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# Modeling, Simulation and Optimization

## - a process for industrial innovation

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**Fraunhofer**

**CHALMERS**

Research Centre

Industrial Mathematics

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Stefan Jakobsson, PhD

Inovação e Matemática

CIESP Sorocaba, September 16, 2014

# Fraunhofer-Chalmers Centre for Industrial Mathematics

- Founded 2001 by the Fraunhofer Gesellschaft and Chalmers University of Technology
- Offers applied mathematics for a broad range of industrial applications
- Projects defined by companies and public institutes on a commercial basis
- Pre-competitive research and marketing with financing from its founders

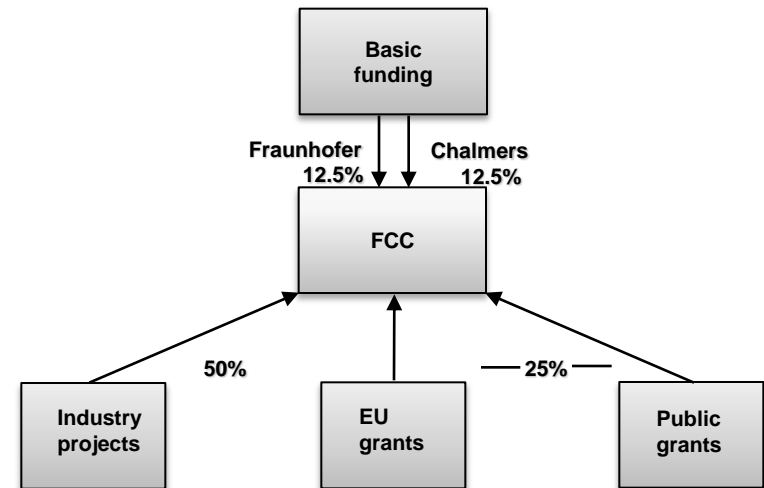
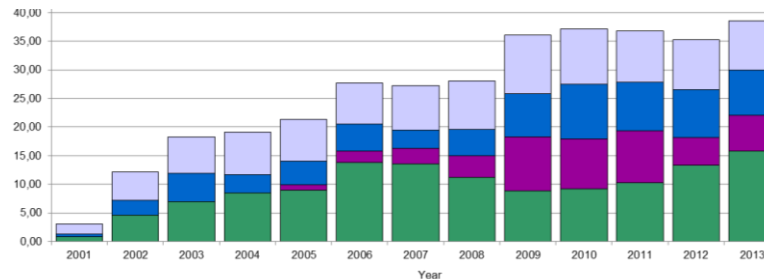


**2001**

**2013**

**4 employees**

**50 full time eq.**



# FCC Departments and focus areas



**Geometry and Motion Planning**

- Automatic Path Planning
- Robotics
- Discrete optimization
- Computer Graphics

The banner features a blue sports car on a reflective surface. Below the title, there is a grid of 18 small portraits of team members and the Fraunhofer CHALMERS Research Centre Industrial Mathematics logo.



**Computational Engineering and Design**

- Fluid Dynamics
- Electromagnetics
- Structural mechanics
- Optimization

The banner shows a complex industrial structure, possibly a refinery or chemical plant. It includes a grid of 18 small portraits of team members and the Fraunhofer CHALMERS Research Centre Industrial Mathematics logo.



**Systems and Data Analysis**

- Systems Biology
- Image and Video Analysis
- Systems, Prediction and Control
- Industrial Statistics and Quality Engineering

The banner features a close-up of a person's face. It includes a grid of 18 small portraits of team members and the Fraunhofer CHALMERS Research Centre Industrial Mathematics logo.

More than 100 clients and 200 projects

- ➔ Short term consultancy projects
- ➔ Tailored software development and training
- ➔ Long term research collaborations

Main focus areas

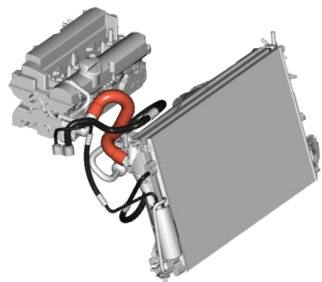
- ➔ Automotive
- ➔ Wood and paper
- ➔ Pharmaceuticals

Upcoming areas

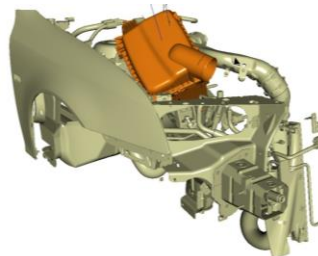
- ➔ Electronics
- ➔ Energy



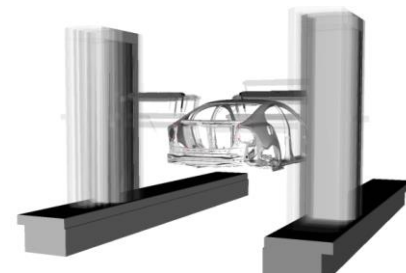
*IPS is a math based software tool for automatic verification of assembly feasibility, design of flexible components, motion planning and optimization of multi-robot stations, and simulation of key surface treatment processes. IPS successfully implements the potential of the virtual world.*



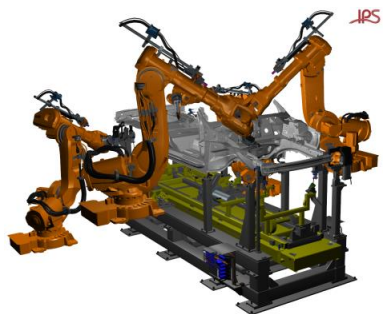
Flexible Structure Simulation



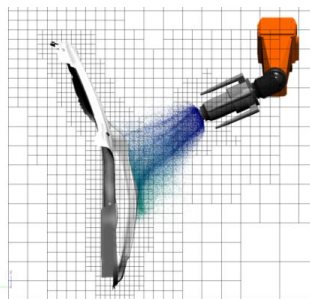
Assembly Path Planner



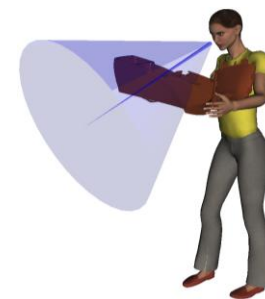
Inspection Path Planner



Robot Path Planner



Virtual Paint



IMMA



# Design and Simulation of Flexibles

- Modern cars are full of cables and flexibles of different properties.
- Many quality problems in the automotive industry are related to flexible parts

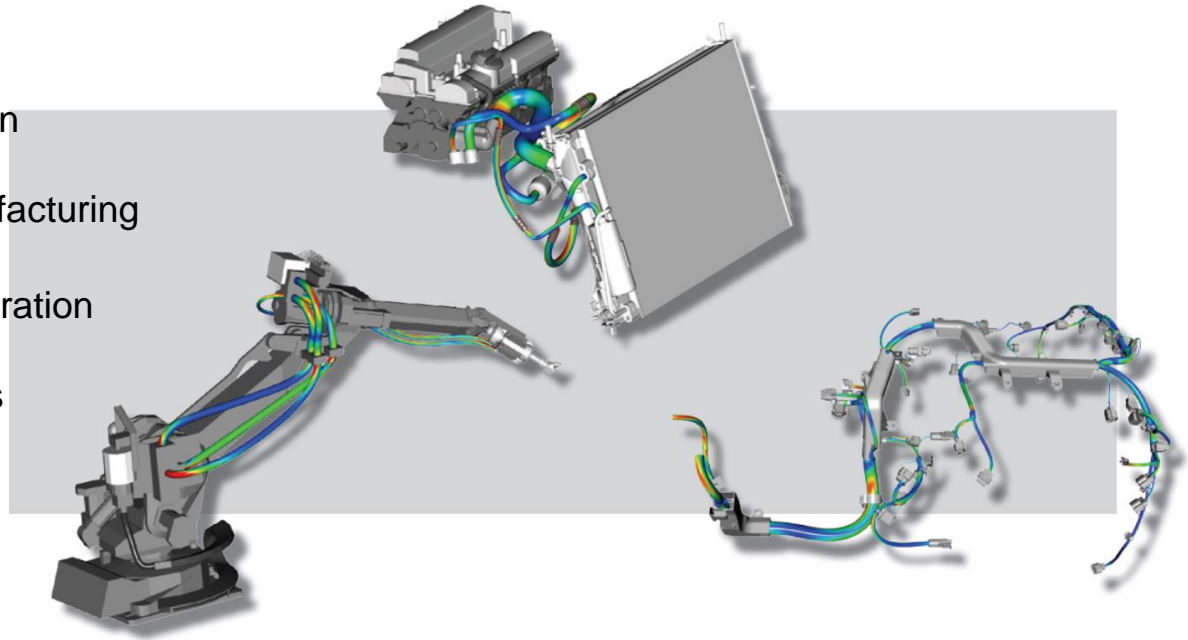
Methods and digital tools for efficient geometrical packing, assembly path planning and analysis of flexible parts

## ➡ Applications

- Engine packing and design
- Robot cable dress pack
- Wiring harness and manufacturing

## ➡ Analysis

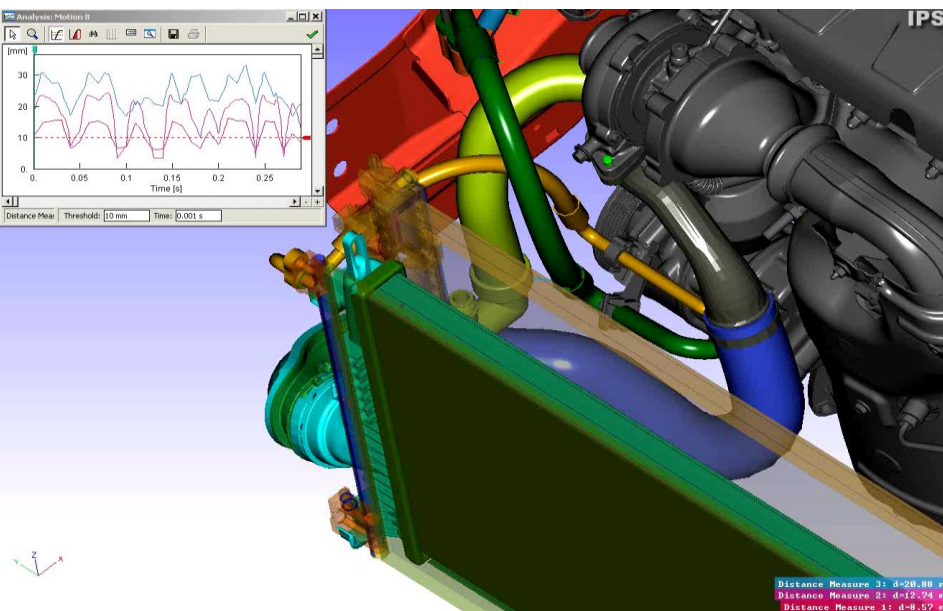
- Stress analysis under operation
- Cable routing
- Shortest distance analysis



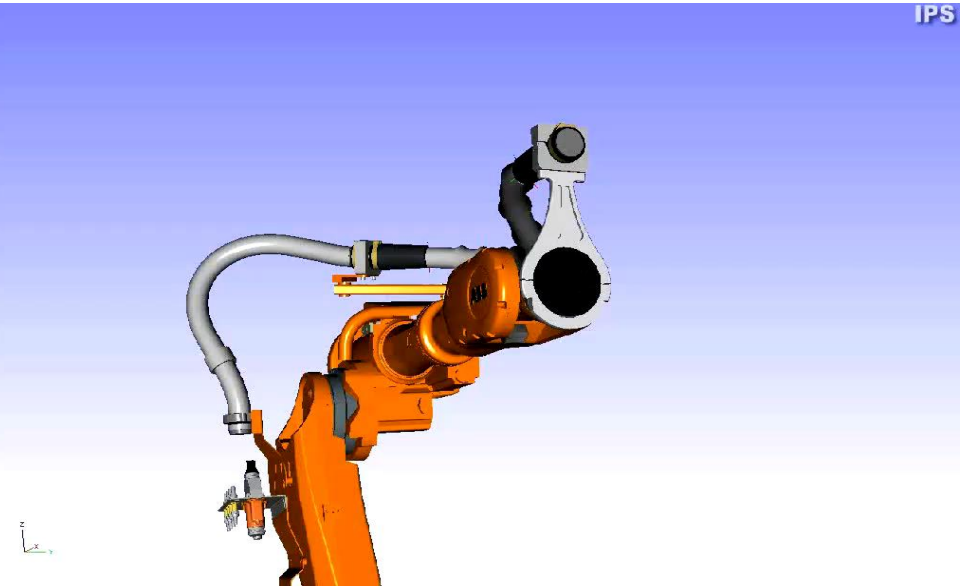
# Simulation of flexible parts:

Cables, hoses, pipes and harnesses

## Shortest distance analysis



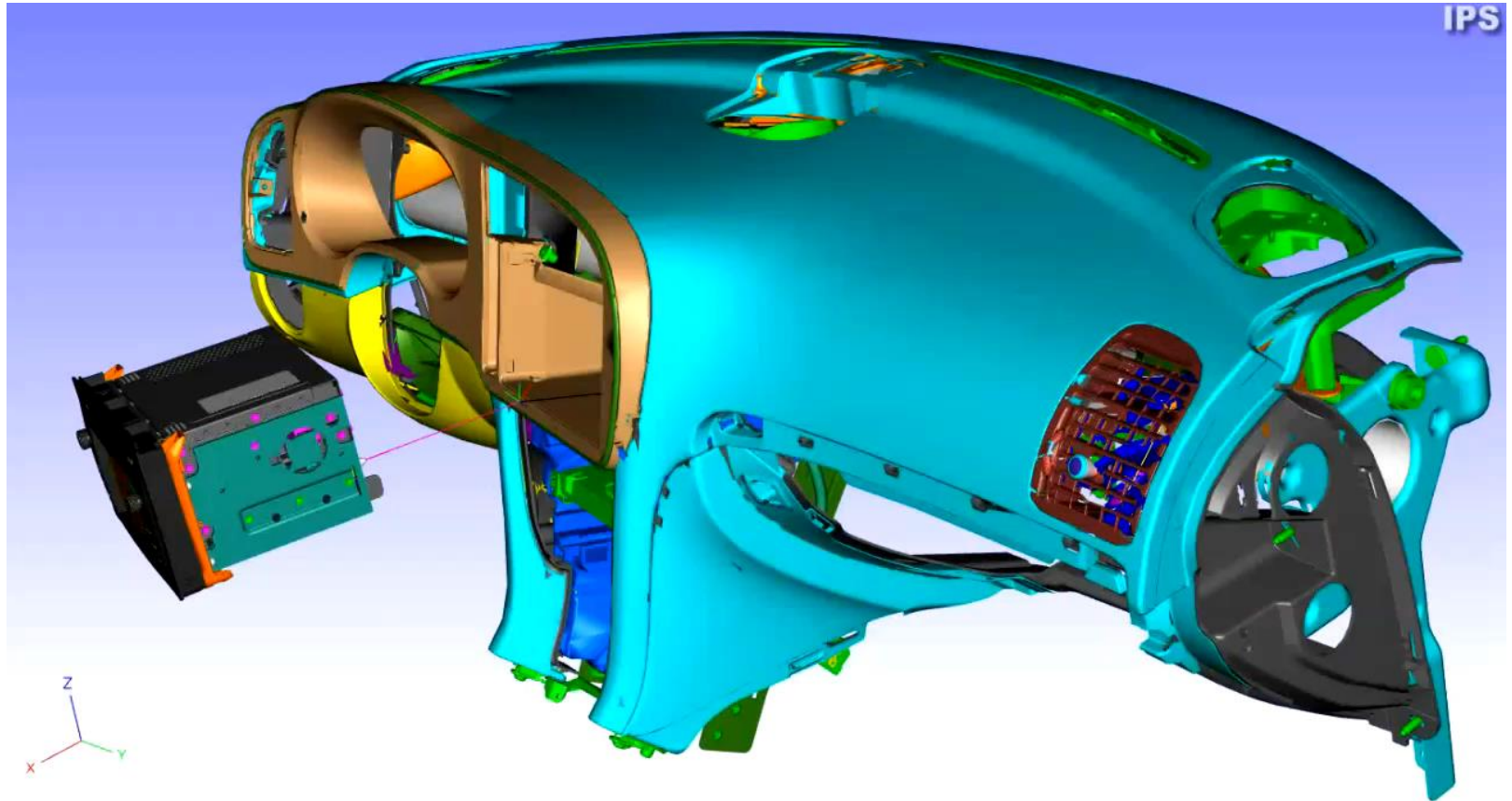
## Simulation of robot cable dress pack





# Simulation of flexible parts and visualization: Mounting of radio

Simulation can help to decide optimal cable lengths and improve mounting procedures to avoid pinching and rubbing of cables.



# Body Window Method:

Does the new car model fit into the old production line?

- Often no blueprint of the production line is available
- The new car model might be larger or of different shape

Car model



Scanned production line



## Solution

- Scan the production line
- Find largest volume that can pass through the paint shop without collisions
- The cutout can then be used to guide early design

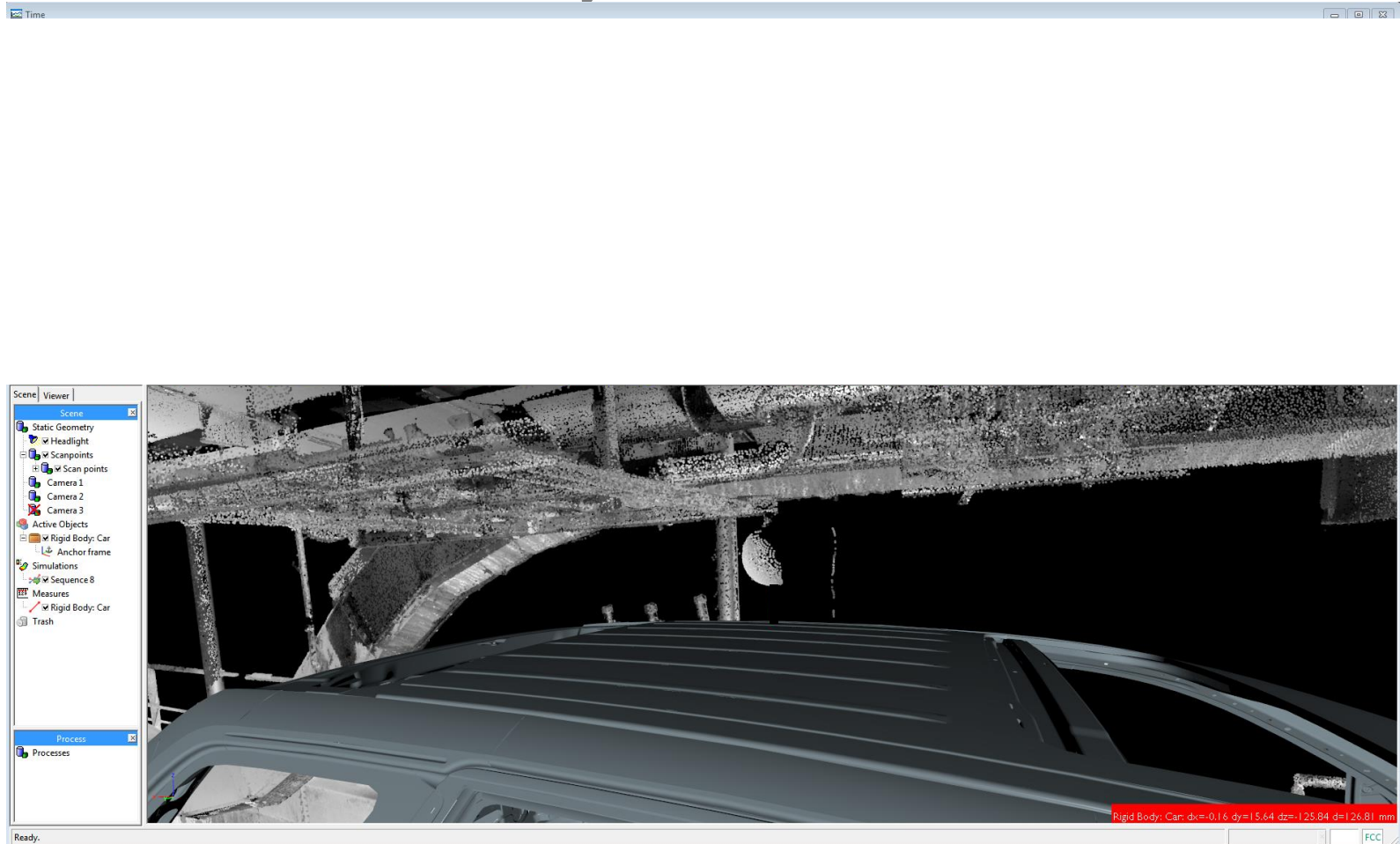






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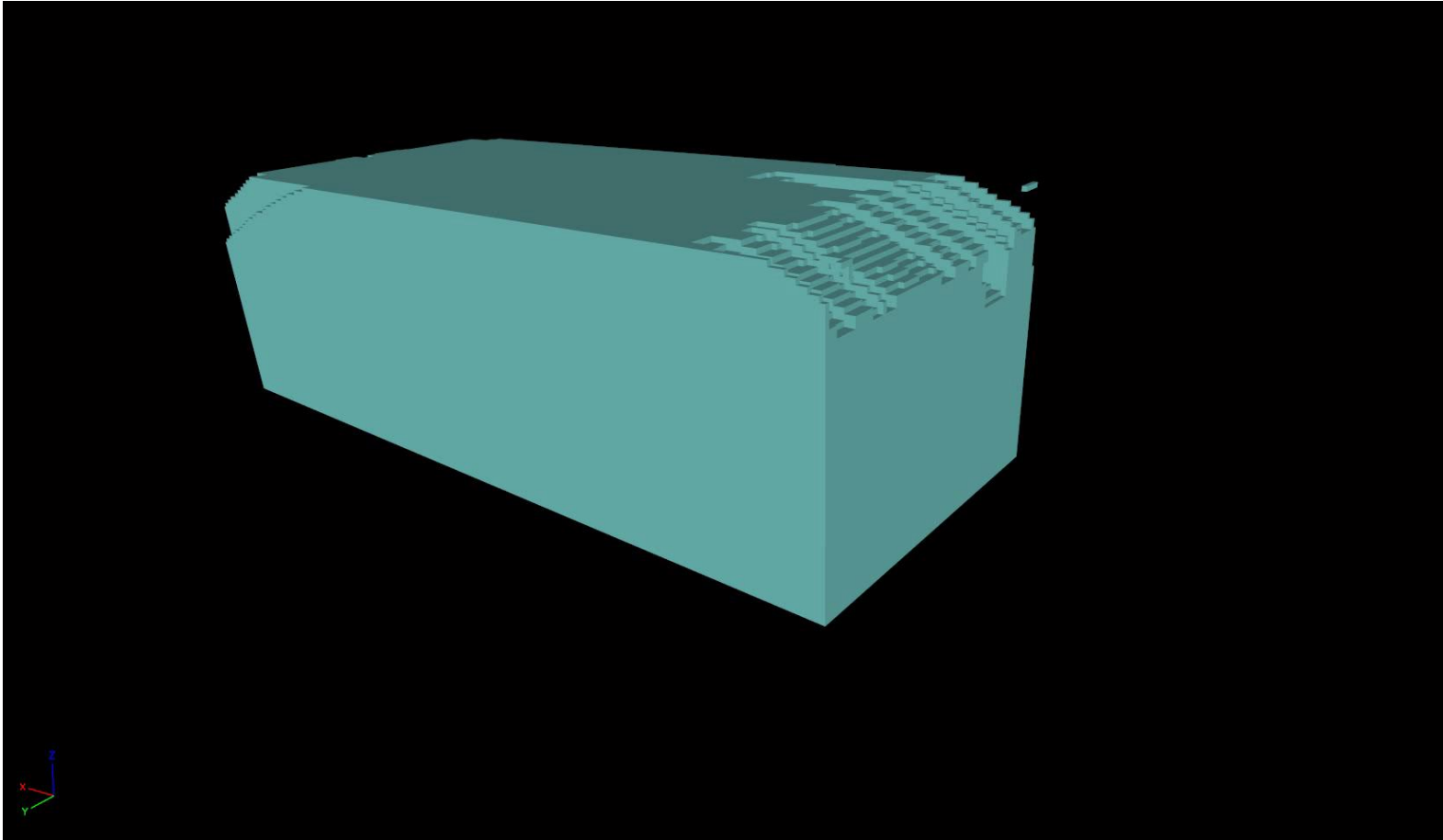
# Shortest Distance Analysis



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# Largest volume that can pass

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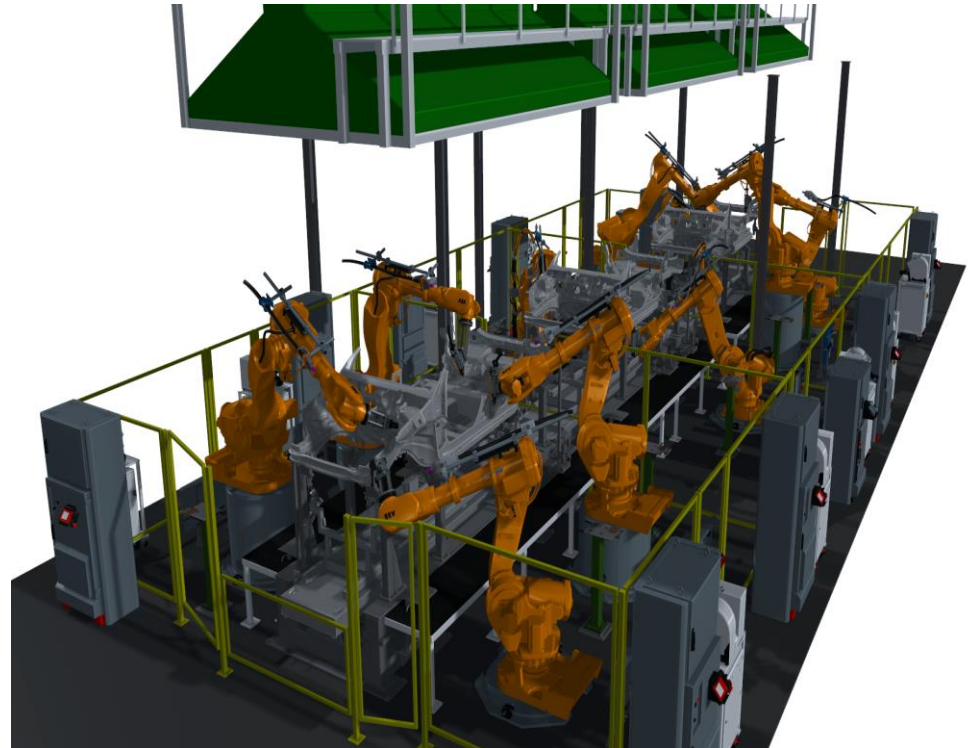
# Optimization of Multi-Robot Station Lines

Algorithms and software for automatic collision free motion planning and cycle time optimization

## Problem:

Distribute the workload among the robots to ensure:

- Collision free paths
- Good quality
- Short cycle time





# Optimization of Multi-Robot Station

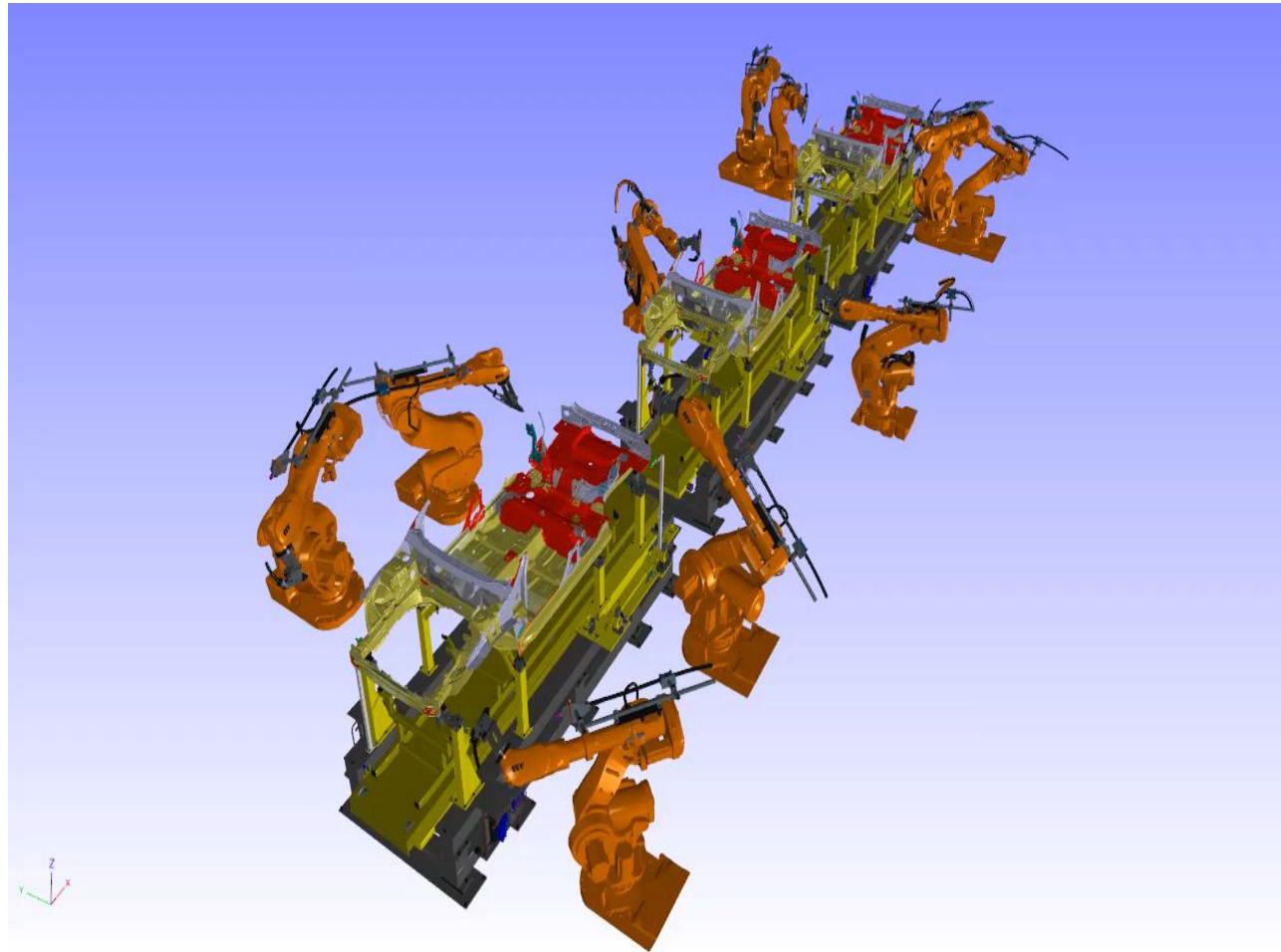
Line balancing, sequencing, and coordination

## Body-in-White

- About 300 steel sheet metal parts
- About 4000 spot welds
- Workload distributed to several hundred industrial robots in up to 100 stations

## Results

- 75% faster startup
- 25% improved cycle time



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# Virtual Paint Factory

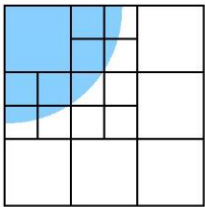
## Project Goals

- ➔ Innovative software for process simulation in automotive paint shops
- ➔ Exclude on-line activities in full production
- ➔ Reduce environmental impact
- ➔ Increase product quality

## Paint shop processes

- ➔ Spray painting
- ➔ Sealing and cavity wax
- ➔ Electro coat
- ➔ Oven curing

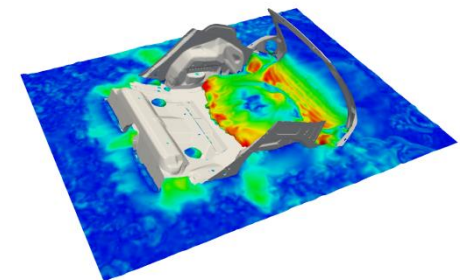
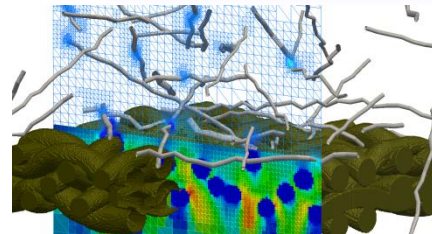
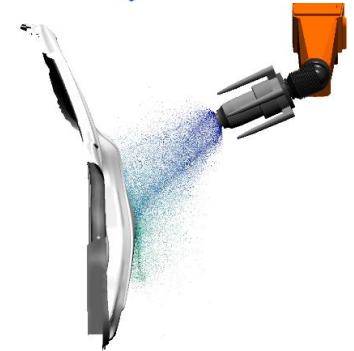
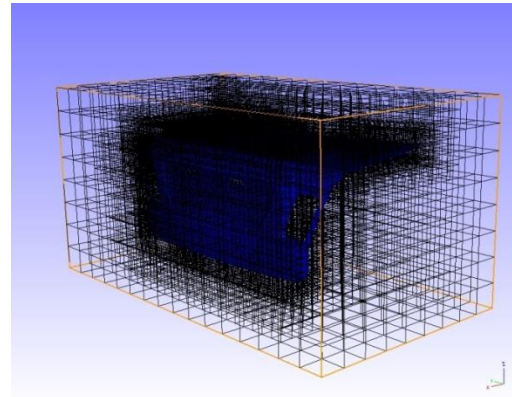
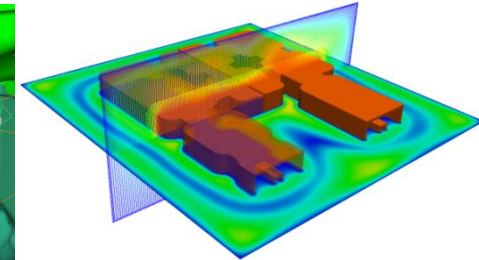
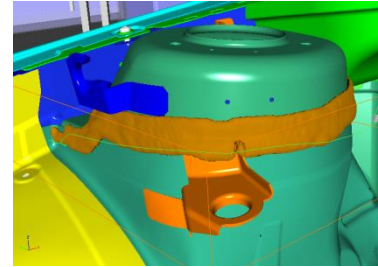




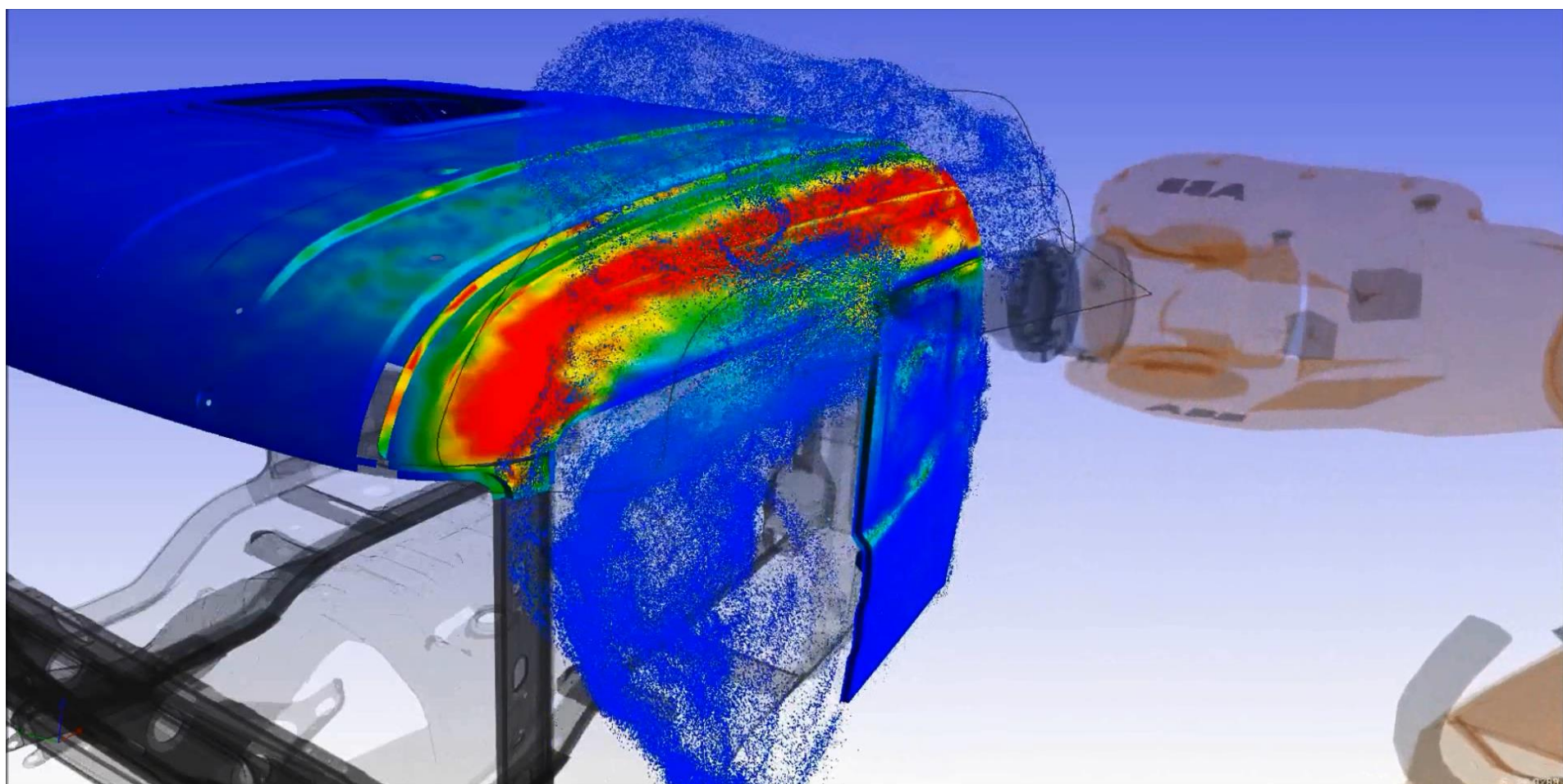
# – Immersed Boundary Octree Flow Solver

## IBOFlow

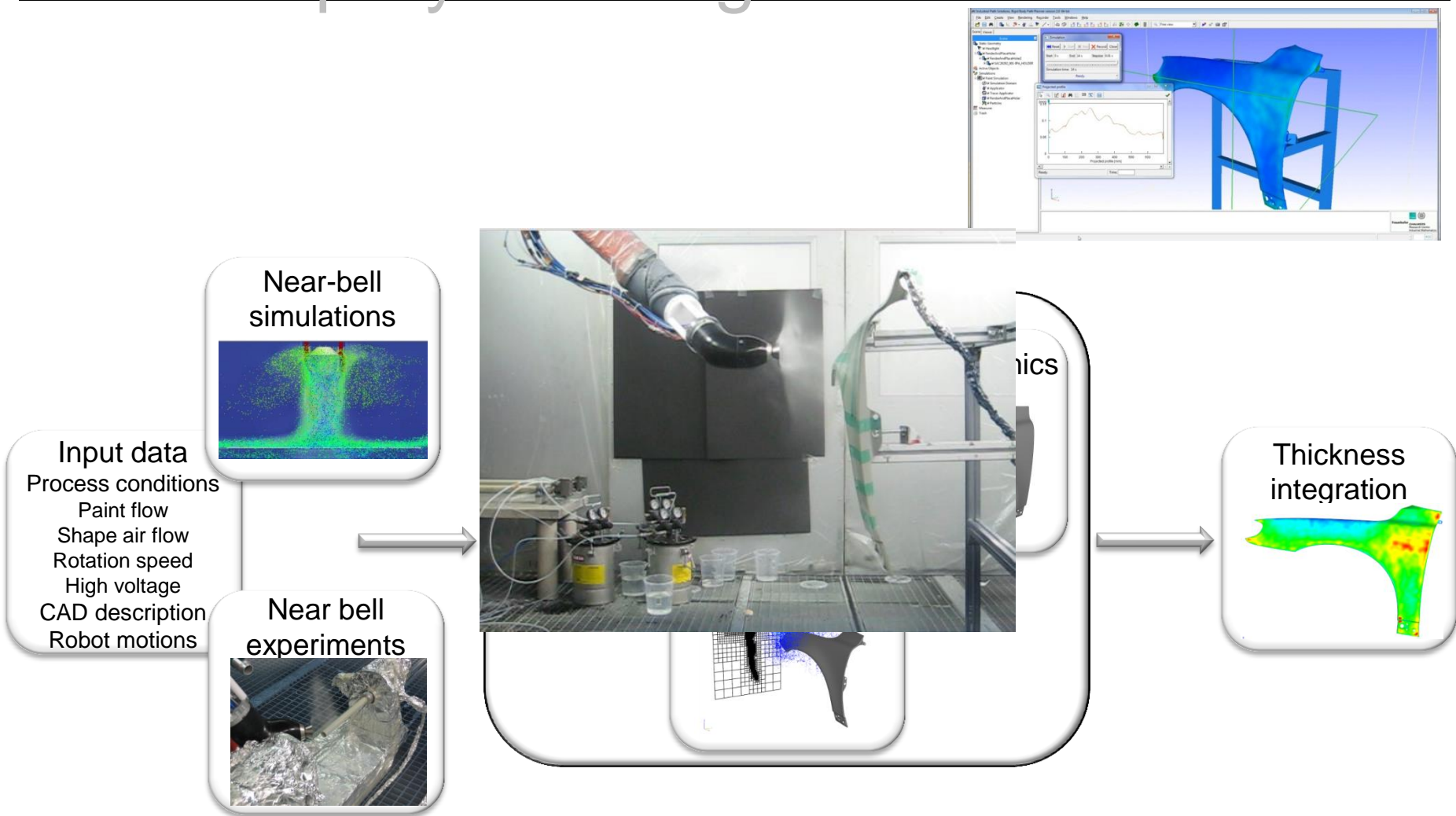
- Incompressible Navier-Stokes solver
- Co-located finite volume discretization
- SIMPLEC pressure velocity coupling
- Fully dynamic and automatic refinement and coarsening of Cartesian octree grid
- Novel immersed boundary methods
- GPU solver
- Modules
  - Particle and spray models
  - Turbulence models
  - Volume of fluids
  - Structural dynamics
  - Heat transfer
  - Electrostatics



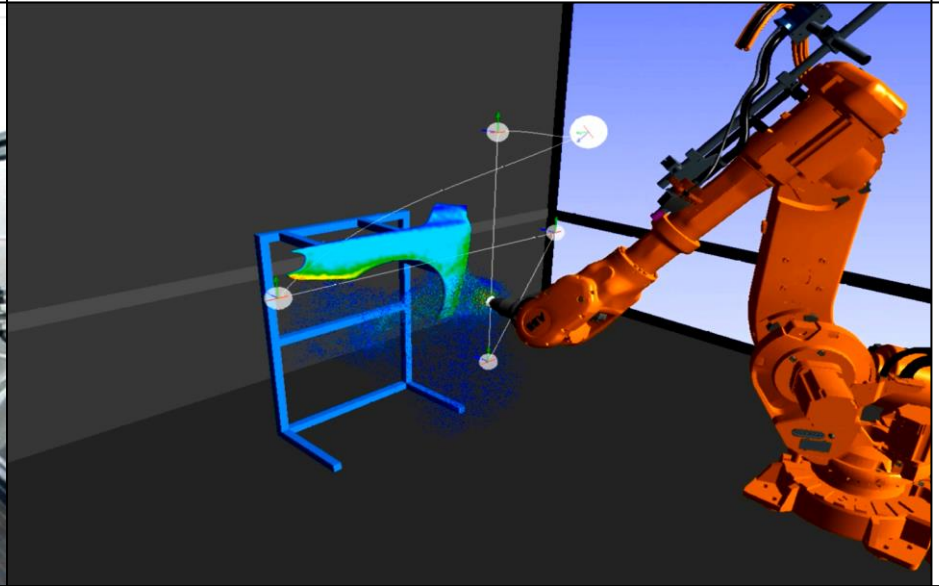
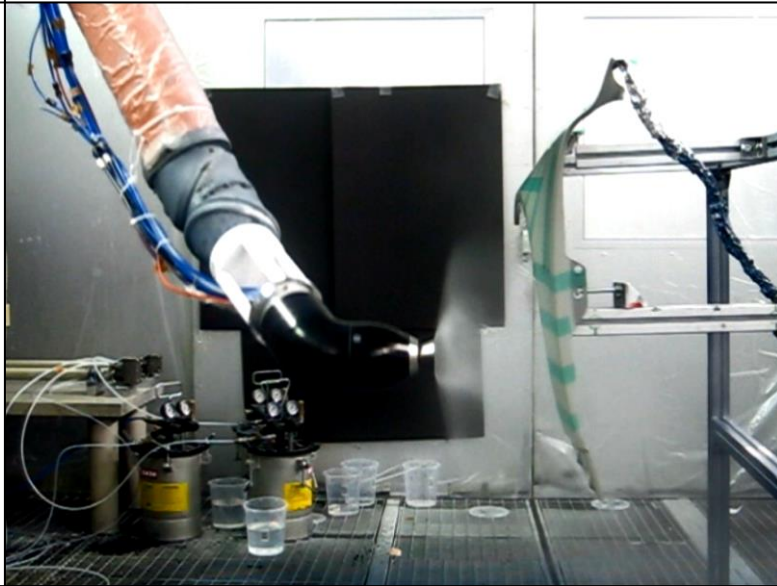




# Virtual Spray Painting



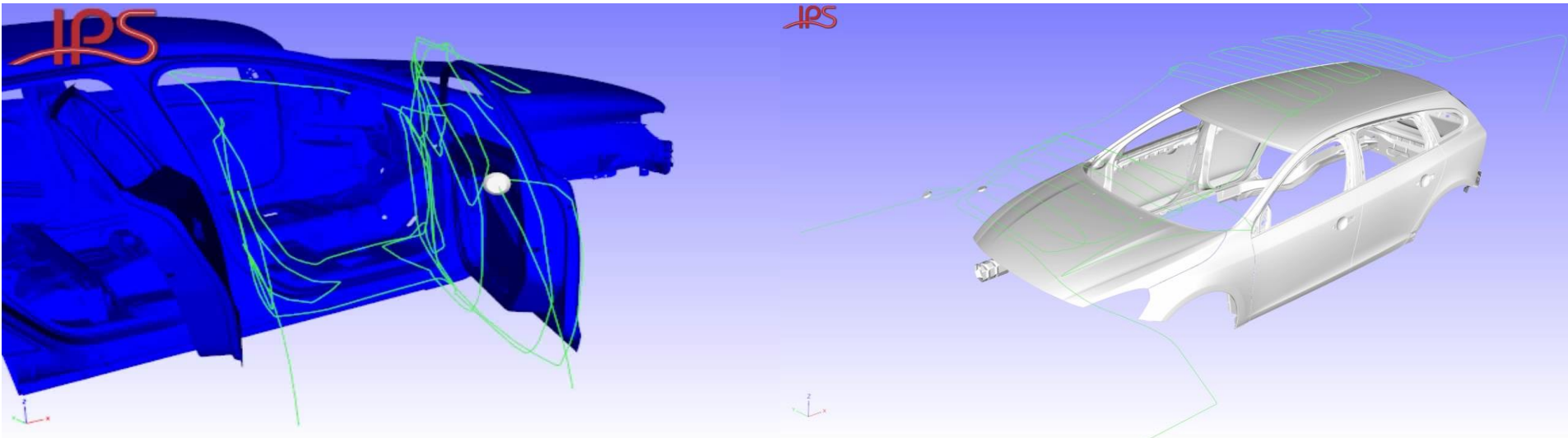
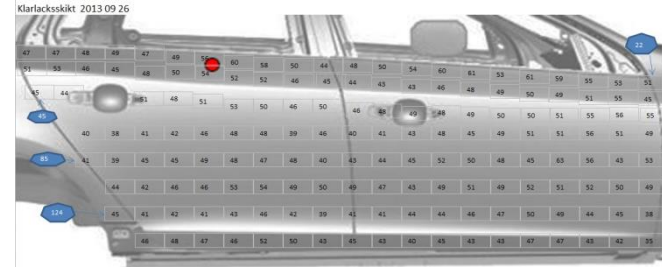
# Volvo V60 Car Fender





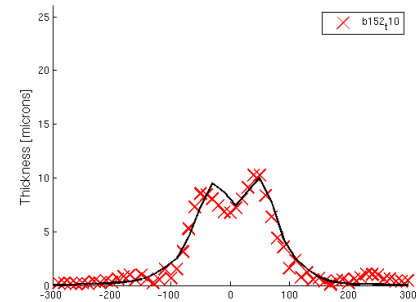
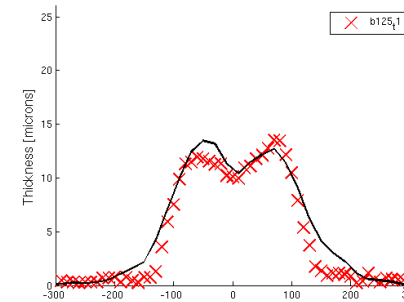
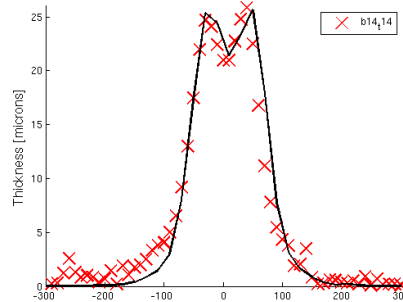
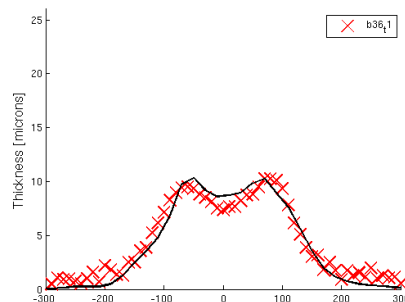
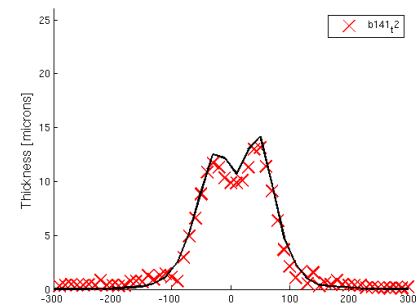
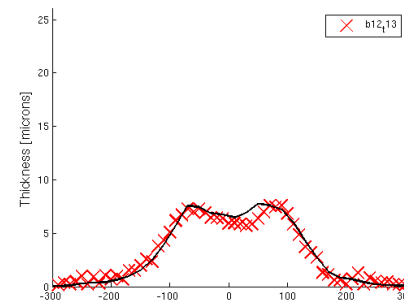
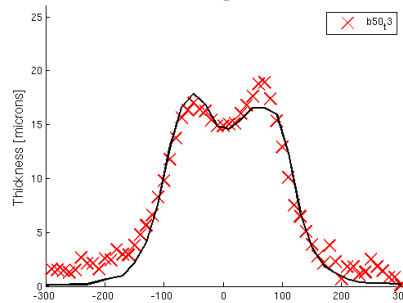
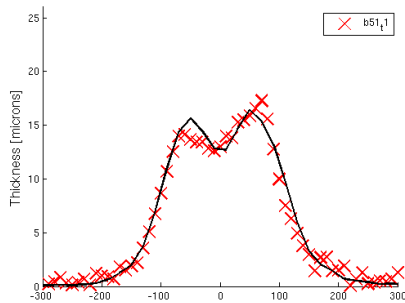
# Full Car Simulation at Volvo

- Gent interior simulation of front door
- Torslanda simulation of full car
  - Simulated horizontal and vertical brushes separately for shorter simulation time
  - Simulation with horizontal brushes finished over night!! (Roughly 2s physical time per hour simulation time on standard computer)
- Saving impacts from the simulation and then importing them together yields full simulation result
- Excellent agreement on car hood – full car validation ongoing



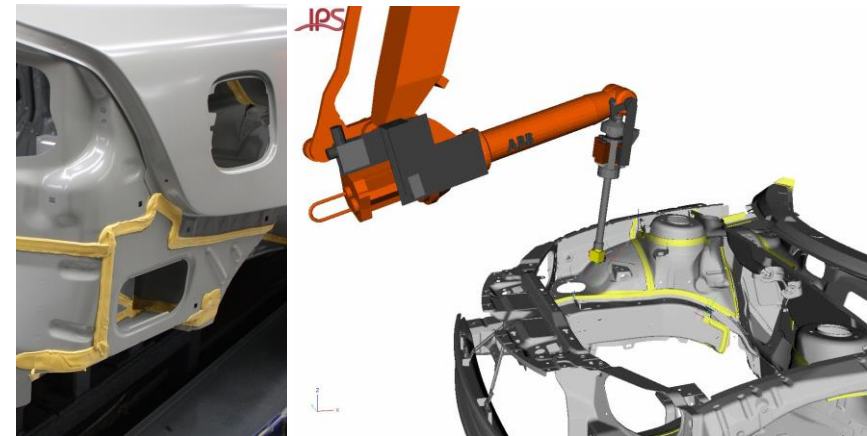
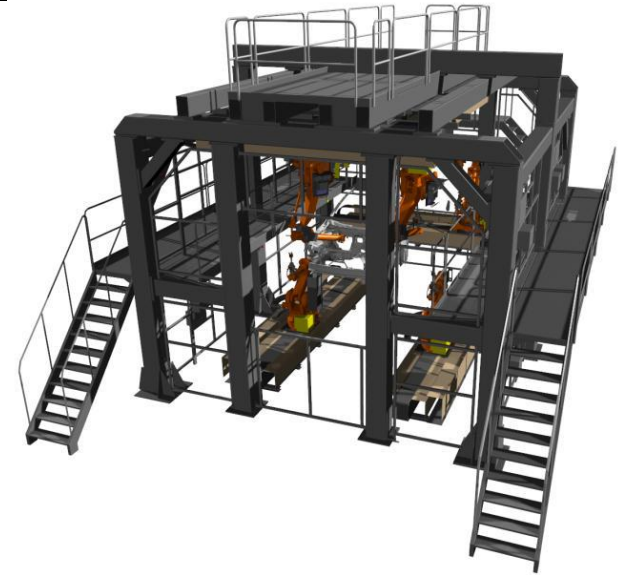
# Full Car Simulation at Volvo

- Generation of exterior paint brushes for clear coat and filler in Torslanda
- Generation of all interior paint brushes used in Gent

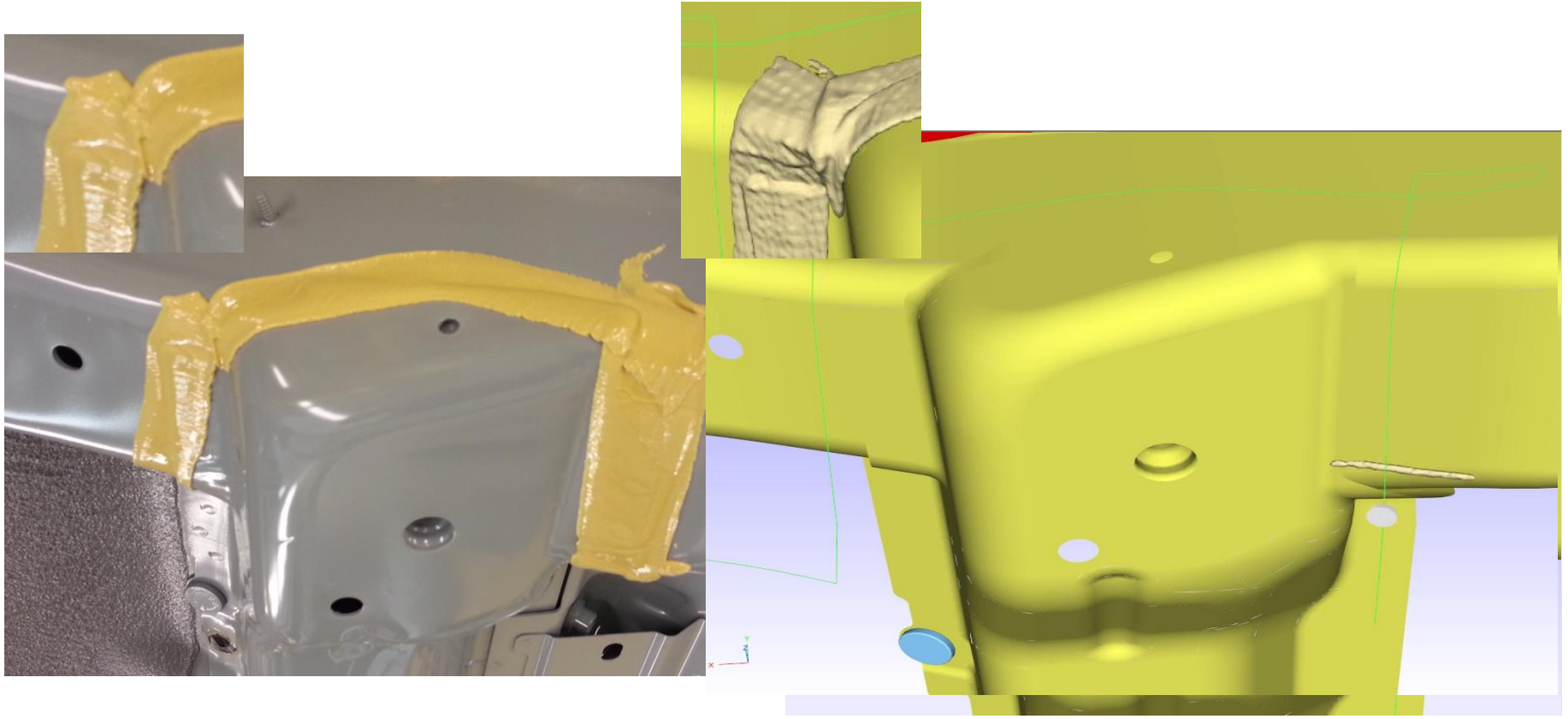


# Virtual Sealing

- Dampen noise and cover cavities where moisture otherwise can create a corrosive environment
- Goals
  - For a given a robot motion predict the thickness of applied material to reduce waste and pinpoint critical regions
  - Automatic generation and optimization of robot motions
- Challenges
  - Complex multi-phase flow modeling and simulation
  - Complex automatic path planning, load balancing and sequencing



# Sealing laydown on a Volvo V60

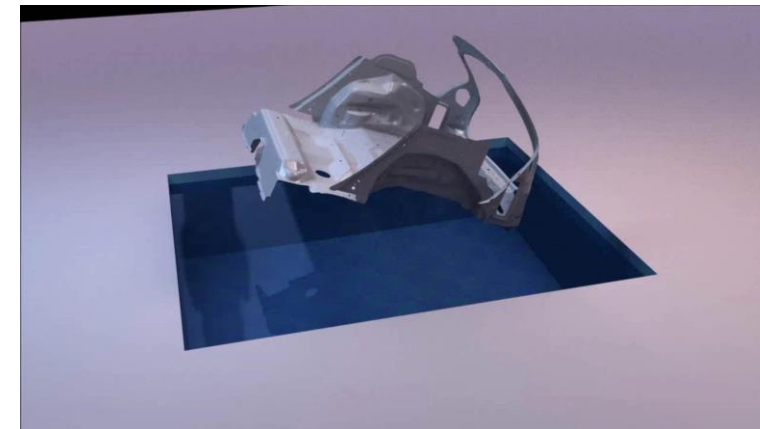
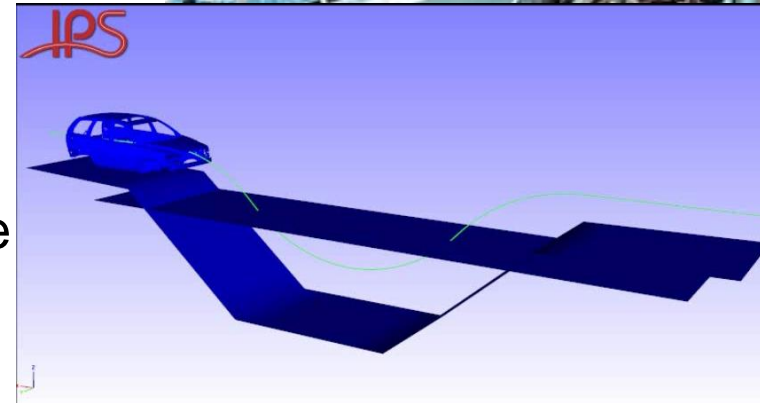


# Virtual Electrocoating

- Object dipped in an electrolyte solution
- Air pocket prediction is important to ensure that all relevant parts are covered in electrolyte
- Electrodeposition is predicted from the electrochemically caused current in the bath

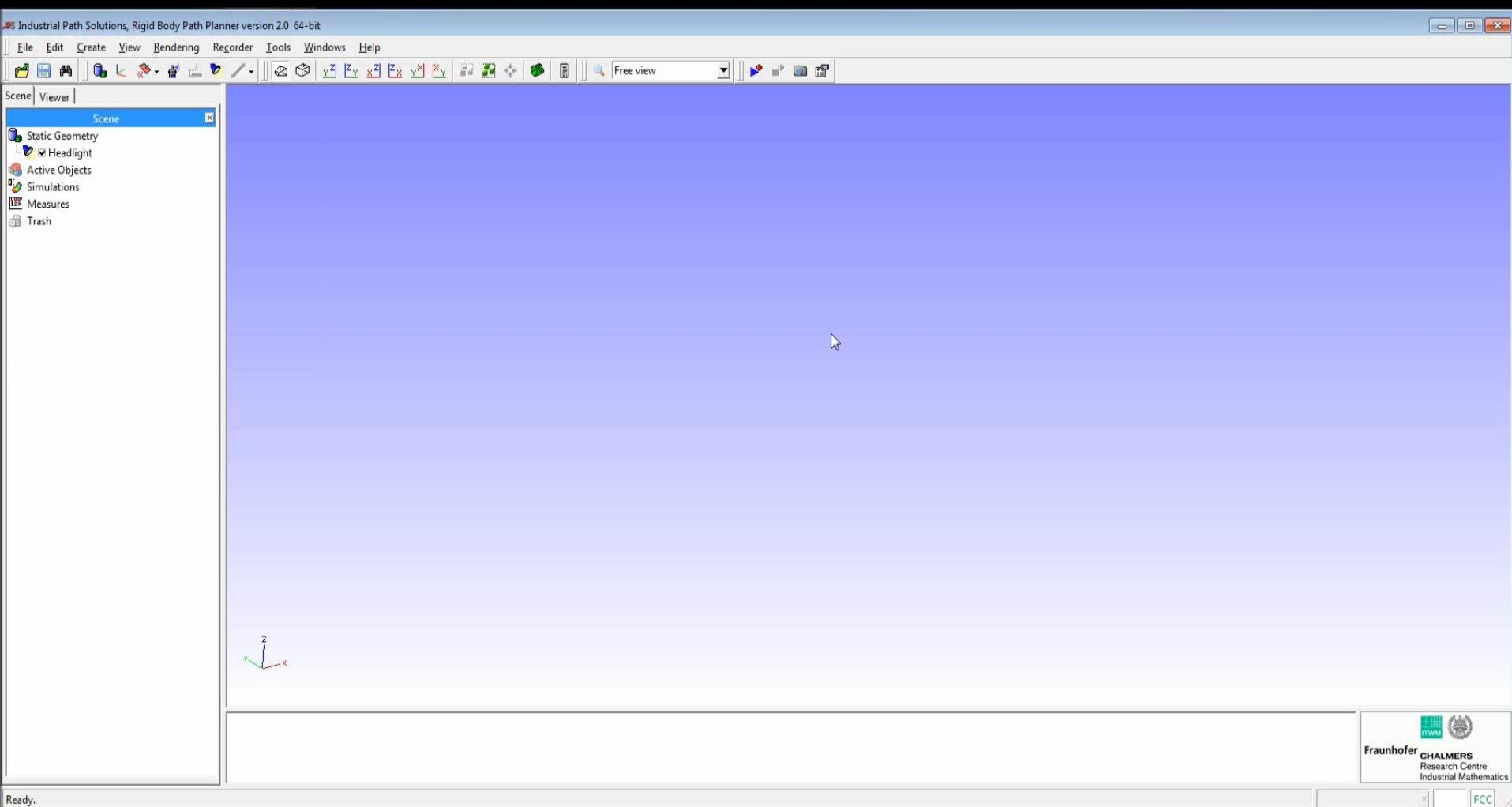
## IPS Virtual Paint solution

- Novel immersed boundary conditions for efficient motion handling
- Adaptive grids
- Volume of Fluid (VOF) module in IBOFlow





# IPS Virtual Paint demo



# FCC in Brazil

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Representative: Stefan Jakobsson, PhD

[Stefan.Jakobsson@fcc.chalmers.se](mailto:Stefan.Jakobsson@fcc.chalmers.se)

*Develop research and business collaborations in strong and strategic research areas for FCC*

## Plans and offers in Brazil:

- Sell software developed at FCC
- Short term consultancy projects
- Long term contract research in collaboration with Brazilian institutes
- Academic exchange
- Co-advising of MSc students with research institutions in Brazil

## Idea for joint MSc project:

- Optimization of robot paths for paint applications



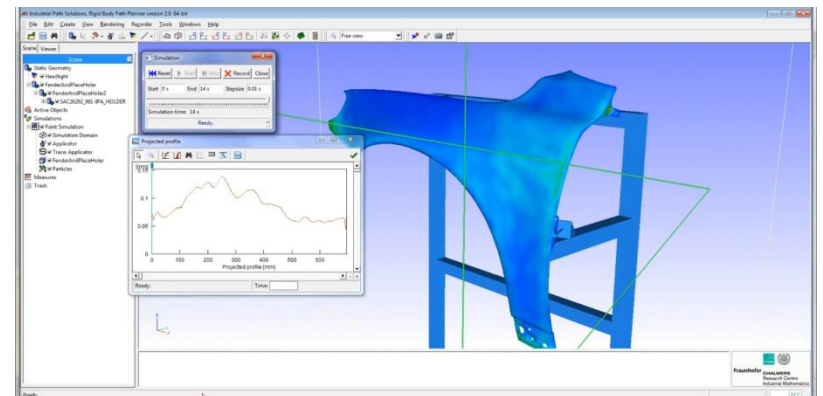
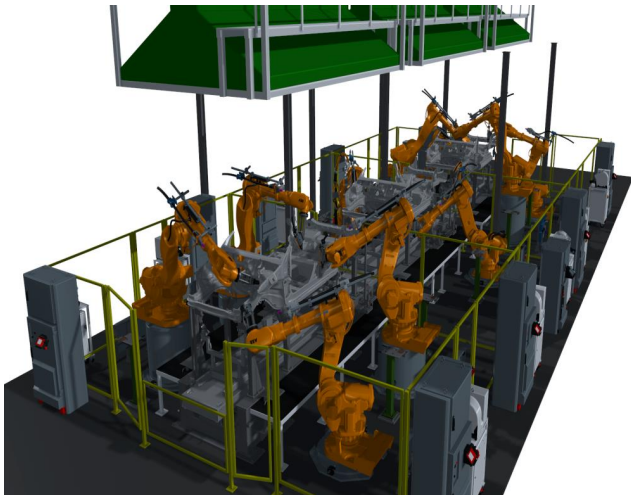
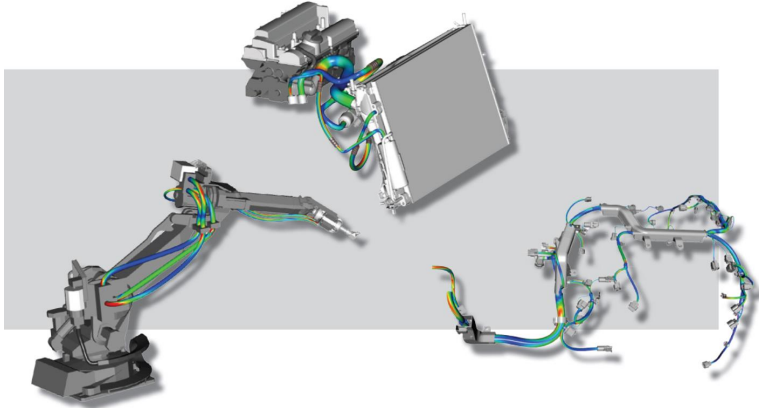
## Collaborators and contacts in Brazil:

- CeMEAI, São Carlos, SP
- Fraunhofer Liaison office Brazil
- The Swedish-Brazilian Research and Innovation Centre (CISB)
- Câmara Brasil-Alemanha
- Universidade Federal de Santa Maria, UFSM, RS



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# Muito obrigado!



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