Design Optimization with 3rd Generation AHSS

VALIDATION PHASE OF:
ICME (INTEGRATED COMPUTATIONAL MATERIALS ENGINEERING) APPROACH TO DEVELOPMENT OF LIGHTWEIGHT 3GAHSS VEHICLE ASSEMBLY

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Vesna Savic – General Motors
Hesham Ezzat – SMDI

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Project Overview

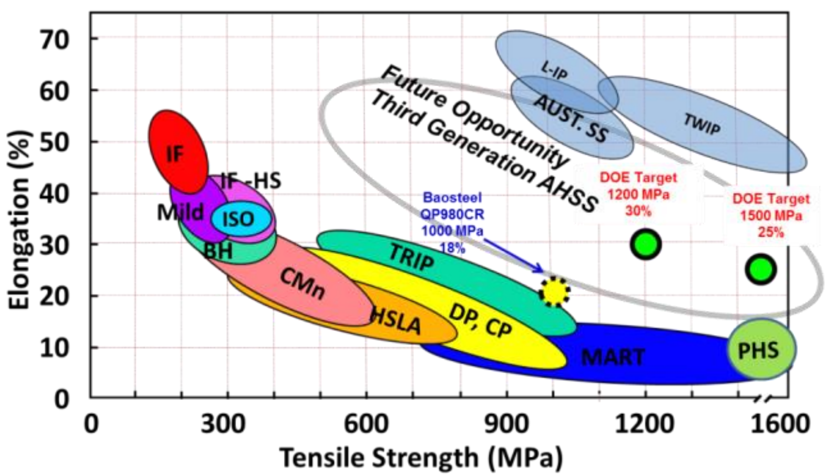
Sponsored by the U.S. Department of Energy (DOE)
Contract #: DOE DE-EE0005976
Contractor: United States Automotive Materials Partnership, LLC

<u>Project Timeline</u>

Start Date:	February 1, 2013
End Date:	January 31. 2017

<u>Project Budget</u>

DOE Share:	$6,000,000
Contractor Share:	$2,571,253



Project Overview

Project Contributors

Universities / National Labs

– Brown University
– Clemson University
– Colorado School of Mines
– Pacific Northwest National Lab
– Ohio State University
– University of Illinois Urbana-Champagne

Industry

– FCA US LLC
– Ford Motor Company
– General Motors Company
– ArcelorMittal
– AK Steel Corporation
– Nucor Steel Corporation
– EDAG, Inc.
– LSTC

Consortia

– Auto/Steel Partnership
– United States Automotive Material Partnership

Range of EDAG and FFT Services

EDAG

PRODUCT DEVELOPMENT

PRODUCTION SOLUTIONS

PLANT CONSTRUCTION

Design concepts

Project management

Control engineering and automation technology

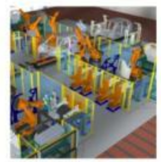
Vehicle development

Quality and documentation management

Production engineering

Function development

EDAG



Production process planning

Vehicle validation

IT services

Factory and logistics planning

Electrics / electronics

Process consulting

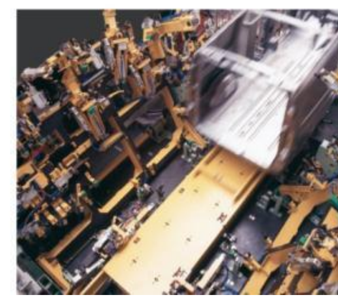
FEYNSINN die wissensWerker

Tooling and vehicle body systems

FFT

Turnkey systems, body in white and assembly

System technologies and products



Project Overview

<u>Project Goal</u>

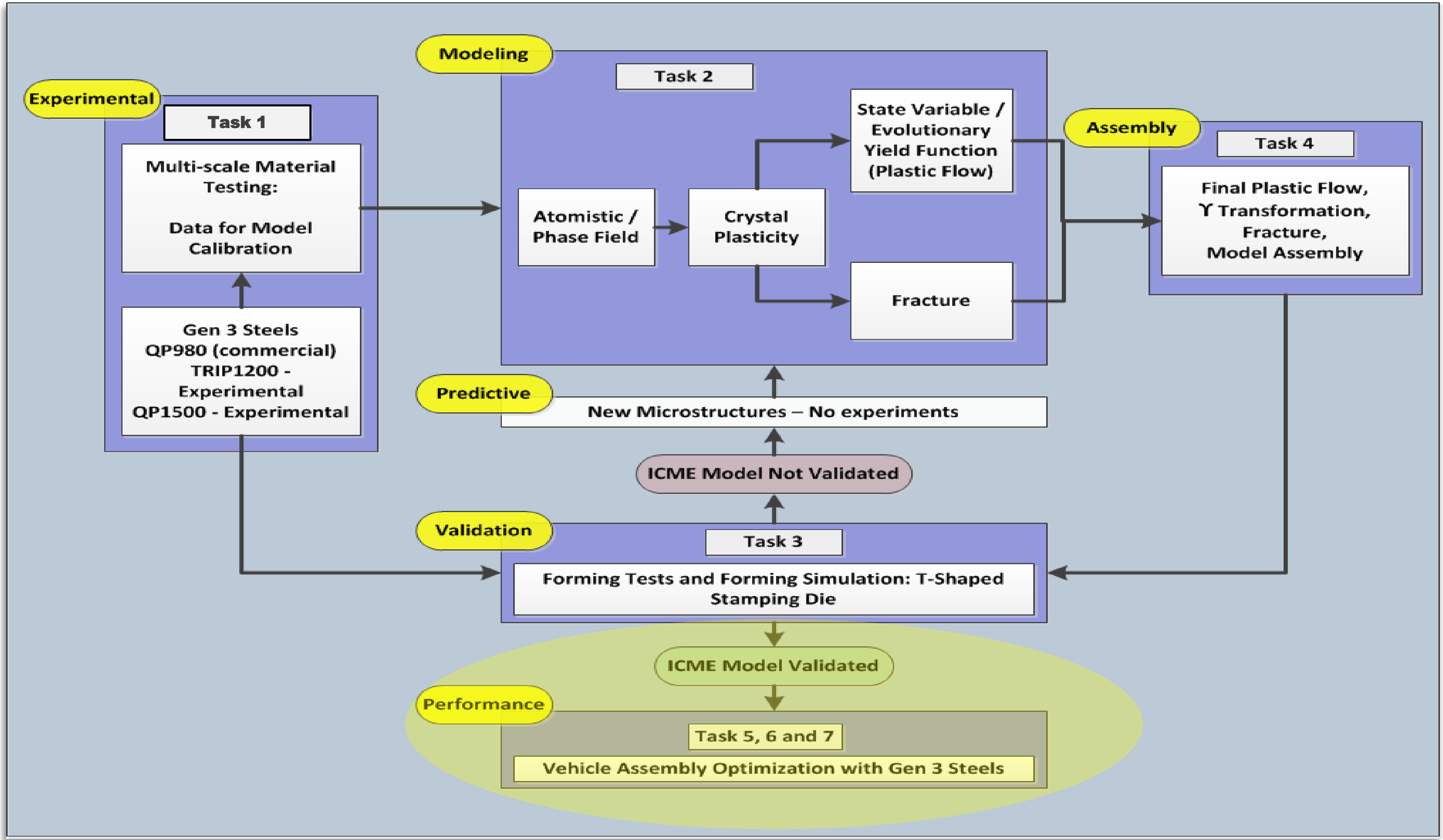
To reduce the lead time in developing and applying lightweight third generation advanced high strength steel (3GAHSS) by integrating material models of different length scales into an Integrated Computational Materials Engineering (ICME) model

<u>Project Objectives</u>

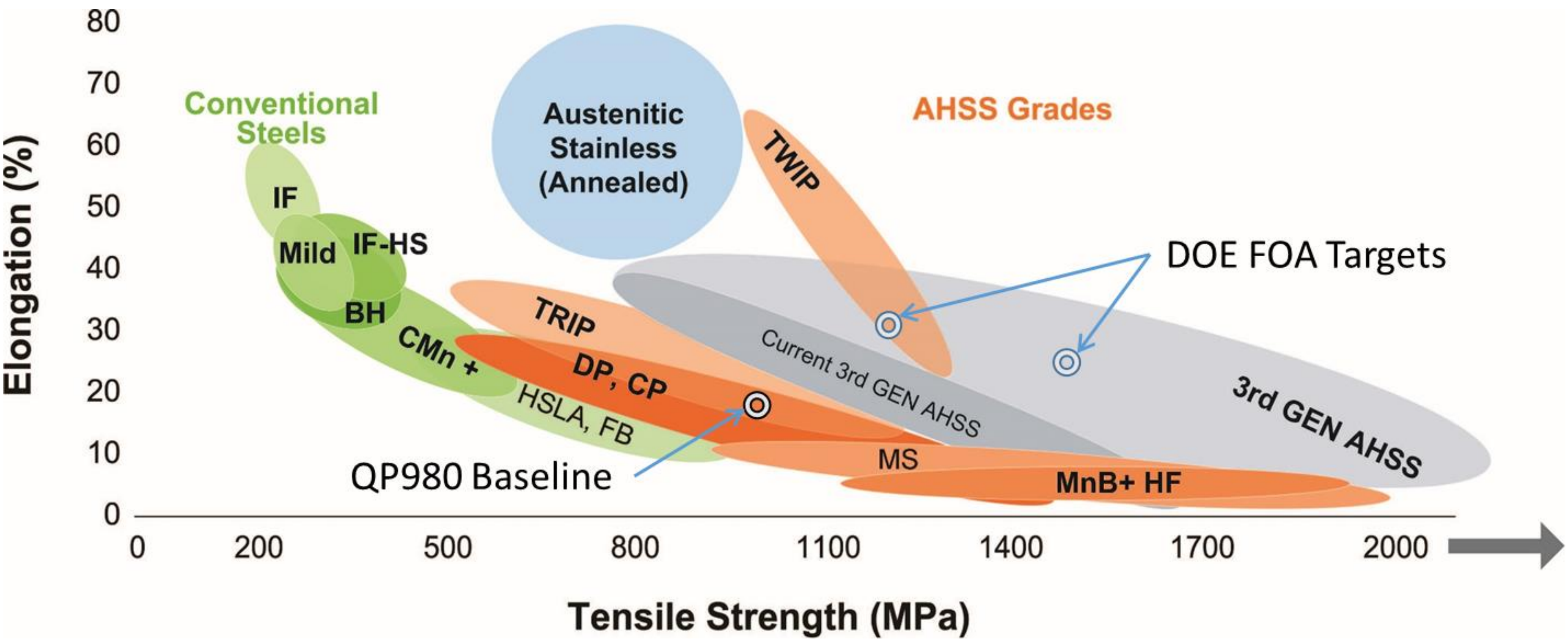
– Identify, validate (within 15% of experiments), and assemble length scale material models for predicting 3GAHSS constitutive behavior for component forming and performance
– Demonstrate the ability to reduce the mass of a vehicle structure* subassembly (consisting of a minimum of 4 parts) by 35% using the ICME 3G AHSS with a cost impact of no more than $3.18 per pound saved and without compromising structural performance .

** Assuming a 2006 or later vehicle*

Approach / Strategy



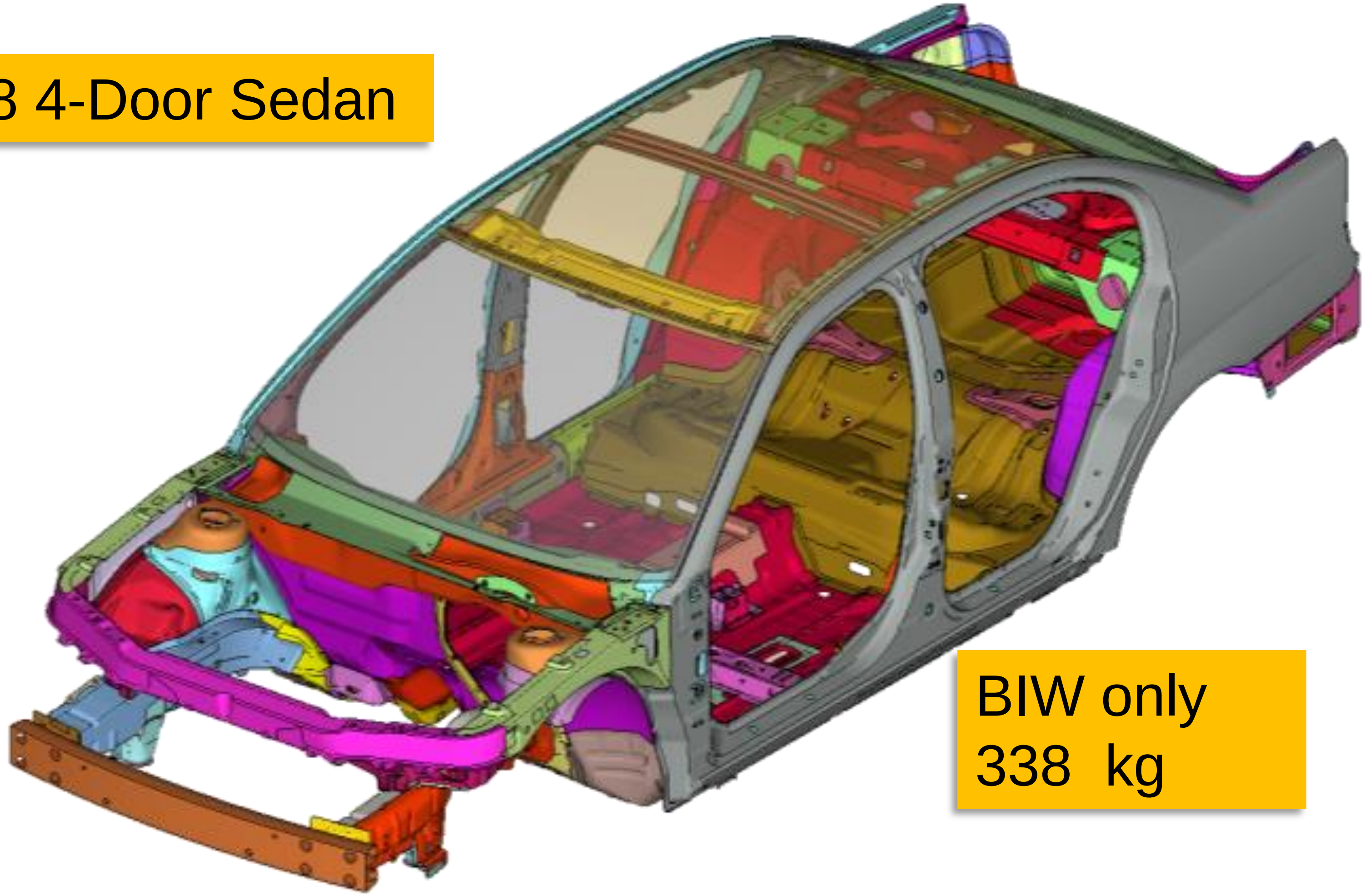
ICME Steel Grade Positioning



Ferrous Sheet Metal Type	Yield Strength MPa	Tensile Strength MPa	Total Elongation (Uniaxial Strain to Failure)	Uniform Elongation
High Strength, Exceptional Ductility	≥800	≥1200	≥30%	≥20%
Exceptional Strength, High Ductility	≥1200	≥1500	≥25%	≥8%

Baseline Vehicle Structure

2008 4-Door Sedan



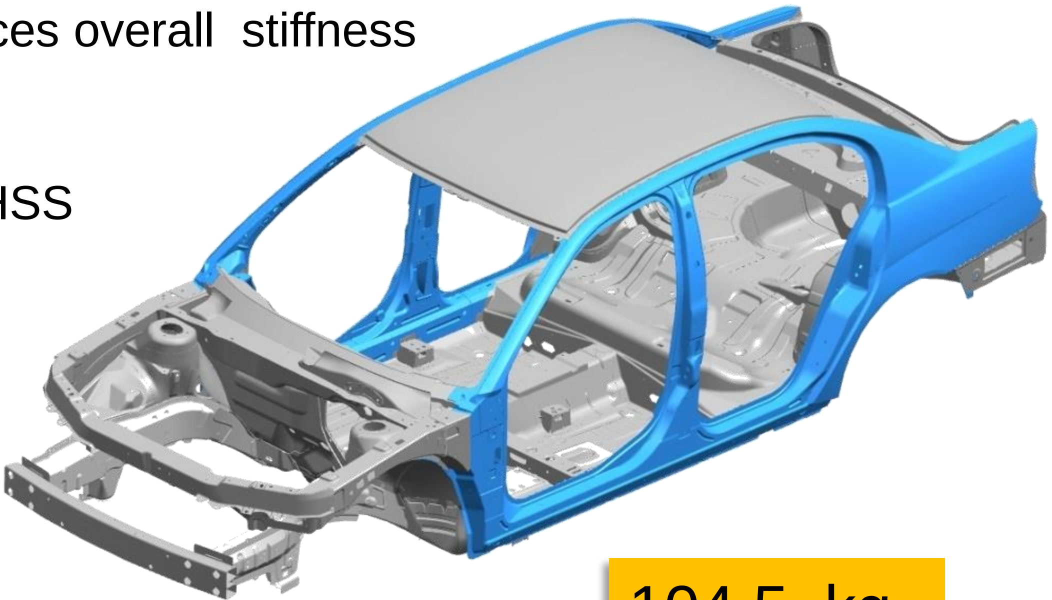
BIW only
338 kg

Baseline BIW FEA Model plus Fixed Glass and Front and Rear Bumper Beams

Selected Structure Assembly

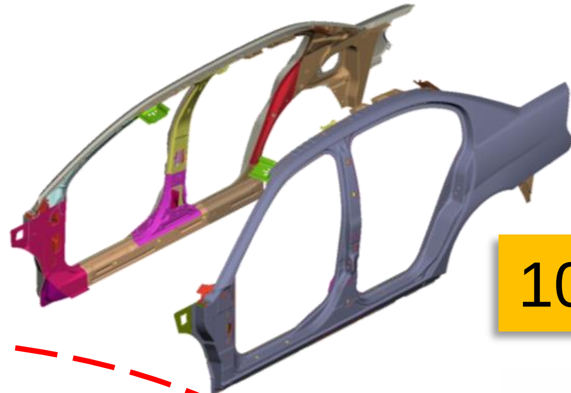
Body Side Assembly Selected for Optimization Study

1. Key structural assembly that influences overall stiffness and major crash load cases
2. Will benefit considerably from 3G AHSS applications
3. LWB One Piece Body side inner
4. Several reinforcements in joints and members
5. LH & RH Body Side Assemblies
   Mass around 105 kg (30% of BIW)



104.5 kg

Selected Structure Sub-assembly



104.5 kg

78.9 kg

Baseline Body Side Inner Assembly
Parts Included in Study

25.6 kg

Baseline Body Side Outer Panels
<u>Not included in the Study</u>

CAE Method

CAE Model

1. Includes BIW, Front and Rear Fixed Glass and Bumpers

2. FEA mesh density 5 mm body side to 10 mm other structure

3. All flanges assumed to be spot welded (35 mm pitch).

4. Parts to be assessed for formability and effect of strain hardening for crash load cases:
    a) Rocker Reinforcement
    b) B-Pillar Reinforcement
    c) Roof Rail Inner
    d) Front Body Hinge Pillar (FBHP) Inner

CAE Load Cases Assessed

1. Side Barrier
2. Side Pole
3. Front Impact
4. Rear Impact
5. Roof Crush
6. Seat Belt Anchorage Strength
7. Body Static Stiffness (Torsion / Bending)
8. Body Normal Vibration Modes

Preliminary baseline calibration crash studies were conducted in order to:

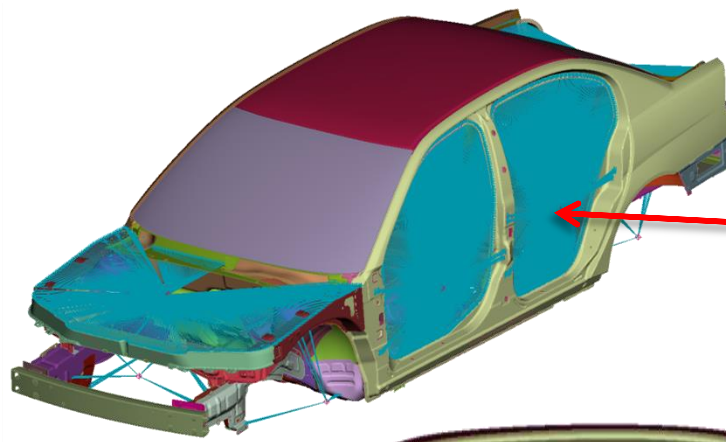
– Appropriately define the load case parameters to account for the analyses being focused only on body structure performance
– Establish structural performance targets for future optimization analyses using the 3G AHSS developed during the course of the project.

LSDYNA Model for Crash Performance

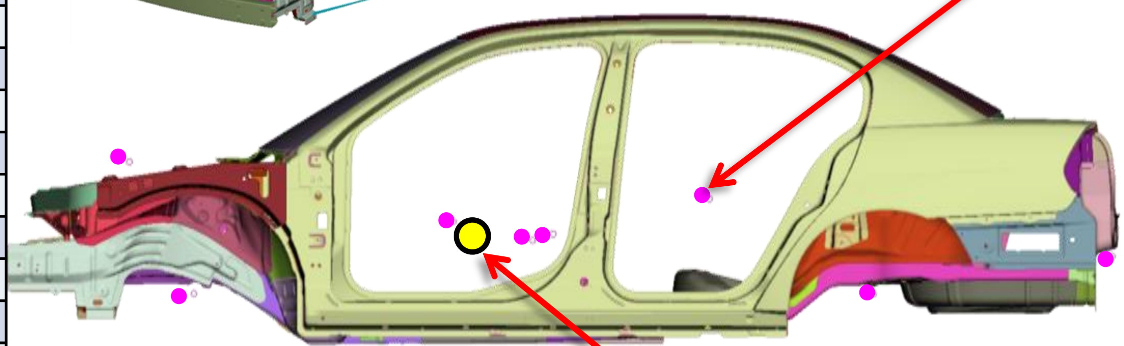
EDAG

Model System Masses

No	Sub System	Structure Mass (kg)
1	BIW	331.6
2	Glass	26.2
3	BIW Adhesives	5.0
4	Door Front Left	28.7
5	Door Front Right	28.7
6	Door Rear Left	26.1
7	Door Rear Right	26.1
8	Rear Suspension	129.7
9	Front Suspension	157.8
10	Powertrain	296.1
11	Steering Column	22.3
12	IP Beam	42.8
13	Front Seat Left	25.0
14	Front Seat Right	23.2
15	Hood	16.2
16	Deck Lid	20.0
17	Fuel tank	74.2
18	Radiator	37.9
19	Rear Bumper/Fascia	17.8
20	Rear Seat System	21.0
21	Occupants	140.0
22	Paint / Latches / Trims /Fenders	93.4
	TOTAL	**1589.8**



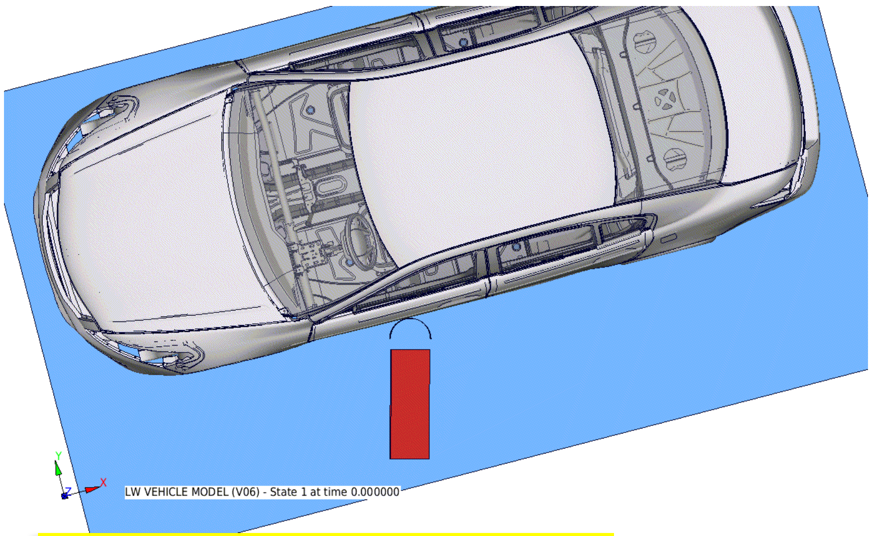
Subsystem represented as nodal masses (purple spots) , constraint with interpolation constraints (blue webs)



Vehicle COG
X 2827.7
Y 20.4
Z 514.5

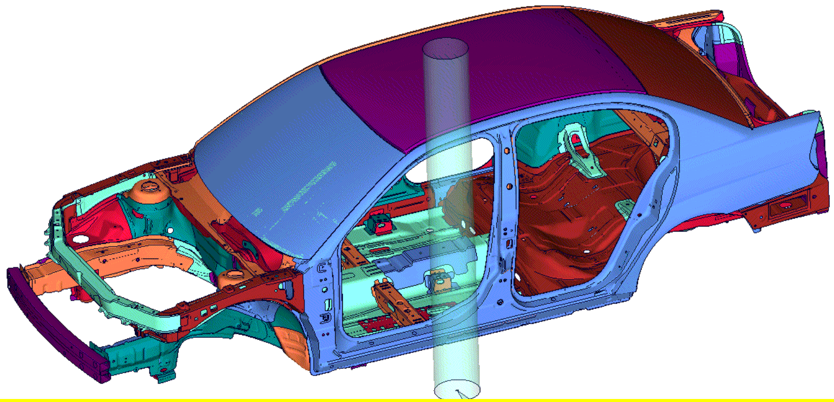
LSDYNA – Modeling Considerations

For crash load cases, initial velocities are reduced so that the new internal energy is 70% of the total internal energy using standard regulation velocities. This is because the model is for a BIW only (i.e., not a full vehicle system model). The 30% energy reduction is a judgment based on experience with prior projects.



Typical Crash System Model.
All subsystems represented

Pole Impact Speed 20mph

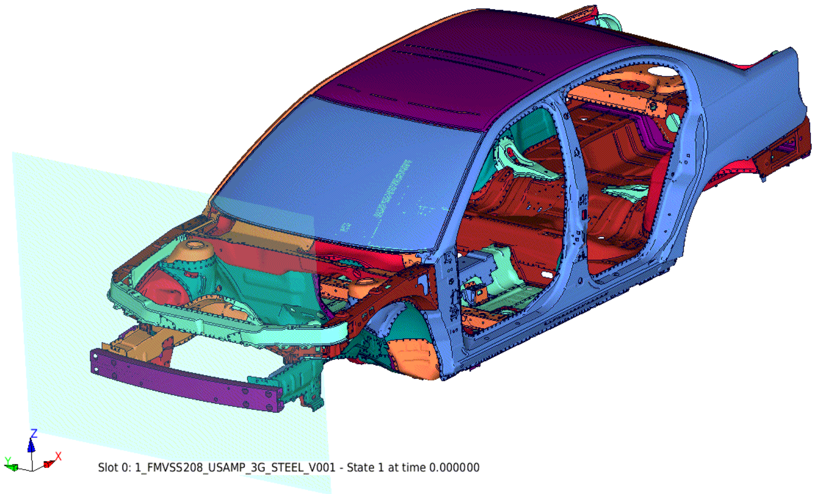


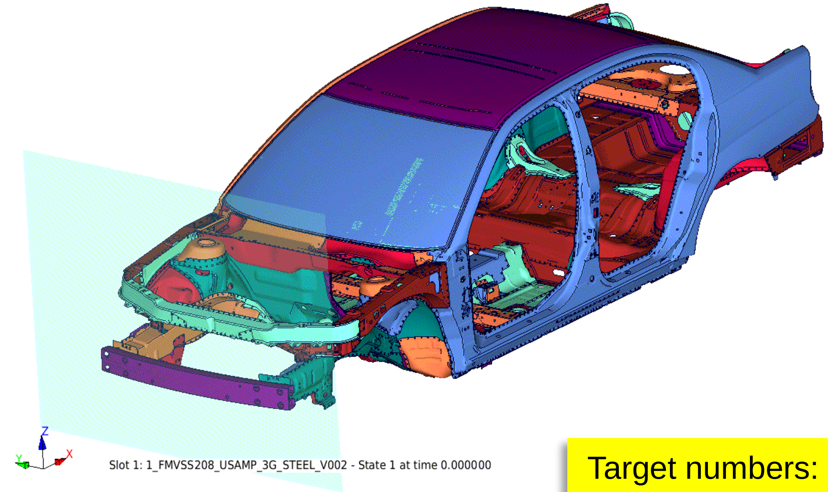
For the ICME study other sub-systems are represented by lumped mass only (i.e., sub-system structures are **NOT** included in the CAE model).
The speed is **LOWERED** to reduce the crash energy to achieve body structure intrusions of similar magnitude of typical Mid-Size Sedan vehicle

Pole Impact Speed 16.7mph

FMVSS208 – Front Rigid Barrier

EDAG



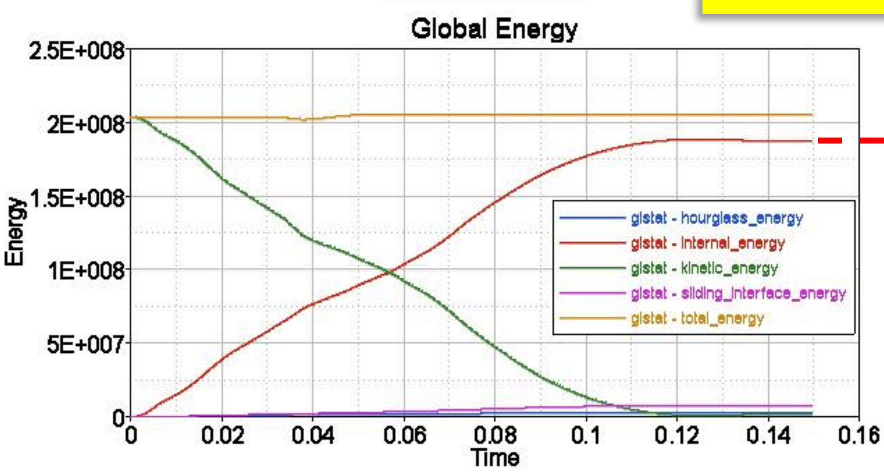


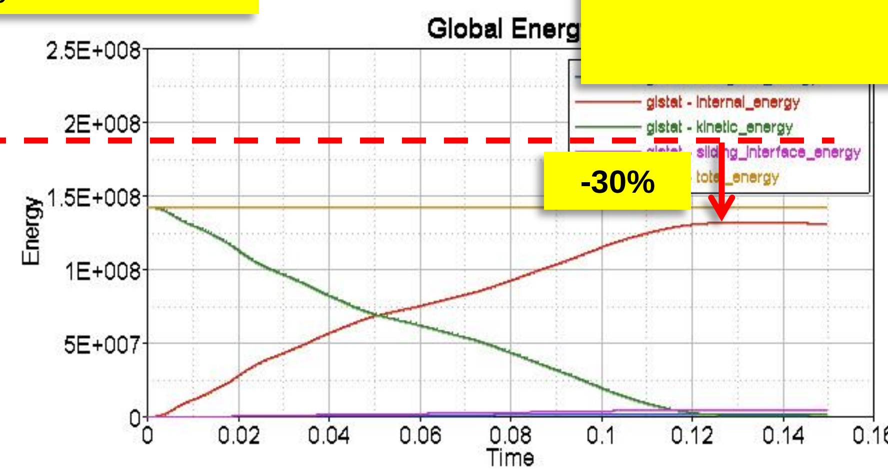
Target numbers:
- Dash Intrusion
- Pulse / TTZ / Dynamic Crush

35 mph

Initial speed lowered to reduce internal energy by 30%

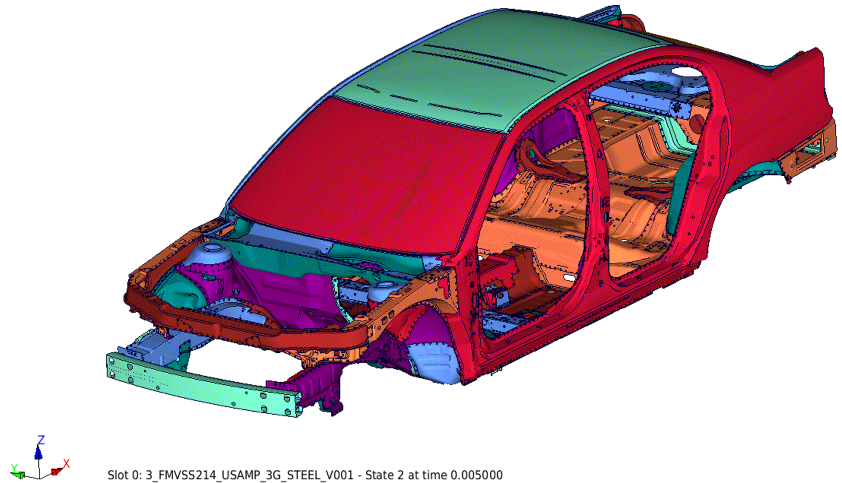
29 mph



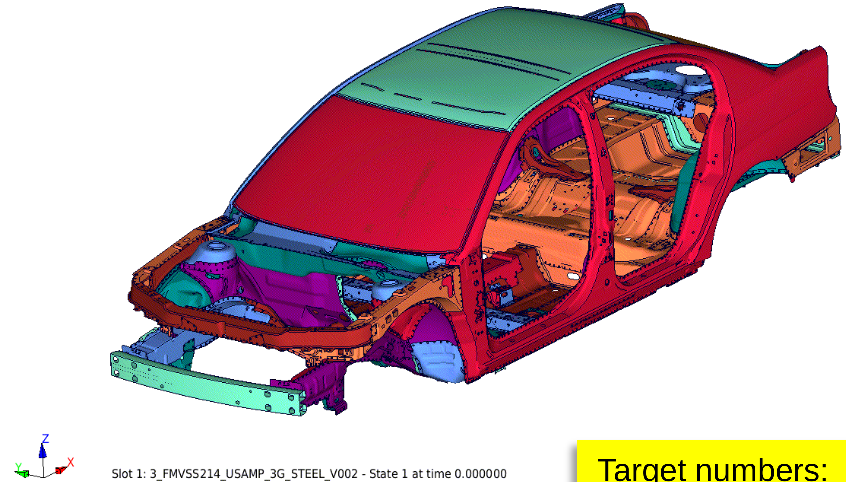


FMVSS214 – Side MDB

EDAG



Slot 0: 3_FMVSS214_USAMP_3G_STEEL_V001 - State 2 at time 0.005000



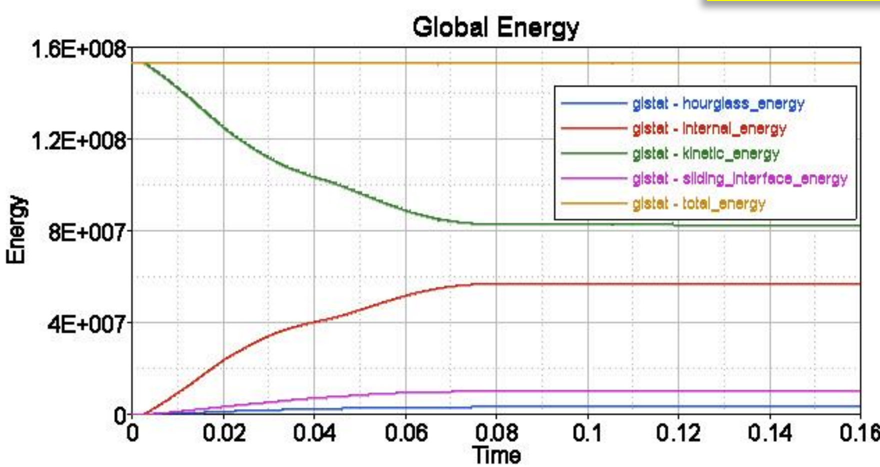
Slot 1: 3_FMVSS214_USAMP_3G_STEEL_V002 - State 1 at time 0.000000

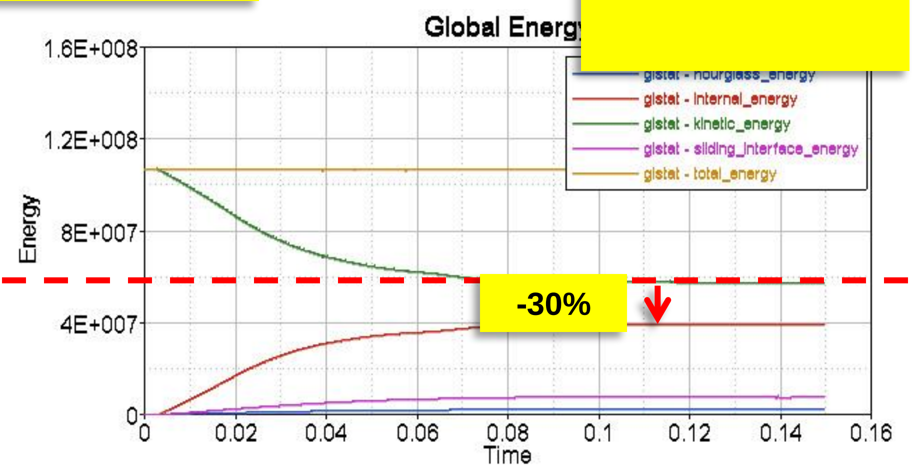
Target numbers:
- B-Pillar Velocity & Intrusion

33.5 mph

Initial speed lowered to reduce internal energy by 30%

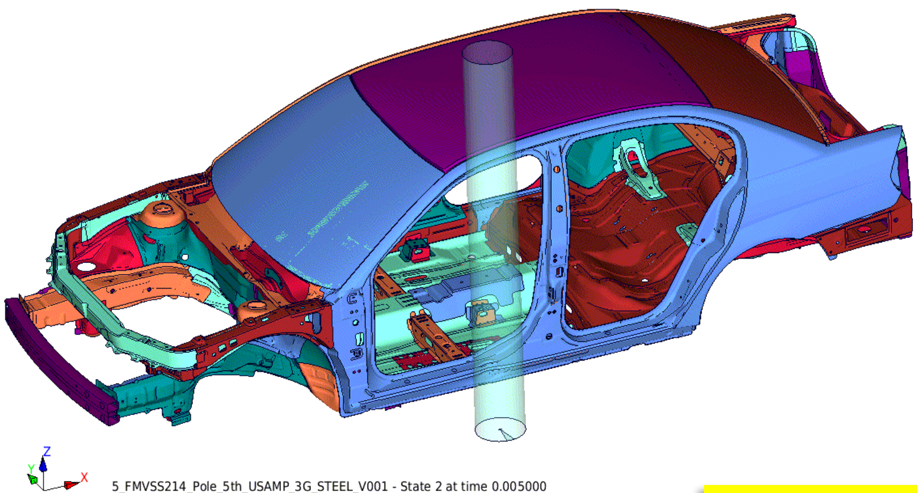
28 mph

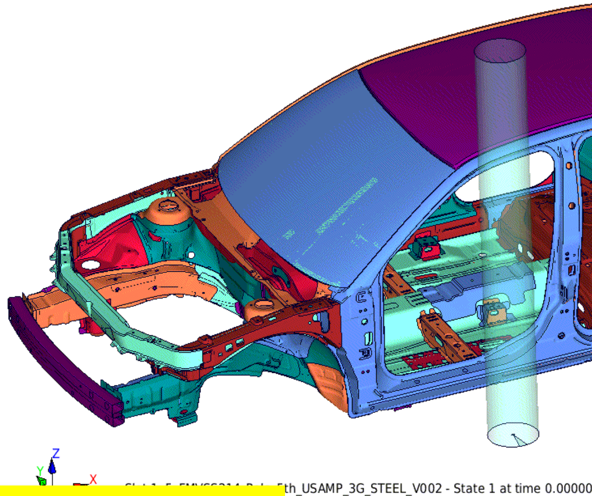




FMVSS214 – 5th Pole Impact

EDAG



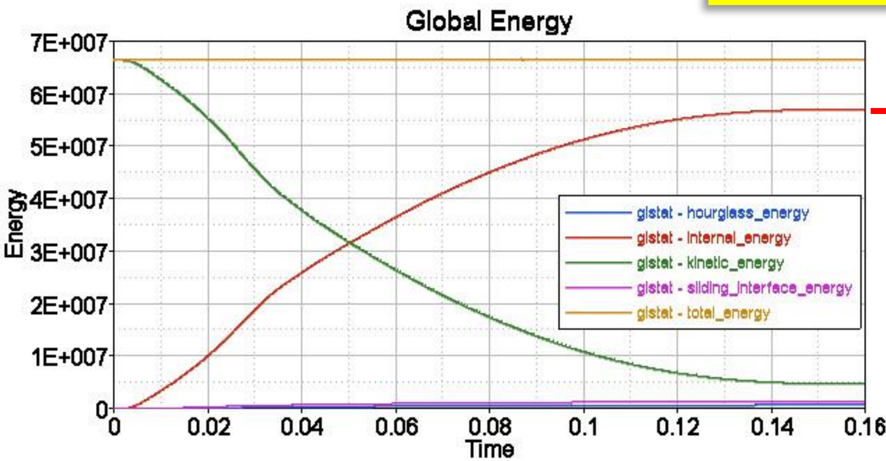


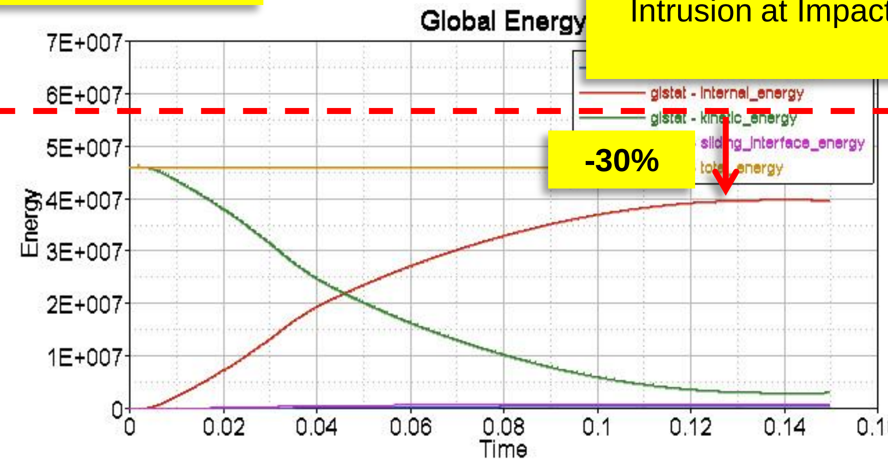
20 mph

Initial speed lowered to reduce internal energy by 30%

16.7 mph

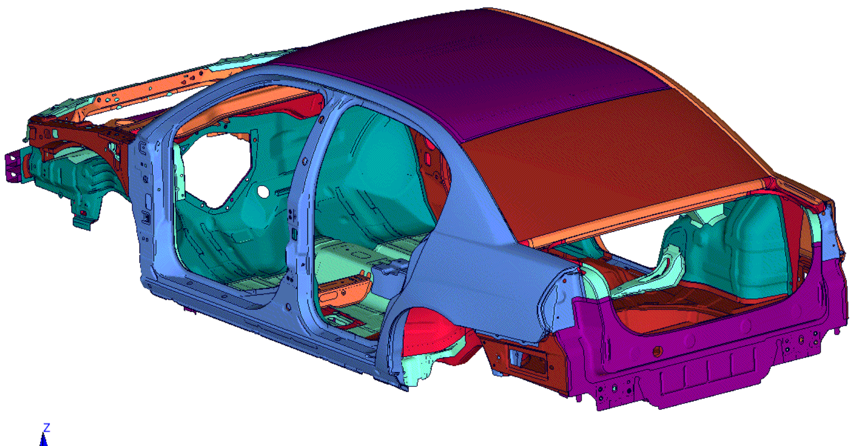
Target numbers:
- B-Pillar Velocity & Intrusion
- Roof Rail / Rocker Intrusion at Impact

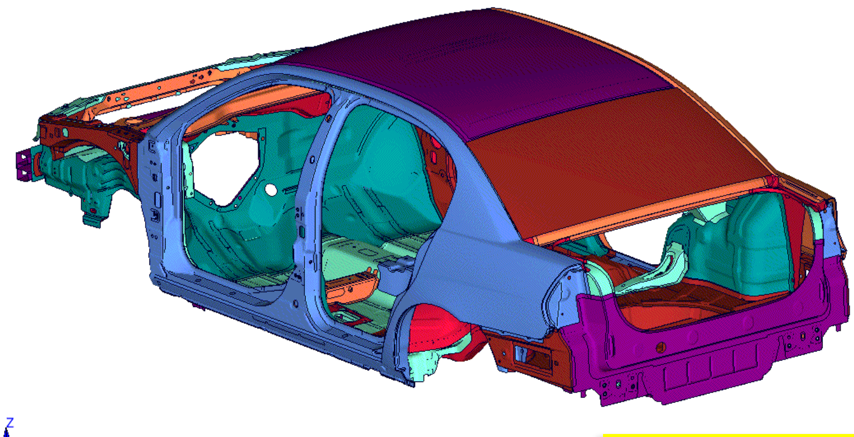




FMVSS301 – Rear Barrier

EDAG



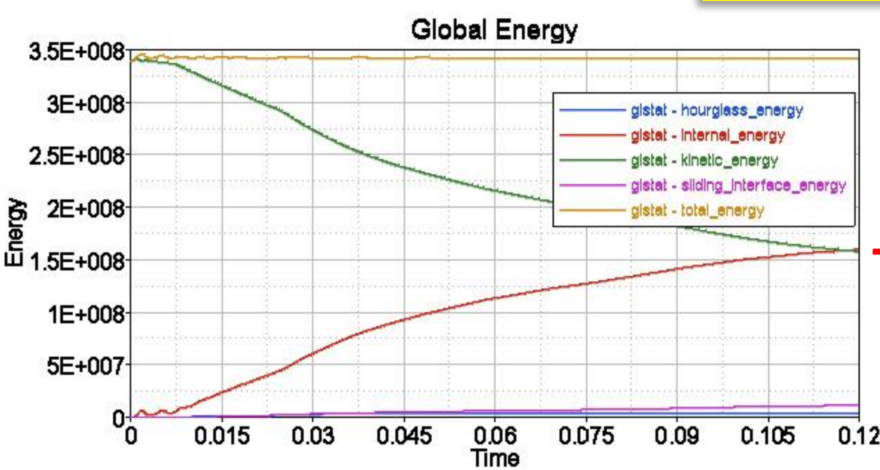


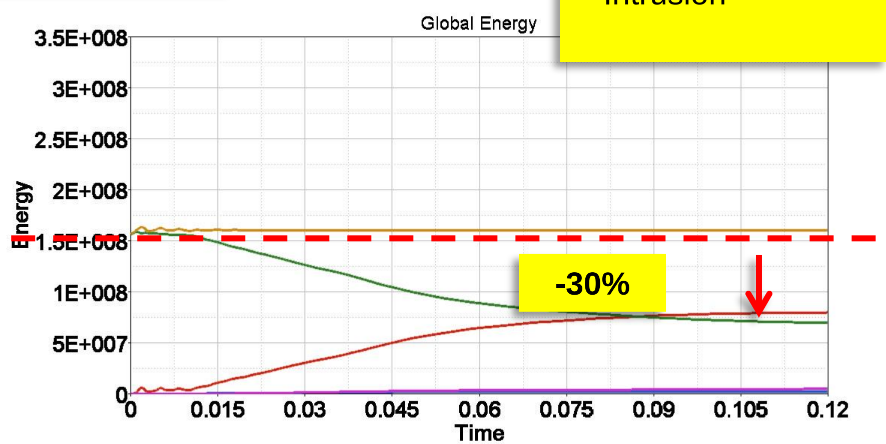
Target numbers:
- Rear Intrusion
- Pulse
- Beltline / Dog Leg Intrusion

50 mph

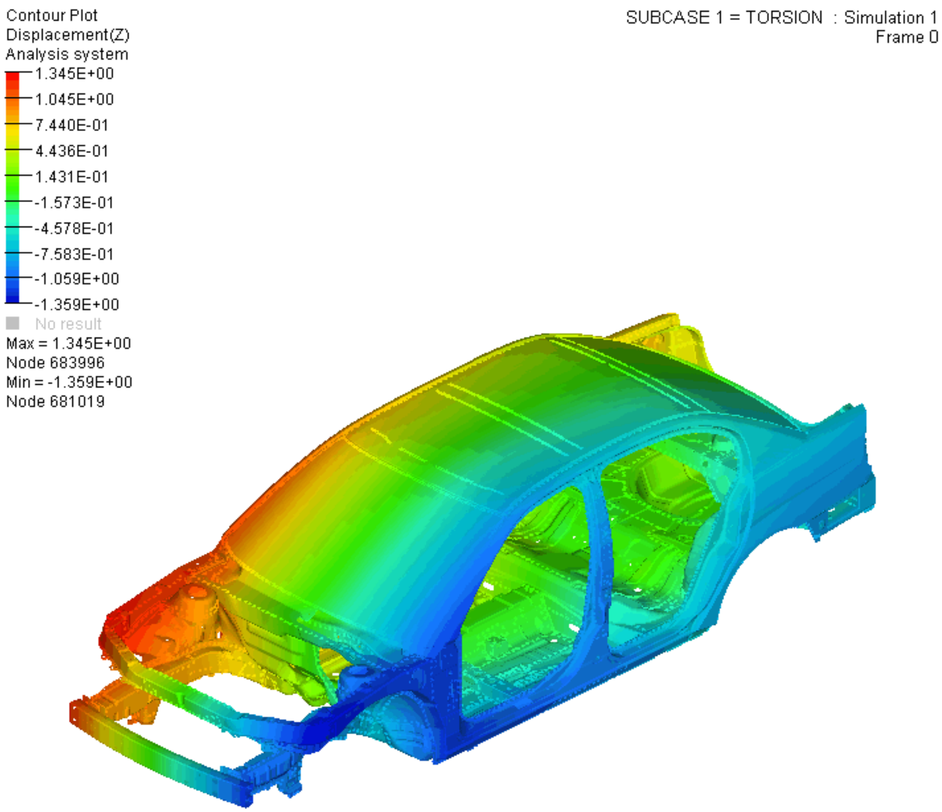
Initial speed lowered to reduce internal energy by 30%

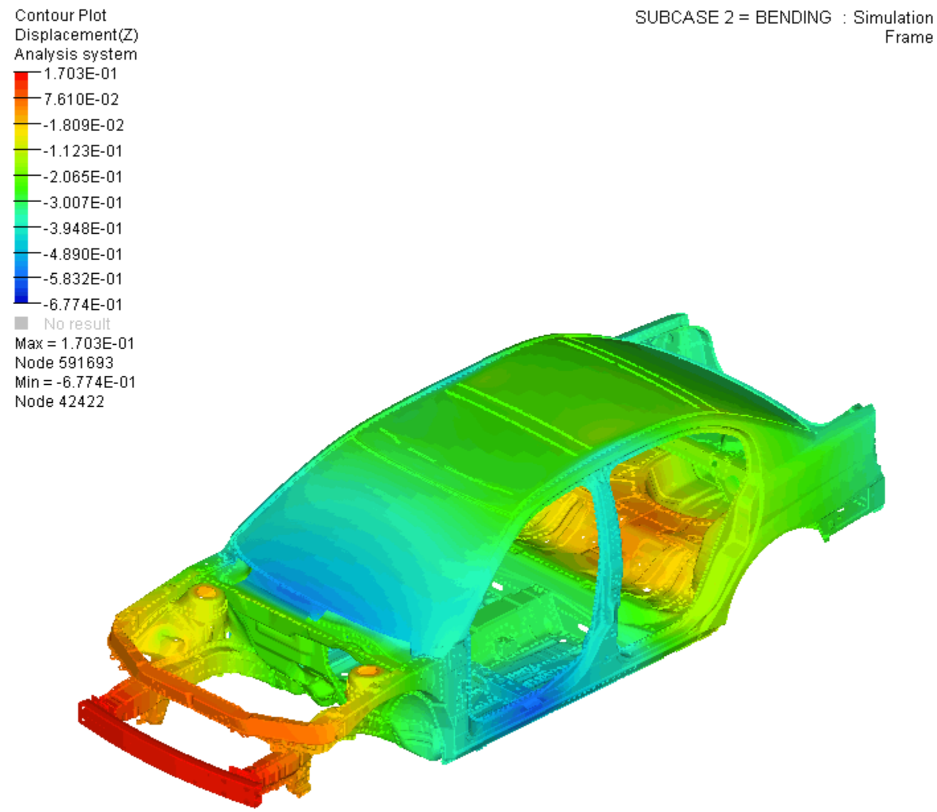
34 mph





Baseline Static Stiffness



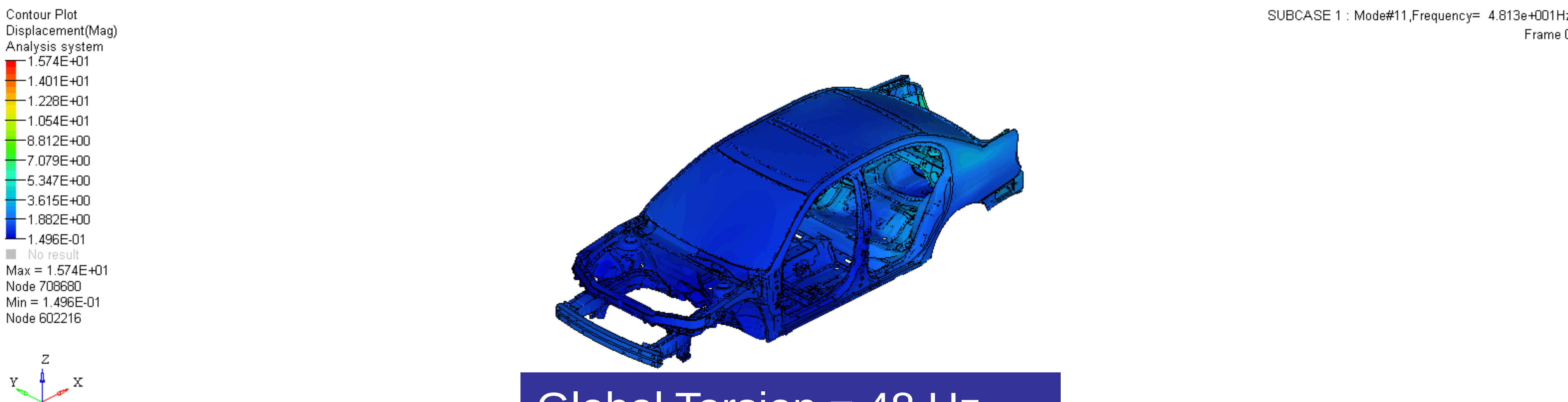


Torsion = 12.9 kN-m / deg.

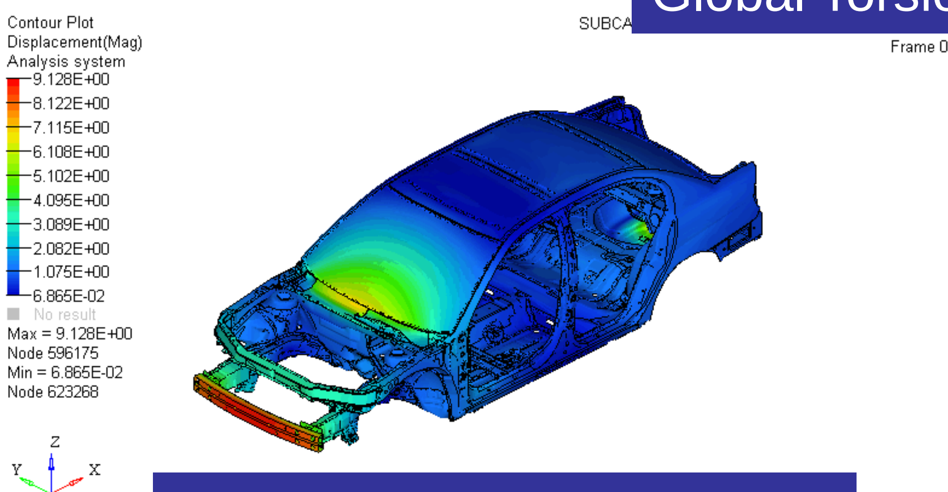
Bending = 7,707 N/mm

BIW Baseline Normal Modes

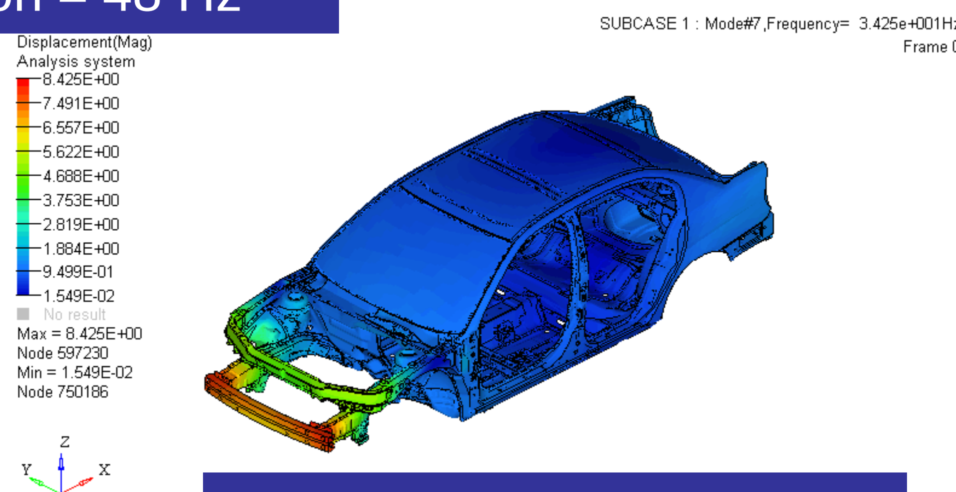
EDAG



Global Torsion = 48 Hz



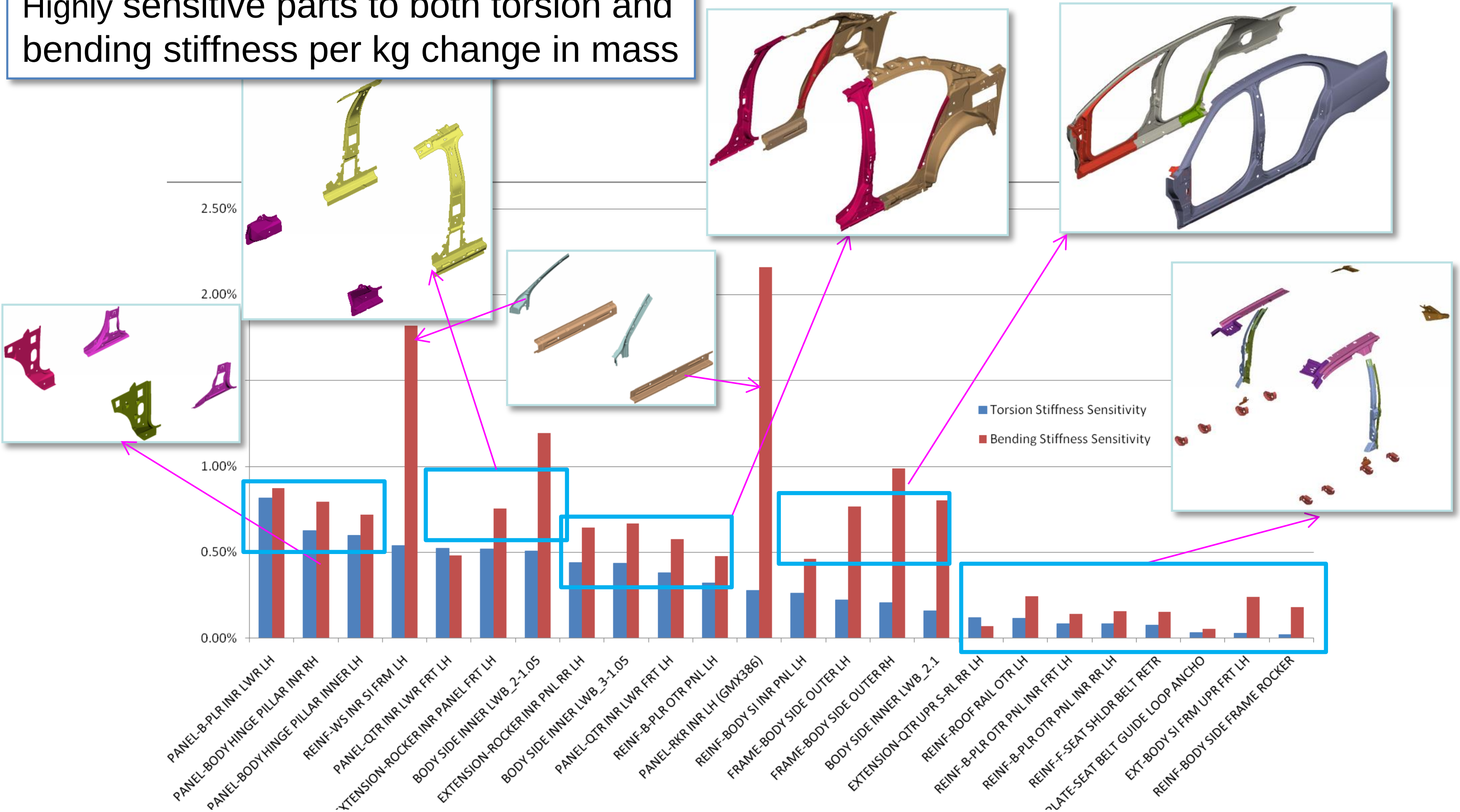
Vertical Bending = 46 Hz



Lateral Bending = 34 Hz

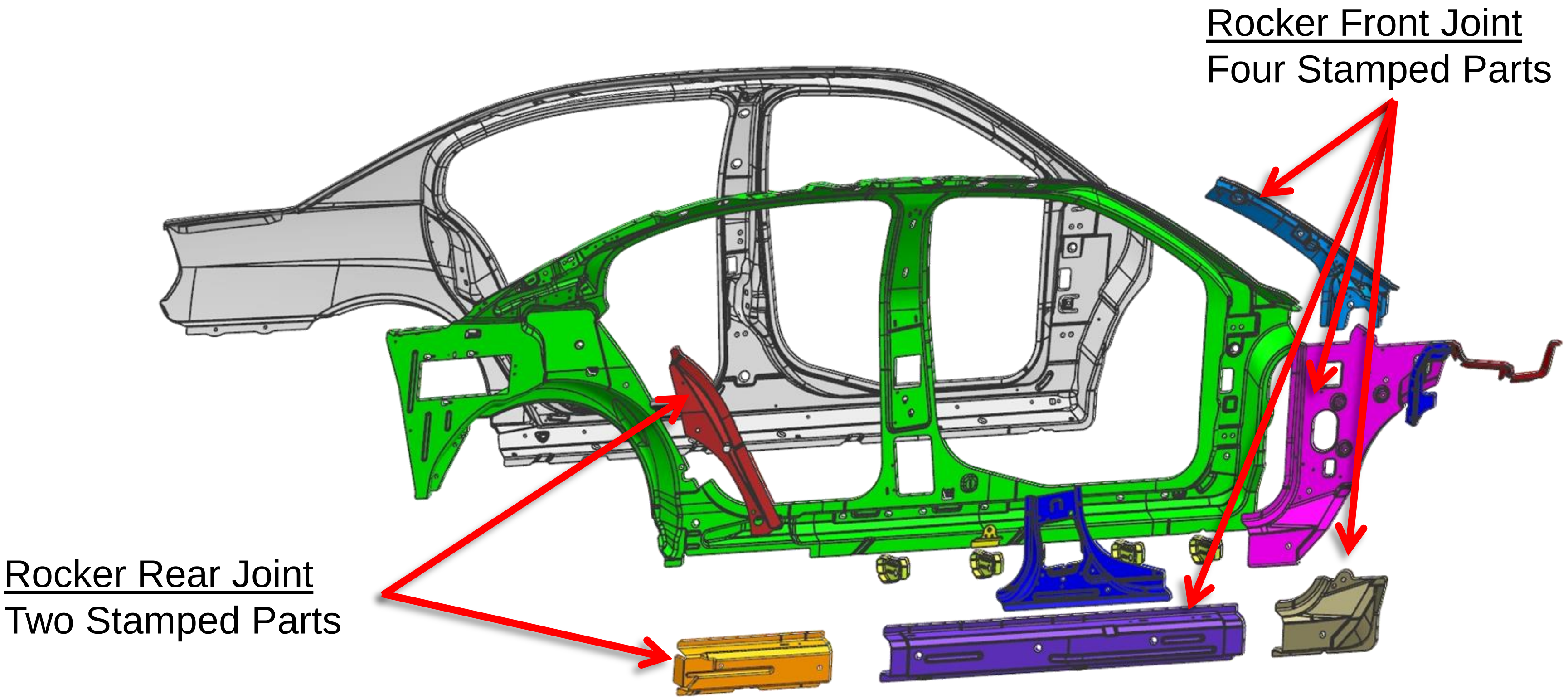
NVH Gauge Sensitivity Analysis

Highly sensitive parts to both torsion and bending stiffness per kg change in mass



Body Side Assembly – Baseline Construction

EDAG



Preliminary Optimization – Iteration 3

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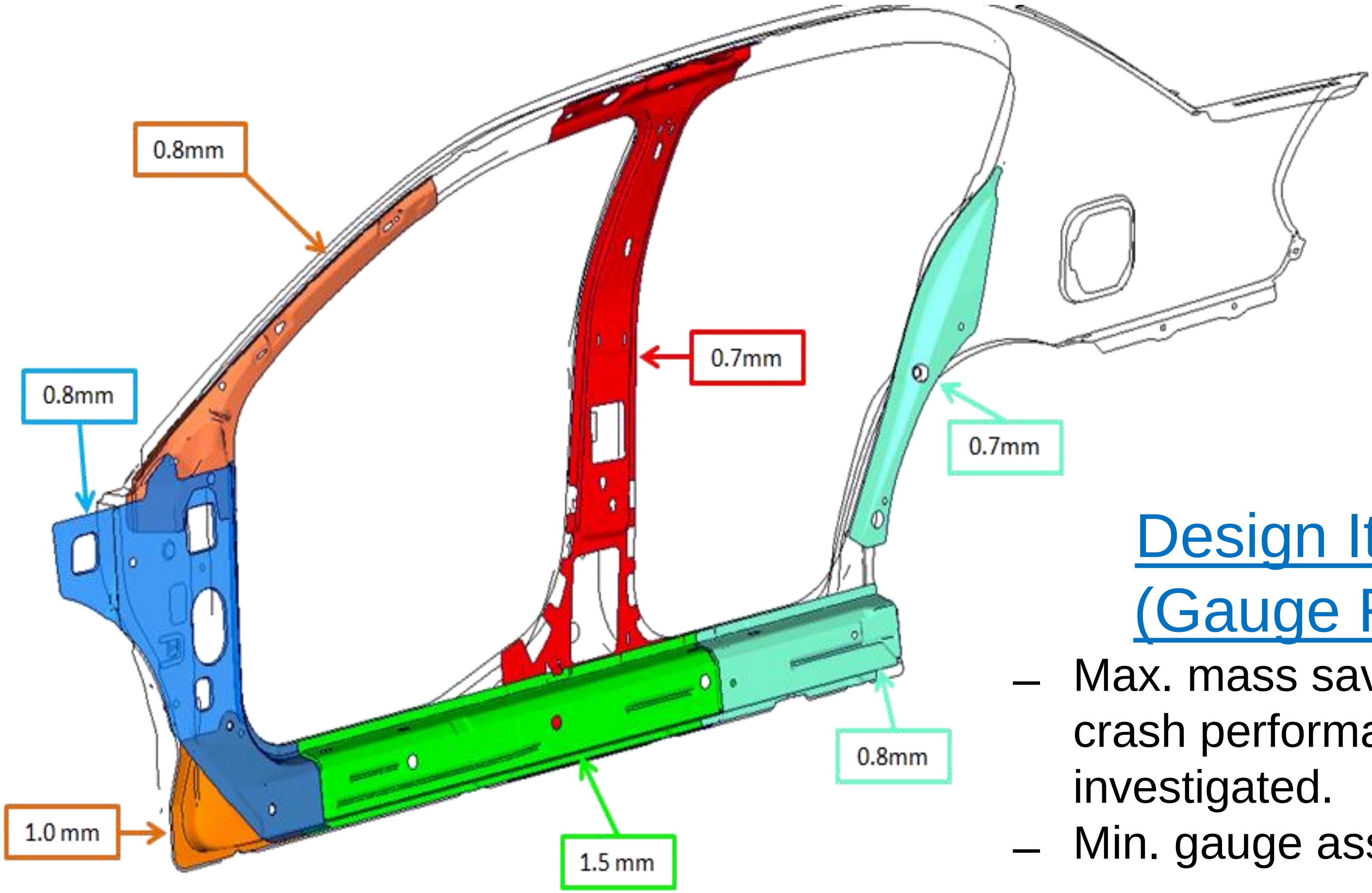


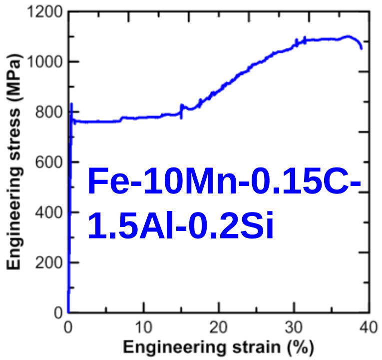
Design Iteration #3 (Gauge Reduction)

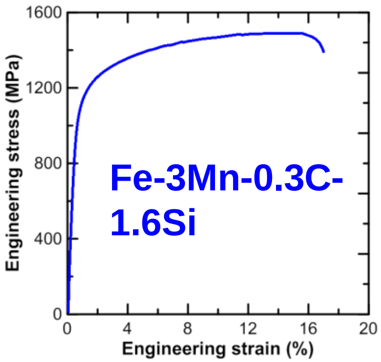
- Max. mass saving while meeting crash performance was investigated.
- Min. gauge assumed 0.6 mm

Results (Using Preliminary Grades) – Iteration 3

EDAG

Assembly	Baseline Mass (kg)	Optimized Mass (kg)	Delta Mass (kg)	Delta Mass %
Body Side Outer Panels	25.6	25.6	0	0%
Body Side (all other panels)	78.9	50.7	28.2	**35.8%**





No Change

Mild 140/270

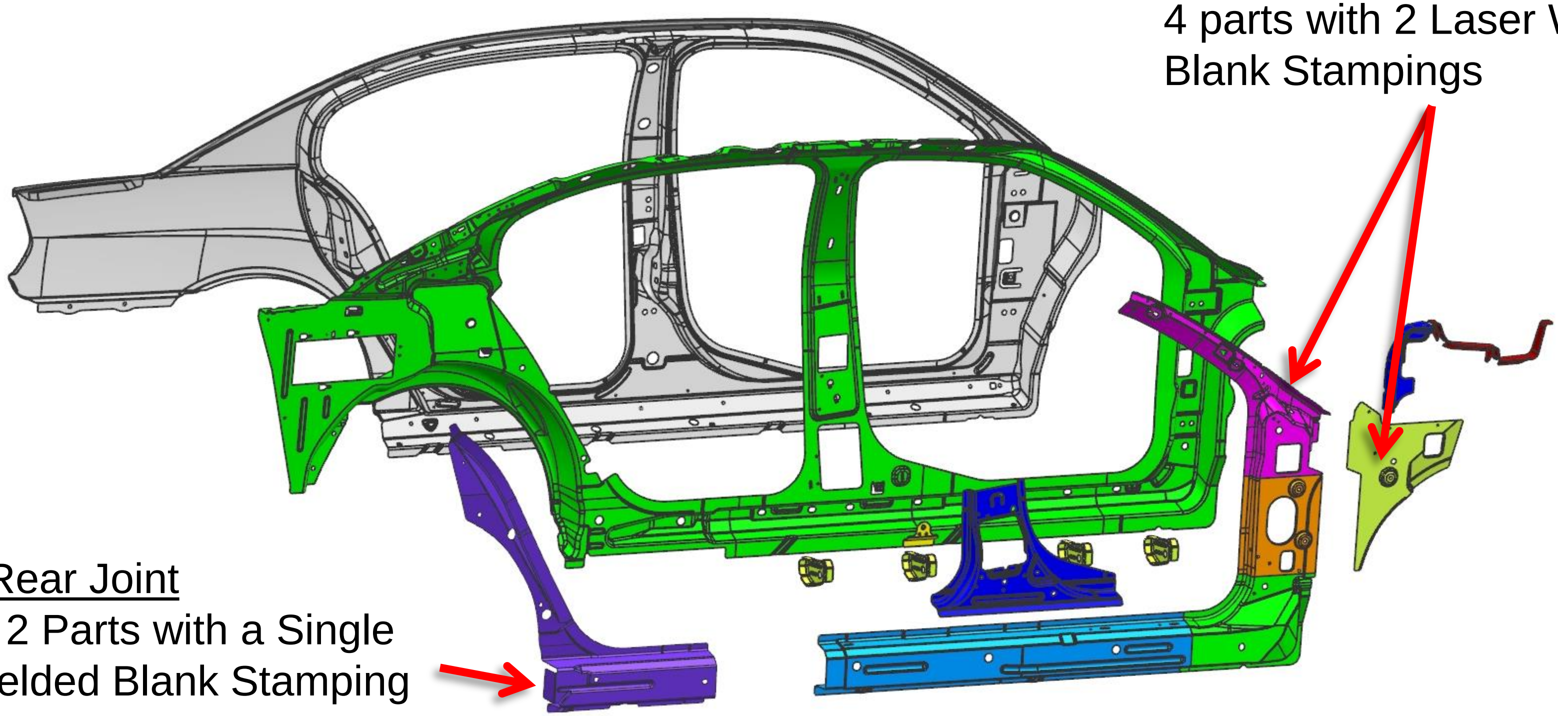
LSDYNA MAT24 – with strain rate C=100,000, P=3
Approximately 20% increase in strain rate hardening

BIW Static Stiffness Results – Iteration 3

Iteration	Torsion Stiffness(kN-m/Deg)	% Diff from Baseline
Baseline	12.9	
Iteration 3	11.6	-9.5%

Iteration	Bending Stiffness(N/mm)	% Diff from Baseline
Baseline	7707.5	
Iteration 3	6139.4	-20.3%

Body Side Assembly – Design Option 1

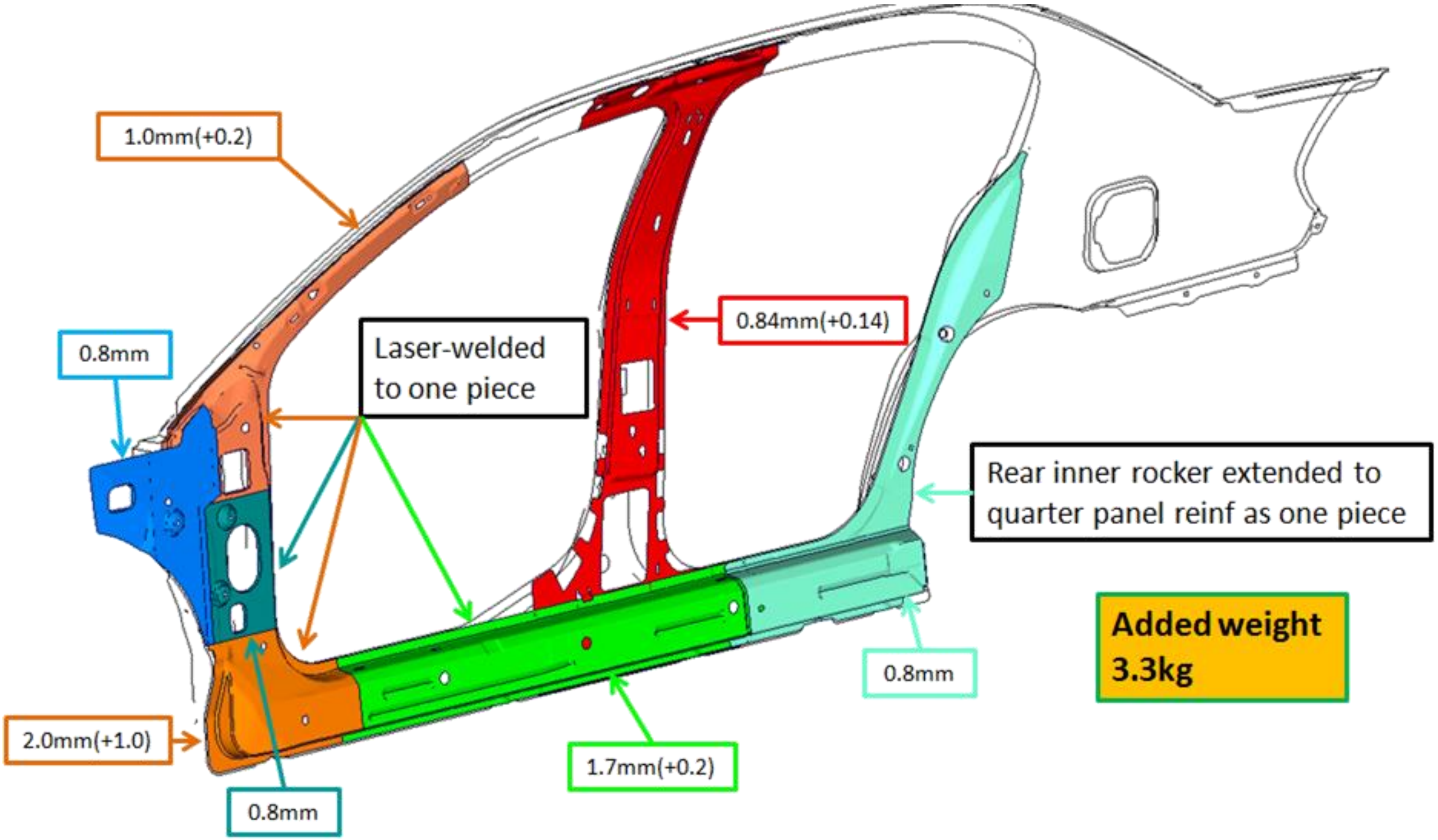


<u>Rocker Front Joint</u> Replace 4 parts with 2 Laser Welded Blank Stampings

<u>Rocker Rear Joint</u>
Replace 2 Parts with a Single Laser Welded Blank Stamping

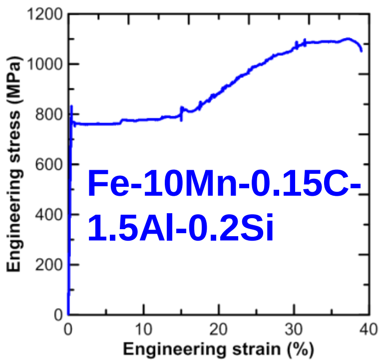
Preliminary Optimization – Iteration 4

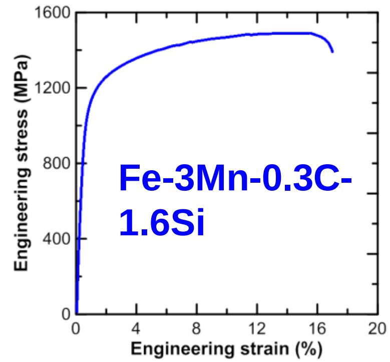
EDAG



Results (Using Preliminary Grades) – Iteration 4

Assembly	Baseline Mass (kg)	Optimized Mass (kg)	Delta Mass (kg)	Delta Mass %
Body Side Outer Panels	25.6	25.6	0	0%
Body Side (all other panels)	78.9	54.0	24.9	**31.6%**





No Change

Mild 140/270

LSDYNA MAT24 – with strain rate C=100,000, P=3
Approximately 20% increase in strain rate hardening

BIW Static Stiffness Results – Iteration 4

Iteration	Torsion Stiffness(kN-m/Deg)	% Diff from Baseline
Baseline	12.9	
Iteration 3	11.8	-8.6%

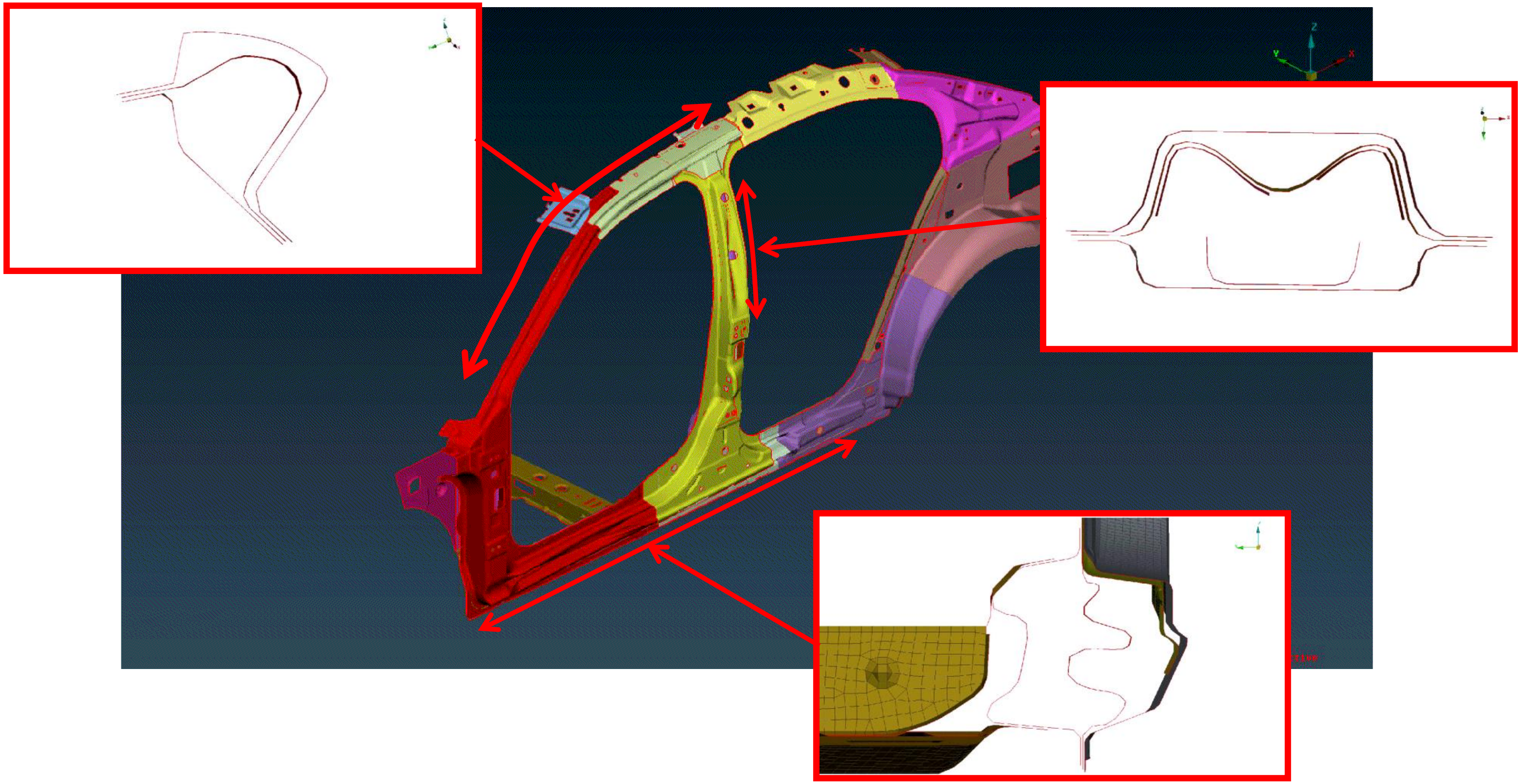
Iteration	Bending Stiffness(N/mm)	% Diff from Baseline
Baseline	7707.5	
Iteration 3	6501.6	-15.6%

Project Status and Initial Calibration Studies

1. Completed Baseline Crash and NVH assessments and established performance targets for project
   - Defined crash load cases' parameters to account for the project being focused only on body structure analyses
   - Completed the body side part's gauge sensitivity with respect to static torsion and bending stiffness.
   - Completed side impact and roof crush assessments with "3G" steel properties
   - Assessed mass reduction potential using the newer grades
   - Assessed NVH degradation due to gauge reduction
2. Generated design iterations using preliminary material grade (not final properties) in order to:
   - Establish a strategy for balancing mass reduction, crash, and NVH performance (prior to receiving final project steel grade properties)
3. Constructed a Baseline Technical Cost Model for future assessment of the cost impact of the optimized solution

3G (Gauge, Grade & Geometry) Optimization

EDAG



Project Next Steps – Complete 1/31/2017

1. Generate final design concepts that balance performance and required mass reduction (Geometry / Gauge)

2. Conduct final performance assessments using ICME generated steel grades

3. Finalize on-cost assessments through the established Technical Cost Model

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