Steel Processing Properties and Their Effect on Impact Deformation of Lightweight Steel Structures

Srdan Simunovic
Computational Materials Science Group
Oak Ridge National Laboratory
http://www-cms.ornl.gov

ornl
Bringing Science to Life

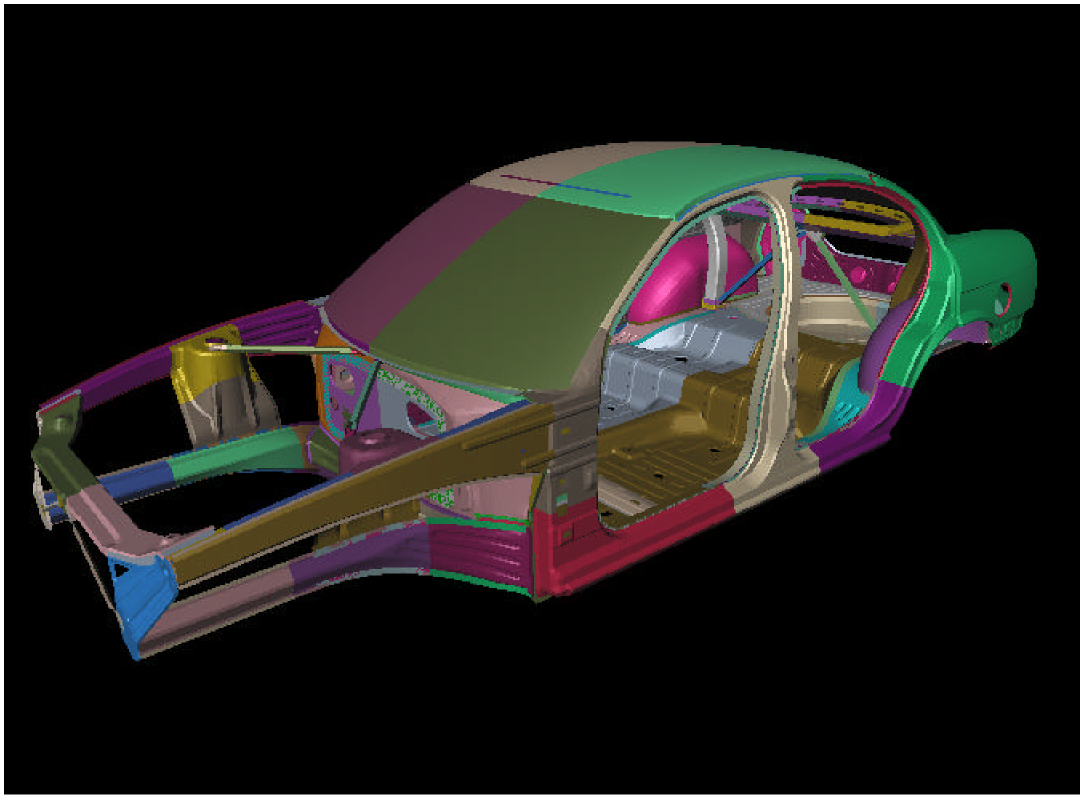
Objectives

- To investigate and document the effects of advanced material processing, forming and joining techniques on lightweight steel auto body structural performance in high strain rate deformation conditions
- To investigate modeling approaches for automotive crash simulations of high strength steels

Project Deliverables and Impact on Industry

- Advancement in predictive modeling capabilities of high strength steels to aid in accelerated vehicle design development
- Integration of material processing into structural simulation model
- Evaluation of influence of forming conditions of high strength steels on vehicle impact properties
- Evaluation of compatibility of new vehicle design with the existing U.S. car fleet

Ultra Light Auto Steel Body



Developed by AISI and Porsche Engineering

Utilizes new steel processing technologies and materials.

Employs holistic design approach

Phase 1

1. Develop a partnership between AISI member companies, ULSAB design teams, and Oak Ridge National Laboratory
2. Select candidate lightweight steel vehicle designs for analysis

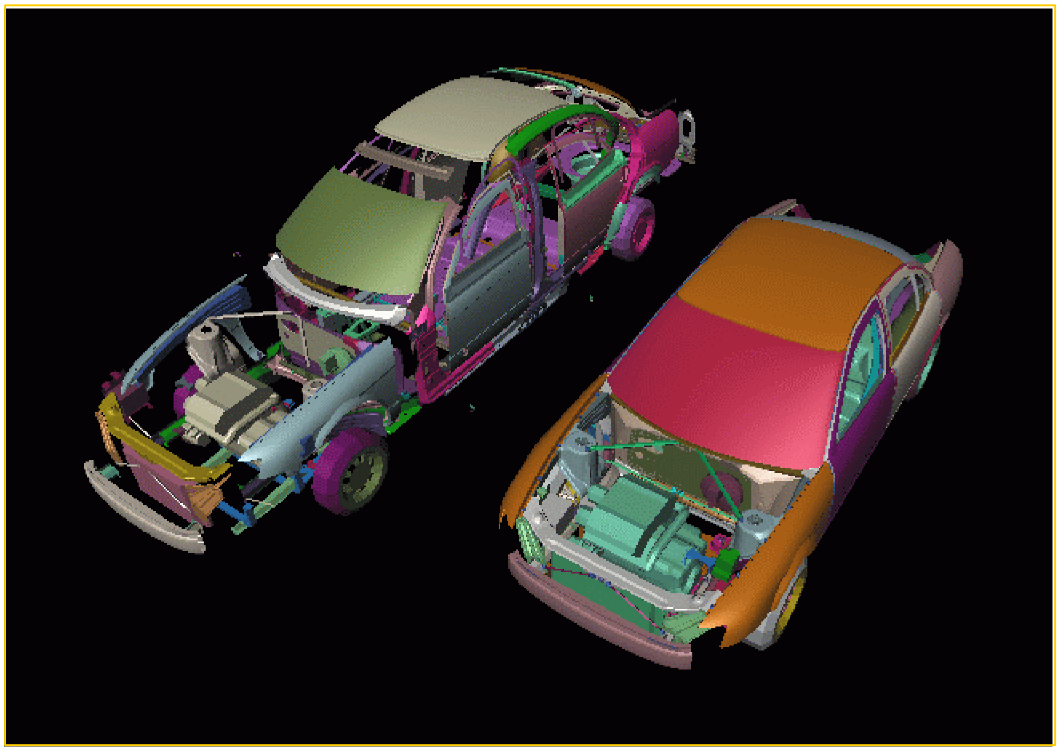
Phase 2

1. Develop finite element models for computational study of new lightweight steel design
2. Incorporate material processing and manufacturing effects into structural finite element model of the vehicle
3. Develop parametric computer models that will allow for:
   - modifications of material structural properties based on processing and manufacturing conditions
   - modifications of vehicle geometry
4. Investigate the effects of material processing and manufacturing on vehicle structural performance

Project Status

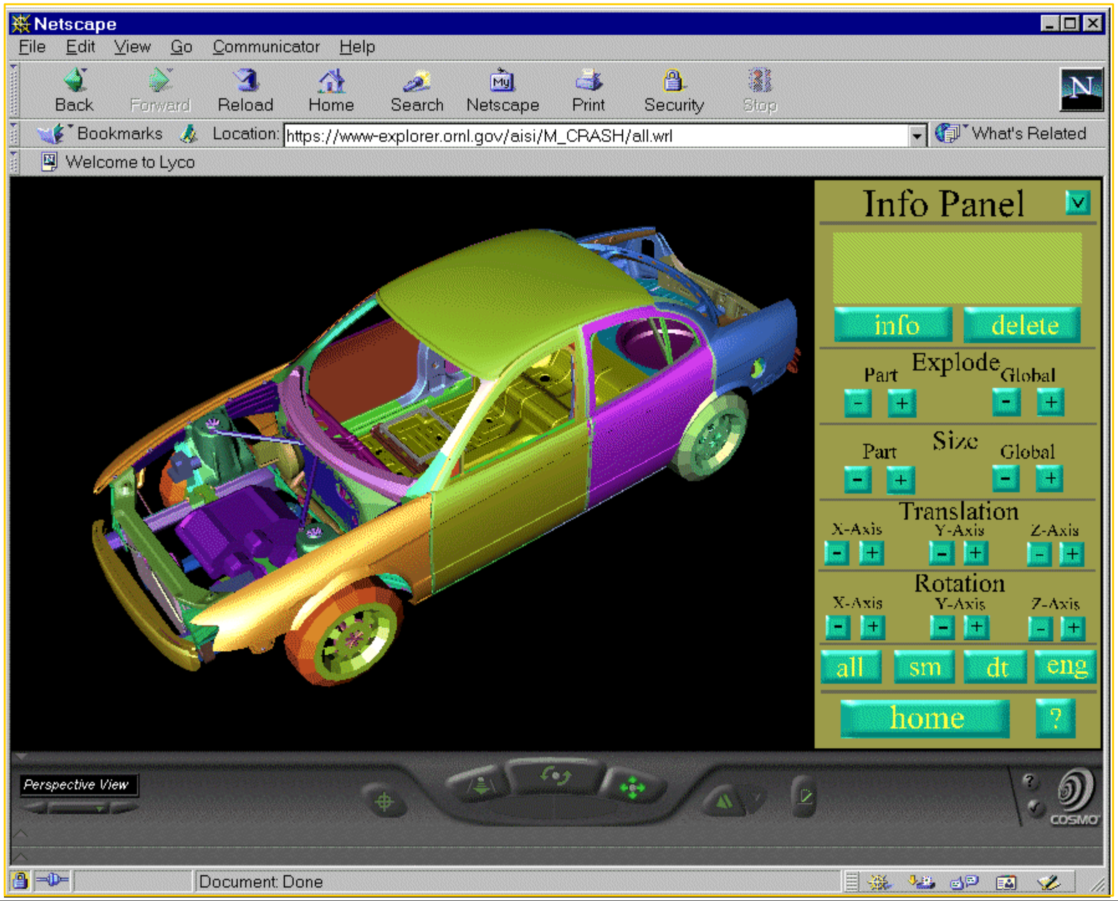
- Developed material models for ULSAB materials that include effects of strain rate using Auto/Steel Partnership experiments
- Performed computational crash simulations with new material models
- Investigated effects of strain rate on crash performance
- Performed various material substitution studies
- Performed forming simulations of front crash structures
- Incorporated forming data into crash models
- Developed interactive Web-based tools for analysis of ULSAB simulations

ULSAB Crash Model



Suspension, engine package, and bumper system were added to simulate realistic crash situations

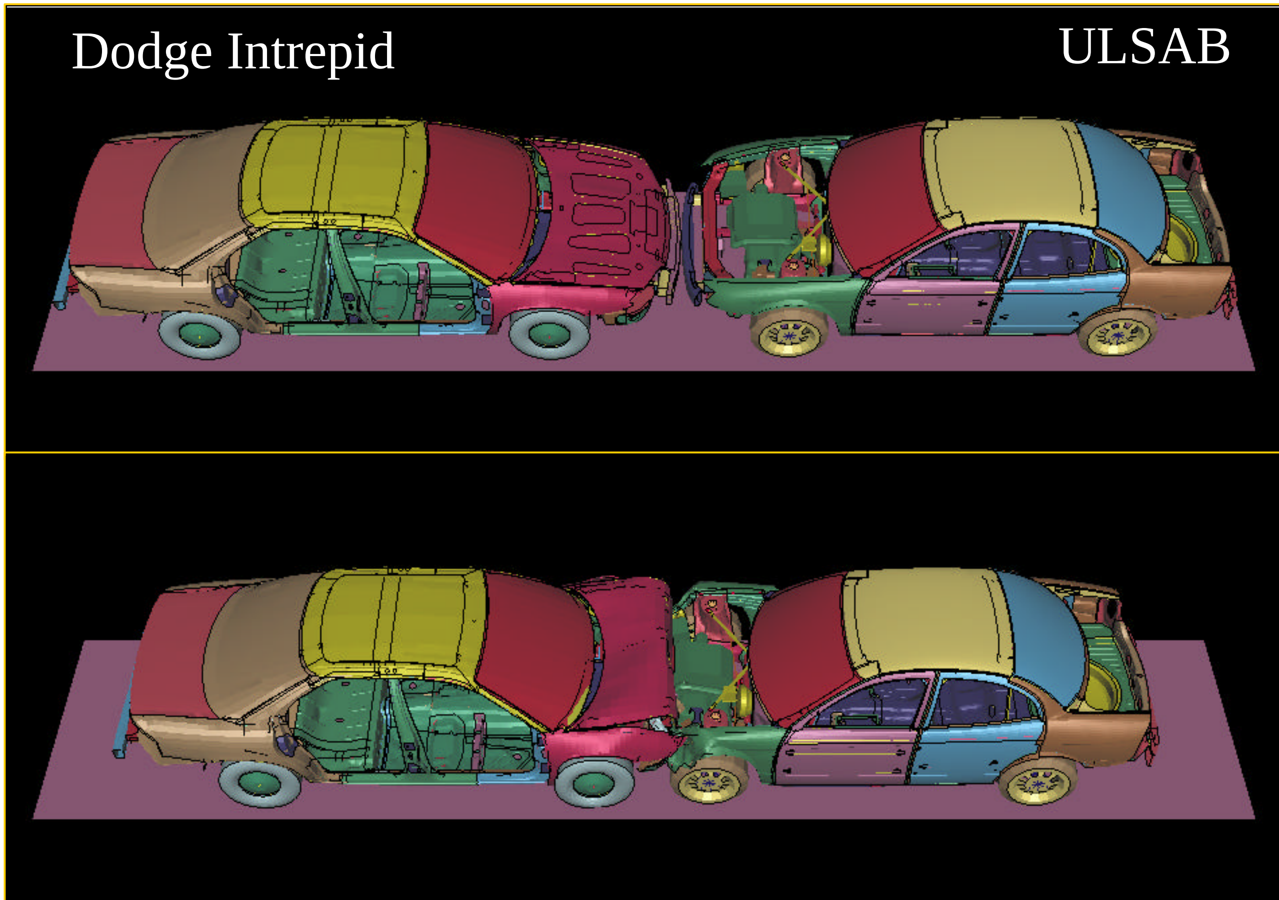
WWW Interface



Developed WWW interface for FEM model manipulation

Model components are parametrized to allow for simple model manipulation and generation

Crash Compatibility Studies

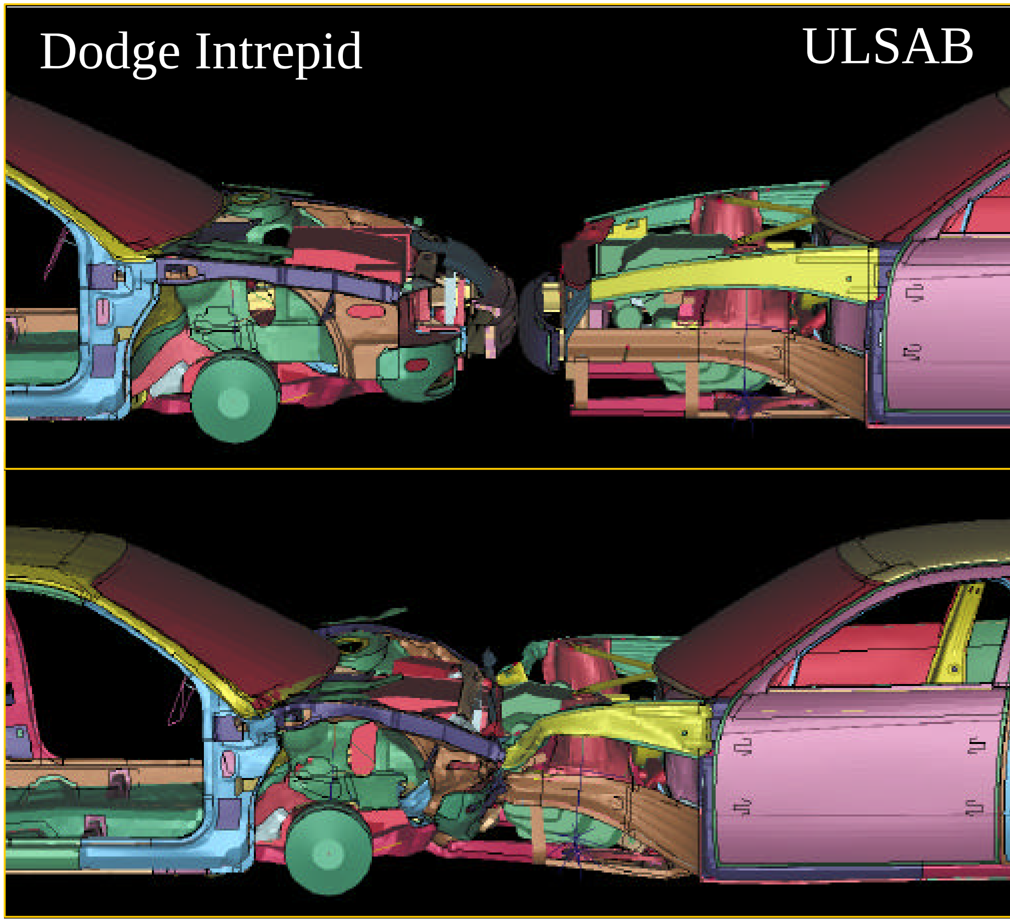


Car-to-car simulations are performed between ULSAB and existing U.S. car fleet vehicles

Results are used to evaluate aggresivity of ULSAB design

Bringing Science to Life

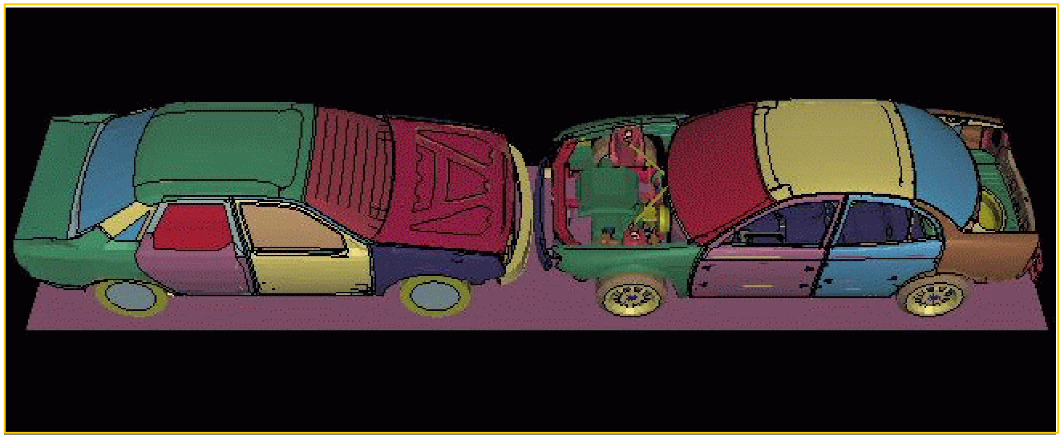
ULSAB - Dodge Intrepid, Side View

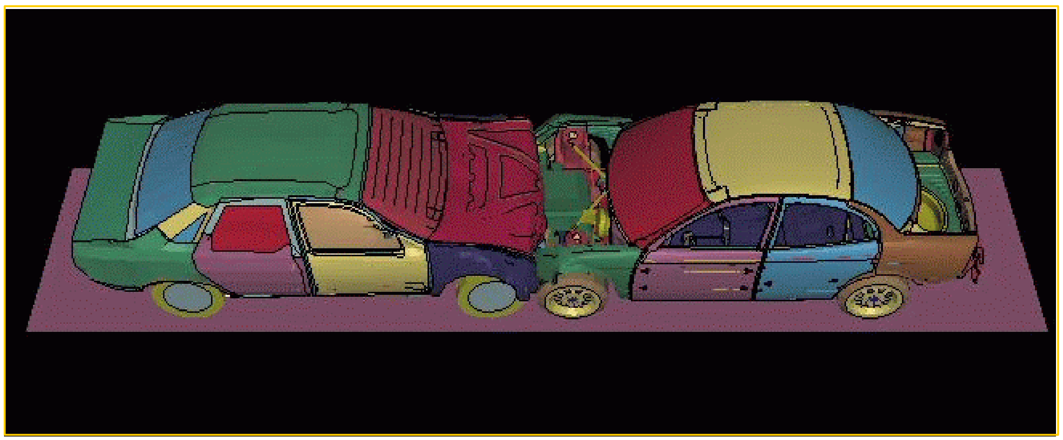


Simulation shows comparable deformation in main energy absorbing components and indicate compatibility between two vehicles

ornl
Bringing Science to Life

ULSAB Compatibility Study





Car-to-car simulations are performed between ULSAB and existing U.S. car fleet vehicles

Results are used to evaluate aggresivity of ULSAB design

Bringing Science to Life

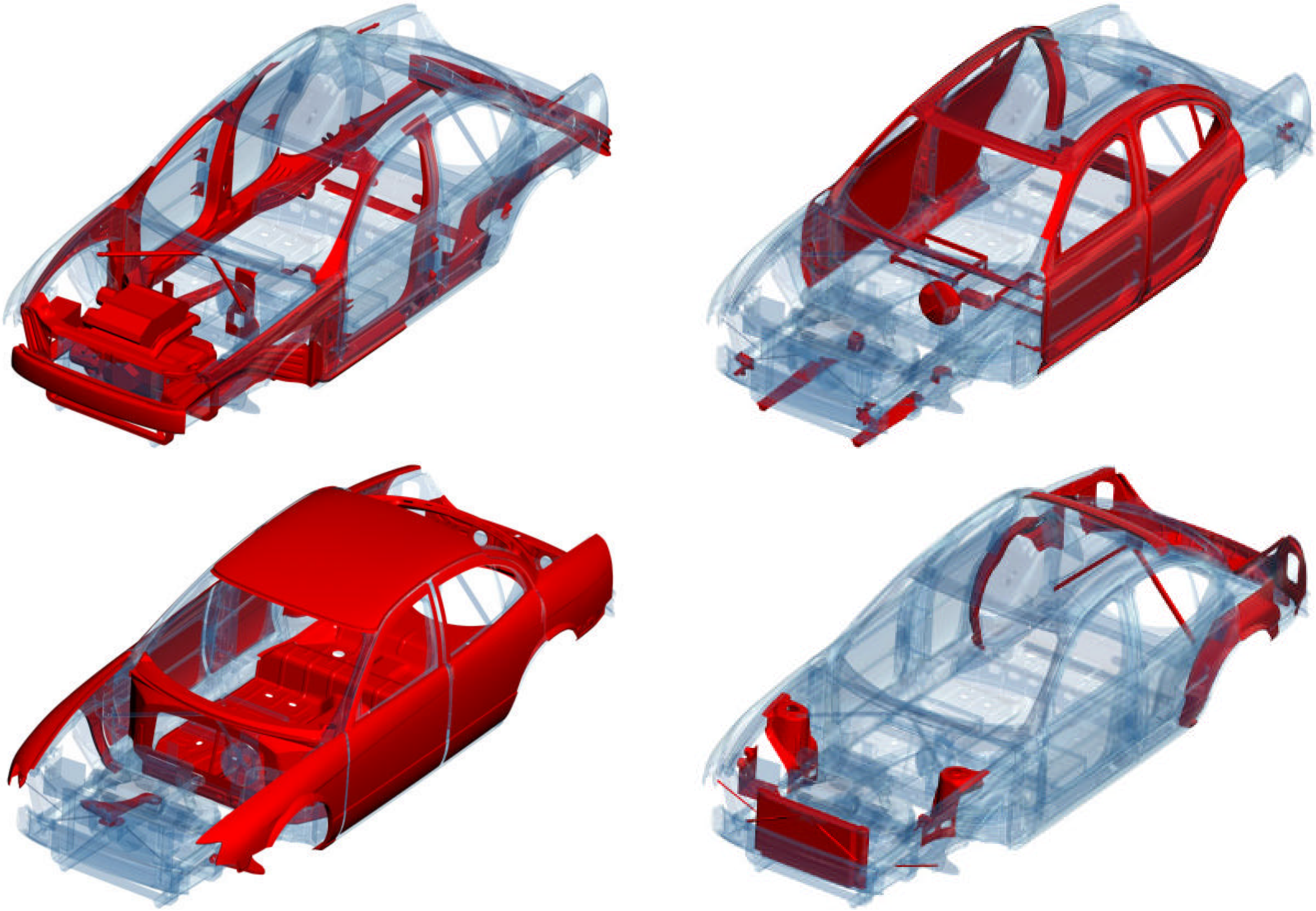
Strain Rate Sensitivity Study of ULSAB

Bringing Science to Life

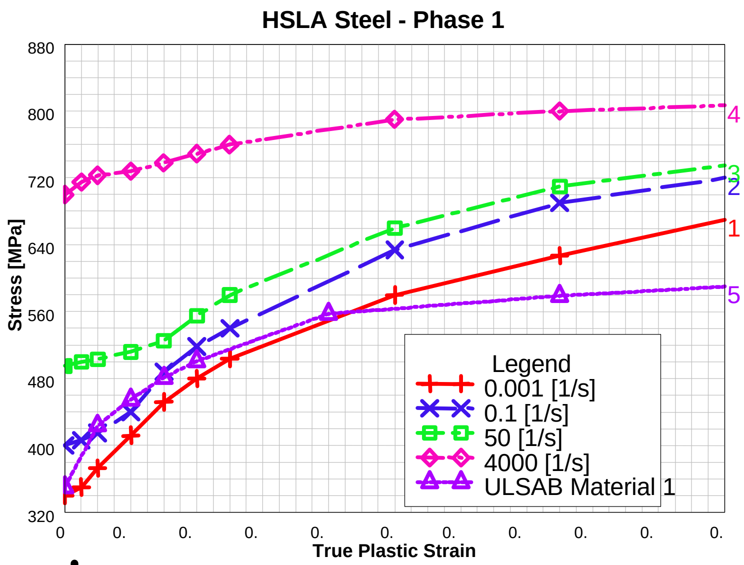
Strain Rate Sensitivity Study - Overview

- Objective
  - Perform study of strain rate effects in ULSAB
- Approach
  - Combine ULSAB computational models and Auto/Steel Partnership data on steel strain rate sensitivity
- Benefits
  - Developed data for FEM computational modeling of high strength steel impact problems
  - Determined feasibility and advantages of strain rate dependent constitutive material models for ULSAB computational models

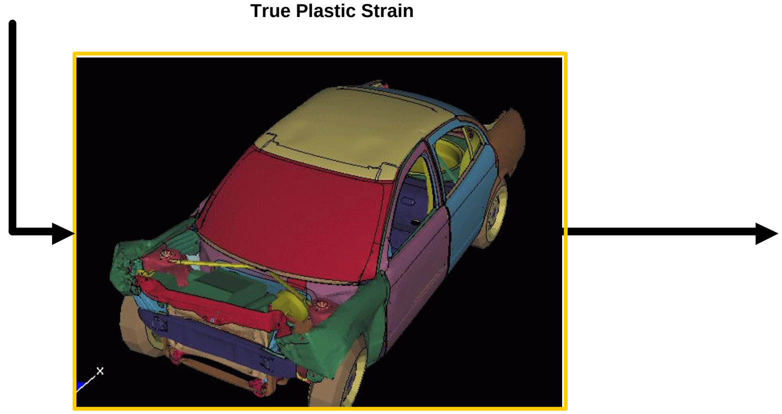
ULSAB Material Systems

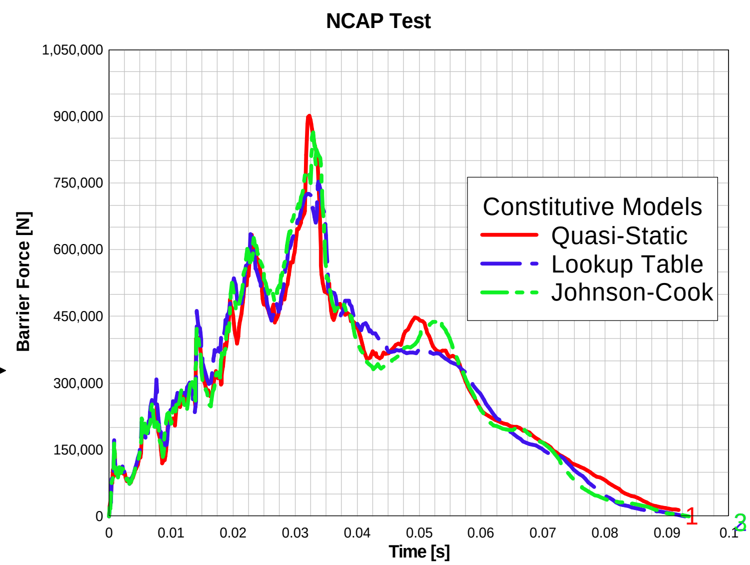


Bringing Science to Life



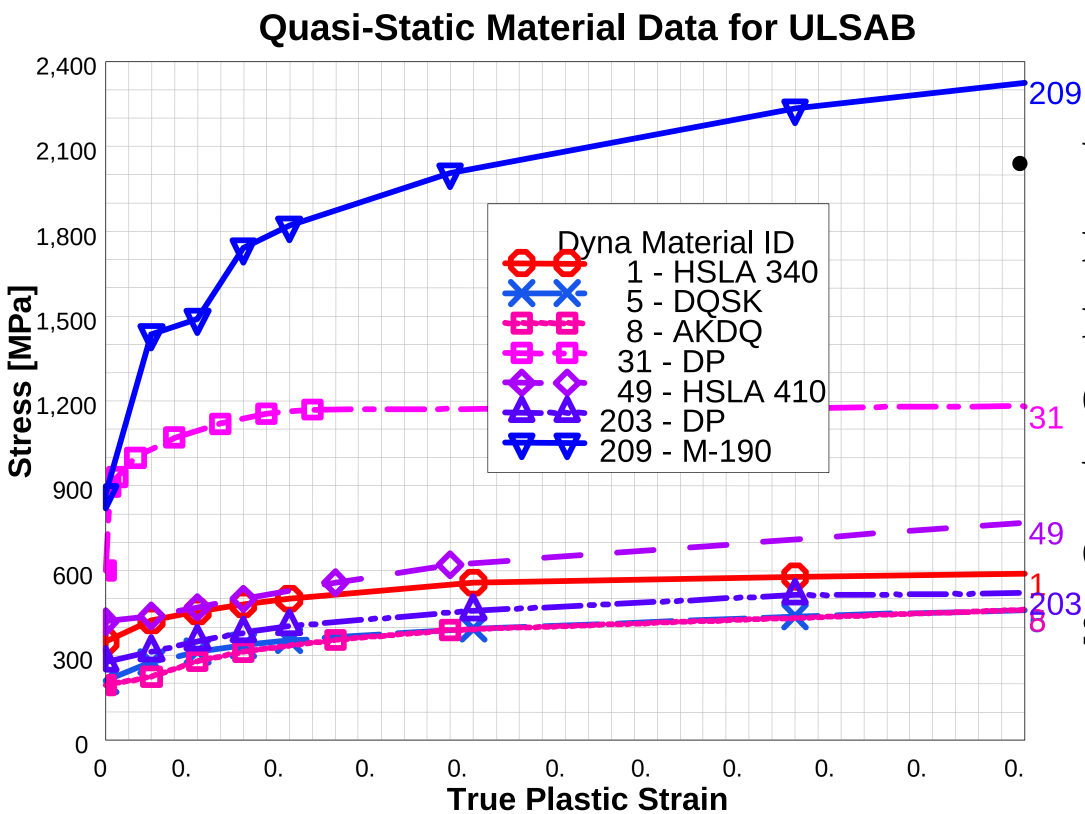
Advanced material models are used for crash simulations and design analysis



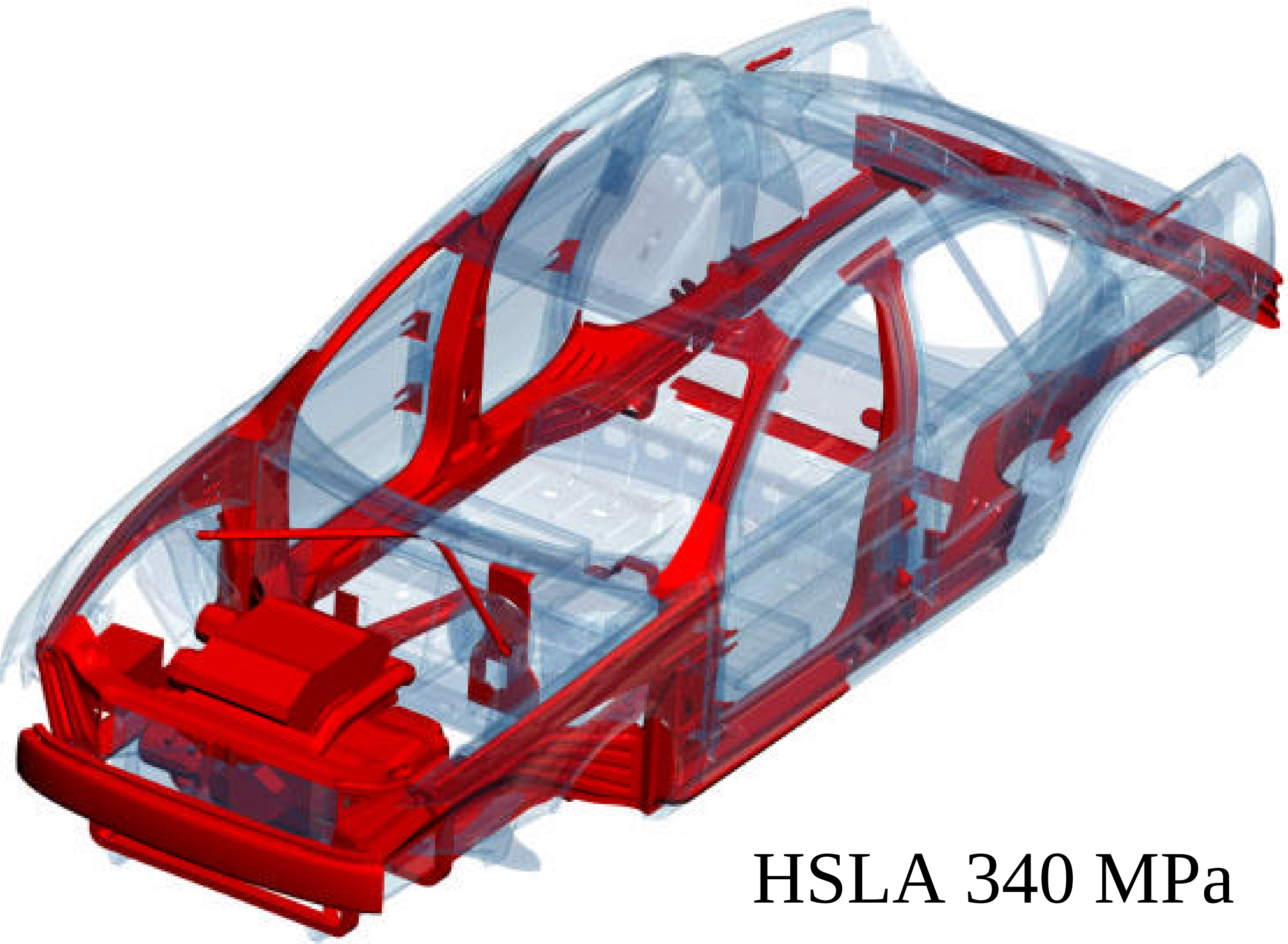


Bringing Science to Life

ULSAB Materials Correlation

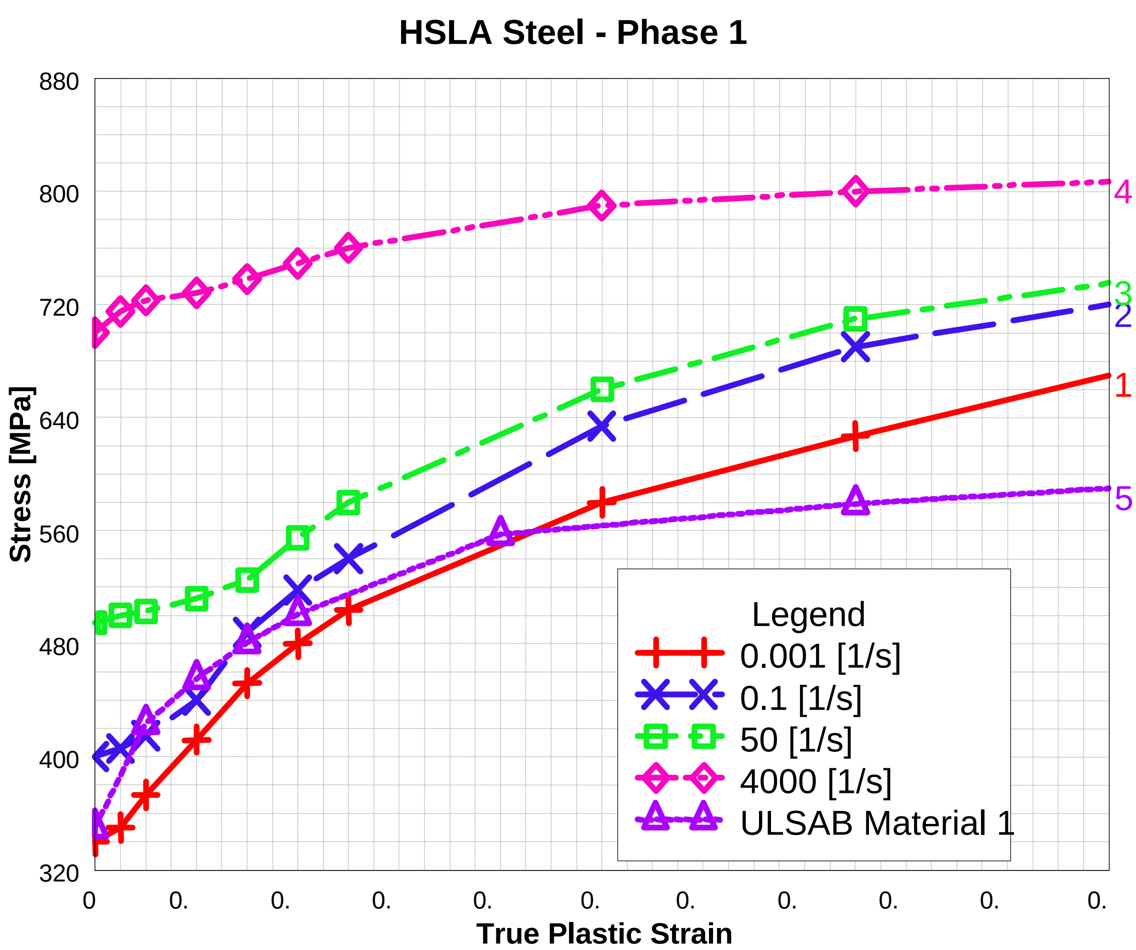


- ULSAB design materials were matched to material experiments and used in computational simulations



HSLA 340 MPa

Bringing Science to Life

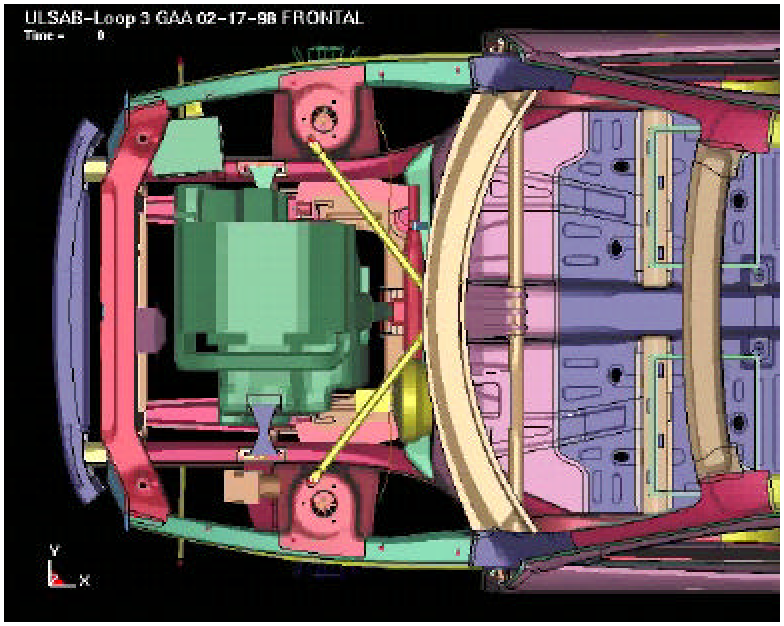


Experimental data for various strain rates

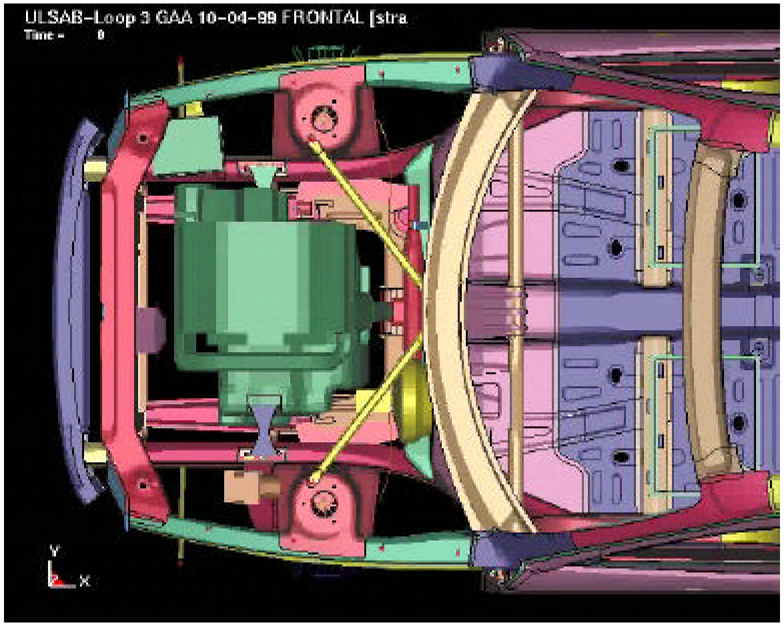
Original ULSAB design uses quasi-static data data only

Strain Rate Sensitivity Study

Model based on quasi-static material data



Model based strain-rate sensitive material data

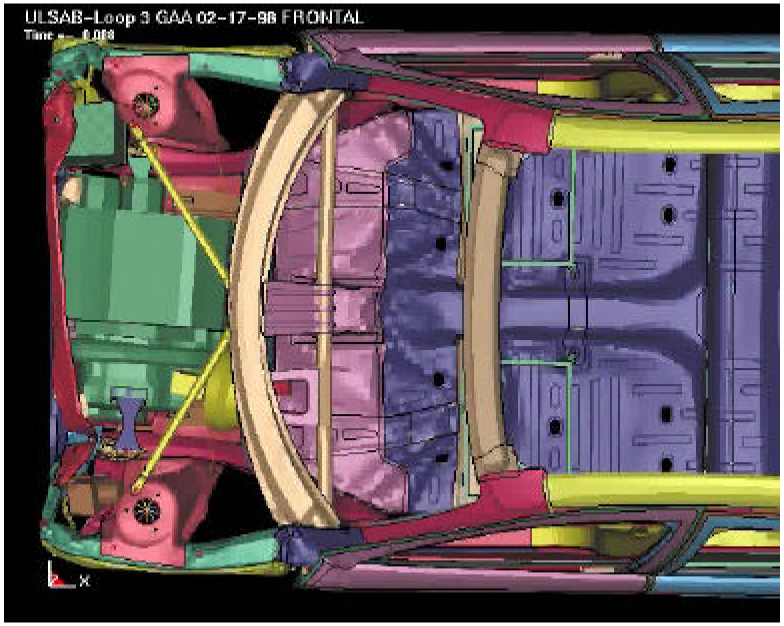


Modeling shows reduced crush distance for strain-rate sensitive material model

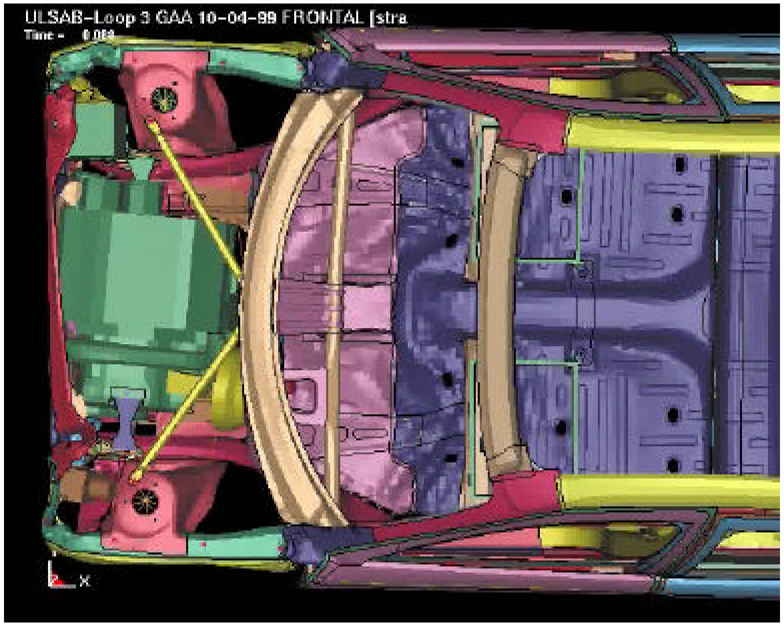
ornl
Bringing Science to Life

Strain Rate Sensitivity Study

Model based on quasi-static material data



Model based strain-rate sensitive material data



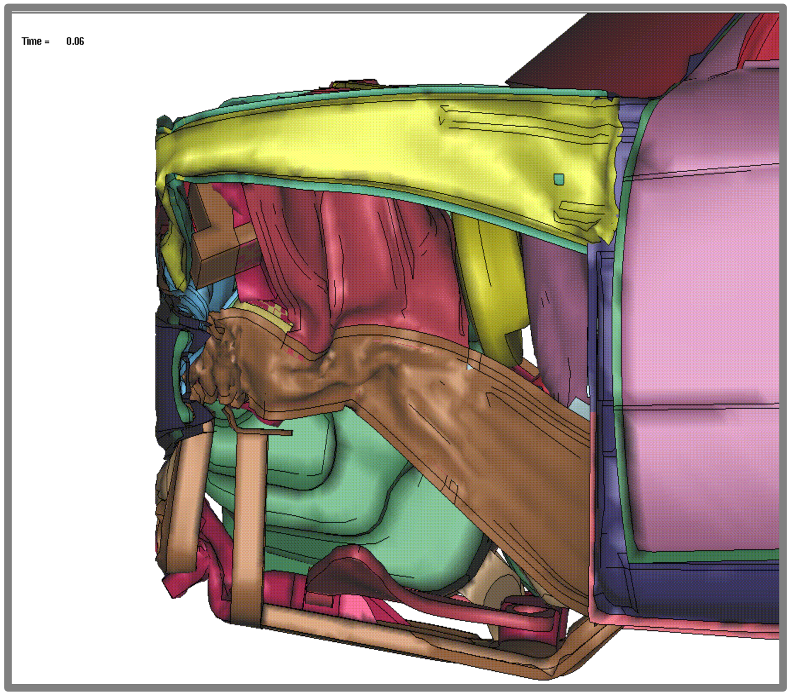
Modeling shows reduced crush distance for strain-rate sensitive material model

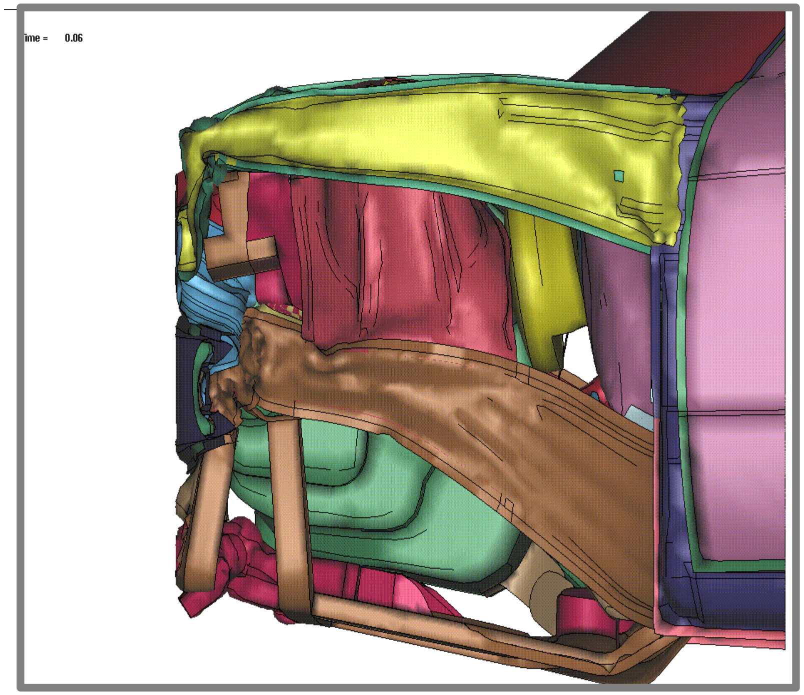
ornl
Bringing Science to Life

Strain Rate Sensitivity Study

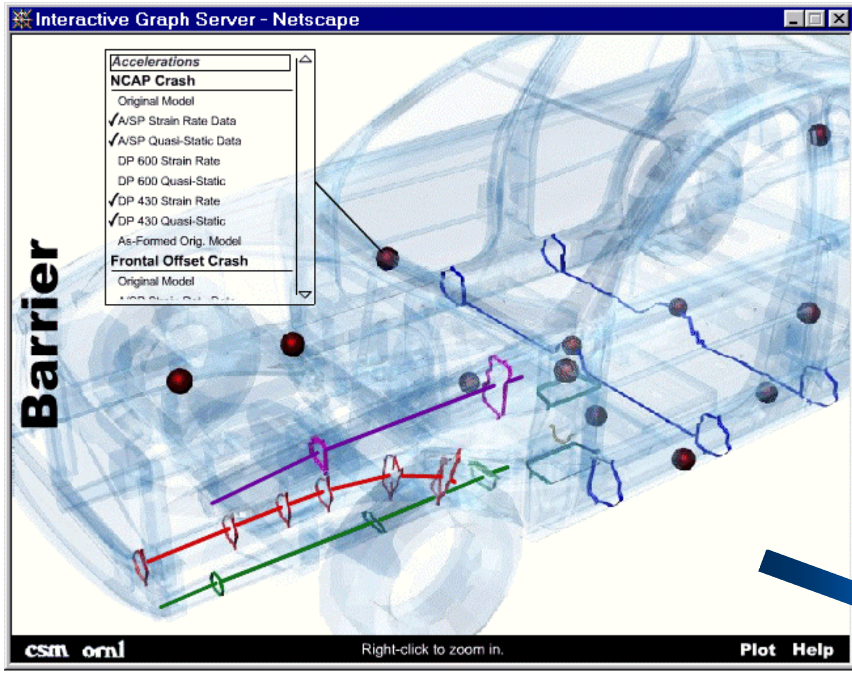
Model based on quasi-static material data

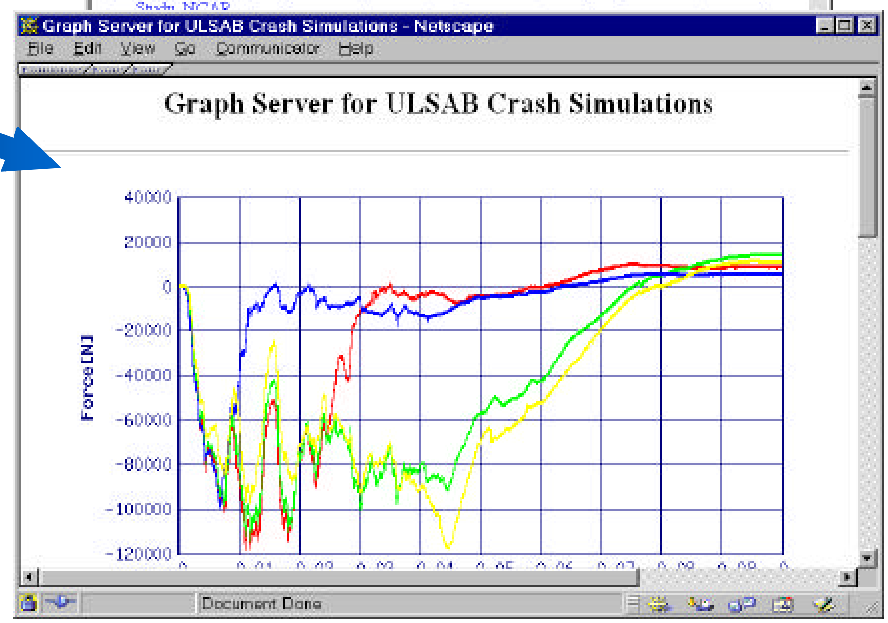
Model based strain-rate sensitive material data





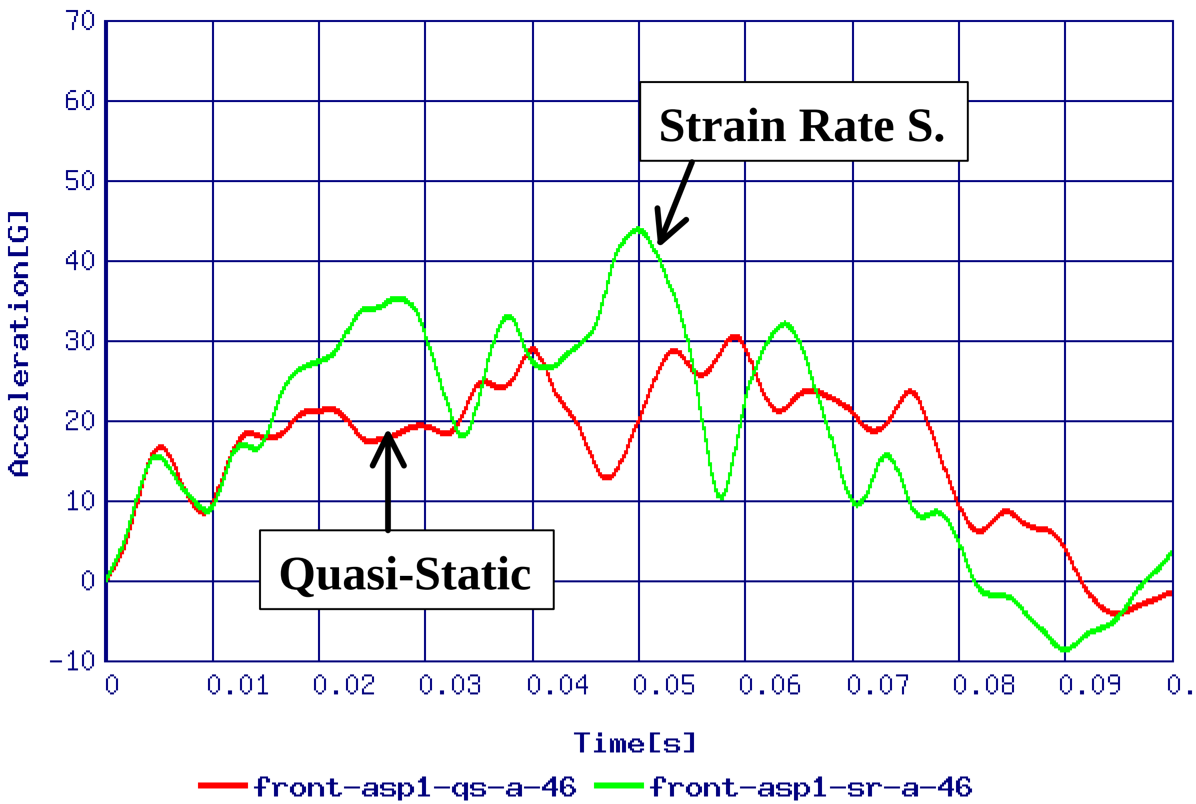
Complexity of the model requires multiple data sets to be analyzed and compared





Interactive Web-based system was developed for model analysis and collaboration between AISI and ORNL

Crash Simulation Results

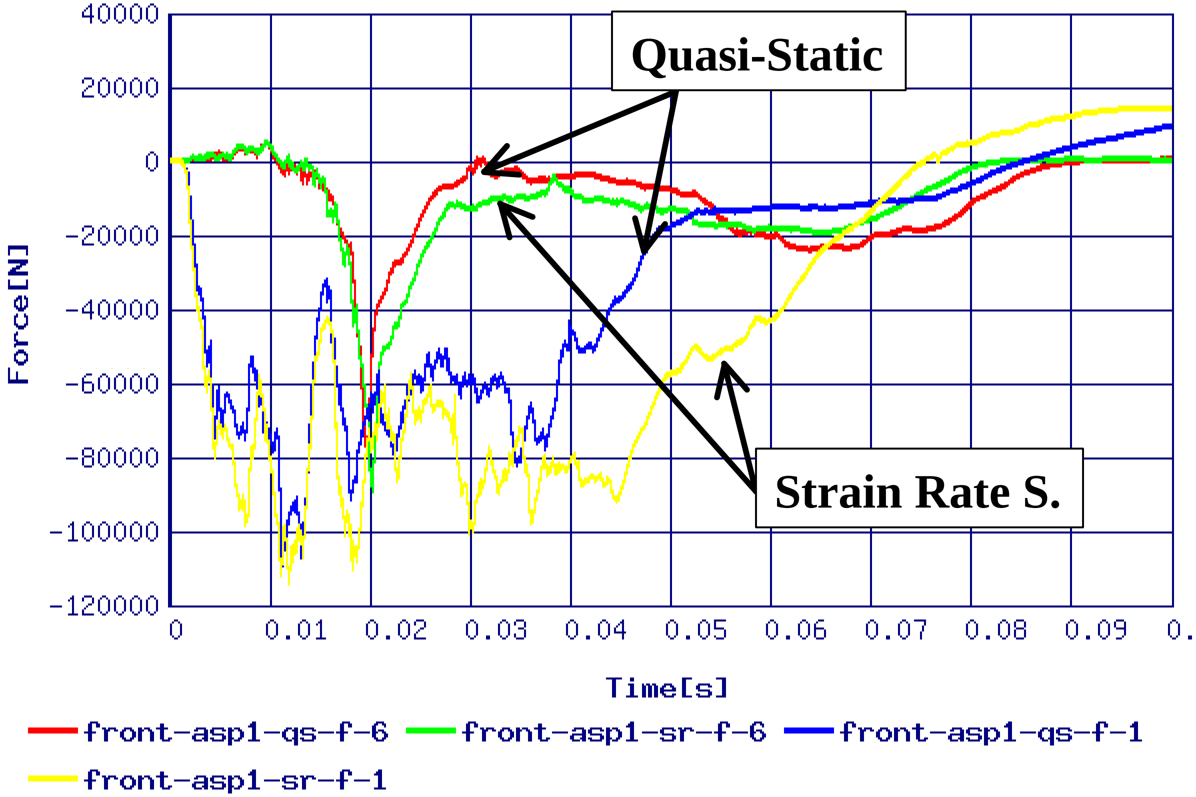


Graph shows acceleration in the center of the vehicle

- green: model with strain rate sensitivity
- red: model without strain rate sensitivity

Bringing Science to Life

Force Distribution in Front Rails



Strain rate sensitivity results in different dynamics of load transfer

ornl
Bringing Science to Life

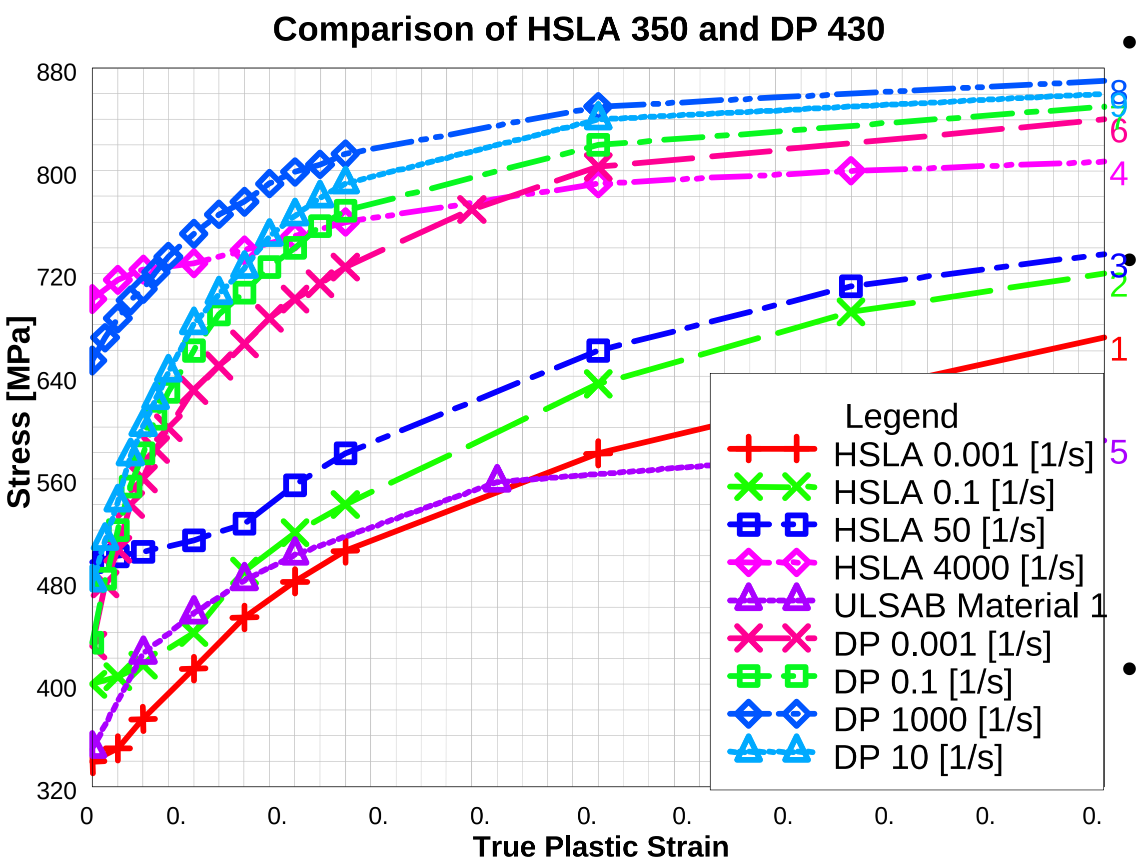
Strain Rate Study Conclusions

- Simulations show influence of strain rate effects on ULSAB modeling
  - Crush distance is reduced with introduction of strain rate sensitivity in the model
  - Dynamics of load transfer can change with introduction of strain rate sensitivity
  - **Modeling can make a big role!**
  - New research project has been initiated with A/SP on modeling impact collapse of steel structures
- Incorporation of strain rate material properties is important for accurate modeling and ultimately for light-weighting

Material Substitution Studies

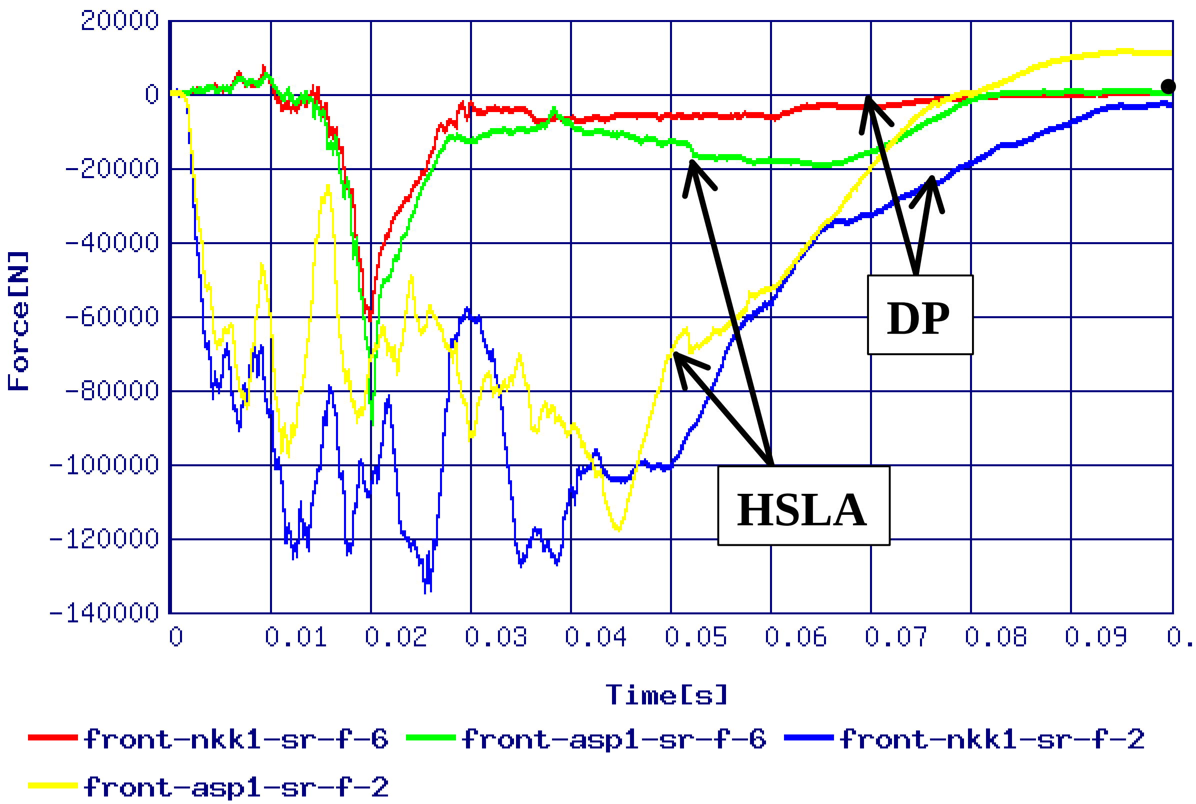
ornl
Bringing Science to Life

HSLA350 – DP430 Material Substitution



- Materials have similar yield point
- Strain hardening and strain rate sensitivity is significantly different
- Current ULSAB design is based on yield value only

Force Distribution in Front Rails



- Strain rate sensitivity results in different dynamics of load transfer

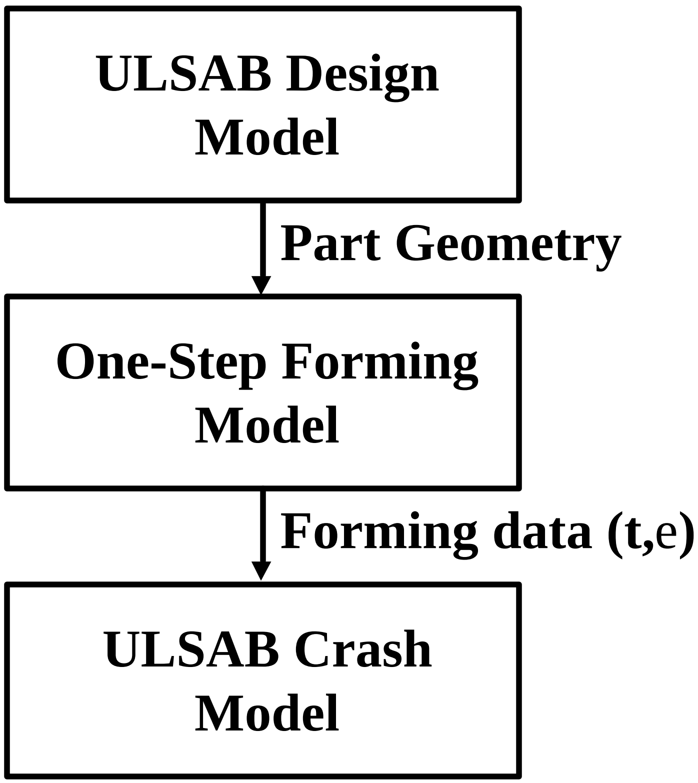
Substitution Study Conclusions

- Simulations show influence of difference in strain rate hardening between different designs
  - Crush distance is reduced for DP steel design
  - Dynamics of load transfer changes between HSLA and DP designs

Effects Part Forming on Vehicle Performance

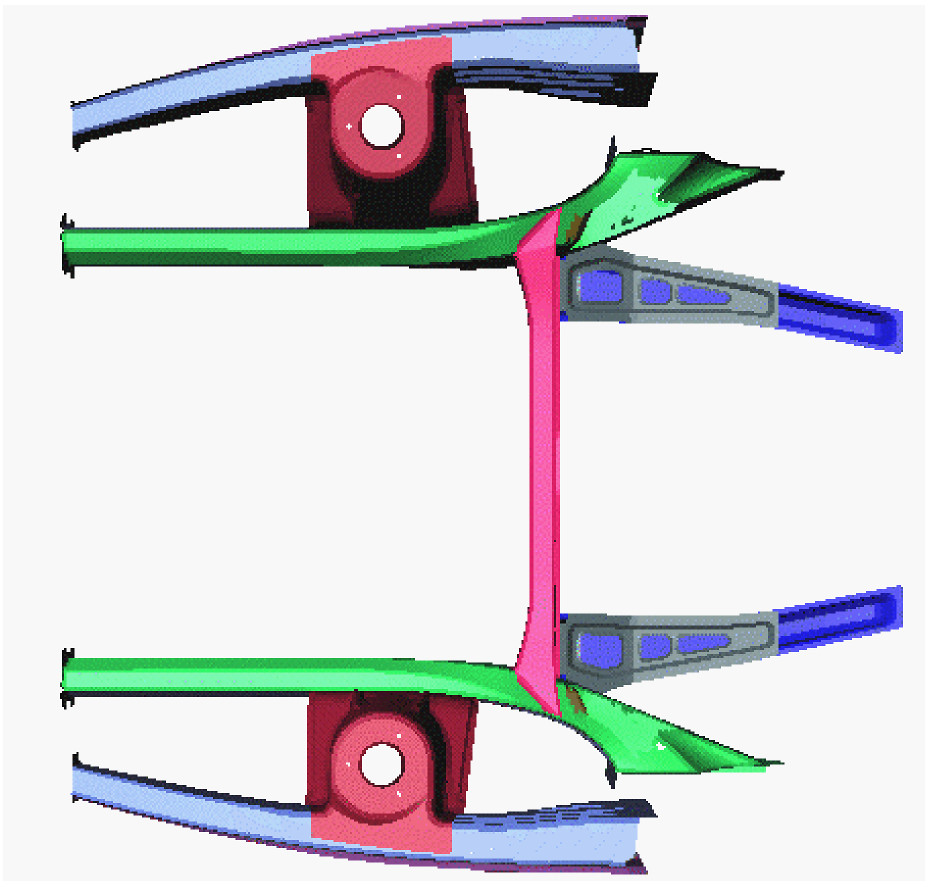
ornl
Bringing Science to Life

Incorporation of Forming Data into Crash Model



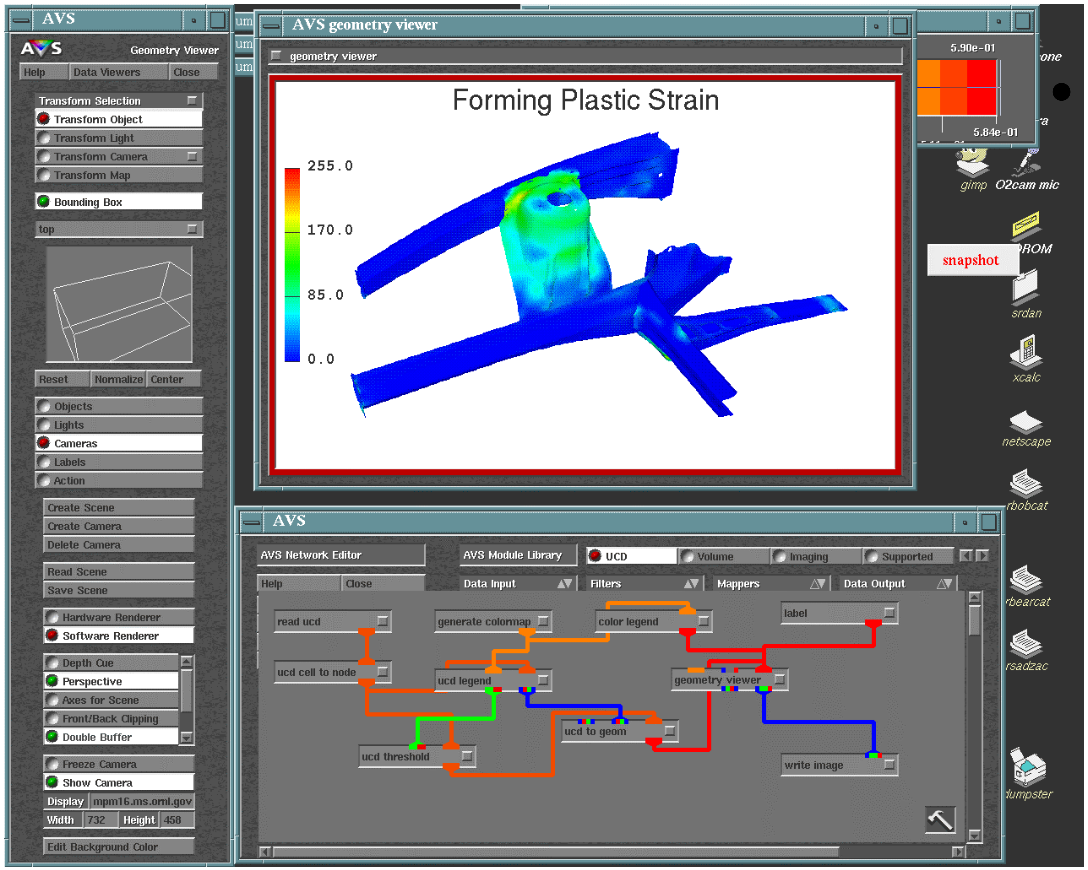
- One-Step forming was done by AISI member companies
- Forming data sent to ORNL
- ORNL incorporated forming data into crash model and performed simulations

Analyzed Parts



- Main front crash structure
- Currently does not include subframe
- Forming data consists of thickness change and plastic strain

Forming Simulations



Forming results are currently analyzed and preliminary crash simulations are under way

Future Work

- Finalize impact simulations to evaluate ULSAB compatibility with vehicles representing the current U.S. car fleet
- Finalize forming and crash simulations with as-formed part properties
- Evaluate effects of forming on performance
- Document developments and findings of the project

Project Deliverables and Impact on Industry

- Advancement in predictive modeling capabilities of high strength steels to aid in accelerated vehicle design development
- Integration of material processing into structural simulation model
- Evaluation of influence of forming conditions of high strength steels on vehicle impact properties
- Evaluation of compatibility of new vehicle design with the existing U.S. car fleet