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On the Threshold of the 21st Century
O.C. Zienkiewicz, T.J.R. Hughes & R.L. Taylor

Advances in Computational Mechanics Software - with Diffpak as the example
H.P. Langtangen

In Memory of Prof. John Martin

Why the Supersonic Car Didn´t Fly
K. Morgan, O. Hassan & N. Weatherill

Global Ozone Monitoring - A Multidisciplinary Mechanical Analysis
T. Rolvag, T.A. Svidal & B. Haugen

USACM News

Conference Debrief

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Book Report

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Bulletin for The International Association for Computational Mechanics

Nº 8

January 2000

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IACM Expressions

Published by
The International Association for Computational Mechanics (IACM)

Editorial Address
IACM Secretariat, Edificio C1, Campus Norte UPC, Gran Capitán s/n, 08034 Barcelona, Spain. Tel: (34) 93 - 401 6039, Fax: (34) 93 - 401 6517, Email: iacm@etseccpb.upc.es
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Front Cover
Why the Supersonic Car Didn´t Fly, K. Morgan, O.Hassan and N. Weatherill. Pages 14 - 18, Figures 1 and 5

contents

On the Threshold of the 21st Century
2 *Thoughts from O.C. Zienkiewicz*
4 *Thoughts from T.J.R. Hughes*
6 *Thoughts from R.L. Taylor*

8 Advances in Computational Mechanics Software with Diffpak as the Example
H.P. Langtangen

13 In Memory of Prof. John Martin

14 Why the Supersonic Car Didn´t Fly
K. Morgan, O. Hassan and N. Weatherill

20 Global Ozone Monitoring - a Multidisciplinary Mechanical Analysis
T. Rolvag, T.A. Svidal and B. Haugen

25 USACM News
United States Association for Computational Mechanics

28 Conference Debrief - ECCM´99

30 Conference Debrief - 2nd International Workshop on the Trefftz Method

32 IACM Special Interest Conferences

33 Book Report

34 Conference Notices

36 SEMNI - The Spanish Society for Numerical Methods in Engineering

37 IACM News

38 Conference Diary Planner

editorial

Who are we?

The IACM was established nearly twenty years ago by an international group of scholars and practitioners to promote, coordinate and organize activities in the field of Computational Mechanics. It is primarily an organization consisting of national and regional member organizations. Currently, 21 such organizations representing 34 countries are Affiliated Members of IACM. These organizations remain independent of IACM with their own governance and local activities but cooperate with IACM for the common good.

The IACM supports and promotes courses, workshops, Special Interest Conferences, and national and regional congresses. It also organizes the World Congress on Computational Mechanics. The last World Congress was held in Buenos Aires in the summer of 1998. The next World Congress will be held in 2002 in Vienna, Austria.

The IACM also recognizes contributions to the field through awards, such as the Congress Medal (the Gauss-Newton Award), the IACM Award, the Computational Mechanics Award, the Award for Young Investigators, and the Fellows Award.

News of the IACM and its member societies is published here, in IACM Expressions. All individual members of IACM and members of affiliated societies receive Expressions.

The IACM serves as a voice and advocate for Computational Mechanics in the international community. Relationships have been established with other organizations which have Computational Mechanics involvement. For example, IACM is an Affiliated Member of the International Union of Theoretical and Applied Mechanics (IUTAM).

Thomas J. R. Hughes

On the threshold of the 21st century

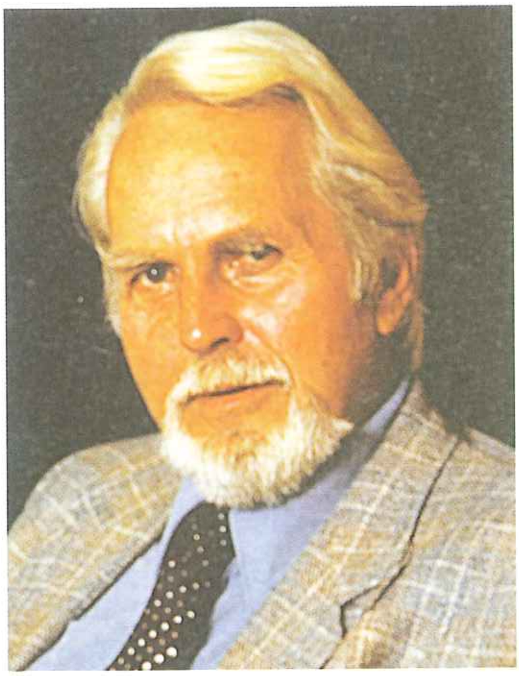
thoughts from O.C. Zienkiewicz

"... the subject of space sub-division into elements must be further developed."

The subject of computational mechanics or perhaps more generally the subject of obtaining useful numerical results to physical problems of science and engineering posed by appropriate differential equations is the creation of the present century. In the 19th century the foundations of mechanics, behaviour of solid material and that of fluids in motion and also of electro magnetics had been laid. The fundamental equations were established but their analytical solution were only possible for very simple cases. Such solutions could at best provide only a guide to describe behaviour of man made art effects. However, more was needed and numerical solutions for problems well beyond those which were capable of analytical treatment was necessary. Here I believe the first work of significance was that of L.F. Richardson who in 1910 published an analysis of a gravity dam using the finite difference approximation and solving a small number (250) of discrete equations in the finite difference manner.

The first part of the century was marked by many theoretical developments which were subsequently to shape our present knowledge and which contributed to much successes we have today. The work of Ritz, of Galerkin, of Trefftz are just a few achievements which come immediately to mind. However, of great importance and of fundamental significance to me was the work of Richard Southwell. In the very early thirties he established the fundamentals of stiffness analysis using here a direct approach much hailed by engineers some twenty years later. Further, he introduced an efficient iterative process which he named "the systematic relaxation of constraints". A few years later he realised that the structural problem was completely analogous to that posed by the finite difference approximation to discrete equations and therefore he entered that arena solving many problems of engineering interest in a practical way. The problems on which he worked initially were often surrounded in secrecy because these were tackled in the early years of the war and an axisymmertic tube under pressure load could well become a barrel of a gun. For this reason many of his achievements were held secret in the private proceedings of the Royal Society which were not publicly available until the war was ended. Some years later he published two books dealing with such applications.

Prof. Olgierd C. Zienkiewicz



It was my good fortune to join Southwell's team at that time and to start working with him in 1943 for a doctoral degree which I achieved in 1945 almost simultaneously with the end of the war. It seems to me that Southwell's work presented the essentials of the finite element process. He realised that the approximate components of finite difference equations could always be interpreted as the properties of structural members with particular stiffnesses. Indeed such approximation to elastic continua had been made almost at the same time independently in the United States by Hrenikoff and McHenry who presented the so called frame and lattice analogies to the elastic continuum respectively.

It was some ten years later that Turner together with Clough and Martin produced the idea of approximating directly the elastic continuum. Indeed some more years passed before the link between such an approximation and various general approximation methods such as Ritz and Galerkin were available.

However, it was Southwell and his team that produced the first significant numerical answers and I feel that his contribution has been somewhat forgotten internationally.

To some extent it was the computer which was responsible for the demise of relaxation methods. Such methods when used by an intelligent human being could assess the maximum residual much more rapidly. This was impossible for any computer at that time available. However, in the context of finite differences the form of equations was always identical being derived from a regular mesh. For this reason such equations could be held in the users head rather than consulted from the machine storage and thus quite large problems with numbers of variables approaching one thousand could be solved manually. It was many years before the computers were developed to deal with such large systems.

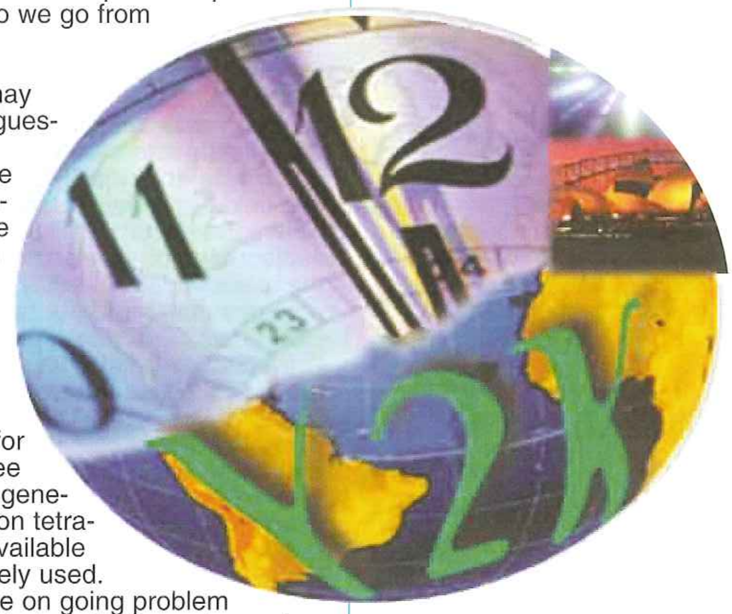
I believe however that the most important contribution of Southwell is that of his realisation that the finite difference approximation is almost identical to the structural stiffness process. This permits not only the satisfaction of the computational method but also a deeper understanding of the solution process.

The work of Southwell was propagated throughout the world by many of his disciples including Leslie Fox, Deryck Allen, Shaw in Australia and others including myself.

The development of the finite element method in which continua could be divided into irregular shapes was clearly a major step forward. This coupled with the very rapid development of the computer allowed the method to became the major one in the field of numerical analysis from 1960 onwards. I shall not discuss here the major steps which have been taken to develop the subject to its most economical present form. The question I would like to pose is what will happen to the subject of computational mechanics in the next century and where should our research

The rapid development of computers has meant that at various stages the optimal finite element approach has changed. In the sixties the discovery and development of isoparametric, higher order, elements permitted the solution of large problems with a existing storage available at the contemporary computers of the time. Indeed the isoparametric, higher order, elements retained much of their popularity as the approximation per degree of freedom is better than with simple linear elements. However, for other reasons the return to low order elements has been made. One of the areas where this happened is that of dynamic, plastic impact analysis where explicit codes could be built on foundations of simple elements to produce accurate and answers despite a very large number of unknowns.

From the eighties onwards similar approaches have dominated the fluid mechanics area. Here the simple element replaced, or is in the process of replacing, the finite difference approximations. Now millions of variables do not seem to present many problems due to the advances in present day computers and their parallel operation. So where do we go from here?



Perhaps I may offer a few guesses. First, it seems to me that the subject of space sub-division into elements must be further developed. Today automatic mesh generators for two and three dimensions generally based on tetrahedra are available and are widely used. However, the on going problem of division into hexahedral volume elements is yet in its rappers and no dramatic improvement has been made here lately. On the other hand, it is possible to avoid the mesh generation by use of meshless variables and simply proceed with analysis by automatically distributing some approximation points through out the volume of the object being analysed in a manner which will ensure the optimal results. Much work on this has been done or is on going and I believe that in the near future we shall see dramatic changes in the design of such methods.

There are many areas today where active work is being pursued. Conferences in which rather abtuse keywords such as "domain decomposition, stabilization, discontinuous Galerkin" appear to be a matter of daily occurrence. I will not predict which one of these will become a world winner. However, it is absolutely essential that the fundamental work in numerical analysis should continue as in the future more applications through digital means must be made and I wish all success to researchers in presenting the new directions which will become a fundamental importance. ●

by
Olgierd C. Zienkiewicz
University of Wales, Swansea
Wales
Extracts from his opening speech ECCM Conference, Munich, September 1999

*Man is flying too fast for a world that is round.
Soon he will catch up with himself in a great rear-end collision and Man will never know that what hit him from behind was Man.*
James Thurber

Once a man would spend a week patiently waiting if he missed a stage coach, but now he rages if he misses the first section of a revolving door.
Simeon Strunsky

On the threshold of the 21st century

thoughts from T.J.R. Hughes

"The past is a bucket of ashes, so live not in your yesterdays, nor just for tomorrow, but in the here and now. Keep moving and forget the post-mortems. And remember, no one can get the jump on the future."
Carl Sandburg

There is right now tremendous international interest in the area of "bioengineering," the union of engineering methodology and biological processes. This turns out to be a very broad field and my particular interest in it is in the sub-field of cardiovascular mechanics. Although I did my Ph.D. thesis on the subject of arterial pulse propagation in the major vessels, I never pursued research in the field subsequently until Dr. Christopher Zarins joined Stanford University as Chief of Vascular Surgery a few years ago. When I finished my thesis 25 years ago I felt that the type of analytical and computational research that I had achieved expertise in was not capable of making a significant impact on thepractice of vascular medicine. Surgeons at the time were simply not technologically oriented and thus not interested. In some sense computational technology was too advanced for practical consumption but in some other ways it was too primitive. For example, there was no computer visualization technology at the time and the results of simulation could not be realistically seen and thus not appreciated. When I first met Chris I wanted to show him something that indicated how we might be able to exploit computational mechanics on problems of blood flow, but what I had to show was primarily examples of trains, planes and automobiles. They were impressive but unrelated. The nearest thing to a blood vessel calculation I had was a simple simulation of a garden hose problem in which the hose was oscillating back and forth and water was squirting out of one end. I was not too proud of this simulation but it was the best I could come up with on short notice. I showed an animation of the results to Chris and he said to me "This technology is going to revolutionize vascular surgery." I remember thinking that this was a man with a vision and I knew at that instant that the time was now right. This experience also demonstrated that interactive, three-dimensional visualization was a key technology in communicating the results of computer simulation. This is just one of many computer technologies that will play major roles in bioengineering.

Book on the heart and blood circulation by William Harvey


EXERCITATIO
ANATOMICA DE
MOTV CORDIS ET SANGVINIS IN ANIMALIBVS,
GVILIELMI HARVEI ANGLI,
Medici Regii, & Professoris Anatomiæ in Collegio Medicorum Londinensi.

FRANCOFVRTI,
Sumptibus GVILIELMI FITZERI.
ANNO M. DC. XXVIII.

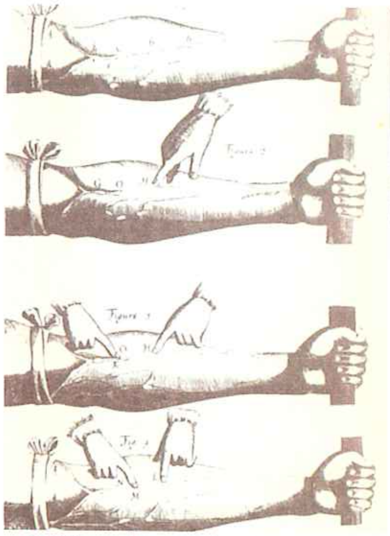
Major advances in fields usually occur because something simple but profoundly important occurs. What is happening in bioengineering that makes the time right now for an explosion of important advances? I have asked this question to many ardent supporters of bioengineering but I have not come away with a belief that many really know why it is all about to happen. I believe my colleague Charles Taylor, the Director of the Vascular Research Laboratory, has discovered the answer.

Charley is an expert on numerous technologies that are important constituents in solving problems of cardiovascular mechanics. Charley was the first to calculate the blood flow in an anatomic model of a real person. He has done many calculations of blood flow in models of his own anatomy. The source of these models is medical imaging data obtained from magnetic resonance imaging (MRI), computerized axial tomography (CAT scan), and ultrasound. Most of us have had direct experience with one or more of these technologies. It turns out that medical imaging data can be converted to geometrical data from which mathematical models can be built. This is a completely new use of medical imaging data. There are a number of technologies involved in the process but it is the end result that has significant consequences. Each individual patient's anatomy can be converted to a mathematical model for the analysis of disease and the planning of medical interventions. The type of design optimization that is done in engineering can now, in principle, be done in planning surgery, for example. This would represent a shift in medicine from the traditional diagnostic paradigm to a predictive one. Charley, Chris and I are currently implementing this vision in a web-based surgical planning system.

Such a system will typify the changes that are about to take place in medicine. The simple reason these changes are about to happen now is the availability of individual patients' anatomic and physiologic data and the ability to convert them to a model with predictive capabilities. Physics, chemistry, biology, mathematics and mechanics can all be built into the computational model. This represents a union of these disciplines with the exact anatomy and physiology of each patient. It represents a profound coming together of two previously distinct worlds and the possibilities are truly mind-boggling. We are headed towards a future in which our entire beings will be computerized for medical purposes. Eventually we may be as aware of how we look and function on the inside as on the outside! It does not take too much imagination to realize that this will bring about advances in the ability to provide quality medical care. Contrast this vision to what is currently available, typically a hanging file in a physician's office containing some hand written notes.

When new sources of extracting data are discovered, it usually presages periods of scientific advances. Think of how the telescope and microscope have changed the world. Medical imaging is the window into human biology.

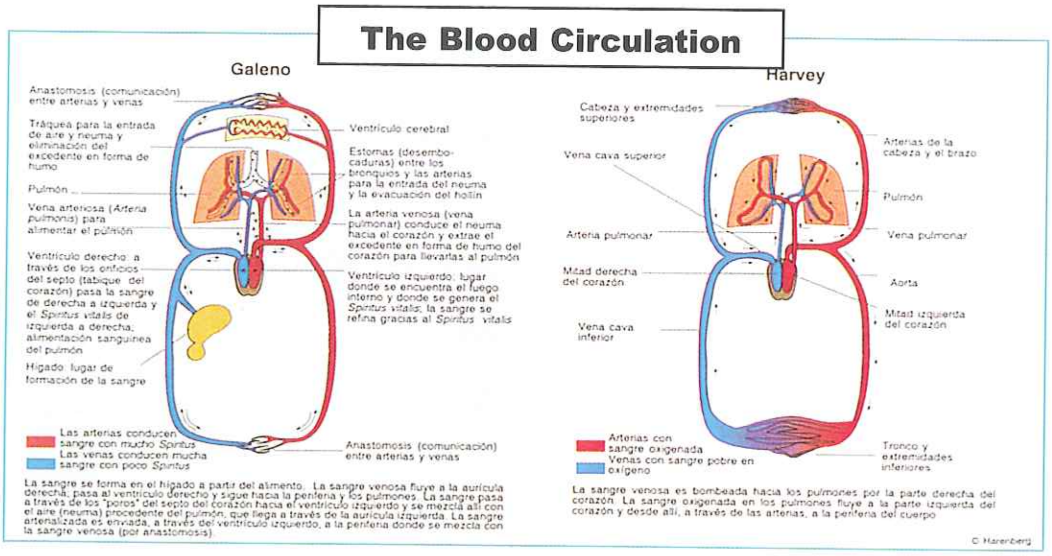
Last spring semester I held the Cattedra Galileiana, a visiting chair in honour of Galileo, at the Scuola Normale Superiore in Pisa. During my time in Italy I visited places where Galileo had been active. One such location was the University of Padua, where Galileo taught for many years. My hosts, Professors Maria Morandi Cecchi and Bernhard Schreffler, arranged for me to present a lecture in the Palazzo Bo where one can see, among other things, Galileo's lecturn, and the anatomical theatre that Fabrici d'Aquapendente constructed in 1595. (Fabrici was also Galileo's personal physician.) This theatre allowed up to 300 students to observe dissections. Anatomical studies of this kind were revolutionary and even illegal, but provided the faculty and students of the University with an enormous source of data. William Harvey, an Englishman, who is credited with the discovery of the circulation of blood, studied at Padua in 1598, states in the introduction to his De Motu, "I do not profess to learn and teach Anatomy from the axioms of the Philosophers, but from Dissections and the Fabric of Nature." Harvey clearly benefited from the anatomical research at Padua that enabled him to see how the heart, arteries and veins actually worked. However, he could not see how the venous side of the circulation was connected to the arterial side through the capillaries because the capillaries are too small to be seen with the naked eye or magnifying glass, and he did not have the benefit of a microscope. For the completion of the circulation system he relied on reasoning and analysis. It parallels what I see to be the opportunity today. We are now the beneficiaries of an enormous source of medical imaging data. Combining what we can now see with our ability to reason and analyze, I believe that a future of exciting discoveries awaits. ●



William Harvey´s demonstration on blood flowing in veins, on which he based his theory of circulation

" I do not feel obliged that the same God who has endowed us with sense, reason and intellect has intended us to forgo their use. "
Galileo Galilei

by
Thomas J.R. Hughes
President, IACM



On the threshold of the 21st century

thoughts from **R.L. Taylor**

" ... there is no greater joy than the successful completion of a task which involves the marriage of solid mechanics, development of an appropriate finite element theory, coding and testing an implementation, and - finally - performing a viable first analysis."

As we enter the year 2000 and the new millennium it provides a time to reflect on some activities related to computational mechanics I have enjoyed during the last forty-two years. In this article my reflection is based mostly on work related to the analysis of nearly incompressible solids.

My introduction to the finite element method occurred during my student days at the University of California. In a 1958 course offered by Ray W. Clough I was introduced to the use of 3-noded triangular elements for elastic plane stress analysis -- this was 2 years before Ray devised the now internationally famous name 'finite element method'. My own research in the field started in the mid 1960's in collaboration with Karl Pister. We were attempting to estimate interactions between solid propellants and rocket motor cases using displacement based finite element analysis programs and soon encountered difficulties in solving nearly incompressible linear elastic models of the propellant. Eventually, we devised a 'solution' to the problem by implementing the variational method proposed by *Herrmann*. [Ref.. 1 & 2]. Our first successful element was a composite quadrilateral composed of four linear displacement triangles with a constant 'pressure'. Later the composite element was replaced by an isoparametric 4-noded quadrilateral interpolation (now often referred as the Q1-P0 element).

In the late 1960's we extended our implementation to perform thermo-mechanical analysis by assuming a `thermo-rheologically simple´ viscoelastic behavior. [Ref. 3] This class of problems also exhibits near incompressible behavior for long time simulations under constant loadings. By this time I believed that difficulties related to nearly incompressible analyses by finite element methods were solved! Later I discovered the folly of this belief and to this day I find that difficulties still persist for some element classes.

In 1968 on an airplane trip to Dayton, Ohio, Ray Clough introduced me to Olek Zienkiewicz. Through this meeting I spent my 1969-70 sabbatical leave at Swansea during which a close friendship and continued scientific interaction with Olek developed. In this period we discovered the benefits of reduced integration to improve behavior of finite element solutions for problems with constraints. Also, in a series of papers related to the patch test we achieved what we believe to be the requirements for mixed elements to possess in order to effectively and accurately treat nearly incompressible problems.

Much of this work is summarized in the 4th edition of our co-authored finite element book [Ref. 4] and more will appear in the 5th edition to be published during this millennium year 2000.

Olek Zienkiewicz, Ed Owen, Bob Taylor and Tom Hughes (1971)

Upon returning from my second sabbatical to Swansea in 1984 I entered into another collaboration which also changed my perspective and knowledge about finite element methods. The late Juan Carlos Simo had arrived in Berkeley shortly before to pursue his doctoral studies. Our initial research interaction involved work on the return mapping algorithm for implicit finite element plasticity calculations [Ref. 5 & 6] -- another area requiring solution of nearly incompressible problems. Indeed, the joy of achieving 'quadratic convergence' was born! We also collaborated on the development of solution methods and elements for large deformation, elastomeric problems where Juan's magic in computing tangent operators for complex expressions was demonstrated [Ref. 6].

Tom Hughes, Bob Taylor and Ted Belytschko (1971)

After Juan's untimely death in 1994 and my retirement from regular university duties my life entered another new phase. During the last five years I have enjoyed extended visits to Barcelona, Spain, and the interaction with Eugenio Oñate and his colleagues. Indeed, through the vitality and activities of this group I am reminded of my early years at Berkeley where the same type of 'camaraderie' existed. In recent visits to Spain I have again been exposed to the need for elements to treat the nearly incompressible problem -- this time it is for triangular and tetrahedral elements for use with the automatic mesh generators found in typical finite element solution environment [Ref. 8]. Here, the many contributions from mathematics and fluid mechanics provide a starting point for developing such elements. While some progress has resulted from my initial investigations even more questions arise, thus, providing some initial focus for study in the first year of the new millennium.

It is through my interaction with many colleagues during the last four decades that the seeds of knowledge were sown and nurtured. I certainly owe a debt of gratitude to all those who have contributed to my deeper understanding of finite element methods and the field of computational mechanics. To me there is no greater joy than the successful completion of a task which involves the marriage of solid mechanics, development of an appropriate finite element theory, coding and testing an implementation, and - finally - performing a viable first analysis.

As the year 2000 starts I expect to see the same sustained progress in solving problems by computational means as I have observed in past decades. Computers will continue to become bigger, faster, and cheaper to assist in increased activities involving interaction between fields of physical behavior. The many new contributions to the field I have observed at the recent IACM Congress in Buenos Aires, USCM meeting in Boulder, and ECCM99 in Munich are solid examples of growth in the field and I fully expect them to continue during the next forty years - hopefully, I will be able to continue to learn from my associations with others for most of these years! ●

by
Robert L. Taylor
Berkeley, California

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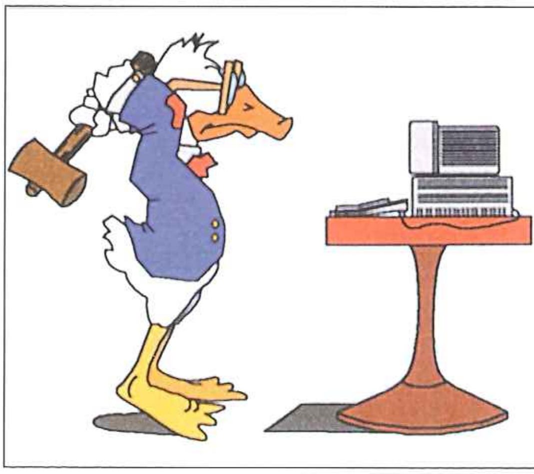

"I´m looking forward to this Y2K thing. I have found a perfect excuse for everything that goes wrong around here."

Advances in Computational Mechanics Software with Diffpack as the Example

by
Hans Peter Langtangen
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Norway

" Building software for models ... is a very complicated and time-consuming process. "

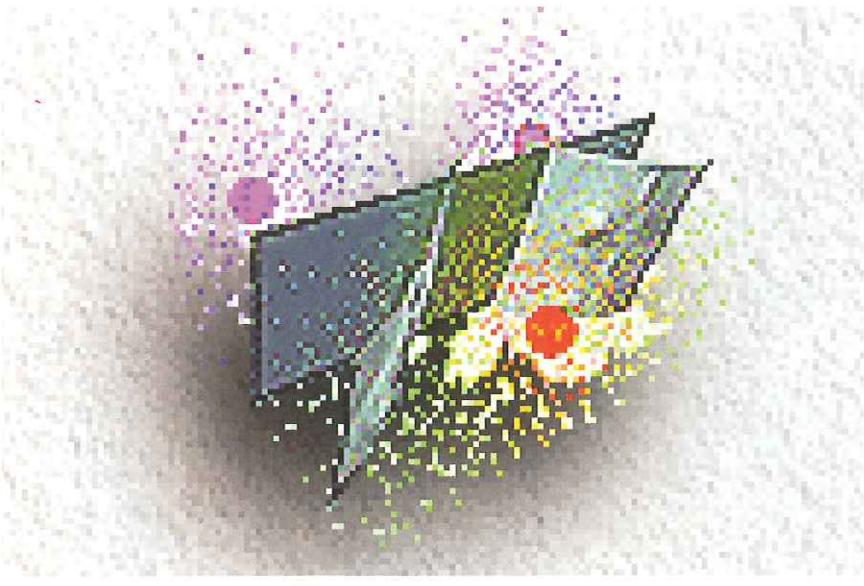
Many scientists and practitioners have experienced that software development and maintanence tools represent a more limiting factor for rapid progress of computational mechanics than more effective numerical methods and hardware, which traditionally have been the topics of greatest interest in research. Metal processing is an example where the models involve large systems of partial differential equations (PDEs), describing flow, deformation, heat transfer, and phase changes of a multi-component mixture, coupled through numerous constitutive relations. The whole model might also be embedded in a framework for optimal design of the process (see [9] and [10]). Building software for models of this complexity is a very complicated and time-consuming process.

Traditionally, computational mechanics software has been tailored to a specific application domain. From a mathematical and numerical point of view, however, widely different physical applications may lead to the same set of program statements. Hence, code reuse is strongly motivated by the mathematics, at least conceptually. The mentioned example from metal processing illustrates the point: The models for fluid flow, solid deformation, and heat transfer appear in many other contexts, and duplicates of the numerics for the involved equations are scattered all over numerous CFD and structural analysis codes. Ideally, the implementation of the metal processing simulator should be a high-level plug-and-play operation with existing modules for flow, deformation, and heat transfer, and a new module containing the constitutive relations specific to the current physical problem. In practice, code reuse is not that easily accomplished. We lack widespread use of software constructs and programming standards that encourage the necessary modularity for code reuse. Also, many practitioners in computational mechanics are not aware of the extensive development of new programming styles and software tools during the last decade. The purpose of this article is to highlight what can be achieved by adopting new programming languages and software development techniques. In particular, we shall report experiences with the development framework Diffpack, provided by Numerical Objects (www.nobjects.com), which has been used to build, among other things, a complicated metal processing simulator in the advantageous way we outlined above [7,9,10].

Flexibility is another key factor for successful application of numerical simulations; different models and solution methods need to be compared to increase the reliability of the computations. This means that computational mechanics software should ideally offer a wide range of numerical approaches and enable the user to customize the model by adding or removing terms and equations at run time. Such flexible combination of software modules requires a high degree of modularity and sophisticated selection mechanisms; direct implementation of this functionality in plain Fortran 77 might end up as an impossible task for a human.

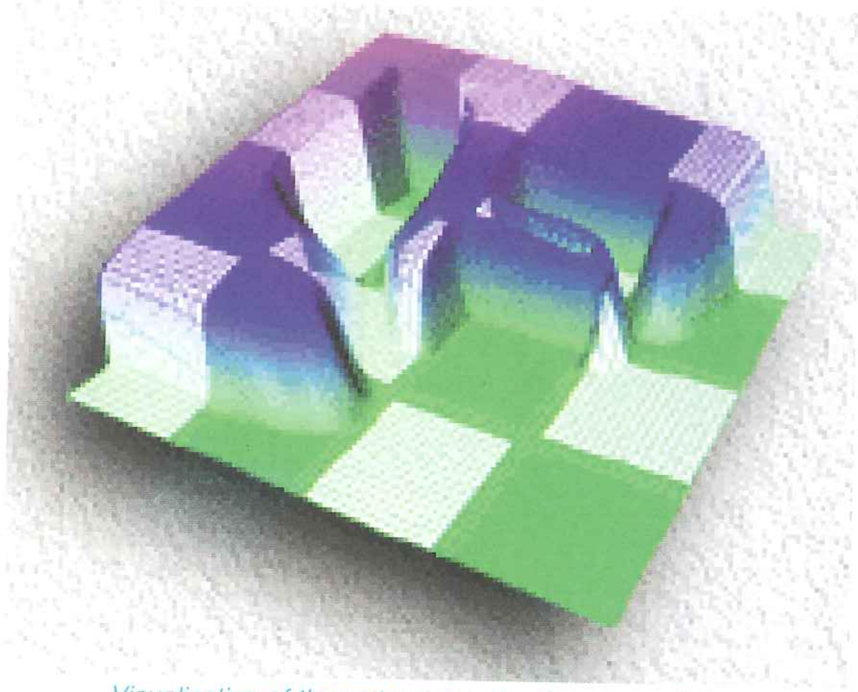
The request for flexibility, modularity, and code reuse are major issues in non-numerical computing as well. There, new programming methodolgies and supporting languages have been central in accomplishing the mentioned demands. PC software relies today heavily on object-oriented programming and is implemented mostly in C++ and Java. The use of these languages and new programming paradigms, such as object-oriented programming and template (generic) programming, has attracted an increasing interest in scientific computing during the nineties. Migration of techniques from computer science to scientific computing must be done with great care, as the software constructs and tools from computer science

Visualization of an adaptive mesh computation in 3D



might not be compatible with the strong computational efficiency requirements in scientific computing. "Efficiency" has, however, many aspects. Optimal combination of human efficiency and number crunching efficiency is probably one of the aims of computational mechanics software.

Numerous packages for numerical simulation, employing new implementation technologies, have appeared during the last decade, and programming with objects in C++, Java, and Fortran 90 has received quite some attention at conferences. The references [1,5,7,8] provide a glimpse of various activities. Without doubt, programming with objects has proved to be productivity enhancing and is now successfully established also in the scientific computing community. Along with this development, many universities apply Java as the introductory programming language, a fact that will make widespread future demand for object-oriented software in science and engineering.



Visualization of the water saturation from a parallel two-phase flow simulation in a heterogeneous oil reservoir. The solvers employ finite elements for the pressure equation and higher-order finite difference schemes for the saturation equation. Parallellization is accomplished by a domain decomposition technique, where the checkerboard pattern of domains are visible in the figure.

Diffpack

Diffpack [4,6] was started as a research project in the beginning of the nineties, focusing on applying object-oriented programming and the C++ language to develop flexible, modular, and resuable software components for solving PDEs. Through the years, Diffpack has evolved into a flexible programming environment for PDE solvers and has been applied worldwide in diverse application areas, ranging from fluid and solid mechanics to finance and medicine.

The underlying idea of the design of Diffpack is that different applications share a common mathematical and numerical structure. This common structure can be implemented in a software kernel, with "slots" for problem - dependent information. To create an application code, the programmer implements only the problem-dependent information and relies on the kernel for the numerics that can be shared among applications. The result of such an approach is two-fold: the development time of application codes is significantly reduced, and the reliability is increased by utilizing general components that are well tested in many other applications. The disadvantage is that leaving as much numerics to general libraries as possible might reduce the flexibility of the implementation and, e.g., the ability to utilize special structures of the problem for code optimization. Our answer is to provide a layered design, where the bottom layer of the package contains pure C (or Fortran) array manipulations to ensure high computational efficiency, the next layers add abstractions and convenient programming interfaces, and the very top layer merely combines PDE solvers and constitutive models into new systems of PDEs. Rapid prototyping utilizes the most abstract layers, while fine-tuning of the code is enabled by operating directly at the desired lower-layer objects. More specific information about the design of Diffpack can be found in [2,3,6].

Programming with objects

Objects contain data and functions operating on the data. A matrix is a simple example. A matrix object typically contains a memory segment holding the matrix entries, integers for the number of rows and columns, and various functions for extracting entries, multiplying matrices with vector objects and other matrix operations from linear algebra. The implementation of an object is in C++ and Java made in terms of a class, while in Fortran 90 the equivalent concept is a module.

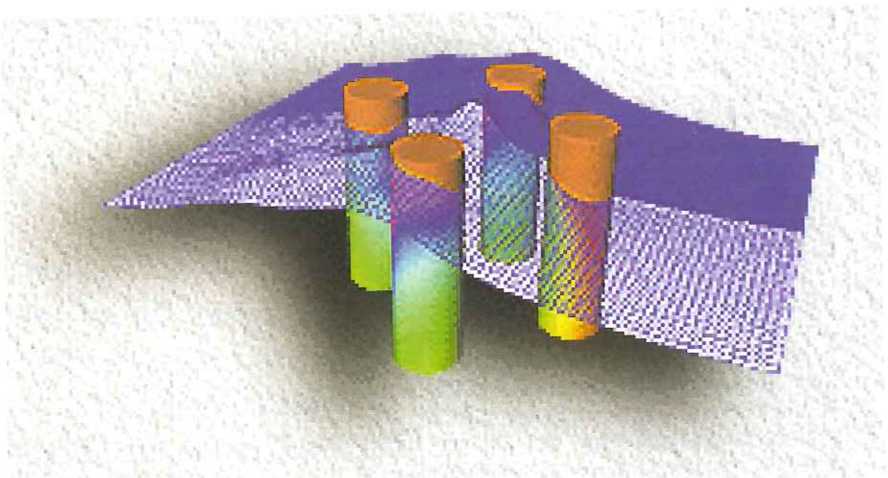
In the PDE world, many matrix formats exists and must be available to the user of a simulation package, preferably in a transparent way. Each matrix format can be represented as a class. All matrix classes should hide their internal representation of the matrix data and only show a common set of operations on matrix objects for public use. One can then collect the matrix classes in a class hierarchy, with an "abstract" generic matrix class as parent for all the format-specific classes. This generic parent class, often called base class or super class, contains no data; it just specifies a common interface to all matrix objects.The point of object-oriented programming is to program only in terms of the base class. This hides all the intricate details of sparse matrix storage schemes and the bunch of arrays that frequently pollute Fortran 77 codes when calling, e.g., linear system solver routines. nstead, the matrix appears as a single base class object.The magic of object-oriented programming is that the compiler generates information such that the computer keeps track, at run time, of which matrix format is hidden under the name of a base class; the programmer never needs to know whether the base class matrix actually is a banded or a diagonal matrix.In case it is a diagonal matrix, launching a matrix-vector product will automatically lead to a transparent call to the tailored matrix-vector product implementation in the diagonal matrix class. Optimal efficiency is hence not disturbed by programming with base classes.

"... what can be achieved by adopting new programming languages and software development techniques."

" ... different models and solution methods need to be compared to increase the reliability of the computations."

A similar approach can be used to make class hierarchies for different vector formats, linear system solvers, preconditioners, solvers for nonlinear algebraic systems, and so on. Throughout the code that applies solvers and preconditioners, one can only see track of the base class, not storage structures or algorithmic details of the individual numerical strategies. Adding a new preconditioner does not affect any linear solver and vica versa. With just a recompilation, the code calling linear solvers with immediately work with the new methods. Such mechanisms contribute to modularity and extensibility, as well as flexibility in combining different numerical approaches.

Grids constitute another example on the usefulness of object-oriented programming. The Diffpack finite element engine was implemented using a plain grid class. Some years later, different types of adaptive grid classes, enabling local mesh refinements, were added to the libraries. With a couple of new functions in the interface of the original grid class, this class could act as a base class for the adaptive grid classes. In practice, it meant that all the existing library code and applications (after a recompilation) immediately worked with any of the new adaptive grid classes.



Simulation of water surface waves in the vicinity of an oil platform. Diffpak is used here as a part of a simulator based on spline-descretization of the equations of full 3D nonlinear potential theory.

The application code is also programmed as a class, which merely collects objects for grids, fields over grids, linear systems and solvers together with problem-dependent information about the PDEs being solved. In a finite element application, the programmer's work is limited to implementing input for physical parameters in the problem, a function for setting essential boundary conditions, and a function for sampling the integrands in the variational formulation. If the programmer wants more control, e.g. avoiding numerical integration and providing a problem-dependent preconditioner, this is straightforward. PDE solver classes can be combined to solve systems of PDEs or embedded in algorithms for optimization of design or process features. The bottom line is that objects let you build with bricks and walls instead of gluing matches.

When all parts of a package is built on object-oriented concepts, one obtains a high degree of flexibility with respect to adding new functionality and combining numerical approaches and mathematical models. Put in another way, the functionality of the package grows exponentially as new modules are incorporated.

Support for parallel computing, domain decomposition, generic multigrid modules, and mixed finite elements have been successfully incorporated as add-on modules to the Diffpack libraries (though sometimes with small adjustments in minor parts of the libraries). It sounds reasonable that such fundamental numerical approaches would require careful consideration in the design phase of a generic package like Diffpack.

Nevertheless, our experience shows that a clean design in terms of classes and class hierarchies provides the necessary modularity for allowing easy integration of new modules into an existing library. More importantly, existing applications can with the order of 10 lines of code utilize adaptivity, or multigrid, or parallel computing, or a combination of all.

We remark that the way we use object-oriented programming in Diffpack is currently supported by C++ and Java, but unfortunately not by Fortran 90/95.

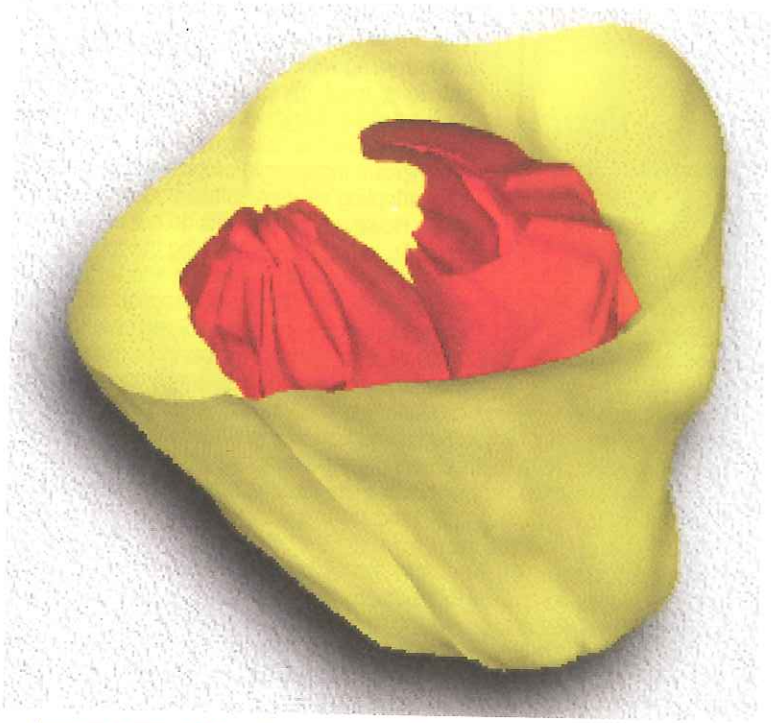
What has Diffpack been used for?

The basic idea of Diffpack, namely that one can provide a generic library and create small-size application codes to solve a wide range of PDE problems, is by now clearly demonstrated. Some examples on existing Diffpack simulators cover

- the equations of applied mathematics (Poisson, heat, and wave equations),
- transient thermo-elasticity,
- several types of Navier-Stokes solvers,
- large-strain elasto-plasticity for metal forming,
- optimization and design of metal forming processes,
- multi-phase porous media flow,
- stochastic groundwater flow,
- fluid-structure interactions,
- flow processes with melting and solidification,
- thermal injection molding processes with free surfaces,
- fully 3D nonlinear potential theory for water waves,
- Boussinesq models for tsunami propagation, option price modeling,
- the electrical activity in the heart.

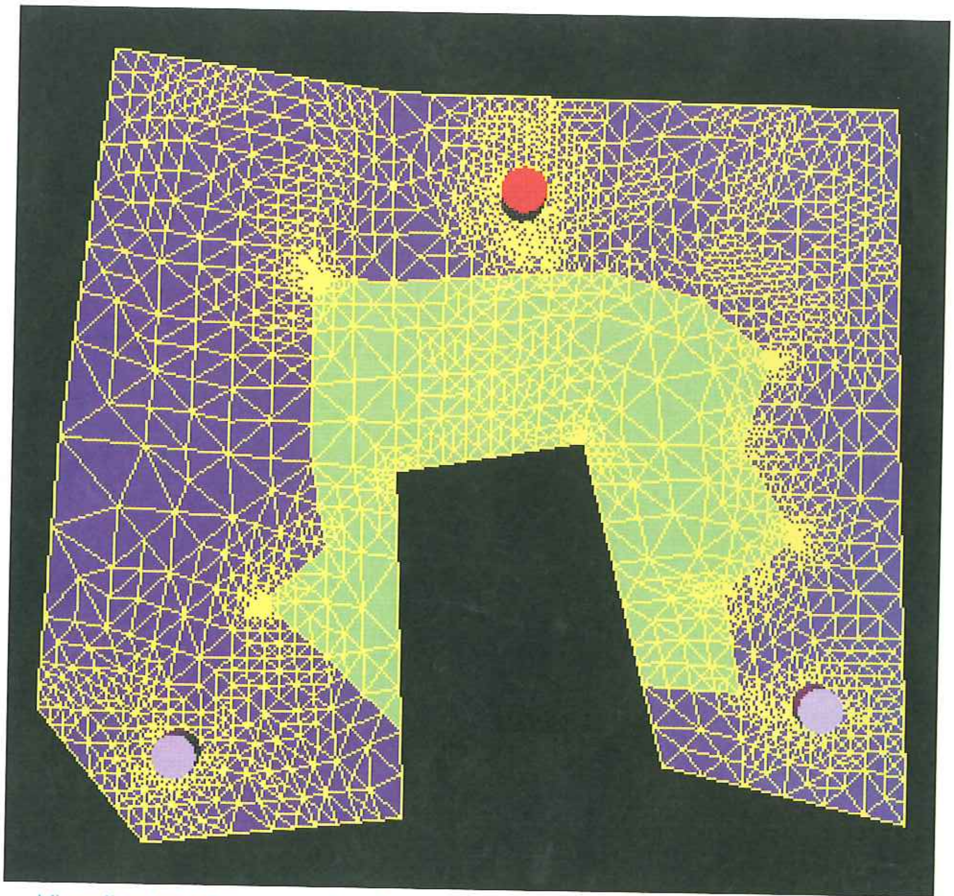
Many of the mentioned simulators employ adaptivity, parallel computing, multigrid, and problem-dependent optimizations. As one can see from the list, the application of Diffpack to computational mechanics is extensive and will probably increase significantly when support for advanced numerical methods migrate from the research level to the commercial Diffpack distribution.

The real advances in computational mechanics software must also incorporate full problem solving environments, with advanced easy-to-use graphical interfaces to grid generation, problem definition, simulation, visualization, and report generation. Diffpack's focus is on being a flexible, high-quality numerical engine in such problem solving environments. Grid generation and visualization are therefore not part of Diffpack, although the package comes with simple tools for this purpose to get started smoothly. The Diffpack distribution provides an extensive set of interfaces to preprocessors and visualization software for professional use. Diffpack has various types of user interfaces: a command-line mode, a file mode, and a GUI. The Windows version has a full-fledge graphical working environment that integrates visualization by Vtk. These environments are tailored to programmers and researchers, not end-users of industrial applications. The main source for learning Diffpack and its view on numerics and applications is the book [6], see www.nobjects.com/Book. Associated with the book is a CD-ROM containing a test version of Diffpack along with all the sample applications from the book. The examples cover heat transfer, wave phenomena, thermo-elasticity, elasto-viscoplasticity, and viscous fluid flow, whereas the numerics concentrates on finite element methods, finite difference schemes, and iterative methods for linear systems, exposed in a form that maps conveniently over to Diffpack code.



Isosurfaces of the electric potential in the cardiac muscle and the surrounding tissue, computed by a model involving a reaction-diffusion equation, an elliptic equation, and a large number of ODE´s for various state variables. The purpose of the modelling is to find better quantitive measurement methods for myocardial infarction and ischemia.

Computational efficiency is a major issue when prototype solvers from research are to be migrated to industrial codes, and the use of C++ could in this regard be of concern. C++ certainly gives lots of tools for creating very inefficient numerical code, but it also gives you some tools to beat Fortran 77 efficiency [7, ch. 2]. Our experience is that a careful use of C++, with as much number crunching as possible in lower layers, using only "do-loops" and plain arrays, combined with object -orientation for administering the program flow in higher layers, results in code that comes close to Fortran 77 on benchmarks. While Diffpack codes have a high degree of built-in flexibility, e.g. finite element codes work with all kinds of elements in 1D, 2D, or 3D, benchmarking often involves tailored Fortran codes with lots of hand optimizations. The structure of the general Diffpack code enables a programmer to add optimized code in an afternoon which limits the flexibility and takes advantage of special structures in the problem and special choices of elements. Again, object-oriented programming is a key technology for going from a general to a specialized/optimized application code in a clean and fast way and for letting the two versions of the code exist side by side, sharing everything that is in common.



Visualization of a geometry of a porus media flow application, utilizing adaptive finite elements, error estimation, multigrid, and parallel computing. The discs represent wells (singularities), while the blue and green areas are regions with different permeability.

> *" ... flexible combination of software modules requires a high degree of modularity and sophisticated selection mechanisms, ... "*

Concluding remarks

This article has focused on the advantage of programming with objects when developing computational mechanics software, referring to Diffpack as a real-world example. Without doubt, the author and his colleagues have experienced a significant increase in programming effectivity after adopting modern software tools and techniques. However, the benefits do not come for free. An investment in learning the tools is necessary, likewise an interest and taste for generalizations. It might well happen that the major breakthrough from applying new productivity-enhancing software tools in computational mechanics must wait until a new generation of code writers is educated. A more offensive development of the field requires the experienced people of today to spend more time on monitoring the rapid evolvement of programming tools and techniques. ●

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In Memory of
Prof. John Martin
17 October 1999

John Martin would have been profoundly embarrassed by this gathering.

The thought that so many of us would have given of our time to come here, and to reflect on his life and death, would have perplexed him. John Martin shunned attention, and never seemed to understand what people were on about when they extolled his many talents and virtues.

As a recent example of this exasperating modesty of the man, let me relate to you something that occurred shortly before John was to receive an honourary doctorate from UCT in June of this year. I had been asked to deliver the citation. John called me to say that he really could not understand why he was to receive the degree, but since there was nothing he could do about it, could I please keep my citation as simple as possible. All the while he apologised for having, in his words, the presumption to meddle in this way. I listened, and considered that I always heeded his advice, and bowed to his superior wisdom - and then, for once, totally ignored his plea.

I knew John Martin for 26 years. He was my teacher, my mentor, and an inspirational research leader and collaborator. As I entered the new, and at times scary world, of Deanship he was on hand again to guide, in his inimitably subtle and gentle way. John Martin was a caring and immensely generous individual, as many of his colleagues and former students will attest.

In the little time I have had to reflect on the life of John Martin, since receiving the news of his death yesterday, a host of images and memories have come flooding back: of the great fun we had in the early days as the research group which he founded took shape; of the spirited discussions in the group, in which staff and students participated - he certainly knew how to turn one on to research. I recall his striking intellectual courage in successfully tackling research problems that many an expert would have found too daunting. His magisterial contributions assured him, a long time ago, a place in the pantheon of the great mechanicians. I have been reflecting also on John Martin's inexorable rise: to Dean, and then to Deputy Vice-Chancellor; and on the elegance and distinction which he brought to every office he held.

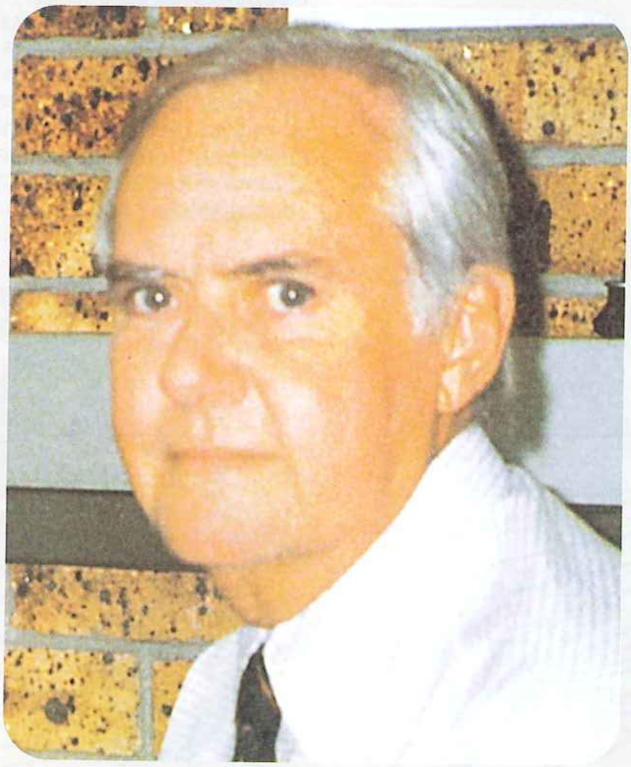
Just two years ago John Martin celebrated his 60th birthday. Eager colleagues and former students responded with enthusiasm to invitations to contribute to his Festschrift. Many also responded with letters to John, which would have left him in no doubt as to the fondness and esteem in which he was held. I have not had the time yet to pass on to some of these friends, in all parts of the world, the very sad news of his death.

We at UCT have been so blessed to have have had the privilege of being able to rub shoulders with a teacher and colleague of the calibre of John Martin for over a quarter of a century. As we come to terms with the sudden loss of this most gentle of men we would do well, I think, to reflect on the realisation that John Martin died within the precincts of the institution about which he cared so much, to which he had given so much of his life, and within which he has left a legacy of astounding proportions. He died as he would have wished, by causing the minimum of inconvenience to those around him. We mourn his passing, but at the same time we rejoice in the life and achievements of a great scholar, and a great South African.

I am sure that the entire university community would join me in extending our heartfelt sympathy to John's widow Jill, their sons Neil, Andrew and Peter, their wives and children, and to his sister Liz Harris.

A tribute to John Martin, read at the memorial gathering on October 8th, 1999

Daya Reddy
University of Cape Town
South Africa



Why the Supersonic Car Didn´t Fly

by
Kenneth Morgan, Oubay Hassan and Nigel Weatherill
University of Wales, Swansea

" The major challenge was not to design a vehicle that could attain very high speeds, but to ensure that it could do this safely. "

The first World Land Speed Record was set by Count Gaston de Chasseloup-Laubat in Achéres, France on December 12 1898. Driving an electric vehicle, he set the Record at 39 mph. Since that initial event, the Record has been broken around sixty times and some of the major milestones achieved before 1997 are noted in Table 1. Initially, electric cars dominated and it was not until 1902 that a car powered by an internal combustion engine captured the Record. The first jet powered record breaker was Donald Campbell's *BLUEBIRD* in 1964. In the 1920s, Pendine Sands in South Wales was an attractive location for record breaking. In fact, the Record was broken 5 times on Pendine Sands during this period by Malcolm Campbell and Parry Thomas. They took the Record from 146 to 175 mph. interestingly, seventy years later, Pendine was also to play a role in assisting in the successful development of the supersonic car *ThrustSSC*. The exact nature of this role will be described later in this article. The full list of record breakers is dominated by British and American drivers while France, for example, has not held the record since 1924.

Figure 1
An artist´s early impressions of ThrustSSC at speed on the Black Desert in Nevada

In a Record attempt, the recorded speed is the average speed achieved, over a measured mile, in two runs which must be made in opposite directions within a time interval of less than one hour. The vehicle must possess some basic characteristics e.g. it must have four wheels and a driver!

The *ThrustSSC* Project

In the early 1990s, Richard Noble, who held the Record at that time with the speed of 633 mph attained by *Thrust2*, began to think about breaking the Record again. An obvious initial target was 700 mph, but as this was not too far from the speed of sound at ground level, which is around 760 mph, he decided to assemble a team to attempt to take the Record to supersonic speed. Experience had shown, and we'll touch upon this again shortly, that this was not just going to be a matter of making minor modifications to *Thrust2*. This attempt was going to require a completely new design.The major challenge was not just to design a vehicle that could attain very high speeds, but to ensure that it could do this safely. This posed certain major technical difficulties. For example, to maintain the rigidity of the structure and the integrity of the wheels at high speeds required the identification of suitable materials; to ensure the basic stability of the car required adequate control mechanisms; an appropriate propulsion system had to be selected and an understanding of the aerodynamics of the vehicle was required. In this article, we will only concentrate upon certain aspects of the aerodynamic design, as it was in this area that our work on computational fluid dynamics made an impact in the *ThrustSSC* project. Those interested in discovering more about this, and other aspects of the supersonic car project, should consult the excellent text by Richard Noble [1] or the book produced by members of the *Thrust* Team [2].

Basic Aerodynamic Design

The overall aerodynamic design of *ThrustSSC* was the responsibility of Mr Ron Ayers. Important features of his basic original design are apparent in *figure1*, which is an artist's early impression of *ThrustSSC* at high speed on the Black Rock Desert in Nevada. The moving vehicle is subjected to the aerodynamic forces of lift and drag, and the magnitude of these forces is governed by the vehicle's shape and speed. The design shows a long slender shape, to produce a low drag and also a small drag variation with increasing speed. The long wheel-base provides for stable steering and the longitudinal distribution of cross-sectional area of the vehicle is smooth. The power is provided by two Rolls Royce Spey jet engines. With the use of two engines, positioned as shown in the *figure 1*, the centre of gravity can be located towards the front of the vehicle, for enhanced stability, and the front wheels can be widely spaced, to improve resistance to roll. In addition, the driver can be positioned, in the strongest part of the vehicle, near the centre of gravity, enabling rapid feedback response. Yaw stability is provided by a conventional highly swept tail-fin, with the horizontal fin mounted high to avoid the jet efflux from the engines. The attitude of the vehicle is controlled by an active suspension system. The technical soundness of these initial considerations helped ensure that this artist's early impression looked remarkably similar to the final design.

Assuming that the engines will produce enough thrust to overcome the drag at all speeds, the key problem for the designer is to optimise the shape to ensure that the lift force remains within bounds; too large a positive lift will invalidate the assumption that gravity will keep the vehicle on the ground, while a significant negative lift would destroy the vehicle's suspension. In the aerospace and related industries, the aerodynamic performance of new designs has traditionally been investigated by testing scale models in wind tunnel experiments.

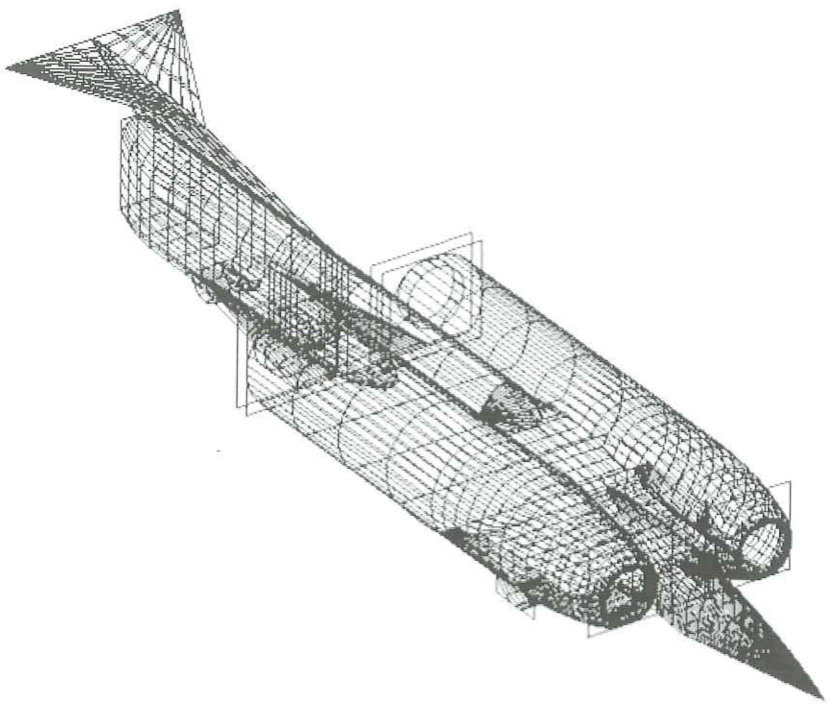


Figure 2
The geometrical description of the vehicle surface

Although wind tunnel testing has been a key ingredient in the design of most aircraft in use today, the approach is lengthy and expensive, with a single modern design often utilising thousands of hours of tunnel testing time. In addition, the building of scale models is costly, with minor changes in geometrical shape often requiring the construction of a new model, while the tunnels are expensive to build and operate and have limited applicability for a full range of flight conditions.

" Following the sun, we left the old world."
Inscription on one of Columbus´s caravels

Figure 3
Distribution of computed pressure contours for the vehicle at supersonic speed.

The high speed wind tunnel testing of aircraft in cruise conditions normally involves air being passed over models which are held well away from the tunnel walls. For *ThrustSSC*, the correct experimental procedure should involve moving a model at high speed relative to a stationary simulated ground or moving the simulated ground at high speed with respect to a stationary model. Tunnel facilities capable of creating either of these scenarios were not available. This meant that, if tunnel testing was to be employed, the best that could be envisaged would be tests in which a model was held at rest close to a simulated stationary ground in a high speed stream. In fact, this approach had already been employed, with a limited degree of success, in the aerodynamic design of *ThrustSSC*. It is now known that this vehicle was operating at the limits of its capability, and it has been estimated that it would have lost contact with the ground if its peak speed had been only seven miles per hour faster [2]. Thus, it was felt that an alternative approach was necessary if the aerodynamic performance of *ThrustSSC* was to be confidently predicted over a range of speeds up to supersonic.

" ... the key problem for the designer is to optimise the shape to ensure that the lift force remains within bounds."

Computational Fluid Dynamics

Over the past thirty years, there have been significant developments in the use of computer simulation methods for analysing the aerodynamic performance of aerospace vehicle designs [3]. During this period, as wind tunnel costs have increased, the cost of high performance computers has decreased, and computers capable of performing certain complex flow simulations are now widely available. In 1992, we were asked to consider if the computational fluid dynamics techniques that we had developed could be applied to assist in the design of *ThrustSSC*.

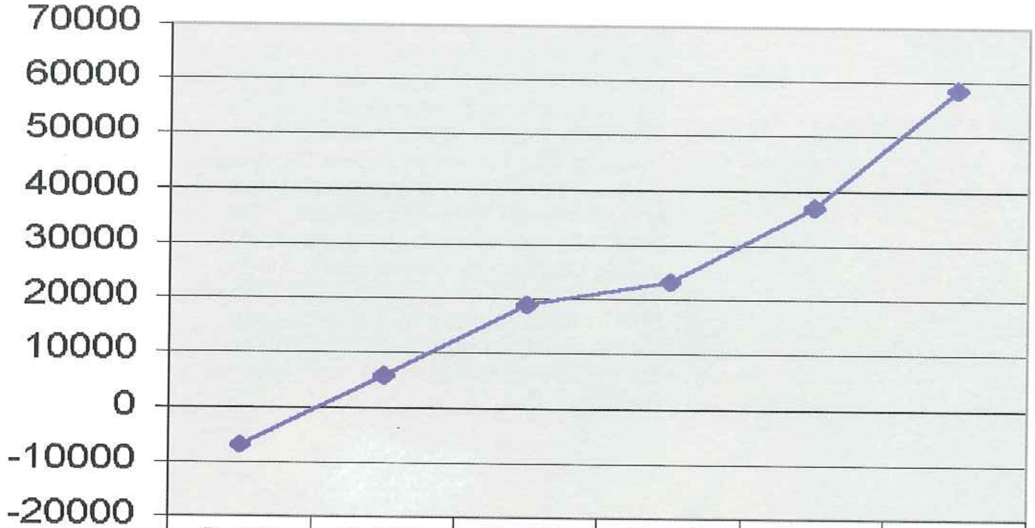
Computational fluid dynamics has its own associated shortcomings, generally related to difficulties in modelling mathematically, and computing, flows involving the complex phenomena associated with extremes of aerodynamic design, such as the prediction of flow separation and turbulence. Lower order mathematical representations of fluid flow, involving simpler flow physics, can avoid some of these difficulties, while still providing useful information for many practical aerodynamic flows [4]. In the context of *ThrustSSC*, it was decided that a lower order computational model, based upon the assumption that the fluid was inviscid, would be appropriate. As no large regions of separated flow were likely to occur within the projected speed envelope, it was reasonable to expect that such a model would be capable of producing a good approximation to the distribution of pressure over the vehicle. This information would enable the lift force on the vehicle to be estimated. By adopting this choice of model, it was also possible to ensure that many different geometrical shapes could be analysed within the time and financial constraints that were being imposed by the project. Following the initial design phase, and before the decision was taken to proceed with the construction of *ThrustSSC*, the validity of employing this form of computational model would be investigated by performing a limited series of experimental rocket sled tests on a scale model of the vehicle. The results of this validation exercise will be presented below.

Table 2
Computed forces and moments on the vehicle components at different Mach Numbers

	M=0.75				M=0.85				M=0.95			
	F_x	F_y	F_z	M_y	F_x	F_y	F_z	M_y	F_x	F_y	F_z	M_y
Nose	2880	-18042	-2647	-4650	4280	-27546	-2966	-5097	6541	-42682	-2983	-4939
Centre Body (Top)	-7017	43148	71337	-106185	-8442	58085	94762	-109792	-6376	88725	141641	-133698
Centre Body (Bottom)	3425	-311	-62214	80245	5818	785	-72716	74487	8570	3107	-115864	147292
After Body & Fin	1078	16693	3754	-26504	1416	23342	5240	-38878	2285	26540	7978	-50980
Tail Plane	701	-172	-5152	50220	967	-232	-6828	67438	1286	-275	-8738	86728
Rear Wheel	602	-0.45	220	-1938	874	-0.3	434	-3797	914	-0.05	-155	1355
Engines (Inside)	1466	864	830	1900	2208	1155	1148	2649	3180	1441	1471	3482
Total	3134	42180	6128	-6912	7121	55589	19074	-12990	16400	76856	23350	49240

Flow Modelling for *ThrustSSC*

Modelling the air flow over *ThrustSSC* was accomplished by using the FLITE3D computer system at the University of Wales Swansea. The input to this system is the definition of the vehicle geometry, in the form of an assembly of mathematically defined surfaces and their intersection curves. The computational domain was defined to be the region surrounding the vehicle, and extending a prescribed distance from it in all directions. For computational efficiency, it was assumed that the flow was symmetric about the vertical plane through the central axis of the vehicle from the nose to the tail, so that only the flow over one-half of the vehicle was simulated.



	0.65	0.75	0.85	0.95	1.05	1.15
Fz	-6776	6128	19074	23350	37064	58869

Figure 4
Computed variations of lift with Mach numbers for the full vehicle

The FLITE3D system requires that the computational domain be divided into an unstructured assembly of tetrahedral cells. To accomplish this, the boundary of the domain is first discretised into an assembly of triangular planar facets and the discretisation of the domain volume then follows. These discretisation processes are fully automatic and generate points, at cell vertices, according to a user-specified point spacing distribution function [5,6].

The equations governing the inviscid rotational flow of air are the unsteady compressible Euler equations, together with the perfect gas equation of state. The solution algorithm of FLITE3D is based upon an integral Galerkin approximate variational formulation of the problem [7]. To produce a practical algorithm for the simulation of high speed flows, consistent stabilisation and discontinuity capturing terms have to be added to this basic formulation. In the algorithm, the solution is assumed to vary linearly over each tetrahedral cell.

Finite difference procedures are employed to discretise the time dimension and the solution is advanced to steady state by using a standard multi-stage explicit time stepping procedure. The computational implementation was designed to maximise efficiency on CRAY supercomputers with vector architecture and multi- tasking facilities.

The results of any computational simulation may be presented in both qualitative and quantitative form. An overall impression of the flow is obtained by using black and white, or colour-shaded, contours of selected flow variables. From such plots, flow features such as shock waves are readily detected. A more detailed analysis of the predicted aerodynamic performance can be determined from quantitative data, such as the contribution made to the lift and pitching moment by the individual geometrical components.

The Simulations

Initially, computational simulations were employed to assist in the design of the nose cone and of the engine intakes. For these simulations, only the flow over the front section of the vehicle was analysed. This phase was followed by full vehicle simulations, which included the effects of the powered engines. For this stage, the geometry of the vehicle was described by an assembly of 56 surfaces, as illustrated in *figure 2*. A rectangular box was employed to define the outer surface of the computational domain. The point spacing distribution function, which controls the domain discretisation process, was constructed so as to ensure that an adequate density of points was achieved in perceived critical areas of the domain. Based upon these considerations, a typical discretisation of the boundaries of the domain consisted of around 50,000 triangles, while a typical volume discretisation involved about 1 million tetrahedra. The computations were performed on a CRAY C90 computer and each steady state simulation required about 1 hour of cpu time.

" As both Mercury and Apollo programs have shown, our science and technology are so powerful that, if an intense effort is made, we can do almost anything we want in say, ten years - provided we are not in conflict with the laws of nature."
Hannes Alfvén

Typical output from the computer simulations is displayed in *figure 3*, which shows the distribution of contours of pressure on the ground and over the vehicle surface at supersonic speed. The quantitative data extracted from these computations provided the necessary information to drive the optimisation of the aerodynamic design. The facility to extract data particular to individual geometrical components of the vehicle, as shown in *table 2*, was important in the evolution of the shape. In *figure 4*, the computed lift is displayed for vehicle Mach numbers in the range 0.65 to 1.15.

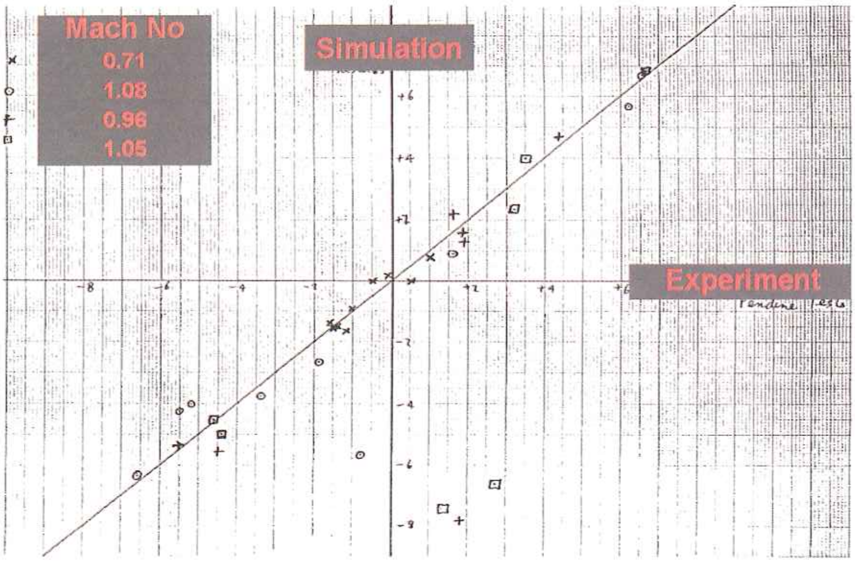


Figure 6
The comparison between the pressure values observed in the Pendine experiments and the values predicted in the computer simulation.

It is clear that the lift increases rapidly as the vehicle approaches and exceeds the speed of sound. In this Figure, the unit on the vertical axis is pounds. Since the weight of the fully loaded vehicle is around 20.000 pounds, it is apparent that the lift needs to be reduced if the vehicle is to remain in contact with the ground at high speed. The lift could be altered by changing the vehicle shape. An alternative would be to change the attitude of the vehicle. In this case, the lift is altered as a different effective shape is presented to the oncoming air stream.

Figure 5 shows the computed effect of a change of this type. It compares the variation of lift with Mach number for the vehicle in its normal attitude with that for the vehicle with its attitude changed to one degree nose down. The result of this change is seen to be significant, with the predicted lift decreasing with Mach number in the nose down case. Although these results were encouraging, and indicated that the aerodynamics of a supersonic vehicle could be controlled, independent validation of the modelling approach was necessary before a vehicle, designed on the basis of these predictions, could be operated confidently at high speeds.

Valuation of the Simulation Procedure

The FLITE3D computer system had been extensively validated on aerospace geometries for a wide range of vehicle Mach numbers. However, it had never been applied previously to the simulation of a vehicle travelling at transonic and supersonic speeds near the ground. The ground effects, including reflection of shock waves between the ground and the underside of the vehicle, were unknown but clearly important in the design process. To check the validity of the mathematical and computational modelling that was being adopted, the *ThrustSSC* Team decided to undertake rocket sled tests at the Defence Test and Evaluation Organisation (DTEO) at Pendine Sands in South Wales. At the testing ground, 13 rocket powered runs were performed, using a 1:25 scale model of the vehicle. The model was fitted with nine pressure sensing gauges on its upper and lower surfaces and vehicle Mach numbers of 0.71, 0.96, 1.05 and 1.08 were attained. Computational simulations were performed at Swansea without access to the test data. A detailed comparison between the computational and test data was then undertaken by Ron Ayers. His original plot of corresponding pressure values is shown in *figure 6*. Perfect agreement between the computational results and the test data would have resulted in a straight line at 45 degrees to the horizontal axis. The plot, therefore, shows a remarkable correlation between the two data sets. In addition, if conventional correction techniques for inviscid flow are applied [8], even the data points which do not appear to lie on the straight line are also brought into agreement.

This comparison, which was undertaken at the end of the initial design phase, validated the use of the computational fluid dynamics procedure for simulations of the flow over *ThrustSSC*. This exercise was critical to the success of the aerodynamic design process, as the excellent agreement which had been achieved provided Ron Ayers with the confidence necessary to enable him to use computational fluid dynamics

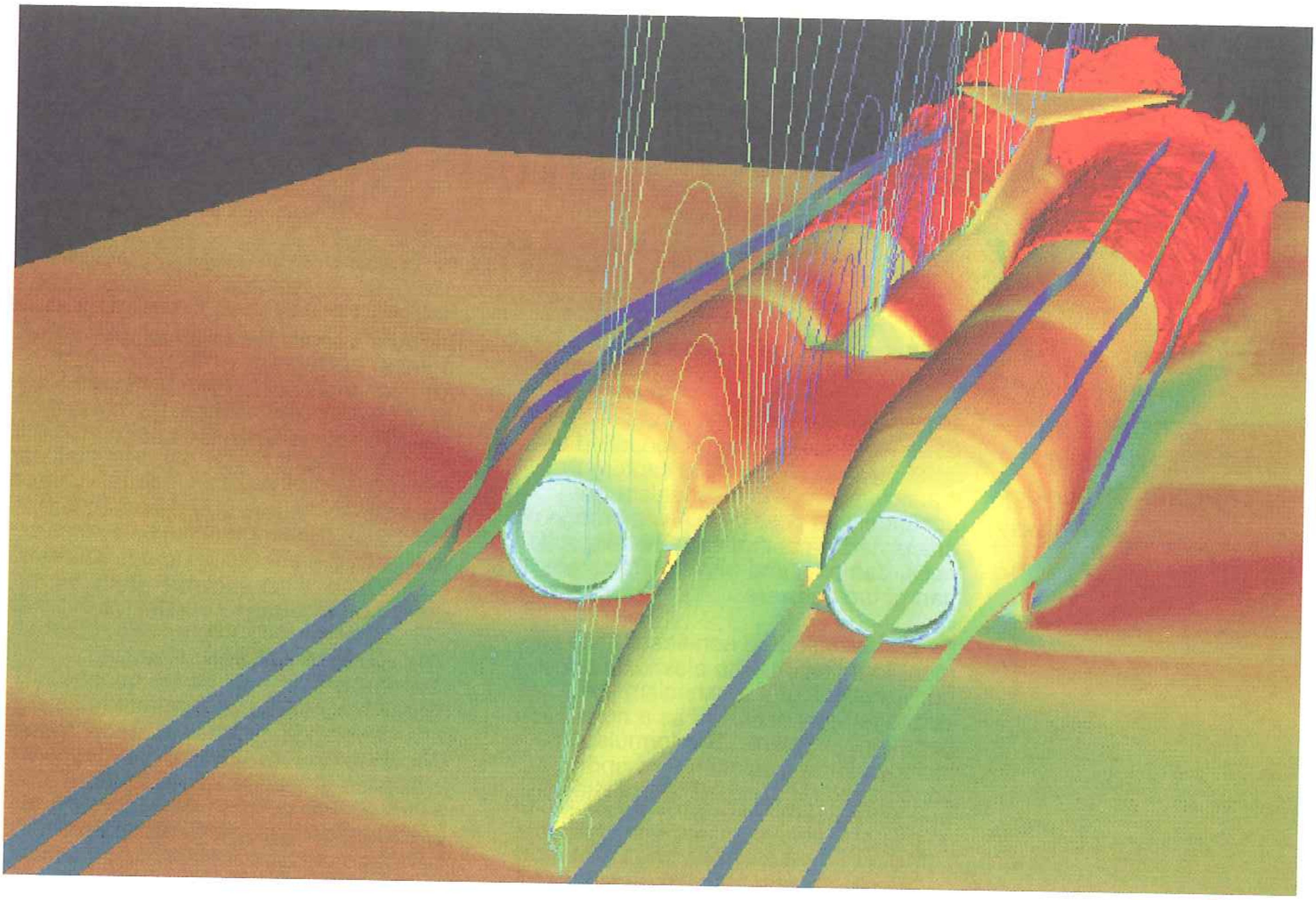


Figure 5
Computational Fluid Dynamics simulation of ThrustSSC

predictions to guide and support design modifications throughout the full speed range. In particular, based upon results such as those shown in *figure 5*, *ThrustSSC* was operated with a variable attitude of between zero and one degree nose down during the record breaking attempts.

Conclusion

Computational fluid dynamics technology, originally designed and developed to support the aerospace industry, was successfully used, over a period of five years, to assist in the design of the supersonic car *ThrustSSC*. The accuracy of the approach was validated by comparison with independent results produced by employing rocket powered models at the Pendine Testing Range in South Wales. At about 10 am Nevada time on October 15th 1997, *ThrustSSC* broke the World Land Speed Record and reached a supersonic speed of Mach 1.02 (763.035 mph).

Acknowledgments

The authors would like to acknowledge the support and encouragement that they received throughout this project from Ron Ayers, who provided the key aerodynamic design input and the geometrical definition of *ThrustSSC*, and Richard Noble. ●

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"The journey is the reward."
Tao saying

Global Ozone Monitoring

a Multidisciplinary Mechanical Analysis

by
*Terje Rolvag,
Trond Arnme Svidal
and Bjorn Haugen*
*FEDEM Technology
Norway*

The Fedem software consists of an integrated Finite Element (FE), Multibody Mechanical System (MBS) and Control System modeller and solver. Each mechanism body is modelled by finite elements in order to capture the elastic effect of the mechanism as accurately as possible. A wide range of articulated joints that can handle stiffness, damping and friction effects are part of the software.

Fedem is based on non-linear finite element formulation. The elastic and rigid-body motions of a mechanism are solved together, i.e. solved as a non- linear geometric problem. The formulation includes large displacements and rotations based on updated coordinate frames for each FE model.

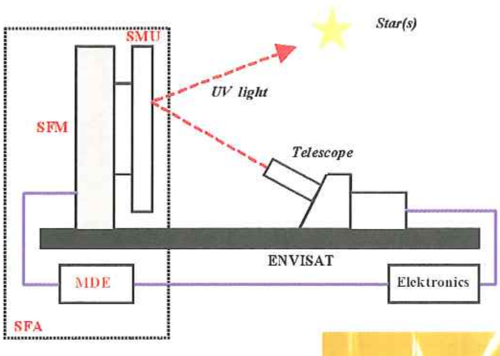


Figure 2 - above Overall GOMOS architecture

Figure 1 - below The GOMOS mechanism

In order to optimise solution speed, the number of Degrees of Feedom (DOFs) for each individual FE model is reduced by super-element techniques with possible additional Craig-Bampton modes/DOFs.

This makes Fedem a highly versatile tool for analysing mechanical systems with possible control systems. The capabilities of the software are best described by analysis examples.

The GOMOS Steering Front Assembly

The GOMOS (Global Ozone Monitoring was developed by Matra Marconi Space (MMS) for the low Earth orbit ENVISAT-1 mission of the European Space Agency. The purpose of GOMOS is to provide a daily global geographical coverage of ozone vertical distribution by the stellar occultation technique.

The GOMOS instrument *(figure 1)* embodies an UV-visible spectrometer fed by a fixed telescope. A Steering Front Mirror (SFM) is used to track preselected stars while they are setting behind the atmosphere. During this occultation, the star spectrum becomes more and more attenuated by the absorption of ozone, and the ozone vertical distribution can be accurately derived. A schematic overview is given in figure 2.

The Off-Load Device

During launch, until the mirror has been placed in orbit, the mirror mechanism is locked to a SFM subsystem. This comprises a redundant brushed DC motor that rotates a cam through a reduction gear (1:112) as shown in *figure 3.* The cam operates a Bearing Off-Load Device Arm (BOLD-arm) pivoted at the housing opposite the cam. As the cam follower attached to the free end of the BOLD-arm is lifted, the BOLD-arm contacts the outer shafts at its centre, and moves the shafts axially. After contact with the support towers, additional cam lift deflects the BOLD-arm and the turntable, and locks the turntable in position.

The cam profile includes a small detent (over center characteristics) at the fully locked position that will ensure that the cam will not rotate off during launch operation even if a considerabe amount of strain energy is stored in the SFM.

The off-load operation is activated in orbit by driving the cam back from its equilibrium position using the DC motor. When the cam has passed the small detent, the stored strain energy will drive the cam and the motor/gear-head assembly 310 degrees back to the initial position.

After the offload release the Turntable is free to rotate and GOMOS can start to track stars and perform ozone measurements.

Off-Load Problems
During testing of the off-load operation the cam rotated beyond its over-centre position. The release of the stored strain energy caused rapid acceleration of the off-load DC motor, which again gave an extremely high shock impulse when the motor hit the end stops. The torque generated was sufficient to shear the end stop and cause considerable damage to the motor gear head.

The off-load actuator was replaced and a system of parallel resistors were introduced around the motor to increase the eddy current damping from the redundant motor. This considerably reduced the off-load release rate and completely eliminated the shock pulse at the end of the off-load release.

Why Simulation?
The damage caused by the off-load test release was an expensive and time-consuming experience. One of the key questions that had to be answered after the test failure was:

Could the failure have been predicted?

The only way to determine this was to establish a virtual prototype of the SFM and simulate the off-load test. This was not a straightforward task because all electrical, control and mechanical components had to be included in the virtual SFM model in order to provide reliable simulation results.

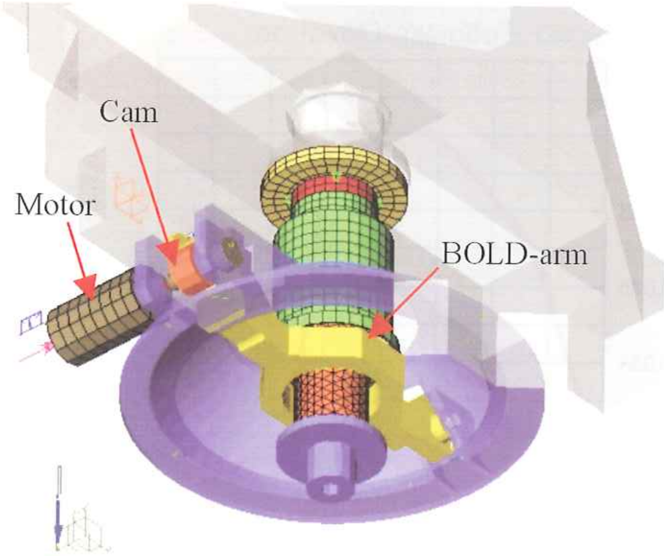


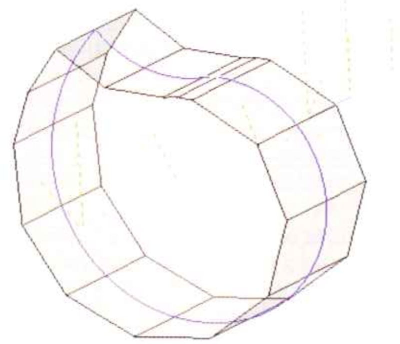
Figure 3
GOMOS SFM Model

The modelling and simulation of the GOMOS SFM involved test, draftsmen, structural and control system engineers from MMS and analysts from FEDEM. The most demanding task for the analysts was to understand the overall mechanical system and hence select what information they needed to complete the model.

The Model
A finite element mesh represented the structural stiffness, and mass distribution, of each link. These meshes were assembled to form the mechanical system in the FEDEM modeller, as shown in *Figure 3*. The total number of DOFs was reduced from 42290 to 384 by applying super-element reduction of each individual link. A more in-depth account of the simulation can be found in [Rølvåg-Humphries 98].

" ... The purpose of GOMOS is to provide a daily global geographical coverage of ozone vertical distribution by stellar occultation technique. "

Figure4
The CAM profile



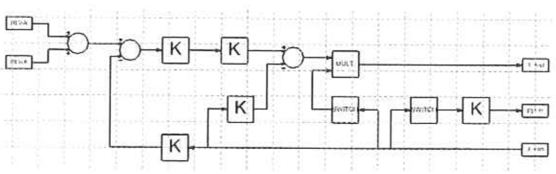


Figure 5
The Control System

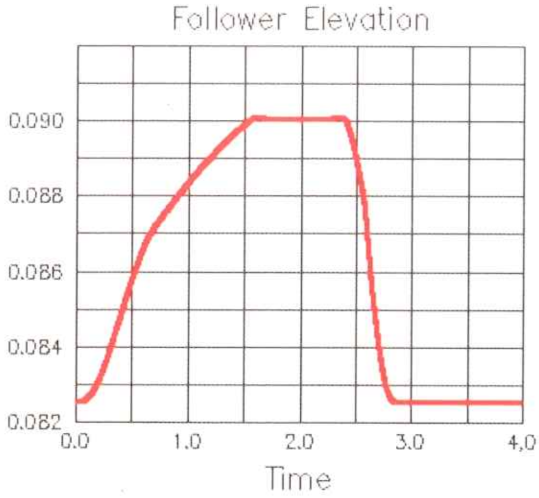


Figure 6
Cam Elevation

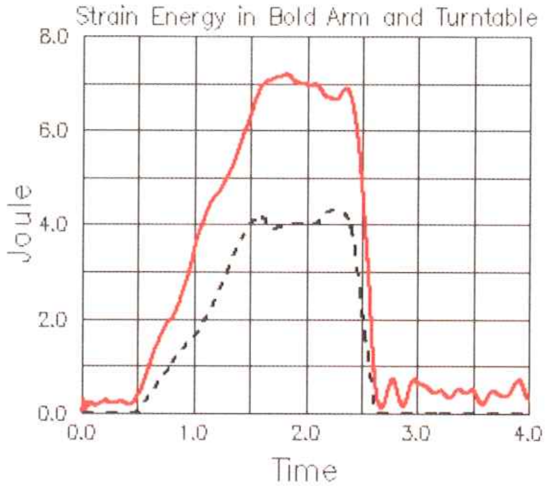


Figure 7
Applied Strain Energy

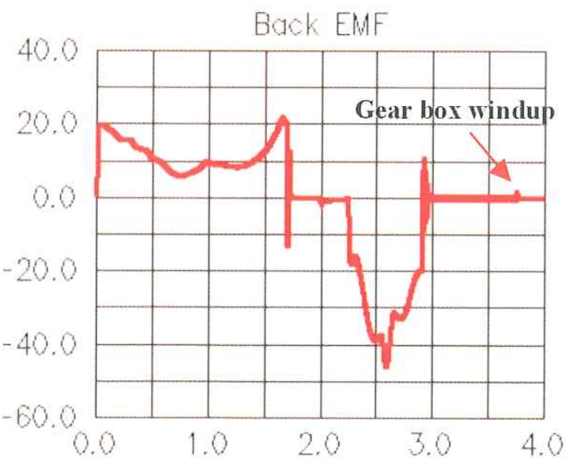


Figure 8
Initial Back EMF

Figure 6 shows the follower elevation caused by rotating the cam. The effect of the cam detent can be seen at the top of the curve.

The cam is driven 310 degrees by a motor gear-head assembly, which employs two DC brushed torque motors in a tandem configuration. A gear joint (ratio 1:112) incorporating the correct gearbox inertias and stiffness represents the gear unit.

The FEDEM model of the control system with DC motors is shown in Figure 5. The blocks and connections are defined in the integrated Fedem Control Modeller.

The control system has 2 input and 1 output blocks. The input blocks are the applied voltage source (37 Volts) and a velocity measurement, which is connected to a sensor on the GOMOS mechanism model. The sensor is applied on the high-speed side of the gear-head and passes the joint velocity to the control system (feedback measurement).

The output block is representing the net generated motor torque applied to the gear-head.

Simulation Results

The simulations were carried out in two steps representing the on-load and off-load operations respectively. The on-load simulations were first performed in order to calibrate the GOMOS SFM model against the available measurements.

The on-load simulations did accurately predict the amount of stored strain energy and reaction forces between the various links in the SFM model. A plot of the stored strain energy in the BOLD-arm and Turntable assembly (dashed line) is shown in *figure 7.*

The off-load simulations were carried out to identify how much Eddie current damping had to be applied on the redundant motor to avoid damage to any of the mechanical or electrical components. The initial damping due to back EMF is shown in *figure 8.* This damping was not sufficient to avoid damage on the GOMOS SFM. More Eddie current damping was then introduced on the redundant motor.

The simulations also showed that the torsional gear box flexibility caused a measured back EMF peak after the voltage source was switched off. This was due to a wind up effect / angular deflection of the gearbox that caused a rotational velocity of the high-speed side of the gear box/axles. The back EMF is proportional to the angular velocity and hence caused a sudden increase in the measured voltage as *figure 8* shows.

Stress results were not of great importance in these studies, but were used to verify that the element meshes and joints were properly selected with respect to the transfer of reaction forces between the various

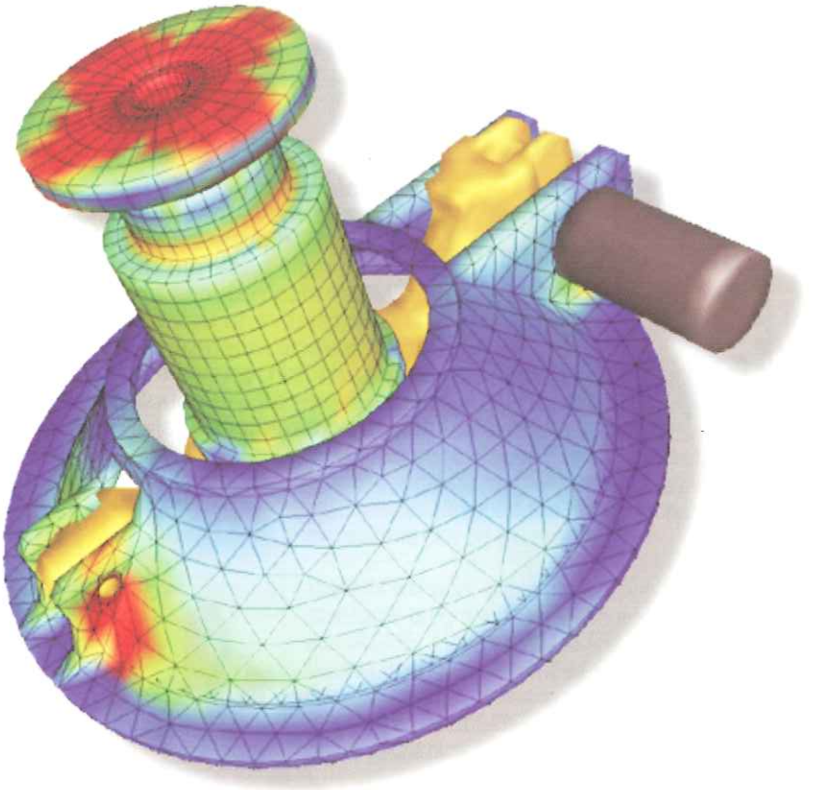


Figure 9
GOMOS Stress Distribution

mechanism links. The stress results did also indicate which structural parts that could have been damaged. *Figure 9* shows a snapshot of the stress distribution at a selected time step.

Summary
In this project the FEDEM software allowed engineers from different disciplines to input their know-how into a single database and solve all variables simultaneously.

The results were very accurate with respect to strain energy distribution, reaction forces, elevation distances and motor back EMF. Parameters describing the free elevation distance, cam profile and the control system could easily be changed to evaluate the performance of the GOMOS SFM.

If FEDEM simulations had been performed prior to the off-load test, it would have been possible to predict the accident that damaged the GOMOS SFM. If the project had been more simulation driven, the proper amount of damping could have been selected, and a safe and reliable off-load test operation could have been performed.

The Neos Tricept® 805 Robot
The *tricept® 805* is made by Neos Robotics. The patented design minimises bending deflections and focuses all forces down to the wrist, giving tricept its high rigidity. Accuracy better than 50µm can be achieved thanks to a patented Direct Measuring System, DMS. The *tricept® 805* provides excellent dynamic features, 5-10 times higher than conventional CNC-machines with the same accuracy. Path velocity up to 65 m/min and path acceleration of 2G can be reached, and *tricept® 805* is equipped with the latest and most advanced Siemens control system "Sinumerik 840D". Because of high performance and rigidity in combination with full five-axis machining capability, *tricept® 805* is ideal for mass production applications. The exceptional actuator capacity of up to 4.5 tons, also enables mounting of press fit parts such as valve guides and valve seats.

Neos Robotics used FEDEM to simulate the relative deformations of the tool center point (TCP) in different working-positions of a prototype of their TM805 robot, (figure 10). In this regard one wanted to identify critical areas regarding structural stiffness of the robot. One needed to detect the links that were most significant for improving the TCP stiffness.

Detecting possible vibration problems introduced by the spinning machining tool was also of great importance. This was done by finding the eigenfrequencies in a critical range relative to the machining tool speeds, and judging the actual displacement at the TCP from the associated eigen-vectors.

" The damage caused by the off-load teat release was an expensive and time-consuming experience. "

Figure 10
Prototype of the Tricept® 805 Robot

The Model
The finite element meshes for the 55 individual links was assembled in FEDEM. The total number of DOFs for all the links was about 430000, which was reduced to about 2250 by super element reduction of each link. Modeling of the joints incorporated the correct bearing stiffnesses according to manufacturer specifications. Positioning of the TCP for the various stiffness-test configurations was simple using the integrated FEDEM control system.

Analysis Results
Analysis of the TCP stiffness was within 4% of measured values for all robot positions. The vibration analysis detected 19 eigenfrequencies under 100 Hz.

The analysis showed that a new design for the Pillar, Support and Upper Platform had to be made in order to meet the stiffness specifications. Based on the simulations a new design was made. This is shown in *figure 12*.

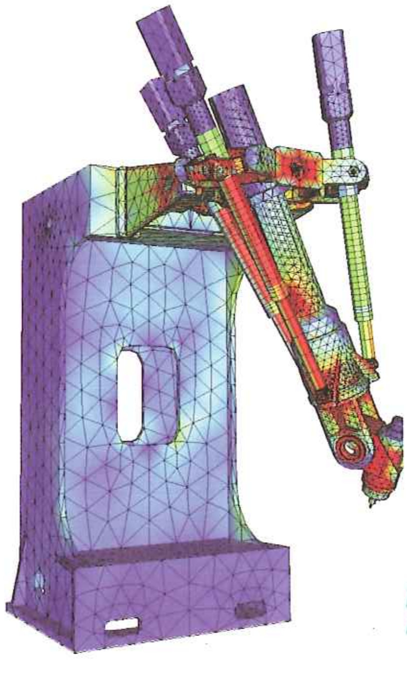


Figure 11
Prototype Stress Distribution

Conclusions
Our experience is that Multidisciplinary Mechanical Analysis builds bridges betwe en traditionally separate design disciplines. MMA also reduces problems, costs and time relative to doing virtual prototyping in several different analysis packages. In addition; analysis results are more reliable when all the coupled systems are solved simultaneously. ●

Figure 1
Final Version of the Tricept® 805 Rob

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USACM ad hoc Committee on

Verification and Validation in Computational Solid Mechanics

Goal

The United States Association for Computational Mechanics (USACM) recognizes there is a need for assessing the credibility of computational solid mechanics simulations and has set as a goal the establishment of standards by which the credibility of computational solid mechanics simulations can be assessed.

USACM will work within the existing approved standards program of an appropriate organization [ASME, AIAA, ASCE] to first establish Guidelines, then Recommended Practices, and finally recommend Standards for the Verification and Validation of Simulations in Computational Solid Mechanics.

Objective

The ad hoc committee on Verification and Validation in Computational Solid Mechanics will pursue the establishment of Guidelines as the necessary first step toward the goal of developing standards for numerical simulations in solid mechanics.

Approach

The ad hoc committee will establish a membership representative of the broad interests in the solid mechanics community to include representatives of the USACM, US Government agencies especially the Department of Defence and Department of Energy, commercial developers of software used in computational solid mechanics, users of such commercial software, solid mechanics experimentalist, and academia.

Building on similar efforts by the American Institute of Aeronautics and Astronautics (AIAA) in the development of the Guide for Verification and Validation of Computational Fluid Dynamics Simulations [AIAA G-077-1998], the ad hoc committee will develop a set of Guidelines for computational solid mechanics computations. The committee will then seek acceptance of the developed Guidelines by an appropriate organization within the required ANSI approved standards program.

Terminus

The ad hoc committee will present to the USACM Executive Committee for approval the recommended Guidelines, and standards program acceptance methodology. Upon approval by the USACM Executive Committee, and subsequent standards program acceptance, the ad hoc committee will provide the USACM Executive Committee with a recommendation for future activities and the ad hoc committee will be terminated. ●

Len Schwer
USACM Member-at-Large (Len@Schwer.net)

USACM Committee on

Meshfree Methods

The relatively recent and significant presence of "meshfree" methods in the computational mechanics community has prompted the formation of a USACM Committee on Meshfree Methods to promote the emerging role of meshfree methods. The committee is being organized by J.S. Chen (chair - University of Iowa), and Mark Christon (vice-chair - Livermore Software Technology Corporation).

The meshfree committee will foster the research, development and application of meshfree methods and will work to recognize outstanding technical contributions that advance the state-of-the-art in meshfree methods and applications. A draft of the rules of operation for the meshfree committee is currently being revised and membership for the committee is being solicited. For more information, contact J.S. Chen (jschen@icaen.uiowa.edu) or Mark Christon (christon@lstc.com).

The USACM Committee on Meshfree Methods has started to support meshfree research activities by co-sponsoring a Workshop on Meshfree Methods to be held at the Four Points Sheraton near Chicago's O'Hare Airport, June 11-13, 2000. The workshop, organized by Center for Computer-Aided Design (CCAD) at The University of Iowa, will be held in two parts: Part I - Method Development and Applications: Four Points Sheraton near Chicago O'Hare Airport, IL. June 11-13, 2000. Part II - Theory and Computation: Iowa City, IA. September (dates to be announced), 2000.

This workshop is jointly sponsored by the National Science Foundation (NSF) and the Defence Advanced Projects Research Agency (DARPA) under the Optimized Portable Algorithms and Application Libraries (OPAAL) program awarded to CCAD at The University of Iowa. The theme of this workshop is to expedite collaboration among engineering researchers, mathematicians, computer scientists, and industrial engineers to address key issues in the fundamental theory, numerical algorithms, and industrial applications of meshfree method. For more information, please contact Workshop Organizing Committee chair, J.S. Chen (jschen@icaen.uiowa.edu). ●

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USACM NEWS

Fifth US National Congress on Computational Mechanics

University of Colorado at Boulder, August 4-7, 1999

The 5th Congress of the U.S. Association for Computational Mechanics, USACM, was held at the Boulder Campus of the University of Colorado, on Wednesday through Friday, August 4-6, 1999. It convened 566 regular participants and 134 students, including 186 participants from abroad. The Congress was followed by a Short Course on Saturday, August 7, 1999, which was attended by 75 participants.

Robert Taylor receives the von Newman Award

The large number of participants clearly demonstrates that the field of Computational Mechanics is still experiencing substantial growth. It spans from computational mathematics and numerical solution of large-scale mathematical-physical problems, to innovative computer simulations in applied mechanics and computational engineering. The major themes of the Congress were recent developments in computational methodologies and innovative applications. The topics encompassed a wide spectrum of disciplines, starting from non-traditional Finite Element Analysis, to Multi-Physics Problems in science and engineering, including new aspects in High Performance Computing. The main objective was to bring together the diverse computational communities, and to promote the interaction between computational researchers and software developers in universities and industries.

Leo Franca receives the Richard Gallagher Medal from Terry Gallagher

The Local Organizing Committee, comprised of Charbel Farhat, Carlos Felippa, K.C. Park, Stein Sture and Kaspar Willam, made a determined effort to involve engineering scientists not only from academia and government research laboratories, but also from major software houses. A key aspect of USACM congresses is the reliance on MiniSymposia organized by scientists and practicing engineers. Part of this outreach was to include a substantial number of colleagues to get actively involved in the development of the Congress program. We were pleased to announce that over 80 individuals volunteered their time and effort to organize 40 MiniSymposia which ranged from single six paper sessions to a nine session symposium with 49 papers in one case. Altogether, the Congress program featured 700 Invited and Contributed Papers on computational methodologies and applications which were organized into 131 sessions comprising 40 MiniSymposia during the three day Congress. The Book of Abstracts and the Program may be viewed on the congress web site http://civil.colorado.edu/usnccm99/ together with selected photographs from the Congress Banquet.

One noteworthy MiniSymposium, entitled History of the Finite Element Method, was organized by K.C. Park and E.L. Wilson to bring together pioneers of the early days of that highly influential technology. Ray W. Clough, Richard MacNeal, and Ted Pian delivered Keynote Lectures. Alf Samuelsson and Olek Ziekiewicz were not able to attend, but their lectures were ably delivered by Pal Bergan, Kenneth Runesson, Roger Owen and Robert L. Taylor.

Aside from the intensive technical program the social activities were highlighted by the Congress Banquet on Thursday, August 5, 1999 held at the Glenn Miller Ballroom of the University of Colorado Boulder. At the end of the banquet the president of USACM, Mark Shephard, and the Chairman of the Award Committee, Ted Belytschko, presented the von Neumann Award to Robert L. Taylor of the University of California at Berkeley, who followed with a number of thoughtful remarks.

Another special award was the new Richard Gallagher Medal sponsored by John Wiley & Sons, which was awarded to Leo Franca of the University of Colorado at Denver, by Terry Gallagher in a touching ceremony.

The two photographs document these highlights of a festive evening which started with torrential rains and ended on a high and emotional note. Topical social activities included a barbecue at 10,500 ft at the CU Mountain Research Station on Friday evening which was organized by Stein Sture and attended by more than 200 people. The Rocky Mountain hike to Pawnee Pass and Peak attracted 64 wanna-be mountaineers on Saturday. Both events benefited from glorious weather. ●

Kaspar Willam
for the Local Organizing Committee of USNCMM99

USACM AWARDS

The U.S. Association of Computational Mechanics recognized outstanding contributions to the field at its banquet at the Fifth U.S. National Congress on Computational Mechanics, which was held at the University of Colorado.

Robert L. Taylor, Professor Emeritus, University of California at Berkeley received the John von Neumann Medal. The citation read; "for the development of innovative computational methods in solid and structural mechanics and constitutive theory, and for the development and wide dissemination of computer programs embodying these procedures." Previous recipients are Tinsley Oden, Ivo Babuska, Richard Gallagher and Thomas J.R. Hughes.

The other USACM awards conferred included:
Computational Mechanics Award:
Richard MacNeal, former Chairman, Mac-Neal Schwendler Corporation

Computational Fluid Mechanics Award: Mohammed Hafez, University of California at Davis

Computational Science and Engineering Award: Carlos A. Felippa, University of Colorado at Boulder

R.H. Gallagher Young Investigator Award: Leopoldo P. Franca, University of Colorado at Denver

Edward L. Wilson, University of California at Berkeley, Joe Flaherty, Rensselaer Polytechnic Institute and Tayfun Tezduyar, Rice University became Fellow of USACM.

This was the first time for the R.H. Gallagher Young Investigator Award. The Award comes with a silver medal and a cash prize, which were conferred on Dick Gallagher on his retirement as Editor of the International Journal for Numerical methods in Engineering. His widow, Terry Gallagher, graciously designated USACM as the proprietor of the award.

Sixth US *National Congress on Computational Mechanics*

August 1-4, 2001
Hyatt Regency Dearborn
Dearborn, Michigan USA

Join us in Dearborn, Michigan for the 6th US National Congress on Computational Mechanics, the official congress of the US Association for Computational Mechanics, an affiliate of the International Association for Computational Mechanics.

The Congress is a great venue for communicating ideas and for meeting colleagues. A broad spectrum of topics will be presented on recent developments in computational methods and industrial applications of simulation and design.

Persons interested in organizing topical MiniSymposia sessions for the Congress are invited to contact Greg Hulbert (contact information below) with a tentative topic title and estimated number of sessions by March 15, 2000.

Local Organizing Committee:
K. Garikipati, K. Grosh, G. Hulbert (Chairman), N. Kikuchi, C.W. Mousseau and R.-J. Yang

Inquiries should be addressed to:

Greg Hulbert
Computational Mechanics Laboratory
Mechanical Engineering and Applied Mechanics
University of Michigan
2250 G.G. Brown
Ann Arbor, Michigan 48109-2125
(voice) 734-763-4456
(fax): 734-647-3170
email: hulbert@umich.edu

USACM Technical Committees

The US Association for Computational Mechanics (USACM) is in the process of forming a set of technical committees that will focus on critical issues associated with the advancement of specific computational mechanics technologies.

A number of committees are currently being proposed including:

- Committee on Meshfree Methods, contacts J.S. Chen (jschen@icaen.uiowa.edu) or Mark Christon (christon@lstc.com) (a short description of this committee is included in this issues of IACM Expressions)
- Committee on Integration of Computational Mechanics and Manufacturing (ICMM), contact Jian Cao (jcao@nwu.edu)
- Committee on Verification & Validation, contact Len Schwer (Len@Schwer.net) (a short description of this committee is included in this issues of IACM Expressions)
- Committee on Materials Performance, Reliability & Process Modeling Contacts Somnath Ghosh (ghosh.5@osu.edu) or Robert Tryon (design@persystek.com)

If you are interested in any of these committees, please email the appropriate contact given above. If you would like to propose an additional committee please contact:
Wing Kam Liu
(w-liu@nwu.edu).

conference debrief

ECCM´99

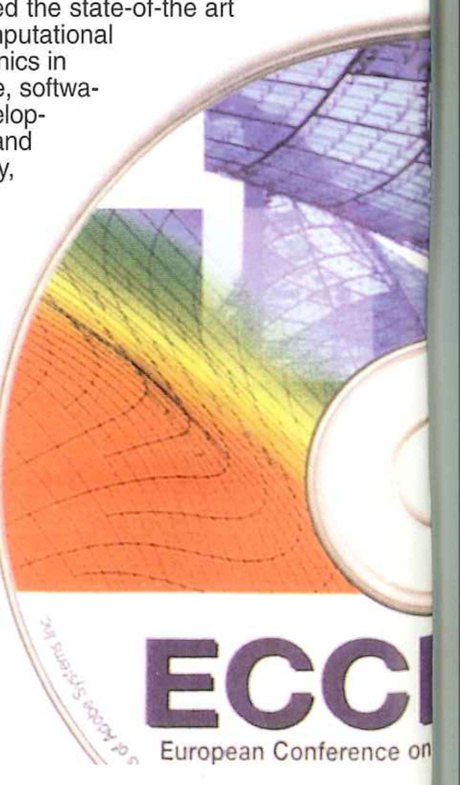
European Conference on Computational Mechanics

The first European Conference on Computational Mechanics - ECCM'99 - from **August 31 to September 3, 1999** was held in Germany at the **Technische Universität München**. On behalf of the European Council of Computational Mechanics it was organized by the German Association for Computational Mechanics (GACM) and the Technische Universität München with Professor Walter Wunderlich as the chairman of the Organizing Committee.

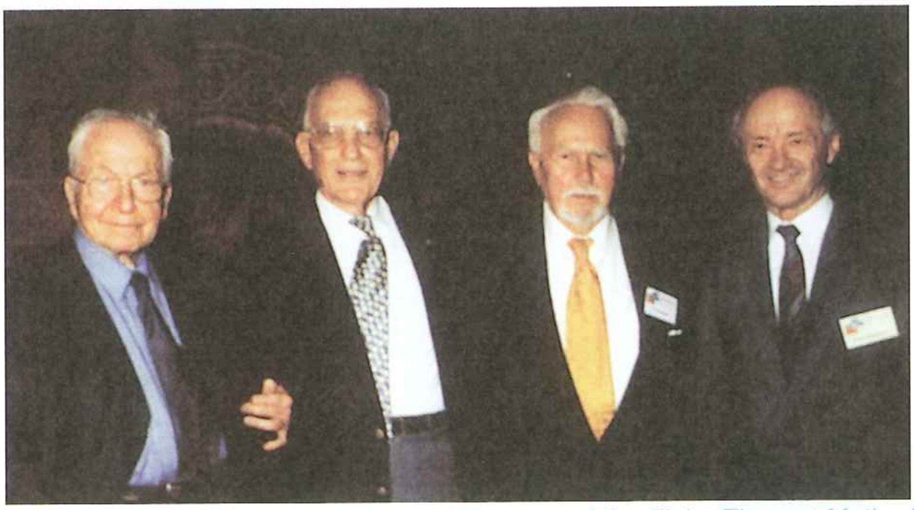
The idea for this first European Conference on Computational Mechanics goes back to 1996/97 when the 11 European branches of the International Association for Computational Mechanics (IACM) - representing 20 European countries - decided to found the European Council for Computational Mechanics (ECCM), with Olek Zienkiewicz as one of the driving forces, and Erwin Stein as the first chairman. Its goal - as a European steering and organizing board - was to coordinate and promote European activities in scientific and industrial computer-based engineering. Its members were delegated by the 11 European associations for Computational Mechanics who also served on the Scientific Board of the ECCM'99 conference.

In this context it may be useful to briefly illustrate the links between ECCM and ECCOMAS, the European Community on Computational Methods in Applied Sciences. The latter association has been organizing European conferences on Numerical Methods in Engineering and Computational Fluid Dynamics (CFD) every four years since 1992. The first meeting was held in Brussels in 1992, the second in Paris in 1996, and the next one will be held in 2000 in Barcelona. In addition, a number of interim meetings have focussed on Computational Fluid Dynamics and related fields, whereas the areas of Computational Solid and Structural Mechanics as well as Coupled Problems were less well represented. For this reason, the focus of ECCM '99 was on the latter subjects, and as such it was the first European conference of this kind. In 1998 the boards of IACM and ECCOMAS formally decided that in the future ECCOMAS will represent IACM in Europe and that it also will be responsible for the European activities of IACM. As a consequence, ECCM will merge with the new structure, and its tasks will be carried out jointly by the Executive Board of ECCOMAS and the respective new European committees. At a board meeting of ECCOMAS during the conference in Munich it was decided that ECCM will act within ECCOMAS as the European Committee for Computational Solid & Structural Mechanics and Fluid-Structure-Interaction(ECCSM) and that the ECCM conference series will be continued under this name.

The main aim of ECCM'99 was to promote the development of numerical methods in civil, mechanical, naval, aeronautical, and bioengineering, and their application in engineering practice. Its scientific program reflected the state-of-the art of Computational Mechanics in science, software development, and industry, and it



brought together about 500 researchers and practitioners from 40 countries. Altogether, about 370 lectures were given on the current state of research and advanced engineering practice in this field. The spectrum of the lectures was remarkably wide and included such fields as material modelling, adaptive methods and error control, geomechanics, composites, concrete, contact problems, forming processes, plates and shells, structural dynamics, reliability and safety, optimisation, fluid-structure-interaction, and further aspects of related element and meshless methods. It was a remarkable coincidence that the three pioneers of Computational Mechanics, John H. Argyris, Ray W. Clough and Olek C. Zienkiewicz were able to follow the invitation to give addresses at the conference.



Pioneers of the Finite Element Method
Prof. J.H. Argyris, Prof. R.W. Clough and Prof. O.C. Zienkiewicz together with Prof. W. Wunderlich

In the Opening Session J. H. Argyris gave a very personal summary of the development of the stiffness approach in structural analysis and the circumstances of his involvement as early as 1943. In his address "On the Threshold of the 21th Century" O.C. Zienkiewicz gave his thoughts on the early development of numerical methods and his assessment of their present status and future possibilities.

The opening session also contained the first plenary lecture given by R. L. Taylor. The other three plenary lectures were given in the closing session by R. Ohayon, D. R. J. Owen and H. A. Mang, In this session R.W. Clough also gave his special address "Thoughts about the origin of the finite element method" in which he reflected on the direct stiffness approach in the Fifties and the subsequent development of what he called the Finite Element Method.

The conference was accompanied by an extensive social program including a get-together-party, a reception, and a Bavarian style dinner as well as an excursion with a boat trip on lake Ammersee and a visit to the beer garden of Schloß Andechs.

Among these events the official reception represented one of the highlights. It took place at the beautiful "Kaisersaal" of the "Residenz".

Greeting addresses were given by the State Secretary in the Bavarian State Ministry of Education and Culture and by the President of the Technische Universität München. Their attendance underlined the significance of ECCM'99 as well as its importance for the university and the state Bavaria.

The next European conference in this series will take place in Cracow, Poland, in the year 2001. It will again focus on the field of Computational Solid and Structural Mechanics and Coupled Problems, and will accentuate the increasing importance of international research and applications in this vital scientific and engineering discipline. ●

2nd International Workshop on the Trefftz Method

The first Workshop was held in 1996, the 70th anniversary of the 1926 paper by Trefftz, in Cracow and organised by the Institute of Mechanics and Machine Design at Cracow University of Technology. The 2nd Workshop was held from **15th to 17th September 1999** in **Sintra, Portugal**, organised by Professor J.A. Teixeira de Freitas and colleagues from the Department of Civil Engineering at IST, Technical University of Lisbon. For this second Workshop the theme was widened to encompass general high performance global, sub-domain, and finite element formulations which are related to Trefftz, or may compete with Trefftz, but have similar potentials for high performance.

Some 43 participants from 18 countries took part, and the group photograph taken on the steps of the Sintra National Palace indicates the beautiful surroundings which were conducive to a successful Workshop. Amongst those participating were a number of younger Ph.D. students. Unfortunately two of the original re-activators of the Trefftz type method, Prof. J. Jirousek, to whom this Workshop was dedicated, and Prof. O.C. Zienkiewicz, were unable to attend, but the Workshop arranged for letters of appreciation and best wishes to be sent to them.

The developments reported covered a variety of formulations in the context of solid mechanics: elastostatics and dynamics, linear and non-linear material; heat conduction, electrostatics, and fluid mechanics. Presentations were made from the viewpoints of engineering pragmatism and mathematical rigour. Both viewpoints have their place, and the need to verify with experimental data was also recognized.

The four main invited speakers reviewed the following topics:

- Prof. Herrerra discussed the systematic use of fully discontinuous Trefftz basis functions, and assembly by various combinations of direct/indirect, overlapping/non-overlapping formulations for solving general problems governed by partial differential equations.
- Professor Ladeveze considered a key issue in the design of elastic structures: that of modelling dynamic behaviour in the range of medium frequencies. In such cases the extension of low frequency finite

Delegates on the steps of the Sintra National Palace element methods to medium frequencies would necessitate unreasonably large numbers of degrees of freedom, and calculations for medium frequencies remained an open problem. A new variational approach was presented in the context of the response to a given forcing frequency in the medium range. This approach was based on the use of local dynamic Trefftz functions.

❒ Professor Stein presented an overview of complementary variational Ritz and Trefftz methods in the context of error estimation. The importance of establishing bounds to error estimations was emphasized, and a new method to create such bounds was proposed based on the use of generalised Trefftz functions with local Neumann problems.

❒ Professor Sze reviewed the locking problems associated with conventional elements used to model shell problems. He proposed the use of solid elements without rotational degrees of freedom to represent shells, with elements based on hybrid stresses and enhanced with assumed natural strains. Such elements were demonstrated to give good results, and were particularly proposed for modelling smart structures where mechanical and piezoelectical effects are coupled.

Delegates attending the 2nd International Workshop on the Trefftz Method

The remaining presentations covered a wide range of Trefftz or Trefftz related methods and applications.

❒ hybrid-Trefftz elements in the context of machine design of plated structures, e.g. plates on elastic foundations, folded plates, plates with openings, plates with "infinite" extent, design optimization, and error estimation and adaptivity.

❒ theoretical developments of general hybrid formulations with dual side variables in place of the more conventional nodal variables, and non-variational concepts. Assembly of domains by Galerkin or collocation methods, developments in 2D and 3D modelling for elastodynamic and elastoplastic problems by hybrid-Trefftz formulations.

❒ other Trefftz formulations for solid mechanics applications: based on polynomial Trefftz functions with domains assembled to satisfy boundary integral forms of Betti's reciprocal theorem; Trefftz finite element method based on collocation of displacements at boundary nodes and a variational formulation to satisfy the natural boundary conditions in a weak form and interelement continuity via Lagrange multipliers; dynamic wave functions for coupled structural-acoustic problems in the medium frequency range; and a spectral method based on truncated series of continuous global orthogonal functions.

❒ Trefftz formulations suited for 2D heat conduction and Stokes fluid flow problems where the Trefftz functions may need to satisfy harmonic or biharmonic equations; and for 3D problems where Trefftz polynomials satisfy all of the Stoke's equations.

❒ meshless methods applied to 3D problems governed by Poisson or Helmholtz equations where finite element modelling would be very time consuming. These methods were considered in the context of interesting problems concerning heat flux in the earth's mantle and acoustic waves in car bodies.

❒ mixed type formulations for elasticity where stability questions were of importance, these were addressed by use of numerical inf-sup tests.

❒ theoretical derivations of upper and lower bounds for the errors in approximate stress fields from any formulation. These errors were classified and derived as equilibrium errors and compatibility errors, and the lower bounds were proposed as possible local error estimators for use in adaptive procedures. Stress errors were also considered within hybrid equilibrium models, and these were quantified as compatibility defaults and by non-conventional dual analyses to give upper bound error measures used in adaptive procedures.

❒ in the context of smoothing discontinuous stress fields, alternative smoothing techniques were presented based on local Trefftz fields and the use of L2 or energy norms.

Finally, a range of interesting methods aimed at more specific applications with complex non-linear problems were also presented:

❒ flexible multi-body dynamics where displacements of flexible bodies are simulated by finite elements and joints are constrained by penalty methods. Modelling included simulation of large displacements and strains as well as hyperelastic behaviour.

❒ shells with material and geometric non-linearities formulated as a nonlinear initial value problem with explicit time integration, plus an embedded linear boundary value problem modelled by finite elements.

❒ fracture mechanics in rock modelled as an elastic brittle material with multiple pre-existing cracks. Formulated as a displacement discontinuity method based on stresses and displacements.

❒ non-linear electrostatic and hyperelastic problems requiring discontinuous finite element approximations to model electrical or mechanical discontinuities when limit loads lead to material breakdown.

Full versions of the papers presented will be submitted for publication in a special issue of the international journal Computer Assisted Mechanics and Engineering Sciences. The Workshop closed with the intention of continuing this series ●

E.A.W.Maunder,
Department of Engineering, School of Engineering and Computer Science, University of Exeter, UK

IACM

Special Interest Conferences

FEF 2000

Finite Element in Flow Problems

Austin, Texas
April 30 - May 4, 2000
11th conference in the series

Venue: Thompson Conference Centre
The University of Texas at Austin

Organisers: Graham F. Carey and J. Tinsley Oden

Objectives: To provide a forum for presentation and discussion of current research and development in the area of finite element methodology applied to problems of fluid flow and transport. Topics of interest include advances in (1) methodology, (2) algorithms and (3) applications.

Related issues such as paralled CFD, coupled flow problems and treatment of nonlinearity will also be covered for applications to incompressible Newtonian flows, compressible gas dynamics, non-Newtonian fluids, suspensions, turbulence, acoustics, fluid structure interaction and other flow types.

Other topics such as grid generation, flow visualisation and post-processing are of interest.

Local Organising Committees:
G.F. Carey and J.T. Oden (co-chairs)
C. Dawson, L. Demokowicz,
J. Killinderis, M.F. Wheeler

Hosted By
TICAM
The University of Texas at Austin

Sponsored by:
The University of Texas at Austin
IACM - International Association of Computational Mechanics
US Association for Computational Mechanics

Programme:
The programme will consist of keynote lectures, special lectures and contributed papers in the subject areas.

For further information contact:
fef2k@ticam.utexas.edu
Tel: (1) 512-471 46 76
Fax: (1) 512-232 33 57
Web Page:
http://www.itcam.utexas.edu/FEF2000

COMPLAS

6th International Conference on Computational Plasticity

Barcelona, Spain
11 - 14 September 2000

Objectives: COMPLAS 2000 will address both the theoretical bases for the solution of plasticity problems and the numerical algorithms necessary for efficient and robust computer implementation. The ability to provide numerical simulations for increasingly complex problems is advancing rapidly due to both remarkable strides in computer hardware development and the improved maturity of computational procedures for non-linear systems. Significant advances have been made in the formulation and implementation of algorithms for static and dynamic problems involving finite strains, complex contact interaction laws, constitutive material behaviours including multi-physics or multi-physics or multi-scale effects, progressive large scale fracturing, etc. Such advances, however, demand a closer interaction between numerical analysis and material scientists in order to produce theoretical models which provide a response in keeping with fundamental material principles and experimental observations. The conference aims to act as a forum for practitioners in the field to discuss recent advances and identify future research directions.

Conference Topics: Multi-fracturing solids, High velocity impact, Composites, Damage, fracture and fatigue, Multi-physics problems, Multi-scale material models, Paralles processing computations, Environmental and Geosciences, Multi-body and non-linear dynamics, Forming process simulations, Contact problems, Biomechanics, Granulationan processes, Advanced material models, Innovative computational models and Industrial applications.

Venue: The conference will take place in the heart of Barcelona,harbour area, in the cities new World Trade Centre in conjunction with the ECCOMAS 2000 conference (see page 35).

For further information:
CIMNE, Edificio C,1, Compus Norte UPC
C/Gran Capitan s/n, 08034, BCN, Spain
Tel: (34) 93-401 64 87
Fax: (34) 93-401 65 17
Mail: eccomas2000@etseccpb.upc.es
Web: http://www.cimne.upc.es/eccomas/complas/default.htm

10 - IACMAG

The 10th International Conference on Computer Methods and Advances in Geomechanics

Tucson, Arizona, USA, January 7-12, 2001.

Theme: The theme of the conference will be Fundamentals Through Applications. The conference will encourage participation of the practicing community with the aim to relate fundamental developments with practical applications.

It is proposed to develop an Industry Exchange and Interaction (IEI) program through special paper sessions, panel discussions on issues and needs in practice, short courses and exhibition of computer methods and applications for practical problems. Hence, active participation of practitioners is encouraged and solicited.

Topics: Computer Methods, (Semi-Analytical Methods, Reliability, Neural Networks, Computer Aided Engineering), Constitutive Modeling (Localization, Softening, Healing), Integrative Modeling, Macro-Micro-Nano Scale Responses of Materials, Validation of Constitutive and Computer Models, Laboratory and Field Testing, Dynamic and Earthquake Analysis and Liquefaction, Geoenvironmental Engineering, Soil-Structure and Rock-Structure Interaction, Ground Improvement, Tunnels, Underground and Mine Openings, Petroleum Geomechanics, Energy Optimization in Mining, Petroleum Geomechanics, Infrastructure Geomechanics, Foundations , Flow, Consolidation and Settlement , Pavements and Mass Transport Support Systems, Slopes, Excavations, Dams, and Retaining Structures, Education

All submissions and requests for information should be directed to:
10 IACMAG Conference
c/o Engineering Professional Development
The University of Arizona
1224 N. Vine Avenue
Tucson, AZ 85719-4552 USA
Tel: 520-621-3054;
FAX 520-621-1443
Email: epd@engr.arizona.edu

book report - book report

Structural Analysis of Historical Constructions II
Possibilities of numerical and experimental techniques

P. Roca, J.L. Gonzáles, E.Oñate and P.B. Lourenco (Eds.)
374 pages, 1997, US$ 80, CIMNE, Spain.

The growing concern about the preservation of the architectural heritage is motivating great innovation in the techniques of analysis, numerical or experimental, which can be applied to assess the state of conservation and determine the actual needs of repair of ancient constructions.

This book includes the transcription of the presentations given by a set of specialists during the II International Seminar on Structural Analysis of Historical Constructions, held in Barcelona on November 4 - 6, 1998.

Together with its companion book - the previous volume issued after the first seminar on the same subject - it is intended to provide the reader with comprehensive and updated information on general methodology, analysis techniques and practical cases. •

Mechanical Engineer´s Handbook
Second Edition

M. Kutz, New York, USA (Ed.)
2,376 pages, 1998, US$ 165.00, John Wiley & Sons Ltd.

Because mechanical engineering encompasses such a range of topics, managers from a diverse spectrum of professions require access to the foundations of this broad knowledge base.

The Mechanical Engineers Handbook supplies all of the necessary critical information in an easy-to-use single volume format. In addition, the cross referencing of the Handbook adds extra searchability and utility.

This edition focuses on the explanation of the concepts and how to use them, as well as including new chapters covering Composites, Concurrent Engineering Technologies, Virtual Reality and Ergonomic Factors in Design. •

Fluid Dynamics
Theoretical and Computational Approach

Z.U.A. Warsi, Mississippi State University, US (Ed.)
1998, US$ 89.95, Springer - Verlag.

Fluid Dynamics presents the basic development of equations in coordinate-invariant form and their use in solving problems in laminar and turbulent flows. Topics include classical boundary layer theory and the Navier-Stokes solutions, structure of turbulent flows, turbulent boundary layers and the mean turbulent equations, as well as linear and non linear turbulence modelling.

This book presents a thorough examination of fluid dynamics by combining fundamental principles with systematic, mathematical and computational approaches.

Fluid Dynamics enables students and professionals to grasp and assimilate a constructive framework for modern fluid dynamics, providing a set of algorithmic tools to create useful physical and computational results. •

The Wiley Engineer´s Desk Reference
Second Edition

S.I. Heisler, Heisler Associates, California, USA (Ed.)
600 pages, 1998, UK£ 55.00, John Wiley & Sons Ltd.

This is the second edition of a best selling book for any and all professional engineers and those students who are on track to become engineers. As with the first edition, coverage runs the scope of every topic that engineers need to apply in their day-to-day jobs. It has been said that this is the ¨one book that an engineer should pack when travelling¨- it is a reference that will be picked up and used daily.

This edition has been thoroughly updated to include new information on composite materials, semiconductors and computer appliances. It also contains new material covering air pollution as related to combustion engineering. •

conference notices

IASS-IACM 2000
Fourth International Colloquium on Computation of Shell & Spatial Structures

The Fourth International Colloquium on computation of shell & spatial structures will be held on the island of Crete, in the city of **Chania**, **Greece** on **5-7 June 2000**.

This series of colloquiums is a forum for discussion of the recent advances on various aspects of the analysis and design of shell & spatial structures.

Researchers and designers are invited to exchange their achievements and experience on related topics.

The scope of the Colloquium encompasses the role of computational methods and tools in the analysis and design of shell & spatial structures and will include the following topics:
- geometric and material nonlinear analysis
- static and dynamic buckling analysis
- dynamic and chaotic behaviour
- computer aided design and visualization
- form finding and optimization
- sensitivity analysis
- shape, topology and sizing optimization
- composite structures
- stochastic and reliability analysis
- error control and adaptivity
- high performance computing.

The Prefecture of Chania, situated in the western most sector of Crete is rich in natural beauty. Its prominent aspects are the landscape, the sea and its warm and dry climate, which constitute a unique place for recreation and travel.

For further information please contact:
Prof. M. Papadrakakis
Institute of Structural Analysis & Seismic Research
National Technical University of Athens
Zografou Campus,
Athens 15773, Greece
Tel: (+30) 1 7721694
Fax: (+30) 1 7721693
e-mail: mpapadra@central.ntua.gr

NC'2000
Second International ICSC Symposium on NEURAL COMPUTATION

NC''2000 will be held at the **Technical University of Berlin**, Germany on **May 23-26, 2000.**

The science of neural computation focuses on mathematical aspects to solve complex practical problems, and it also seeks to help neurology, brain theory and cognitive psychology in the understanding of the functioning of the nervous system by means of computational models of neurons, neural nets and subcellular processes.

Topics include:
Computational Neural Network Models, Neurophysiologically Inspired Models, Software and Hardware Implementations and Neural Network Applications.

Updated information is available from:
Prof Hans Heinrigh Bothe
Tel: (46) 19-10-3786
Fax: (46) 19-10-3463
Email: hans.bothe@tib.oru.se

CST 2000
5th International Conference on Computational Structures Technology

CST 2000 will be held in **Leuven, Belgium** on **6 - 8 September 2000** and will run concurrently with the Second International Conference on Engineering Computational Technology.

Some of the topics to be covered are: Parallel Processing, Supercomputing, Domain Decomposition and Partitioning, MIMD Architectures, Distributed Computing and Networking, Artificial Intelligence and Knowledge Based Systems, Novel Software Tools and Development Environment, Virtual Reality, Algorithms for Vectorization and Parallelisation, Genitic Algorithms, Neural Networks, Object Oriented Methods, Computational Intelligence and Evolutionary Processes.

Enquiries should be sent to:
Prof. B.H.V. Topping
Tel: (44) 131-332 10 20
Fax: (44) 131-332 30 60

p and hp Finite Element Methods: Mathematics and Engineering Practice

A conference in honour of the 65th Birthday of Prof. Barna Szabo.

The main objective of the conference, to be held on **31 May to 2 June 2000** in Washington University, **St Louis, USA**, is to bring together researchers with interests in the mathematical, engineering practice and computational aspects of the p and hp (and high-order/spectral) methods for the solution of partial differential equations (mainly associated with solid and fluid mechanics.)

Topics will include: - p and ho-BEM
- A-priori and a-posteriori error estimation
- efficient solution algorithms for systems of equations generated by p and hp methods
- application of methods to non-linear problems
- practical application of high-order methods in engineering practice
- connection of high-order methods to dimension reduction and plate/shell models
- high-order methods and their coupling with CAD systems
- high-order time-space methods
- treatment of singularities by high-order methods
- high-order methods applied to bio-mechanical systems.

For further information contact:
Dr Zohar Yosibash on
Tel: (972) 7-64 77 103
Email: zohary@pversion.bgu.ac.il

3rd Japan - Turkey Workshop on Earthquake Engineering

The Third Japan-Turkey Workshop on Earthquake Engineering to be held on **February 21 - 25, 2000** at **Istanbul Technical University**, marks the end of the JICA Project "Earthquake Disaster Prevention Research Canter" that was initiated in 1993.

The selected topics for the workshop are the recent theoretical or experimental research findings related to : Repair and strengthening, Aseismic design, Structural testing, Liquefaction, Design earthquake characteristics, Microzonation methodologies, Early damage estimation, Disaster management, Earthquake Monitoring Networks

It is envisaged that this workshop will be another opportunity for discussing the recent developments related to earthquake, earthquake engineering, disaster management, and earthquake monitoring networks with the participation of scientists and engineers.

The workshop will cover the following selected themes: Repair and strengthening and structural testing, Microzonation for geotechnical hazards, and Early damage estimation and disaster management .

For further information contact
Prof. Dr. M.Hasan Boduroglu
Istanbul Technical University
Faculty of Civil Engineering
Maslak 80626, Istanbul -Turkey
Tel (90)-212 285 3797
Fax (90)-212 285 6587
E-mail: bodurogl@itu.edu.tr ●

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

ECCOMAS 2000 will be held in **Barcelona, Spain** from **11 - 14 September 2000** and will incorporate the V1 International Conference on Computational Plasticity (COMPLAS VI).

ECCOMAS was created in 1993 with the aim of providing a high level of coordination of scientific conferences and other activities in Europe in the field of Computational Methods in Applied Science and to represent the interests of IACM within Europe.

Some 1400 papers are scheduled and can be grouped under the following two general topics: **Scientific Topics** (with the subheadings of Computational Fluid Dynamics, Computational Solid and Structural Mechanics, Computational Mathematics and Numerical Methods, Computational Electromagnetics, Computational Chemistry and Multidisciplinary Topics,) and Industrial Applications.

During ECCOMAS 2000 an exhibition on computer hardware, software, books and other products of interest will be available, as well as a full social programme.

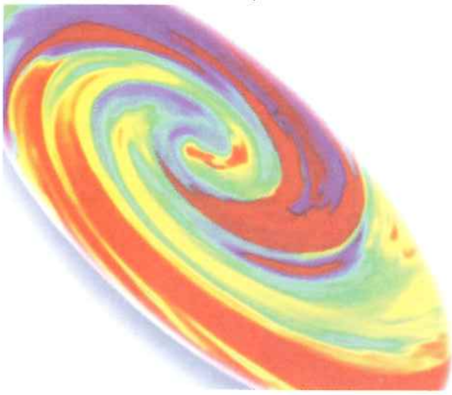
For more information contact:
Tel: (34) 93-401 64 87
Fax: (34) 93-401 65 17
Mail: eccomas2000@etseccpb.upc.es
Web: http://www.cimne.upc.es/eccomas

EUROMECH 2000
8th European Turbulence Conference

This conference, held under the auspice of the European Mechanics Society will be held in **Barcelona, Spain** on **27 - 30 June 2000**, will be devoted to the fundamental aspects of fluid turbulence that are of interest to engineers, physicists and mathematicians.

Turbulence is one of the major unsolved problems at the beginning of the 21st century which has direct application to many aspects of science and in our day to day life.

This conference aims at the following general areas: Instabilities and Transition, Experimental Techniques, Direct Numerical Simulation,

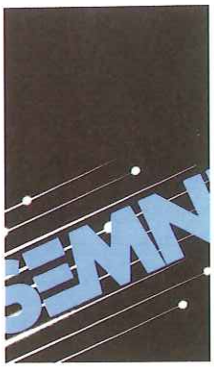


Compressible Turbulence, Transport and Mixing, Geophysical and Environmental Flows, Vortex Dynamics and Intermittency and Scaling.

Further enquiries please contact:
Euromech 2000,
CIMNE,
C1 Campus Nord,
Univ. Politecnica de Catalunya
Gran Capitan s/n,
Barcelona, E-08034
Spain
Tel: (34) 93-401 74 41
Fax: (34) 93-401 65 17
Web: http://www.cimne.upc.es ●

SEMNI

The Spanish Association for Numerical Methods in Engineering



The basic aims of the Spanish Association for Numerical Methods in Engineering (SEMNI) are the organisation and coordination in Spain of all kinds of activities related to numerical methods in engineering as well as being the Spanish representative in the International Association for Computational Mechanics (IACM).

The headquarters of SEMNI are located at the International Centre for Numerical Methods in Engineering (CIMNE) at Barcelona.

SEMNI is linked to similar association in different countries like the Groupe pour l'Avancement des Méthodes Numériques de l'Ingénieur in France, the United States Association for Computational Mechanics and the Asociación Argentina de Mécanica Computacional (ACMA). SEMNI also belongs to the European Community on Computational Methods in Applied Sciences (ECCOMAS).

Currently, SEMNI has over 400 members in Spain as well as in other countries. Some of the main activities of SEMNI include the organisation of technical workshops as well as the Spanish Conference on Numerical Methods in Engineering. The first was held in June 1990 in the Canary Islands, the second in La Coruña (Galicia) in June 1993, the third in Zaragoza in June 1996, and the fourth was held in Seville in June 1999. The fifth will be held in Madrid in June 2002.

SEMNI, in cooperation with AMCA, organised the 4th IACM World Congress on Computational Mechanics, held in Buenos Aires in 1998 and is also organising the European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS) to be held in Barcelona from 11 - 14 September 2000.

SEMNI, besides organising seminars and courses, also publishes a Newsletter and a quarterly Index Bulletin in which the current contents of more than 70 international journals related to numerical methods in engineering are summarised.

Executive Council of SEMNI:

President:
Eugenio Oñate (Univ. Politécnica de Cataluña)

Vice President:
Francisco Michavila (Univ. Politécnica de Madrid)

Secretary:
Gabriel Bugeda (Univ. Politécnica de Cataluña)

Council Members:
Manuel Casteleiro (Univ. de La Coruña)
Manuel Doblaré (Univ. de Zaragoza)
Antonio Huerta (Univ. Politècnica de Cataluña)
Miguel Cervera (Univ. Politècnica de Cataluña)
Fermin Navarrina (Univ. de LaCoruña)
Javier Oliver (Univ. Politècnica de Cataluña)
Josè Goicolea (Univ. Politècnica de Madrid)
Josè Dominguez (Univ. de Sevilla)

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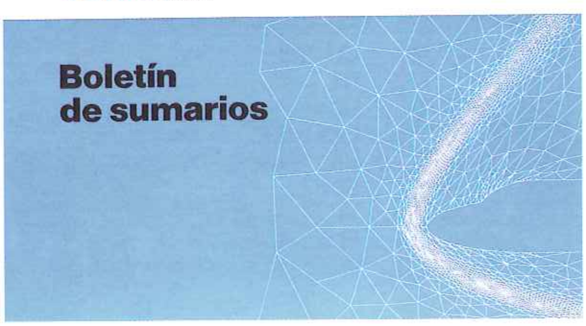
SEMNI Sociedad Española de Métodos Numéricos en Ingeniería



iacm news

In Memory of Prof Ernest Hinton
Professor Ernest (Ernie) Hinton died on Thursday 18th November after fighting a valiant battle against illness with enormous courage and dignity.

He was a leading figure in the international Computational Mechanics community and his personal contribution to the success of Swansea in this field was considerable. He was a highly respected individual, acting as editor to several international journals and was a member of several national committees on finite element methods.

Ernie's work in finite elements, related to structural mechanics and optimisation in particular, will be remembered by future generations of researchers. His friends and colleagues will also recall a courageous man of integrity with a highly developed Liverpudlian wit and a keen intellect.

PACM
Prof Tadeusz Burczynski of Silesian Technical University in Glieice has been elected the new President for the Polish Association of Computational Mechanics (PACM).

CSMA
France has also had elections. **Prof. Olivier Allix** of LMT/ENS Cachan has been elected President of the Computational Structural Mechanics Association (CSMA).

SPINOZA Award 1999
Prof René de Borst of the Netherlands Organization for Scientific Research has been awarded the SPINOZA prise for 1999. This prise is considered the highest scientific award in the Netherlands and amounts to Dfl 3.000.000 research money.

Chinese Academy of Sciences
On the 8th June 1998, the Chineese Academy of sciences announced the election of eight foreign members. Two of these are members of the IACM council - **Prof. Jaques Louis Lions (France)** and **Prof. Olgierd C. Zienkiewicz (UK).**

Of the other six members, three are Nobel Laureates and five come from the USA. They are:**Dr. Helmut Moritz** - Geophysics (Austria), **Dr. Steven Chu** - Laser Physics (USA), **M.M. Li** - Thin film surface (USA), **R.A. Marcus** - Thermo-chemistry (USA), **E.S. Kuh** - Electric circuits (USA), **B.C. Burchfiel** - Geology (USA)

ASME International
In November 1998, **Prof. O.C. Zienkiewicz** also received the Timoshenko Medal from the American Society of Mechanical Engineers - their highest award for contributions to science and mechanics.

Academia Nazionale Dei Lincie
In addition to these two awards, **Prof O.C. Zienkiewicz** was elected as a foreign member of the "Academia Nazionale Dei Lincei" Rome on 3 August 1999. He shares this honour with the past president of the Royal Society, Sir. Michael Atiyah.

CORRECTIONS
In the conference diary planner of Expressions 7/99 there is a misspelling in the email address of: **IASS-IACM 2000 Colloquium.** It should read as follows -

mpapadra@central.ntua.gr

The Insititue of Civil Engineers
Numerical Methods in Engineering

The Zienkiewicz Silver Medal and Prize

The Zienkiewicz Prize was instituted in 1998 following a donation by John Wiley & Sons Ltd to commemorate the work of Professor O.C. Zienkiewicz CBE DSc FRS FEng, of the Institute for Numerical Methods in Engineering, University of Wales, Swansea. The Prize of 1000 pounds and a silver medal is awarded biannually to a post-graduate researcher under the age of 35 for the paper selected from those submitted to the Judging Panel which contributes most to research in the field of Numerical Methods in Engineering.

Papers should be submitted to the Institution of Civil Engineers no later than 30 June 2000 for consideration by the Judging Panel during July/August 2000.

Papers should be addressed to: The Awards Section (Zienkiewicz Prize), Institute of Civil Engineers, One Great George Street, Westminster, London SW1P 3AA.

conference diary planner

21 - 25 February 2000 **3rd Japan - Turkey Workshop on Earthquake Engineering**
Venue: Istanbul, Turkey
Contact: M.H. Boduroglu, Tel: (90) 212-285 37 97, Fax: (90) 212-285 65 87, Email: bodurogl@itu.edu.tr

17 - 19 April 2000 **VI Congresso Nacional de Mecanica Computacional**
Venue: Avern, Portugal
Contact: P. Vila Real, Tel: (351) 34-37 00 49, Fax: (351) 34-37 09 53, Email: pvreal@ccivil.ua.pt

30 April - 4 May 2000 **FEF 2000 - Finite Elements in Flow Problems 2000**
Venue: Austin, Texas, USA
Contact: G. Carey, Tel: (1) 512-471 46 76, Fax: (1) 512-323 33 57, Email: fef2k@ticam.utexas.edu

23 - 26 May 2000 **NC 2000 - 2nd International ICSC Symposuim on Neutal Computation**
Venue: Berlin, Germany
Contact: H. Heinrich Bothe, Tel: (46) 19-10 37 86, Fax: (46) 19-10 34 63, Email: hans.bothe@ton.oru.se

31 May - 2 June 2000 **p-FEM200 and p & hp Finite Element Methods: Mathematics and Engineering Practice**
A conference in honour of the 65th birthday of Prof. Barna Szabo
Venue: Washington University, St. Louis, USA
Contact: Z. Yosibash, Tel: (1) 972-7 647 71 03, Fax: (1) 972-7 647 28 13, Email: zohary@pversion.bgu.ac.il

5 - 7 June 2000 **IASS-IACM 2000 - 4th International Colloquium on Computation of Shell & Spatial Structures**
Venue: Chinia, Crete, Greece
Contact: M. Papadrakakis, Tel: (30) 1-772 16 94, Fax: (30) 1-772 16 93, Email: mpapadra@central.ntua.gr

6 - 9 June 2000 **European COST F3 Conference on System Edentification & Structural Health Monitoring**
Venue: Universidad Politecnica de Madrid, Spain
Contact: Conference Web Site: http://www.dmpa.upm.es/SHM/

21 - 23 June 2000 **VEEPCAR 2000 - 4th International Meeting on Vector and Parallel Processing**
Venue: Porto, Portugal
Contact: Tel: (351) 2-204 35 70, Fax: (351) 2-204 36 93, Email: congress.porto@abreu.pt

27 - 30 June 2000 **EUROMECH - 8th European Turbulence Conference**
Venue: Barcelona, Spain
Contact: ETC8 Secretariat, Tel: (34) 93-401 74 41, Fax: (34) 93-401 65 17, Web: http://www.cimne.upc.es

27 June - 1 July 2000 **FEM3D - Finite Element Methods for Three-Dimensional Problems**
Venue: University of Jyvaskla, Finland
Contact: Mrs J. Brandt, Tel: (358) 14-260 2780, Fax: (358) 14-260 2731, Email: fem3@mit.jyu.fi

10 - 14 July 2000 **1st International Conference on Computational Fluid Dynamics**
Venue: Kyoto, Japan
Contact: N. Satofukat, Email: iccfd@fe.mech.kit.ac.jp, Web: http://www.fe.mech.kit.ac.jp/iccfd/

21 - 25 August 2000 **16th IMACS World Congress 2000**
Venue: Lausanne, Switzerland
Contact: Fax: (1) 732-445 05 37, Email: imacs@cs.rutgers.edu

6 - 8 September 2000 **CST 2000 - 5th International Conference on Computational Structures Technology &**
ECT 2000 - 2nd International Conference on Engineering Computational Technology
Venue: Leuven, Belgium
Contact: B. Topping, Tel: (44) 131-332 10 20, Fax: (44) 131-332 3060, Email: buro@saxe-coburg.co.uk

11 - 14 Sept. 2000 **ECCOMAS 2000 - European Congress on Computational Methods in Engineering and Applied Science**
COMPÑAS 2000 - 6th International Conference on Computational Plasticity
Venue: Barcelona, Spain
Contact: B. Schmitt, Tel: (34) 93-401 64 87, Fax: (34) 93 - 401 65 17, Email: eccomas2000@etseccpb.upc.es

16 - 18 October 2000 **APCS 2000 - 6th Asian Pacific Conference on Shell and Spatial Structures**
Venue: Seul, Korea
Contact: Tel: (82) 331-290 75 53, Fax: (82) 331-290 75 70, Email: tjkwun@yurim.skku.ac.kr

7 - 12 January 2001 **VIACMAG - 10th International Conference on Computer Methods and Advances in Geomechanics**
Venue: Tuscon, Arizona
Contact: Tel: (1) 520-621 3054, Email: epd@engr.arizona.edu

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