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IT-Solutions for CAE

Master Complexity of Version Management in SDM by AI-Driven Assistance

Management of CAE Model Evolution During a Development Program

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Introduction: Simulation Data Management

SCALE.SDM

Simulation Setup
Input Data Handling

Result Data
Storage & Evaluation

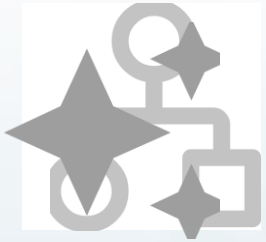
Monitor
Project Targets

Collaboration

Flexibility & Integration

Standards

Open APIs



Transparency

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Introduction: Master Complexity of Version Management in SDM by AI-Driven Assistance

Challenge of Complexity

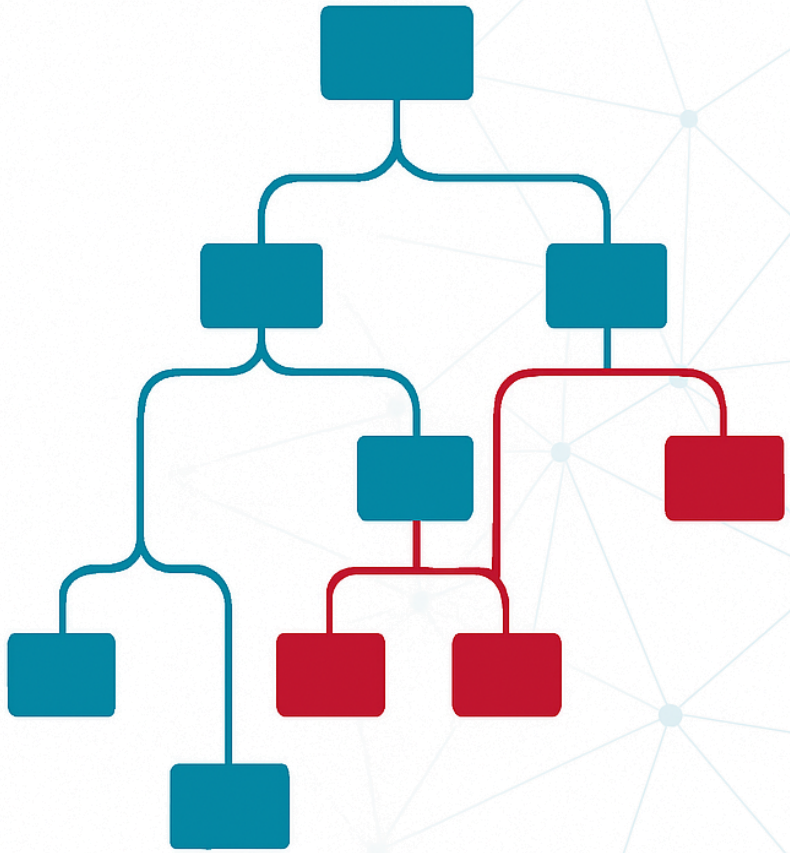
- Countless CAE model iterations
  Simulation-based design generates numerous CAE model iterations, each with subtle yet critical differences.
- Collaboration between numerous users
  Coordinating multiple simulation versions across distributed engineering teams

AI-Driven Assistance

- Streamlining change documentation
  Leveraging AI streamlines change tracking and automates the documentation process
- Redefining discoverability
  Transforms complex version data into actionable insights

Transforming SDM

- Improved collaboration
  Integration of these technologies paves the way for more agile and efficient CAE model evolution



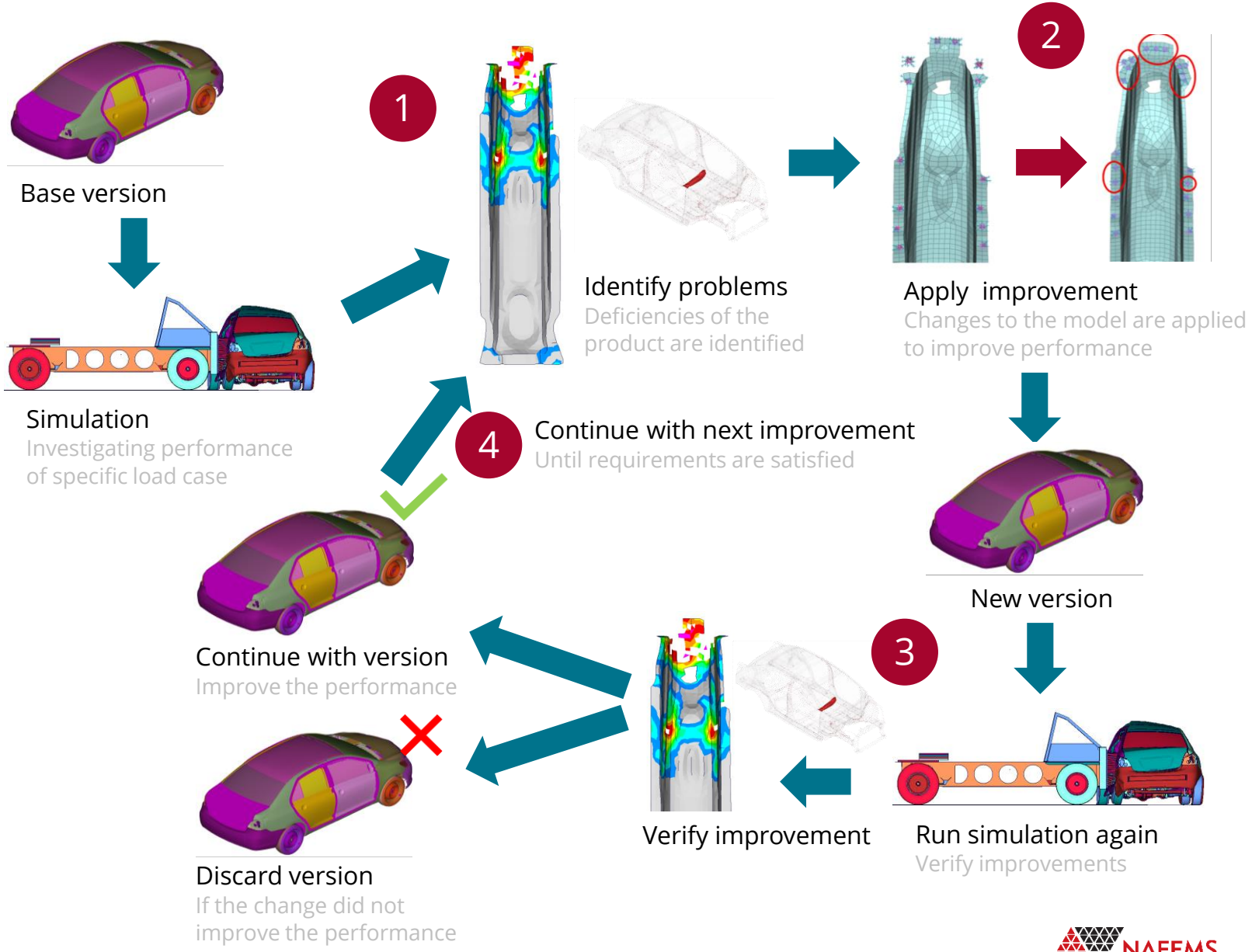
Overview of CAE Model Evolution in SDM

Virtual Product Development

an iterative process

1. **Choose a base Version**
   - Think of changes to improve the behavior
2. **Apply the changes**
   - Run the simulations
3. **Evaluate the results**
   - Chose the best
4. **Start over with 1.**

Repeat until you are satisfied



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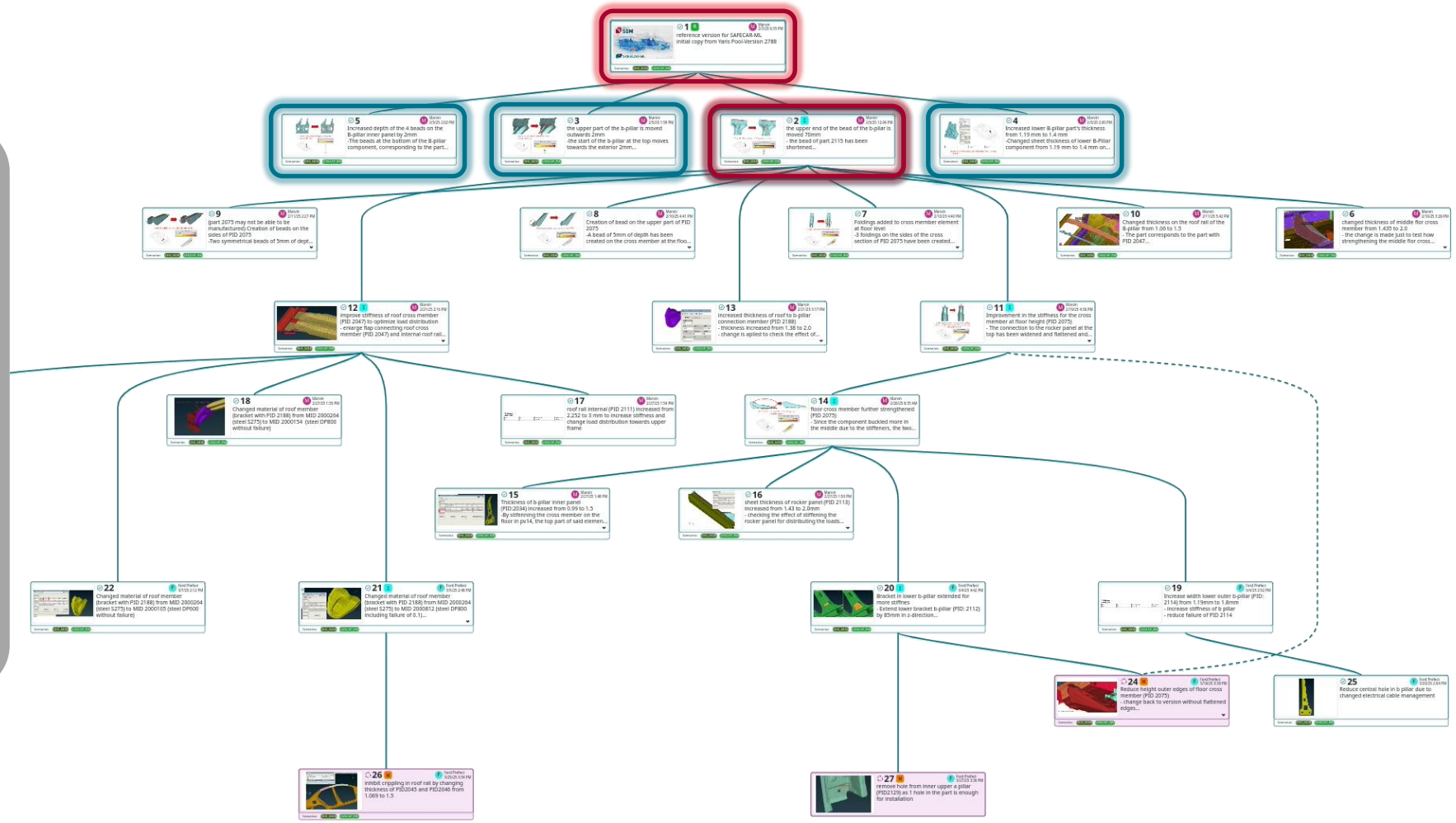

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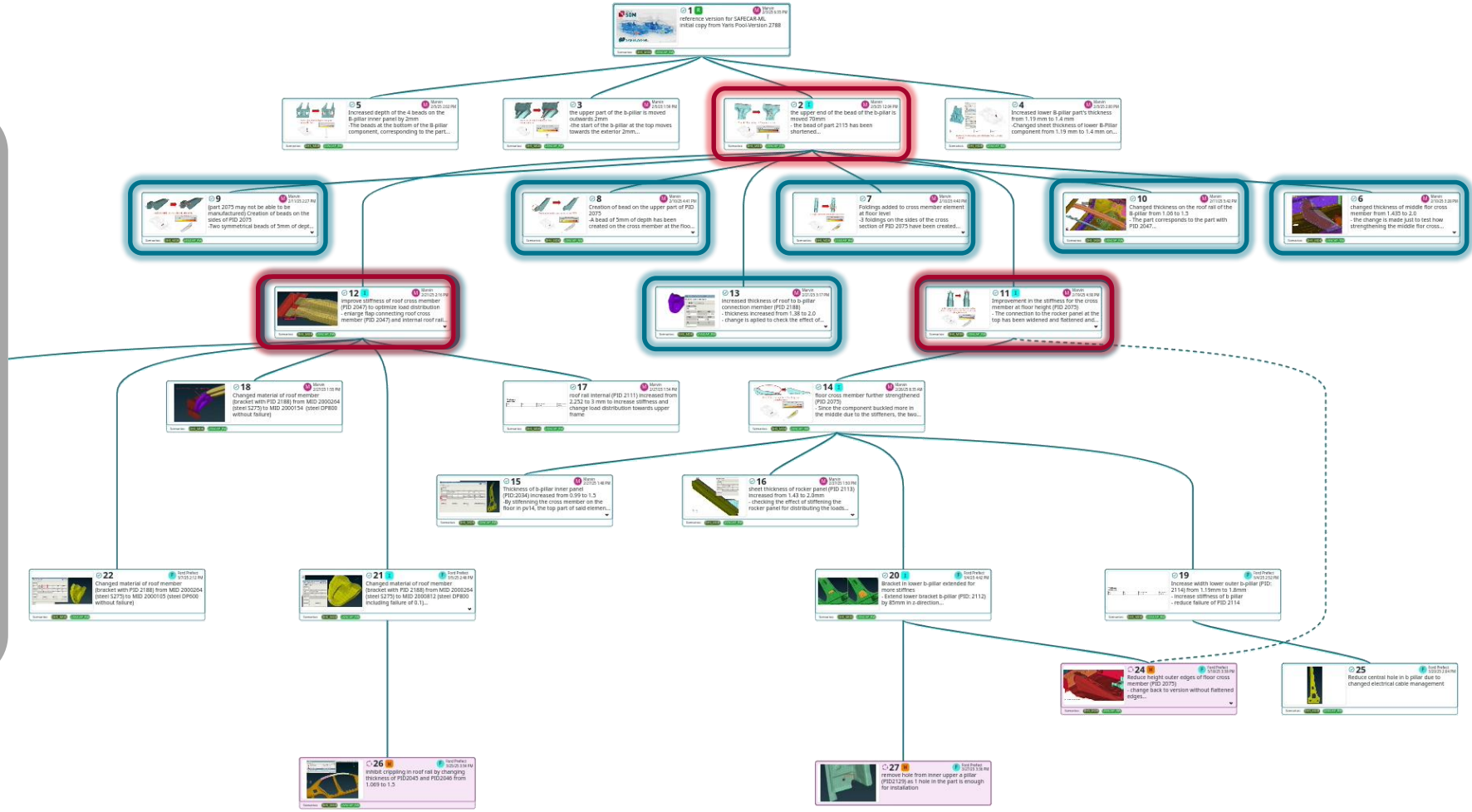

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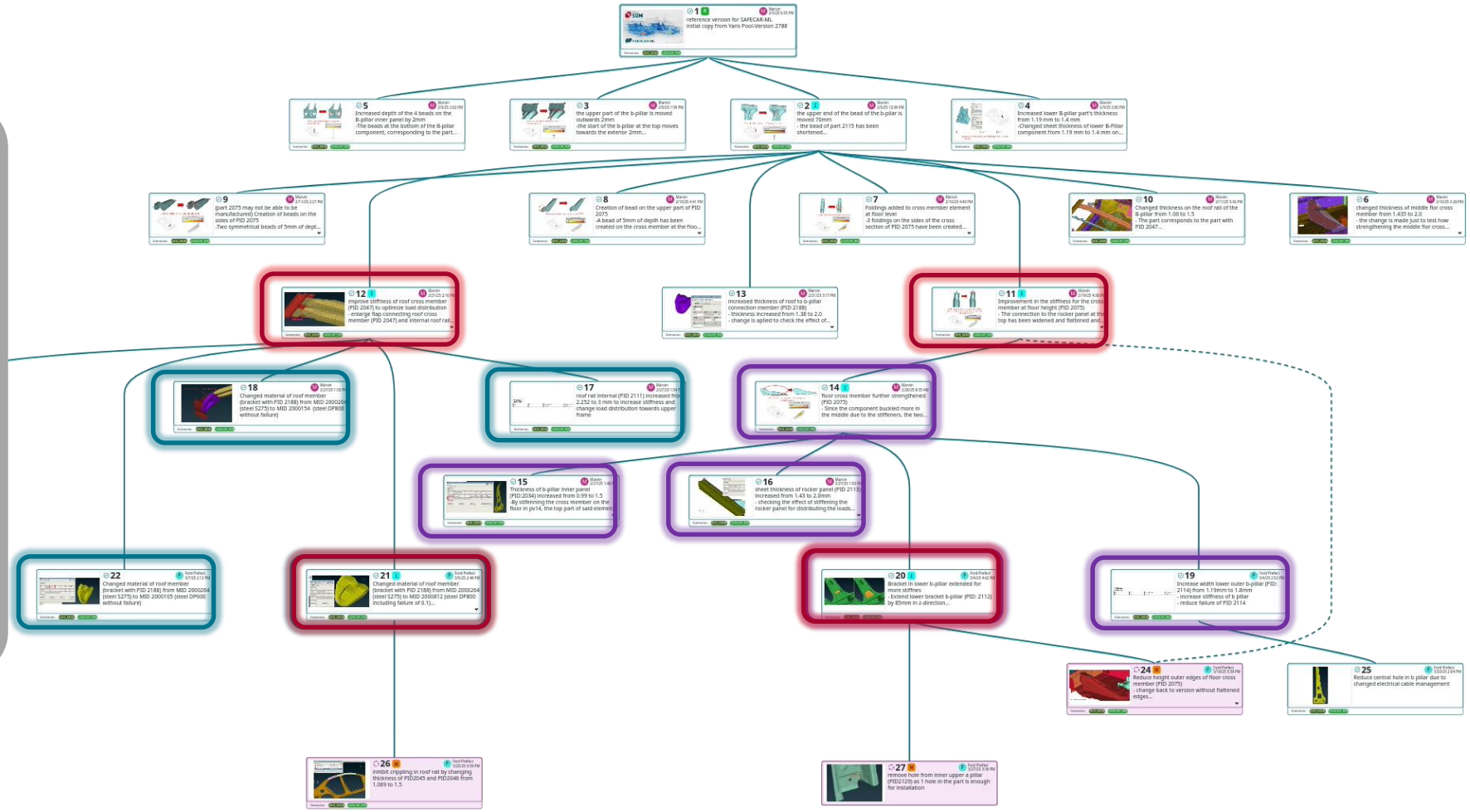
Repeat until you get the best



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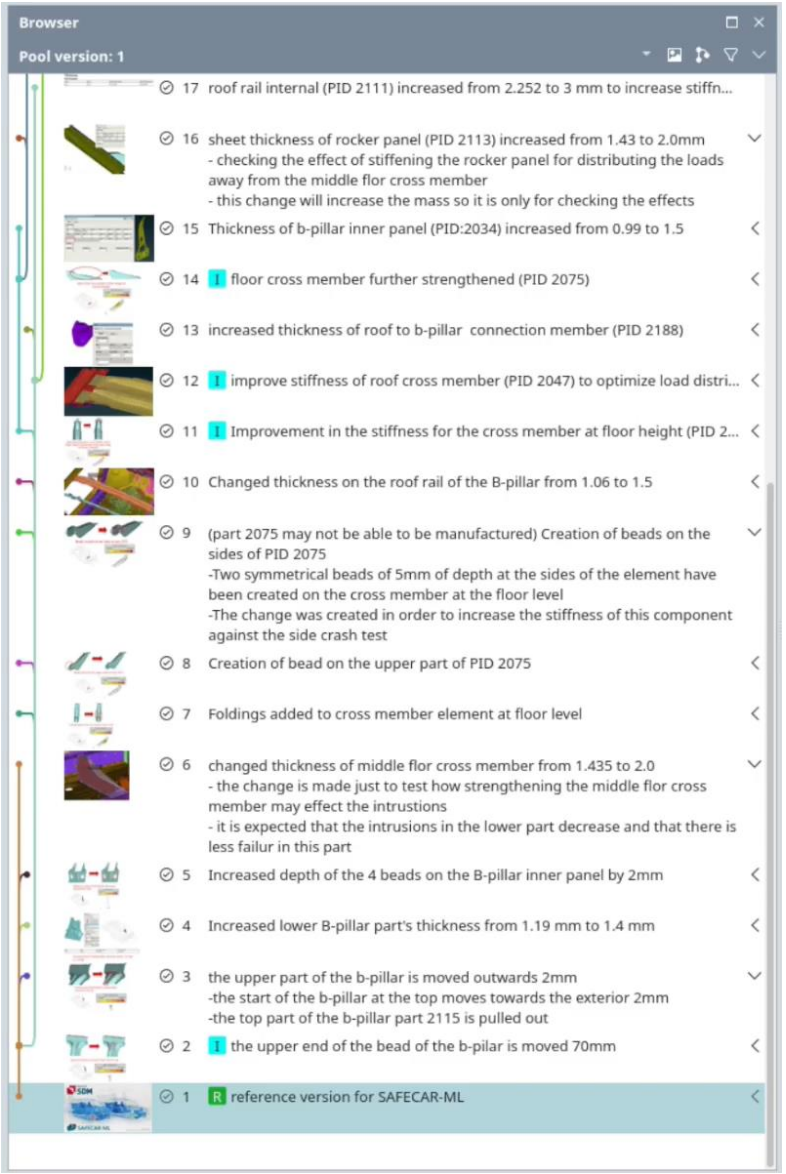
Robust Version Management

Why?

- Capture and document every state of the design process
  Timestamps, authorship, change comments, documentation …
- Enable discoverability
  Timestamps, authorship, change comments, documentation …
- Facilitating comparison and merge operation
  Even in large iterative revision cycles
- Prevent errors and rework
  By creating transparency and maintaining a reliable rollback mechanism

Versions for everything

- Each component
  Solver includes, preprocessor files, materials, control cards, configurations, …
- Parameters
  Design parameters, solver and HPC parameters, …
- Processes & scripts
  Preprocessing, postprocessing, check scripts, HPC and job submission, …
- The whole project
  One version for the whole simulation input data



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UI Elements for Version Control in SDM

Rail Graph

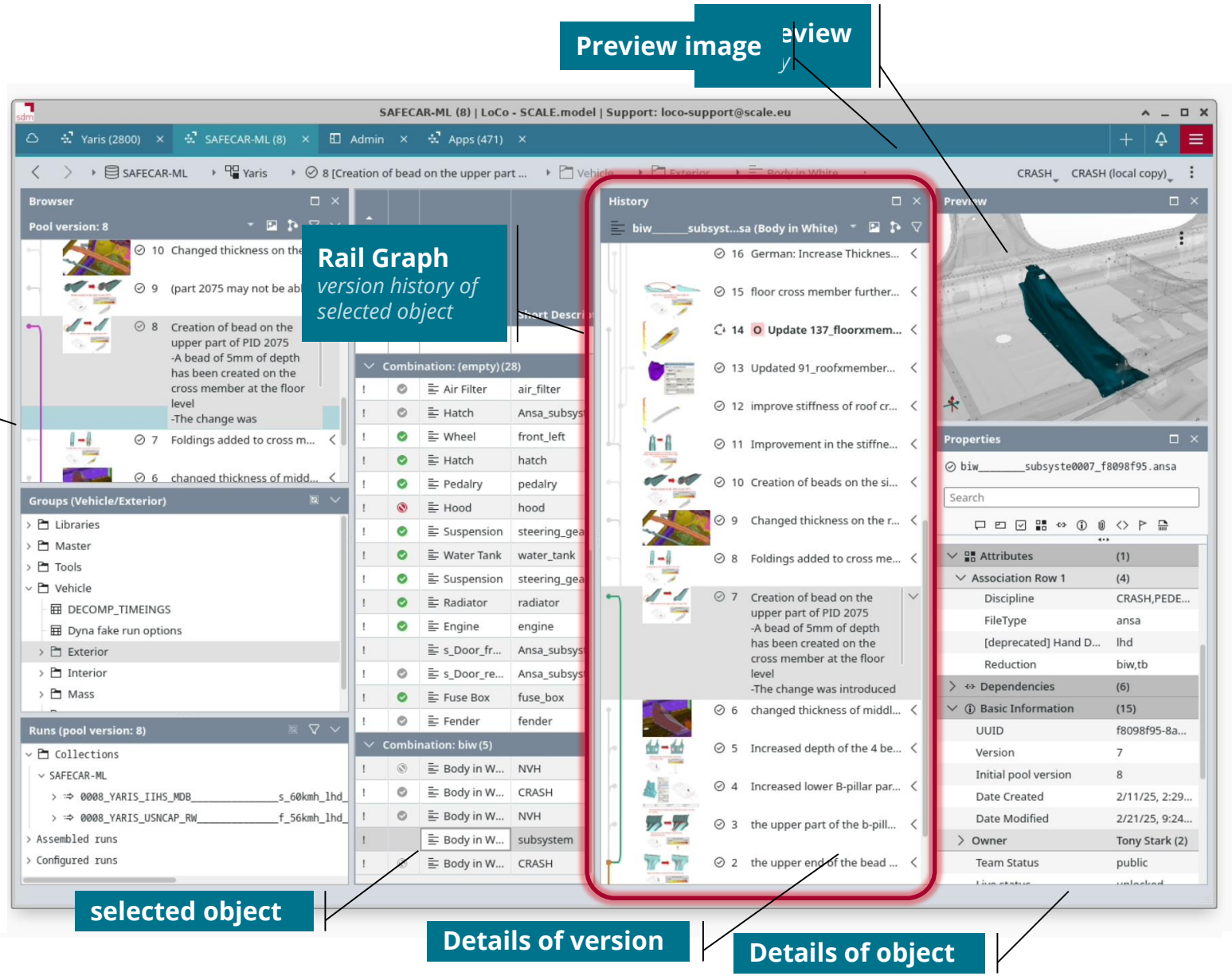
- Navigation
  Always aware of version context
- Quick insights
  Shows versions of selected data instantly

History Graph

- Big picture
  Tailored for the navigation of many versions
- Detailed insights
  For each selected version
- Summary of changes
  Additional …

Compare & Merge

- Understand differences
- Merge changes of different branches



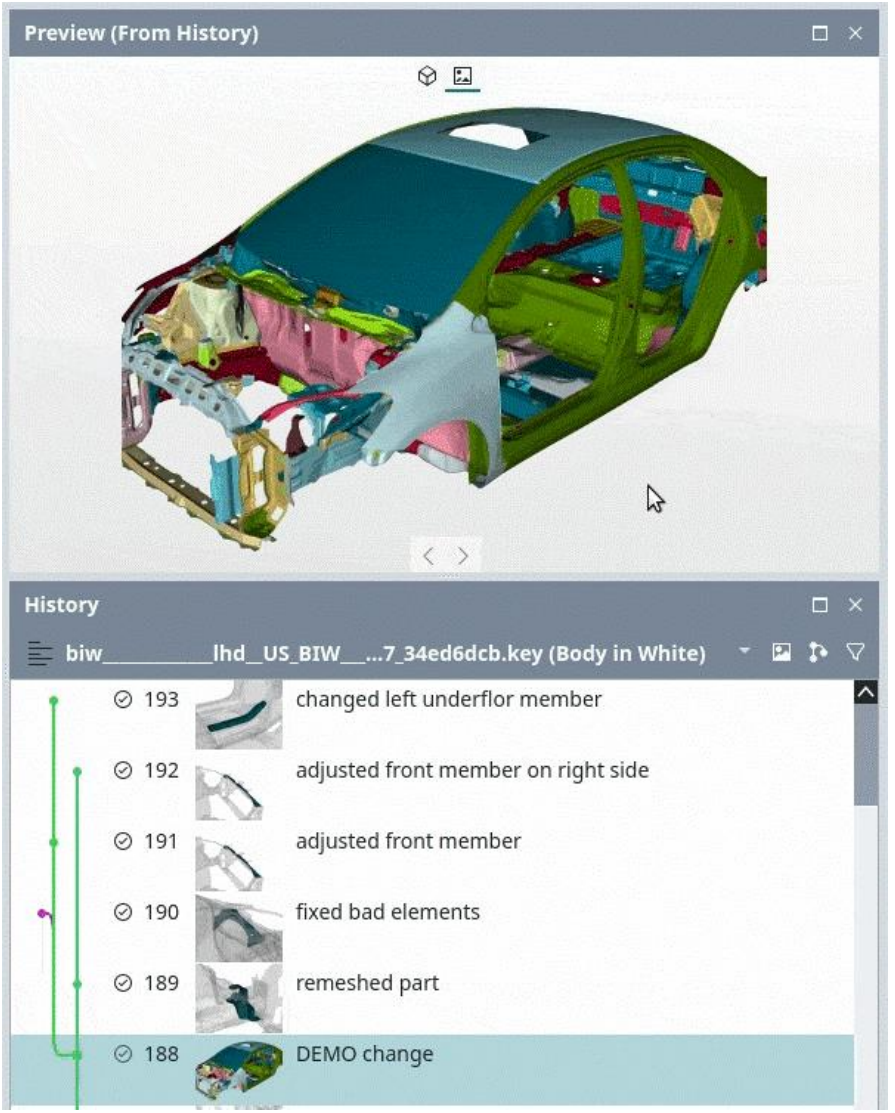
3D Previews for Rapid Visualization of Changes

3D Previews

- Provide immediate visual context
  Instantly reveals model state for quick visual assessment
- Faster orientation in SDM
  Speeds up navigation within the SDM environment
- Understand changes
- Interactive 3D navigation
  Enables dynamic rotation, zoom, and geometry exploration

Features

- Auto-generated after each change
  Previews are created with every modification of a solver file
- Interactive visualization compare of changes
  Visually highlights modifications between versions for rapid understanding of changes
  - Changes made to the currently selected file
  - Differences between files
    highlighting the changes made for each of the compared files
- Creation of static images
  Generates snapshots for documentation and sharing



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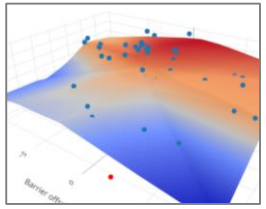
AI and Simulation Data Management

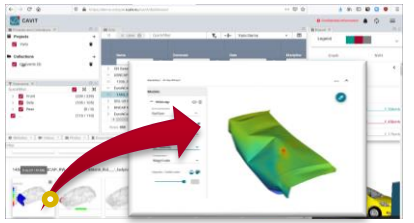
Learn from Simulation Results

Predictions, classifications, detection of unwanted behavior, …

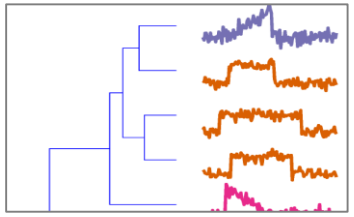
- Data Analysis
- Event Detection
- Time series classification
- Data-driven Reduced Order Models (ROMs) , Physics-Informed Neural Networks (PINNs)



Data Analysis
Neural Network based Regression Models



Event Detection
Automatic detection of unseen behavior

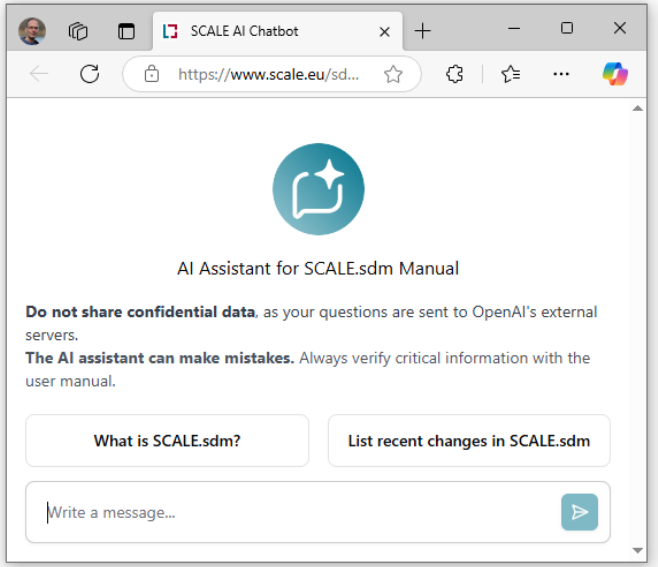


Time Series Classification
Labeling / Error Detection

Discovering and Creating Simulation-related Content in the SDM System

LLM-based generative AI for discovering SDM data and CAE documentation to aid new content creation

- Chat assistant for talking with the documentation
  SDM and CAE user manuals, documents stored in the SDM system, …
- **System for assisting the creation of change documentation**
- Integrations in CAE preprocessing tools
  Text-based assistant for solver files in editors, tools integrated in CAE tools e.g. for meshing, …
- Outlook: Search and summarization on the data stored in the SDM system



Outlook: Perform complex tasks in the SDM system

Agentic AI and tool use with LLMs (MCP server)

- LLM based automatization beyond classical approaches

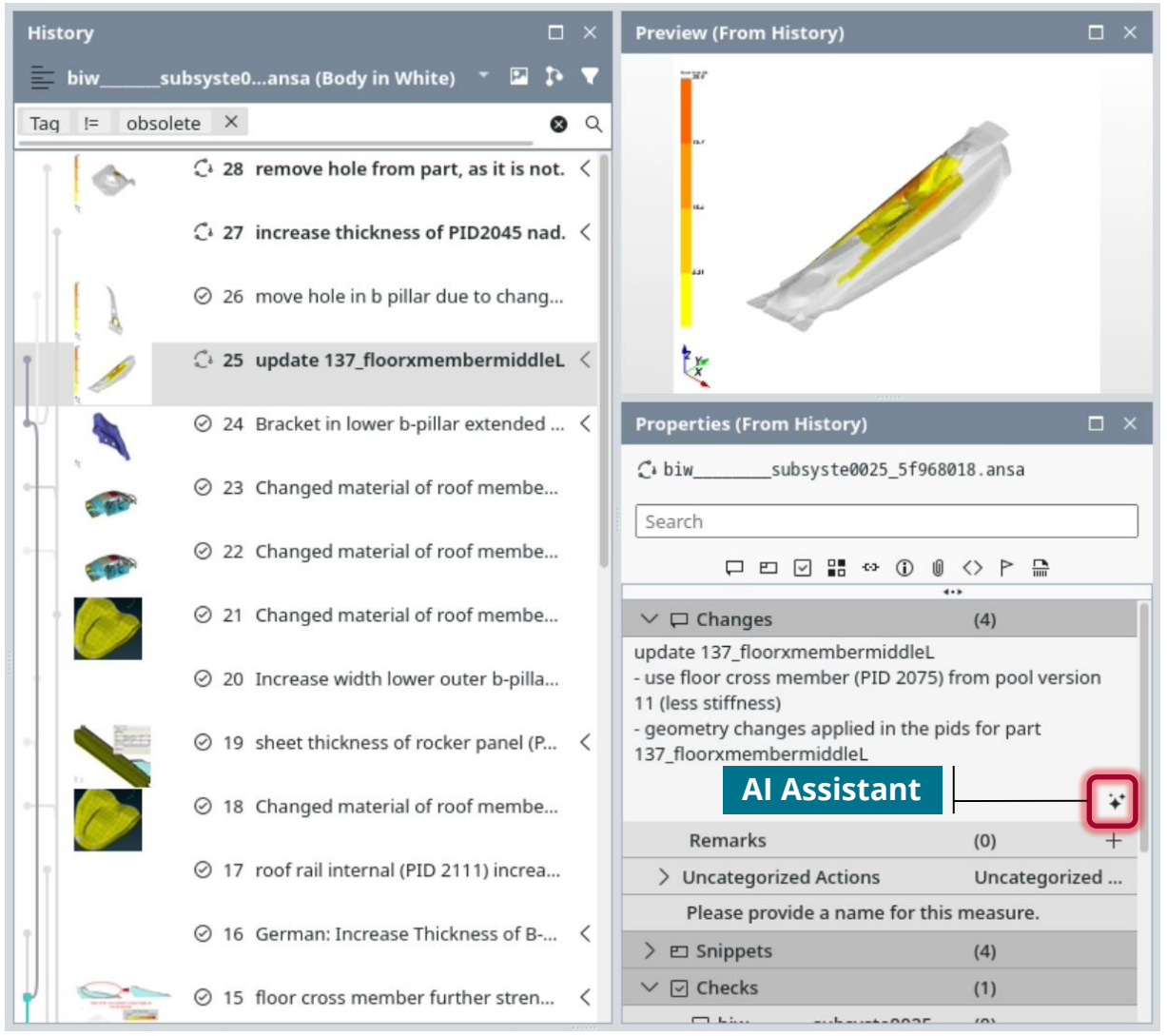
AI-Driven Assistance for Change Documentation

The Problem

- Writing change documentation is boring
  „Dokumentation ist wie eine Krawatte –
  sie ist optional, aber sie rundet das Gesamtbild ab.“
- **Consequence:** bad change documentation
  Discoverability is sacrificed, loss of knowledge
- Good change documentation is key
  Understanding model evolution, discovery, collaboration, …

Goals

- Facilitate change documentation
  Make it effortless, enhance the motivation for the engineer
- Augment change documentation
  By using automatically extracted details
- AI that understands the nature of changes
  Get change description even for geometry updates



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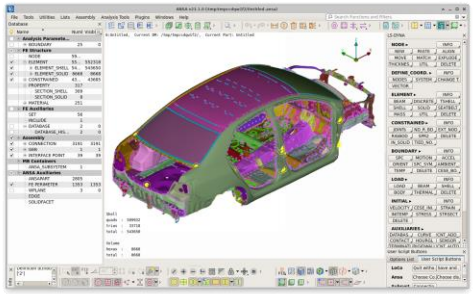
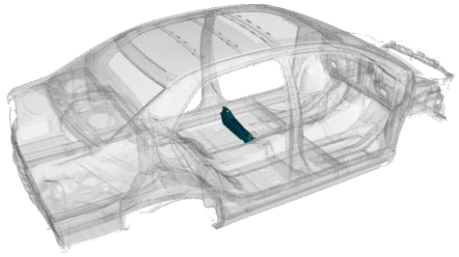
Pipeline for AI Comment Generation

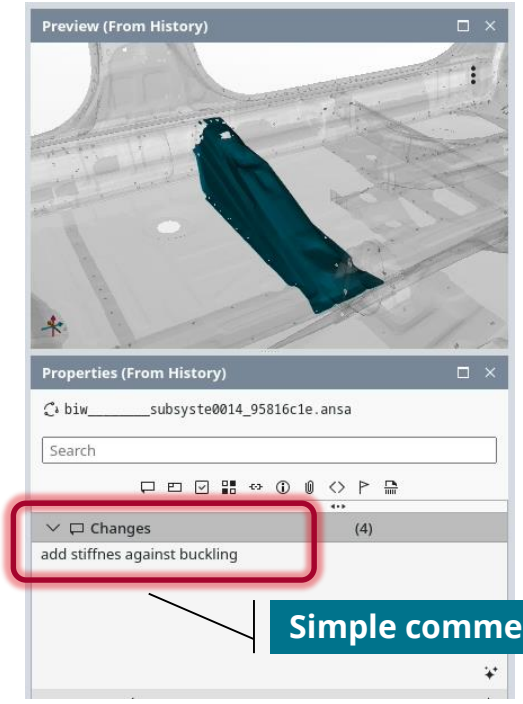
Problem
Revealed by simulation



Changes
Applied in CAE preprocessor



Modified version



Simple comment

User is prompted for change documentation but only provides a simple comment for context

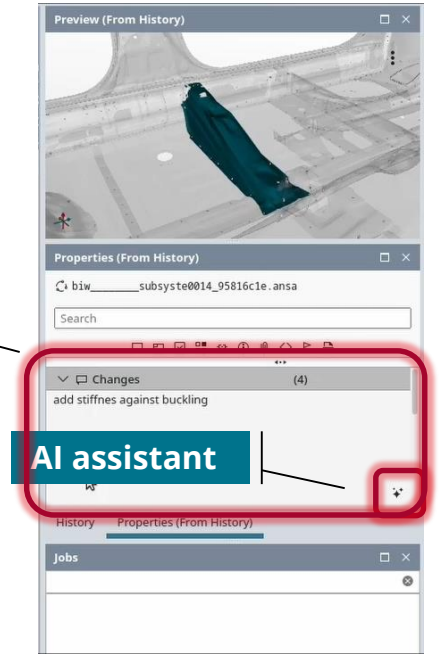
Model Compare

Automatic change extraction

Prompt for LLM
Generated from

- Modelcompare Output
- Context provided by user

AI assistant



Augmented change documentation

Enhanced change description:

Update 137_floorxmembermiddleL stiffness

- add stiffness against buckling: Applied changes to part 137_floorxmembermiddleL (PID 2075) for enhanced buckling stiffness
- Updated geometry details in the pids

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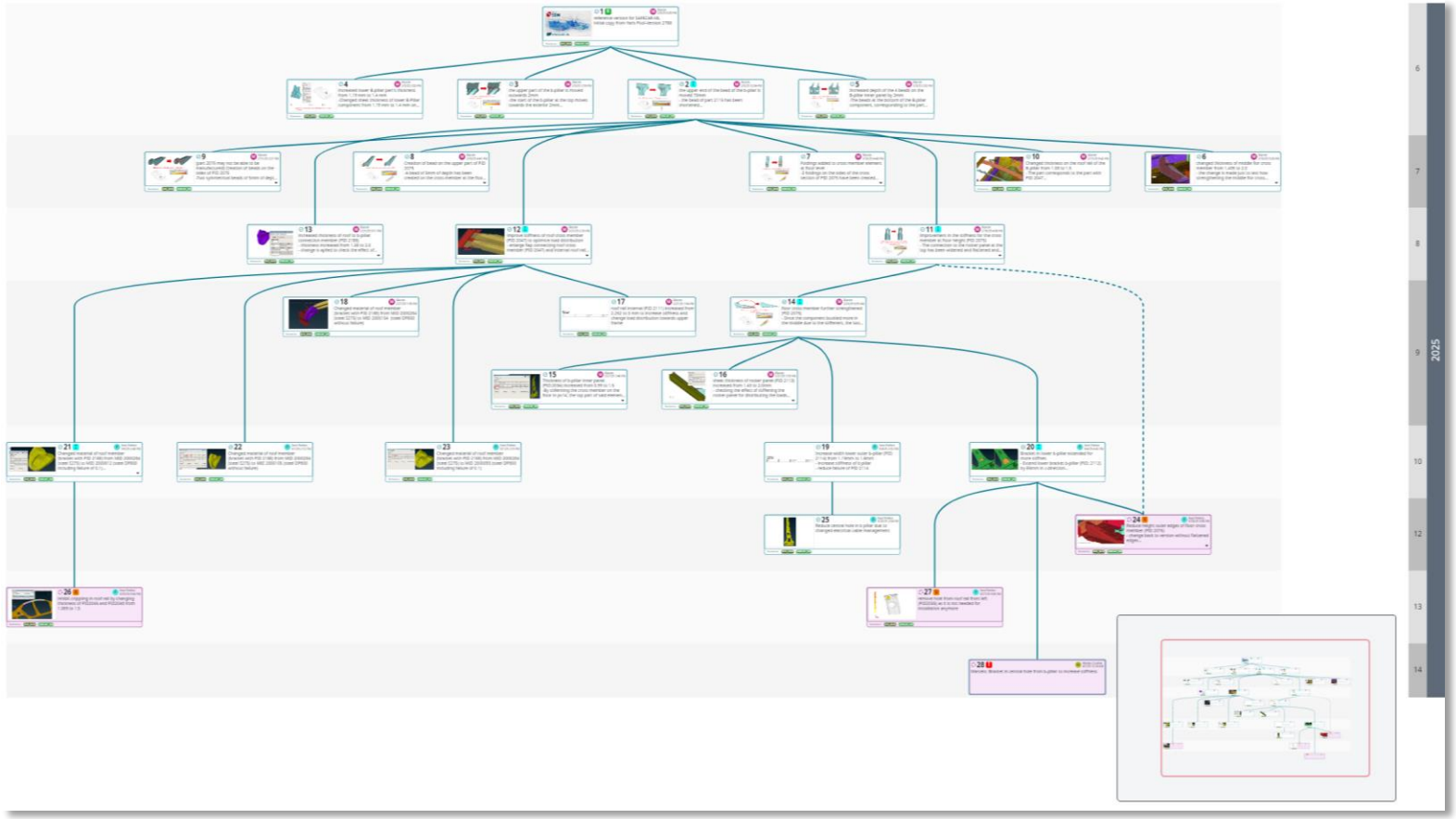
SAFECAR-ML Research Dataset & Vision

SAFECAR-ML

ML-based automatic classification and
semantic description of measures
for the CAE vehicle development

Goals

- Dataset for LLM fine tuning
  Modal model that uses geometry and produces text
- 100+ well documented changes
  - Carefully written change comments
  - Additional documents e.g. images for each change
  - Simulation results with summary of observations
- Dataset will be made
  publicly available
  For research and noncommercial use
- Development of LLM models for automatic
  creation of semantic descriptions of changes



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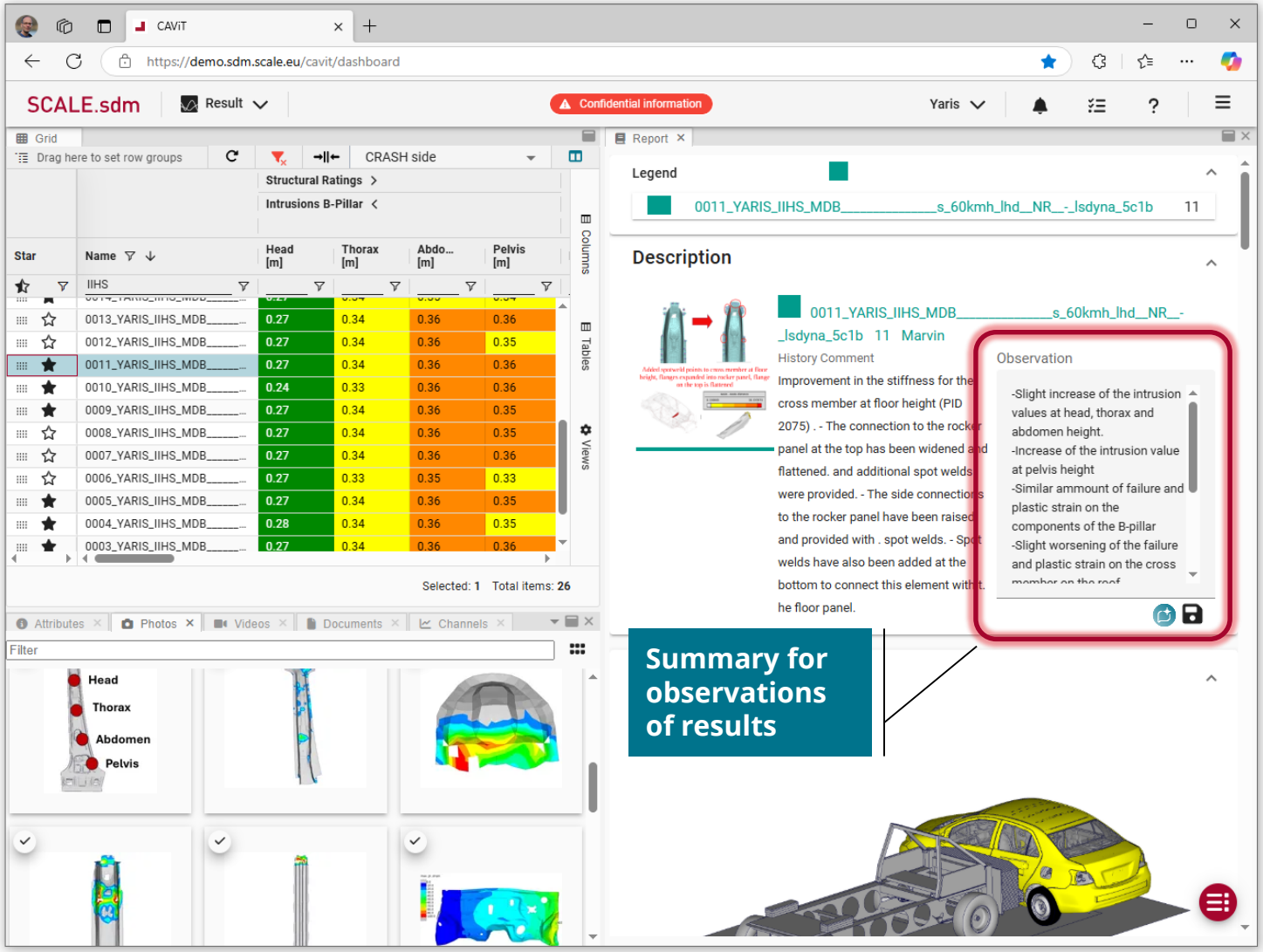
Outlook & Conclusion

- Create automatic summaries for results
  - Retrieve data from key results
  - Create prompt to the LLM to make a
  - Use existing observations for style and context
- Research thinking models for making recommendations on further changes
  - Integrate all change comments and observations in RAG system
- Automatization
  - Create MCP server for connecting LLMs
  - Enable LLM tool use for search, retrieval and automatization beyond classical approaches



Conclusion:

- LLM based AI will provide new tools to facilitate the usage of SDM-System and leverage an increased utilization of the knowledge stored in the SDM-System

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SO LONG, AND THANKS

FOR ALL THE FISH

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

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