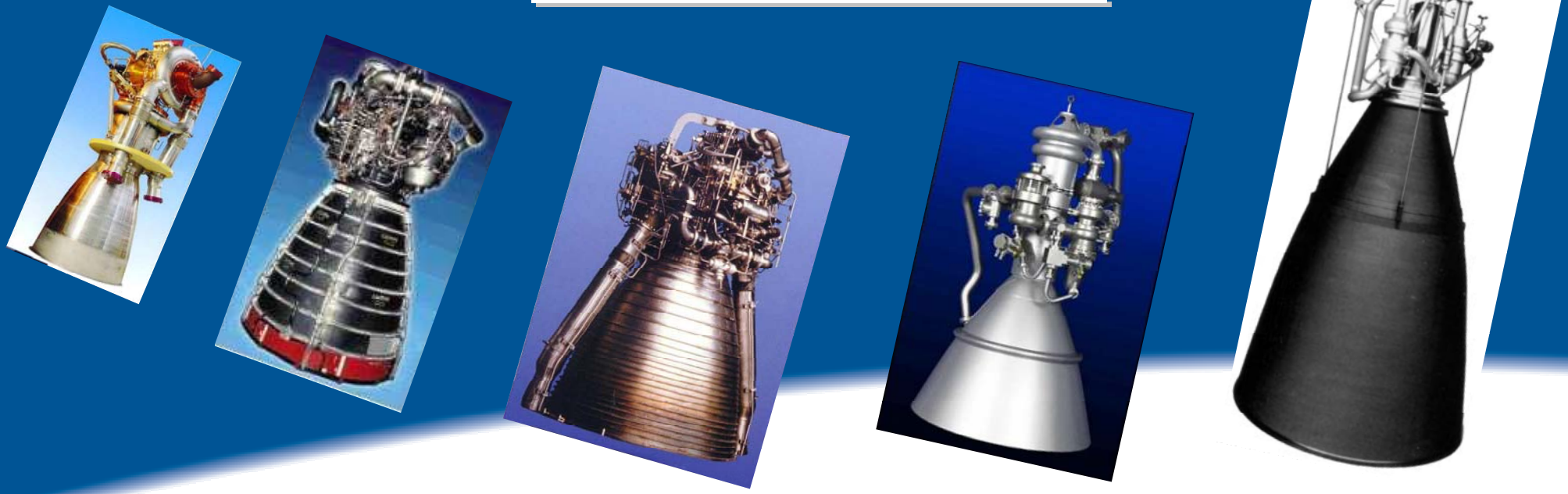
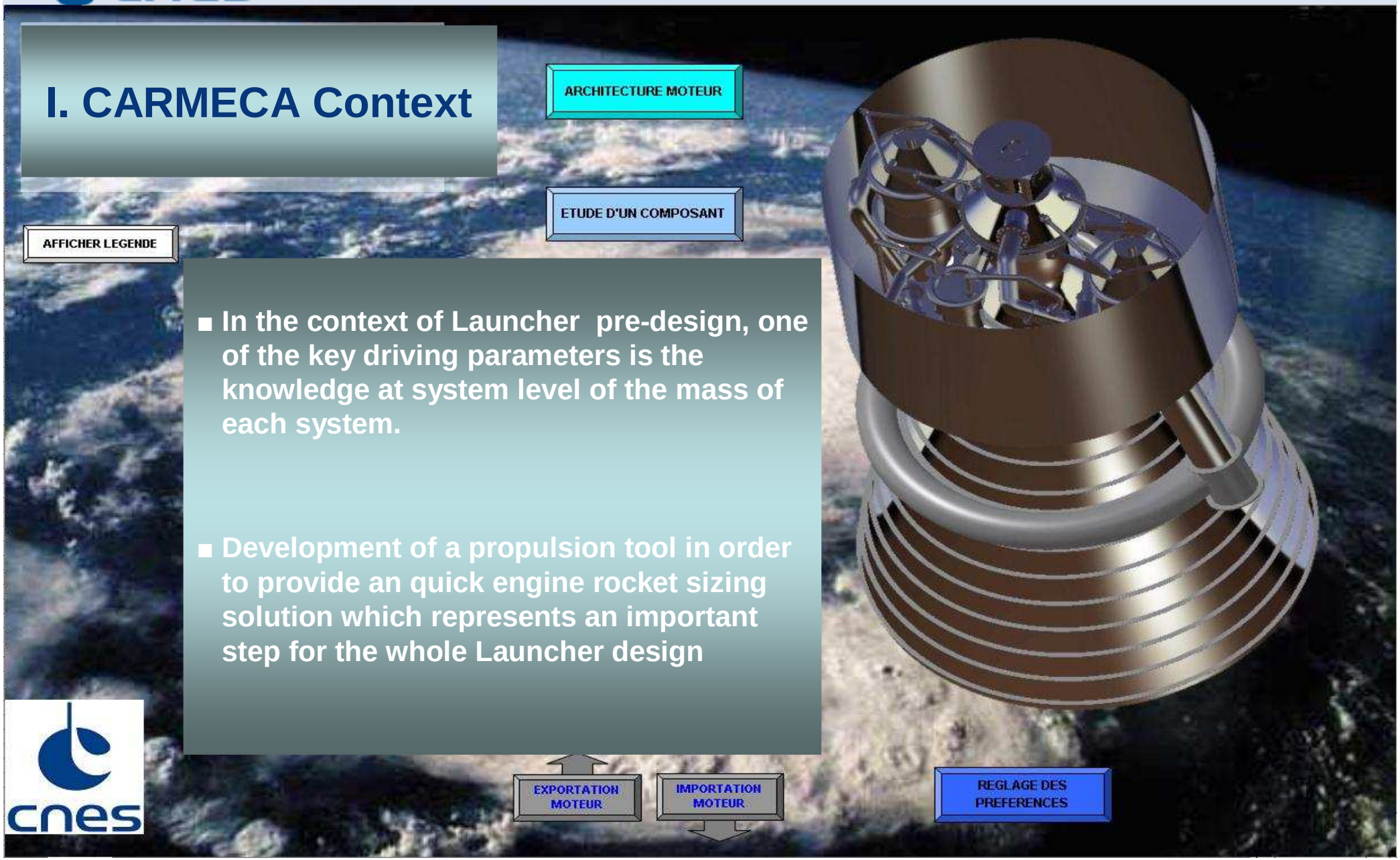
CENTRE NATIONAL D'ÉTUDES SPATIALES

CARMECA



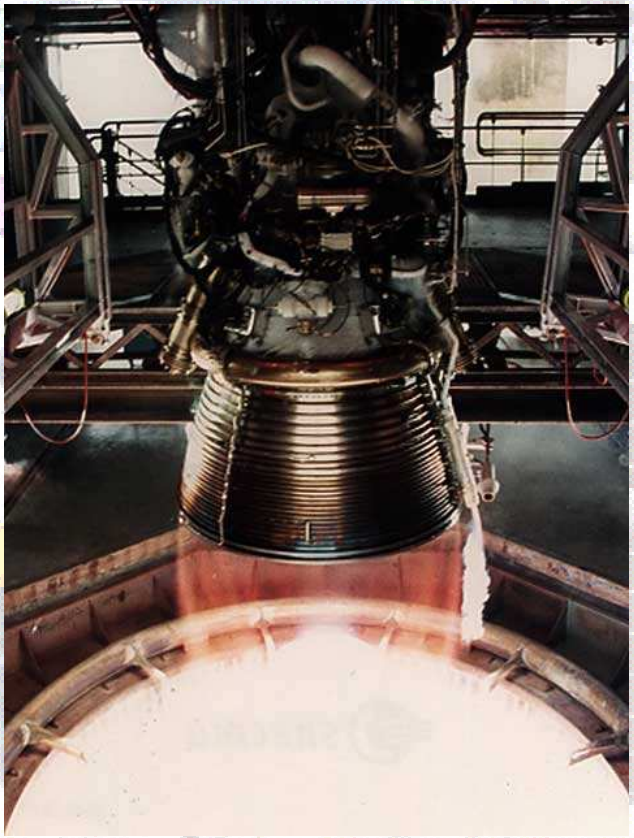
Propulsion tool for a rapid engine rocket sizing solution

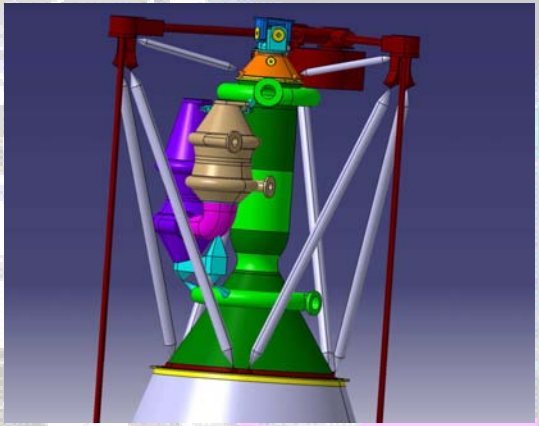
I. CARMECA Context

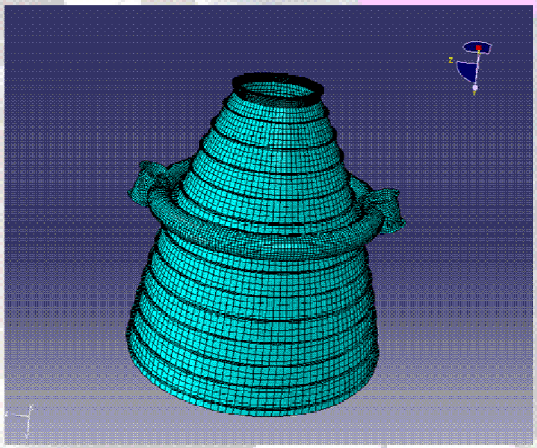


- In the context of Launcher pre-design, one of the key driving parameters is the knowledge at system level of the mass of each system.
- Development of a propulsion tool in order to provide an quick engine rocket sizing solution which represents an important step for the whole Launcher design

Content







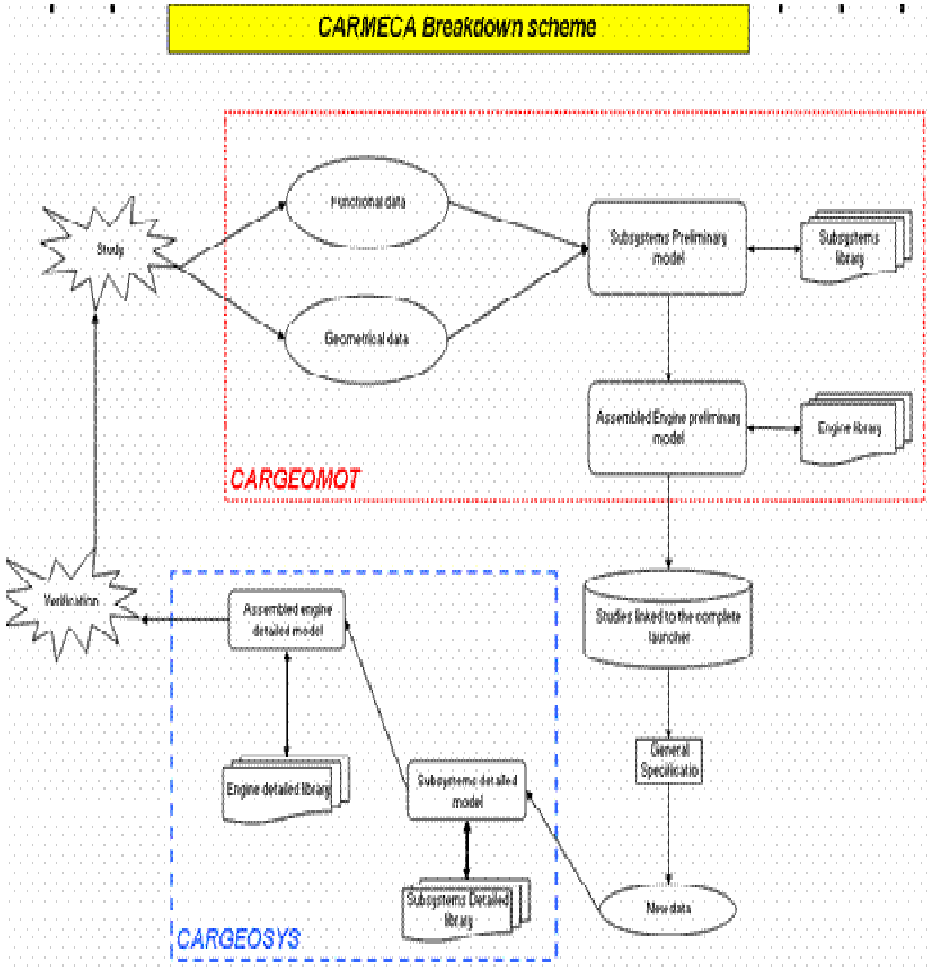
II. CARMECA Overview

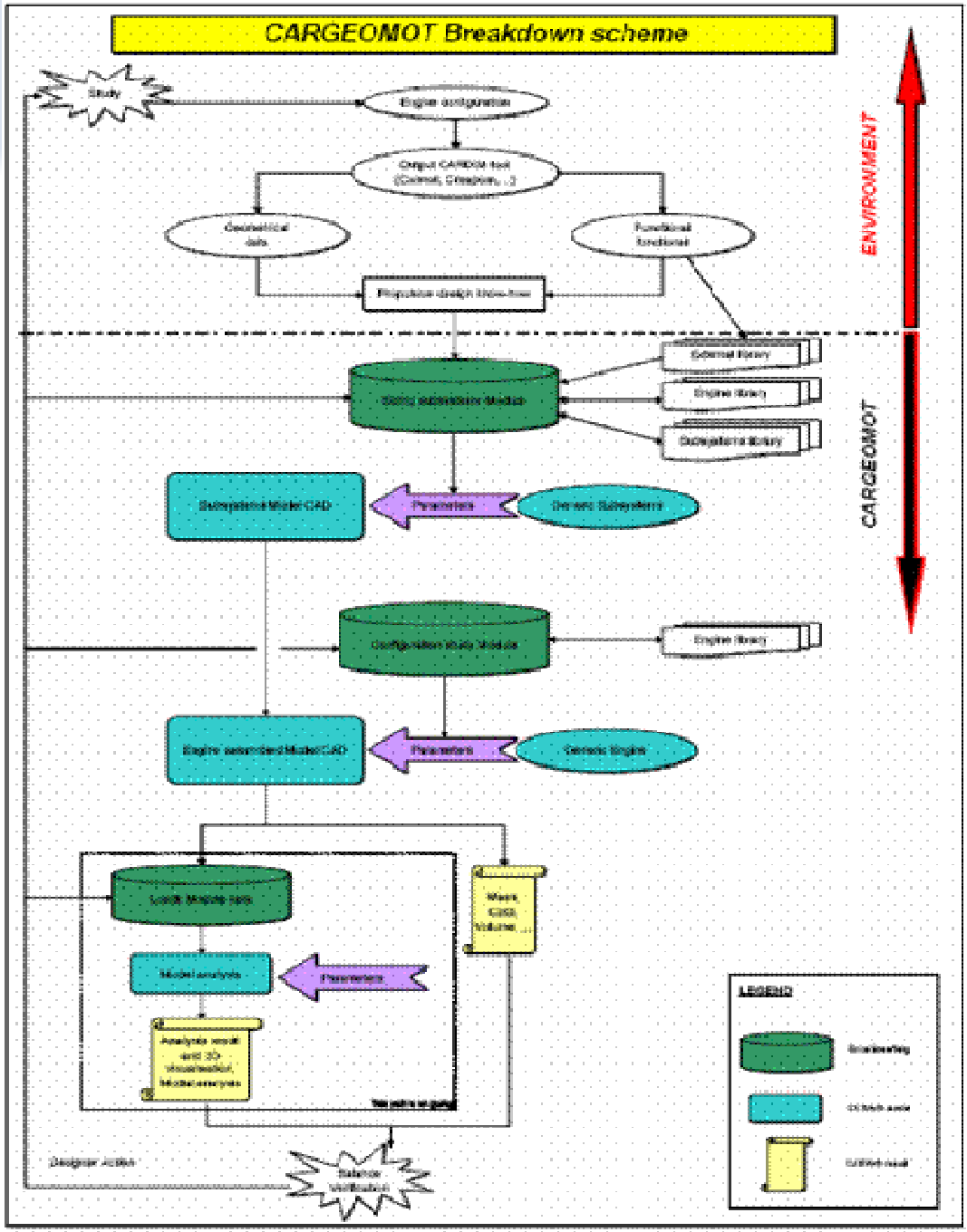
CARMECA, a versatile and efficient propulsion tool to provide quickly an engine rocket sizing solution:

- **Configuration study with a 3D CAD visualization**
- **Mass, inertial moment**
- **Modal analysis**
- **Refined mechanical analyses (ongoing)**
- **2 modules:**
  - **CARGEOMOT : Engine sizing and design module taking into account functional data and state of the art rules. It provides a 3D visualization and modal analysis with an interactive feature for an engine configuration study,**
  - **CARGEOSYS : Engine sizing module that takes into account the external efforts and provides geometrical and mechanical precise details for an advanced phase engine design.**

- **Capabilities extend from high level design to detailed conceptual design**

III. CARMECA features: structure





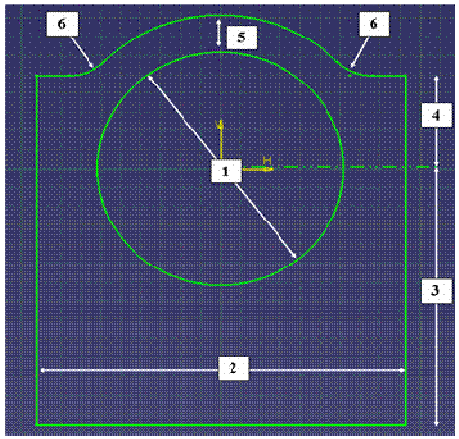
III. CARMECA features

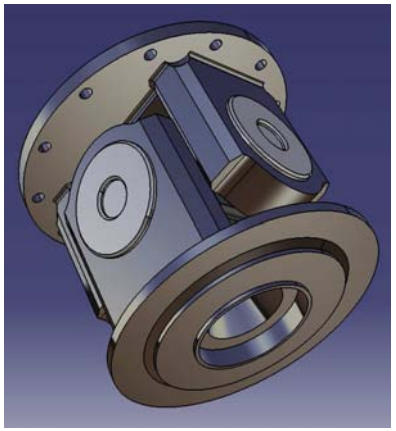
- Coupling with others CNES launcher Directorate functional engine rocket propulsion tools (CARDIM): thermodynamic study, functional and/or geometrical data ⇨ reliability product result
- 3D CAD « generic » parametric engine model designed with the respect of the engine thermodynamic cycle ; restraint key parameters ⇨ ideal for rapid propulsion trade studies and 3D visualization
- Sizing based on the art of rules, historical data ⇨ knowledge management
- Simplified and friendly user interface in Microsoft Excel and Macro Visual Basic with an automatic data conversion to CATIA V5. ⇨ Ergonomic and easy human machine interface
- At each subsytem is associated a design window ⇨ Interactivity, Reactivity
- Libraries ⇨ To store in a database the CARMECA CAD existing engines or new projects, material data

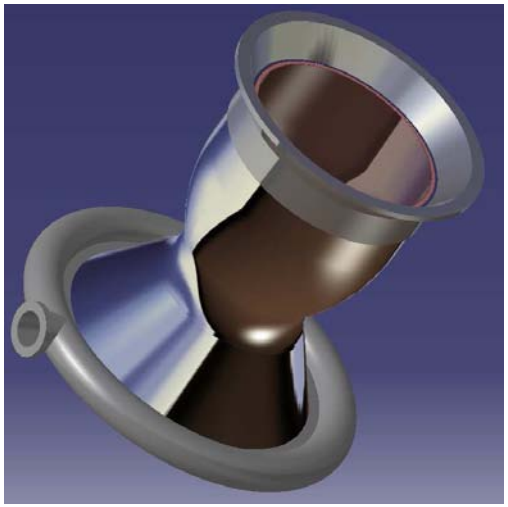
↳With CARMECA, it is possible to size a new complete engine rocket or to improve a subsystem in the architecture of a well known engine.

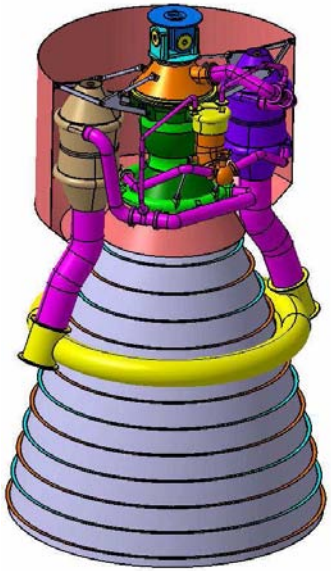
III. CARMECA features: 3D CAD « generic » model and vizualisation

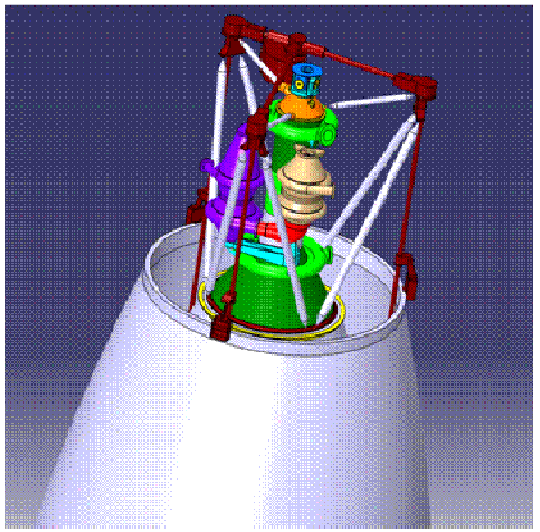
- Gimbal,
- Turbopumps,
- Combustion chamber,
- Nozzle extension (extendable, stowed)
- Gaz generator, preburner (if present in the configuration)
- ...

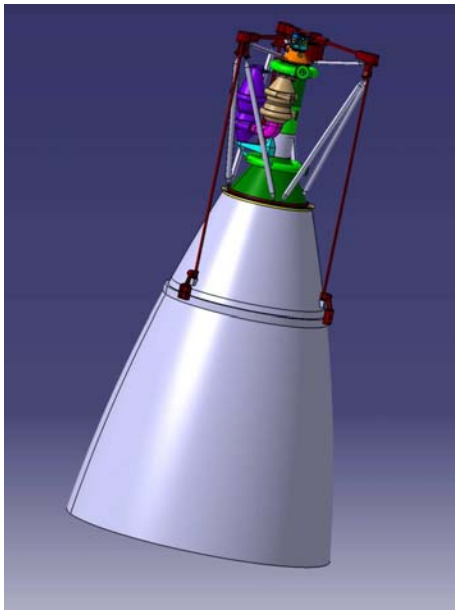






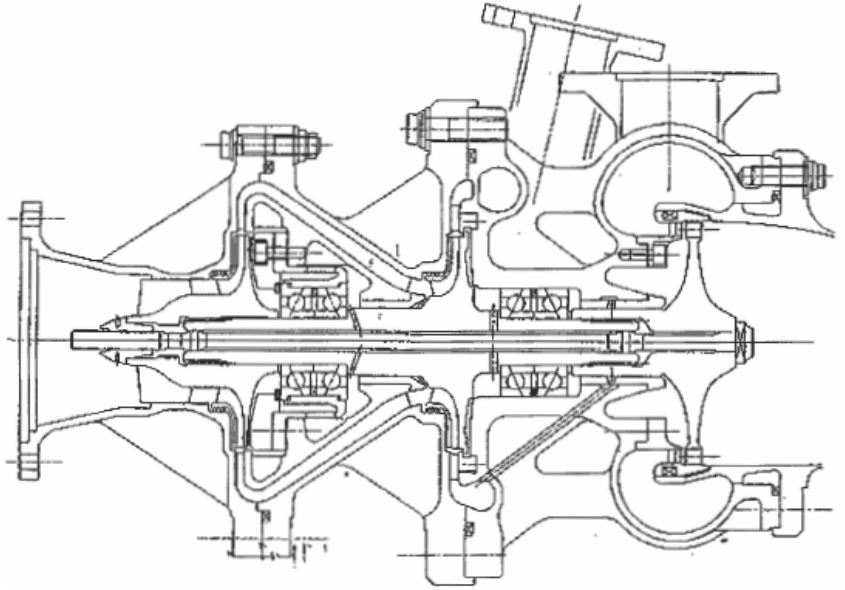




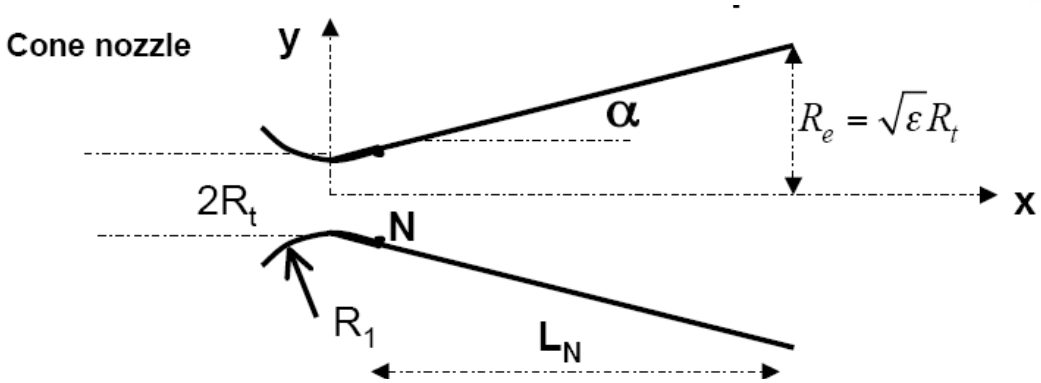


III. CARMECA features: sizing rules

- **Sizing laws associated to each susbsystem,**
- **Empirical formulas,**
- **Engineers know-how.**

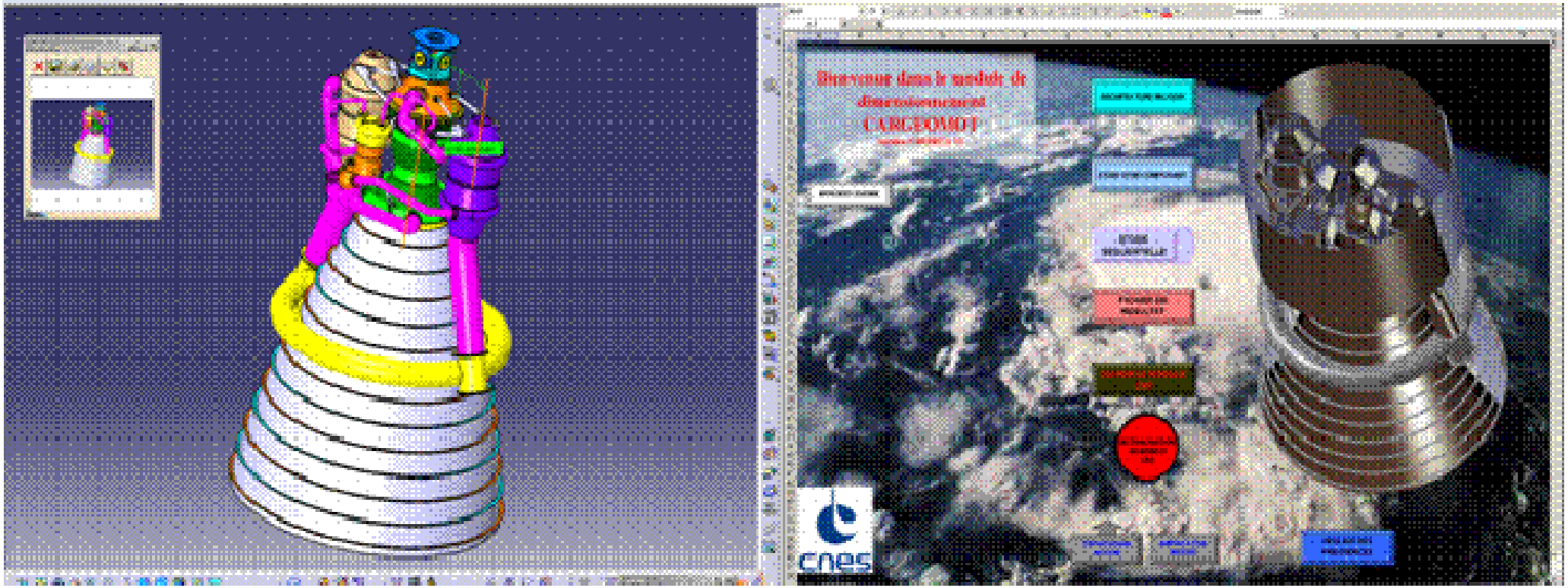


TPH



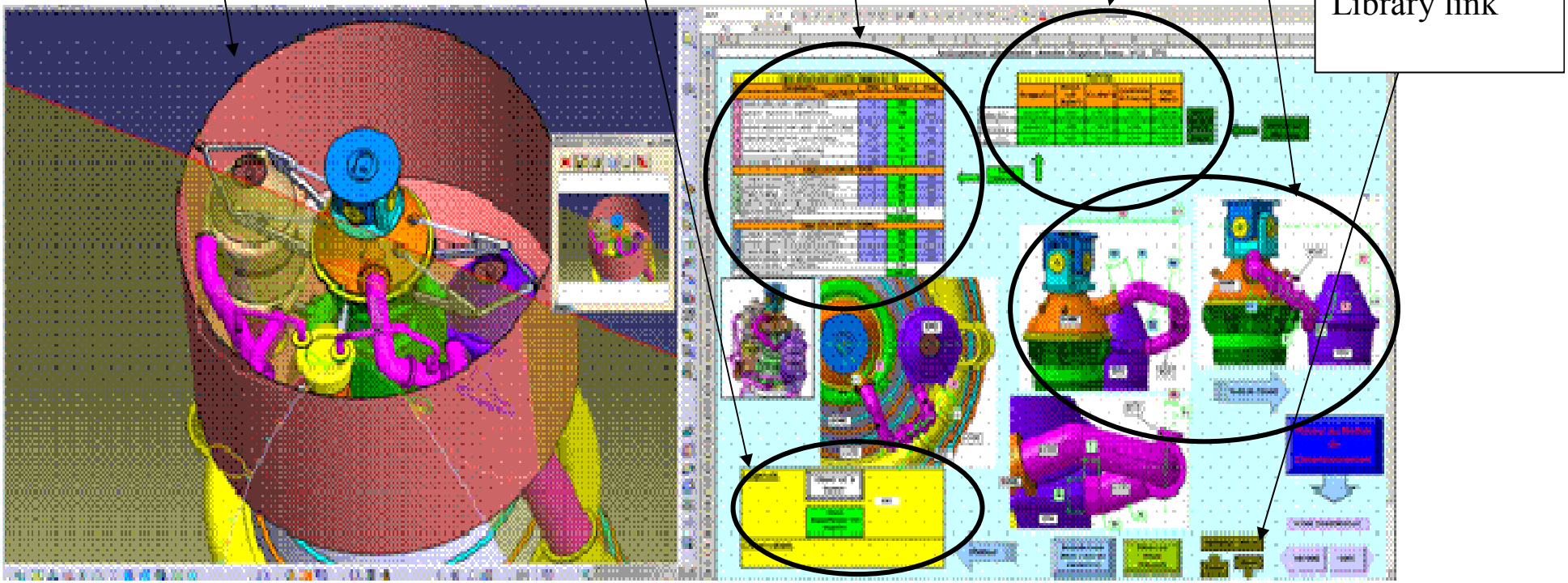
$$L_N = \frac{R_t\left(\sqrt{\varepsilon}-1\right)+R_1\left[\frac{1}{Cos\alpha}-1\right]}{Tan\alpha}$$

III. CARMECA features: user interface



- Double screens
- Definition of thermodynamic cycle and engine architecture type
- Engine design step by step or free design loop (subsystem to study)

III. CARMECA features: design module



- At each subsystem, design module and excel sheet associated,
- Images and quality values guiding the user for the sizing understanding
- The CARMECA operator is also free to act and introduce data to reproduce a better design.

III. CARMECA features: libraries

- To take into account the different thermodynamic cycles through the « generic » model and to store complete engines or subsystems already studied

F1 (USA)

LE-7 (Japan)

HM7 (UE)

KVD (Russia)

IV. Results: Aestus

Mass comparison

- **Aestus thrust chamber mass and inertia**

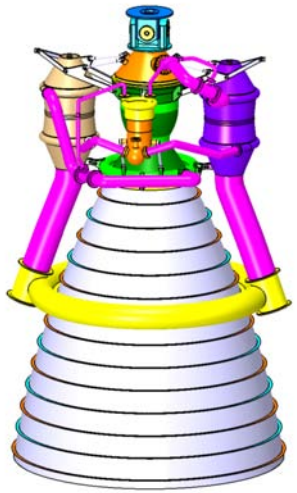
		CAD /Definition File (%)
	Mass (Kg)	5,2
	Gx (mm)	24,36
	Gy (mm)	*
	Gz (mm)	*
Inertia moments	Ixx (kg * m²)	5,17
	Iyy (kg * m²)	10,3
	Izz (kg * m²)	10,3

- **Coherent values for AESTUS.**
- **Differences mainly due to simplified hypothesis and rules of art used in the modelisation.**

IV. Results: Vulcain 2

Mass comparison

- **Vulcain 2 mass and inertia**



▪**Turbopumps.** Still important mechanical design details linked to the pump and the turbine which need to be improved, even if the result for both is satisfactory.

▪**Gas Generator.** Difference principally due to the geometry. Some design rules are under consideration to improve the result.

▪**Combustion Chamber.** Result quite satisfactory thanks to the functional data available. Mechanical considerations are under study for in any case improving the result.

▪**Nozzle.** As above.

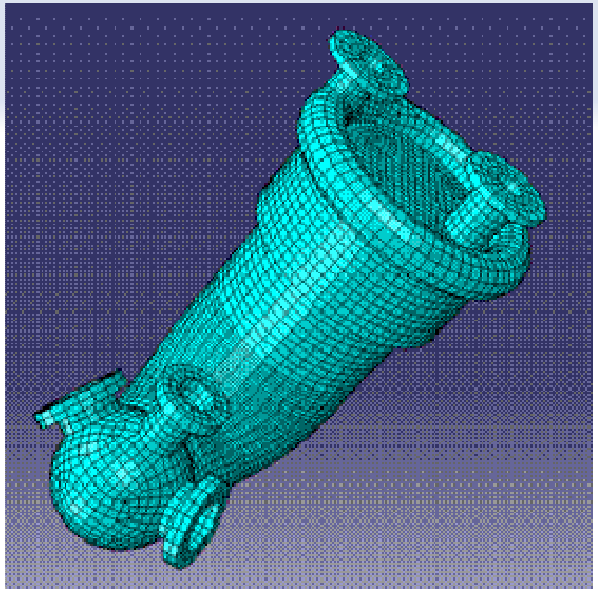
▪**Gimbal joint.** Result satisfactory. To find other design rules to have more possibilities to answer at a whatever gimbal joint design demanded.

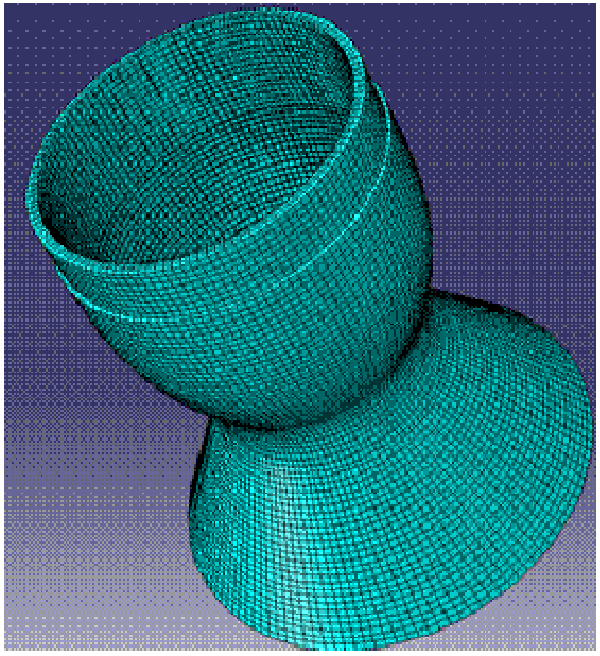
VERIFICATION	
Vulcain 2 versus Vulcain 2 by CARMECA	**Scattering Result**
Turbo pump H2	**-14.43%**
Turbo pump O2	**-15.49%**
Gas Generator	**-10.81%**
Combustion Chamber	**-7.67%**
Gimbal joint	**- 3.86%**
Nozzle	**-9.08%**

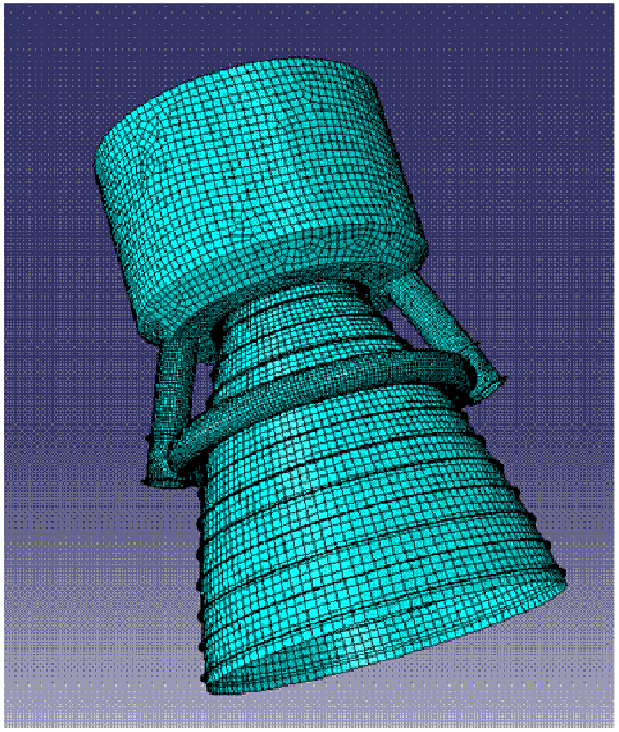
IV. Results: Vulcain 2

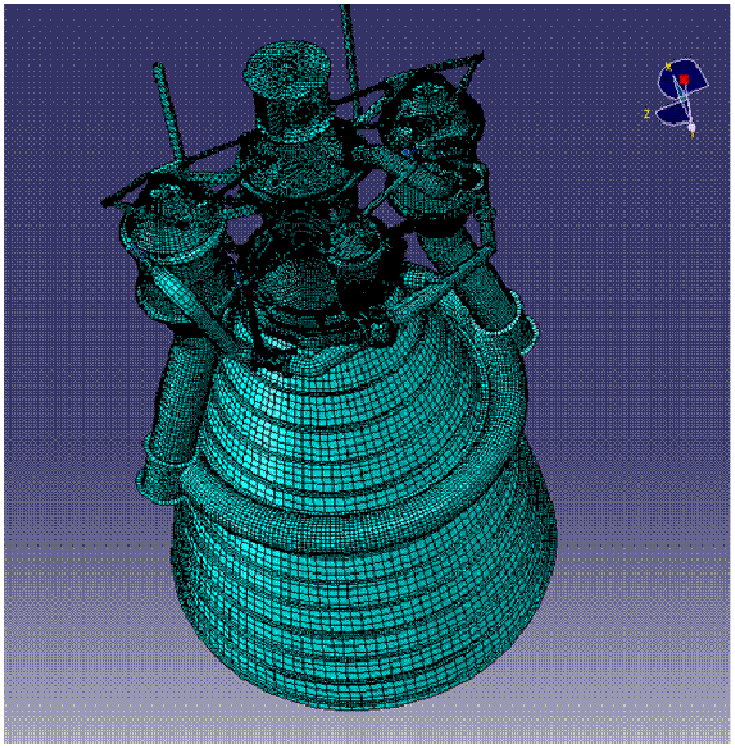
Modal analysis:

- Performed with Abaqus v.6.8 code
- Interface associative module CATIA/Abaqus in order to facilitate architecture modifications and remeshing





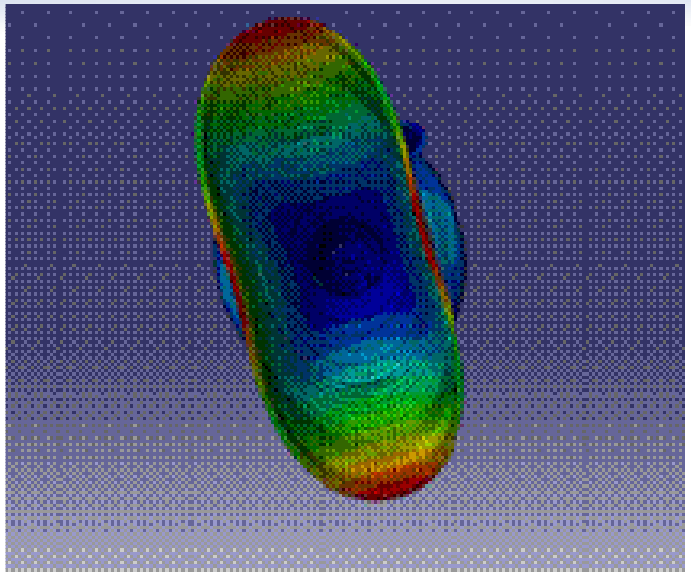




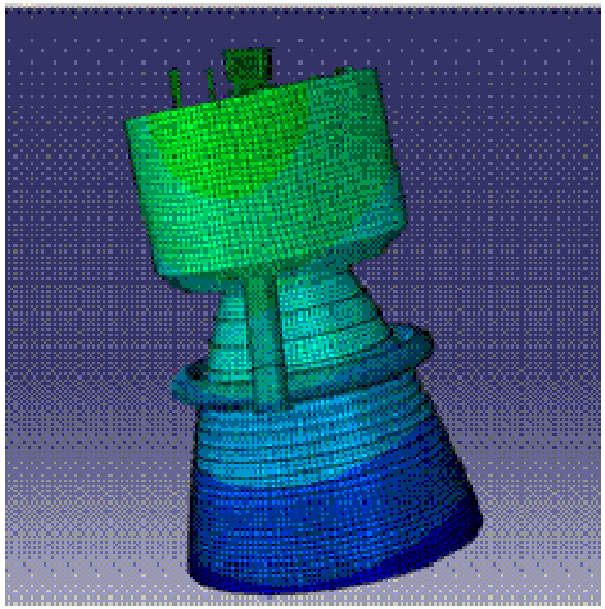
IV. Résults: Vulcain 2

Modal analysis:

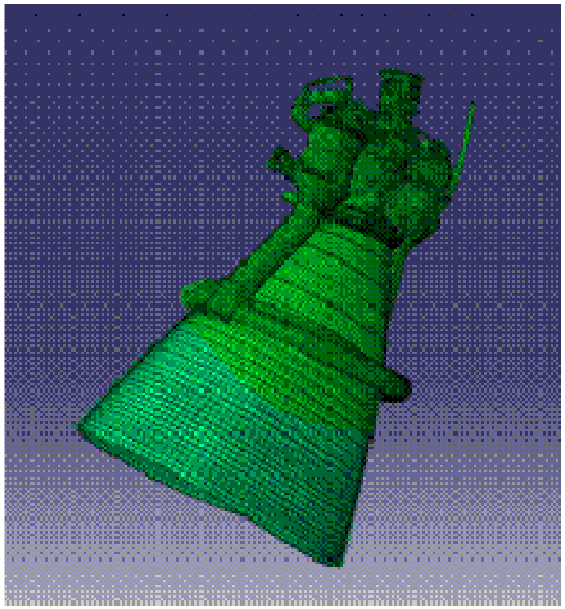
- Encouraging first results (acceptable error)
- Good agreement between test and CARMECA model



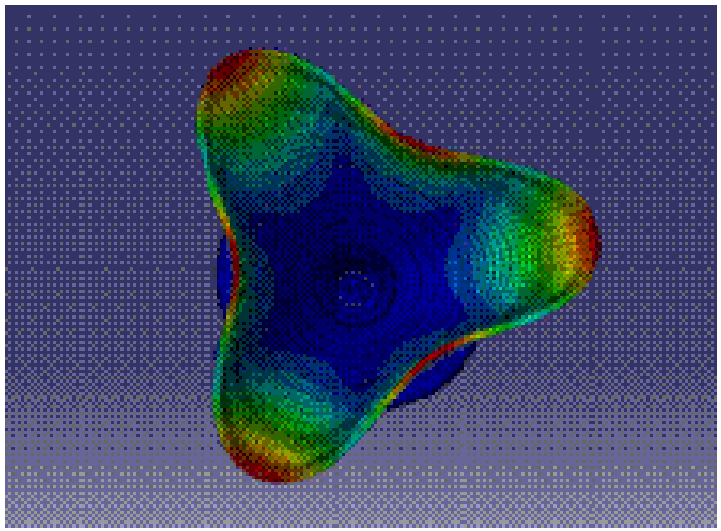
scattering ovalisation mode: 10%



scattering pendulum mode: 4%



scattering flexion mode: 6%



scattering 3 waves mode: 5%

V. Conclusion

- **CARMECA gives for the engine rocket a rapid answer about the mass, inertial moments, modal analysis, 3D CAD geometry and configuration solution through the use of a “generic” parametric model.**

- **Ergonomic and intuitive use through the combination of sizing module Excel/Visual Basic and CAD software.**

- **CARMECA models first results bring a satisfactory assessement of mass and modal behaviour.**

- **Consolidation of CARGEOMOT by improvement of sizing rules**

- **Development of CARGEOSYS for a refined mechanical design.**

VI. Questions

Thank you for your kind attention