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Facilitating Virtual Testing at an Industrial Level by Simulation Data Management

The Future of Virtual Certification for Automotive Crash Safety

Bengaluru, India
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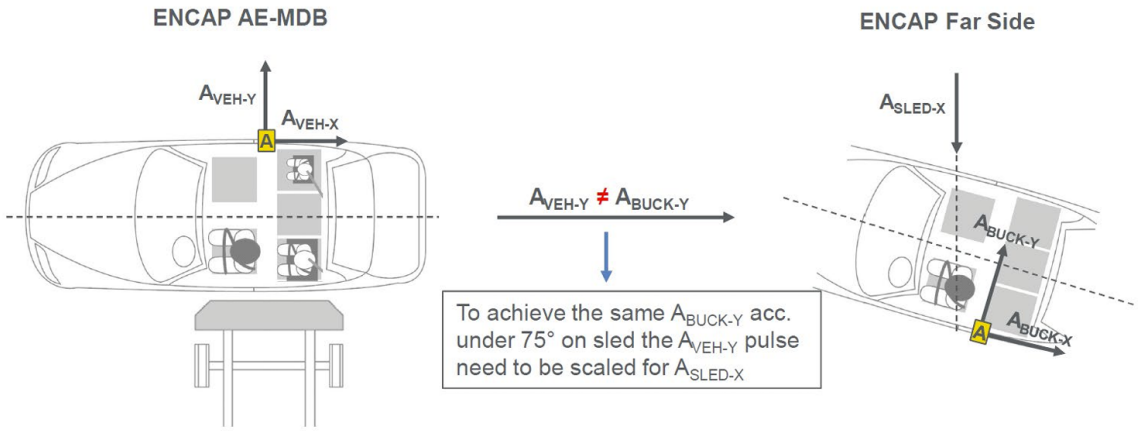
Far Side Occupant Test – Virtual Certification

- No physical tests by Euro NCAP
  - Replace physical tests by simulation
- OEM submits 8 simulation results:
  - 2 for model *Validation*
  - 6 for virtual testing (*VT*) or certification
- Euro NCAP checks data and accepts it
- OEM performs physical sled test
- Euro NCAP validates simulation model
- Euro NCAP rates virtual testing load cases



This marks a significant shift in methodology.

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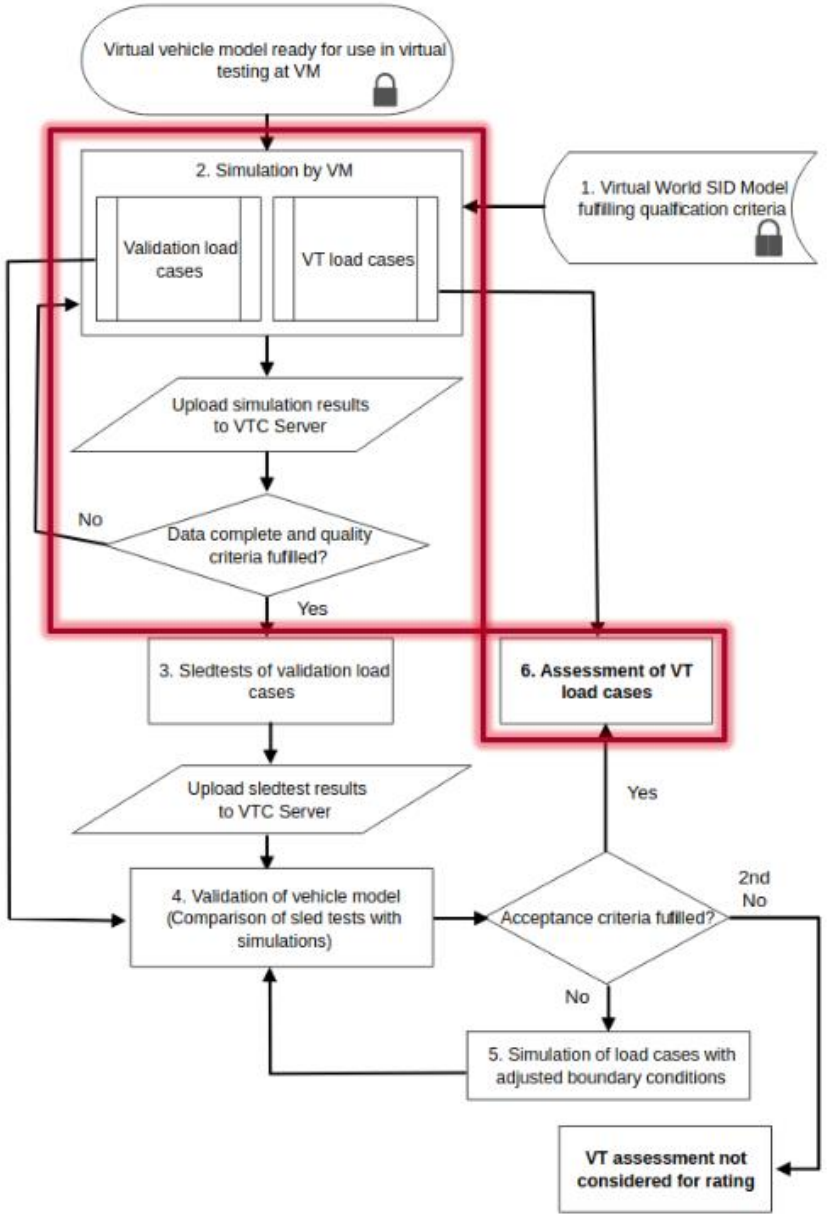
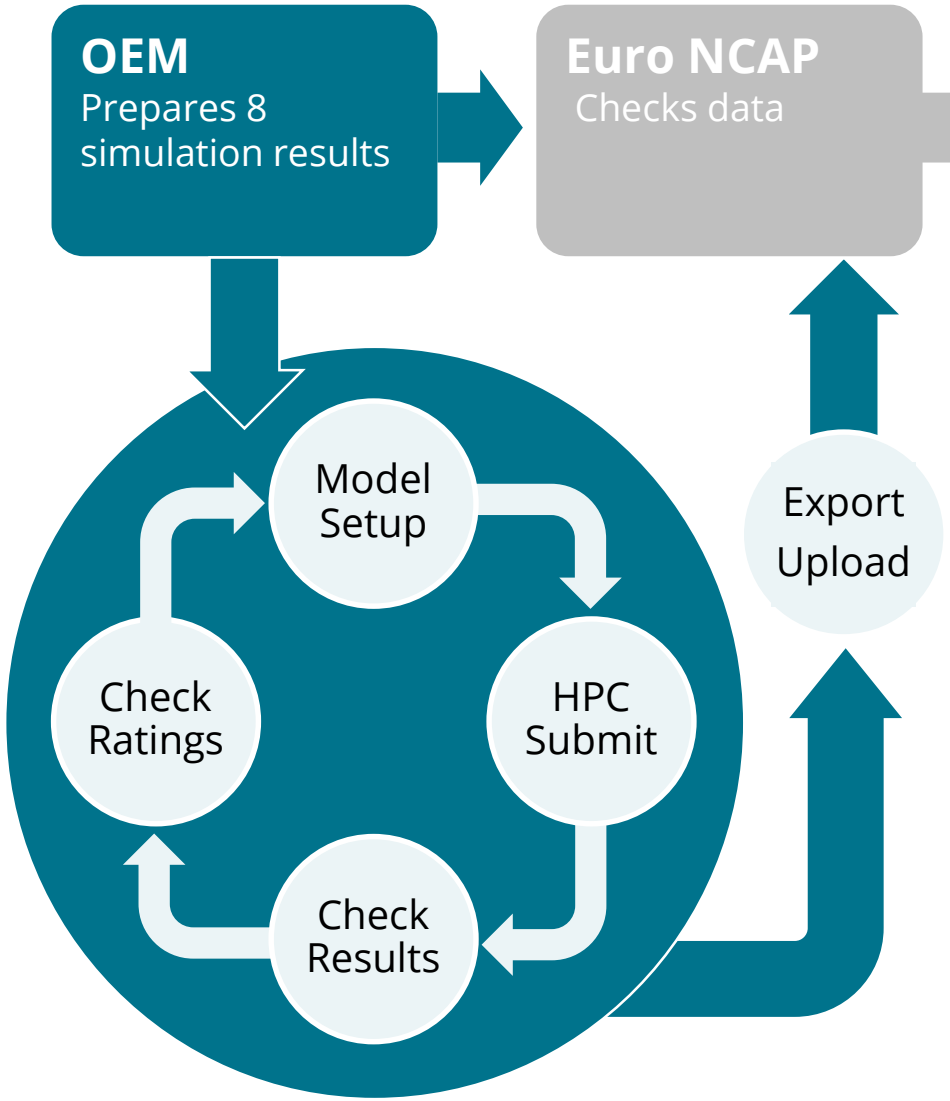
- Euro NCAP validates simulation model
- Euro NCAP rates virtual testing load cases
- CAE Engineer needs and objectives
  - Data preparation and completeness
  - Euro NCAP quality criteria
  - Static model parts
  - Rating values



[1] EuroNCAP: EUROPEAN NEW CAR ASSESSMENT PROGRAMME, 18 May 2023, page nb. 3
https://cdn.euroncap.com/media/77236/euro-ncap-vtc-simulation-and-assessment-protocol-v10.pdf

Virtual Testing Workflow and Challenges



OEM must provide *8 simulation results*:

- *115 mandatory curves, multiple key values, 6 mandatory videos*
- Mandatory unchanged model parts – "*static model parts*"
- *quality conditions* (energy, mass, computation time ratios)

OEM goals

- Successful model *check* and *validation*
- Good *rating* values

OEM own requirements for the workflow (iterative process):

- Precise *documentation* and *traceability*
- *Automated result* preparation
- *Automated checks*

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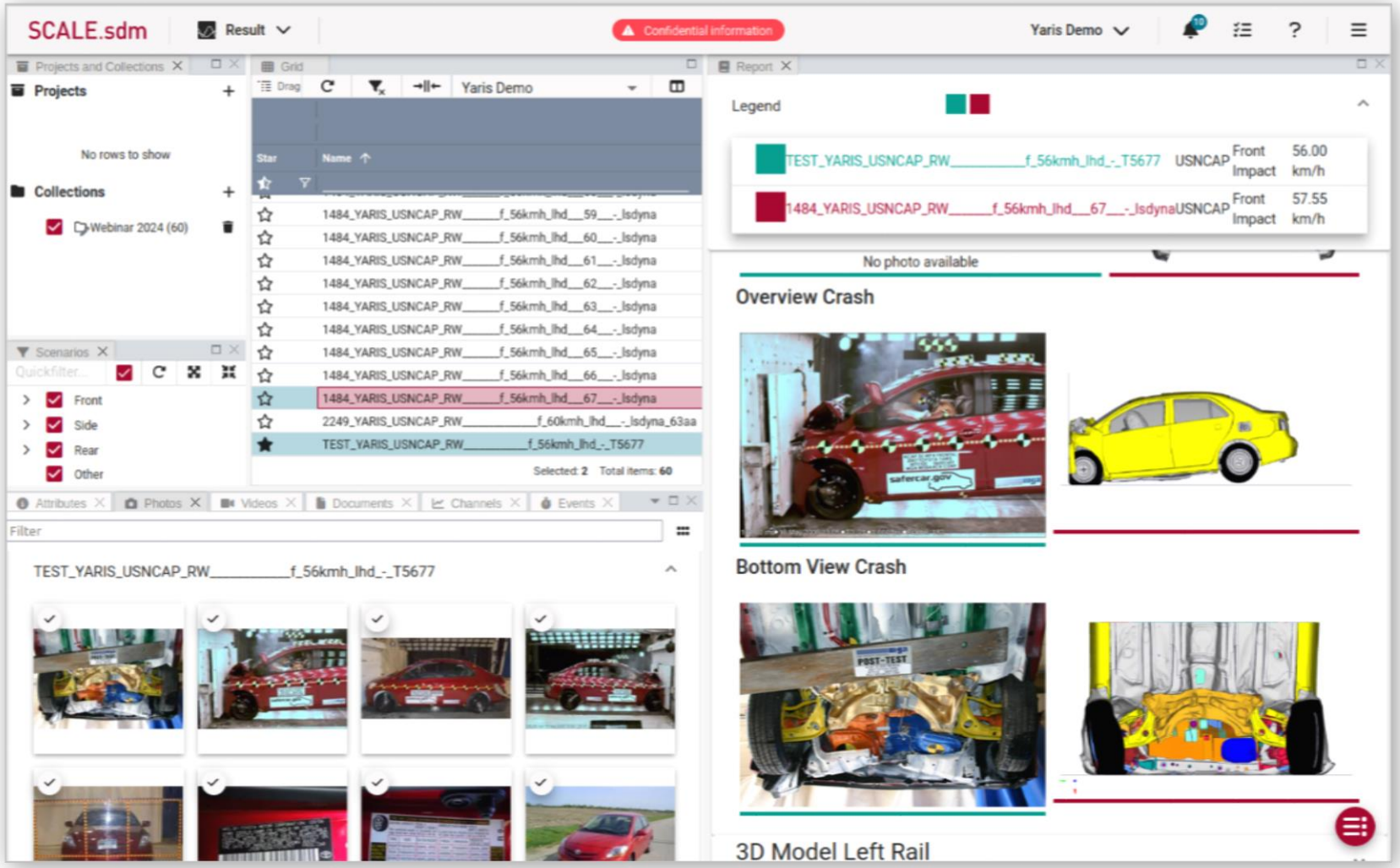
How Simulation Data Management (SDM) Can Help

- Single point of truth
  for input and output, simulation and 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



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Setup in SDM: **Requirements**

- Project setup in SCALE.sdm
  - Responsibilities
  - Milestones
  - Requirements

    thresholds for measurements

- Quantity and quality criteria for Euro NCAP

  assuring the quality of the simulation result data
  - Energy of dummy and whole system
  - Added mass
  - Simulation run time
  - Reasonable displacements

- Rating criteria for Euro NCAP

  used everywhere for coloring in order to always have an eye on the critical values for the rating
  - Accelerations
  - Forces
  - Displacements

Thresholds for quality criteria

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

Thresholds for EuroNCAP rating criteria

6.3 Table 7.: EuroNCAP VTC (10)			
	✓	Head a3ms	-∞ ≤ x < 80.00 / 80.00 ≤ x < ∞
	✓	Abdomen compression	0.000 ≤ x < 65.00 / 65.00 ≤ x < ∞
	✓	Chest compression	0.000 ≤ x < 50.00 / 50.00 ≤ x < ∞
	✓	Head excursion	0.000 ≤ x < 80.00 / 80.00 ≤ x < ∞
	✓	Head HIC (15 ms)	-∞ ≤ x < 700.0 / 700.0 ≤ x < ∞
	✓	Lumbar Fy	0.000 ≤ x < 2.000 / 2.000 ≤ x < ∞
	✓	Lumbar Fz	0.000 ≤ x < 3.500 / 3.500 ≤ x < ∞
	✓	Lumbar Mx	0.000 ≤ x < 120.0 / 120.0 ≤ x < ∞
	✓	Pubic symphysis force	0.000 ≤ x < 2.800 / 2.800 ≤ x < ∞
	✓	Neck moment y	0.000 ≤ x < 50.00 / 50.00 ≤ x < ∞
Static bending, NVH (1)			

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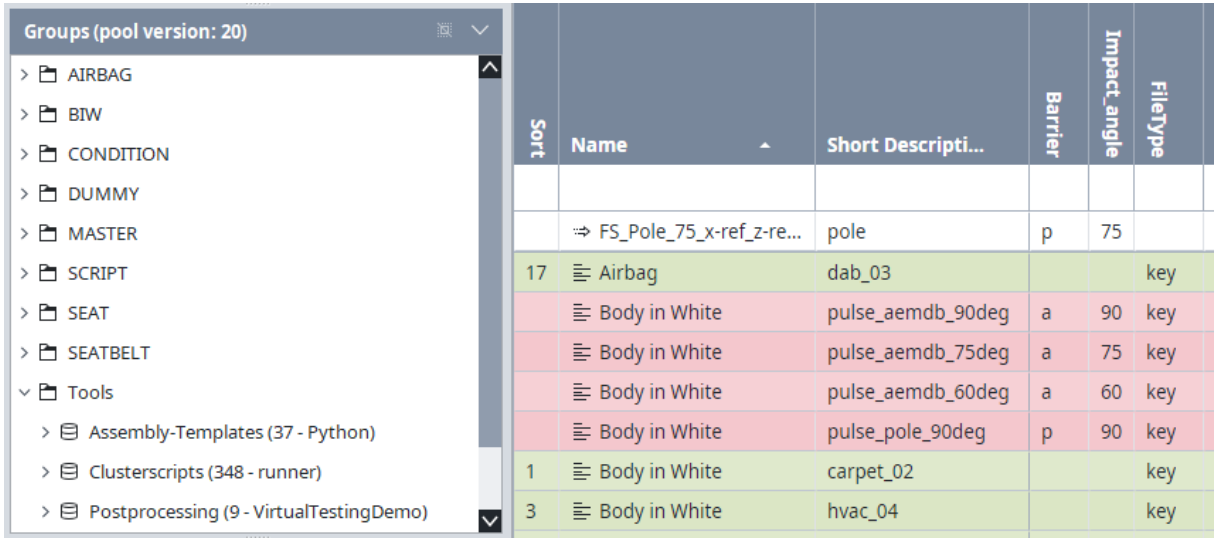
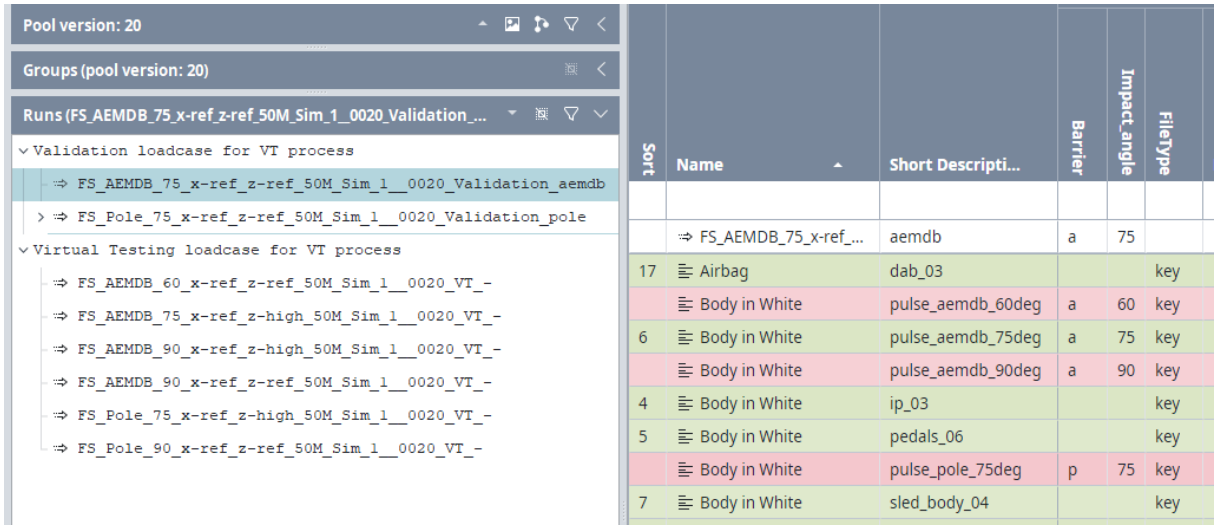
Setup in SDM: **Model Setup**

- Modular structure
  version control, parametrization
  imported, versioned, managed
- Shared data among users and load cases
  includes, parameters, …
- Parameterization
  restraint system parameters
- Attribute based load case definition
  more efficient alternative to a matrix-based approach





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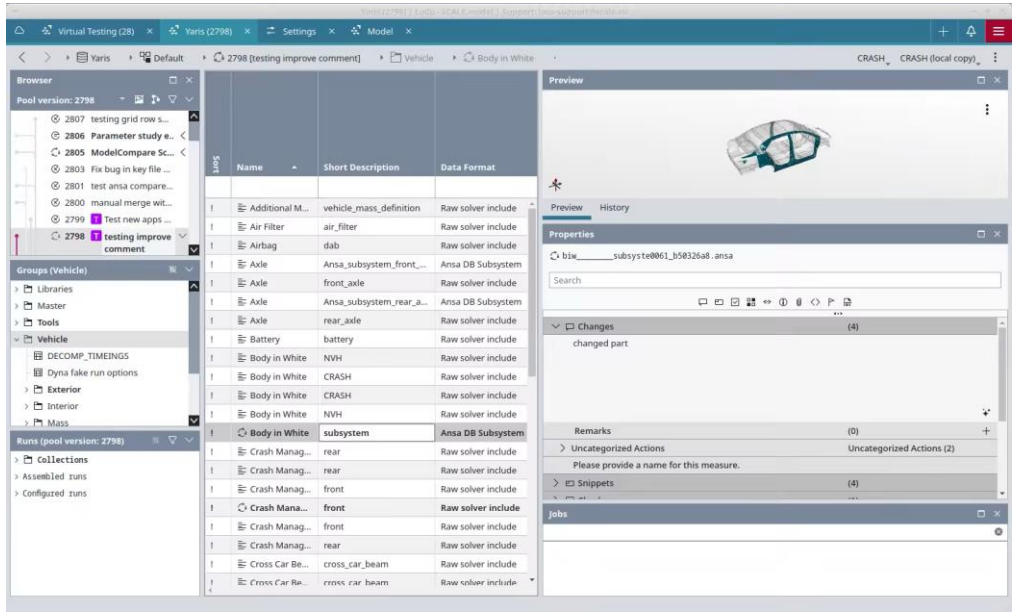
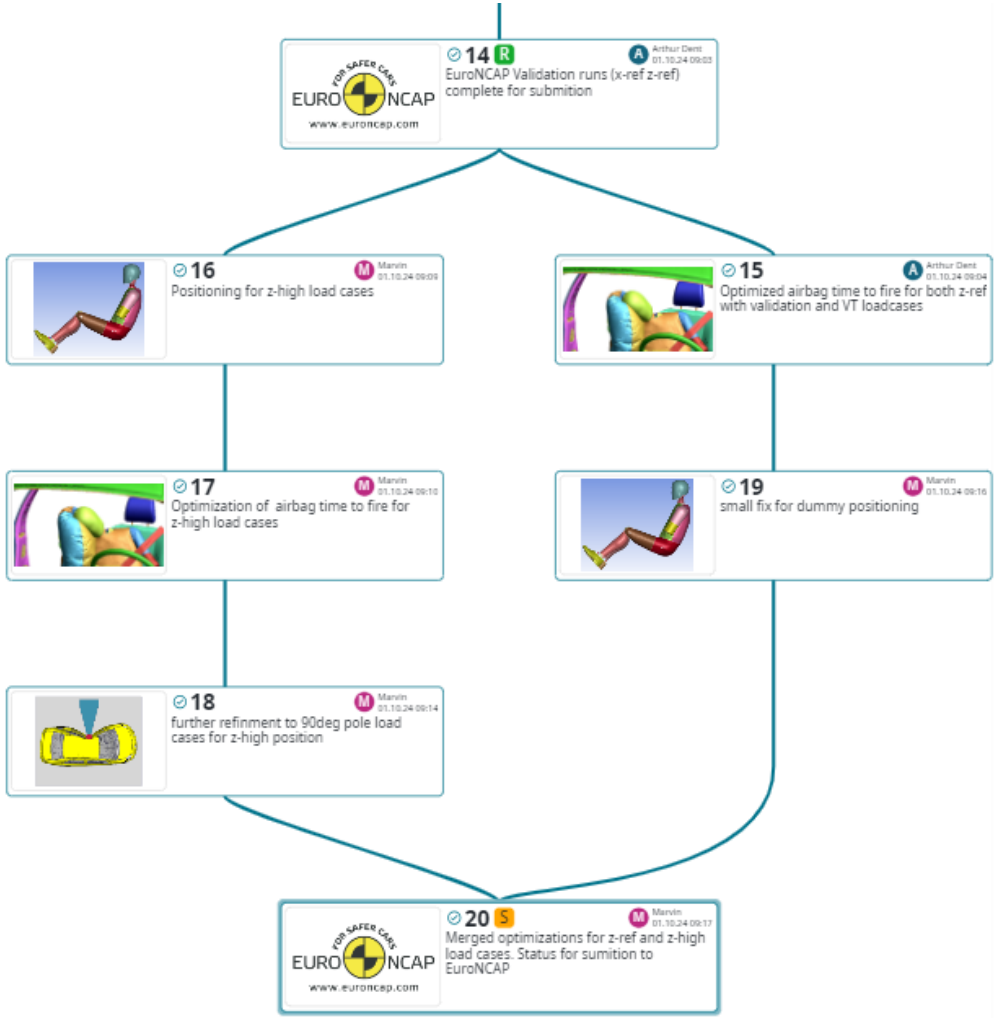
Setup in SDM: **Version Control**

- Documentation
  any change can be documented in much detail with text, images, documents, AI generated description
- Traceability
  each change is automatically captured and can be traced any time later
- Collaboration
  anyone in the team can see and access every change of other team members





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Setup in SDM: „**Static Model Parts**“

- “static model parts” needed

  Proof that certain data of the model has not changed with respect to the validation models

- Format of “static model parts"

  disassembled into groups to allow teamwork

  - Should work for only some lines

- Entities that are allowed to change

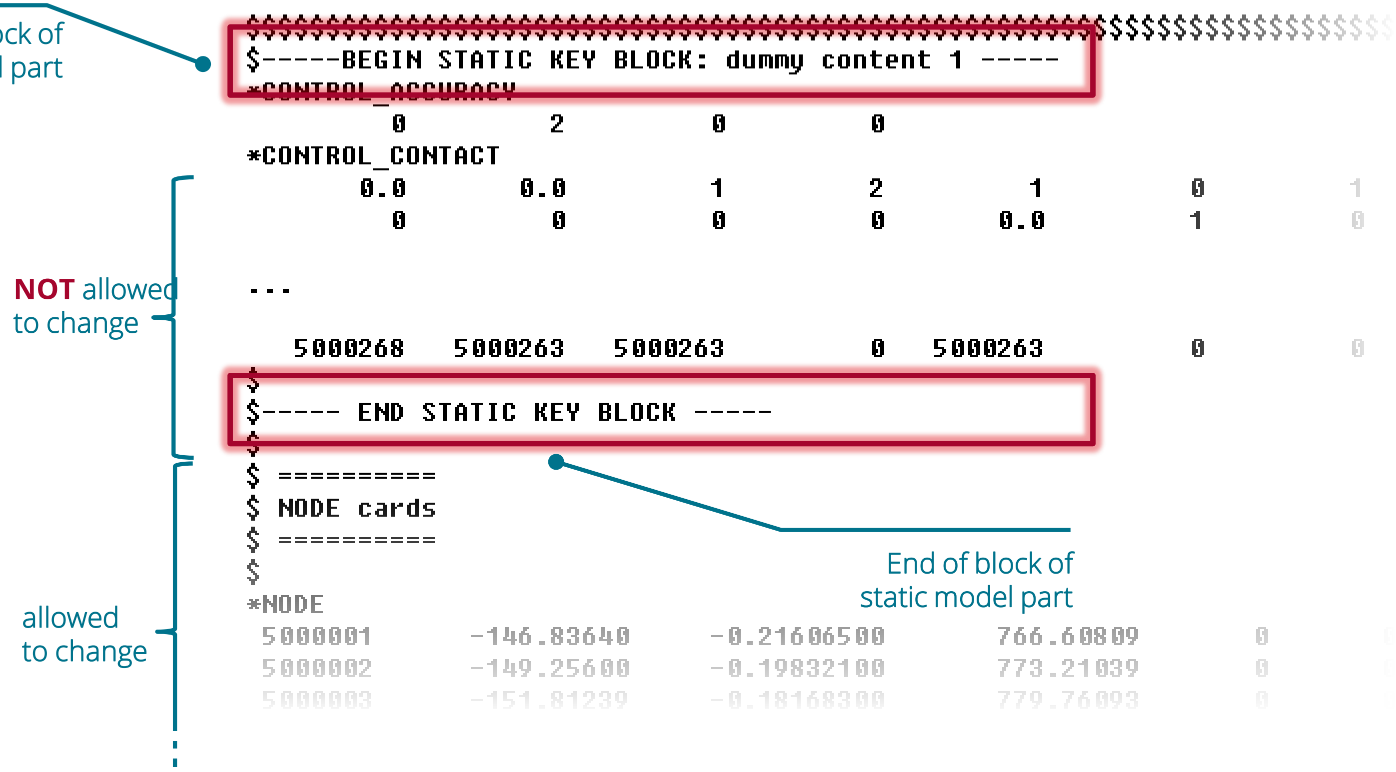
  with respect to Euro NCAP

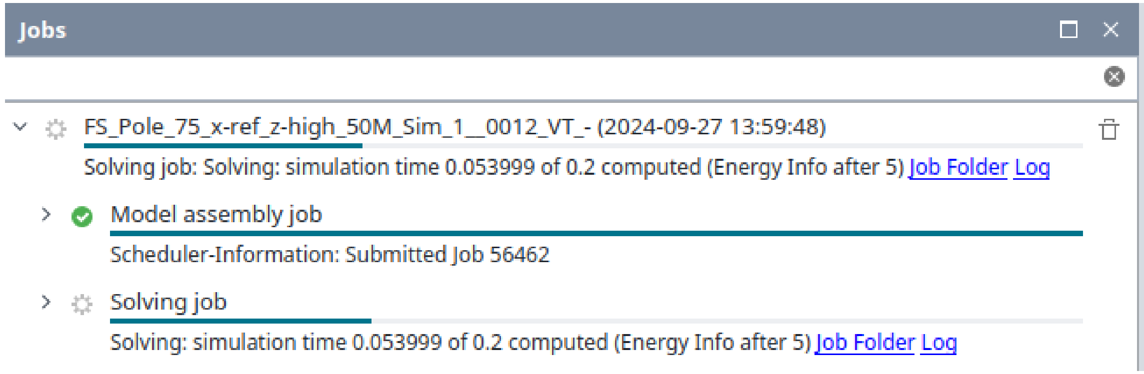
  - Crash pulses for sled acceleration
  - Nodes of dummy & seat

- Advantage of setup in SDM

  automation, consistency, efficiency

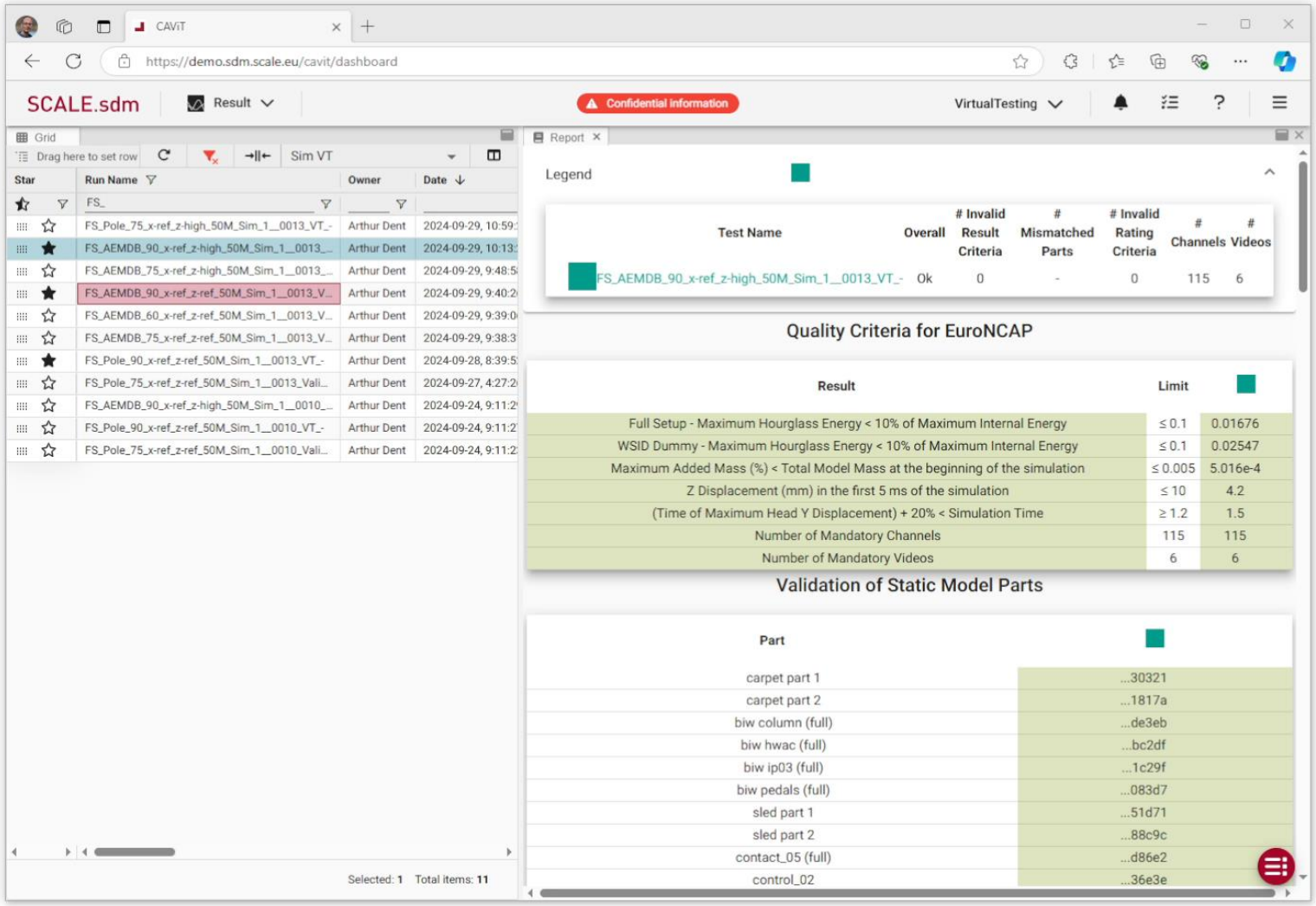
  - Automatic calculation of hashes upon assembly
  - Integration of hashes in reports for assessment
  - Integrated in job-submit and carried out for each simulation





Setup in SDM: **Assessment of Results**

- Interactive web report
  - Runs everywhere in any web browser
  - Select simulations
  - Compare on the fly
- Access to all simulations & tests
  - Search
  - Filter
- Custom reports
  - Access to all data of selected simulations
  - Tables with key results
  - Colored assessments from defined requirements
  - Channel plotter
  - Synchronous video playback



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Setup in SDM: **Quality Criteria of Data**

- Quality criteria for Euro NCAP

  compare for each selected simulation

  - Hourglass Energy of WSID Dummy & full Setup
  - Added Mass
  - Displacements of Dummy

- Summary of "static model parts"

  compare to validation simulation and see instantly where are unintended changes

  - 1st column 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: **Rating Criteria**

- Rating criteria for Euro NCAP

  compare for each selected simulation see instantly where are still problems

  - Accelerations
  - Forces
  - Displacements
  - …

- Channel plotter

  inspect and compare all channel data from selected simulations

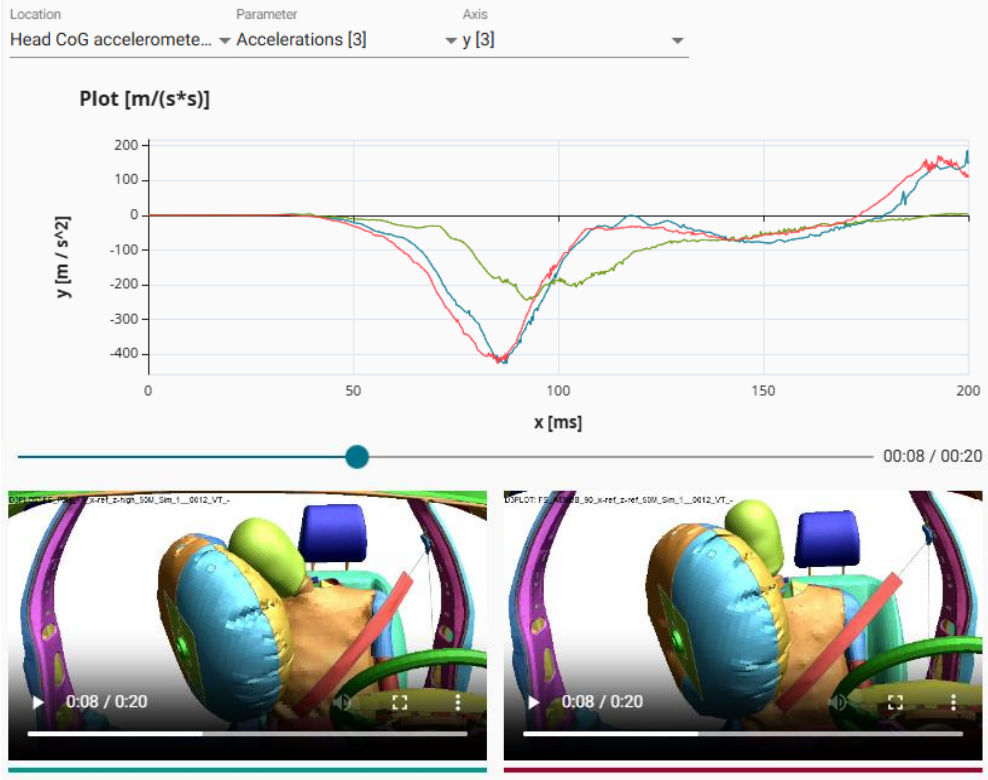
  - Interactively select and deselect simulations
  - Choose location, parameter and axis to be displayed

- 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	**2.07 kN**	0.404 kN
Lumbar Fz	≤ 3.5	0.126 kN	1.01 kN	0.106 kN
Lumbar Mx	≤ 120	5.95886 N m	**120.588 N m**	8.51914 N m
Head excursion	≤ 80	44.3 mm	45.8 mm	45.6 mm



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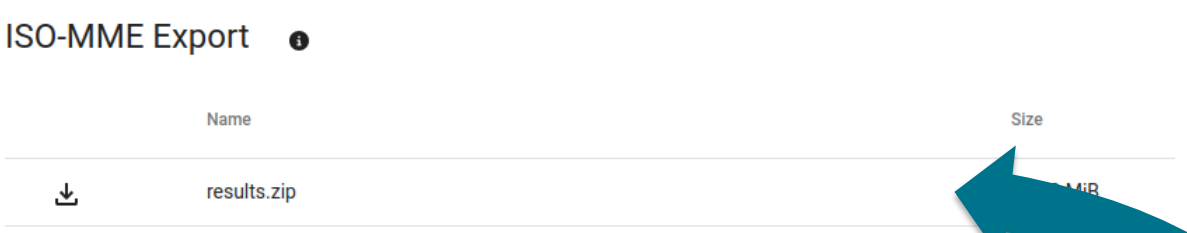
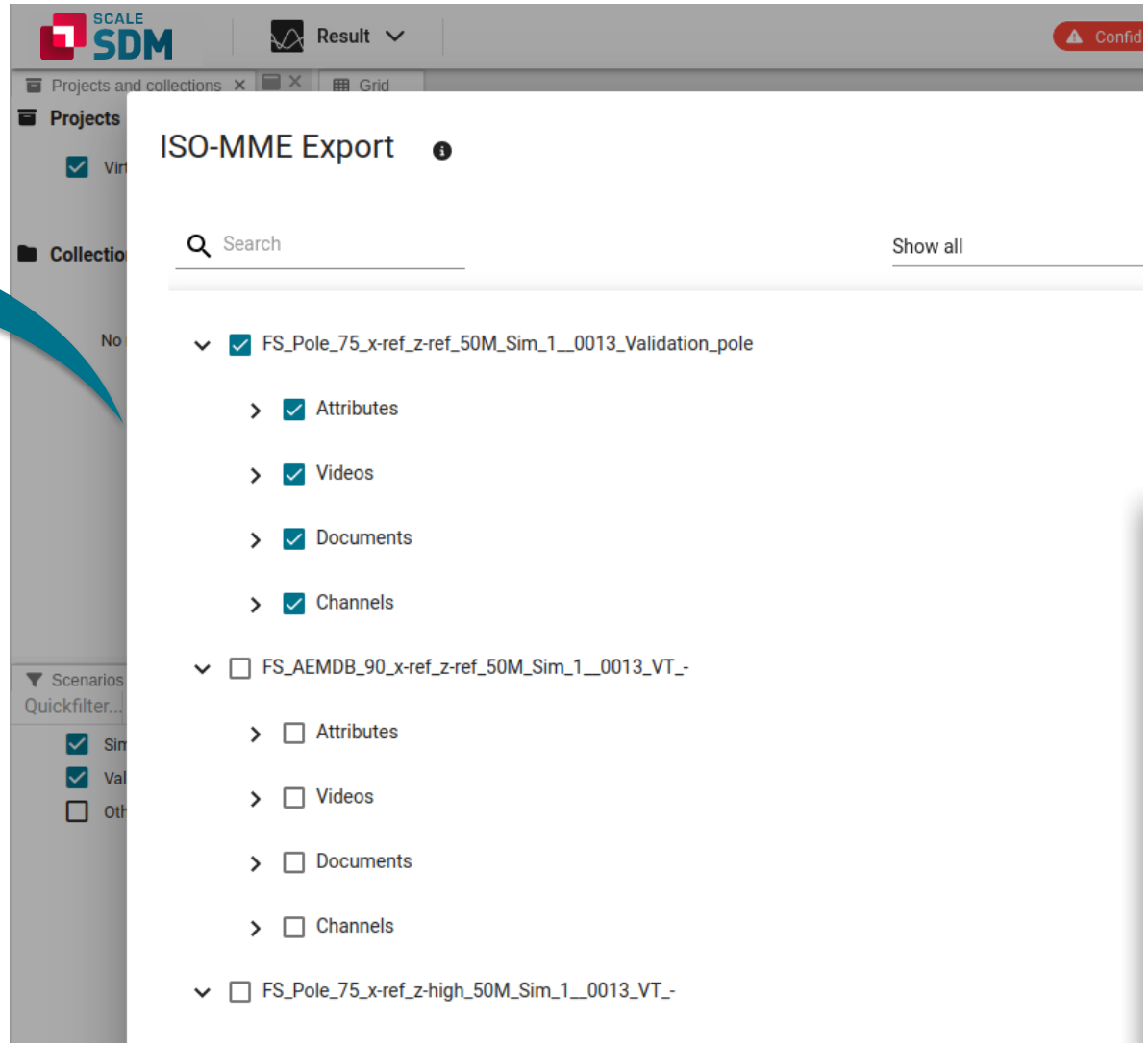
Setup in SDM: **Export and Upload**





- Select Simulations / Tests
  - Select the 8 simulation results
  - Export directly as ISO-MME

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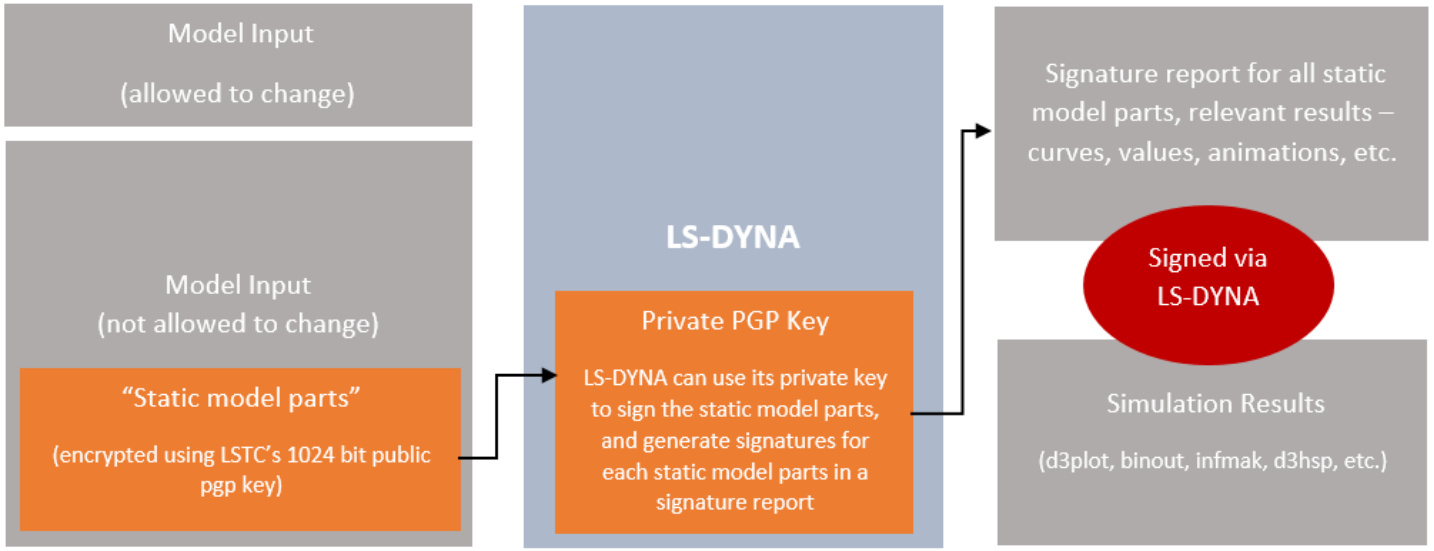
Safeguarding against data manipulation

- Signing instead of hash
  - Would allow to proof 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 cannot proof that “static model parts” do not contain any model data that is somehow tampering the simulation results in 1st place
  - All output needs to be signed, and it would be probably best if the output complies to the requirements of Euro NCAP (e.g. channels and key results already in ISO-MME)
  - Need to be implemented by developers of solvers

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Summary and Outlook

- 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

- Using an SDM-System for the Virtual Testing use cases
  - Efficient integration of the iterative development process
  - Version control, traceability and documentation
  - Automated result data preparation and checks

- Challenges & Outlook:
  - Safeguarding against malevolent data manipulation
  - Mechanisms on the FEM solvers side mandatory but not sufficient

SO LONG, AND THANKS

FOR ALL THE FISH

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

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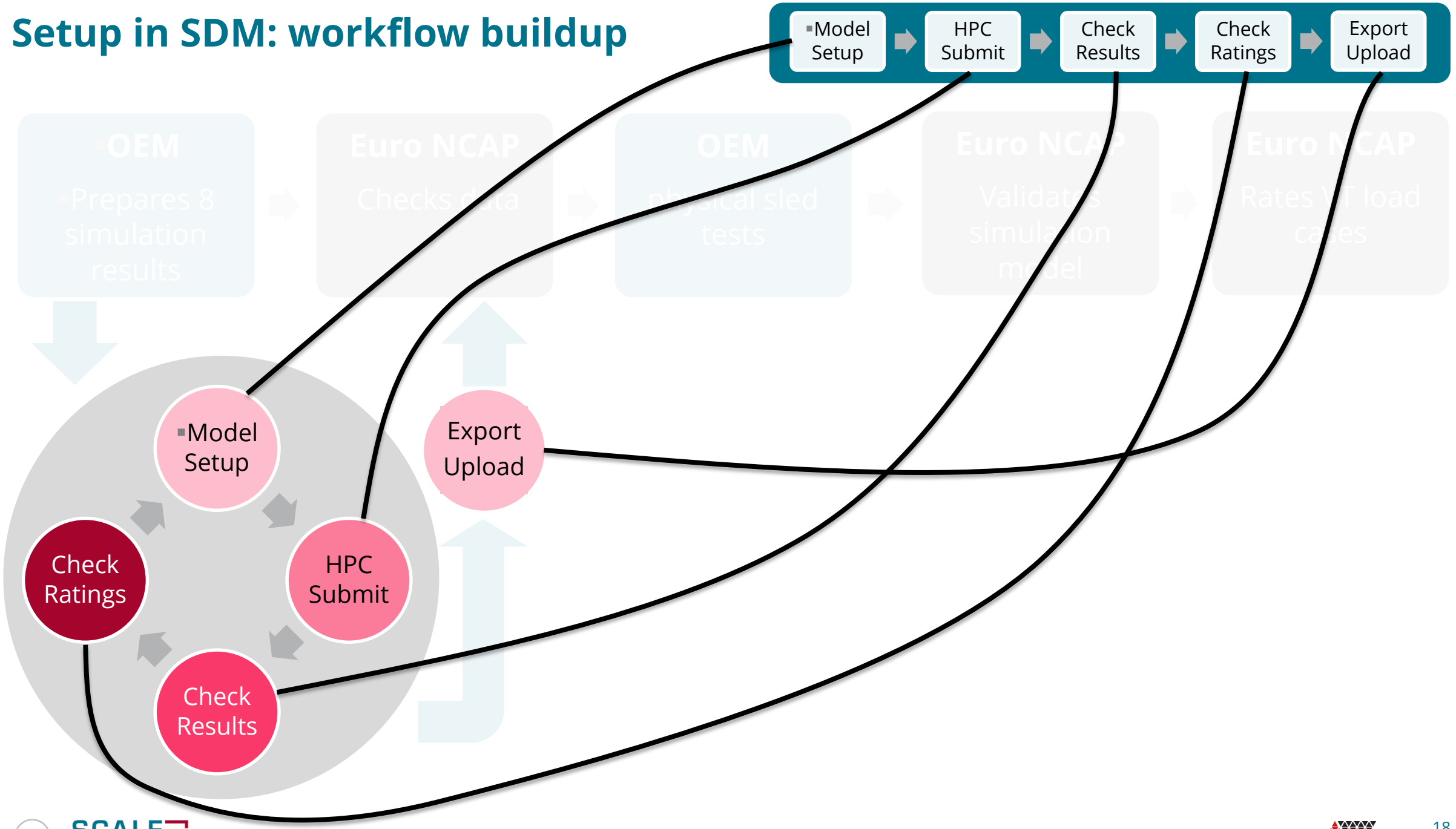
Setup in SDM: workflow buildup



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