

# Facilitating Virtual Testing at an industrial level by Simulation Data Management

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**SCALE** 

IT-Solutions for CAE

# Content

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- EuroNCAP Virtual Testing workflow
- Motivation
- Why SDM
- Setup in SDM
- Workflow summary
- Summary and outlook



# EuroNCAP Virtual Testing workflow

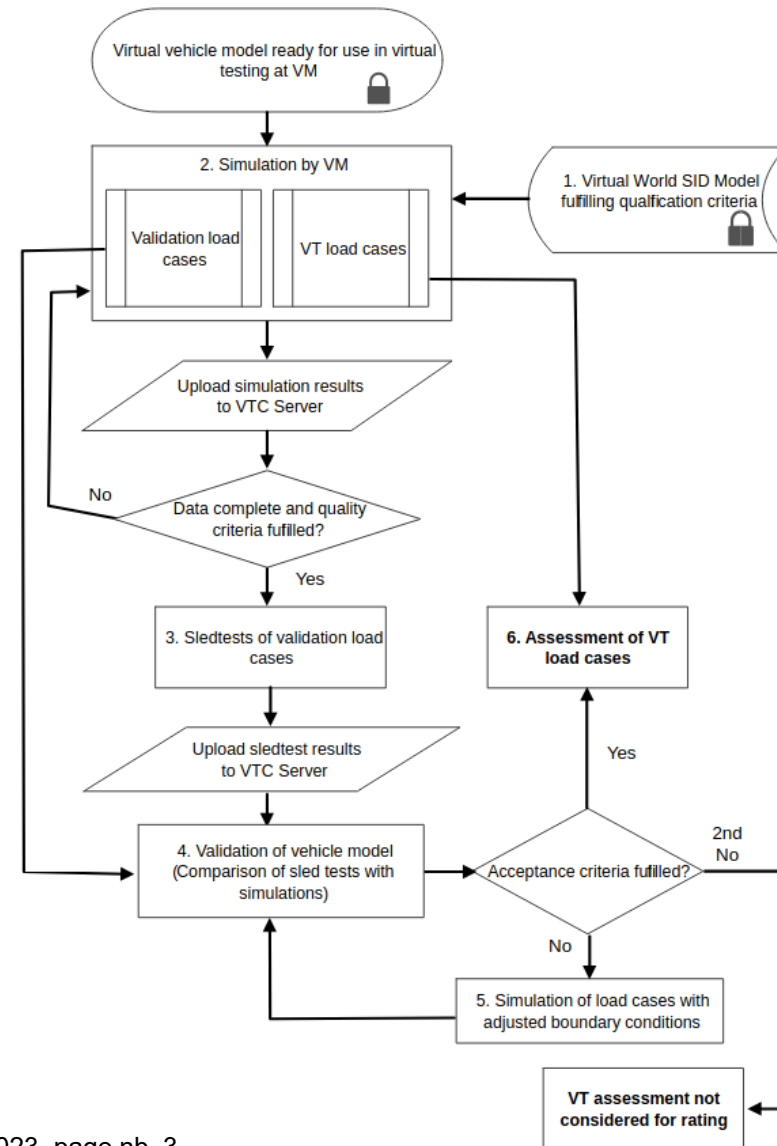
Why Virtual Testing? -> replace physical tests by simulation

## Virtual Testing (VT) workflow

- OEM prepares simulation results (Step 2)
- EuroNCAP checks data and accepts it
- OEM performs sledtest
- EuroNCAP validates simulation model
- EuroNCAP rates VT load cases

## CAE Engineer needs and objectives

- Data preparation and completeness
- EuroNCAP quality criteria
- Static model parts
- rating values



# EuroNCAP Virtual Testing workflow

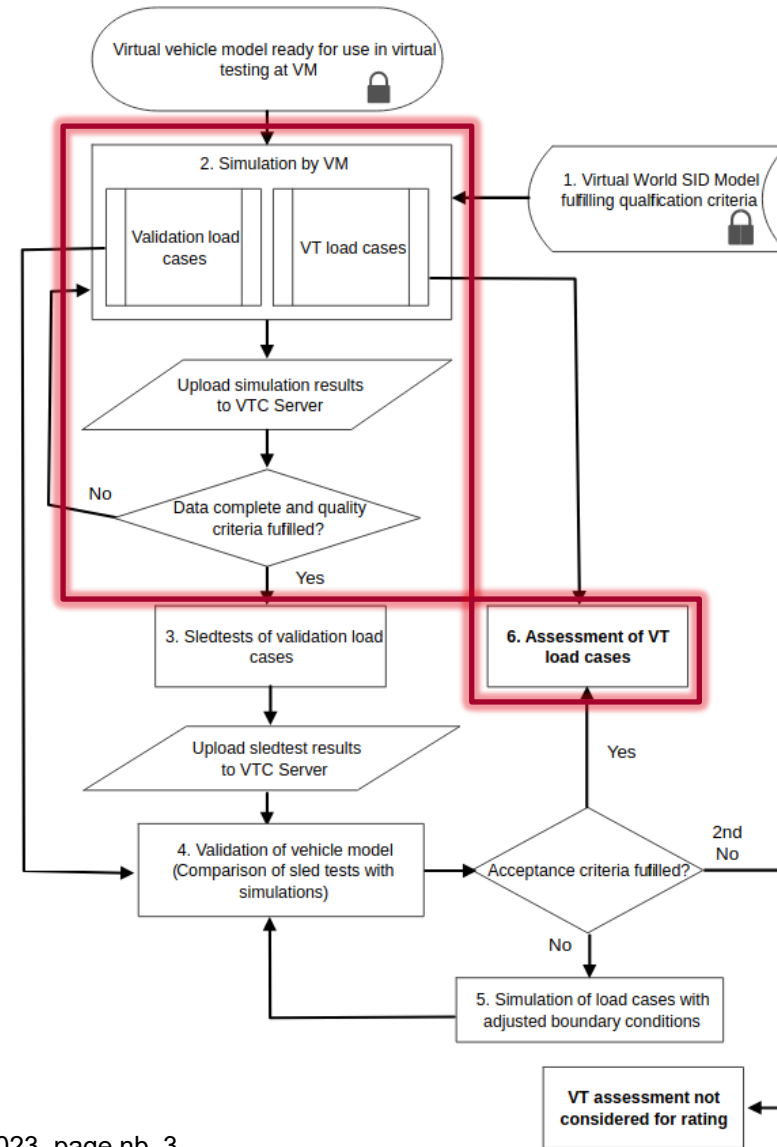
Why Virtual Testing? -> replace physical tests by simulation

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# Why SDM?

- Single point of access  
*simulations, tests*
- Collaboration  
*teamwork, sharing of data, speedup of development*
- Standardized data structure  
*homogeneous visualization, evaluation, assessment*
- Predictable & robust assessment  
*automatic generation of hashes, extraction of key-results, reports*
- Traceability and documentation  
*each change by each user is captured and documented*

The screenshot displays the SCALE.sdm software interface. At the top, there's a header with 'SCALE.sdm', a 'Result' dropdown, a 'Confidential information' warning, and a 'Yaris Demo' dropdown. Below the header, there are several panels:

- Projects and Collections:** Shows a list of projects and collections. The 'Collections' section is expanded to show 'Webinar 2024 (60)'.
- Scenarios:** A list of test scenarios with checkboxes for 'Front', 'Side', 'Rear', and 'Other'. The 'Front' scenario is selected.
- Table of Scenarios:** A table listing various test scenarios with columns for 'Star', 'Name', and 'Selected'. The selected item is '1484\_YARIS\_USNCAP\_RW\_\_\_\_\_f\_56kmh\_lhd\_\_67\_-\_Isdyna'.
- Legend:** A legend showing two entries: 'TEST\_YARIS\_USNCAP\_RW\_\_\_\_\_f\_56kmh\_lhd\_-T5677' with a green square and '1484\_YARIS\_USNCAP\_RW\_\_\_\_\_f\_56kmh\_lhd\_\_67\_-\_Isdyna' with a red square.
- Overview Crash:** A section titled 'Overview Crash' showing a photo of a red car in a crash test facility and a yellow 3D model of the car.
- Bottom View Crash:** A section titled 'Bottom View Crash' showing a photo of the car's chassis and a 3D model of the chassis.
- 3D Model Left Rail:** A section titled '3D Model Left Rail' showing a 3D model of the car's left rail.

# Setup in SDM: Requirements

- Project setup in SCALE.sdm
  - Responsibilities
  - Milestones
  - Requirements
  
- Quality criteria for EuroNCAP
  - Energy of dummy and whole system
  - Added mass
  - Simulation run time
  - Reasonable displacements
  
- Rating criteria for EuroNCAP
  - Accelerations
  - Forces
  - Displacements

## Thresholds for EuroNCAP quality criteria

WSID: Houghlass / Internal Energy	$-\infty \leq x < 0.1000$	$0.1000 \leq x < \infty$
Simulation Run Time / Max. Y Displacement ti...	$-\infty \leq x < 1.200$	$1.200 \leq x < \infty$
Max. H-point Z displacement (first 5ms)	$-\infty \leq x < 10.00$	$10.00 \leq x < \infty$
Full Setup: Houghlass / Internal Energy	$-\infty \leq x < 0.1000$	$0.1000 \leq x < \infty$
Added / Total Mass	$-\infty \leq x < 0.005000$	$0.005000 \leq x < \infty$

## Thresholds for EuroNCAP rating criteria

6.3 Table 7.: EuroNCAP VTC (10)			
✓	Head a3ms	$-\infty \leq x < 80.00$	$80.00 \leq x < \infty$
✓	Abdomen compression	$0.000 \leq x < 65.00$	$65.00 \leq x < \infty$
✓	Chest compression	$0.000 \leq x < 50.00$	$50.00 \leq x < \infty$
✓	Head excursion	$0.000 \leq x < 80.00$	$80.00 \leq x < \infty$
✓	Head HIC (15 ms)	$-\infty \leq x < 700.0$	$700.0 \leq x < \infty$
✓	Lumbar Fy	$0.000 \leq x < 2.000$	$2.000 \leq x < \infty$
✓	Lumbar Fz	$0.000 \leq x < 3.500$	$3.500 \leq x < \infty$
✓	Lumbar Mx	$0.000 \leq x < 120.0$	$120.0 \leq x < \infty$
✓	Pubic symphysis force	$0.000 \leq x < 2.800$	$2.800 \leq x < \infty$
✓	Neck moment y	$0.000 \leq x < 50.00$	$50.00 \leq x < \infty$

> Static bending, NVH (1)

# Setup in SDM: Model setup

- Modular structure  
*imported, versioned, managed*
- Shared data among load cases  
*includes, parameters, ...*
- Parameterization  
*restraint system parameters*

Groups (pool version: 20)

- > AIRBAG
- > BIW
- > CONDITION
- > DUMMY
- > MASTER
- > SCRIPT
- > SEAT
- > SEATBELT
- > Tools
  - > Assembly-Templates (37 - Python)
  - > Clusterscripts (348 - runner)
  - > Postprocessing (9 - VirtualTestingDemo)

Sort	Name	Short Descripti...	Barrier	Impact_angle	FileType
	⇒ FS_Pole_75_x-ref_z-re...	pole	p	75	
17	⇒ Airbag	dab_03			key
	⇒ Body in White	pulse_aemdb_90deg	a	90	key
	⇒ Body in White	pulse_aemdb_75deg	a	75	key
	⇒ Body in White	pulse_aemdb_60deg	a	60	key
	⇒ Body in White	pulse_pole_90deg	p	90	key
1	⇒ Body in White	carpet_02			key
3	⇒ Body in White	hvac_04			key

## Outlook:

- Crash pulses from pre simulation  
*automatically created from crash simulation*

Pool version: 20

Groups (pool version: 20)

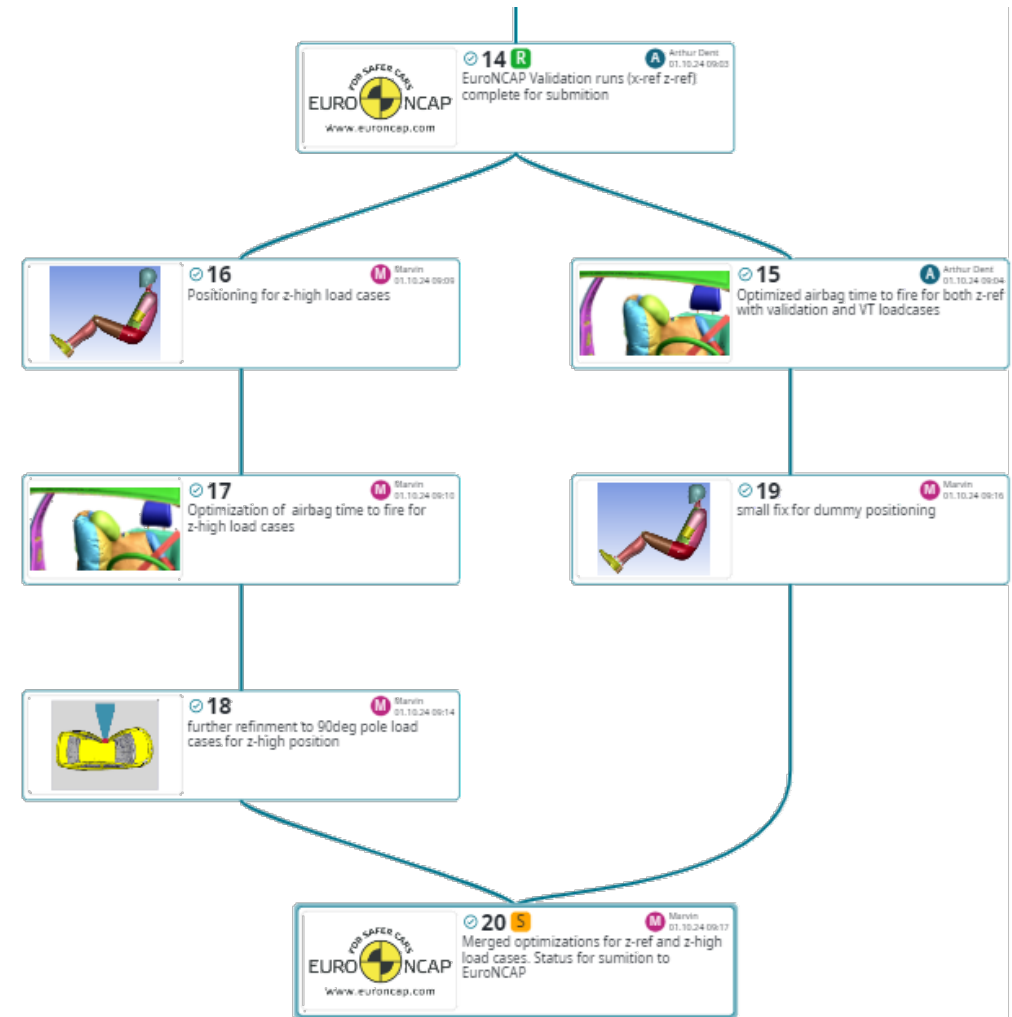
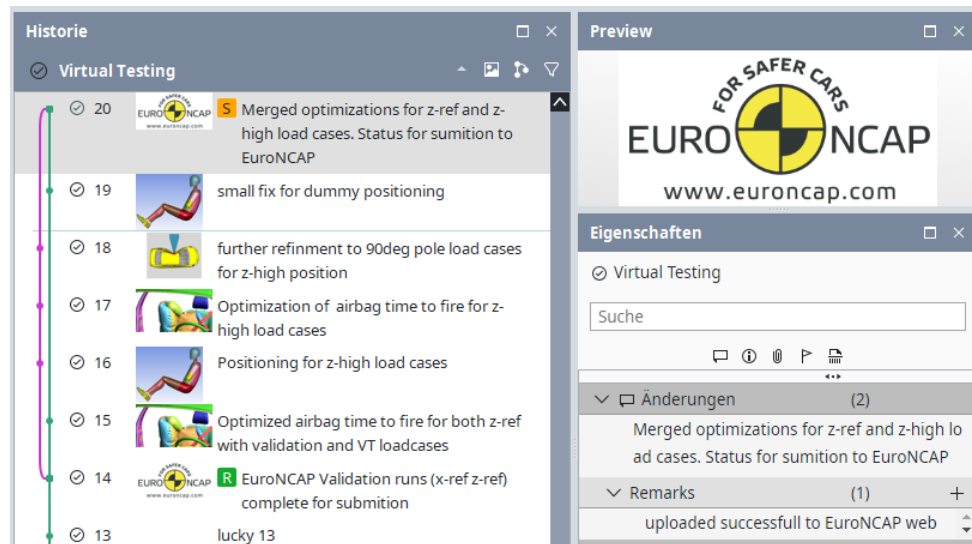
Runs (FS\_AEMDB\_75\_x-ref\_z-ref\_50M\_Sim\_1\_0020\_Validation\_...)

- Validation loadcase for VT process
  - ⇒ FS\_AEMDB\_75\_x-ref\_z-ref\_50M\_Sim\_1\_0020\_Validation\_aemdb
  - ⇒ FS\_Pole\_75\_x-ref\_z-ref\_50M\_Sim\_1\_0020\_Validation\_pole
- Virtual Testing loadcase for VT process
  - ⇒ FS\_AEMDB\_60\_x-ref\_z-ref\_50M\_Sim\_1\_0020\_VT\_-
  - ⇒ FS\_AEMDB\_75\_x-ref\_z-high\_50M\_Sim\_1\_0020\_VT\_-
  - ⇒ FS\_AEMDB\_90\_x-ref\_z-high\_50M\_Sim\_1\_0020\_VT\_-
  - ⇒ FS\_AEMDB\_90\_x-ref\_z-ref\_50M\_Sim\_1\_0020\_VT\_-
  - ⇒ FS\_Pole\_75\_x-ref\_z-high\_50M\_Sim\_1\_0020\_VT\_-
  - ⇒ FS\_Pole\_90\_x-ref\_z-ref\_50M\_Sim\_1\_0020\_VT\_-

Sort	Name	Short Descripti...	Barrier	Impact_angle	FileType
	⇒ FS_AEMDB_75_x-ref_...	aemdb	a	75	
17	⇒ Airbag	dab_03			key
	⇒ Body in White	pulse_aemdb_60deg	a	60	key
6	⇒ Body in White	pulse_aemdb_75deg	a	75	key
	⇒ Body in White	pulse_aemdb_90deg	a	90	key
4	⇒ Body in White	ip_03			key
5	⇒ Body in White	pedals_06			key
	⇒ Body in White	pulse_pole_75deg	p	75	key
7	⇒ Body in White	sled_body_04			key

# Setup in SDM: Traceability and documentation

- **Documentation**  
*any change can be documented in much detail ... description, images, documents, ...*
- **Traceability**  
*each change is automatically captured and can be tracked down later*
- **Collaboration**  
*anyone in the team can see and access every change of other team members*





# Setup in SDM: Job submission and result data preparation

- Job submission to HPC clusters
  - Fast job submission with efficient data transfer
  - Server component for specific HPC integration
  - Live job feedback to the user
- Solver specific assembly
  - Solver independent SDM system
  - Python Assembly template as solver specific “API”
- Hashing process for static model parts
  - Crash pulses for acceleration of sled
  - Nodes of dummy & seat
- Automated result data storage and preparation
  - Extraction of result data in ISOMME format
  - Easy integration of third party software (Oasys)

The Properties window displays the configuration for a simulation job. The title bar reads "Properties". The main content area shows the job name "FS\_Pole\_75\_x-ref\_z-high\_50M\_Sim\_1\_\_0020\_VT\_-". Below the job name are several icons: a play button, a cloud icon, a "Data check" toggle switch, and a search input field. A toolbar with various icons is visible below the search field. The main content is organized into a tree view with the following sections:

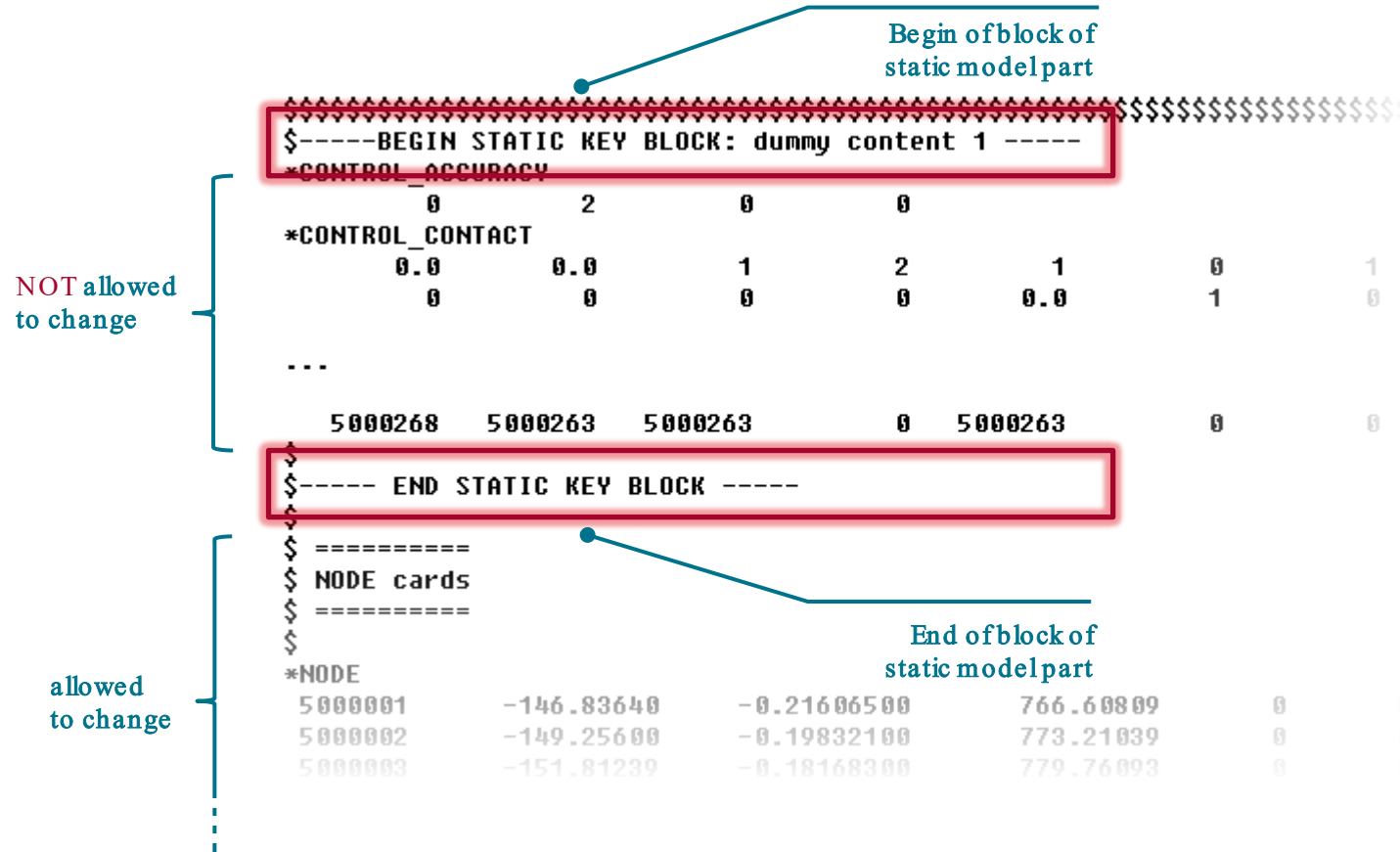
- Pool Version Changes (1)
  - Merged optimizations for z-ref and z-high load cases. Status for sumition to EuroNCAP
- Assembly (4)
  - Problematic entries (0)
- Scripts (2)
  - extract\_6vtc\_videos (checkbox)
  - unpack\_txz\_copy\_results (checkbox checked)
- Common (4)
  - Template SCALE/scale.py

The Jobs window displays a list of simulation jobs. The title bar reads "Jobs". The list contains the following entries:

- FS\_Pole\_75\_x-ref\_z-high\_50M\_Sim\_1\_\_0012\_VT\_- (2024-09-27 13:59:48)
  - Solving job: Solving: simulation time 0.053999 of 0.2 computed (Energy Info after 5) [Job Folder Log](#)
  - Model assembly job
    - Scheduler-Information: Submitted Job 56462
  - Solving job
    - Solving: simulation time 0.053999 of 0.2 computed (Energy Info after 5) [Job Folder Log](#)
- FS\_AEMDB\_90\_x-ref\_z-high\_50M\_Sim\_1\_\_0012\_VT\_- (2024-09-27 13:59:49)
  - Solving job: Solving: simulation time 0.053999 of 0.2 computed (Energy Info after 5) [Job Folder Log](#)

# Setup in SDM: static model parts

- Static model parts
  - Most/certain model parts must not change between LCs
  - Example: entire dummy except NODEs
- Hash
  - Computed unique and short string for a large text block
  - Changes as soon as even one character changes in input
- LS-DYNA Input
  - Yet non existing card syntax assumed
  - Hashing automatism
  - Fast and effective hash comparison



# Setup in SDM: Assessment of Results

- Access to all simulations & testst
  - Search
  - Filter
  - ISOMME Export
- Interactive and custom web reports
  - Runs in any web browser
  - Access to all data of selected simulations
  - Compare on the fly in case of multi selection
  - Tables with key results
  - Colored assessments from defined requirements
  - Channel plotter
  - Synchronous video playback
- EuroNCAP VT web report
  - Legend with overview and overall check
  - Sections for each result category

The screenshot displays the SCALE.sdm web interface. On the left, a 'Grid' table lists simulation runs with columns for 'Star', 'Run Name', 'Owner', and 'Date'. The selected run is 'FS\_AEMDB\_90\_x-ref\_z-high\_50M\_Sim\_1\_0013\_VT\_'. On the right, a 'Report' window is open, showing a 'Legend' table with columns for 'Test Name', 'Overall', '# Invalid Result Criteria', '# Mismatched Parts', '# Invalid Rating Criteria', and '# Channels Videos'. Below the legend, the report is divided into sections: 'Quality Criteria for EuroNCAP', 'Validation of Static Model Parts', and a table of 'Part' results.

Test Name	Overall	# Invalid Result Criteria	# Mismatched Parts	# Invalid Rating Criteria	# Channels	# Videos
FS_AEMDB_90_x-ref_z-high_50M_Sim_1_0013_VT_	Ok	0	-	0	115	6

Result	Limit	
Full Setup - Maximum Hourglass Energy < 10% of Maximum Internal Energy	≤ 0.1	0.01676
WSID Dummy - Maximum Hourglass Energy < 10% of Maximum Internal Energy	≤ 0.1	0.02547
Maximum Added Mass (%) < Total Model Mass at the beginning of the simulation	≤ 0.005	5.016e-4
Z Displacement (mm) in the first 5 ms of the simulation	≤ 10	4.2
(Time of Maximum Head Y Displacement) + 20% < Simulation Time	≥ 1.2	1.5
Number of Mandatory Channels	115	115
Number of Mandatory Videos	6	6

Part	
carpet part 1	...30321
carpet part 2	...1817a
biw column (full)	...de3eb
biw hwac (full)	...bc2df
biw ip03 (full)	...1c29f
biw pedals (full)	...083d7
sled part 1	...51d71
sled part 2	...88c9c
contact_05 (full)	...d86e2
control_02	...36e3e

# Setup in SDM: Assessment of Results – Quality criteria of data

- Quantity and Quality criteria for EuroNCAP  
*compare for each selected simulation*
  - Hourglass Energy of WSID Dummy & full Setup
  - Added Mass
  - Displacements of Dummy
  - Number of required Channels and Videos
  
- Summary of “static model parts”  
*compare to validation simulation and see instantly any unintended model changes*
  - 1<sup>st</sup> column is the reference simulation (from validation)
  - Subsequent columns from other simulations of other load cases

Quality Criteria for EuroNCAP				
Result	Limit			
Full Setup - Maximum Hourglass Energy < 10% of Maximum Internal Energy	≤ 0.1	0.01943	0.01871	0.001888
WSID Dummy - Maximum Hourglass Energy < 10% of Maximum Internal Energy	≤ 0.1	0.02882	0.02759	0.005757
Maximum Added Mass (%) < Total Model Mass at the beginning of the simulation	≤ 0.005	5.016e-4	5.016e-4	5.016e-4
Z Displacement (mm) in the first 5 ms of the simulation	≤ 10	4.2	4.2	
(Time of Maximum Head Y Displacement) + 20% < Simulation Time	≥ 1.2	1.5	1.5	
Number of Mandatory Channels	115	115	115	61
Number of Mandatory Videos	6	6	6	6

Validation of Static Model Parts			
Part			
carpet part 1	...30321	...30321	...30321
carpet part 2	...1817a	...1817a	...1817a
biw column (full)	...de3eb	...de3eb	...de3eb
biw hwac (full)	...bc2df	...bc2df	...bc2df
biw ip03 (full)	...1c29f	...1c29f	...1c29f
biw pedals (full)	...083d7	...083d7	...083d7
sled part 1	...51d71	...51d71	...51d71
sled part 2	...88c9c	...88c9c	...88c9c
contact_05 (full)	...d86e2	...d86e2	...d86e2
control_02	...36e3e	...36e3e	...36e3e
dummy content 1	...1670a	...9592a	...1670a
dummy content 2	...5414c	...5414c	...5414c
seat part 1	...813c9	...813c9	...813c9
seat part 2	...3ca67	...3ca67	...3ca67
seat belt content	...61b01	...61b01	...61b01
seat belt part 2	...df543	...467cf	...df543

# Setup in SDM: Assessment of Results – Rating criteria

- Rating values for EuroNCAP

*compare for each selected simulation*

*see instantly which values don't match the requirements*

- Accelerations
- Forces
- Displacements
- ...

- Channel plotter

*inspect and compare all channel data from selected simulations*

- Interactively select and deselect simulations
- Chouse location, parameter and axis to be displayed
- Easy to identify missing required channels

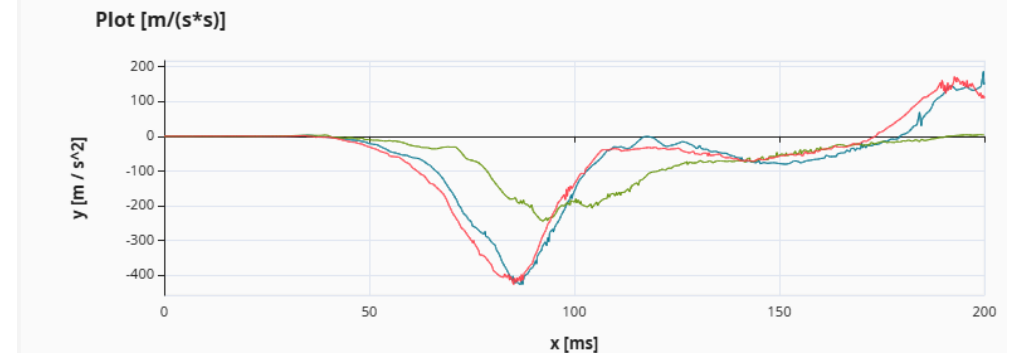
- Video player

*inspect and compare all videos from selected simulations*

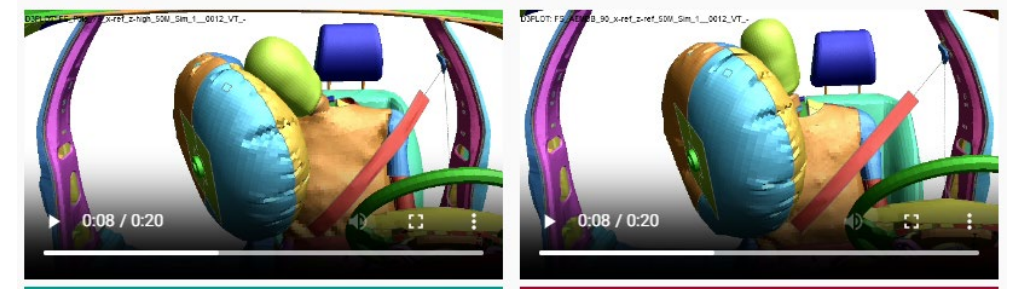
- Synchronously play videos side by side to compare load cases
- Inspect videos frame by frame with common slider for all videos

Assessment Criterion	Limit	█	█	█
HIC15	≤ 700	169	33.67	143.8
A3ms	≤ 80	43.31 G	23.76 G	41.9 G
Upper Neck Fz	≤ 3.74	0.296 kN	0.465 kN	0.192 kN
Upper Neck MxOC	≤ 248	21.9608 N m	142.298 N m	24.4736 N m
Upper Neck MyOC	≤ 50	22.7058 N m	46.3669 N m	14.2845 N m
Lower Neck Fz	≤ 3.74	0.154 kN	0.054 kN	0.115 kN
Lower Neck Mx(base of neck)	≤ 248	6.24678 N m	0.496497 N m	4.60146 N m
Lower Neck My(base of neck)	≤ 700	11.7259 N m	7.50386 N m	5.74929 N m
Chest compression	≤ 50	0.0	0.0	0.0
Abdomen compression	≤ 65	0.0	0.0	0.0
Pubic Symphysis force	≤ 2.8	0.0	0.0	0.0
Lumbar Fy	≤ 2	0.423 kN	<b>2.07 kN</b>	0.404 kN
Lumbar Fz	≤ 3.5	0.126 kN	1.01 kN	0.106 kN
Lumbar Mx	≤ 120	5.95886 N m	<b>120.588 N m</b>	8.51914 N m
Head excursion	≤ 80	44.3 mm	45.8 mm	45.6 mm

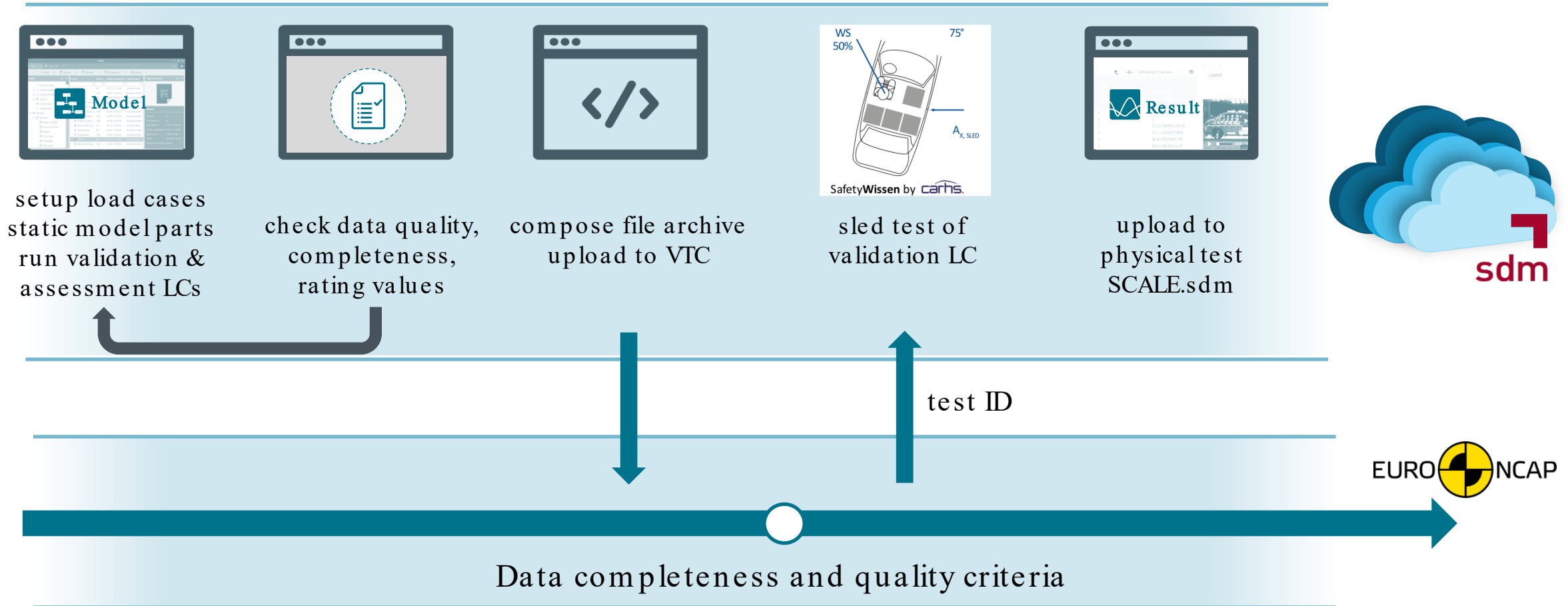
Location: Head CoG acceleromete... Parameter: Accelerations [3] Axis: y [3]



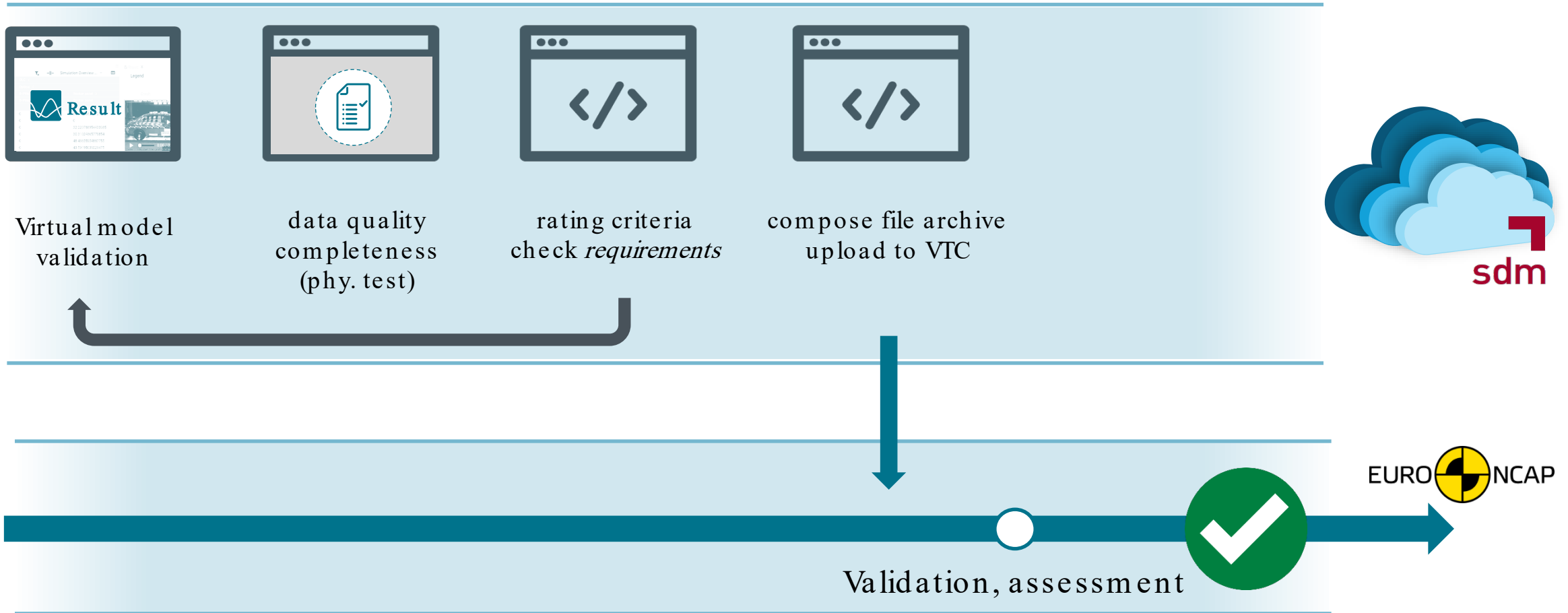
00:08 / 00:20



# Workflow summary

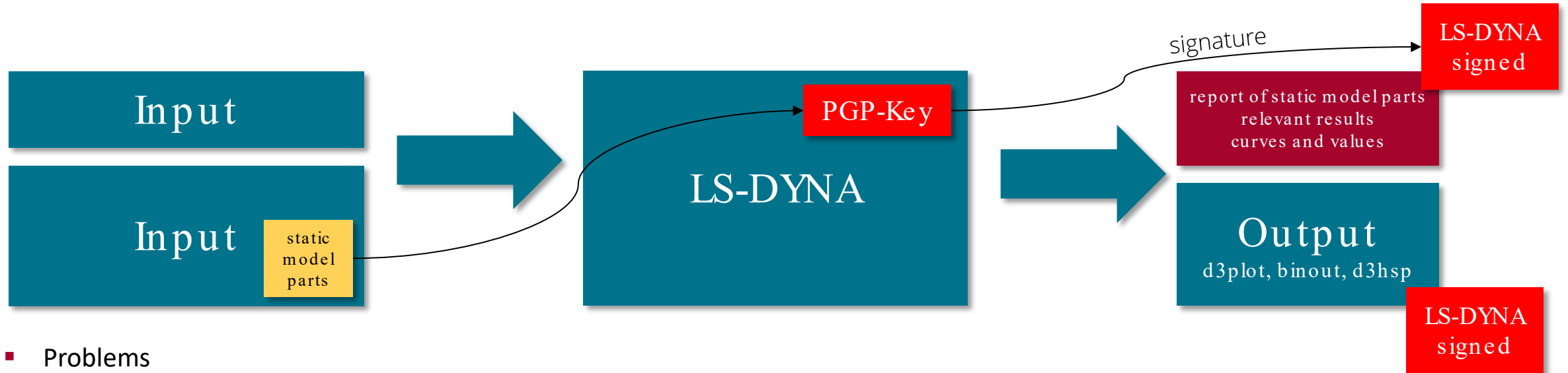


# Workflow summary



# Safeguarding against data manipulation

- Signing instead of hash
  - Would allow to prove that a given input was used to create a specific output (simulation result)
  - “static model parts” of OEMs would not need to be disclosed to testing authority



- Problems
  - Signatures can not proof that “static model parts” do not contain any model data that is somehow tampering the simulation results in the 1<sup>st</sup> place
    - e.g. how to proof that crash pulses are not tempered such that a certain rating is achieved?
  - All output needs to be signed, and it would be probably best if the output complies to the requirements of EuroNCAP (*e.g. channels and key-results already in ISO-MME*)
  - Need to be implemented by FEM solver developers



# Summary and Outlook

- Using an SDM-System to streamline the VTC process
  - Automated result data preparation and checks
  - Efficient integration of the iterative development process
  - Traceability and documentation
- Virtual Testing workflow at an industrial level
  - High complexity in the CAE world (model, load cases, processes)
  - Virtual testing adds to the complexity
  - Tools for efficient data and process management required for a productive usage
- Challenges & Outlook:
  - Safeguarding against manipulation has some open questions to be solved
  - ...



# SO LONG, AND THANKS

FOR ALL THE FISH



<https://www.linkedin.com/company/scale-gmbh/>

**SCALE**

IT-Solutions for CAE

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