Fraunhofer and Sidact Software

- FEMZIP – Compression of simulation results
- SDMZIP – Compression of sets of simulation results
- DIFFCRASH – Robust Design: Identification of areas in geometry causing scatter of simulation results

FEMZIP

SDMZIP

DIFFCRASH

CHALLENGE

- In order to improve engineering design …
  - more simulations are performed
  - larger, more detailied Models are used

» Large amounts of data are generated!
(several PetaByte per year)
The data has to be …
  - analyzed
  - exchanged
  - archived

» Network connections and storage space can become bottlenecks!

SOLUTION

Data Compression

- Two fundamentally different compression approaches:

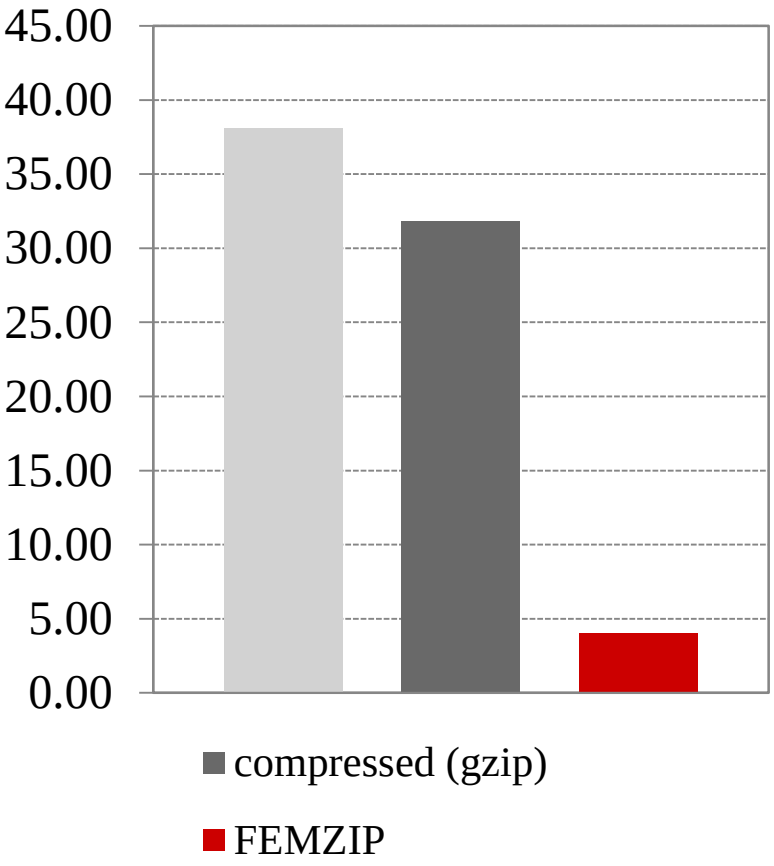
- **Lossless Data Compression**
  The original data can be restored identically from the compressed data

- **Lossy Data Compression**
  The original data **cannot** be restored identically from the compressed data

» With lossy data compression schemes a much stronger reduction can be achieved!

Data Compression

- Floating-point data **cannot** be efficiently compressed losslessly:

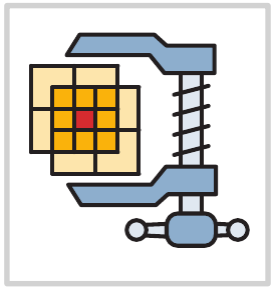


» A compression factor of only 1.2 is obtained

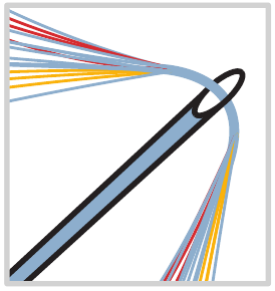
» The solution is **FEMZIP**

Airflow simulation around a car:
6 variables, 43 million elements,
21 time steps

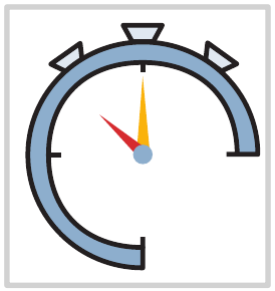
Advantages



Reduced Archive Size
Storage and backup capacities can hold more simulation results



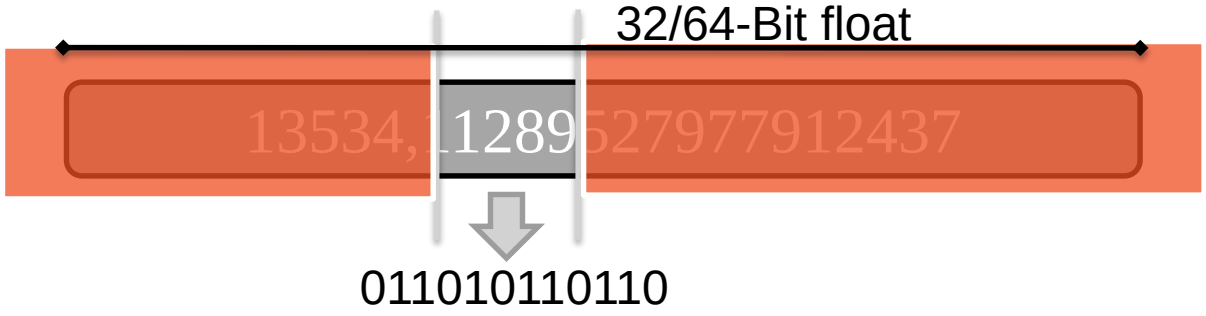
Shorter Data Transfer Times
Simulation results can be transfered significantly faster



Quicker Data Loading
Compressed data can be loaded quicker into post processors

Lossy Data Compression

- **Quantization**
  Floating point data is rounded to a given precision and mapped into the integer domain.
- **Prediction**
  A bijective transformation is performed to prepare those integers for encoding purposes (reduce entropy).
- **Encoding**
  Afterwards an entropy encoding method is used which removes redundant bits.



» **FEM***ZIP* achieves compression factors of about 10!

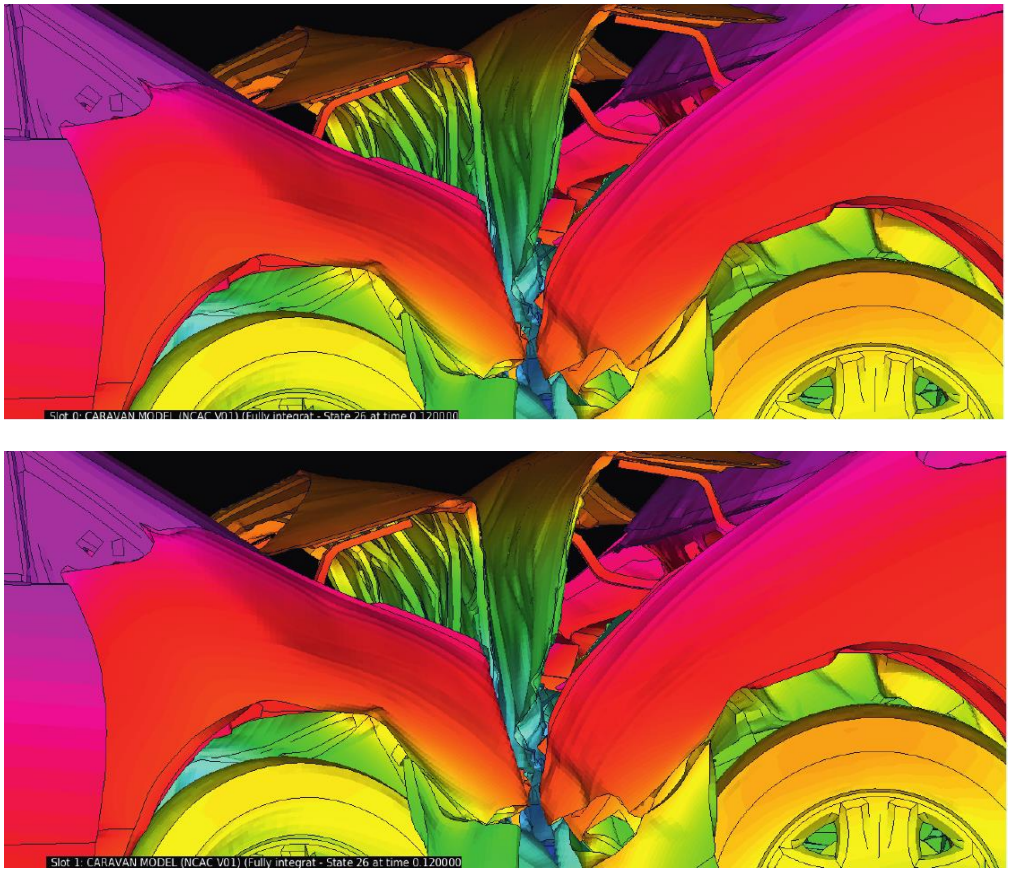
Parameter File

```
FEMZIP Standard Configuration File   (mm, s, Tons, N)

  Number of extra values per shell:              5
  Number of extra values per solid:              6
  Number of extra values per thick shell:        5

   Node values: precision
         coordinates                    :        0.10000000
         velocities                     :        10.0000000
         accelerations                  :        10000000.0
   Shell values: precision
         sigma                          :        1.00000000
         epsilon                        :        0.00100000
         bending_moment                 :        1000.00000
         shear_resultant                :        10.0000000
         normal_resultant               :        10.0000000
         thickness                      :        0.00100000
         internal_energy                :        1.00000000
   Thick shell values: precision
         sigma                          :        1.00000000
   Solid values: precision
         sigma                          :        1.00000000
   1D-element values: precision
          axial_force                   :        10.0000000
         s_shear_resultant              :        10.0000000
         t_shear_resultant              :        10.0000000
         s_bending_moment               :        1000.00000
         t_bending_moment               :        1000.00000
        torsional_resultant              :       1000.00000
```

Lossy Data Compression

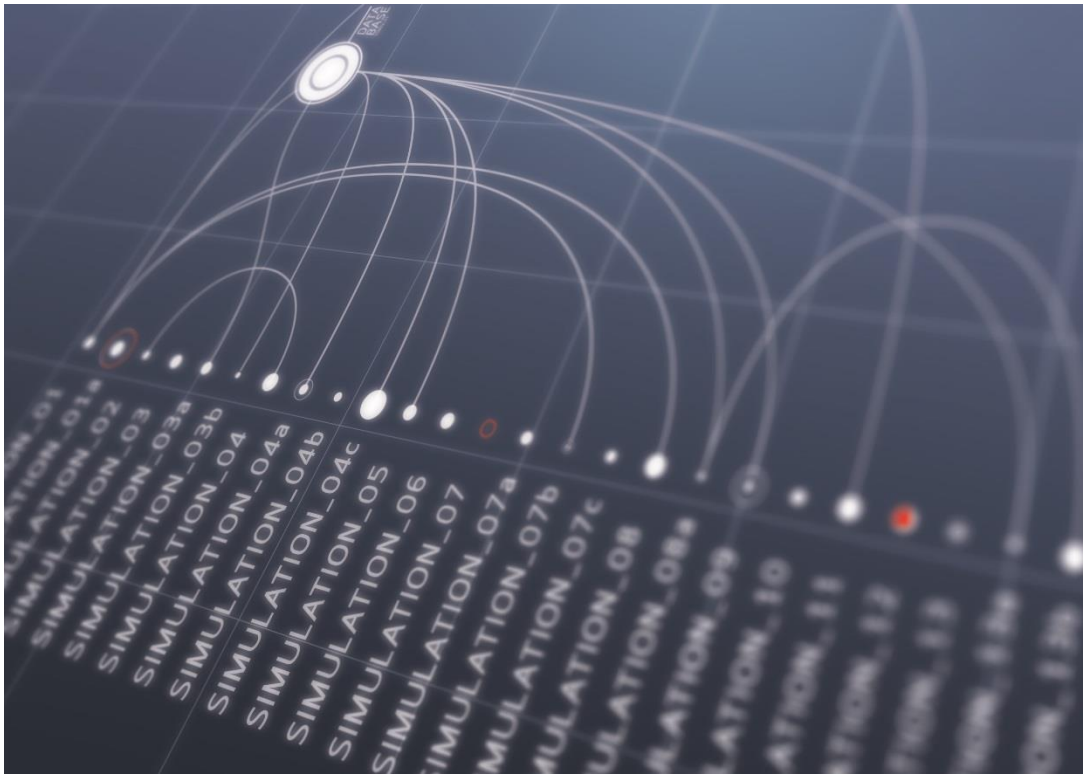


- The visual appearance of the original and the compressed results is shown. While a compression factor of 8.8 was achieved no difference is noticeable.

Source: topcrunch.org

SDMZIP:

Compressing sets of simulation results

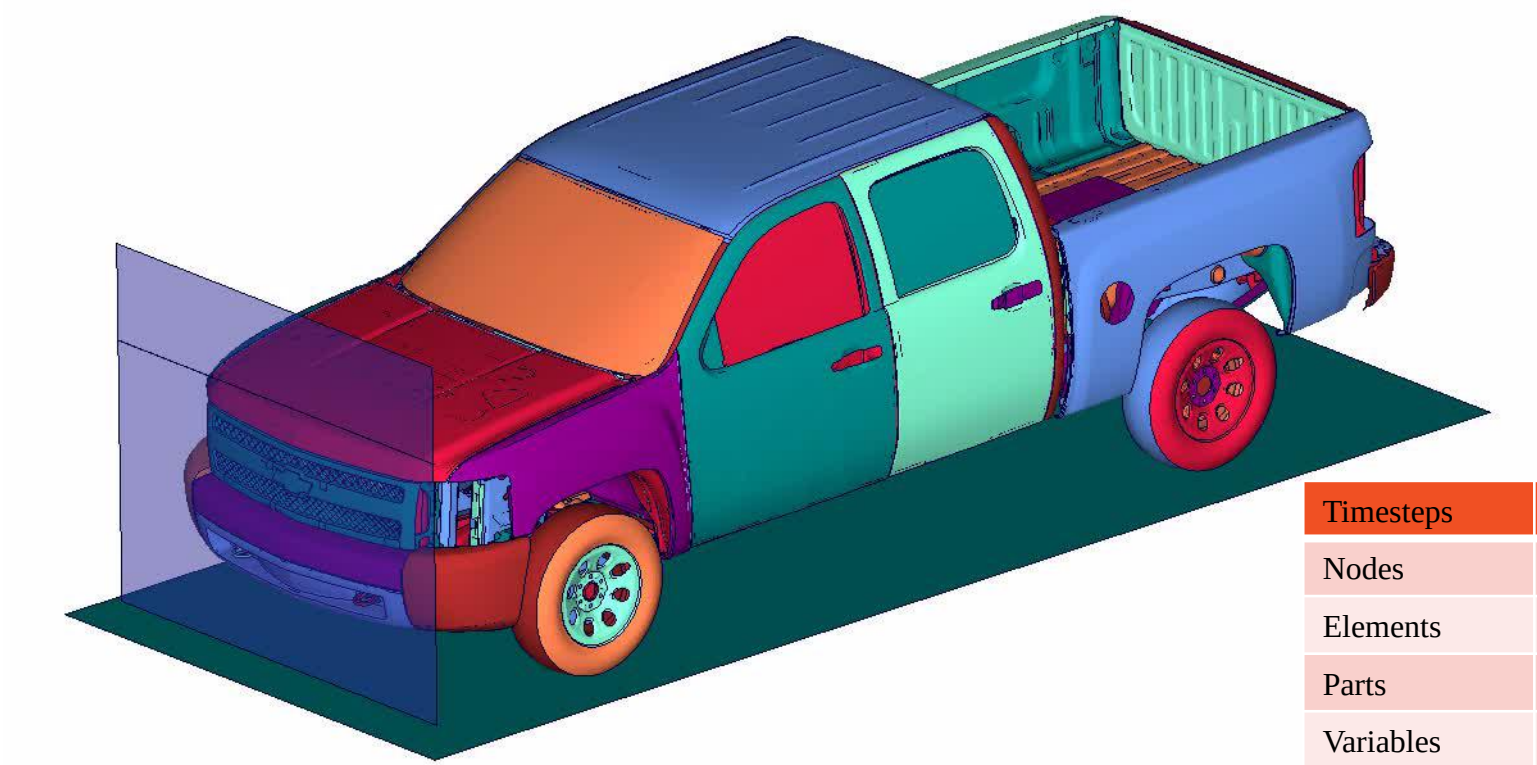


Compression of simulation results

Standard solution for industry applications

- Lossy compression of a single simulation result
- Versions for several data formats
- Continuing improvement
- Integrated decompression in several postprocessors
- Compression rates of 15 to 30

Example: Chevrolet Silverado simulated using LS-DYNA



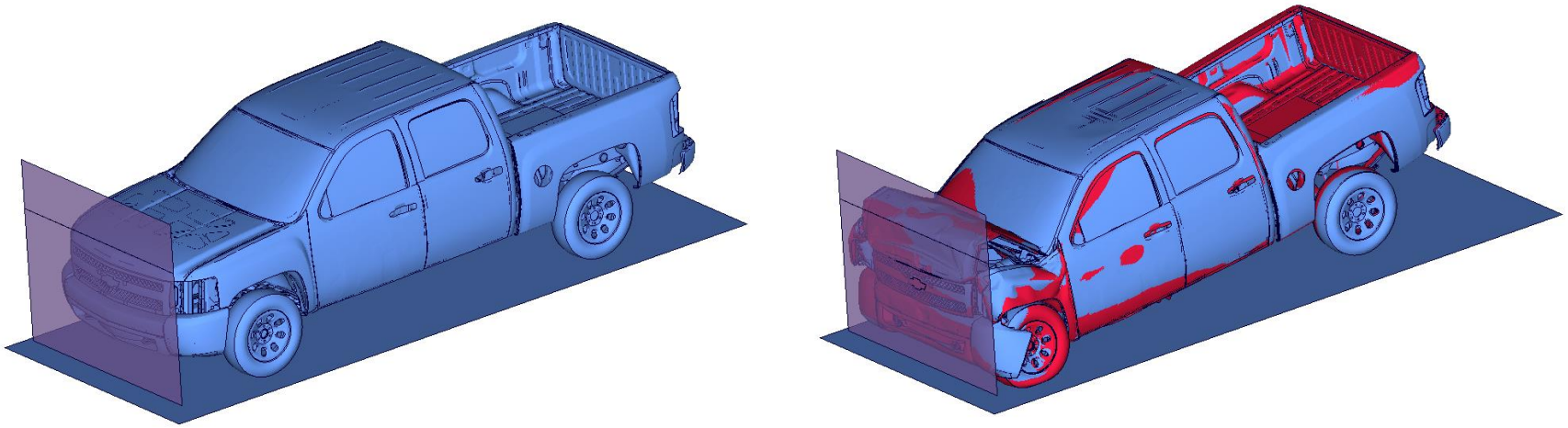
Timesteps	38/152
Nodes	942,749
Elements	929,181
Parts	679
Variables	14

Compression results

Single simulation
- Original size: 1,525.1 MB
- FEMZIP size: 55.9 MB
- Compression rate: 27.28

Additional simulation
- Original size : 1,525.1 MB
- FEMZIP size : 56.25 MB
- Combined compression rate: 27.19

Comparison: Two simulations, first and last timestep



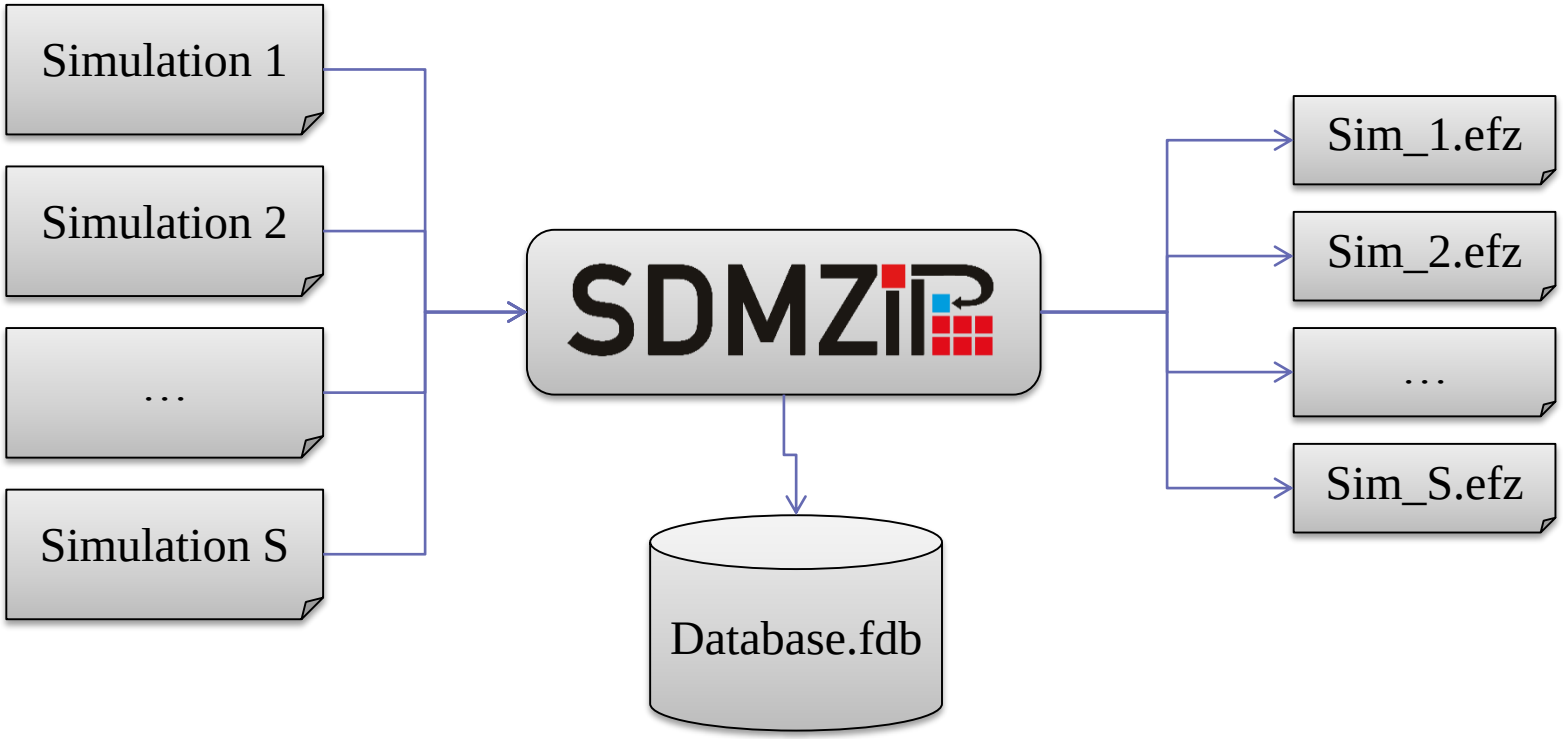
- Are the simulations disparate?
- Can the commonalities be exploited?

Recently developed:

New software for compression of sets of simulation results

- Lossy compression
- Information is processed part-based
- Modular storage concept
- Commonalities of similar simulations is aggregated

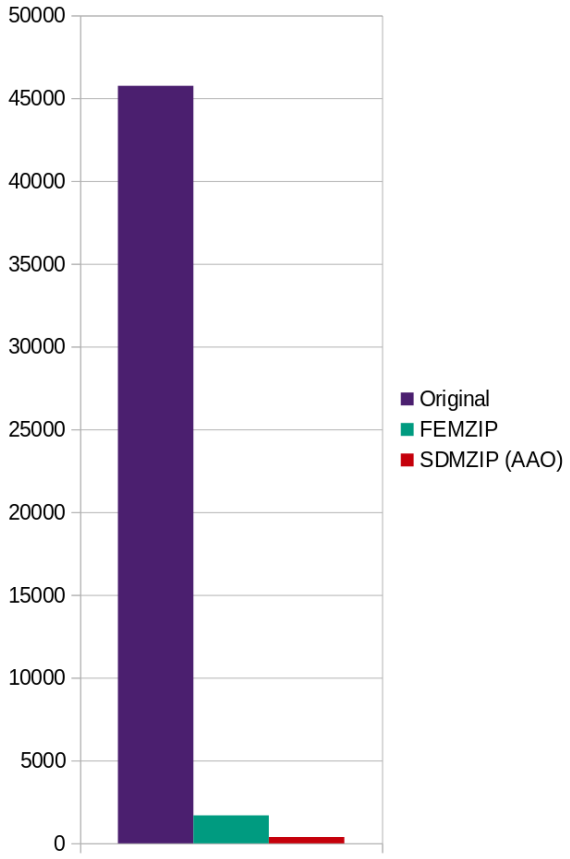
Compressing sets of simulation results



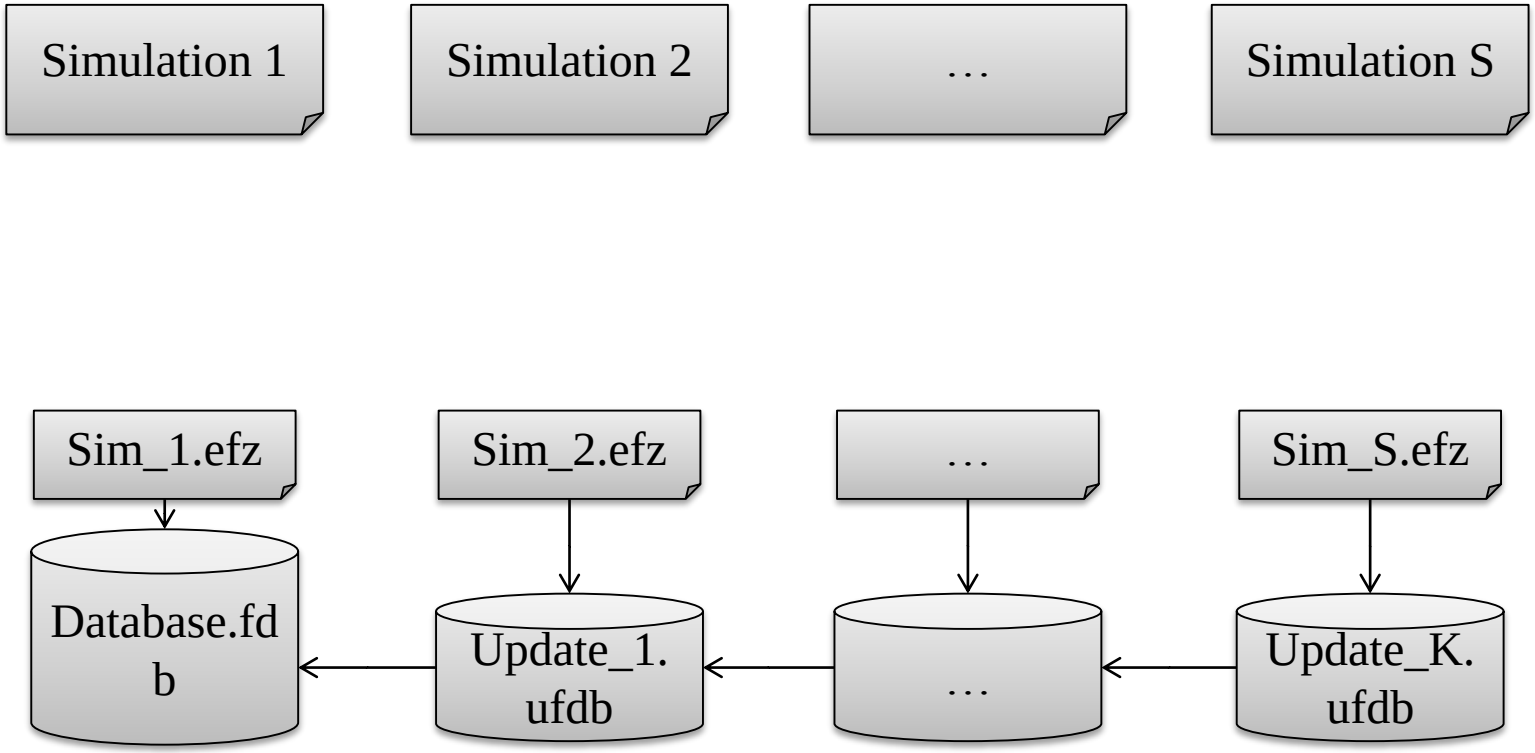
Compression results

30 Simulations, with 38 timesteps:

- Original size: 45,752.58 MB
- FEMZIP size : 1,684.54 MB
- SDMZIP size : 379.23 MB
  - Database : 110.17 MB
  - *.efz ca. : 8.98 MB

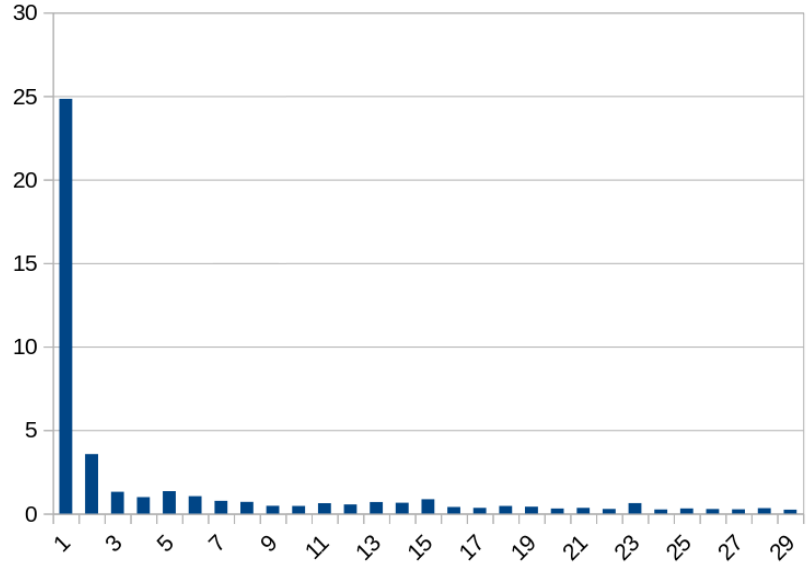


Incremental compression



Database development for 30 simulations

Size of databases in MB for incremental compression.

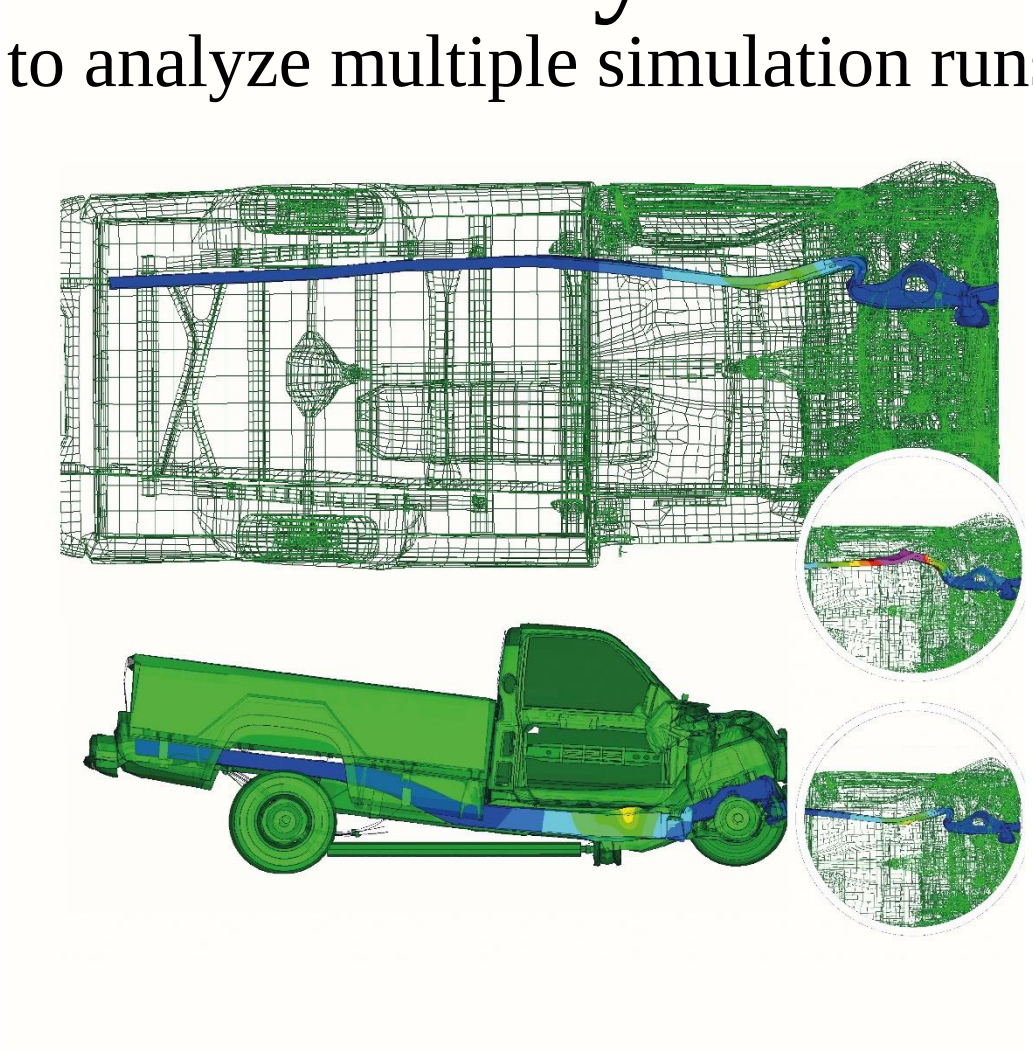


Size of *.efz ca. : 19.01 MB

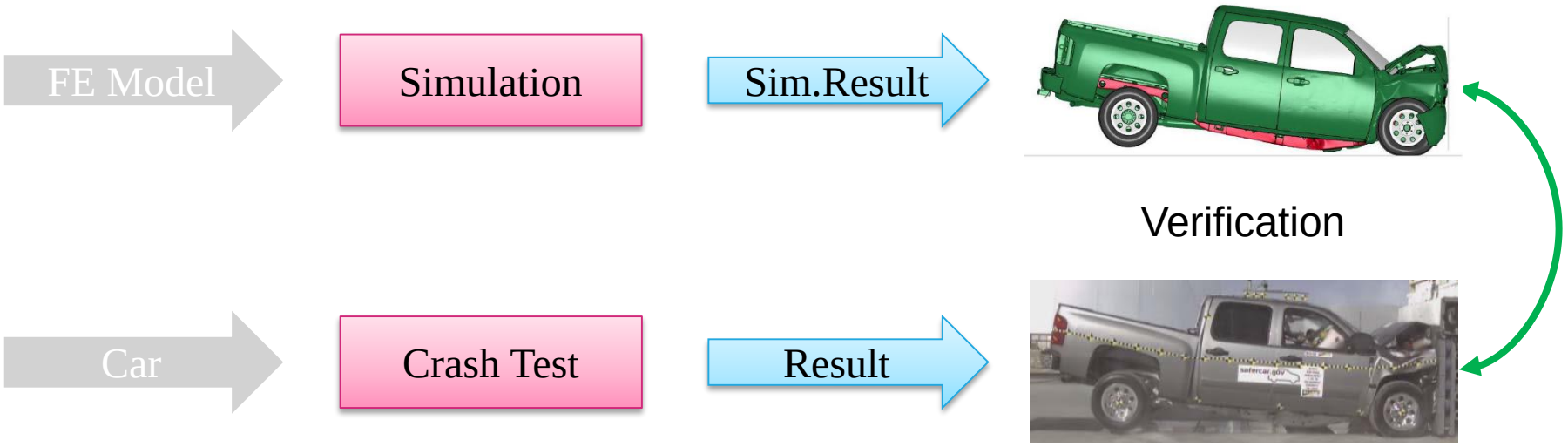
Results vary depending on:

- Similarity of simulations
- Time resolution

Robustness analysis –
process to analyze multiple simulation runs

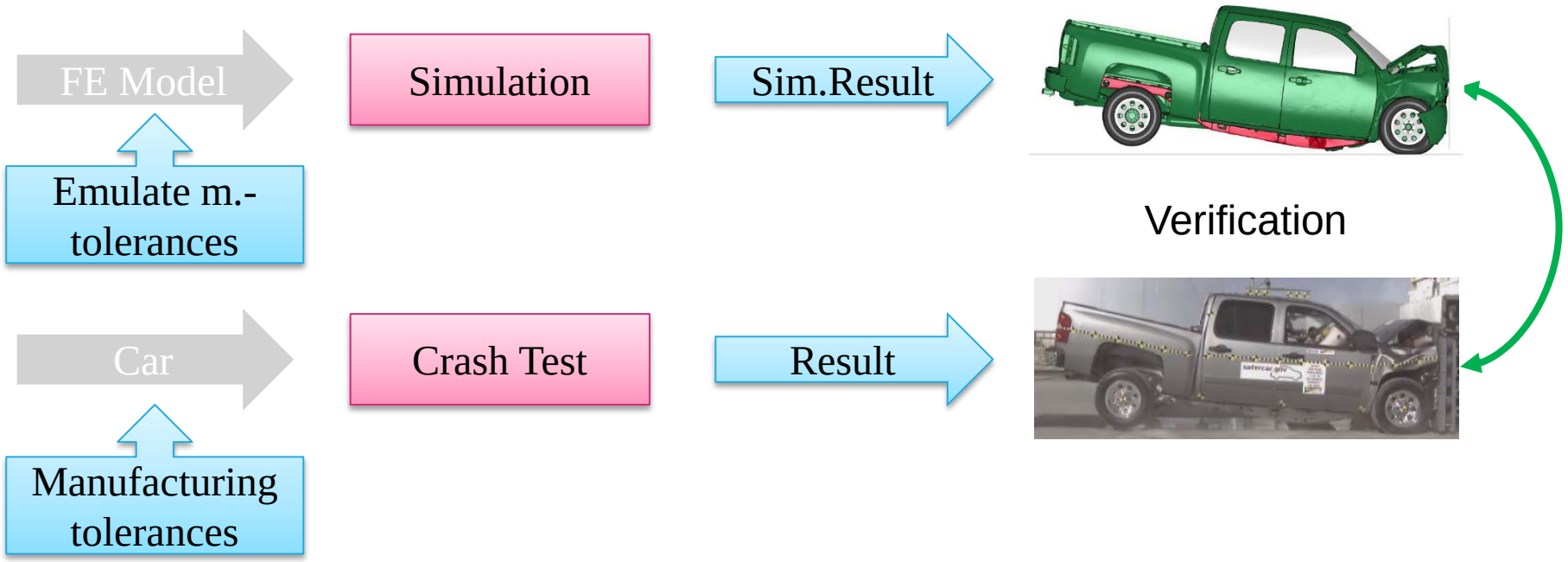


Process



"The model has been developed by The National Crash Analysis Center (NCAC) of The George Washington University under a contract with the FHWA and NHTSA of the US DOT“
http://www.ncac.gwu.edu/vml/models.html

Process



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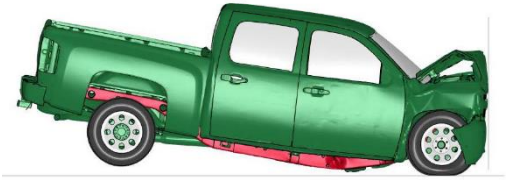
Process

FE Model

Emulate m.-tolerances

Simulation

Sim.Result



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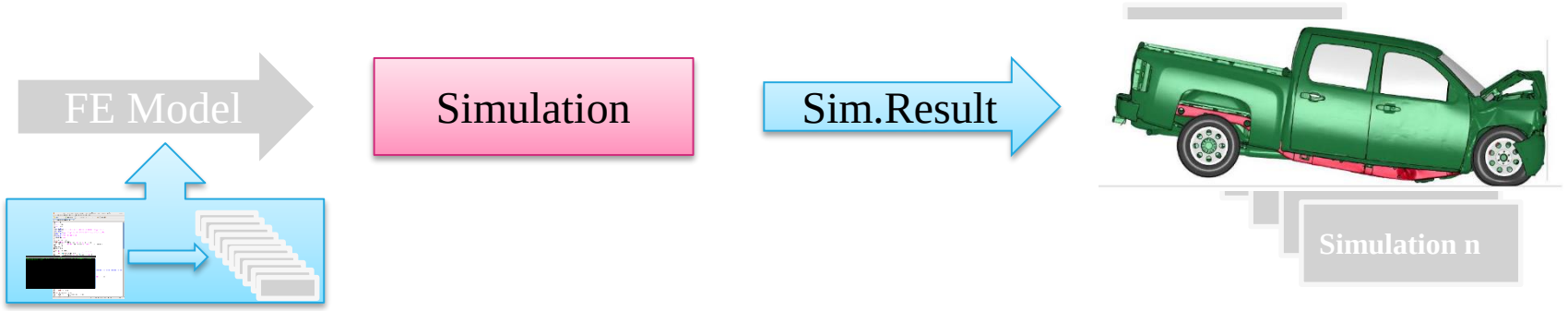
Process



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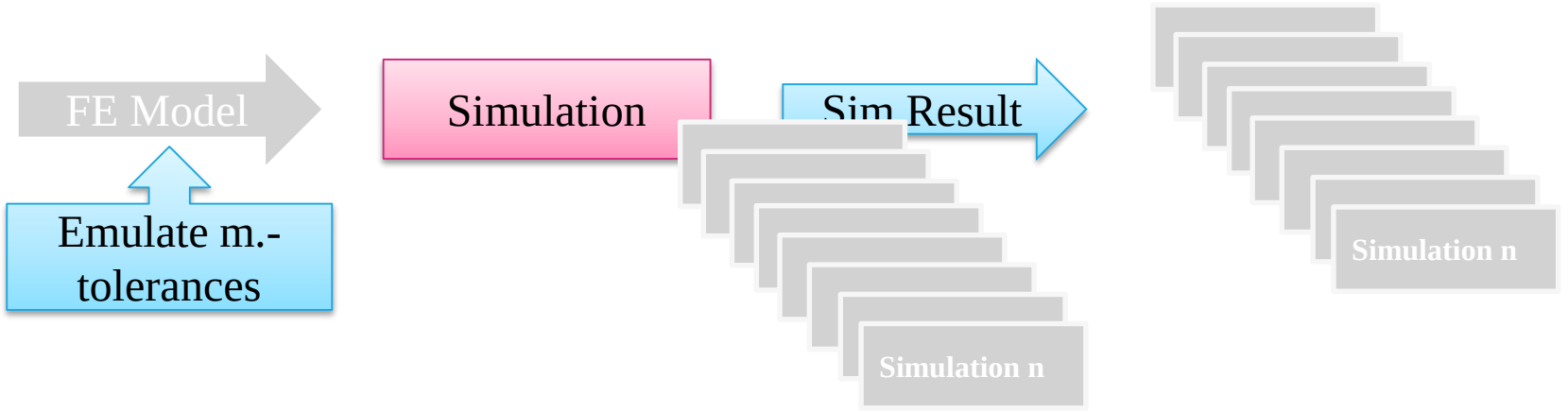
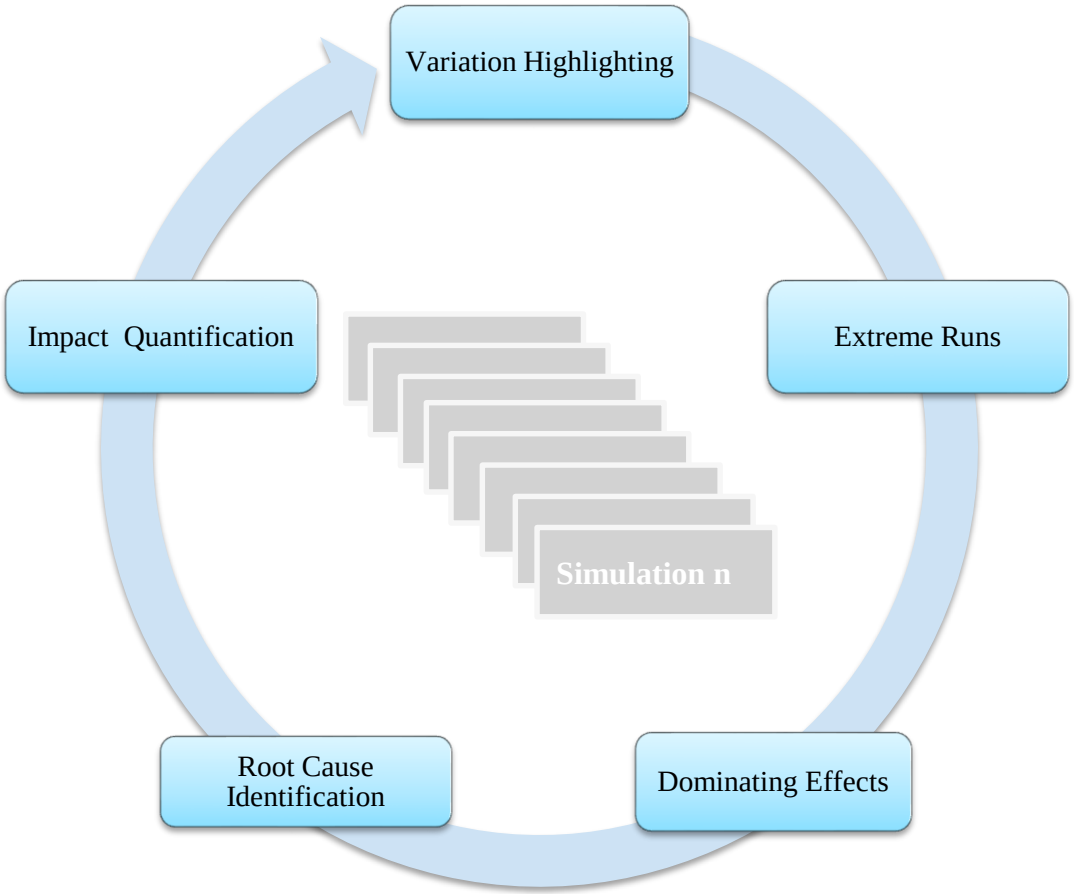
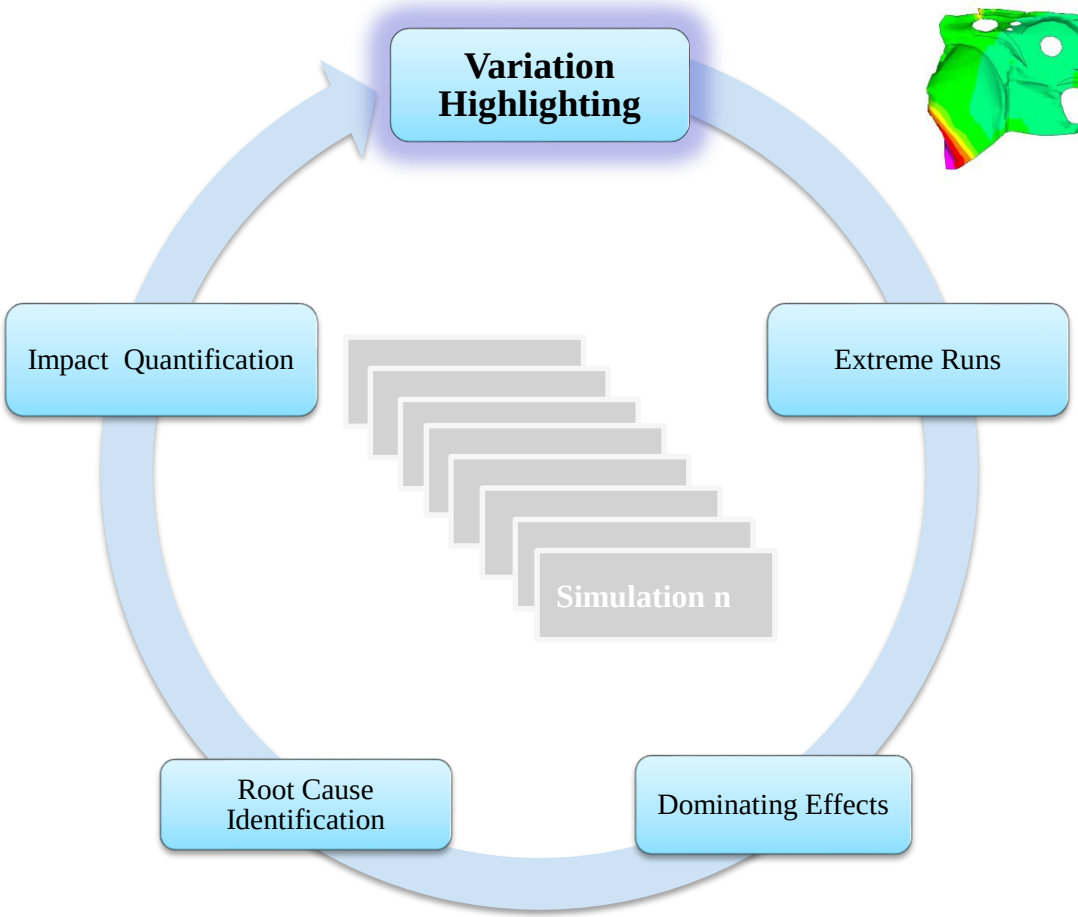

FE Model
Emulate m.-tolerances
Simulation
Sim Result
Simulation n
Simulation n

Methods


Variation Highlighting
Extreme Runs
Dominating Effects
Root Cause Identification
Impact Quantification
Simulation n

Methods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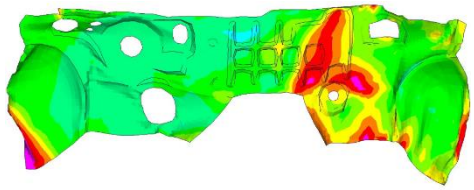
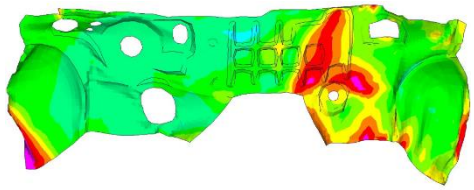
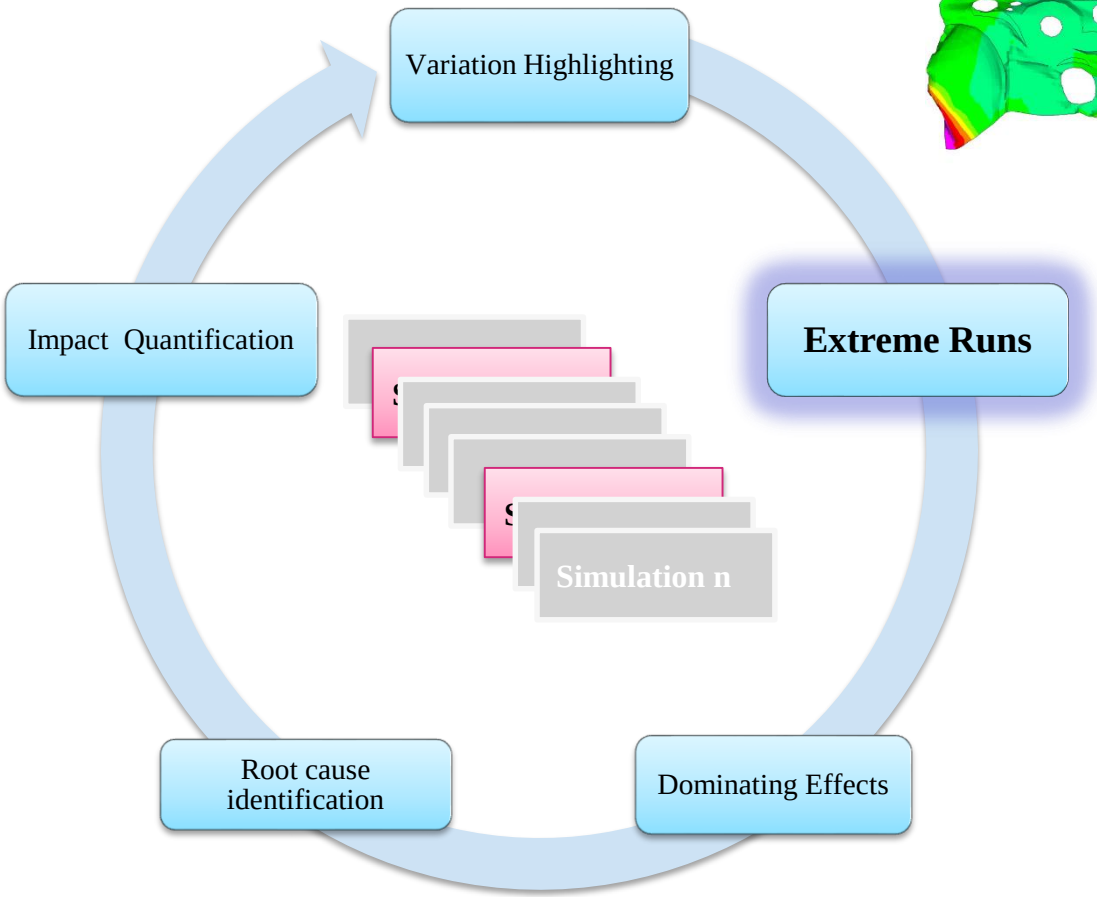


Methods

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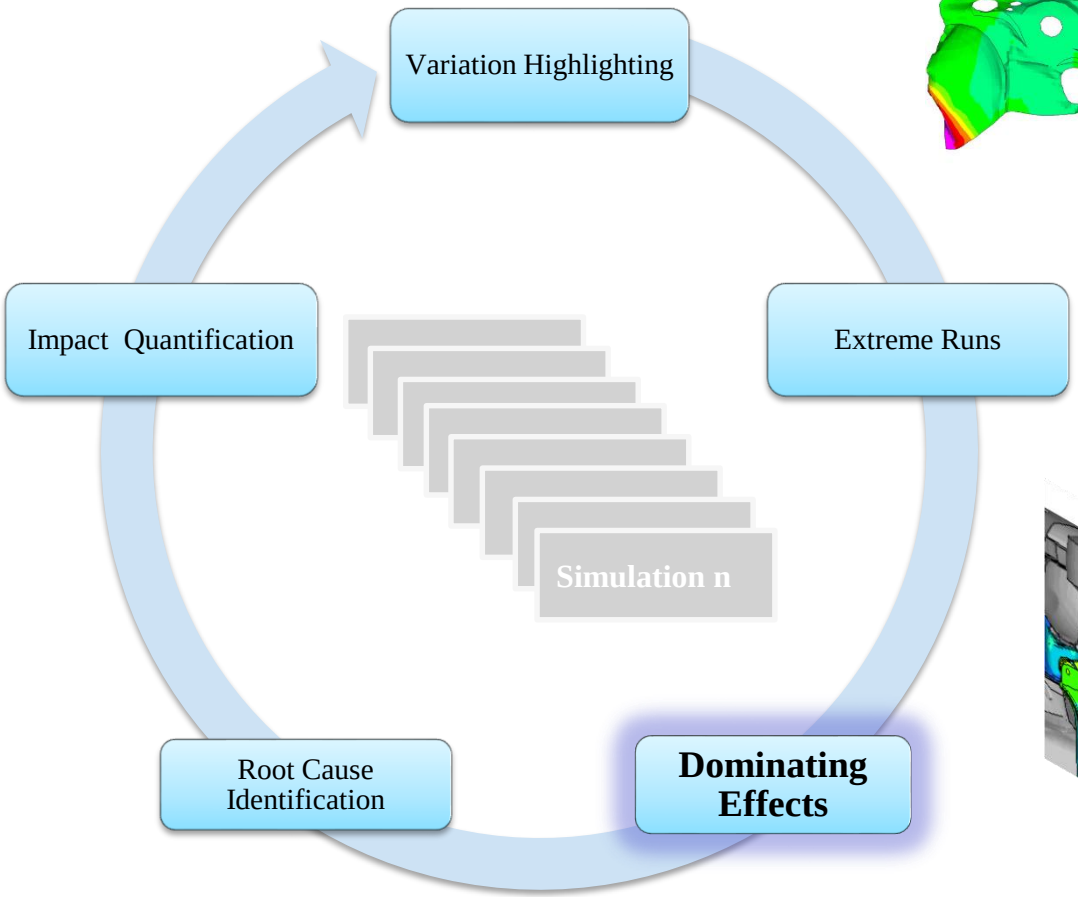
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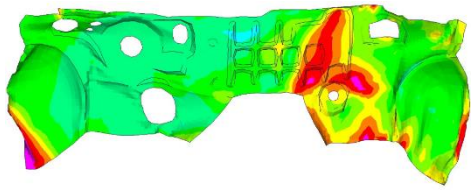

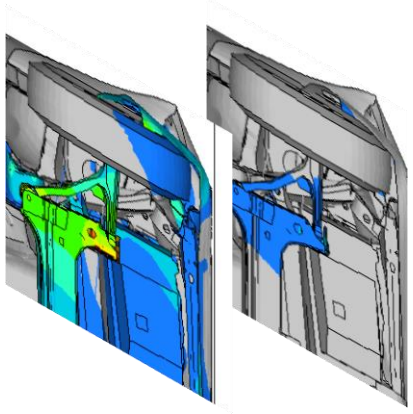

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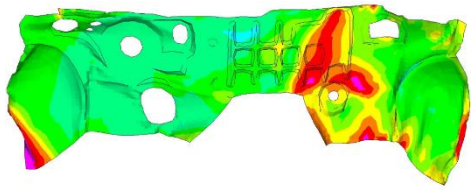

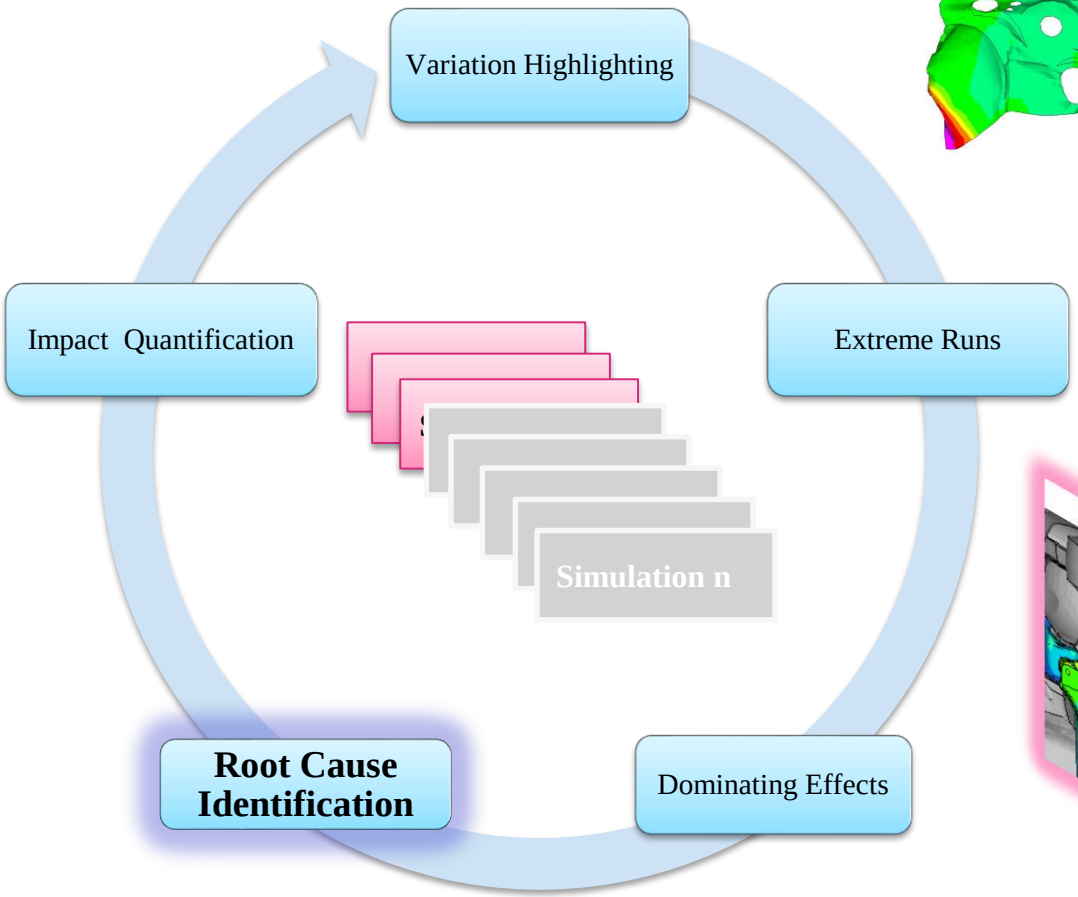
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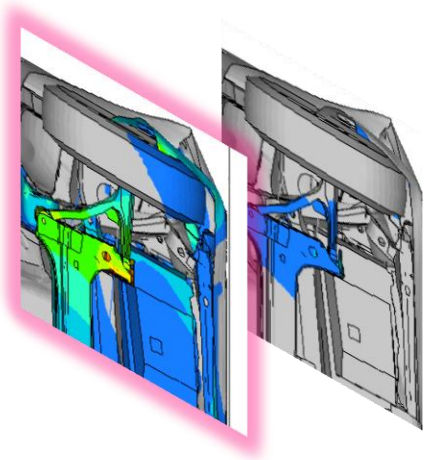
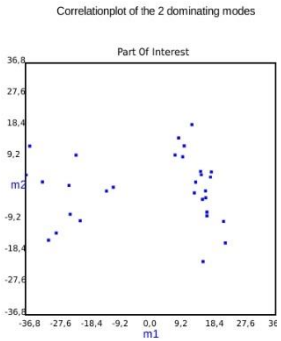
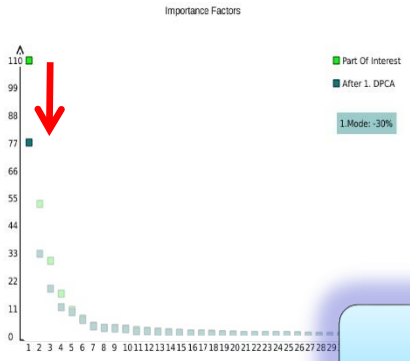
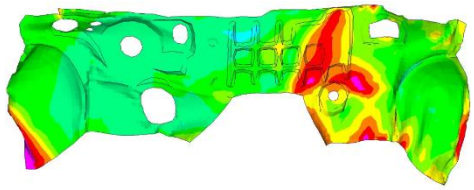



Correlationplot of the 2 dominating modes
Part Of Interest
m1
m2

Methods





Variation Highlighting

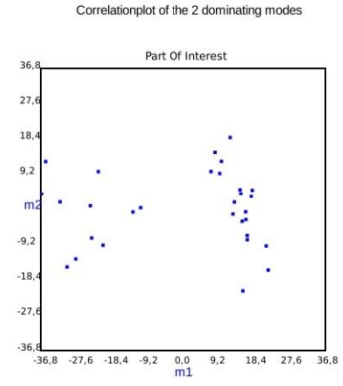
Extreme Runs

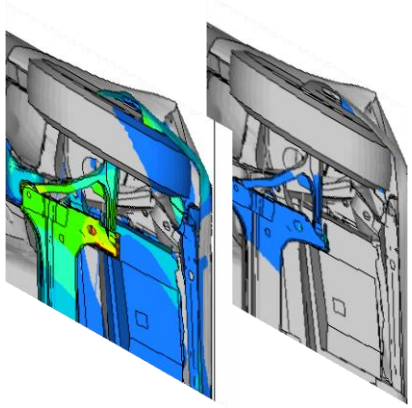
Dominating Effects

Root Cause Identification

Impact Quantification

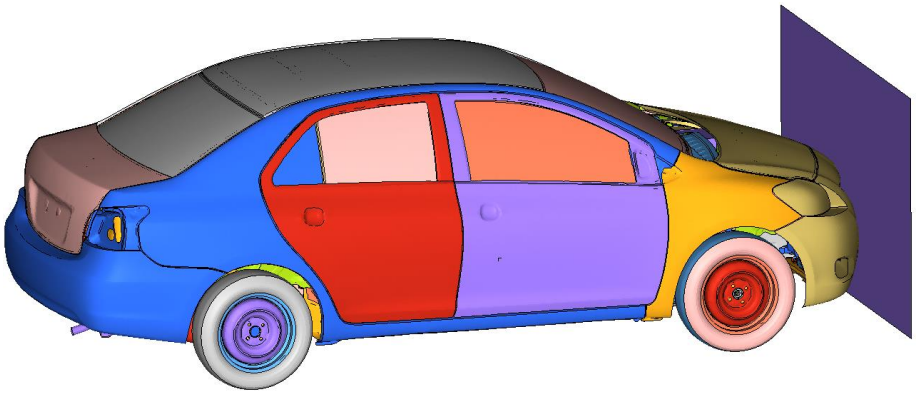
Simulation n





Example: Toyota Yaris

Toyota Yaris



Model	Toyota Yaris
Year	2010
Number of Parts	917
Finite-Elements	1,514,068

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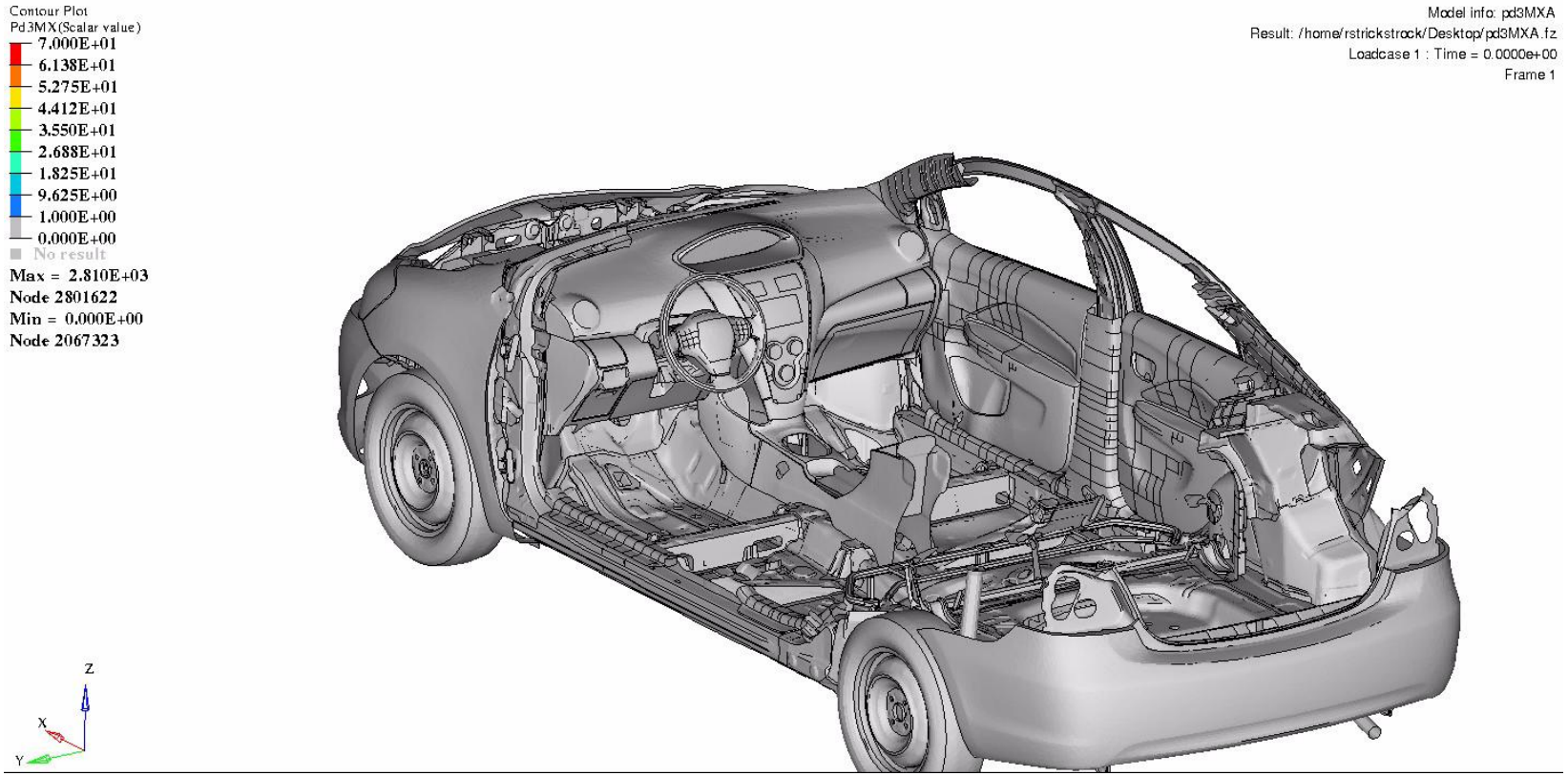
Example: Toyota Yaris

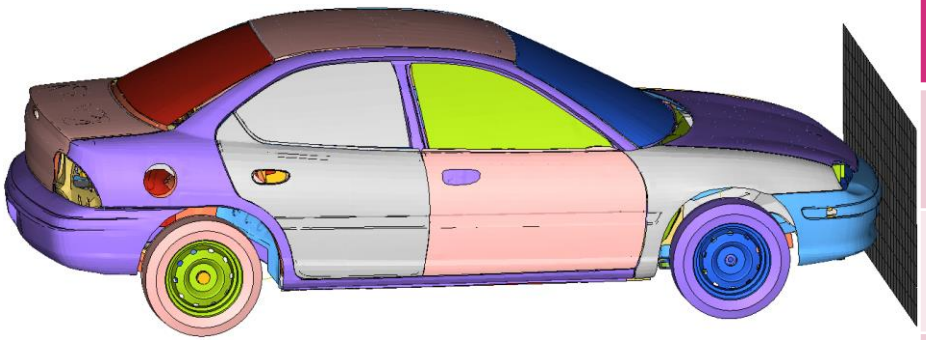


Maximum variation of node position in [mm]

ARUP

Example: Chrysler Neon

Chrysler Neon



Model	Chevrolet Silverado
Year	2006
Number of Parts	712
Finite-Elements	1062140

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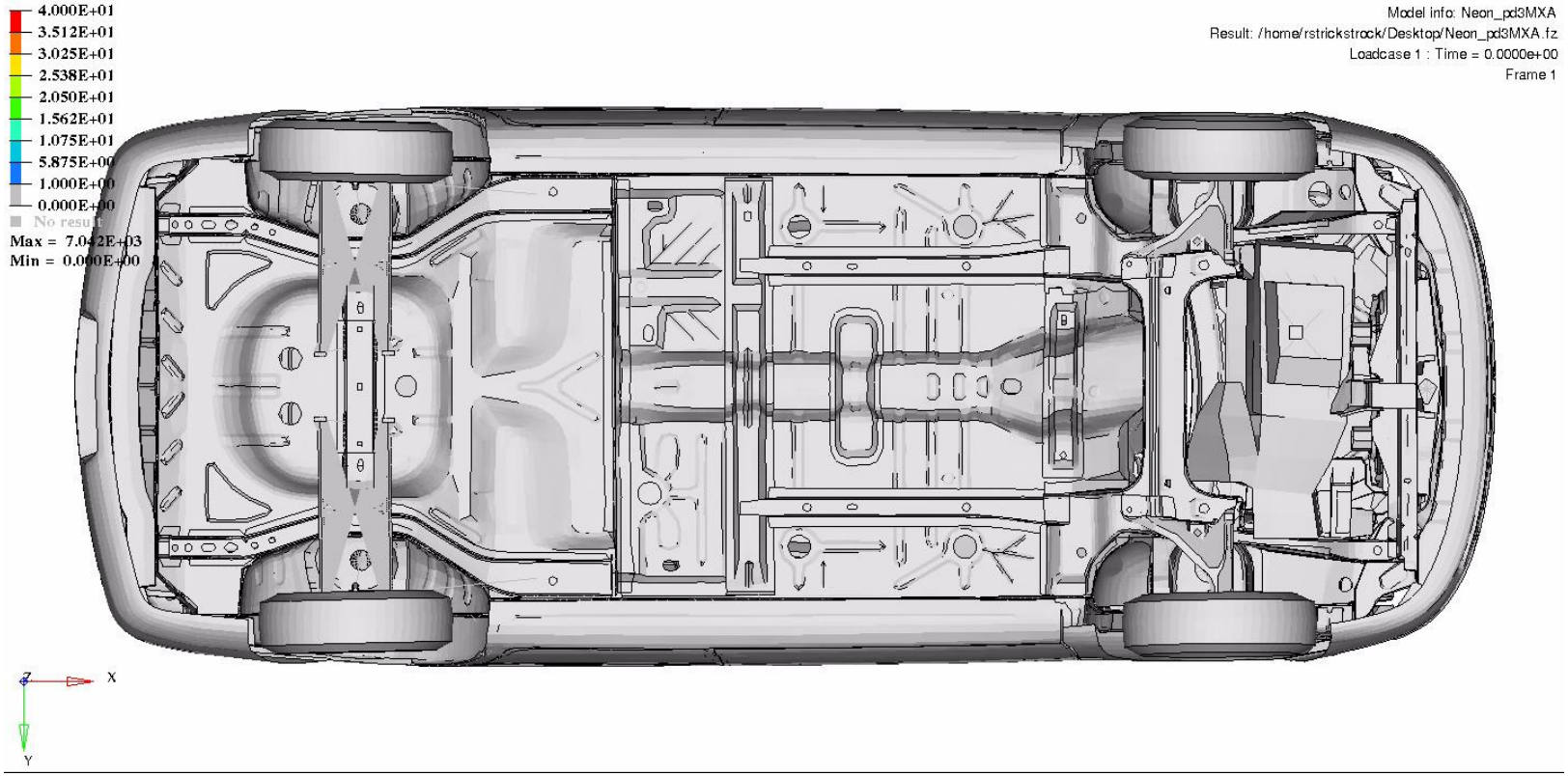
Example: Chrysler Neon



Maximum variation of node position in [mm]

ARUP

Summary

- Production tolerances can have a big impact on simulation results
- Easy emulation of thickness variation triggers model instabilities
- More robust design