

um  
2026

# Automation of composite cryogenic tank design and optimization for space launcher application

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Structural Design Engineer at AVIO S.p.A.



# Agenda

## What is AVIO?

Company overview

## Problem Description

Manual process explanation

## Process Automation

Switching from manual to automate operation

## Conclusions & Next Steps

Closing remarks and future actions



# What is AVIO?

Avio S.p.A. is a leading player in the **space propulsion** sector. The company played a key role in the design, manufacturing and integration of space launcher and tactical missiles.

**Founded in 1912** and based in Colleferro it offers competitive solutions for launching institutional, governmental and commercial payloads.



# Company sites



**AVIO USA**  
Headquarter  
Arlington, Virginia



**AVIO Guyane**  
Launch Base  
Kourou, French Guyane



**AVIO**  
Test Facility  
Perdasdefogu, Italy



**AVIO**  
Branch of AVIO  
Paris, France



**AVIO**  
Laboratory  
Airola, Italy



**AVIO**  
Headquarter  
Colleferro, Italy



**AVIO**  
Production Center  
Rivalta di Torino, Italy

# Problem Description

Development of Composite Cryogenic Tank (CCT).

A storage system designed to contain and manage cryogenic propellants at extremely low temperatures for liquid propulsion systems.

The tank integrates structural and functional requirements into a single component, enabling efficient system-level integration in advanced aerospace architectures. CCT dimensioning with respect to internal pressure and flight loads is strongly driven by the **mass target**.

Its **structural complexity**, derived from the manufacturing technology, take us to a **time-consuming manual process** definition, for a monolithic type V CCT.



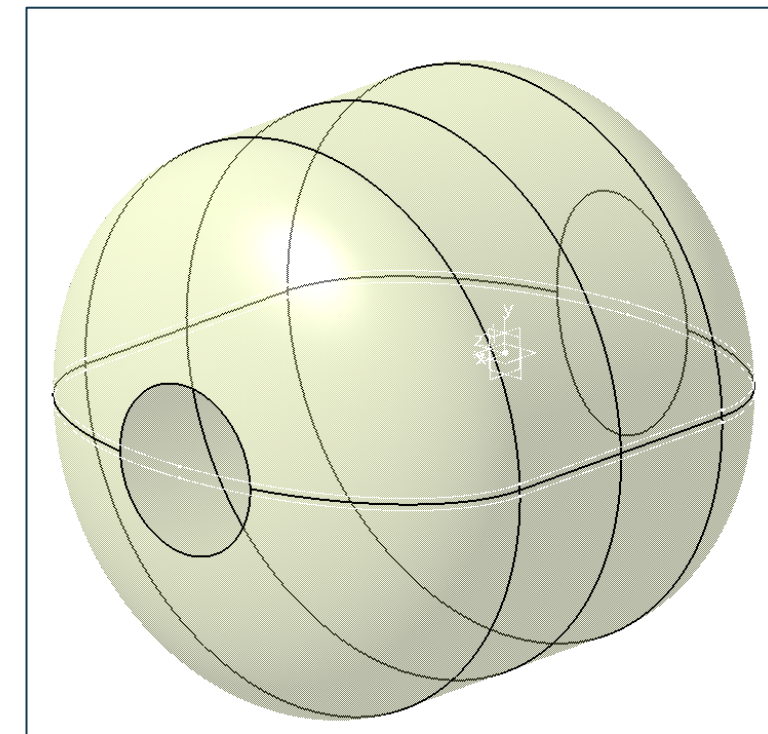
# Problem Description

## Development of Composite Cryogenic Tank (CCT).

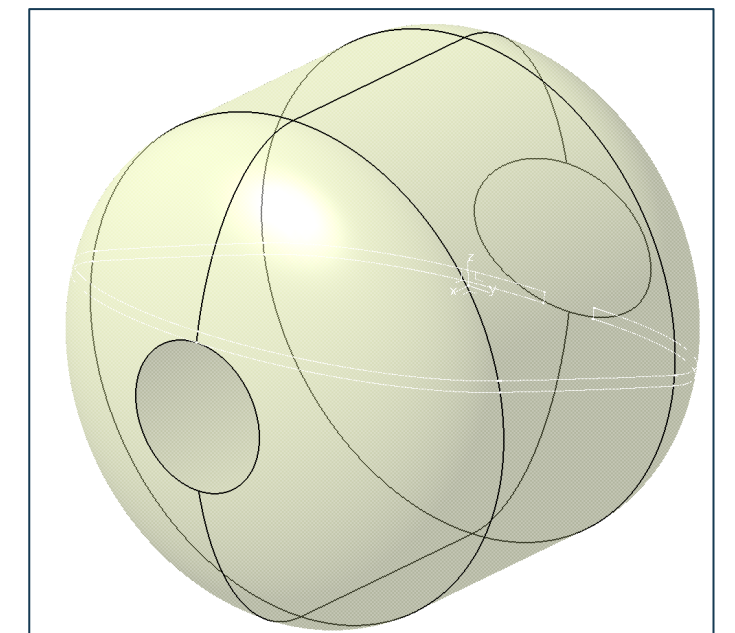
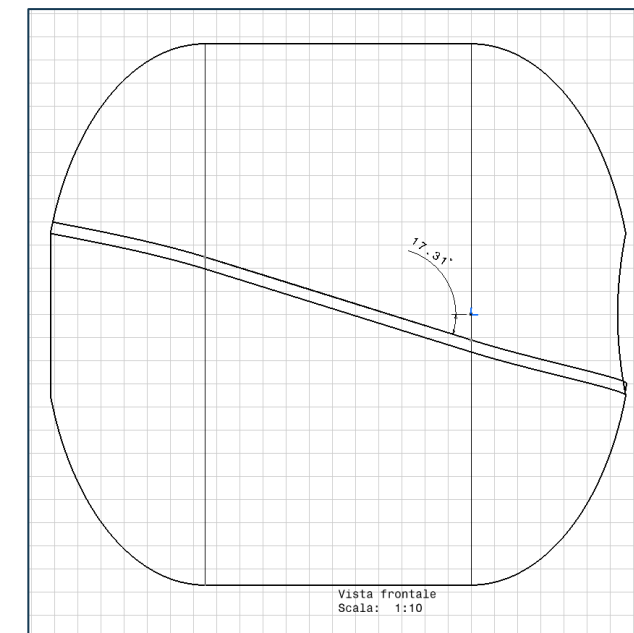
A storage system designed to contain and manage cryogenic propellants at extremely low temperatures for liquid propulsion systems.

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Typical meridian trajectory



Typical geodesic trajectory

# Manual Process



Parametric CAD design



Parameter modification and export



Mesh generation



Mapping of the properties



Pre-processing



Simulation and post-processing



Restart

# Manual Process



Parametric CAD design



Parameter modification and export



Mesh generation



Mapping of the properties



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Simulation and post-processing

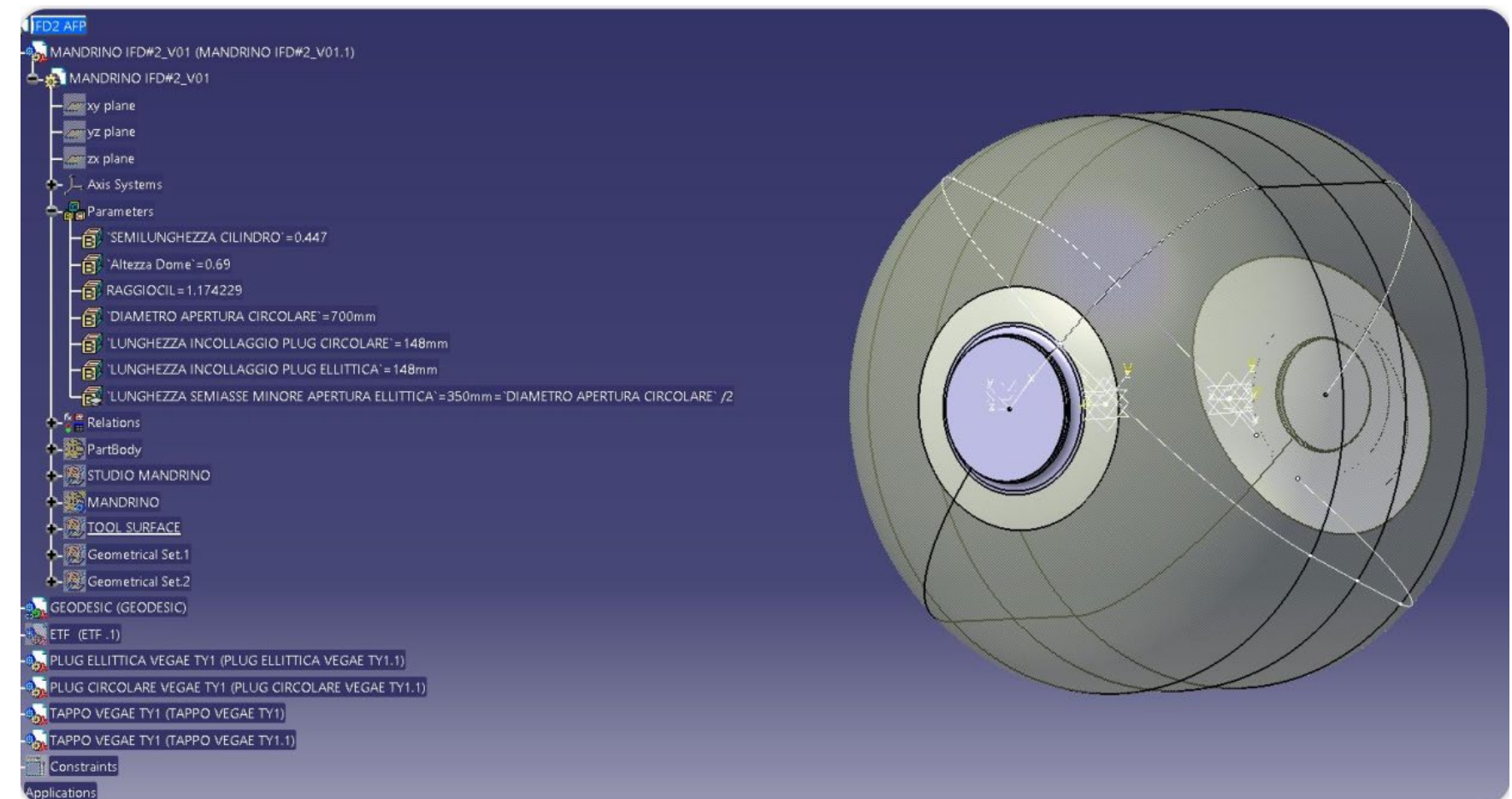


Restart



Tank body, circular and elliptical plugs, circular closure plates and tool surfaces are realized in *CATIA*.

The entire assembly is designed parametrically in order to facilitate subsequent modifications based on the results obtained from the various structural analysis loops.



# Manual Process



Parametric **CAD** design



Parameter **modification** and export



Mesh generation



Mapping of the properties



Pre-processing



Simulation and **post-processing**

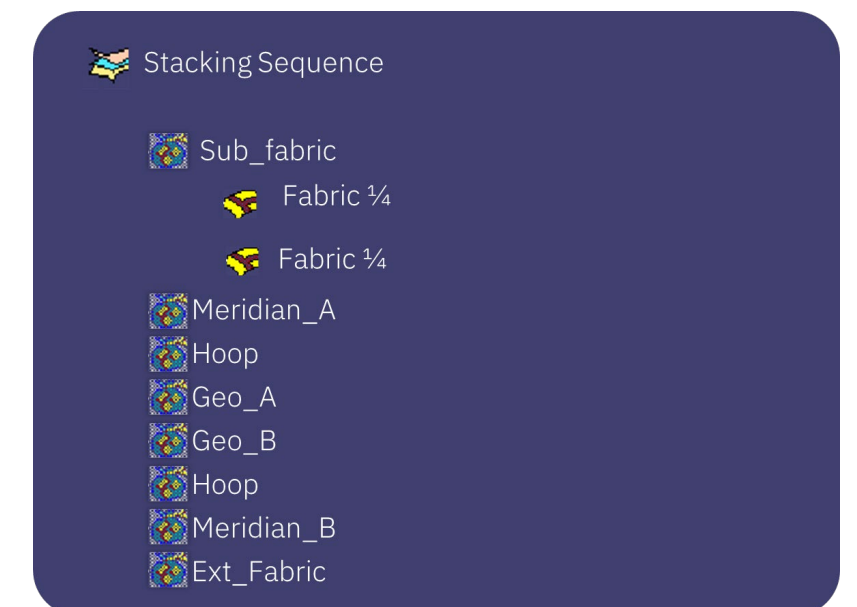
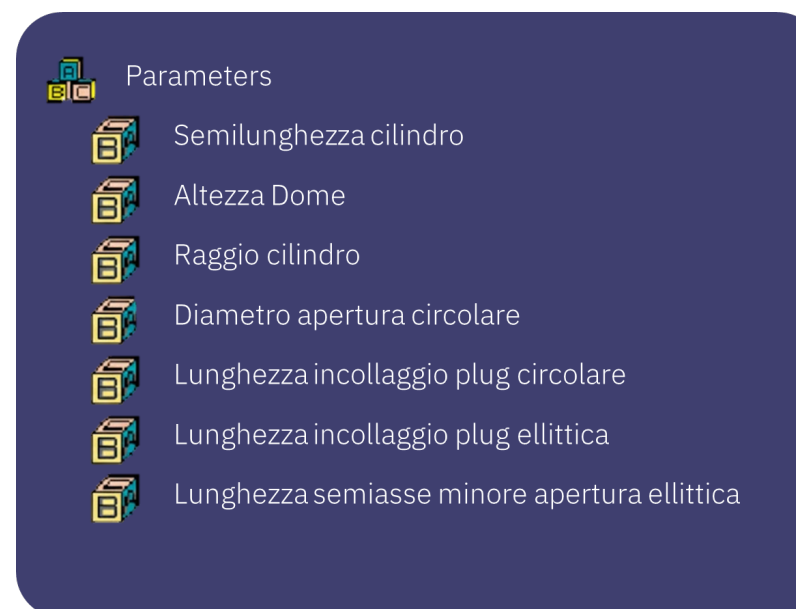


Restart



Tank main dimensions as well as the stacking sequence of the body are settled as the principal parameters of the design.

During each design loop, these parameters are manually modified directly within the *CATIA* working environment, taking into account several design constraints, including the tank volume and the ratio between the dome height and the cylinder diameter.



# Manual Process



Parametric **CAD** design



Parameter **modification** and export



**Mesh** generation



Mapping of the properties



Pre-processing



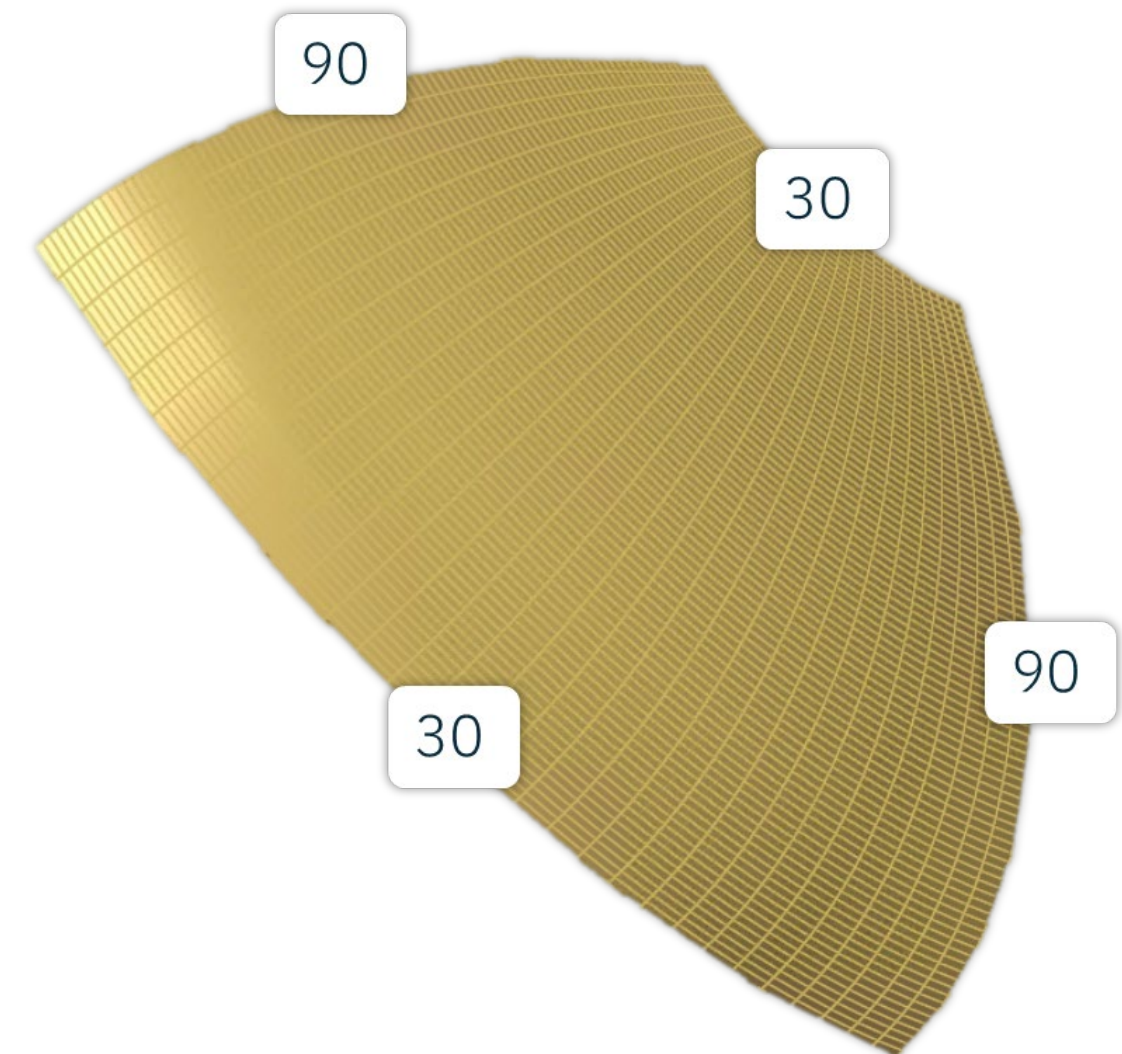
Simulation and **post-processing**



Restart

A structured mesh of the tool surface is generated in *Hypermesh* by modifying manually the number of elements on each edge of the surface.

The mesh density affects both the accuracy of the results and the representativeness of the model, since the properties of the laminate stacking sequence are mapped onto the mesh itself, as reported in the following slide.



# Manual Process



Parametric **CAD** design



Parameter **modification** and export



**Mesh** generation



Mapping of the properties



Pre-processing



Simulation and **post-processing**



Restart

At this point, the material properties have to be mapped on the mesh previously generated.

To perform this operation the entire assembly, have to be re-opened in *CATIA* and through *Composite Link* tool the material properties are transferred on the FE mesh.

# Manual Process



Parametric CAD design



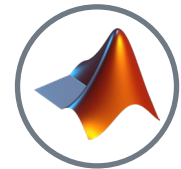
Parameter **modification** and export



Mesh generation



Mapping of the properties



Pre-processing



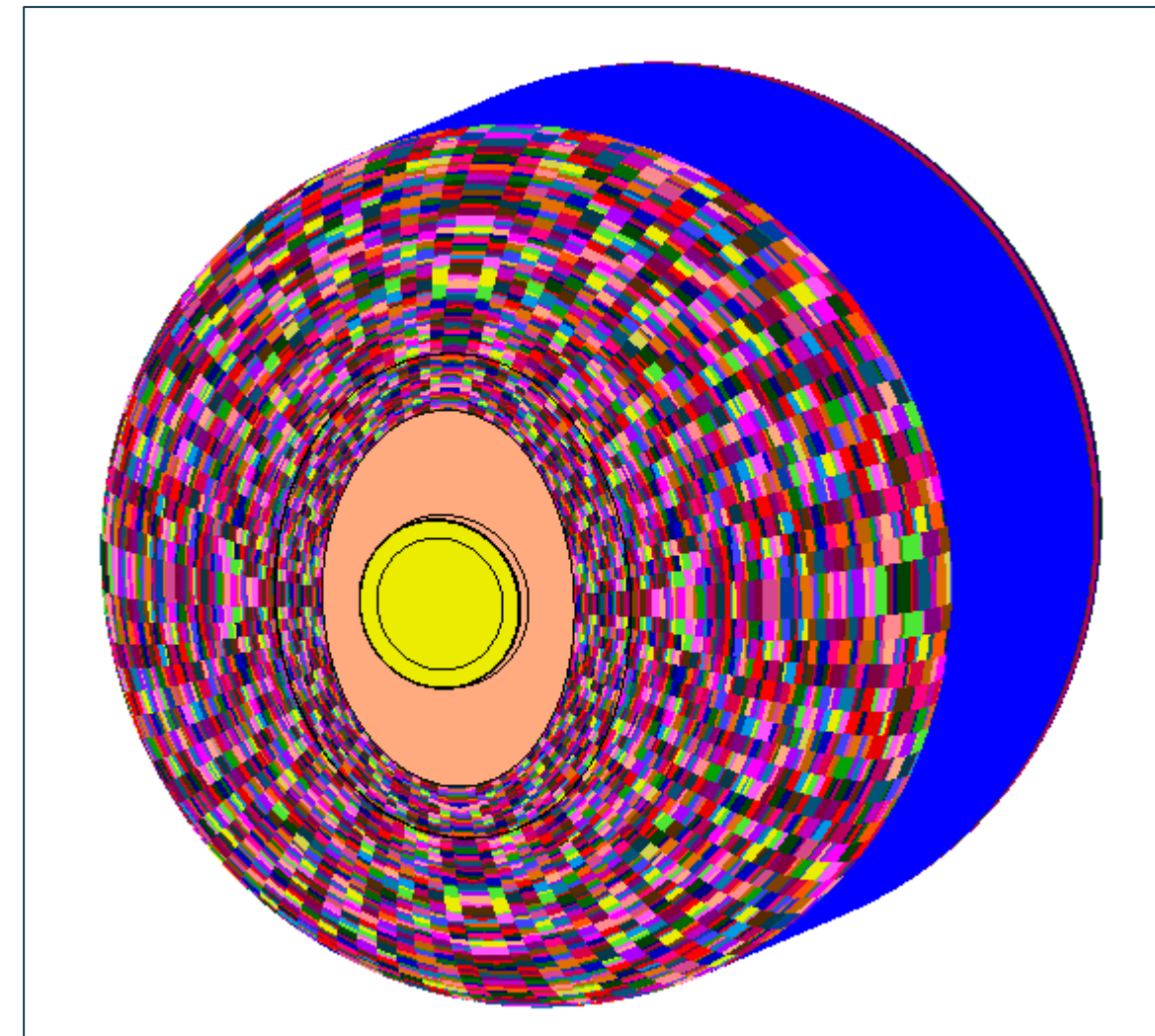
Simulation and post-processing



Restart

BDF format file is exported from *CATIA* and then imported in *MSC Mentat*.

Through dedicated *MATLAB* scripts, procedures are generated to be executed in *MSC Mentat* in order to finalize the mesh and assign the material properties. Finally, boundary conditions and external loads are applied.



# Manual Process



Parametric **CAD** design



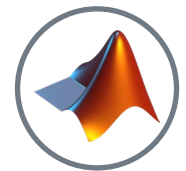
Parameter **modification** and export



**Mesh** generation



**Mapping** of the properties



Pre-processing



Simulation and **post-processing**



Restart

FEM analysis is performed with *MSC Marc* and after its conclusion main results, as deformation, failure indices, stress and displacement are extracted.

# Manual Process



Parametric **CAD** design



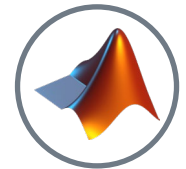
Parameter **modification** and export



**Mesh** generation



Mapping of the properties



Pre-processing



Simulation and **post-processing**



Restart

All the steps must be repeated until the optimized configuration is reached.

Current workflow challenges:

- Time-consuming operation
- Manual and error-prone procedures
- Multiple stakeholders with different technical backgrounds
- Interaction among different software environments

➔ Opportunity to leverage *modeFRONTIER* for workflow automation and optimization

# Process Automation



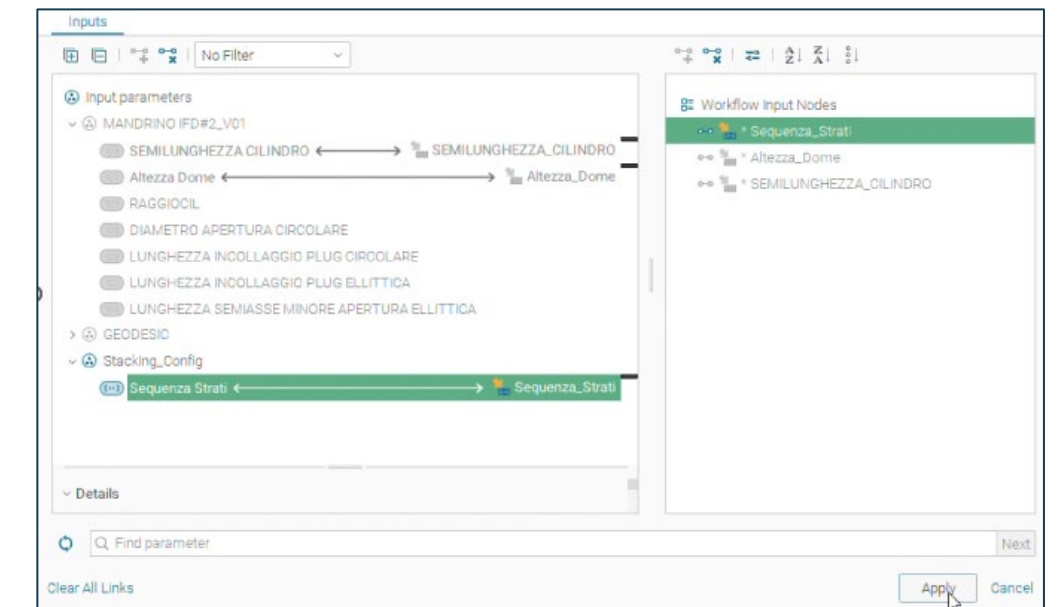
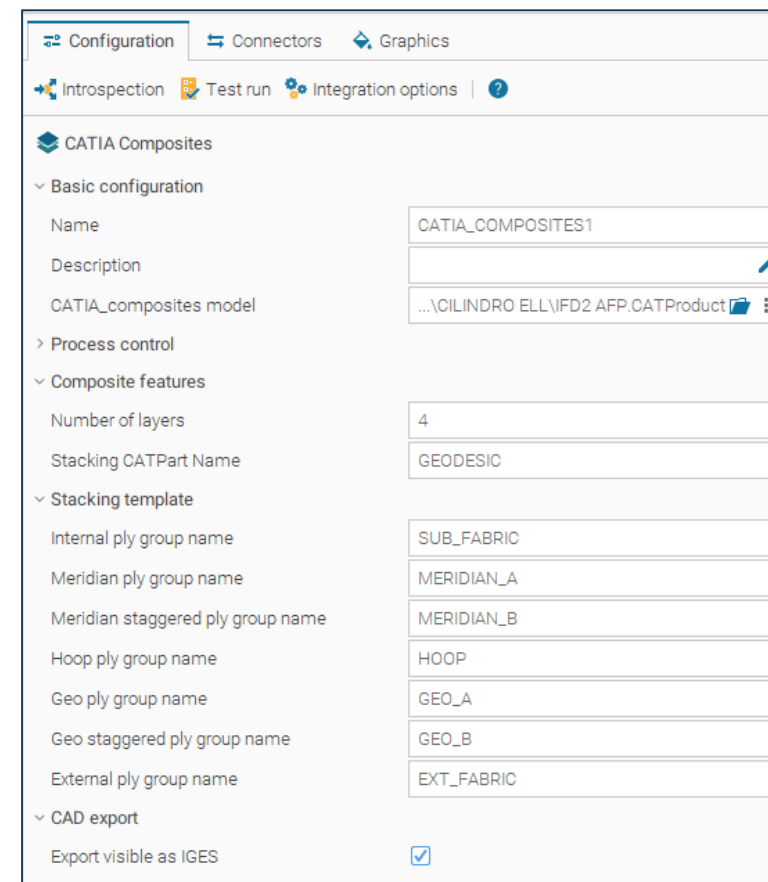
The activity described below is a proof of concept implemented for the dome of the tank.

## Parameter modification

Connection between *modeFRONTIER* and *CATIA* represented the first major obstacle during the automation process.

With standard CATIA node, stacking sequence cannot be modified so a custom node was developed, establishing a connection with *CATIA* via the COM interface.

CATIA\_COMPOSITES



# Process Automation



mF

Configuration Connectors Graphics

Introspection Test run Integration options

CATIA Composites

Name	...	Default value	...	Lower bound	Upper bound
0	Sequenza_Strati[0]	1.00000		1.00000	3.00000
1	Sequenza_Strati[1]	2.00000		1.00000	3.00000
2	Sequenza_Strati[2]	1.00000		1.00000	3.00000
3	Sequenza_Strati[3]	3.00000		1.00000	3.00000

Composite features

Number of layers:

Stacking CATPart Name:

Stacking template

Internal ply group name:

Meridian ply group name:

Meridian staggered ply group name:

Hoop ply group name:

Geo ply group name:

Geo staggered ply group name:

External ply group name:

CAD export

Export visible as IGES:

NB: 1 = meridian; 2 = hoop; 3 = geodesic

## Stacking Sequence

SUB\_FABRIC  
MERIDIAN\_A  
MERIDIAN\_B  
HOOP  
GEO\_A  
GEO\_B  
EXT\_FABRIC  
SUB\_FABRIC  
MERIDIAN\_A  
HOOP  
MERIDIAN\_B  
GEO\_A  
-----  
GEO\_B  
MERIDIAN\_A  
HOOP  
MERIDIAN\_B  
EXT\_FABRIC



# Process Automation

mF

Configuration
Connectors
Graphics

Introspection
Test run
Integration options
?

CATIA Composites

Name	...	Default value	...	Lower bound	Upper bound
0	Sequenza_Strati[0]	1.00000		1.00000	3.00000
1	Sequenza_Strati[1]	2.00000		1.00000	3.00000
2	Sequenza_Strati[2]	1.00000		1.00000	3.00000
3	Sequenza_Strati[3]	3.00000		1.00000	3.00000

▼ Composite features

Number of layers

Stacking CATPart Name

▼ Stacking template

Internal ply group name

Meridian ply group name

Meridian staggered ply group name

Hoop ply group name

Geo ply group name

Geo staggered ply group name

External ply group name

▼ CAD export

Export visible as IGES

Stacking Sequence

SUB\_FABRIC  
 MERIDIAN\_A  
 MERIDIAN\_B  
 HOOP  
 GEO\_A  
 GEO\_B  
 EXT\_FABRIC

SUB\_FABRIC  
 MERIDIAN\_A\_1  
 HOOP\_1  
 MERIDIAN\_B\_1  
 GEO\_A\_1  
 -----  
 GEO\_B\_1  
 MERIDIAN\_A\_2  
 HOOP\_2  
 MERIDIAN\_B\_2  
 EXT\_FABRIC

NB: 1 = meridian; 2 = hoop; 3 = geodesic

# Process Automation



mF

Configuration
Connectors
Graphics

Introspection
Test run
Integration options
?

CATIA Composites

Name	...	Default value	...	Lower bound	Upper bound
0	Sequenza_Strati[0]	1.00000		1.00000	3.00000
1	Sequenza_Strati[1]	2.00000		1.00000	3.00000
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3	Sequenza_Strati[3]	3.00000		1.00000	3.00000

▼ Composite features

Number of layers:

Stacking CATPart Name:

▼ Stacking template

Internal ply group name:

Meridian ply group name:

Meridian staggered ply group name:

Hoop ply group name:

Geo ply group name:

Geo staggered ply group name:

External ply group name:

▼ CAD export

Export visible as IGES:

NB: 1 = meridian; 2 = hoop; 3 = geodesic



Stacking Sequence

SUB\_FABRIC

MERIDIAN\_A\_1

HOOP\_1

MERIDIAN\_B\_1

GEO\_A\_1

---

GEO\_B\_1

MERIDIAN\_A\_2

HOOP\_2

MERIDIAN\_B\_2

EXT\_FABRIC

SUB\_FABRIC

MERIDIAN\_A

MERIDIAN\_B

HOOP

GEO\_A

GEO\_B

EXT\_FABRIC



# Process Automation



**mF**

Configuration | Connectors | Graphics

Introspection | Test run | Integration options | ?

CATIA Composites

Name	...	Default value	...	Lower bound	Upper bound
0	Sequenza_Strati[0]	1.00000		1.00000	3.00000
1	Sequenza_Strati[1]	2.00000		1.00000	3.00000
2	Sequenza_Strati[2]	1.00000		1.00000	3.00000
3	Sequenza_Strati[3]	3.00000		1.00000	3.00000

Composite features

Number of layers: 4

Stacking CATPart Name: GEODESIC

Stacking template

Internal ply group name: SUB\_FABRIC

Meridian ply group name: MERIDIAN\_A

Meridian staggered ply group name: MERIDIAN\_B

Hoop ply group name: HOOP

Geo ply group name: GEO\_A

Geo staggered ply group name: GEO\_B






External ply group name: EXT\_FABRIC








CAD export

Export visible as IGES:

NB: 1 = meridian; 2 = hoop; 3 = geodesic

## Stacking Sequence

-  SUB\_FABRIC
-  MERIDIAN\_A\_1
-  HOOP\_1
-  MERIDIAN\_B\_1
-  GEO\_A\_1

-  SUB\_FABRIC
-  MERIDIAN\_A
-  MERIDIAN\_B
-  HOOP
-  GEO\_A
-  GEO\_B
-  EXT\_FABRIC

- 
-  GEO\_B\_1
  -  MERIDIAN\_A\_2
  -  HOOP\_2
  -  MERIDIAN\_B\_2
  -  EXT\_FABRIC



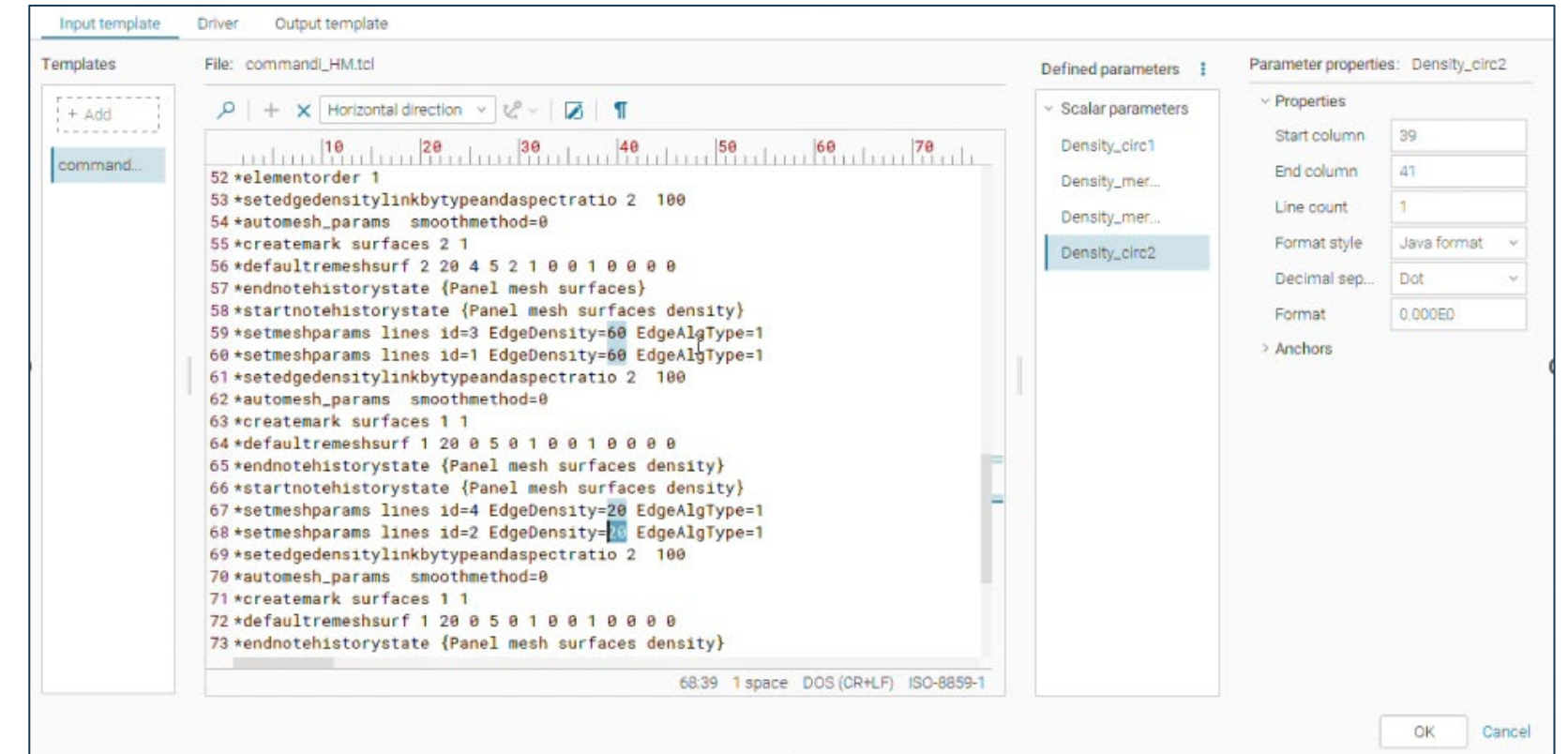
# Process Automation



## Mesh generation

Mesh preparation step with *Hypermesh* was simply implemented using an EasyDriver node.

Meshing tool is executed in batch mode launching a TCL file that contains the mesh seedings for each surface edge. These values are settled as input parameters for the node.



## Mapping of the properties

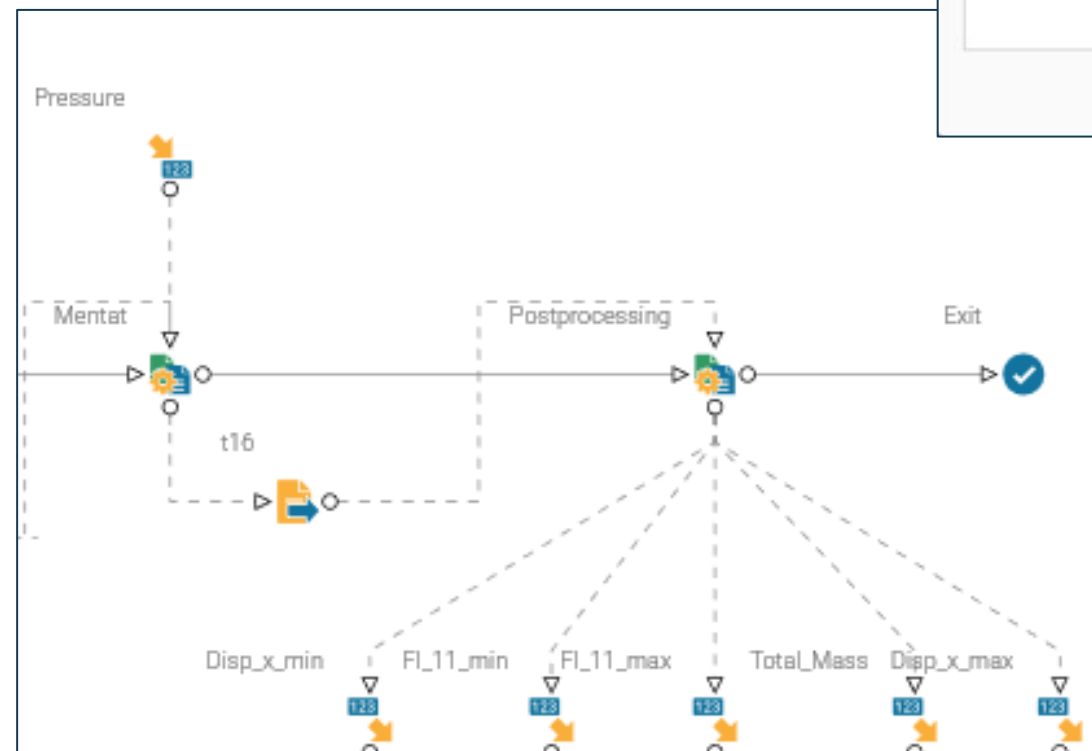
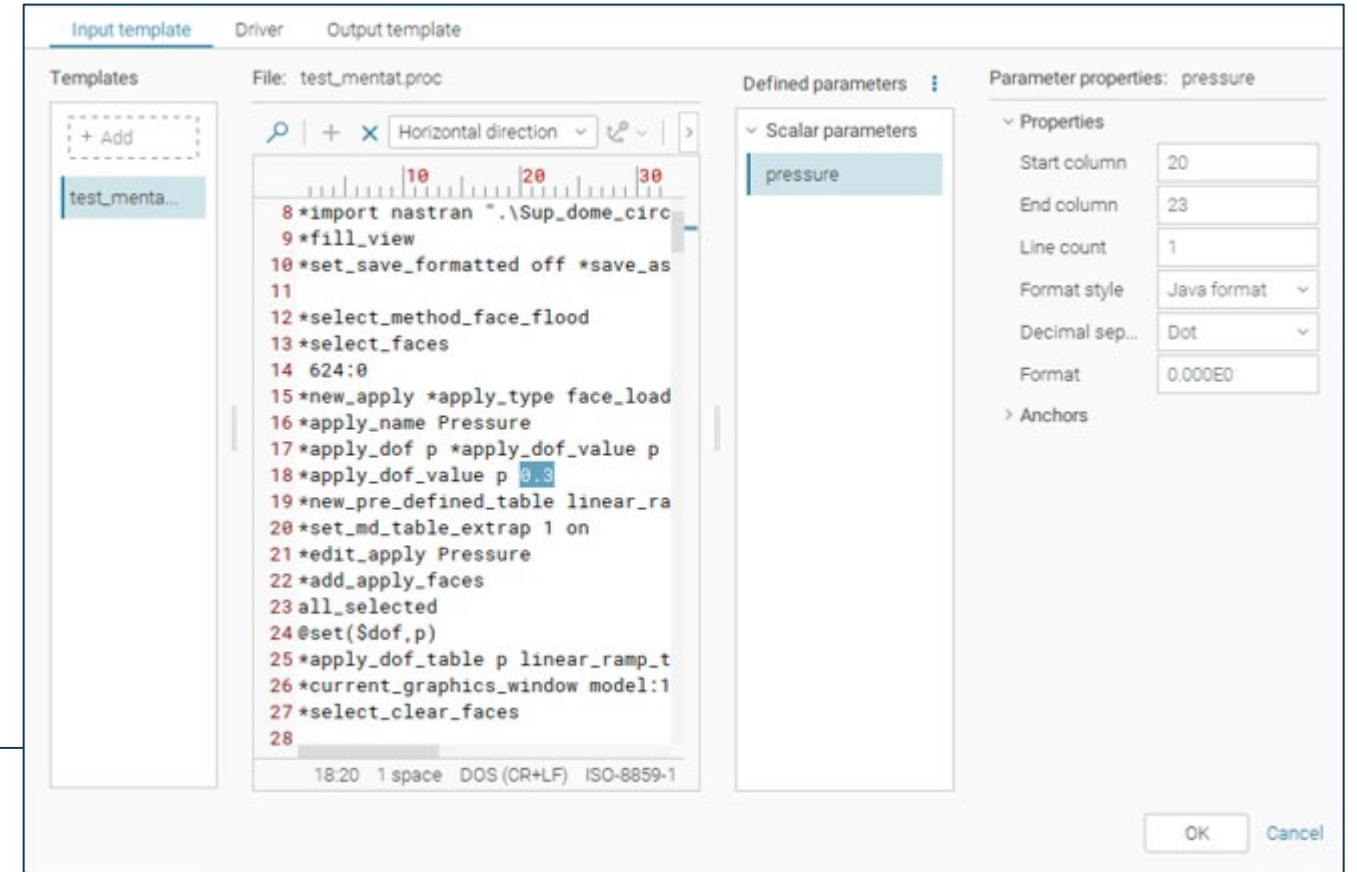
Geometrical and material properties mapping on the mesh is implemented via a DOS node via batch mode.

# Process Automation



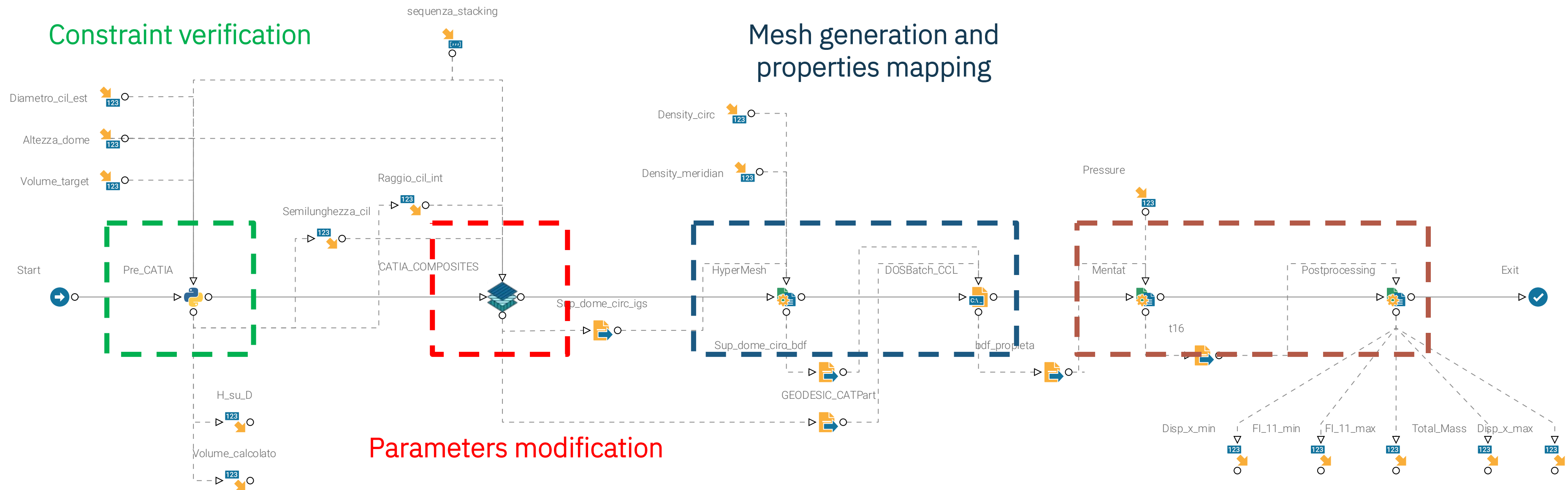
Pre-processing, simulation and post-processing Connection with *MSC Mentat* is introduced via ad EasyDriver node. External loads and constraints represent main input for the PCL file that is launched in batch mode.

Failure indices, displacements and overall mass are reported as the main output of the FE analysis using a dedicated node.



# Process Automation

Process recap and *modeFRONTIER* workflow

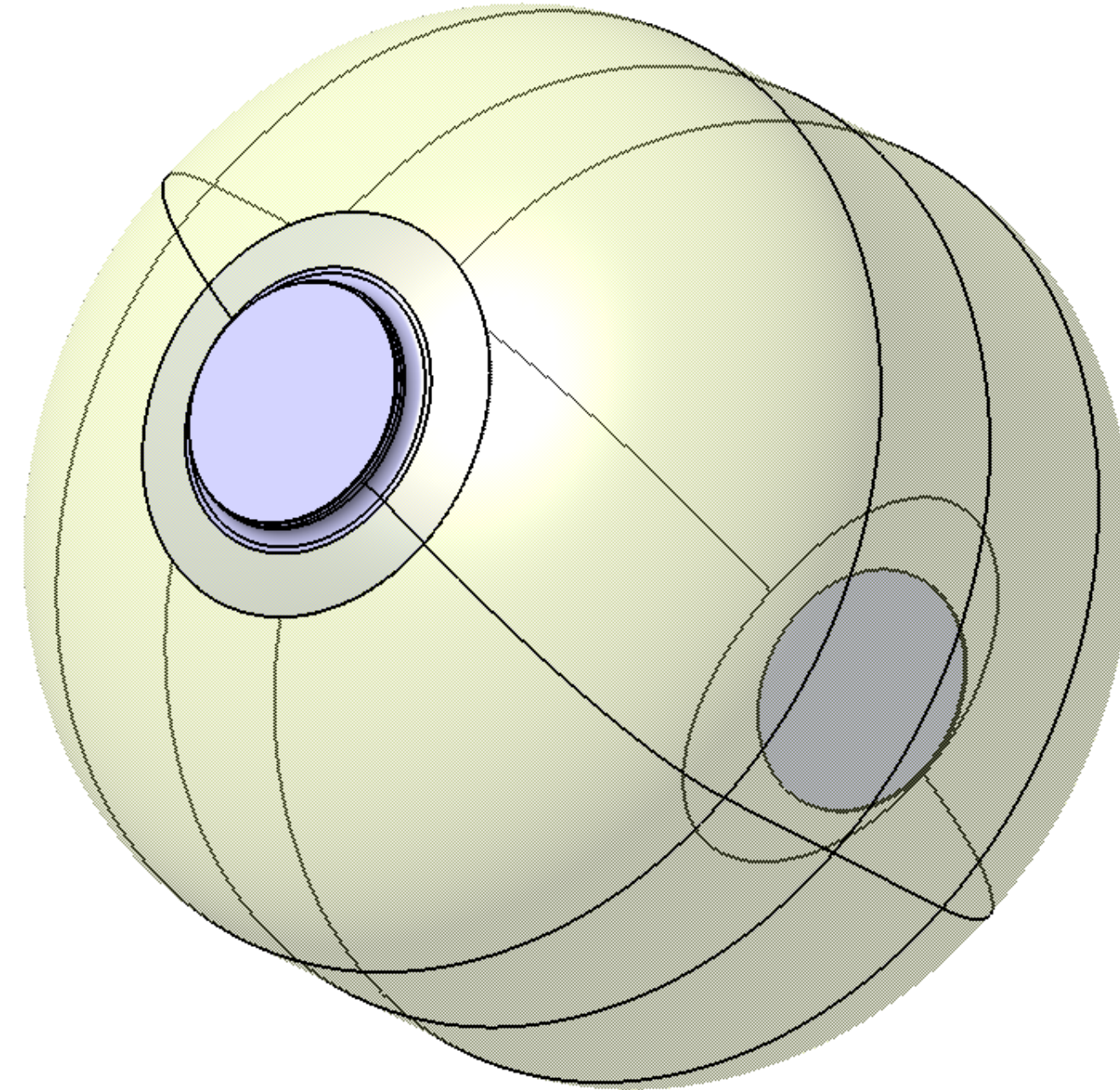


# Conclusion

Feature	Manual Process	Automated Process
Time Saving	1 design / 1 day	150 design / 2 days
Design Space	Limited iterations	PC Capabilities
Methodology	Intuition-based	Data-driven
Usability	Experties required	User-friendly
Traceability	Manually traced	Organized files
Post-processing	External tools	Integrated
Re-usability	Case-dependent	Extensible

# Next Steps

- Finalize use case
- Optimization strategy tuning
- Structure optimization
- Extend to other configurations
- Extend to other projects



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# Thank you

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