Facilitating Virtual Testing at an industrial level by Simulation Data Management

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IT-Solutions for CAE

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- Motivation
- Why SDM
- Setup in SDM
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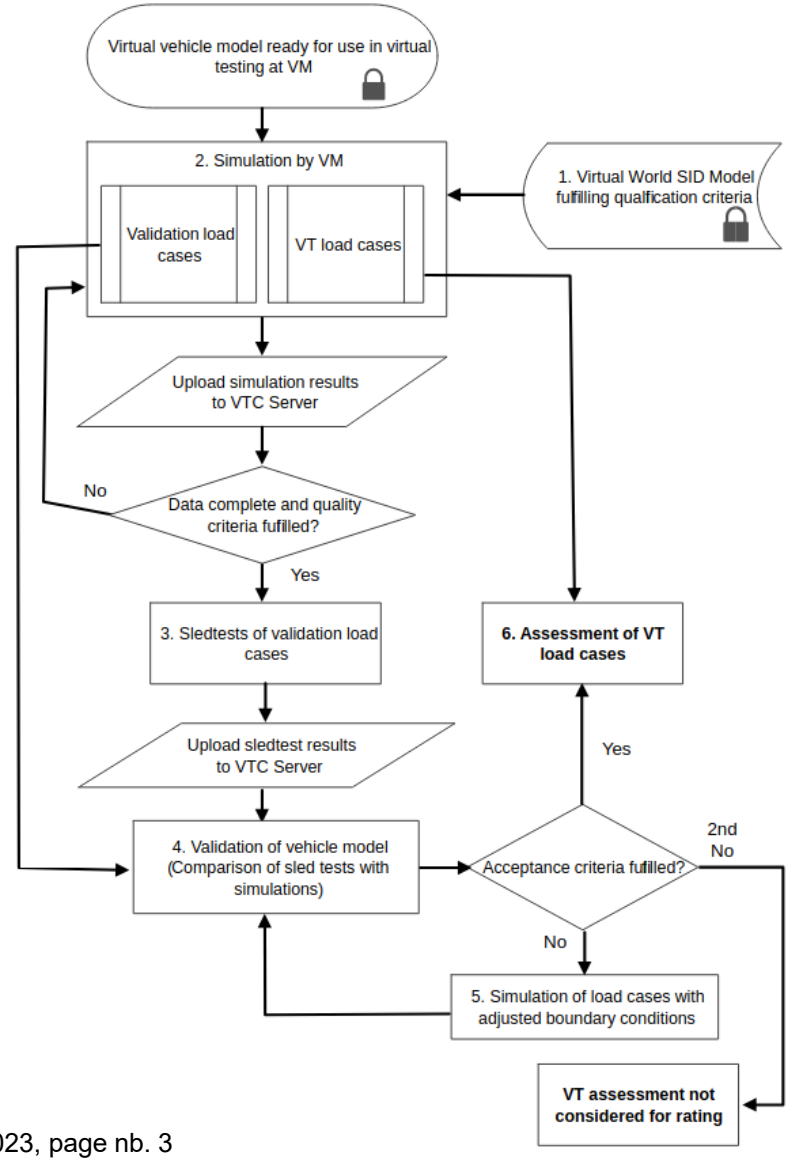
EuroNCAP Virtual Testing workflow

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



[1] EuroNCAP: EUROPEAN NEW CAR ASSESSMENT PROGRAMME, 18 May 2023, page nb. 3
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EuroNCAP Virtual Testing workflow

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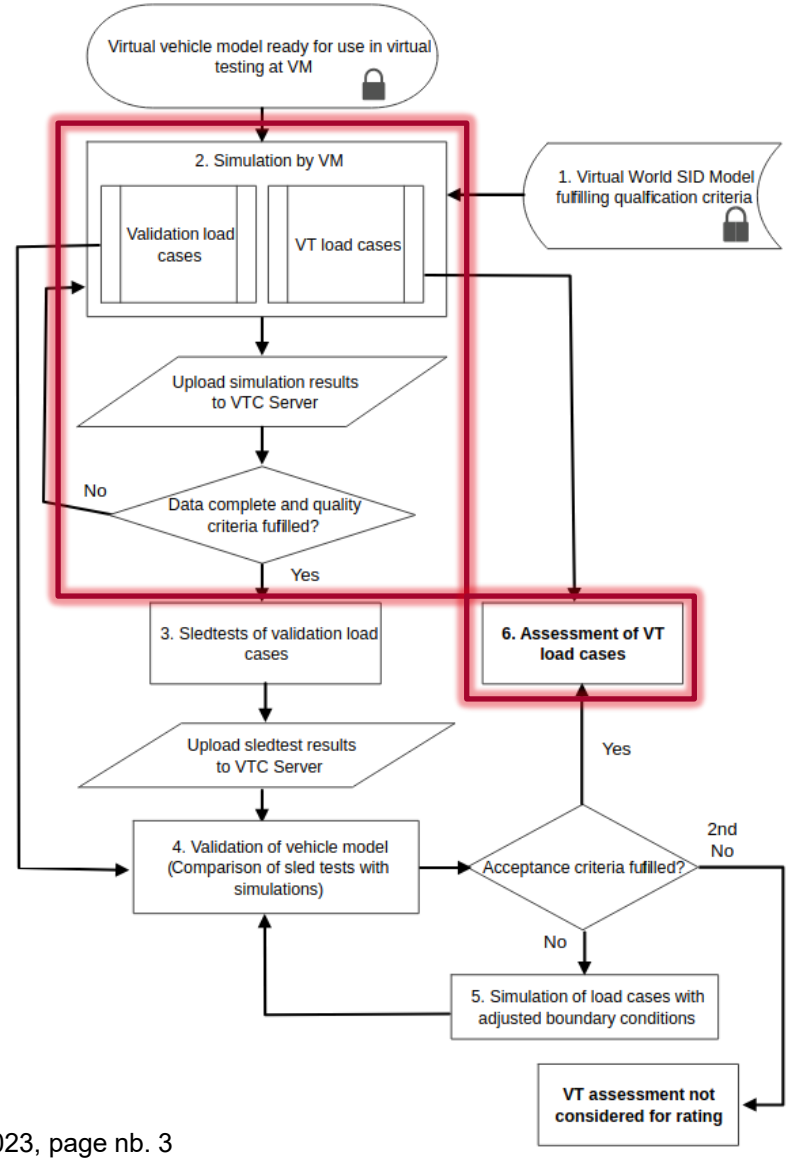

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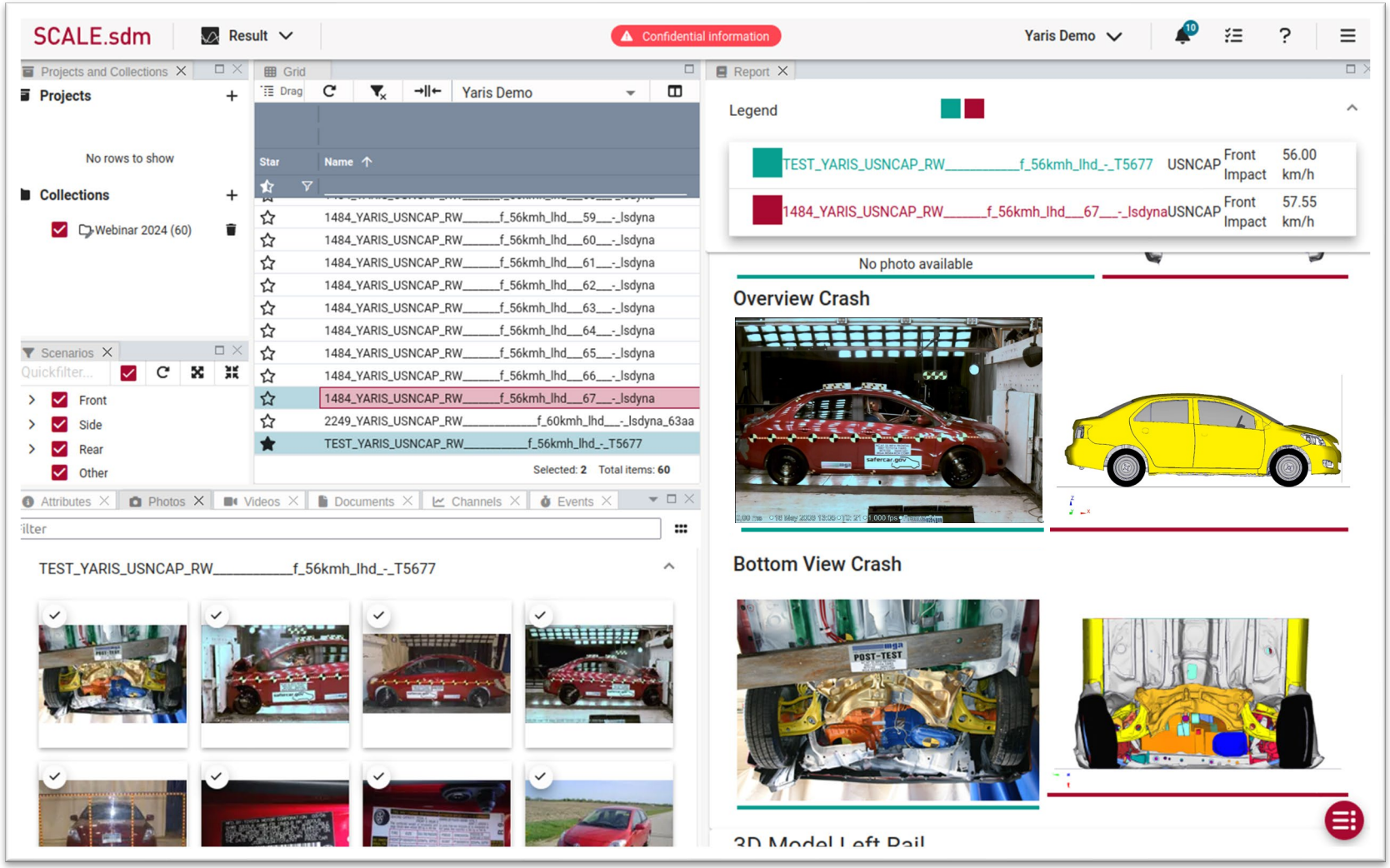
Why SDM?

- 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



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: 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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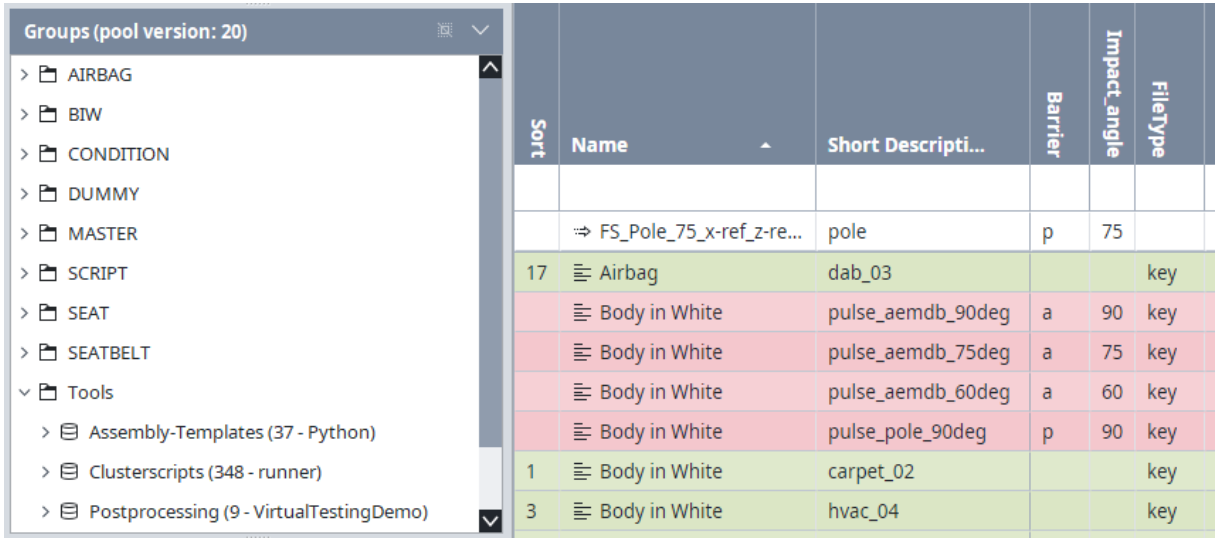
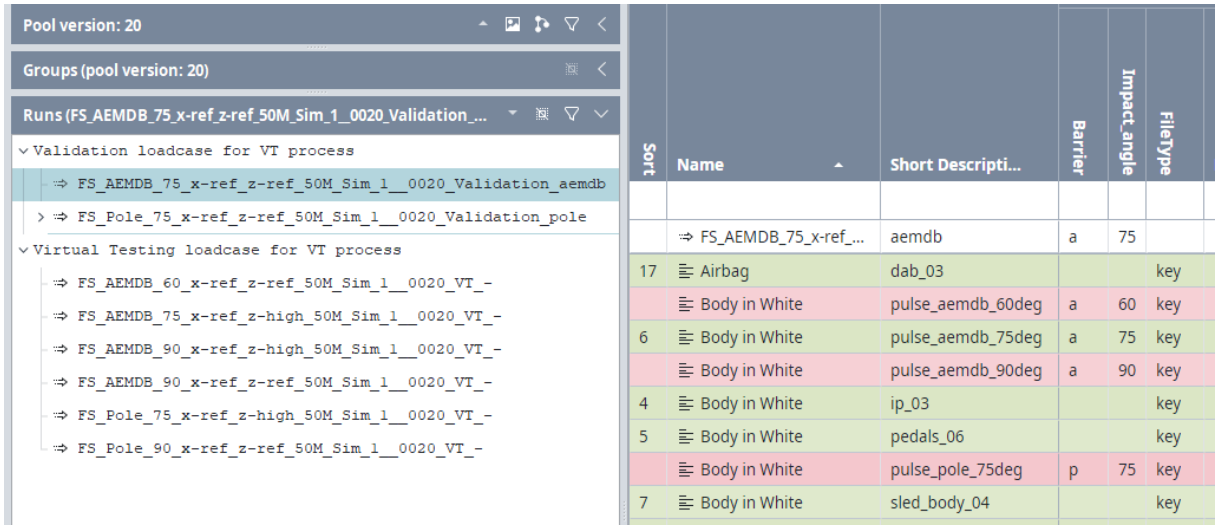
Setup in SDM: Model setup

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

Outlook:

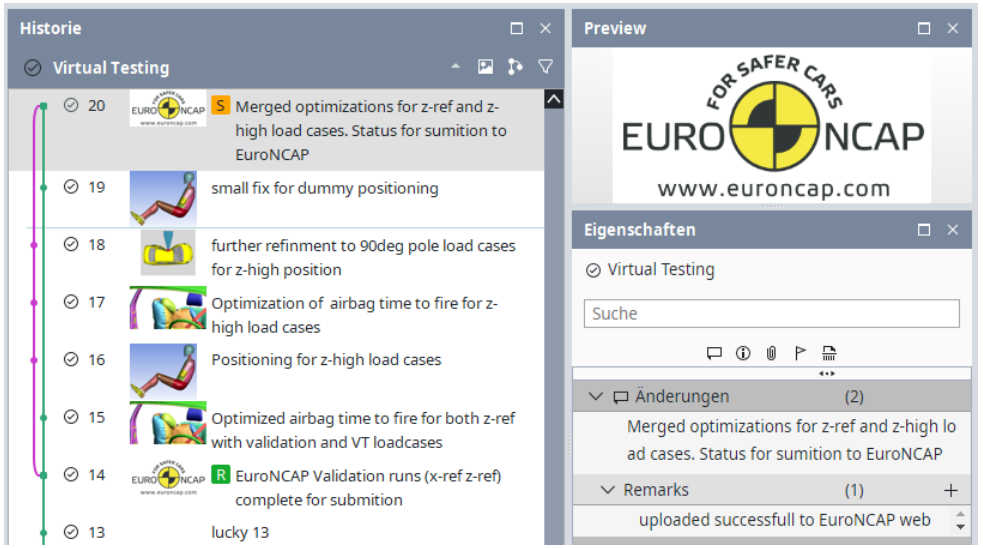
- Crash pulses from pre simulation
  automatically created from crash simulation

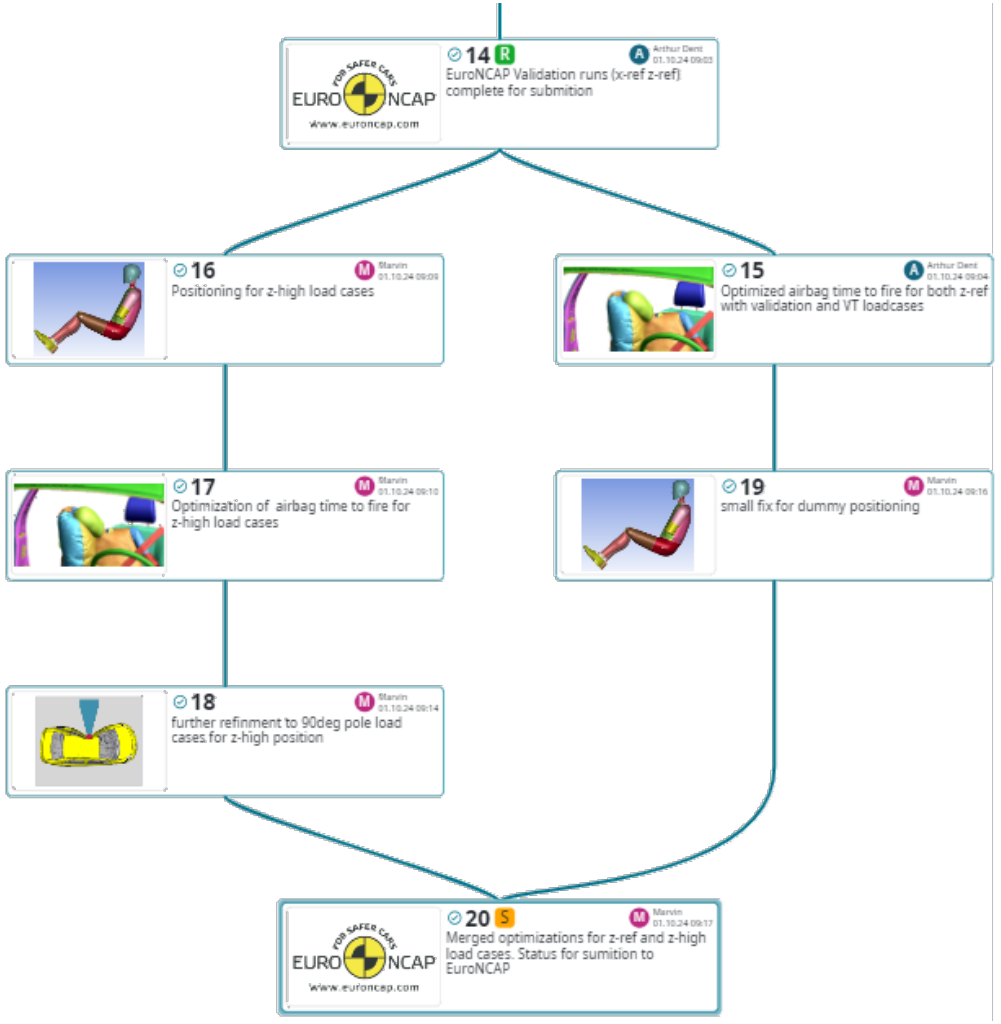




Setup in SDM: Traceability and documentation

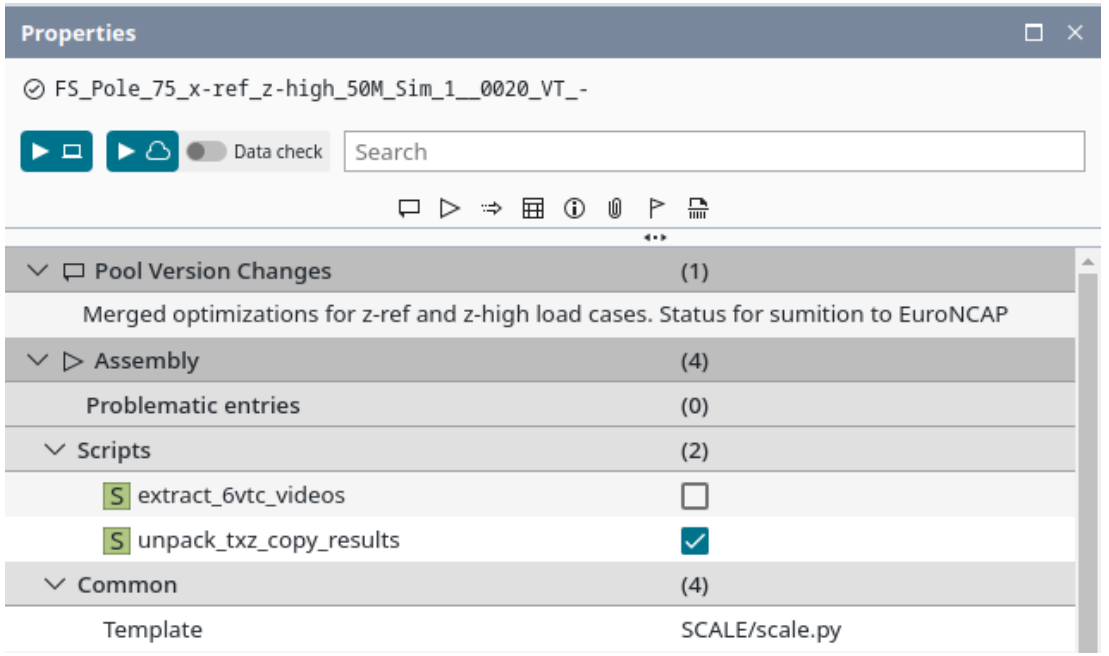
- Documentation
  any change can be documented in much detail … description, images, documents, …
- Traceability
  each change is automatically captured and can be tracked down later
- Collaboration
  anyone in the team can see and access every change of other team members

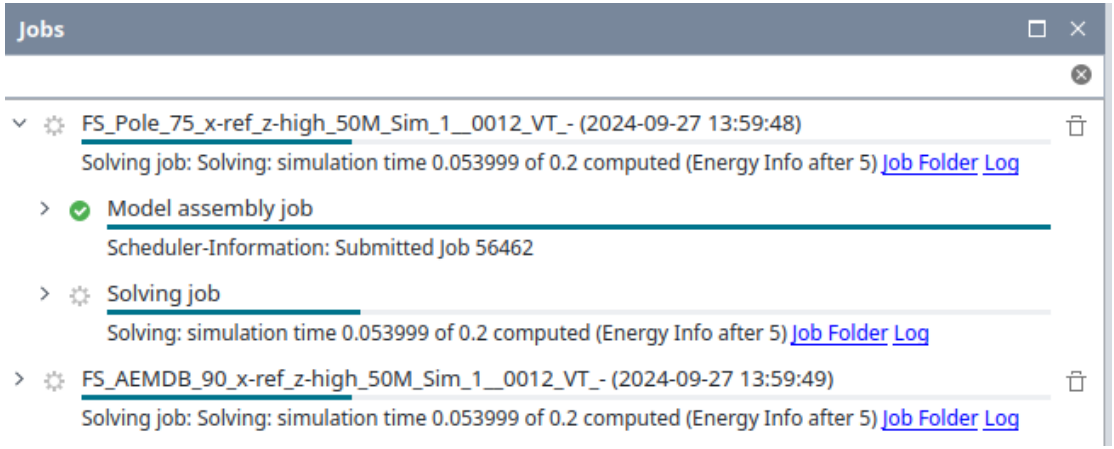




Setup in SDM: Job submition and result data preparation

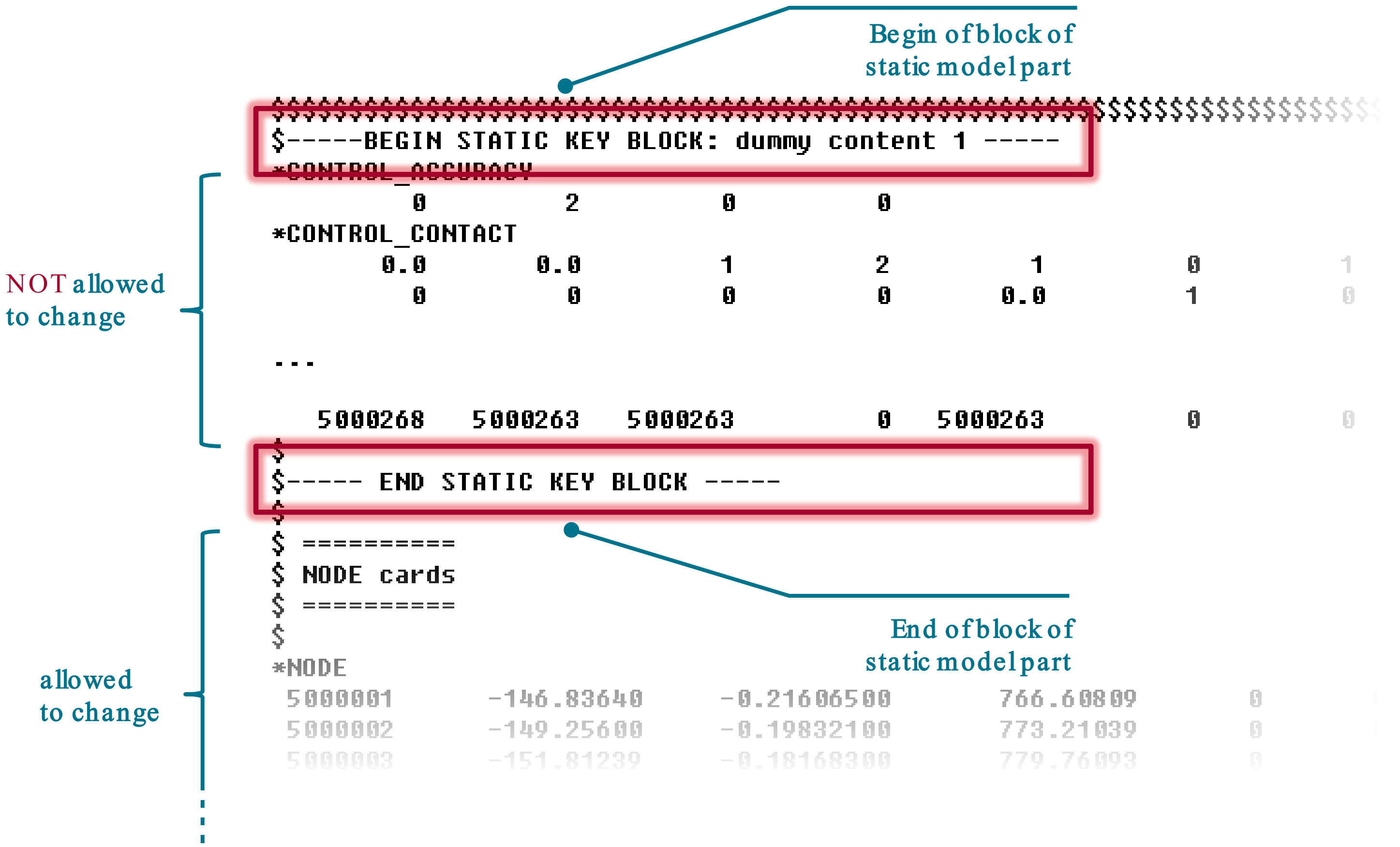
- Job submition to HPC clusters
  - Fast job submition with efficient data transfer
  - Server component for specific HPC integration
  - Live job feedback to the user
- Solver specific assembly
  - Solver independent SDM system
  - Python Assembly template as solver specific “API”
- Hashing process 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)





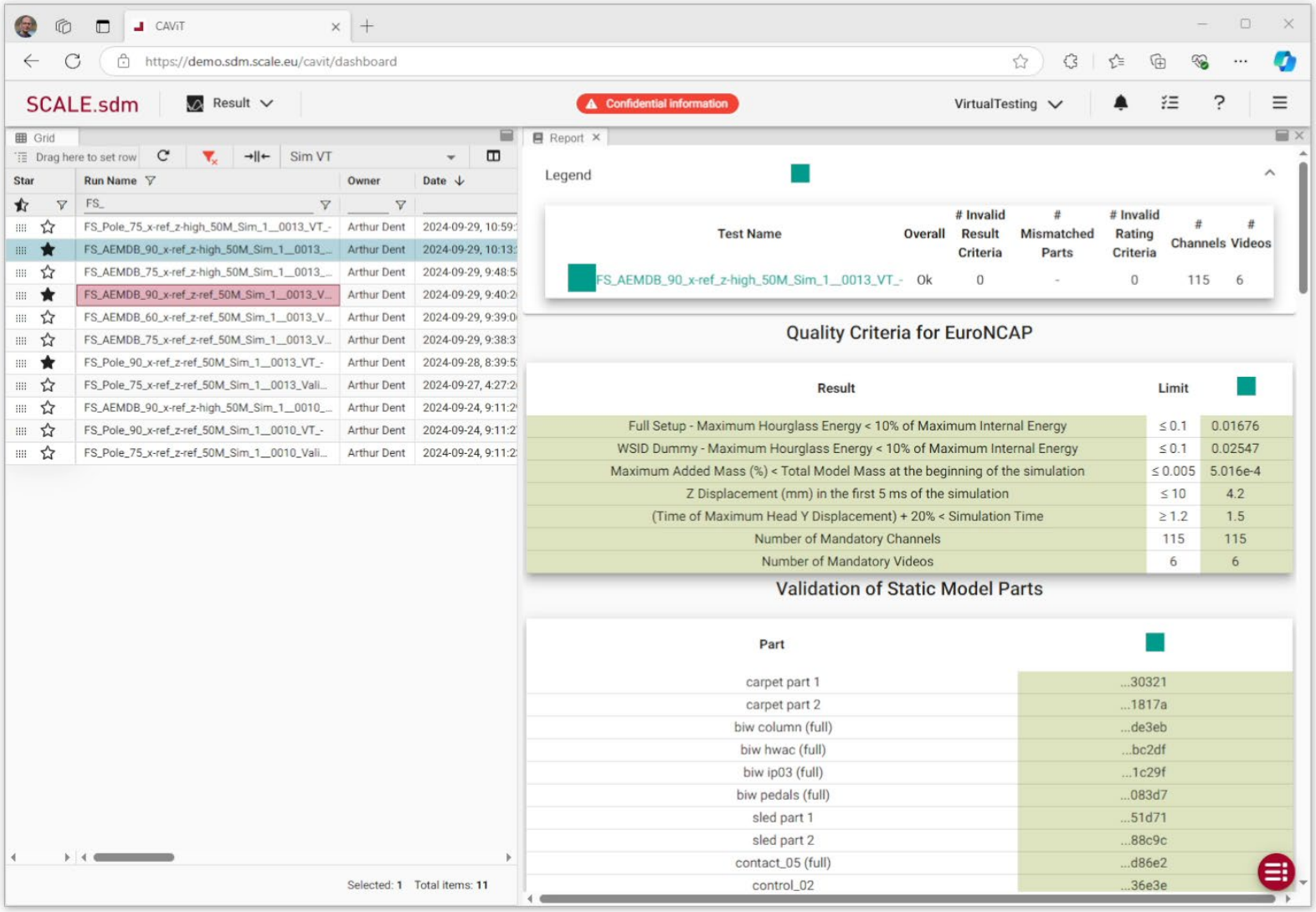
Setup in SDM: static model parts

- 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



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
  - 1st 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

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Setup in SDM: Assessment of Results – Rating criteria

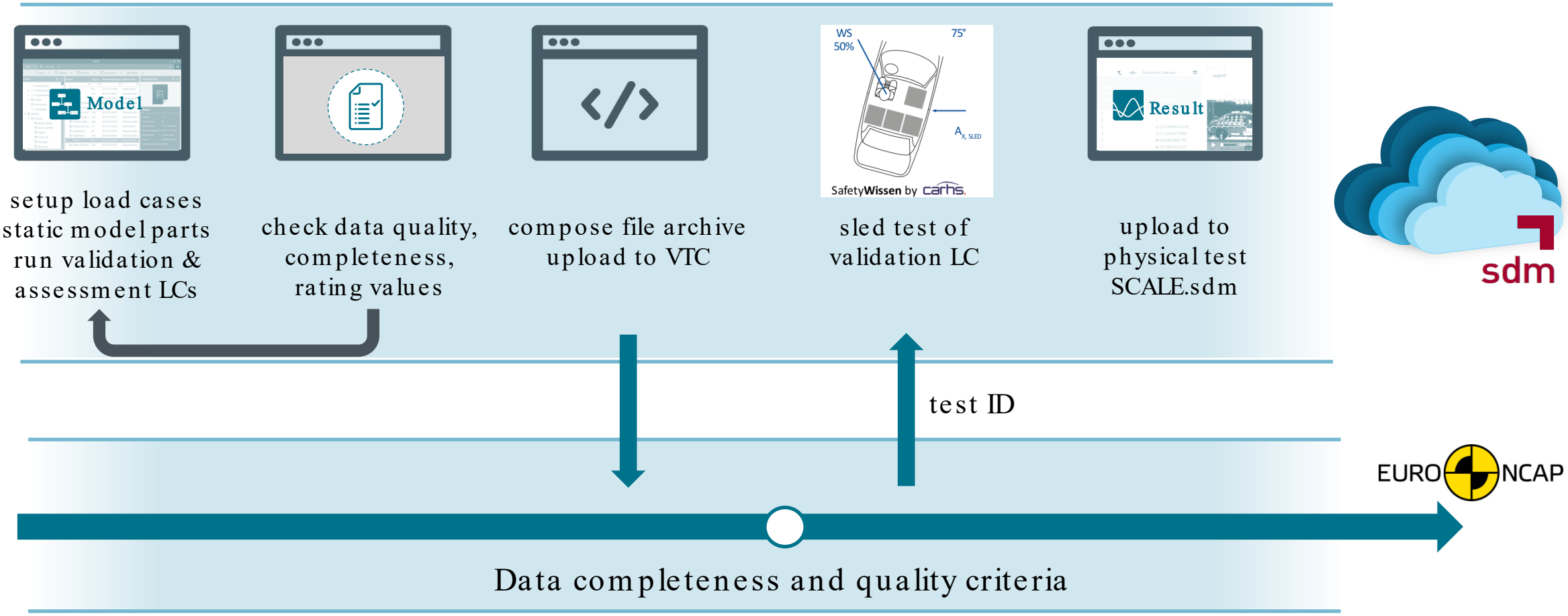
- Rating values for EuroNCAP
  compare for each selected simulation
  see instantly which values don't match the requirements
  - Accelerations
  - Forces
  - Displacements
  - …

- 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	**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

Workflow summary



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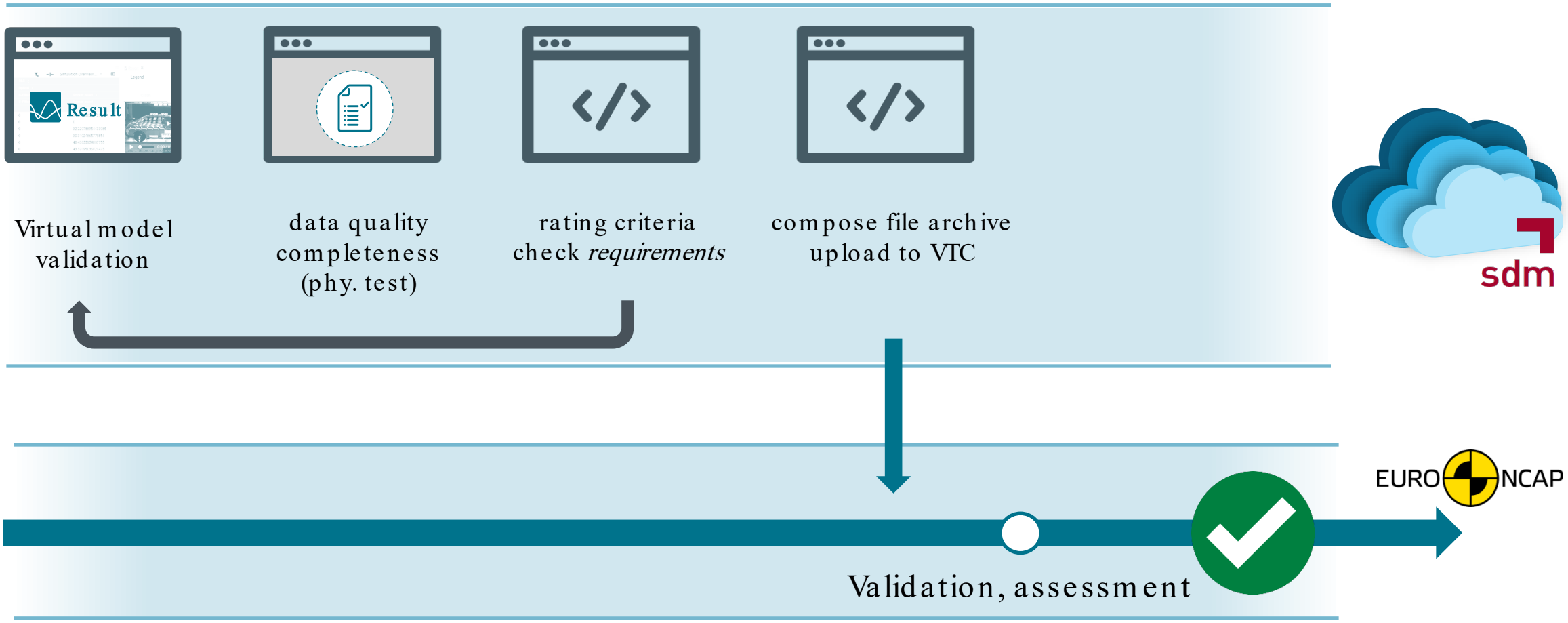
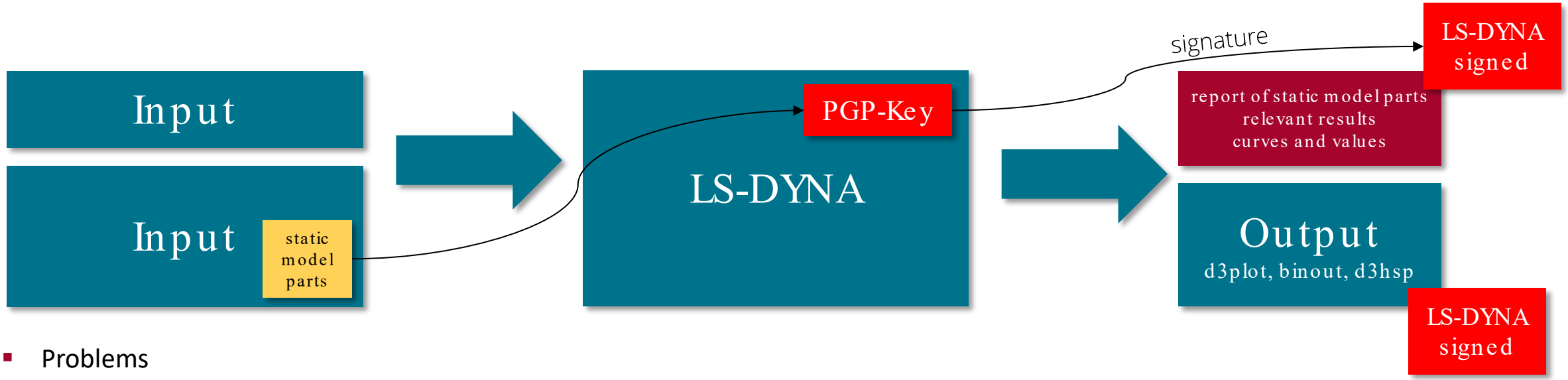


Safeguarding against data manipulation

- 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 can not proof that “static model parts” do not contain any model data that is somehow tampering the simulation results in the 1st 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/

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