

um
2026

From High Fidelity CFD to Reduced Order Modeling for Launcher Aerodynamics using ndAI

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Agenda

PADA1 Project presentation

Micro launcher with hybrid propulsion development

Study context

Aerodynamic studies, CFD simulations

Workflow and CFD simulations automation

Run CFD simulation from anywhere thanks to VOLTA

Reduced Order Model creation and training

Results exploitation



PADA1 Project introduction



PADA1 Project consortium



Responsible for engine development
Performance, combustion, tests

Responsible for Launch Vehicle system – Design and Optimization
Engine optimization, system engineering, CFD analysis



Responsible for ground segment
Telecommunication, FTS

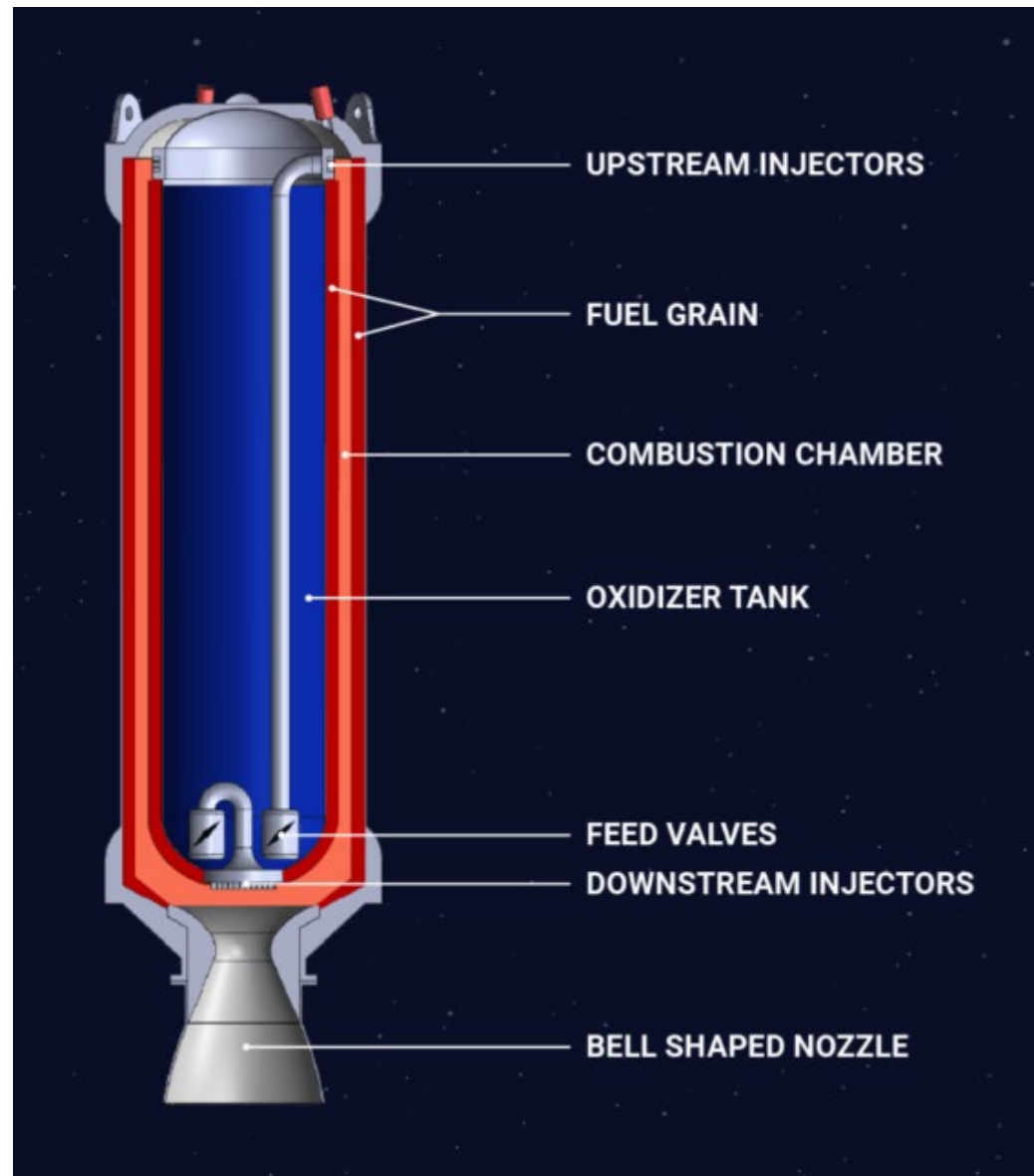


This project is financed by bpifrance and the France2030 program



PADA1 Project

Overall Objective : Developing a hybrid demonstrator Baguette One to build the first hybrid micro launcher OB-1 able to place payloads up to 250 kg on circular orbits at 300 km



Baguette One



- Suborbital Launcher
- Launched from France in 2026
- Demonstrates the feasibility of the engine
- Allows to adjust some engine parameters for OB-1

Orbital Baguette One (OB-1)



- Two Stages Launcher
- 8 Hybrid engines for the whole Launcher
- Sequential Jettisoning
- Target orbit : Equatorial Circular Orbit 300 km
- Max payload mass : 250 kg
- First lift-off in 2027

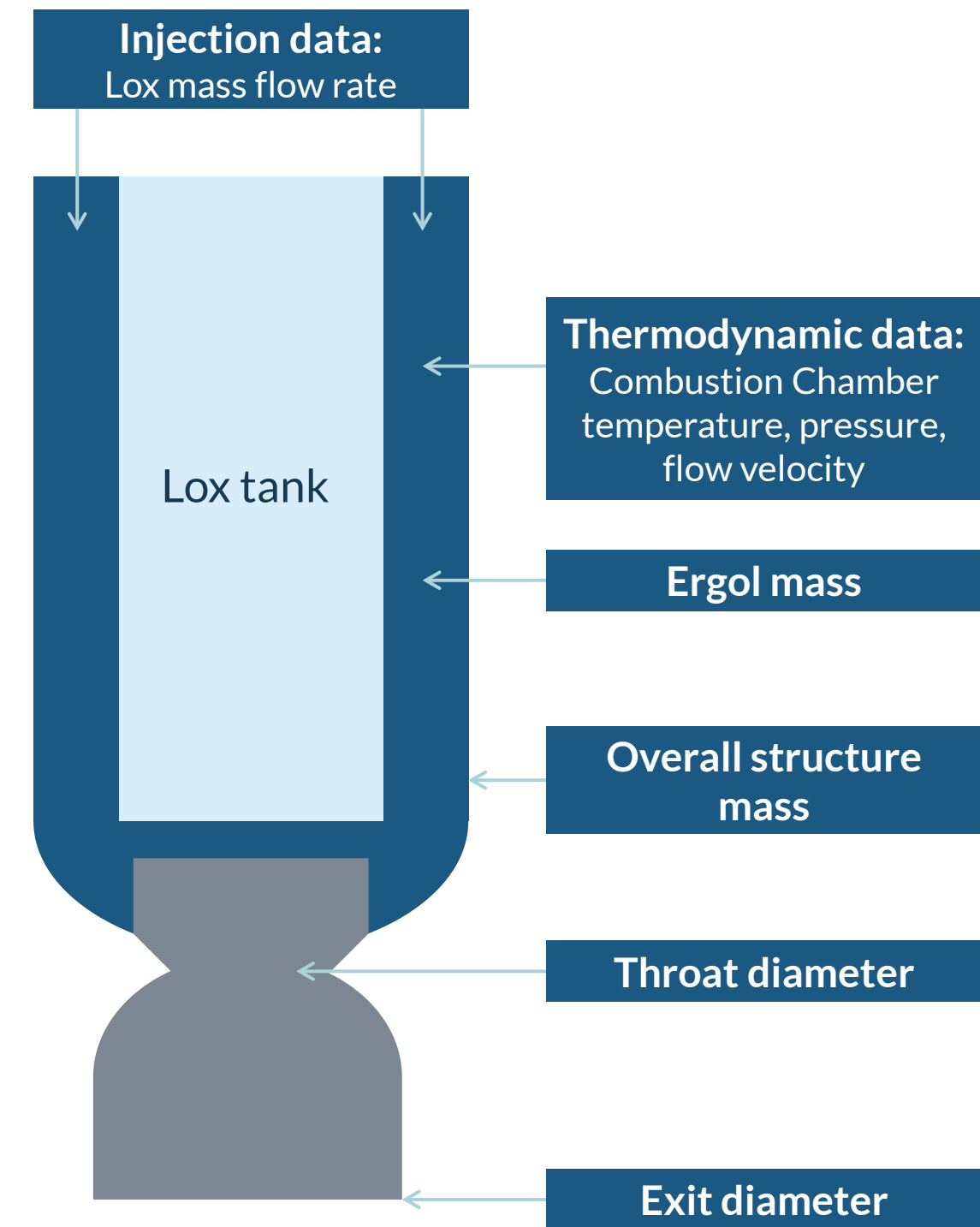
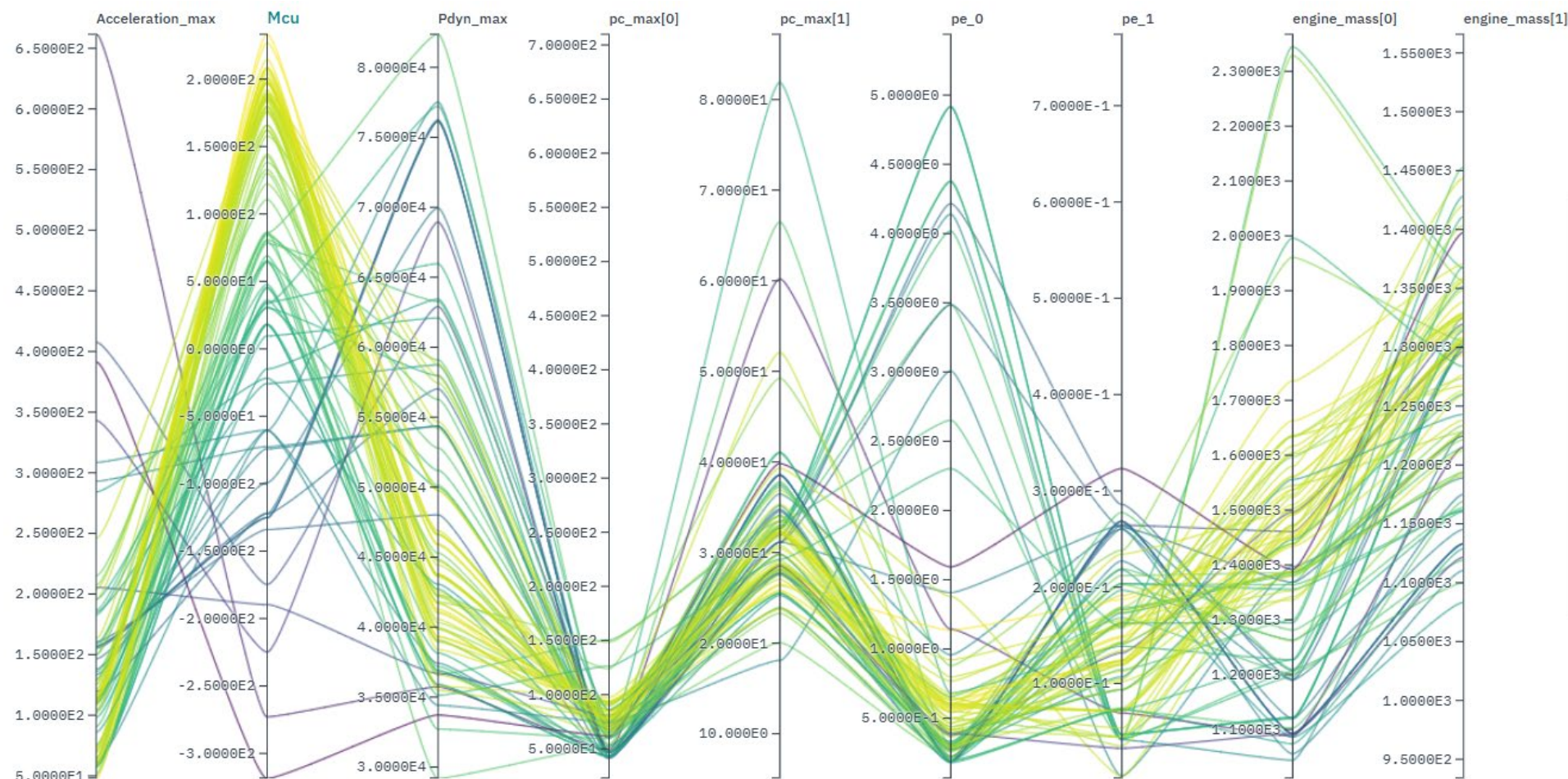
PADA1 Project – CT Expertise

Multi Disciplinary Optimization

Engine Architecture Optimization:

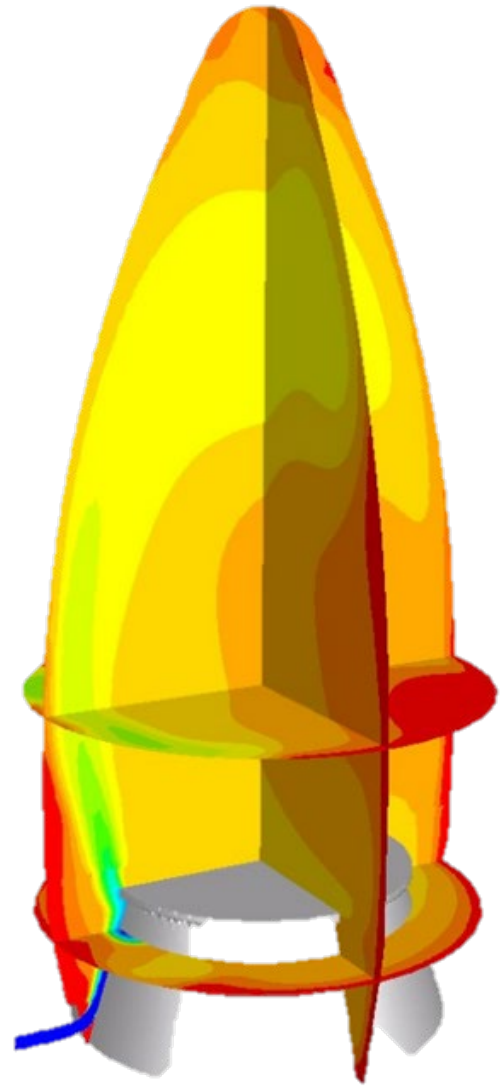
- Injection/thermodynamic data
- Structure geometry
- Staging and trajectory definition

→ Helps to find the best compromise between several solutions



PADA1 Project – CT Expertise

CFD simulations

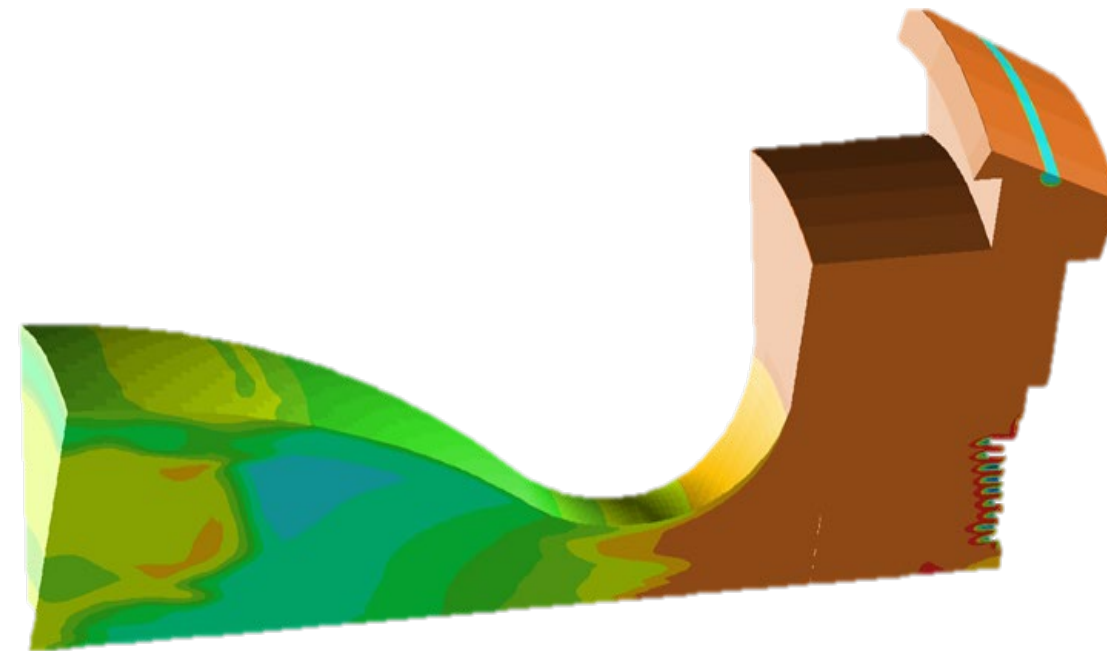
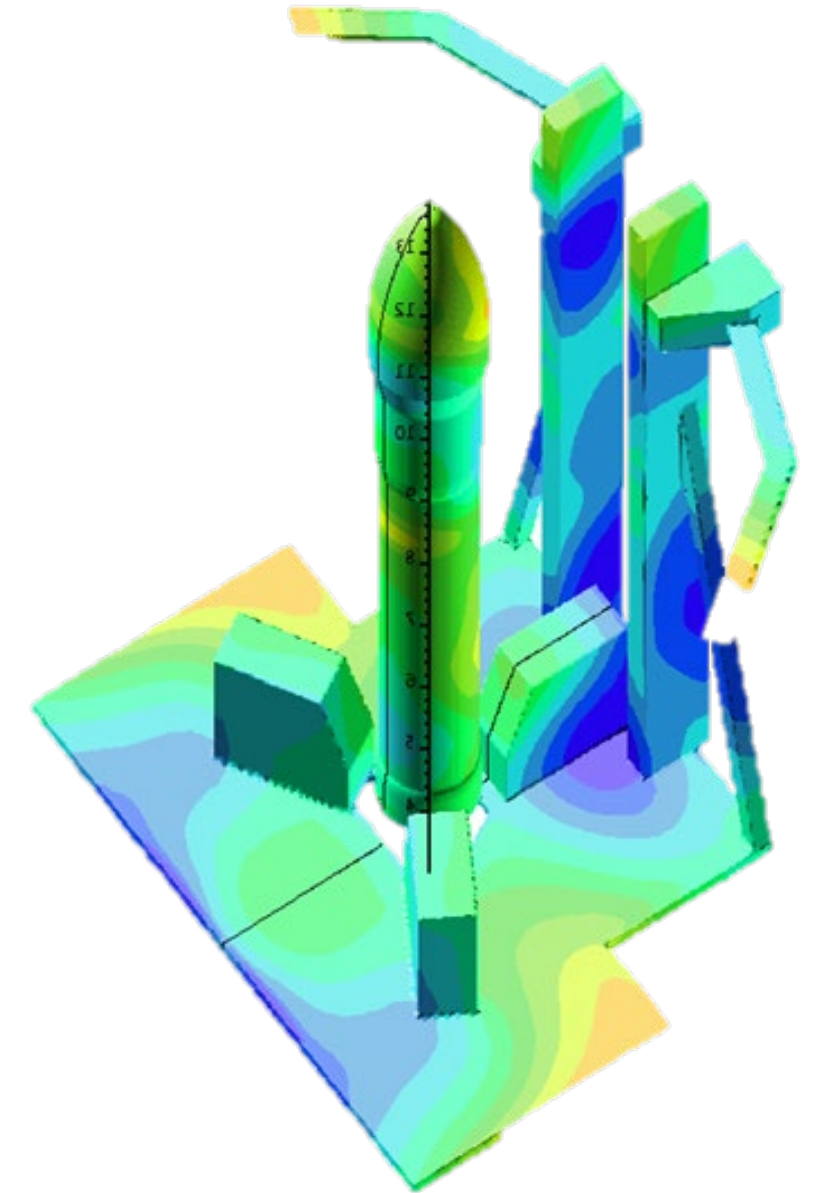


Own CFD software CPS_C developed for more than 30 years and currently used by CNES (French Space Studies Center)

Efficient in many application fields as combustion chamber flow description, jet impact on a Launchpad, aerothermal description inside an open volume, external aerodynamic impact on space vehicle, ...

Allows to size external or internal systems while preventing problems that could be encountered in real life

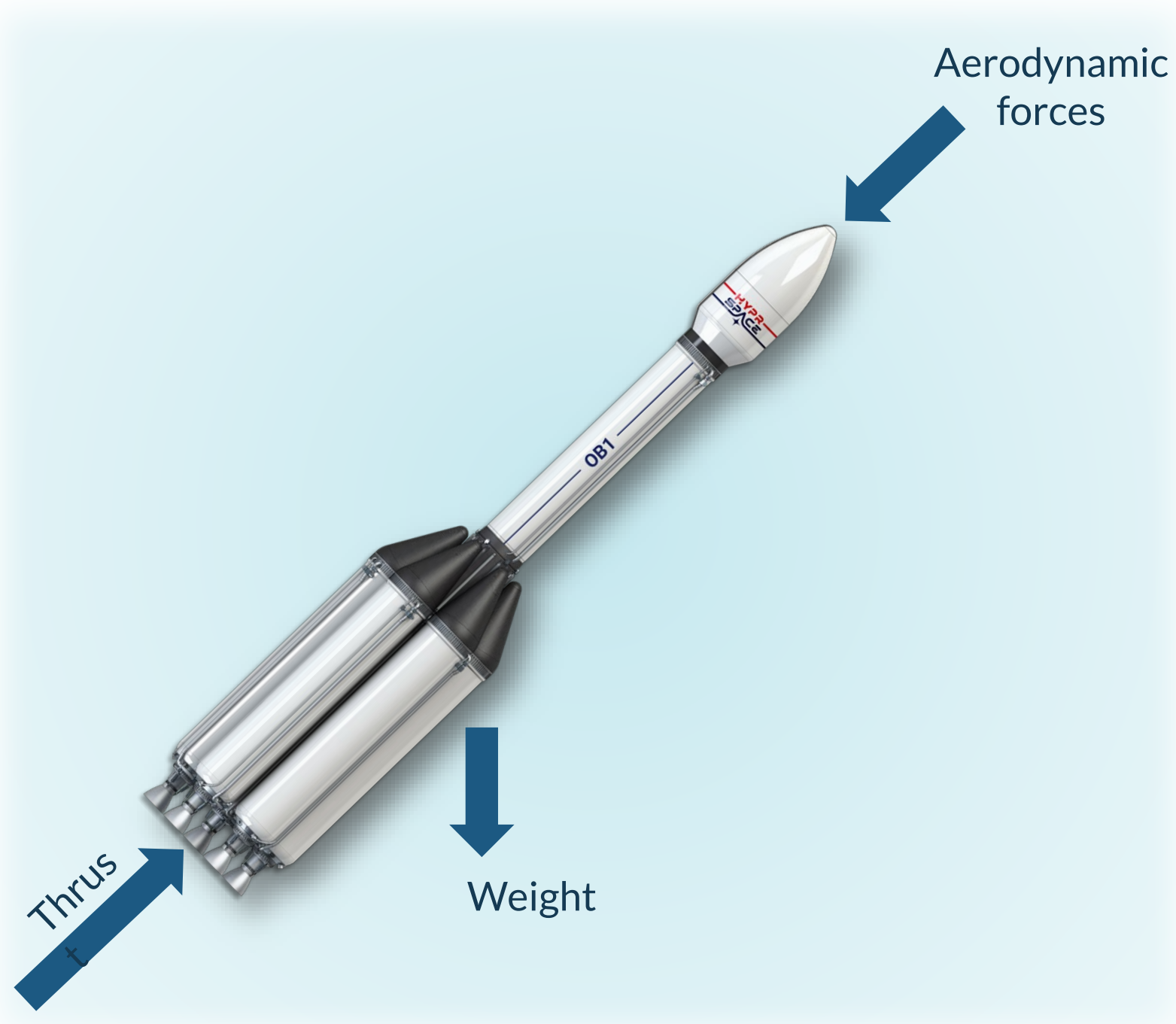
Allows to compute difficult flow fields in a reduced amount of time thanks to a powerful HPC



Study context



Study Context

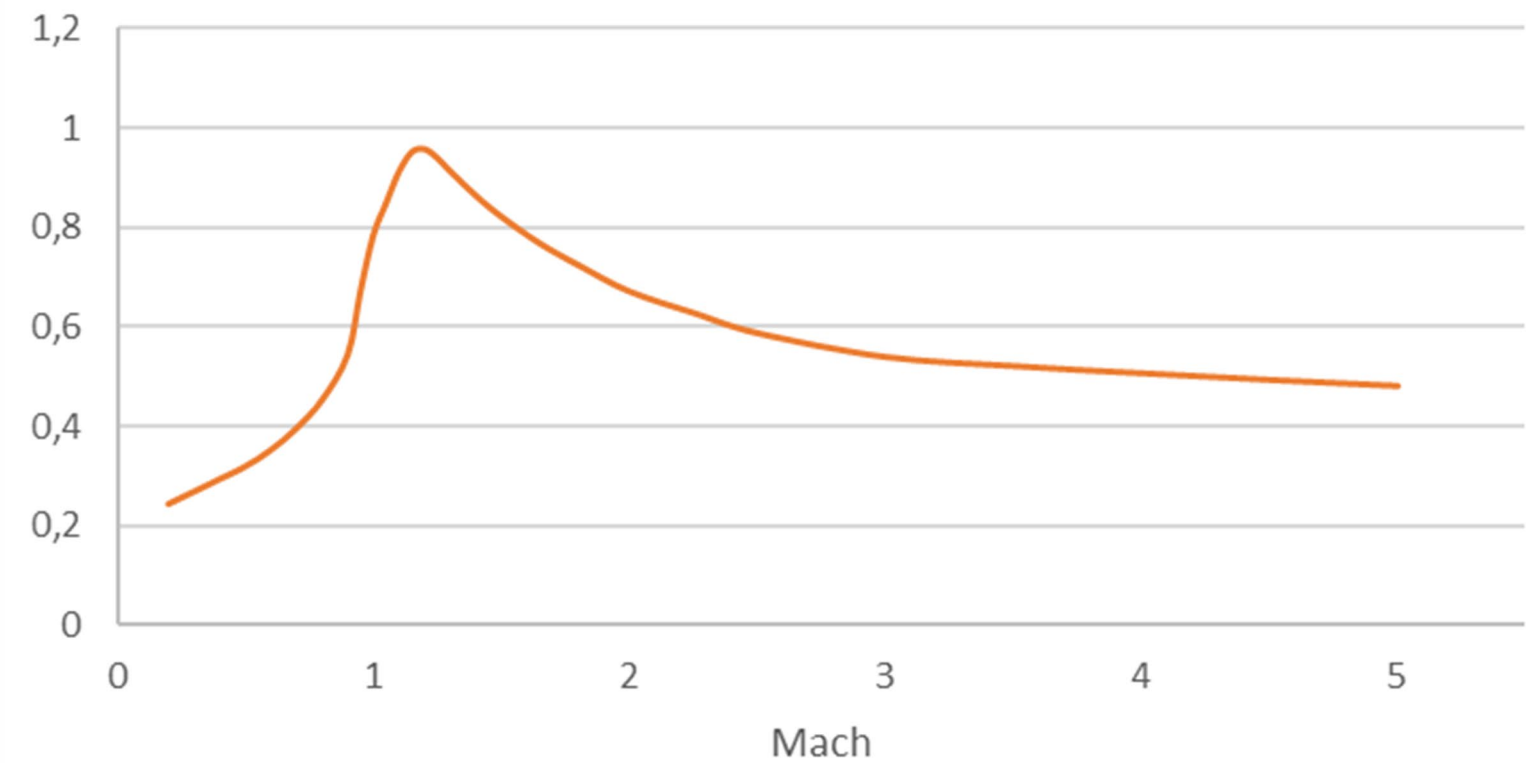


Aerodynamic forces

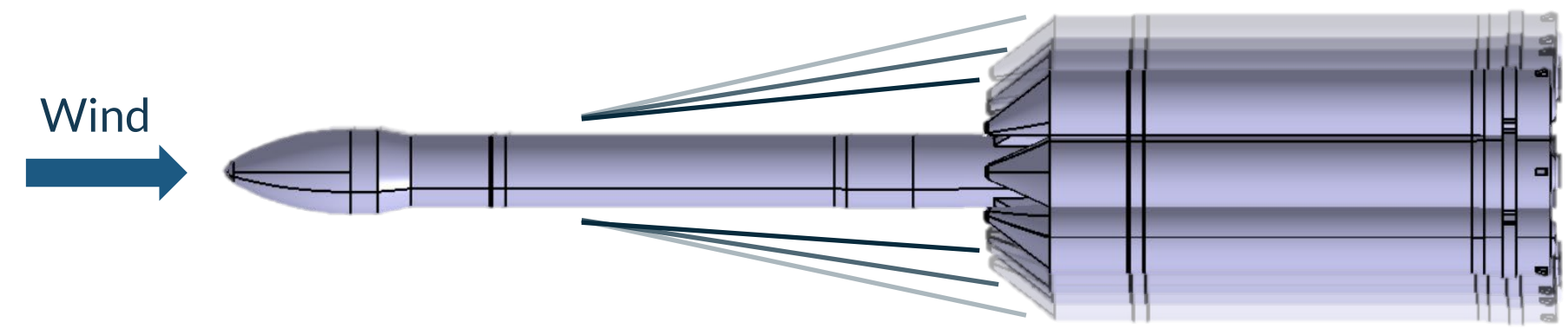
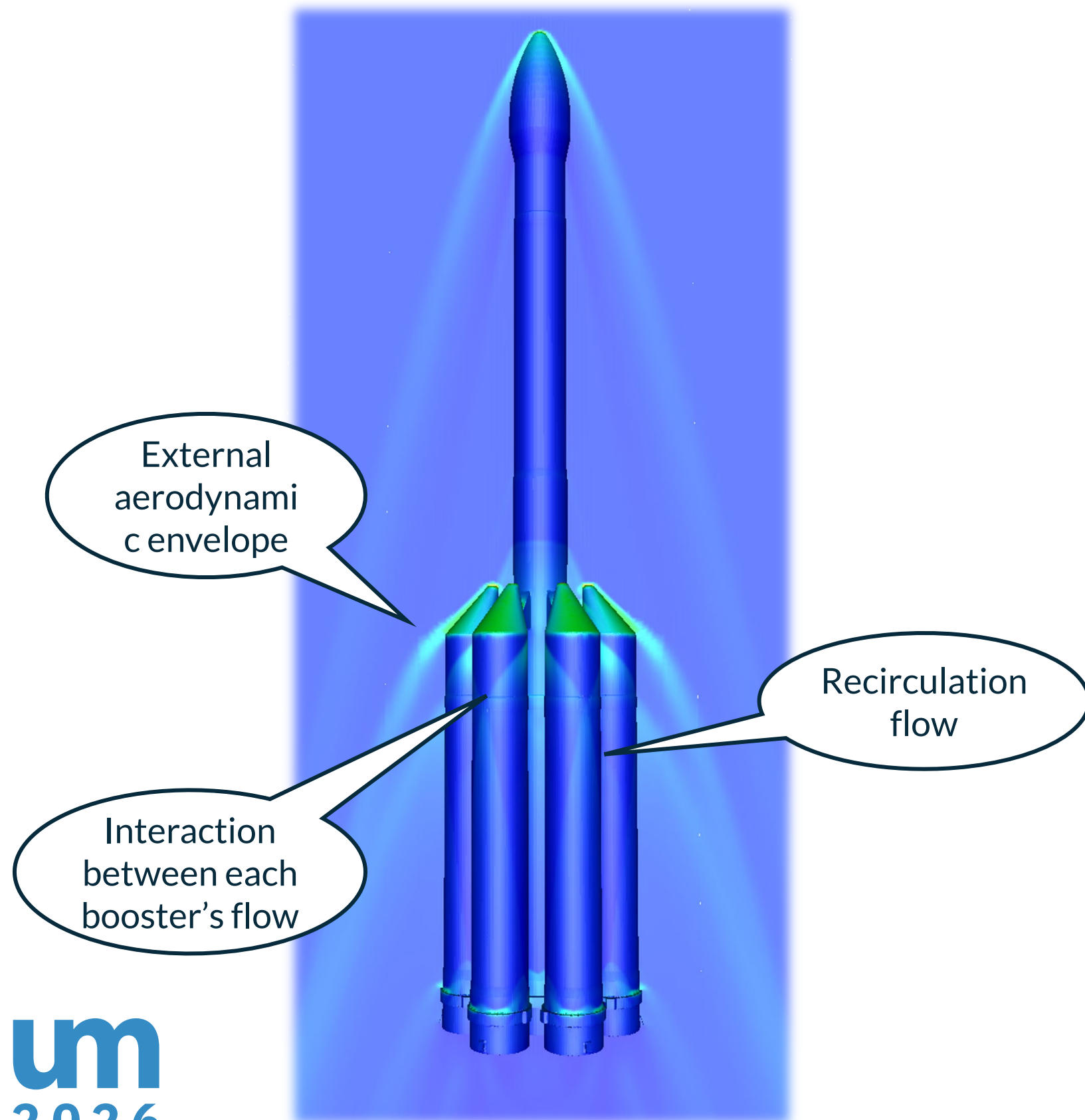
- Are directly linked to the surface area of the studied vehicle
- Reach its maximum in transonic regime (near the speed of sound)
- Are responsible for the maximum efforts encountered during the flight

➔ It is important to have an accurate description of the flow repartition around the launcher to hold the loads

Drag coefficient in function of Mach number



Study Context



- More the distance between boosters and central body increases, larger will be the surface area encountered by the wind and more important will be aerodynamic forces
- Several other phenomenon occur while moving the distance between boosters and central body, as the air flow recirculation between both
- The addition of those phenomenon leads to a complex estimation of the non-linear aerodynamic behavior

Simulation time

- One simulation lasts about 6 hours to converge
- For one configuration, a hundred simulations are needed
- ➔ It could take months to get all the results

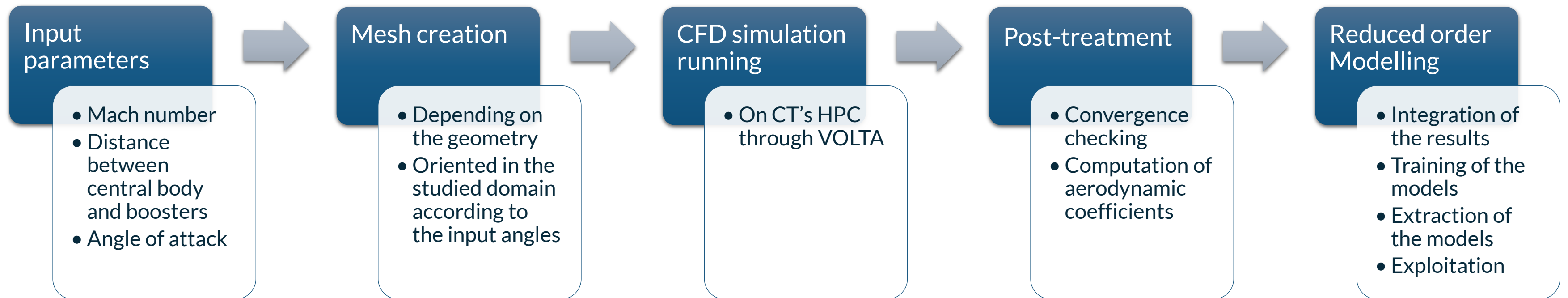
Important work to simulate every cases depending on all the input parameters for each configuration

➔ A Reduced Order Model allows to estimate quickly all the behaviors

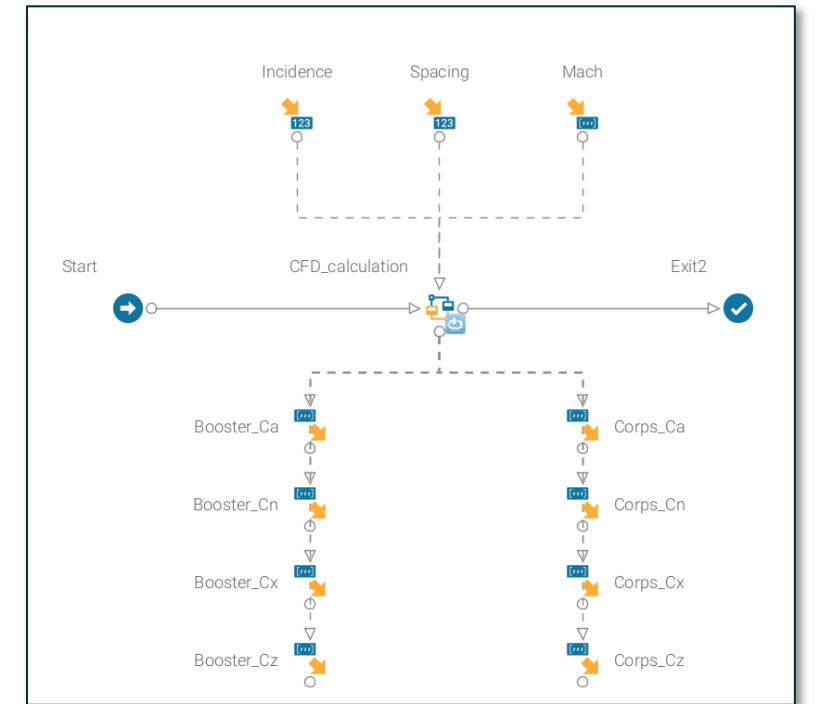
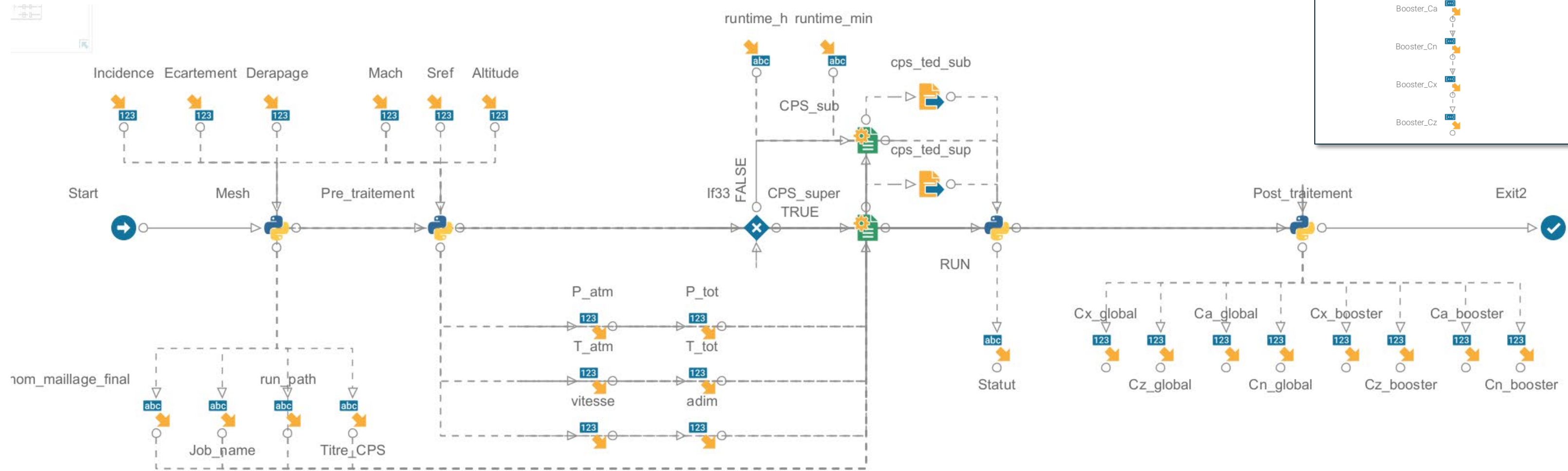
Workflow and CFD simulations automation



Workflow and CFD simulations automation



Workflow and CFD simulations automation



- Meshing of the studied geometry
- Creation of working folders with associated mesh

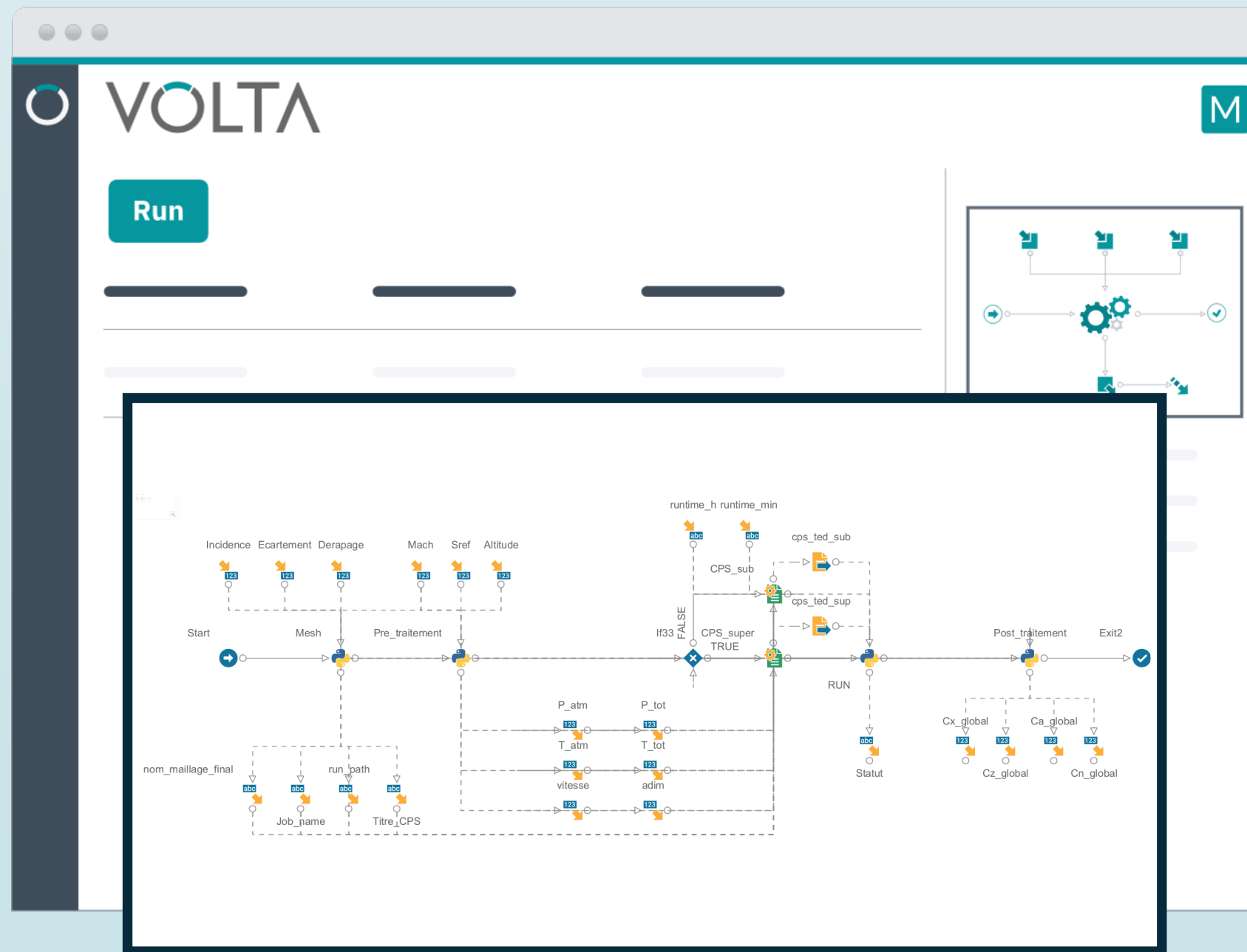
- Pre-treatment data calculation
- Definition of the studied case

Setting of the simulation

Run of the simulation

- Post-treatment of software outputs
- Aerodynamic coefficients calculation
- Exportation of the data

VOLTA



Network connected laptop



HPC

VOLTA

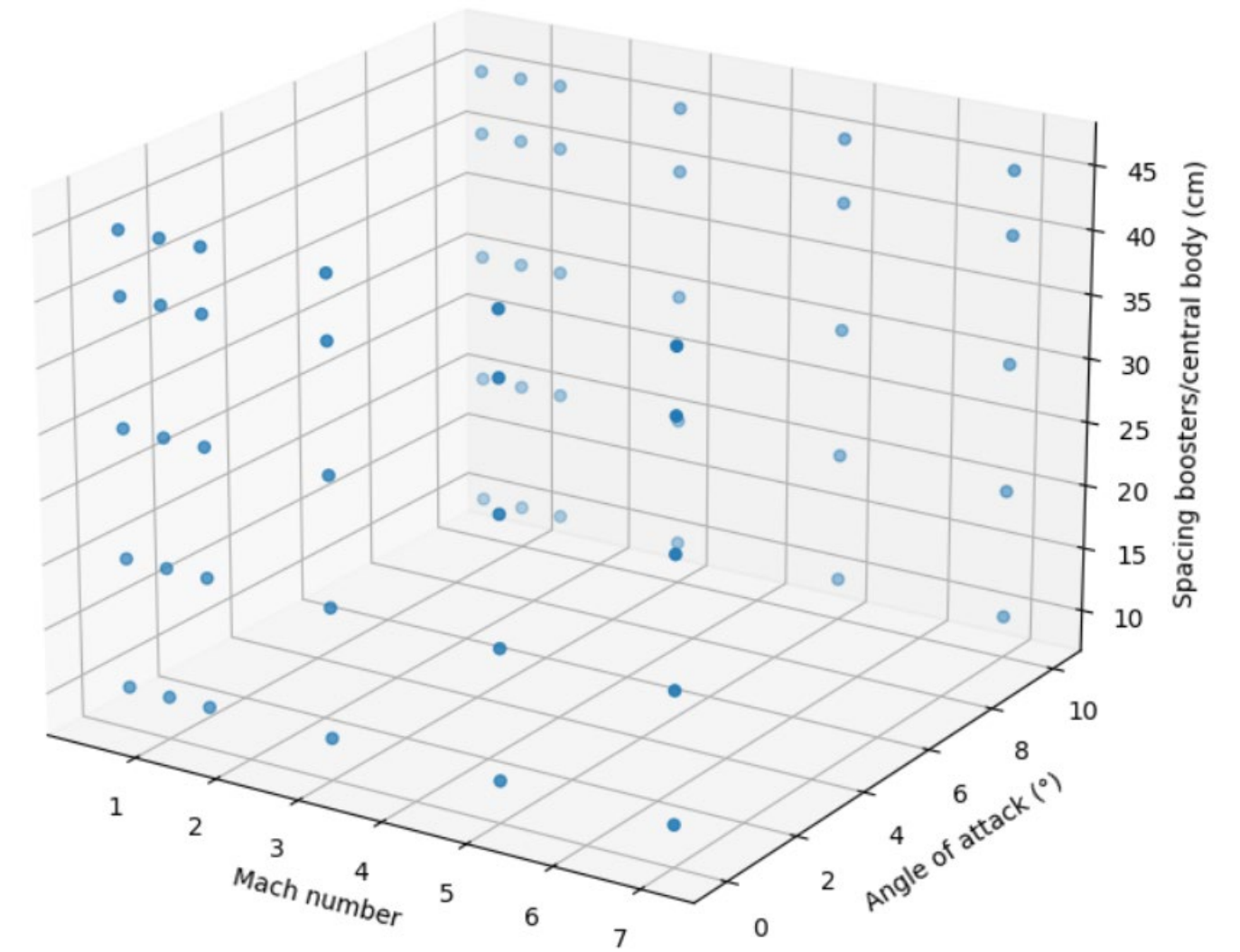
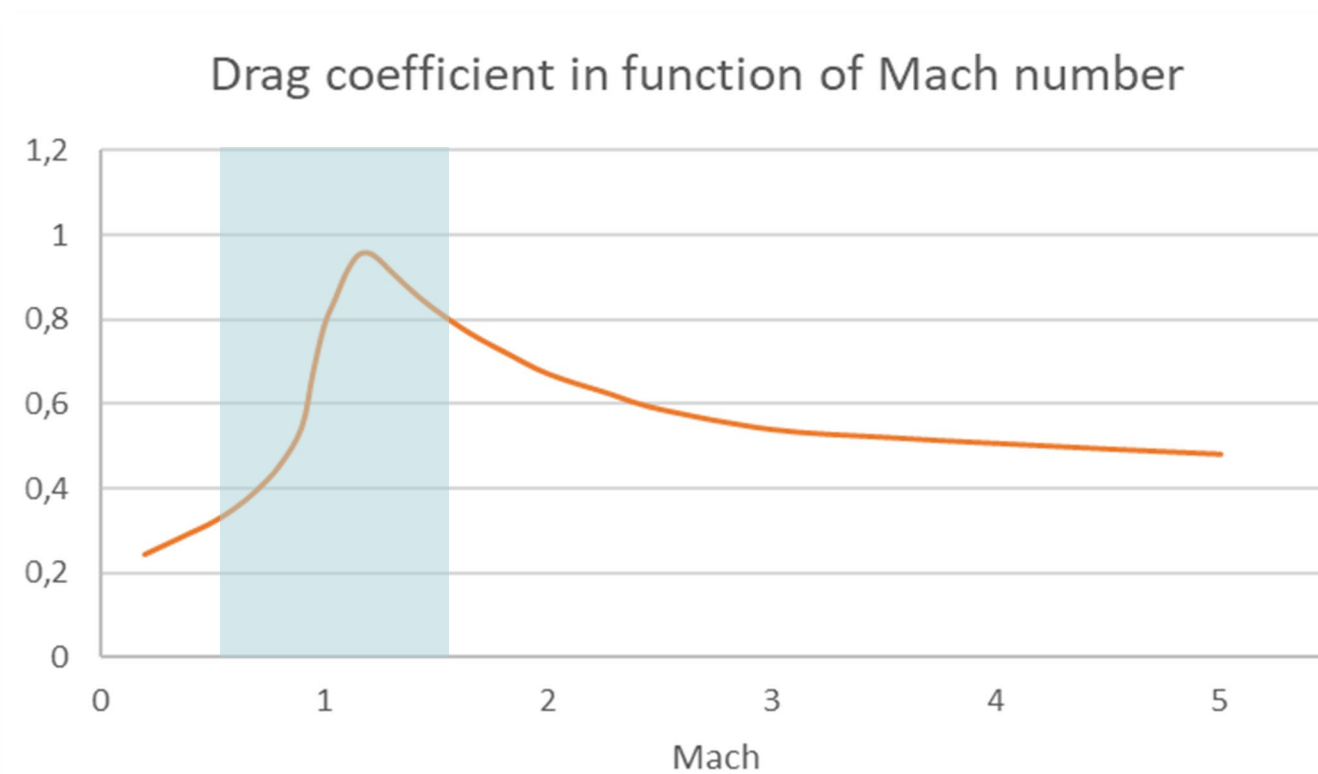
Reduced Order Model creation and training



Reduced Order Model creation and Training

Objective

- Define the range of study for each variable
- Distribute a correct number of points for each of them
- Not too much points are needed
- Provide high quality results



Repartition of the studied points

Reduced Order Model Training and Validation

The screenshot shows the modeFRONTIER 2026R1 - database1 (VOLTA project) interface. The main window displays a table with 10 designs. The 'Session' table is selected, showing columns for ID, Altitude, Incidence, Spacing, and Boosters_Ca[0-2]. A chart titled 'Multi-vector - Vector Comp ...' is overlaid on the bottom, plotting 'Corps_Cx' against 'Vector Components' (0 to 5). The chart shows multiple curves representing different designs, with values ranging from approximately 3 to 13.

ID	Altitude	Incidence	Spacing	Boosters_Ca[0]	Boosters_Ca[1]	Boosters_Ca[2]	Boosters_Ca[3]
1	0.00000	0.00000	10.0000	3.30669	6.08256	5.91195	5.91195
2	0.00000	10.0000	10.0000	3.53353	6.72685	7.73328	6.72685
3	0.00000	0.00000	20.0000	3.82482	6.65733	7.22988	5.91195
4	0.00000	10.0000	20.0000	4.03581	7.54972	8.29827	6.72685
5	0.00000	0.00000	30.0000	3.94672	7.16703	8.07547	5.91195
6	0.00000	10.0000	30.0000	4.34855	8.02072	8.84080	6.72685
7	0.00000	0.00000	40.0000	3.92152	7.40657	8.73403	5.91195
8	0.00000	10.0000	40.0000	4.47701	8.33454	9.86378	5.91195
9	0.00000	0.00000	45.0000	4.11921	7.72234	9.17394	5.91195
10	0.00000	10.0000	45.0000	4.45873	8.54808	9.18883	5.91195

- Import in nD Modeler application the designs to train the ROM directly from the modeFRONTIER Design Space.
- The training set must contains :
 - The inputs (Incidence, Spacing)
 - The outputs (e.g. drag coefficient or Corps_Cx in function of the Mach number)

The screenshot shows the nD Modeler application dialog box. It prompts the user to 'Select a table that contains data for ROM model training. Error designs won't be uploaded.' The 'Tables' section shows a list of tables with columns for Name, Total, Virtual, and Error. The 'Session table' is selected, showing 20 total designs, 0 virtual, and 0 error. The 'Statistics' section shows a table with columns for Variables, Min, Max, and Mean. The 'Preview' section shows a table with columns for Variables, Min, Max, and Mean. The 'Open nD Modeler application' button is visible.

Name	Total	Virtual	Error
1 Session table	20	0	0
2 Session	10	0	0

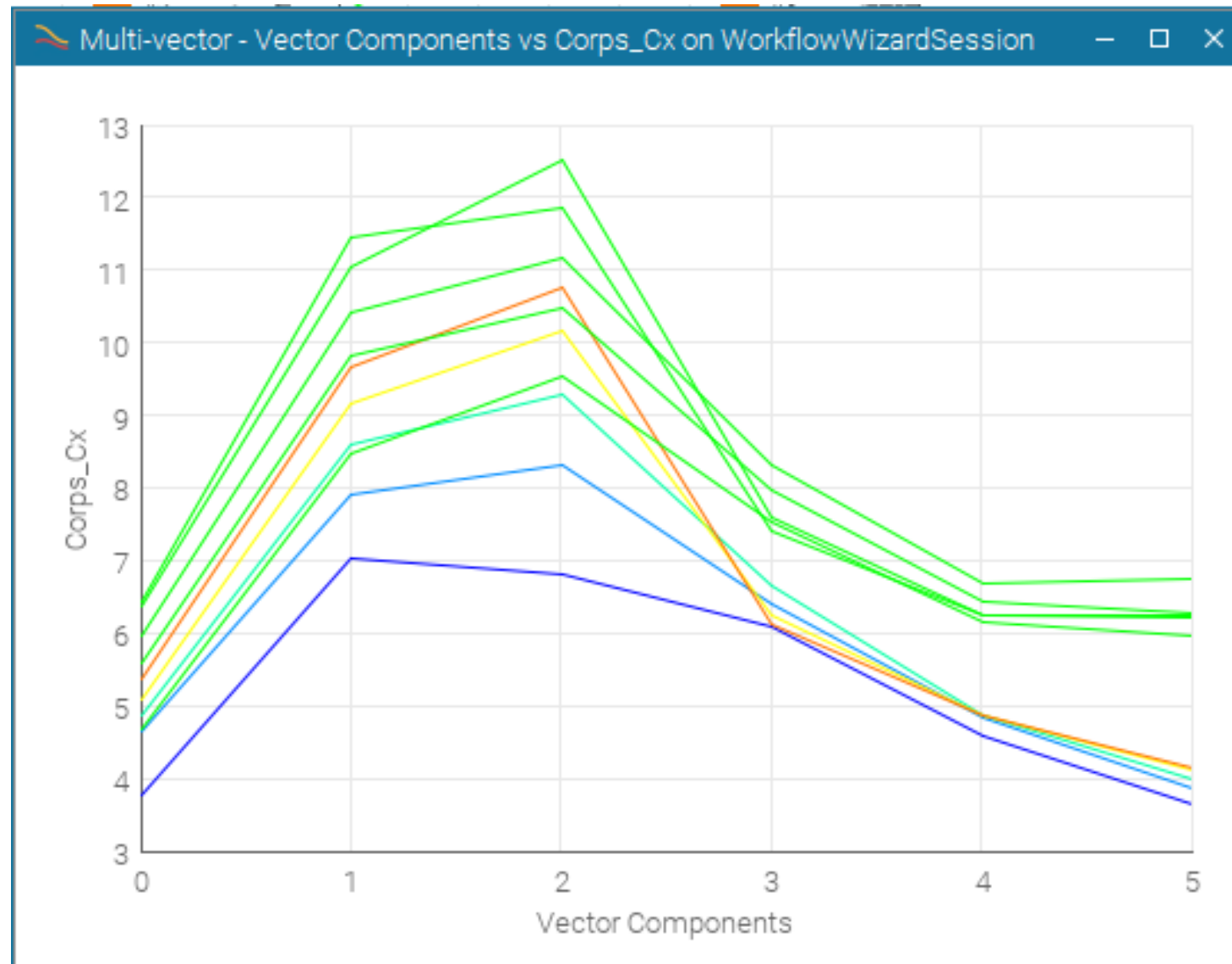
Variables	Min	Max	Mean
1 Altitude	0.00000	0.00000	0.00000
2 Incidence	0.00000	10.0000	5.00000
3 Spacing	10.0000	45.0000	29.0000
4 Boosters_Ca[0]	3.30669	4.47701	3.99726
5 Boosters_Ca[1]	6.08256	8.54808	7.42157
6 Boosters_Ca[2]	5.91195	9.86378	8.29827

Reduced Order Model Training and Validation

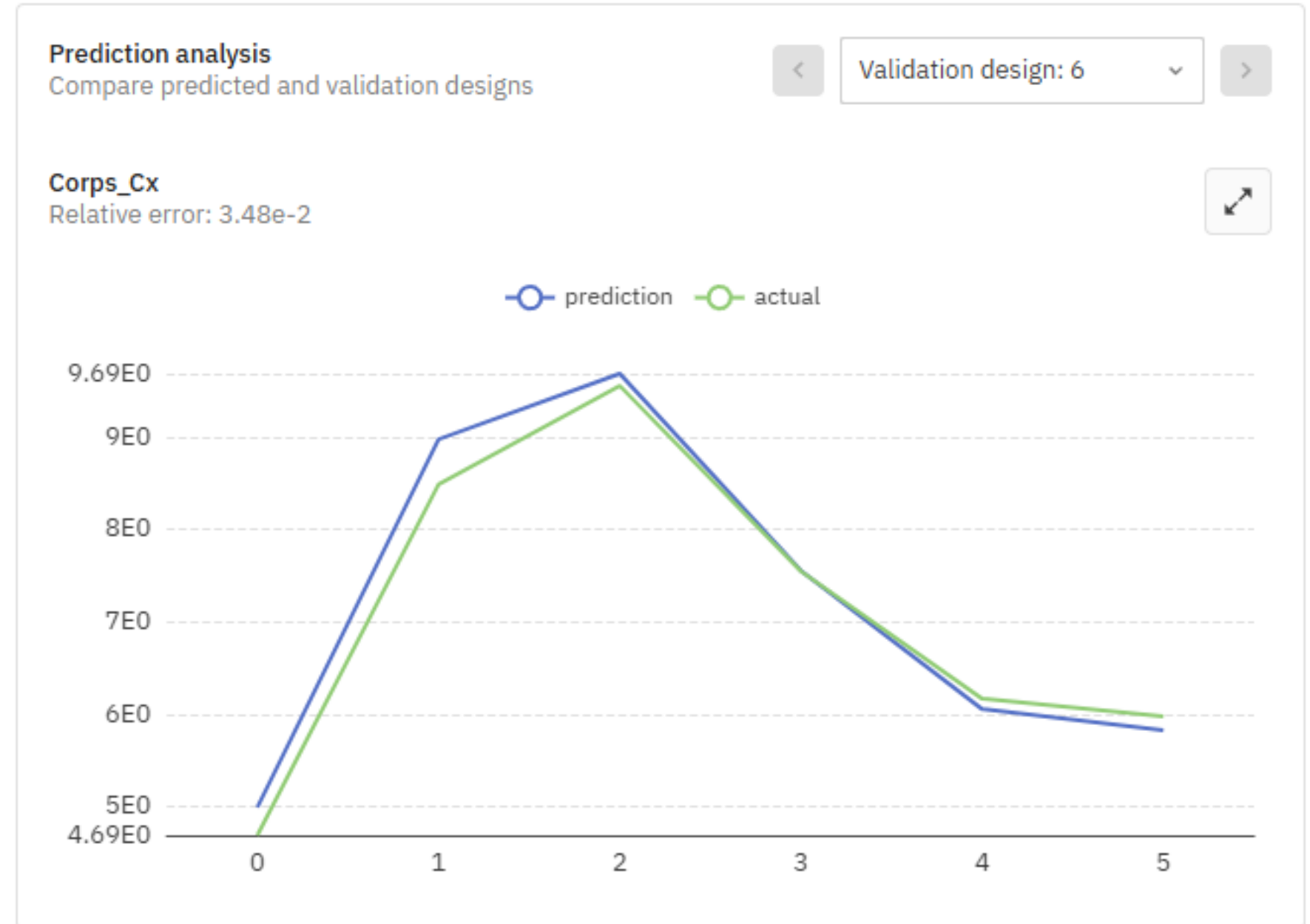


Reduced Order Model Training and Validation

Training Set



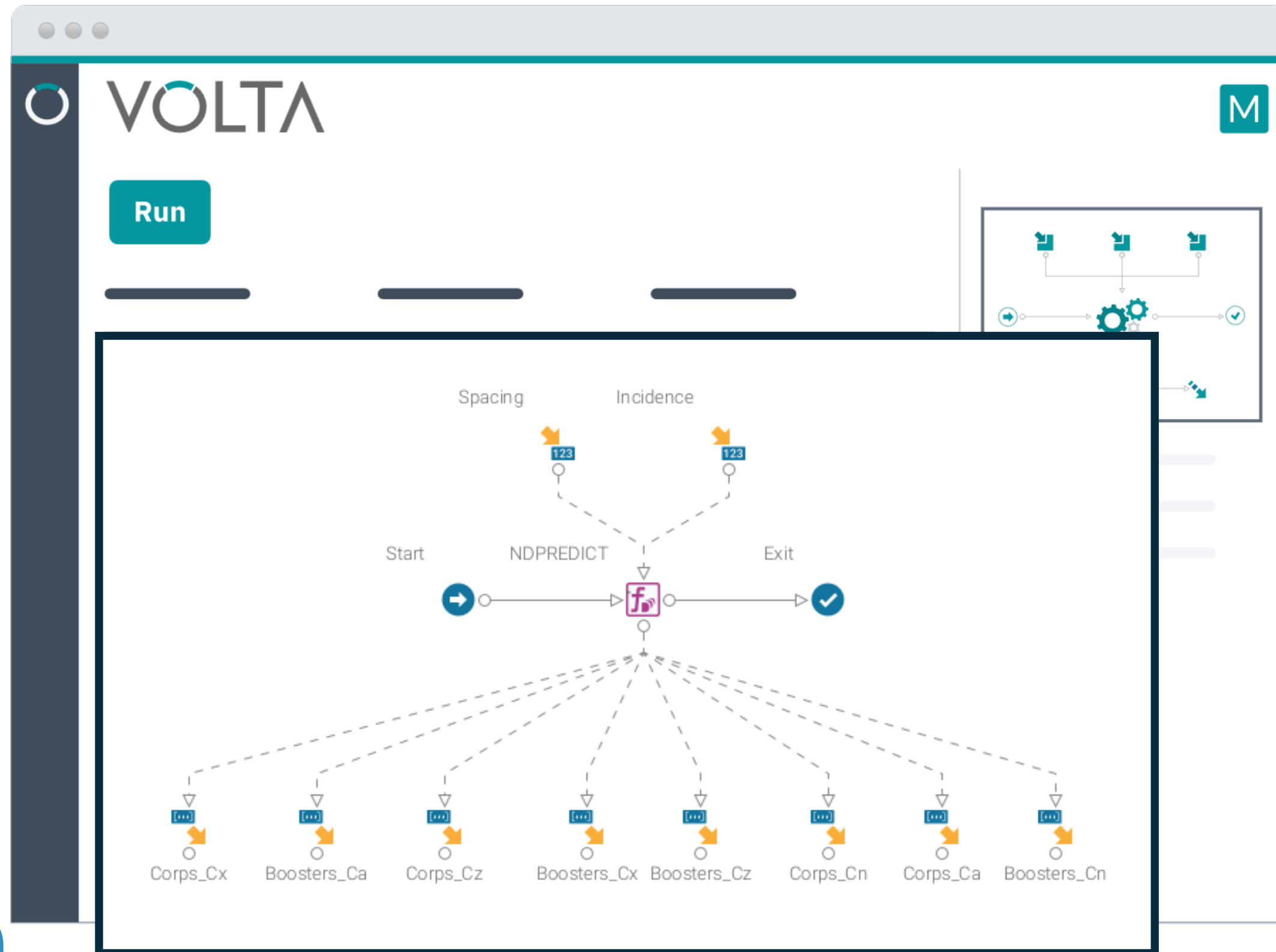
Validation Design



Results exploitation



ROM prediction workflow



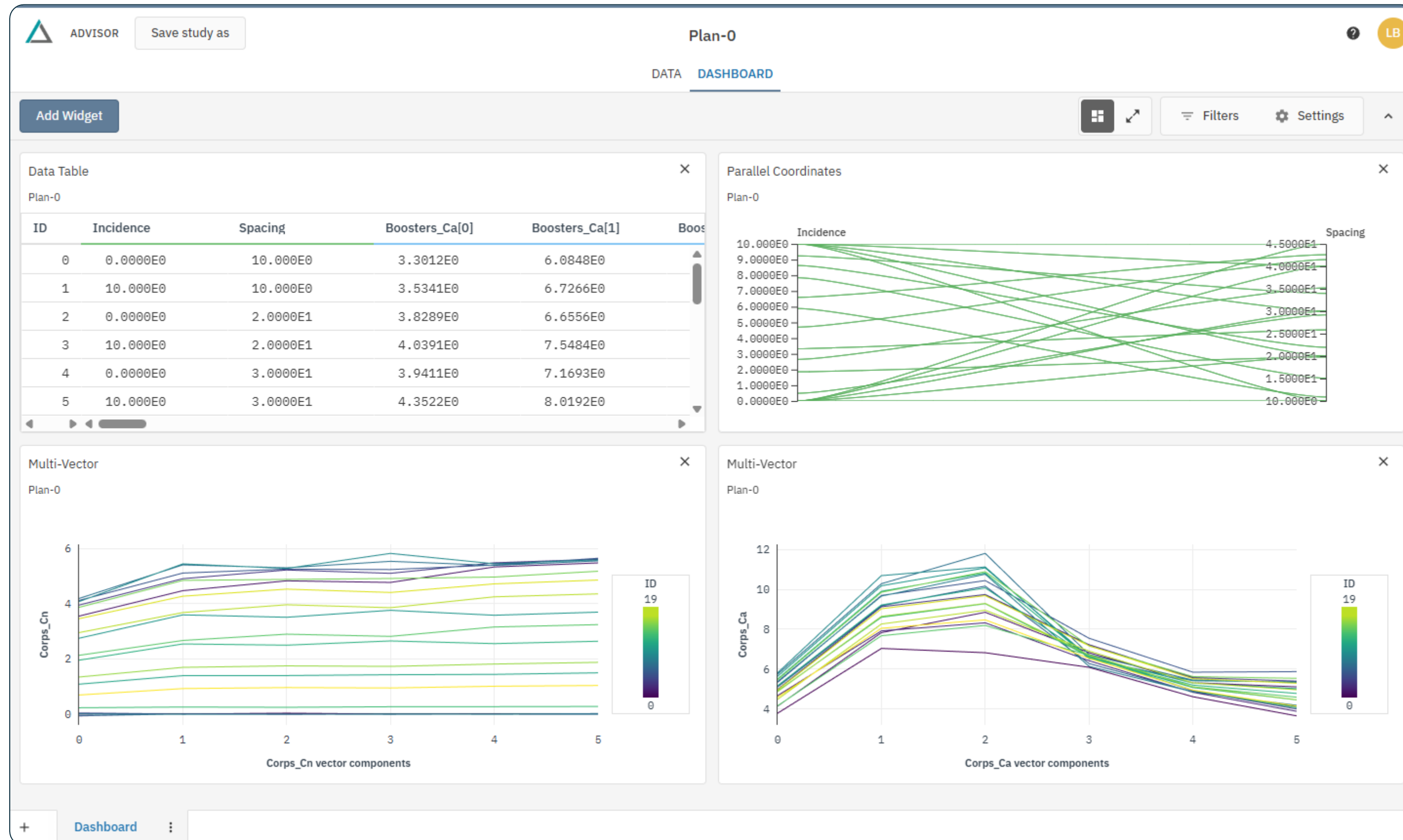
ROM consumers:
colleagues and
managers



The screenshot shows the 'Run Model / Input Domain' interface. At the top, there are three options: 'Single run', 'DOE', and 'Optimization'. Below these is a table with columns for NAME, TYPE, VALUE, LOWER BOUND, UPPER BOUND, STEP, and BASE. The table contains several rows of data.

NAME	TYPE	VALUE	LOWER BOUND	UPPER BOUND	STEP	BASE
---	o					
---	o					
---	o					
---	o					
---	o					
---	o					
---	o					
---	o					
---	o					
---	o					

Predictions in VOLTA Advisor



Predictions in VOLTA Advisor

ADVISOR Save study as Plan-0

DATA DASHBOARD

Add Widget

Filters Settings

Data Table Plan-0

ID	Incidence	Spacing	Boosters_Ca[0]
0	0.0000E0	10.000E0	3.3012E0
1	10.000E0	10.000E0	3.5341E0
2	0.0000E0	2.0000E1	3.8289E0
3	10.000E0	2.0000E1	4.0391E0
4	0.0000E0	3.0000E1	3.9411E0
5	10.000E0	3.0000E1	4.3522E0

Parallel Coordinates Plan-0

Filters
Choose the variables and categories you want to show

Type variable or category or dataset name here

Variables Clear

Incidence Plan-0 INPUT

0.0000E0 10.000E0

Min Max

Highlight 1.1180E0 7.7640E0 Clear

Filter - - Clear

Update Filter

Multi-Vector Plan-0

Corps_Cn

Corps_Cn vector components

ID 19 0

Multi-Vector Plan-0

Corps_Ca

Corps_Ca vector components

ID 19 0

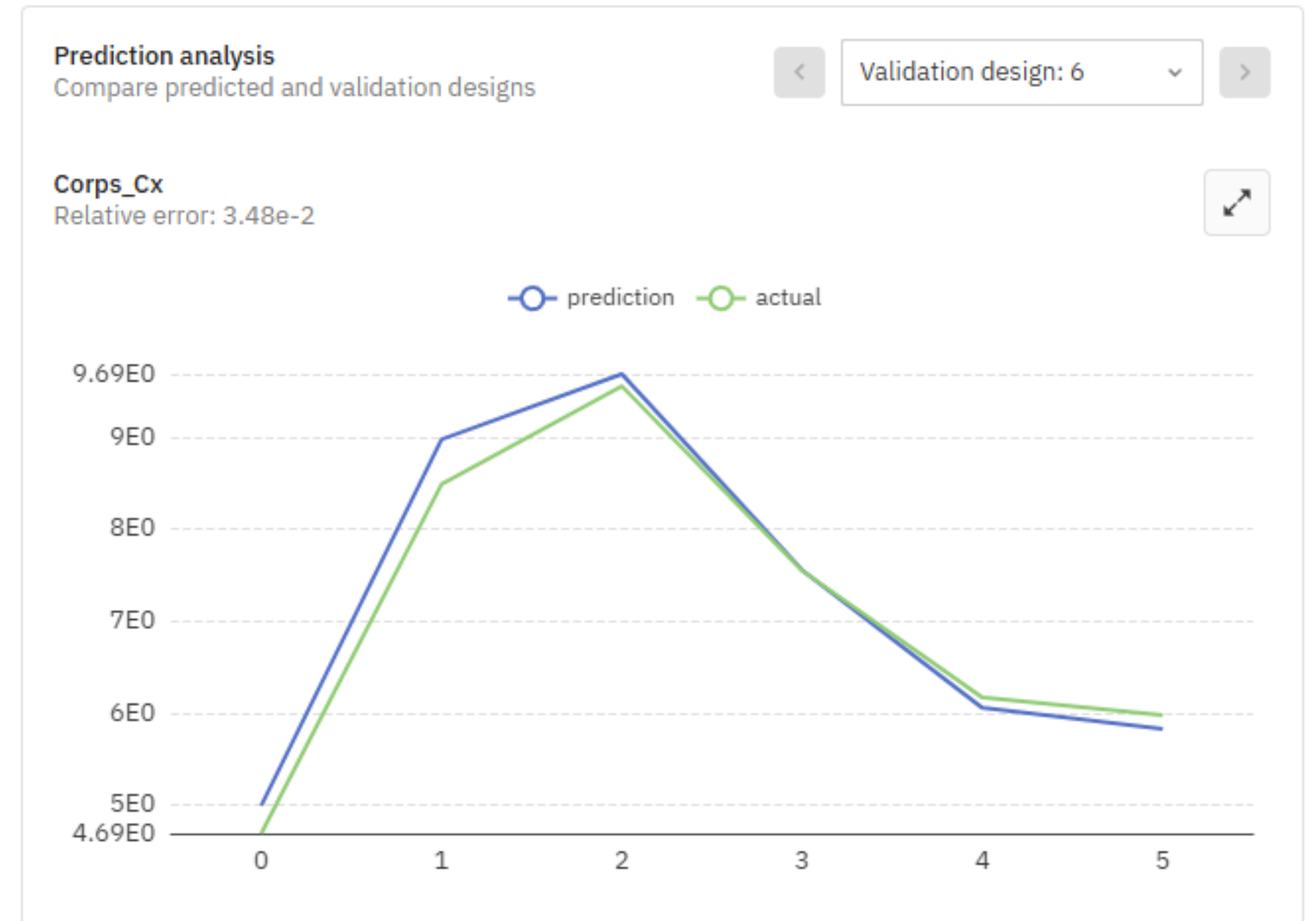
Dashboard

Conclusion



Conclusion

- The ROMs are representative of the complex behavior of the aerodynamic flow depending on several parameters
- 60 simulations required to create the model
- Allows to get a maximum relative error of $3,48 \cdot 10^{-2}$ for the points used to train the model
- Time ratio of 30 seconds vs months
- These high-fidelity models are accessible and can be used by every team members through VOLTA



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Thank you

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