to have a strong research presence in national computational science and engineering programs. Of particular note is the DiaMonD center, a Mathematical Multifaceted Integrated Capabilities Center funded by the US Department of Energy. DiaMonD research is addressing the applied mathematical and computational science challenges of a data-to-decisions approach to modeling and simulation of complex problems. DiaMonD is codirected by Karen Willcox and includes CCE faculty Youssef Marzouk and Ruben Juanes.

In last year's future plans, we mentioned that CCE would examine computational engineering education more broadly and chart a course for a CCE educational presence, including considering opportunities afforded by the SB in engineering for computational curriculum coordination and development at the undergraduate level, and PhD options at the graduate level. Spearheaded by Nicolas Hadjiconstantinou, with contributions from Markus Buehler, momentum for a PhD program in computation science and engineering grew through AY2013, resulting in a letter from Ian Waitz (dean, School of Engineering) to Christine Ortiz (dean, Graduate Education) in support of a PhD program in computational science and engineering (May 22, 2013). Approval by the Committee on Graduate Programs was received in early June. Four departments are participating in the new PhD program—Civil and Environmental Engineering (Course 1), Mechanical Engineering (Course 2), Chemical Engineering (Course 10), and Aeronautics and Astronautics (Course 16).

Future Plans

In the coming year CCE will build the administrative and academic structures (and the associated admissions, oversight, and assessment processes) that are required to implement the PhD program in computational science and engineering. We also plan to extend our engagement with the student body through support of the MIT student chapter of the Society for Industrial and Applied Mathematics.

Faculty Highlights

Faculty affiliates of CCE have been recognized for their achievements.

Markus Buehler received the 2013 Robert Lansing Hardy Award on March 5 at the annual meeting of the Mineral, Metals and Materials Society, in San Antonio, TX, recognizing his “innovative work in computational materials science of biological, bio-inspired and synthetic materials, focused on mechanical properties and in particular deformation and failure.”

In May 2013, Dean Waitz announced that Markus Buehler would be the next head of the Department of Civil and Environmental Engineering, effective 1 July 2013.

In November 2012, the Electrical Engineering and Computer Science Department announced that Pablo Parrilo was one of the three recipients of the Faculty Research and Innovation Fellowship (FRIF). The FRIF is given to recognize senior EECS faculty members for outstanding research contributions and international leadership in their fields.

In December 2012, Anthony Patera was named Honorary Member of the Société de Mathématiques Appliquées et Industrielles. In January 2013, he received the Chaire d'Excellence from the Fondation Sciences Mathématiques de Paris.

Alfredo Alexander-Katz was promoted to the rank of associate professor.

Jongyoon Han was promoted to full professor.

Professor Jaime Peraire was named a fellow of the American Institute of Aeronautics and Astronautics.

Anthony T. Patera, Codirector
Ford Professor of Engineering
Professor of Mechanical Engineering

Karen Willcox, Codirector
Associate Department Head, Aeronautics and Astronautics
Professor of Aeronautics and Astronautics