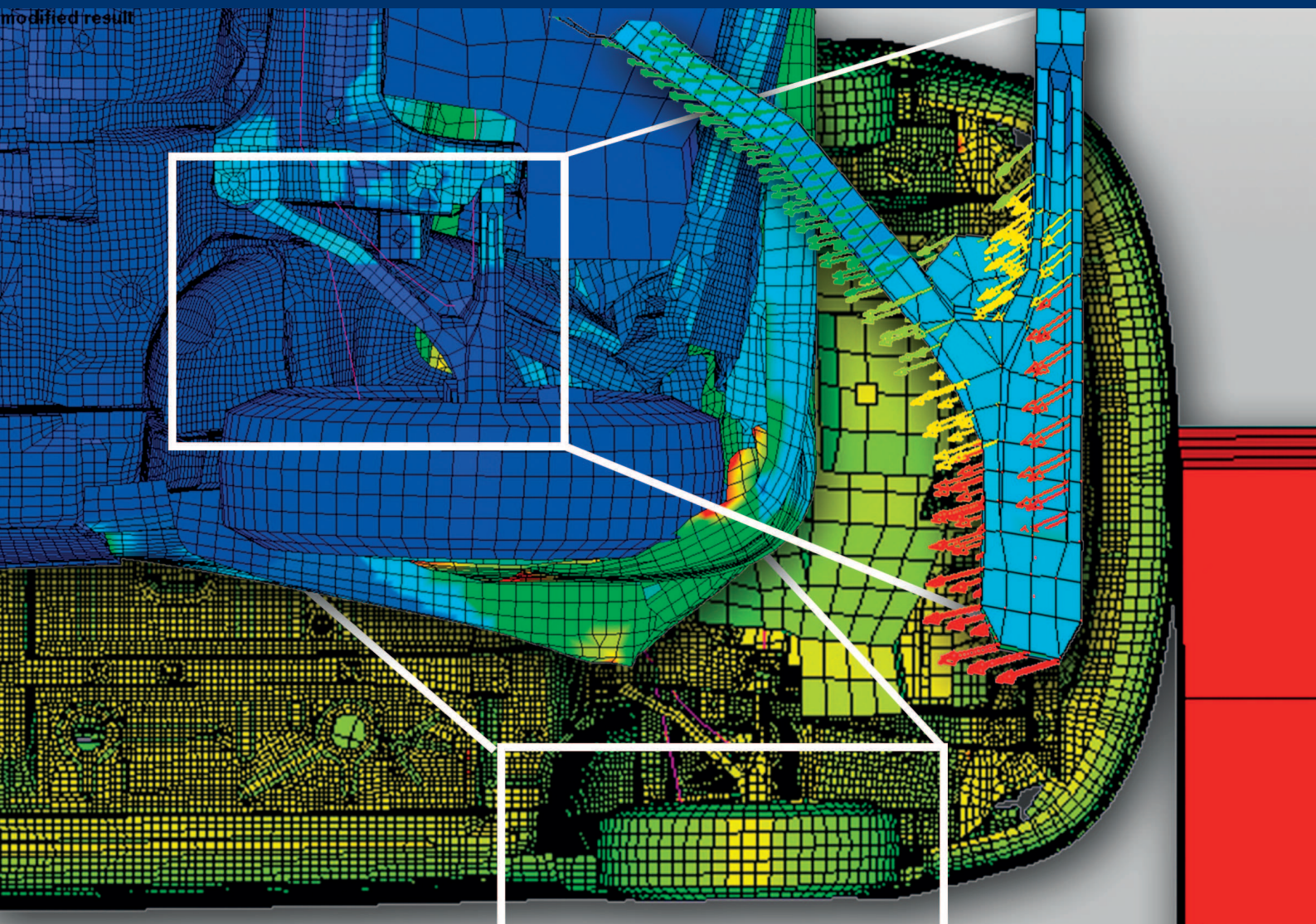
Fraunhofer
SCAI

FRAUNHOFER INSTITUTE FOR ALGORITHMS
AND SCIENTIFIC COMPUTING SCAI

# COMPUTER-AIDED ROBUST DESIGN



# MOTIVATION

The robustness and quality of production processes and products suffers from variations of

- material properties
- process parameters
- variations in geometry
- and other influences

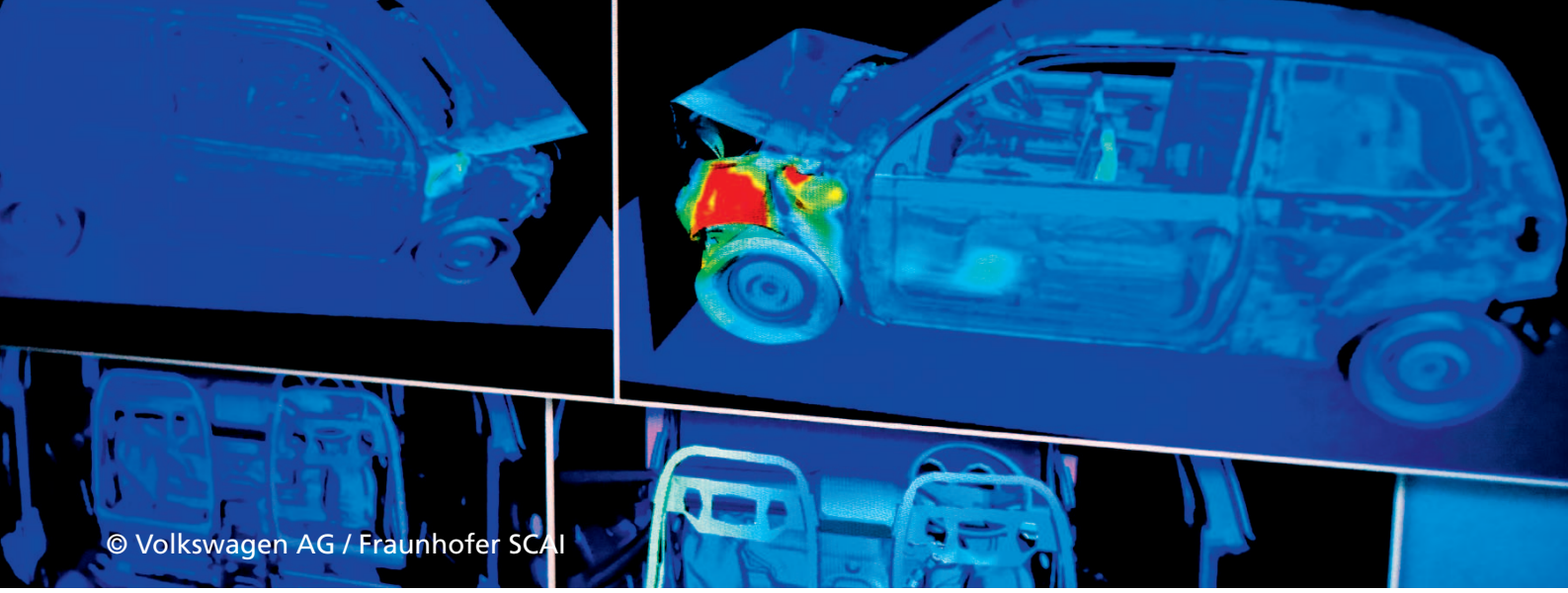
Analyzing and controlling the effects of these variations helps to find robustly optimal settings under realistic conditions. Computer-aided robust design and intuitive exploration of design spaces and simulation results thus belong to the most challenging research and development tasks with an extremely high relevance for industry.

**Application Areas addressed by Fraunhofer SCAI**

- automotive industry, e.g. crash simulation, metal forming, casting
- microelectronics and semiconductor physics
- oil and gas reservoir management
- chemistry
- fluid mechanics
- molecular dynamics

**Goals**

- device optimization and product configuration
- analysis of process steps and chains, process optimization
- calibration of material models, (history) matching of simulation models




## TASKS

- Sensitivity and robustness analysis with an efficient reduction of the design space
- Meta modeling (response surface modeling) and advanced design-of-experiment techniques
- Multi-objective robust design-parameter optimization
- Process chains (e.g. metal forming ⟶ crash)
- Efficient interpolation, compression, visualization of simulation data on fine grids

## OFFERS

**Software Products**

- *DesParO:*
  Software for interactive, multi-objective robust design-parameter studies and optimization
- *DIFF-CRASH:*
  Software for scatter and stability analysis of crash simulations

**Services**

- Robust design studies
- Consulting
- Customer-tailored software solutions

DESPARO

# INTERACTIVE, MULTI-OBJECTIVE ROBUST DESIGN-PARAMETER STUDIES AND OPTIMIZATION

## Benefits for developing Processes and Products

- intuitive, interactive exploration for a truly global view of your production process, product configuration, material model or simulation model
- high-quality up-to-date (response surface) meta modeling made efficient, reliable, versatile, and easy-to-use
- almost optimal configurations with a low number of simulations or physical experiments
- batch tools and software libraries for automation and an easy integration into standard workflow tools, other optimizers, and simulation software

## Special Features

- iterative refinement and robust, fully local tolerance prediction of meta model
- parameter sensitivity analysis, even for simulation results on highly resolved grids
- reduction of the design space, extraction of main tendencies, compression of data bases
- fast interpolation and visualization of simulation results on highly resolved grids

## Technical Details

DesParO is available for Linux and Windows systems in the following versions:

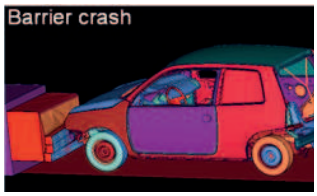
- stand-alone interactive exploration tool
- stand-alone batch tool for integration into optimizers and workflow tools
- SDK (software development kit) library for integration into software packages

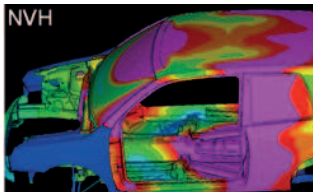

## FAST INTERPOLATION AND VISUALIZATION

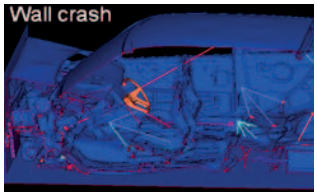
As an additional core competence, we offer fast interpolation and visualization of simulation data on fine grids.

In particular, this allows fast previews of optimal designs which have been found by means of DesParO.

## EXAMPLE




Multi-disciplinary optimization of a Volkswagen Lupo model

**Optimization Task takes into Account**

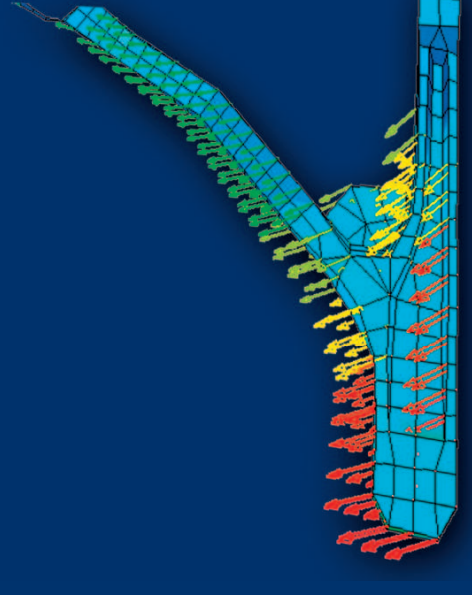
- maximum intrusions in different critical points
- maximum acceleration, first eigenfrequencies and torsional stiffness

**Main Objective**

- reduction of total mass
- design parameters: thicknesses of 15 parts

**Result of Optimization with DesParO**

⟶ 1.5 kg mass reduction with all 11 constraints robustly satisfied.



# SCATTER AND STABILITY ANALYSIS OF CRASH SIMULATIONS

DIFF-CRASH is a software package for the scatter and stability analysis of crash simulations. Physical bifurcations and numerical instabilities in simulation packages often cause extremely sensitive dependencies of simulation results on even the smallest model changes.

Instabilities can be triggered by

- small changes of the input deck (e.g. position of a barrier or variations of parameters)
- numerical differences due to parallel computing (e.g. permutation of compute nodes)
- round-off errors, when running the same model on different computer architectures

Our tool DIFF-CRASH helps to

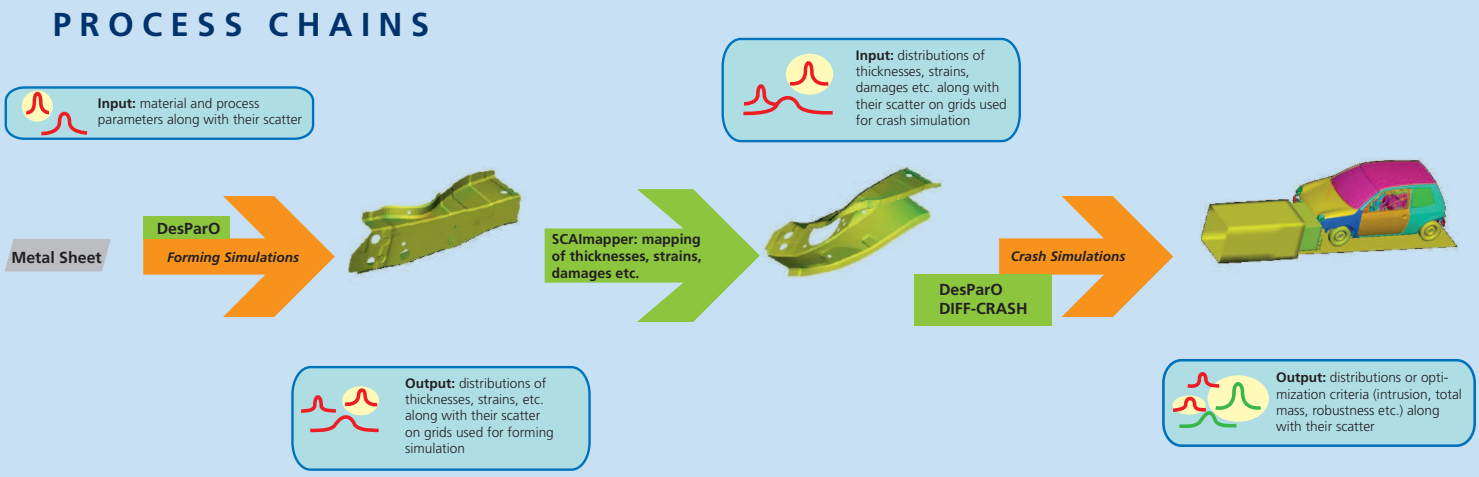
- find critical scatter regions by means of statistical methods, similarity measures, global/local trend analysis and visualization methods
- identify possible sources of instabilities

**Special Features**

DIFF-CRASH

- comes with new GUI and user guidance (version 4.5 and higher)
- comes with novel mathematical methods and acceleration (version 5.0 and higher)
- takes the results of several simulation runs of PAM-CRASH or LS-DYNA* and analyzes the evolution of local scatter of the results w.r.t. simulation time
- adds its results to PAM-CRASH or LS-DYNA output for visual analysis
- can directly launch ANIMATOR and LS-PrePost*
- is available on a variety of platforms including Windows and Linux
- can handle FEMZIP-compressed data files

* Further file formats and postprocessors upon request.




# DIFF-CRASH WORKFLOW / PROCESS CHAINS

## DIFF-CRASH Workflow

Progression of a typical DIFF-CRASH analysis

1. Simulation runs for the model are performed
   – by varying, for instance, barrier positions, material parameters or thicknesses slightly,
   – and/or by permuting the ordering of compute nodes for parallel runs
2. By means of DIFF-CRASH up to three steps can be performed:
   (a) basic statistical analysis for identifying and visualizing
      – critical scatter regions
      – sets of extreme simulation runs
      – evolution in time
   (b) global analysis for identifying and/or visualizing:
      – main trends and similarities in scatter evolution
      – possible sources of instabilities
      – a ranking of component parts
      – a scatter evolution diagram with color-separation for component parts
   (c) local analysis, focusing on selected regions or components

## Efficient Statistical Analysis and Robust Design of Process Chains

Often, products are fabricated by means of a series of process steps. In order to obtain realistic information on relevant parameters and properties of the overall process and resulting products, at least the most important process steps and arising variations should be analyzed. We provide efficient methods and software tools for the analysis of process chains as, for instance:

- metal forming / casting ⟶ crash simulation
- semiconductor process ⟶ device ⟶ circuit simulation

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