What's New at TICAM?

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I. Introduction

The readers of Expressions may recall that in an early issue an announcement was made of the creation of a new academic and research program at The University of Texas. The program was designed to be interdisciplinary and to bring together the scientific and engineering disciplines necessary to address major research problems in computational mechanics and computational science and to advance the broad fields of computer simulation of physical events and systems. A major component of this initiative was the creation of TICAM, the Texas Institute for Computational and Applied Mathematics, an organized research center with a mission of creating the infrastructure to facilitate basic research in computer modeling and computer simulation. Another major component was the creation of an academic program, the CAM Program, which leads to a Ph.D. degree in CAM. The program is interdisciplinary, involving participation of fourteen academic departments and three colleges, the original emphasis being on computational engineering and science but, along the way, complemented by a new program in computational finance. CAM faculty hold tenure-track or tenured positions in mathematics, computer sciences, physics, chemistry, astronomy, geology, and the biological sciences, and all of the academic departments within the College of Engineering. New faculty have also been hired in the Department of Management Science and Information Systems to provide graduate study and research opportunities in the budding area of computational finance. The CAM/TICAM programs feature a number of organized research units, a unique academic program, a unique visiting scholars program, a fellowship program for CAM students, and significant computational facilities. I will comment further on each of these components in the paragraphs below.

II. The Institute

While TICAM faculty hold tenured positions in the participating departments, they also participate in research clusters or research centers. A research cluster is a group of TICAM faculty from two or more academic disciplines, graduate students, postdoctoral students, staff research scientists, and visiting scholars who work together jointly on a TICAM research project.
The Research Centers are standing organized research units dedicated to research in focused areas of computational sciences.

TICAM thus is an umbrella for various research centers, providing the administration, management, and overall infrastructure for interdisciplinary research. The administration of TICAM consists of a Director, a position which I currently hold, and an Assistant Director for Engineering, a position currently held by Professor Leszek Demkowicz of the Aerospace Engineering and Engineering Mechanics Department, and an Assistant Director for Computational Science, currently held by Professor J.C. Browne, Department of Computer Sciences. The Director is chairman of an Advisory Board consisting of center directors and at-large members who participate in making policy decisions on the use of Institute resources.

In initiating the program, a number of endowed chairs were created for the purpose of bringing into the Institute leading researchers in various areas of computational mechanics and computational science. Currently there are six so-called CAM chairs, and an additional three endowed chairs held by senior professors who are actively involved in TICAM research. The primary source of operational funds for the Institute is indirect cost returns from organized research projects. TICAM now has around 50 projects funded primarily by industry, government laboratories and federal research agencies. These funds support a technical staff, clerical staff, and 15 full-time untenured research scientists. TICAM thus provides the office space, clerical help, computational equipment and facilities, systems support, and basic administrative support for research of faculty members who participate in TICAM research projects.
III. TICAM Centers and Chairs

As noted above, there are several organized research centers that are under the TICAM umbrella and these have TICAM chair holders as directors. The TICAM chair-holders, centers, and research groups are listed as follows:

- **Center for Subsurface Modeling (CSM).** The Director of this Center is Professor Mary F. Wheeler, CAM Chair II, who holds the Ernest and Virginia Cockrell Chair in Engineering. In the spirit of the interdisciplinary nature of the program, Professor Wheeler holds appointments in the Departments of Aerospace Engineering and Engineering Mechanics, Petroleum and Geosystems Engineering, and Mathematics. Wheeler's group is engaged in fundamental and applied research in developing computational and simulation tools for oil reservoir simulation, groundwater flow, pollution remediation and control, and basic issues of modeling flow through porous media.

  Professors Todd Arbogast, Department of Mathematics, and Clint Dawson, Department of Aerospace Engineering and Engineering Mechanics, devote a major percentage of their time to CSM. CSM also manages an industrial affiliates program in which 10 major petrochemical industries participate in supporting basic research efforts.

- **Center for Computational Visualization (CCV).** Professor Chandrajit Bajaj, Department of Computer Sciences, is Director for the Center for Computational Visualization and holds the CAM Chair IV. An international authority on visualization and computer graphics, Professor Bajaj has recently been involved in the development of a new CD visualization laboratory which is developed to do basic research in computer visualization, and to provide cutting edge visualization tools to other research projects within TICAM.

- **Computational Fluid Dynamics Laboratory (CFD Lab).** The Director of the Computational Fluid Dynamics Laboratory is Professor Graham F. Carey, Richard B. Curran Centennial Chair in Engineering. Carey also is a Professor of Aerospace Engineering and Engineering Mechanics. A leader in the development of finite element methods for fluid dynamics, Carey has developed one of the most active research groups in TICAM.

- **Center for Numerical Analysis (CNA).** Professor David Young, Professor Emeritus of Mathematics and holder of the Ashbel Smith Chair in Natural Sciences, was the Director of CNA. Although recently retired, Professor Young still maintains an active presence within TICAM and continues his renowned research in iterative methods for linear algebraic systems.

- **Center for Computational Finance (CCF).** Professor Patrick Jaillet, Head of the Department of Management Science and Information Systems and B.M. (Mack) Rankin, Jr. Professor in Business, is the Director for the Center for Computational Finance. It is a remarkable fact that many of the models of modern finance, in particular those for option pricing, share similarities with
much of the models of computational mechanics. This is an exciting new program, and has attracted the interest of many of the CAM graduate students.

- **Applied and Computational Mathematics.** CAM Chair I is held by Professor Jerry Bona who holds joint appointments in the Departments of Mathematics and Physics. Bona is an internationally renowned authority on nonlinear wave phenomena and he has worked extensively in the mathematical foundations of this subject as well as on computational algorithms for these classes of problems.

A number of other distinguished mathematicians are associated with TICAM. These include Professor Luis Caffarelli, Sid Richardson Chair of Mathematics and an active member of the CAM faculty, and Professor Irene Gamba, Professor of Mathematics, who specializes in the theory and numerical analysis of problems in kinetic theory of gases and compressible flow problems. More recently, Professor Jack Xin has been added to this group. Professor Takis Souganidis is a recent addition to the faculty together with Professor Thaleia Zariphopoulou, who works in stochastic control theory and has a key role in the work at TICAM's Center for Computational Finance.

- **Computational Mechanics.** Professor Ivo Babuska, Robert Trull Chair of Engineering, is Senior Research Scientist at the Institute and is Professor of Aerospace Engineering and Engineering Mechanics. A world leader in the mathematical foundations of finite element methods and in their application to key engineering problems, Babuska directs a large number of research projects, and conducts a regular seminar with CAM students called the Forum.

- **Computational Biology.** A new group in mathematical and computational biology is being formed, which currently consists of Professor David Hillis, Director of the Program in Biological Sciences, Professor Tandy Warnow, Computer Sciences, and Professor Robin Gutell, Molecular Biology.

In addition, a number of other faculty from the participating departments are actively involved in TICAM projects. These include, in particular, Professor J.C. Browne, Computer Sciences, Professor Gregory Rodin, Department of Aerospace Engineering and Engineering Mechanics, Professor Robert van de Geijn, Computer Sciences, Professor William Beckner, Mathematics, Professor John Kallinderis, Aerospace Engineering and Engineering Mechanics, Professor Ralph Showalter, Mathematics, Professor Indirjit Dhillon, Computer Sciences, and several others. Professor Mike Marder, Physics, and Professor Alan Cline, Computer Sciences, devote significant time to management of the CAM program.

The idea that the resolution of the major open problems in the computational sciences requires an interdisciplinary effort, involving collaboration from individuals with different but complementary backgrounds and expertise is the cornerstone of TICAM. Such interdisciplinary research can be successful if three basic ingredients exists: 1) a willingness of the participants to devote their time and energy to participate in interdisciplinary seminars and research, 2) students, who are the "glue" that binds interdisciplinary programs,
and 3) the Institute, which provides the infrastructure to facilitate interdisciplinary research.

**IV. The Academic Program: CAM**

A rather unique academic program, leading to the Master of Science and Ph.D. degrees in Computational and Applied Mathematics, has been developed which essentially resides between the Colleges of Natural Sciences, Engineering, and Business, reporting not to the Deans of these colleges, but rather to the Dean of the Graduate School. Thus the CAM Program is independent of Engineering, Natural Sciences, and Business and has developed its own requirements for degrees in CAM.

From its inception, the CAM Academic Program was never designed to be a very large program, accepting only the best students from science, mathematics, engineering. Today, it has the highest entrance scores of any academic department in The University of Texas. CAM students come from diverse backgrounds: engineering, mathematics, physics, computer sciences, and recently biology and finance.

CAM students are expected to "demonstrate a graduate level of proficiency" in three fundamental academic areas:

- **Area A, Applicable Mathematics.** Area A encompasses coursework and examinations in the mathematical foundations of the computational sciences. At present, this primarily involves mathematical physics, functional analysis and partial differential equations. All students are required to take a body of coursework in these areas and to pass a written qualifying exam in Area A before proceeding to dissertation work.

- **Area B, Numerical Analysis and Scientific Computation.** In Area B, students are expected to take a body of coursework in numerical analysis and scientific computation, generally including scientific programming and parallel computation. As in Area A, students must also pass qualifying examinations in Area B.

- **Area C, Mathematical Modeling and Applications.** With the assistance of a CAM/TICAM faculty member, all students are expected to develop and propose an Area C concentration of course work in a viable and relevant area of mathematical modeling and applications. These include such topics as computational fluid mechanics, solid mechanics, electromagnetics, solid state physics, kinetic theory of gases, control and estimation theory, mechanics and physics of porous media, etc. The students, with the help of the CAM faculty member, are expected to propose an Area C concentration which generally consists of a number of courses in a well-defined discipline; the list of courses may span several departments. For example, an Area C concentration in Electromagnetic Field Theory may involve collections of graduate and undergraduate courses from electrical engineering, physics and possibly mathematics. The number of courses, their depth and sophistication, in general,
depend on the background and interest of the individual student. A qualifying examination is also administered in Area C.

Upon completion of qualifying examinations in Area A, B, and C, the student is expected to write a dissertation proposal for research that includes components of all three areas. The degree is awarded upon completion of the dissertation and satisfactorily defending it in a final examination.

The CAM Program is administered by a committee of nine faculty drawn from participating academic departments, with interests representing the three areas, Areas A, B, and C. This committee, called the CAM Graduate Studies Subcommittee, meets regularly, monitors the progress of each CAM student, manages and cultivates the various coursework requirements and exams, and handles the important issue of admission to the Program. Unlike some academic programs, in CAM the GSSC monitors the work and progress of every student. Every CAM student is expected to make steady progress toward the completion of the degree.

All CAM students are supported by fellowships, research assistantships, or teaching assistantships. All CAM students are supplied an office area, a workstation or computing terminal, and access to the Institute’s high performance computing facilities.

The CAM Fellowships. The CAM Graduate Studies Committee also administers the CAM Fellowship Program. These are fellowships supported by a large endowment. These generous fellowships provide a substantial stipend, benefits, and tuition for outstanding graduate students. Approximately three CAM Fellowships are awarded per year.

V. The TICAM Visitor’s Program: TICAM Faculty Fellowships.

A centerpiece of TICAM is the TICAM Fellowship Program, also supported by a large endowment donated by a private foundation. The program supports visits by leading international researchers who collaborate with TICAM Faculty on on-going research. Recipients of a visiting fellowship must be hosted and supported by an active member of a TICAM program. TICAM Fellowships are designed to support visits from two weeks up to one year, and these fellowships have been responsible for bringing to the Institute many of the world’s leading researchers in the computational sciences and engineering. Around 250 leading computational scientists have participated in the visitors’ program since its inception. Among visitors, I mention Professor Olek Zienkiewicz, first President of the IACM. A large number of visitors from western Europe, eastern Europe, Asia and South America, Australia, and China have participated in the program.

Visitors are provided a desk at the Institute and access to TICAM and University facilities. Ordinarily, visitors participate in one of the TICAM seminar series and many also produce records of their research work at TICAM in the form of TICAM Reports. Incidentally, the TICAM Reports series is a popular collection of scientific reports summarizing research results at the
Institute. Around 35 of these reports are developed each year and many of them are co-authored by TICAM Visiting Fellows and TICAM Faculty.

This is what TICAM is now. Below I record what is new at TICAM.

VI. What's new at TICAM #1. ACES Building.

I am very pleased to report that through generous donations of the O'Donnell Foundation of Dallas, Texas, and The University, a new building has been constructed which will house the principal laboratories, faculty, and research units in broad areas of computational science and engineering within The University. Dedicated to Applied Computational Engineering and Science, the structure is called the ACES Building. Centrally located on the UT campus, adjacent to the Department of Computer Sciences, Department of Chemistry, Aerospace Engineering and Engineering Mechanics, and the Experimental Sciences Building, it is in the proximity of the Department of Mathematics, Physics and Astronomy, and the College of Business and the Department of Geology. This 176,000 sq. ft. structure, a five-story building, contains state-of-the-art research facilities for basic research in computer and computational science and engineering. In addition to the TICAM centers mentioned earlier, the building includes complementary centers and research groups from the Department of Computer Sciences and the Department of Electrical and Computer Engineering. These include the Center for Computer Architecture, the Center for Software Engineering, and research groups in parallel and distributed computation, visualization and graphics, and intelligent systems and robotics.

The building features modern facilities for visualization, videoconferencing, distance learning, and related technologies. The ACES Building is not a classroom building; rather it is a facility devoted to graduate study and fundamental research in computer and computational sciences and engineering. It is to house all of the TICAM facilities and centers and provide a home also for visitors hosted by the TICAM Visiting Fellows' Program.

Fig. 3 The ACES Building, the new home of TICAM
VII. What's New at TICAM #2. The TICAM Visualization Laboratory.

This is a state-of-the-art visualization laboratory and arena, housed in the ACES Building, that will provide a modern facility for computer visualization. The TICAM Visualization Laboratory will feature a unique visualization laboratory which contains a cylindrical screen for seamless visualization, plus arrays of screens and projectors that will facilitate research and in interactive and collaborative visualization. It will also provide a resource for the incorporation of modern visualization tools into a variety of TICAM projects. Initially, the computer power for the visualization center will be provided by a 24-processor SGI Onyx Graphics Engine as well as a 128-processor graphics cluster. The entire facility is viewed as an extraordinary addition to the existing TICAM infrastructure.

VIII. What's New at TICAM #3. New People, New Horizons

- Plans and proposals are under consideration that would expand the scope of TICAM and the TICAM Program even further to include other disciplines and research units that are expected to be housed in the ACES Building. This may in result in an expansion of the scope and mission of the Institute to a much broader realm, including units of computer science and engineering that support and enrich the computational sciences in computational engineering. This new incarnation of the Institute may well be devoted to not only the computational and computer sciences, but also to broader disciplines in what is now called Information Technology.

- New faculty are also expected to be either recruited or to find a home in the new facility. Professor James Bramble, internationally recognized authority in numerical analysis, particularly for fundamental contributions to finite element methods, domain decomposition methods, eigenvalue problems, and other areas, has recently moved to Austin and will occupy and office in the new ACES building. Plans are to develop a number of new positions in computational science, engineering, and in mathematics that will be bring leading researchers and academicians under the umbrella of TICAM.

Epilogue.

Upon reflecting on what appears to be a relatively rapid development of this unique academic program, I am reminded of a number of questions that are normally raised by those who first are confronted with the unconventional ideas on which the program is based. First, a typical question is: where does a student who graduates from such an interdisciplinary program find employment? I am always tempted to give up a rather flippant answer: anywhere they want! The fact is, the graduates of the CAM Program are highly sought after by academia, industry, and government laboratories. Our experience has been that graduates of the CAM Program typically get offers from many organizations, and finally assume a position related to their own special interests. The first graduate of the CAM Program, for example, received five offers for employment, all in academia: one in a department of applied mathematics, two in computer
sciences, and two in academic departments in engineering that were developing programs in computational engineering. The individual, who had an engineering background, ultimately chose an academic career in an engineering department and is now pursuing research in computational mechanics. By all indications, CAM graduates are highly valued by diverse segments of academia, industry, and government and generally are directed in one way or another by their dissertation, their advisor, their earlier training in mathematics, computer sciences, engineering, the natural sciences or business.

Another common question is one I have already answered: how can truly interdisciplinary research in education be accomplished in view of natural biases imparted to students and faculty by the traditional academic disciplines and departments? The answer is that this is a delicate thing, and can be accomplished only with the cooperation and hard work of the individual scientists involved in the programs. As noted earlier, the “glue” that makes such interdisciplinary work possible is the students themselves. These students take coursework and find themselves competing and interacting with other students with different backgrounds: engineers must learn some mathematics, mathematicians must learn some engineering, engineers, computer scientists, and mathematicians must learn some science such as physics, biology, chemistry, or they must learn to apply the principles of mathematics and science to other areas, such as finance. These students find themselves taking classes together, working on common projects, interacting in their usual class and work environments as students within the Institute. This can be a powerful educational and intellectual experience. It produces a new and special class of academician, equipped with modern mathematics, a significant knowledge of modern computer science, and an understanding of how these disciplines may impact on important areas of mathematical modeling and simulation.

I believe that the approaches adopted in the development of these new programs also represent a new vision of the field of computational mechanics and that this new vision is where the future of much of science and engineering will reside. CAM students have an opportunity to immerse themselves in a new learning environment which may very well displace traditional routes to the computational sciences.

Finally, I look back in time and remember that the development of TICOM, the Texas Institute for Computational Mechanics, was progenitor of TICAM: an Institute, a club, a fraternity, developed nearly 30 years ago by myself and a few individuals who held with great passion the view that modern computational methods and devices would forever change the way that mechanics is done and conceived by all future generations (see Fig. 4). Now I see that these same ideas and principles transcend the traditional mechanics and spill over into dramatically broad areas of science and mathematics that for historical reasons were once the province of physics, chemistry, biology, and other areas. To me, “mechanics is mechanics,” a discipline concerned with the effects of the action of forces on bodies, and this includes all the disciplines somewhat artificially claimed by many other areas of science in the past. Our computational and mathematical tools, therefore, apply to these problems as well. Therefore, these
disciplines are fair game for the broad collection of tools, concepts, and devices that are under the realm of Computational Mechanics.

Fig. 4. TICOM circa 1975; left-to-right, seated: Roger Broucke, Randy Bank, Noboru Kikuchi, Tinsley Oden, Linda Hayes, Eric Becker, Pol Spanos; standing, Morris Stern, Graham Carey, Roy Craig, David Hibbitt, Jose Roesset, Phil Johnson

I view this idea as a challenge for IACM: broaden the definition of mechanics. Include in the circle of ideas and the circle of people working in computational mechanics all of those who seek to develop computational approaches to simulate and study broad classes of phenomena that involve the action of forces on bodies and interpret this mission in the broadest sense. The subject, I believe, will not advance to its potential heights unless we approach these problems in a broad interdisciplinary context.