

The International Center for Numerical Methods in Engineering (CIMNE)

**A Partner for Education, Research and
Technology Transfer in Computational
Engineering and Applied Sciences**

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A PARTNER FOR EDUCATION, RESEARCH AND TECHNOLOGY TRANSFER IN COMPUTATIONAL ENGINEERING AND APPLIED SCIENCES

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1 OVERVIEW OF CIMNE

The International Center for Numerical Methods in Engineering (CIMNE) is a research organization created in 1987 at the heart of the prestigious Technical University of Catalonia (UPC) as a partnership between the Government of Catalonia and UPC. The aim of CIMNE is the development of numerical methods and computational techniques for advancing knowledge and technology in engineering in applied sciences.

CIMNE's headquarters are located at the heart of the Technical University of Catalonia (UPC) in Barcelona. CIMNE has also premises at different buildings in several campus of UPC . CIMNE has also offices in Spain in Madrid, Terrassa and Ibiza. In 2005 CIMNE started its international expansion and since then has created the following international branches: CIMNE Latinoamerica (Non profit Foundation in Santa Fe, Argentina); CIMNE USA (Non profit Corporation in Washington DC, USA); CIMNE Singapore (Non profit Corporation in Singapore).

CIMNE employs some 200 scientists and engineers who work in the different offices of CIMNE around the world (Barcelona, Madrid, Washington DC (USA), Singapore, Santa Fe (Argentina), Beijing and Shanghai (China). CIMNE has also established a network of 28 Classrooms and Joint Labs in partnership with Universities in Spain and 10 Latin American countries.

The research and technology development (RTD) activities of CIMNE cover a wide spectrum of topics ranging from classical engineering fields such as civil, mechanic, environmental, naval, marine and offshore, food, telecommunication and bio-medical engineering, computer sciences and applied sciences such as material sciences bio-medicine, computational physics, nature, social and economic sciences and multimedia sciences, among others.

Over the last 25 years CIMNE has taken part in over 2000 RTD projects in cooperation with some 500 enterprises, universities and research centers worldwide.

The RTD activities of CIMNE are complemented by education and training activities via Master Courses, short courses and seminars, and CIMNE Coffee talks. CIMNE scientists supervise doctorate students in cooperation with several universities in Spain and worldwide.

The publication Department of CIMNE publishes books, monographs, research reports and technical reports. The Congress Department of CIMNE organizes international conferences and workshops in the different areas of CIMNE. It has organized 140 conferences since 1987.

CIMNE has a vocation for transferring the scientific and technical outputs from RTD projects to the industrial sector. This is effectively carried out in cooperation with companies from different sectors that exploit and market the CIMNE technology. CIMNE has actively promoted the creation of spin-off companies, some of them totally or partially owned by CIMNE, that play an important role in the industrialization and exploitation of CIMNE technology.

CIMNE maintains close cooperation links with many universities and RTD centers in the field of computational engineering and sciences worldwide. CIMNE has access to the computing facilities of several supercomputer centers in Spain and Europe.

CIMNE has been identified as one of the International Centers of Excellence on Simulation-Based Engineering and Sciences in a recent National Science Foundation (NSF) report [Glotzer et al., WTEC Panel Report on International Assessment of Research and Development in Simulation Based Engineering and Science. World Technology Evaluation Center (wtec.org), 2009].

The following sections briefly explain the strategy of CIMNE for education, dissemination research and technology transfer. We also describe the main academic and scientific activities, as well as the RTD lines of the CIMNE departments and the spin-off companies and products developed at CIMNE.

2 THE CYCLE OF IDEAS

2.1 From ideas to prototypes

The mission and activity of CIMNE can be clarified if we examine what we call the **Cycle of Ideas**. Figure 1 shows a scheme of the transit of an idea, from the instant it originates until it is transformed in an industrial and commercial success. Similarly as it happens in other biological environmental cycles (the water cycle or the cycle of plants, for instance), the cadencies and tempos are very important in the cycle of ideas.

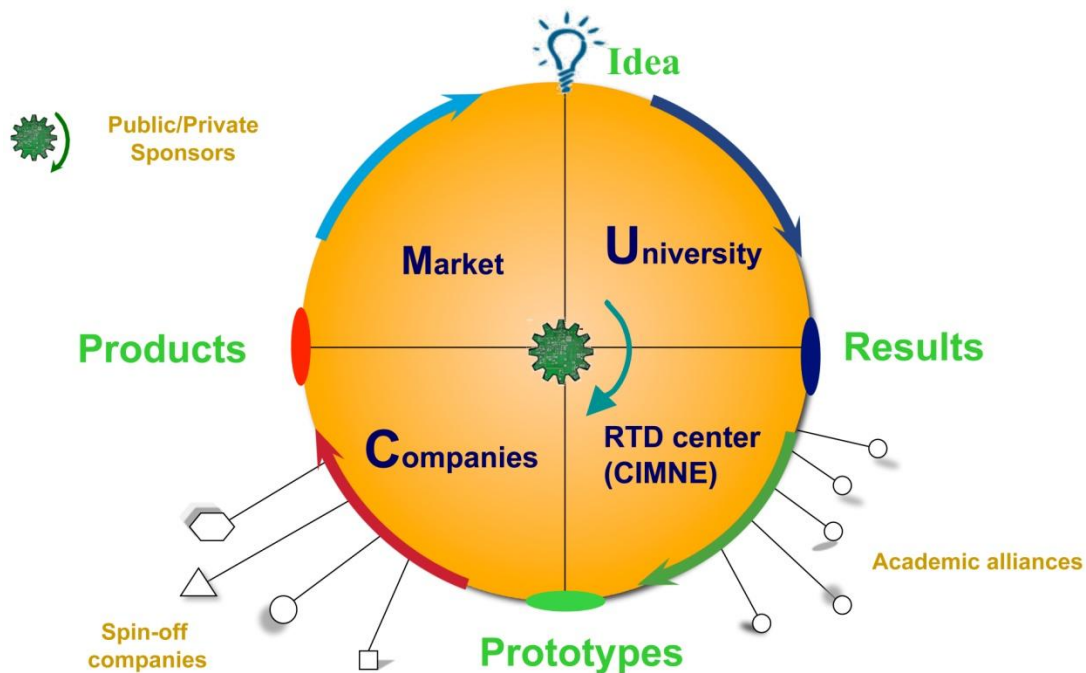


Figure 1. The Cycle of Ideas

Ideas (and here we basically refer to scientific advances) usually originate in university environments, where many professionals have the mission of thinking, studying, investigating and eventually discovering new areas of knowledge. The idea (the new discovery) would be equivalent to a seed, in the sense that even being very important (essential) it is far from becoming a fruit.

The idea matures in its "tour" by the first quadrant of the Cycle (the University) until it produces tangible results (thesis, papers, computer programs, physical devices, etc.). These "results", if they are not filed and protected, can be easily lost. This leads to undesirable repetitions or duplications.

What to do then with the results of an idea? The best is that they can evolve until they reach the level of a prototype; i.e. until they became something (a software code, a system, a device, etc.) that works in a contrastable manner in the hands of a person different from the author. The transit of a result to a prototype is not a trivial one and it demands an organization, efficient and capable staff and resources that are usually far from the ordinary means of a university group. The best alternative is, therefore, that the idea follows its route on specialized institutions, adjacent to the university, such as CIMNE, with the specific mission to transform knowledge into tangible things (prototypes) in cooperation with other RTD organizations worldwide.

2.2 From prototypes to product and market

Can a prototype be released into the market with a guarantee of success? The answer is (probably) no. The distance between a prototype and a product is typically a long one. Getting a product is an objective in itself and mixing it up with RTD tasks is not advisable and leads to frustrations. Products should be developed in companies where specialists devote their time and talent exclusively to obtaining, validating and documenting a product, as well as to defining the marketing plan.

Once a product has finally reached the market, it would enter into the last quadrant of the Cycle of Ideas. There the objective is commercial success. In order to reach that, the company should establish the necessary alliances around the world. The Cycle ends up with the return of a part of the profits from the marketing of the product to the place from where the idea originated (the University).

Clearly, the "rotation speed" of the idea around the Cycle can be increased with the help of funding from external public and private sponsors, as it is metaphorically shown in the figure. These concepts are in fact very simple. However it is typically very difficult to put them into practice. Creating and transforming ideas and knowledge into useful products is the key mission of CIMNE.

3 TRAINING AND DISSEMINATION

3.1 Courses and Seminars

CIMNE hosts since 1989 a Master Course on Numerical Methods in Engineering in presential mode (in English) and in the e-learning mode (in Spanish). Both the Master and Ph.D. degrees are awarded by UPC. Since 2007 CIMNE is also the Secretariat and Managing organization of a Master in Computational Mechanics sponsored by the Erasmus Mundus Programme of the EC jointly organized by UPC and the Universities of Swansea (UK), Nantes (France) and Stuttgart (Germany).

CIMNE organizes regularly short courses (20-30 hours) on selected topics in computational engineering delivered by distinguished scientists and engineers. Some 25 research seminars of 1-2 hours duration are also organized annually at CIMNE.

The CIMNE Coffee talks are 40 minute presentations delivered by an invited scientist (typically a CIMNE researcher) with the aim of presenting the advances on a specific research line . The talks are preceded by coffee and pastry and are closed by an informal debate between all attendants . Some 30 CIMNE Coffee talks are annually held at the different CIMNE premises.

3.2 International Conferences

CIMNE is a regular organizer of international conferences on advanced topics of computational engineering and sciences. CIMNE has organized **105** conferences since 1987. The full list can be found in www.cimne.com.

3.3 Publications

CIMNE has an active policy for publication and dissemination of the outputs derived from the research activities (total of 550 papers since 1987). Apart from the publication in scientific journals, CIMNE has its own Publication Department which publishes regularly Books (130), Monographs (193), Research Reports (370) and Technical Reports (625). Number in parenthesis indicates the titles published by CIMNE since 1987. The list of the publications can be found in www.cimne.com.

3.4 Scientific Organizations

CIMNE is the permanent Secretariat of the following scientific organizations:

- a) International Association for Computational Mechanics (www.iacm.info).
- b) European Community on Computational Methods in Applied Sciences (www.eccomas.org).
- c) Spanish Association for Numerical Methods in Engineering (www.cimne.upc.es/semni).
- d) Pilot Center of European Research Community in Flow, Turbulence and Combustion (www.cimne.upc.es/ercoftac).
- e) Unesco Chair in Numerical Method in Engineering (www.cimne.com).

3.5 Visiting Scientists

CIMNE regularly hosts distinguished scientists from universities and research centers from Europe and worldwide. An average of 25 senior scientists and 30 junior scientists visit CIMNE annually in periods ranging from 2 weeks to 8 months.

3.6 The CIMNE Classroom Network

CIMNE Classrooms are physical spaces for cooperation in education and RTD activities created jointly by CIMNE and one or several universities around the world. The CIMNE Classrooms carry out training activities at graduate and postgraduate levels and RTD projects in cooperation with enterprises. Currently there are 24 CIMNE Classrooms in the following countries: Spain (6), Argentina (4), Mexico (3), Venezuela (3), Colombia (2), Brasil (2), Cuba (1), Chile (1), Perú (1) and El Salvador (1). For more information visit www.cimne.com.

4 RTD ACTIVITY

4.1 The magic tetrahedron

The overall RTD mission of CIMNE has evolved over the years towards providing comprehensive solutions for solving problems that affect human beings. This can be achieved by integrating existing knowledge in a particular field with quantitative information emanating from prediction methods (i.e. computational-based techniques) and experimental measurements. The link between these four concepts: the problem to be solved, computational methods, experimental methods and existing knowledge is well represented by the so-called *magic tetrahedron* shown in Figure 2.

Each of the nodes in the tetrahedron is connected to the other three by lines that represent information pipelines (possibly internet). The intensity of the flow along the lines that interconnect two nodes would vary depending on the requirements for solving the problem.

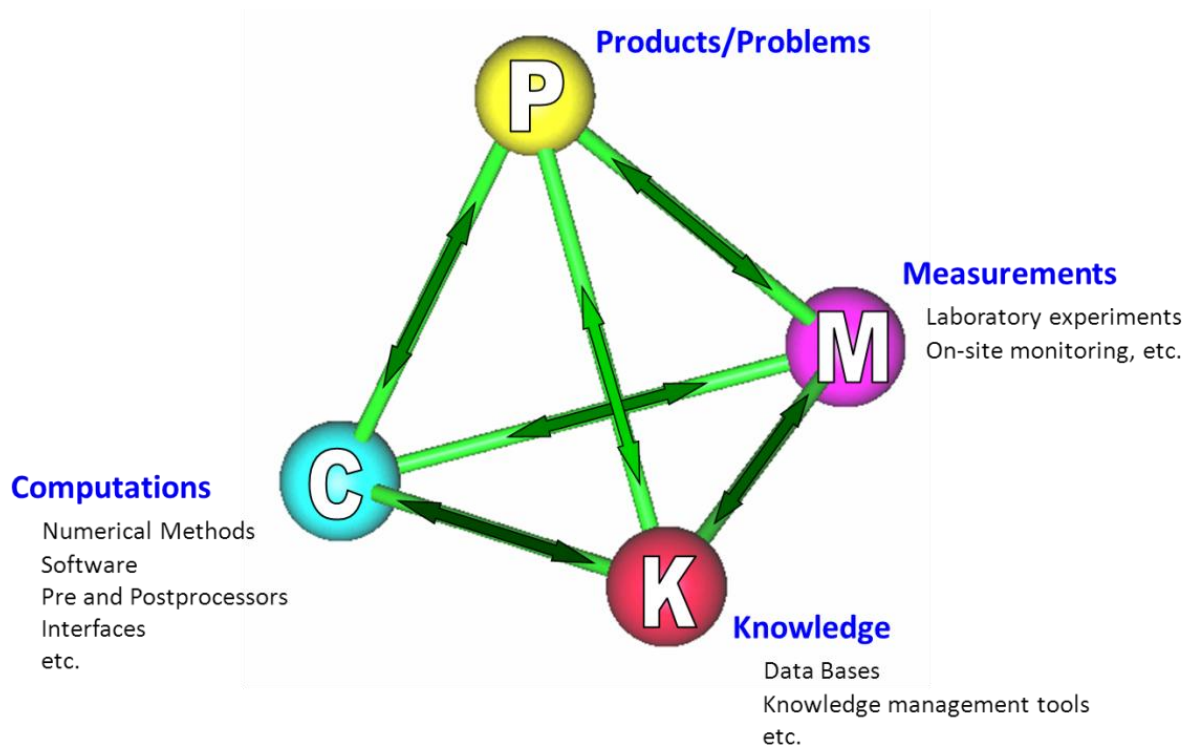


Figure 2. The magic tetrahedron linking problems, computations, measurements and knowledge

4.2 Research Lines

The research lines of CIMNE cover many basic and applied fields in computational engineering mechanics. This research is of application to a wide range of practical fields including civil, aerospace, mechanical, naval, marine, food production and telecommunication engineering. Other applications include manufacturing processes, energy and environmental problems. Some relevant problems where the computational methods developed at CIMNE are applied include (the list is no exhaustive): Structures with standard and composite materials; Analysis of dams; Structural analysis of vehicles; Study of the load carrying capacity and vulnerability of structures to natural hazards (floods, earthquake, tsunamis, etc.); Geotechnical engineering problems and ground water flow; Thermal-mechanical coupled problems in engineering; Numerical simulation of sheet metal forming , casting and welding processes; Fluid-structure interaction; Shape optimization in aeronautical engineering; Aerodynamics of aircrafts and land vehicles; Blast, crashworthiness and impact problems on structures; Ship hydrodynamics; Computational electromagnetics; Flow of granular materials; Food manufacturing processes; Mesh generation; Geometry and data interfacing; Graphic visualization ; Decision Support Systems in engineering; Large scale and parallel computing.

The research activities of CIMNE are carried out in cooperation with RTD organizations, universities and companies worldwide. The research is funded either via competitive proposals, for instance from the EC and the National Research Plan of Spain, or directly by industry. CIMNE has participated since 1987 in some **170** EC funded projects, out of a total of over 1200 RTD

projects (800 of which funded by industry). To this we must add 10 international projects and some **100** projects directly funded by industry.

We list below the key RTD areas of the different Departments of CIMNE. Namely: **Aerospace Engineering**; **Bio-Medical Engineering**; **Building, Energy and Environment**; **Civil Engineering**; **Information and Communication Technology**; **Manufacturing Processes**; **Marine and Naval Engineering**; **Natura**; **Pre and post processing**; **Social and Economical Modeling** and **Technology Transfer Services**.

4.3 RTD lines of CIMNE Departments

Aerospace Engineering

Development of unstructured grid stabilized finite element and meshless methods for analysis of fluid flows. 3D adaptive mesh refinement techniques for compressible/incompressible flows. Optimum shape design in aerodynamics combined with adaptive mesh refinement. Structural analysis of composite aerospace structures. Aeroelastic analysis of parachutes. New pre/post processing tools (GiD) for aerospace engineering. 3D unstructured mesh generation. New algorithms for multidisciplinary problems in aerospace engineering: aeroelasticity, thermal flows, electromagnetics, aeroacoustics, etc.

Bio-Medical Engineering

Numerical methods for modelling and simulation of biomechanical and bio-medical engineering problems. Simulation of the mechanics of the cardiovascular system and the heart. Study of the mechanics of the urology system. Fluid-dynamic analysis of the blood flow in vessels. Decision support systems in biomedical engineering.

Building, Energy and Environment

Numerical methods for analysis and design of energy sustainable constructions. Numerical methods for acoustic analysis and design of structures with enhanced materials. Methods for analysis of recycling processes of natural and artificial wastes for energy saving and environmental applications. Development of computational methods for analysis and design of wave power plants. Decision support systems for the energy and environment .

Civil Engineering

Structural analysis of civil constructions under static and dynamic loads: bridges, dams, buildings, harbor structures, hydraulic structures, etc. Numerical method for studying the safety and durability of structures and constructions. Optimization methods in structural engineering. Finite element methods for analysis of textile membranes and inflatable structures. Computational methods for analysis of structures with new materials. Numerical methods for multidisciplinary problems in civil engineering. New decision support systems for the construction sector integrating wireless sensor networks, data bases, calculation methods and AI technology.

Information and Communication Technology

New Internet tools for supporting management and training activities of individuals and organizations. Methods for integrating and managing wireless sensors in Internet platforms. Development of health monitoring methods for constructions and buildings using wireless sensors and ICT. Integration of geographic informations tools into decision support systems. Application of ICT to manufacturing processes in industry.

Manufacturing Processes

Finite element methods for analysis of sheet stamping processes. Numerical methods for analysis of mould filling, solidification and cooling in casting processes. Numerical methods for life predictions of manufactured parts. Optimum design methods for manufacturing processes in metal and plastic industry. Finite element methods for simulation of welding and riveting processes. Numerical methods for multidisciplinary problems in the manufacturing industry. Decision support systems for the forming and manufacturing industries.

Marine and Naval Engineering

Numerical methods for hydrodynamic analysis of vessels. Finite element methods for analysis of composite materials and structures in ships accounting for fluid-structure interaction effects. Numerical methods for analysis of off-shore constructions. Numerical methods for environmental problems in naval and marine engineering. Optimum shape design methods for ships. Numerical methods for multidisciplinary problems in naval and marine engineering. Decision support systems in naval and marine engineering, integrating wireless sensor networks, data bases, computer simulation methods and AI technology.

Natura

Water desalination and purification.. Chemical methods for energy storage. Climate adaptation. Risk events studies.

Pre and post processing

Development and maintenance of the GiD pre and post processing system (www.gidhome.com). Development of methods for generating structured and unstructured meshes. Development of input data technology for large scale computational problems. Graphical visualization techniques for large scale simulation problems. Generation of input data for finite element analysis from medical images. Integrations of geographical information systems (GIS) with pre and post processing tools and finite element analysis codes.

Social and Economical Modeling

Multi-agent simulation models and tools for social and economic simulation. Analysis and modeling of business actor networks and value chains in the digital sector. Research into financial market dynamics using realistic multiagent simulations. Research in system-level financial risks and counter performativity of financial valuation and risk models.

Technology Transfer Services

Solution of multidisciplinary problems with the numerical method and software developed at CIMNE. Customization of software codes developed at CIMNE for specific applications. Validation of numerical methods and codes developed at CIMNE.

5 TECHNOLOGY TRANSFER ACTIVITIES AND SPIN-OFF COMPANIES

CIMNE has a vocation of transferring the outcoming of its RTD activities to the industrial sector. The technology transfer activities of CIMNE is materialized by **providing services** to companies, using CIMNE based technology and tools and by the **exploitation and marketing** of CIMNE technology and products via a partnership program with companies. This is mostly channeled via the network of spin-off companies created by CIMNE.

5.1 CIMNE technology services

CIMNE helps companies to solving problems in engineering and applied sciences by using the computational, experimental and knowledge-based technology accumulated in CIMNE since 1987. The industrial CIMNE partnership is established via direct contact, or by the joint participation in RTD projects with funding from external agencies at international (i.e. European Commission), or national level.

5.2 CIMNE spin-off companies

CIMNE has established a network of spin-off companies specialized in different fields of engineering and applied sciences. These companies, partially or totally owned by CIMNE, exploit and market worldwide the products and technology originally developed at CIMNE.

The industrial network of CIMNE-owned companies include the following (in order of creation).

STRUCTURALIA S.A.

Created in 2001 and 27% owned by CIMNE.

Structuralia provides e-learning and education services to the construction sector in Spain. The company was sold to the US Company KAPLAN (Washington Post holding) in June 2011 (www.structuralia.com).

COMPASS Ingeniería y Sistemas S.A.

Created in 2002 and 24% owned by CIMNE.

COMPASS specializes in development and market of software in the civil engineering, naval, marine and offshore sector. COMPASS also provides engineering services in these fields (www.compassis.com).

INGENIA AIE

Created in 2005 and 10% owned by CIMNE.

INGENIA AIE is an industrial cluster formed by CIMNE and 9 enterprises in Spain . INGENIA specializes in technology development and services in aeronautic engineering and the air and surface transport sectors (www.ingenia.aero).

CIMNE TECNOLOGIA S.A.

Created in 2012 and 100% owned by CIMNE.

The mission of CIMNE Tecnología is to act as a holding for the different companies created to market the technology and products of CIMNE.

SISTEMAS ENERGÉTICOS AVANZADOS, S.A.

Created in 2012 and 100% owned by CIMNE Tecnología S.A.

The mission of Sistemas Energéticos Avanzados (Advanced Energy Systems) is to industrialize and exploit the new information technology and system developed at CIMNE for energy efficiency management in buildings and urban communities.

INERGY S.A.

Created in 2012 and 50% owned by CIMNE Tecnología S.A.

The mission of INERGY is to market the information technology and system developed at CIMNE for energy efficiency management in engineering and architecture. INERGY has also as a partner the company GASSO Auditores SL, specialized in auditing services for municipalities and urban communities.

TECNOLOGÍAS AVANZADAS PARA EL OCIO S.L.

Created in 2012 and 100% owned by CIMNE Tecnología S.A.

Tecnologías Avanzadas para el Ocio (TAOC) (Advanced Technology for Leisure) specializes in providing and marketing services and products of interest to the tourism and leisure sectors. This includes APP and internet services for promoting touristic activities in beaches and sea areas (www.beaching.com) and multimedia activities for the audio and video industrial sectors, among others.

COMPUTATIONAL AND INFORMATION TECHNOLOGY S.A.

Created in 2012 and 100% owned by CIMNE Tecnología SA .

The mission of Computational and Information Technology (CITECHSA) is to provide engineers solutions to companies using numerical technology and software products developed at CIMNE.

BUILDAIR ASIA-PACIFIC INC

Created in 2012 and 20% owned by CIMNE Tecnología SA.

BuildAir Asia-Pacific , located in Singapore, specializes in distributing and marketing the inflatable structures and related technology of BuildAir SA in the Asia-Pacific region.

BUILDAIR Ingeniería y Arquitectura S.A.

Created in 2002 and 5% owned by CIMNE Tecnología SA.

BuildAir specializes in the design, construction, market and maintenance of inflatable structures for a variety of applications in engineering and architecture. The products of BuildAir include small to very large inflatable shelters and pavilions for leisure and industrial activities, aircraft hangars and emergency/logistic services, among other applications. BuildAir also develops and markets inflatable beams and inflatable bridges for application in the civil engineering and construction field, and the emergency and logistic sector, among other applications.

LYNKOS S.L.

Created in 2012 and 15% owned by CIMNE Tecnología S.A.

LYNKOS specializes in offering technology solutions, products and services to companies and organizations in the so-called *internet of things* sector.

FRESH WATER NATURE S.L.

Created in 2012 and 100% owned by CIMNE Tecnología SA.

Fresh Water Nature (FWN) specializes in the development and marketing of the fresh water production technology developed and patented by CIMNE. This technology can be effectively used for sea water desalinization by potabilization of water in an innovative and economical form.

MOBILE MEDIA EXPERIENCES S.L.

Created in 2012 and 30% owned by TAOC SL.

The mission of Mobile Media Experiences is to develop and exploit innovative inflatable pavilions integrating state of the art, audio and video multimedia systems and technology for a variety of applications in the cultural, leisure and tourism sectors.

6 CIMNE. A PARTNER FOR EDUCATION, RESEARCH AND BUSINESS OPPORTUNITIES IN COMPUTATION ENGINEERING AND APPLIED SCIENCES

6.1 A partner for education in computation engineering and applied sciences

CIMNE and the Technical University of Catalonia (UPC) offer students of all nationalities the opportunity to accessing high education courses and degrees at Bachelor and M.S. levels in most areas of computational engineering and applied sciences. Courses are taught mainly at UPC or in partner universities of the Catalonian university network for specialities not covered by UPC. Students are tutored by CIMNE and UPC academic experts in the different fields .

6.2 A partner for research in computational engineering and applied sciences

CIMNE and UPC offer graduate students of all nationalities the opportunity to perform doctorate studies and research work aiming to obtaining a Ph.D. degree at UPC in a wide range of topics in engineering and applied sciences. Doctorate students are supervised by CIMNE and UPC specialists in the different fields. Opportunity exists for “sandwich” type of doctorate degrees allowing students to develop part of their doctorate at UPC and CIMNE premises and the other part at their home university under the joint supervision of academic staff from UPC/CIMNE and the home university from where the student originates.

6.3 CIMNE. A partner for business opportunities

CIMNE offers a partnership to companies and organizations worldwide for joint exploitation of products and services.

The list of business opportunity currently available is the following.

6.4 CIMNE products

Integrated systems and products	CIMNE partner company
Energy efficiency management system	Inergy SL
Inflatable structures (pavilions, shelters, hangars, bridges, etc.)	BuildAir SA
Fresh water production system (desalinization, potabilization, etc.)	Fresh Water Nature SL
Leisure management systems (i.e. www.beaching.com)	Tecnologías Avanzadas para el Ocio SL
Inflatable multimedia pavilions	Mobile Media Experiences SL

Software codes	
Stampack code for sheet metal forming analysis (www.quantech.es/stampack)	Quantech ATZ SA
VULCAN code for casting analysis (www.quantech.es/vulcan)	Quantech ATZ SA
Fraktalis software platform for the management, communication and cooperative work of organizations, enterprises and communities via internet	CIMNE Tecnología SA
GESTURB code for optimal design of engineering services in urban development areas	CIMNE Tecnología SA
SIGPRO code for support to project management activities in RTD organization	CIMNE Tecnología SA

6.5 Computational services

CIMNE offers computational services in all areas of engineering in cooperation and partnership with the companies of the CIMNE industrial network.

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