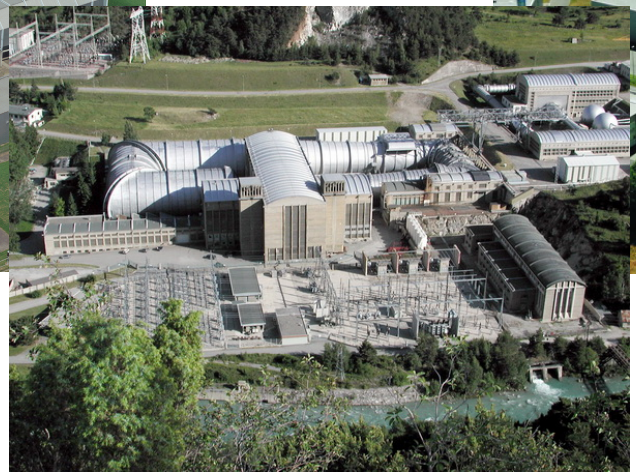
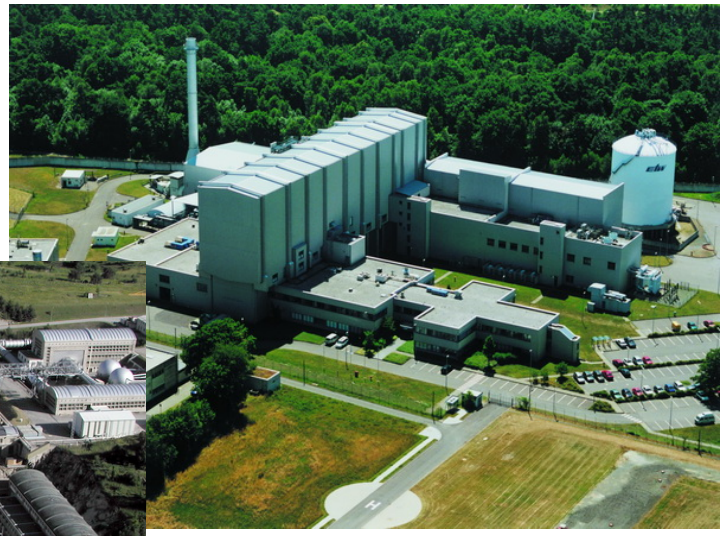
Wind Tunnels are a major part of a very specific research infrastructure

DNW



ONERA



ETW

Existing major wind tunnels constitute a major asset, which places Europe in an excellent situation and provide essential R&D testing services to the aerospace community.

They are used by research and industry to perform research work spanning from fundamental to applied research close to the final product.

A specific European support : ESWIRP

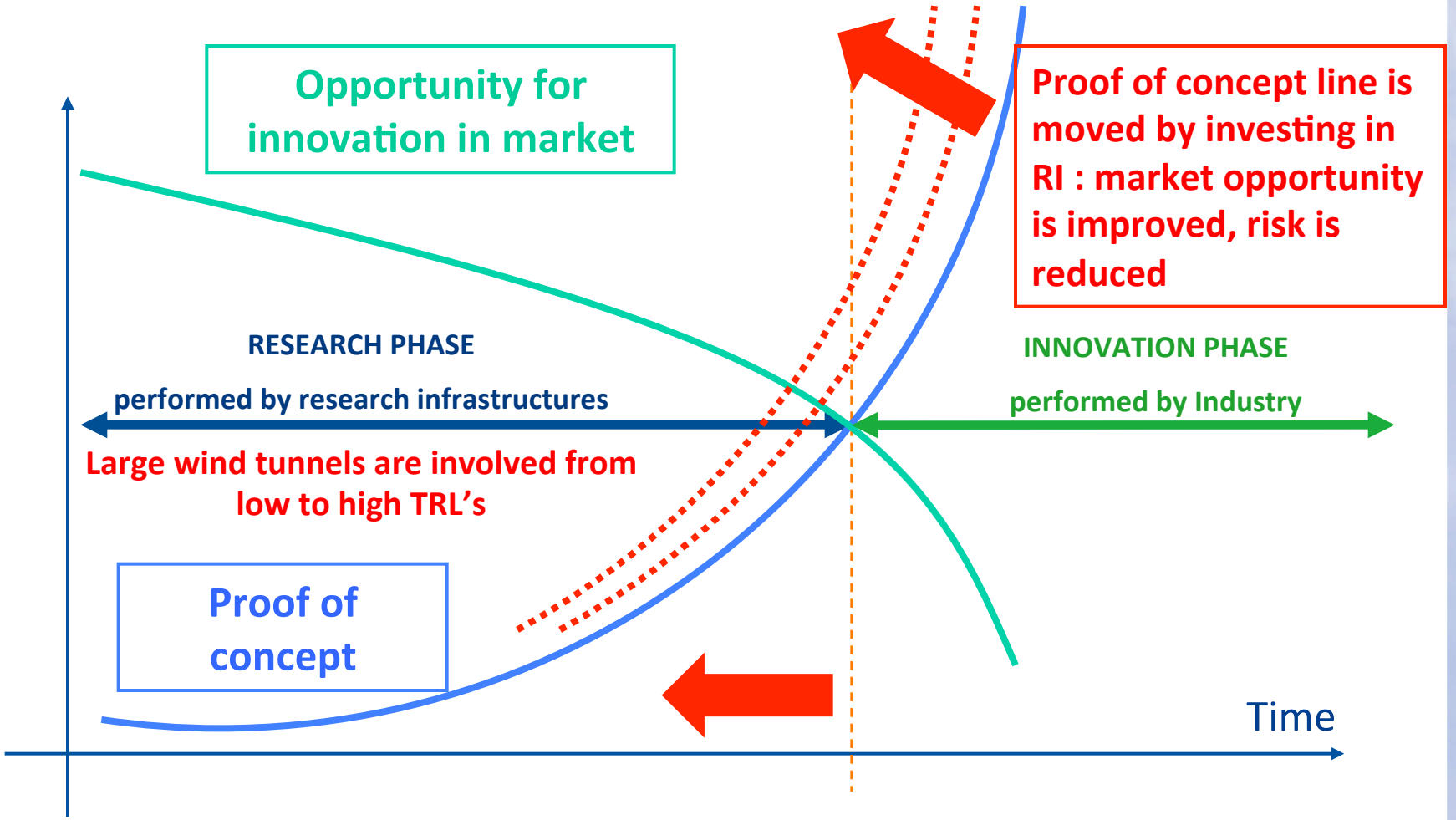
- ESWIRP « European Strategic Wind tunnels Improved Research Potential »
  FP7 – call “infrastructures”, starting date 01/10/2009 ; duration 4 years
- 3 partners (ONERA ; DNW ; ETW) : 7.5 M€ European support

- Objectives :
  - Improve the performance capabilities of three strategic facilities, selected as per ACARE definition of strategic wind tunnels (LLF, ETW, S1MA) ;
  - provide TNA to major infrastructures, essentially used by industry, for the benefit of the academic community ;
  - improve already existing links between the 3 WT operators

German-Dutch Wind Tunnels

ONERA
THE FRENCH AEROSPACE LAB

Large wind tunnels perform research work over a very wide spectrum



Existing design tools available for aircraft manufacturers.

Past experience

Theory and codes (CFD)

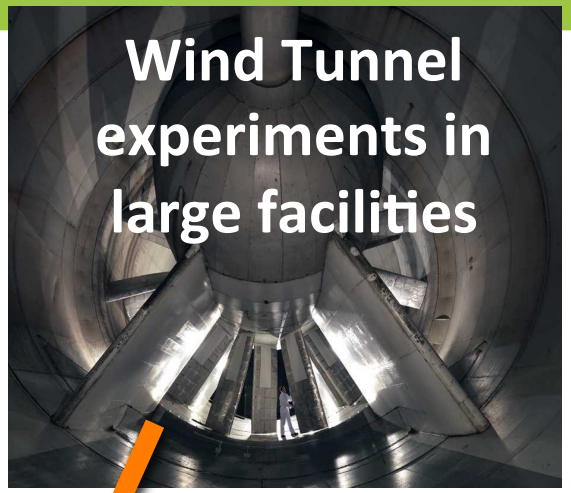
$$\sum_{i=1}^{n} u_j \frac{\partial u_i}{\partial x_j} = \nu \Delta u_i - \frac{\partial p}{\partial x_i} + f_i(x,t) \qquad (x \in$$

$$\operatorname{div} u = \sum_{i=1}^{n} \frac{\partial u_i}{\partial x_i} = 0 \qquad (x \in$$

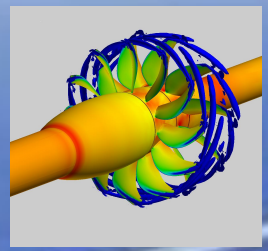
itions

$$u(x,0) = u^{\circ}(x) \qquad (x \in \mathbb{R}^n).$$

Wind Tunnel experiments in large facilities



New product having a potential for innovation



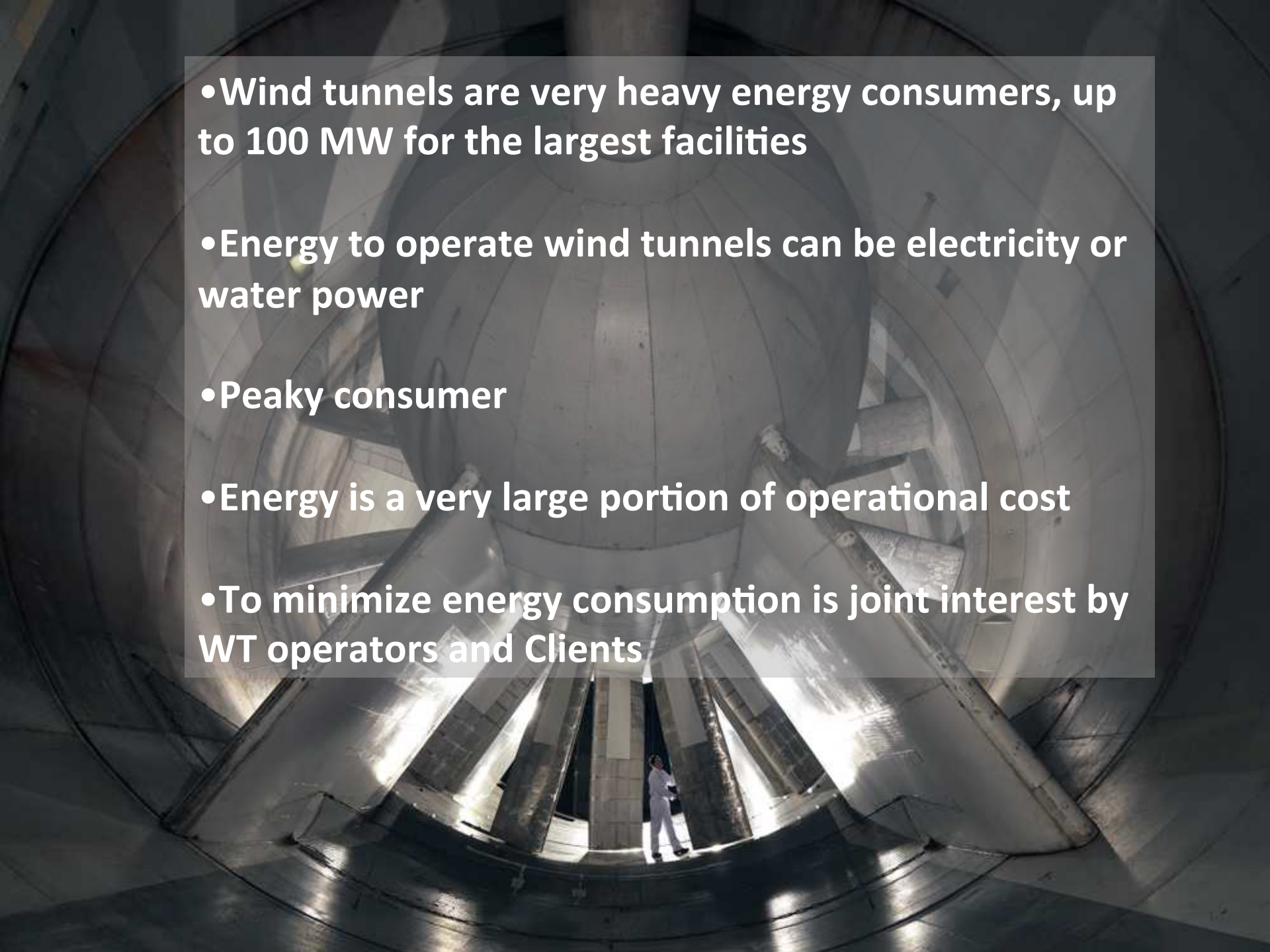
Large WTs are critical simulation tools to evaluate the potential of innovative ideas *throughout* the design cycle

What is innovation in aircraft design ?

- An innovative aircraft will find a market and will beat the international competition. Design margins need to be minimized

- Key criteria are : performance, fuel consumption, environmental noise footprint, greenhouse gas emissions, safety and comfort for passengers. All are focused to reduce environmental impact, make flying a cheaper and safer way of travelling

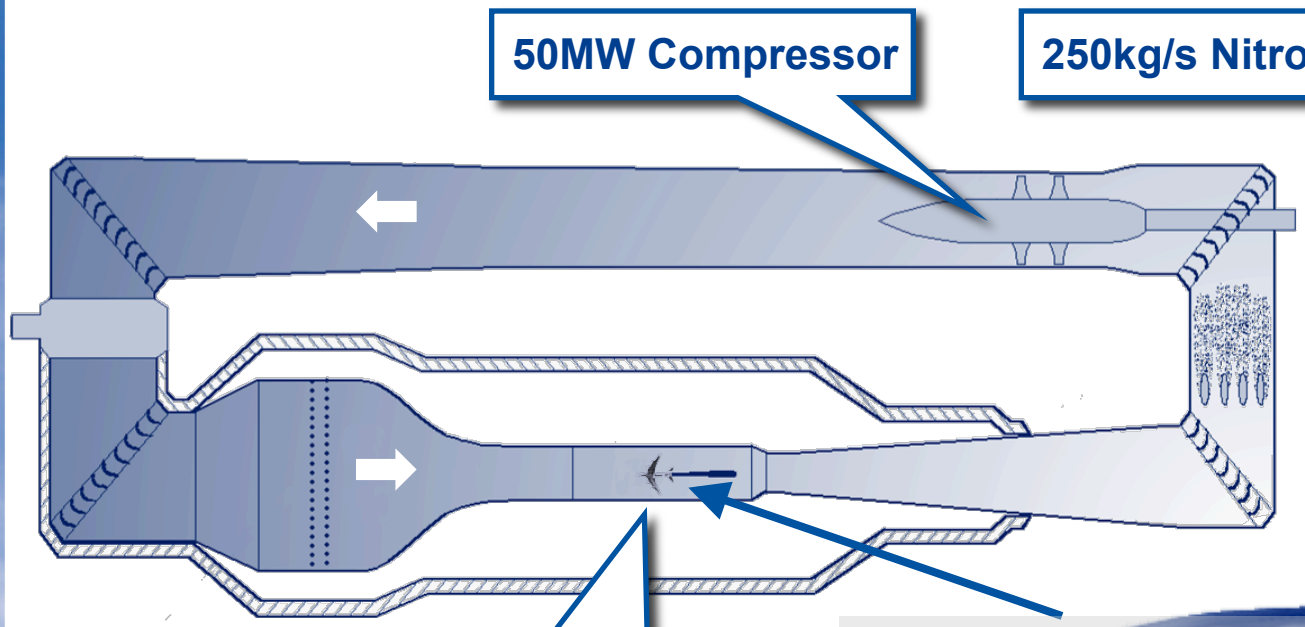
- Design engineers focusing on development of new aerodynamic configurations beyond current evolutional trends (wings / fuselage / engines ; aero / structural design ; dynamic flight control….)



- Wind tunnels are very heavy energy consumers, up to 100 MW for the largest facilities
- Energy to operate wind tunnels can be electricity or water power
- Peaky consumer
- Energy is a very large portion of operational cost
- To minimize energy consumption is joint interest by WT operators and Clients

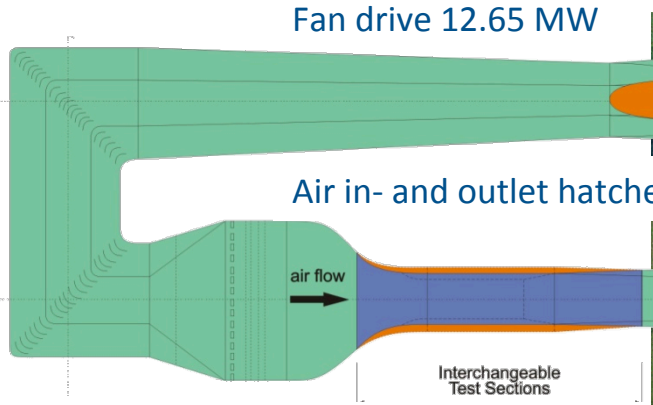
European Transonic Windtunnel ETW

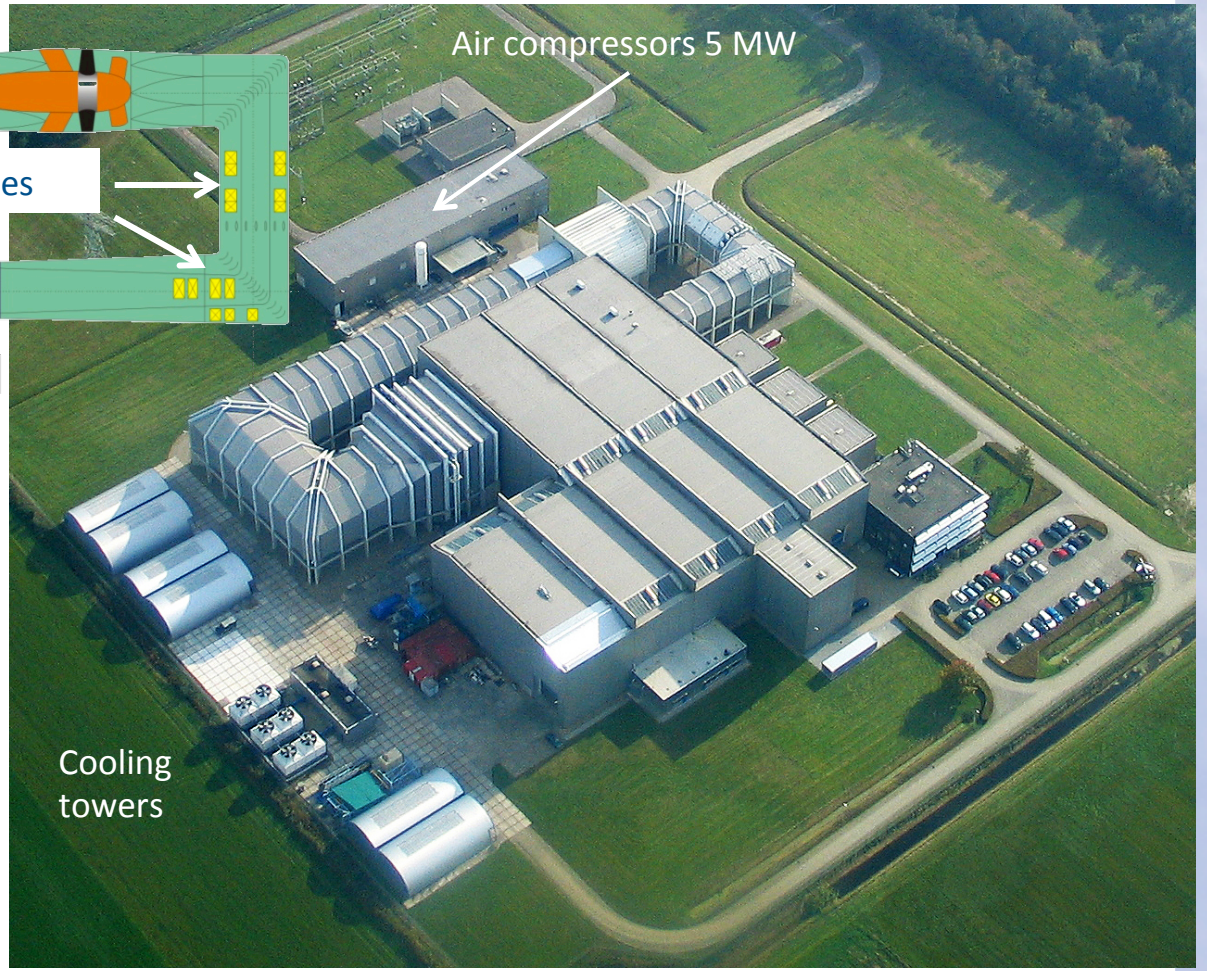
- **Wind tunnel for aerospace research & development testing**, e.g. A380 take-off, cruise, landing aerodynamics at realistic flight conditions
- **Cryogenic operating principle** to achieve aerodynamic (Mach- & Reynolds-) similarity at reasonable energy consumption



Annual consumption about **8 GWh and 40,000 tons LN2**

Large Low-Speed Facility LLF





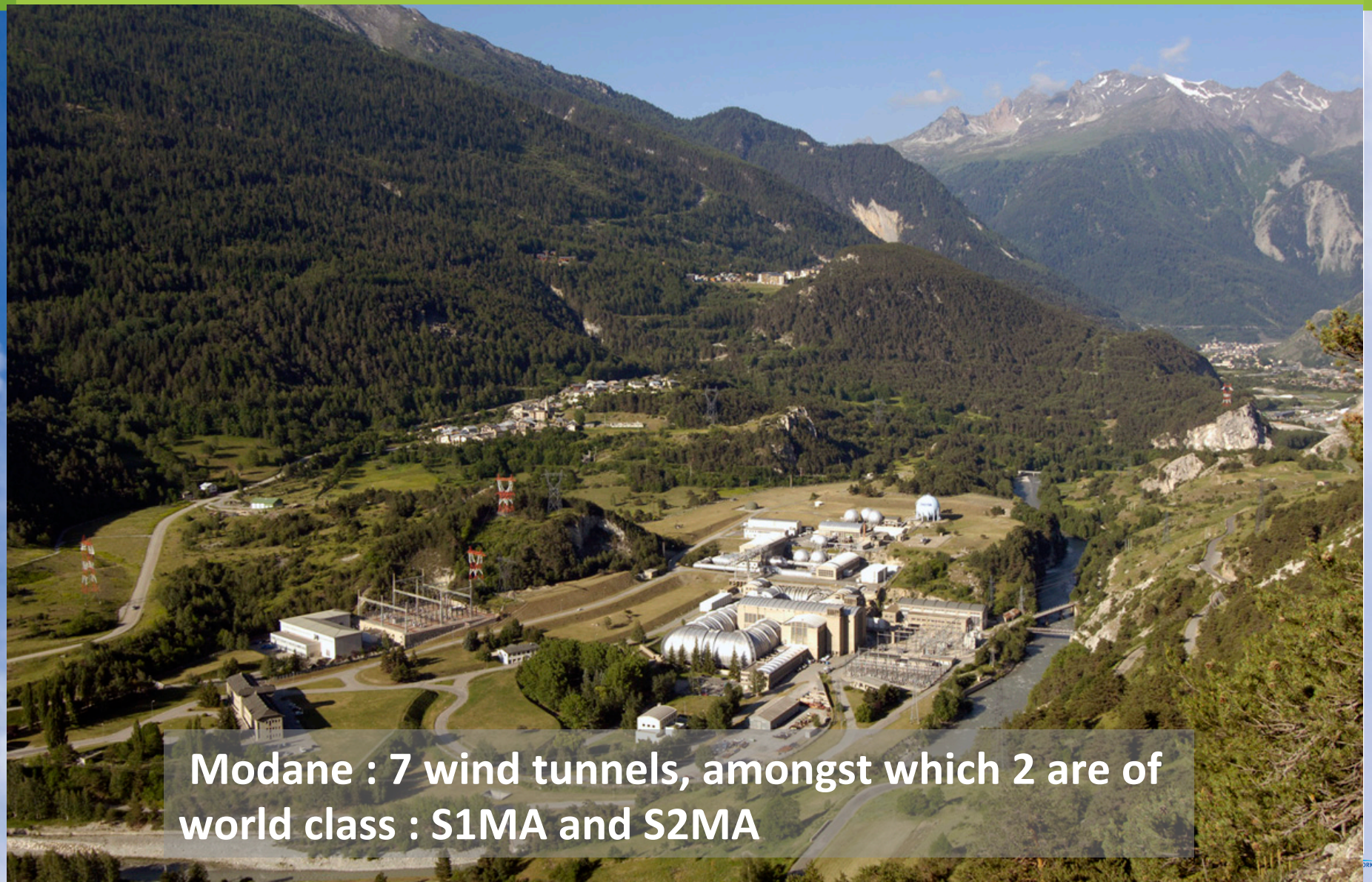
Atmospheric closed-circuit wind tunnel

Wind tunnel and equipment require ~ 20 MW max

Typical annual electricity consumption 6 GWh

Electricity costs 10 to 15% of operational costs

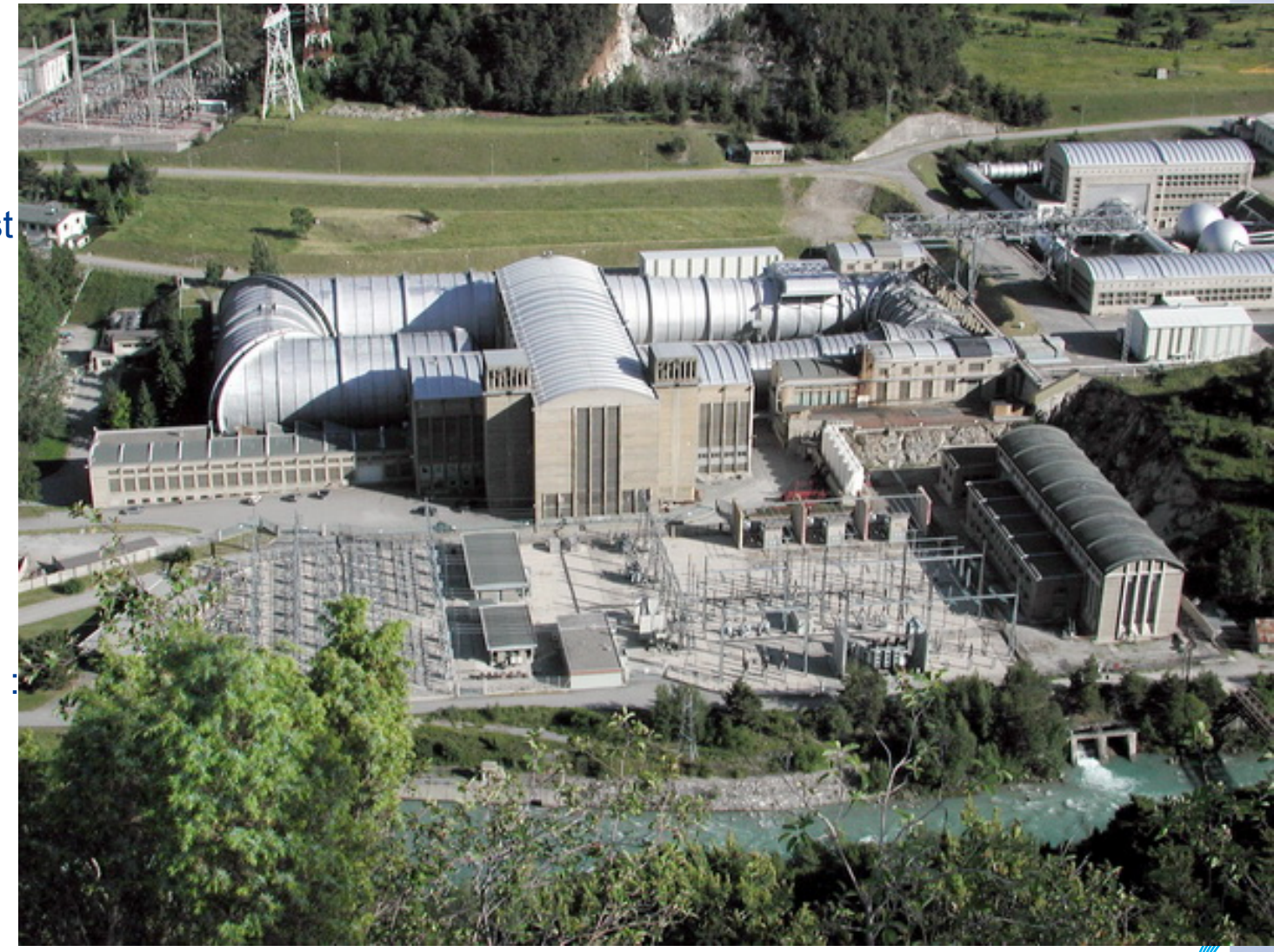
Modane (French Alps)



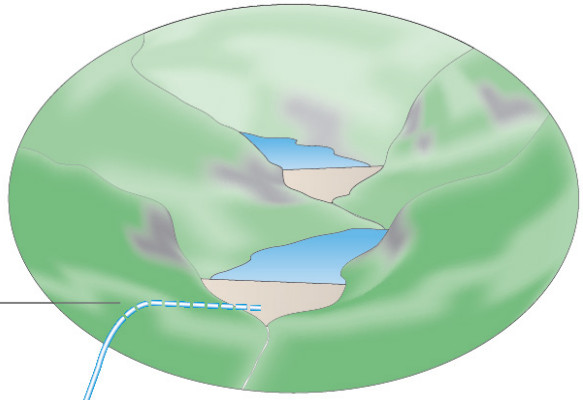
Modane : 7 wind tunnels, amongst which 2 are of world class : S1MA and S2MA

ONERA S1MA Infrastructure

- Continuous flow Wind Tunnel
- Test section size : 8 m diameter, largest section : 24 m
- Mach Number range : 0,05 -> 1
- maximum flow of air : 10 tons/s
- Typical model size : 3.5 m span
- Designed for high productivity

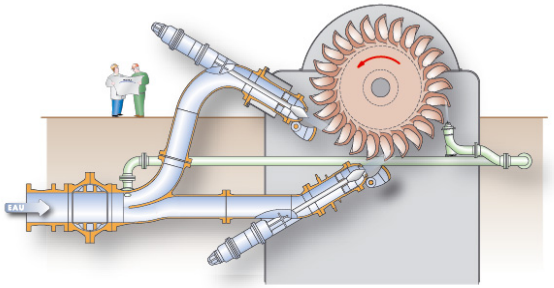


S1MA : a “green” tunnel operated with no fossil energy and no energy transport



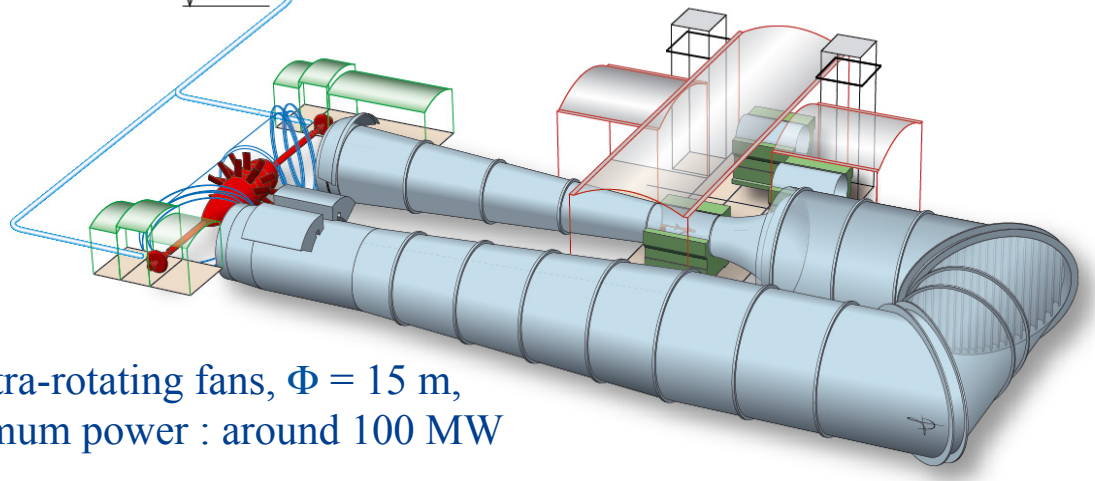
2 water reservoirs, capacity
12 000 000 m^3

2 Pelton turbine, Φ = 5m,
maximum RPM : 240



Water head :
800 m

Pressurized water pipe :
Φ : 1.4 m ;
Maximum flow : 12m^3/s



2 contra-rotating fans, Φ = 15 m,
maximum power : around 100 MW

Steel shell, maximum
diameter : Φ = 24 m

Water reservoirs 12 million m^3

Main fans of S1MA

Typical transport aircraft models

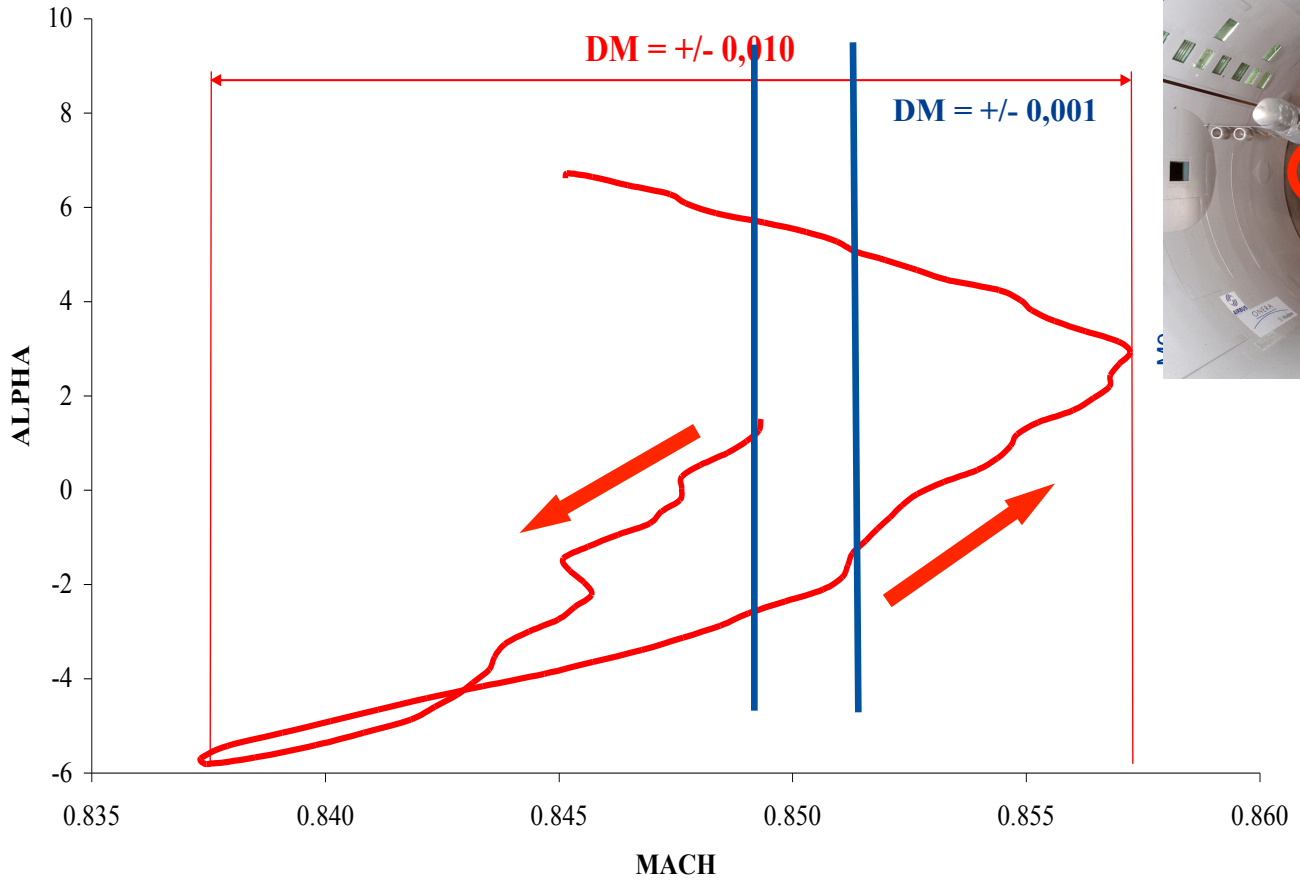
Typical model span is 3.5 meters

Ways for improvement of energy management

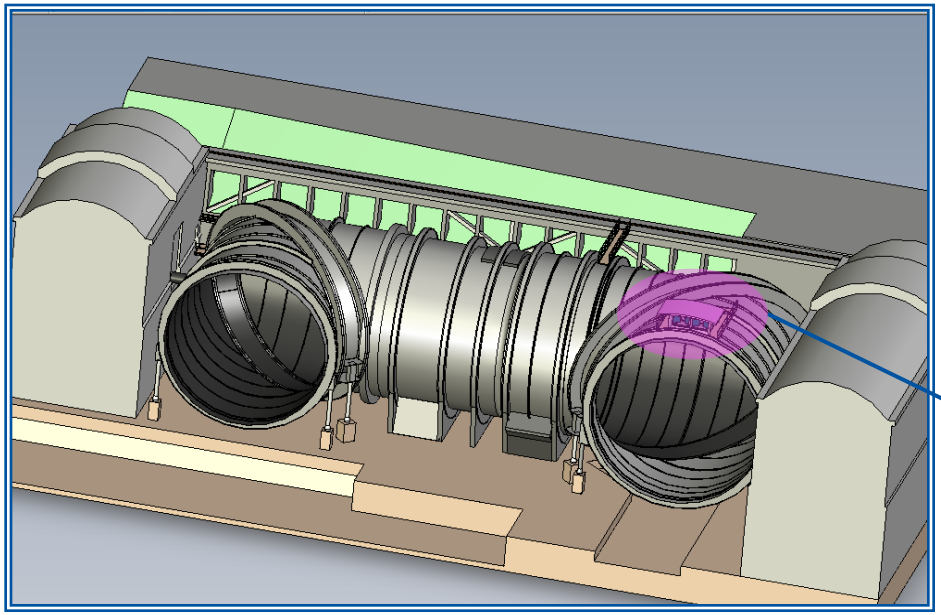
- Total power available on site : slightly above 100MW
- Energy cost charged by the supplier (EDF). Energy cost is a large (and increasing) portion of operational cost
- Several actions for improving the global efficiency and minimize energy consumption :
  - Negotiate cost reduction against planned use of energy (penalties if not adhered too)
  - Improve the process itself : perform faster set point changes, improve stability of flow parameters and consequently reduce number of data point and testing time (potential saving around 15 % in cost and 10% in time)
  - Improve efficiency of fan (saving is around 10 %)
- Possible usage of wasted water : cool down computers for instance

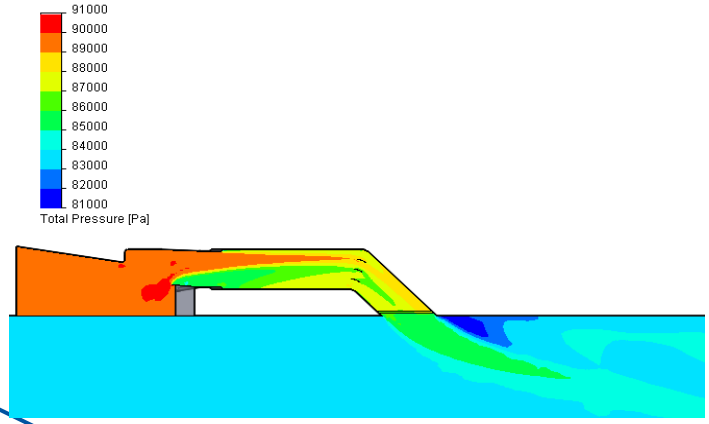
Objective to improve Mach number stability by a factor 10

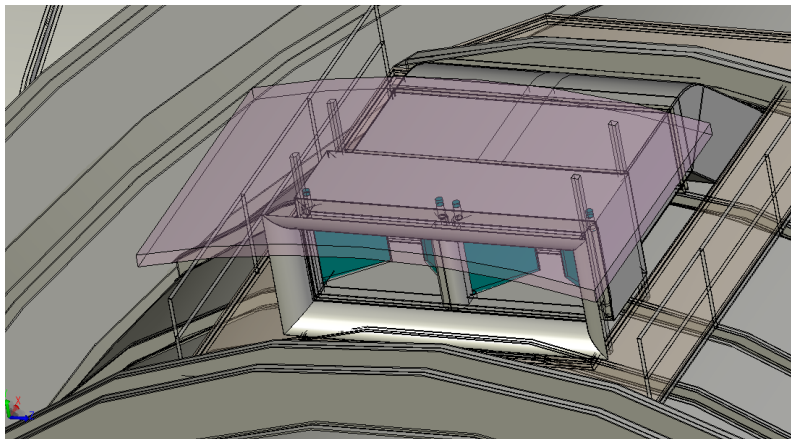
Mach number drift during a continuous sweep of model incidence



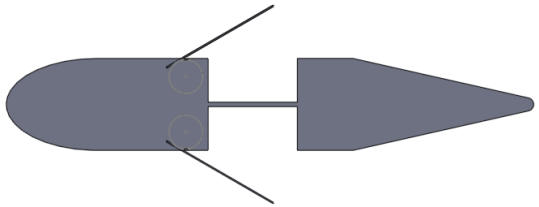
Additional air inlet

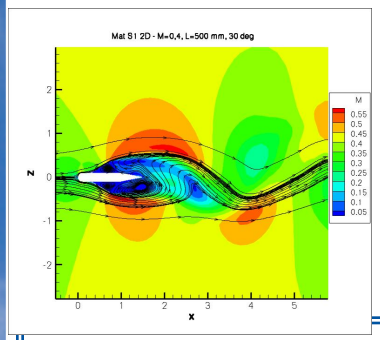


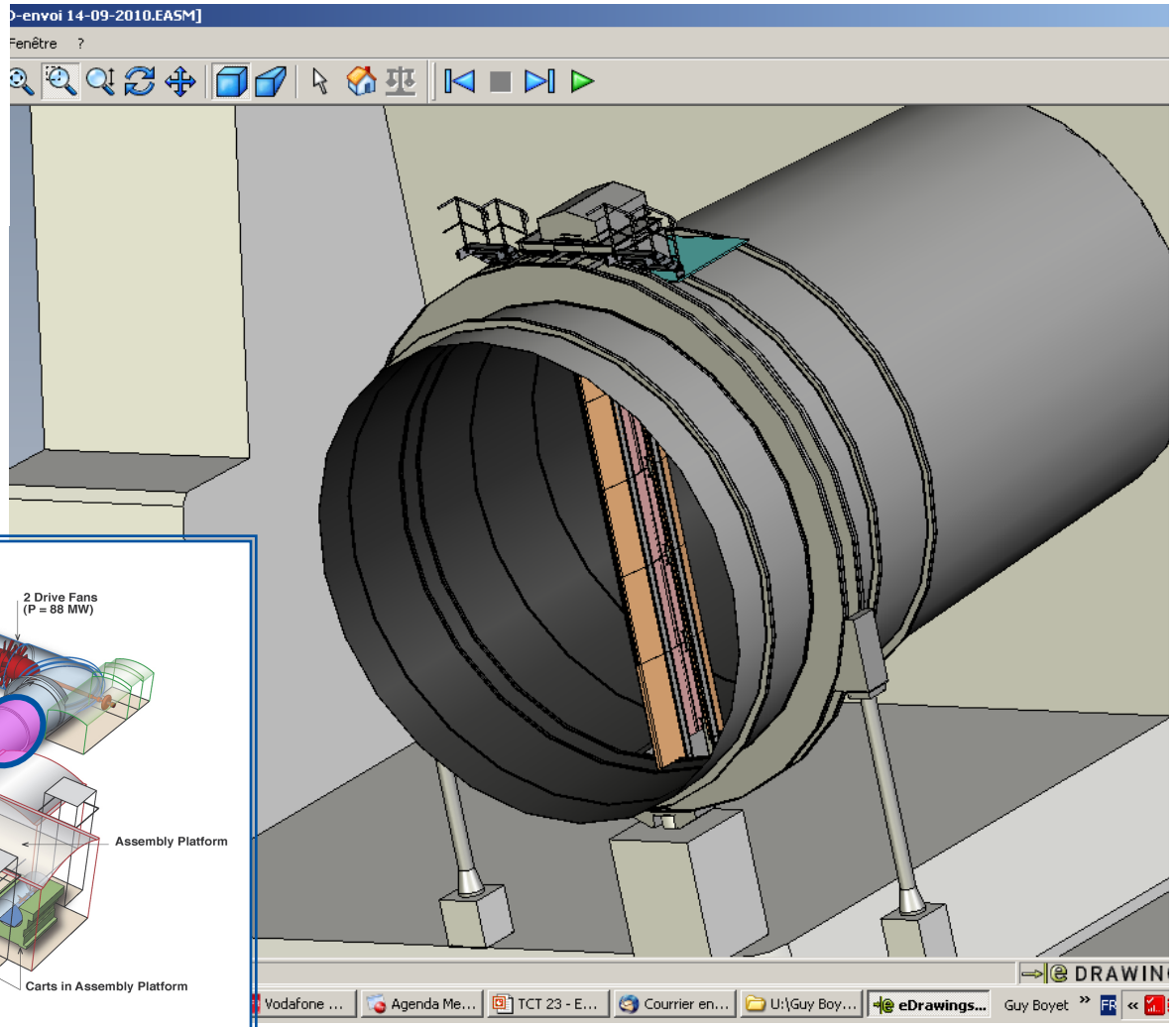


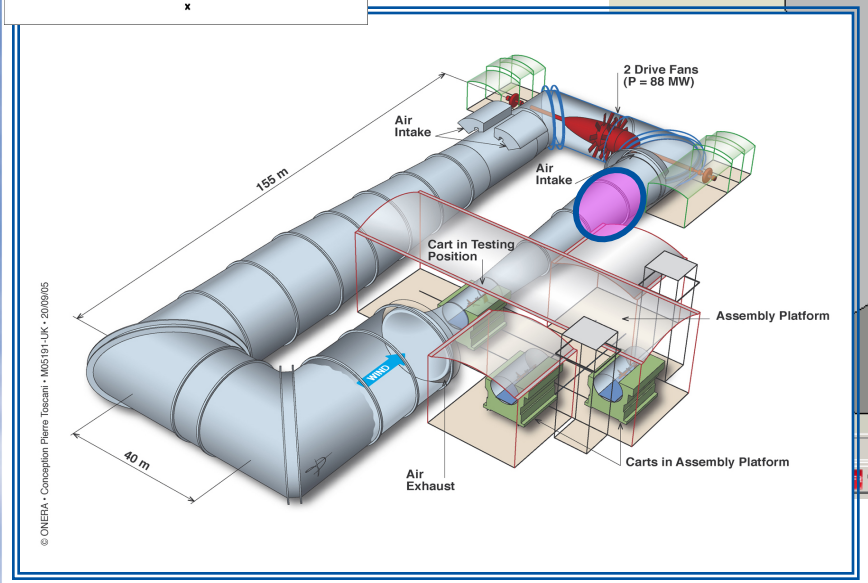


Possible hardware implementation : Vertical mast with moving flaps









Thank you