

Model Traceability Procedure for an Automotive-Safety Virtual-Testing Framework

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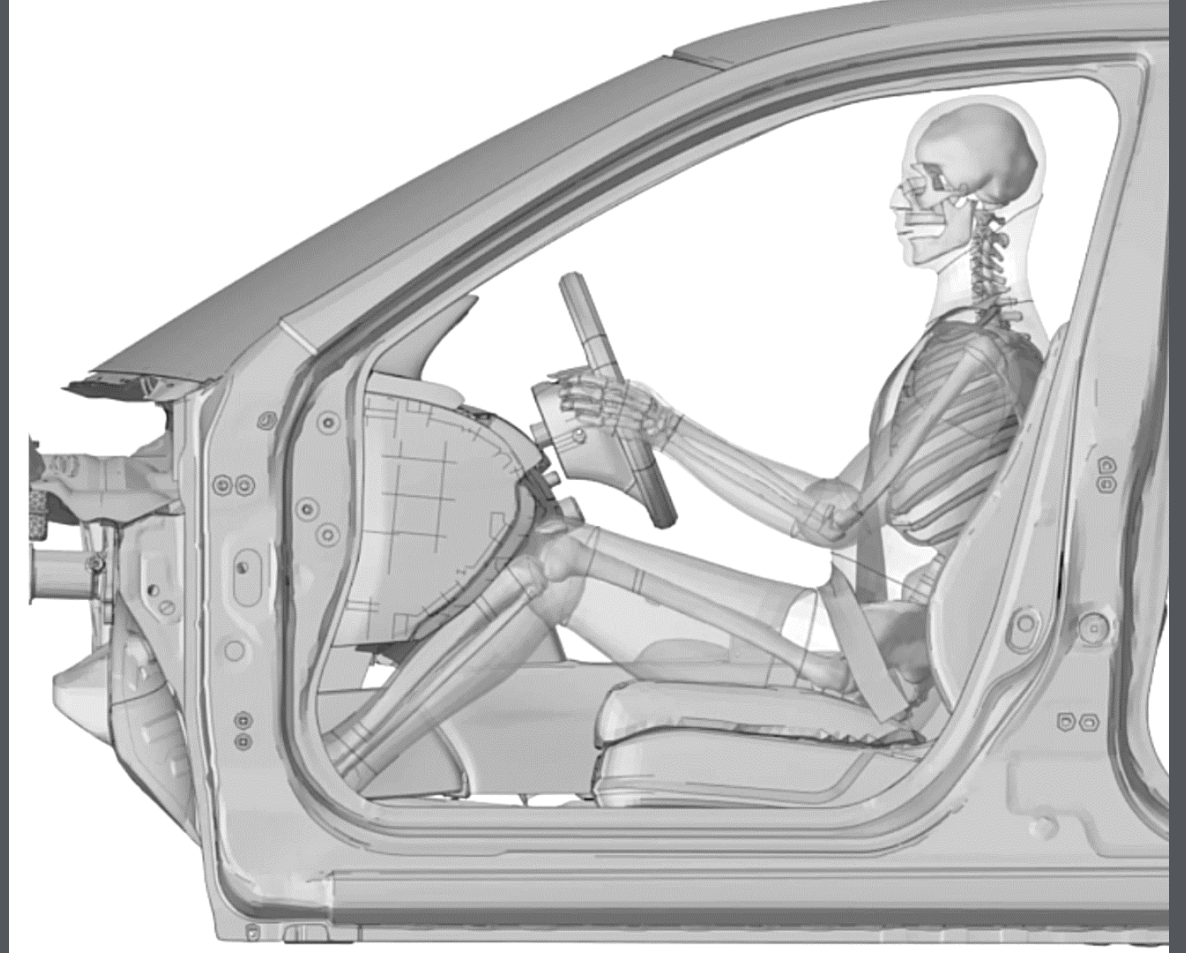
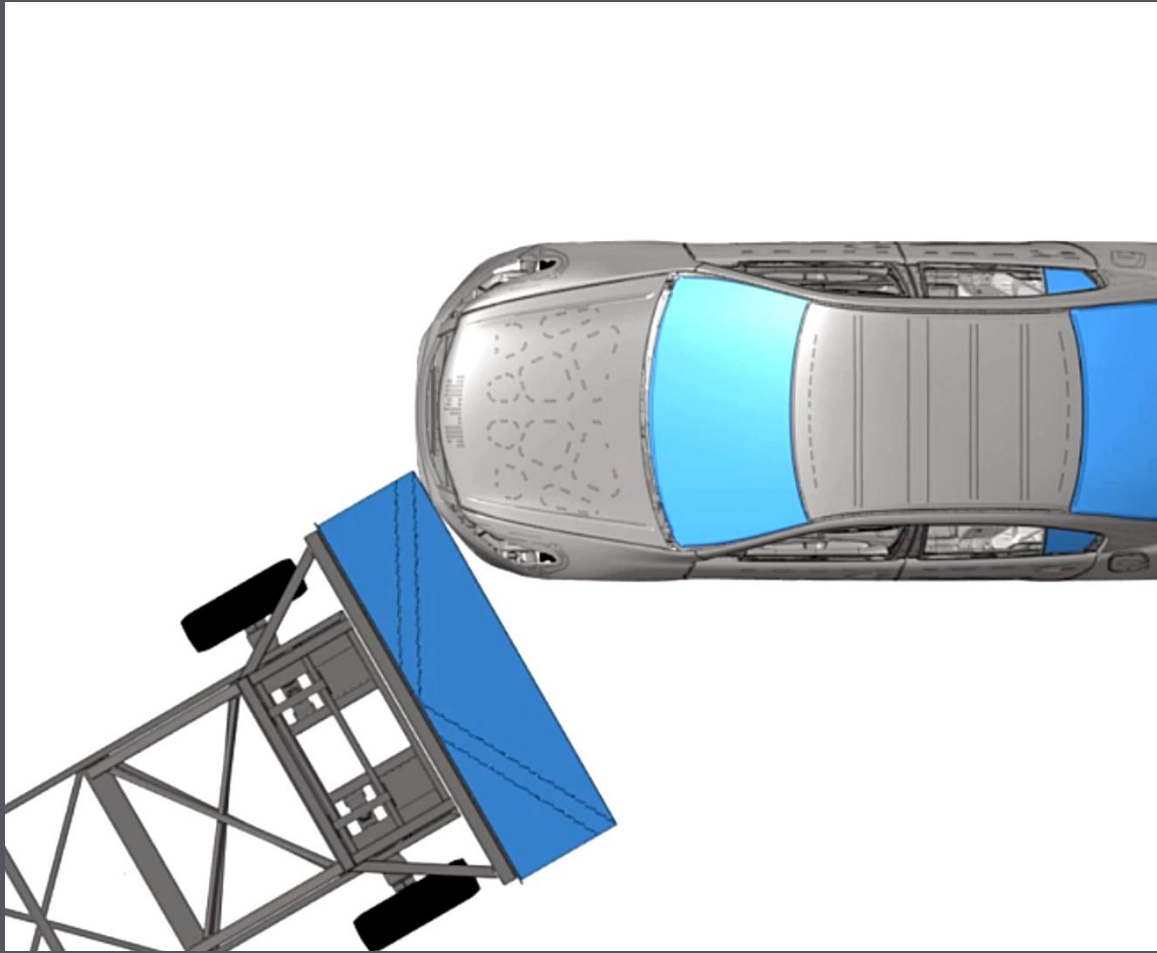
Background



Virtual testing

building safety design
robustness

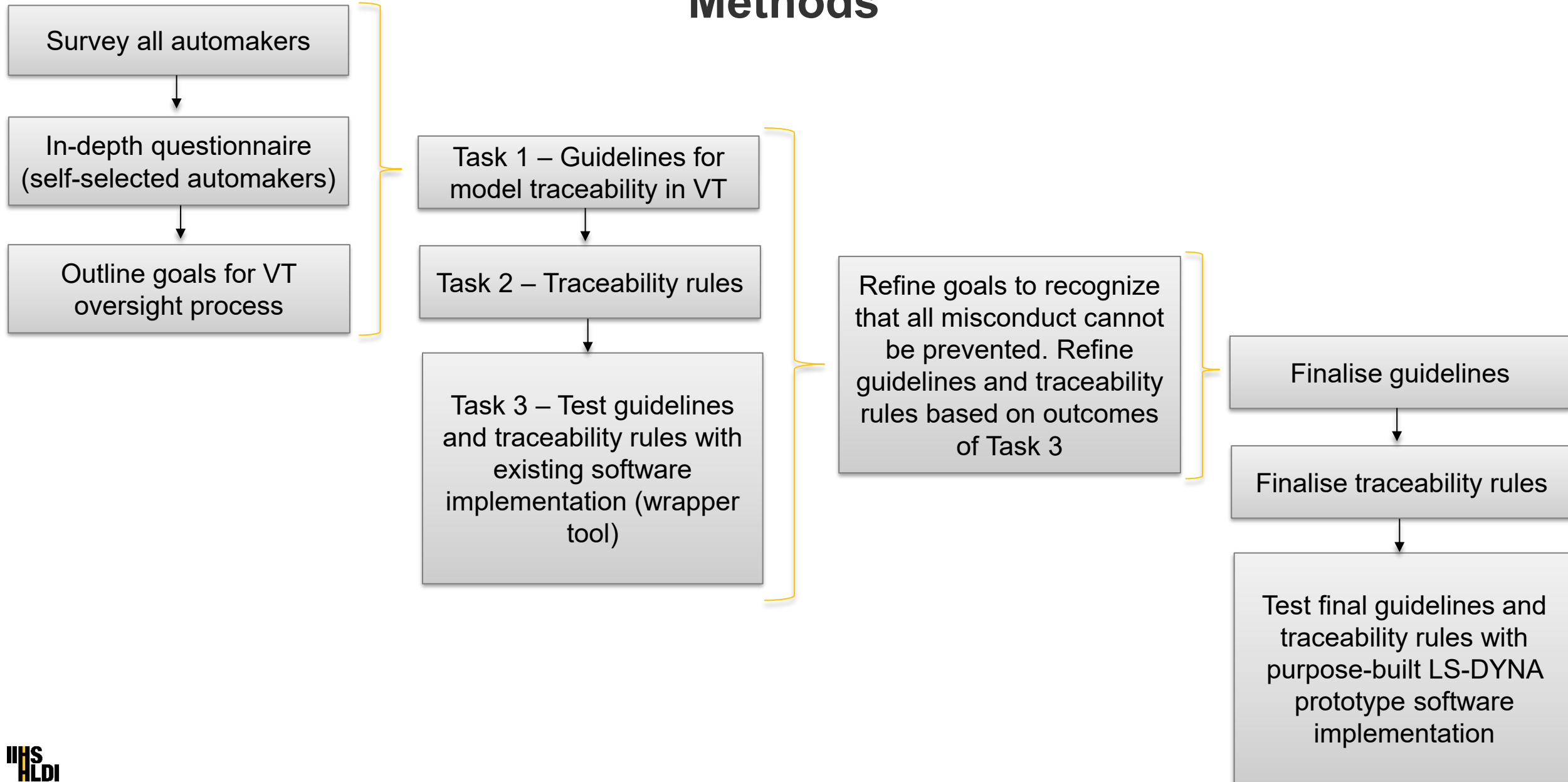




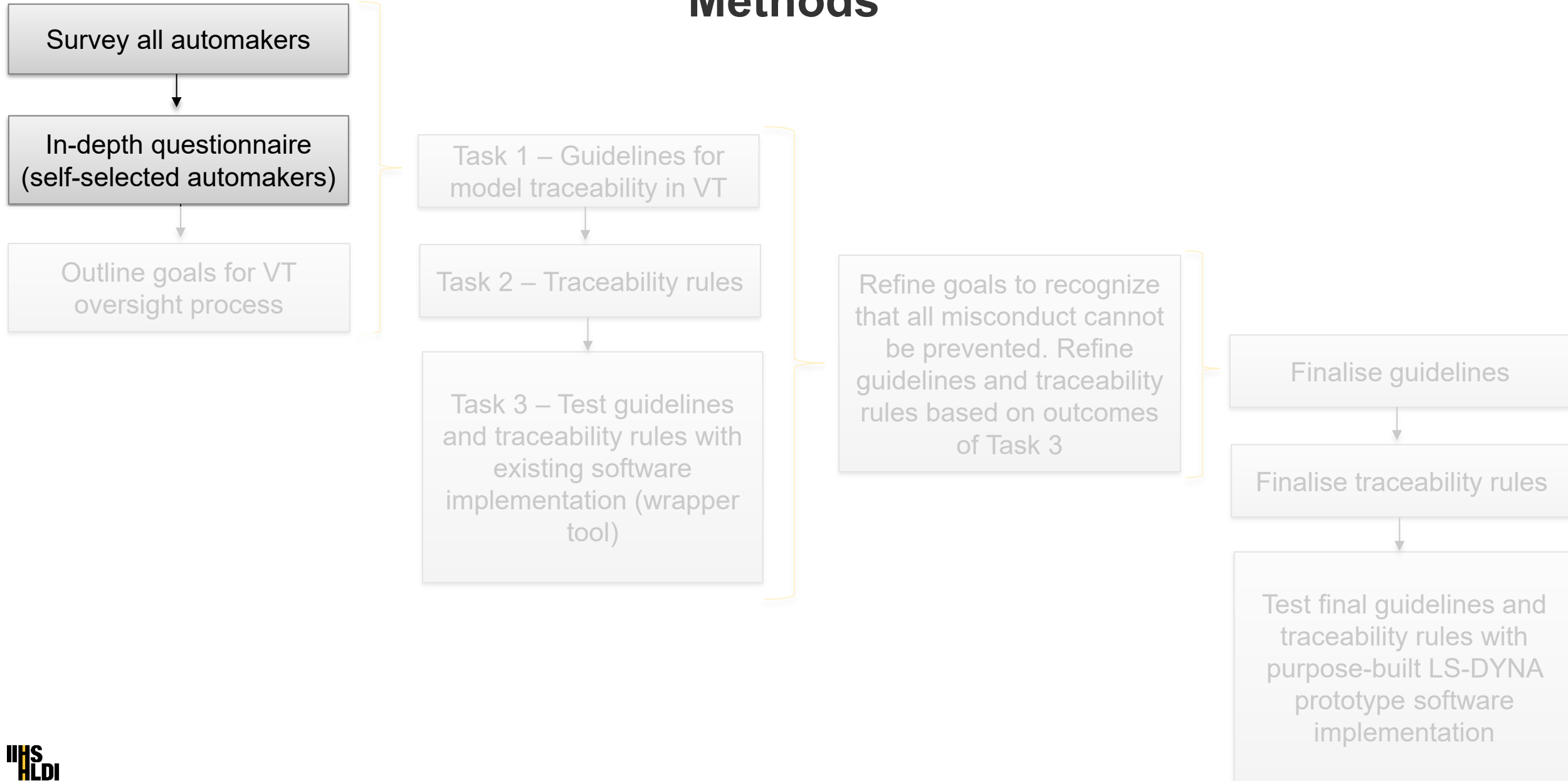
Research goal

Develop a procedure to build confidence in simulation outcomes used in a virtual testing framework

Methods



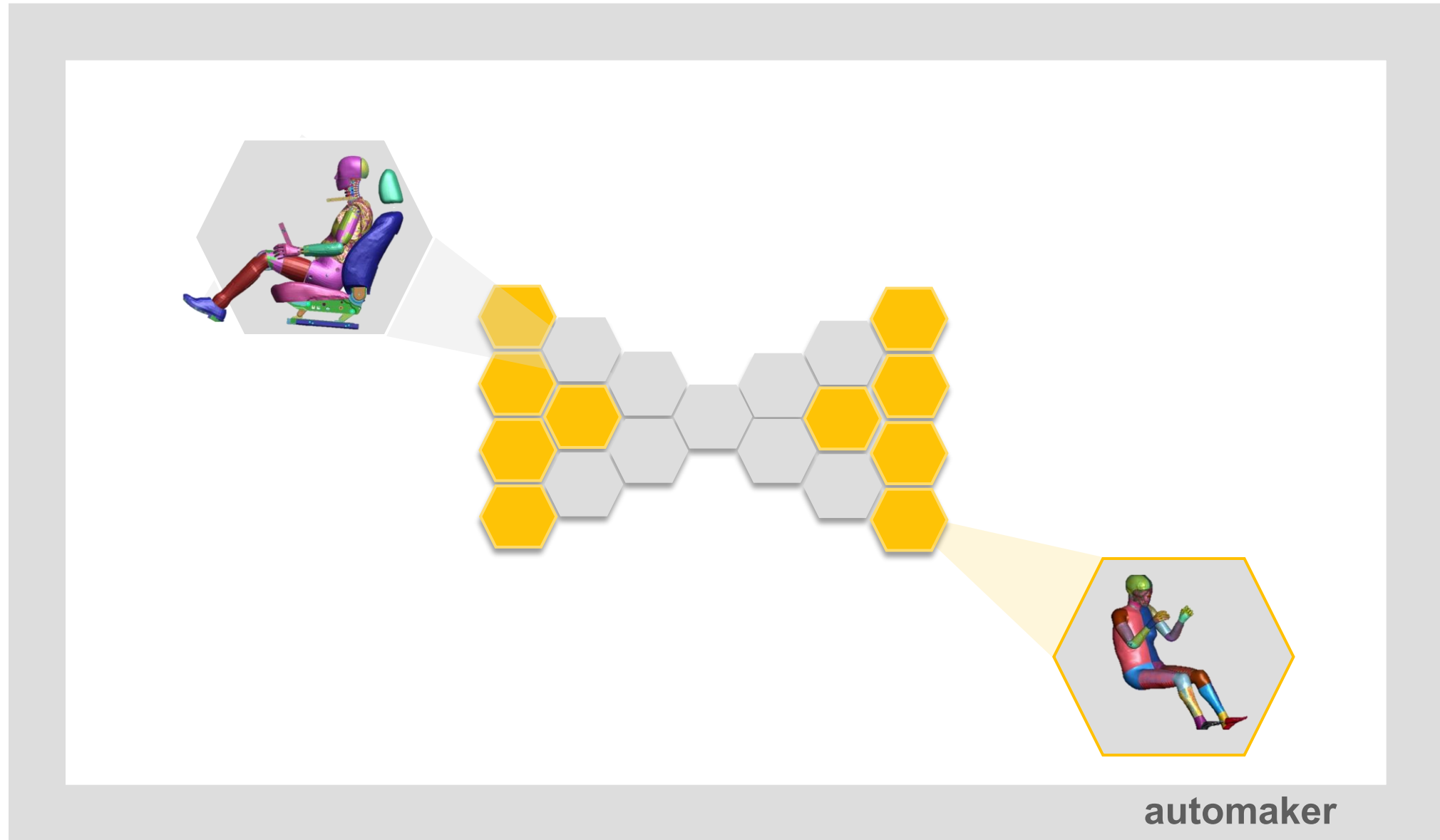
Methods



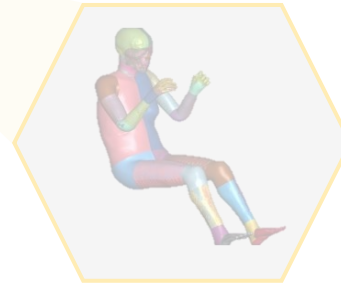
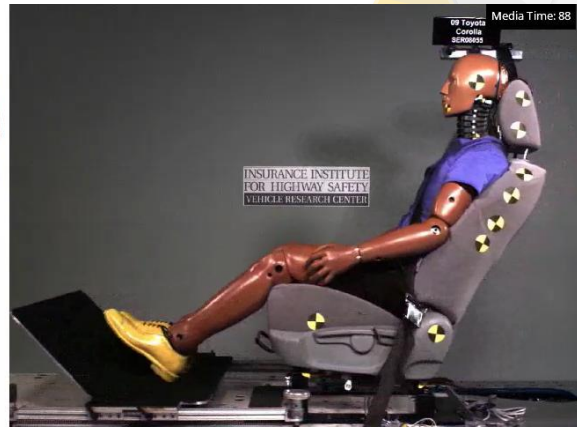
Automaker survey and questionnaire

- ▶ Protection of intellectual property in model sharing
- ▶ Maintaining the integrity of company specific modeling practices when using their models
- ▶ Simulations run by automakers are the most feasible path forward for VT, with transparency and oversight to prevent misconduct
- ▶ Virtual testing has most value where physical tests cannot be conducted
- ▶ Hurdles include variability in model accuracy, effects of software differences, trust in simulation and sufficient oversight mechanisms

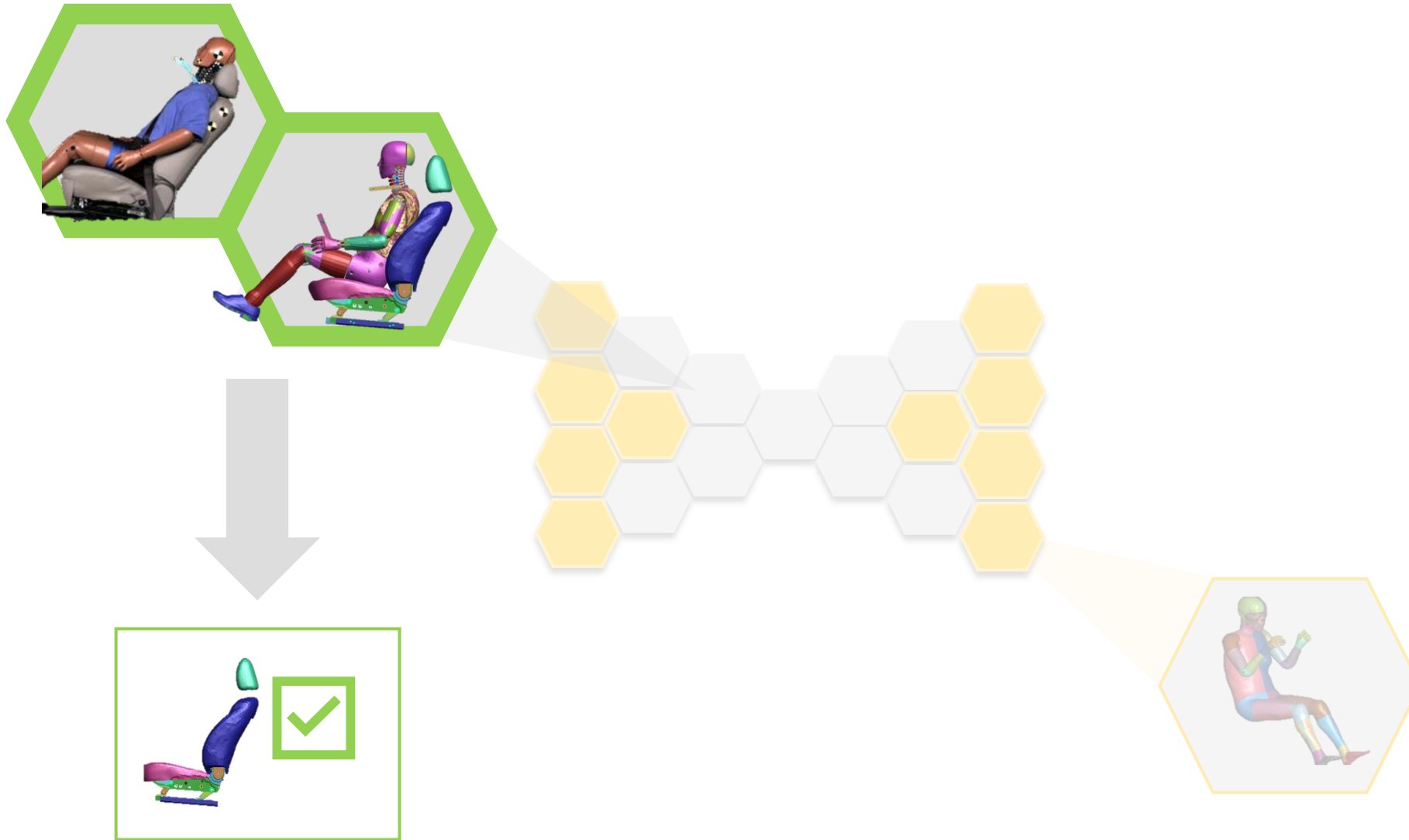
Virtual testing framework



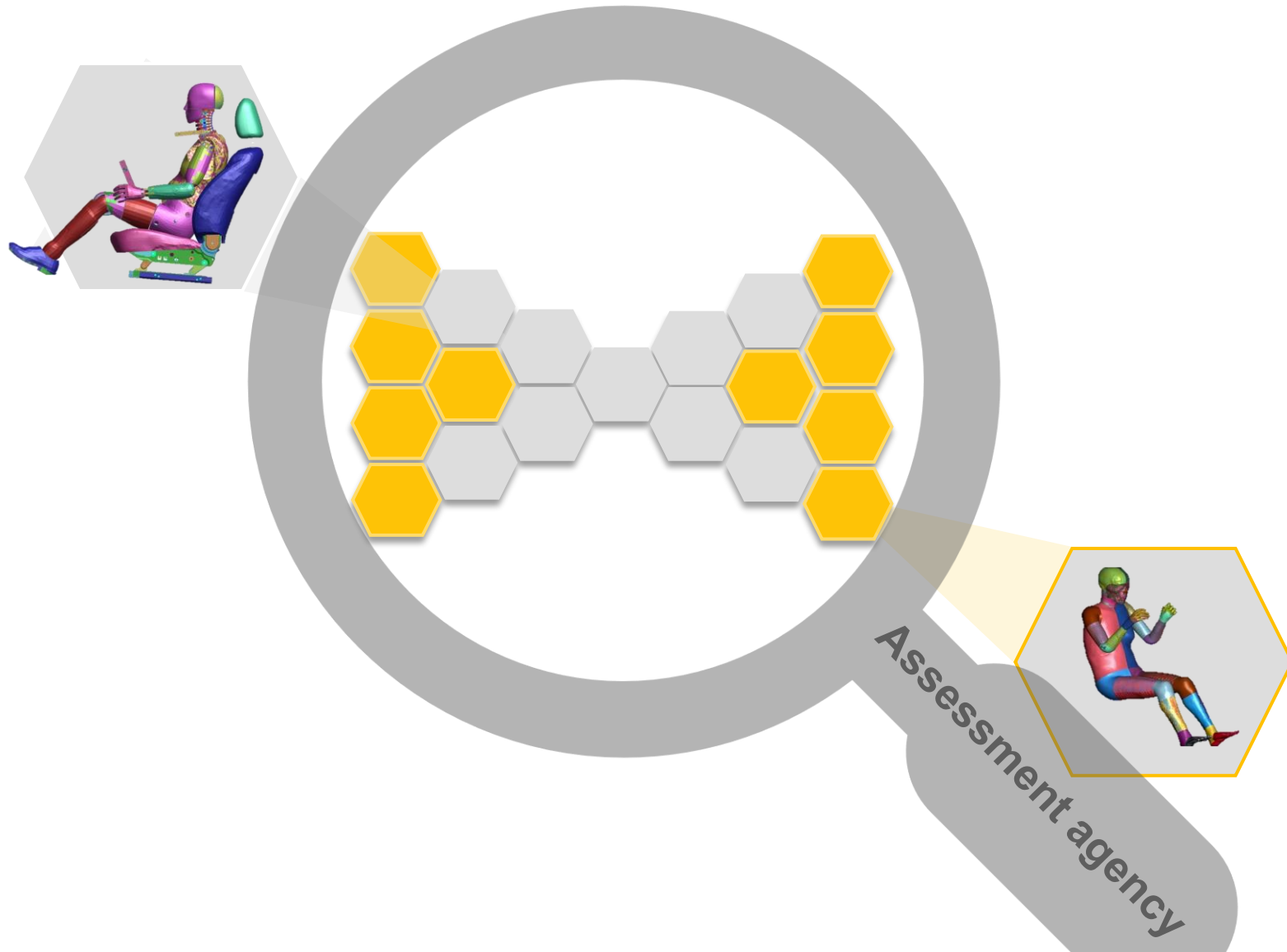
Virtual testing framework



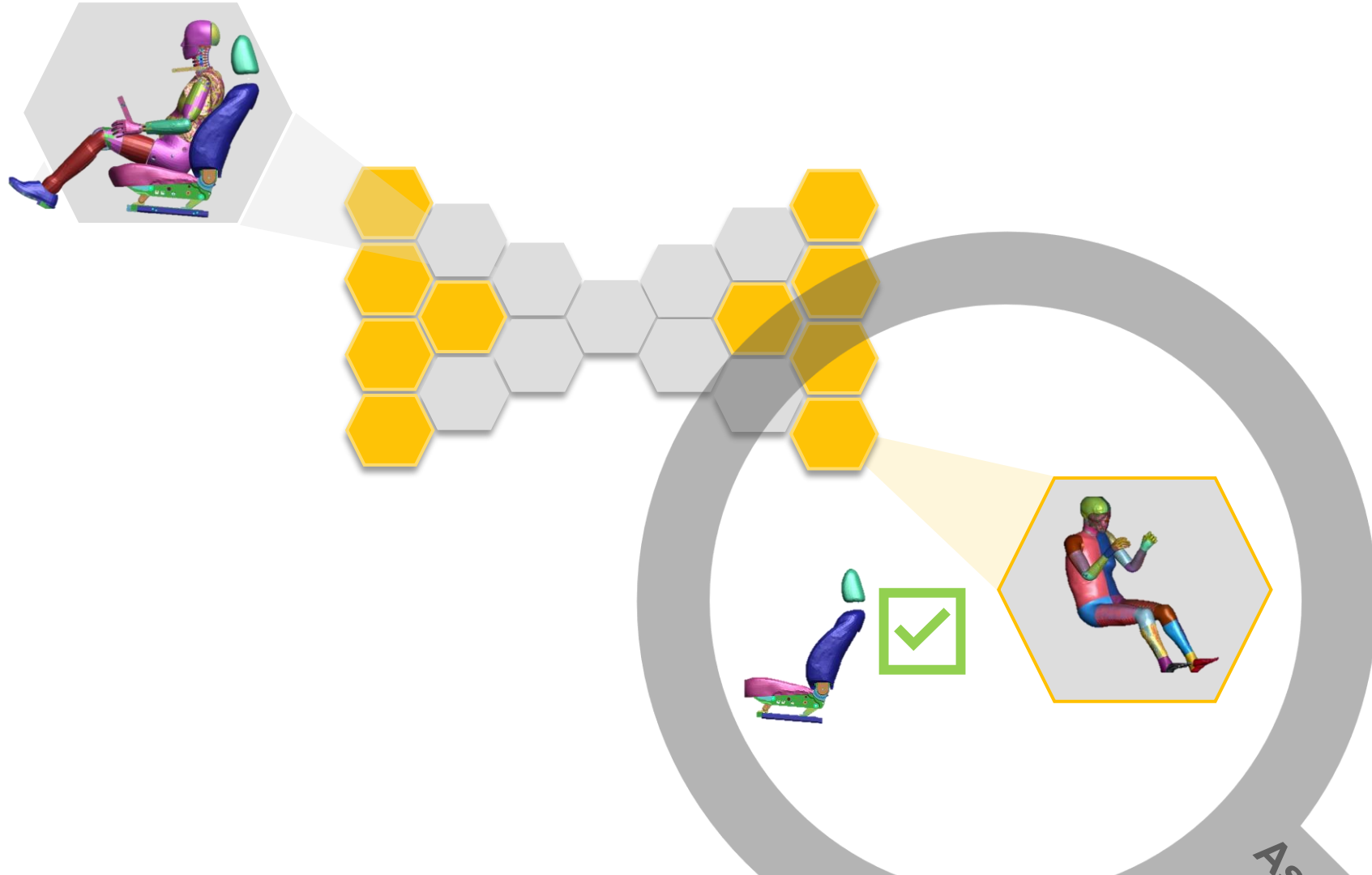
Virtual testing framework



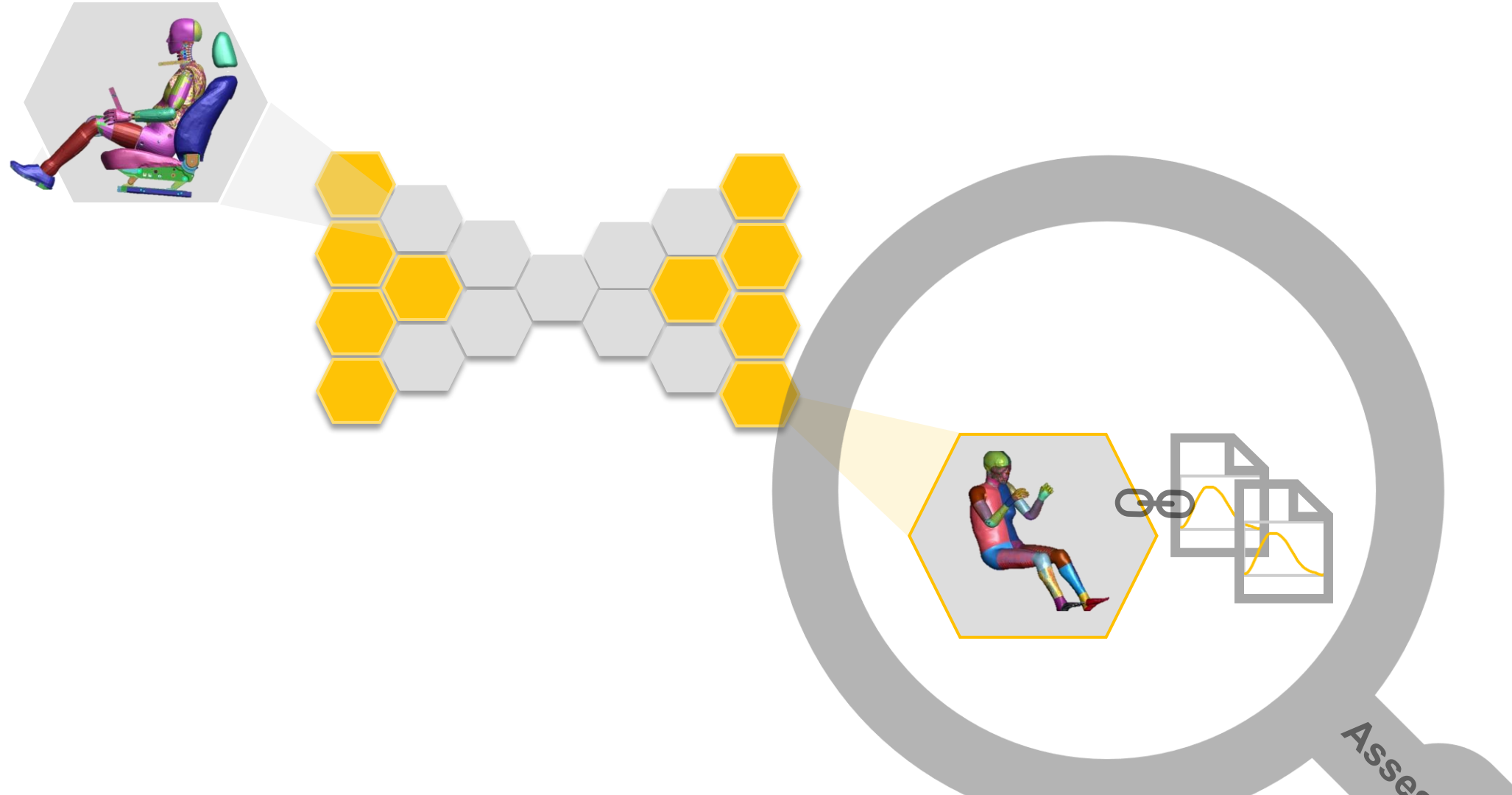
Virtual testing framework



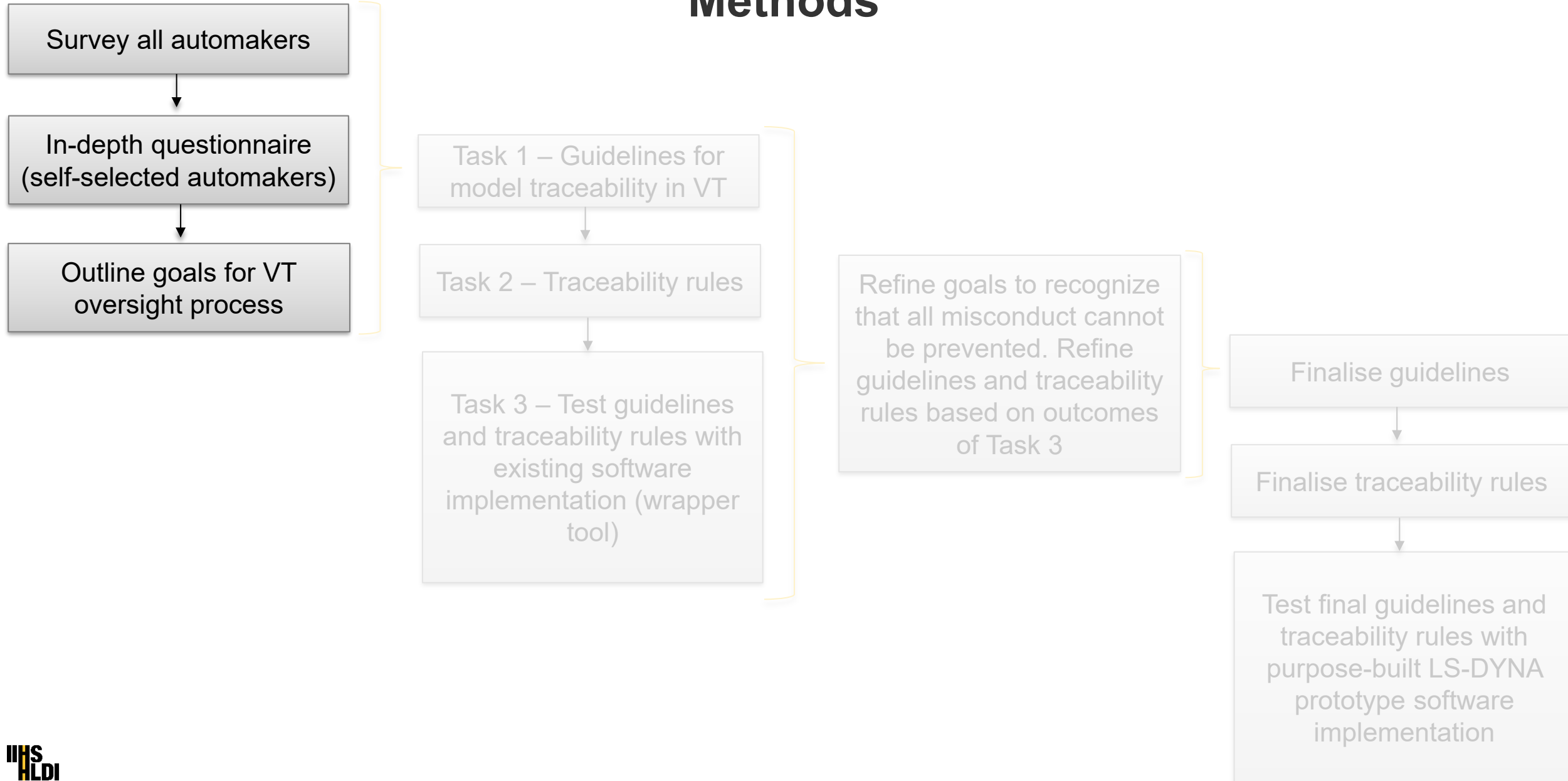
Virtual testing framework



Virtual testing framework



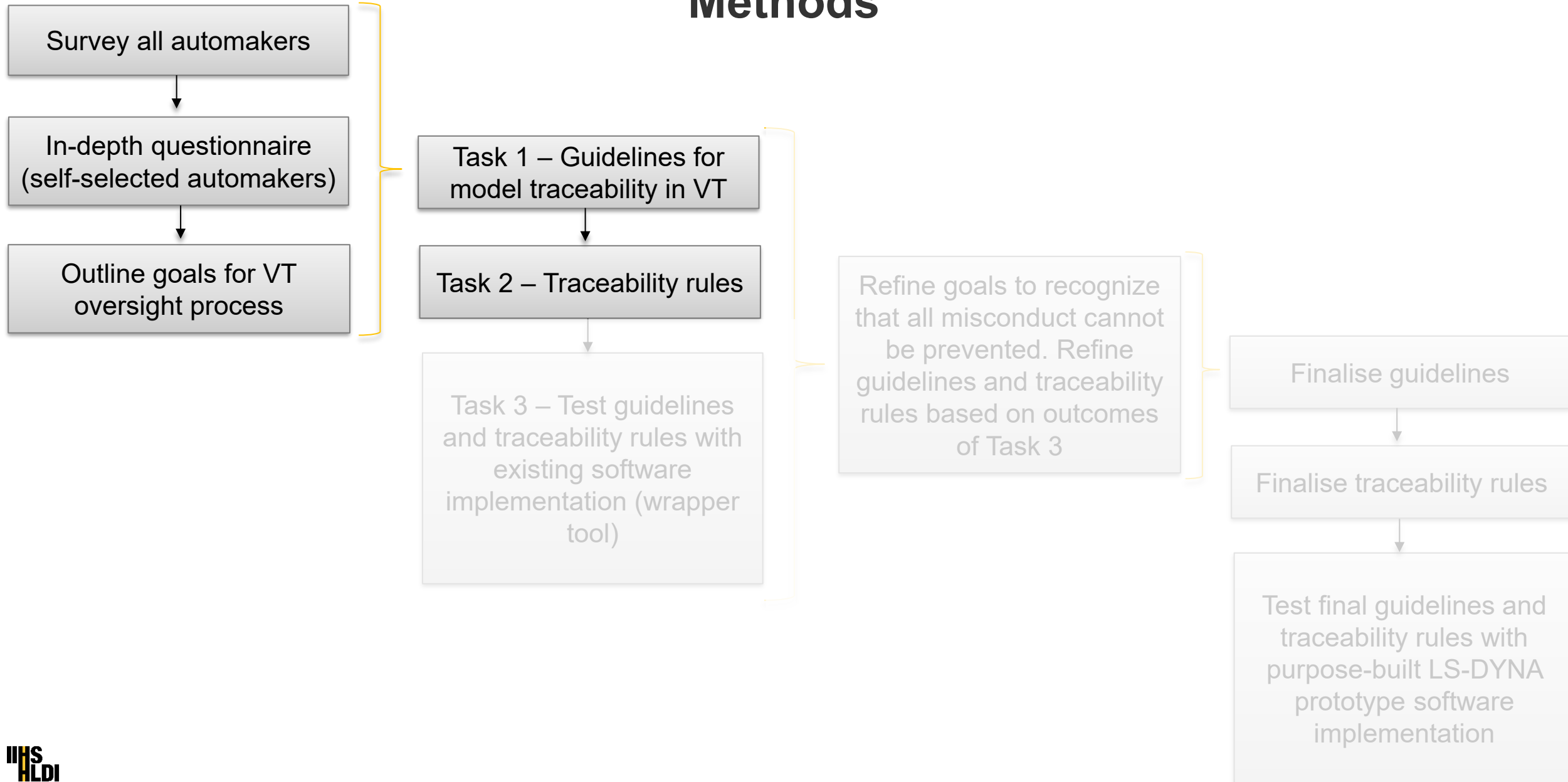
Methods



Goals for developing VT oversight process

- ▶ Identify the minimum amount of information and oversight mechanisms necessary to ensure that results from automaker's simulations come from trusted models
- ▶ Identify the methods and tools needed to trace models from validation to assessment and to check inputs and outputs from the simulations

Methods

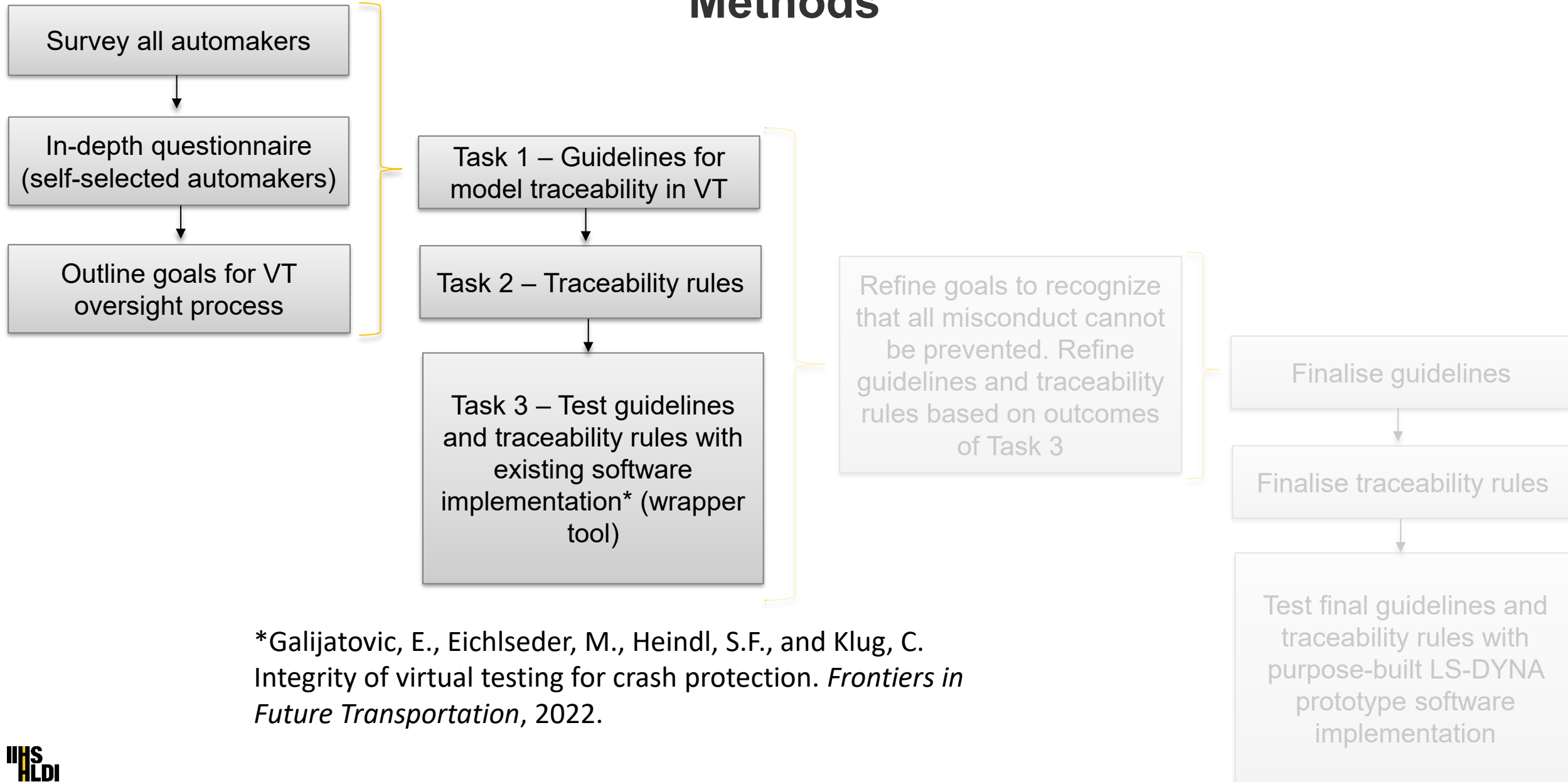


Traceability guidelines and rules

Tasks 1 and 2

- ▶ Confirm that the information reported to the assessment agency comes from the inputs and outputs run by the solver.
- ▶ Confirm that the simulation outputs come from the simulation inputs.
- ▶ Confirm that no inappropriate changes have been made between validation and assessment load cases in the simulation.
- ▶ Accommodate necessary changes to the simulation inputs between validation and assessment load cases (e.g., nodal coordinates for a different seat position).
- ▶ Protect the intellectual property of automakers and suppliers
- ▶ Rules and software must be technology and platform agnostic
- ▶ Assessment agency must be able to confirm traceability without requiring software license

Methods



*Galijatovic, E., Eichlseder, M., Heindl, S.F., and Klug, C. Integrity of virtual testing for crash protection. *Frontiers in Future Transportation*, 2022.

Testing existing wrapper tool*

Task 3

▶ Strengths

Tracked model changes automatically by hashing individual include files

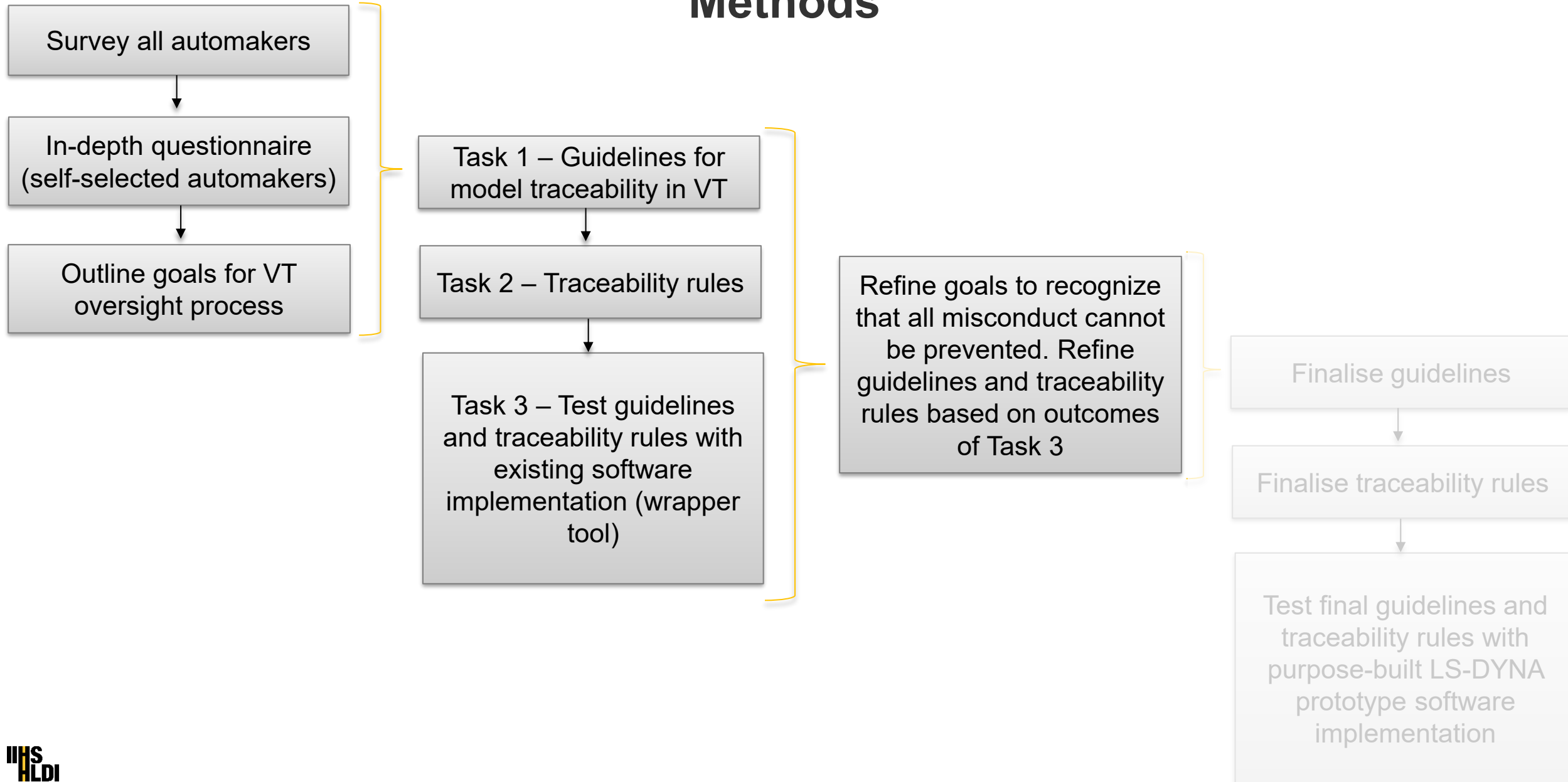
▶ Weaknesses

Software external to the FE solver introduced vulnerabilities:

- Not recognizing the use of a restart file to initialize the simulation
- Source code modification
- Substitution of solver output files

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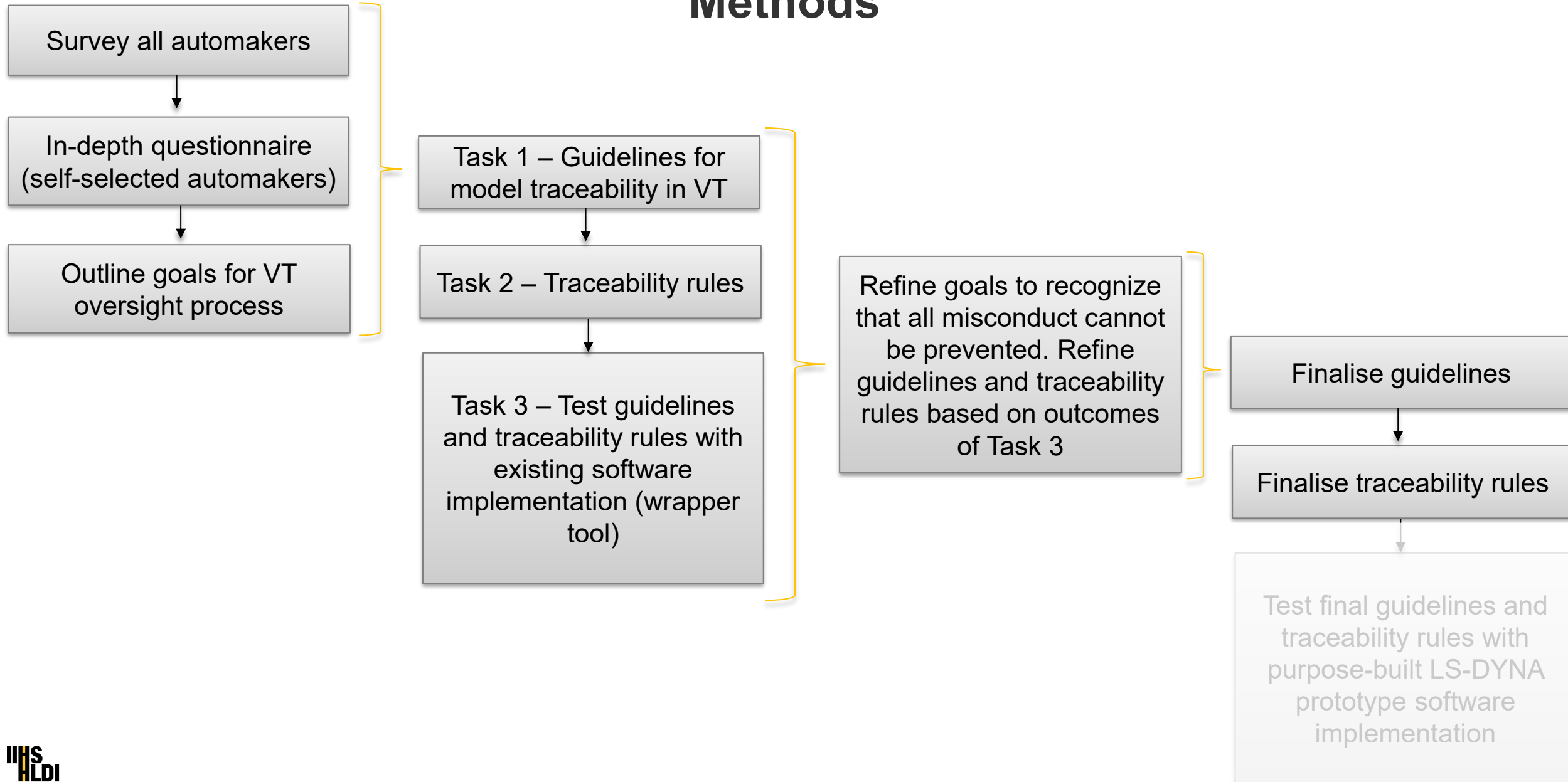
Methods



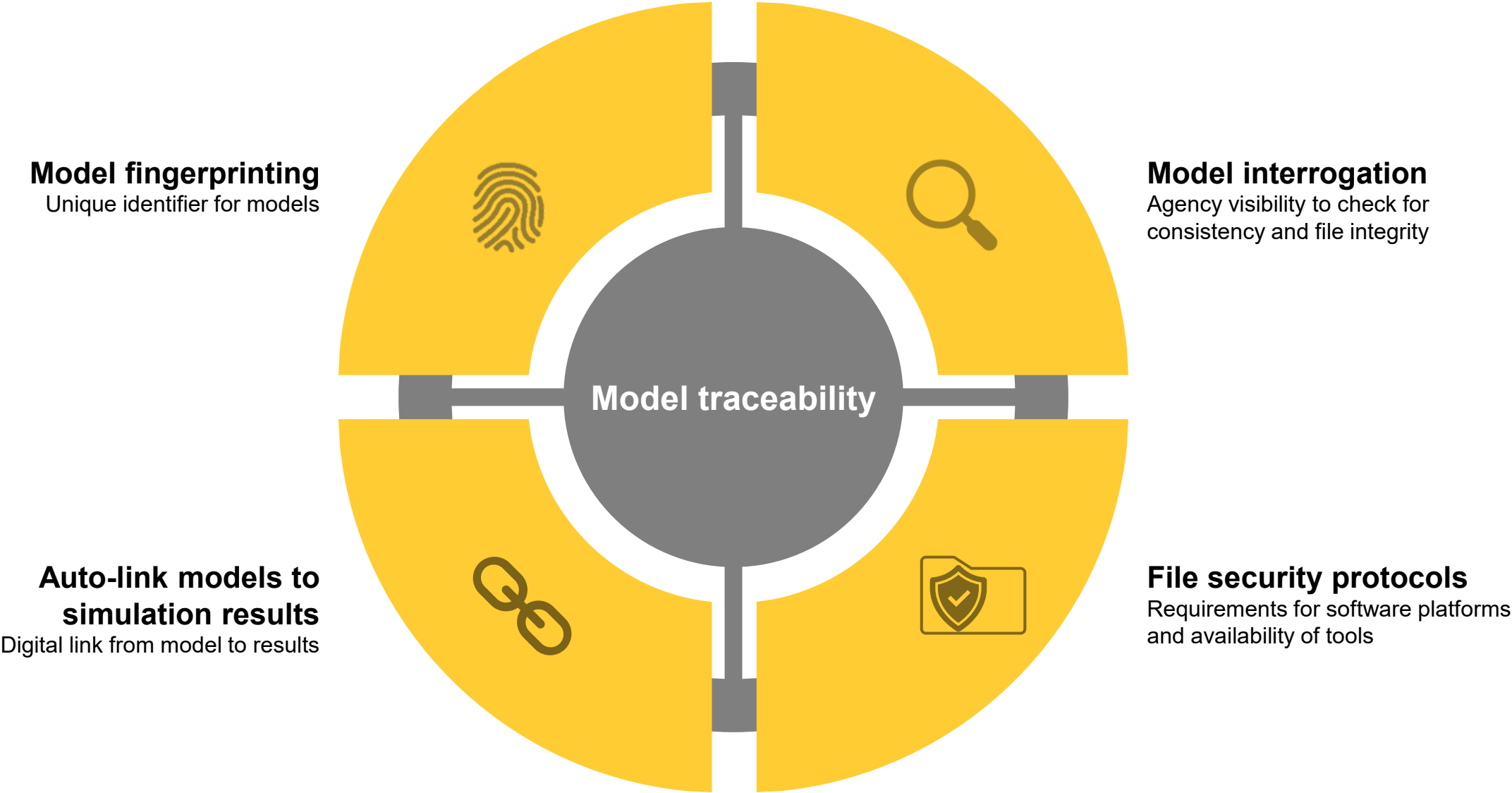
Refining

Instead of aiming to eliminate all potential vulnerabilities in the virtual testing process, which could prove impossible, the oversight process should raise the threshold for vulnerabilities

Methods



Model traceability requirements





Model fingerprinting

- ▶ Fingerprint or unique identifier (e.g., checksum, hash) of inputs and outputs
- ▶ Parsing model into portions that can be *locked* or *open*
 - *Locked* - Must not change between validation/certification and assessment
 - *Open* - Appropriate changes due to differences in validation and assessment are allowed



Auto-link models to simulation results

- ▶ Secure digital link between fingerprints for locked portions of model, open portions of model and results
 - Outputs to a secure summary file
 - Executes without intermediary human interaction
- ▶ Assessment agency access to verify file genealogy
 - Outputs come from reported simulations
 - Locked portion has not changed from validation to assessment



File security protocols

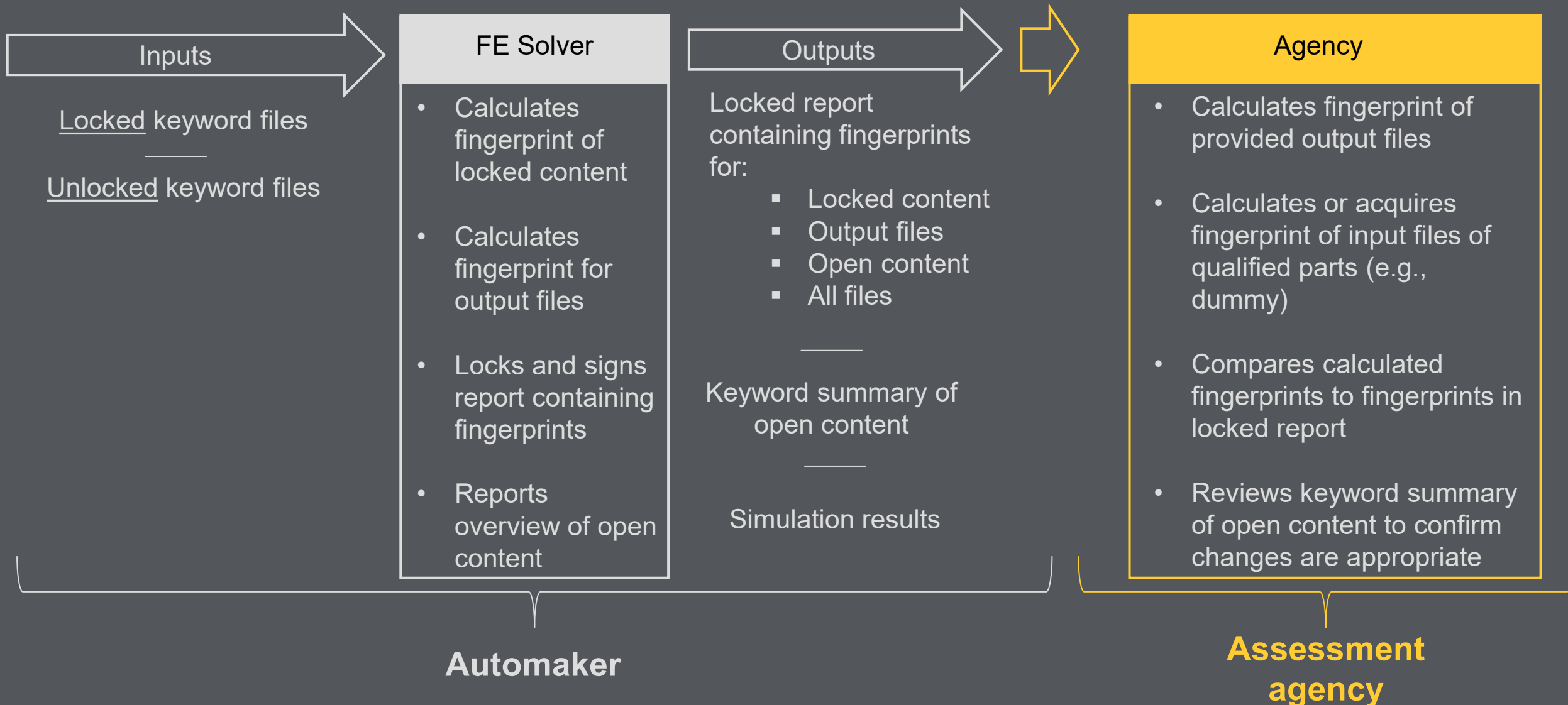
- ▶ Fingerprinting and summary file security protocols accomplished with publicly available tools
- ▶ Requirements should be technology and platform agnostic



Model interrogation

- ▶ Assessment agency access to the validation and assessment simulations for a basic check of test conditions
 - Solver output files, simulation video, energy results, results used for assessment
- ▶ Assessment agency visibility of the model and simulation to examine for consistency and intentionally deceptive actions
 - List of keywords included in the open portions and locked portions

Traceability workflow



Virtual testing framework with traceability

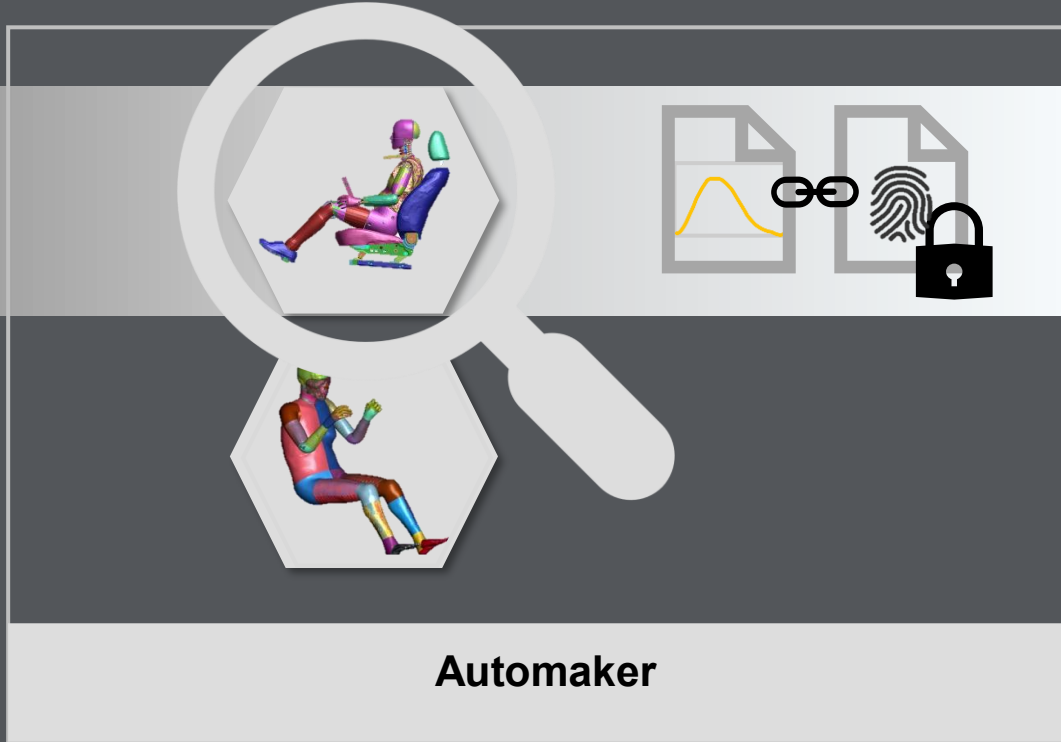
FE Solver



Automaker

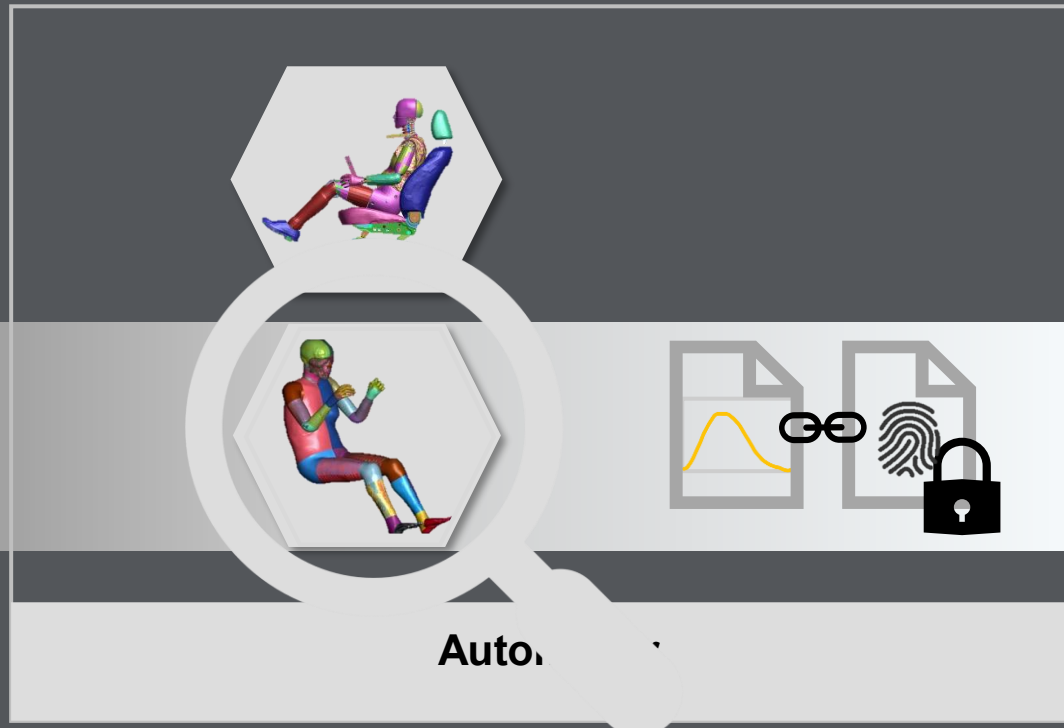
Virtual testing framework with traceability

FE Solver

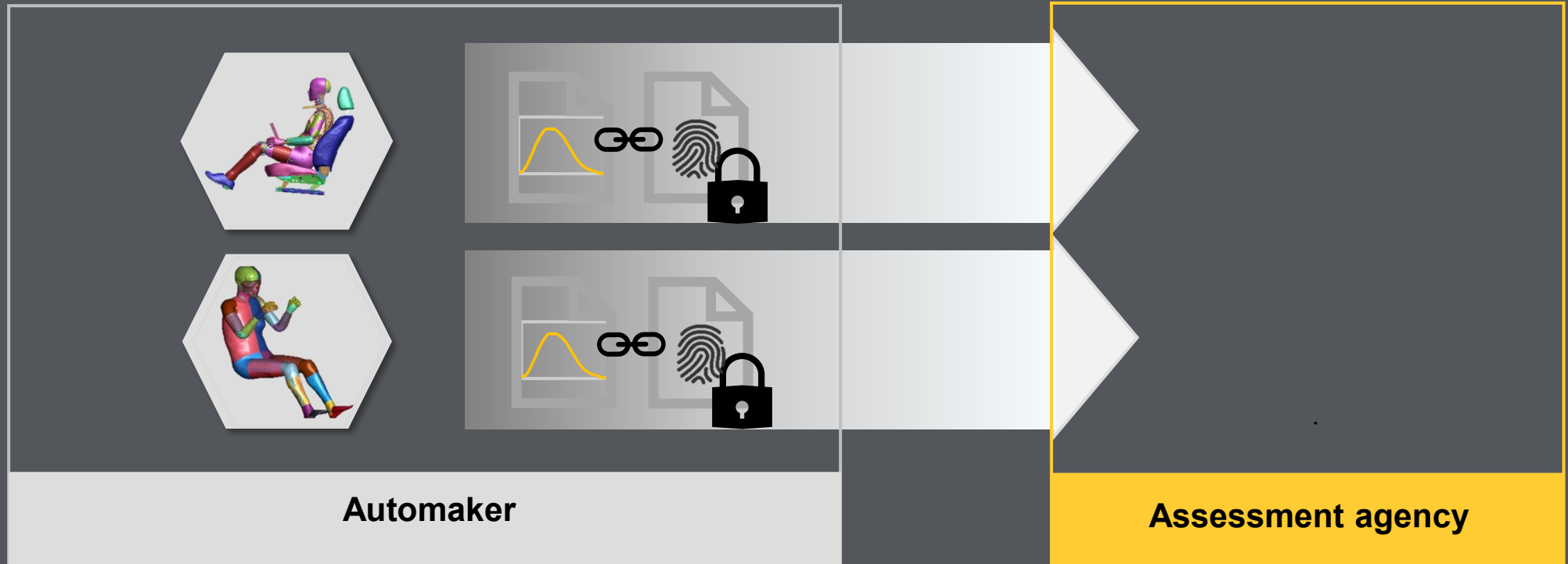


Virtual testing framework with traceability

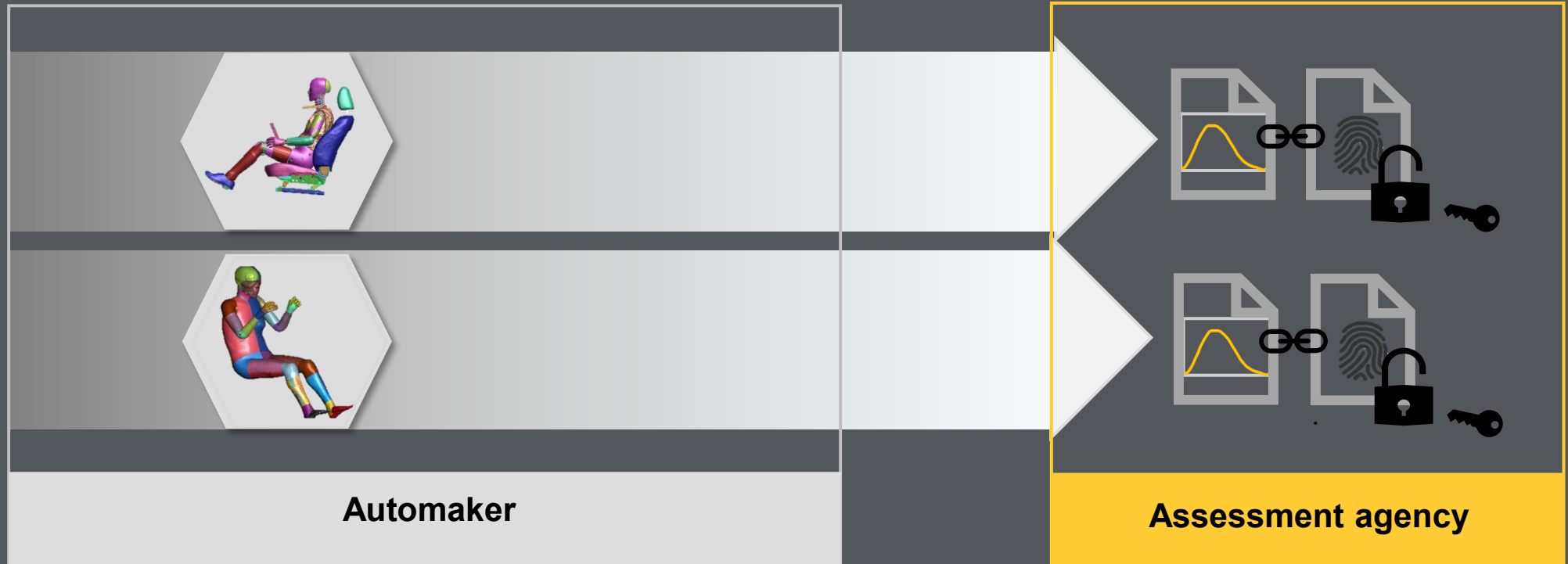
FE Solver



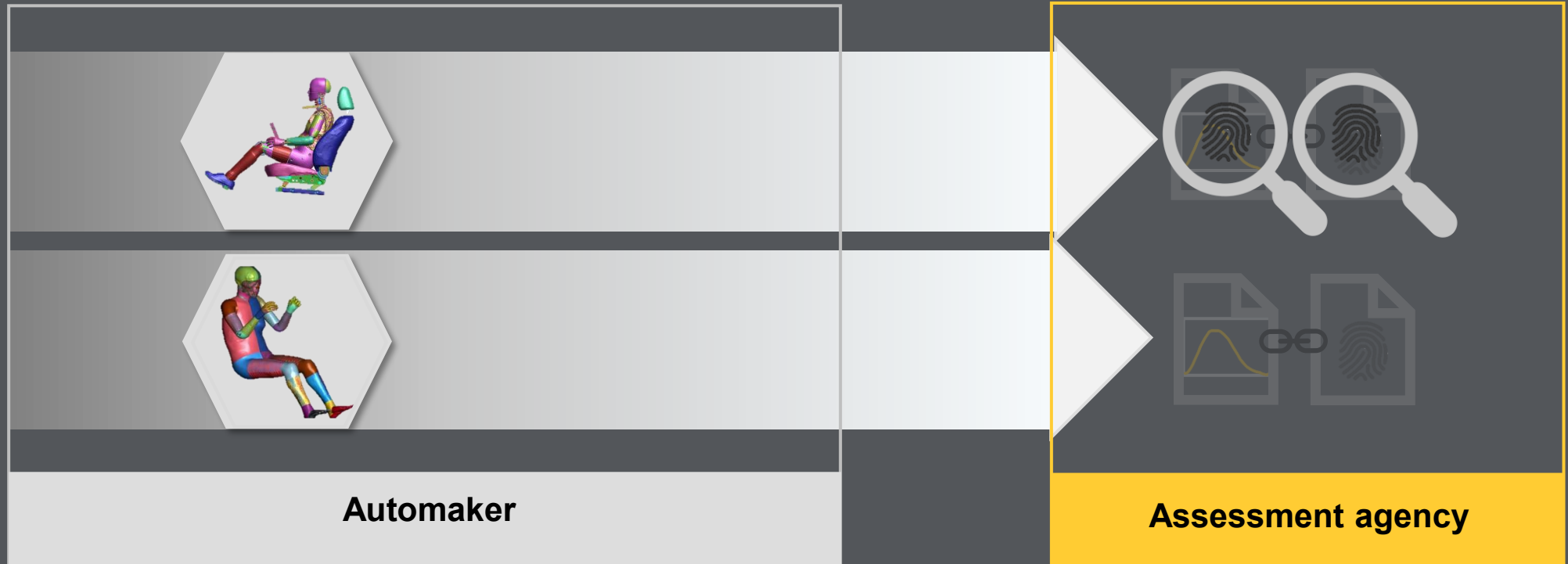
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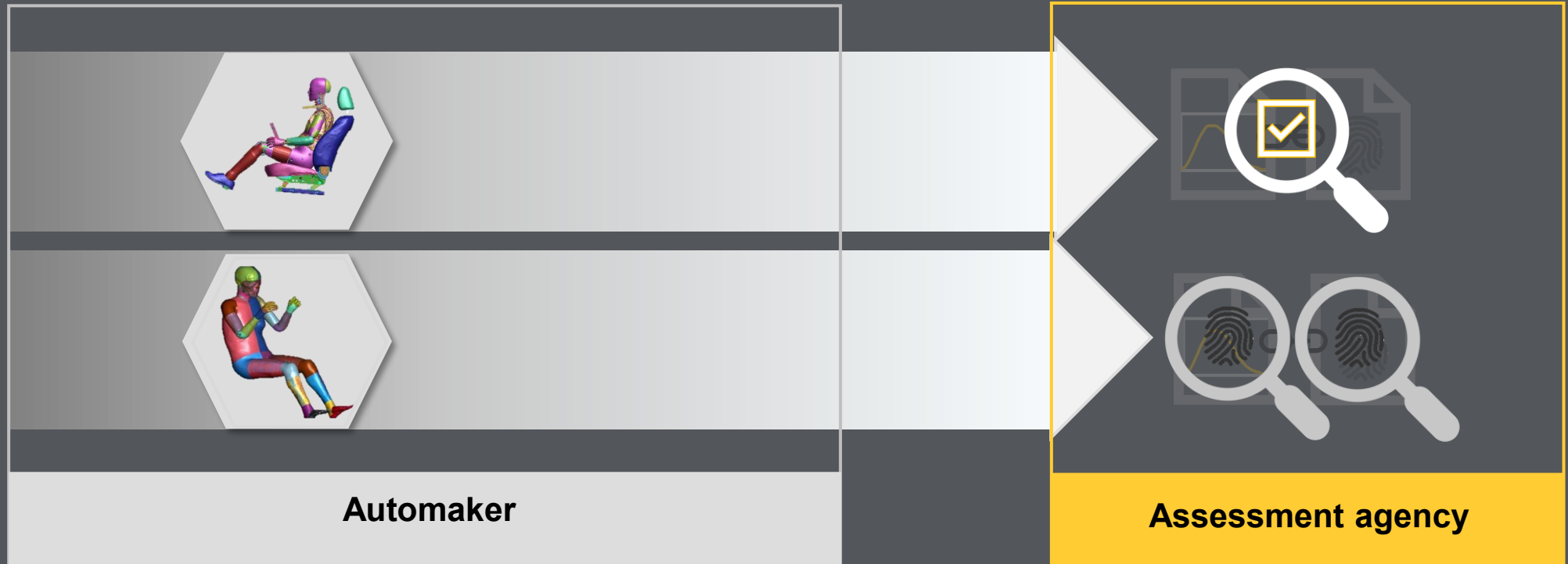
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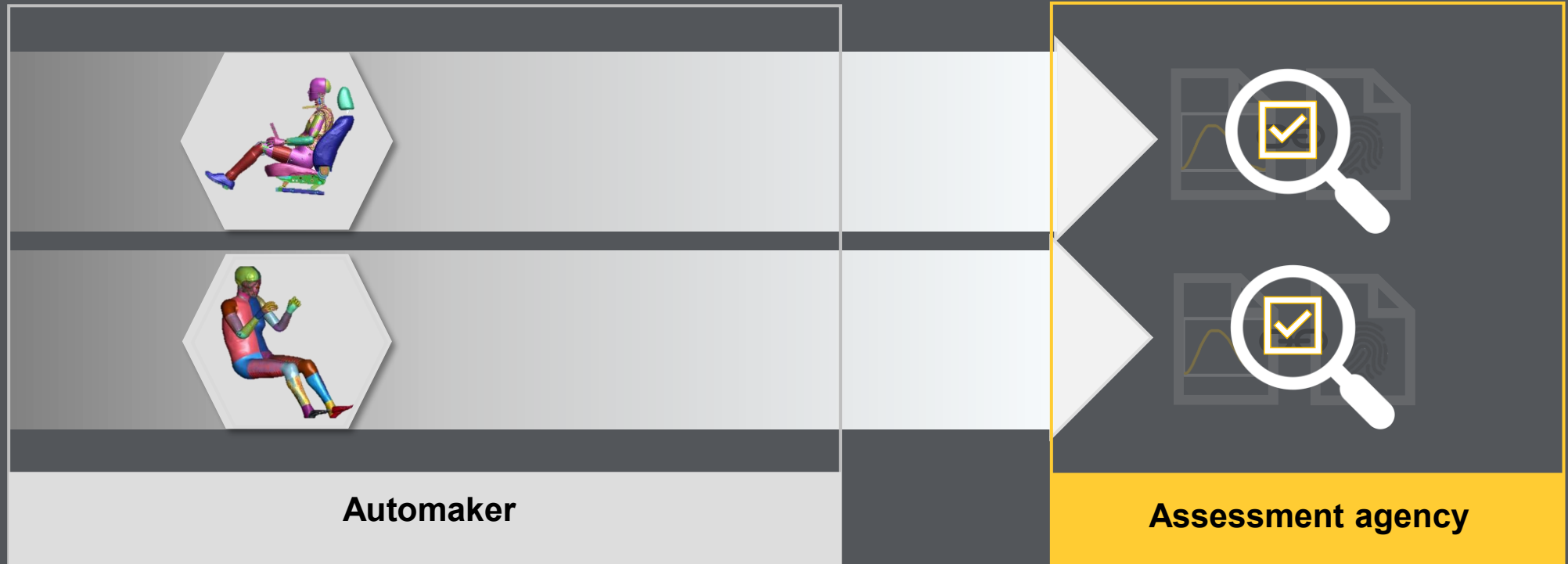
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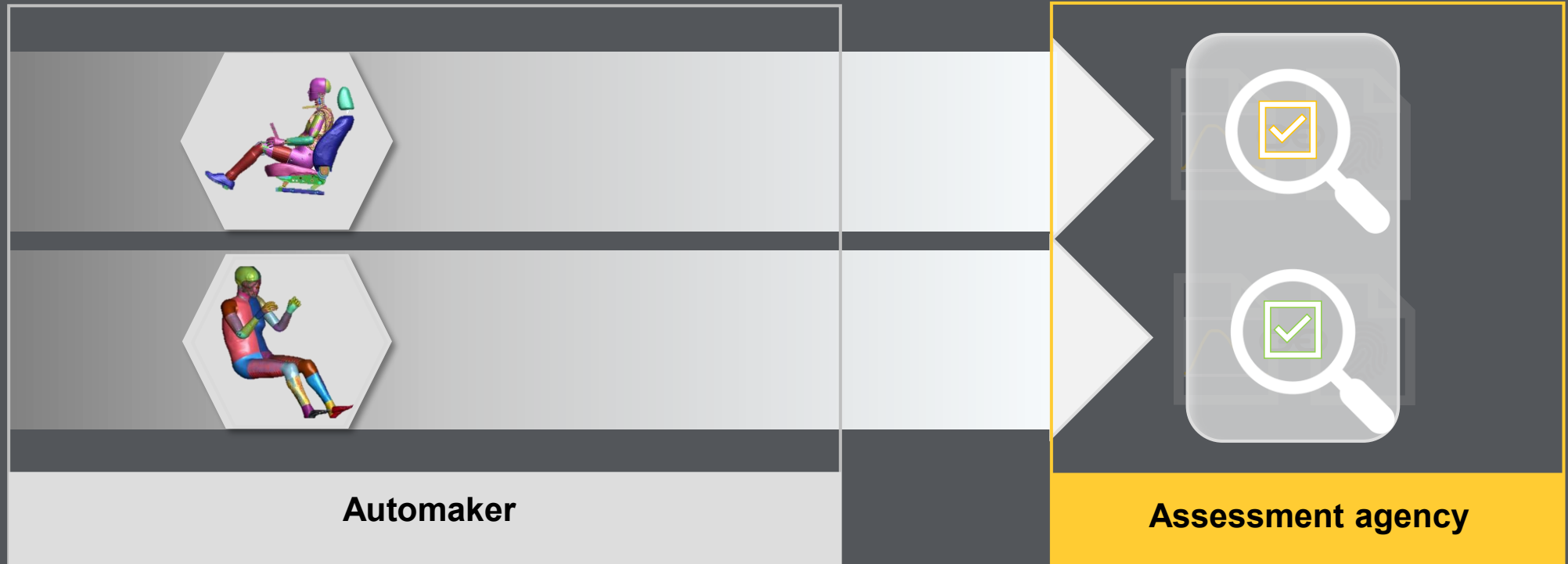
Virtual testing framework with traceability



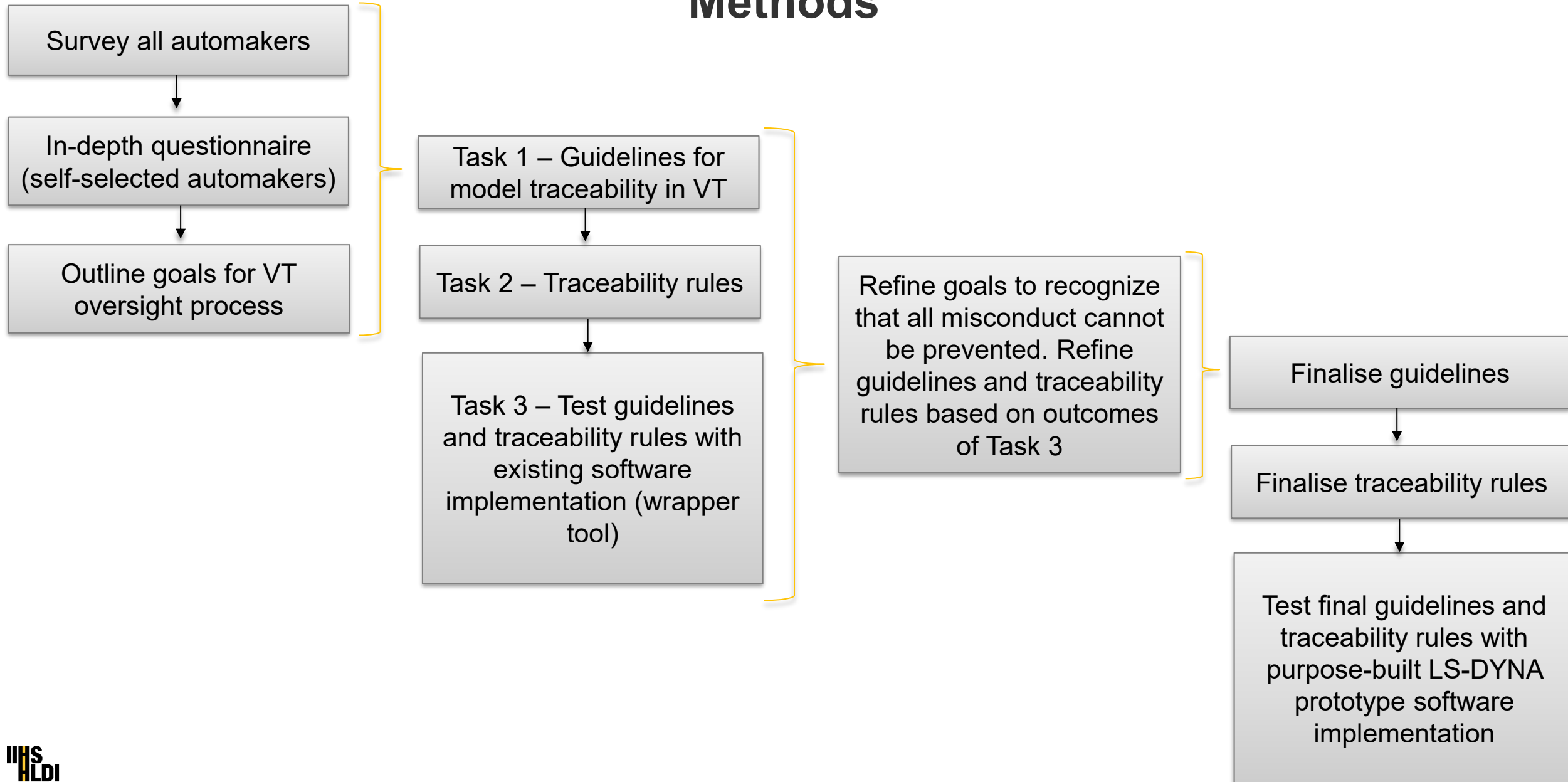
Virtual testing framework with traceability



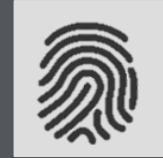
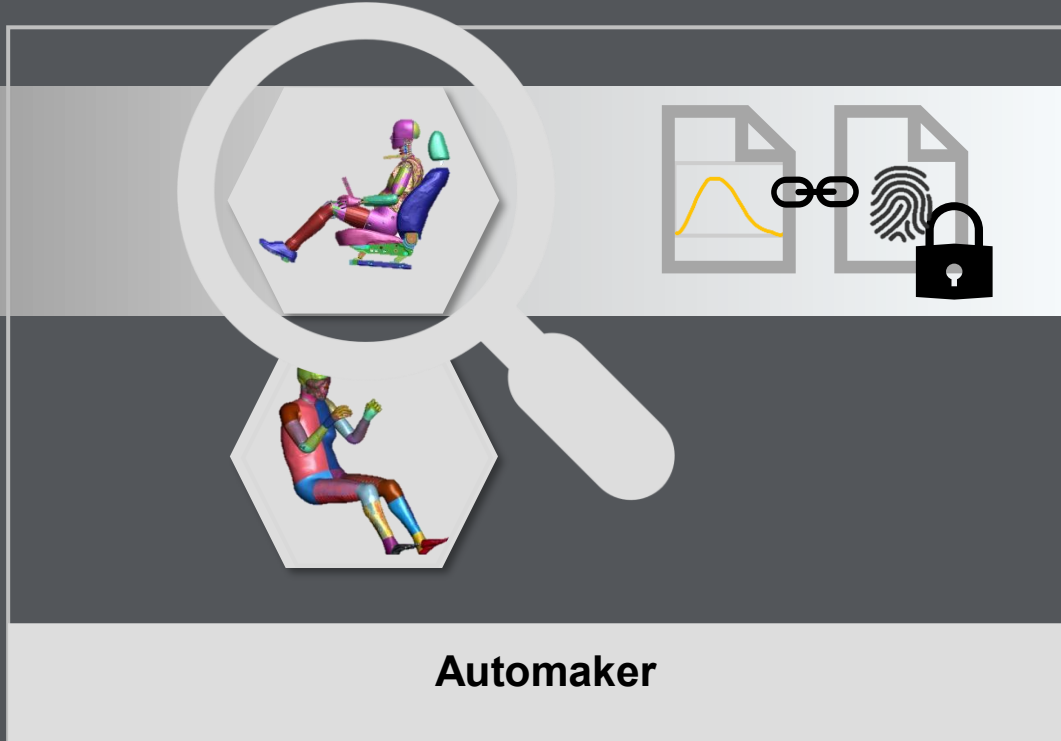
Virtual testing framework with traceability



Methods



LS-DYNA implementation



- LS-DYNA uses new keywords *HASH and *HASH_END to mark the blocks for LS-DYNA to create a hash
- LS-DYNA hashes created with open source sha256 hash algorithm
- Currently, hashes are written at the end of the d3hsp information output file
- LS-DYNA encrypts d3hsp files using asymmetrical public-key cryptography where the sender locks the file with a private key using open source (GPG) encryption and the recipient can open and view, but not edit, the files with a public key

Stress testing LS-DYNA protoype

- ▶ Encrypted and unencrypted FE human surrogates
 - BioRID, WorldSID, THUMS
- ▶ Confirmed
 - Hash individual and combined keywords, full include files and encrypted portions of the model
 - Different hashes are reported with modifications to the inputs (pulse, seat, human surrogate or seat belt)
 - Successful extraction of hashes from d3hsp file and comparison to binary output files
 - GPG signature confirmed to originate from the d3hsp file
- ▶ Limitations
 - Preprocessors are currently not compatible with the hashing feature
 - Cannot customize data in input information summary (currently whole d3hsp is hashed)
 - Cannot report hashes in independent text file (currently at the end of the d3hsp)
 - Hashes change even if only comments change
 - Cannot pare down binary file to only information needed by the assessment agency

Conclusions

- ▶ A procedure for model traceability in virtual testing was developed where simulation are run by automakers and uses the FE solver to:
 - Confirm information reported to the assessment agency comes from the inputs and outputs run by the solver
 - Confirms no inappropriate changes have been made between validation and assessment load cases
 - Accommodates necessary changes between load cases
 - Protects intellectual property
- ▶ Procedure helps increase trust in simulation for assessment agencies to encourage more robust safety solutions by broadening the scope of assessments

Future work

- ▶ Work with other solvers to develop traceability functionality
- ▶ Continue work to identify the information needed in addition to fingerprints to confirm that only appropriate changes have been made
- ▶ Work to develop tools that aid in sharing only the necessary information

Acknowledgements

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Highway Loss Data Institute

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THANK YOU



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