Model-Driven Systems Engineering for Virtual Product Design

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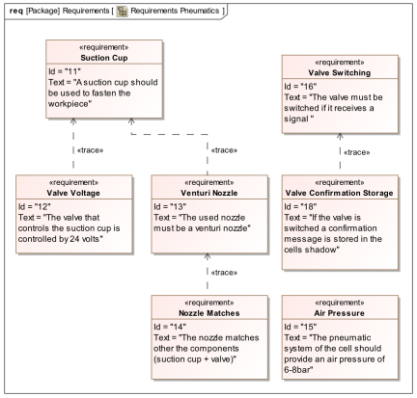
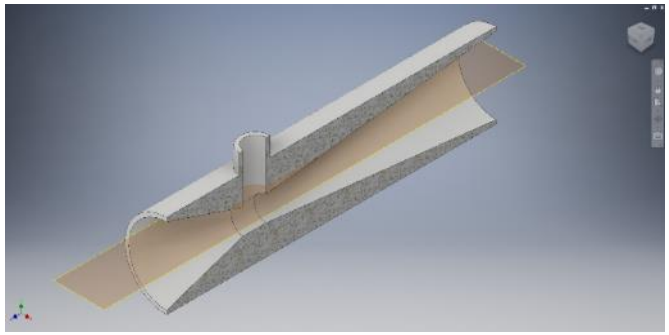
Heterogeneous Models in the Development of CPSs



1. Requirements



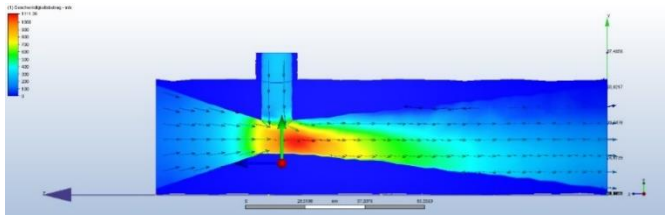
2. Design

$$Q = v_1 A_1 = v_2 A_2$$

$$p_1 - p_2 = \frac{\rho}{2}(v_2^2 - v_1^2)$$

$$Q = A_1 \sqrt{\frac{2}{\rho} \cdot \frac{(p_1 - p_2)}{\left(\frac{A_1}{A_2}\right)^2 - 1}} = A_2 \sqrt{\frac{2}{\rho} \cdot \frac{(p_1 - p_2)}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

3. Analysis



4. Verification

What is MBSE and its Relationship to MDSE?

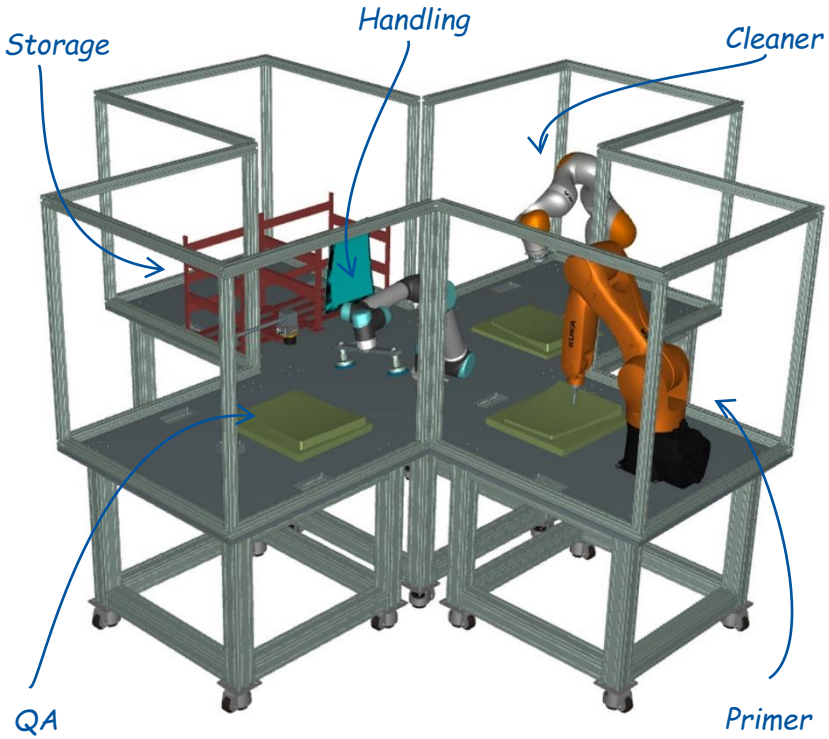
*"**Model-based systems engineering (MBSE)** is the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities […]."*
– INCOSE Systems Engineering Vision 2020 [INC07]

Definition

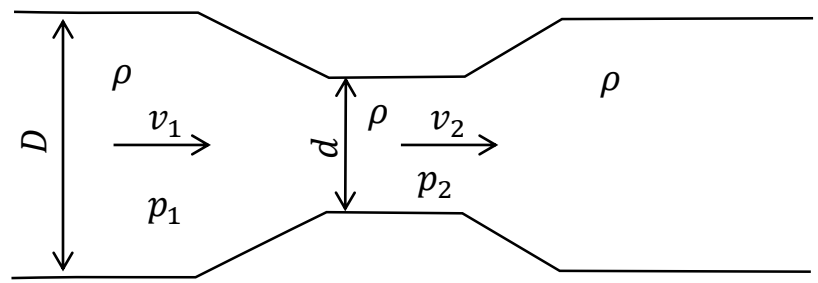
Model-Driven Systems Engineering (MDSE) is a MBSE methodology in which system models are the key artefacts of the engineering process. For that reason, system models created in a MDSE approach must be sufficient to generate (by model refinement or transformation) other descriptions that address system requirements, design, analysis, verification, and validation activities.

[INC07] INCOSE. Systems Engineering Vision 2020, September 2007.

Case Study: ICECAT Demonstrator



Venturi Nozzle



Parameters

- D : Inlet diameter
- d : Compression diameter
- v_1 : Inlet flow velocity
- v_2 : Compression flow velocity
- p_1 : Inlet pressure
- p_2 : Compression pressure
- ρ : Fluid density

Requirements

1. A venturi nozzle should create a vacuum for a suction cup to fixe the car windows
2. The pneumatic system operates with a pressure of 6-8 bar.

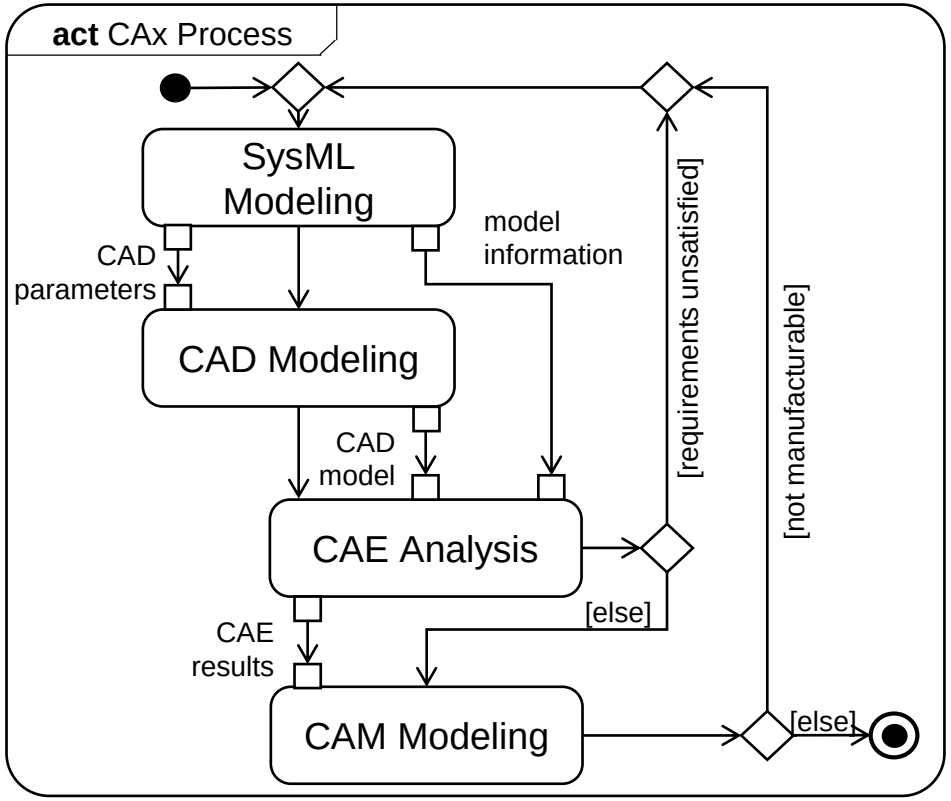
What is Virtual Product Development?

Definition

Virtual product development is a practice to support all phases of the product development process using a digital environment for design, simulation, and manufacturing.

- **Virtual Product Design**
  - Describes: 2D/3D Geometry
  - Model: CAD model
- **Virtual Product Simulation**
  - Describes: Computer simulation based on design model
  - Model: CAE model
- **Digital Manufacturing**
  - Describes: Virtual to “real” product transformation
  - Model: CAM model

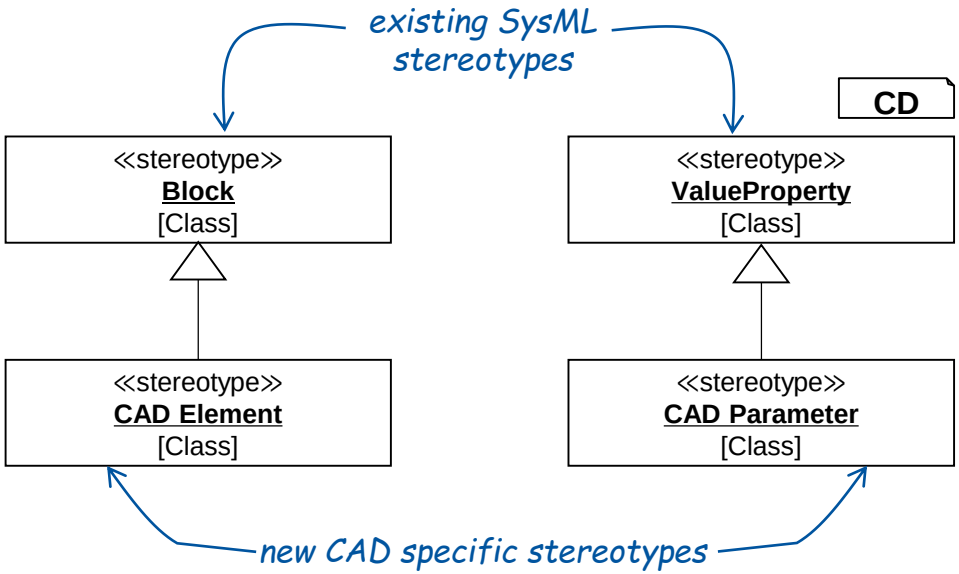
Virtual Product Development as a SysML-CAx Process Chain



- **Activities**
  - SysML Modelling
  - CAD Modelling
  - CAE Analysis
  - CAM Modelling
- **CAx-Process-Chain**
  - CAD-CAE
  - CAD-CAM

⇨ **Missing Link:** SysML-CAD

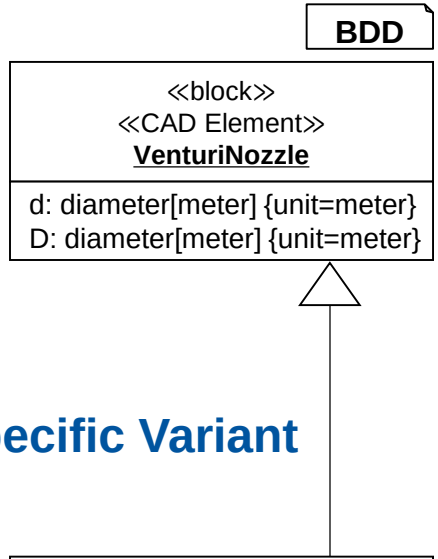
A SysML Profile for a CAD Connection

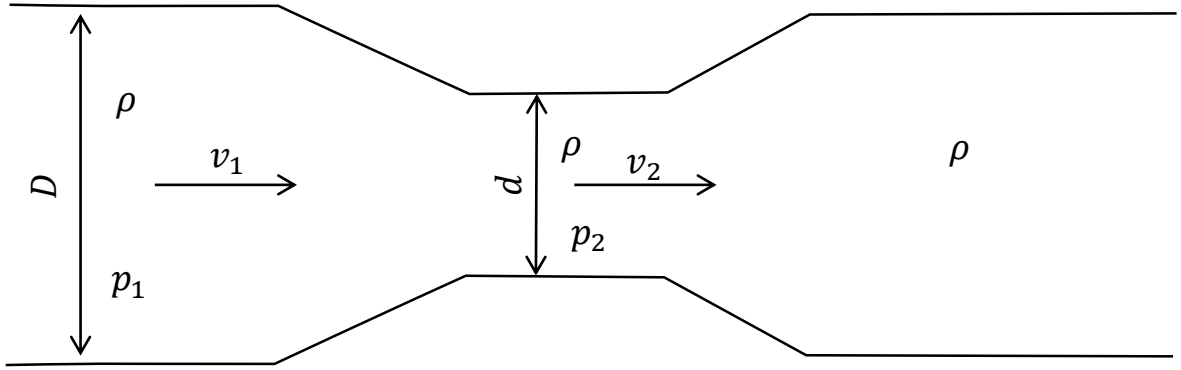


- **SysML Profiles**
  - Extend UML related languages
  - SysML is a profile extension of the UML
- **Concepts**
  - Blocks: CAD Element
  - Values: CAD Parameters
- **Idea:** Model parameters of a parametric design in SysML BDD

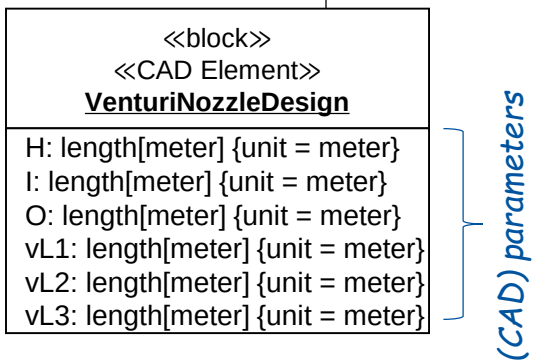
Creating Abstract and Concrete Venturi Nozzle Designs

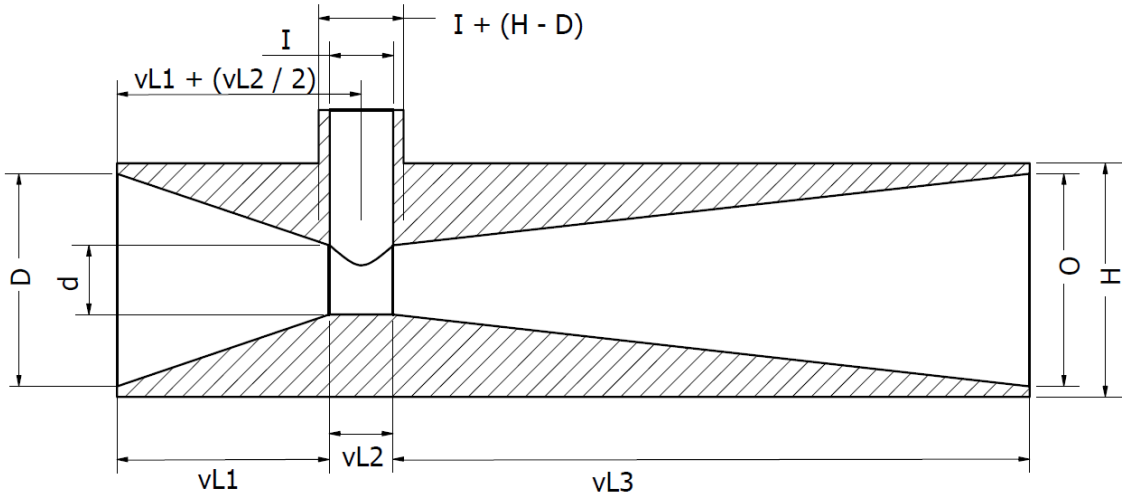
General Solution



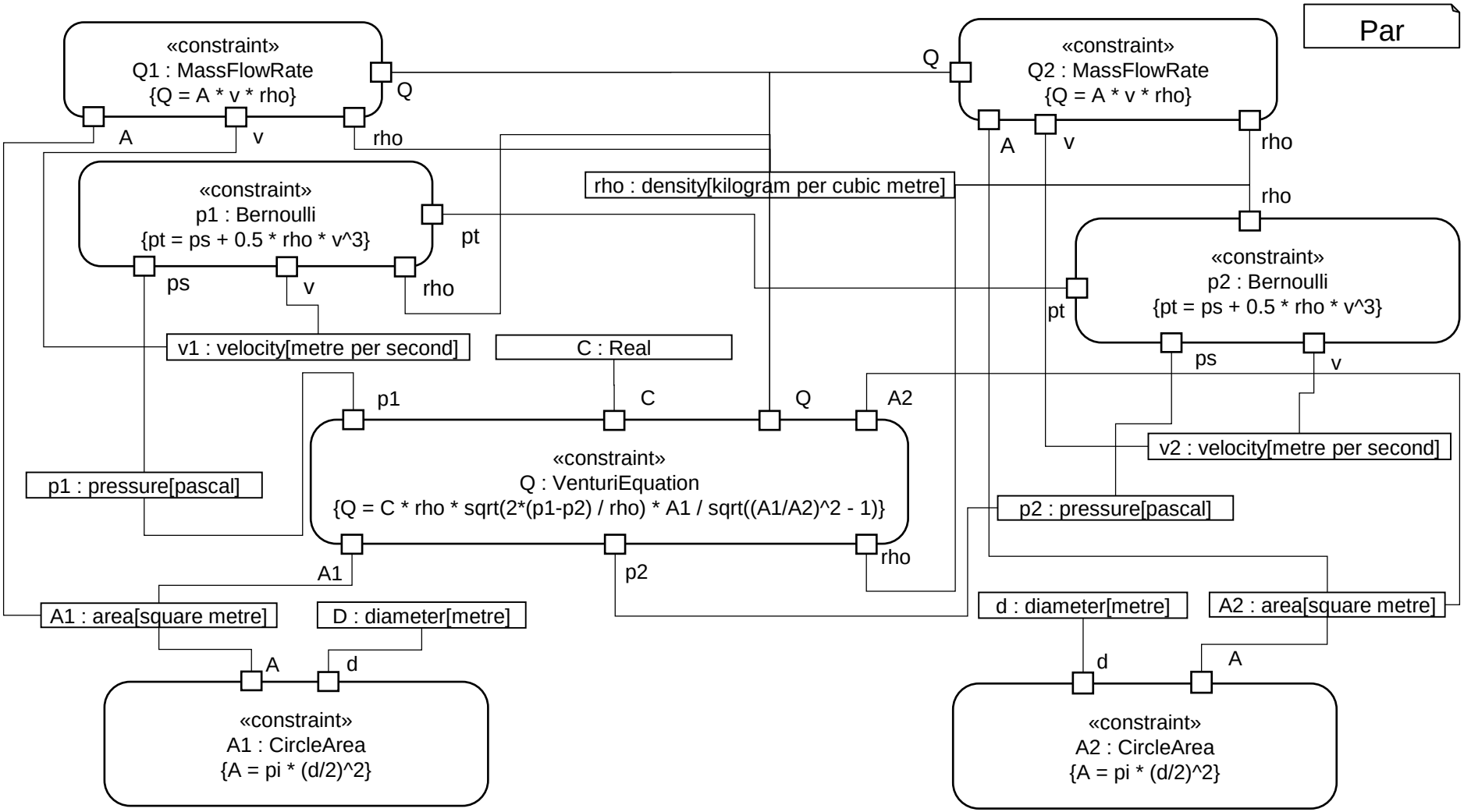


Specific Variant

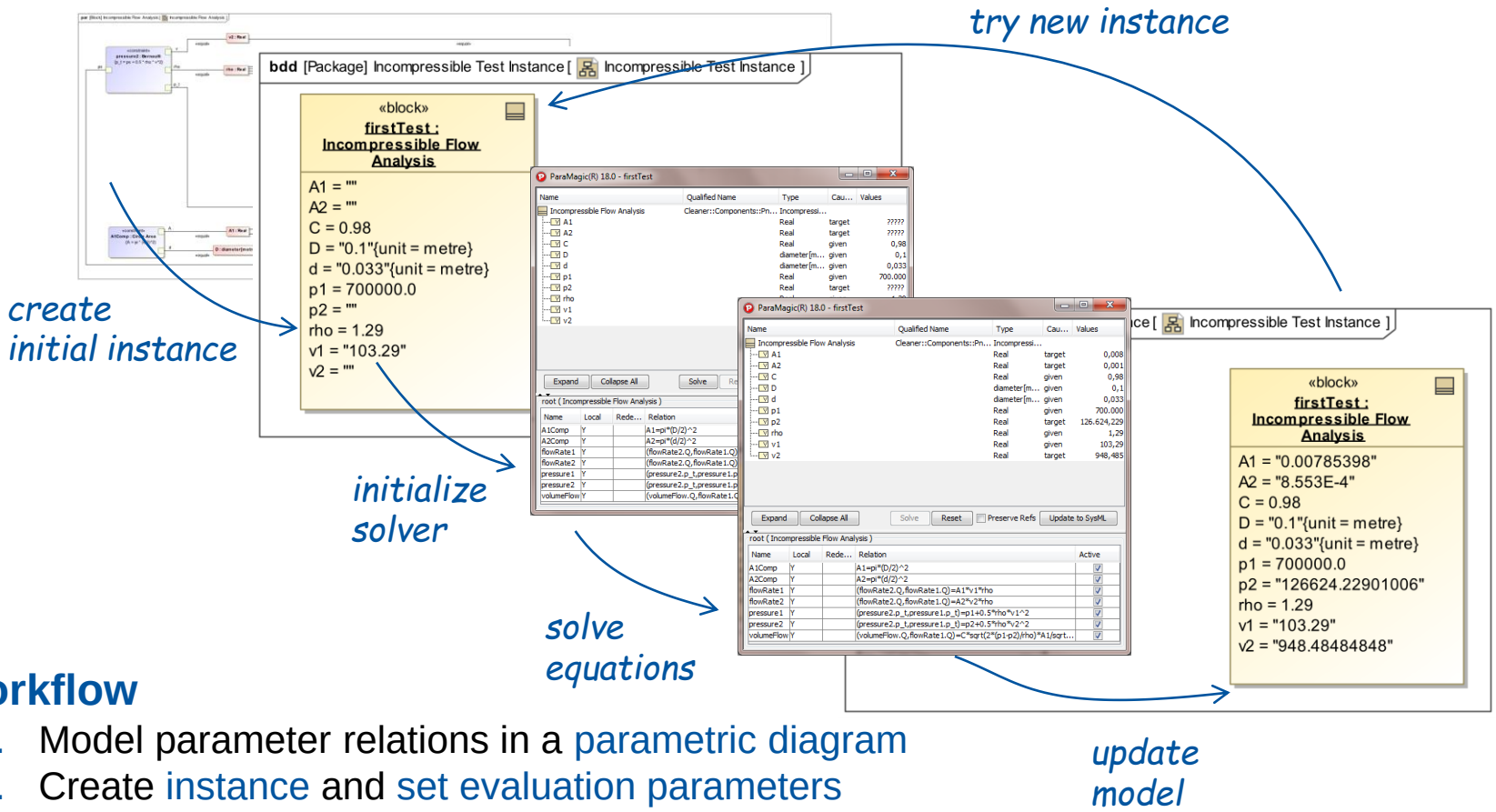




Parametric Diagram of a Flow in a Venturi Nozzle



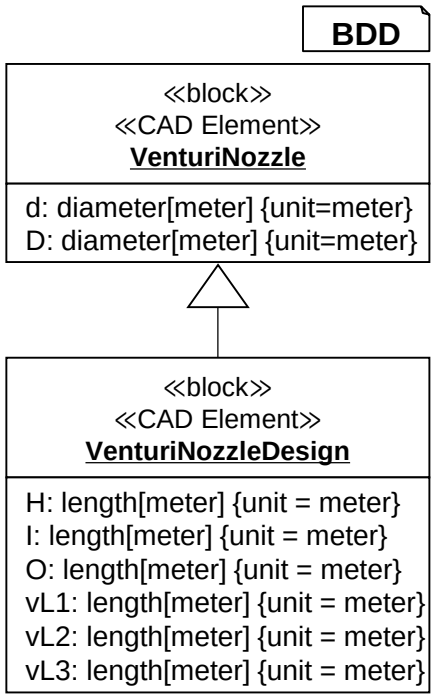
Flow and Parameter Estimation using MagicDraw's ParaMagic Plug-In

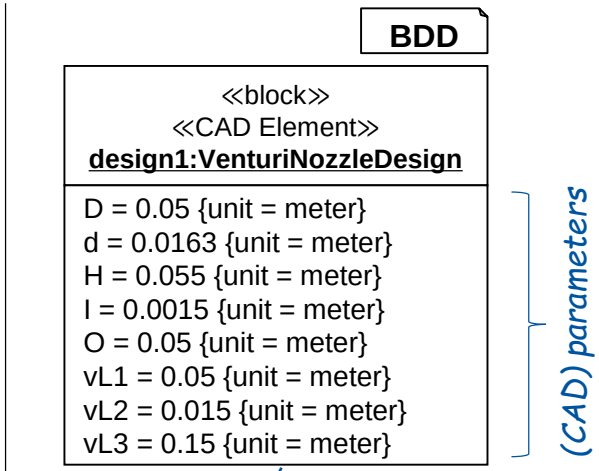


Workflow

1. Model parameter relations in a parametric diagram
2. Create instance and set evaluation parameters
3. Initialize solver
4. Solve equations
5. Update model and repeat until suited solution was found

How to Generate and Excchange CAD Parameters?



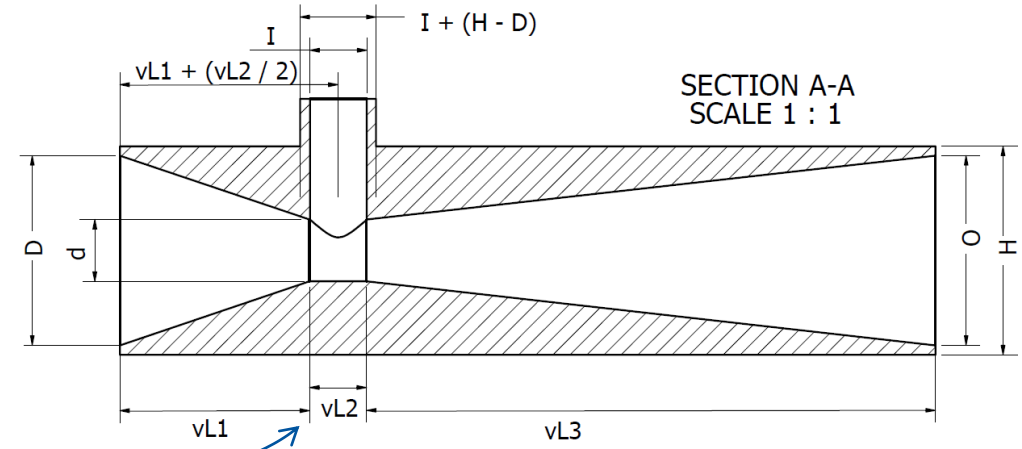


generate parameters

Workflow

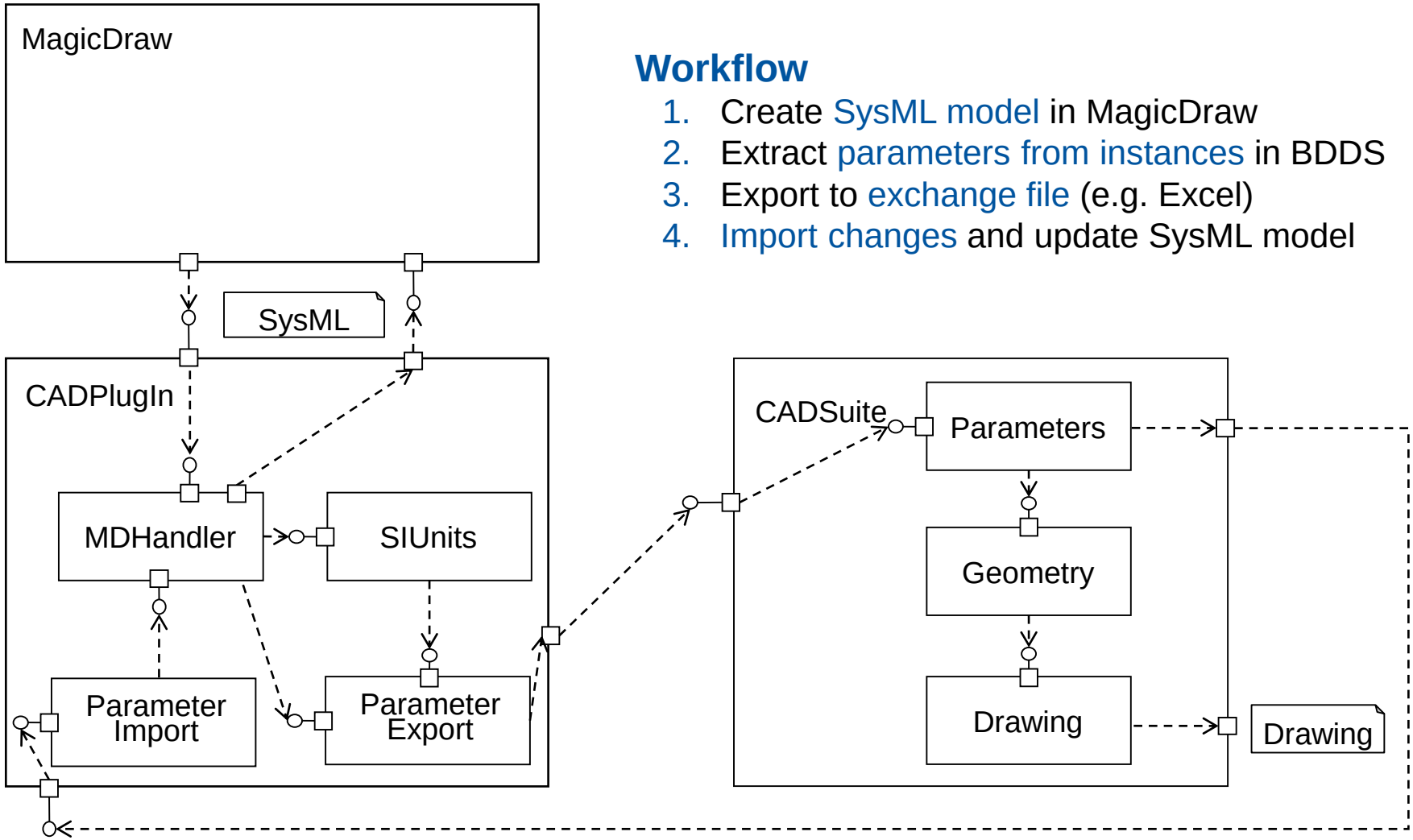
1. Create block instances
2. Generate parameter exchange table
3. Derive dimension for a parametric CAD tool (e.g. Autodesk Inventor)

Name	Value	Type/Unit
D	0.05	m
d	0.0163	m
H	0.055	m
…		



derive dimensions

Parameter Generation Tool: A MagicDraw CAD Plug-In



Workflow

1. Create SysML model in MagicDraw
2. Extract parameters from instances in BDDS
3. Export to exchange file (e.g. Excel)
4. Import changes and update SysML model

Conclusion and Outlook

- **Contribution**
  - MDSE Definition
  - SysML-Based methodology for virtual product development
  - SysML-CAD process chain and tools
  - CAD-Profile for SysML

- **Possible future works**
  - SysML support for other CAx process chains
  - Tool support for general engineering in SysML
    - Model reuse (Libraries)
    - Parameter estimation and optimisation using parametric diagrams
    - (Automated) Testing
  - Integration of control software descriptions

Most Relevant Slides

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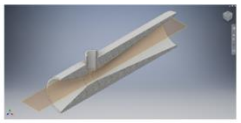

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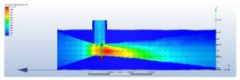

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TODO:ZITAT

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General Solution

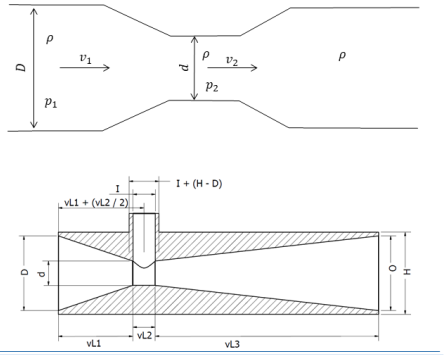
BDD

«block»
«CAD Element»
VenturiNozzle
d: diameter[meter] {unit=meter}
D: diameter[meter] {unit=meter}

Specific Variant

«block»
«CAD Element»
VenturiNozzleDesign
H: length[meter] {unit = meter}
I: length[meter] {unit = meter}
O: length[meter] {unit = meter}
vL1: length[meter] {unit = meter}
vL2: length[meter] {unit = meter}
vL3: length[meter] {unit = meter}

(CAD) parameters



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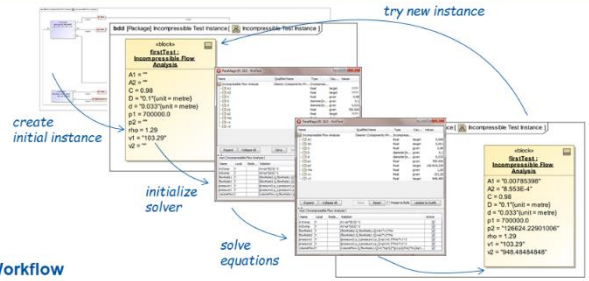

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