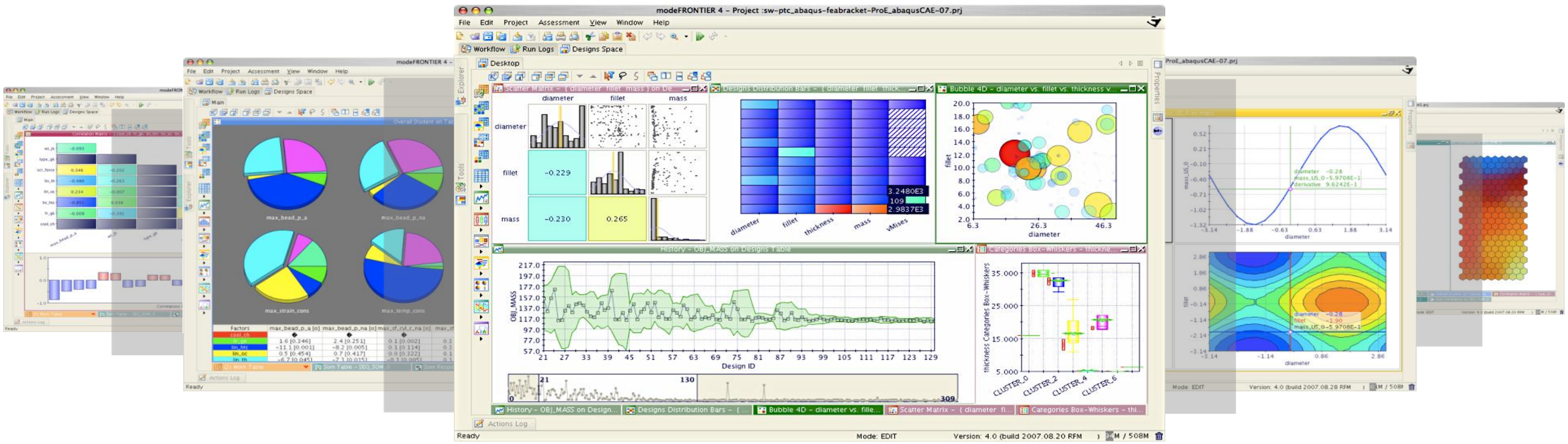
The concept behind modeFRONTIER

Some conceptual fundaments for introducing the modeFRONTIER design environment

For more information visit:
www.esteco.com or send an e-mail to:
modeFRONTIER@esteco.com

modeFRONTIER
the multi-objective optimization and design environment

Defining modeFRONTIER



modeFRONTIER is a multi-objective optimization and design environment, written to allow easy coupling to almost any computer aided engineering (CAE) tool, whether commercial or in-house.

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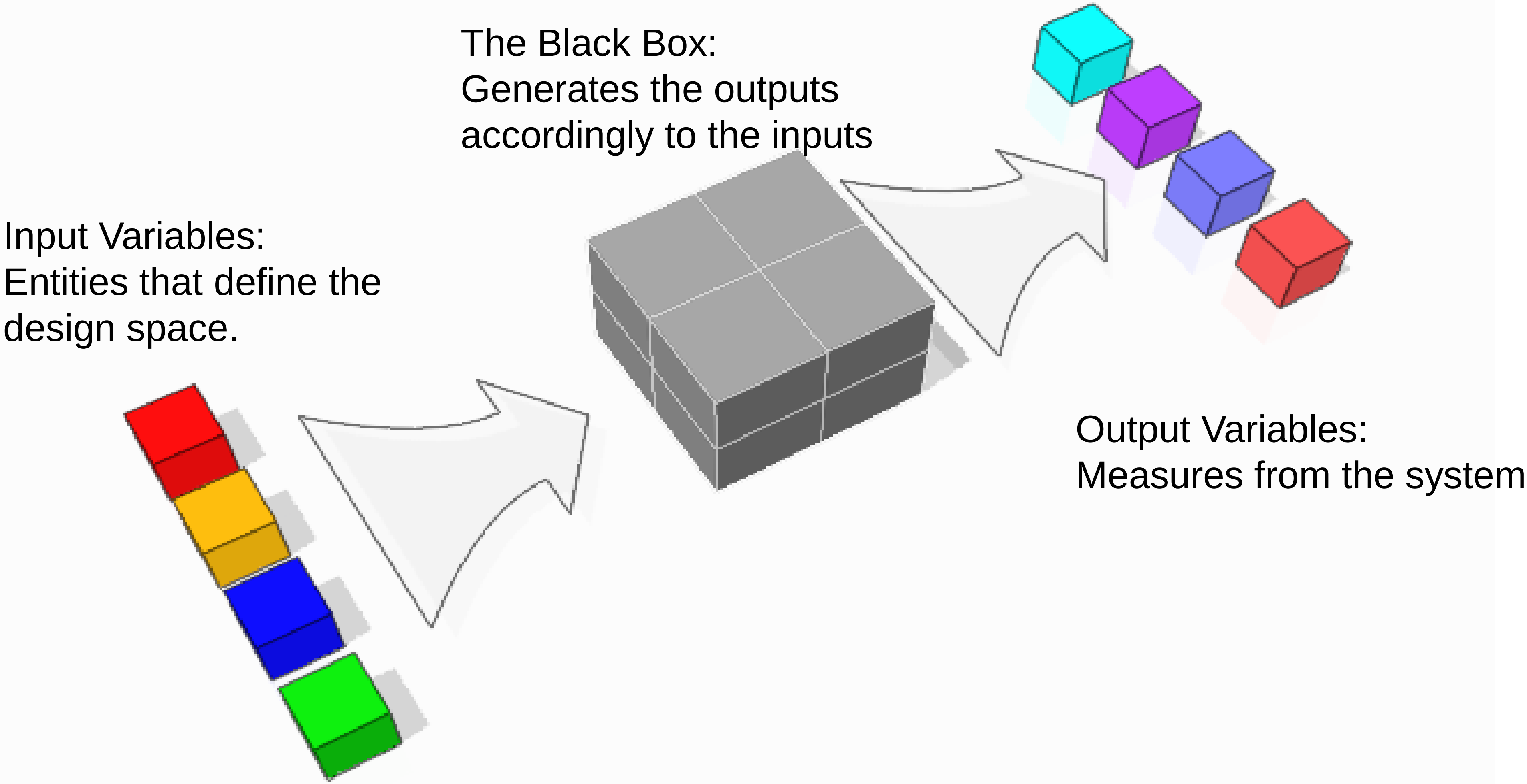
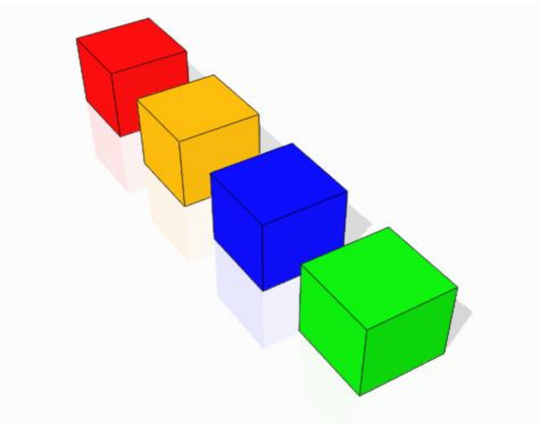


The input variables



Variables:

Variables are the free parameters, i.e. the quantities that the designer can vary or the choices the designer can make.

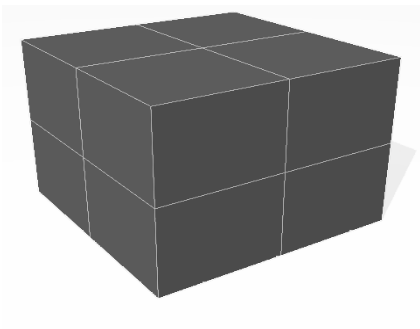
Continuous variables:

- point coordinates
- process variables

Discrete variables:

- components from a catalogue
- number of components

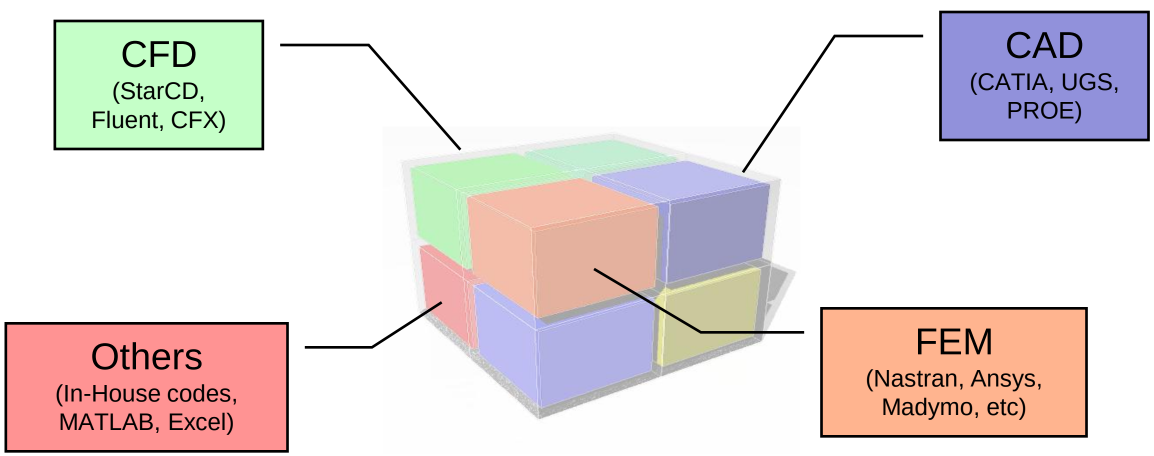
The Black Box



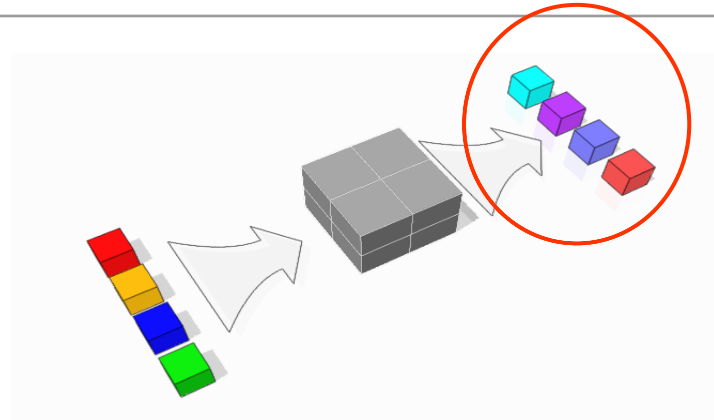
The black box can be:

- A set of solvers that models and solves in a numerical manner the design problem (e.g. CAD/CAE tools)
- A set of experiments that produces some data

Multi-disciplinary Scenario



The output variables



The **output variables** are a measure of the system response and/or performance, i.e.:

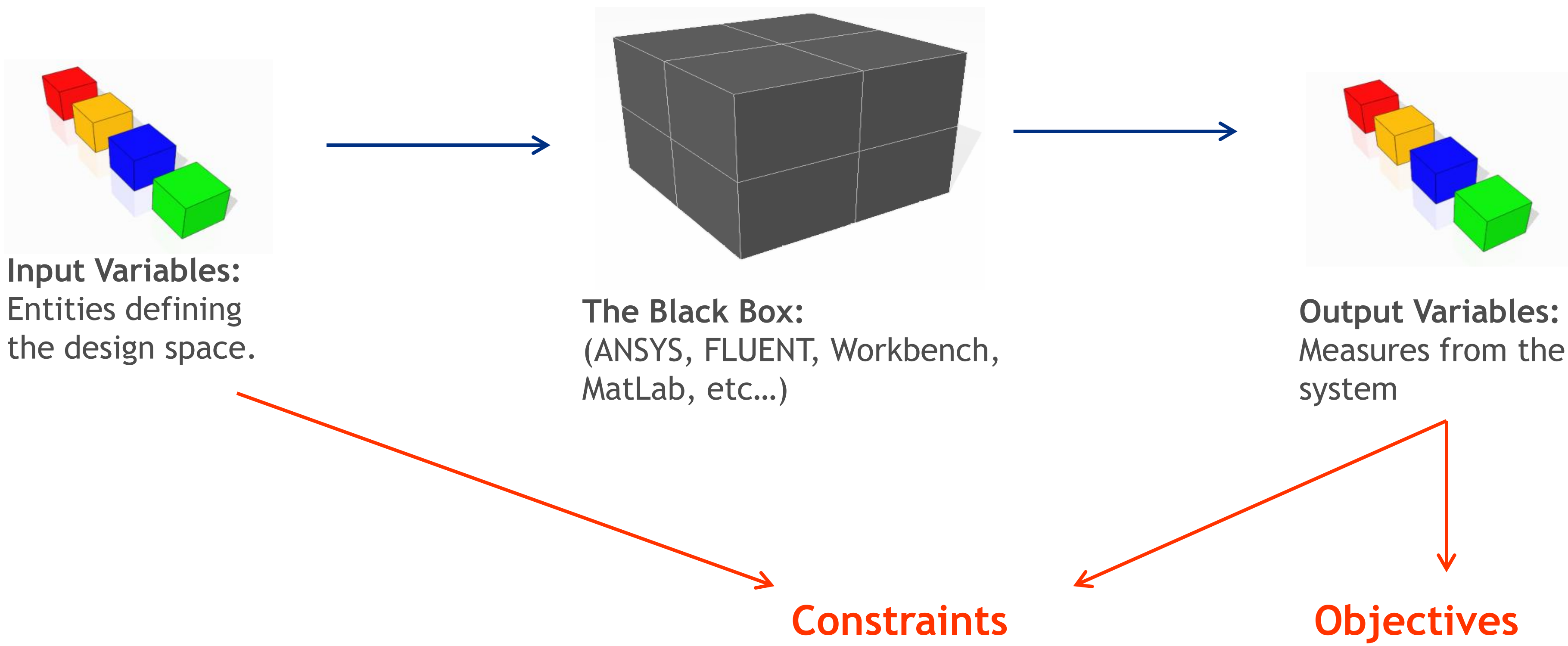
acceleration, speed, consumption, confort,…

deformation, stress, mass, volume,…

lift, drag,…

defects, number of failures, cost,…

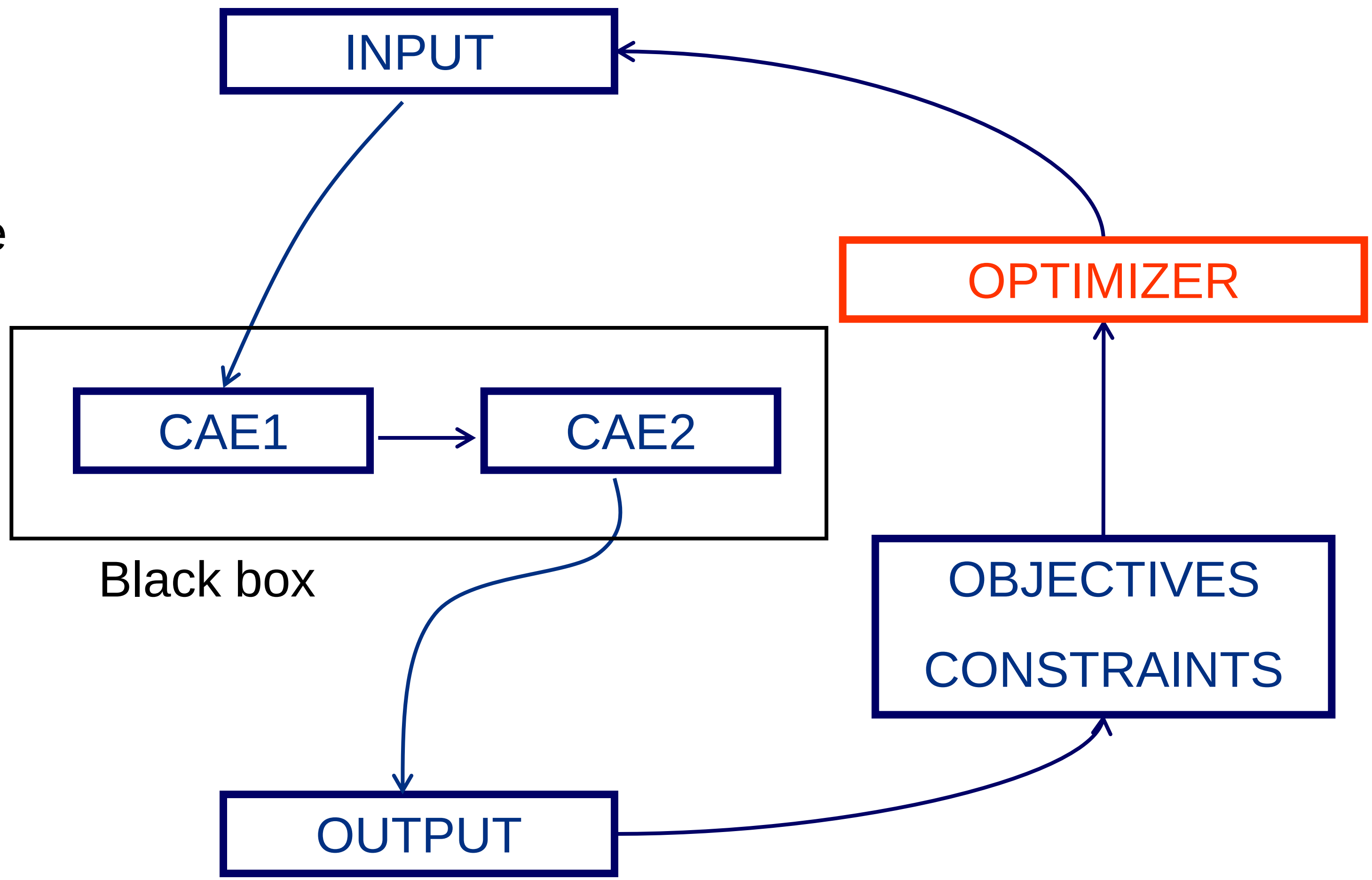
….



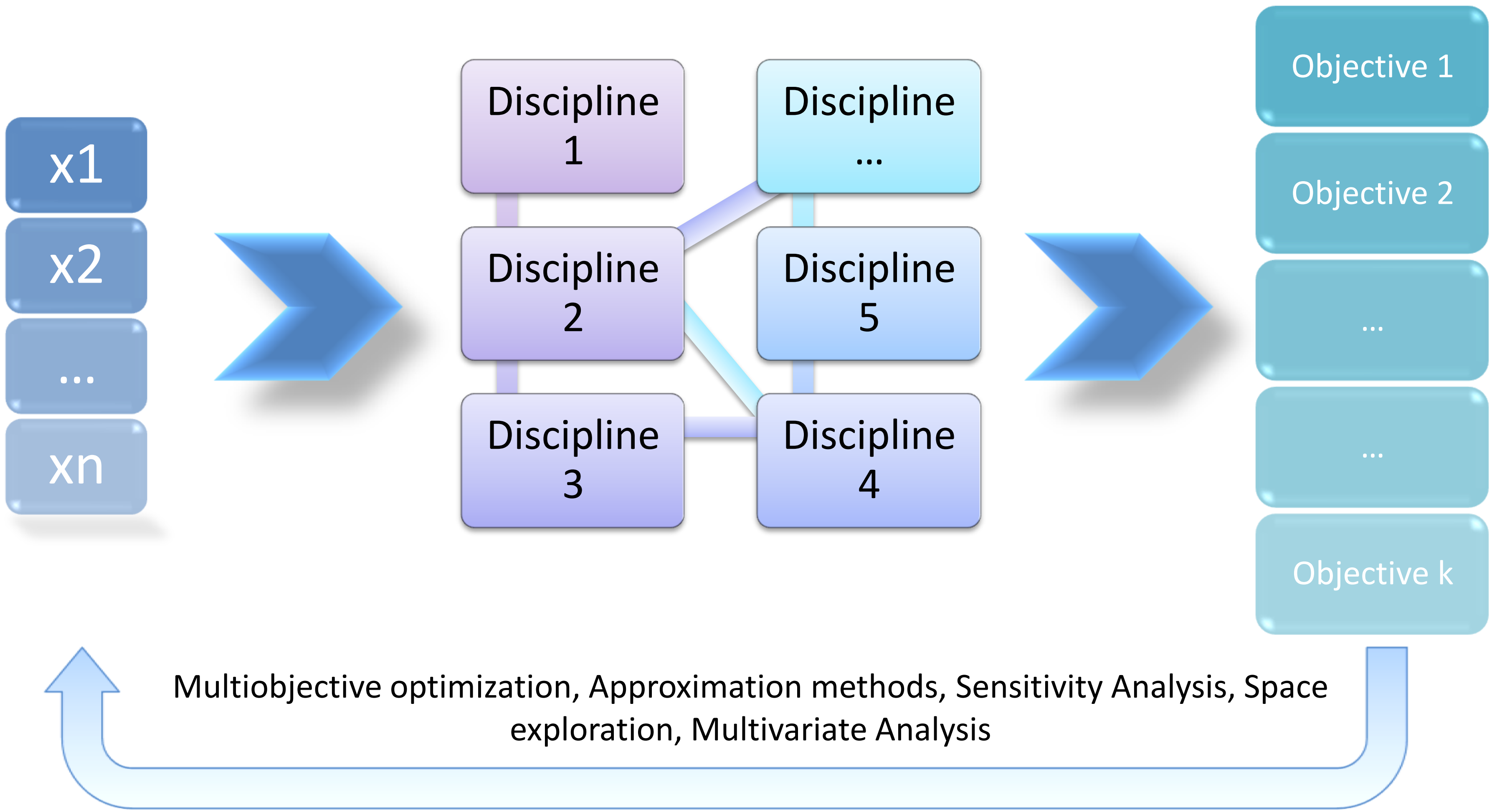
Optimization means to find a set of system configurations (input variables) that meets the objectives and satisfy the constraints

The optimization can be multiobjectives

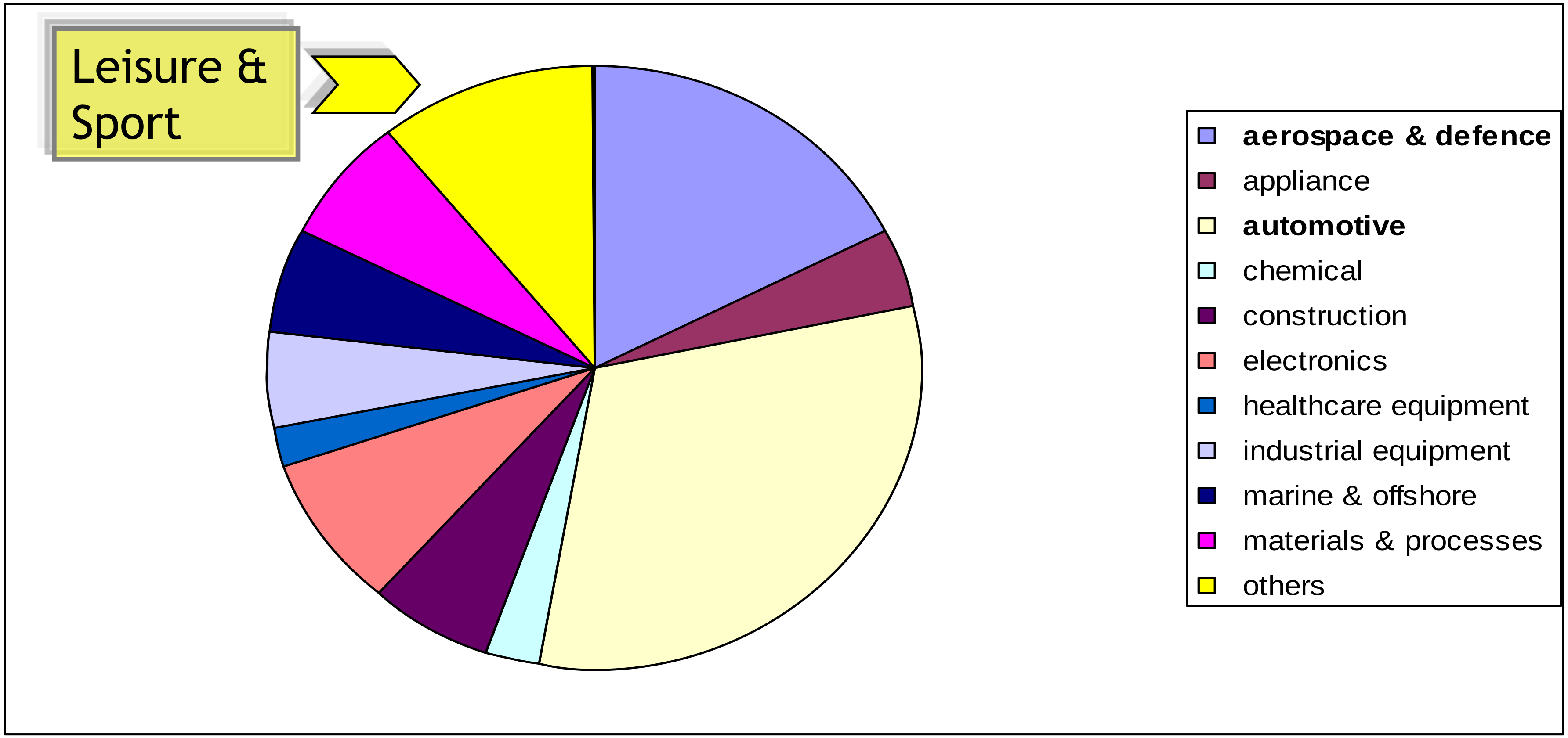
Many softwares can be used to describe the behavior of the system under exam



Multidisciplinary Optimization - MDO



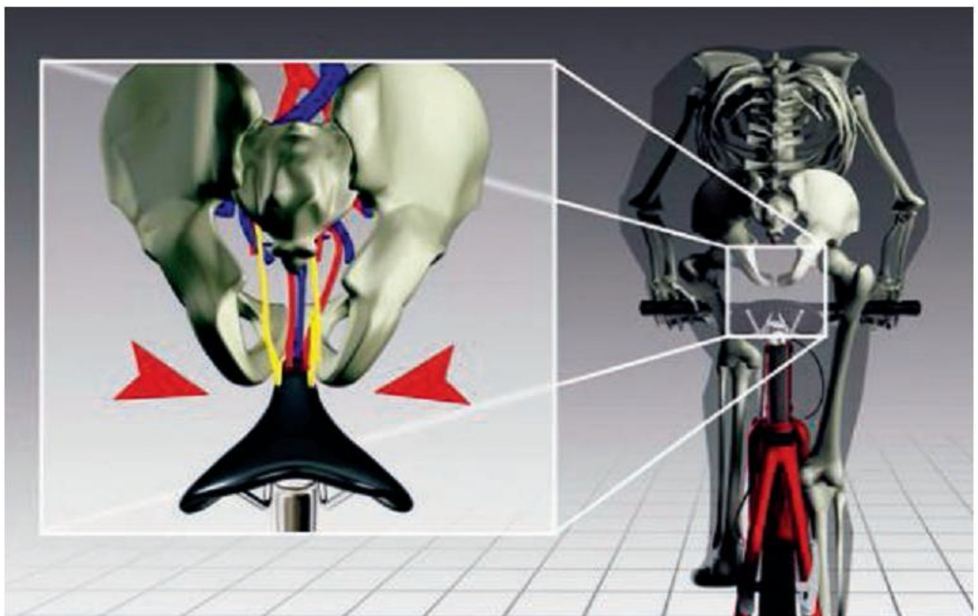
EMO and its fields*

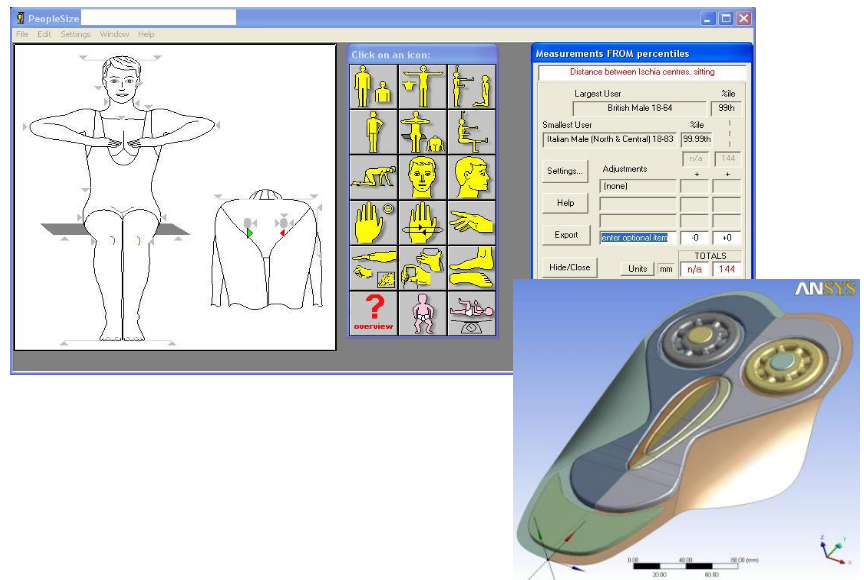


*On a database of 148 real world applications

Leisure & Sport Applications

- Study of innovative solutions of a cycle wear crotch pad for **Campagnolo**
- The optimization considered the ergonomic level of the crotch pad function of both geometry and materials.





Innovation – HOW ?

Objective: Product **innovation** for high performances

⇩

Technologic issue (**cost**) – appearance/ **Marketing** – **performances**

⇩

Simplified product analysis ⇒ Decrease in cost

Alternative materials ⇒ Stiffness and energetic absorption

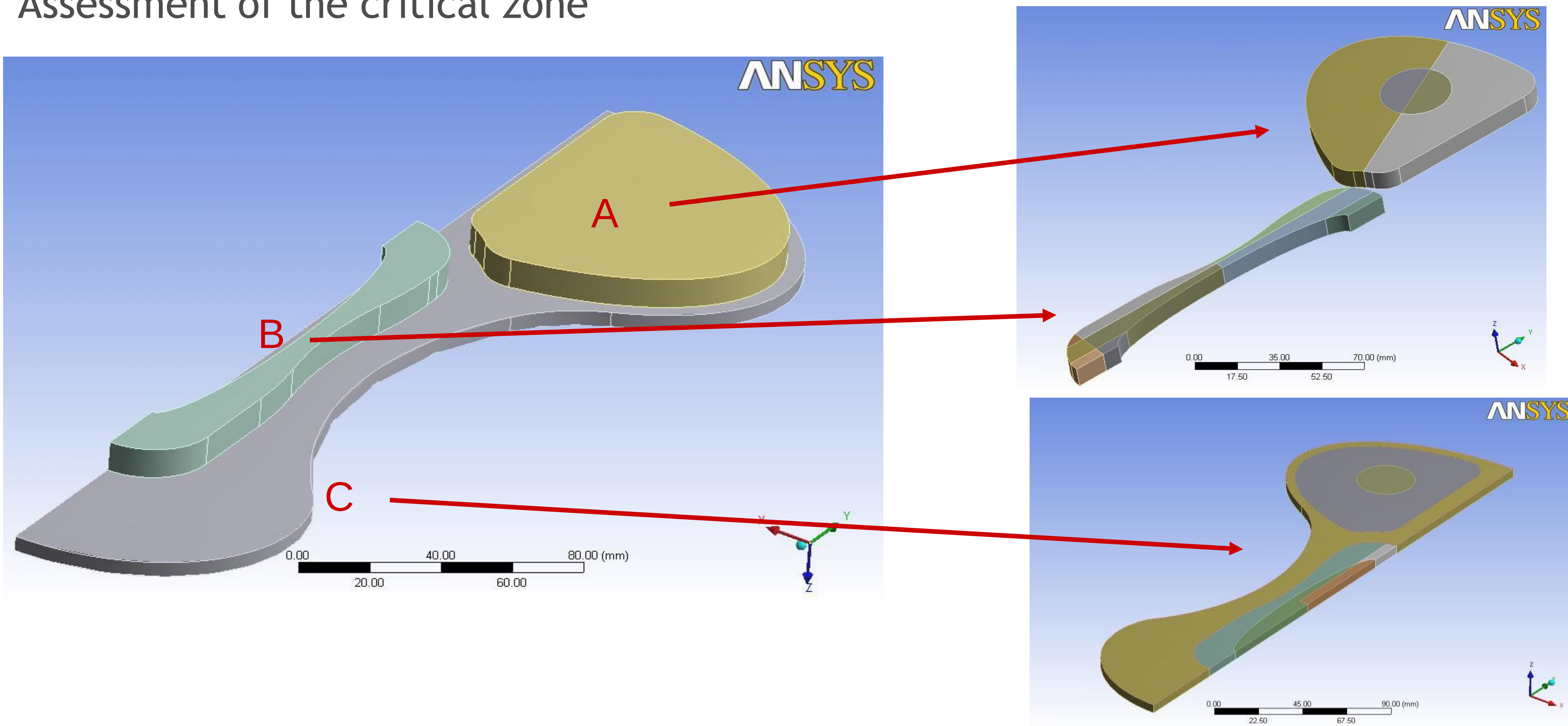
Ergonomic/Marketing ⇒ Independence by anthropomorphic features

Ergonomic improvement ⇒ Shape and thickness modification

Parametric models carrying out

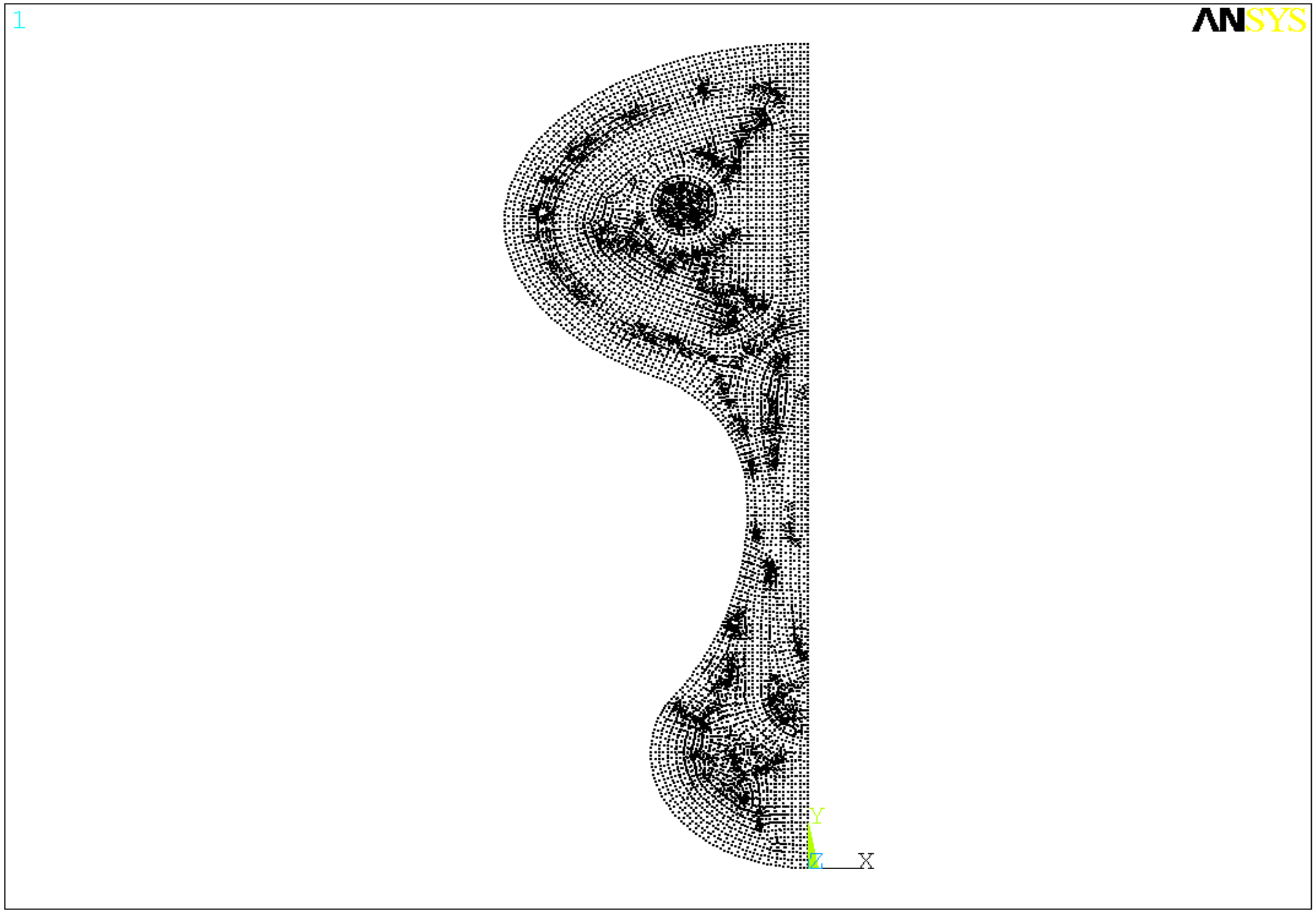
Objective : **Ergonomic improvement ⇒ Shape change, thickness, material**

Assessment of the critical zone



Parametric models carrying out

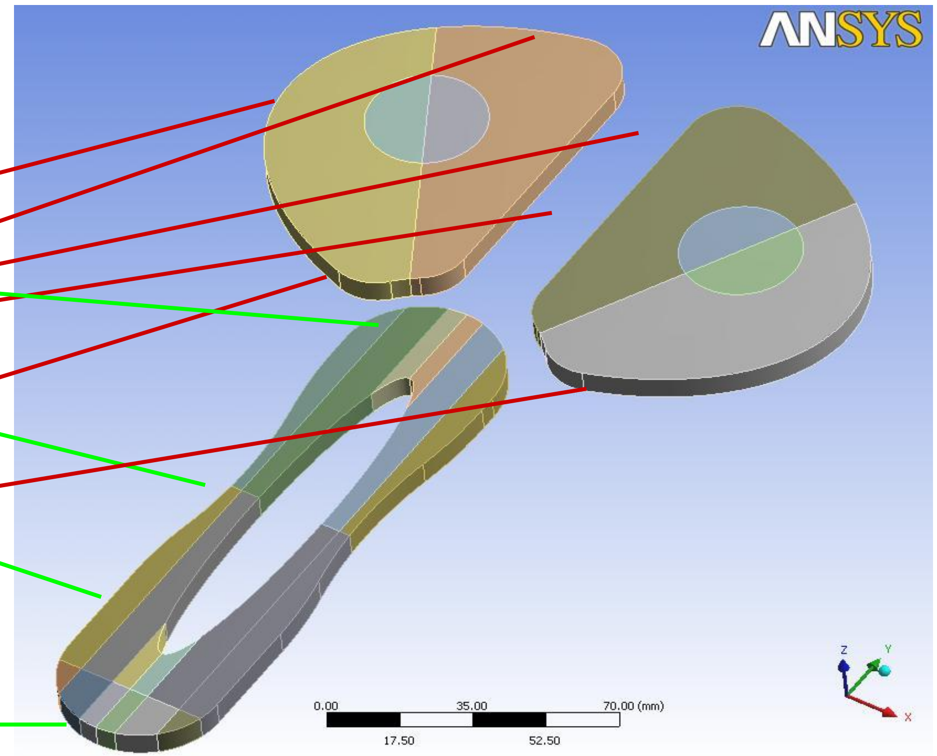
Objective: **Ergonomic improvement ⇒ Shape, thickness, weight change**



Geometric parameters

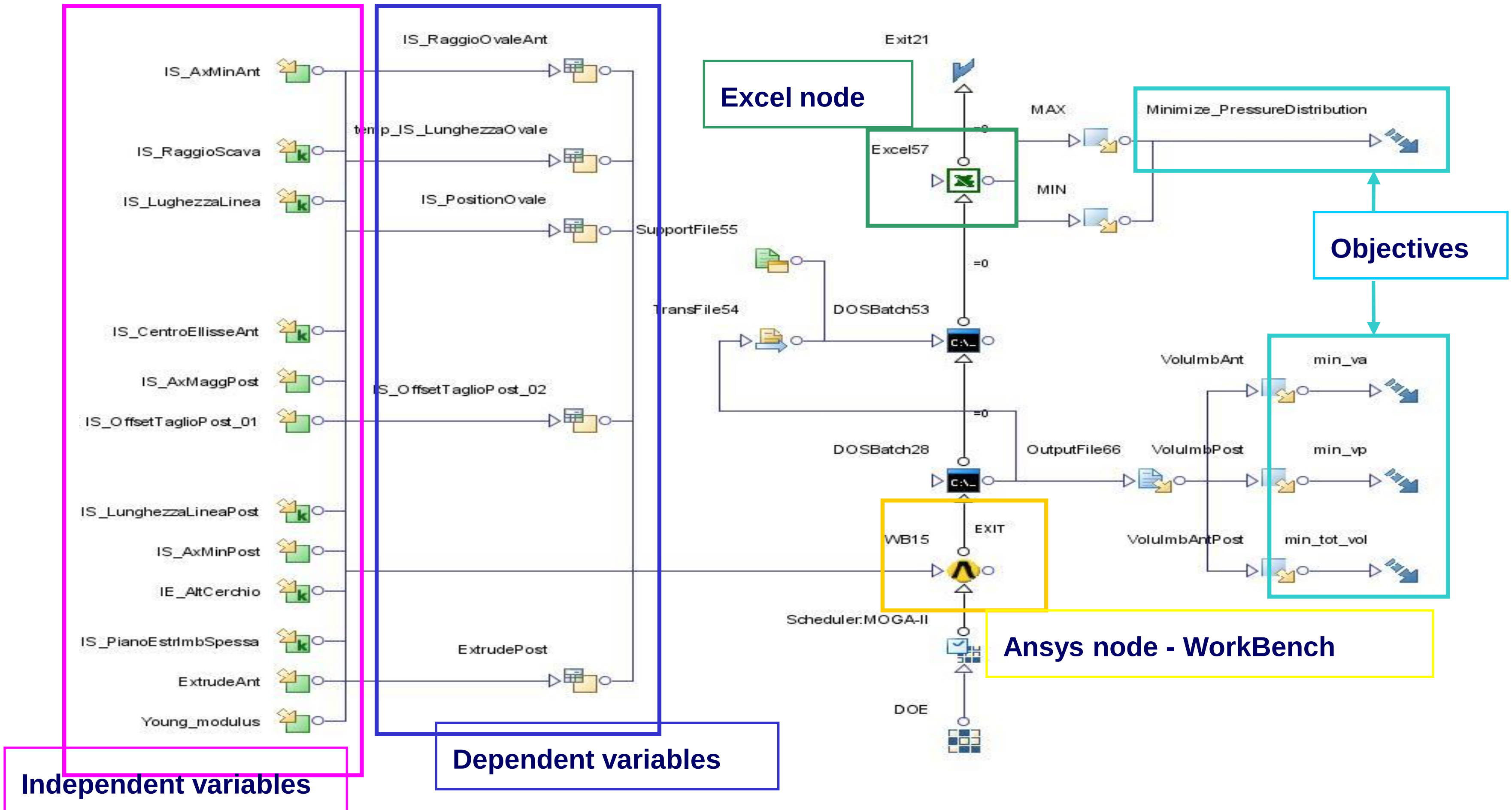
Simulation CAD parameters. These parameters have been implemented in modeFRONTIER.

CAD Parameters	
IE_AxMaggPost	95
IE_AxMinPost	55
IE_AltCerchio	140
IE_AxMaggAnt	60
IE_AxMinAnt	50
IE_AltAnt	50
IS_AxMinAnt	9
IS_RaggioOvaleAnt	21
IS_RaggioScava	120
IS_LunghLinea	308
IS_LunghOvale	120
IS_PositionOvale	261
IS_CentroEllisseAnt	130
IS_AxMaggPost	80
IS_OffSet_TaglioPost_01	11
IS_OffSet_TaglioPost_02	11
IS_LunghLinea_Post	150
IS_AxMinPost	52
Supp_Larghezza	100
Supp_Altezza	320
Supp_Position	5
Extrude_Imb_estesa	5
Extrude_Imb_post	7
Piano_estr_Imb_estesa	11
Piano_estr_Imb_spessa	-5
Piano_estr_Supp	-10
Extrude_Imb_Ant	7
PlaneOffSet_SolidoPremente	0,705
Plane01_SolidoPremente	30
Plane02_SolidoPremente	5
Dist_Ischemica_Y	260
Dist_Ischemica_X	-45
Dist_Ischemica_Raggio	15



Optimization process

Workflow

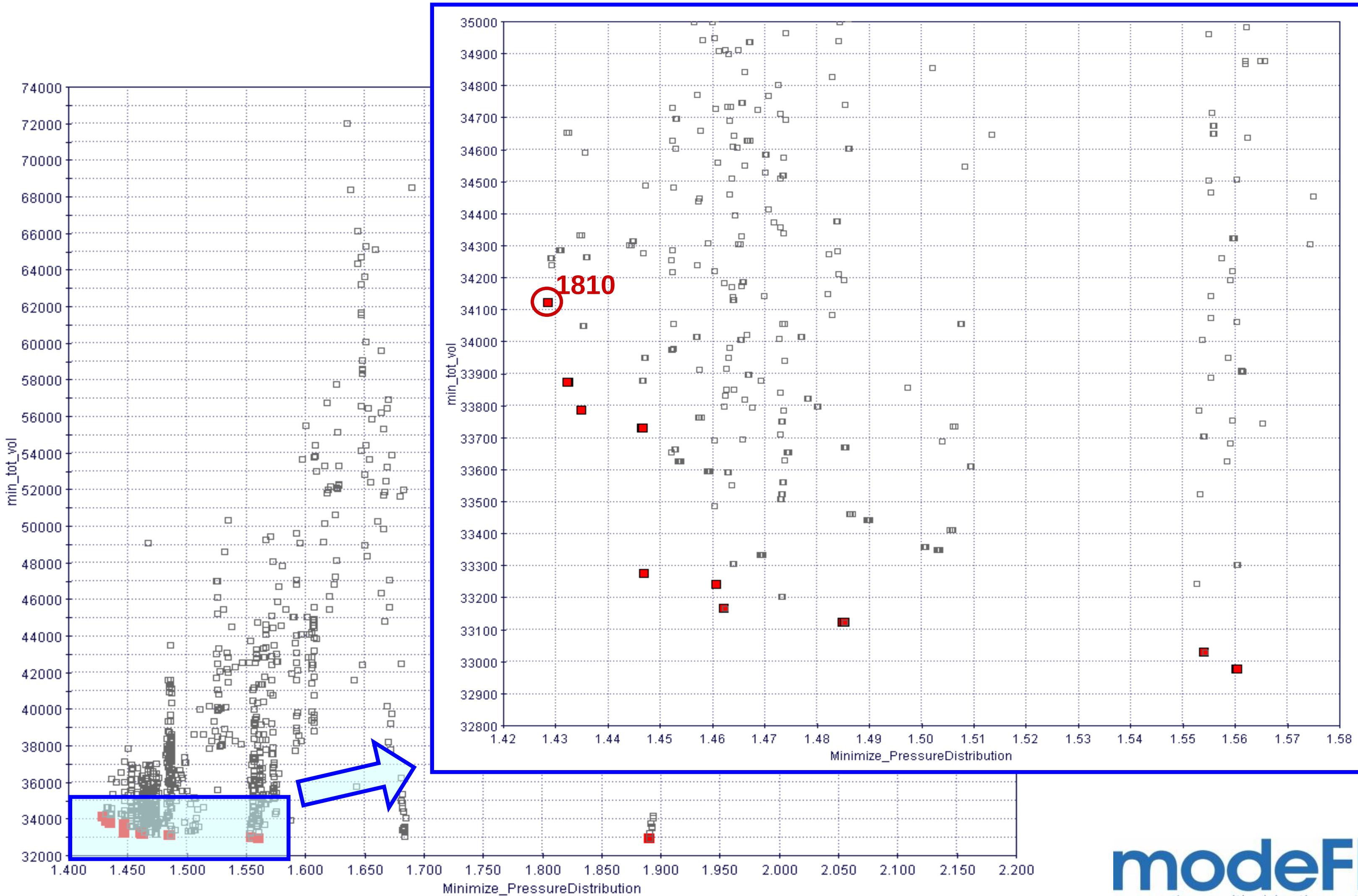


Optimization process

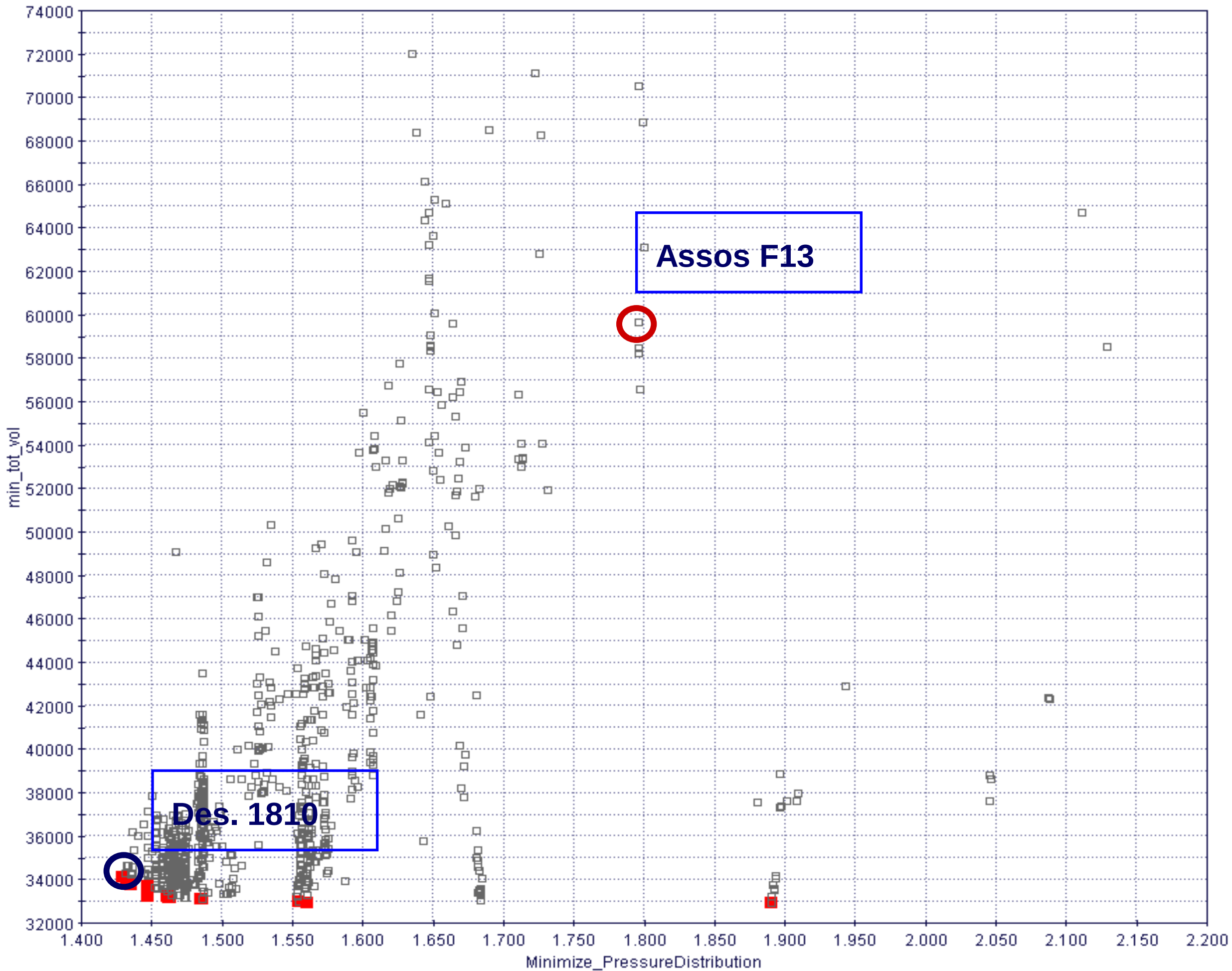
The optimization process:

- **Input variables**: Geometry, materials mechanical properties
- **Objectives**: Minimization of back and front cushions volume, minimization of pressure distribution and its maximum value.
- **DOE**: Sobol (50 designs initial population)
- **Optimisation algorithm**: MOGA II

Optimization process



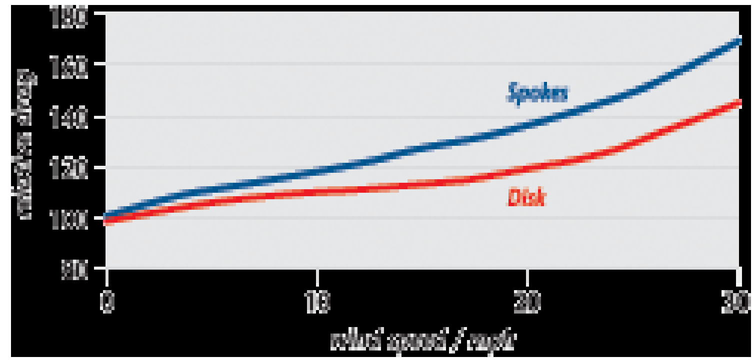
Optimization – Assos F13



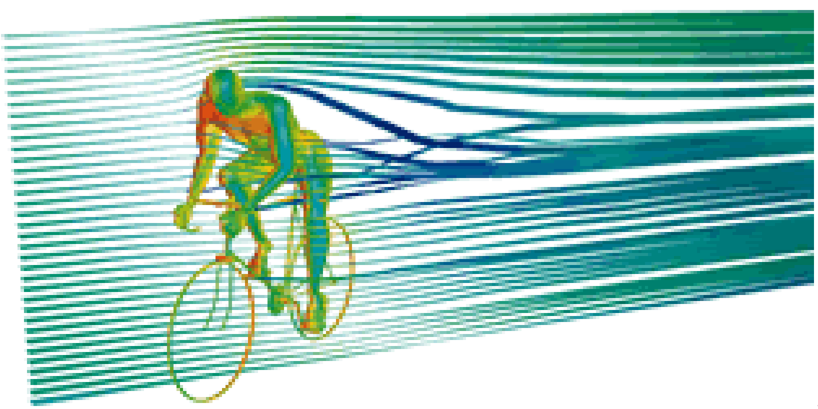
Comparison between initial configuration and optimal points

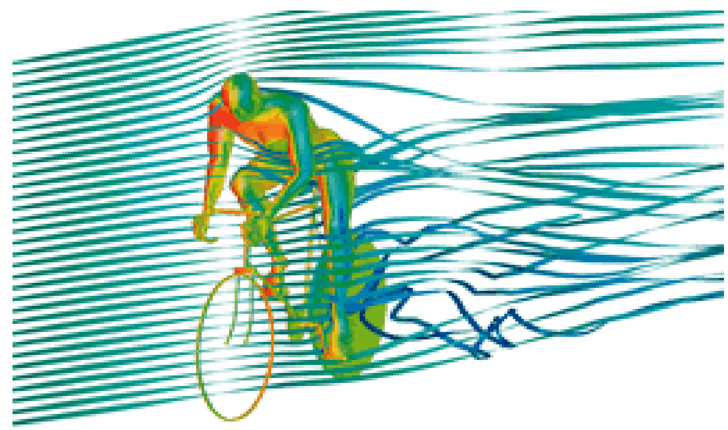
http://www.campagnolosportswear.com/

Example of Applications: Biomechanics

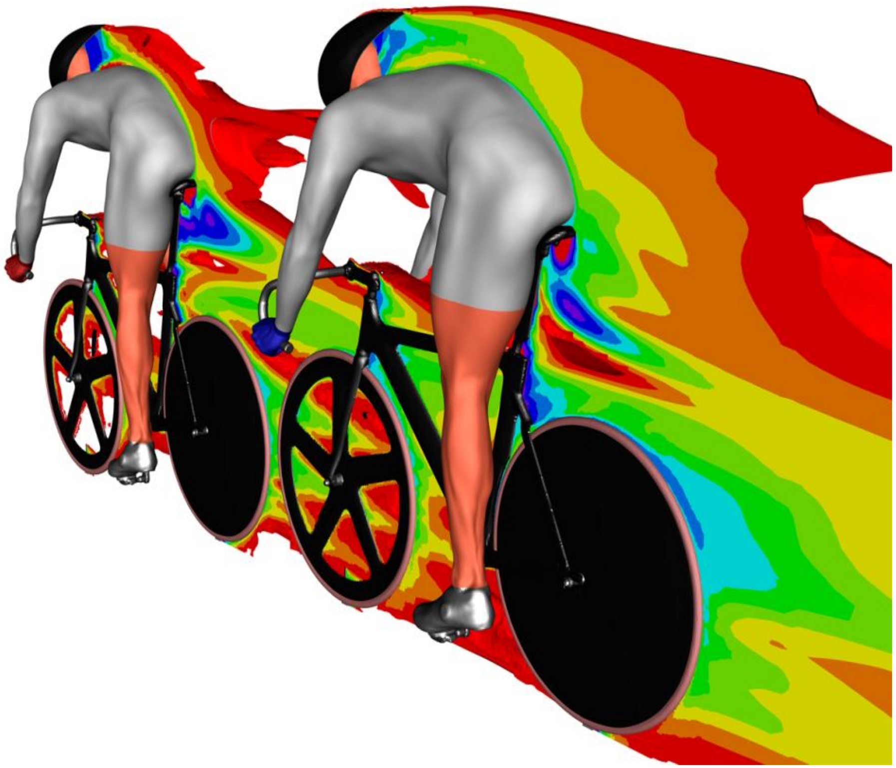


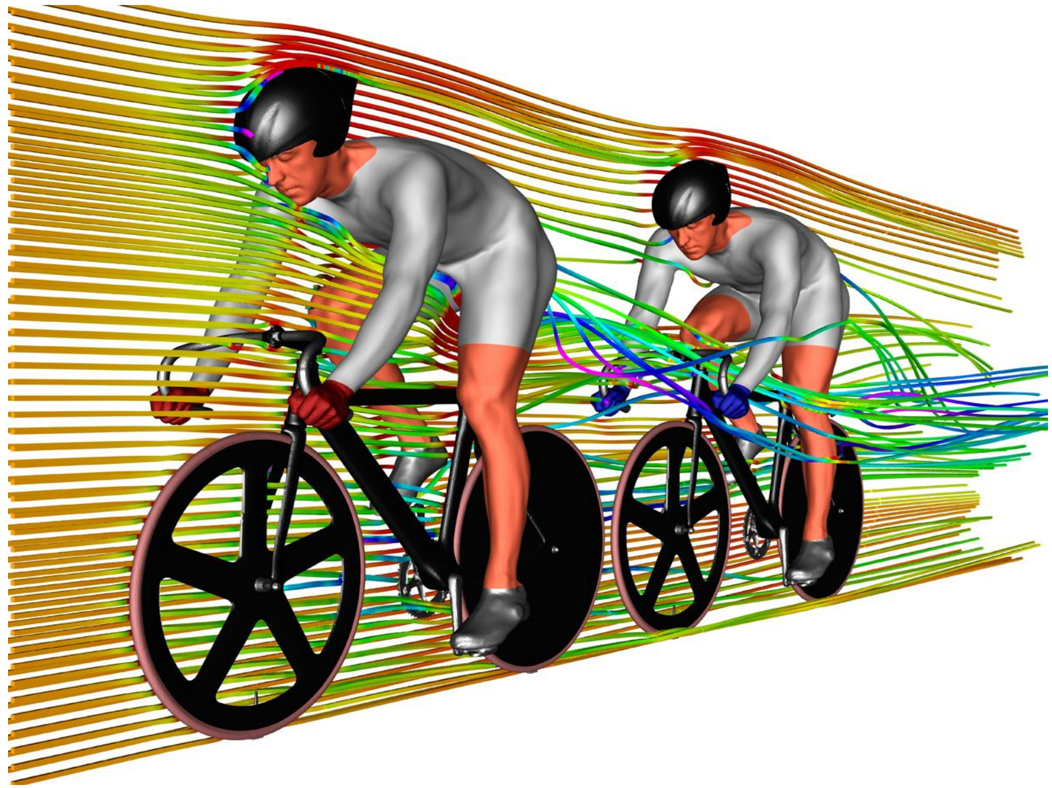
Graph of relative drag difference between a cyclist using a rear wheel with and without a disk in a range of crosswinds



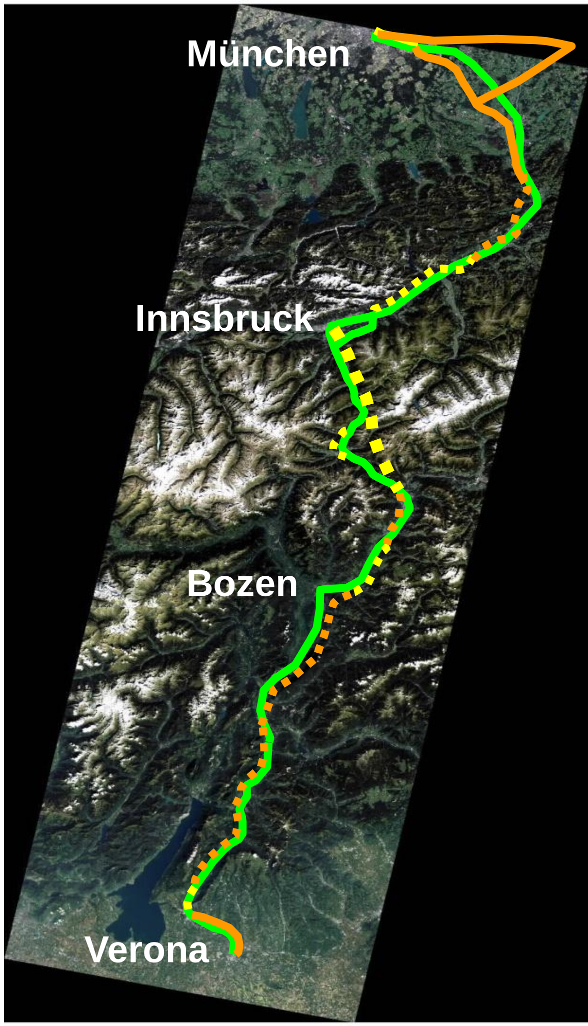


Example of Applications: Biomechanics





Constructions - Brenner Railway Base Tunnel

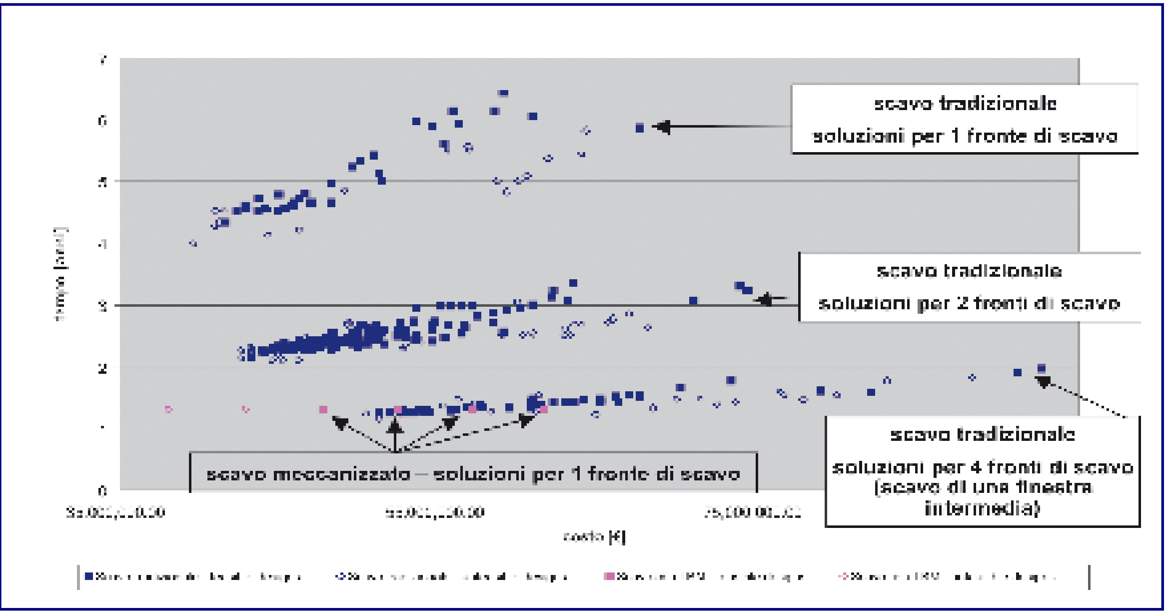


- Two single track railway tunnels connecting Fortezza (Italy) and Innsbruck (Austria).
- Tunnel section: 72,4 m2
- Length: 56 km
- Up to 1650 m under the Alps
- Tunnels about 70 apart, connecting galleries every 330 meters

The problem:

- **Uncertainities** of data on the mechanical behaviour of the rock mass
- Passing from south to north, the tunnel will be drilled throug granite, paragneiss, schist, gneiss, marble, phylite.
- It also crosses the Periadriatic Seam, caused by the collision of the African plate and the European Continent

Examples – Constructions - Transportation



Time and Cost Reduction

modeFRONTIER tasks

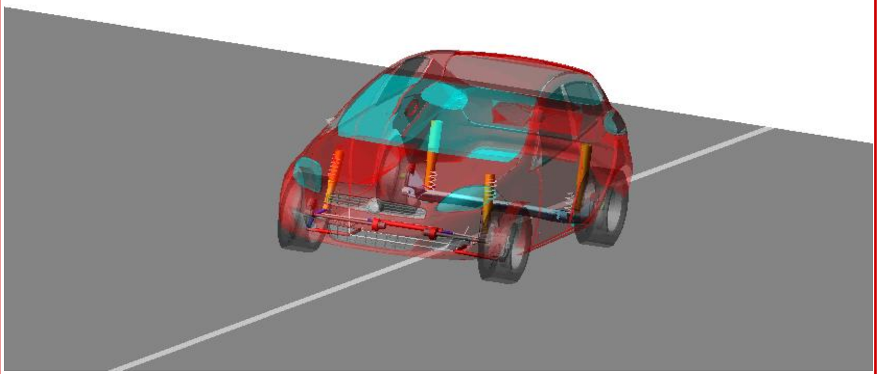
- Reliability analysis (general) – and documentation
- Reliability analysis with respect to rock models (behaviour of the mass during borging)
- Senario and decion on the best excavation method.

Automotive Application

Courtesy of **Fiat**

The aim of this activity is to **OPTIMIZE CONFLICTING ASPECTS** in terms of **Handling performances** as well as **Ride&Comfort performances**.

Handling

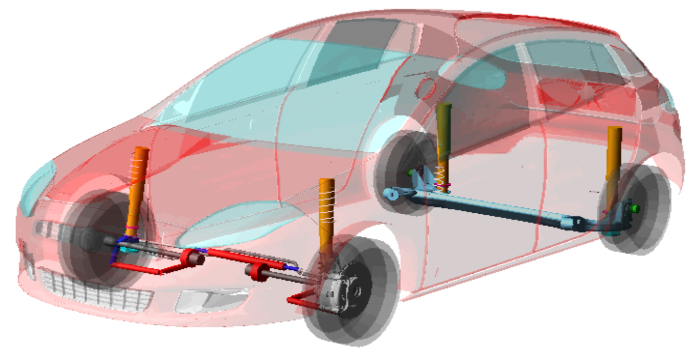


Stability and response of the vehicle

Understeer
Side-slip angle
Rolling
Yaw speed

Vs

Comfort

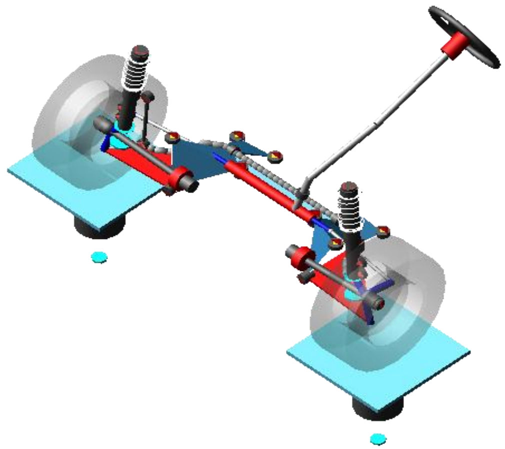


Comfort for driver and passengers

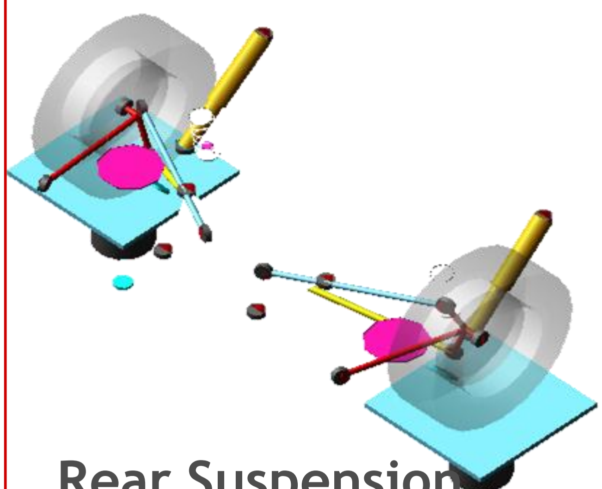
Peak accelerations
Time of dissipation after impact
RMS of low frequency accelerations
on uneven road, highway, obstacles

The study results in a set of vehicle set-up, concerning suspension vertical and longitudinal stiffness, elasto-cinematic behavior, optimizing both aspects without forgetting the robustness of the solution.

Full-vehicle MSC.ADAMS/Car Models



Front Suspension



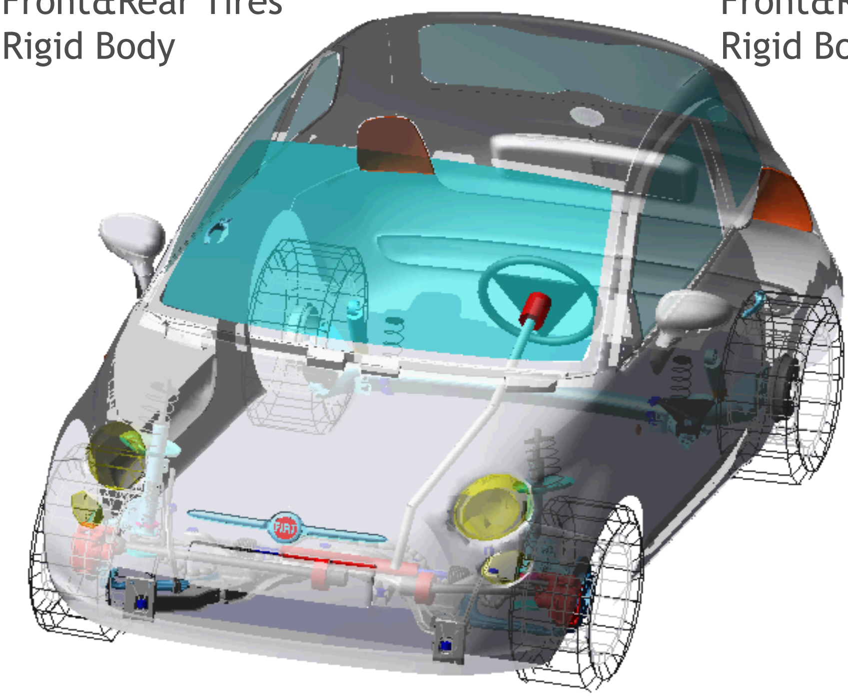
Rear Suspension

Assembly Handling

Front Suspension (incl. flexible subframe)
Rear Suspension
Steering
Antirollbar
Conceptual Driveline
Front&Rear Tires
Rigid Body

Assembly Comfort

Front Suspension (incl. flexible subframe)
Rear Suspension
Steering
Antirollbar
Engine
Front&Rear Tires
Rigid Body



Definition of Input variables

<u>Vehicle parameters</u> able to influence both the <u>Ride-Comfort</u> and <u>Handling</u> performance

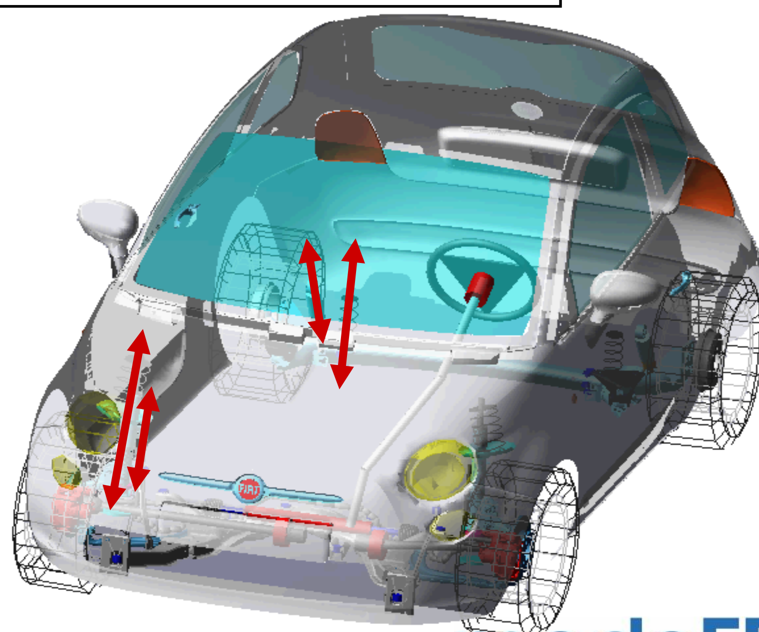
VERTICAL STIFFNESS AND ROLLING STIFFNESS

VERTICAL DAMPING

LONGITUDINAL STIFFNESS AND DAMPING

ELASTO-CINEMATIC CHARACTERISTICS

<u>Input variables:</u>
Spring Stiffness and preload
Bumpstop clearance and characteristics
Anti-roll-bar diameter
Damper characteristics
Bushing characteristics

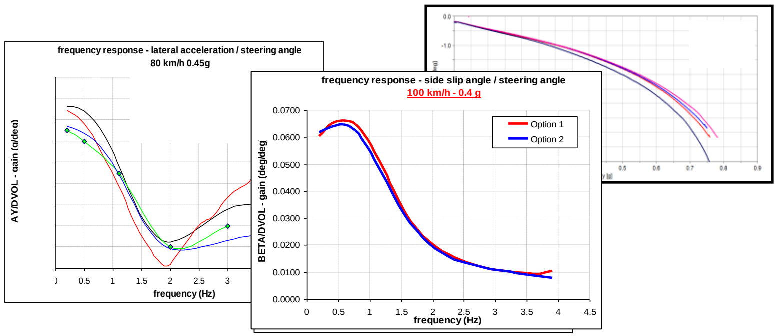


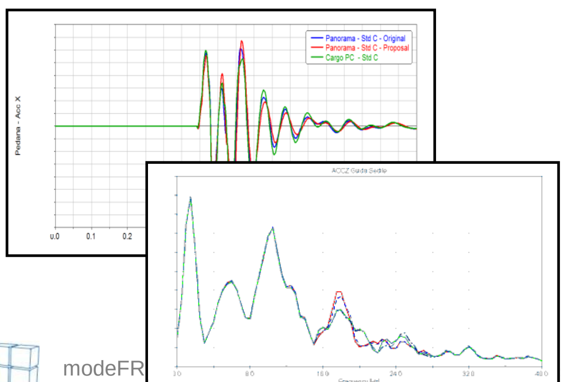
Objectives and Constraints

Objectives:

- Key synthesis Handling parameters (understeer, sideslip curve, yaw, rolling - gains, time delays)

- Key synthesis Comfort parameters (peak accelerations, time dissipations, RMS/RMF)





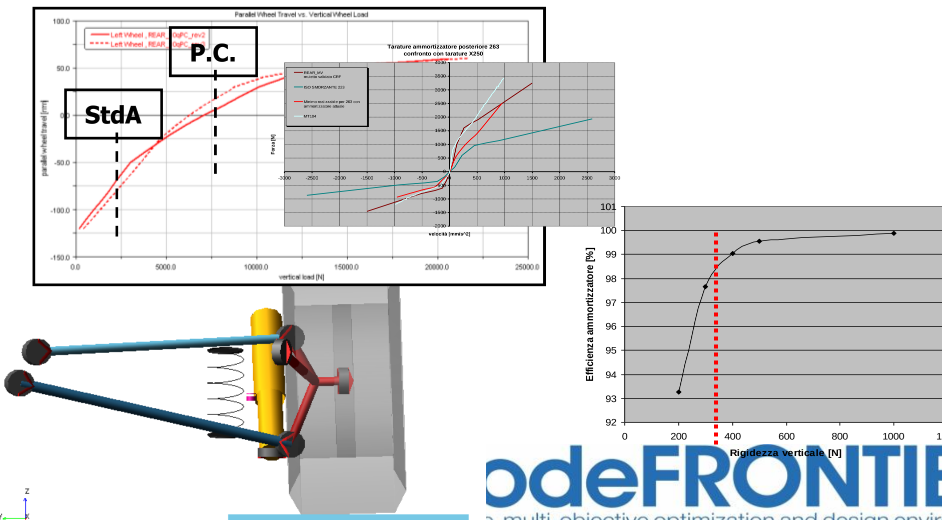
Constraints:

- Ride height in various load conditions

- Feasibility of the components for .ex. rate between axial and radial bushing stiffness, damper characteristics, bumpstop length and characteristics etc.

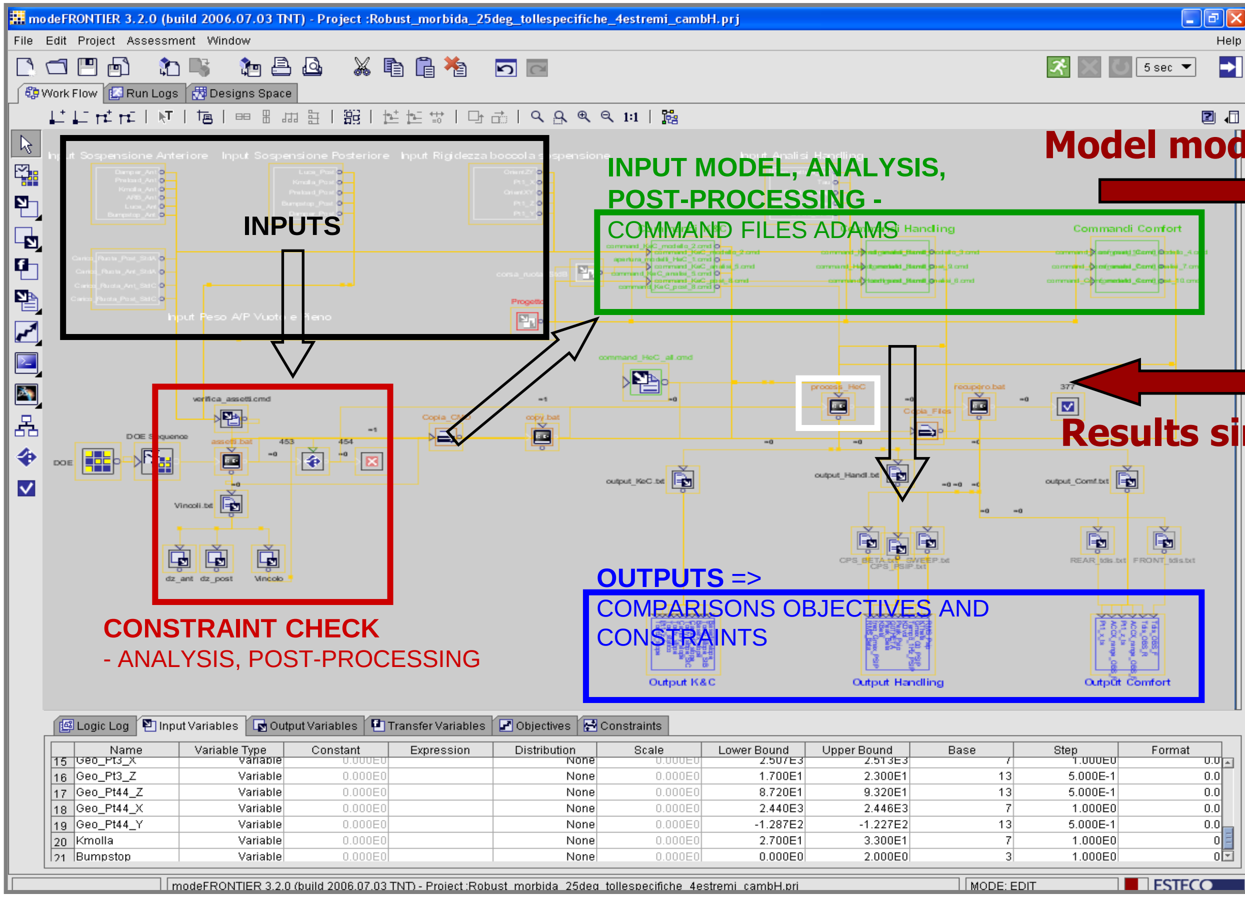
- Top mount stiffness for damper efficiency

- Performance constraints

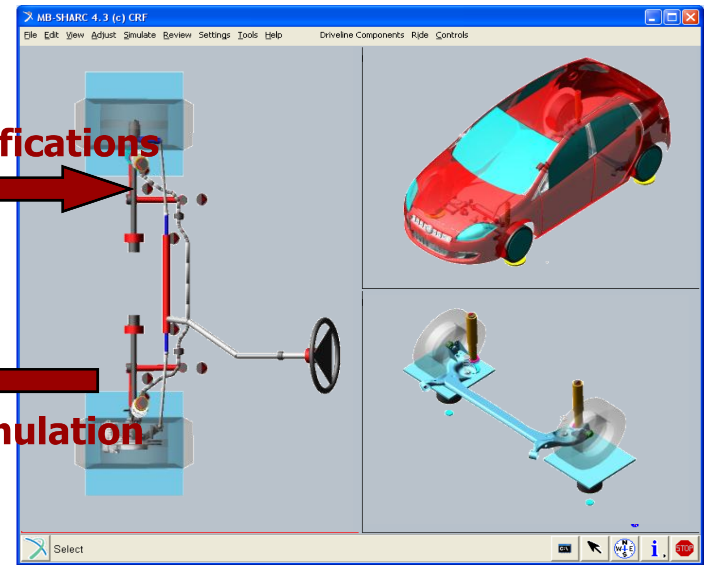


Coupling modeFRONTIER & ADAMS/Car

modeFRONTIER



MSC.ADAMS Car

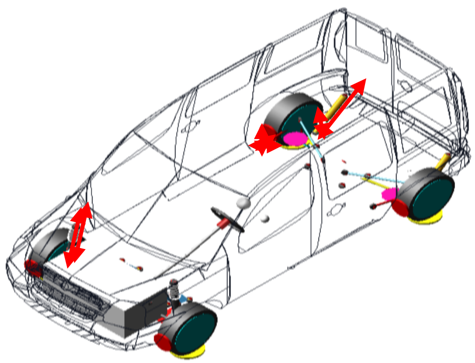


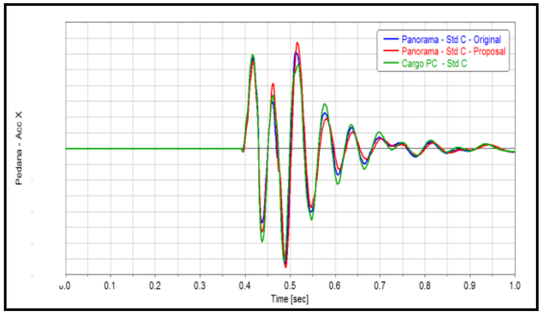
Example Process includes modifying and launching
3 models (K&C, Assembly Handling e Comfort),
7 analysis (4 K&C, 2 Handling e 1 Comfort).
Every run requires approx. 5min => weekend 2.5ggr = about 800 run

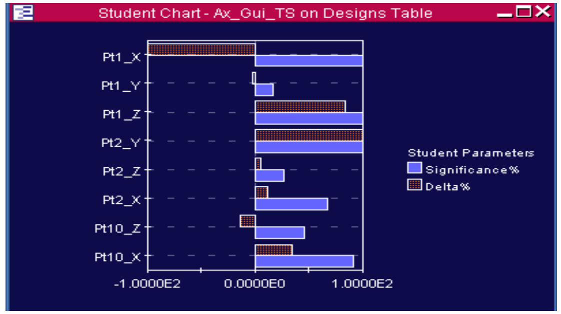
DOE Study and Optimization Method

Influence Study: 8 Input variables, 4 Targets for example

DOE Study Sobol/Full-factorial => Excluding input variables (and constraints/objectives) + Adapting range of study



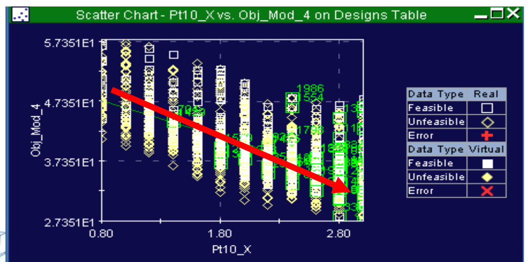


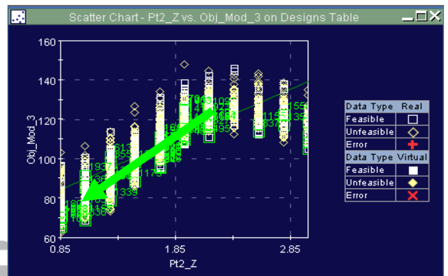


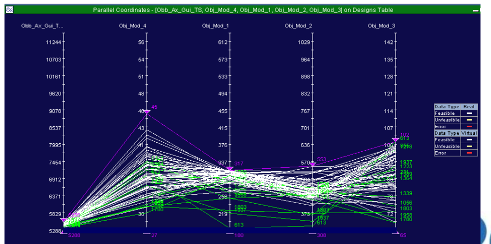
Optimization with limited numbers of variables, objectives, constraints - <u>real or virtual response surfaces</u>

Pareto FRONTIER => Selection of "optimum" solutions related to the particular project vehicle target setting

Verification of optimum solutions belonging to Pareto FRONTIER

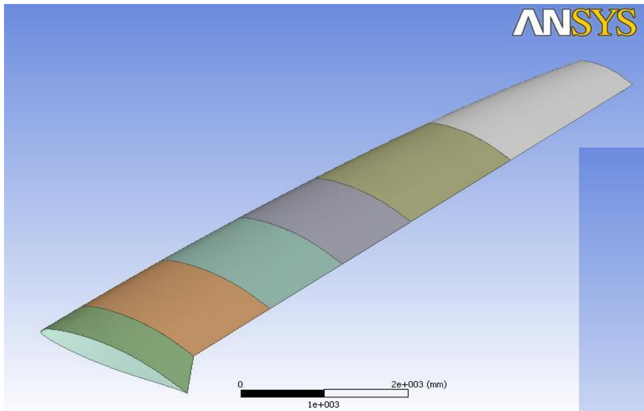




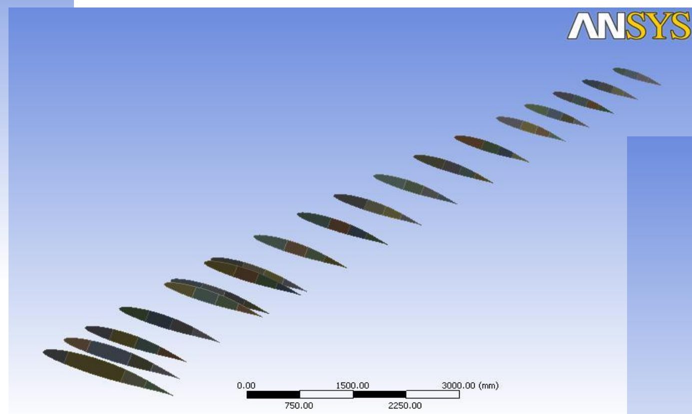


Aerospace Application

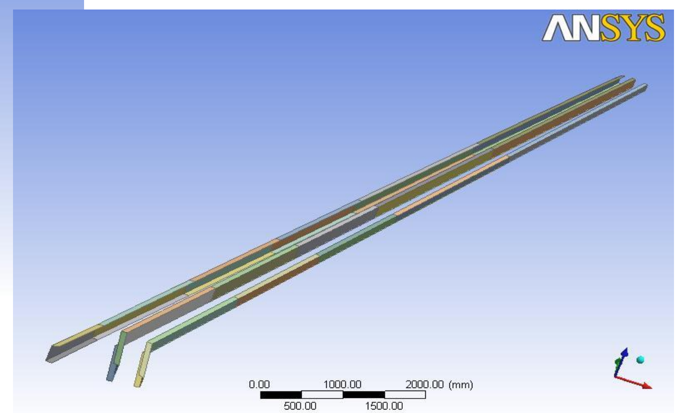
The geometric model built-up in Catia V5 has been imported into ANSYS WorkBench 11.0.



Superfici Alari (Skins)



Centine (Ribs)



Longheroni a C (Spars)

Courtesy of **Alenia Aeronautica**

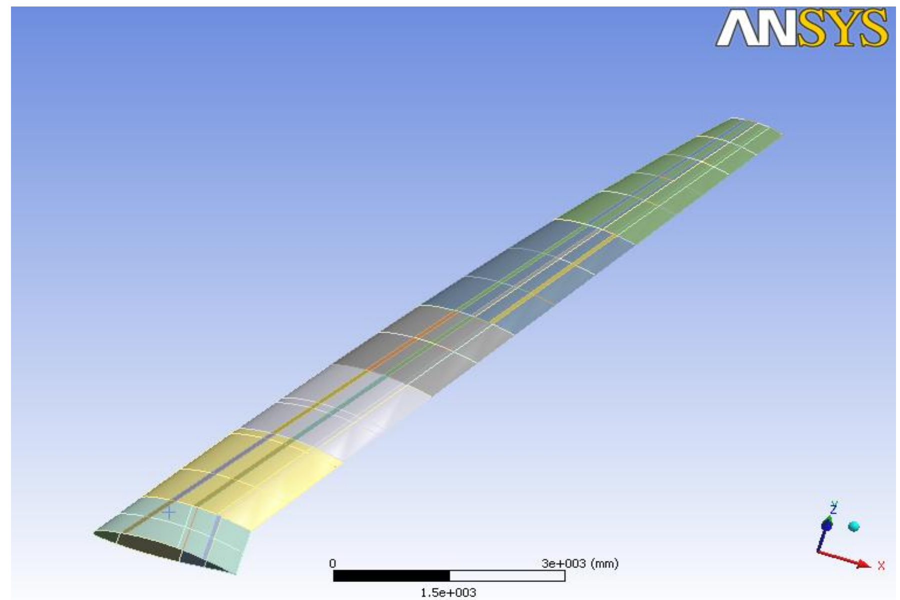
Geometric model set-up

Subdivision of the wing into 6 parts

In this way it is possible to reduce the number of skins while getting closer to the tip of the wing (more efficient optimization process)

Different values of skin and caps structural parameters between the wing underside and the top surface

With the aim to get the best material performances



The input variables values (thickness, skins number, …) are constant within every 6 parts

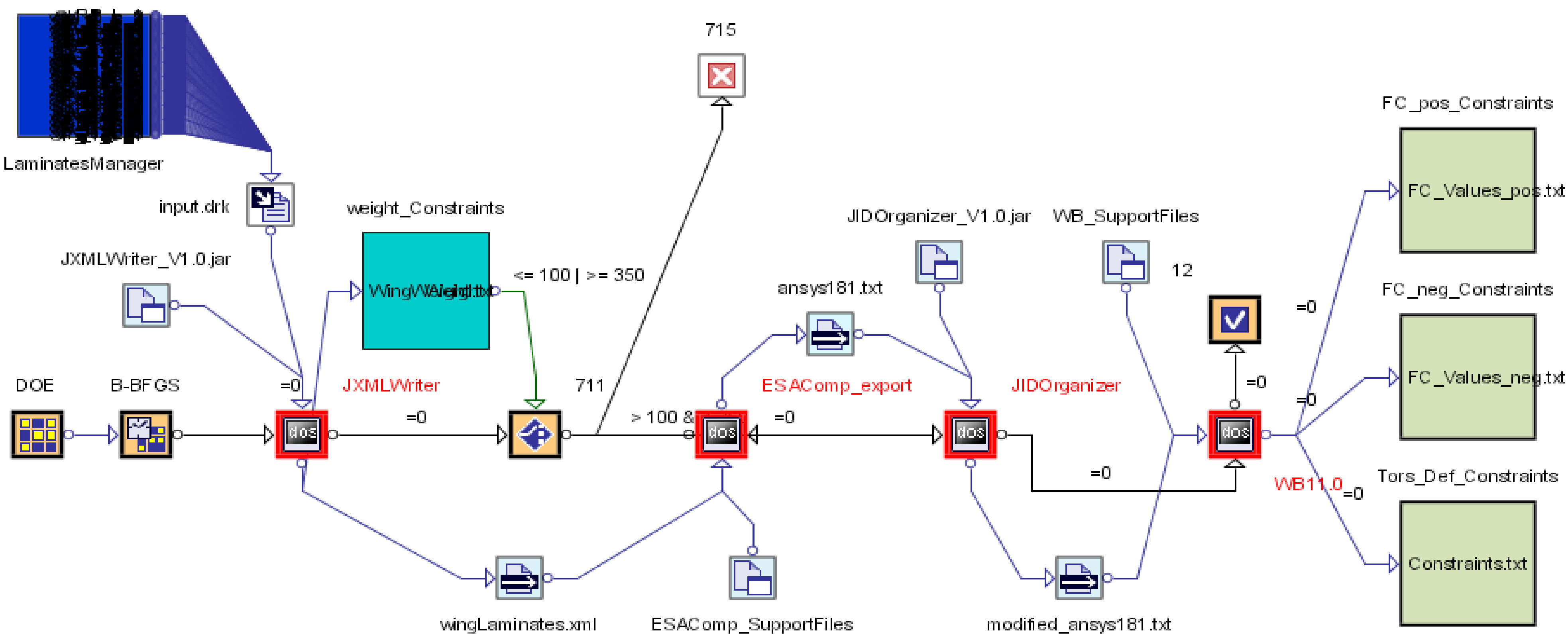
Optimization strategy

The optimization process has been sub-divided into the 2 following phases:

1. Firstly, the whole design space has been explored with the scope to get the **global optimal solution**. This initial search exploited the **MOGA-II**

2. In a second step, the more important input parameters have been further investigated, while the remaining ones have been fixed to constant values. This approach enabled to get more accurate solutions. In this phase **both MOGA-II and B-BFGS** (hybrid approach) have been used.

Workflow modeFRONTIER



DATA FLOW

17 input variables + 67 constants

29 output variables

1 objectives

30 constraints

LOGIC FLOW

DOE: 4 best designs fase 1

Optimizer: B-BFGS

DOE: 16 best designs B-BFGS

Optimizer: MOGA-II

CPU TIME

Around 680 analyses

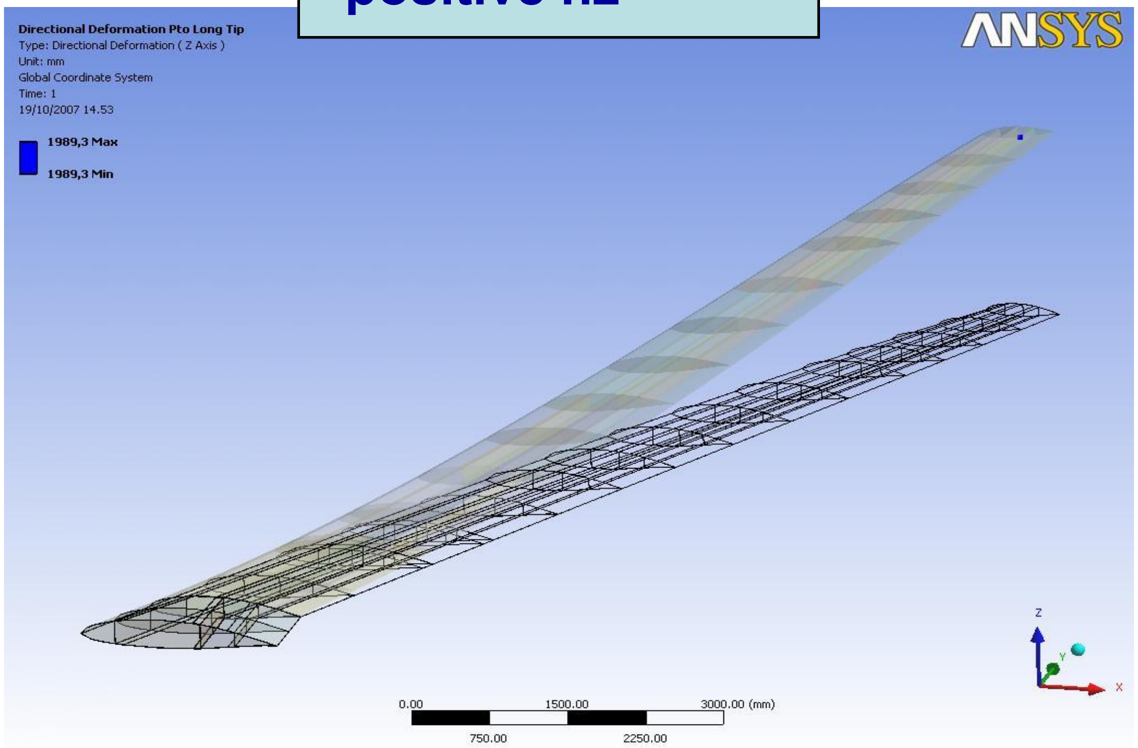
10’ per run

➔ around 4.5 days

Results

The flexural and the total deformation (torsion and flexural) are depicted. In both cases (positive and negative nz) the maximum deformation values belong to the feasibilty domain.

“positive nz”



Wing tip deflection (1989.3 mm)

Total deformation (torsion < 7°)