COMPUTATIONAL SCIENCE, ENGINEERING & MATHEMATICS: PATH TO DEGREE

Fall 2017

Todd Arbogast

Chair of the Graduate Studies Committee

Center for Subsurface Modeling of the
Institute for Computational Engineering and Sciences (ICES)
and
Department of Mathematics

The University of Texas at Austin
Computational science and engineering (CSE) is an exciting and emerging field of rigorous interdisciplinary scientific study. The use of mathematical modeling is growing rapidly and used

- to understand the dynamics of complex systems, and
- to make predictions about their behavior.

Traditionally, the pillars of science are theory and experiment. Today, CSE is becoming the third pillar, providing a link between the first two pillars through high performance computing and simulation.
The CSEM Degree Program

CSEM Students, Fall 2015
The Name of the Graduate Program

From 1993 to 2009, the graduate program name was

Computational and Applied Mathematics (CAM)

The program is now called

Computational Science, Engineering, and Mathematics (CSEM)

(we say “CoSEM” or “C-SEM” or “C-S-E-M”)

Our program is a forerunner in the areas of interdisciplinary

- computational science and engineering;
- mathematical modeling;
- numerical analysis;
- applied mathematics.
Overview of CSEM

CSEM is interdisciplinary. To analyze, model, and simulate a system, researchers must develop a broad and deep understanding of the three CSEM Concentration Areas:

- **Area A.** Applicable mathematics;
- **Area B.** Numerical analysis and scientific computation;
- **Area C.** Applications and mathematical modeling of a natural, engineered, social, or other system.

A disciplinary view misses the surprisingly complex ways these interact.

Each student must demonstrate breadth and proficiency in each of the three concentration areas. Research for CSEM dissertations must demonstrate an interdisciplinary theme and draw on knowledge from the three CSEM concentration areas.
CSEM Leadership (2017)

- Dr. J. Tinsley Oden, Director of ICES
- Dr. Todd Arbogast, Chair of the Graduate Studies Committee (GSC)
- Dr. Clint Dawson, Graduate Advisor
- Ms. Stephanie Rodriguez, Graduate Coordinator [mornings only]
- CSEM oversight: The Graduate Studies Subcommittee (GSSC)
Program Outcomes

1. **Education and training**
   Each student will develop technical understanding of and graduate level proficiency in computational science, engineering, and mathematics, as defined by three interdisciplinary CSEM Concentration Areas.

2. **Interdisciplinary Research**
   Each CSEM Ph.D. student will do original, interdisciplinary research in applied mathematics and computational science and engineering.

3. **Communication Skills**
   Each student will be able to communicate research results intelligibly to a broadly trained audience, both in written and oral form. CSEM students will learn skills required to work in research groups to solve complex interdisciplinary problems.

4. **The Scientific Community**
   The student will develop a broad understanding of the field of computational science and engineering, both inside and outside of his or her chosen field of application (Area C).

5. **Employment**
   Each graduate will secure an entry level position in academia or a public or private research laboratory specializing in interdisciplinary computational science and engineering research or technical services.
## Current Student Body

<table>
<thead>
<tr>
<th>Category</th>
<th>#</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>Total</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>62</td>
<td>77.5%</td>
</tr>
<tr>
<td>Females</td>
<td>18</td>
<td>22.5%</td>
</tr>
<tr>
<td>Minorities</td>
<td>3</td>
<td>7.9%    (of US)</td>
</tr>
<tr>
<td>US Citizens</td>
<td>38</td>
<td>47.5%</td>
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<tr>
<td>Foreign</td>
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<tr>
<td>CAM Option</td>
<td>26</td>
<td>32.5%</td>
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<tr>
<td>CSE Option</td>
<td>48</td>
<td>60.0%</td>
</tr>
<tr>
<td>Masters Only</td>
<td>6</td>
<td>7.5%</td>
</tr>
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</table>
Degree Requirements
Web Sites

The CSEM web site:
http://www.ices.utexas.edu/graduate-studies/

Under the link for Student Resources:

● The CSEM Ph.D. requirements:
  http://www.ices.utexas.edu/graduate-studies/phd-requirements/

● The CSEM M.S. requirements:
  http://www.ices.utexas.edu/graduate-studies/ms-requirements/

These slides: Linked from my mathematics home page
http://www.ma.utexas.edu/users/arbogast/

CSEM Wiki page:
https://wiki.ices.utexas.edu/csem
CSEM Masters Degree

Options. Fulfill one of the following

1. Thesis and 24 credit hours of coursework plus 6 credit hours of thesis preparation (30 credit hours total);
2. Report and 30 credit hours of coursework plus 3 credit hours of report preparation (33 credit hours total);
3. 36 credit hours of coursework. Note: Ph.D. candidates will fulfill this requirement. Be sure to request your degree!

This is a two-year program of study. (A full graduate load is 3 courses or 9 credit hours per semester).

Requirements.

• Course selection must be approved by the Graduate Advisor.
• At least 24 hours taken for a letter-grade in the 3 CSEM Areas.
• At least 6 hours in each CSEM Area.
• All Graduate School requirements must be fulfilled.
• Overall grade point average 3.0 (B) or better.
• Reports and Theses require an advisor from the CSEM GSC and a reader to approve the document.
1. **Coursework.** 12 courses total, 4 in each of the 3 areas. 6 core courses required in the first year. GPA 3.25 or better.

2. **Preliminary Exams.** Areas A, B, and C exams at end of first year.

3. **Ph.D. Dissertation Committee.** The adviser, faculty from Areas A, B, and C, and 1 more. At least 3 from different UT departments.

4. **Admission to Ph.D. Candidacy.** Student proposes plan of research.
   - **Abstract.** How Areas A, B, and C form an integral part of the proposed research. Approved by GSSC.
   - **Dissertation proposal.** Approved by the Dissertation Committee.
   - **Candidacy exam.** Tests depth and breadth of knowledge. Administered by the Dissertation Committee.

5. **Ph.D. Degree.** Dissertation and oral defense.
1. Coursework
Two starting points (the two degree options):

1. Computational and Applied Mathematics (CAM) Option
   [more math, less applications background]
2. Computational Science and Engineering (CSE) Option
   [more applications, less math background]

Upon entering the program, each student must elect an option.

The key question is: Can you handle graduate level mathematics?

The single ending point (a single degree):
Doctor of Philosophy with a major in Computational Science, Engineering, and Mathematics
Required Grade Point Average

CSEM Concentration Area work

- Cumulative GPA 3.25 (B/B+) or better
- One area GPA of 3.5 (B+/A-) or better

Remark: Texas uses the following grade scale.

\[
\begin{align*}
A & : 4.00 \text{ grade points} & C & : 2.00 \text{ grade points} \\
A- & : 3.67 \text{ grade points} & C- & : 1.67 \text{ grade points} \\
B+ & : 3.33 \text{ grade points} & D+ & : 1.33 \text{ grade points} \\
B  & : 3.00 \text{ grade points} & D  & : 1.00 \text{ grade points} \\
B- & : 2.67 \text{ grade points} & D- & : 0.67 \text{ grade points} \\
C+ & : 2.33 \text{ grade points} & F  & : 0.00 \text{ grade points}
\end{align*}
\]
First Semester

Three required courses.

Area A. Functional analysis

- **CAM**: CSE 386C/M 383C Methods of Applied Mathematics I
- **CSE**: CSE 386M/EM 386M Functional Analysis in Theoretical Mechanics

Area B. Numerical linear algebra

- CSE 383C/CS 383C Numerical Analysis: Linear Algebra

Area C. Applications and modeling

- CSE 389C Introduction to Mathematical Modeling in Science and Engineering I
Second Semester

Three required courses.

Area A. Mathematical Methods

- CAM: CSE 386D/M 383D Methods of Applied Mathematics II
- CSE: CSE 386L/EM 386L Mathematical Methods in Engineering and Science

Area B. One course chosen from:

- CSE 383L/M 387D Numerical Treatment of Differential Equations
- CSE 383M Statistical and Discrete Methods for Scientific Computing

Area C. Applications and modeling

- CSE 389D Introduction to Mathematical Modeling in Science and Engineering II
Next Five Semesters

Complete all coursework by 7th semester (December 2020)

Area A. Two approved graduate courses (total 4 courses or 12 hours)
- At least 2 courses must be listed or cross-listed with the Mathematics Department.

Area B. Two approved graduate courses (total 4 courses or 12 hours)
- Optional CSE 380 Tools and Techniques in Computational Science
- One course could be at the undergraduate level, if appropriate.

Area C. Two approved graduate courses (total 4 courses or 12 hours)
- In a field consistent with the student’s proposed research area.
- One course could be at the undergraduate level, if appropriate.
- Approved by both the student’s dissertation advisor and the Graduate Advisor.
2. Preliminary Examinations
Preliminary Examinations

- Three written exams are given at the end of first year:
  - Area C Friday, May 25, 2018;
  - Area B Tuesday, May 29, 2018;

- Covers the material of the 6 required first year courses (each student is tested on the courses he or she took).

- The student must demonstrate graduate level proficiency in the CSEM Concentration Areas.

- Failure results in one of:
  - take a make-up exam before the start of the Fall semester;
  - repeat that particular exam the following year;
  - leave the program.

- Success means you can concentrate your energy on Ph.D. level research!
3. Ph.D. Dissertation Committee
Dissertation Advisor

The CSEM Graduate Studies Committee (GSC) consists of the faculty who can advise Ph.D. students (a list is on the CSEM web page).

Every student must select an advisor willing to supervise his or her dissertation and give advice on course work. You must find an advisor during your first year, that is, by May 2018.

Prior to this, the Graduate Advisor and possibly a faculty mentor will advise the student on course work.
Composition of the Graduate Studies Committee (GSC)

Total faculty: 55 (five are in two departments)

**College of Natural Sciences faculty (28):**

13 Mathematics
7 Computer Science
2 Physics
5 Chemistry & Biochemistry
1 School of Biological Sciences

**College of Engineering faculty (27):**

13 Aerospace Engineering & Engineering Mechanics
5 Mechanical Engineering
3 Electrical & Computer Eng.
3 Petroleum & Geosystems Eng.
1 Civil Engineering
1 Chemical Engineering
1 Biomedical Engineering

**Jackson School of Geosciences (4):**

4 Geological Sciences

**Institute for Computational Engineering and Sciences (1):**

1 Research Scientist
The dissertation committee consists of the advisor and faculty from:

1. area A;
2. area B;
3. area C;
4. any relevant faculty outside the GSC.

At least three must be in distinct UT departments through positive time appointment.

The Graduate Advisor must approve the committee.
4. Admission to Ph.D. Candidacy

Before the end of the sixth semester (August 2020),
the student must propose research for the Ph.D. dissertation.
Proposal Abstract

**Write:** Write a concise abstract of the dissertation proposal.
- About 0.5 to 1 page giving general background on the research area and identification of the problems to be addressed.
- About 1 to 1.5 pages discussing how Areas A, B, and C will form an integral part of the proposed research.
- The text of the abstract must fit in 2 pages total.
- Perhaps 0.5 page of important references and possibly courses taken.

**Meet:** Meet with each member of the dissertation committee to discuss:
- the abstract
- the role of the committee member
- the background knowledge expected of the student and types of questions that might be asked at the proposal presentation

The abstract must be signed by each member of the committee.

**Submit:** Submit to the GSSC for approval. Allow at least 1 month!

Is the research interdisciplinary and draw on Areas A, B, and C?
The proposal must be set in 11 or 12 point font and conform to standard U.S. letter dimensions using one inch margins.

1. **Title page.** Title, student, date, committee.
2. **Proposal abstract.**
3. **Description of the proposed work.** At most 20 pages.
   a. Technical background and relevant literature
   b. Objectives, significance, and originality
   c. Work completed to date
   d. Work yet to be completed and methodology or approach
4. **References.**
5. **Vita.** One to two page vita: degrees earned, awards, papers published or in preparation, and technical talks or posters.
6. **Timeline.** To complete the proposed work.
7. **Appendices.** At most 10 pages of additional material.

**Remark.** The structure is like a research grant proposal.
Admission to Ph.D. Candidacy

Two weeks past submission of the dissertation proposal.

**Part 1:** Private oral presentation to the committee, about 45 minutes.

**Part 2:** Qualifying examination by the committee, about 1 hour.
- Explore details of the proposal
- Test depth and breadth of background knowledge relevant to the proposed research
- Test ability to integrate ideas from areas A, B, and C
- Somewhat greater depth and breadth expected in
  - **CAM:** Area A as opposed to Area C
  - **CSE:** Area C as opposed to Area A
- Failure: require additional course work and examination within 1 year.

**Part 3:** Graduate School application for admission to Ph.D. candidacy.
5. Ph.D. Degree
Ph.D. Dissertation and Defense

Dissertation: A written dissertation ("long essay") of research results, generally advocating a coherent thesis ("a statement or theory put forward as a premise to be maintained or proved").

Defense:

- Public, oral seminar presentation of about 45 minutes plus questions.
- Private meeting with the dissertation committee to face questions and orally defend the work.

The dissertation committee must approve both the dissertation and the defense.

- Should complete by the end of the tenth long semester (May 2022).
- Practically must be completed before the end of the fourteenth long semester (May 2024).

The dissertation and oral defense must follow appropriate Graduate School requirements and procedures.
• Last 7 years: 54 CSEM Ph.D. graduates.
• Average time to degree was 5.97±1.30 years.
• Minimum 3.5 years, Median 6.0 years, Maximum 9 years.
6. Miscellaneous
**Regular Duties**

**ICES Seminars**
- **Research seminars:** Research seminars are given most Tuesdays and Thursdays at 3:30 in the ICES seminar room, ACE 6.304.
- **ICES Forum:** Usually given around noon on Fridays, and targeting graduate students.

Your attendance is **required!**

(10 seminars per semester)

**Annual Progress Reports**

Each student is required to prepare an annual progress report of

- coursework
- research activities
- financial support
- etc.
Probation and Petitions

Probation: A student failing to satisfy the requirements of the program in a timely manner will be put on probation by the GSSC, and his or her progress will be monitored closely. The student will stay on probation until satisfactory progress is achieved. A student may stay on probation for a maximum of two long semesters.

Appeals and Petitions: The student may appeal to or petition the CSEM GSSC for waiver or alteration of any CSEM requirement, except for waiver of an exam or waiver of a Graduate School degree requirement.
First Year Summary

- Courses
  - 2 Area A
  - 2 Area B
  - 2 Area C
- Preliminary Examinations in late May
- Seminar attendance (10 per semester)
- Selection of dissertation advisor by May 2018
- Annual progress report (due early in the Fall 2018)
1. **Coursework.** 12 courses total, 4 in each of the 3 areas, within 3.5 years. 6 core courses required in the first year. GPA 3.25 or better (one 3.5 or better).

2. **Preliminary Exams.** Areas A, B, and C exams at end of first year.

3. **Ph.D. Dissertation Committee.** The adviser (select by end of year), faculty from Areas A, B, and C, and 1 more. At least 3 from different UT departments.

4. **Admission to Ph.D. Candidacy.** Student proposes plan of research.
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5. **Ph.D. Degree.** Dissertation and oral defense.
**Student Societies**

*Student Chapter of SIAM*
Affiliated with the Society for Industrial and Applied Mathematics (SIAM). A society for all those interested in mathematics and its applications: any major, undergraduate, graduate, and faculty.

*Student Chapter of USACM*
Affiliated with the U.S. Association of Computational Mechanics.

*UT-Austin Graduate Student Assembly*
CSEM students will elect their representative.

*CSEM Student Leaders*
Elected in the Fall. Organize socials and bring concerns to the GSSC.

CSEM Wiki page:
https://wiki.ices.utexas.edu/csem
Research in ICES

Some of the ICES Core Faculty

Peter O'Donnell, Jr. Building for Applied Computational Engineering & Sciences
ICES Researchers

ICES is home to more than 300 People!

- Core Faculty, 41
- Research Staff, 82
- CSEM Students, 73
- Visiting Scholars, 54
- Administrative Staff, 25
- Affiliated Faculty, 77
**Life Sciences**
- Center for Cardiovascular Simulation (Sacks et al.)
- Center for Computational Life Sciences and Biology (Elber)
- Center for Computational Oncology (Yankeelov, Oden, Rylander)

**Geosciences**
- Center for Computational Geosciences and Optimization (Ghattas, Bui-Thanh, Heimbach)
- Center for Subsurface Modeling (Wheeler, Arbogast, Delshad)
- Computational Hydraulics Group (Dawson)
- Computational Research in Ice and Ocean Systems Group (Heimbach)

**Physical Sciences**
- Center for Computational Materials (Chelikowsky, Demkov, Sanchez)
- Center for Computational Molecular Science (Henkelman, Bonnecaze, Makarov, Stanton)
- Center for Predictive Engineering & Computational Sci. (Moser et al.)
- Computational Mechanics Group (Hughes et al)
- Electromagnetics & Acoustics Group (Demkowicz)
- Parallel Algorithms for Data Analysis and Simulation Group (Biros)
Mathematics and Computer Science

- Applied Mathematics Group (Gamba et al.)
- Center for Big Data Analytics (Dhillon, Ravikumar)
- Center for Distributed and Grid Computing (Pingali)
- Center for Numerical Analysis (Engquist et al.)
- Computational Visualization Center (Bajaj, Dhillon)
- Science of High-Performance Computing Group (Van de Geijn, Stanton)

Center for Computational Geosciences and Optimization
## ICES Research Metrics

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<tr>
<th>Faculty Metric</th>
<th>2013-14</th>
<th>2014-15</th>
<th>2015-16</th>
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<tbody>
<tr>
<td>Core Faculty</td>
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<td></td>
<td></td>
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<tr>
<td>Medals, Prizes &amp; Honors</td>
<td>106</td>
<td>111</td>
<td>103</td>
</tr>
<tr>
<td>Refereed Journal Publications</td>
<td>429</td>
<td>381</td>
<td>345</td>
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<tr>
<td>Total Citations</td>
<td>&gt; 436,502</td>
<td>&gt; 485,322</td>
<td>&gt; 515,446</td>
</tr>
<tr>
<td>Editorial Boards</td>
<td>183</td>
<td>184</td>
<td>181</td>
</tr>
<tr>
<td>Seminars &amp; Lectures</td>
<td>402</td>
<td>410</td>
<td>400</td>
</tr>
<tr>
<td>Workshops Hosted</td>
<td>10</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Active Research Projects</td>
<td>147</td>
<td>153</td>
<td>164</td>
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<tr>
<td>Total Funding</td>
<td>$92.5M</td>
<td>$79.0M</td>
<td>$68.6M</td>
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<tr>
<td>Income</td>
<td>$17.2M</td>
<td>$17.2M</td>
<td>$19.2M</td>
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<tr>
<td>Expenses</td>
<td>$17.4M</td>
<td>$18.1M</td>
<td>$17.4M</td>
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<tr>
<td>Number of postdocs</td>
<td>51</td>
<td>45</td>
<td>48</td>
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<tr>
<td>Visitors program faculty</td>
<td>47</td>
<td>47</td>
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<th>Student Metric</th>
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<tr>
<td>Total enrollment</td>
<td>75</td>
<td>73</td>
<td>73</td>
<td>70</td>
<td>75</td>
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<tr>
<td>Authored or coauthored articles</td>
<td>29</td>
<td>28</td>
<td>27</td>
<td>32</td>
<td>36</td>
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<tr>
<td>Presented papers/seminars</td>
<td>25</td>
<td>34</td>
<td>33</td>
<td>39</td>
<td>39</td>
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</table>
Recent CAM/CSEM Ph.D. Graduates

Fall Graduation 2013
1. Taus, Matthias; Fall 2015; Isogeometric Analysis for Boundary Integral Equations.
3. Young, Jonathan; Spring 2016; Computational Discovery of Genetic Targets and Interactions: Applications to Lung Cancer.
4. Ellis, Truman; Spring 2016; Space-Time Discontinuous Petrov-Galerkin Finite Elements for Transient Fluid Mechanics.
6. Sakamoto, Yusuke; Summer 2016; One Cell as a Mixture: Simulation of the Mechanical Responses of Valve Interstitial Cells.
10. Neupane, Prapti; Summer 2016; Advances Towards a Multi-Dimensional Discontinuous Galerkin Method for Modeling Hurricane Storm Surge Induced Flooding in Coastal Watersheds.
CSEM Employment (past 4 years)

Industry (18)
- 3Red Group
- AlphaWorks Capital Management
- Applied Underwriters
- CD-adapco
- Cerner Corporation
- Citium Advisors LLC
- Energy Solutions International
- Google
- Hewlett Packard Enterprise
- Hi Fidelity Genetics
- I.M. Systems Group, Inc.
- Indeed.com
- Insight Data Science
- Microsoft
- Oracle
- Schlumberger
- Silobreaker, Ltd. (Sweden)
- Two Sigma Investments

Government (5)
- Argonne National Laboratory
- Karolinska Institutet (Sweden)
- Lawrence Livermore Nat'l Lab
- NATO
- Sandia National Labs

Academics (18)
- Brown University
- Duke University
- EPFL (Switzerland)
- Florida State University
- Georgia Institute of Technology
- Massachusetts Institute of Tech.
- Princeton
- Rice University
- Stanford University
- TU Vienna
- United States Military Academy
- University of California, San Diego
- University of California, San Francisco
- University of Central Florida
- University of Chicago
- University of Notre Dame
- University of Texas at Austin
- Virginia Tech
Survey of Alumni—Employment

57 Alumni, 23 completed surveys

9% Post-doctoral researcher (2)

13% Industry (3)
  ● Schlumberger, Houston, Texas (2)
  ● Tech-X Corp., Boulder, Colorado

13% Government Laboratories (3)
  ● Sandia National Laboratories, New Mexico (2)
  ● Basque Center for Applied Mathematics, Spain

22% Academics, Non-tenure track (5)

43% Academics, Tenure track (10)
  ● Caltech
  ● Carnegie Mellon University
  ● CICESE, Ensenada, Mexico
  ● North Carolina State University
  ● Rice University
  ● SUNY, Buffalo
  ● Texas Tech University
  ● University of California, Berkeley
  ● University of California, San Diego
  ● University of Colorado, Boulder

Academic Disciplines
  ● Applied Mathematics (2)
  ● Civil Engineering (1)
  ● Computational Science (2)
  ● Mechanical Engineering (4)
  ● Petroleum Engineering (1)
“I received extremely good training in computational and applied mathematics! The wide range of courses and faculty were exceptional!”
— Tarek Zohdi, Chancellor’s Professor, Will C. Hall Endowed Chair, Chair of Computational & Data Science & Engineering Program, Mechanical Engineering, University of California at Berkeley

“The CAM program made a significant positive difference in my career—it trained me to tackle complex problems in an interdisciplinary manner by combining intuition-based engineering/physics with precise mathematics and efficient computation, which I believe to date is the most effective way to tackle such problems. I use the same approach to train my own students and feel happy to see them develop into effective computational mechanics researchers. The CAM program also gave me access to excellent professors, many of them serve as role models to me even now.”
— Murthy Guddati, Professor of Structural Engineering & Mechanics, Civil Engineering, North Carolina State University
Welcome to CSEM!

We hope your time here is stimulating, challenging, rewarding, and enjoyable!