

**Conference on Industrial Design Optimisation for Fluid Flow
Munich, 28-29 March 2012**

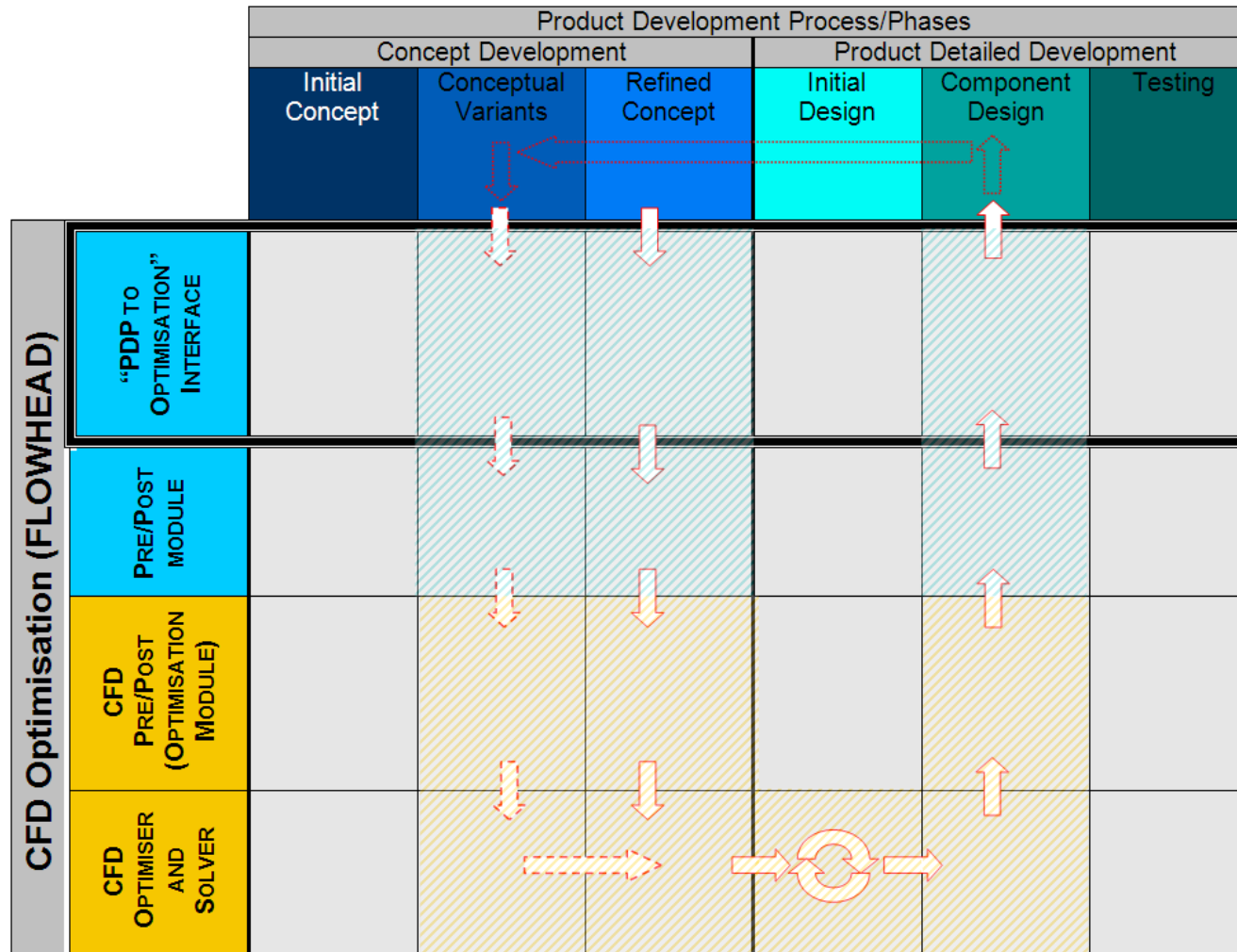
Interfacing of optimisation workflows with the product development process



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3Clab, Technical University of Sofia**

Existing automotive industry PDPs analysis

- PDPs and CFD optimisation (FLOWHEAD) – embedding of workflows



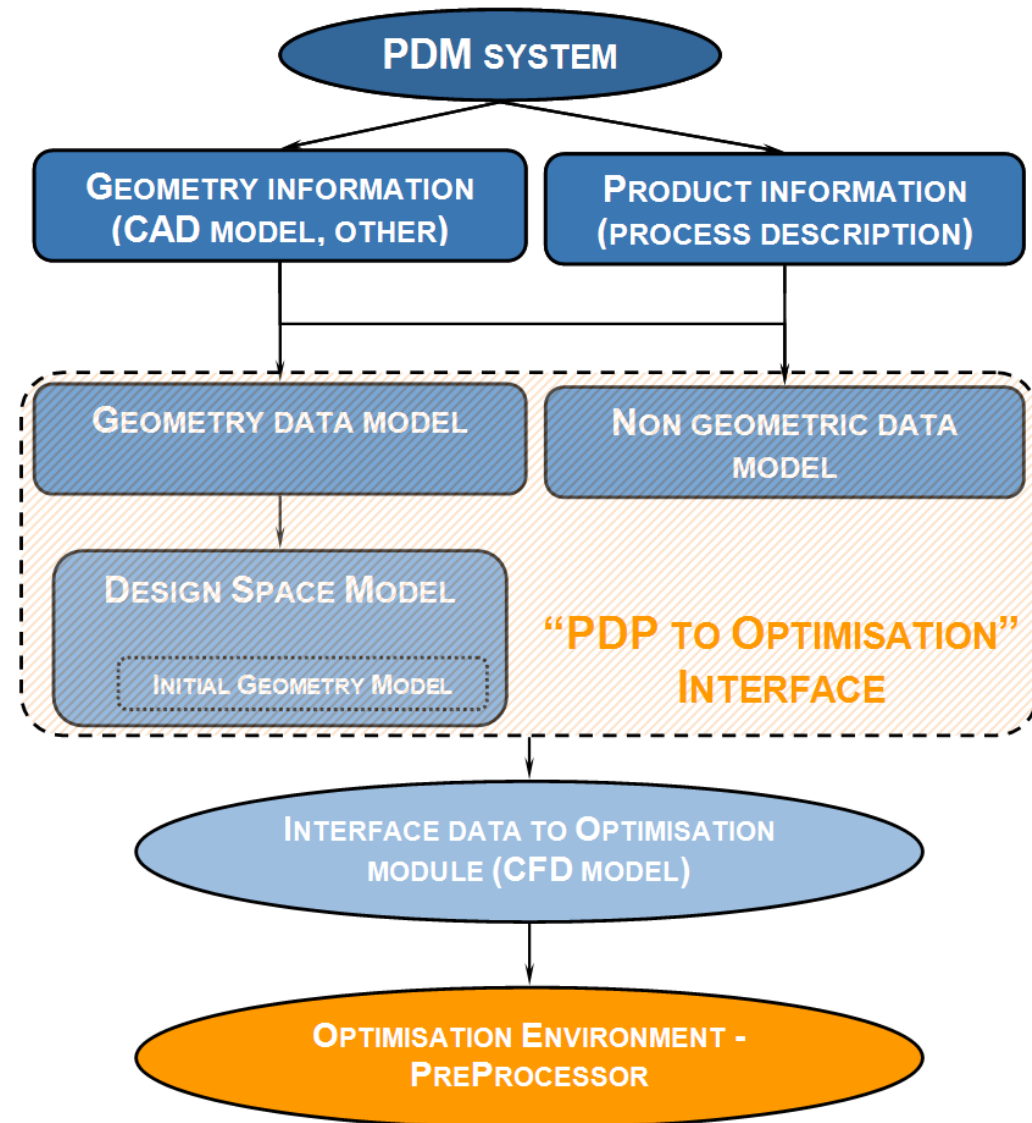
Existing automotive industry PDPs analysis

Two main interfaces:

- PDM to CAD/SDM Model;
- CAD/SDM to CFD Model.

Two types of information is transferred:

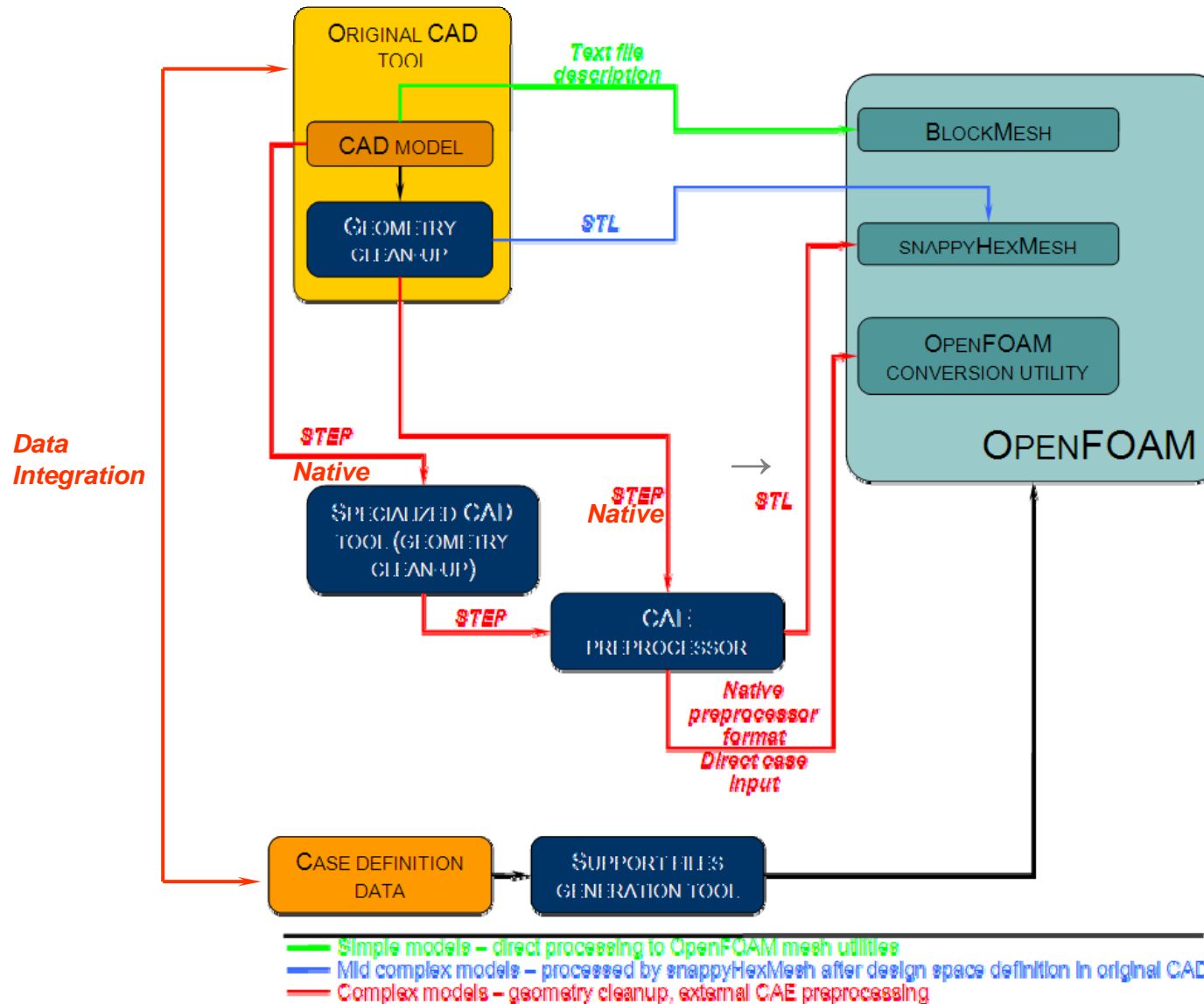
- Geometric;
- Non geometric.



Major steps needed to transfer data to optimisation module

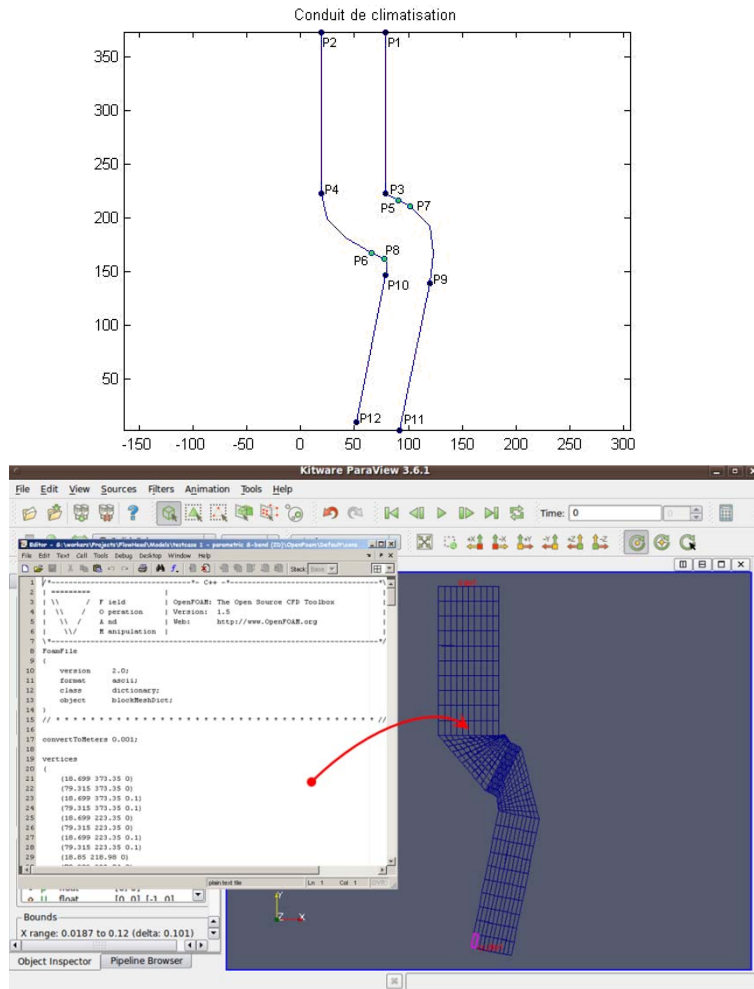
- **Stage: PDP:**
 - “Extract” model/design space from available in the PDP stage geometry model
 - Define the task (objective function, parameters, etc.)
- **Stage: Preprocessing:**
 - Model data transfer
 - Geometry clean-up
 - Mesh generation
- **Stage: Interface to optimization module:**
 - Model set-up
 - Model transfer to optimization module
 - Manufacturing constraints
- **Stage: Post processing (Interface back to pdp):**
 - Optimized geometry transfer back in CAD model

Combined approach for data interfaces



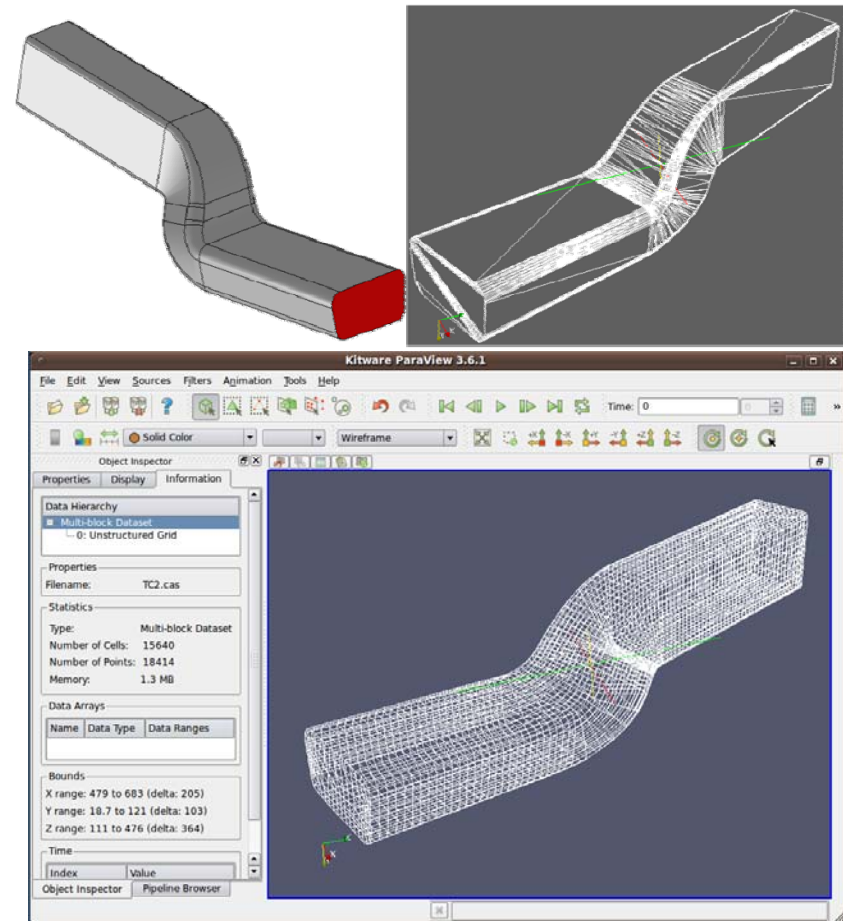
Test cases: simple and mid complex models

Simple model (text file description)



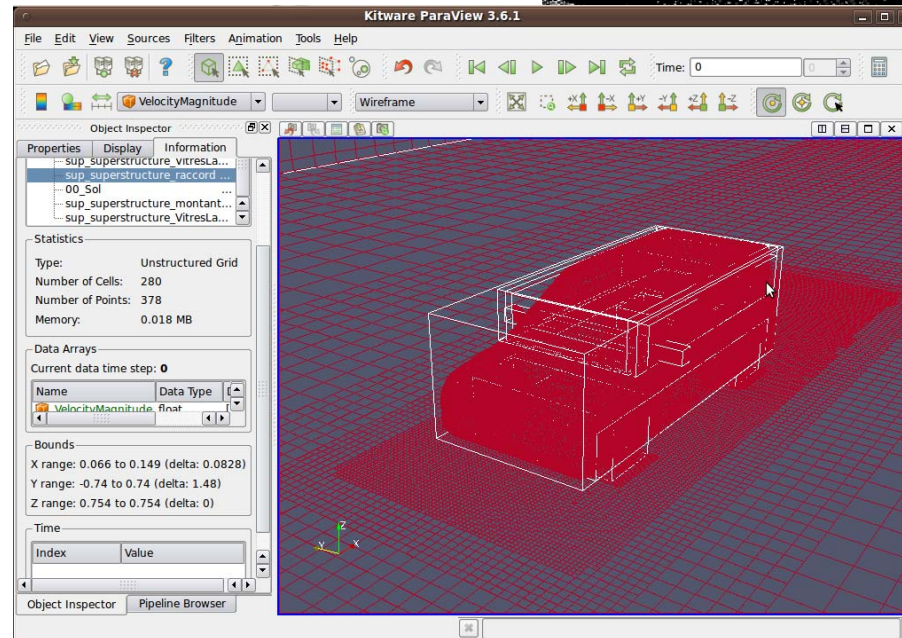
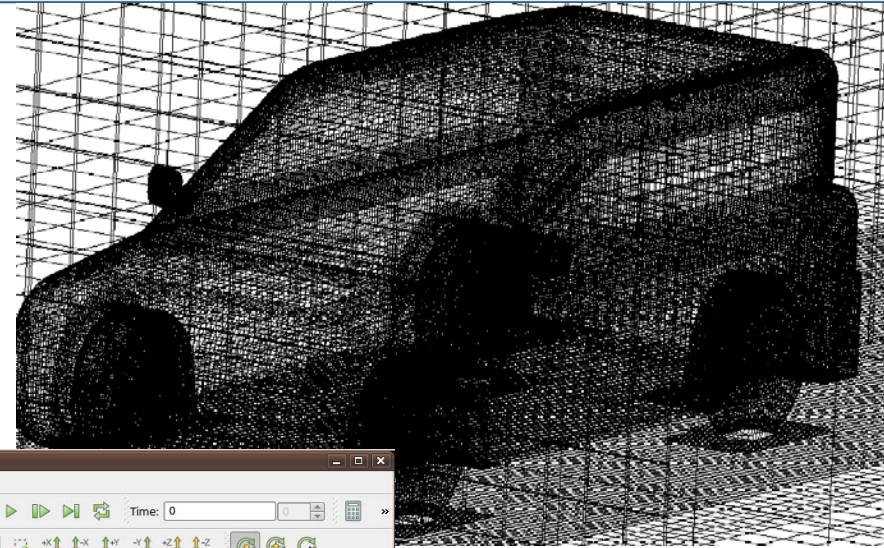
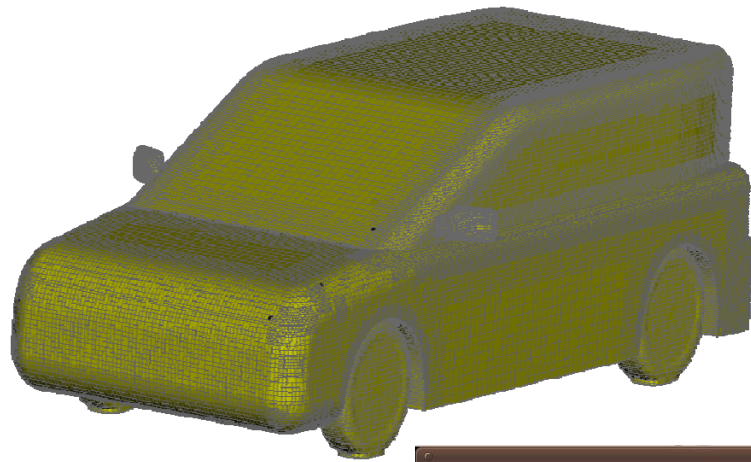
No1 Parametric S-bend 2D

Mid complex model (direct STL to OpenFOAM environment)



No2: Airduct VW Golf Plus – 3D

Test cases: complex models



No7 Side mirror

Complex models: Geometry clean-up of design space

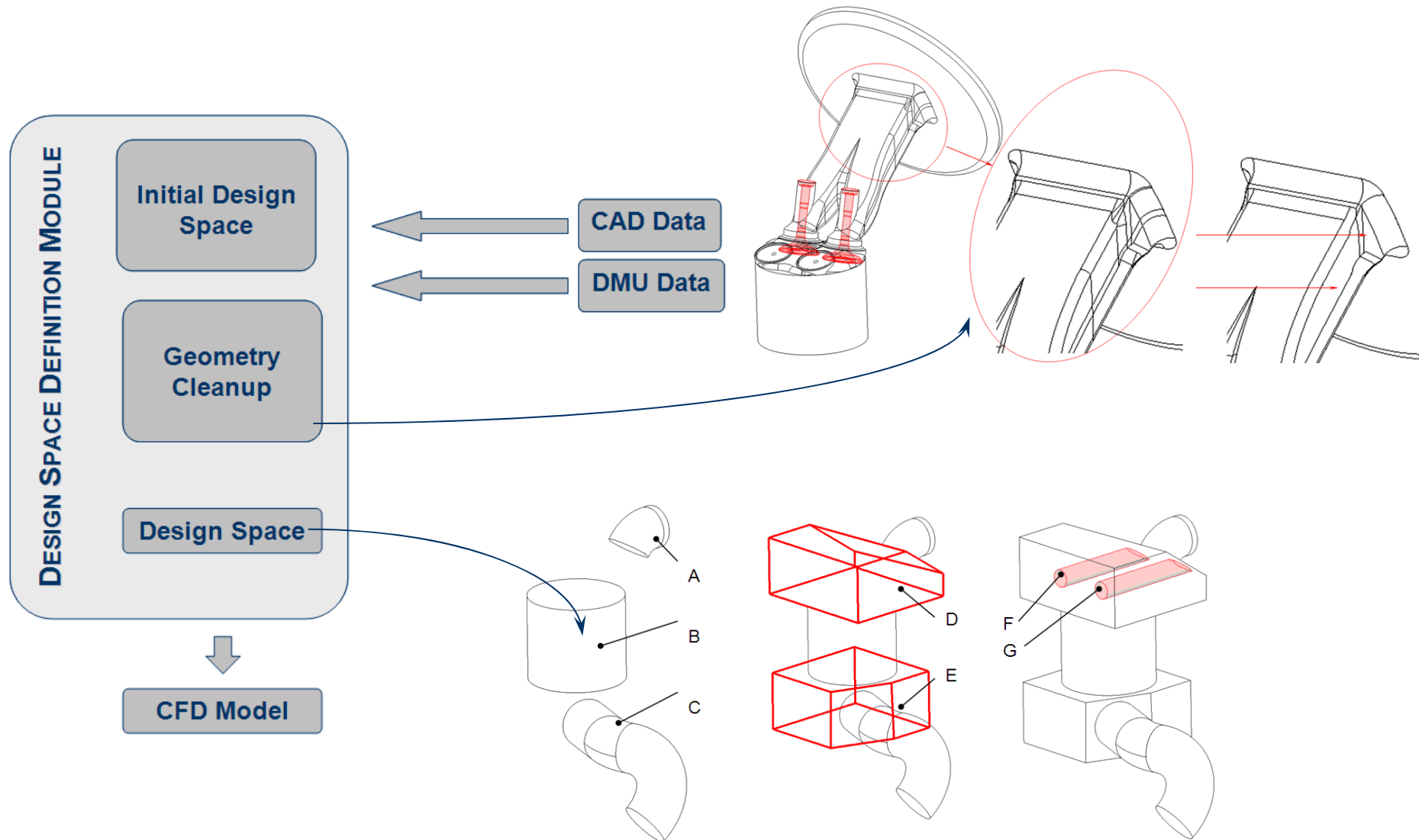
Tools, used for initial design space cleanup could be:

- Conventional CAD tool (CATIA, NX, Pro/E, SW, etc.) only – the design space is formed in a CAD program entirely;
- Conventional CAD and CAE Preprocessing tools – initially defined in CAD environment design space is additionally formed in the CAE preprocessor, used also for mesh generation;
- Specialized CAD tool and CAE Preprocessing – entire initial design space could be cleaned up using available tools in specific CAD tools with or without initial preparation in the conventional CAD system.

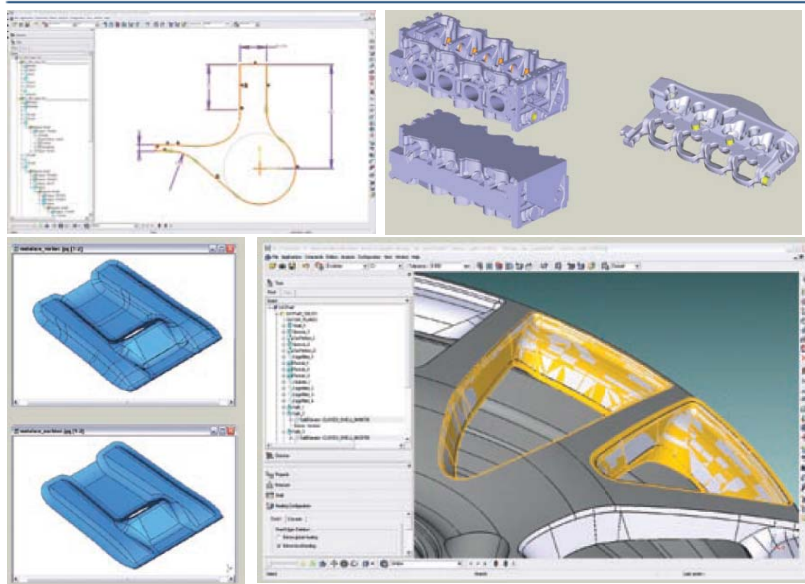
Different practices for design space definition, using CAD tools, exist. Most common are:

- volume operations (Boolean, additional geometry modeling)
- cross sections (definition of characteristic cross sections).

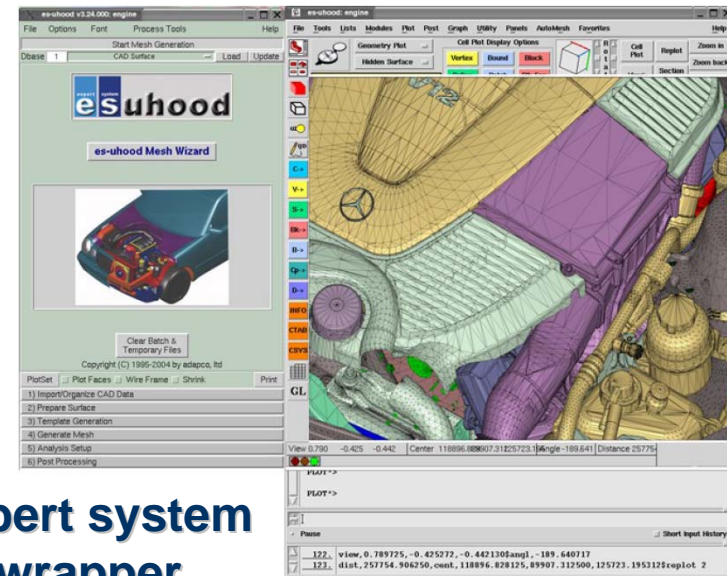
CAD Geometry Preprocessing to CFD optimization



Geometry clean-up using specialized modules (samples)



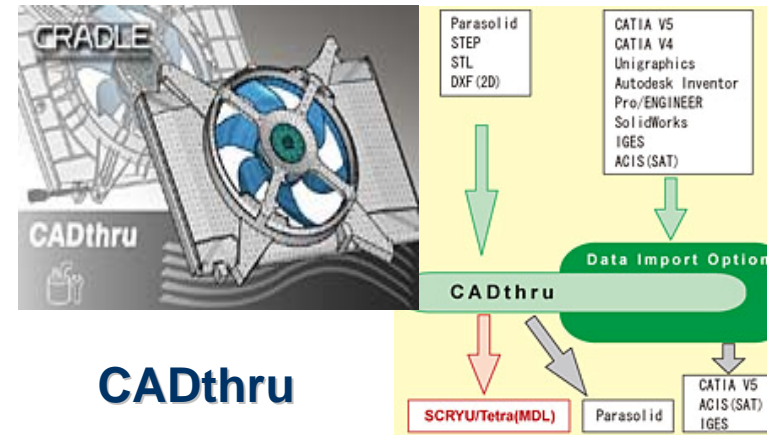
3D_Evolution



Expert system wrapper

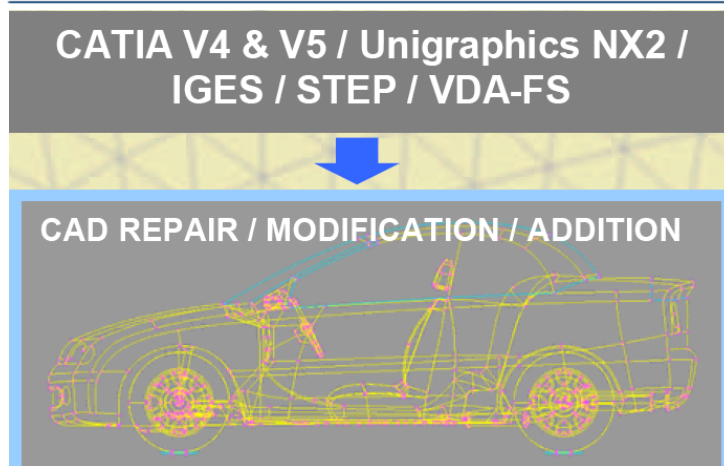


PowerDELTA & PowerCLAY

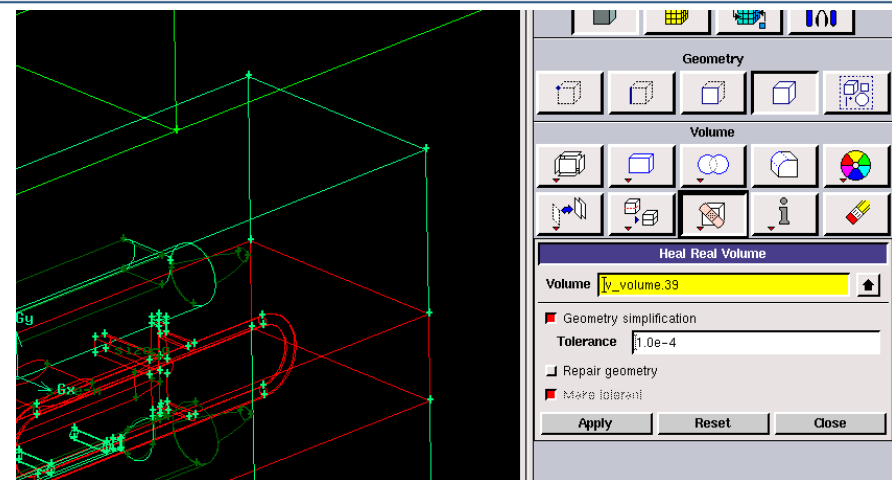


CADthru

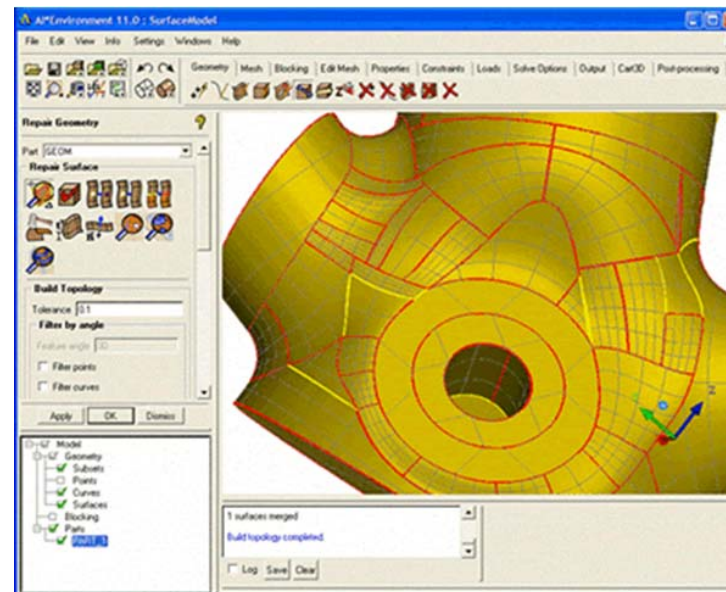
Geometry clean-up using conventional preprocessors (samples)



ANSA



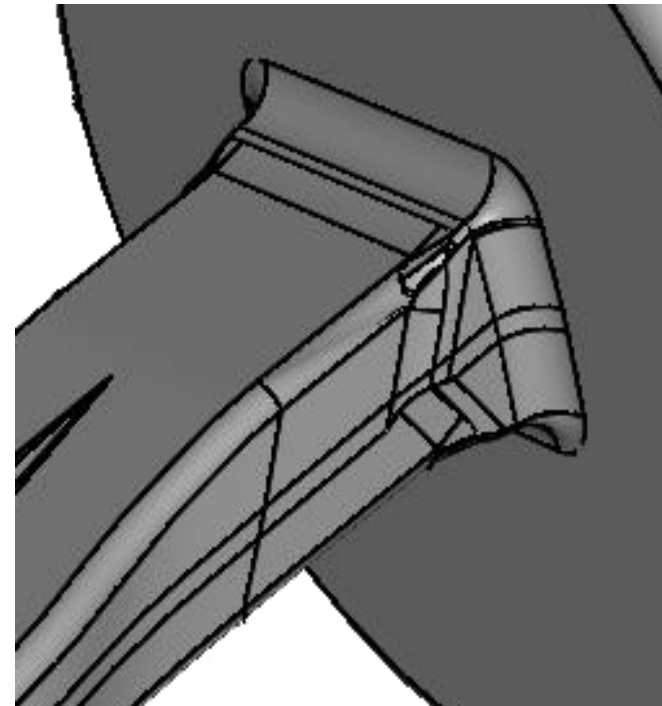
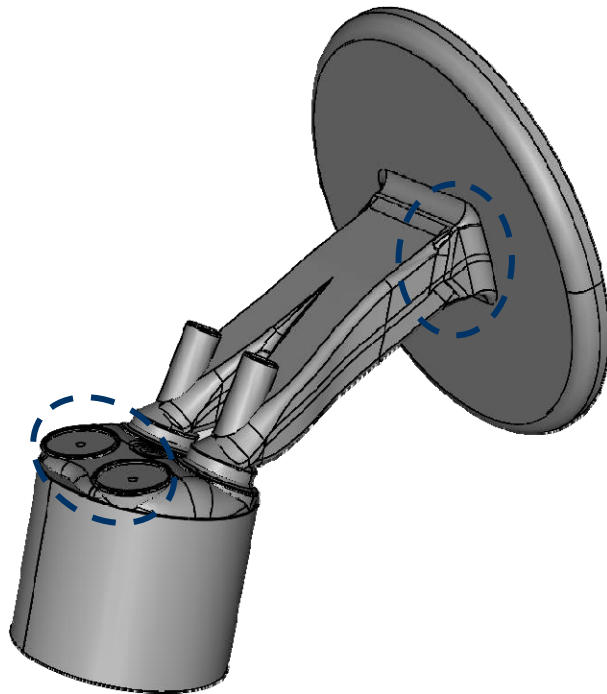
GAMBIT



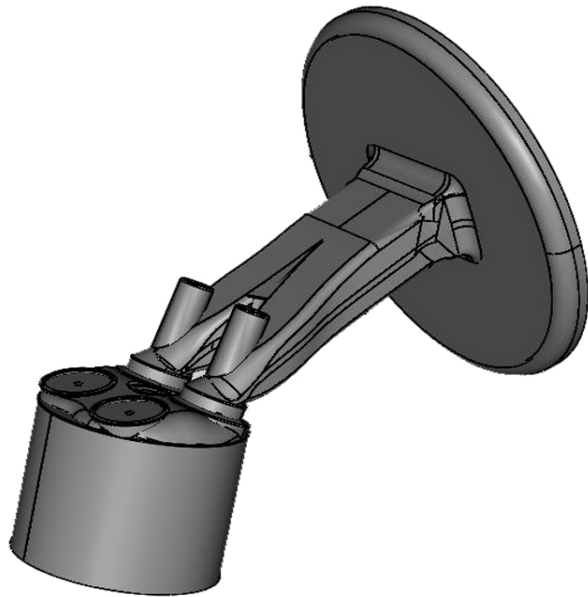
ANSYS ICEM CFD

Geometry Clean-up: Sample

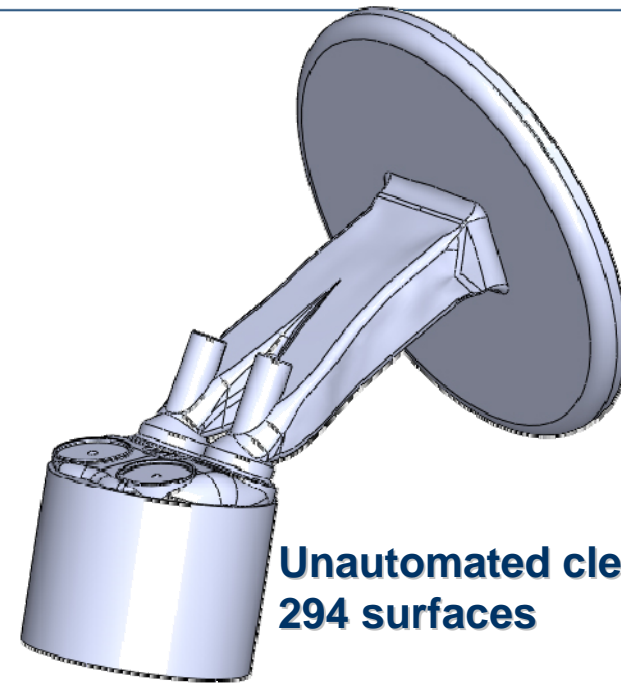
Initial design space: 424 surfaces



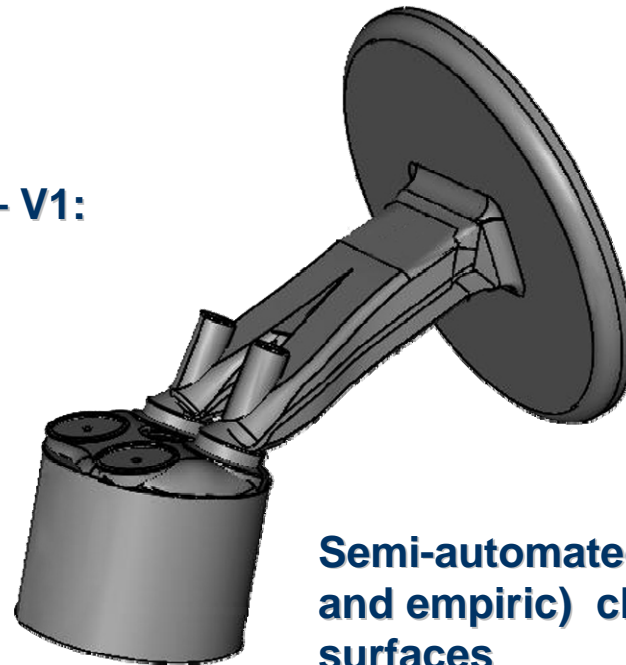
Geometry Clean-up: Sample



**Automated clean-up – V1:
258 surfaces**

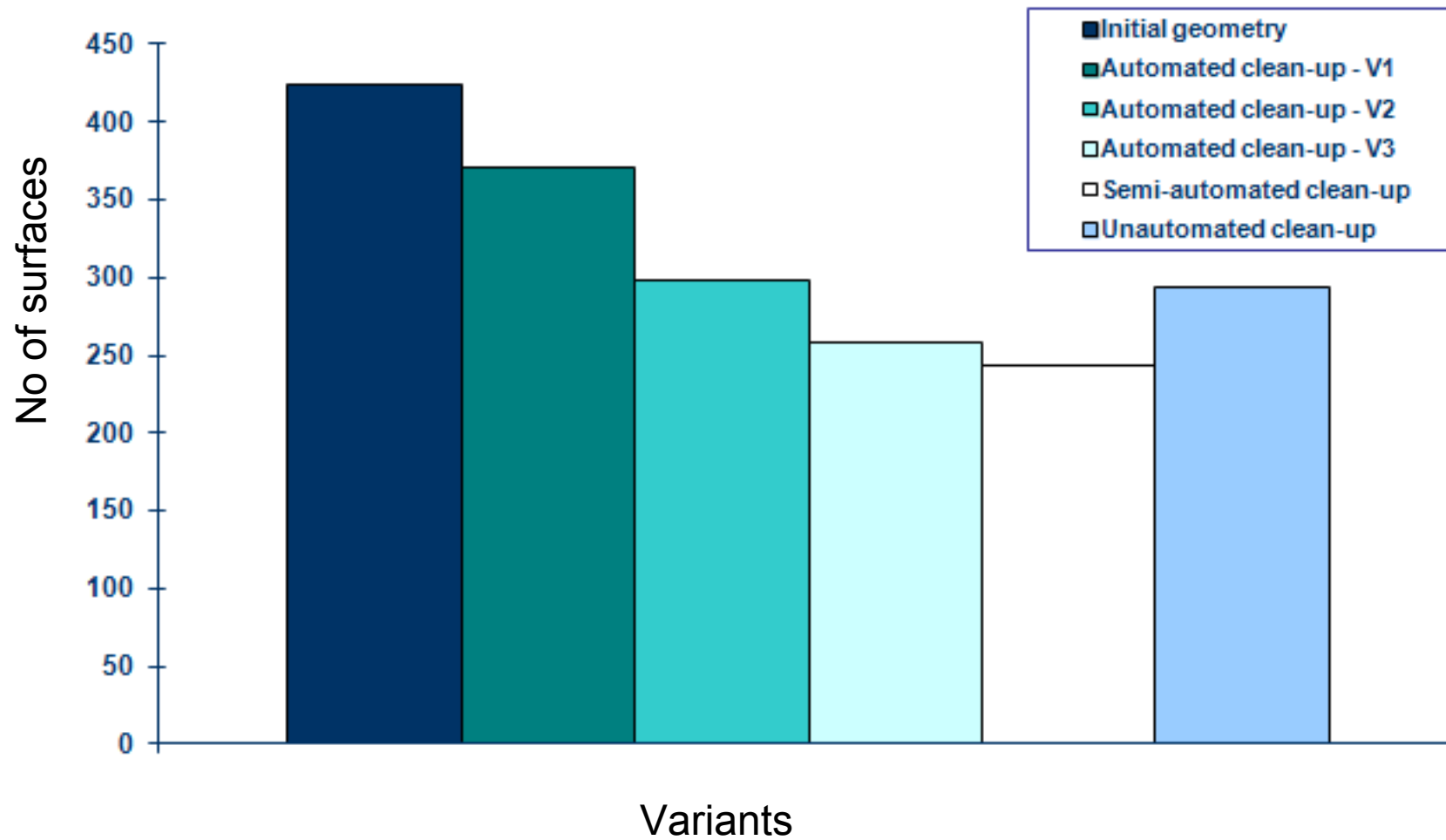


**Unautomated clean-up:
294 surfaces**

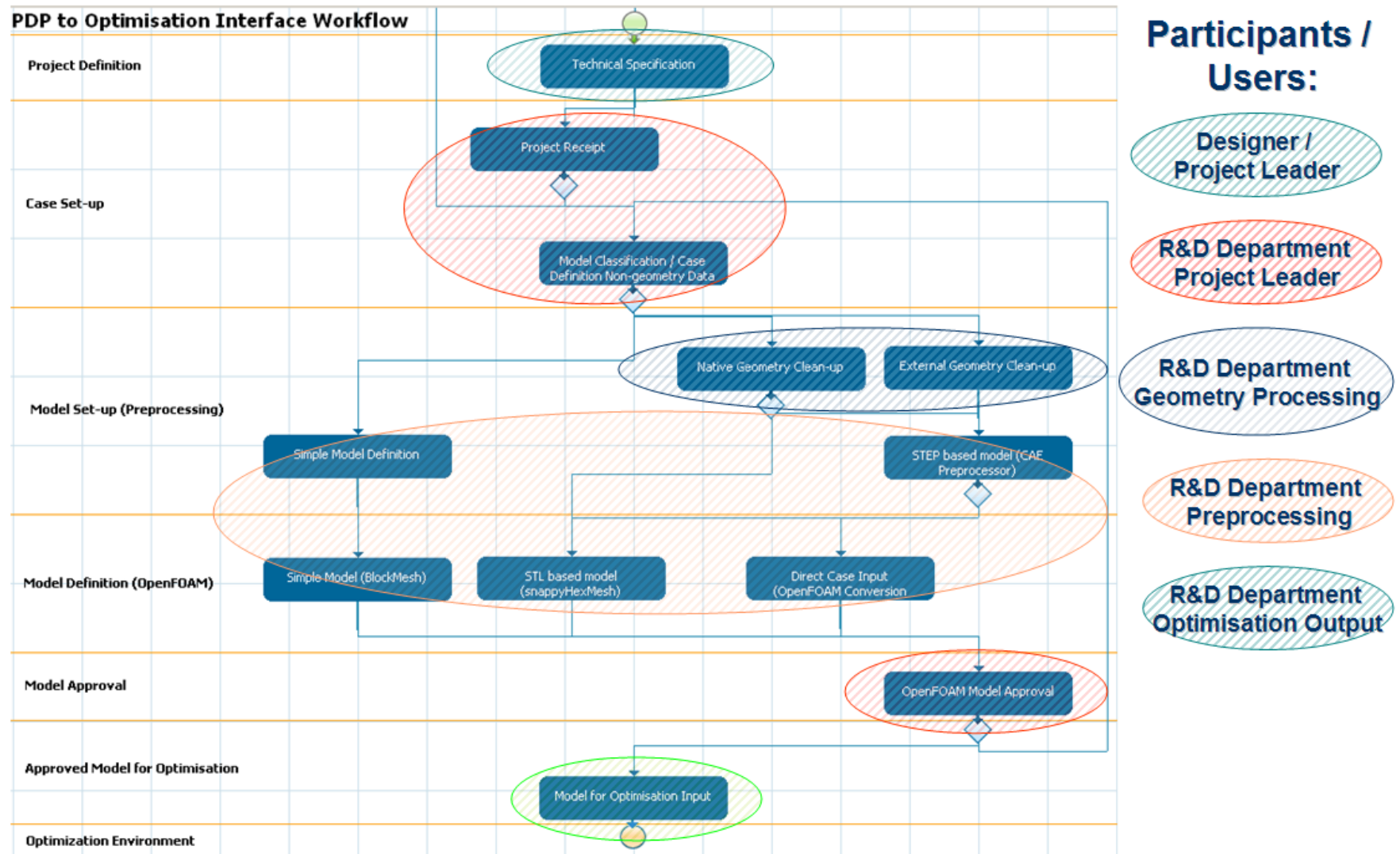


**Semi-automated (automated
and empiric) clean-up: 244
surfaces**

Geometry Clean-up: Results



PDP to Optimisation Interface Workflow Software Solution



PDP to Optimisation Interface Workflow Software Solution

WORKFLOW:

Technical Specification

- Definition
- Description
- CAD Data

Project Receipt

- Notification
- TechSpec Review
- Project Receipt

Model Classification

- Optimisation Case Definition
- Geometry Processing

- Notification
- Download Input Data
- Define Output
- Upload Output Data

- Preprocessing
- Notification
- Download Input Data
- Define Output

- Upload Output Data
- OpenFOAM Case Definition

- Notification
- Download data
- Upload Output Data

- Model Approval
- Model Finalisation

- Notification
- Download data
- Upload Modified Data

The screenshot shows the 'FLOWHEAD' software interface. On the left is a navigation menu with sections for 'Cases', 'Documents', and 'Documents'. The main area displays the 'Technical Specification Definition' form for Case #29. The form includes fields for Project Designation (TESTCASE#4), Project Title (CATALYTIC CO), Requested By (Designer), Reported To (Designer), Date of Request (25/08/2011), and End Date (08/09/2011). Below the form is a table of attached files:

| Title | Version | Creator | Comment | Created Date | Download | Delete |
|----------------------------------|---------|--------------------|---------|---------------------|----------|--------|
| catalytic_converter_dead.stp | 1 | Design Development | | 2011-08-25 09:43:19 | Download | Delete |
| catalytic_converter_dead.CATPart | 1 | Design Development | | 2011-08-25 09:41:02 | Download | Delete |

Below the table is a 3D CAD model of a purple and grey mechanical part.

Download and review

The screenshot shows the 'Uploaded Documents' table for Case #29. The table lists the following documents:

| Filename | Comments | Type | Version | Origin Task | Created By | Create Date | Download |
|----------------------------------|----------|----------------|---------|-------------------------|--------------------|---------------------|----------|
| catalytic_converter_dead.stp | | Input Document | 1 | Technical Specification | Design Development | 2011-08-25 09:43:19 | Download |
| catalytic_converter_topo.jpg | | Input Document | 1 | Technical Specification | Design Development | 2011-08-25 09:41:30 | Download |
| catalytic_converter_dead.jpg | | Input Document | 1 | Technical Specification | Design Development | 2011-08-25 09:41:18 | Download |
| catalytic_converter_dead.CATPart | | Input Document | 1 | Technical Specification | Design Development | 2011-08-25 09:41:02 | Download |
| README.txt | | Input Document | 1 | Technical Specification | Design Development | 2011-08-25 09:39:34 | Download |

Page 1/1

PDP to Optimisation Interface Workflow Software Solution

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Optimisation Case Definition

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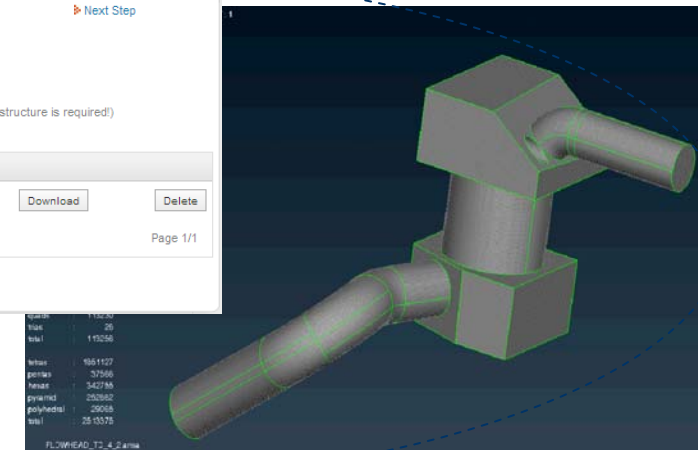
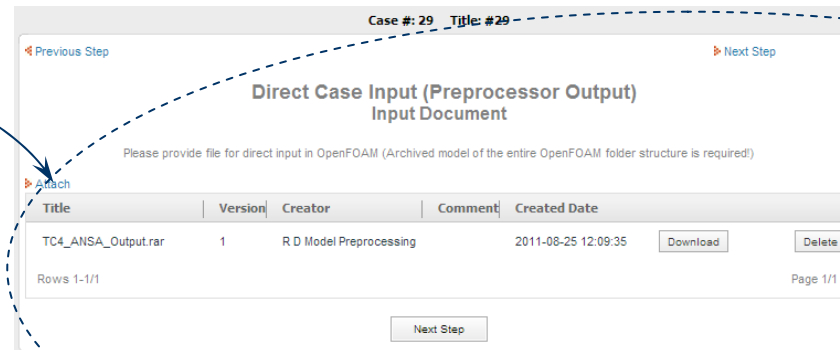
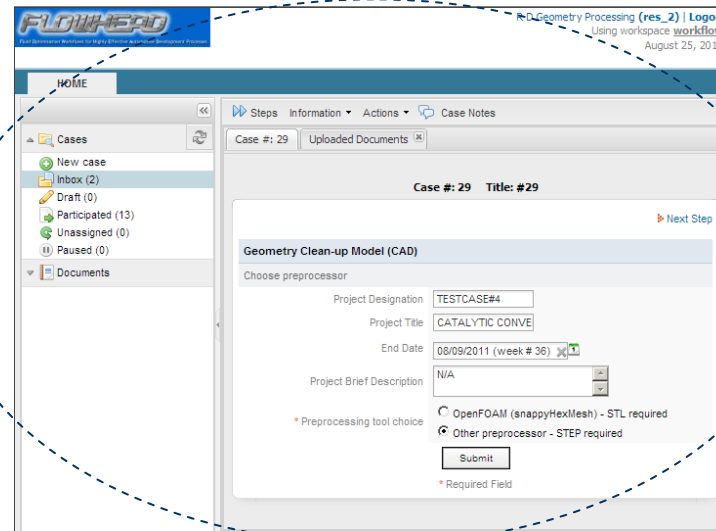
Preprocessing

- Notification
 - Download Input Data
 - Define Output
 - Upload Output Data
- OpenFOAM Case Definition

- Notification
- Download data
- Upload Output Data

Model Approval
Model Finalisation

- Notification
- Download data
- Upload Modified Data



PDP to Optimisation Interface Workflow Software Solution

WORKFLOW:

Technical Specification

→ Definition

→ Description

→ CAD Data

Project Receipt

→ Notification

→ TechSpec Review

→ Project Receipt

Model Classification

Optimisation Case Definition

Geometry Processing

→ Notification

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→ Define Output

→ Upload Output Data

Preprocessing

→ Notification

→ Download Input Data

→ Define Output

→ Upload Output Data

OpenFOAM Case Definition

→ Notification

→ Download data

→ Upload Output Data

Model Approval

Model Finalisation

→ Notification

→ Download data

→ Upload Modified Data

The screenshot displays a web-based interface for a workflow. At the top, it shows 'Case #: 29' and 'Title: #29'. The main content area is titled 'Converted in OpenFOAM model Input Document' and contains the instruction: 'Please provide file for OpenFOAM model (Archived model of the entire OpenFOAM folder structure is required!)'. Below this is an 'Attach' section with a table listing attachments:

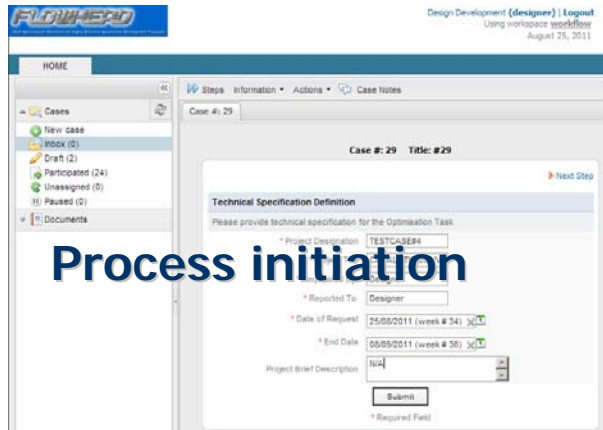
| Title | Version | Creator | Comment | Created Date | Download | Delete |
|------------------|---------|-------------------------|---------|---------------------|----------|--------|
| TC4_OpenFOAM.rar | 1 | R D Model Preprocessing | | 2011-08-25 12:19:58 | Download | Delete |

Below the table, it indicates 'Rows 1-1/1' and 'Page 1/1'. A 'Next Step' button is located at the bottom of the attachment section. To the right of the attachment section, there is a 'Next Step' button. Below the attachment section, there is a 'Next Step' button. The interface also features a 'FLOWHEAD' logo and a user profile section for 'R.D. Optimisation Preparation (res_4)' with a 'Logout' link and the text 'Using workspace workflow' and the date 'August 25, 2011'. At the bottom, there is a navigation bar with 'HOME' and a list of actions: 'Read', 'Unread', 'All', 'Process', 'All Processes'. A table below the navigation bar shows a list of cases:

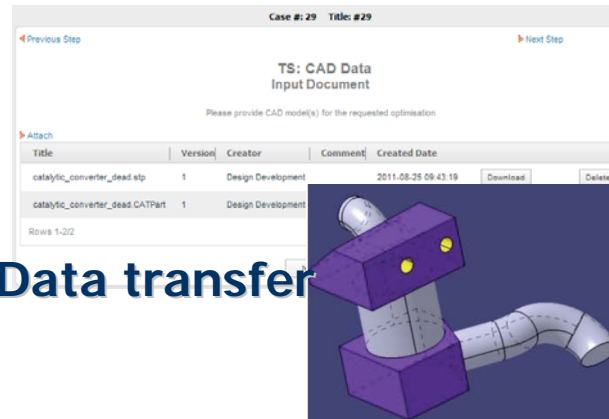
| Case | Task | Priority |
|------|------------------------------|----------|
| #29 | Model for Optimisation Input | NORMAL |

The interface also includes a sidebar with a 'Cases' section containing options like 'New case', 'Inbox (1)', 'Draft (0)', 'Participated (4)', 'Unassigned (0)', 'Paused (0)', and 'Documents'.

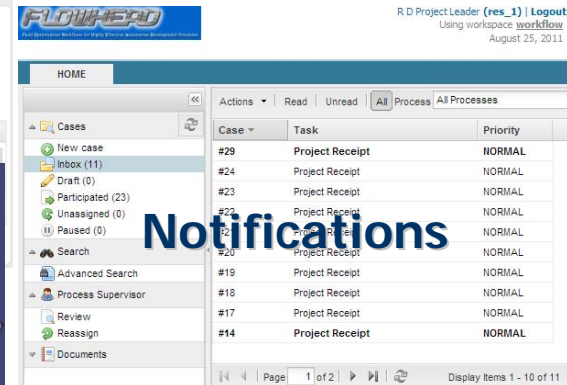
PDP to Optimisation Interface Workflow Software Solution



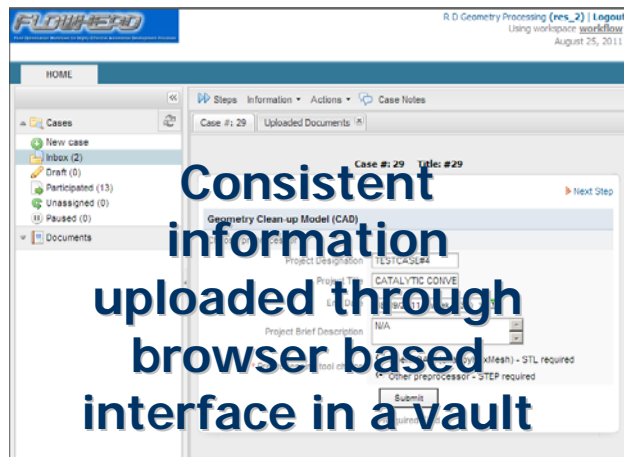
Process initiation



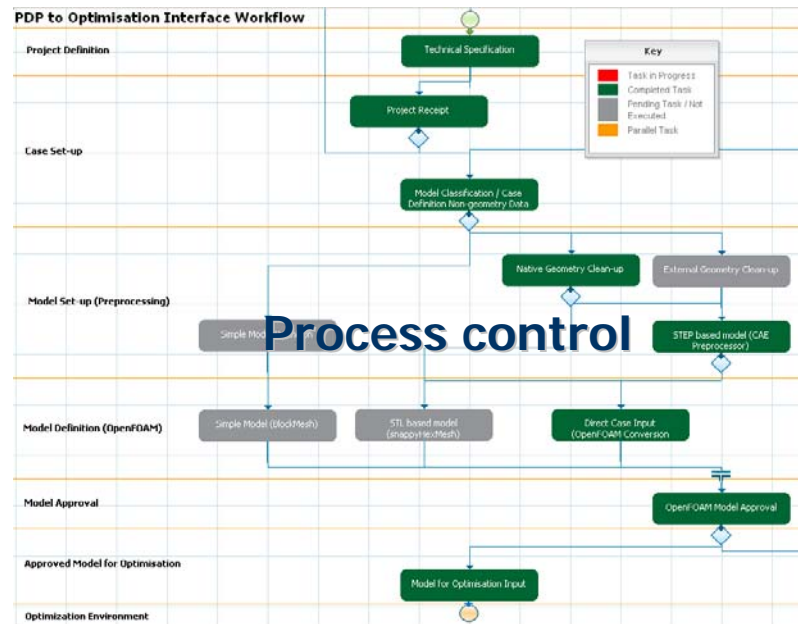
Data transfer



Notifications



Consistent information uploaded through browser based interface in a vault



Process control

Major features in the Interface Workflow Software Solution

- **Browser-based interface was developed as demo case**
- **Management of groups and users**
- **Internal and possible mail notifications**
- **Consistent information in vault**
- **Possible connection to external databases**
- **Open Source (Possible customization)**

Manufacturing Constraints in 2 Groups

| Processing Operations | | Assembly Operations | |
|-----------------------|----------------------------|---------------------|--------------------|
| Shaping | Solidification processes | Joining processes | Welding |
| | Particulate processing | | Brazing |
| | Deformation processes | | Soldering |
| | Material removal processes | | Adhesive Bonding |
| Property-enhancing | Heat treatment | Mechanical assembly | Threaded fasteners |
| Surface processing | Cleaning | | Press fitting |
| | Surface treatments | | Molding inserts |
| | Coating | | Integral fasteners |
| | Thin film deposition | | |

Major Constraints:

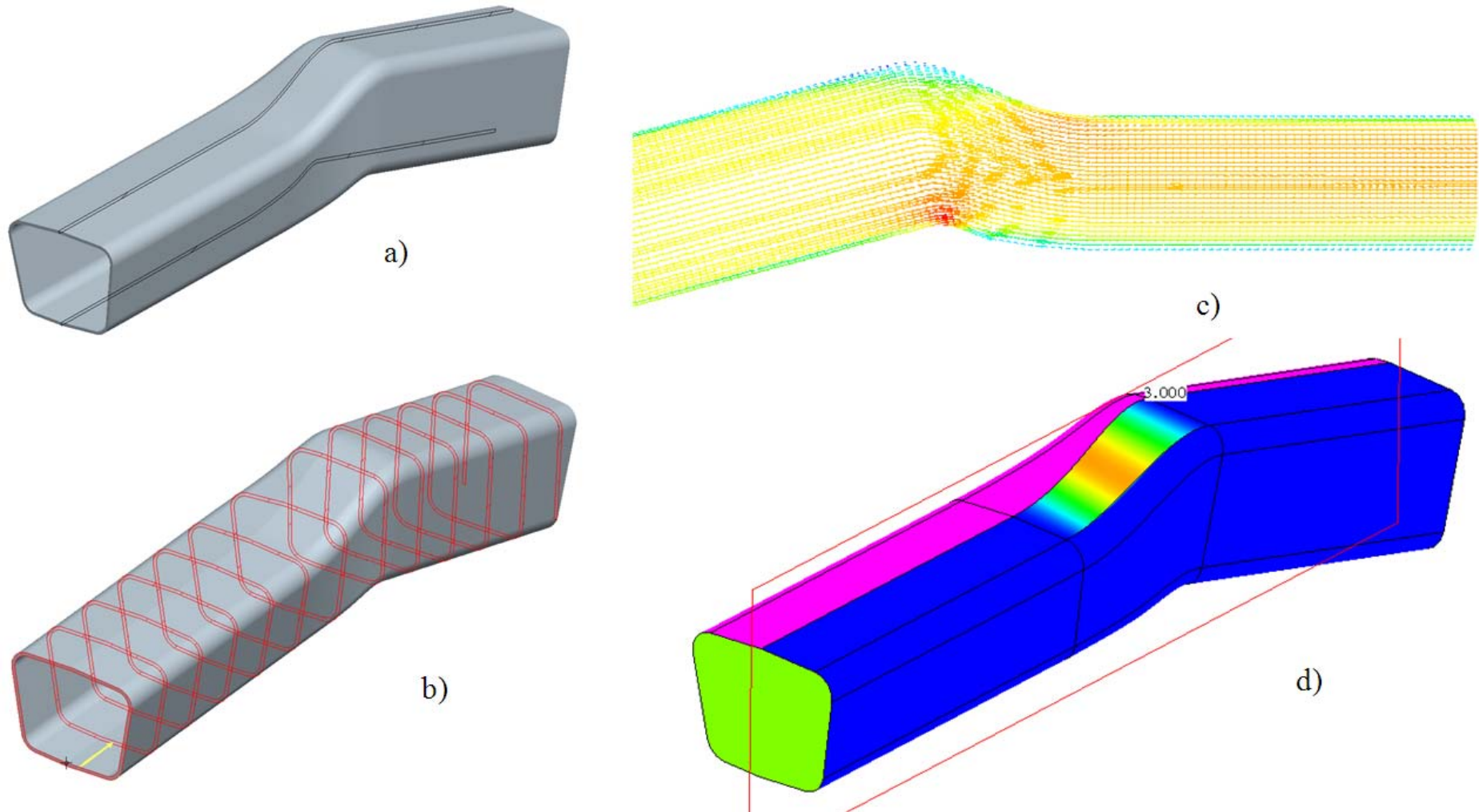
❑ Processing Operations:

- ✓ Parting line / ejection direction;
- ✓ Draft angles;
- ✓ Wall thickness;
- ✓ Radius/curvature;
- ✓ Warpage;

❑ Assembly Operations:

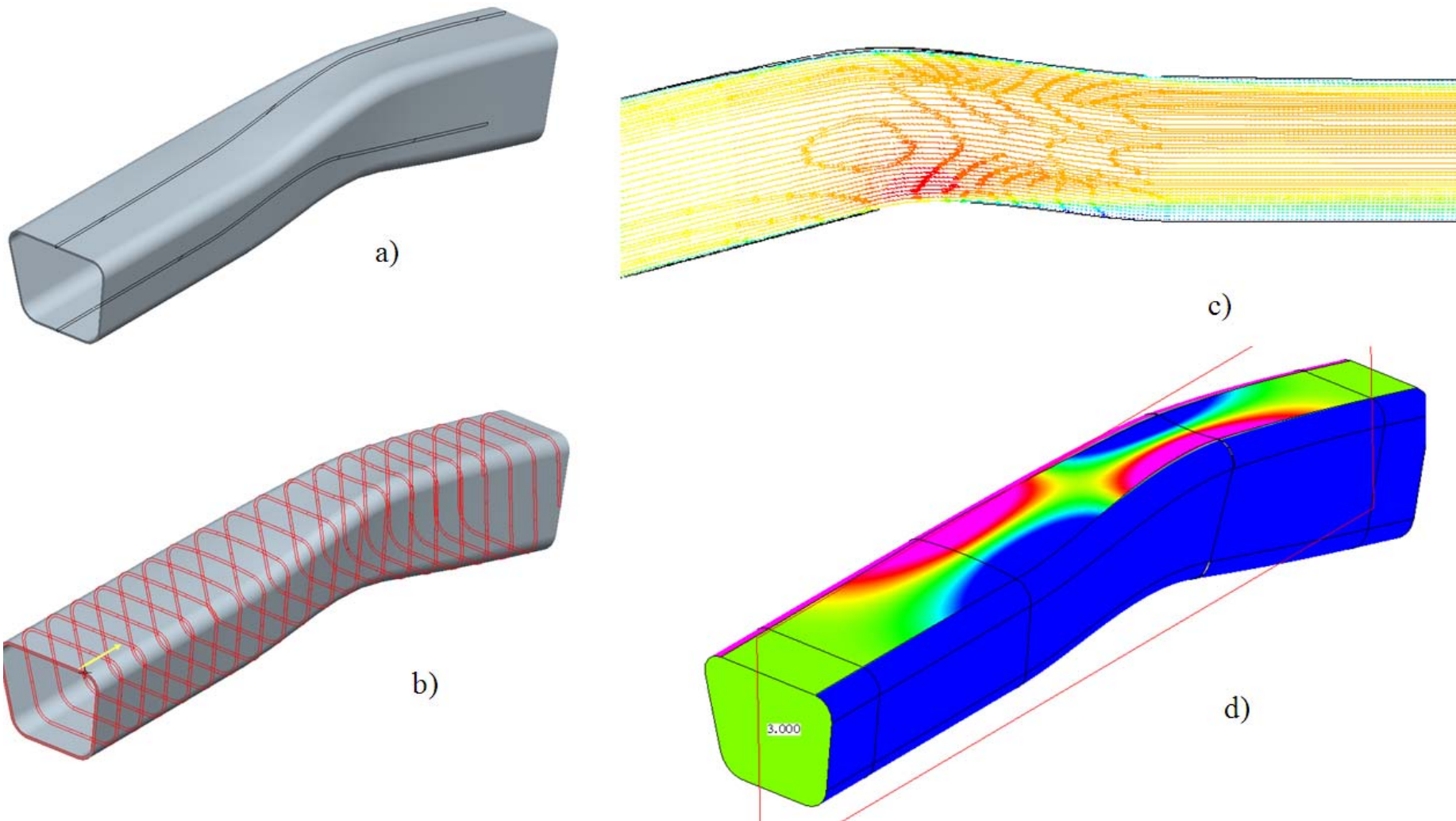
- ✓ Accessibility

Check of Initial Design Space



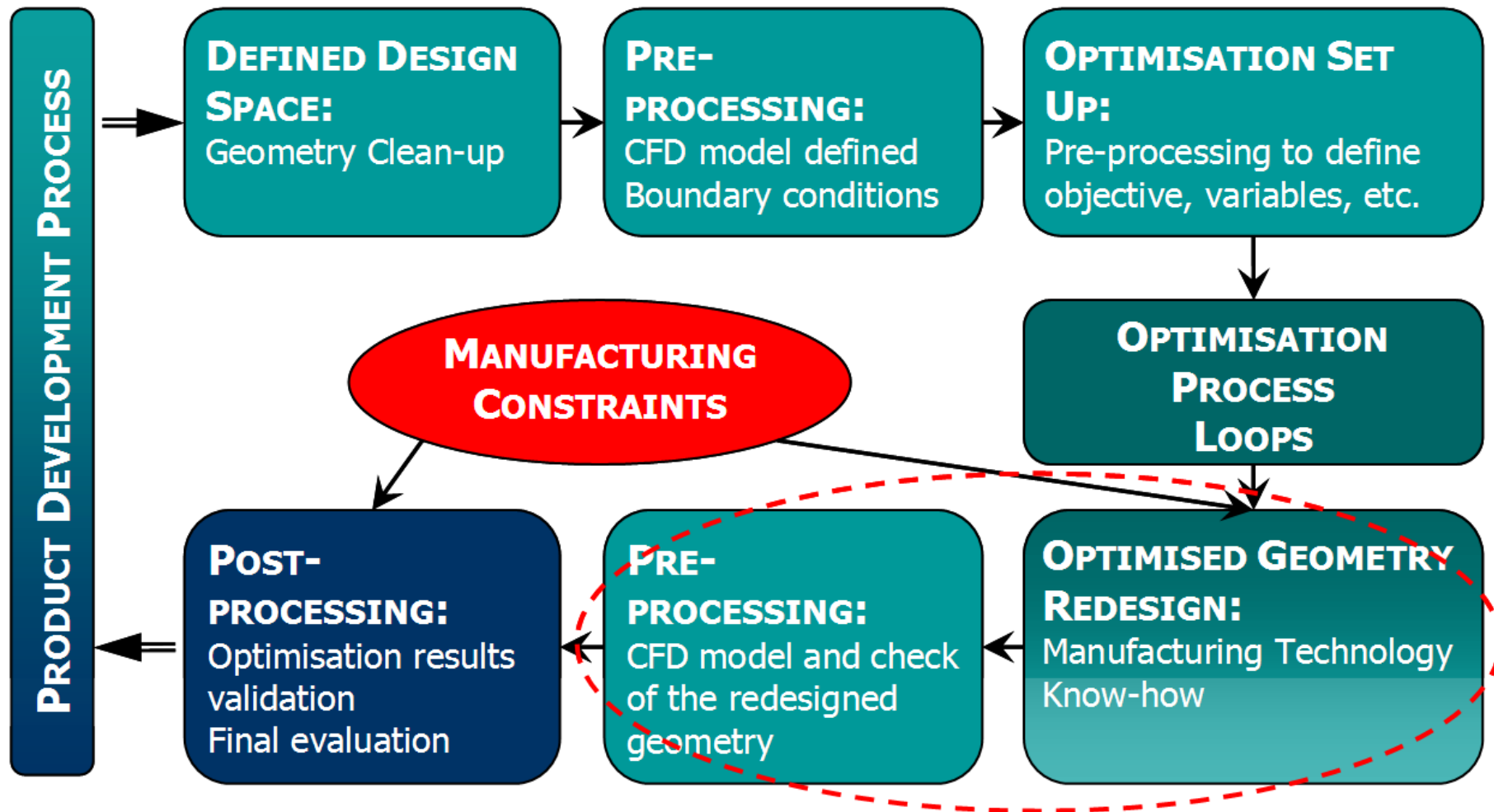
a) Design geometry – blast moulded structure; b) Thickness check; c) CFD solution results; d) Draft check

Check of Optimised Design Space



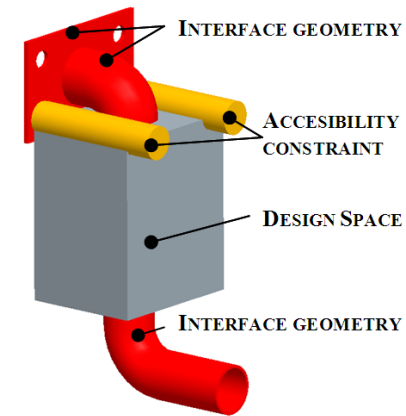
a) Design geometry – blast moulded structure; b) Thickness check; c) CFD solution results; d) Draft check – shadowed zones available

Typical Application of Manufacturing Constraints in CFD Optimisation Workflow



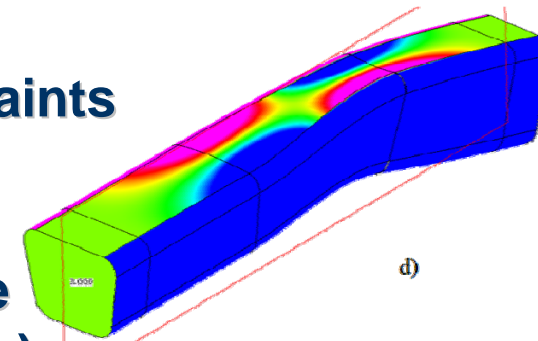
Manufacturing Constraints Implementation in Optimisation Workflow

**Preliminary Manufacturing Constraints
(that influence the initial design space)**

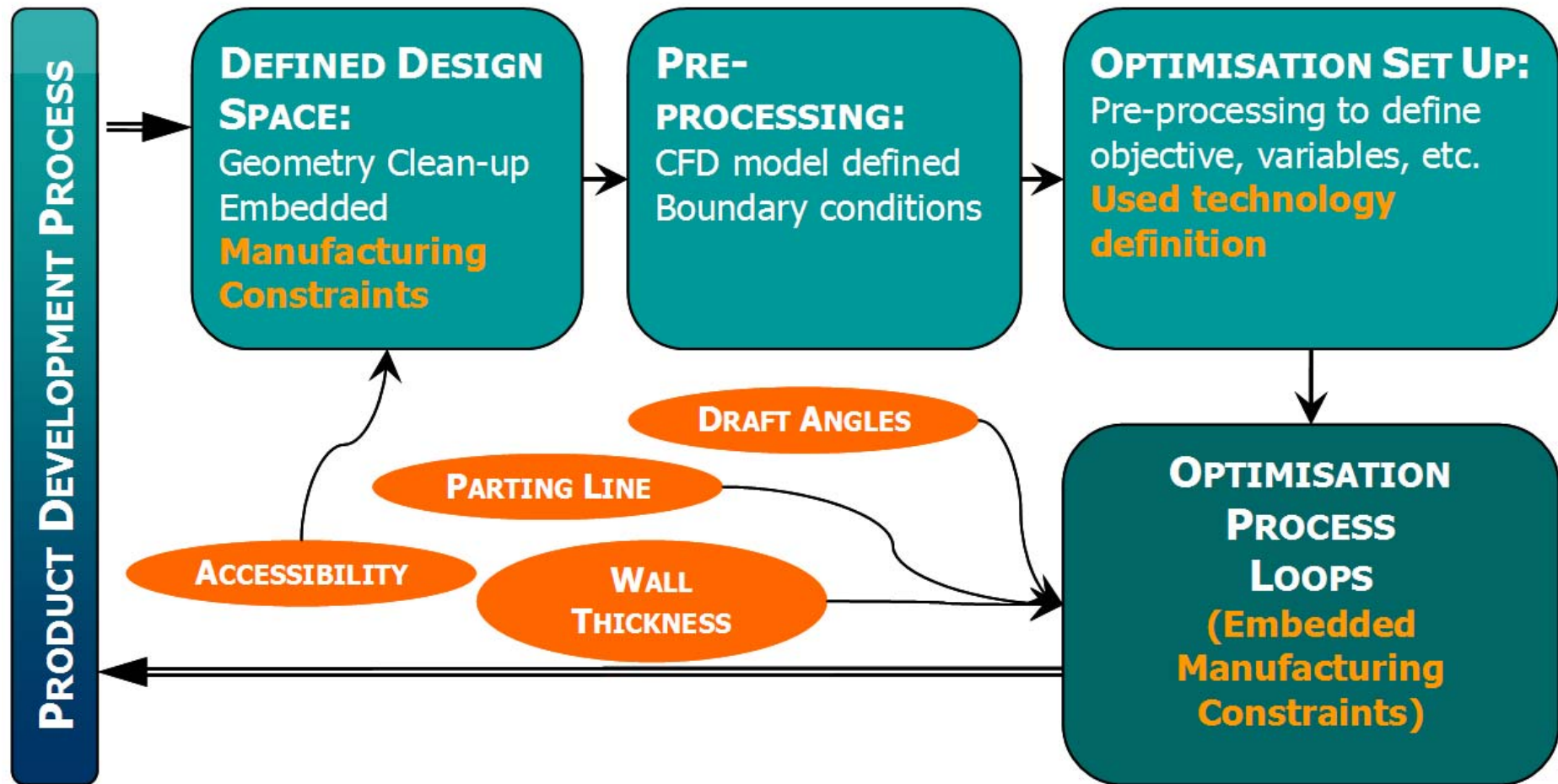


Major groups of Constraints

**Optimisation
Manufacturing Constraints
(that depends on
technology for
manufacturing the
particular geometry)**



Modified CFD Optimisation Workflow – with embedded manufacturing constraints in “Design Space Definition” and “Optimisation Process Loops”



Summary

- A combined approach for PDP to CFD optimisation data interface is developed, based on provided analysis of existing automotive industry PDPs
- Approach verification is performed based on predefined test cases (airduct and side mirror)
- A user-friendly interface, suitable for PDP integration, is developed to enable simple preparation of CFD optimisations – automated assistance of model generation; user-friendly preparations of the optimisations; effective and robust data storage of results, models; compatibility to existing systems;
- A process for the generation of design spaces for CFD topology optimisation based on CAD and/or DMU data is developed;
- Relevant manufacturing constraints are identified and analysed
- General Optimisation Workflow with embedded manufacturing constraints was worked out.

**THANK YOU FOR YOUR
ATTENTION**