ESTECO INTERNATIONAL USERS' MEETING

Scaling Simulation Impact in a Small Team using modeFRONTIER, VOLTA and Runbox

Dr. Kay Schmidt
Cummins Deutschland GmbH

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PUBLIC

Outline

Focus:
Practical, real-world use cases
Rather than system architecture

2 MINUTES
Cummins – Who we are
Insert descriptive text here.

2 MINUTES
MDO Activities in the DTB
Simulation driven doser and pump development

3 MINUTES
Example – Temperature Field Simulations
From Single Simulations to Design Space Understanding

3 MINUTES
Example – Pump Membrane
Insert descriptive text here.

4 MINUTES
Example – Swirl Atomizer Development
A tool to support rapid decision making

4 MINUTES
Example – Pump Suction Performance
Addressing customer demands

2 MINUTES
Summary

Who we are

Powering a more prosperous world

190	**Countries and territories***
67,400	**Global employees**
107	**Years of industry leadership**
13,000	**Cummins certified dealer locations**

** Approximation of countries and territories with Cummins service. As published in the 2025 10K found on cummins.com.*

Five operating segments

Cummins has a long track record of delivering leading power solutions. As we look ahead, we know our industries and regions will continue to change, and we are committed to bringing our customers the right technology at the right time.

Engine

Power Systems

Components

Distribution

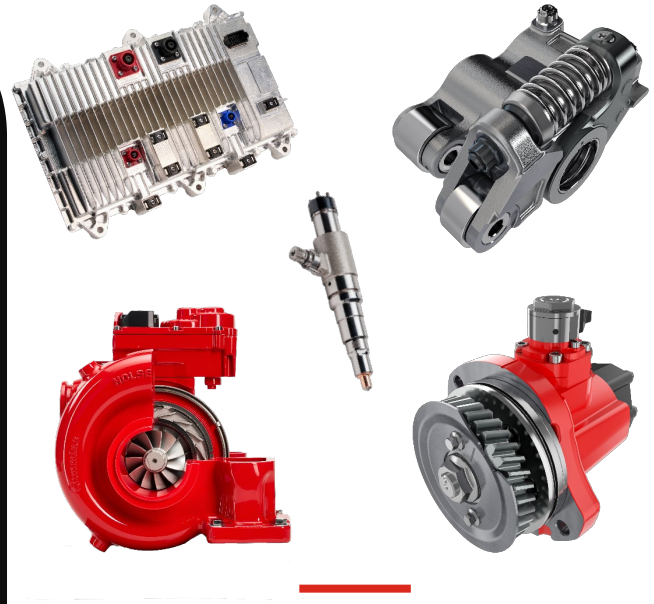
Accelera™ by Cummins

Components of a more powerful tomorrow

Providing dependable powertrain component technologies for today, tomorrow, and beyond

Cummins Emission Solutions

Reliable aftertreatment systems and technologies to meet or exceed emissions regulations and custom integration capabilities for unique challenges



Cummins Components and Software

Leading engine components that deliver reliable software, hardware, air handling, fuel injection, and valvetrain performance – creating custom integrations for complex solutions

Cummins Drivetrain and Braking Systems

Dependable drivetrain systems leading the industry across axles, brakes, suspensions, drivelines, and aftermarket parts.

Aftertreatment solutions

CUMMINS EMISSIONS SOLUTIONS

Leading

Global designer, integrator, manufacturer and distributor of exhaust aftertreatment systems and components

20+ Years of aftertreatment experience

13 Manufacturing facilities

AND

7 Technical centers around the globe

CORE TECHNOLOGIES

Diesel Oxidation Catalyst (DOC)

Diesel Particulate (DPF) Filter

Selective Catalytic Reduction (SCR) System

Doser Technology

Ammonia delivery system

Controls

Thermal Management

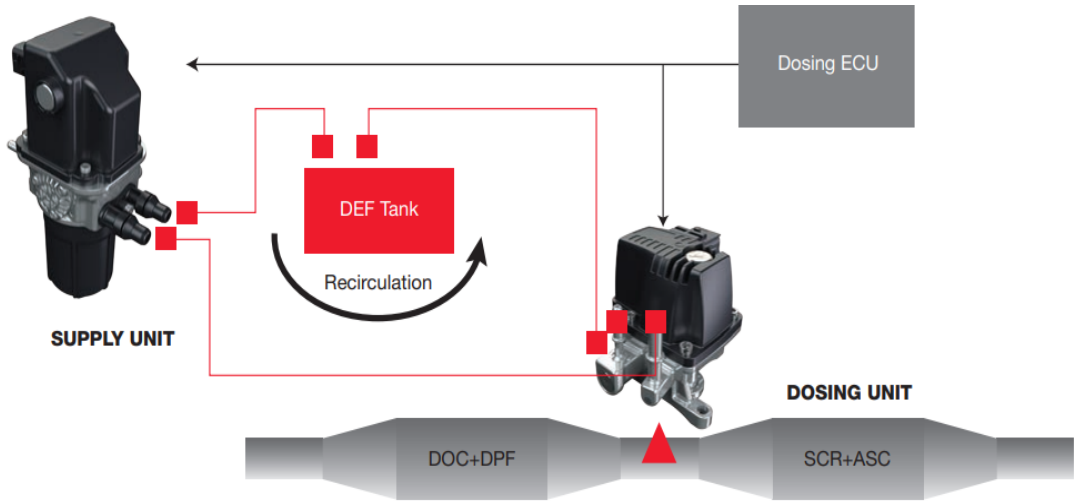
Multiple **integration programs** with non-Cummins OEMs and engine manufacturers

MDO activities in the DTB

Simulation driven doser and pump development

Doser Technology Business

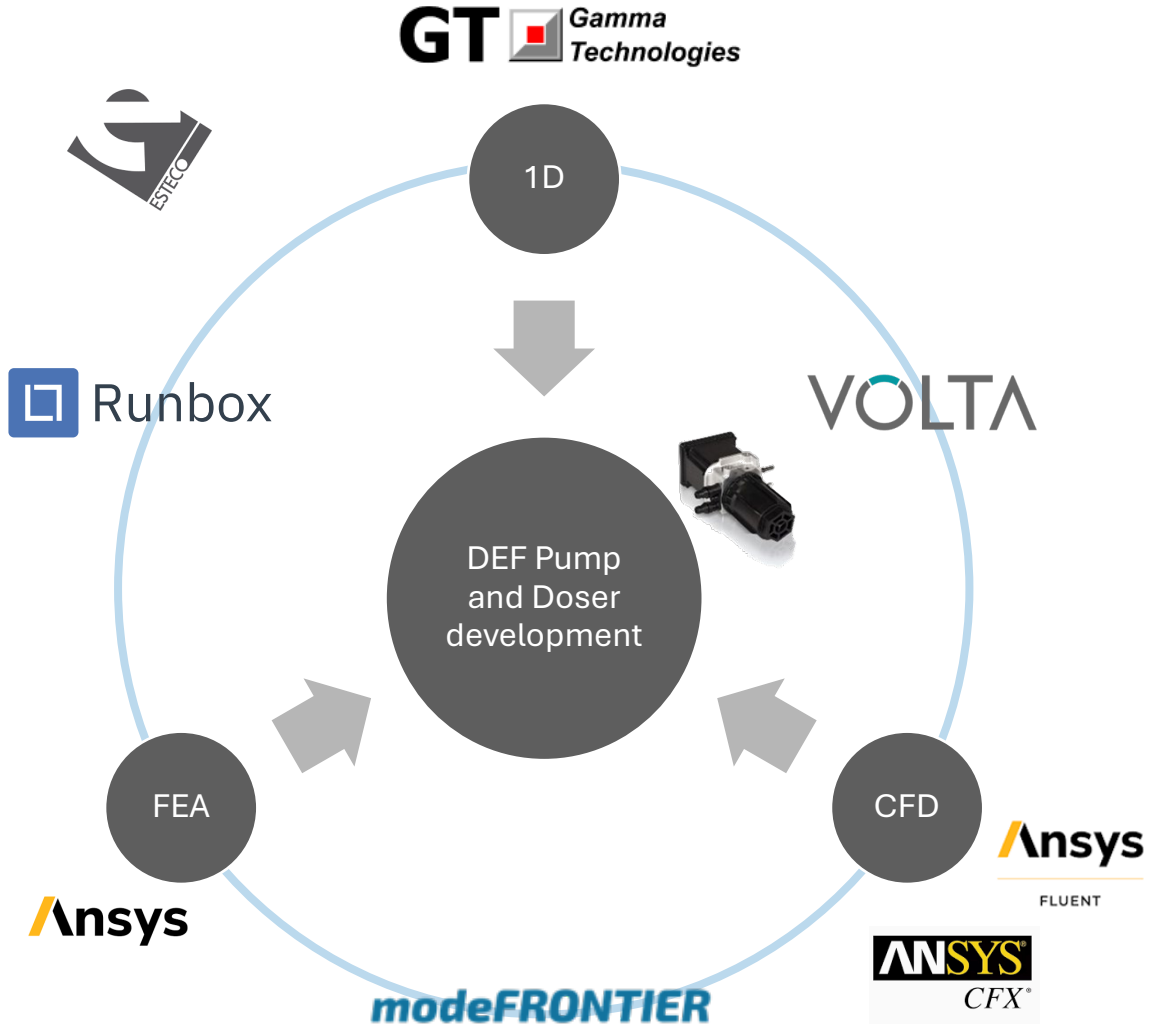
Simulation Driven Product Development of SCR Dosing Systems



SCR Single Dosing System

ASC = Ammonia Slip Catalyst
DOC = Diesel Oxidation Catalyst
ECU = Engine Control Unit

DEF = Diesel Exhaust Fluid
DPF = Diesel Particulate Filter
SCR = Selective Catalytic Reduction



Why automation & democratization are necessary

Effective Support of the design team

AI generated picture

Decision windows are short

Design questions arise early – but expert analysis is usually available too late.

Experts are a bottleneck

Repetitive simulation tasks consume SME capacity needed for method development and validation.

Single results do not support decisions

Designers need sensitivities and trends, not isolated simulation reports.

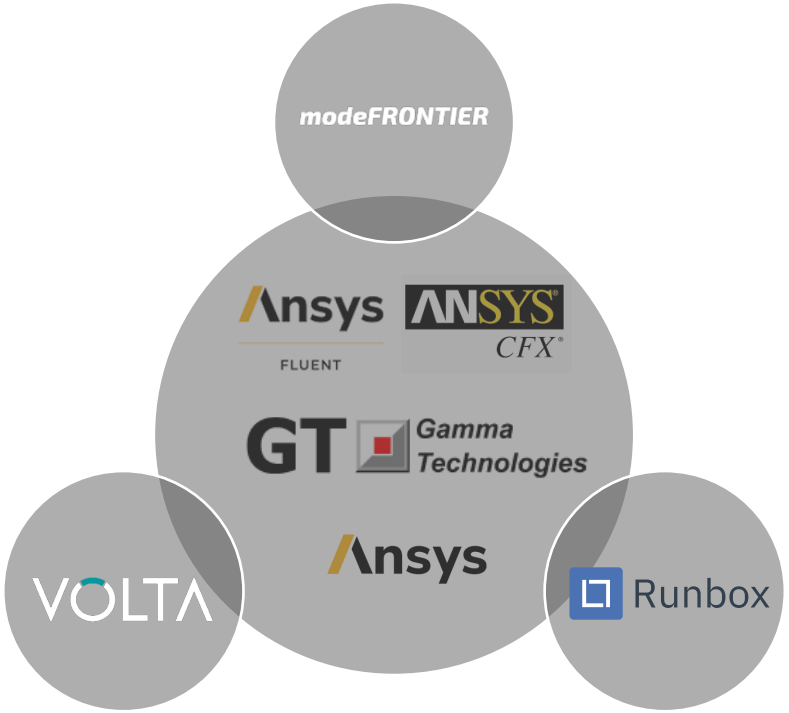
Our approach addresses these constraints – not by simplifying physics, but by restructuring workflows.

How the following examples fit into our framework

Supporting the product development of DEF pumps and dosers

Core Activities

- Multidisciplinary Design Optimization (MDO)
- Workflow Automation & Process Integration
- Coupling of Simulation Models (CFD, FEM, System Models)
- Design Exploration (DoE, Surrogate Models)
- Robust Design & Sensitivity Analysis



Value Creation & Scaling

- Standardized and reusable workflows
- Reduced analysis lead times
- Improved consistency and traceability
- Deployment via VOLTA for non-expert users (Democratization)
- Cross-team availability of analytical methods

Examples will follow

Temperature Field Simulations
Pump Membrane
Swirl Atomizer Development
Suction Performance

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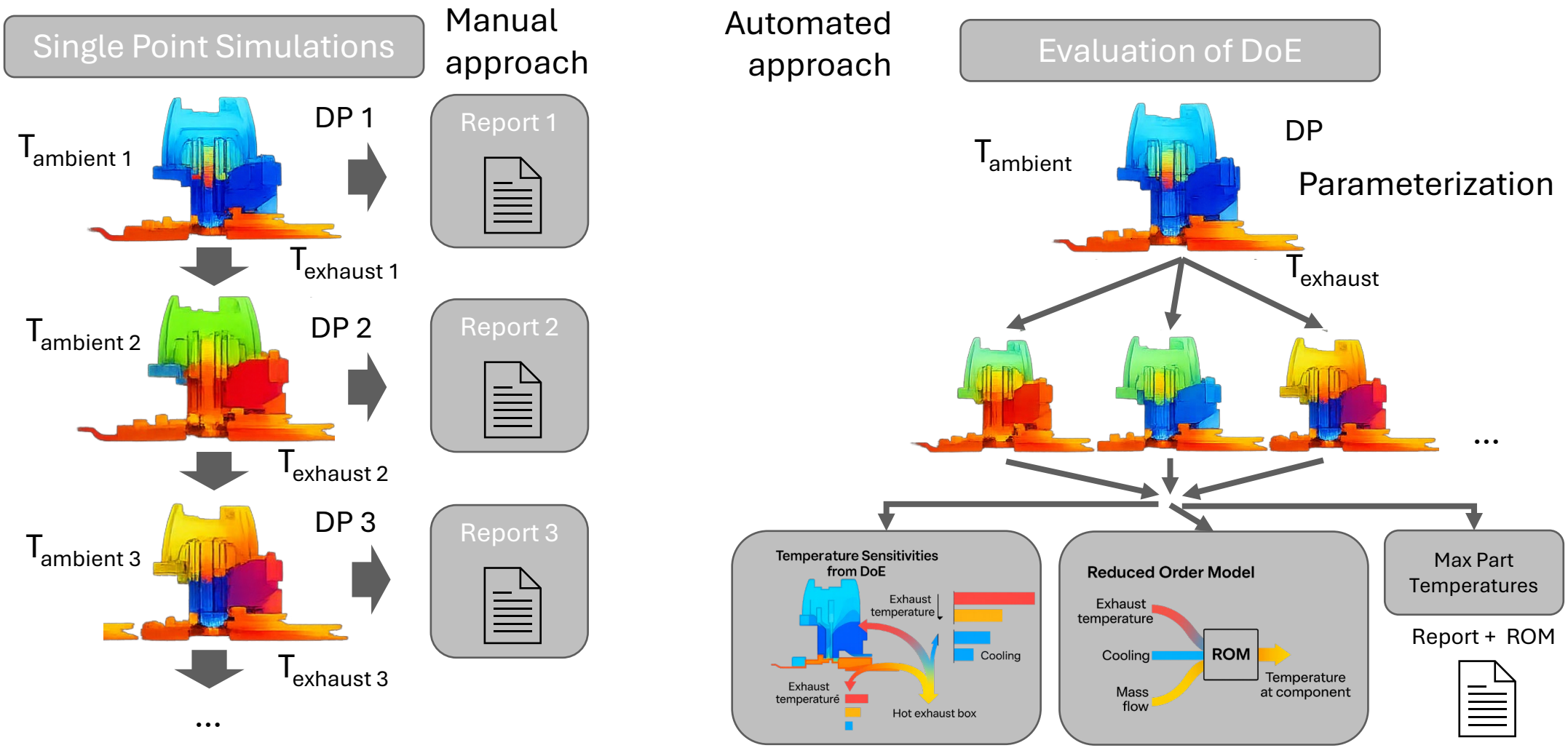
Example – Temperature Field Simulations

From Single Simulations to Design Space Understanding

Temperature Field Simulations

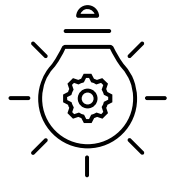
From Single Simulations to Design Space Understanding



Temperature Field Simulations

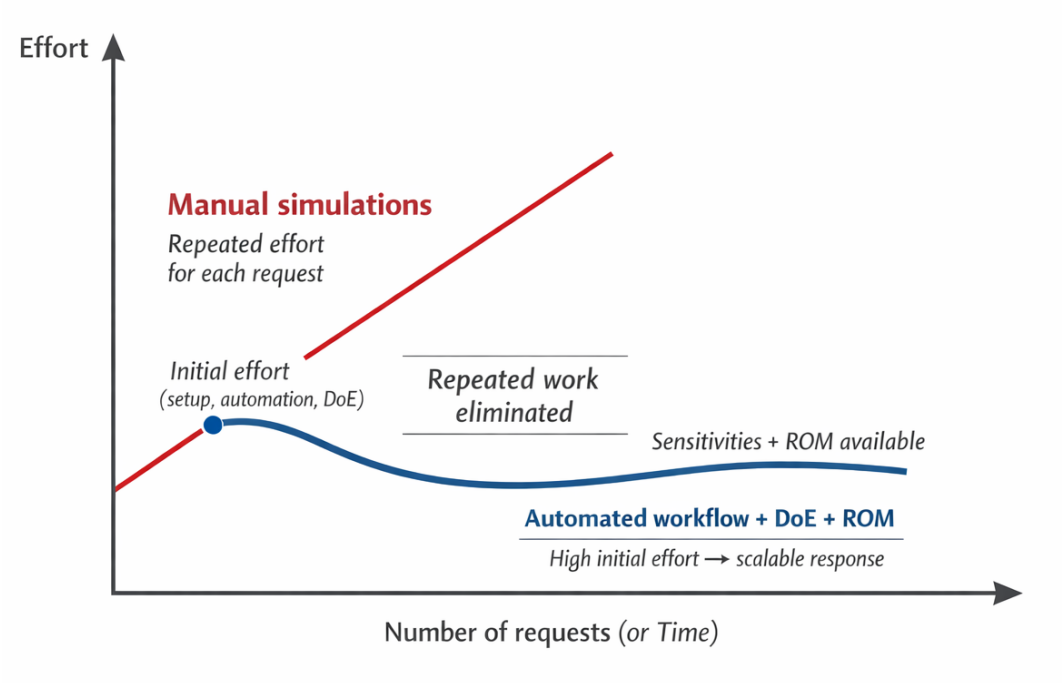
From Single Simulations to Design Space Understanding

Key Takeaways



Key Takeaway – Temperature Field Simulations

- Repeated design questions exposed a structural inefficiency: manual single-point simulations created high effort and slow response times.
- By automating and parameterizing the workflow, we invested more effort upfront – but shifted from delivering single results to providing sensitivities and reduced order models.
- This enabled faster decision-making and eventually reduced the need for direct analyst involvement.



We shifted effort from repeated execution to one-time preparation – and that changed the scalability completely.

Example – Pump Membrane

A tool to support rapid decision making

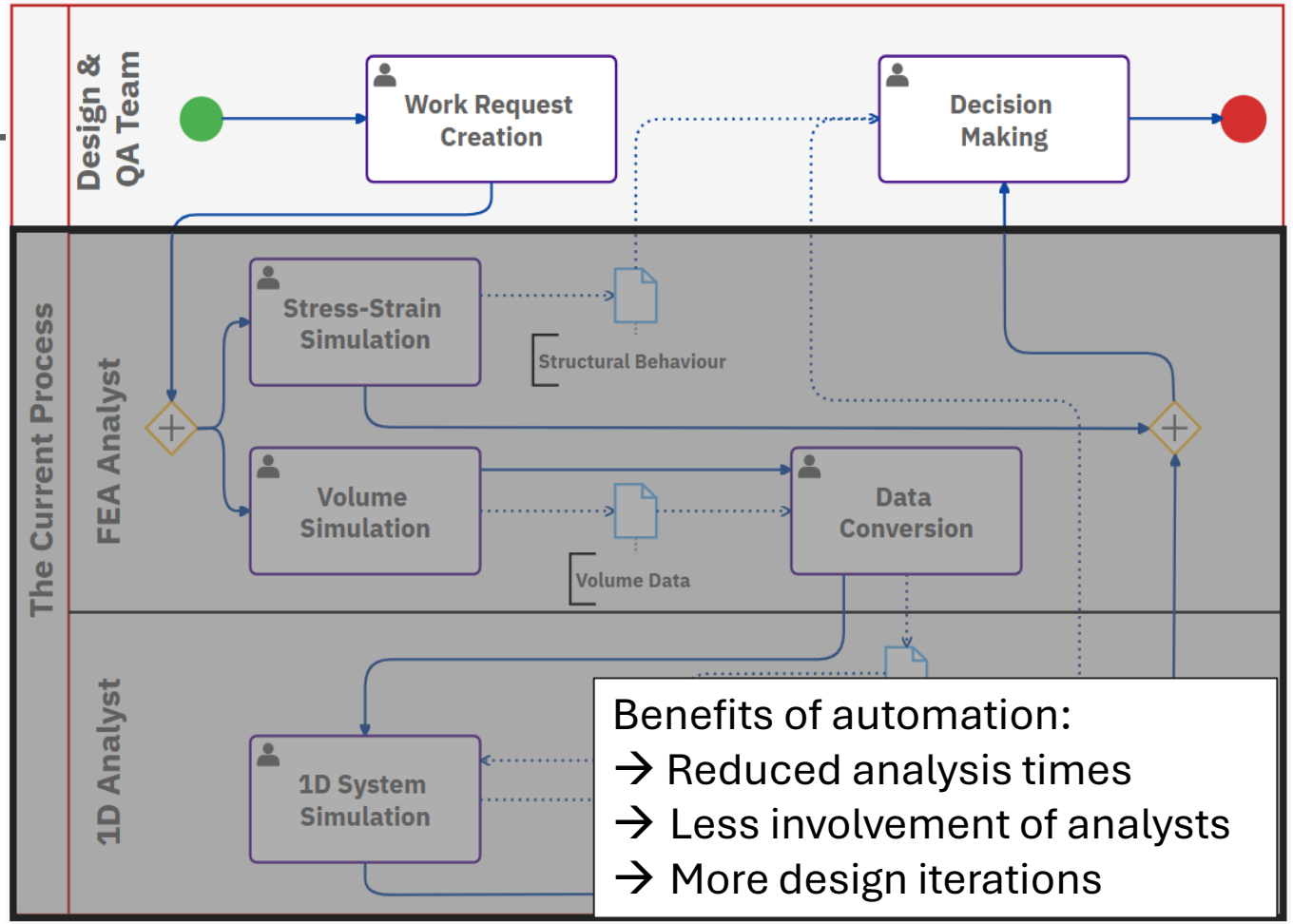
Decision Making Process of a Pump Membrane Design

Workflow before automation and democratization

Current Product Support (CPS) topics:

- Material change
- Supplier change
- Root cause analysis
- Manufacturing problem
- Etc..

DEF Pump Membrane



Benefits of automation:
→ Reduced analysis times
→ Less involvement of analysts
→ More design iterations

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Decision Making Process of a Pump Membrane Design

Automated and democratized workflow

Current Product Support (CPS) topics:

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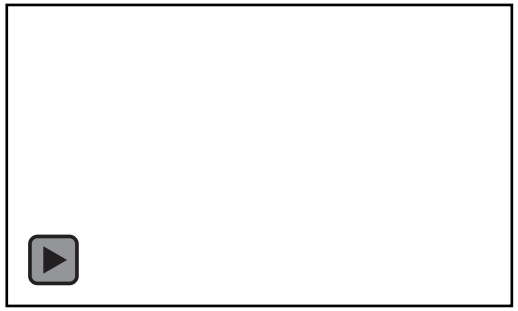
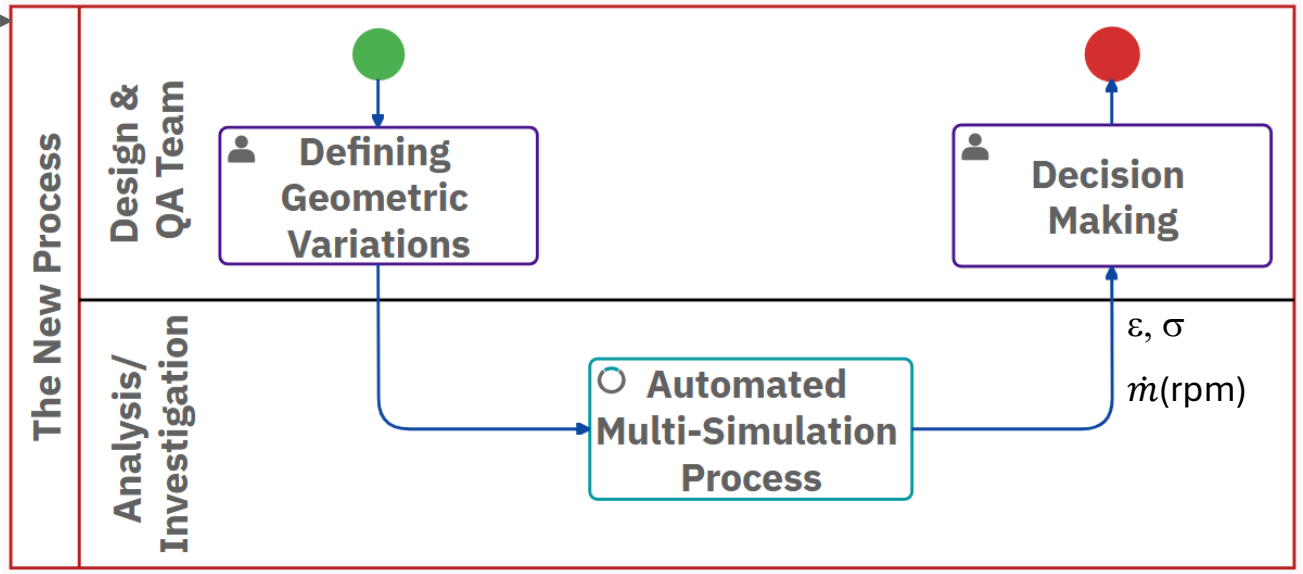
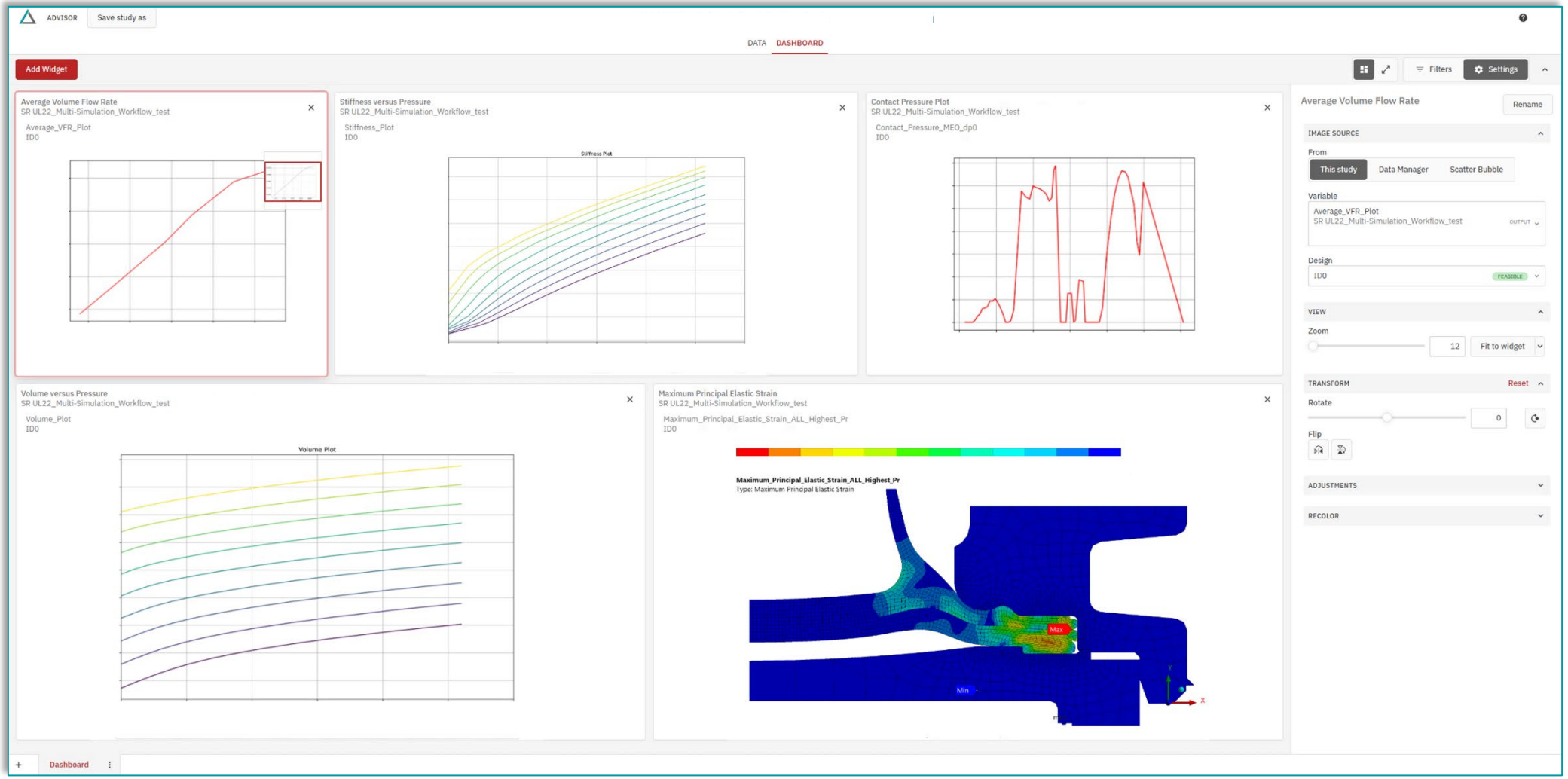
DEF Pump Membrane





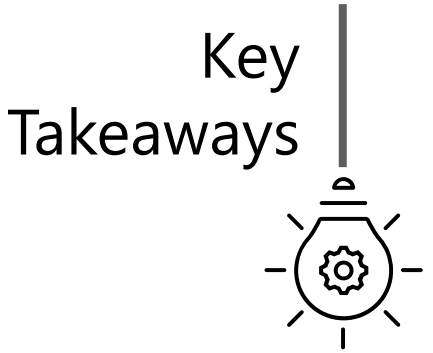
Example - Pump Membrane

Dashboard impression



Decision Making Process

A tool to support rapid decision making



Key Takeaway – Pump Membrane

- The main impact was not faster simulations – but enabling simulation where it previously did not happen.
- By removing the barrier of work requests, engineers can run analyses directly via a simple web interface.
- Simulations that were previously skipped due to effort are now routinely executed in the background.

The key change was not that simulations became faster – the key change was that simulations started happening

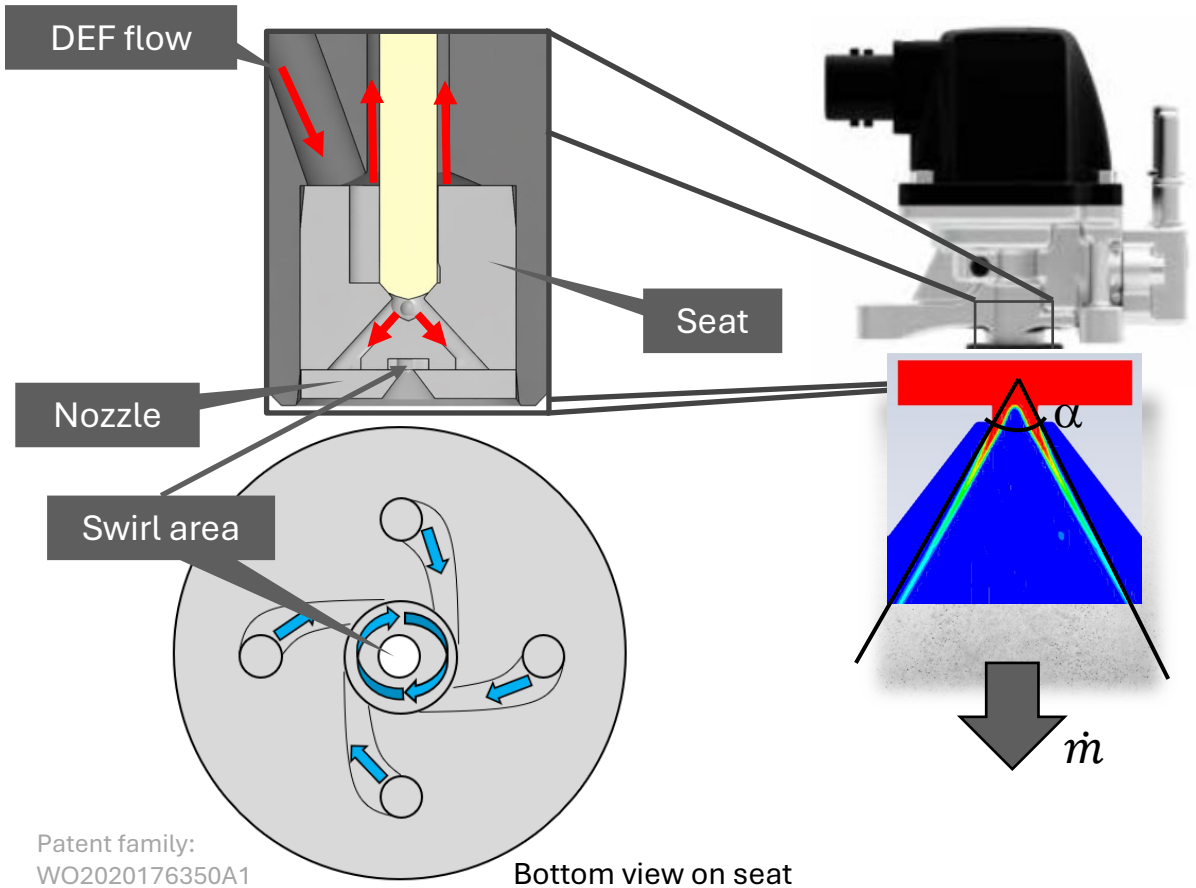
Example – Nozzle Development

From simple to complex with design maturity

Example: Development of a Swirl Atomizer

From simple to complex with design maturity

Detail of CMI Seat and Nozzle



Patent family:
WO2020176350A1

Bottom view on seat

Doser

- Different targets and constraints for each development effort
  - Mass flow rate α
  - Spray/lamella angle $\dot{m}$
  - Droplet size
  - …
- Transition from testing-intensive to simulation-based approach with highly democratized methods
  - Accelerated development
  - Less physical prototype costs
  - Traceability

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Example: Development of a Swirl Atomizer

$\alpha = X \quad \dot{m} = Y$

∞ designs

Business Process Management

3 to 5 designs

1 design

Analytical Design Optimization

3D CFD (low fidelity)

3D CFD (high fidelity)

Testing (Experimental)

Robustness Analysis

Final and Robust Design

$\alpha, \dot{m}$

Design Engineer

Wrapping a Business Process around the workflow helps to improve

- Process
- Task
- Traceability
- Version Control
- Parameterization and automation

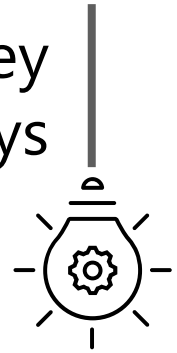
The Design Engineer runs a Simulation Based Product Development Process without directly involving an Analyst. Since 3D CFD is fully automatized and run times are low, a robustness analysis can be launched using MDO tools made available for designers

Use these validated data will receive a final and

VOLTA

Example – Swirl Atomizer Development

From simple to complex with design maturity



Key Takeaway – Nozzle Development

- Increasing simulation maturity enables a transition from isolated analyses to a fully integrated, simulation-driven development process.
- By combining analytical methods, automated CFD workflows and robustness analysis, designers can explore, optimize and validate designs within one consistent framework.
- This establishes simulation as a scalable and reproducible backbone of product development.

This is where simulation stops being a tool – and becomes the process

Example – Pump Suction Performance

Addressing customer demands

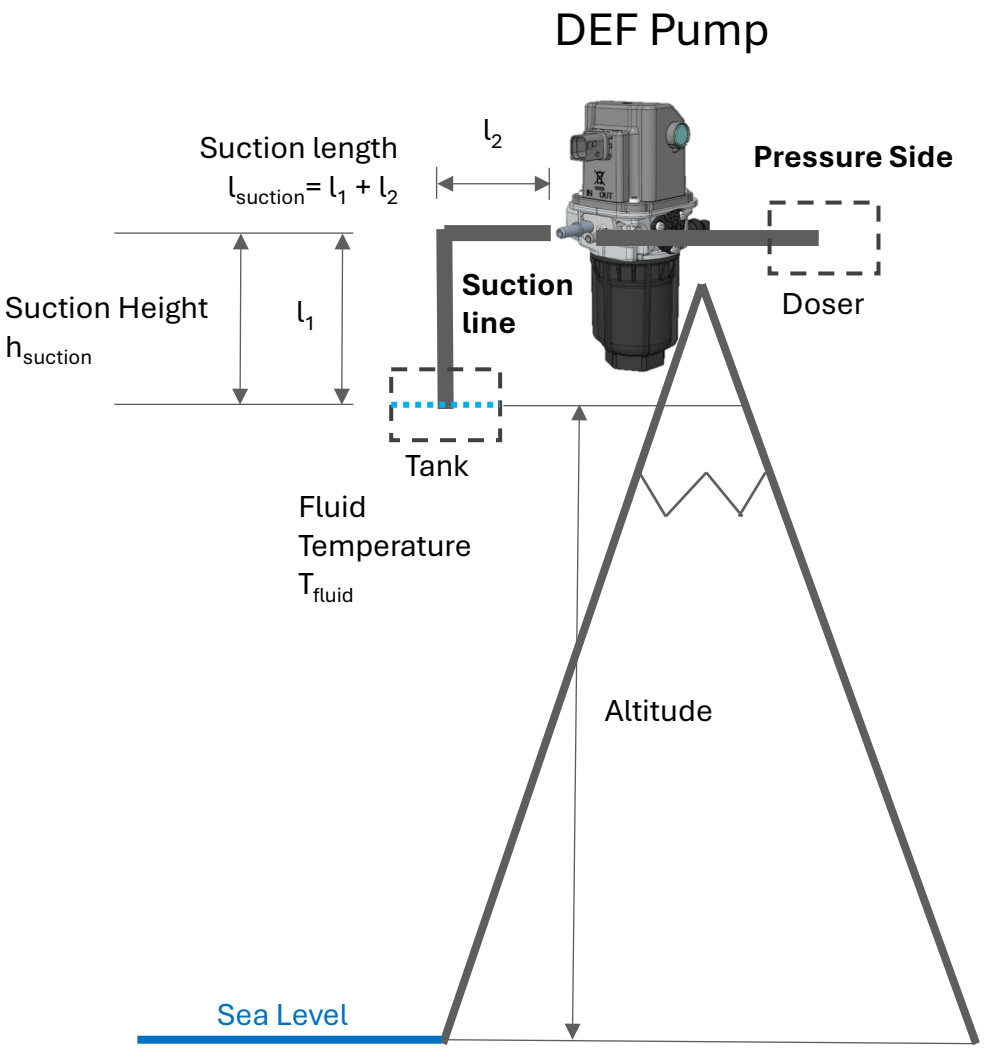
DEF Pump Suction Performance

Project Background

<u>Customer Request</u>
Several clients approached Doser Engineering to assess suction performance in specific (slightly out of spec) applications of our dosing systems. Suction performance evaluation was requested to be evaluated as a function of fluid temperature and altitude for defined suction line configurations.

<u>Challenge</u>
Due to the lack of direct test data, determination was done by manually performed simulations. This process was time-consuming and required multiple individual runs to gather sufficient data for each configuration.

<u>Solution</u>
To streamline the process, we developed an automated 1D simulation workflow. Engineers can now access and execute simulations via a user-friendly web interface, making suction performance estimation more efficient and accessible across teams.



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DEF Pump Suction Performance

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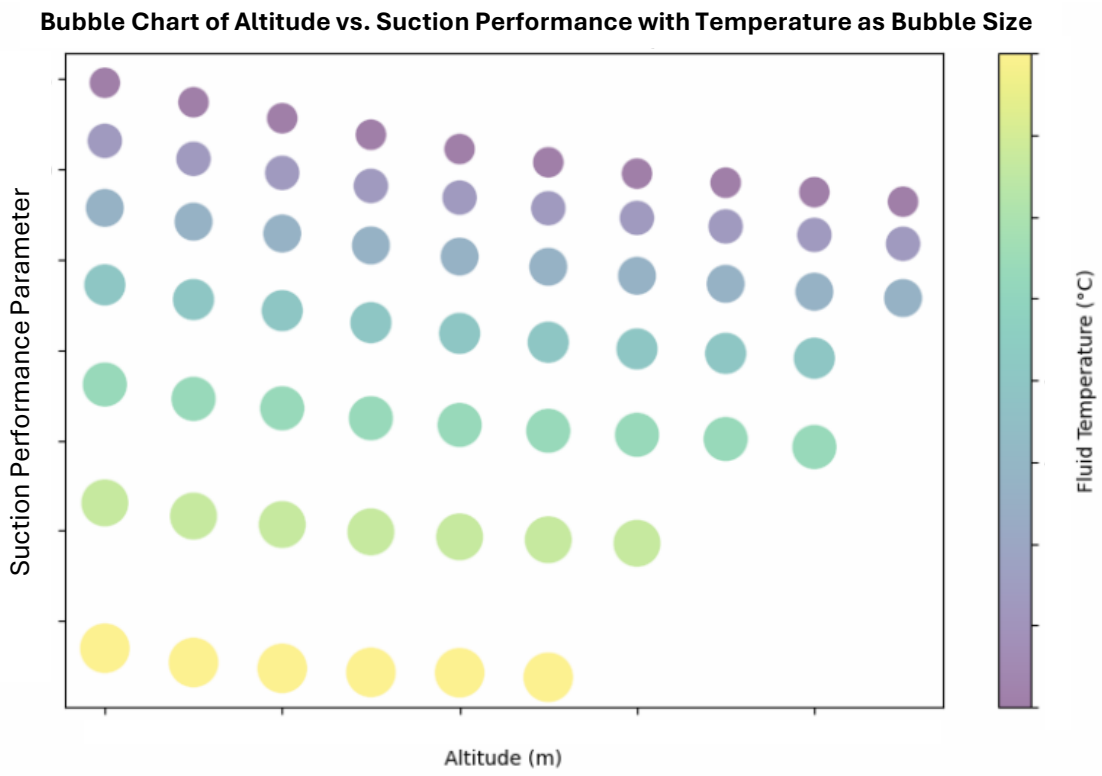
Desired Output for Suction Performance Evaluation



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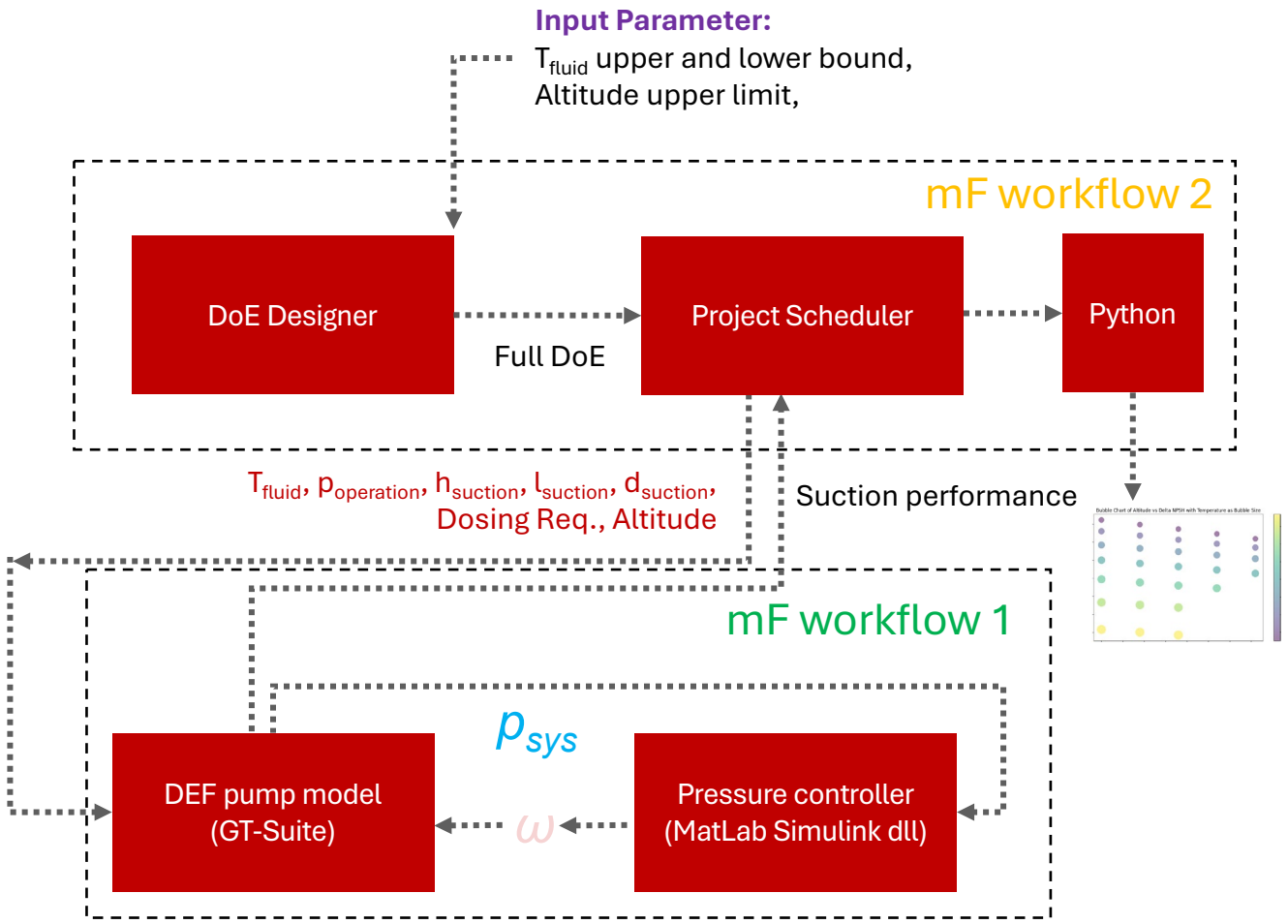
Democratization of Pump Suction Performance

mF Workflow Schematics

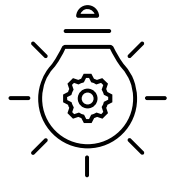
- A modeFRONTIER workflow (1) was developed, which incorporates a pressure controller that maintains a constant system pressure (p_{sys}) by adjusting motor speed.
- This workflow can also compute suction performance based on specified input parameters by determining the minimum pressure within the pump chamber ($p_{pc,min}$) during a pump stroke.
- To create the required graph showing the relationship between the suction performance parameter, fluid temperature, and altitude, a second mF workflow (2) was established, which sets up a DoE based on predefined input limits and parameters and executes all necessary runs.



Example – Pump Suction Performance

Addressing customer demands

Key Takeaways



Key Takeaway – Pump Suction Performance

- Customer-driven requests exposed the limitations of manual, case-by-case simulation.
- Automation transformed these analyses into a scalable and repeatable evaluation process.
- This extends the reach of simulation beyond engineering – enabling teams like customer engineering or sales to generate informed, simulation-based responses directly during customer interaction.

Simulation is no longer something we do for the customer – it becomes something we use with the customer

Summary and Outline

Final Summary

Simulation – The backbone of decision-making

Final Summary

- We moved from answering individual questions to understanding design spaces.
- We enabled simulation where it previously did not happen.
- We integrated simulation into the daily workflow of design engineers.
- We extended simulation beyond engineering into customer-facing processes.

Simulation is no longer a bottleneck …

… – it becomes the backbone of decision-making across the organization.

What about the role of simulation experts?

The Future of Analysts and SMEs

- Automation reduces repetitive analysis work
- But it increases the need for robust models, validation and method development
- Simulation is used by more people, in more decisions, across the organization

We do less manual execution – but we influence far more decisions

Thank you for your attention

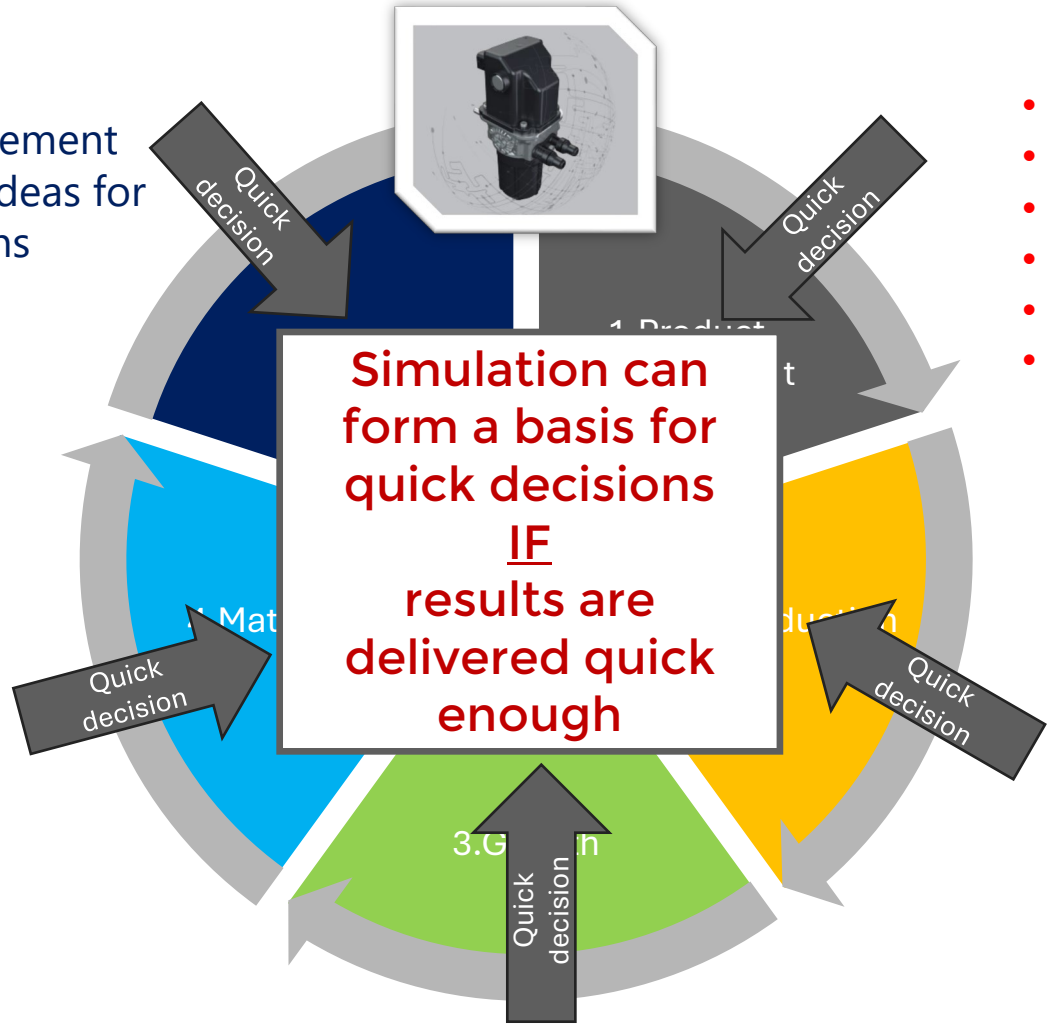
Q+A

kay.schmidt@cummins.com

Appendix

Product Lifecyle – A need for quick decisions

- Cost & Supplier Management
- Generating innovative ideas for new product generations



- Virtual Prototypes
- Design Optimization
- Reduced Development Time
- Cost Savings
- Improved Quality and Reliability
- Optimized Material Usage

- Cost & Supplier Management
- Product improvements

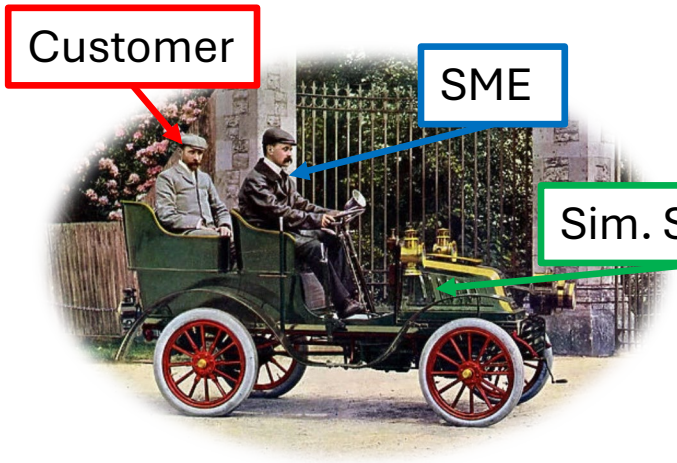
- Quality Assurance
- Cost Management
- Product Robustness
- Etc.

- Opening up new areas of application
- Winning new customers
- Cost & Supplier Management

What about the role of simulation experts?

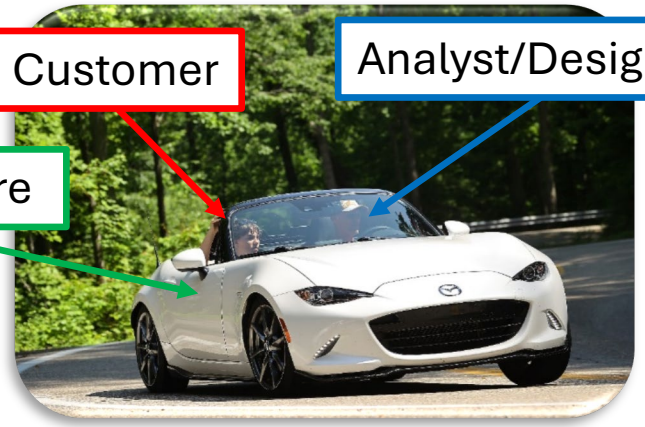
The Future of Analysts and SMEs

Simulation Support



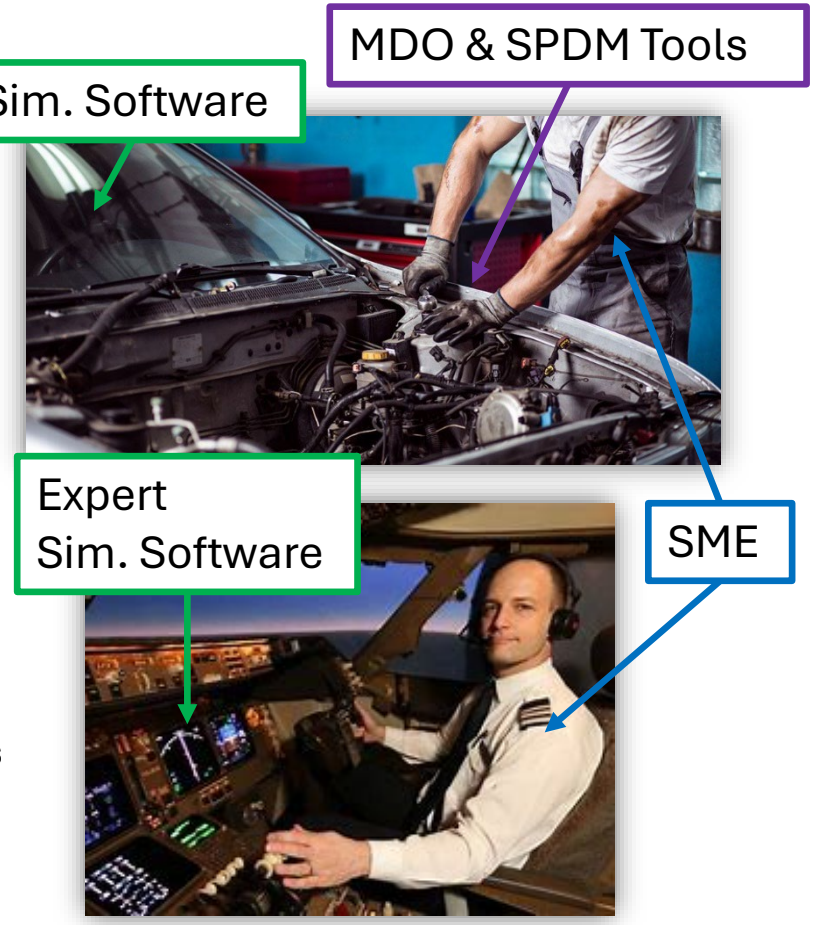
- SME (driver) had to use software (vehicle) that was difficult to use, and power was limited.
- The ride for the customer was a little „bumpy“ and „inconvenient“.

ALD Environment



- Analysts can use powerful software (car is more powerful and easier to drive)
- Customer can also be the driver (Designer)
- „Smooth“ ride for the customer

SBPD Environment



- Analysts/Designer are still the drivers
- SME is the motor mechanic
- MDO & SPDM software equal tools that can modify their vehicle (create easy to use analysis tools)
- SME also able to use expert software