100 years of fluid mechanics

Hes·SO GENÈVE
Haute Ecole Spécialisée
de Suisse occidentale

h e p i a
Haute école du paysage, d'ingénierie
et d'architecture de Genève

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CMEFE - Competence group in fluid mechanics
and energetics

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"Those who devote their life to Science may justly be proud, like those who, students such as you, may devote several years of their lives to a scientific discipline, since there is nothing finer, despite the work and hardship this entails, than the chance to join the search for truth about nature and mankind."

"Study allows you to discover the infinite richness of human knowledge, the incredible diversity of creatures – from the largest to the smallest – the magnificence of the universe, the marvels of nature. Learn also to thank the Creator for life. Identify the organic and fundamental connection between religion and culture, a link that has always been at the core of the finest civilizations."

"The task of university is also to teach, but in essence it is there to enable those who attend – who already have a mind of their own, albeit relatively undeveloped, and some experience of life – to think for themselves. The role of university is to liberate man's intellectual and spiritual potential and to help him free himself – yet this liberation is an honest and personal action."

Jean-Paul II,

extracts from speeches made during meetings with students in Kinshasa, Leuven and Lublin between May 1979 and May 1985.

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The cmefe team

100 YEARS OF FLUID MECHANICS

The laboratories at the origin of the cmefe are 100 years old. To mark the occasion we are publishing the present booklet. It is not a historical document retracing the history of the institution with great accuracy, but rather a message of friendship and recognition to all those who have passed through its doors in the past and who still do so today.

The history of fluid mechanics in Geneva is a love story. Firstly because the city is built on the Rhône, one of Europe's finest rivers; and secondly because many companies based in Geneva excel or have excelled in this discipline. They include the company Charmilles, which produced hydraulic turbines, and also the company Hispano, whose founder Mark Birkigt was one of the first students of the School of Arts and Crafts of Geneva, the precursor of the current School.

The pages that follow describe a number of cmefe activities and invite you to share with us our 100 years of passion for one of the greatest sciences.

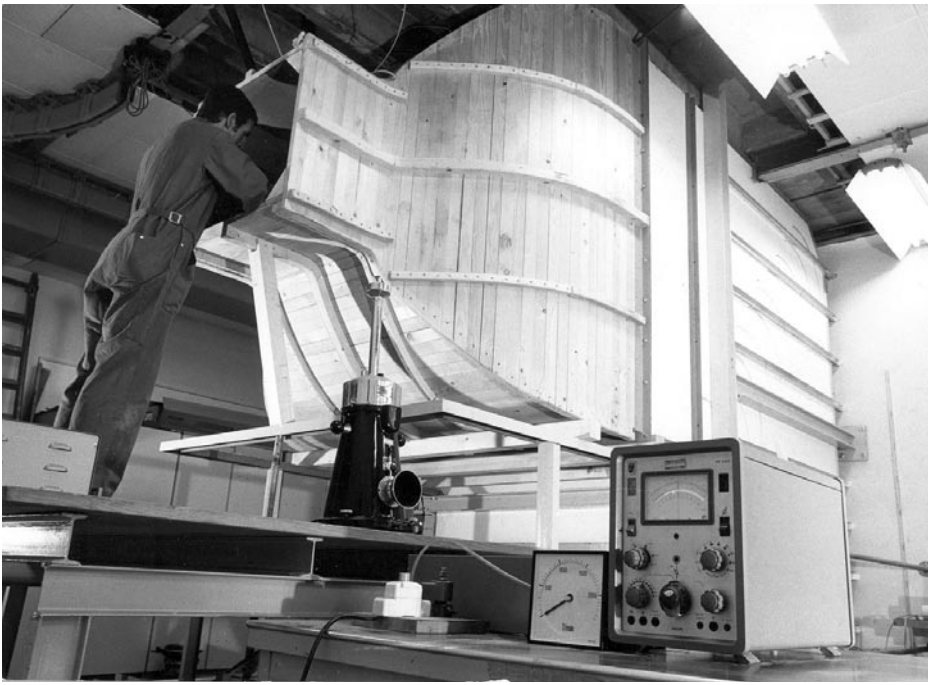
The cmefe team

BACKGROUND

The aerotechnics and hydraulics laboratories of the Geneva School of Engineering, formerly the School of Arts and Crafts, have existed since 1905. The School, located next to Cornavin station, moved subsequently to the rue de la Prairie in the district of Les Délices. The activities of these laboratories focused mainly on the fields of light aircraft and glider aerodynamics, hydraulics and engines.

Work undertaken since has been much wider in scope:

- Aeronautics
- Rockets, Pulsated Over Heated Water Rocket (Pohwaro), liquid and powder propulsion systems
- Aerodynamics of buildings
- Sport
- Measuring systems
- Aerodynamics of trains and other vehicles

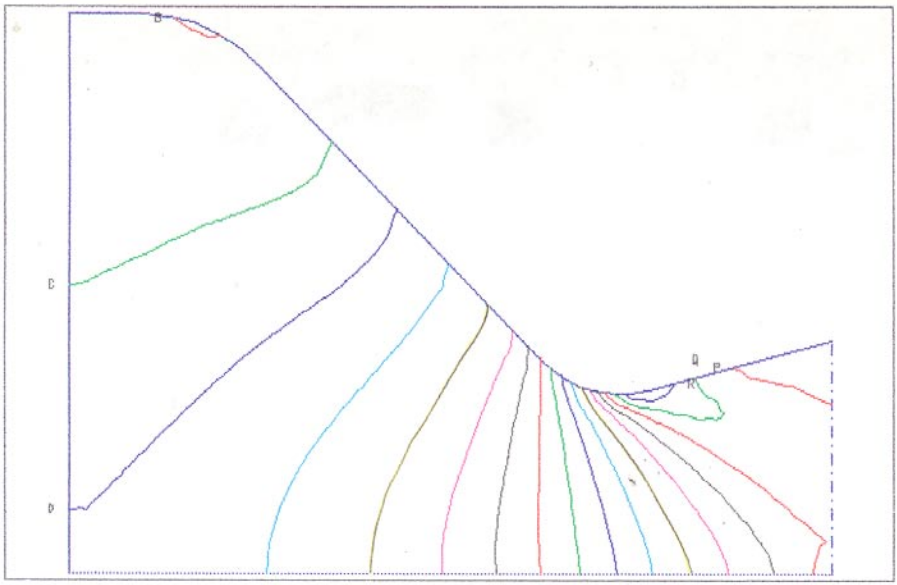


Assembly of a teaching wind tunnel (1970)

Since the 1980s, numerical modelling has also featured largely in projects. In 1982, a calculation code for supersonic flows was developed, followed by a code for transonic flows (1984).

In 1987, the aerotechnics laboratory relocated to a site under the Pont-Butin in Le Petit-Lancy (Geneva) in premises formerly belonging to the company Hispano. An old tunnel designed originally for rail traffic, it was fitted out as a laboratory and today contains modern research facilities. These include:

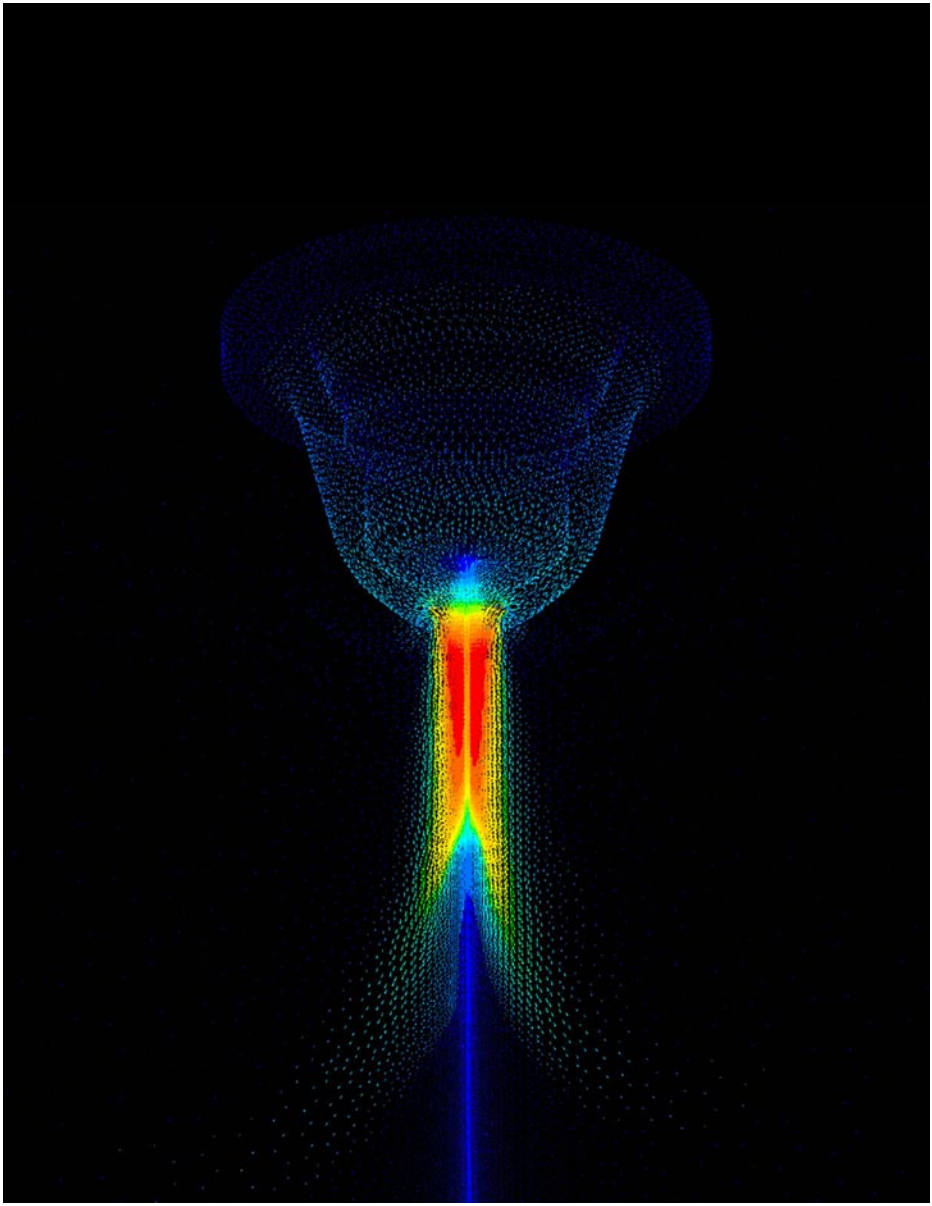
- A large size subsonic wind tunnel
- A laboratory housing subsonic and supersonic wind tunnels, as well as machine-tools
- A room for the calibration of aerodynamic balances
- Offices and work rooms
- Fuel storage areas
- A flow simulation computation room



Simulation of transonic flows (1984)

cmefe large subsonic wind tunnel (1995)

At the same time, the laboratory of applied energetics was transferred to the old Verntissa factory in Vernier (Geneva). In 2002, the aerotechnics and applied energetics laboratories, together with the hydraulic machines laboratory, were regrouped in a single entity, the cmefe, the Competence Group in Fluid Mechanics and Energetics.



CFD modelling of a dielectric jet (2005)

SKILLS

For many years the cmefe has developed research activities in the following fields:

- Experimental fluid mechanics
- Flow modelling
- Energetics
- Heat science

Strategic objectives:

To provide answers to contemporary questions, the research activities of the cmefe are aligned with two main objectives, namely:

1) Application of fluid mechanics

- Aerodynamics inside and outside constructions
- Aerodynamics of transport systems and their components
- Environment
- Optimisation of industrial processes
- Cooling of electronic systems
- Enhanced performance of sports equipment

2) Energetics

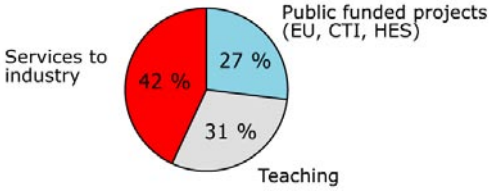
- Transformation of renewable energies
- Development of techniques for the use of bio-fuels
- Exploitation of heat emissions for the production of electricity
- Optimal energy management

ACTIVITIES

The cmefe is a partner in numerous industrial developments and research projects. You will find in the following pages a summary of some of our activities.
With regard to resources, their distribution over the past three years has followed the pattern shown in the figure below. Services to industry are assignments carried out for clients and billed by the hour or service. EU, CTI or HES projects are those financed in part by Swiss or European government institutions.

Finally, the last tranche represents the teaching activities of the cmefe financed by the HES-SO (University of Applied Sciences Western Switzerland) and the cantons. The cmefe accords particular interest to contracts with industry.

We believe this is an excellent way of putting our students in contact with the world that awaits them. We have observed that they respond very well to this approach.



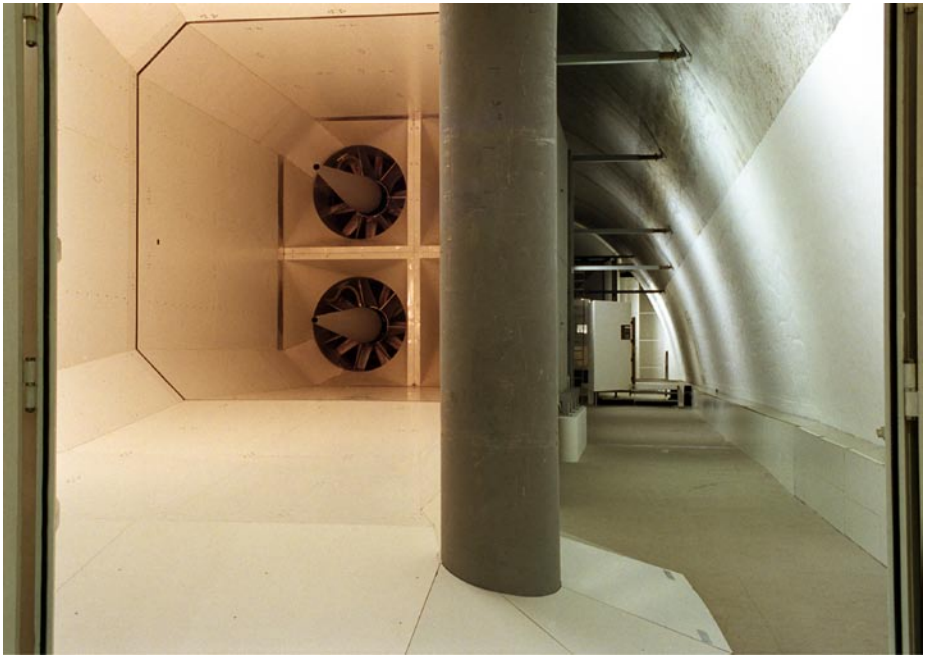
Distribution of resources

LARGE SUBSONIC WIND TUNNEL

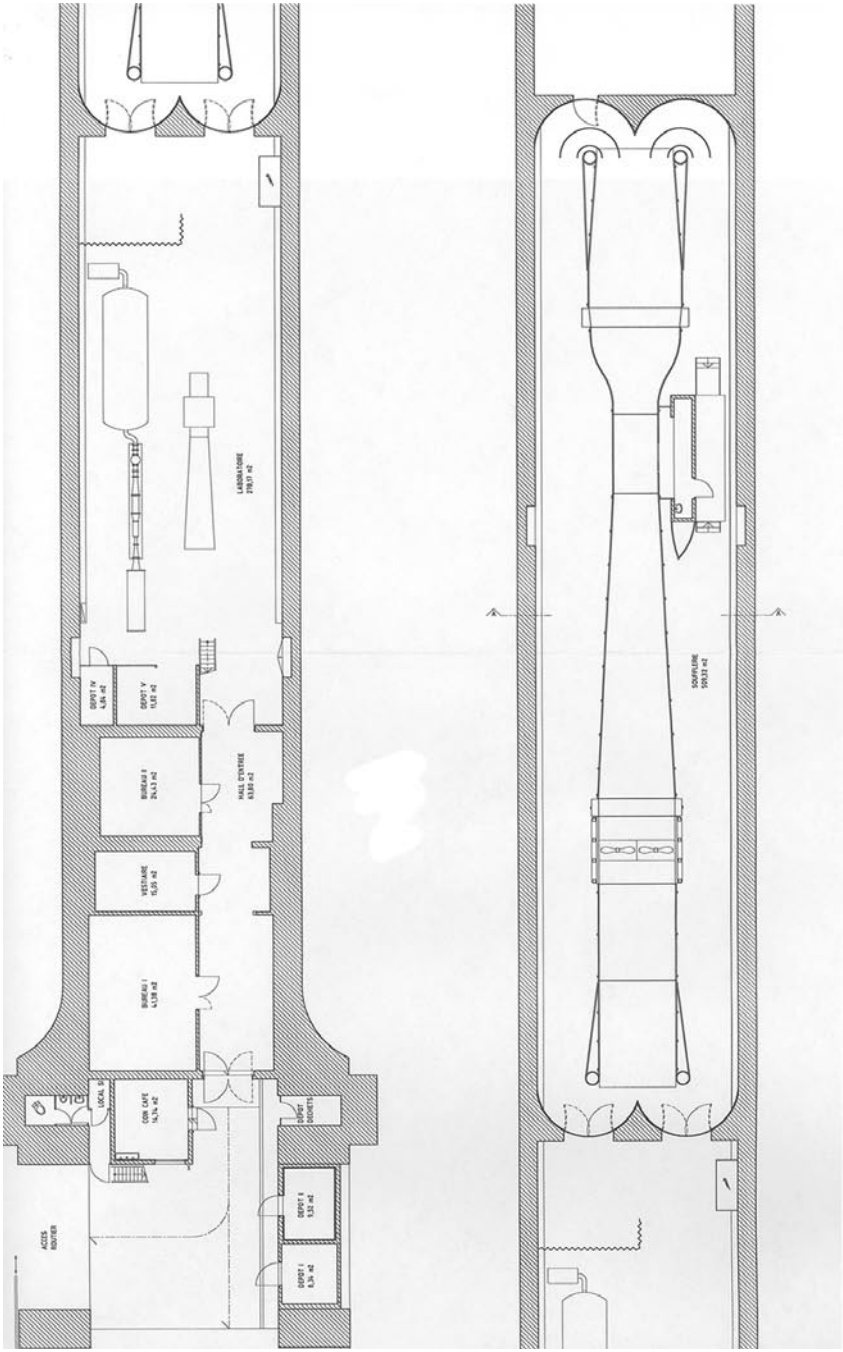
Design of the cmefe large subsonic wind tunnel began in 1987. A concept similar to that developed by Eiffel was devised by Michel Perraudin and Patrick Haas. It was installed in a former tunnel intended originally for rail traffic. The air return is not free. It takes place in the annular space between the construction and the reinforced concrete walls of the tunnel.

The curve of the convergent nozzle was produced using numerical models based on singularity methods, the accuracy of which was improved by semi-empirical data.

Construction of the assembly was completed in 1995. The shell of the construction was built by contractors however a large part of the wind tunnel was produced thanks to contributions from the Cantonal Employment Office of the Canton of Geneva. It is constantly being improved to make the most of the latest innovations.



Large subsonic wind tunnel



Plan view of the installation

Characteristics:

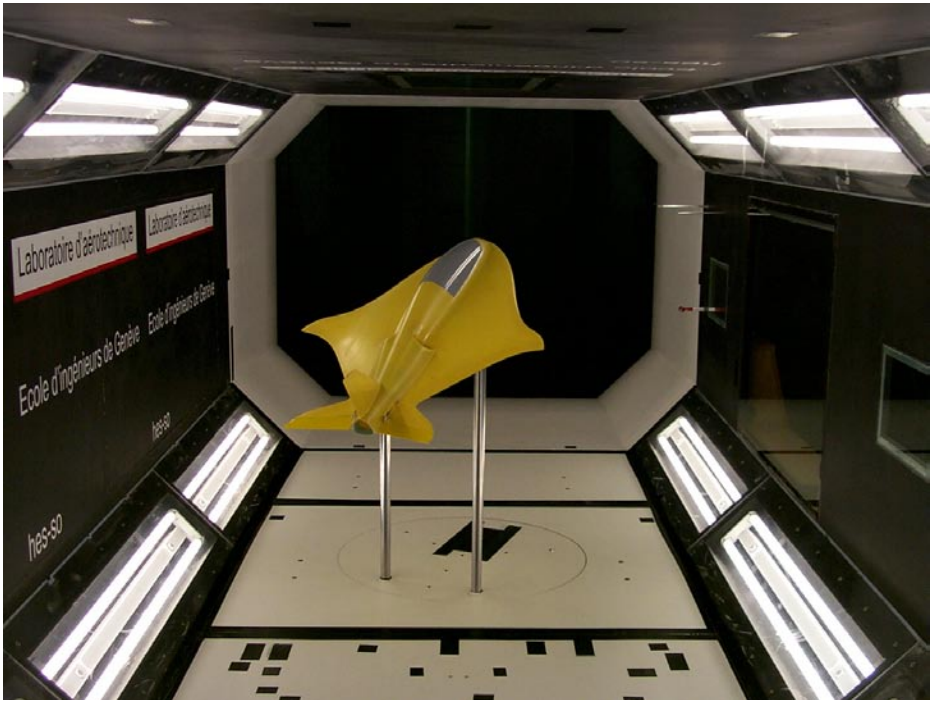
Length: 55 m
Maximum cross-section: 4.6 m x 4.6 m

Test section:

Dimensions: 4 m x 2 m x 1.5 m
Maximum speed: 80 m/s (approx. 300 kph)

Power:

Axial fans: 4 x 10 blades ø 1.4 m
Unit power: 75 kW
Total maximum output 300kW (408HP)
Air flow: 240 m3/s or 756,000 m3/h
Operating temperature: between 15° and 30° C



Development of the Smartfish aircraft

View of the laboratory

Preparation for a test

AERODYNAMIC BALANCES

The measurement of forces and moments acting on reduced models or human subjects is realised by complex systems involving specialised technologies. Right from the start cmefe has actively developed units of this type for its own use.

Two types of balance were developed; three to six-component static balances (three forces and three moments) and dynamic balances with resolutions of up to 0.1 newtons and a capacity of 5’000 newtons.

Close contacts with leading European aerospace research centres have enabled us to realise systems numbering amongst the most sensitive and stable in the world.

Completing this range of equipment is a computerised data acquisition system and a calibration room equipped with a range of different stands.

A six-component tensometric gauge balance

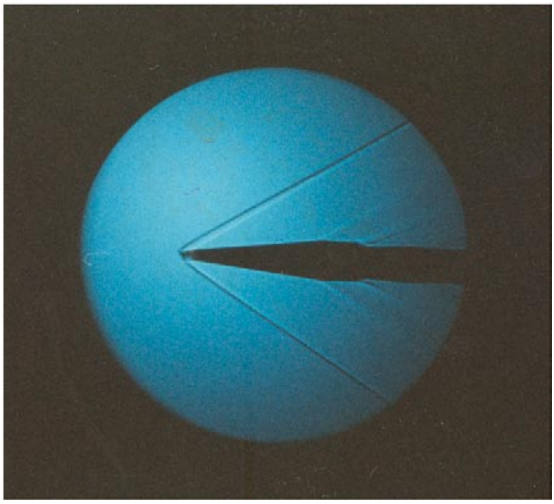
SUPERSONIC WIND TUNNEL

The cmefe has a blow-down supersonic wind tunnel. Flows with mach numbers exceeding 2.4 (approximately 3',000 km/h) are generated by air expansion in a tube fitted with a nozzle. The flow is visualised by a Schlieren type optical system.

Tank:
Capacity: 20 m3 – 16 bar
Working temperature: 100 deg. C

Test section:
Type: rectangular 120 x 80 mm
Interchangeable tubesnozzles: mach 1.4 – 1.8 – 2.4

Power:
Pressurising time: 9 hours, operating time: 90 s
Two-stage compressor 7.5 kW
Shock waves with a flow rate ofin a flow with mach 2.4



Shock waves and expansion waves in a flow at mach 2.4

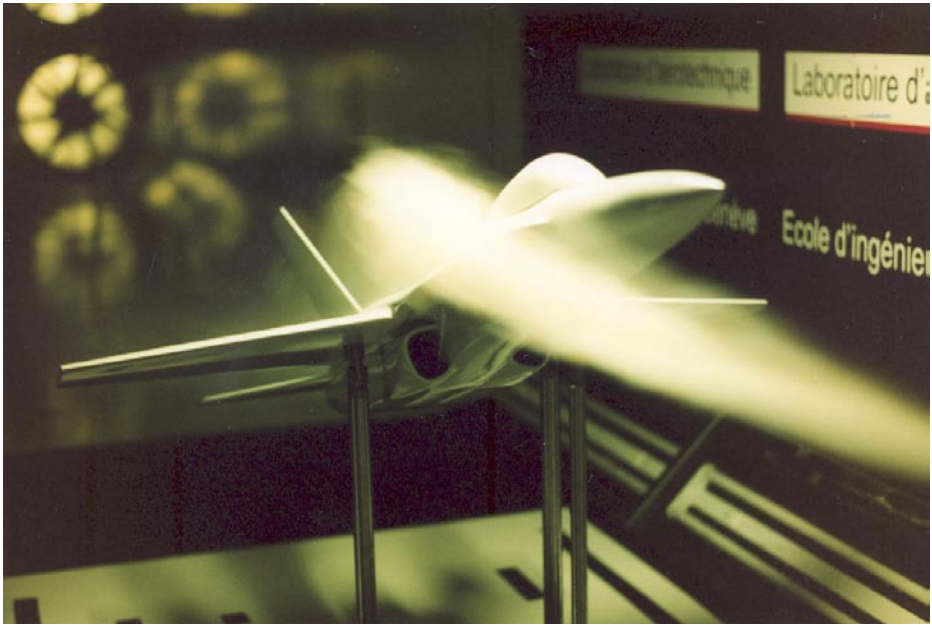
VISUALISATION METHODS

The cmefe has developed several flow visualisation methods. The following images were realised in connection with work on leading edge as well as tip vortices, which develop at wing tips or any other lifting surfaces.

The characterization of turbulence structures is the basis of the understanding of aerodynamic phenomena occurring around a body. It allows the development of hyperlifting effects devices to reduce forward motion drag or to optimise any kind of performance.

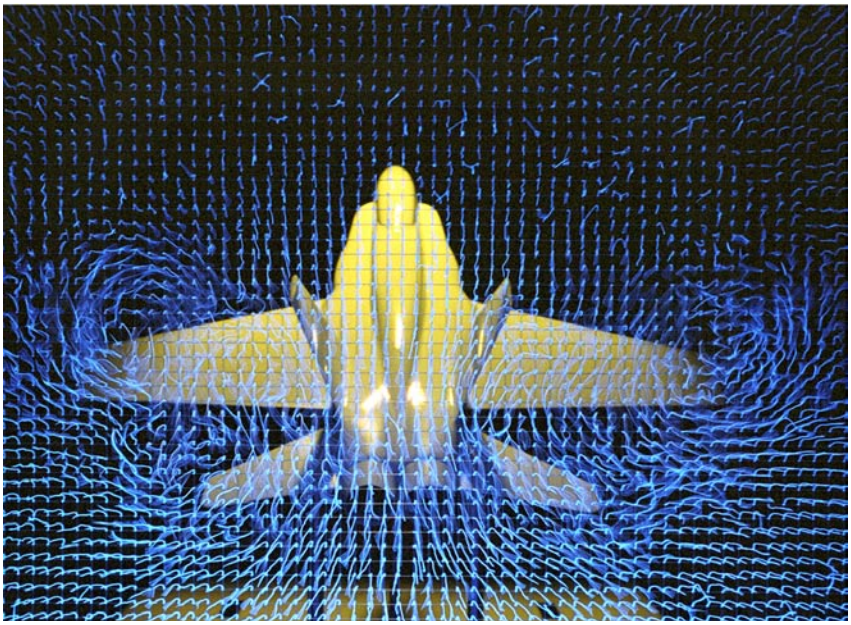
These systems are not simply research tools but are also extremely useful educational tools. They permit the illustration of basic aerodynamic phenomena and also serve as an aid to the teaching of fluid dynamics.

Model mounted on motor driven pylons

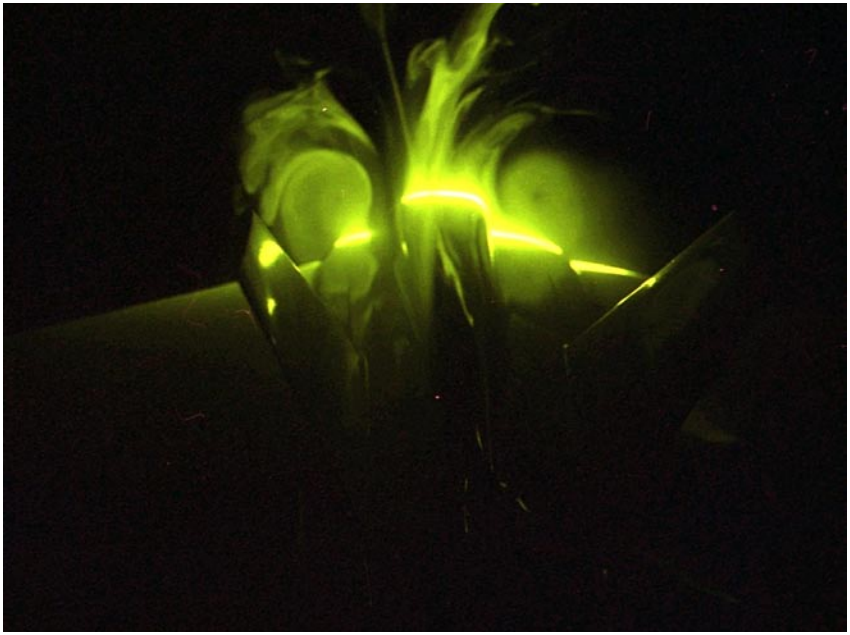


Injector nozzle and smoke generator

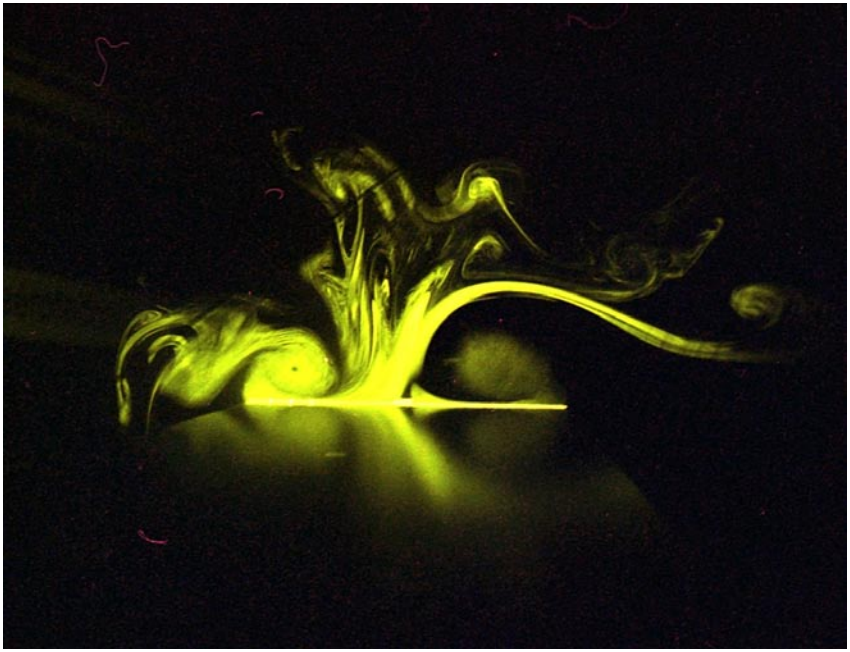
Visualisation of leading-edge turbulent structures



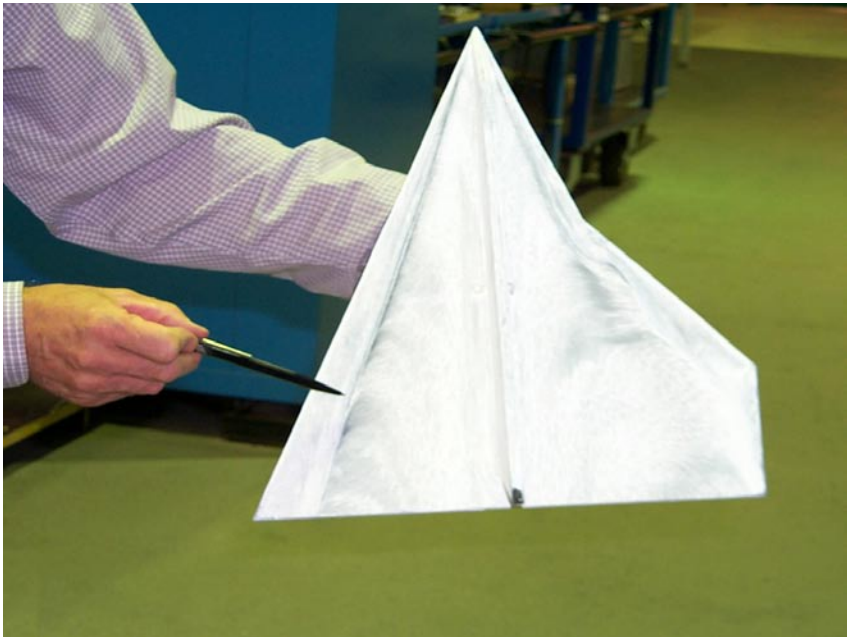
Visualisation using a grid of tufts



Visualisation of turbulent structures with a laser sheet



Transient vortical structures



Visualisation of boundary-layer flows

VERTICAL WIND TUNNEL

The cmefe developed a vertical wind tunnel intended for the study of a body in free fall. A powerful fan produces pulses of air in a slightly divergent tube. The models are released from the upper extremity of the installation. They stabilise at a particular height in the tube when the weight is exactly compensated by the aerodynamic resistance. This installation was a development basis for parachute bags intended for humanitarian drops.

Vertical wind tunnel

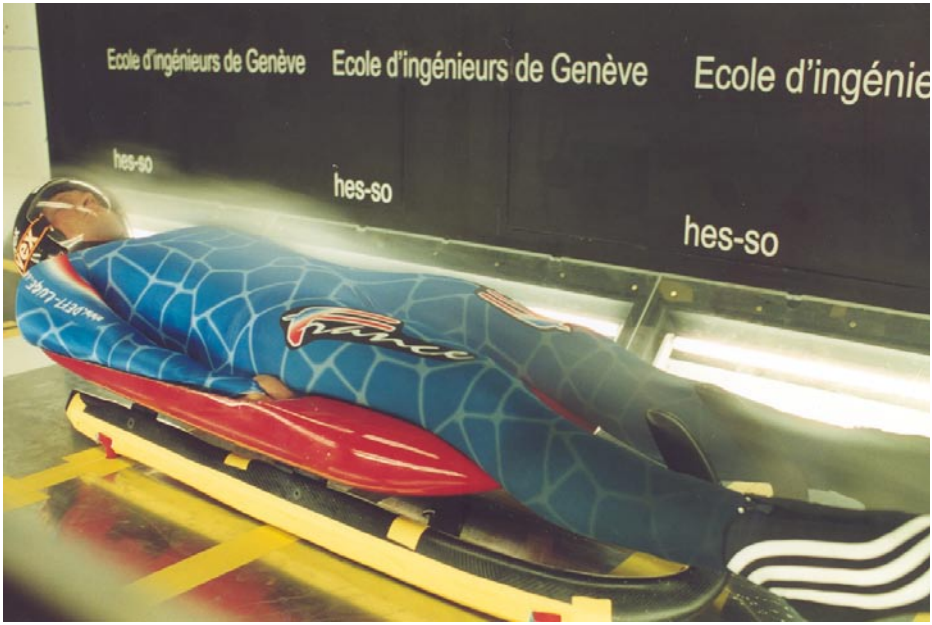
SPORTS AND EQUIPMENT

For around 15 years, winter sports have represented an important field of activity for the cmefe. Skiers, lugers and ski-jumpers from several European countries train regularly in the large Geneva wind tunnel.

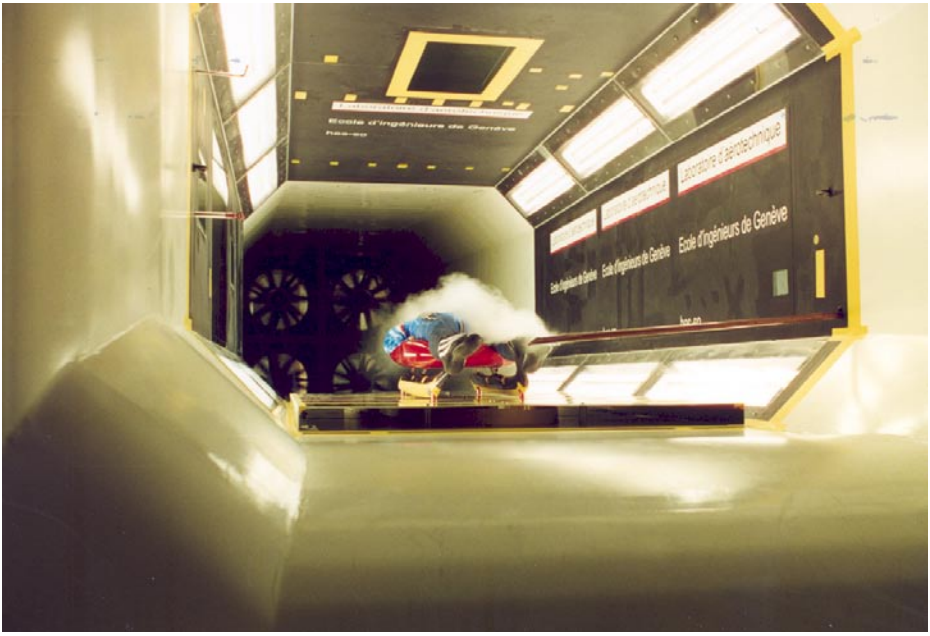
Tests involving human beings are a complex phenomenon. The repeatability of tests, measurement of the body position of individuals human subjects and safety aspects create a range of constraints that call for particular expertise.

The cmefe has helped to establish several world records. It also plays a part in the development of equipment. Its research is currently focused on understanding and measuring surface drag.

Speed skiers



France Olympic Team



View from the tranquilisation chamber

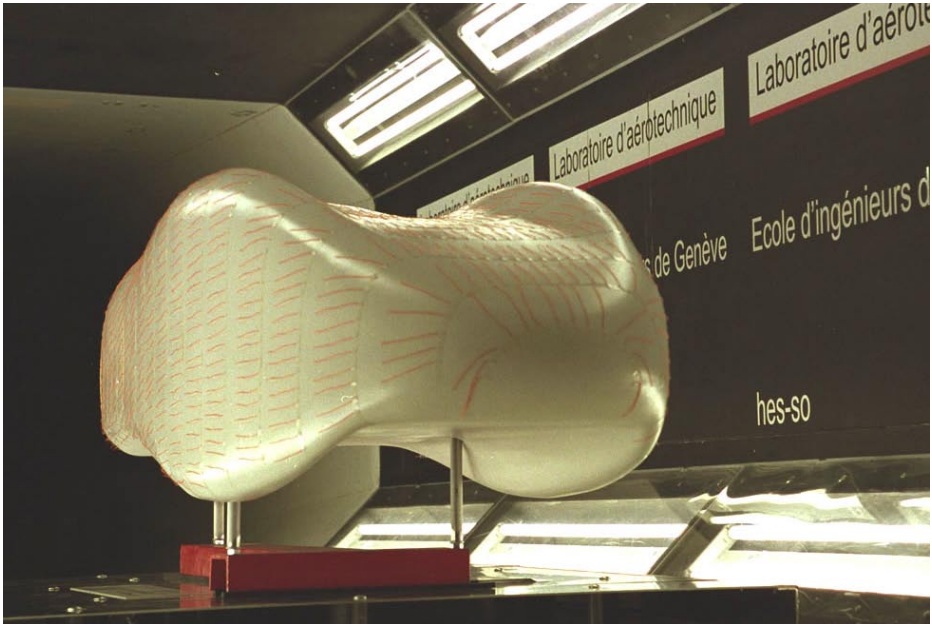
ECO-MOBILES

The University of Applied Sciences Western Switzerland takes part each year in the eco-marathon organised by Shell on the Nogaro circuit in the south of France. In May 2004, the Consomini vehicle made by the Haute Ecole de l'Arc Jurassien, Fribourg School of Architecture and Engineering and the Geneva School of Engineering covered the equivalent of 1,200 km on one litre of petrol at an average speed of 30 kph. The project also won two awards.

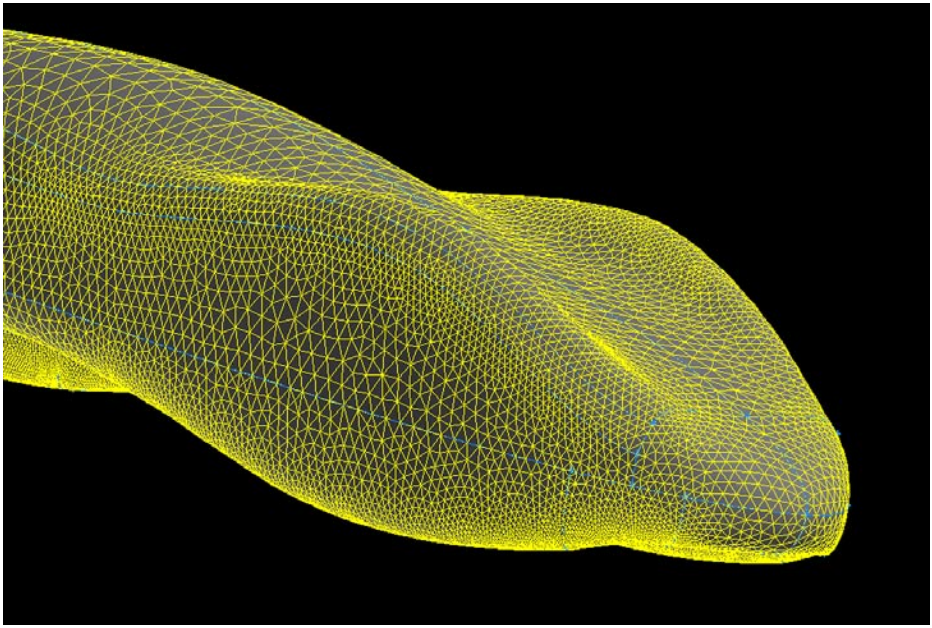
The cmefe is a partner in this project. It carried out the aerodynamic study of the vehicle and ran test campaigns and digital simulations with a view to optimising its rolling resistance.

A three-dimensional scanning technique was used to capture an image of the modified model at the end of the study.

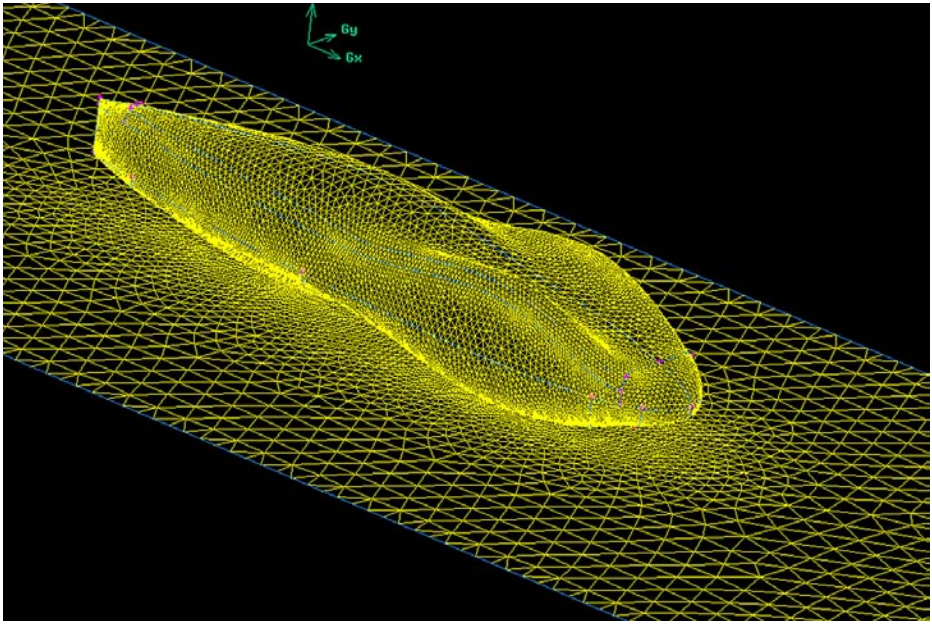
The Consomini vehicle



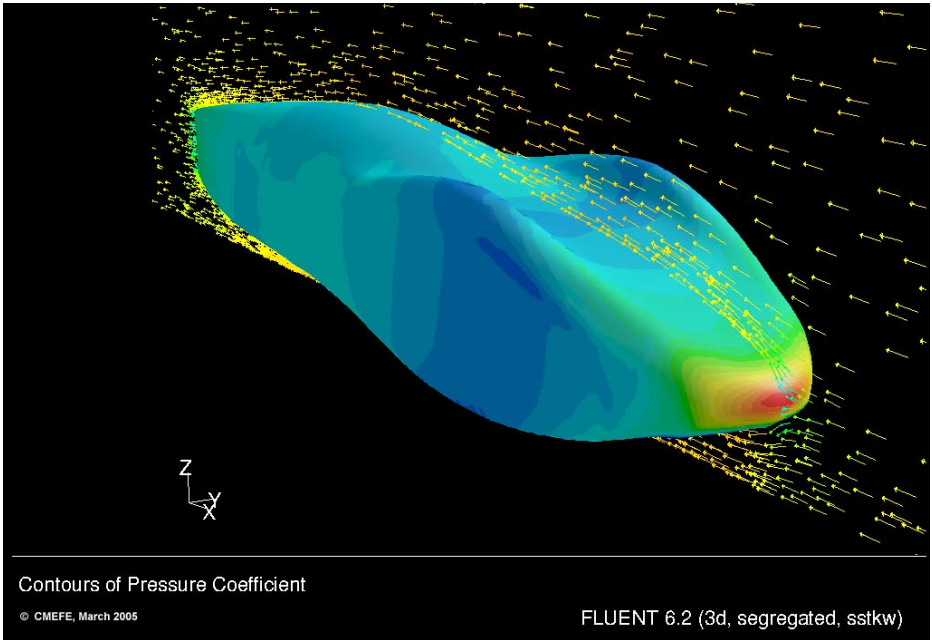
Full-scale aerodynamic study



Mesh used for CFD flow simulation



Mesh computed using size functions



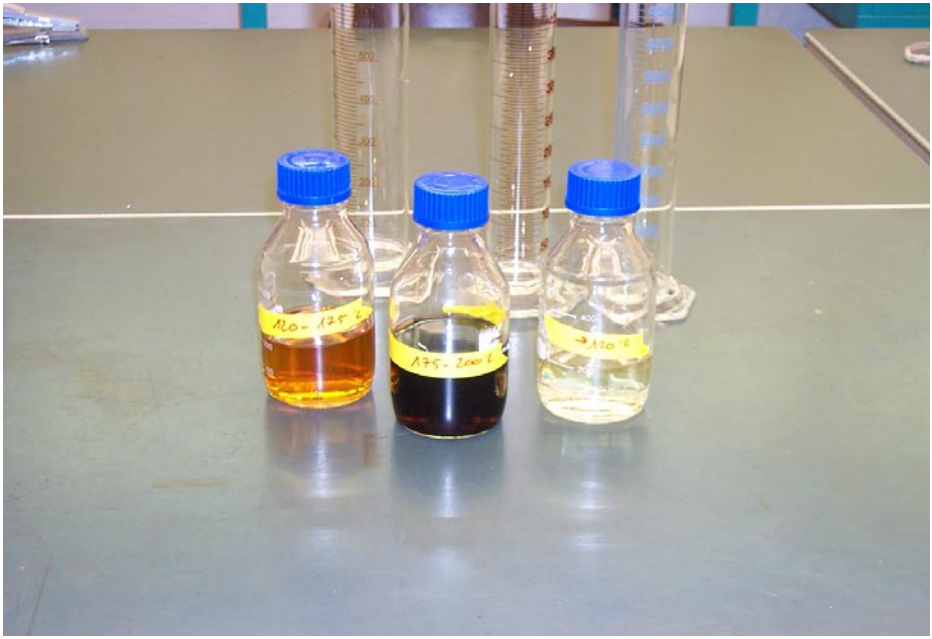
Study of pressure and velocity fields

BIOMOBILE.CH

A second eco-mobile was created by the HES-SO. This vehicle is intended to take part in the Shell Eco-marathon running on bio-fuel derived entirely from vegetable waste. The project is being carried out in collaboration with the Geneva company Biocarb SA.

Part of the innovation attributable to the fuel used resides in the fact that it is not intended solely for diesel engines, as is the case for example with colza oil. The fuel can be used in conjunction with traditional engines operating according to a constant volume thermodynamic cycle. As a result, most vehicles currently on the road are possible candidates, even small capacity engines such as those powering two-wheelers, garden equipment, etc.

The manufacturing process of this fuel also differs from that used to produce ethanol, such as for example in Brazil using sugar cane or in Europe during the war.



Bio-fuel produced from vegetable waste

Biomobile.ch on the Nogaro circuit (France) in May 2005

The aim of the Biomobile.ch project is to produce an eco-mobile with a rate of CO2 emissions per kilometre that is as low as possible.

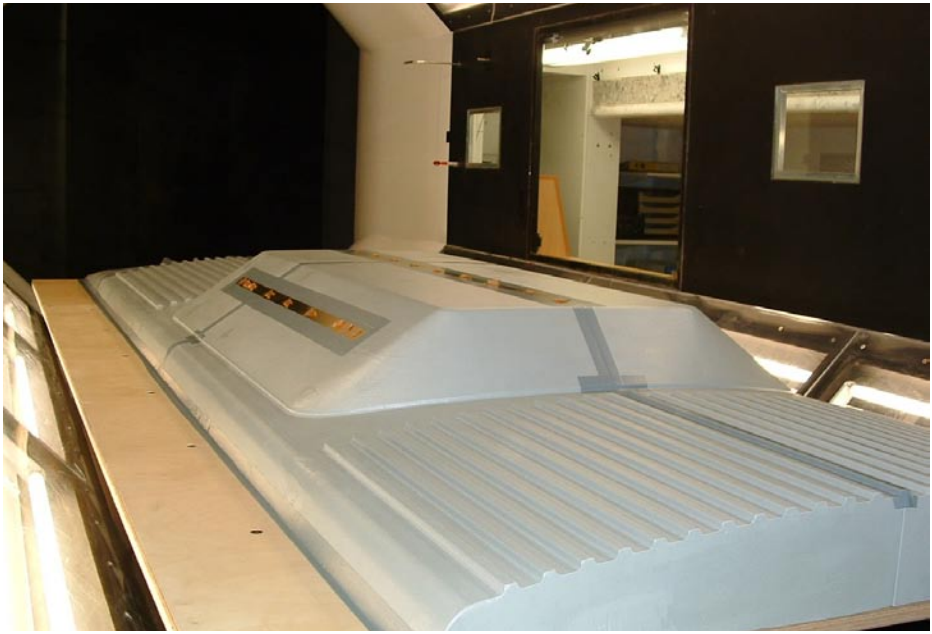
FRESH AIR INLETS FOR HIGH-SPEED TRAINS

The cmefe is developing inlets for the air-conditioning units of high-speed trains. A project financed by the University of Applied Sciences Western Switzerland has been carried out, as well as diploma and term-based work.

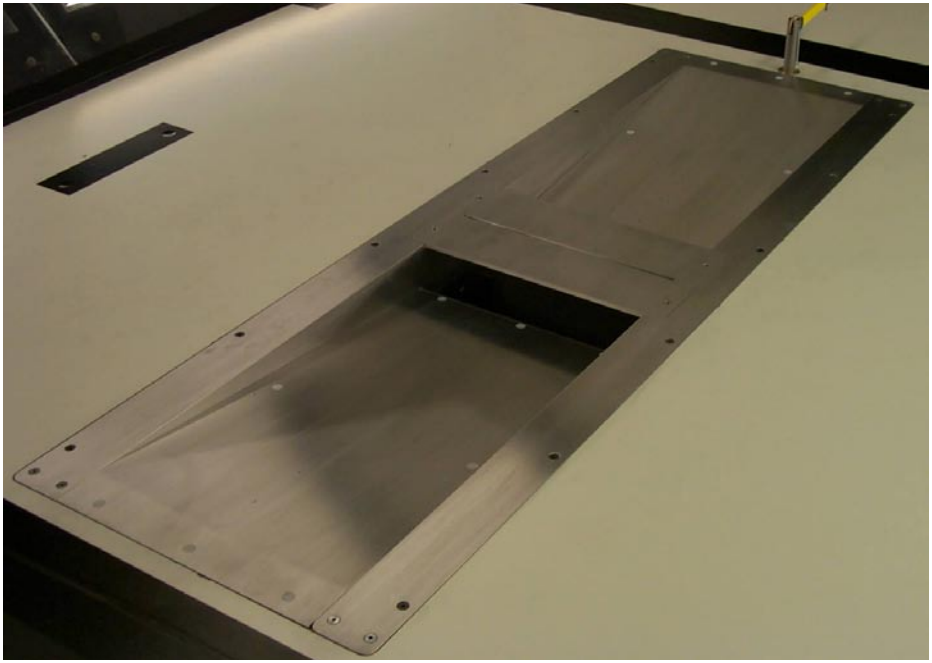
The aim is to design a fresh air inlets that ensures a zero pressure coefficient at the point of entry. The pressure at this point is therefore equal to atmospheric pressure and no longer varies according to the speed of the train. When such conditions are obtained, dimensioning of the thermal capacity of the air-conditioning unit is optimal, since the flow of fresh air is itself also constant. The study contains theoretical, numerical and experimental parts.

The establishment of criteria of similitude of physical phenomena is a particularly important aspect of the project.

Machining of one of the models using a five-axis machine-tool



Flow study near an air-conditioning unit



One of the fresh air inlet developed

CARMEN* - A HYDRO-THERMAL MODEL OF THE RHONE

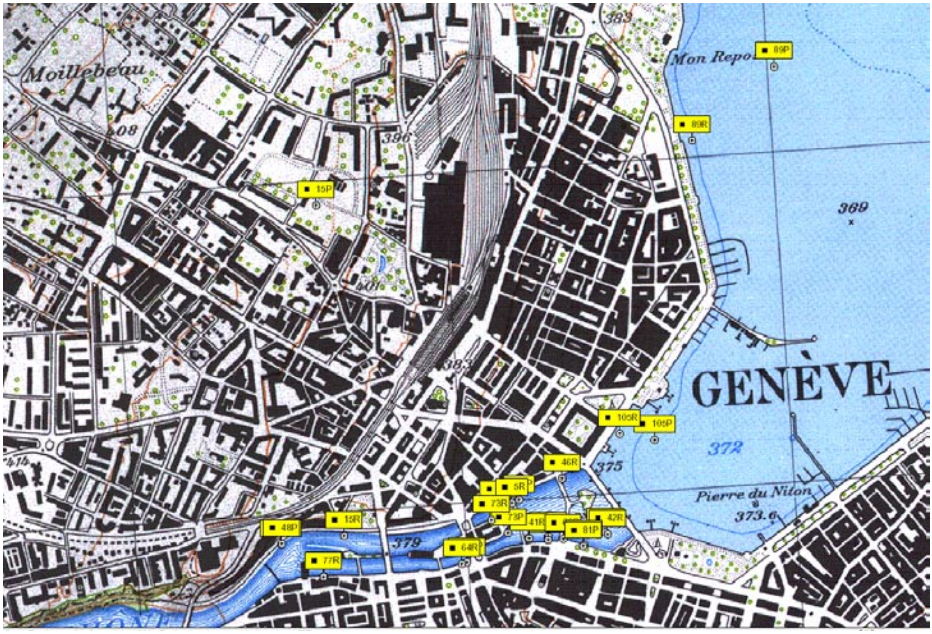
The objectives of the CARMEN project are to realise a hydraulic and thermal model of the urban Rhône river using a finite-volume CFD approach. The existence in Geneva of a simulation model will permit the evaluation of the impact of heat disposal from cooling.

A study group on the thermal state and the biology of the Rhône comprising the CUEPE (University of Geneva Centre for the Study of Energy Problems), the Department of the Interior, Agriculture and the Environment (DIAE), the Cantonal Energy Service (SCenE) and the cmefe was created in May 2005.

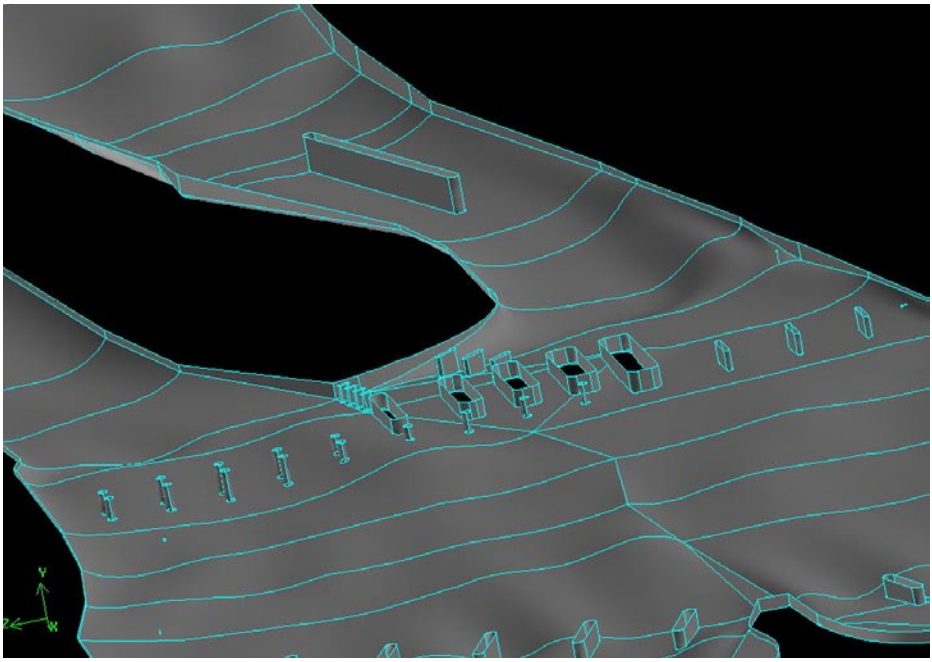
This is an important project with an educational perspective. Beyond the extraordinary aesthetic aspect, it allows us to make our students aware of the environmental impacts of a project.

* *This beauty, wandering through the town, attracting many covetous glances*

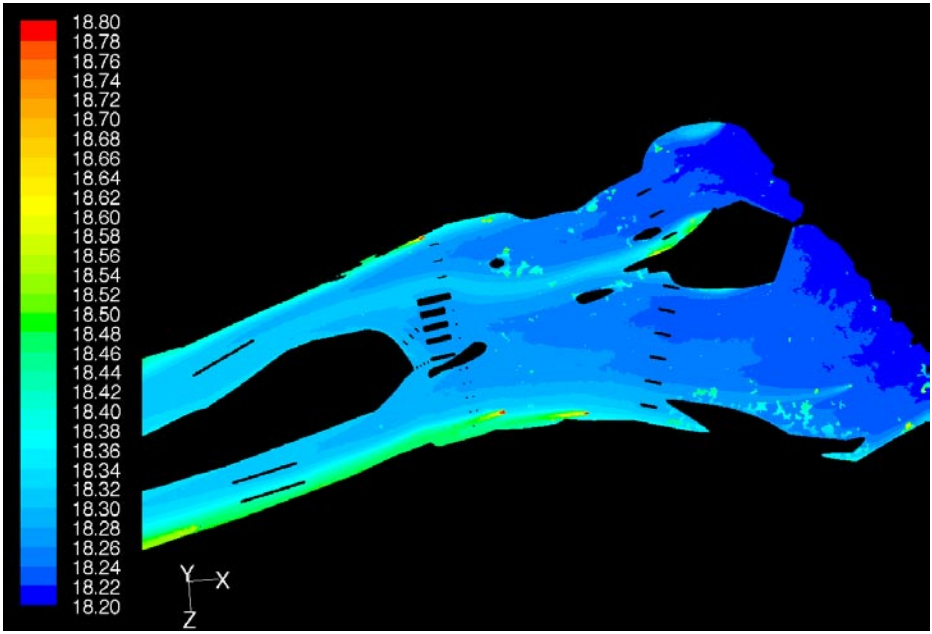
The Rhône river seen from the cmefe (Pont-Butin)



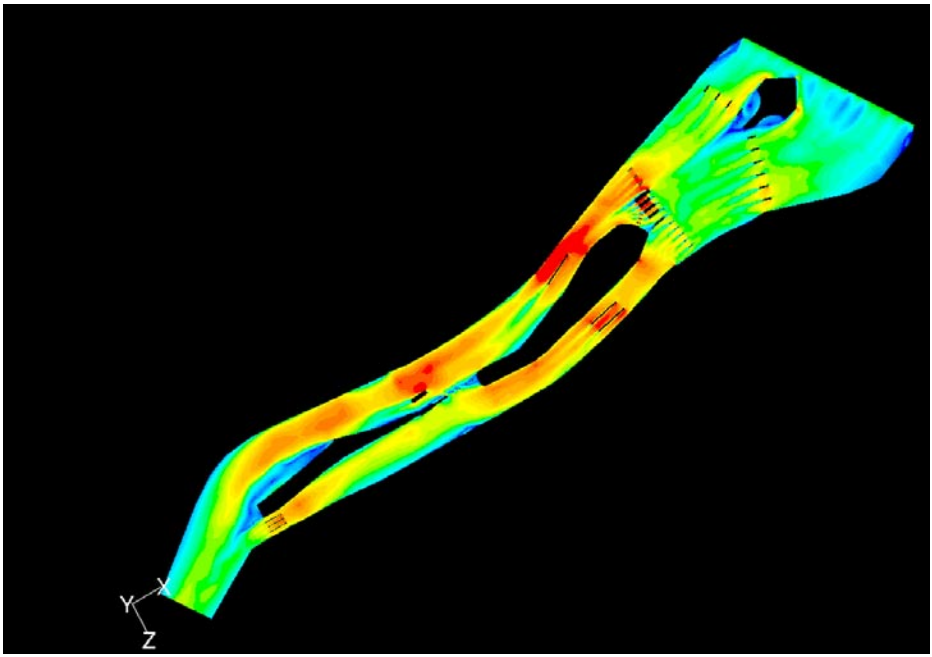
Heat waste locations in the urban Rhône



Detail of the river bed at the "Pont de la Machine"



Temperature and plume distribution



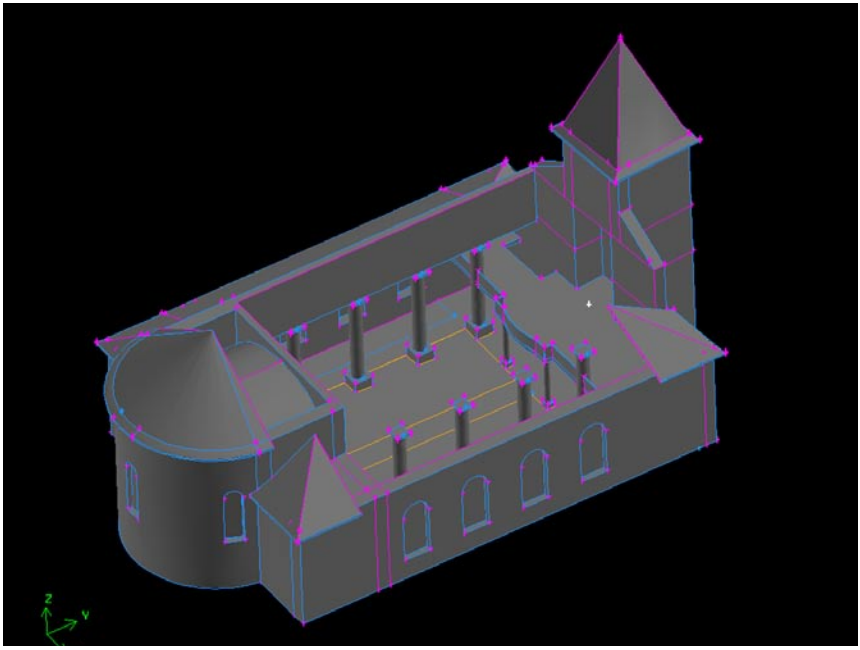
Fluid velocity on the surface of the Rhône

SIMULATION OF THE CONVECTIVE FLOWS IN A CHURCH

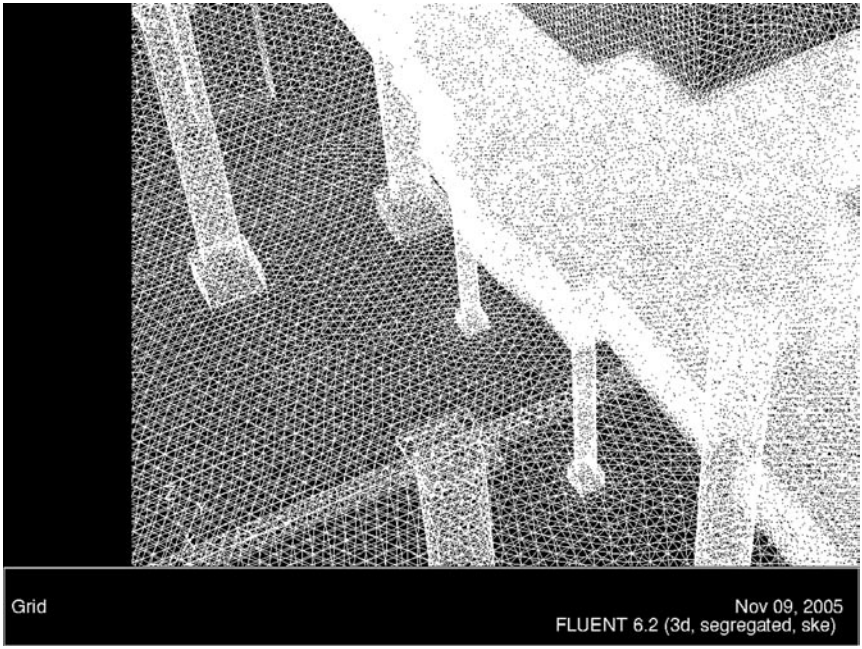
The simulation of flows in a large building or one with particular characteristics allows the development of concepts suitable for heating, ventilation or air conditioning that have minimal impact on architectural aspects.

The cmefe simulates flows generated by natural convection or forced inlets. The study of an opera hall was carried out in 2004. More recently, the Roman Catholic Church of Geneva assigned to the cmefe the study of flows in the church at Compesières. This edifice, dating from 1270, was said to have been given by the Bishop of Geneva Aymon de Menthonnay to the order of St John of Jerusalem, known as the Order of Malta. The church was extended in 1633, then rebuilt in 1834 to give it its present form. Renovation work and archaeological digs are currently in progress.

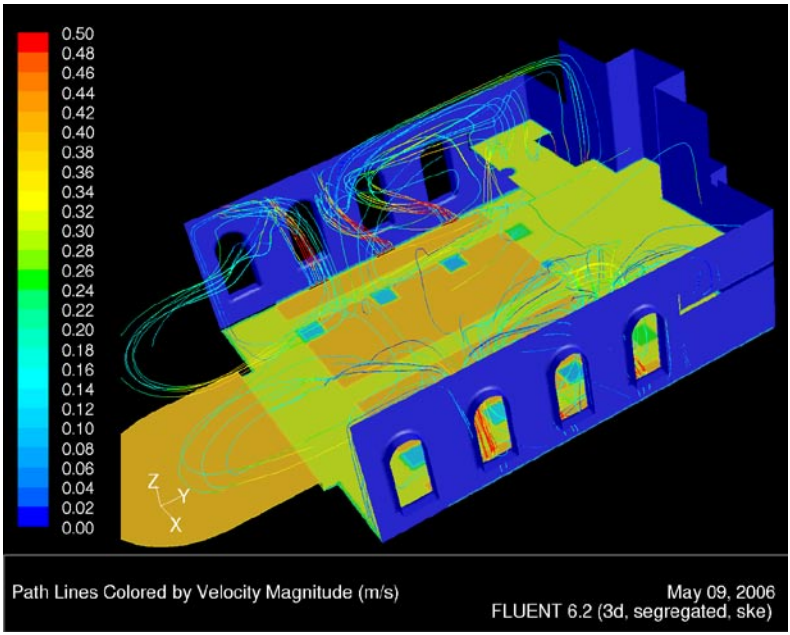
The church and Château de Compesières (Geneva)



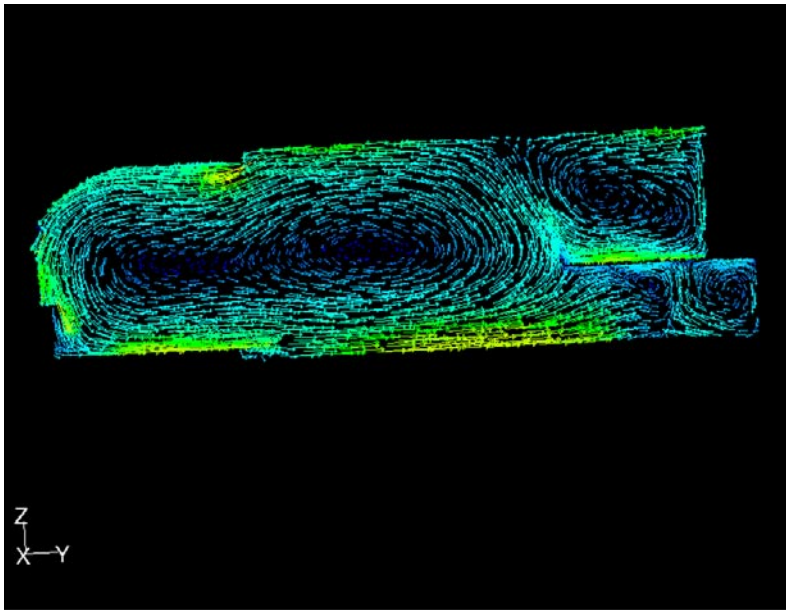
Geometric model of the church



Tetrahedral mesh geometry



Air particle trajectories



Velocity field in the median plane of the church

To obtain more information about the activities of the cmefe do not hesitate to contact us:

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