STATUS AND CHALLENGES OF SAFETY CAE IN VEHICLE DEVELOPMENT

Dr. Steffen Frik
Adam Opel AG
Safety CAE Integration & Interior CAE

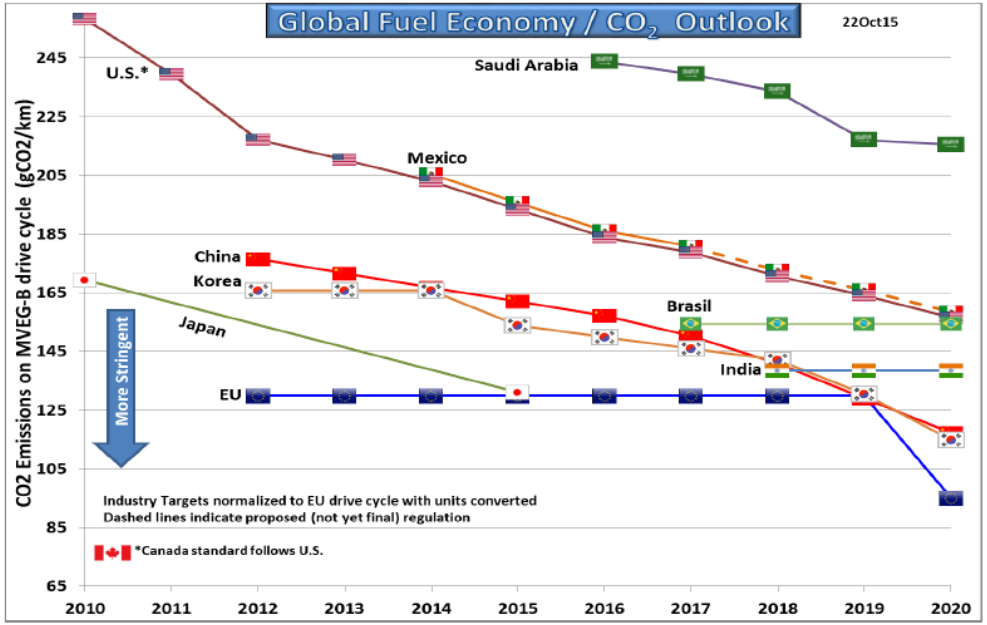
AGENDA

1. Introduction
2. Advanced material modeling
3. Optimization and robustness
4. Child safety
5. Integrated safety
6. Summary

INTRODUCTION

CO_2 Global Regulatory Landscape

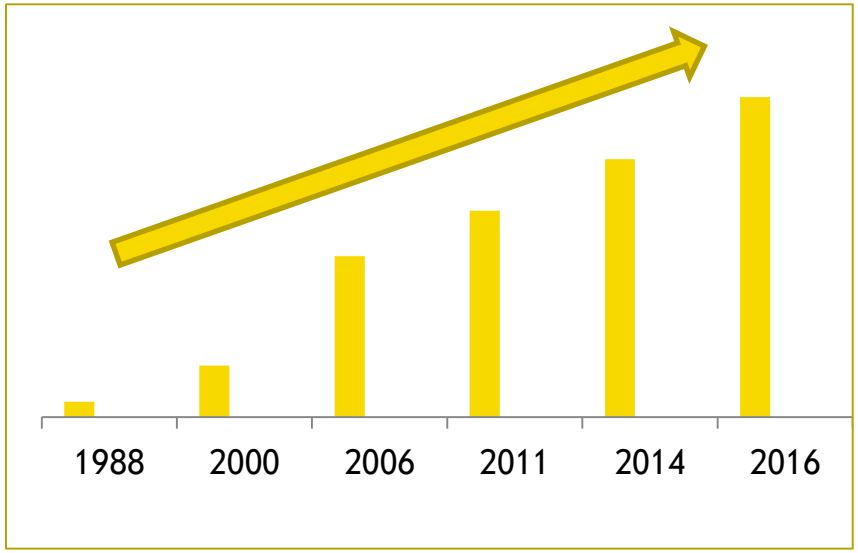
- More stringent fuel economy / CO_2 requirements drive use of alternative materials and joining methods
- CAE based development process requires predictive models of these materials and connections
- Comprehensive MDOs allow optimization of vehicle structures and occupant protection
- Special challenge: small and compact car segments with high focus on costs



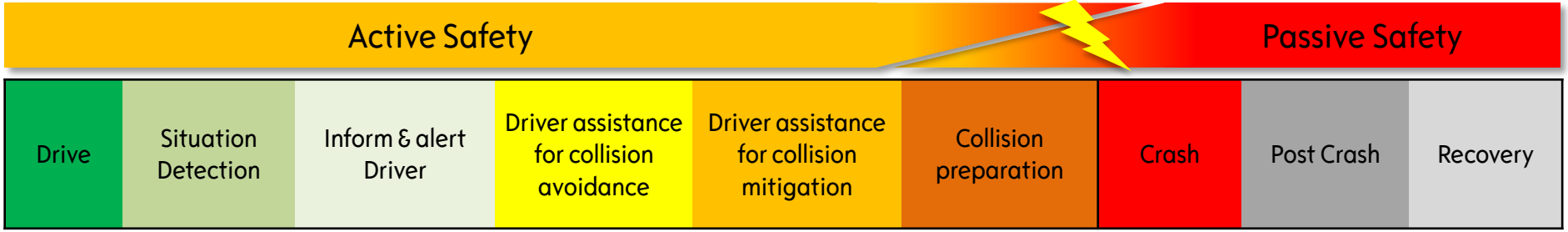
INTRODUCTION

Global Regulatory, Consumer Metrics, and Inhouse Loadcases

- More and more stringent loadcases with partly even contradicting requirements
- New CAE applications (e.g. pedestrian sensing, airbag misuse, human body models, interaction with vehicle dynamics, …)
- Balancing requires massive CAE support
- Robustness assessment of optimized solutions
- Role of CAE will be even more important



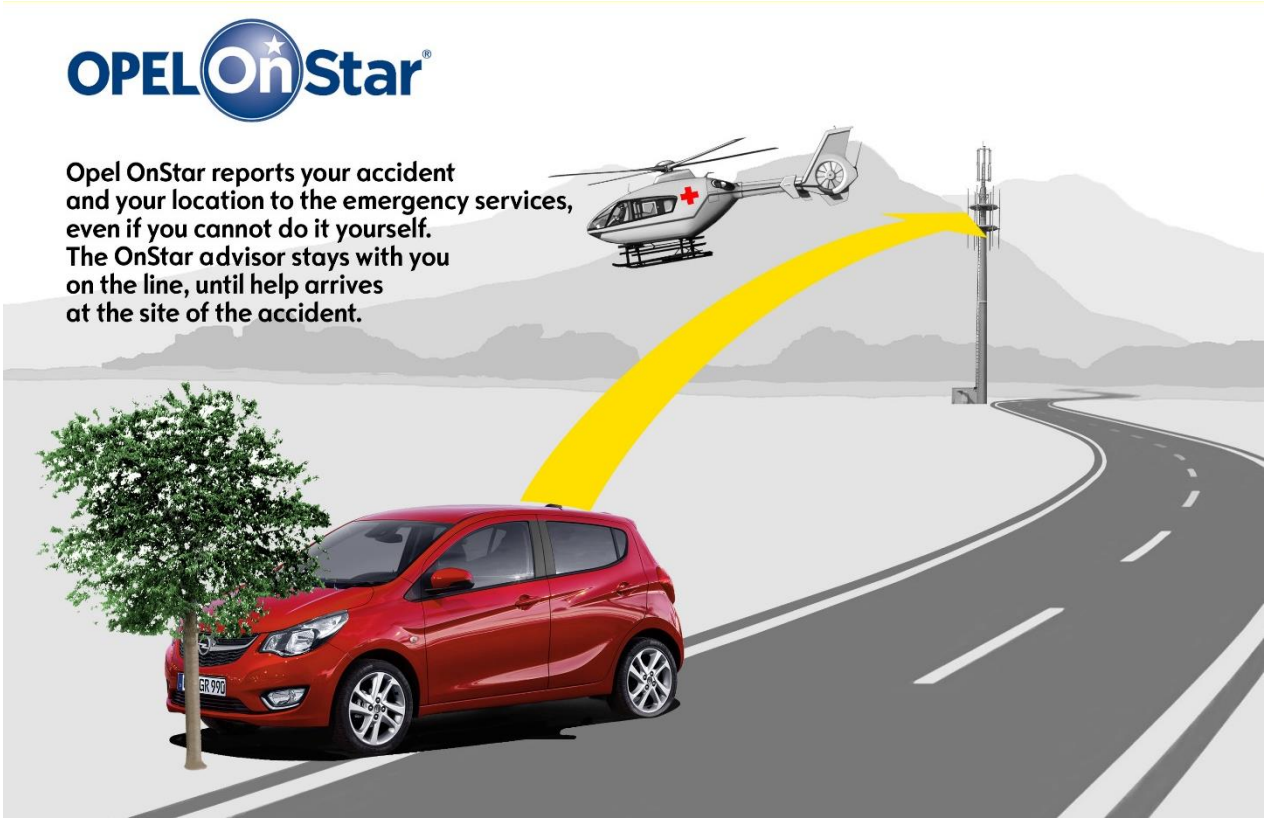
INTRODUCTION



Current safety topics:

- Electronic Stability Control (ESC)
- 'PreSafe' Systems (Motorized Seatbelt, Close Windows, Seat Adjustment…)
- E-Call / OnStar
- Lane Departure Warning (LDW)
- Autonomous Emergency Braking (AEB)
- Passive Safety Functions (Energy Absorption, Airbag, Pretensioner, …)
- Blind Spot Detection
- Adaptive Cruise Control (ACC)
- PostCrash Systems (Door unlock, battery disconnect, HV shutdown …)
- Lighting (AFL, Matrix LED)

INTRODUCTION



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MATERIALS

Demand for affordable lightweight solutions requires broad mix of

- Traditional and advanced (HSS, UHSS) steels
- Aluminum and other light metal alloy panels
- Casting materials
- Thermoplasts
- Composites (CFK, …)

Tasks:

- CAE needs to capture their mechanical properties with the required accuracy
- Special focus on material rupture
- Comprehend local effects due to the manufacturing process

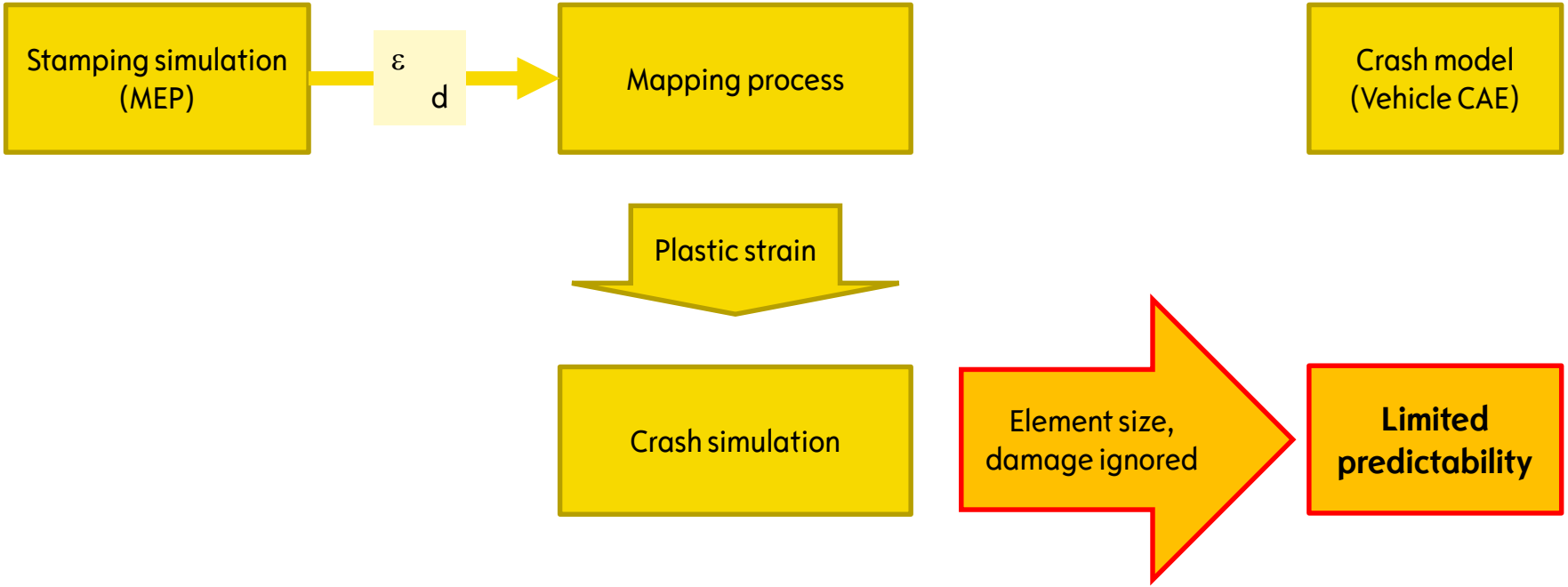
MATERIALS

Implemented manufacturing effects:

- Work-hardening effect
- Pre-damage of steels during stamping (with GISSMO)
- Bake-hardening effect of steels
- Anisotropy of reinforced and unreinforced thermoplasts due to injection molding
- CFK (manufacturing defines material properties)

MATERIAL MODELING (STEEL)

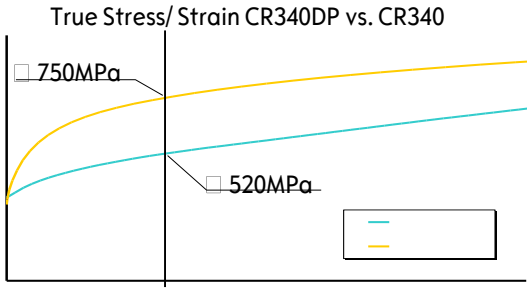
Traditional process (presented in 2005):

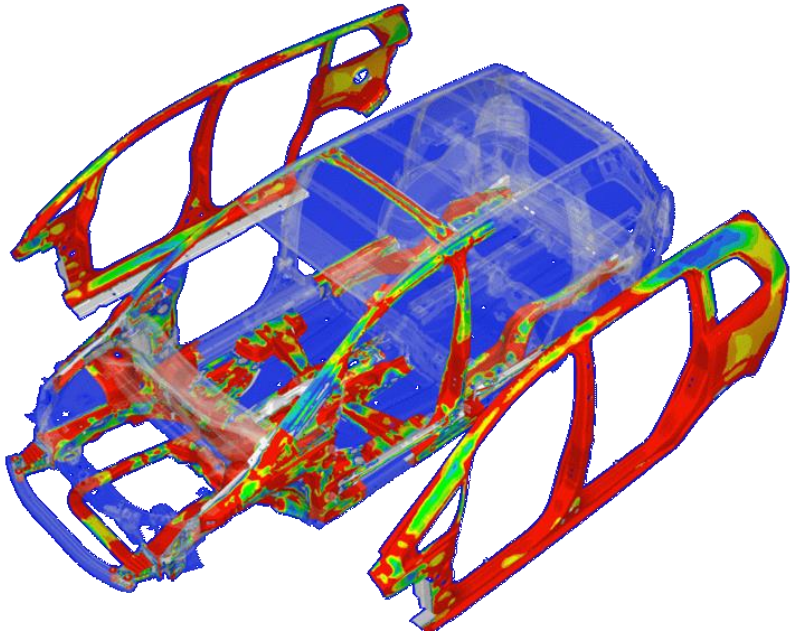


MATERIAL MODELING (STEEL)

Traditional process (presented in 2005):

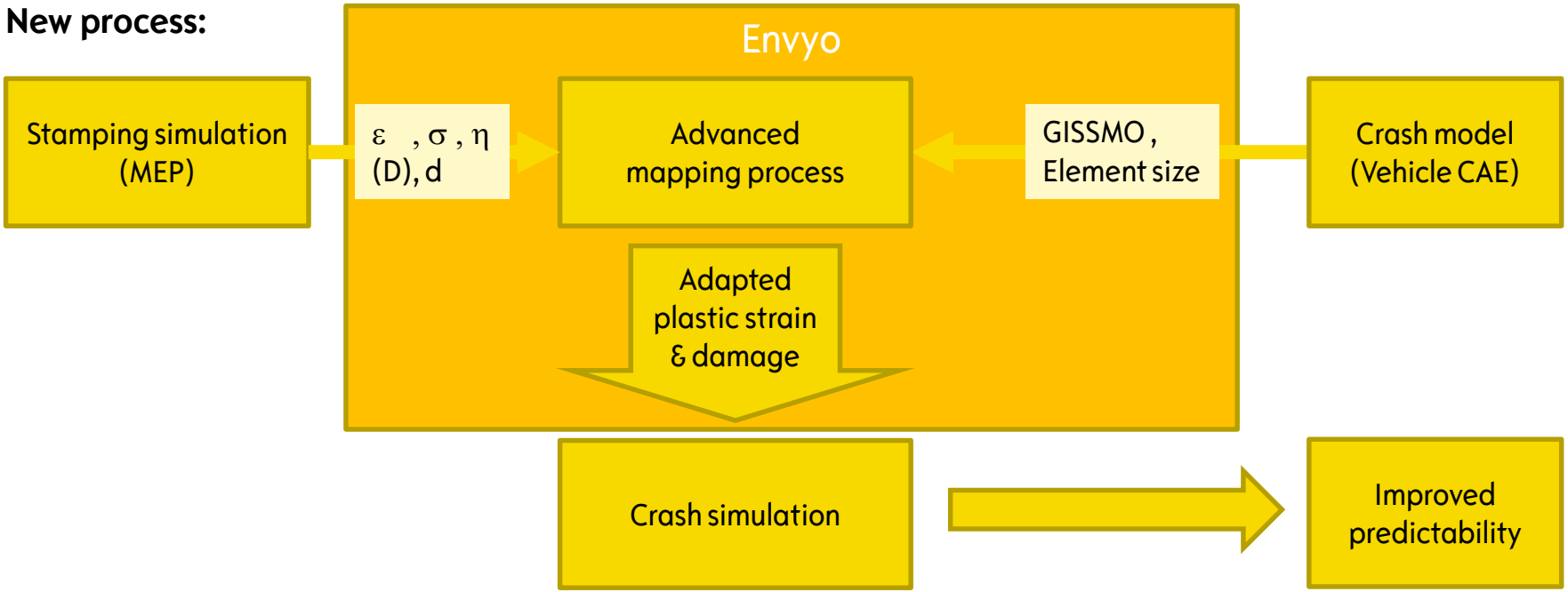
- Applied to all main load carrying structures
- Particularly important for material with significant „work hardening“ effects (e.g. dual-phase & TRIP steels)
- Clear improvement in prediction of deformation patterns





MATERIAL MODELING (STEEL)

New process:



MATERIAL MODELING (THERMOPLASTS)

Background:
Successful application of Ultrasim® (BASF) for many vehicle programs for many years

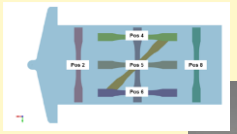
2006 2008 2009 2010

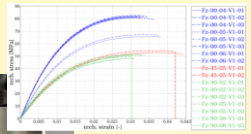
… and many more

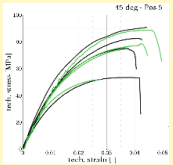
Need to establish similar methodology for other thermoplasts

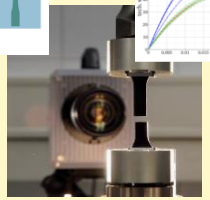
MATERIAL MODELING (THERMOPLASTS)

Process chain

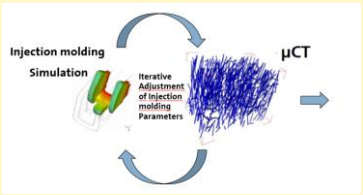


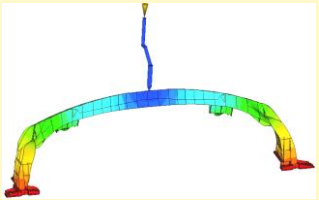




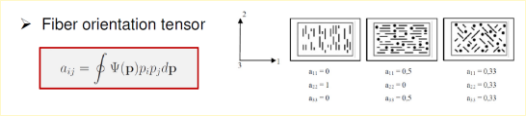


Material Testing and Parameter Identification for *Mat_157

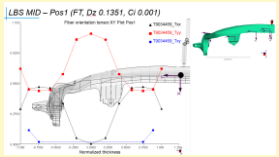




Fiber Orientation with Moldflow®



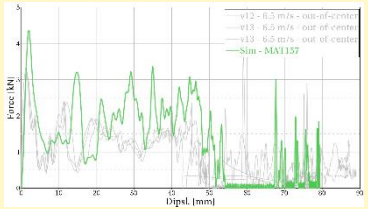
Envyo (Homogenization and Mapping)

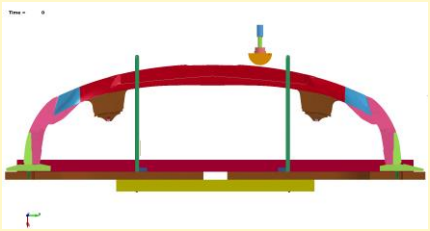


MATERIAL MODELING (THERMOPLASTS)

Successful implementation and validation for various components
Example: Lower Bumper Support

Validation





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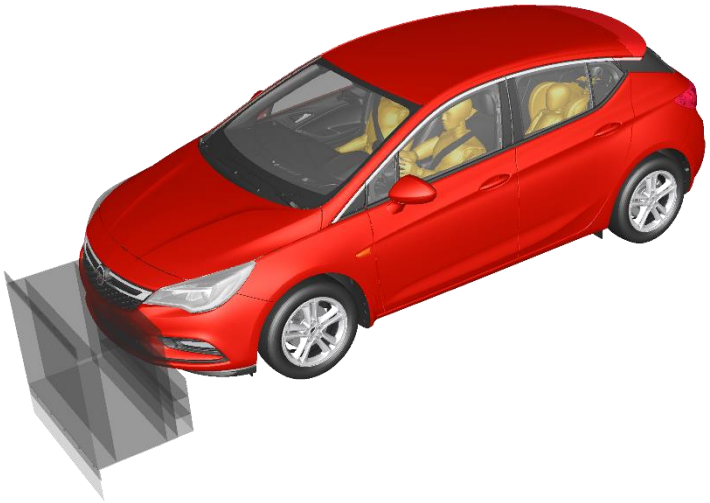
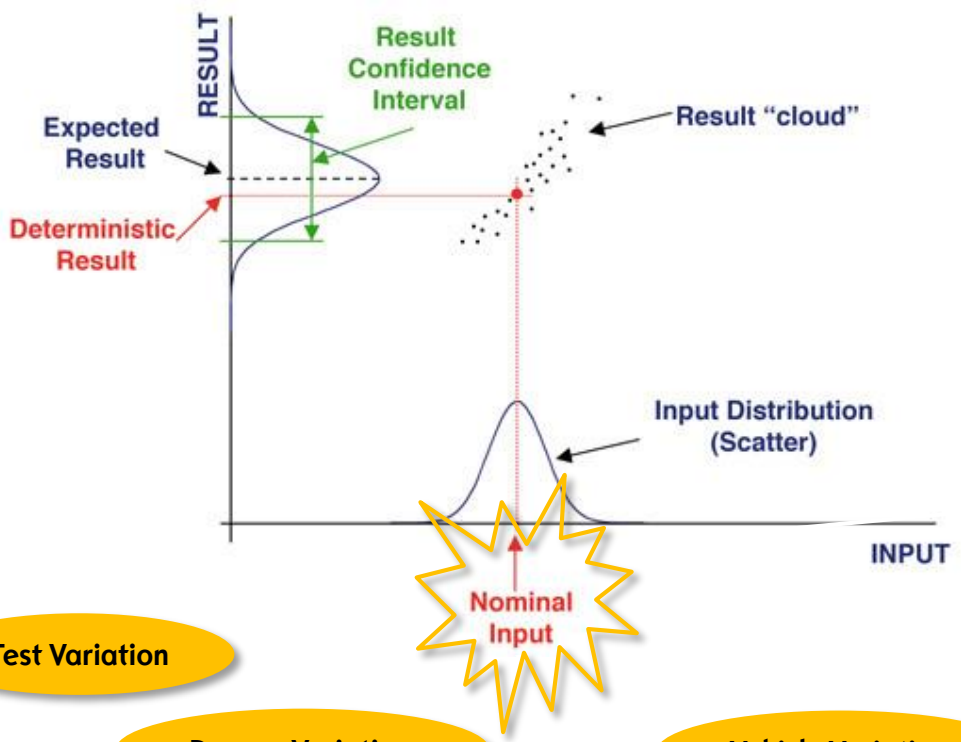
OPTIMIZATION AND ROBUSTNESS

Application of advanced optimization tools (example Opel Astra)

- Topology optimization (components & subsystems)
- Sizing optimization (rear upper body)
- Multidisciplinary (sizing) optimization (full vehicle)
  - crash loadcases
  - body, chassis, NVH loadcases
- Many more local structure optimizations
- Restraints optimization
- Overall vehicle mass reduced by at least 130kg despite increased structural performance



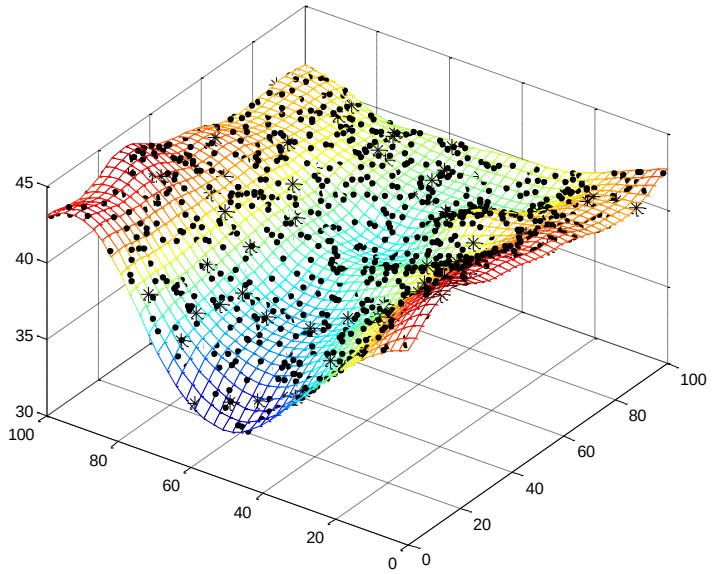
OPTIMIZATION AND ROBUSTNESS



OPTIMIZATION AND ROBUSTNESS

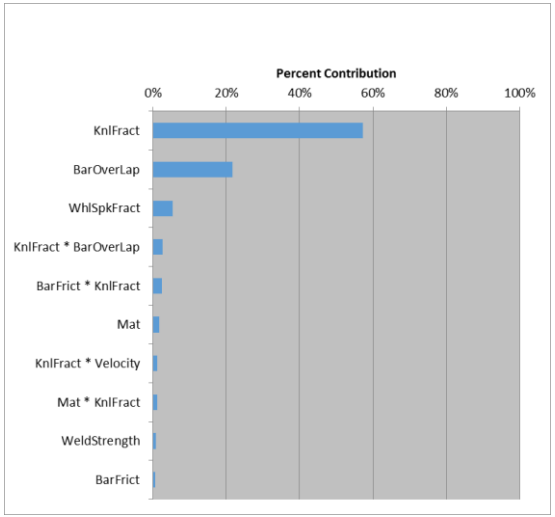
Variation studies for vehicle and test parameters

- Determine amount of variation
- Understand root cause of variation
- Develop countermeasures to reduce variation and to achieve a robust system behaviour

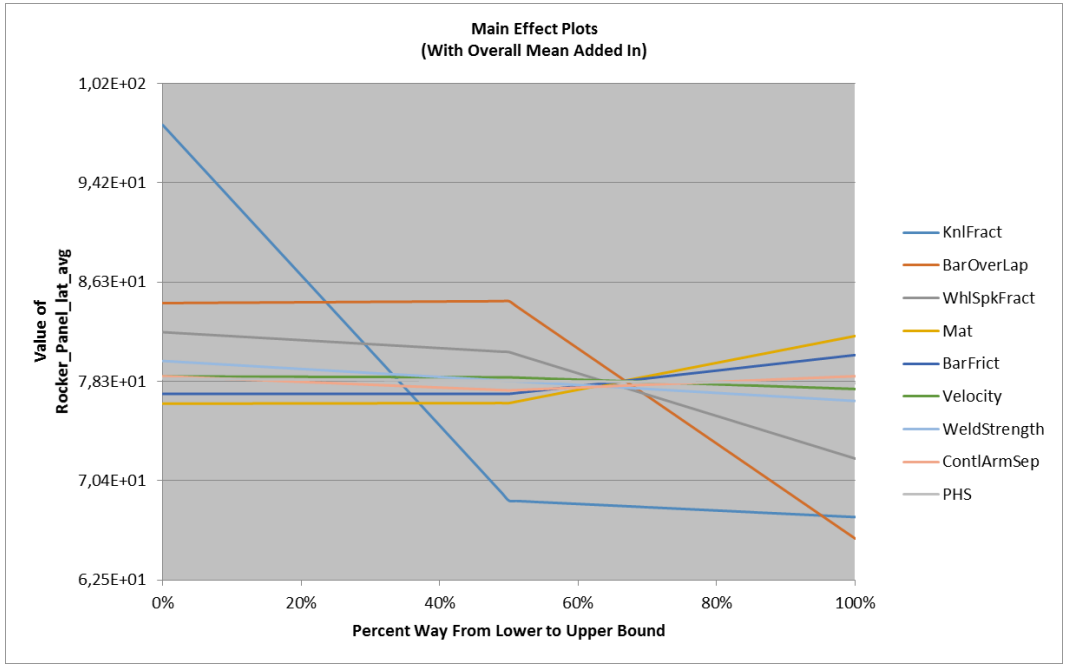


OPTIMIZATION AND ROBUSTNESS

ANOVA evaluation

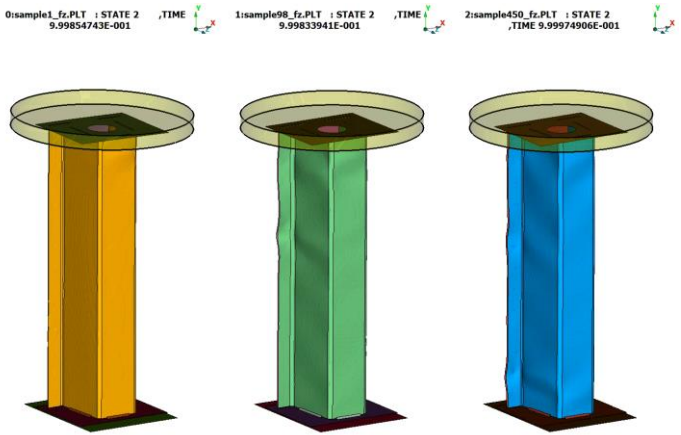


Methodology needed to extend analysis to deformation patterns



OPTIMIZATION AND ROBUSTNESS

Evaluation of deformation modes and their similarity (Presentation by C. Diez)



Virtual drop-tower test of a rail:
1000 pertubations

Scalar measures (total displacement, energy absorption) give first indication but are lacking important information

OPTIMIZATION AND ROBUSTNESS

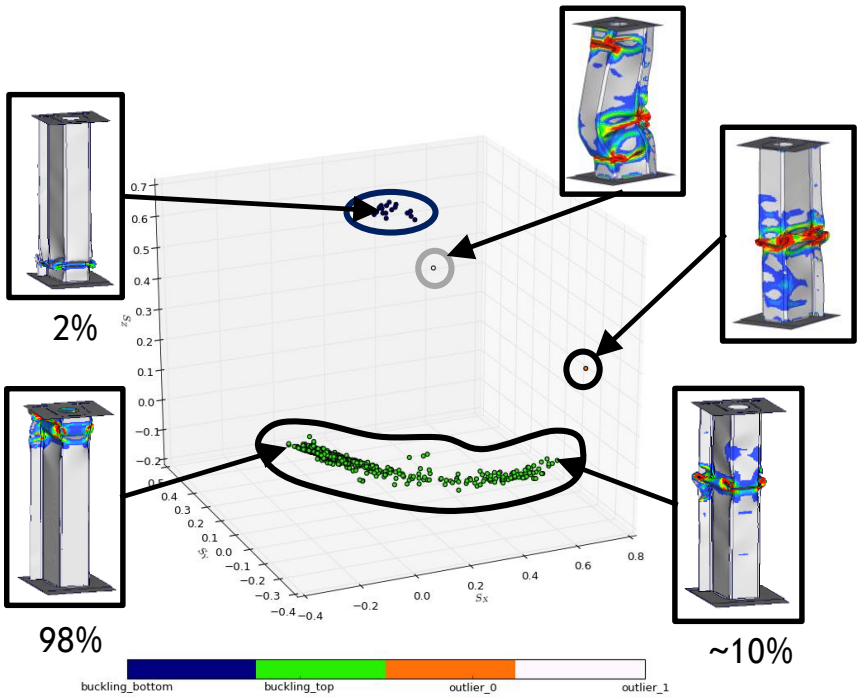
Distance matrix $\boldsymbol{D}^{(1000\times1000)}$

<u>Multi-Dimensional-Scaling:</u>

- Reconstructs coordinates from distances
- Visualizes distances

<u>Agglomerative Clustering:</u>

- groups simulations with small distances in between (hierarchy)
- Outlier detection
- Semi-manual for validation and user interest filtering



OPTIMIZATION AND ROBUSTNESS

How do we make that happen?

- Global HPC cluster
  - enables leveraging of resources among the development centers (time zones, holidays, project peak loads)
  - optimization tasks requiring hundreds of full vehicle crash simulations can be planned and executed without impacting ongoing development work

- Standardized application of optimization tools during the development process

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CHILD SAFETY

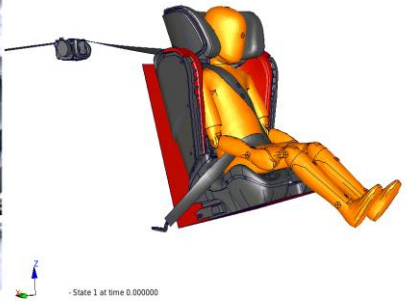
From Lab

Disassembly

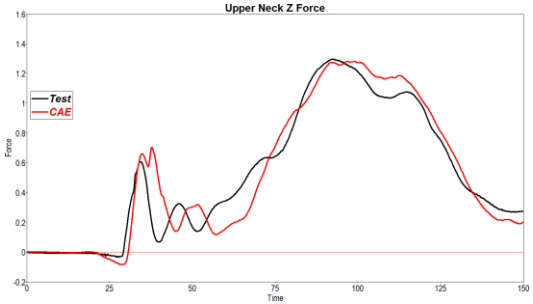
Scanning

To Computer

Testing



Correlation simulation



Correlation

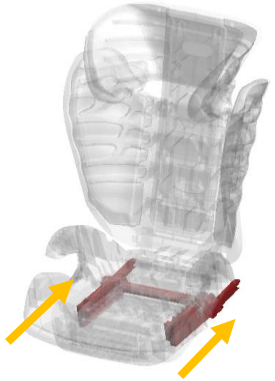
CHILD SAFETY

All CRS have Primer mechanisms for easy positioning

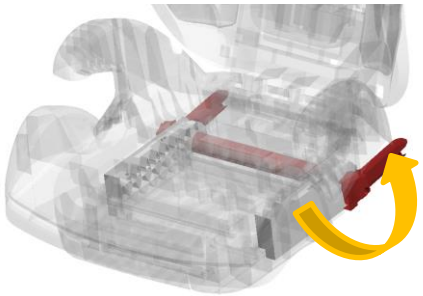
Headrest

Backrest

Isofix tray

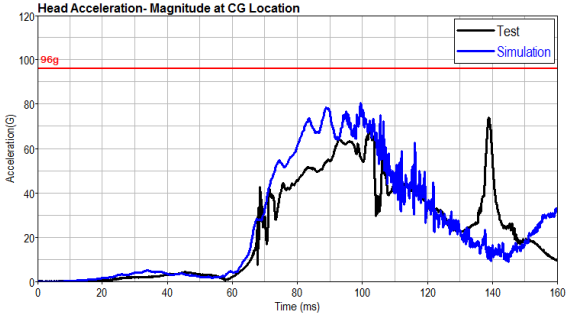


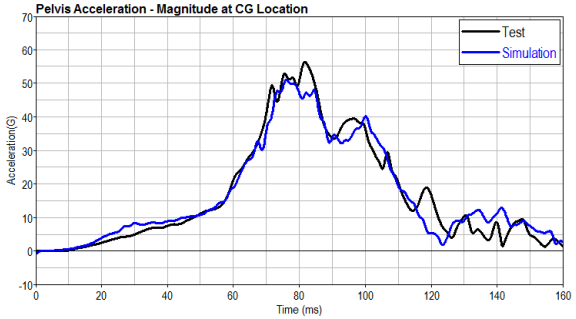
Isofix lever

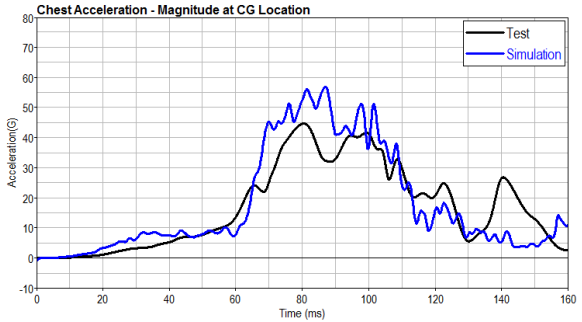


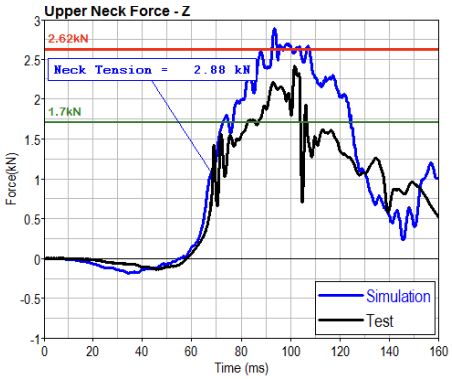
CHILD SAFETY

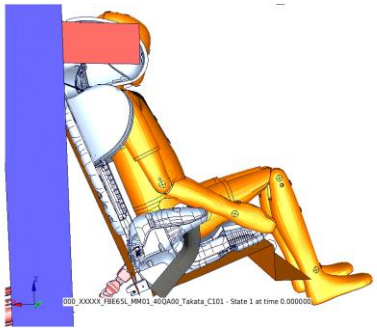
Frontal impact correlation (generic pulse)

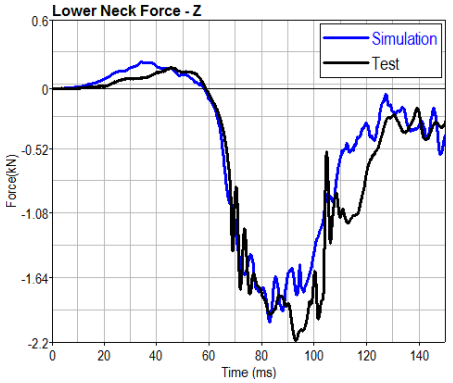






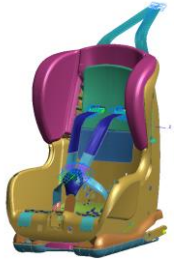


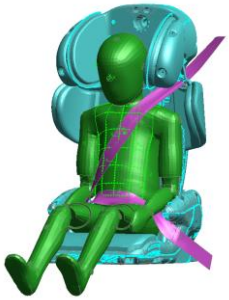




CHILD SAFETY

Available CRS Models (Group 0, 1, 2/3, booster)





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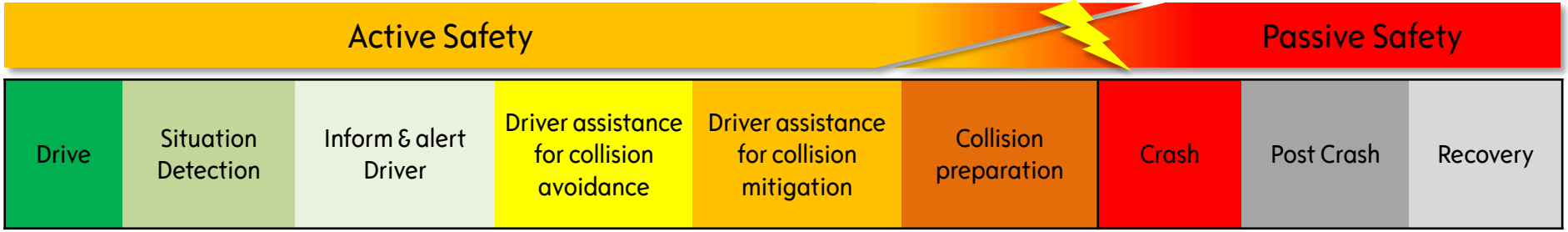

Examples:

- Lighting (AFL, Matrix LED)
- Adaptive Cruise Control (ACC)
- Blind Spot Detection
- Lane Departure Warning (LDW)
- Autonomous Emergency Braking (AEB)
- Electronic Stability Control (ESC)
- 'PreSafe' Systems (Motorized Seatbelt, Close Windows, Seat Adjustment…)
- Passive Safety Functions (Energy Absorption, Airbag, Pretensioner, …)
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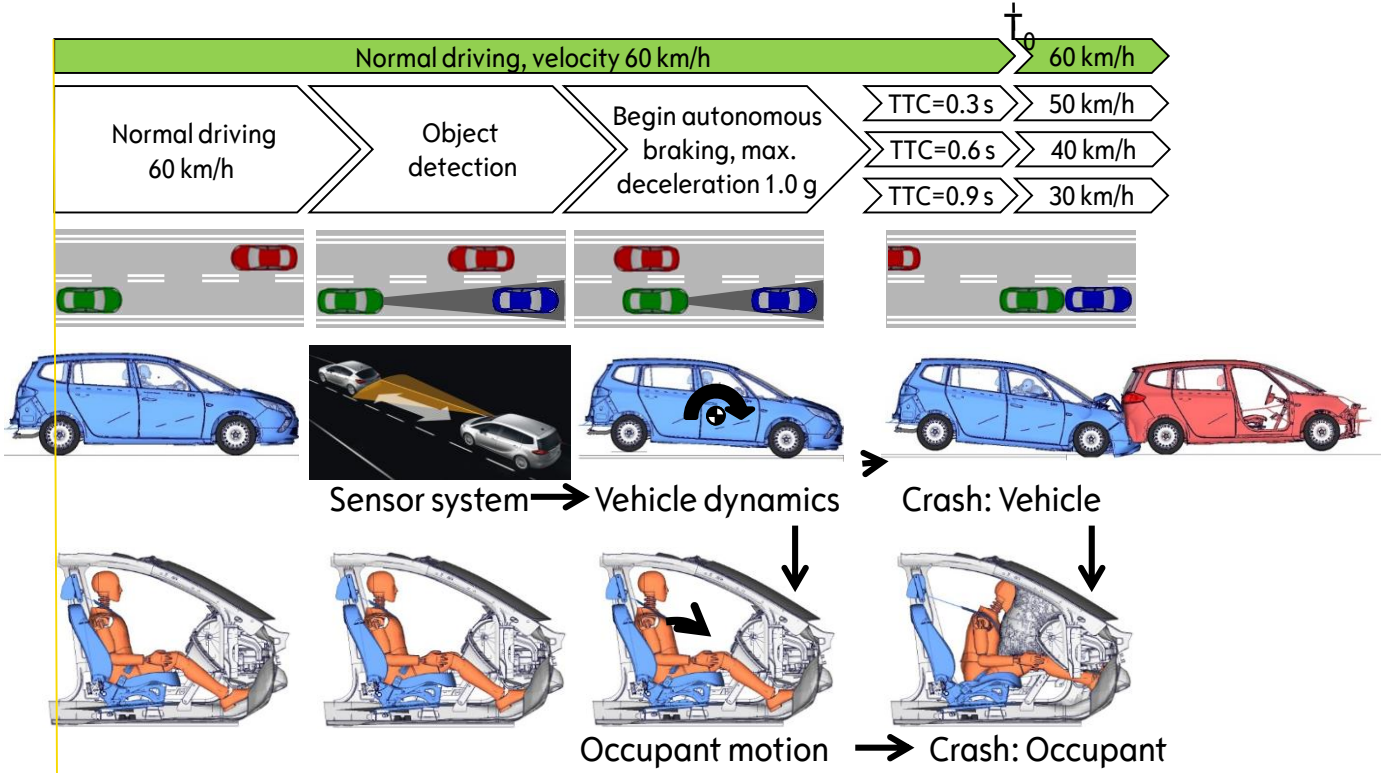
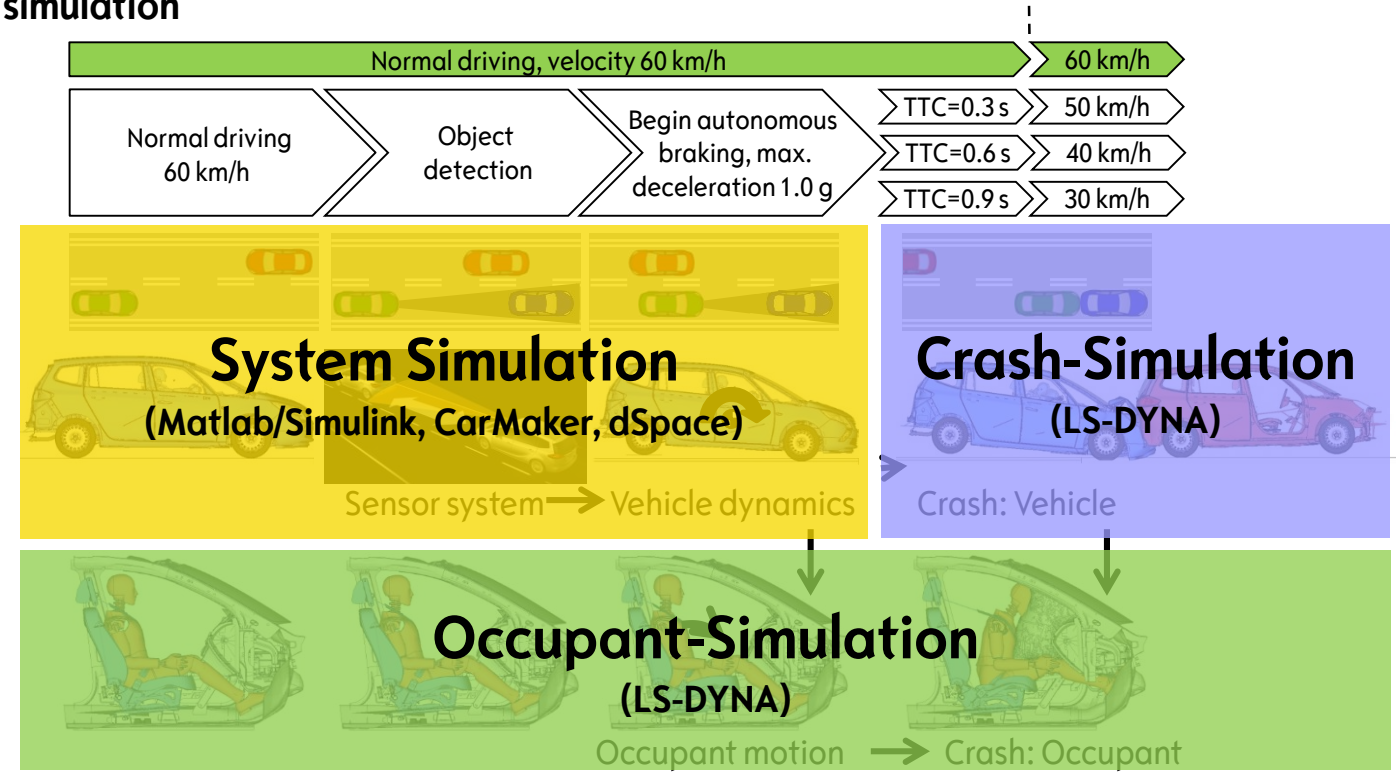
- E-Call / OnStar

INTEGRATED SAFETY



INTEGRATED SAFETY

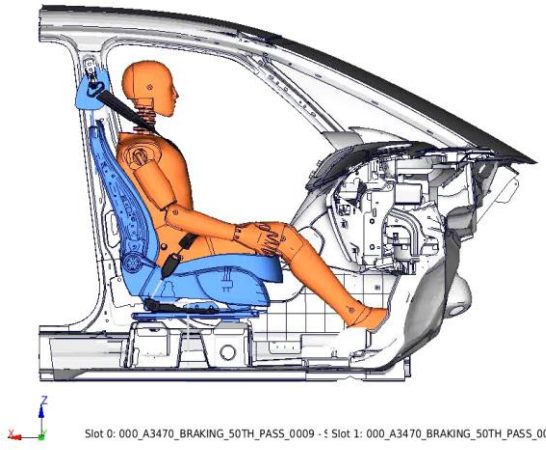
Integrated simulation

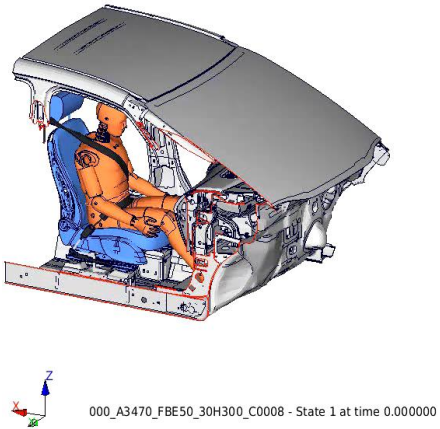


INTEGRATED SAFETY

2-Step FE-Approach

- Simulation 1: occupant motion while braking
  - With vehicle pitch from vehicle dynamics simulation
- Simulation 2: occupant simulation in crash
  - Initial conditions: dummy-position after simulation 1, vehicle pitch and velocity, pre-stress

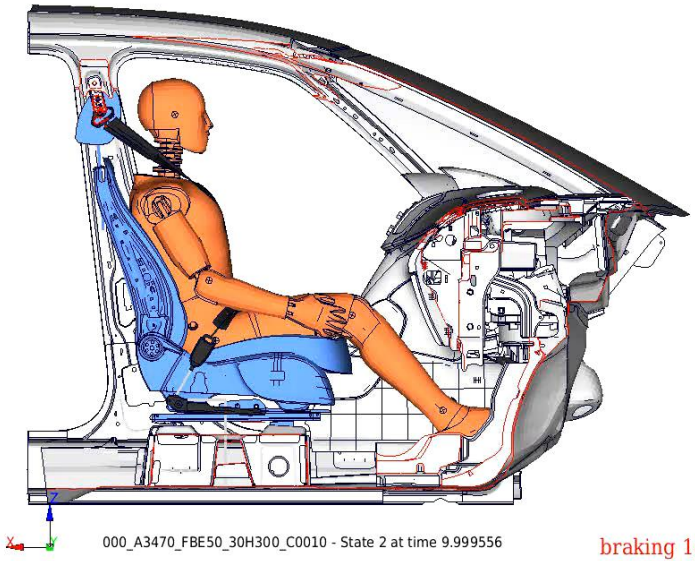




INTEGRATED SAFETY

1-Step FE-Approach

- Advantage: no deviation due to missing initial conditions
- Disadvantage: CPU-time very high



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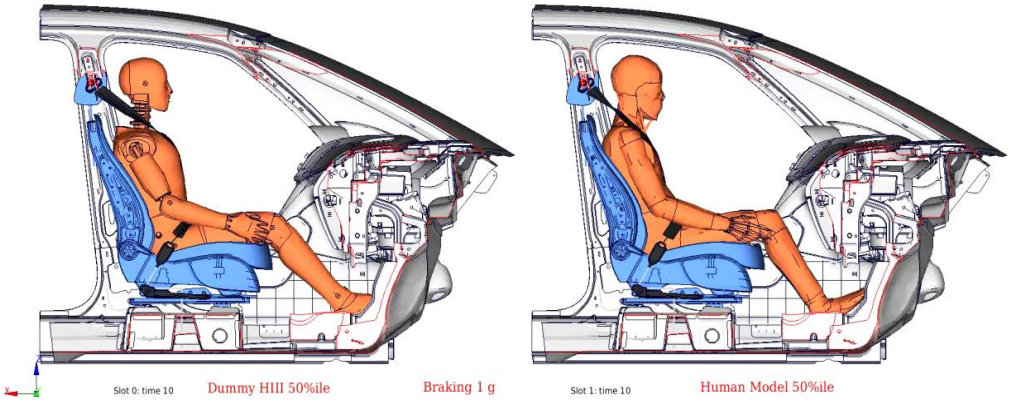
braking 1g

INTEGRATED SAFETY

Outlook

- Dummy-kinematics while braking different from human kinematics
- Human models needed
- Muscle activity also influences kinematics and under investigation



Dummy

Human Model

SUMMARY

- Today, Safety CAE is much more than just structure development
- However, there is more to be done to enhance structure development
  - more advanced material models
  - increased need for manufacturing process simulation
  - detailed subsystem modeling and correlation
- Increased need for optimization and robustness analyses
- In the future, there will be an even higher focus on integrated safety


Dr. Steffen Frik
GG GV 120
THANK YOU