



Computational Science & Engineering 2009
Minisymposium 86: Graduate Education in
CS&E: Needs, Trends, Risks, and Chances

SIAM's Role in Supporting and Developing Computational Science & Engineering

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Outline

- Current scope of CS&E activities in SIAM
- History of SIAM and CS&E
 - Defining CS&E graduate education
 - Bridging cultures
- Future of SIAM and Graduate Education in CS&E*
 - How can SIAM advance CS&E education?
 - How can CS&E education advance SIAM?

* including participant input

Discussion seeds

- CS&E is poorly understood by most academic leaders, faculty, and students
 - some haven't considered its “paradigm-shifting” claims seriously at all
 - some believe it is a trivial aggregation of familiar specialties
 - some claim it earnestly as theirs, but only understand a slice
- SIAM's has contributions to make in
 - demonstrating and policing the intellectual content of CS&E
 - disseminating awareness of CS&E and its ripeness
 - becoming the “hub” society for CS&E for people whose primary society is ACM, APS, ASME, IEEE, etc. (“SIAM: your second society”)

Discussion seeds

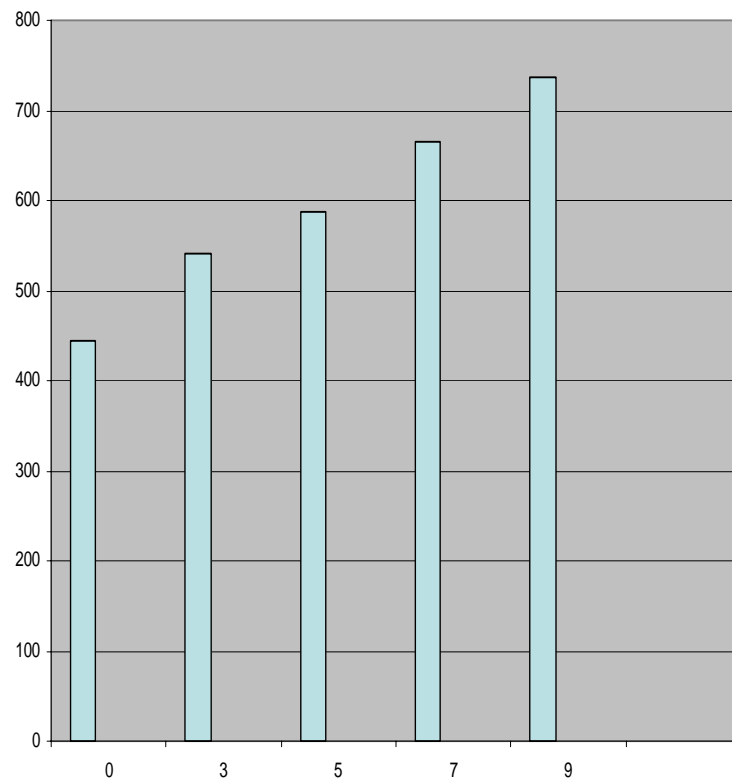
- As an organization of some 10,000 members, SIAM must do these things without becoming *only* CS&E
 - that is, without neglecting its important roles or losing its constituent roots in many less vertically integrated intellectual domains in applied mathematics and computer science

Scope of CS&E in SIAM

- Biennial conference
- Activity group
- Book series
- Journal activity
- Washington presence
- Career activities
- Prizes
- Communications

Biennial conference

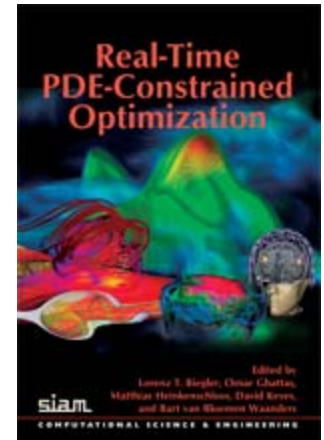
- CSE09, March, Miami (736)
- CSE07, February, Costa Mesa (666)
- CSE05, February, Orlando (587)
- CSE03, February, San Diego (541)
- CSE00, September, DC (444)



Activity group

- SIAG-CSE new officers (1/1/09-12/31/10)
 - Chair: Tamara Kolda
 - Vice Chair: Kirk Jordan
 - Program Director: Ulrich Ruede
 - Secretary/Treasurer: Carol Woodward
- SIAM's largest of 16 activity groups
 - and most rapidly growing
- More student members than regular members (one of four SIAGs for which this is true)
 - educational activities are very appropriate for our demographics 😊
- Interestingly, the SIAG is dominantly led by lab and industry people, not by academics

Book series



- SIAM CS&E series
 - Omar Ghattas, editor-in-chief
- Six titles to date, beginning in 2006
 - [Introduction to the Numerical Analysis of Incompressible Viscous Flows](#)
William Layton
 - [Numerical Methods for Evolutionary Differential Equations](#)
Uri M. Ascher
 - [An Introduction to Modeling and Simulation of Particulate Flows](#)
T. I. Zohdi
 - [Real-Time PDE-Constrained Optimization](#)
Edited by Lorenz T. Biegler, Omar Ghattas, Matthias Heinkenschloss, David Keyes, and Bart van Bloemen Waanders
 - [Computational Methods for Multiphase Flows in Porous Media](#)
Zhangxin Chen, Guanren Huan, and Yuanle Ma
 - [Solving PDEs in C++: Numerical Methods in a Unified Object-Oriented Approach](#)
Yair Shapira

Journal activity

- No SIAM journal (yet)
- Journal proposal often discussed
- Experiment in 2008: special issue of SISC
 - anecdotally, a well-received issue
 - excerpts from the editorial preface to follow
- After more feedback from readers and internal discussion among the editors, this experiment could become a regular feature

Washington presence

- SIAM's Committee on Science Policy
 - New VP, Reinhard Laubenbacher
 - Meets twice per year in DC for two days each time
- Goals of CSP
 - hear from and influence program directors of agencies that have significant leadership in applied and computational mathematics
 - educate staffers and lawmakers regarding opportunities and exigencies in applied and computational mathematics research

Career Activities in CS&E

- At the conferences
 - CSE09
 - Career Development Night
 - CSE07
 - Career Fair
 - CSE05
 - Short courses
 - CSE03
 - Short courses
- On the webpages
 - Internship listings

Communications

- SIAG-CSE listserve
- *SIAM News* features

Prizes

- SIAM-ACM Prize in CS&E
 - 2003 Bell & Colella
 - 2005 Brandt
 - 2007 Shu
 - 2009 Moler
- New Student Prize (Ruede, Bungartz, et al.) awarded at the conference

History of SIAM and CS&E

- Minutes of first business meeting (2003)
 - “Need to attract ‘domain scientists’ (physicists, engineers, etc.). View CS&E as a ‘big tent’ multidisciplinary. SIAM is positioned to be the society for CS&E.”
- CS&E and Supercomputing have evolved into a complementary conference pair and SIAG pair
 - many SIAM’ese are members of both SIAGs, though there are significant nonoverlapping segments of each
- The Petzold report (1999) on CS&E education can perhaps be considered SIAM’s *magna carta* on this interdisciplinary domain

Outline of Petzold report

- Introduction
 - ‘third leg’ motivation
- Definition of CSE
 - good definition, bad Venn diagram
- CS&E as an Emerging Discipline
 - 6 examples of engineering, 4 of science
- Enabling Technologies of CSE
 - ‘Moore’s Law for Algorithms’ chart
- CSE Graduate Education
 - Objectives, curriculum, 6 examples (Stanford, Texas; Illinois, Purdue; ETH, KTH)
- Broadening the Student Experience
 - Internship deemed “absolutely essential”
- Role of SIAM
 - (next slide)

Role for SIAM (Petzold report)

1. Define the core areas and scope of this field.
2. Outline ideas for curriculum.
3. Examine SIAM's existing journals and determine whether there is a place for CSE research as we have defined it.
4. Hold conferences on CSE.
5. Establish a special interest group (SIAG) on CSE.
6. Create an electronic CSE Bulletin Board that would include the following: discussion forum; pointers to graduate degree programs; infrastructure for universities, government and industry to post internship opportunities and for students to post resumes; infrastructure for universities, government and industry to post job opportunities and for job seekers to post resumes
7. Publish information of use for CSE education, for example articles specifically oriented to teaching in CSE programs or courses.
8. Publish CSE textbooks.
9. Publish CSE research books.

Pre-history of SIAM and CS&E

- Run-up to CS&E in SIAM is fun to trace back to visionary documents from both the enabling technologies and the applications side, and to federal responses, mainly from NSF and DOE

Formative visions about computational science



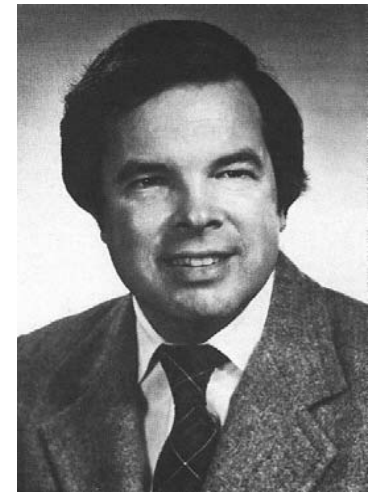
The “third leg” quotation (1986)

“During its spectacular rise, the computational has joined the theoretical and the experimental branches of science, and is rapidly approaching its two older sisters in importance and intellectual respectability.” – Peter D. Lax, in *J. Stat. Phys.*, 43:749-756

ET publishes in Apps journal

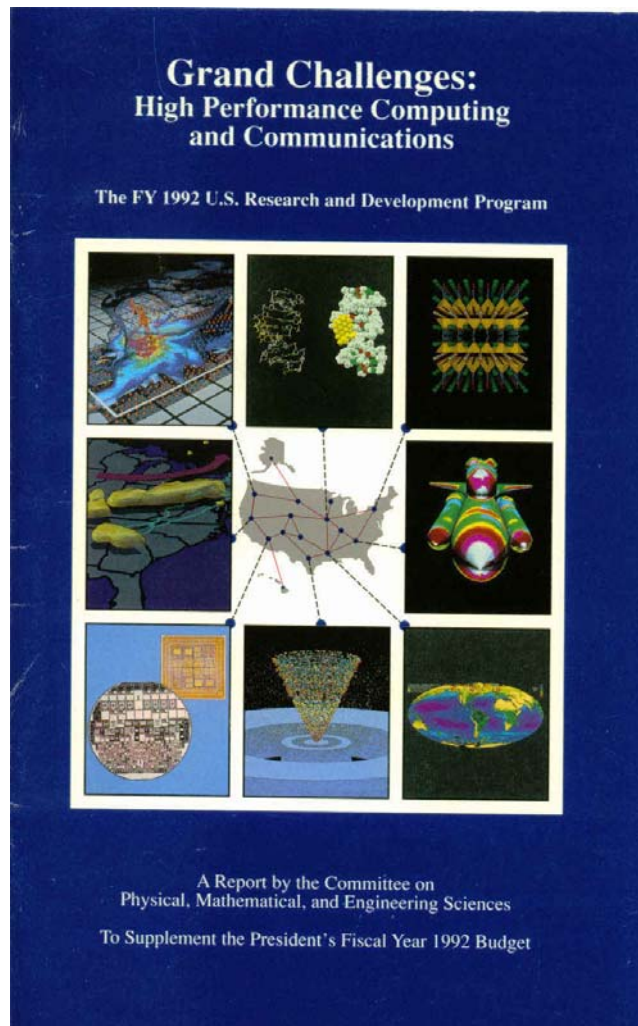
The “Grand Challenge” quotation (1989)

“A few key areas with both extreme difficulties and extraordinary rewards for success should be labelled as the “Grand Challenges of Computational Science.” [They] should define opportunities to open up vast new domains of scientific research, domains that are inaccessible to traditional experimental or theoretical models of investigation.” – Kenneth G. Wilson, in *Future Generation Computer Systems*, 5:171-189



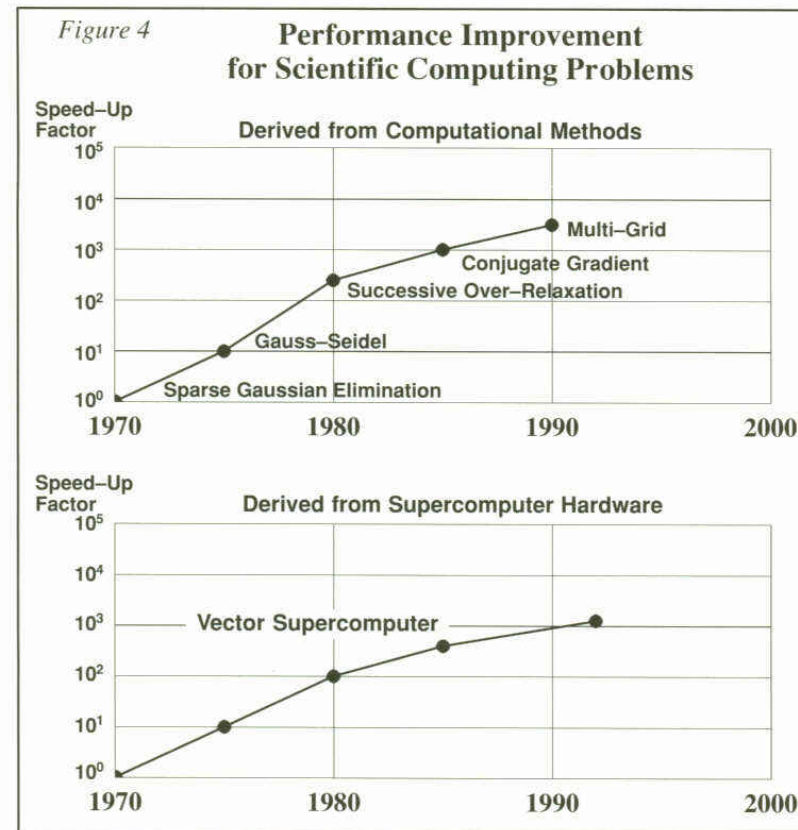
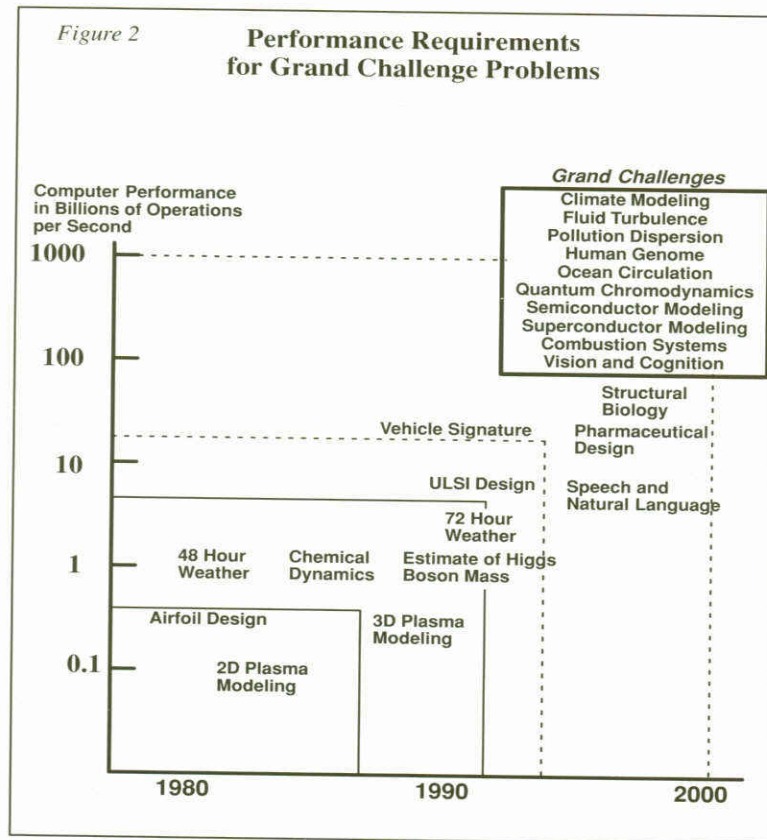
Apps publishes in ET journal

HPCC Bluebook (1992, OSTP)



- Proposed 30% increase in federal support of HPCC (to \$638M/yr)
- Four major components:
 - High performance computing systems
 - Advanced Software Technology and Algorithms
 - National Research and Education Network
 - Basic Research and Human Resources

HPCC Bluebook (1992, OSTP)



HPCC bluebooks, 1994-2005



<http://www.nitrd.gov/pubs/bluebooks/>

The Annual Supplement to the President's Budget (referred to as the Blue Book until FY 2005), summarizes the goals and objectives of the IT R&D Program and highlights many of the Program's accomplishments and plans.

Can simulation produce more than “insight”?

“The purpose of computing is *insight*, not numbers... the purpose of computing numbers is not yet in sight.”

— R. W. Hamming (1961)

“The computer literally is providing a new window through which we can observe the natural world in exquisite detail.”

— J. S. Langer (1998)

“What changed were simulations that showed that the new ITER design will, in fact, be capable of achieving and sustaining burning plasma.”

— R. L. Orbach (2003, in Congressional testimony about why the U.S. is rejoining the International Thermonuclear Energy Reactor (ITER) consortium)

From preface to special issue

- Result of a special call for papers that was announced at Costa Mesa, Feb 07
- Three guest editors-in-chief, one-time editorial board of 22 well-known researchers in CS&E
- 89 papers submitted and subjected to a review process as rigorous as the standard review procedures of SISC, with additional topical filter
- 26 papers were selected for publication based on combination of quality and appropriateness in defining the theme of CS&E
- Some quality submissions not selected for this issue may eventually appear as regular papers in SISC or other journals
- *“We believe that this volume may be considered a milestone of case studies marking the current state of the art for research in CS&E by example.”*

From preface to special issue

- **CS&E research does not primarily seek to achieve new results for a given domain science but rather to provide new computational tools to researchers**
- **Even though these tools are regularly developed to address challenging problems in specific domain sciences, they are generally transferable to other applications**
- ***“For example, a method to simulate large ensembles of interacting particles may be useful to an astrophysicist studying galaxy formation as well as to a nanotechnology researcher exploring molecular dynamics. If the methods were not transferable to other applications, a collection of papers of such wide span of different applications into a single volume would be of dubious value.”***
- **Ultimately, CS&E aims at developing a universal set of simulation methods and tools for the scientists and engineers of the future**

From preface to special issue

- **CS&E research differs from research in mathematics or computer science in that it is oriented at one or more realistic applications of a domain science or engineering discipline**
- **Such problems often involve complicated three-dimensional geometries, multiple interacting scales, heterogeneities, anisotropies, and multi-physical or biological descriptions**
- **They often thwart rigorous proofs of accuracy or efficiency, and so CS&E research must regularly address validation and verification by other means than traditional mathematical analysis**
- ***“CS&E research cannot be limited to any single step of the simulation pipeline. A mathematical simulation algorithm is useful in CS&E only when it is also implemented on a real computer, and a new parallel processing paradigm becomes relevant for CS&E only when it is demonstrated to be applicable for a large-scale numerical computation.”***



From preface to special issue

- ***“Of course, research for an individual piece of the CS&E pipeline, such as the development of a new finite element method, may also be very useful for progress in CS&E, but taken by itself such a development remains merely work in numerical analysis. In other words, CS&E is not just a new name for existing computational disciplines, nor – least of all – is it just mathematics in which the proofs are half finished. In fact, as opposed to other mathematical sciences, CS&E often achieves its progress through a clever combination of techniques and methods employed for the different stages of the CS&E pipeline. In such a case, the innovation of excellent research may consist in the creativity needed to synthesize a computational solution for a complex problem from the right building blocks.”***
- **All papers share a focus on the development of innovative computational methodology in the context of challenging applications, in the spirit of the rationale above**

Future of SIAM and Graduate Education in CS&E: How can SIAM help CS&E?

- Continue to discuss in “birds of a feather” sessions at the conference
- Set curricular standards and expectations
- Offer continuing education courses
- Instruct CSP how to represent effectively
- Document/certify/rank CSE programs (?)
- Institute a prize for young investigators
- Convene engineering and science deans CRA-like to explain what CS&E is

Future of SIAM and Graduate Education in CS&E: How can CS&E help SIAM?

- SIAM becomes the most important professional society in the currently most intellectually robust and cost-effective of the three pillars
- ...