Virtual Product Development with SCALE.sdm

Demonstrated by Playing with LEGO® Car Models as Examples

November 15th, 2023

SCALE

IT-Solutions for CAE

The LEGO® Challenge

WHAT WILL HAPPEN?
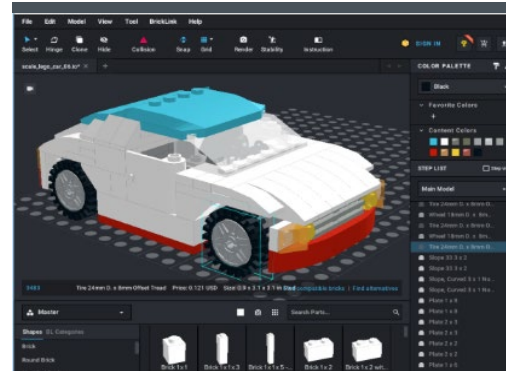

WE SHOULD BE ABLE TO PREDICT THIS **WITH SIMULATION!**

First attempts to set up LEGO® Models

Prototype

Modeling in CAD →

CAD

Rendering →

Rendering

Physical Build →

Real World Model

LDraw.org
Centralised LDraw Resources

LeoCAD

bricklink

http://www.ldraw.org/   https://www.leocad.org   https://www.bricklink.com

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Setup in SDM-System

Goals

design a car that shall ....

- have a cool design
- be indestructible
- let the mini figure survive
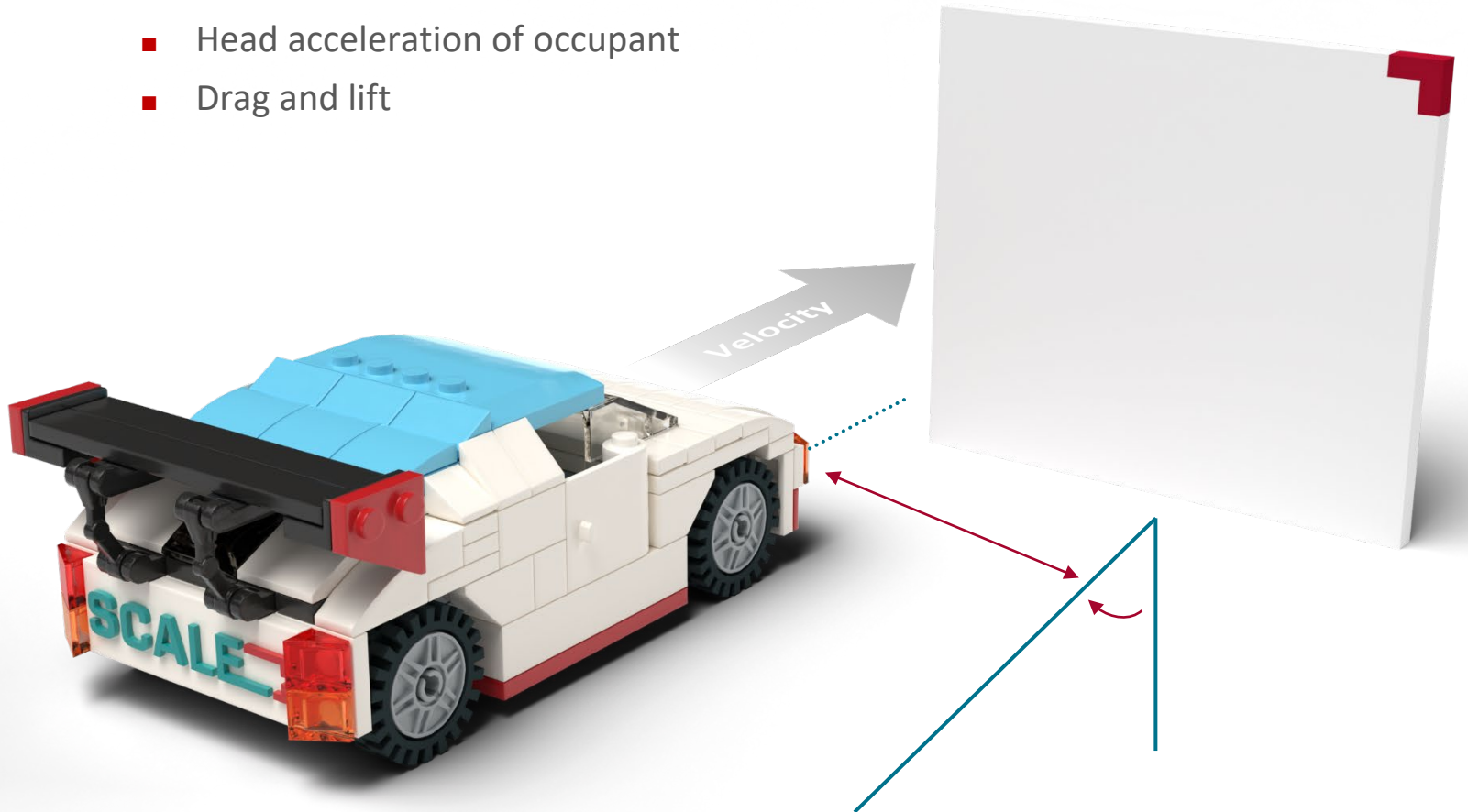- possesses good aerodynamics

Results

things that are to be monitored with respect to the goals

- Level of destruction
- Vehicle deceleration
- Head acceleration of occupant
- Drag and lift

Design & Test Parameters

things that we can vary

- Geometric build of car
- Speed
- Offset
- Angle of impact
- Angle of spoiler

Velocity

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Setup Requirements for the Project

Requirements
technical targets for the project

Structured by category, vehicle and velocity

Thresholds for level of destruction

Thresholds for acceleration

> CFD (8)		
∨ Front Impact (16)		
> AUDI_QUAT... (4)		
> MERCEDES_... (4)		
> RIVIAN_R1T (4)		
∨ SCALECAR (4)		
∨ 20 km/h (2)		
Level of destruction (@20 km/...	Rating of destruction level for LEGO simulation mode...	-∞ < x < 20 — 20 < x < 24 — 24 < x < ∞
max. Acceleration (@20 km/h)	max. Acceleration for LEGO simulation models	-∞ < x < 1200 — 1200 < x < 1500 — 1500 < x < ∞
> 30 km/h (2)		

Milestones
definition of all project milestones and targets

SCALECAR — PoC — v1 — v2 — Slides — NWC23 — Apr 19, 2023
RIVIAN R1T
MERCEDES SLS AMG
AUDI QUATTRO

Jan 2021 — Jul 2021 — Jan 2022 — Jul 2022 — Jan 2023 — Jul 2023

Monitoring
transparent project status at any time

Assessment
individual assessment by users

Project Status
aggregated on each level of requirements

Aggregated status

User assessment

∨ CFD (8)			yellow
			yellow
∨ 30 km/h (4)			green
> MERCEDES_SLS_AMG (2)			yellow
∨ SCALECAR (2)			
Drag (@30 km/h)		0.41	yellow
Lift (@30 km/h)		0.32	green
> 40 km/h (4)			yellow
∨ Front Impact (16)		red	🖐 green
			🖐 green
∨ 20 km/h (8)			yellow
> AUDI_QUATTRO (2)			green
> MERCEDES_SLS_AMG (2)			yellow
> RIVIAN_R1T (2)			🖐 green
∨ SCALECAR (2)			🖐 green
Level of destruction (@20 km/h)		22.62	🖐 green
max. Acceleration (@20 km/h)		1738.03	red

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Manage CAD data in the SDM-System[1]

- **CAD data in the SDM-system**
  imported , versioned, managed

- **Product structure**
  disassembled into groups to allow teamwork

- **Integrated CAD tools**
  can be opened and worked with directly

- **Teamwork**
  changes automatically synced to all team members

Version control for project

One file per part / brick

Version control for a selected part group

Product structure rebuild from LDraw model
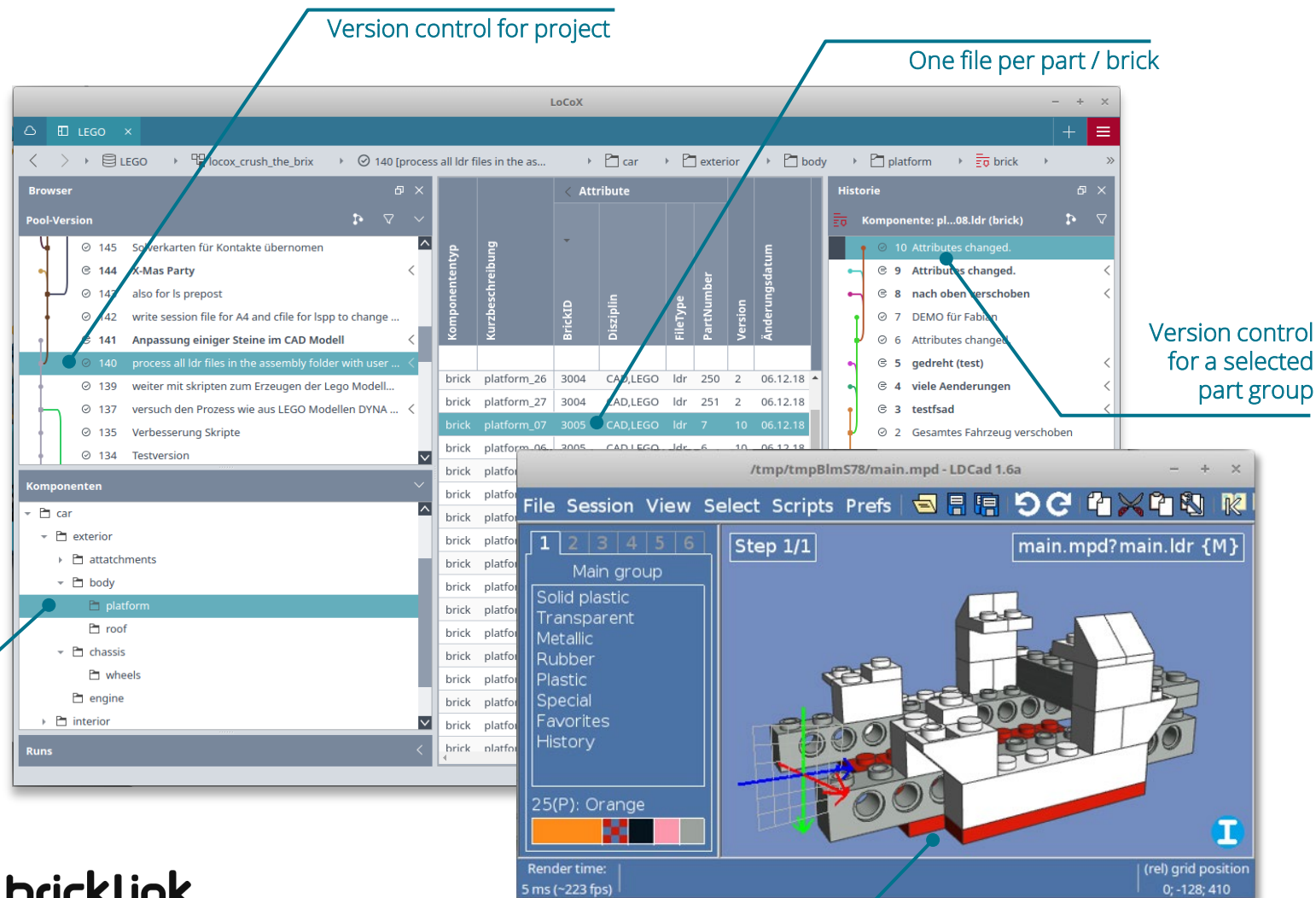
Opening and working with CAD assemblies from within SCALE.sdm

LDraw.org
Centralised LDraw Resources
http://www.ldraw.org/

LeoCAD
https://www.leocad.org

bricklink
https://www.bricklink.com

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[1] C. Knehler, M. Thiele, D. Matthus, P. Friedrich, "Prospects of integrating CAD and CAE in Simulation Data Management",
NAFEMS European Conference Simulation Process and Data Management (SPDM), 28-29 November 2018, Munich, Germany

Meshing of CAD Data[1]

Versions of brick library or individual meshes

Brick opened for meshing directly from SDM-system

Brick library mounted to project

Various representations of CAD geometry and meshed bricks

[1] C. Knehler, M. Thiele, D. Matthus, P. Friedrich, "Prospects of integrating CAD and CAE in Simulation Data Management",
NAFEMS European Conference Simulation Process and Data Management (SPDM), 28-29 November 2018, Munich, Germany

Setup of Load Cases and Solving

Runs

- ▼ SCALECAR
  - ▼ Front impact - Rigid Wall
    - ▸ overlap 100 pct
    - ▼ overlap 25 pct
      - ▸ 10 kph
      - ▼ 17 kph
        - ⇨ 0381_SCALECAR__8stud_H_f_w__17kmh_0_deg_25pct_1st-pos_
        - ⇨ 0381_SCALECAR__8stud_H_f_w__17kmh_30deg_25pct_1st-pos_
        - ⇨ 0381_SCALECAR__8stud_H_f_w__17kmh_45deg_25pct_1st-pos_
        - ⇨ 0381_SCALECAR__8stud_H_f_w__17kmh_60deg_25pct_1st-pos_
        - ⇨ 0381_SCALECAR__8stud_H_f_w__17kmh_90deg_25pct_1st-pos_
      - ▸ 25 kph
    - ▸ overlap 50 pct
  - ▸ car 2 car impact - no barrier
- ▼ AUDI_QUATTRO
  - ▼ Front impact - Rigid Wall
    - ▼ overlap 100 pct
      - ▼ 18 kph
        - ⇨ 0381_AUDI_QUATT
        - ⇨ 0381_AUDI_QUATT

Flexible grouping of runs by their properties

Setup of multiple different scenarios

Setup of multiple cars

Job Monitoring

Jobs

🔍 Filter

- ˅ ▶ 0042_1st-PORSCHE_60.0kmh_0.0_deg_0....TI_0.0_kmh_270.deg_-1145off_-__04fa
  Simulation Job: Solving: 59.12ms of 130.1ms computed KIN=46.7%, INT=2.6% Job
- › ✓ Simulation Job
  Solving: 59.12ms of 130.1ms computed KIN=46.7%, INT=2.6% Job Folder Log

Job submit

ON-PREMISE

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CLOUD

H L R S

rescale
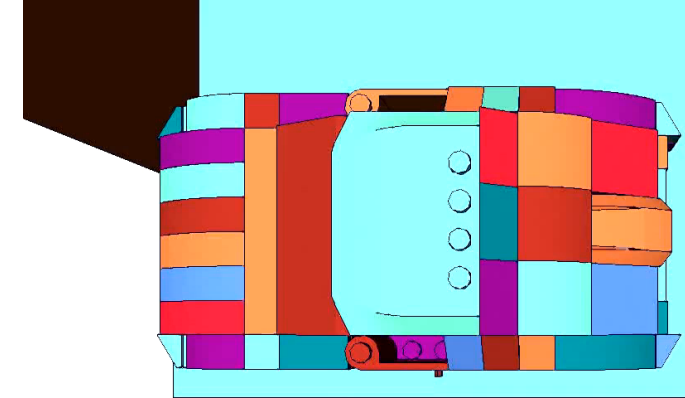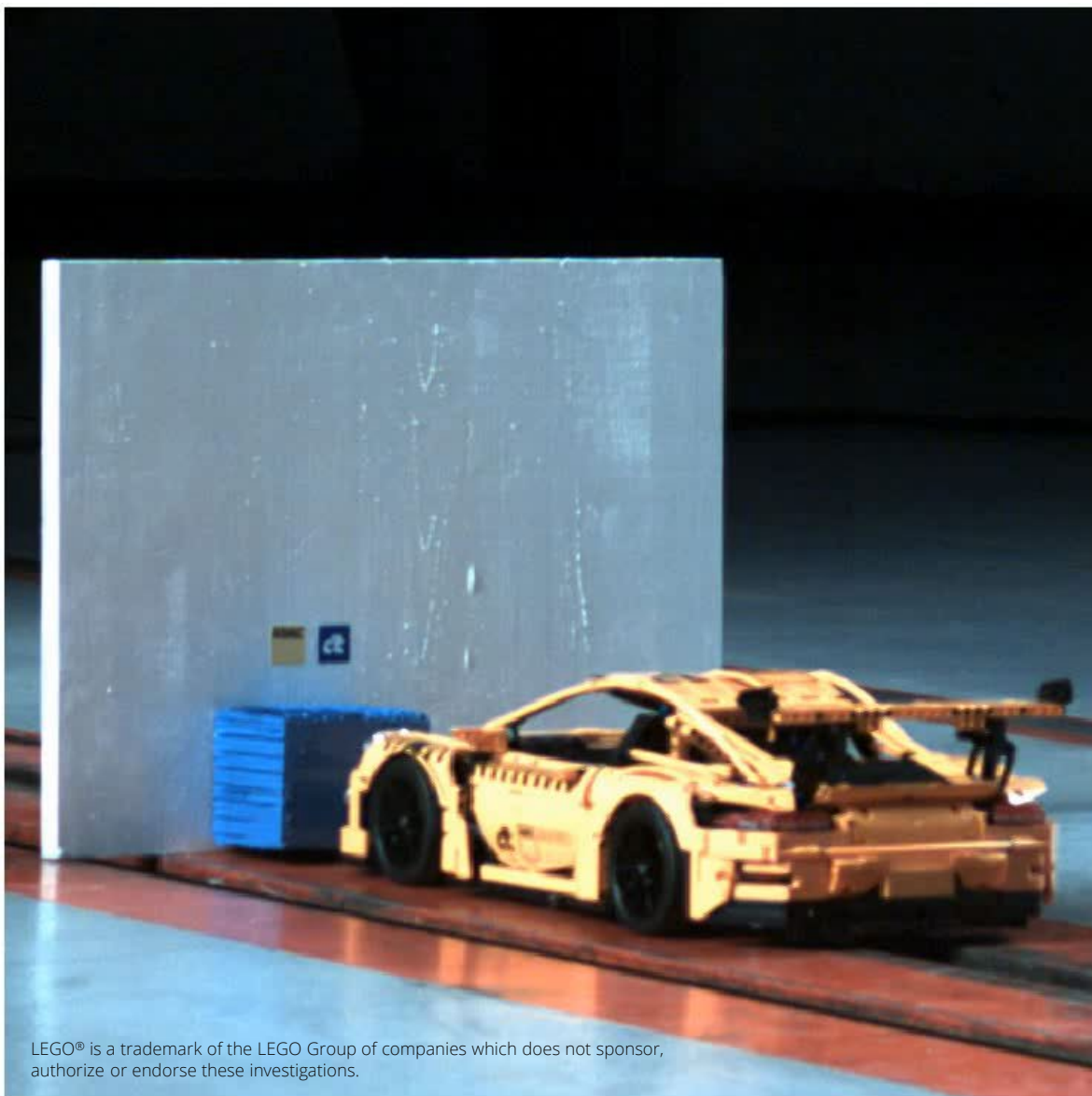
Simulation Results compared to Test
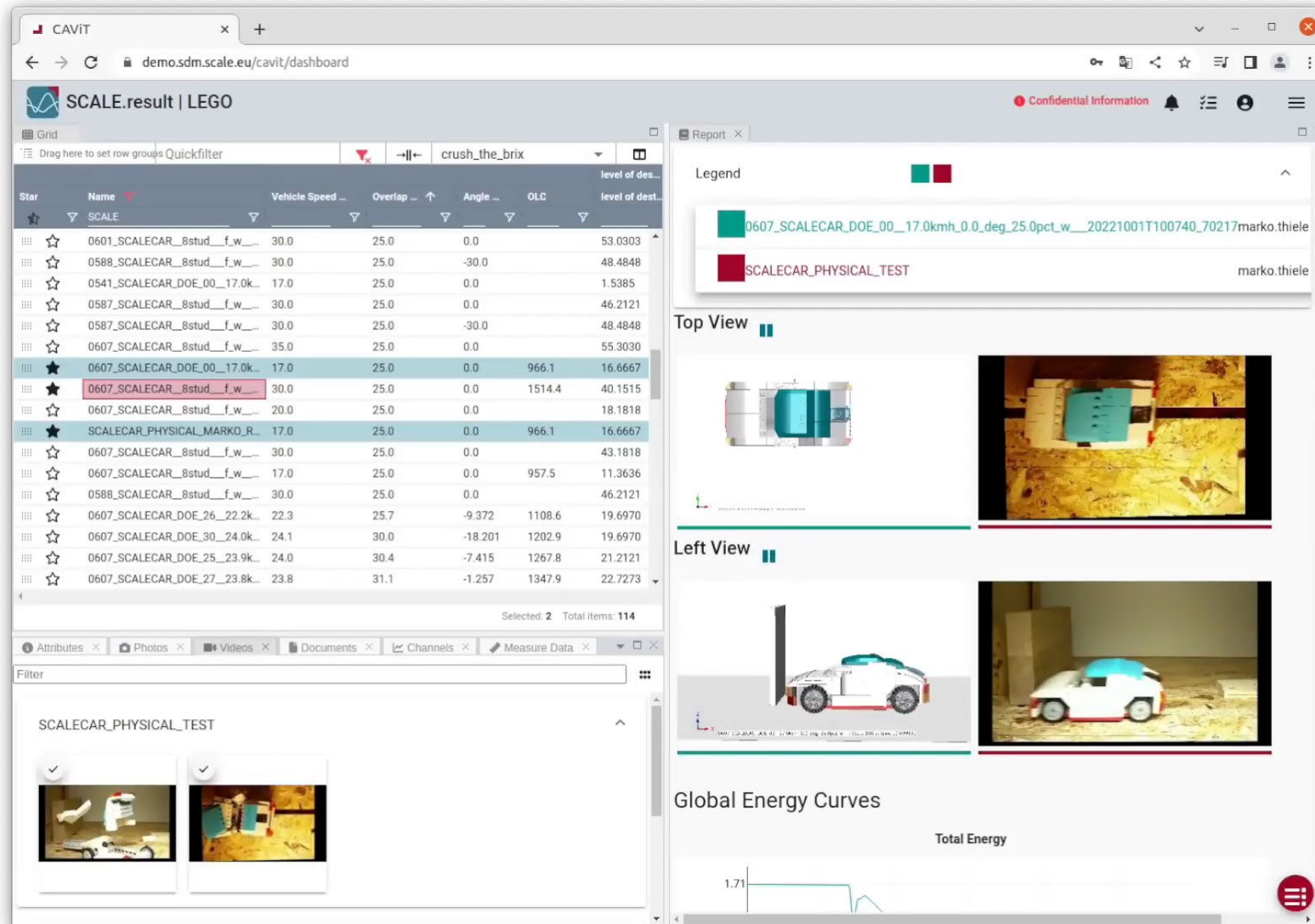
- Simulations correlated with test videos

- Parameters for validation
    - Friction
    - Clamping force
    - DTSTIF

- Basis to start more complex challenges

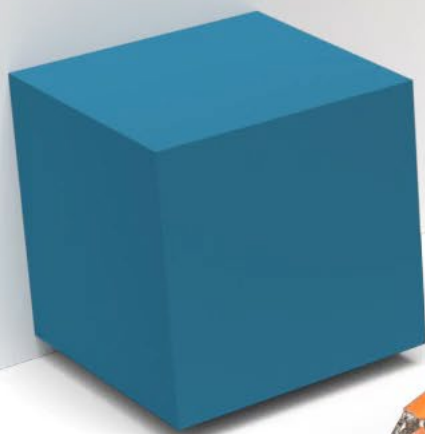# Model created by collaboration with SDM

DYNAmore Corporation USA
- **Nils** (LS-DYNA®)
- **Thomas** (meshing)

SCALE GmbH Dresden
- **David** (software)
- **Peter** (process, submitting to HPC)

DYNAmore France SAS
- **Pierre** (meshing, LS-DYNA®)

SCALE GmbH Ingolstadt
- **Alexandru** (model)
- **Marko** (LEGO® CAD, process, model, …)

Porsche:
2704 bricks
182 different bricks

DYNAmore GmbH Stuttgart
- **Andre** (organization)
- **Thorsten** (meshing, LS-DYNA®)
- **David** (materials)

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# Simulation Results

- 2704 parts (bricks)
- 19.5M elements
- 120ms
- 192CPU
- 22h runtime

0157_PORSCHE__911_-_GT3_RS_o__46kmh_0_de - State 1 at time 0.000000

Simulation Results

- 2704 parts (bricks)
- 19.5M elements
- 120ms
- 192CPU
- 22h runtime

https://youtu.be/LyJ5B---Zdo

The LEGO® Challenge
#legowette

LEGO® is a trademark of the LEGO Group of companies which does not sponsor, authorize or endorse these investigations.

Discipline – Car 2 Car Crash

- **Separate project & discipline**
  car to car crash as simulation discipline

- **Parameterization**
  velocity, angle, offset, ...
  - DOE studies
  - Data analysis

- **Multi-stage-assembly**
  references individual car projects as input

30kph

30kph
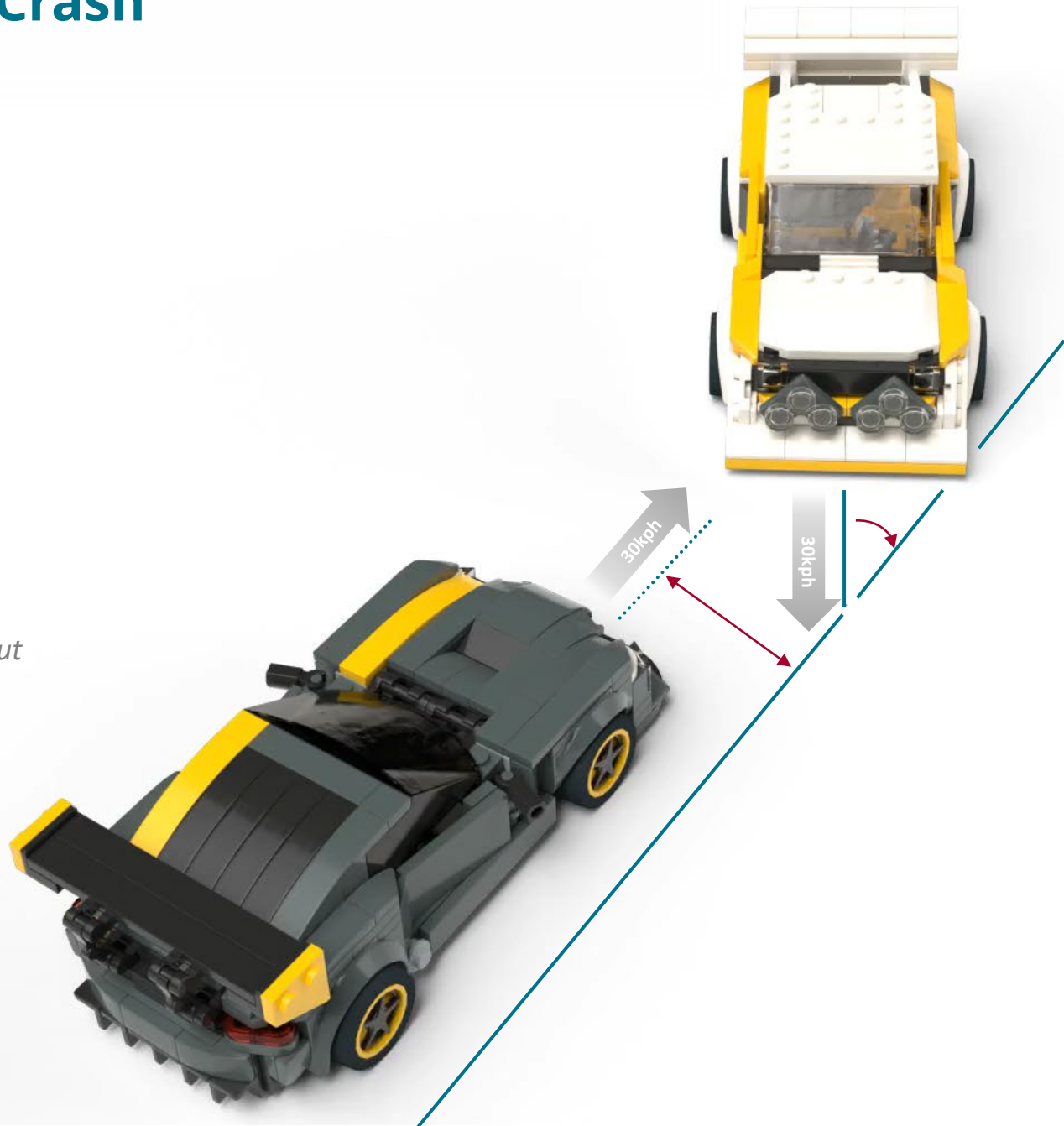
Multi Stage Assembly

Stage 1: create library
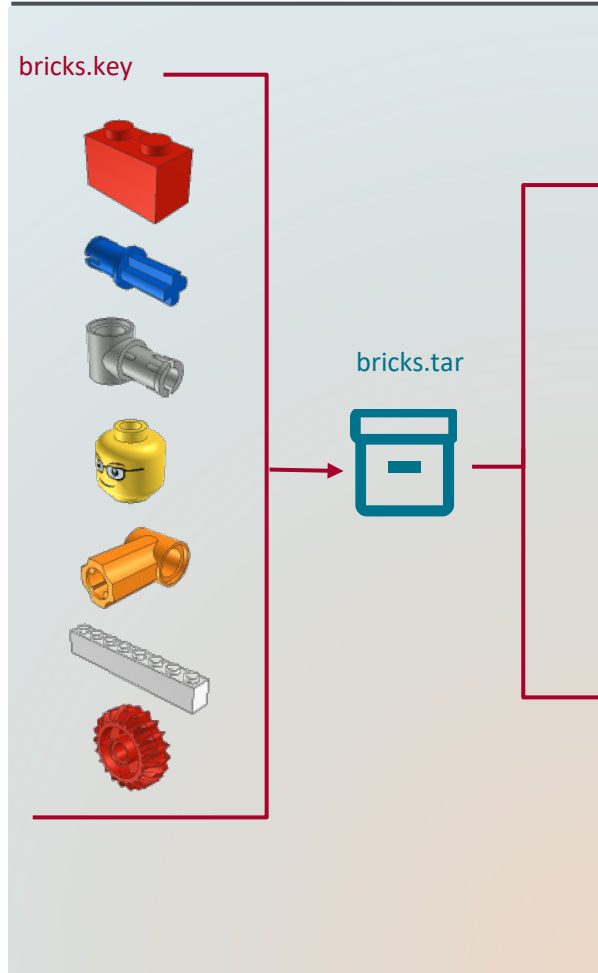
Stage 2: create car model
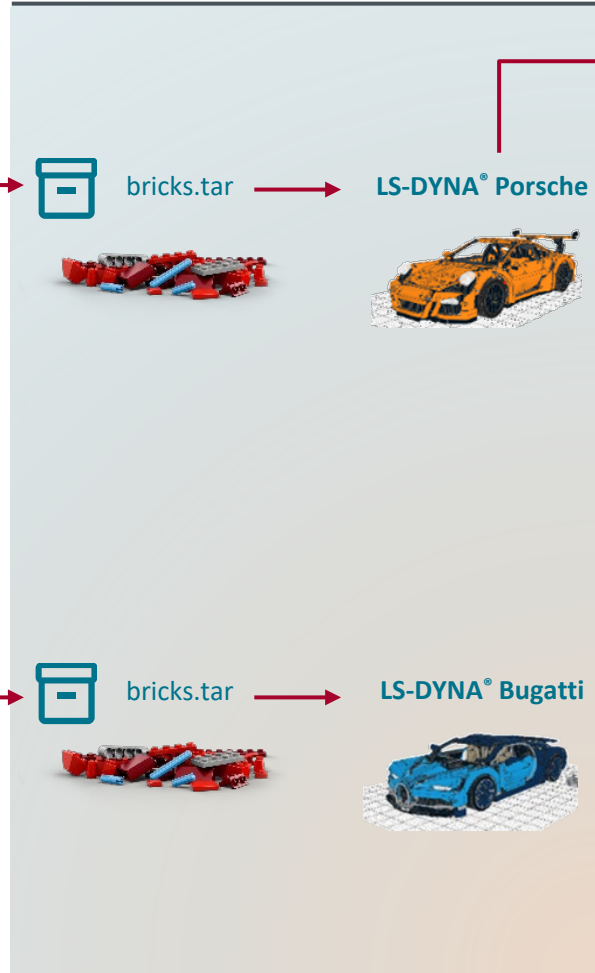
Stage 3: car to car simulation

Stage 4: rendering

bricks.key

bricks.tar

bricks.tar

LS-DYNA® Porsche

bricks.tar

LS-DYNA® Bugatti

porsche.ldr

bugatti.ldr

d3plot.fz

d3plot.fz

crash.blend

crash.mp4

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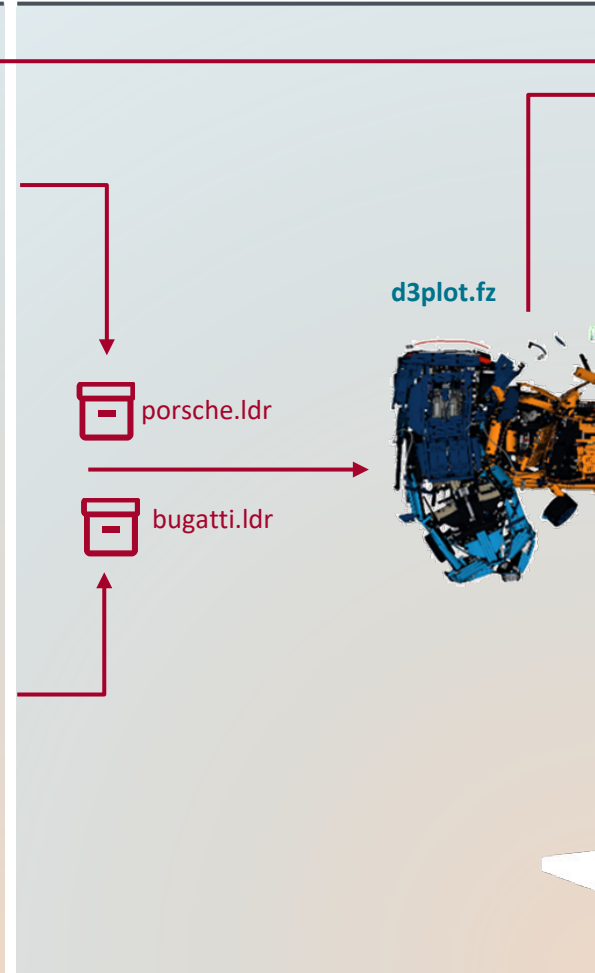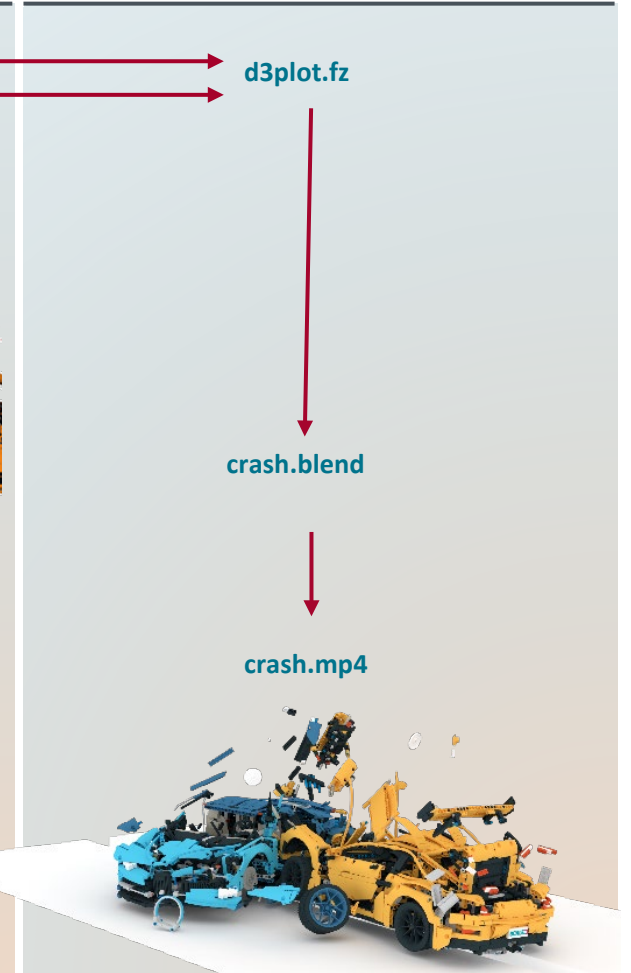
Simulation Results

- 6303 parts (bricks)
- 45.8M elements
- 130ms
- 192CPU
- 54h runtime

Simulation Results
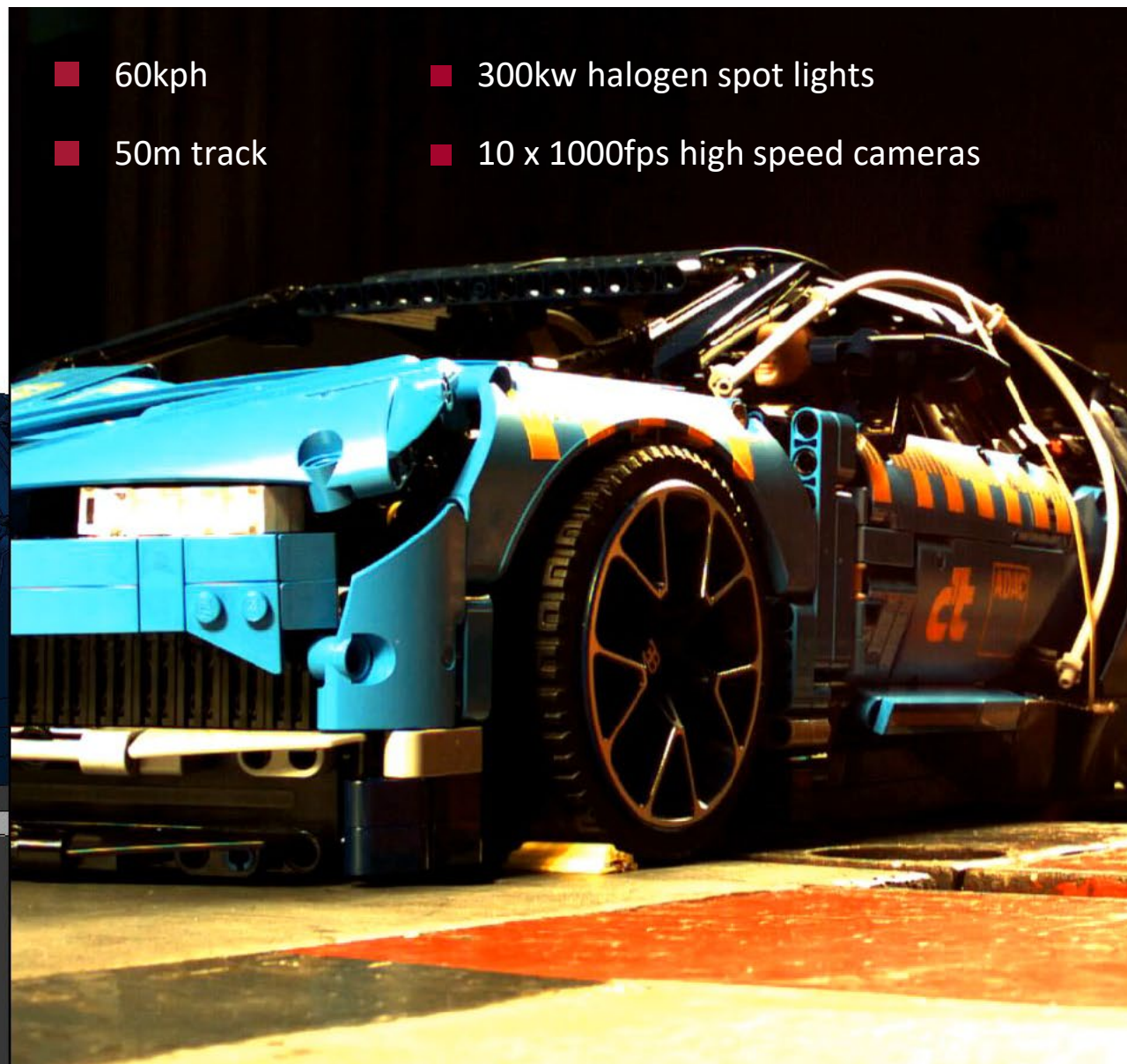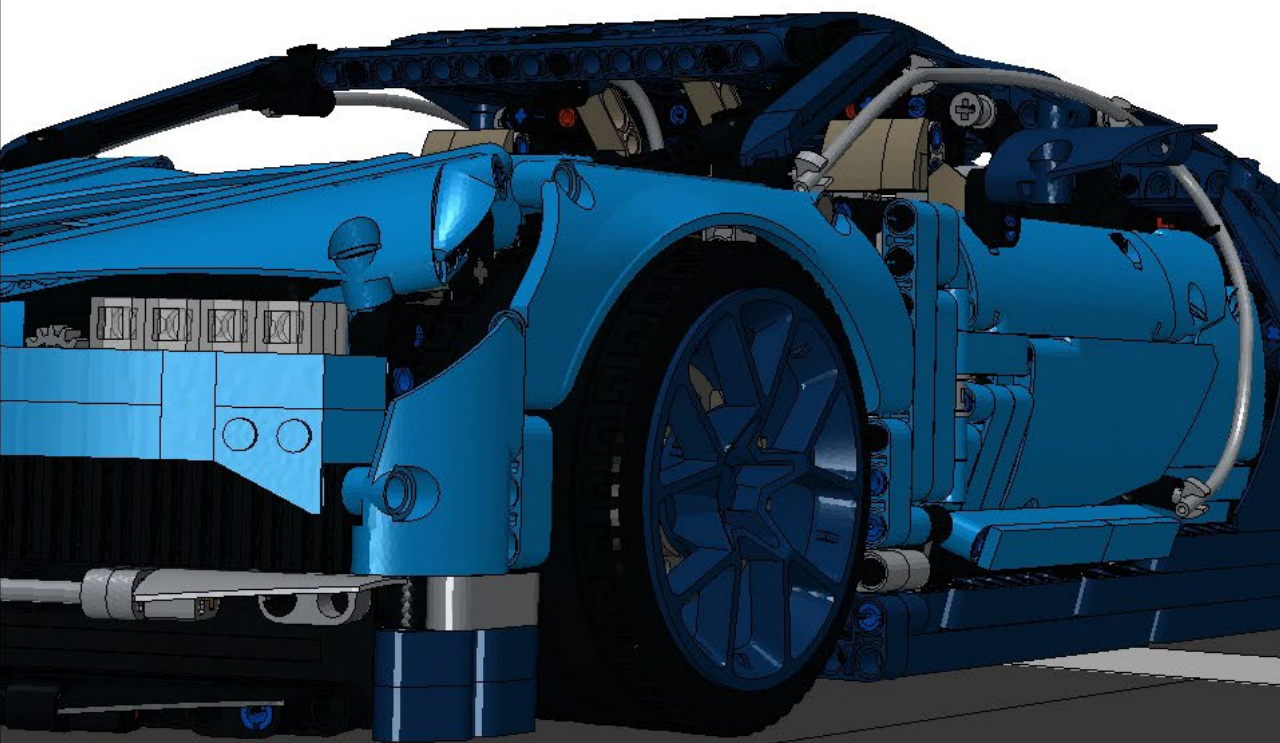
- 60kph
- 50m track
- 300kw halogen spot lights
- 10 x 1000fps high speed cameras

CAE DISCIPLINE: Rendering

LS-DYNA®

- **Simulation of light**
  setup and automated within SDM-System

- **Preprocessor**

  - Blender
    for studio and lighting setup

  - *.blend files
    managed in SDM-system

  simulation

  `d3plot.fz`

  convert

- **Solving**

  `*.blend`

  - d3plot.fz from LS-DYNA
    converted to 1TB blender in ~1 week
    render

  - Solver: Blender
    ~2 days model for 911 frames
    BLENDER

  - Camera perspectives as load cases

  - Videos as results
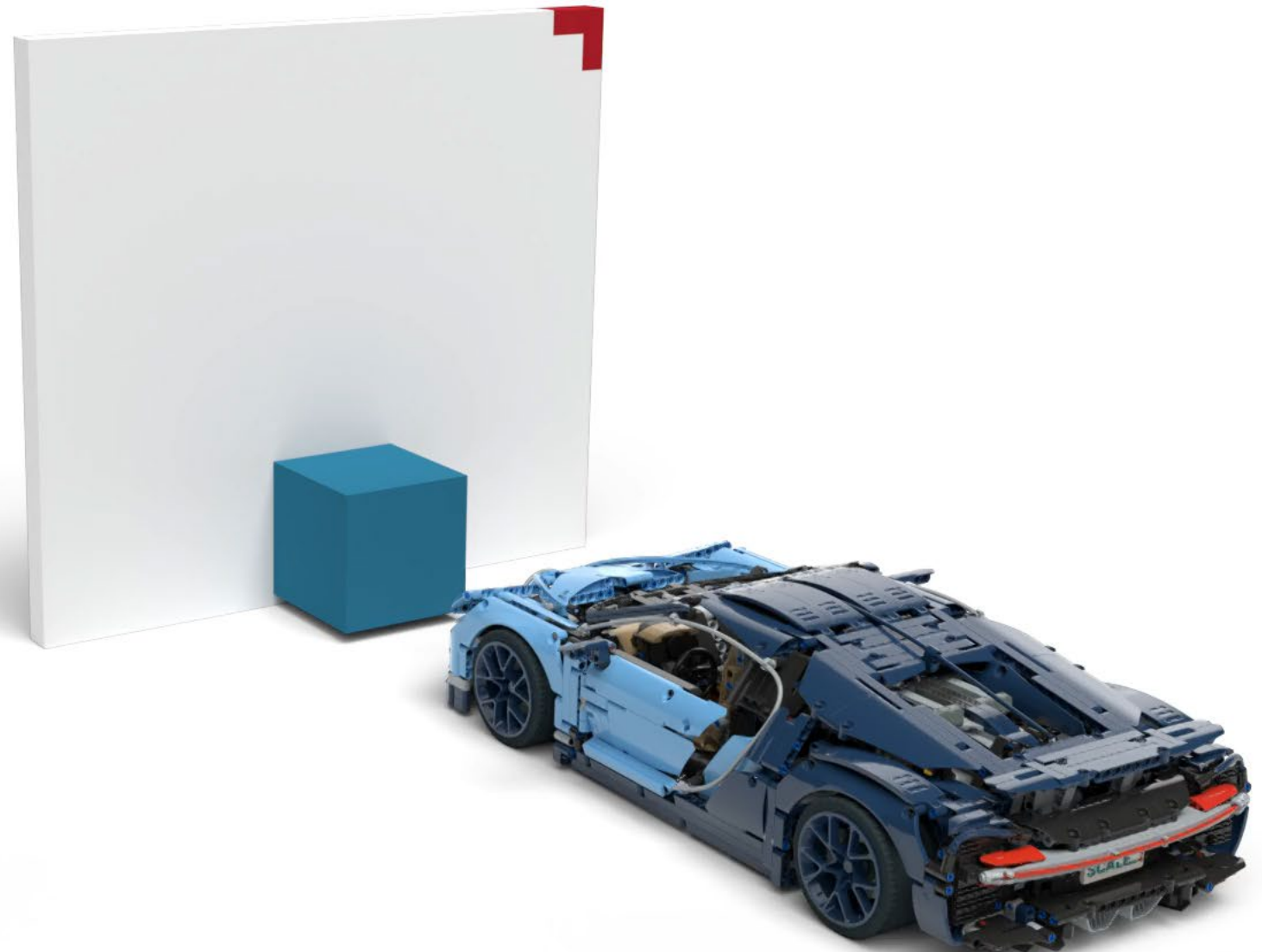
CAE-DISCIPLIN: RENDERING

LS-DYNA®

simulation

d3plot.fz

convert

*.blend

render

BLENDER
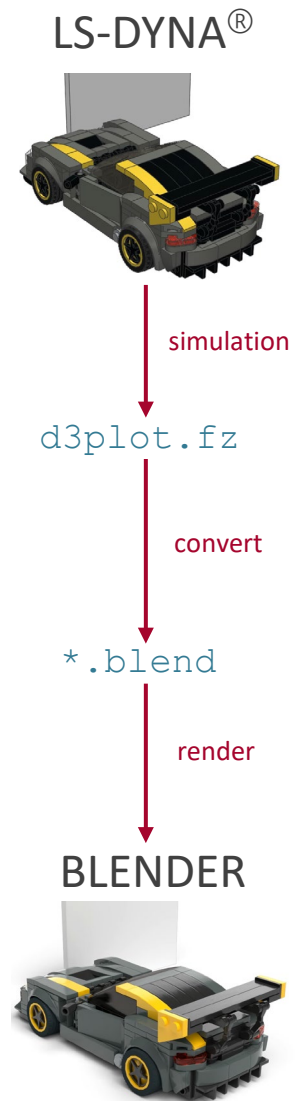
Data Analysis

- DOE and data-analysis
  setup easy within SDM-System
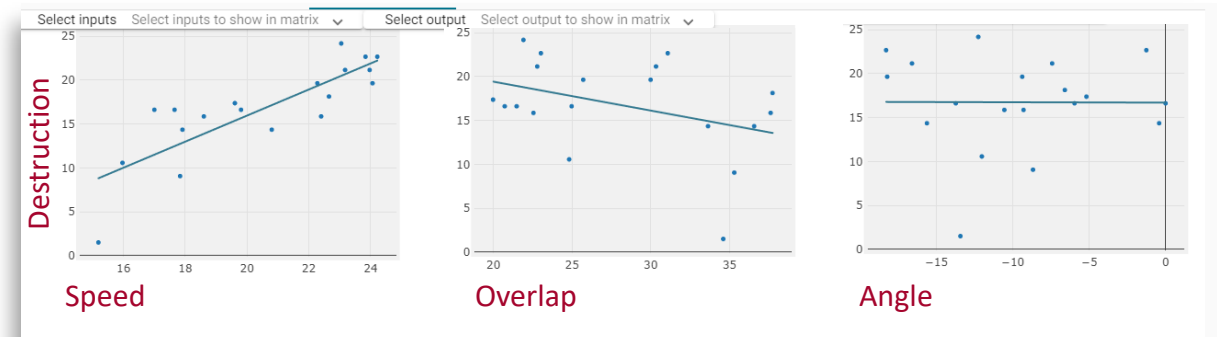
  - Input
    - Speed
    - Offset
    - Angle
  - Output
    - Level of destruction
   - Deceleration

- Analysis
  correlation, trends, meta-models

15-25kph

Speed
Overlap
Angle

Destruction

Destruction

Speed   Overlap   Angle

SCALE
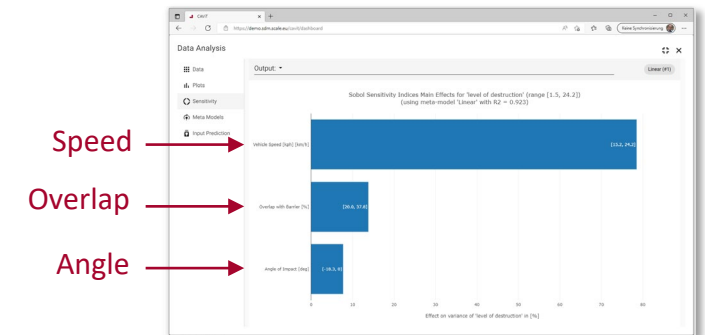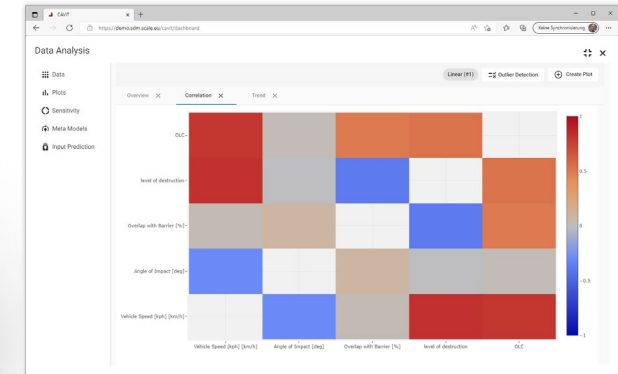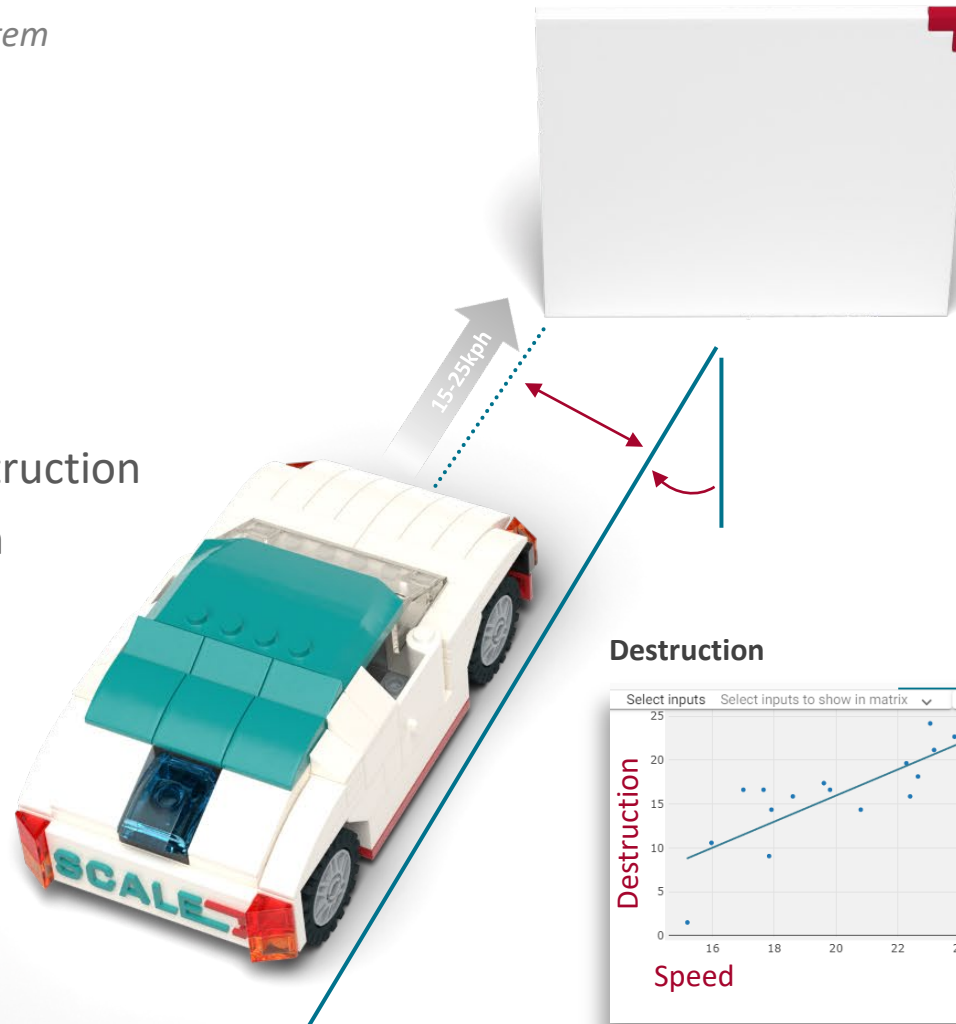
Discipline – CFD

- **Using same geometry as crash**
  separate simulation discipline

- **Fully automatized**
  runs directly after changing CAD geometry
  - Snappy hexmesh
  - OpenFOAM

- **Postprocessing**
  automatic extraction
  - Paraview
  - Images, videos, key-results, …
  - Data cached remotely
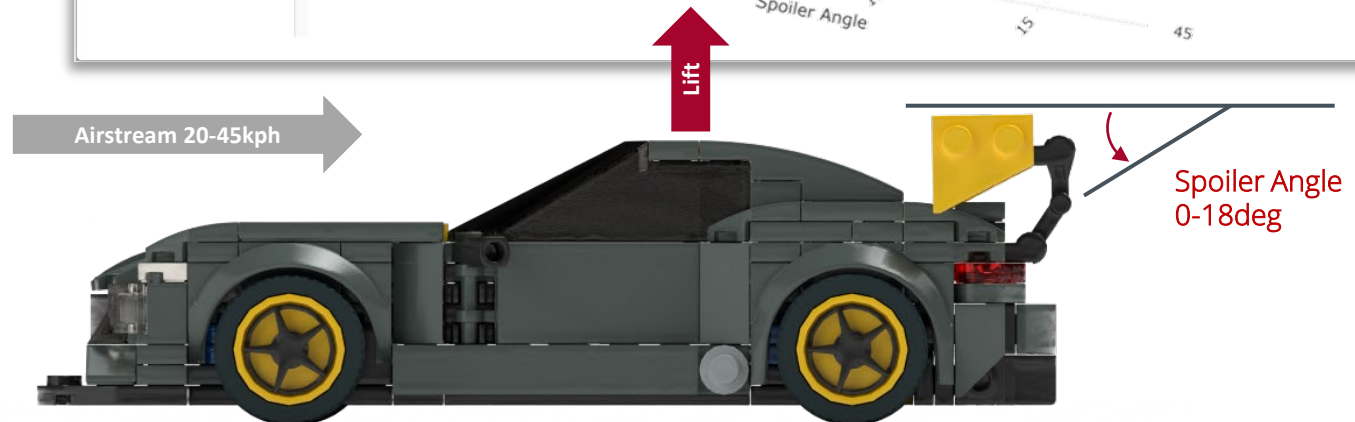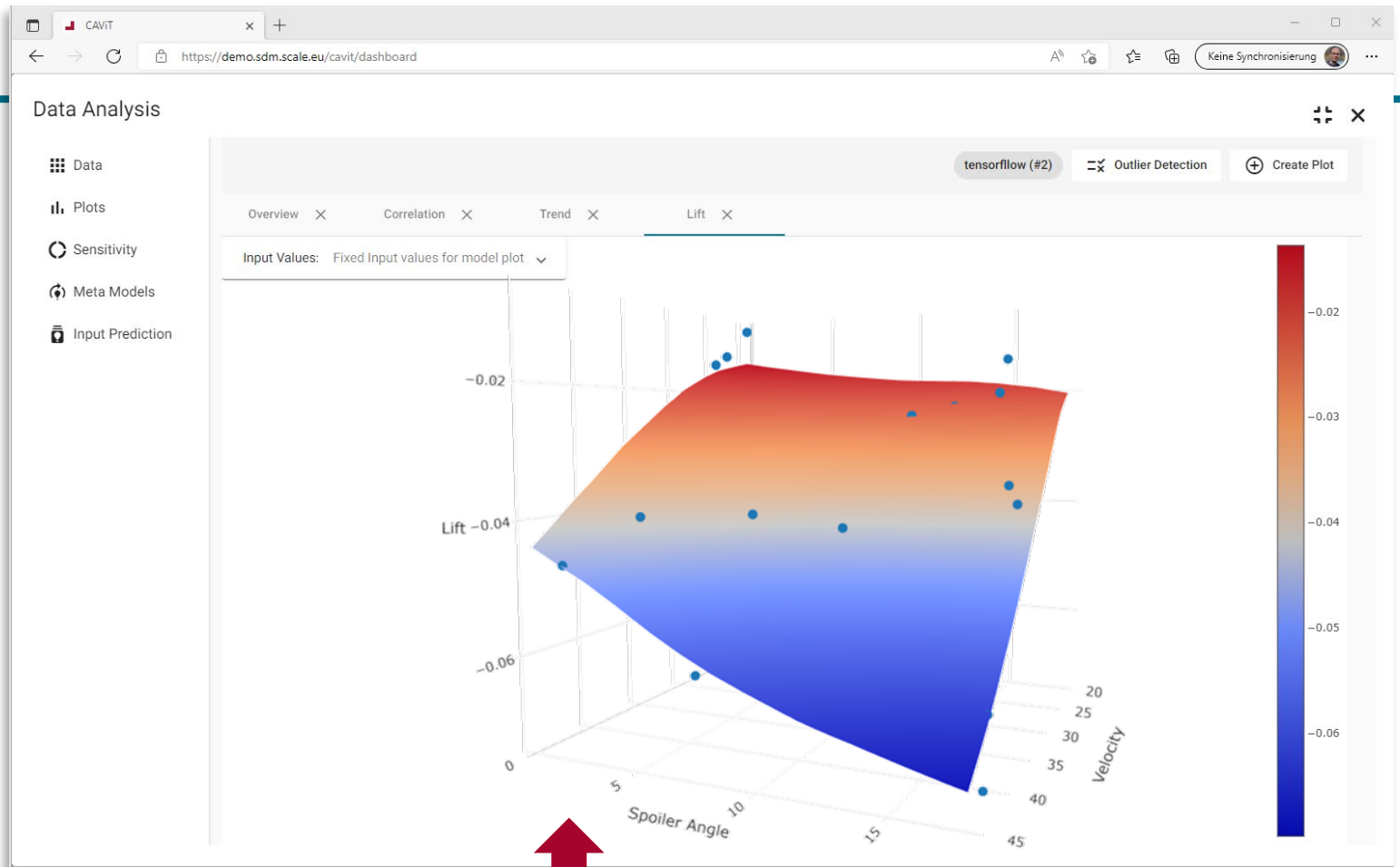   *accessible through VDI workstation*
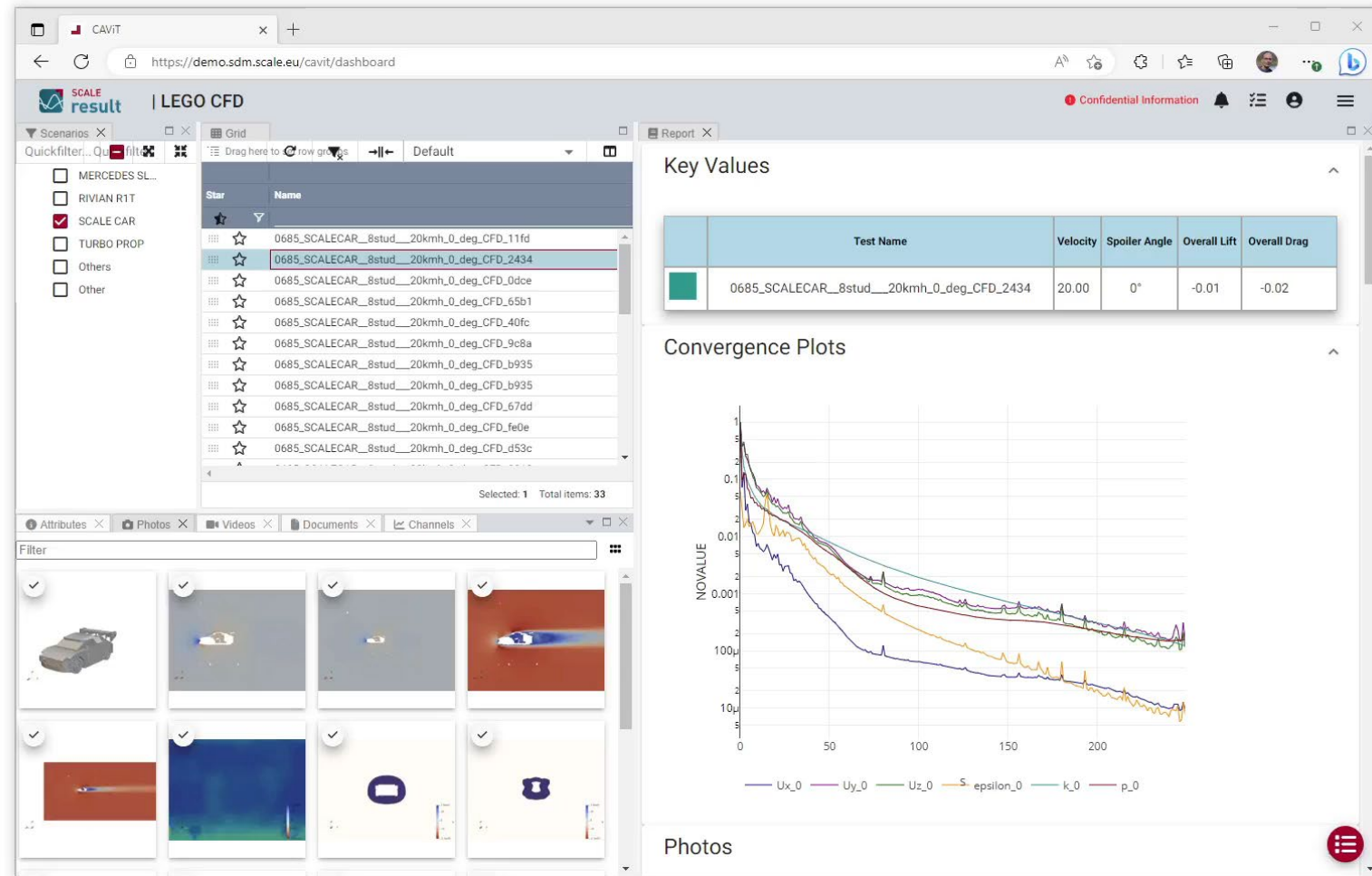
Data Analysis

- DOE and Data-Analysis
  setup easy within SDM-System

  - Input:
    - Velocity
    - Spoiler Angle
  - Output:
    - Drag
    - Lift

- Analysis
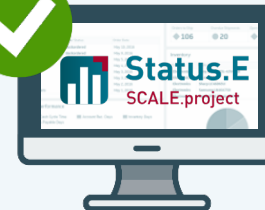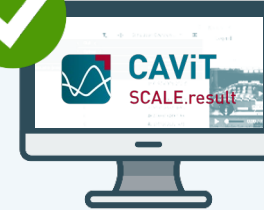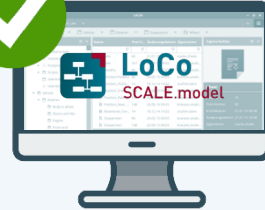 *correlation, trends, meta-models*

IT Architecture

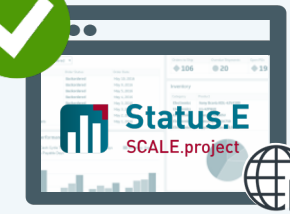**On Premises**

Cloud

sdm

sdm

SCALE.sdm Desktop
Next generation of desktop
applications with desktop
integration and local caches

LoCo
SCALE.model

CAViT
SCALE.result

Status.E
SCALE.project

SCALE.sdm Web Apps
Device independent
lightweight applications

20
22

LoCo
SCALE.model

CAViT
SCALE.result

Status.E
SCALE.project

SDM
Simulation Models

Eval. / Assessment
Reporting

Requirement Setup
Project Monitoring

What's Next

- More models
    - Technic #42115 @ xmas
    - 8 stud wide MOCs

- More simulation disciplines
    - Injection Molding
    - Powertrain
    - Multi body dynamics (MBD)
    - Water splashing (SPH)
    - ...

- More fun with simulation...

- Free models for HPC benchmarking and ...
    models are licensed CC BY-NC-SA 4.0 and can be provided for noncommercial use, reach out to info@scale.eu

SO LONG, AND THANKS

FOR ALL THE FISH

SCALE
IT-Solutions for CAE

THE REAL THING AT 60kph...

3 , 2 , 1 ...

BOOM