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editorial

Personal Recollections of Days Past

In the autumn of 1999 a wonderful conference was held at the Technical University of Munich. This was the first European Conference on Computational Mechanics (ECCM), co-sponsored by IACM and ECCOMAS. The conference chairman was Professor Walter Wunderlich, and the timing of the conference marked his retirement from the TUM. One of the most interesting events at the conference was the bringing together of three of the founding fathers of the finite element method: John Argyris, Ray Clough and Olek Zienkiewicz. They each provided a retrospective on the origins of the finite element method and highlighted their own contributions. It was an historical and moving experience.

When I began working in the field over 30 years ago, Argyris, Clough and Zienkiewicz were already household names. The events in Munich caused me to think back to my first encounters with each of them.

As a young research engineer at General Dynamics Electric Boat Division in the late 1960's, I was developing methods for dynamic analysis and performing comparative studies of consistent and lumped mass formulations. To my surprise at the time, the lumped procedure was producing somewhat better results than the consistent approach. Concerned that I might have done something wrong, I decided to attempt to obtain the opinion of an eminent authority - Ray Clough. I had heard that he had performed similar investigations but I had not been able to find anything in the literature. I wrote Ray a letter describing my results and inquired about his. I vividly recall thinking after I sent the letter that he was probably too busy and too important a man to respond to my inquiry. Shortly thereafter I received a long and thoughtful reply describing his experiences, which were consistent with mine. I was thrilled and showed the letter to all my colleagues! A few years later I met Ray for the first time in Berkeley and was shocked to find out that he felt his work in finite elements was done and that he intended to pursue earthquake engineering thereafter.

The first time I ever saw Olek Zienkiewicz was at MIT where he presented a seminar in the late 1960's. He attracted a huge audience and was very impressive. His introductory transparency depicted a "finite element man" made of triangles. It got a big laugh. My first personal contact with Olek was a letter from him to me. One of the universities that I applied to for the PhD was Swansea. Olek sent me a handwritten offer of a research assistantship. My most vivid recollection of the letter was Olek's statement that I could complete the PhD in two years. Actually, I wanted to spend a lot more time studying so this did not fit my plans. The first time I met Olek face-to-face was when he visited Berkeley. He took Bob Taylor and me to a French restaurant where he stated emphatically that he wanted no sauce on his steak.

John Argyris had been active in the development of matrix methods of structural analysis and finite elements from the very beginning. When I first began studying the subject I read many of his papers. Despite these early contacts with his work, I never met him until the first FENOMECH conference at the University of Stuttgart in 1978. Before the conference began, I ran into him walking on the campus with some young colleagues from his institute. After introductions, he proceeded to make joke after joke. Everybody was laughing. I was surprised that he was so funny. However, as the conference proceeded he appeared to become more and more tense. I recall the conference banquet seemed to go on forever with numerous talks and endless entertainment. It was a big event and at the time was viewed as something of a retirement party for John. As most everyone in the field knows, that retirement did not occur.

The history of computational mechanics and the personalities of the pioneers are fascinating topics. The United States Association of Computational Mechanics (USACM) has held sessions devoted to the history of the subject at its meetings. It is important that there are more events like these, and the one at the first ECCM conference, so that the story of our field is not forgotten and continues to inspire.

Tom Hughes
IACM President

Does Engineering need Science?

by
Carlo Viggiani
Universitá degli Studi di
Napoli Federico II

Does engineering need science?

At first sight, the answer to this question is obviously : "yes". There have been, however, pre-scientific civilisations in which engineering has been practiced at the highest level (for instance, the ancient Egyptians built the great pyramids and regulated the floods of the river Nile). On the other hand, even in the present scientific age, quite a number of engineering operations are devoid of any scientific content. The answer to the title question might thus also be: "no".

Some clarification is needed. In order to contribute to such a clarification, first of all a definition of engineering and a definition of science is needed.

The former is relatively simple. According to the American Peoples Encyclopedia, engineering: "...applies scientific knowledge to the practical problems of creating, operating and maintaining structures, devices and services".

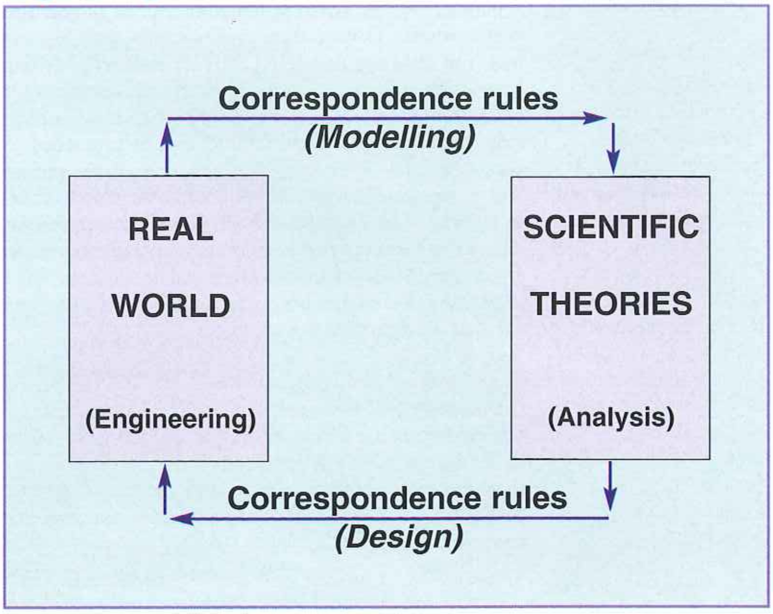
A definition of science is less simple. A crude encyclopedic conception of scientific knowledge credits the existence of a number of sciences deserving equal rank, each characterised by its own specific subject matter: chemistry, ornithology, mathematics, trichology and informatics. In this conception a possible field of knowledge and a name (possibly derived from ancient Greek) are enough to define a new "science", conceived as a container where all the truths concerning the selected field are saved. Sometimes only the name without a subject matter is enough, as in ufology which is supposed to be a science dealing with unidentified objects.

In fact, the simple idea that science is built up just adding a number of certainly true statements is untenable; otherwise a city telephone directory would be a scientific treatise. The French mathematician Poincaré said that "Science is built up with facts as a house is with stones. But a collection of facts is no more science than a heap of stones is a house".

An operational definition of science can be searched in the scientific method. A scientific theory, such as thermo-dynamics or Euclidean geometry, has three essential characters:

- it does not deal with real objects, but with abstract entities specific to each theory. For instance, Euclidean geometry deals with angles and segments; thermodynamics with temperature and entropy. Things such as angles and entropy do not exist in nature;
- the structure of the theory is rigorously deductive. It consists of a small number of fundamental statements (axioms, or principles, or postulates) involving the above entities, and a universally accepted method of deriving an endless number of consequences from them. All the problems that can be formulated within the frame work of a theory can thus be solved, by demonstration and calculus, and there is a general agreement on the solutions among the scientists. In this sense, the truth of the scientific statements is warranted;
- the application of the theory to the real world depends on "correspondence relationships" between the abstract entities of the theory and real objects.

Figure 1:
Engineering vs. Science



Unlike the statements which are internal to the theory, these correspondence relationships have no absolute validity; they have to be checked by experiments and, in any case, their validity is always limited.

For the purpose of the present discussion, we will define the whole of scientific theories as defined above as "exact science" .

The value of exact science is to provide models of the real world, within which a method exists to separate false statements from true ones. The models allow the interpretation and prediction of natural phenomena, by transferring them to a theoretical level by means of the correspondence rules, solving the problems by demonstration and calculus and transferring the solutions back to the real world.

A similar conception is expressed by the following quotation taken from a completely different source:

"Scientific understanding proceeds by way of constructing and analysing models of the segments or aspects of the reality under study. The purpose of these models is not to give a mirror image of reality, but rather to single out and make available for intensive investigation those elements which are decisive. We abstract from non-essentials, we blot out the unimportant to get an unobstructed view of the important, we magnify in order to improve the range and accuracy of our observation. A model is, and must be, unrealistic in the sense in which the word is most commonly used. Nevertheless and, in a sense, paradoxically if it is a good model it provides the key to understanding reality" (Baran, Sweezy, 1966).

SCIENCE AND ENGINEERING

Most branches of engineering, including civil, mechanical, mining, metallurgical and chemical engineering, stem from practical arts that go back to the beginning of civilised life. Others, such as electrical, electronic and nuclear engineering, are an outgrowth of fairly recent discoveries. In both cases the growth of engineering has been concurrent with, and has exercised a profound influence on, the rise of civilisation.

Civil engineering is generally considered the oldest branch. As early as 30 centuries b.C. an Egyptian master builder directed large constructions and huge irrigation projects. He was an advisor of the king and a noble of the court.

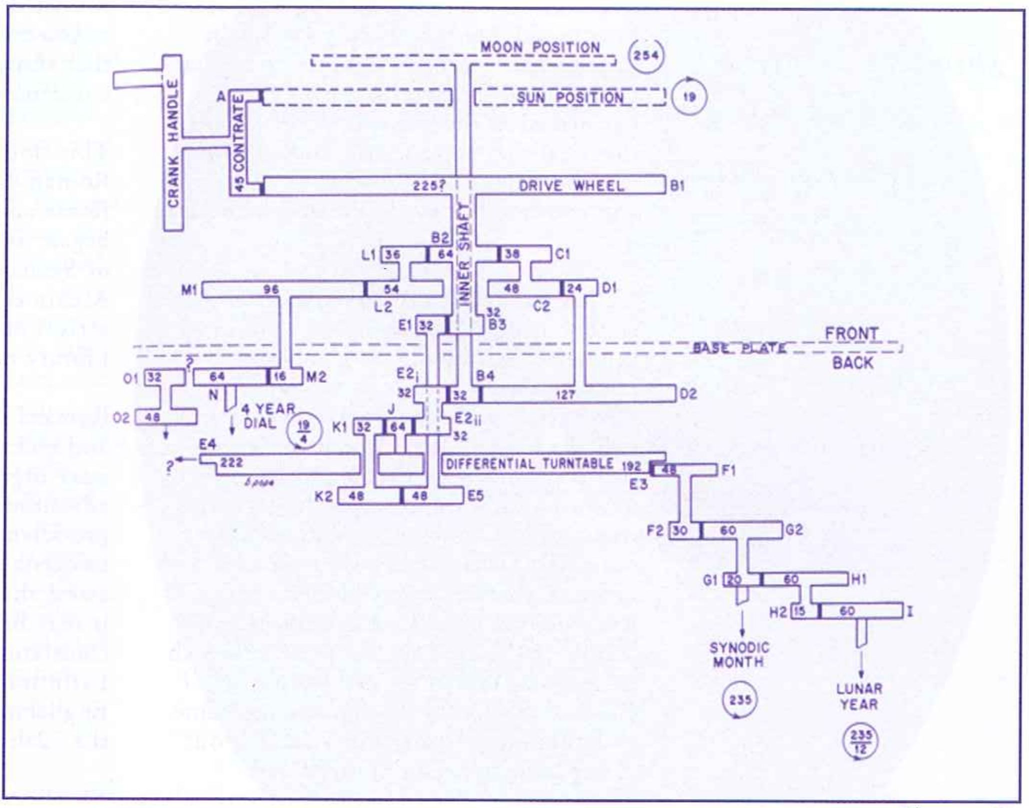


Figure 2:
The Antikythera Mechanism

He was the recipient of an empirical knowledge, accumulated in the previous centuries and limited to specific contexts (e.g., the water regime of the river Nile), not dissimilar from a religion or a myth; and he was not dissimilar from a priest, in the sense he managed something that was not clear to most of the people and probably to himself. He knew how to do things, but not why.

At the other extreme of the social pyramid, the common technician or builder was but a craftsman, at a very low social level, close to a slave. Science is completely out of this picture: myth, religion, priests, slaves are the opposite of science.

In those pre-scientific societies progress could not be but by chance or by trial and error, and thus it was very slow.

This situation prevailed along millennia, until the 3rd century b.C.

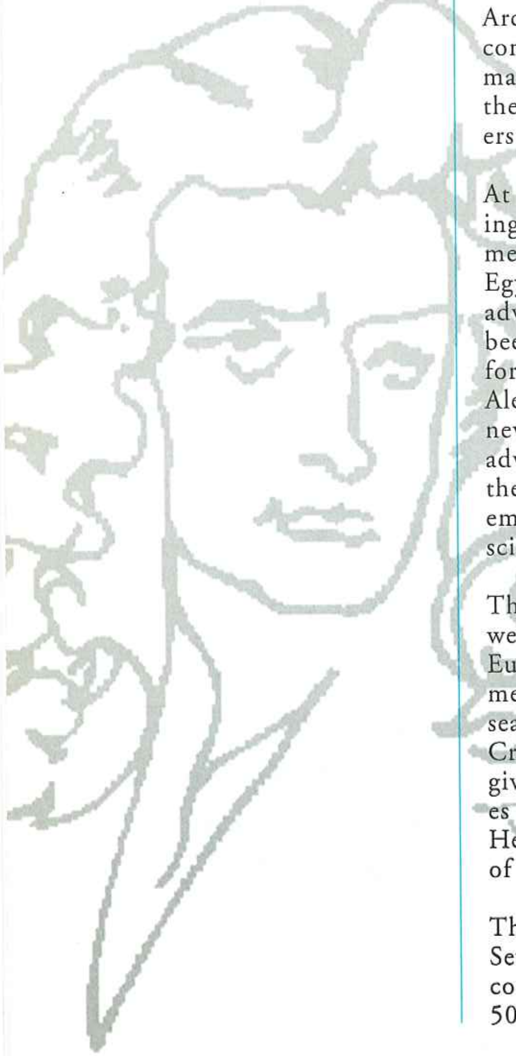
With the outgrowth of the scientific method as defined above, i.e. in the Hellenistic civilisation between the 3rd and the 2nd century b.C. (Russo, 1997),

" Science is built up with facts as a house is with stones. But a collection of facts is no more science than a heap of stones is a house "

it became soon apparent that science allows us to move freely within the theory, arriving at points which are not associated by the correspondence relationships, to anything existing. Therefore the theoretical model allows the construction of a not yet existing object, thus modifying the existing world. In fact, technology and engineering in that period were characterised by a design performed in the framework of scientific theories; they were tightly linked to the methodological structure of exact science and could not come into being without it.

> *" Apart from shouting 'Eurika', Archimedes of Syracuse gave substantial contributions to mechanics, hydrostatics and mathematics. "*

Hellenistic science included substantial contributions in mathematics, optics, geometry, astronomy, mechanics and hydrostatics. The "Elements of Geometry" by Euclid of Alexandria are still the base of our modern geometry; this book has been continuously studied over a period of more than 22 centuries. Aristarchus of Samos introduced helyocentrism in astronomy 18 centuries before Copernicus and Galileo. Eratosthenes of Cyrene determined the length of the meridian of the Earth with an error smaller than 1%. Erophylus of Chalcedony founded scientific medicine and anatomy. Apart from jumping out of the bath shouting "Eureka", Archimedes of Syracuse gave substantial contributions to mechanics, hydrostatics, mathematics. We still use his formula for the volume of a sphere. And many others could be quoted.



At the same time, Hellenistic engineering developed to unprecedented achievements. The ancient empires, such as Egypt and Mesopotamia, were more advanced than Greeks since they had been accumulating empirical knowledge for millennia. With the conquest by Alexander the Great, Greeks went to the new kingdoms and had to manage this advanced reality with the only tool of their superior rationality. They treated empirical knowledge by means of the scientific method.

The Archimedean screw and the cog were invented by applying the results of Euclidean geometry. The Antikythera mechanism (Price 1974), found on the sea bottom between Peloponnisos and Crete, was a sort of perpetual calendar giving the past, present and future phases of the moon. The dioptre reported by Heronis of Alexandria is the forerunner of the modern theodolite.

The lighthouse of Alexandria, one of the Seven Wonders of the ancient world, could be seen from a distance of about 50 km. It was 95 m high, and the lantern and its reflector were designed by the principles of optics. The battleships built by Gero II of Syracuse, under the supervision of Archimedes, were 15 times larger than the previous results in the past times and lined with lead sheets; the discontinuity in naval engineering may be appreciated noting that ships of similar size were again constructed in only the XIX Century.

This flourishing was interrupted by the Roman conquest. The wars between Rome and the Hellenistic kingdoms began, symbolically, with the destruction of Syracuse and the killing of Archimedes in 212 b.C. Soon after the arrival of Caesar in Egypt, the Great Library of Alexandria was set to fire.

Romans were not interested in science and technology, but in political and military organisation. They assumed the advanced Greek technology, but in a pre-scientific way. In a few centuries, the understanding of science disappeared. To assess the interest of Romans in science, it may be remembered that the first translation of Euclid's Elements into Latin was due to Adelard of Bath: an Englishman translating from Arabic in the 12th Century.

The Roman Authors of the imperial age, such as Pliny or Seneca or Vitruvius, were fascinated by the Hellenistic scientific treatises. But they could not follow the scientific arguments, and therefore they just reported the conclusions, that looked to them as unexpected and wonderful.

A late Hellenistic compiler, as Pappus, had remarked that the bees solve an optimisation problem when they build the hexagonal cells of their honeycomb. Among the regular polygons that completely cover a surface, the hexagon is the one with the maximum ratio between the surface and the perimeter. Hence, it allows a minimum of wax walls for a given quantity of stored honey. Pliny the Elder, in his Naturalis Historia, says that the cells are hexagonal because the bees have six legs, and each leg has built a wall. Pliny quotes the measurement of the circumference of the Earth by Eratosthenes, and appreciates the result. Immediately after, he reports the story of Dionysodorus who descended from his tomb down to the centre of the Earth, counting the steps, and thus measuring the radius of the Earth in 42,000 stadia. Pliny comments that the two determinations are in rather good agreement!

Vitruvius, the greatest Roman civil engineer, in his treatise De Architectura, attempts a State of the Art not only of Architecture and Civil Engineering, but also of any kind of technology of his age. After describing the bubble level, Vitruvius blames Archimedes statement that the water surface is not plane but spherical, with the centre in the centre of the Earth. Vitruvius also claims that a good technician has to know literature, history, philosophy, medicine, music and jury, and also (last and least) geometry and mathematics and astronomy. The use of mathematics is that of computing the cost of a building; astronomy is deemed to be useful for distinguishing the cardinal points, and geometry to understand the plumb line and level. Time was ripe for the complete oblivion of science and technology at the fall of the Roman empire, after the barbarian invasions. The darkness of the Middle Ages prevailed over more than a millennium. A few of the achievements of Hellenistic science were saved by the Arabians. It was only in the 17th Century that the scientific method was re-discovered by men like Galileo and Newton; soon after, technology and engineering underwent a new impressive development.

AN EXAMPLE

An interesting example of the power of scientific theories may be found in the history of stress-strain relation of natural materials. As early as in 1690 Gottfried Wilhelm Leibniz introduced the nonlinearity of the stress-strain relation in a letter to Jacques Bernoulli. Leibniz stated that the experimental data which Bernoulli had sent to him in December 1687 from a tensile test on a gut string 3 feet long seemed to fit a hyperbolic curve, in contrast to the experiments of others such as Hooke (1678) and Mariotte (1700), which had supported a linear law (Gerhardt, 1865).

It was left to the 19th century experimentalists to demonstrate that for every solid Hooke s law was only an approximation. Although by 1890 s there was much discussion as to the response function of the non-linear stress-strain law for different solids, including metals, there was ample experimental evidence that the non linearity of small deformations was a reproducible fact.

Dupin (1815), in the Ionian island of Corfu, performed a series of experiments on bending of wooden beams, and concluded that the central deflection was a parabolic function of the applied force.

Figure 3: Portrait of Isaac Newton

Von Gerstner (1831) conducted a series of stretch measurements on steel piano wires, and discovered that the stress-strain were fitted by a parabola.

Later on Hodgkinson (1843, 1844) observed non linear elasticity in wood, cast iron, soft rocks; in all these materials he observed permanent set and time effects.

Louis Joseph Vicat (1834) discovered, and described in detail, the long time aspects of the now widely studied phenomenon known as creep.

In 1849 the British Royal Commission which was appointed to inquire into the application of iron to railways structures recommended the engineering profession that henceforth Hooke s linear law of elasticity should be replaced by a parabolic law. The episode is very significant, not because the British engineering profession complied with the suggestion of the Iron Commission, which it obviously did not, but to note the interesting fact that a Royal Commission in 1849 felt it necessary to make such a factual proposal.

> *" If I have seen further it is by standing on the shoulders of giants. "*
>
> **Isaac Newton**

" But it would be totally misleading to assume that, as a consequence, there is an increasing average scientific qualification. "

On the contrary, other people felt the necessity of eliminating such defects of experimental data and conceived experiments to verify a more fashionable explanation. An example is the contribution to the French Academy by Arthur Jules Morin (1862). On the basis of a few crude tests on wires Morin confidently concluded that the famous Hooke s statement ut tensio sic vis was finally confirmed by observation, dismissing the extensive and accurate previous data by Hodgkinson and others. According to Bell (1973) Morin s experiments are an example not only of shoddy data and superficially drawn conclusions, but also of hasty and persistent acceptance of data and conclusions made respectable by their having appeared on the Comptes Rendues; they were referenced in the literature in the next 30 years.

But it was not a mere coincidence that subsequent generations ignored the recommendation of the British Royal Iron Commission which were based on sound experimental results, and adopted the point of view of Morin whose experiments were practically worthless. The availability of a scientific theory of linear elasticity, rather than attention to experimental details, however well defined, gave impetus to the assumption of linearity. The achievements of the linear elasticity theory are well known to all of us; modern engineering is still largely based on it.

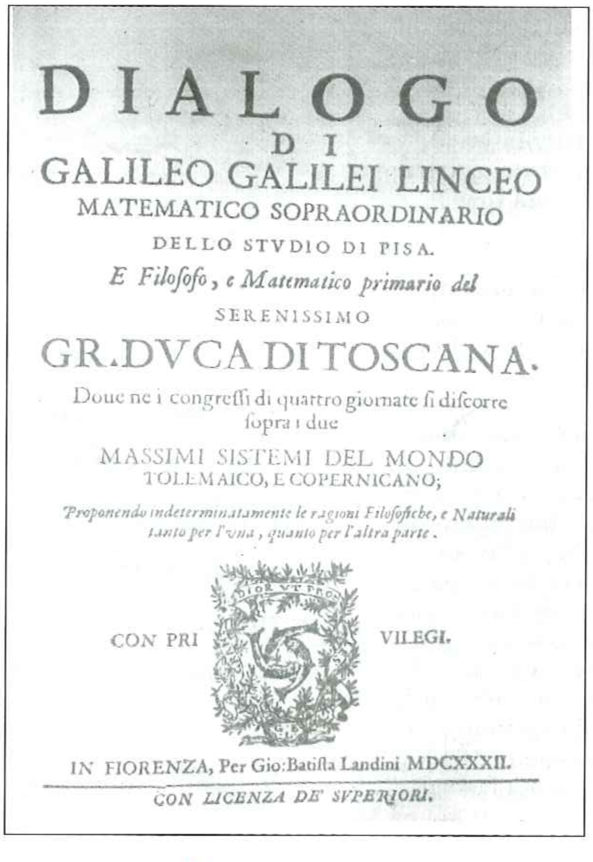


Figure 4:
The frontispiece of Galileo´s Dialogue

DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STVDIO DI PISA.
E Filoſofo, e Matematico primario del
SERENISSIMO
GR.DVCA DI TOSCANA.
Doue ne i congreſſi di quattro giornate ſi diſcorre
ſopra i due
MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;
Proponendo indeterminatamente le ragioni Filoſofiche, e Naturali
tanto per l'vna, quanto per l'altra parte.
CON PRI VILEGI.
IN FIORENZA, Per Gio:Batiſta Landini MDCXXXII.
CON LICENZA DE' SVPERIORI.

THE FORTHCOMING MIDDLE AGES

It is often heard that we live in a world of increasing complexity, requiring higher and higher scientific qualification. But it would be totally misleading to assume that, as a consequence, there is an increasing average scientific qualification.

Designing a computer certainly requires an amount of scientific knowledge much larger than that required to design an old thermionic valves wireless set. On the other hand, the principles on which the old wireless set works were clear not only to the technicians of the industry producing it and to plenty of radiomechanics, but also to quite a number of users. Many persons of my age have constructed amatorial wireless sets. On the contrary, the knowledge and qualifications required to design a computer are concentrated in few american and japanese companies. They are not represented even in the large majority of firms producing computers, which restrict themselves to a mere assemblage.

A computer may be studied: (i) at the level of the hardware; (ii) at the level of programming techniques and (iii) at the level of using commercial software developed by others. The so called diffusion of the computer culture consists essentially of an enormous increase of the people at the third level: the consumers. In the case of the aeronautic industry, the corresponding levels are: (i) the designer of the aircraft; (ii) the pilot and (iii) the passengers: again, the consumers.

A significant number of scientists or high level engineers is no more required; the school is asked to prepare consumers, not scientists. The culture that is diffusing is the culture of user manuals. The culture of the how, not of the why.

To become evolved consumers, the students are given a physical education, a road education, a sanitary and alimentary and sexual education, a civic and physical education, but not a scientific one. It is not by chance that the so called scientific Conferences and Symposia are more and more transforming into social events, promoting essentially trade and tourism.

It is often heard that we live in a world of increasing complexity. But the message that is actually being transmitted is that the reality is too complex to be understood by the human mind. Once again, today the science is felt as a mysterious matter that can be understood and managed by few initiated; the scientists are again considered similar to priests, and the science as a myth or a religion.

While the thin wire connecting us to the ancient culture is on the verge of being definitely broken, the irrationalism is triumphant. Wizards and astrologers have conquered not only the public, but also unbelievable positions, such as a chair of Astrology at La Sorbonne.

In European secondary schools the ancient deductive and demonstrative method is disappearing, together with Euclidean geometry and Latin syntax, which were its support. In American schools, it disappeared many years ago (Hirsch, 1996). As it happened in Rome in the imperial age, theoretical concepts are uprooted from the theories within which they have a meaning and are treated as real objects known only to the initiated. They are used as strange wonders to astonish the public. The students do not know the basis of helyocentrism or atomic theory and accept them by the principle of authority, in the same way they accept quarks, black holes, Big Bangs etc. The evolutionism, which is simple to understand and is supported by simple observations, is more and more opposed by the creationist biologists. Darwin is being expelled from an increasing number of schools in the United States.

The end of Hellenistic science is symbolically put in 415 A.D., when Ipazia, daughter of the famous mathematician Teonis of Alexandria and a mathematician herself, was lynched by a multitude of fanatics for religious reasons. Today the newspapers report that antiscientific secret societies, claiming the necessity of killing all the scientists to save the world, are appearing in the United States.

It is very doubtful that the scientific method, uprooted from the culture that had generated it, can survive in the third millennium. Modern technology may accelerate these processes, but not survive to their accomplishment. Similarly, modern engineering will not survive a generalised disappearance of the scientific culture. A deterioration of civil engineering practice is already visible in the last decades. The simple and dangerous idea that the progress will automatically go on has proven false at least once in the previous history, with the consequence of over a millennium of darkness.

Not only engineering, but the human being needs science, and the use of science in engineering is possible only in the framework of a widespread scientific culture. It is to us, trained in mechanics, to contribute to the spreading of the scientific culture in the academy, in the school, in the profession. ●

Figure 2:
Galileo Galilei Linceo

> "It is very doubtful that the scientific method ... can survive in the third millennium."

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What's New at TICAM?

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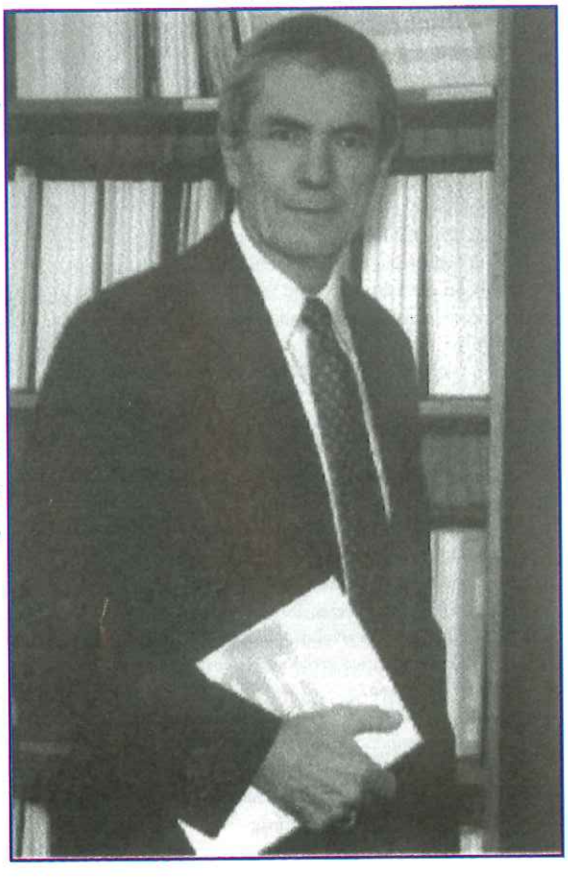
Introduction

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 centre with a mission of creating the infrastructure to facilitate basic research in computer modelling 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.

Figure 1: *Tinsley Oden*



> *"... an organised research centre with a mission of creating the infrastructure to facilitate basic research in computer modelling."*

The Institute

While TICAM faculty hold tenured positions in the participating departments, they also participate in research clusters or research centres. 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 Centres are standing organized research units dedicated to research in focused areas of computational sciences.

TICAM thus is an umbrella for various research centres, 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 centre 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.

TICAM Centres and Chairs

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

☐ **Centre for Subsurface Modelling (CSM).**
The Director of this Centre 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, ground water flow, pollution remediation and control, and basic issues of modelling 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.

☐ **Centre for Computational Visualization (CCV).**
Professor Chandrajit Bajaj, Department of Computer Sciences, is Director for the Centre 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.

☐ **Centre 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.

☐ **Centre 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 Centre 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.

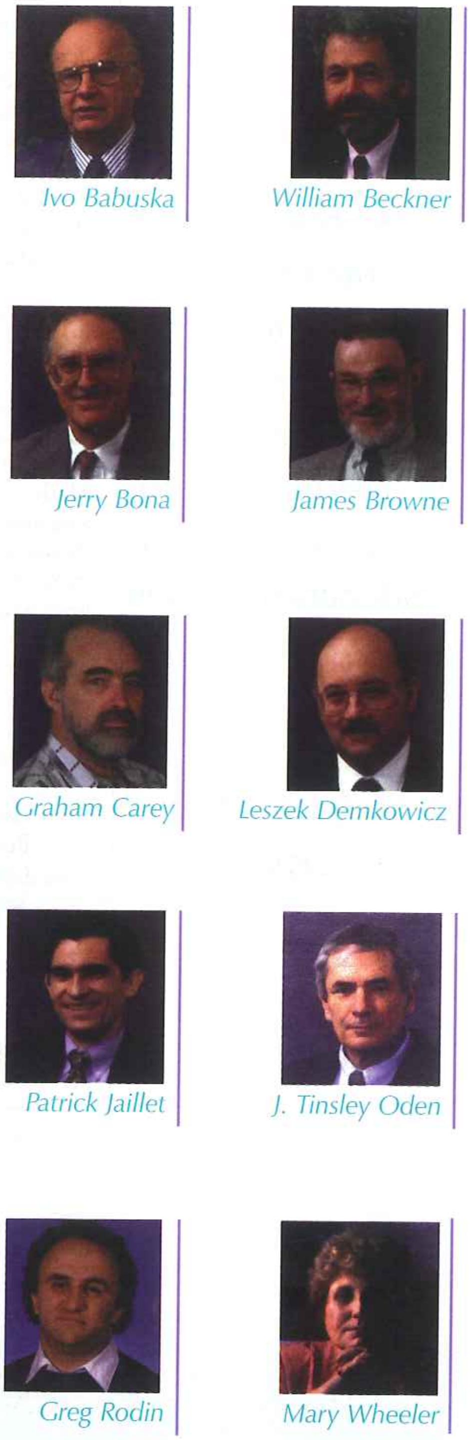

Ivo Babuska · *William Beckner* · *Jerry Bona* · *James Browne* · *Graham Carey* · *Leszek Demkowicz* · *Patrick Jaillet* · *J. Tinsley Oden* · *Greg Rodin* · *Mary Wheeler*

Figure 2:
The TICAM Advisory Board Plus Chandrajit Bajaj and David Young

> *"... 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 ..."*

- **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 prolems. More recently, Professor Jack Xin has been added to this group. Professor Takis Souganidis is a recent addition to the faculty together with Professor T. Zariphopoulou, who works in stochastic control theory and has a key role in the work at TICAM's Centre 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.

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 Modelling 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 modelling 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.

The TICAM Visitor's Program: TICAM Faculty Fellowships.

A centrepiece 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.

> *"Today, it has the highest entrance scores of any academic department in The University of Texas."*

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.

Figure 3:
The ACES Building, the new home of TICAM

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

" 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 any other areas of science in the past"

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 centres mentioned earlier, the building includes complementary centres and research groups from the Department of Computer Sciences and the Department of Electrical and Computer Engineering. These include the Centre for Computer Architecture, the Centre 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 centres and provide a home also for visitors hosted by the TICAM Visiting Fellows' Program.

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 centre 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.

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 modelling 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.

Figure 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

Therefore, these disciplines are fair game for the broad collection of tools, concepts, and devices that are under the realm of Computational Mechanics.

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 inter-disciplinary context. ●

Teaching in Applied Mechanics and CALFEM as a tool

by
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Matti Ristinmaa
Solid Mechanics
Lund University
& Karl-Gunnar Olsson
Building Design
Chalmers University of Technology

CALFEM stands for Computer Aided Learning of the Finite Element Method. The development of the programme began in the late 1970s, in FORTRAN. During the first half of the 1990s, the programme was rewritten as a toolbox for Matlab. However, the same syntax and logic in relation to the teaching of the finite element method and of applied mechanics was kept.

CALFEM can be used to solve heat-conduction problems and potential problems in general, and problems within the fields of structural mechanics and material mechanics. CALFEM contains all the elements of a FEM programme, and it is organised in such a way that the steps taken during a calculation logically emphasise the corresponding steps in the theoretical representation of the finite element method. The various subroutines, whether they are element routines, material routines or system routines, can be inspected by the student. The student can thus verify the computational representation of the finite element method.

In short, CALFEM is optimised to create the synthesis between mechanics and its phenomena, and the finite element method for the solution of complex
problems, with a taste of engineering reality in a teaching environment. In this respect, CALFEM is unique.

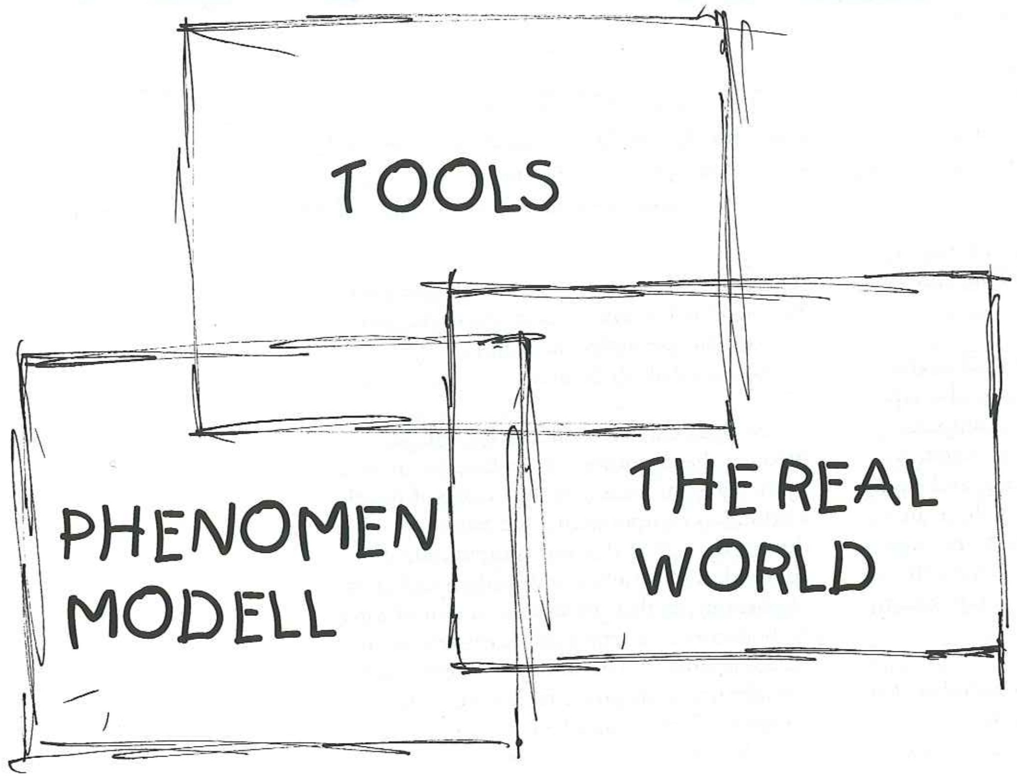
Introduction

Modern mechanics has a precise expression, as it uses mathematics as a working language. The understanding and the interpretation of described phenomena are formulated through mathematical relations and in diagrams. The precision of the descriptions and the complexity of the processes in use have increased, making it necessary to investigate phenomena, using the computer as a tool. Analytical expressions are no longer sufficient or not even accessible. So we reformulate, discretise, and develop a new language with new words and a new structure. Arguments and discussions concerning phenomena are now given in the integral expressions and matrix descriptions derived from the finite element method structure. They are in many ways more easily understood than the corresponding analytical expressions.

Mechanics is at the same time about phenomenon, which can be illustrated and handled in the physical world, and more important still: this is all about using the tools to solve problems that we can see in objects that are tangible. This is the strong point of mechanics: being close to things that can be built and examined.

An important question is how we encourage students to go on being curious enough to examine the phenomena, the patterns, go on being fascinated enough to learn the languages, the tools, and still enjoy building and experiment on tangible things.

Figure 1:
The interaction between the three basic aspects used in training.



In this article, we discuss precisely the interaction between the three basic aspects used in teaching: phenomena, tools and real world applications. The phenomena of mechanics, for example, are plasticity, natural resonance, and stability. Tools refer to computer programmes, computers and measuring devices. Applications are building models, real an d analytical, and first and foremost, connecting them.

How can we make these areas meet, so that the co-operation between them will be strengthened? So that the pleasure of understanding phenomena and learning the language springs out of the urge to do things? So that the grammar of the tools tells about the structure of the phenomena, or invites to experiment with simulations? So that the desire to change, improve, and develop is supported by the pleasure of understanding and of having a language for simulation?

It is with this background in mind we now continue with a discussion on mechanics, applied mechanics, computer use and computer programmes.

A Backswept Wing; from a course in Structural Mechanics

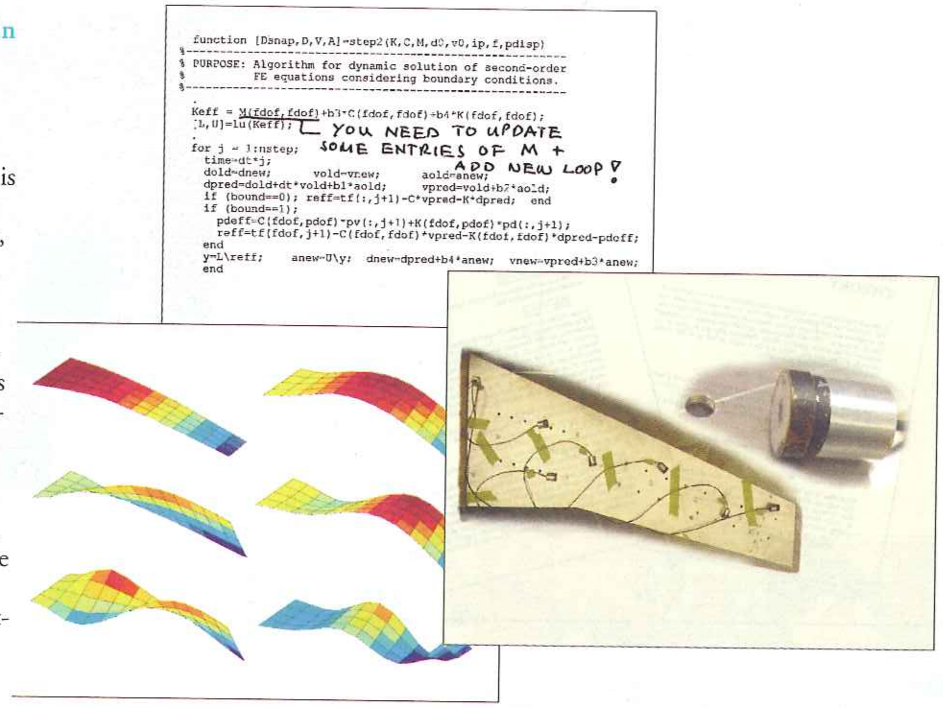
Let us introduce a simple example: a backswept wing (see figure 2). The wing, representing the physical world, is not quite one metre in length and furnished with several holes. In these holes, various objects can be fitted: two wing tanks and an engine, represented by different geometrical bodies. By fixing the wing in a rig, the wing can be excited, by which a number of different cases of load are simulated, for example vibrations generated from engine mountings or landing loads.

This is a problem put to the students in a course in structural dynamics. They are required to perform gauging on the object, analyse the behaviour by computer simulations, and suggest changes to attain certain preset aims, such as: Suggest measures halving the vibration level in the engine mounting. To the problems given exits several solutions. The work leading up to the solutions also have several different alternatives, such as: How do we model the additional masses representing the tanks? Changes can be confirmed by reality .

The physics this course is aiming at is the one described in any book on structural dynamics, for example Anil K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, in which modal analysis, multi-degree of freedom problems, transient analysis, etc., are treated. Specialist literature contains the phenomenological descriptions and their transformation into a mathematical language. At the same time, the phenomena treated in the course must be related to a reality of such a complexity that the students have to use computers and software to be able to solve real problems.

During the course of the work, several problems concerning phenomena as well as simulations occur. Only one problem will be mentioned here: How are we going to handle the situation that the wing tanks are emptied as the journey proceeds? It is easy to describe this reality in terms of structural dynamics the mass terms for a specific part of the mass matrix have to be changed but the fact that you can give different descriptions of the same phenomenon is what captivates you.

" So that the desire to change, improve and develop is supported by the pleasure of understanding and of having a language for simulation."



```
 function [Dsnap,D,V,A]=step2(K,C,M,d0,v0,ip,f,pdisp)
%--------------------------------------------------------------
% PURPOSE: Algorithm for dynamic solution of second-order
%          FE equations considering boundary conditions.
%--------------------------------------------------------------
 .
 Keff = M(fdof,fdof)+b3*C(fdof,fdof)+b4*K(fdof,fdof);
 [L,U]=lu(Keff);
 .
 for j = 1:nstep;
   time=dt*j;
   dold=dnew;        vold=vnew;        aold=anew;
   dpred=dold+dt*vold+b1*aold;         vpred=vold+b2*aold;
   if (bound==0); reff=tf(:,j+1)-C*vpred-K*dpred;  end
   if (bound==1);
     pdeff=C(fdof,pdof)*pv(:,j+1)+K(fdof,pdof)*pd(:,j+1);
     reff=tf(fdof,j+1)-C(fdof,fdof)*vpred-K(fdof,fdof)*dpred-pdeff;
   end
   y=L\reff;    anew=U\y;  dnew=dpred+b4*anew;  vnew=vpred+b3*anew;
   end
```

YOU NEED TO UPDATE SOME ENTRIES OF M + ADD NEW LOOP !

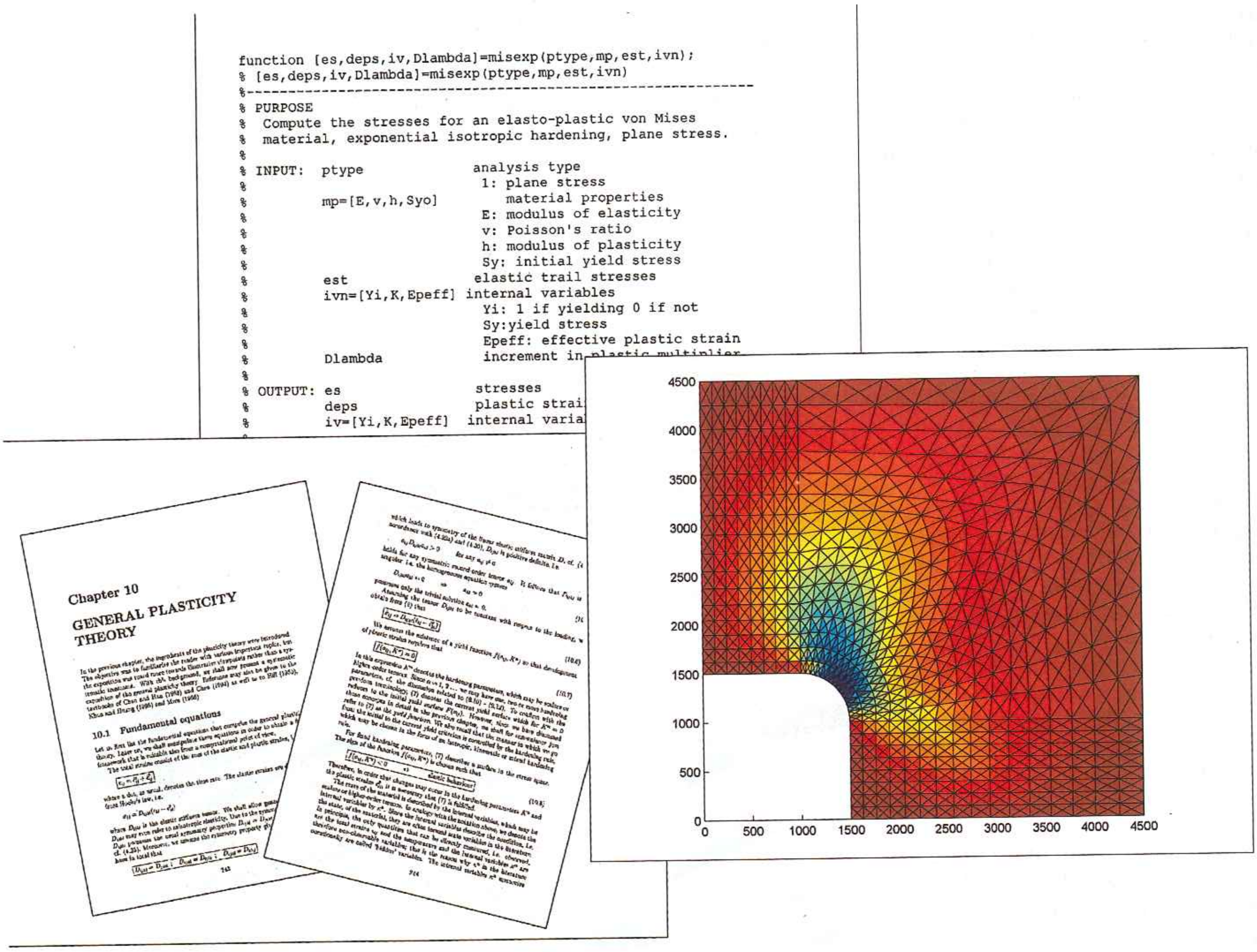
Figure 2:
A physical model of a backswept wing with mounted acceleration gauges.

The figure above also shows a segment of the time integration routine with notes from a discussion with a student about what has to be done. In this way, the programme also becomes part of what is tangible, of the experiment.

Figure 2 shows a physical model of a back-swept wing with mounted acceleration gauges, a close-up of single accelerometer is inserted in the picture. A segment of the routine for time integration of a second-order differential equation with notes to a student is shown at the top. Finally calculated eigenmodes for the wing is shown.

The application in form of the wing causes the commitment to understand the theory, the phenomena, to come naturally. CALFEM allows the student to gain access to, see and understand the finite element method and its strength in practical applications. And in this way these components strengthen each other and they all come together.

- ☐ The fuel in the tank diminishes
- ☐ The element matrix for mass in an element must be changed
- ☐ Update the mass matrix and add a loop.



```
function [es,deps,iv,Dlambda]=misexp(ptype,mp,est,ivn);
% [es,deps,iv,Dlambda]=misexp(ptype,mp,est,ivn)
%-------------------------------------------------------------------
% PURPOSE
%  Compute the stresses for an elasto-plastic von Mises
%  material, exponential isotropic hardening, plane stress.
%
% INPUT:  ptype                 analysis type
%                                1: plane stress
%         mp=[E,v,h,Syo]           material properties
%                                E: modulus of elasticity
%                                v: Poisson's ratio
%                                h: modulus of plasticity
%                                Sy: initial yield stress
%         est                   elastic trail stresses
%         ivn=[Yi,K,Epeff] internal variables
%                                Yi: 1 if yielding 0 if not
%                                Sy:yield stress
%                                Epeff: effective plastic strain
%         Dlambda                increment in
%
% OUTPUT: es                    stresses
%         deps                  plastic strai
%         iv=[Yi,K,Epeff]  internal varia
```

Chapter 10

GENERAL PLASTICITY THEORY

10.1 Fundamental equations

Figure 3:
From a course in material modelling

In CALFEM, the student can make a copy of the routine and make the necessary changes to solve the special cases his or her problem contains. The purpose of CALFEM is indeed to strengthen the connection between, in our case, mechanics, and the finite element method, and to solve problems from the physical world.

The three statements above are all as firmly expressed based on the three interacting areas in the figure above. When the teaching moves about between these areas, the software must not be too complicated. Sometimes, no doubt, less is more.

Some further examples

Above are some further illustrations of this idea of phenomena-tools-real world applications and how CALFEM is used in different courses, which take advantage of the fact that new ideas can easily be implemented and that existing routines can be enhanced. These examples are from courses in material modelling and frame and truss analysis, both of which are given as undergraduate courses. The final example is from a PhD course.

A typical hand-out (Figure 4 below)in the course dealing with material modelling consider the following tasks; a theoretical evaluation of the material (elasto-plastic) model, numerical implementation of the constitutive driver, writing of a non-linear finite element program used to solve a structural problem.

The students task is then understand the essence of the theory given in the textbook, and convert the theory into a numerical code, i.e. the constitutive driver shown in the figure, write a non-linear finite element program where the code is used.

The final exercise in the frame and truss analysis course is a project in designing a bridge. It is organized as a competition. The bases in passing the judgement are the aestitics, the ability to predict both behaviour and failure, and finally the strength/weight ratio.

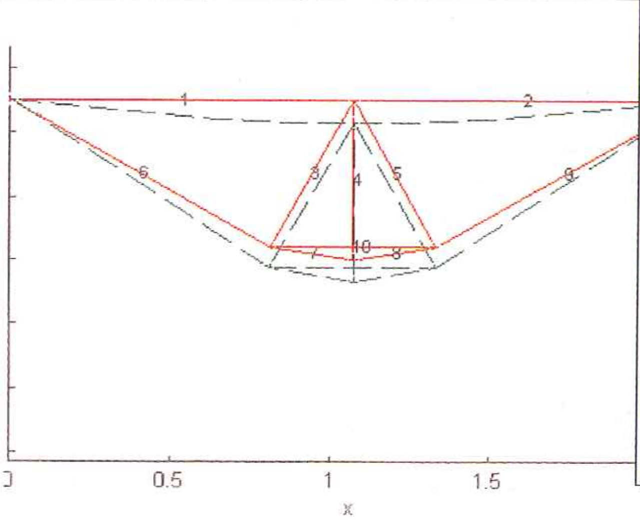
> *" Applications are building models, real and analytical, and the first and foremost, connecting them. How can we make these areas meet, so that the co-operation between then will be strengthened?"*

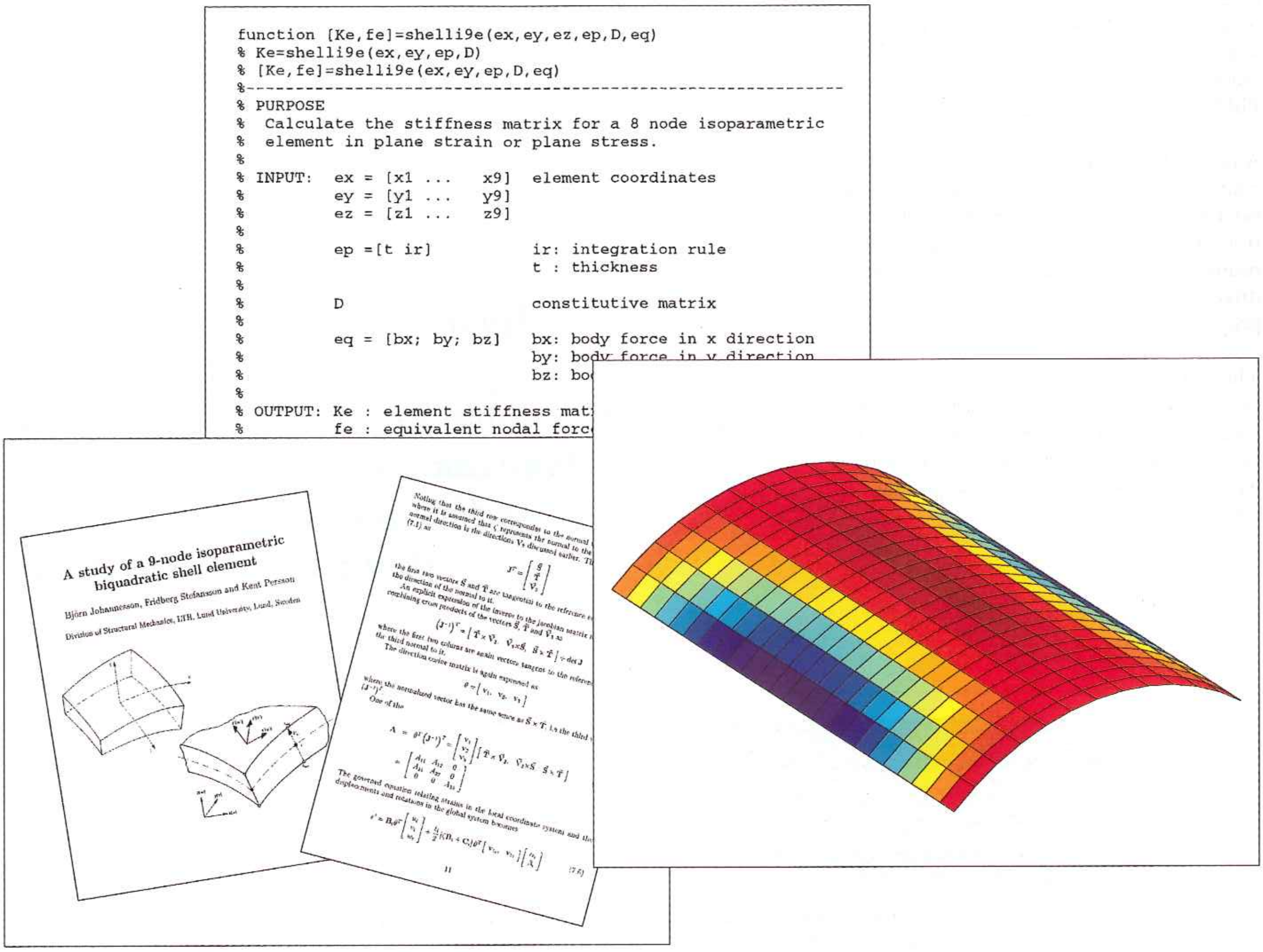
Figure 4:
From a course in frame and truss analysis

```
%----Boundary Conditions -----
bc=[2 0; 4 0; 8 0];

%----Displacement and reaction forces are calculated----
[a,Q]=solveq(K,f,bc);
a2=a;
%----Local displacements are calculated ----
for i=1:10
    if i<=2
        edBeam(i,:)=extract(Edof1(i,:),a);
   else
        edBar(i-2,:)=extract(Edof2(i-2,:),a);
    end
end

for i=1:2
    temp=beam2gs(ex(i,:),ey(i,:),ep1,edBeam(i,:),N(i));
    tempN(i)=temp(1,1);
    M=temp(2,3);
end
for i=3:5
```





```
function [Ke,fe]=shelli9e(ex,ey,ez,ep,D,eq)
% Ke=shelli9e(ex,ey,ep,D)
% [Ke,fe]=shelli9e(ex,ey,ep,D,eq)
%-------------------------------------------------------------
% PURPOSE
%  Calculate the stiffness matrix for a 8 node isoparametric
%  element in plane strain or plane stress.
%
% INPUT:  ex = [x1 ...   x9]  element coordinates
%         ey = [y1 ...   y9]
%         ez = [z1 ...   z9]
%
%         ep =[t ir]          ir: integration rule
%                             t : thickness
%
%         D                   constitutive matrix
%
%         eq = [bx; by; bz]   bx: body force in x direction
%                             by: body force in y direction
%                             bz: bo
%
% OUTPUT: Ke : element stiffness mat
%         fe : equivalent nodal forc
```

A study of a 9-node isoparametric
biquadratic shell element

Björn Johannesson, Fridberg Stefansson and Kent Persson

Division of Structural Mechanics, LTH, Lund University, Lund, Sweden

Figure 5:
From a PhD-course in shell theory

The exercise is from a PhD-course treating shell element. The students have evaluated, with regard element behaviour, different shell elements, published in various scientific articles. The work benefited from the CALFEM structure.

A simple example in heat conduction

Finally, to illustrate the handles of CALFEM, we give a simple example from the general course on the finite element method, the part that deals with potential problems. The example is about heat conduction in a concrete wall with thermal insulation.

The wall is subdivided into five elements and the one-dimensional spring (analogy) element springle is used. Equivalent spring stiffness is k_i = *lambda* A/L for thermal conductivity and k_i = A/m for thermal surface resistance can readily be calculated. A global stiffness matrix, K and a load vector f are defined. The element matrices Ke, are computed using springle and the function assem assembles the global stiffness matrix. The system of equations is solved using solve with considerations to the boundary conditions in bc. The prescribed temperatures are T_1=-17 C and T_6=20 C.

```
>> Edof=[1  1 2
         2  2 3;
         3  3 4;
         4  4 5;
         5  5 6];
>> K=zeros(6);
>> f=zeros  (6,1);
```

```
>> ep1=[ 1/0.07 ];                       ep2=[ 1.7/0.07 ];
>> ep3=[ 0.040/0.10 ];                   ep4=[ 1.7/0.10 ];
>> ep5=[ 1/0.18 ];

>> Ke1=spring1e(ep1);                        Ke2=spring1e(ep2);
>> Ke3=spring1e(ep3);                        Ke4=spring1e(ep4);
>> Ke5=spring1e(ep5);

>> K=assem(Edof(1,:),K,Ke1);                     K=assem(Edof(2,:),K,Ke2);
>> K=assem(Edof(3,:),K,Ke3);                     K=assem(Edof(4,:),K,Ke4);
>> K=assem(Edof(5,:),K,Ke5);

>> bc=[1 -17; 6 20];

>> T=solve(K,f,bc)

T =
   -17.0000
   -16.0912
   -15.5567
    16.8995
    17.6632
    20.0000
```

The temperature values in the node points are given in the vector T. After solving the system of equations the heat flow through the wall is computed using extract and springls.

```
>> ed1=extract(Edof(1,T);
>> ed2=extract(Edof(2,T);
>> ed3=extract(Edof(3,T);
>> ed4=extract(Edof(4,T);
>> ed5=extract(Edof(5,T);

>> q1=spring1s(ep1,ed1)
q1 =
    12.9825

>> q2=spring1s(ep2,ed2)
q2 =
    12.9825
...
>> q5=spring1s(ep5,ed5)
q5 =
    12.9825
```

The heat flow through the wall, equal for all elements, is q=13.0 W/m^2.

Further information

Further information can be searched for at the CALFEM homepage
http://www.byggmek.lth.se/Calfem/

E-mail correspondence to
calfem@byggmek.lth.se. ●

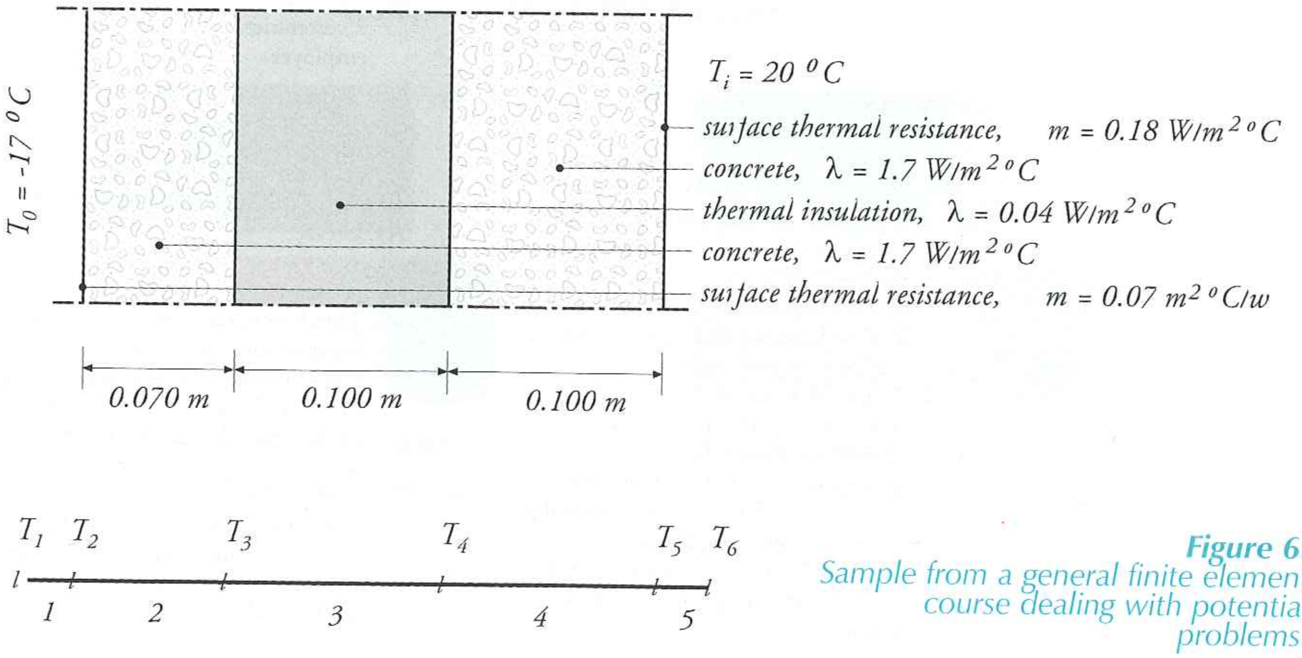


Figure 6:
Sample from a general finite element course dealing with potential problems.

Computational Modelling for the Steel Industry at CINI

by
Eduardo N. Dvorkin
Centre for Industrial Research
FUDETEC
Argentina

INTRODUCTION

The Fundación para el Desarrollo Tecnológico (FUDETEC) is a non-profit organization, established by the TECHINT group of companies in 1989. FUDETEC houses the Centre for Industrial Research (CINI), which is the R&D centre for the engineering and industrial companies of the TECHINT group.

Some of the steel industries controlled by the TECHINT group are:

COMPANY	COUNTRY	PRODUCTION
DALMINE	Italy	Seamless steel tubes
SIDERCA	Argentina	Seamless steel tubes
TAMSA	Mexico	Seamless steel tubes
SIDERAR	Argentina	Flat steel products
SIDOR	Venezuela	Flat steel products

Objectives

The CINI objectives are:

- ❍ To develop scientific applied research and technological research to support the engineering and steel companies of the TECHINT group in the fields of:
  - ✓ Development of new products.
  - ✓ Development and optimization of production processes.
- ❍ To establish a network with institutions performing basic scientific research, such as universities and national labs, in order to transfer scientific knowledge to technological applications.
- ❍ To provide graduate education and training for young engineers and scientists.

Organization

CINI is organized in four departments. These departments cover the different areas of technical expertise that constitute the kernel of the Centre research activities:

Department of Applied Physics
Department of Computational Mechanics
Department of Materials and Corrosion
Department of Mechanical Technology

The CINI staff includes 47 persons (as of December 1999):

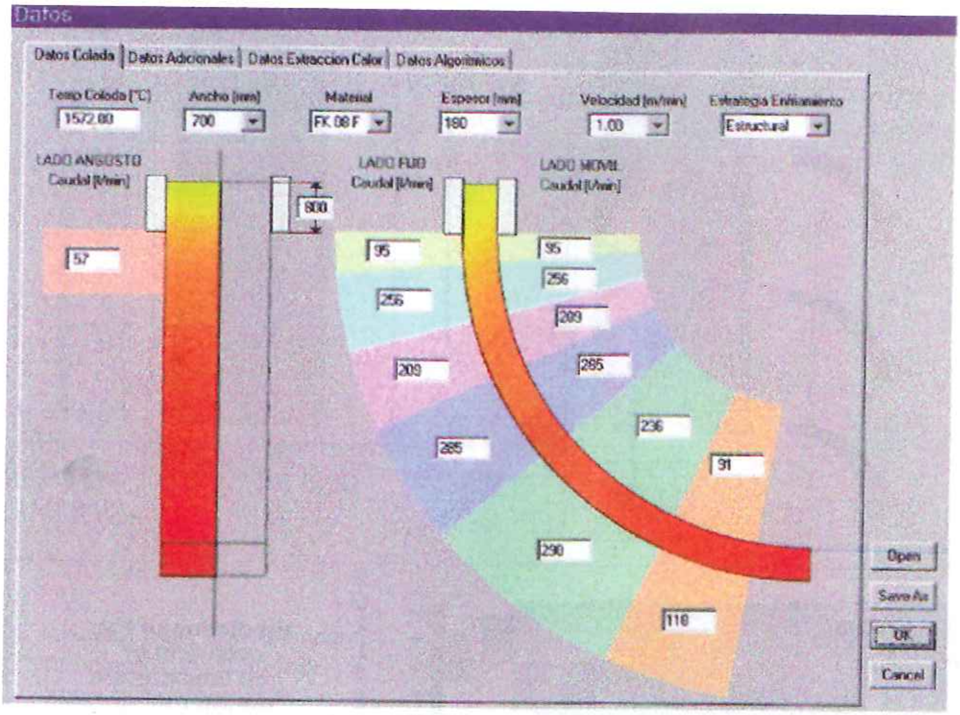
- ❍ 9 with doctoral degrees from different universities in Argentina and abroad
  University of Buenos Aires (Argentina),
  University of El Litoral (Argentina),
  University of Mar del Plata (Argentina),
  Balseiro Institute (Argentina),
  Massachusetts Institute of Technology (U.S.A.),
  Washington University (U.S.A.),
  University of Manchester Institute of Science and Technology (U.K.)
- ❍ 31 with university degrees in Engineering, Physics and Chemistry.
- ❍ 4 technicians.
- ❍ 2 secretaries and 1 administrative employee.

COMPUTATIONAL MECHANICS AT CINI

Objectives

- ✓ The development of finite element formulations and algorithms for modelling the different manufacturing processes involved in the production of flat and tubular steel products and for modelling the service performance of steel products.
- ✓ The analysis of technological problems using numerical simulation methods with specific applications or the steel industry.

⇨ **Simulation of continuous casting facilities**



Temp Colada [°C]: 1572.00
Ancho [mm]: 700
Material: FK 08 F
Espesor [mm]: 180
Velocidad [m/min]: 1.00
Estrategia Enfriamiento: Estructural

Figure 1: *Finite element code CCAST developed at CINI to simulate the solidification of slabs at the continuous casting installation of SIDERAR*

> *"... establish a network with institutions performing basic scientific research, such as universities and national labs, in order to transfer scientific knowledge to technological applications."*

⇨ **Development of the finite element code METFOR for modelling metal forming processes** (flow formulation and elasto-plastic large strains formulation)

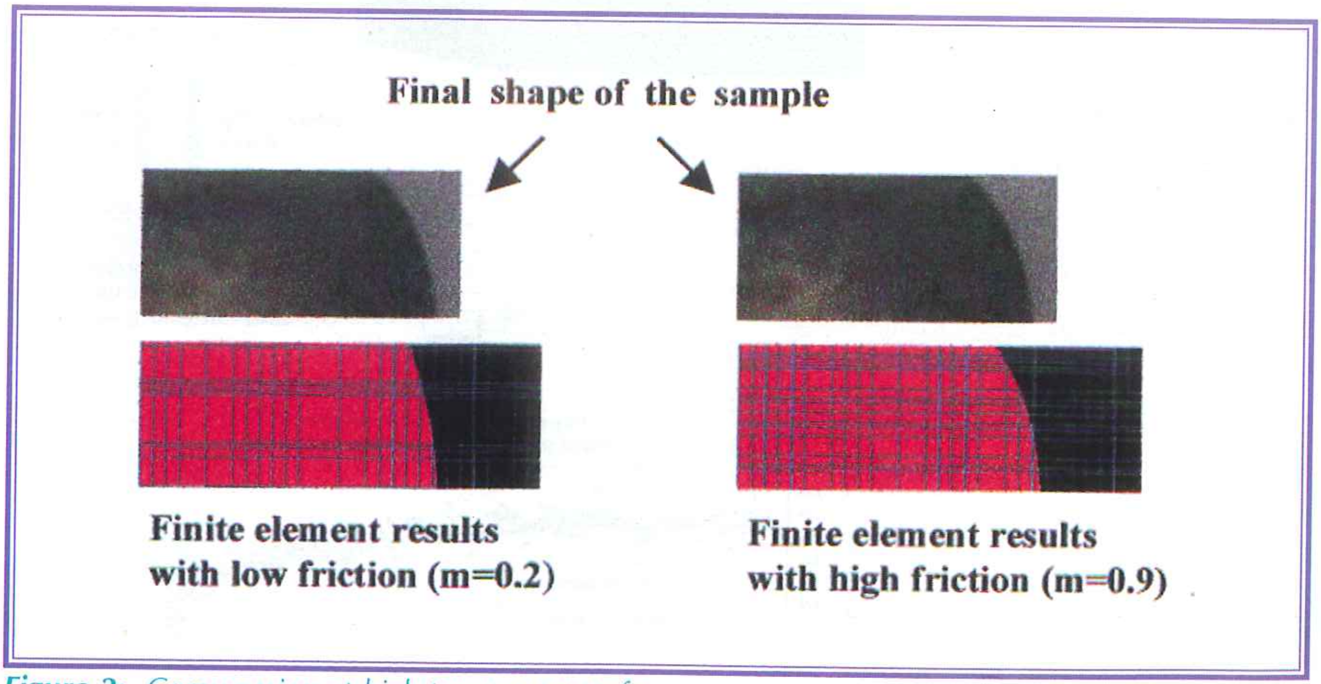


Figure 2: *Compression at high temperature of a cylindrical sample in a Gleeble machine*

- Simulation of different metal forming processes (hot rolling of flat and tubular steel products, cold rolling of flat steel products, forging, stamping, etc.)

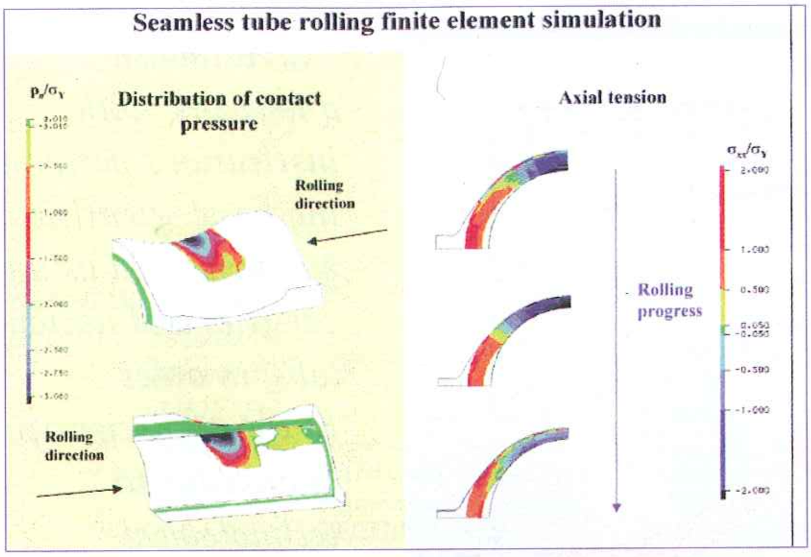
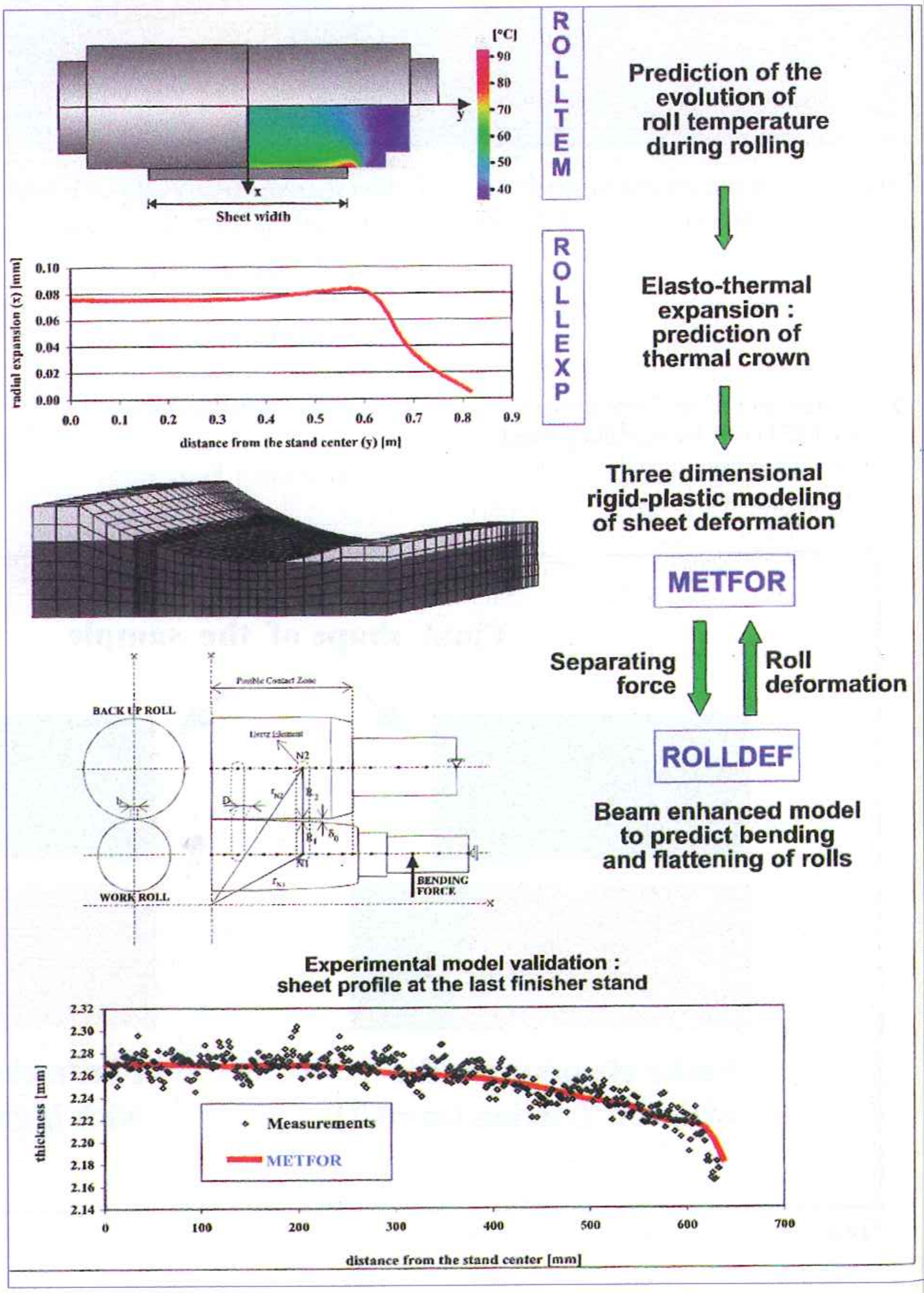


Figure 3: *Finite element simulation of steel seamless tube rolling using* ***METFOR*** *(mandrel rolling at SIDERCAR*

Figure 4: *Finite element simulation of flat steel rolling using* ***METFOR*** *(SIDERAR)*



> *" ... provide graduate education and training for young engineers and scientists. "*

- Development of finite element turbulence models for the analysis of liquid steel flows

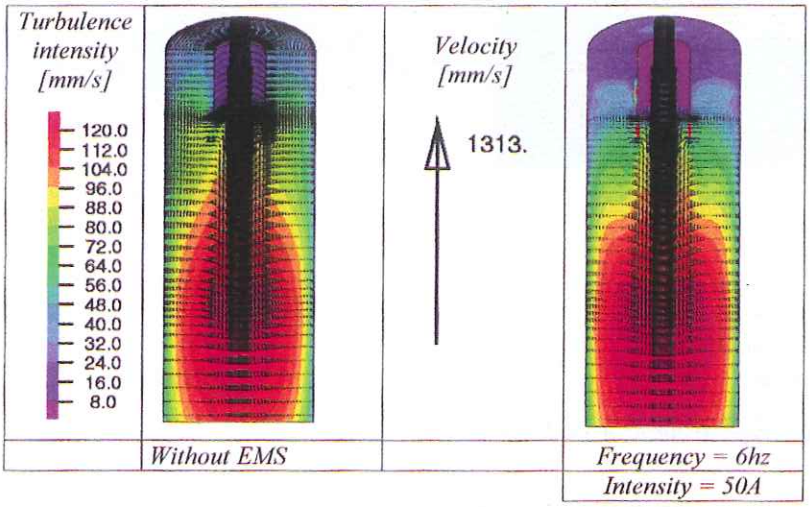


Figure 5: *Model of the liquid steel flow induced by an electromagnetic stirring device at a round bars continuous casting installation at SIDERCA*

- Analysis, using finite element turbulence models, of ladle furnaces, tundishes and submerged entry nozzles utilized in the steel industry

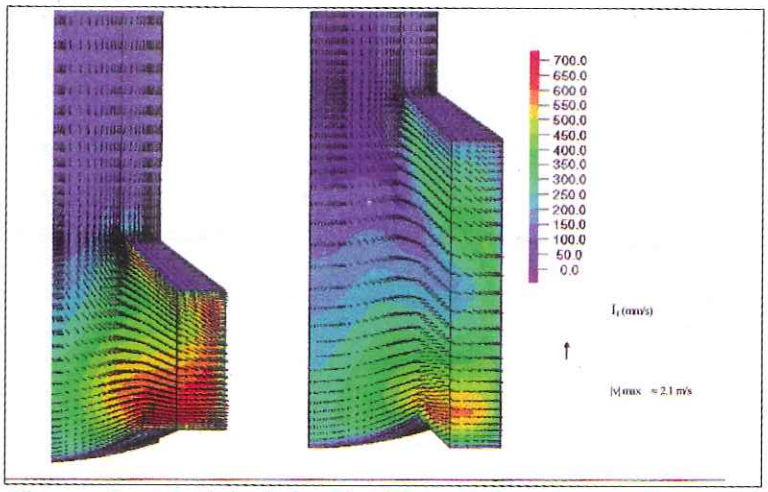


Figure 6: *Model of the liquid steel flow in a submerged entry nozzle used in the continuous casting of rectangular slabs at SIDERAR*

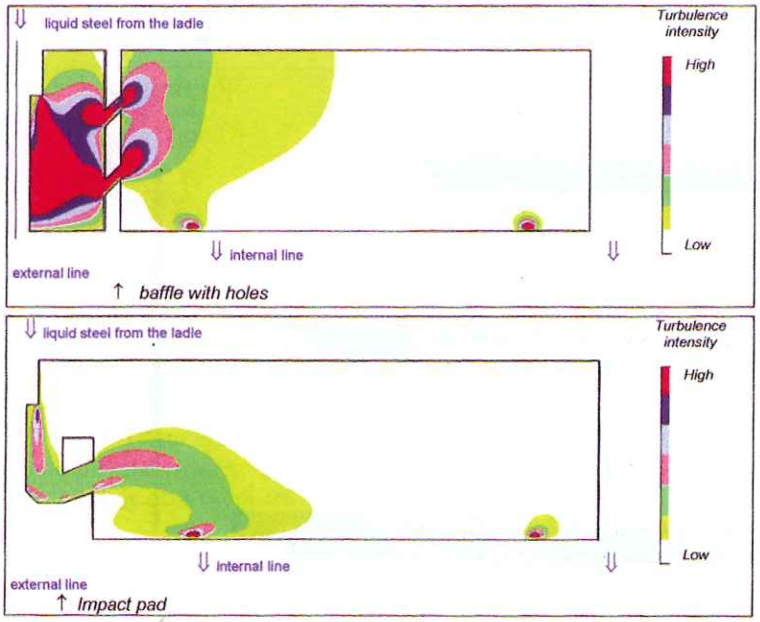


Figure 7: *Model of the liquid steel flow in a tundish when different internal devices are used*

- Analysis, using finite element turbulence models, of heat treatment installations for tubular products

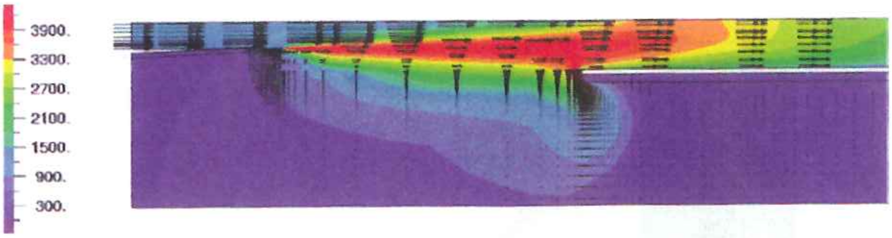


Figure 8: *Model of the facilities at SIDERCA and DALMINE for external / internal quenching of seamless tubes*

- Analysis of the mixing of different steels that are sequentially casted in a continuous casting installation (intermix)

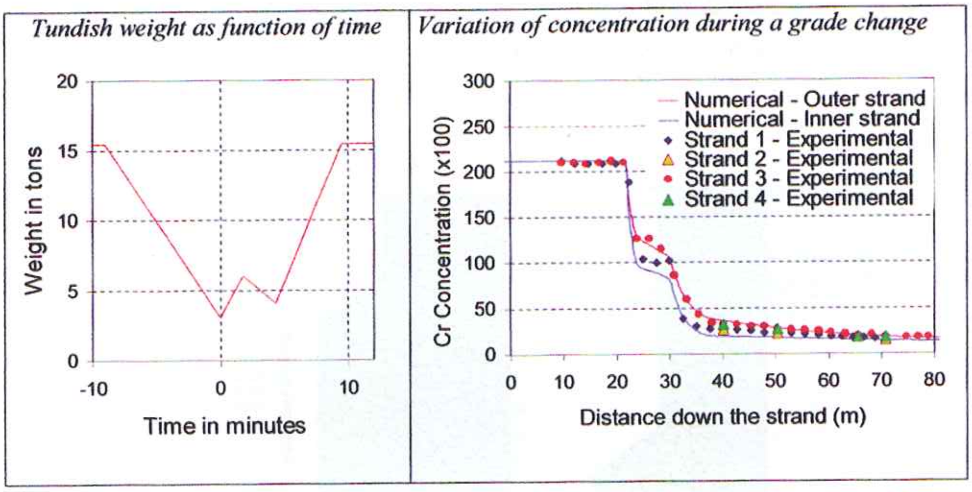
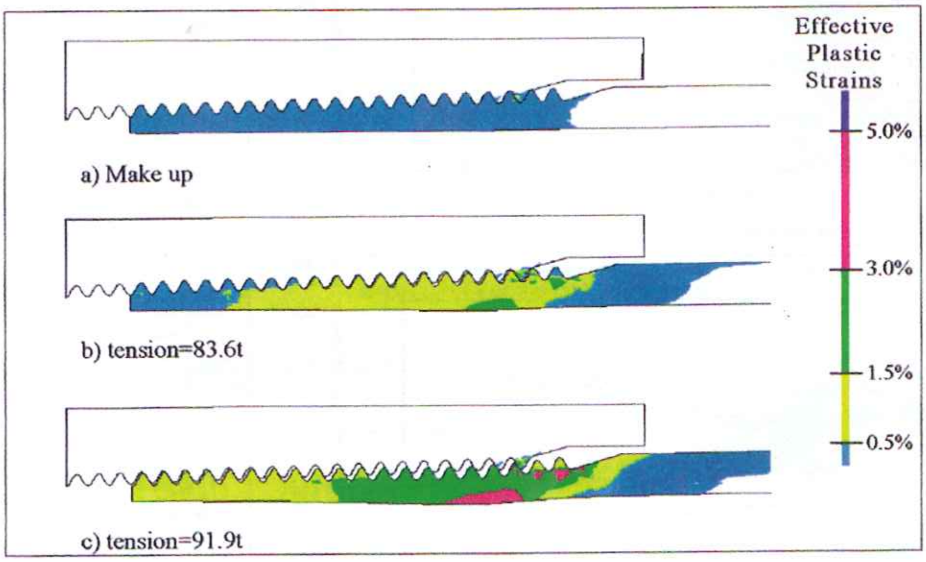


Figure 9: *Model of the chemical composition evolution during the transition between different steels at SIDERCA continuous casting installation*

Structural analysis

- Analysis of OCTG (oil country tubular goods) threaded connections



a) Make up

b) tension=83.6t

c) tension=91.9t

Figure 10: *Finite element analysis of the API-8R threaded connection displaying the "unzipping" of the connection*

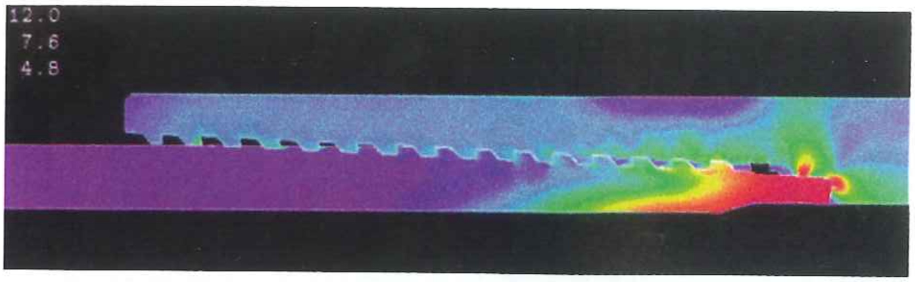
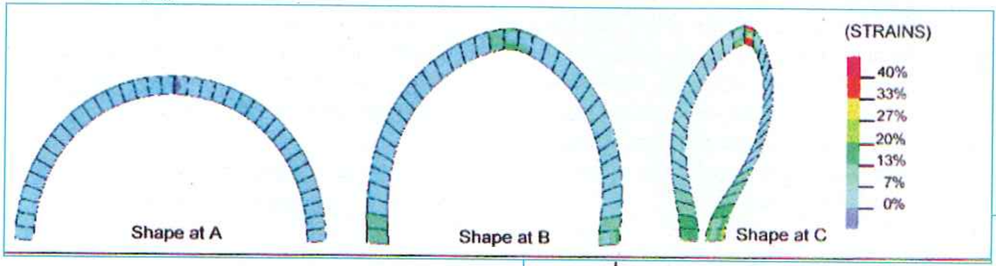


Figure 11: Finite element analysis of a DST premium threaded connection for OCTG

➪ **Analysis of the collapse behaviour of steel pipes including the post-collapse regime**
(e.g. collapse propagation in deep water linepipes)



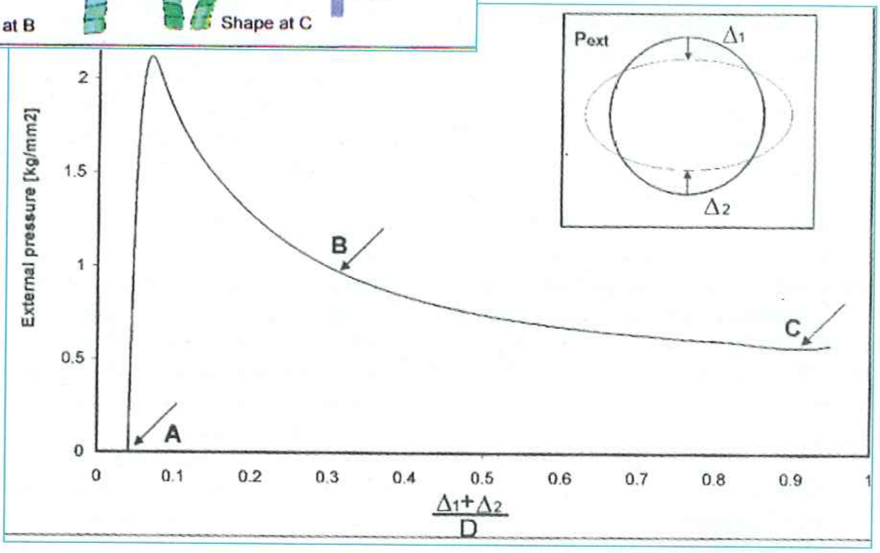


Figure 12: Collapse and post-collapse behaviour of a Deep Water Line Pipe

Finite element software

CODE	PURPOSE	DEVELOPER
ADINA System	Solid Mechanics analyses Fluid Mechanics analyses Thermal analyses	ADINA & R&D, MA, USA CINI added some element formulations
METFOR	Metal Forming analyses	CINI
FANTOM	Fluid Mechanics analyses	CIMNE, Barcelona, Spain CINI added the turbulence models
VOYAGE	Convection-diffusion transport analyses	CINI

- The Computational Mechanics department also developed special purpose codes such as:
- TCROWN: analysis of rolls heating and thermal expansion during the hot rolling of steel plates.
- ROLLDEF: analysis of roll deformation during rolling of steel plates.
- CCAST: thermal analysis of the solidification in a continuous casting facility.
- GRADE: analysis of the chemical composition evolution during the transition between different steels in a continuous casting facility. ●

Two Continents, varied cultures, but one aim?

an interview with Jaume Peraire

Having lived, studies and worked in both Spain, the UK and the USA, what would say were the main educational differences between Latin countries and the USA or the UK

In the UK and the USA the engineering degrees are shorter and more technology oriented than in countries such as Spain or France. The first two or three years of an engineering degree in Spain are spent on fundamentals such as maths or physics. This level of depth is only attained in the USA at the graduate level.

Graduate degrees in Spain lack the prestige and recognition that they have in the US. They are only required or needed for academic positions. In the USA the graduate programs are very well structured. They include a significant amount of course work and are in integral part of a high level education. They are recognized socially and in industry. In that respect the UK is somewhere between the US and Spain.

How does this follow on to University education and ease of successfully attaining higher education?

The combination of a good Spanish, and particularly French, undergraduate degree in Engineering combined with a postgraduate education in the US seems to work remarkably well. European students do generally very well in the United States. There are often some redundancies, specially in basic subjects, but this seems to help to reinforce the fundamentals even further.

Latin degrees are more encyclopaedic and provide a more general education. I think that they are very effective in educating an all round engineer but perhaps they are not as pragmatic and adapted to societys needs as the anglo-saxon degrees. According to the Royal Spanish Academy Dictionary, an engineer is a person with the ability to think or invent promptly and with ease. The Oxford dictionary, on the other hand ,associates the word engineer with the maker or person in charge of engines. These different interpretations gives an idea of the different conceptions of engineering in different countries.

Does language hinder students in study exchanges and in the exchange of information

Clearly language is a barrier to study exchanges, but on the other hand it is a barrier that is often very rewarding to cross. I do not recall any cases were exchange students. or students that carried studies in a culture different from their own, did not recognize the exchange as a positive experience.

This problem is not too severe in engineering where the default language worldwide seems to be English. The problem is probably more severe for Arts and liberal arts degrees.

You are involved in a distance learning programme with Singapore. Does this include an exchange programme in order to also gain these experiences

This last year has been the first of a five year joint experiment between MIT and Singapore. The collaboration has a teaching and a research component. The most innovative part of the program however, has been the successful delivery of a number of courses, leading to Meng degrees, at a distance. The courses were jointly attended by MIT and Singaporean students and were beamed in real time from MIT to Singapore and on occasion, when offered by a Professor in the Singaporean side, from Singapore to MIT. Because of the 12 hours time difference live lectures always took place either at 8-9pm or 8-9am. The result has been very positive and the student-Professor interaction during the lectures eg. Questions, discussions etc has been similar to what we would experience in a traditional class. With further improvements in technology I believe that these type of distance education programs will become more widespread.

You, being Spanish, are renound for your siestas how would you describe the American day?

After living 17 years in the UK and USA, it has been a real pleasure to spend some time in Barcelona. One of the main difficulties I have encountered however, has been coping with the work day schedule, especially if one has a family. In the US the days starts a lot earlier and by five/six o clock one can be at home and spend some quality time with the family. Lunch is a minor event, which often takes less than 30 minutes. Spaniards on the other hand are seldomly at the office before 9 and take longer for their meals. This is often combined with a coffee break in the morning and a coffee break in the afternoon. The result is that people will often spend more hours at work and will arrive home much later than in the US. Family time is often left to weekends only. Obviously trends are changing and while these comments can·t be generally applied, I think they apply to a large number of the faculty I met in the University.

Jaume Peraire is a Professor
living in the USA,
a family man
and a native Spaniard

Ten Commandments for LIFE

1. You either get it, or you don´t.
Become one of those who get it. Break the code of human nature, and find out what makes people tick. Learn why you and other people do what they do, and don´t do what they don´t. Figure out a definite formula for success, thus acquire the knowledge you need to create results you want.

2. You create your own experience.
Acknowledge and accept accountability for your life. Understand your role in creating the results that are your life. Learn how to choose better so you have better. You own your life. If you think you are a victim, you will have no progress and no victory.

3. People do what works.
Identify the payoffs that drive your behaviour and that of others. Start behaving in the positive ways necessary to have what you want. Or just as important, stop behaving in ways that interfere with what you want. You cannot eliminate negative behaviour without understanding why you do it. Control payoffs to control your life.

4. You can't change what you don´t acknowledge.
Get real with yourself about your life and everybody in it. Be truthful about what isn´t working in your life. Stop making excuses and start making results.

5. Life rewards action.
Make careful decisions and then pull the trigger. Learn that the world couldn´t care less about thoughts without action and if you do nothing you get nothing. People don´t care about your intentions, they care about what you actually do.

6. There is no reality, only perception.
Identify the filters through which you view the world. Accept the fact that no matter what happens in your life, how you interpret that event is up to you. Whatever meaning or value a particular event has for you will be the meaning or value that you give it.

7. Life is managed, it is not cured.
Learn to take charge of your life and hold on. This is a long ride and you are the driver every single day. Every day you will face challenges and problems at home or at work. Accept this and you will be less likely to label every problem as a crisis.

8. We teach people how to treat us.
Own, rather than complain, how people treat you. Learn to renegotiate your relationship to have what you want. How you interpret and react to their behaviour determines whether or not they are likely to repeat it.

9. There is power in forgiveness.
Open your eyes to what anger and resentment are doing to you. Take your power back from those who have hurt you. Anger and resentment eat away at the heart and soul of the person who carries them.

10. You have to name it to claim it.
Get clear about what you want. How can you achieve it if you don´t know what it is that you are aiming for? Indecision creates inaction.

Message from the Incoming

USACM President

Under the leadership of Mark Shephard, and the USACM Executive Council, USACM has made a significant impact on Computational Mechanics. The very successful USACM National Congress in Boulder, August 1999, demonstrated USACM's continuing evolution toward becoming the permanent computational mechanics organization in the United States. Moreover, working closely together with the International Association for Computational Mechanics (IACM), which represents 21 national and regional associations, USACM also strengthens its influence, importance and leadership as an international computational mechanics organization. We thank Mark for his many valuable contributions to our Association.

It is my pleasure to inform you that the first USACM student Chapters has been formed at the University of Texas, Austin and other student chapters are underway. If you are interested in forming a student chapter, please visit our web site www.usacm.org/ and follow "the guidelines for forming a USACM Student Chapter."

Four technical committees have been established to foster new research directions, developments and their applications. Detailed committee activity reports will be reported separately through the USACM web page and electronic digest.

USACM was founded, and continues to operate successfully, as an all-volunteer organization, with the Executive Council members providing their time, and the services of their staff, to conduct the business of USACM. Some recent changes have provided an impetus for re-evaluating the manner in which USACM conducts its business, and to consider how best to organize for the future. With the full support of USACM, it is my belief that a report detailing a set of recommendations will be produced and voted on at the USACM National Congress to be held at the Hyatt Regency, Dearborn Meeting, August 13, 2001, www.usnccm.org.

Should you have any suggestions, please do not hesitate to contact me. Please be sure to attend the exciting National Congress in 2001, and bring a friend.

Wing K. Liu

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Computational Mechanics in Modelling of Airdrop Systems

by
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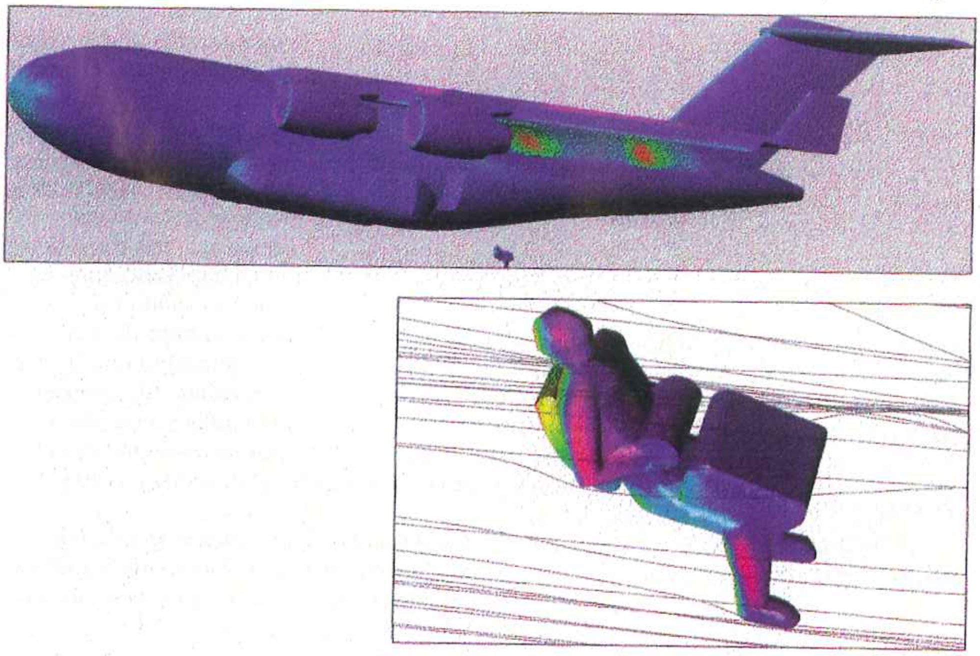
Modelling of airdrop systems is one of the Targeted Challenges of the Team for Advanced Flow Simulation and Modelling (T*AFSM), which is headquartered at the Department of Mechanical Engineering and Materials Science, Rice University, Houston, Texas <http://www.mems.rice.edu/TAFSM/>. Other areas of computational technology and science where the T*AFSM expects to make an impact, and therefore identified as Targeted Challenges , are unsteady flows with interfaces; fluid-object interactions; fluid-structure interactions; air circulation and contaminant dispersion; and aerodynamics and hydrodynamics of complex shapes. The methods developed by the T*AFSM to address these challenges include special numerical stabilization methods; Deforming-Spatial Domain/Stabilized Space-Time formulation; Enhanced-Discretization Interface-Capturing Technique; advanced mesh update methods; Shear-Slip Mesh Update Method; Multi-Domain Method; iterative solution methods for large equation systems; and parallel and multi-platform computing strategies. T*AFSM projects addressing various problems in airdrop systems are carried as collaborative work with researchers from the US Army Natick Solider Centre and NASA Johnson Space Centre. A number of Rice undergraduate and graduate students have been working on these projects, and cadets from the US Military Academy (West Point) have also been participating as summer interns.

Joint projects with Natick Soldier Centre include aerodynamic interaction between a cargo aircraft and a paratrooper or payload separating from that aircraft; aerodynamics of a parachute crossing the unsteady wake of an aircraft; aero-dynamic response of parachutes subjected to wind shears; and aerodynamic interaction between multiple parachutes. Collaborations with the Johnson Space Centre are on simulation of various stages of the parachute systems used in deceleration, gliding and landing of the Crew Return Vehicle of the International Space Station.

Figure 1:
Aerodynamic interaction between a cargo aircraft and a paratrooper separating from that aircraft. Air pressure distribution on the surface of the aircraft and paratrooper, and the streamlines around the paratrooper.



We now give a few examples of simulation of airdrop systems.

When a cargo aircraft with relatively new design is put into operation, the aerodynamic interaction between the aircraft and a paratrooper separating from that aircraft becomes a very relevant issue in terms of successful and effective deployment of paratroopers.

In this simulation, we consider a single paratrooper exiting the aircraft. The purpose is to calculate the path of the paratrooper relative to the aircraft, after his exit from the aircraft but prior to the opening of the parachute, while being subjected to aerodynamical forces in addition to gravity.

The simulation is based an solving the Navier-Stokes equations of incompressible flows for flow around both the aircraft and the paratrooper while their relative positions are changing, coupled with solving the equations of motion for the paratrooper. The Deforming-Spatial-Domain/Stabilized Space-Time (DSD/SST) formulation is used for solving this problem where the spatial domain occupied by air is changing in time.

In updating the mesh as the spatial domain changes in time, we use a mesh moving method where the motions of the nodes are governed by the equations of elasticity, and combine this with remeshing as needed. Reducing the frequency of remeshing is the most important consideration taken into account in the development of the mesh moving method.

Figure 1 shows at an instant the air pressure distribution on the surface of the aircraft and paratrooper, and the streamlines around the paratrooper.

This is one of our preliminary computations for the more realistic surface models we developed very recently for the aircraft and paratrooper, and the computation was carried out on a CRAY T3E-1200.

In a multi-aircraft paratrooper deployment, as a parachute deployed from an aircraft crosses during its descent the wake of the preceding aircraft, it might become subjected to strong, unsteady aerodynamical forces. Although normally the distance between the two aircraft is quite large compared to the length scales of the aircraft, it may not be large enough for the parachute to be spared from these wake effects. Fluid-structure interactions play a significant role in the aerodynamic and structural response of the parachute to the wake effects, and need to be accounted for in numerical prediction of the parachute behaviour.

In addition to the formidable task involved in solving an unsteady fluid-structure interaction problem, the need to accurately solve unsteady flows over long wake regions poses a substantial challenge.

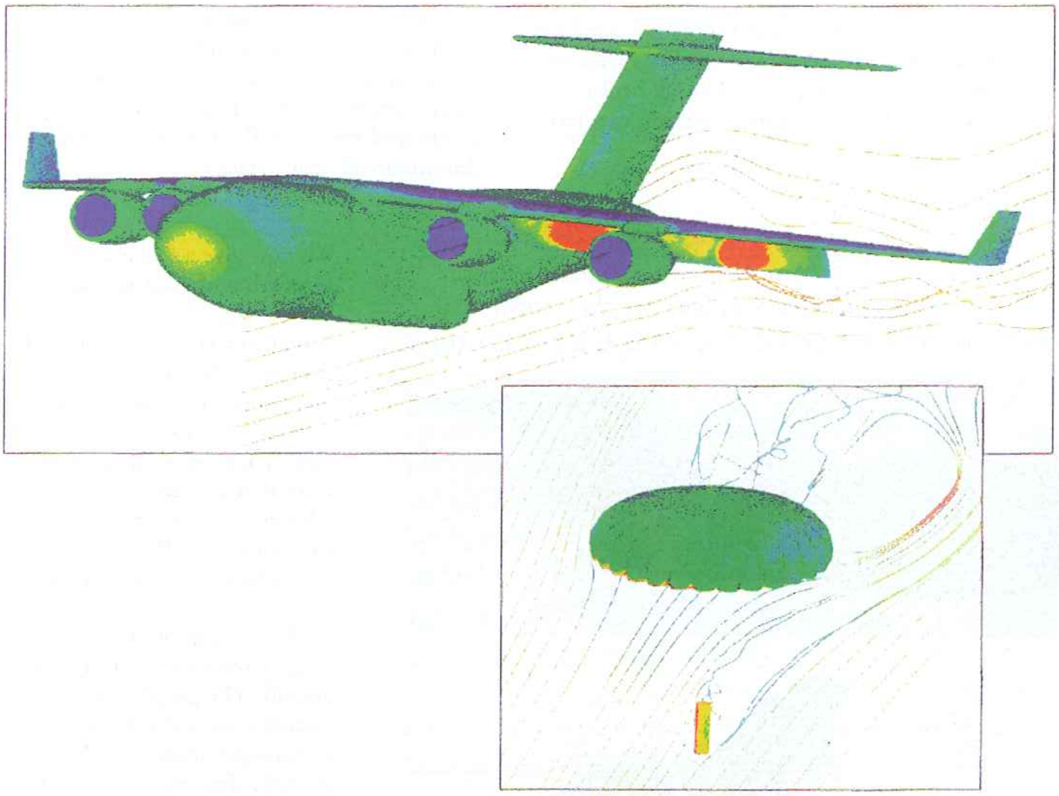


Figure 2:
Aerodynamics of a parachute crossing the unsteady wake of an aircraft. Air pressure distribution on the surface of the aircraft and parachute, and the streamlines around both

This challenge motivated the T*AFSM to develop the Multi-Domain Method (MDM) for the class of simulations requiring computation of the long-wake flows generated by a primary object and, sometimes, influence of this wake on a secondary object placed far downstream.

In the MDM, the problem domain is divided into a sequence of overlapping subdomains. The primary object is placed in the first subdomain, and the subsequent subdomains cover the long-wake regions and secondary objects. While the inflow boundary conditions for the first subdomain are derived from the free-stream conditions, for the remaining subdomains, the inflow conditions for each subdomain is extracted from the subdomain preceding it.

The parachute fluid-structure interactions are computed over a domain that moves with the payload and traverses the space also covered by the domain used for computation of the wake flow. Therefore the parachute domain functions as one of the subdomains of the MDM designed specifically for simulating the parachute fluid-structure interactions considered here. The boundary conditions for the parachute domain are extracted from the flow field computed over the wake domain, at locations corresponding to the positions of those boundaries in the wake domain.

The computation over the first domain, which contains the aircraft, is based on a general-purpose implementation of a semi-discrete stabilized finite element formulation. The computation over the wake domain, which contains no objects, is based on a special-purpose implementation that exploits the simplicity of the mesh to increase the computational speed. The computation over the last domain, which contains the parachute, is based on a general-purpose implementation of the DSD/SST formulation, taking into account the fluid-structure interactions.

Figure 2 represents the general concept, using results from our earlier computations, where the parachute was assumed to be rigid and the payload was of a very simple shape.

The pictures in *Figure 2* show the air pressure distribution on the surface of the aircraft and parachute, and some of the streamlines for both. This computation was carried out on a CRAY T3E-1200.

Normally it will be the Space Shuttle that will be used to transport the Crew to and from the Space Station. However, in some cases, it might be necessary to bring the Crew back sooner than it would take to send the Shuttle up. In such cases, the Crew will be using the Crew Return Vehicle (CRV), which can quickly be launched from the Space Station and can re-enter the atmosphere.

However, the CRV, which is small and of fixed configuration, will only have some parachute systems to first slow it down, then to glide it to the landing area, and finally to land it softly. Using parachutes to glide and soft-land large objects like the CRV is a new concept, and it is difficult to perform laboratory tests with parachutes of the sizes required to land such large objects.

These parafoils can also be used for gliding and soft landing of other classes of large objects, such as food crates or ground vehicles needed in an area that is hard to reach by any means other than a parachute. In the case of the CRV, the ram-air parachute used in gliding and landing operates in six different stages. Figure 3 shows, for the final stage, the air pressure distribution on the surface of the CRV and parachute. This computation was carried out on a CRAY T3E-1200.

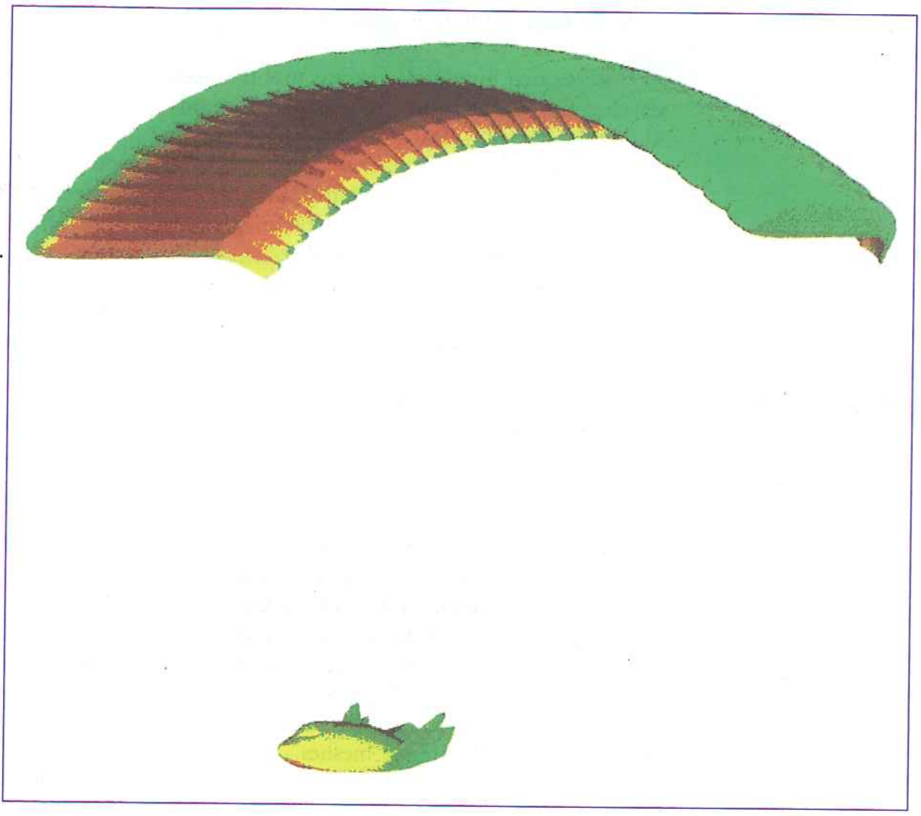


Figure 3:
Final stage of the ram-air parachute used with the Crew Return Vehicle. Air pressure distribution on the surface of the CRV and parachute.

In this article we presented a short overview of how advanced methods of computational mechanics are being employed to address some of the challenges encountered in simulation of airdrop systems. For more on this and related subjects, please visit the T*AFSM web site at <http://www.mems.rice.edu/TAFSM/> and/or watch for the upcoming papers authored by the T*AFSM. ●

Aerolastic Analysis of a Helicopter Rotar in Forward Flight

Flow fields around rotary wings, especially around helicopter rotors, are extremely complex due to strong compressibility and three-dimensional effects. The solution of the governing equations for these flow problems is very difficult and can usually only be achieved with the help of numerical methods.

A sophisticated numerical analysis tool has been developed at the Institut für Aerodynamik und Gasdynamik (IAG), featuring pure aerodynamic as well as aeroelastic simulation capabilities. Fluid and structure codes constitute separate programs which are time-accurately coupled and communicate via TCP/IP socket connections.

The aerodynamic analysis is based on the Euler equations [6-10]. Thus, typical aerodynamic phenomena which are encountered in the unsteady three-dimensional compressible flow field around a helicopter rotor can be properly modelled. The Euler equations are derived in a non-inertial, rotating frame of reference using absolute quantities for the formulation of the conservative variables. Since an aeroelastic analysis requires deformable grids, arbitrary Lagrangian-Eulerian fluxes are employed [4,5]. The governing equations are projected from physical to computational space, transforming the body-fitted structured grids into uniformly-spaced cartesian meshes.

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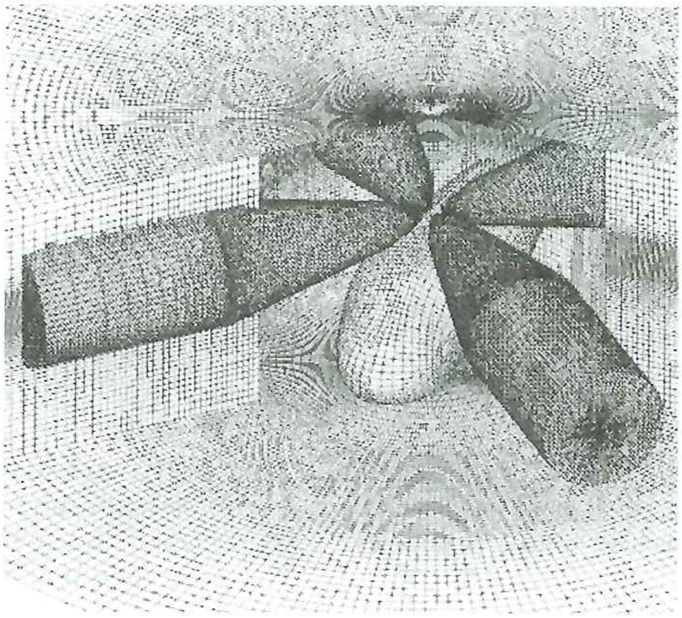
Grid generation for a helicopter model is a laborious task. Due to the complex kinematics of the system, a numerical analysis using a single grid is nearly impossible. The Chimera approach provides a possibility to circumvent these difficulties by discretizing the individual helicopter components in separate grids which are all embedded in a common background grid *(Fig. 1)*. Thus, arbitrary motions can be achieved with a tolerable level of effort.

An efficient implicit LUSGS-algorithm drives the aerodynamic system in time, providing second-order accuracy. A cell-centred finite-volume upwind scheme based on an approximate Riemann solver is used for spatial discretization. Third-order accuracy is achieved by a uniformly-non-oscillatory (UNO) flux evaluation method.

The dynamic behaviour of the rotor blades is simulated by a quasi one-dimensional finite-element method using Timoshenko's beam theory which considers strain displacement, bending, shear and torsional deformation [1, 3]. The dynamic blade model comprises the calculation of coupled flap-torsion as well as coupled flap-lag motion. Blade deflections are implicitly solved in time by integrating the second order linear system of differential equations with the generalized-a-scheme. Fluid structure coupling is achieved by partitioned procedures [2]. An offset between the time scales of fluid and structure solver conserves second-order accuracy of the global algorithm.

Current research activities include the expansion of the aerodynamic solver to the full Navier-Stokes equations with appropriate turbulence modelling as well as further sophistication of the rotor dynamics analysis module. ●

Figure 1: Chimera grids



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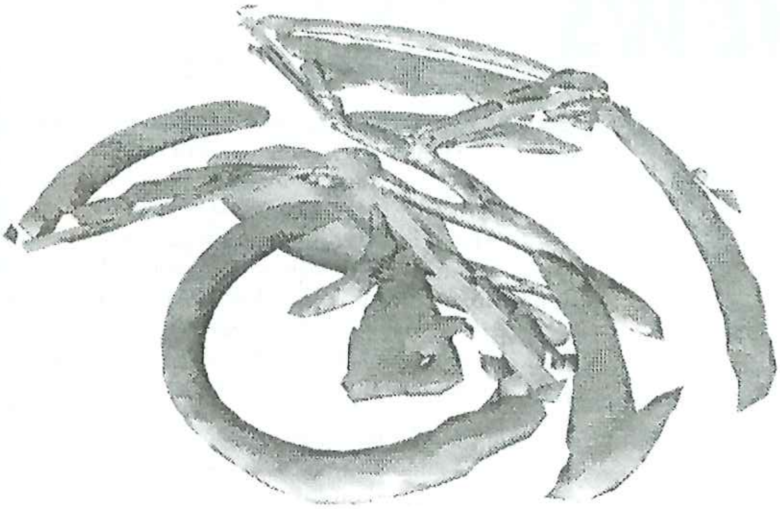

Figure 2:
Wake structure in forward flight

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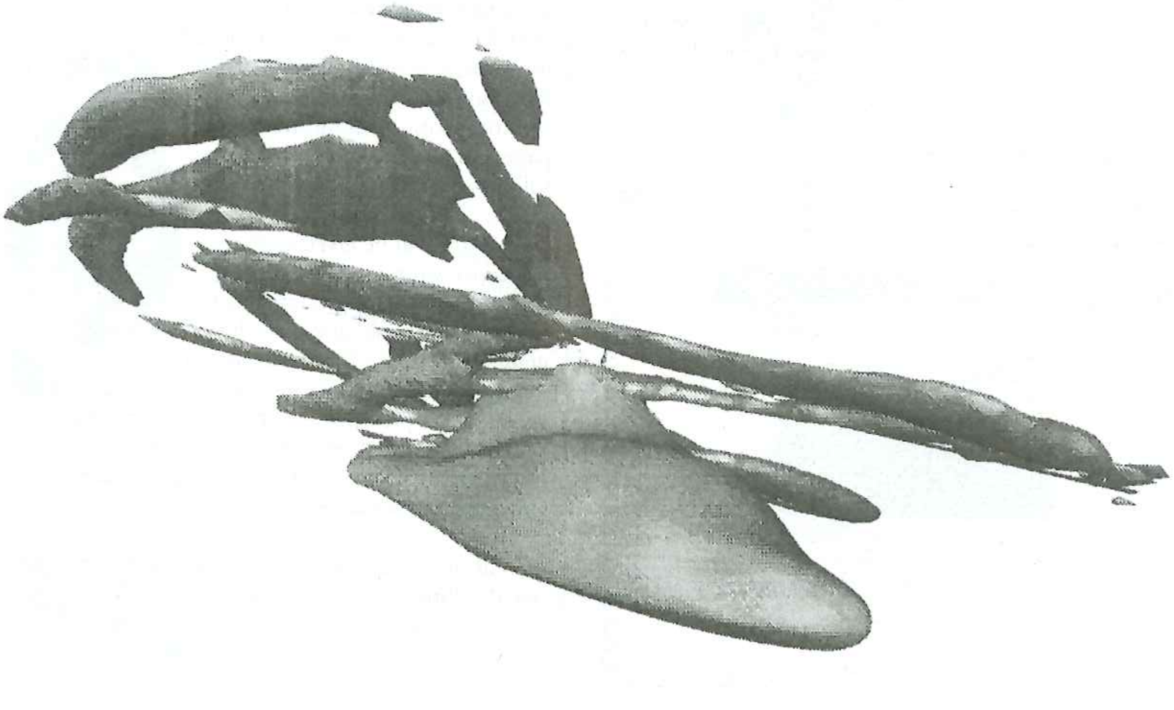
Figure 3:
Bottom side view of wake structure



conference debrief

IASS-IACM 2000

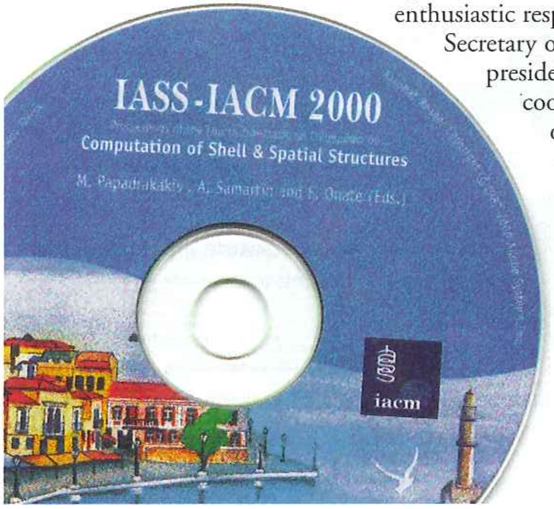
The Fourth International Colloquium on Computation of Shell and Spatial Structures: IASS-IACM 2000 was held from **4-7 June, 2000** in Chania-Crete, **Greece.**

This Fourth International Colloquium followed the previous three Colloquia held in Leuven, Belgium (1986), Tokyo, Japan (1993) and Taipei, Taiwan (1997) organised by the Working Group 13 on Numerical Methods for Shell and Spatial Structures of IASS.

The Colloquium was jointly organised by the National Technical University of Athens, The Greek Association for Computational Mechanics (GRACM) and the Working Group 13 of IASS, and was held under the auspices of the International Association for Shell and Spatial Structures (IASS) and IACM.

The main objective of this Colloquium was to provide an international forum for presentation and discussion of the recent advances on various aspects of the analysis and design of shell and spatial structures and to reflect the state of the art of computational methods in the mechanics, software development and engineering practice of this type of structures.

The idea for this joint Colloquium goes back to 1994 when the chairman of the Working Group 13 of IASS, Avelino Samartin, asked Manolis Papadrakakis to be the host of the Fourth International Colloquium in Greece. In the process of the organisation of this Colloquium the organiser asked for the support of the International Association for Computational Mechanics and got the enthusiastic response of the General Secretary of IACM, E. Onate, and its president, T. Hughes. Such a cooperation fits perfectly with one of the main objectives of both IASS and IACM, to foster the interchange of ideas and to provide fora and meetings for the dissemination of knowledge among various fields and societies. This joint venture proved to be very successful and it was decided to adopt this for future events.



The response after the Colloquium was first announced was more enthusiastic than expected. No less than 340 extended abstracts were submitted and 250 of which were accepted for presentation. Altogether about 300 participants from 35 countries attended the Colloquium.

The Colloquium sessions encompassed a wide range of topics starting from beam and shell finite elements. Modelling issues of cable and membrane structures, deployable structures, reinforced concrete shells. Structural stability, higher order simulation methods, vibration analysis and structural dynamics, stochastic and reliability analysis, geometric and material non-linealities, form finding of membrane, shell and skeletal structures. Optimization, damage mechanics, coupled problems, composites, smart structures, high performance computing.

Co-chairman, E. Oñate attempts his first steps at the local dance `pentozali´ together with the host chairman, M. Papadrakakis

In the opening session J.H. Argyris, Honourary Chairman, recalled his involvement in the design and analysis of some renowned shell and spatial structures, like the suspension roofs of the Munich Olympic stadium and the Boeing 747, structural and thermal analysis of space-crafts Appollo and Hermes and referred to the major milestones in the development of the natural mode method since it was first presents in the 1950 s. Also included was K.J. Bathe·s plenary lecture. Six other plenary lectures were given by E. Onate, W.B. Kraetzig, H.A. Mang, G.I. Schueller, E. Ramm and A. Domingo.

The social activities were highlighted by a reception and a Cretan style dinner, with music and dances and an excursion to Samaria gorge, the longest gorge in Europe.

A copy of the CD-Rom proceedings can be purchased for 30 Euros by email: coll2000@central.ntua.gr ●

ECCOMAS 2000
European Congress on Computational Methods in Applied Science and Engineering

The **ECCOMAS 2000** congress was held at the World Trade Centre, located in the heart of the harbour area of **Barcelona**, on **11 - 14 September 2000**. It was attended by some 1200 delegates from 52 different countries The congress incorporated the **V! International Conference on Computational Plasticity (COMPLAS VI)**.

Papers presented fell within the following categories:

Solid and Structures
Fluid Dyamics
Numerical Methods
Electromagnetics
Computational Chemistry

The content of the papers was collected into a CD-Rom proceedings. A book of abstracts containing 1 page summaries of the 1130 papers presented was also given to the participants. Copies of the CD-Rom proceedings can be obtained from eccomas2000@cimne.upc.es

The conference was organised in some 200 sessions. Typically 27 sessions were run in parallel. A number of Invited Sessions on specialized topics were organised by eminent scientists and engineers. Keynote Lectures were delivered by some 120 distinguished speakers and Plenary Lectures were given by O.C. Zienkiewicz, J.L. Lions, E. Ramm, J. Peraire, A. Garcia Arroyo, T.J.R. Hughes, Z. Cendes, B. Revellin Falcoz and R. Glowinski.

The ECCOMAS 2000 congress was complemented by an exhibition including 31 stands presenting books, software, hardware and demonstrations of different outcomes of research projects mainly sponsored by the European Commission.

Figure 1: *Conference Banquet a the National Museum of Catalunya*

Figure 2: *Barcelona World Trade Centre*

The social programme included a reception at the World Trade Centre and a banquet at the National Museum of Catalunya.

Figure 3: *Conference Room*

Figure 4: *A Group of Speakers at the Conference*

The next ECCOMAS Congress will take place at the **University of Jyaväskylä, Finland** in **June 2004**. For further information please contact Prof Neittaanmäki at pn@math.jyu.fi ●

New Managing Board of ECCOMAS

The new Managing Board of the European Community on Computational Methods in Applied Sciences (ECCOMAS) was elected at the ECCOMAS 2000 congress. Officers elected are:

ECCOMAS President: Eugenio Oñate *(Spain)*
Vice-Presidents: K. D. Papailiou *(Greece)* and N.E. Wiberg *(Sweden)*
Members: C. Hirsch *(Brussels)*, M. Kleiber *(Poland)*, O. Mahrenholtz *(Germany)*, H. Mang *(Austria)*, K. Morgan *(U.K.)*, P. Neittaanmäki *(Finland)*, J. Periaux *(France)*, O. Pironneau (France), M. Primicerio *(Italy)*, E. Ramm *(Germany)*, B. Schrefler, (Italy) and O.C. Zienkiewicz *(U.K.)*.

For information on ECCOMAS please contact: **Eugenio Oñate,** at:
Edificio C-1, Campus Norte UPC, Gran Capitan, s/n, 08034 Barcelona, Spain
Tel: (34) 93 - 205 70 16, Fax: (34) 93 - 401 65 17, Email: onate@cimne.upc.es , or www.cimne.upc.es ●

conference debrief

46th National Conference on Applied and Computational Mechanics

The 6th National Conference on Applied and Computational Mechanics was held from **17th to 19th April 2000** in the University of Aveiro, jointly organised by the Department of Civil Engineering and the Department of Mechanical Engineering of the **University of Aveiro, Portugal,** under the auspice of the Portuguese Society of Theoretical, Applied and Computational Mechanics.
More than 200 delegates attended the Congress. The Conference had 9 invited sessions in the field of Composite Materials, Biomechanics, Metal Forming, Numerical Algorithms and Modelling of Concrete Structures. There were also 20 parallel sessions being 14 in the field of Solid and Structural Mechanics, 4 in the field of Fluid Dynamic and 2 in the field of Applied Mathematic with a total of 166 papers.

Plenary lectures were given by the following speakers:

- ○ Prof. Robert Taylor (University of California, Berkeley, USA) *Large Displacement Beam And Axisymmetric Shell Analysis: Alternatives*
- ○ Prof. J. A. Teixeira de Freitas (Instituto Superior Técnico, Portugal). *Applications with Hybrid and Mixed Finite Elements*
- ○ Prof. Eugenio Oñate (Universitat Politècnica de Catalunya, España) *Posibilidades del Cálculo Finitesimal para Desarrollo de Métodos Numéricos Estables en Mecánica de Fluidos y Sólidos*
- ○ Prof. Nigel P. Weatherill (University of Wales, Swansea, UK) *A Monte Carlo Model to Assess the Impact of Lead Emissions to Drinking Water*
- ○ Prof. Antonio Huerta (Universitat Politècnica de Catalunya, España)*Enrichment of The Finite Element Method With Meshless Methods*

The Proceedings of the Conference was published by the University of Aveiro, ISBN 972-8021-61-5, and copies may be obtained by request from Prof. Paulo Vila Real on email: pvreal@civil.ua.pt. ●

Delegates attending the 6th National Conference on Applied and Computational Mechanics in the University of Aveiro, Portugal

Book Report

The Mathematics of Finite Elements and Applications

J.R. Whiteman (Ed.)
420 pp, 2000, US$ 89
Elsivier

The tenth conference on The Mathematics if Finite Elements and Applications, MAFELAP 1999, was held at Brunel University in June 1999. It has established a pattern of bringing together mathematiticians, engineers and others interested in the field to discuss finite element techniques.

In the MAFELAP context finite elements have always been interpreted in a broad and inclusive manner, and have been taken to include techniques such as finite difference, finite volume and boundary element methods as well as actual finite element methods. The papers in this book reflect this. The increasing importance of modelling, in addition to numerical discretization, error estimation and adaptivity, was again evident in MAFELAP 1999. •

Symmetry Methods for Differential Equations

A Beginners Guide

P.E. Hydon (Ed.)
248 pp, 2000, UK Pounds 44,
Cambridge University Press.

Symmetry is the key to solving differential equations. There are many well-known techniques for obtaining exact solutions, but most of them are special cases of a few powerful symmetry methods. Furthermore, these methods can be applied to differential equations of an unfamiliar type; they do not rely on special `tricks´. Instead, a given differential equation if forced to reveal its symmetries, which are then used to construct exact solutions.

This book is a straightforward introduction to the subject, and is aimed at applied mathematicians, physicists, and engineers. The presentation is informal, using many worked examples to illustrate the main symmetry methods. It is written at a level suitable for postgraduates, and i designed to enable the reader to master the main techniques quickly and easily. The book contains methods that have not previously appeared in a text. These include methods for obtaining discrete symmetries and integrating factors •

Book Report

Principles of Computational Fluid Dynamics

P. Wesseling (Ed.)
642 pp, 2000, DM 169,
Springer.

The book is aimed at graduate students, researchers, engineers and physicists involved in fluid computations. An up-to-date account is given of the present state of the art numerical methods employed in computational fluid dynamics. The underlying numerical principles are treated with a fair amount of detail, using elementary methods.

Attention is given to the difficulties arising from geometric complexity of the flow domain. Uniform accuracy for singular perturbation problems is studies, pointing the way to accurate computational of flows at high Reynolds numbers. Unified methods for compressible and incompressible flows are discussed. A treatment of the shallow-water equations is included. A basic introduction is given to efficient interactive solution methods. •

Computational Contact Mechanics.

P. Wriggers (Ed.)
400 pp, 2000, UK Pounds 55,
Wiley, U.K..

Contact mechanics is a specialist area in engineering mechanics. It deals with non-standard mechanics, which frequently appear in real technical applications. Examples include the simulation of car crashes, human joints, car tyres, rubber seals and metal forming processes. Modern numerical simulation methods are used to model these objects and their behaviour.

Although it is an area of great technical importance, only very few problems involving contact can be solved analytically - for most industrial applications, numerical methods have to be applied since the contacting bodies have complex geometries, undergo large deformations or are affected by other factors.

Although other numerical and analytical schemes can also be used, this book concentrates mainly on finite element techniques for the treatment of contact problems, including new approaches such as adaptive finite element methods. •

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Honourary Doctorates

In March 2000, **Prof Bernhard A. Schrefler** of the University of Padua received a Honourary Doctorate from the St Petersberg State Technical University in Russia.

In October 2000 **Prof. Eugenio Oñate** of University Politecnica de Cataluñya received a Honourary Doctorate from the University Ovidus of Castanza in Romania.

100th Anniversary

The **St Petersberg State Technical University**, now a leading Technical University in Russia, was established in 1899 as Peter the Great St. Petersberg Polytechnical Institute for the purpose of preparing a new type of engineer with good knowledge of physics, mathematics and chemistry.
Today it incorporates 20 faculties and institutes, several special schools, scientific centres and research laboratories transferring knowledge to 20,000 students

ABMEC President

Recently the Associaçion Brasilliera de Mechanica Computaçional has changed its presidency. We welcome the new president of ABMEC, **Prof. Philippe Devloo** of the Faculdade de Engenharia Civil UNICAMP, Cidade Universitária, Brasil.

Venezuela joins IACM

The **Venezueal Association in Numerical Methods in Engineering** has recently become an afficiated member of IACM.
For more information on the activities of the new IACM partner in Venezuela, please contact Prof Miguel Cerrola on Email mcerrola@reaccium.ve

O.C. Zienkiewicz and J.L. Lions Awards

The European Community on Computational Methods in Applied Science and Engineering (ECCOMAS) has recently created the O.C. Zienkiewicz and J.L. Lions award for young scientists. the first awardees are:
- O.C. Zienkiewicz Award on Computational Engineering: **Nikolaus Adams, (Switzerland)**
- J.L. Lions Award on Computational Mathematics: **Ramon Codicha (Spain)**

The awards were delivered at the banquet of the ECCOMAS 2000 congress held in Barcelona on 11 - 14 September 2000.

John Argyris Award

for the best work by a young European researcher in the field of Computational Solid and Structural Mechanics including Fluid-Structure Interaction

Announcing the John Argyris Award for the best research work by a young European researcher in the area of Computational Solid and Structural Mechanics including Fluid-Structure Interaction. This Award has been initiated to honour Professor John Argyris whose research work for more than 50 years had a pioneering impact on computational mechanics both in theory and in practice. Each applicant may submit up to five published papers addressing a particular topic of research before 15 March 2001 to:

Professor Erwin Stein, The John Argyris Award
Institute fur Baumechanic und Numerische Mechanik
Universitat Hannover, Appelstrasse 9A, D-30167 Hannover, Germany

conference notices

WCCM V
Fifth World Congress on Computational Mechanics

Following the success of the four previous IACM World Congresses on Computational Mechanics, which took place in Austin, Texas (1986), Stuttgart, Germany (1990), Chiba, Japan (1994) and Buenos Aires, Argentina (1998), IACM is pleased to announce that the **Fifth World Congress on Computational Mechanics (WCCM V)** will be held from **7 - 12 July 2002** in **Vienna, Austria.**

The venue is the Vienna University of Technology and the first plenary lecture will take place in the Great Hall of Musikverein, world famous from the broadcasts of the New Year's concerts of the Vienna Philharmonic Orchestra.

The IACM congress will be organised jointly by the Austrian National Committee for Theoretical and Applied Mechanics at the Austrian Academy of Sciences (ÖAW), and TU Vienna. Chairmen of WCCM V are Prof. Herbert A. Mang, Secretary General of ÖAW, and Prof. Franz G. Rammerstorfer, Vice Rector for Research of TU Vienna.

Congress enquiries should be sent to:
Tel: (43) 1 - 588 040
Fax: (43) 1 586 91 85
Email: registration@wccm.tuwien.ac.at
WWW: http://wccm.tuwien.ac.at ●

ECCOMAS CFD 2001
Eccomas Computational Fluid Dynamics Conference

The European Community on Computational Methods in Applied Science (ECCOMAS) was created in 1993 with the aim of providing a high level of co-ordination of scientific conferences and related activities in Europe in the field of computational methods for the applied sciences.

The objectives of the ECCOMAS CFD Conference series is to bring together researchers, practical engineers and students working in the general area of computational fluid dynamics. Previous ECCOMAS Computational Fluid Dynamics Conferences have been held in Stuttgart in 1994 and in Athens in 1998. In addition, computational fluid dynamics has been a major topic at the ECCOMAS Congresses in Brussels in 1992, Paris in 1996 and Barcelona in 2000. The **ECCOMAS CFD 2001** Conference will be held at the **University of Wales, Swansea** from **4 - 7 September 2001**. The conference will aim to cover the full spectrum of computational fluid dynamics topics and will also include related areas such as computational electromagnetic, and multidisciplinary applications.

For updated information on the organisation, please visit our website; www.ima.org.uk or mail directly to: post@ima.org.uk ●

APCOM'01
First Asian-Pacific Congress on Computational Mechanics
20 - 23 November 2001

During the last millennium, a series of **Asian-Pacific Conferences (APCOM)** were held successfully in Hong Kong (1991), Sydney(1993), Seoul(1996) and Singapore (1999). It was decided to form the Asian-Pacific Association of Computational Mechanics because of the extensive activities in this field.

The theme of the first congress is "New Frontiers For New Millennium." The specific aims of the congress are:

- To bring together academics, researchers and practitioners to discuss the developments of Computational Mechanics during the last millennium and to set new directions for further developments.
- To bring together engineers, scientists and applied mathematicians in order to encourage cross-fertilisation of ideas and techniques related to computational Mechanics.

Besides the general topics, the following specific topics are proposed in line with the theme of the congress: Micro and nano mechanics, contact mechanics, chemothermomechanics, chaotic systems, meshless methods, smart materials, smart structures, composite structural control, aging of structures, coupled problems, environmental flow problems, multiphase flows in multimedia, virtual reality and graphic visualization,

For information contact Dr. N. Khalili at the University of New South Wales on:
Fax: (61) 2 - 93 85 61 39 or
Email: n.khalili@unsw.edu.au ●

conference diary planner

14 - 16 March 2001
Multiphase Flow 2001 - Computational Methods in Multiphase Flow
Venue: Orlando, U.S.A.
Contact: Tel: (44) 238 - 029 32 23, Fax: (44) 238 - 029 28 53, Email: slwalsh@wessex.ac.uk
WWW: www.wessex.ac.uk/conferences

24 - 28 April 2001
Nafems World Congress 2001 - The Evolution of Product Simulation
Venue: Lake Como, Italy
Contact: Tel: (44) 1355 - 22 56 88, Fax: (44) 1355 - 24 91 42, Email: anne@nafems.com

16 - 18 May 2001
Electrosoft 2001 - Software for Electrical Engineering Analysis and Design
Venue: Lemnos, Greece.
Contact: Tel: (44) 238 - 029 32 23, Fax: (44) 238 - 029 28 53, Email: slwalsh@wessex.ac.uk
WWW: www.wessex.ac.uk/conferences

28 - 30 May 2001
STREMAH 2001 - 7th International Conference on Structural Studies, Repair and Maintenance of Historical Buildings
Venue: Bologna, Italy.
Contact: Tel: (44) 238 - 029 32 23, Fax: (44) 238 - 029 28 53, Email: slwalsh@wessex.ac.uk
WWW: www.wessex.ac.uk/conferences

4 - 6 June 2001
CMEM 2001 - Computational Methods and Experimental Measurements
Venue: Alicante, Spain.
Contact: Tel: (44) 238 - 029 32 23, Fax: (44) 238 - 029 28 53, Email: slwalsh@wessex.ac.uk
WWW: www.wessex.ac.uk/conferences

12 - 14 June 2001
First M.I.T. Conference on Computational Fluid and Solid Mechanics
Venue: Cambridge, M.A., U.S.A.
Contact: Tel: (1) 617 - 253 66 45, Fax: (1) 617 - 253 22 75, Email: kjb@mit.edu
WWW: http://www.firstmitconference.org

18 - 20 June 2001
Contact Mechanics 2001 - Computer Methods in Contact Mechanics
Venue: Seville, Spain.
Contact: Tel: (44) 238 - 029 32 23, Fax: (44) 238 - 029 28 53, Email: slwalsh@wessex.ac.uk
WWW: www.wessex.ac.uk/conferences

26 - 29 June 2001
ECCM - 2001 - 2nd European Conference on Computational Mechanics
Venue: Cracow, Poland.
Contact: Tel/Fax: (48) 12 - 628 25 14, Email: mailto:eccm@pk.edu.pl
WWW: http://www.pk.edu.pl/eccm

1 - 4 August 2001
Sixth US National Congress on Computational Mechanics
Venue: Dearborn, Michigan, U.S.A.
Contact: G. Hulbert, Tel (voice): (734) 763 44 56, Email: hulbert@umich.edu

4 - 7 September 2001
ECCOMAS CFD 2001 - Eccomas Computational Fluid Dynamics Conference
Venue: Swansea, Wales.
Contact: Tel: (44) 1702 -35 40 20, Fax: (44) 1702 - 35 41 11, Email: post@ima.org.uk
WWW: http://www.ima.org.uk

20 - 22 November 2001
APCOM 01 - First Asian-Pacific Congress on Computational Mechanics
Venue: Sydney, Australia
Contact: Fax: (61) 2 - 93 85 61 39, Email: n.khalili@unsw.edu.au
WWW: http://www.civeng.unsw.edu.au/conferences/apcom01/

17 - 19 January 2002
Second International Conference on Numerical Methods in Science and Engineering
Venue: Guanajuato, Mexico
Contact: Tel: (34) 93-401 64 87, Fax: (34) 93-401 65 17, Email: barbara@cimne.upc.es
WWW: http://www.cimne.upc.es

7 - 12 July 2002
WCCM V - Fifth World Congress on Computational Mechanics
Venue: Vienna, Austria.
Contact: Fax: (43 1) 586 - 91 85, Email: registration@wccm.tuwien.at
WWW: http://wccm.tuwien.ac.at/

21 - 26 July 2002
b 02 IFAC - 15th World Congress
Venue: Barcelona, Spain
Contact: Tel: (34) 93-401 64 87, Fax: (34) 93-401 65 17, Email: secretariatnoc@b02.ifc2002.org
WWW: http://www.cimne.upc.es

31 March - 3 April 2003
FEF 03 - 13th International Conference on Finite Elements in Flow Problems
Venue: Miejo University, Nagayo, Japan
Contact: Email: fef03@cmlab.meijo-u.ac.jp
WWW: http://cmlabtp.meijo-u.ac.jp/fef03/index.htlm

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